X-75509

ENGINEERING REFERENCE DATA

WIRE SPRING RELAYS

AF-, AG-, AJ-, AND AK-TYPES

BELL TELEPHONE LABORATORIES
INCORPORATED

X-75509
Check List

This page contains a complete list of all the pages in this Bulletin together with the latest issue date.

Page	Date	Page	Date	Page	Date
Title	3-1-58	II-39	8-1-62	VII-4	3-1-58
Introduction (i)	3-1-58	II-40	8-1-62	VII-5	3-1-58
Table of Contents (ii)	3-1-58	II-41	8-1-62	VII-6	3-1-58
Table of Contents (iii)	3-1-58	II-42	8-1-62	VII-7	3-1-58
		II-43	8-1-62	VII-8	3-1-58
I-1	3-1-58	II-44	8-1-62	VII-9	3-1-58
I-2	3-1-58	II-45	2-10-61	VII-10	3-1-58
I-3	3-1-58	II-46	8-1-62	VII-11	3-1-58
I-4	3-1-58	II-47	2-10-61	VII-12	3-1-58
I-5	3-1-58	II-48	8-1-62	VII-13	3-1-58
I-6	3-1-58			VII-14	3-1-58
I-7	3-1-58	III-1	3-1-58	VII-15	7-30-54
I-8	3-1-58	III-2	3-1-58	VII-16	12-1-53
I-9	3-1-58	III-3	8-1-62	VII-17	3-1-58
I-10	3-1-58	III-4	3-1-58	VII-18	3-1-58
I-11	3-1-58	III-5	3-1-58	VII-19	3-1-58
I-12	3-1-58	III-6	3-1-58	VII-20	7-30-54
I-13	3-1-58	III-7	3-1-58	VII-21	3-1-58
I-14	2-10-61	III-8	8-1-62	VII-22	3-1-58
		III-9	3-1-58	VII-23	12-1-53
II-1	10-1-59	III-10	10-1-59	VII-24	12-1-53
II-2	3-1-58	III-11	8-1-62	VII-25	12-1-53
II-3	8-1-62	III-12	8-1-62	VII-26	12-1-53
II-4	10-1-59	III-13	8-1-62	VII-27	10-1-59
II-5	8-1-62	III-14	8-1-62	VII-28	3-1-58
II-6	8-1-62			VII-29	12-1-53
II-7	8-1-62	IV-1	12-1-53	VII-30	12-1-53
II-7A	8-1-62	IV-2	12-1-53	VII-31	3-1-58
II-8	8-1-62	IV-3	3-1-58	VII-32	12-1-53
II-8A	8-1-62	IV-4	12-1-53	VII-33	3-1-58
II-9	2-10-61	IV-5	12-1-53	VII-34	3-1-58
II-10	10-1-59	IV-6	12-1-53	VII-35	3-1-58
II-11	8-1-62	IV-7	12-1-53	VII-36	12-1-53
II-12	2-10-61	IV-8	10-1-59	VII-37	12-1-53
II-13	8-1-62	IV-9	3-1-58	VII-38	12-1-53
II-14	8-1-62	IV-9A	10-1-59	VII-39	12-1-53
II-15	2-10-61	IV-10	3-1-58	VII-40	12-1-53
II-16	8-1-62	IV-11	12-1-53	VII-41	12-1-53
II-17	2-10-61	IV-12	12-1-53		
II-18	2-10-61	IV-13	12-1-53	VIII-1	3-1-58
II-19	8-1-62			VIII-2	3-1-58
II-20	2-10-61	V-1	12-1-53	VIII-3	3-1-58
II-21	2-10-61	V-2	12-1-53	VIII-4	3-1-58
II-22	8-1-62	V-3	3-1-58	VIII-5	3-1-58
II-23	2-10-61	V-4	3-1-58		
II-24	8-1-62	V-5	12-1-53	IX-1	3-1-58
II-24a	8-1-62			IX-2	3-1-58
II-25	10-1-59	VI-1	3-1-58	IX-3	12-1-53
II-26	8-1-62	VI-2	3-1-58	IX-4	3-1-58
II-27	8-1-62	VI-3	12-1-53	IX-5	12-1-53
II-28	10-1-59	VI-4	3-1-58	IX-6	3-1-58
II-29	2-10-61	VI-5	12-1-53	IX-7	12-1-53
II-30	8-1-62	VI-6	12-1-53	IX-8	3-1-58
II-31	2-10-61	VI-7	12-1-53	IX-9	3-1-58
II-32	8-1-62	VI-8	12-1-53	IX-10	3-1-58
II-33	8-1-62	VI-9	12-1-53	IX-11	3-1-58
II-34	8-1-62	VI-10	12-1-53	IX-12	3-1-58
II-35	8-1-62			IX-13	12-1-53
II-36	3-1-58	VII-1	12-1-53	IX-14	12-1-53
II-37	2-10-61	VII-2	3-1-58	IX-15	3-1-58
II-38	3-1-58	VII-3	3-1-58	IX-16	12-1-53

Page	Date	Page	Date	Page	Date
IX-17	12-1-53	IX-51	3-1-58	X-16	12-1-53
IX-18	3-1-58	IX-52	12-1-53	X-17	12-1-53
IX-19	3-1-58	IX-53	12-1-53	X-18	3-1-58
IX-20	12-1-53	IX-54	3-1-58	X-19	12-1-53
IX-21	12-1-53	IX-55	12-1-53	X-20	3-1-58
IX-22	12-1-53	IX-56	7-30-54		
IX-23	3-1-58	IX-57	7-30-54	XI-1	3-1-58
IX-24	12-1-53	IX-58	7-30-54	XI-2	3-1-58
IX-25	12-1-53	IX-59	7-30-54	XI-3	12-1-53
IX-26	12-1-53	IX-60	10-1-59	XI-4	12-1-53
IX-27	12-1-53	IX-61	3-1-58	XI-5	12-1-53
IX-28	3-1-58	IX-62	3-1-58	XI-6	3-1-58
IX-29	3-1-58	IX-63	3-1-58	XI-7	12-1-53
IX-30	12-1-53	IX-64	3-1-58	XI-8	12-1-53
IX-31	12-1-53			XI-9	12-1-53
IX-32	12-1-53	X-1	3-1-58	XI-10	12-1-53
IX-33	12-1-53	X-2	3-1-58	XI-11	12-1-53
IX-34	12-1-53	X-3	3-1-58	XI-12	12-1-53
IX-35	10-1-59	X-4	3-1-58	XI-13	12-1-53
IX-36	12-1-53	X-5	10-1-59	XI-14	12-1-53
IX-37	12-1-53	X-6	3-1-58		
IX-38	10-1-59	X-7	3-1-58		
IX-39	3-1-58	X-8	10-1-59		
IX-40	12-1-53	X-9	3-1-58		
IX-41	12-1-53	X-10	3-1-58		
IX-42	12-1-53	X-11	10-1-59		
IX-43	12-1-53	X-12	3-1-58		
IX-44	3-1-58	X-12A	3-1-58	Index (iv)	3-1-58
IX-45	3-1-58	X-12B	3-1-58		
IX-46	3-1-58	X-12C	3-1-58	Index (v)	3-1-58
IX-47	3-1-58	X-12D	3-1-58		
IX-48	3-1-58	X-13	3-1-58	Index (vi)	3-1-58
IX-49	12-1-53	X-14	3-1-58		
IX-50	12-1-53	X-15	3-1-58	Index (vii)	3-1-58

INTRODUCTION

This is one of a series of Engineering Reference Data Bulletins containing information on apparatus designed by the Bell Telephone Laboratories, Incorporated, for other than military applications, and manufactured by the Western Electric Company or by other suppliers in accordance with specifications prepared by the Laboratories. It is intended primarily for use by engineers of the Laboratories, and contains information on apparatus which may be rated AT&TCo Standard, A&M Only, Component Part, or Special; codes classified ML; or codes designated for non-associate use. Codes rated Manufacture Discontinued are not included.

Items designated as PREFERRED are those recommended for use wherever practicable. Items not so designated are NONPREFERRED and should not be specified in new applications unless there is no other way of economically accomplishing the desired results. The NONPREFERRED items include (a) the older designs which may have been superseded but are still required for maintenance purposes, (b) designs more expensive to manufacture than others which may perform the same functions, and (c) items in such small demand that they are more costly to furnish.

It is planned to bring this bulletin up to date periodically; however, the information contained herein may not be complete and ratings of the items are not shown. The final selection of apparatus should, therefore, be made on the basis of the usual sources of information such as the Western Electric Apparatus Card Catalog, the manufacturing specifications, and price data. For information regarding the output of apparatus, refer to the Western Electric Report A-822.1.

The bulletin may include some codes of apparatus for which catalog cards will not be found in the Western Electric Apparatus Card Catalog. Such codes are in general rated "Component Part." This rating is applied to apparatus where it is believed that the associated telephone companies will have no need for apparatus card catalog information and orders for the apparatus from the field are not expected.

When apparatus which is not listed on a white card in the Western Electric Apparatus Card Catalog is selected for use in new applications, the Standards Engineer, Department 5241, Bell Telephone Laboratories, Incorporated, 463 West Street, New York, should be notified of the new use and probable demand so that consideration can be given to rerating the apparatus. When such new applications are made within the Laboratories, the selection should first be discussed with the department responsible for the design of the apparatus.

TABLE OF CONTENTS

GENERAL

General

The AF, AG, AJ, and AK relays constitute a new class of relay characterized by card operation of pretensioned wire-spring subassemblies. The important characteristics that have been attained in these new wire-spring relays with respect to the U, UA, UB, and Y relays are:

1. Lower cost.
2. Faster operate and release times.
3. Sensitivity and marginal capability comparable to that of UA relay.
4. Slow release times comparable to those of Y relay.
5. Reduced contact chatter and armature rebound.
6. Negligible contact locking.
7. Fewer open contacts.
8. Reduced contact erosion and faster opening of contacts and low contact load energy.
9. Greater life and adjustment stability and nonaging magnetic material.
10. Low magnetic interference.
11. Spring combination switching capability equivalent to U relay. (Greater spring capacity has been obtained.)
12. Lower cost of wiring.
13. Single contact metal and size (palladium).
14. Lower power consumption.

The various design and engineering characteristics of the wire-spring relays are presented in this specification. The new relays are not interchangeable, from a mounting standpoint, with the U, UA, UB, and Y relays; consequently, equipment as well as circuit engineering is required in applying them in switching systems.

Description

The AF, AG, and AJ wire-spring relays consist of an armature, a core, three molded spring blocks or combs, and a moving card all held together by a spring clamp which has sufficient tension to hold the parts in rigid alignment. There are separate twin-wire blocks for makes and breaks, and a single-wire block which is associated with the twin-wire makes or breaks. The twin wires are actuated by a moving card, making and breaking contact with the contacts of the single-wire block which is stationary. The contacts are arranged in twelve positions in a vertical row. Each position may have a make, a break, a make-break, or a break-make spring combination. The make and break contacts can be operated in three stages of the armature travel, commonly termed late, early, and preliminary.

The AK relay is similar to the AF relay except that the armature and card are divided horizontally, effectively making two relays on one structure. Spring positions 6 and 7 are not used. Only two stages of armature travel, early and late, are used.

Connection to the wiring terminals of all relays is obtained by wrapping the connecting wire around the straight terminal. The terminals are satisfactory for solderless wrapped connections.

Relay Types

There are four types of wire-spring relays, namely, AF, AG, AJ, and AK.

AF Relay

The AF relay is used as the general-purpose relay with a load capability of 18 contact pairs, and is equipped with a short armature (0.062 inch thick and 1/2-inch legs). This armature has been provided to reduce armature rebound when the relay releases. It is always provided with stop discs of 0.006-inch, 0.014-inch or 0.022-inch thickness, as required to meet circuit conditions. The core is zinc-plated and the armature and backstop thinly chromium-plated to eliminate sticking on the backstop. In addition to the operate requirement, nonoperate, hold, or release requirements may be specified for marginal applications. Fig. I-1 and I-2 show the front and rear views of this relay.

AG Relay

The AG relay, which generally has a copper or aluminum sleeve (Fig. I-3) over the center leg of the core, is a slow-release relay to replace the Y relay. Slow-releasing action may also be obtained by the use of a noninductive shunt or a short-circuited secondary winding. It is equipped with a long armature (0.078 inch thick and 1-1/4-inch legs) without stop discs, but embossed where it strikes the core, similar to the Y relay armature. The armature and core are chromium-plated. Hold and release

X-75509

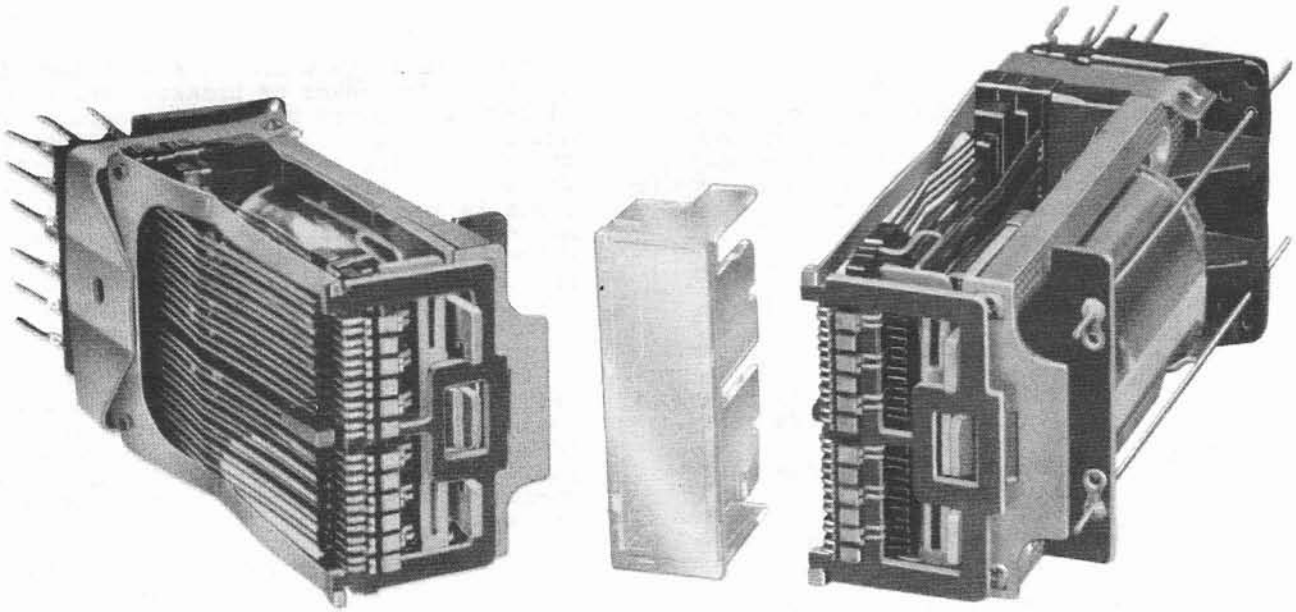


Fig. I-1 - AF Relay (Front View)

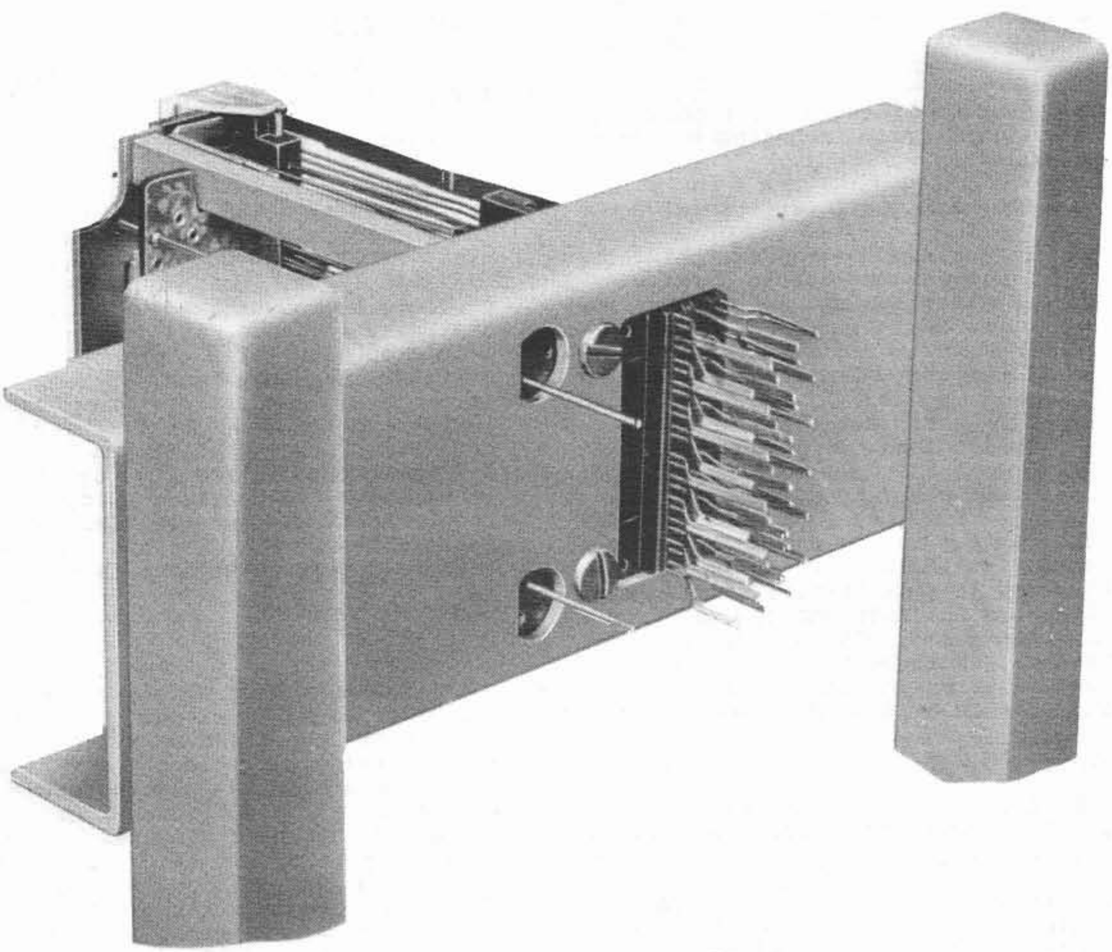


Fig. I-2 - AF Relay (Rear View)

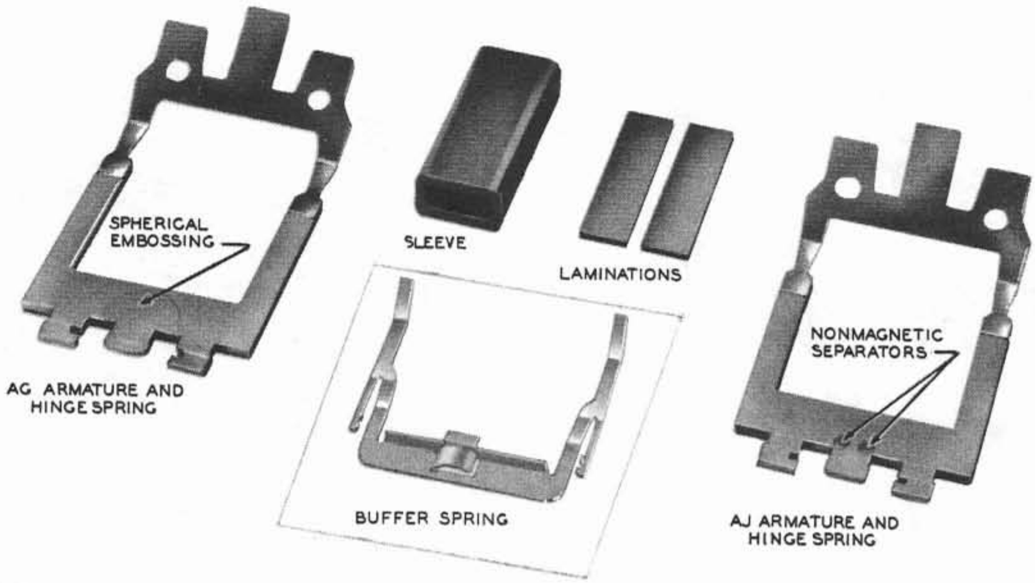


Fig. I-3 - Additional Parts for AG and AJ Relays

X-75509

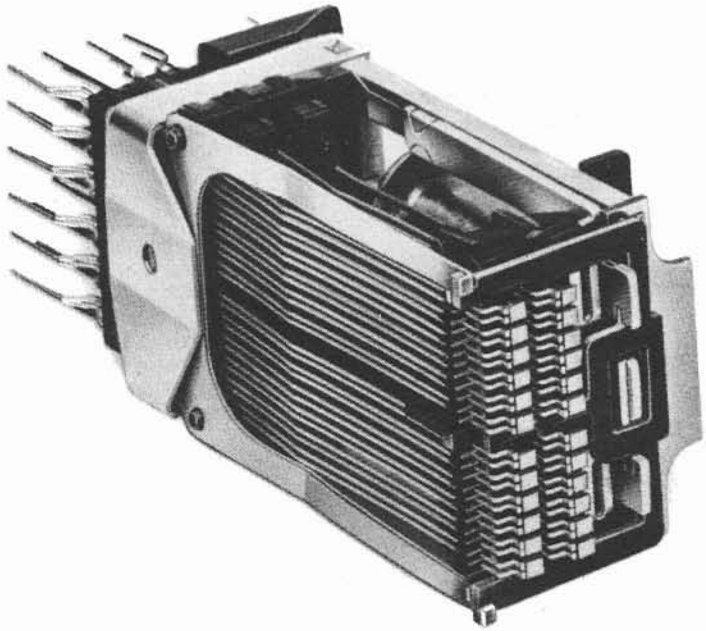


Fig. I-4 - 24-make-contact Relay

requirements are always specified in addition to the operate requirement in order to control the spread between minimum and maximum releasing times.

AJ Relay

The AJ relay is used for operating the heavier spring loads and also for light loads where greater sensitivity is required. It is equipped with the long armature and always provided with 0.006-inch, 0.014-inch, or 0.022-inch thick stop discs, as required to meet circuit conditions. The core is zinc-plated and the armature and backstop thinly chromium-plated to eliminate sticking on the backstop. Nonoperate, hold, or release requirements may be specified for marginal applications.

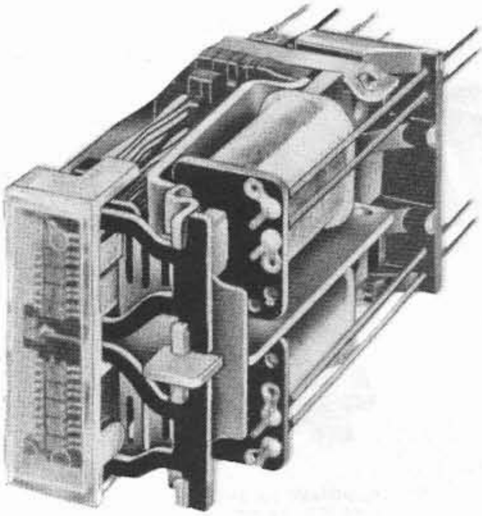


Fig. I-5 - AK Relay

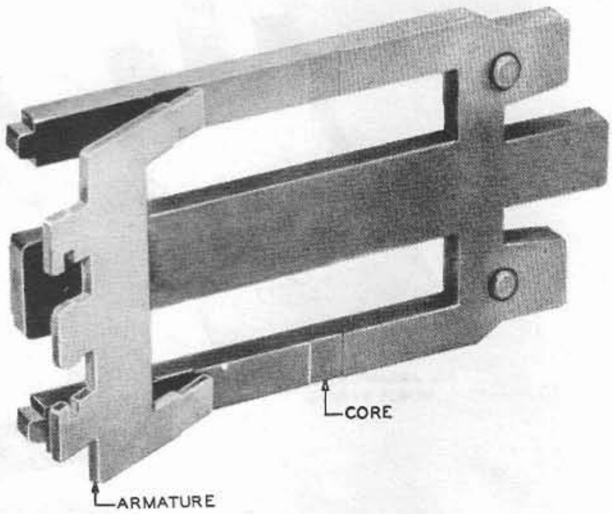


Fig. I-6 - AF Relay Magnetic Structure

The AJ relay may be equipped with core laminations (Fig. I-3) consisting of a strip of iron on each side of the core. This increases the impedance so that the relay is satisfactory for use as a bridged impedance transmission relay. A relay equipped with core laminations will also pull heavier spring loads.

24-make-contact Relay

A special variety of the AJ relay has been made available for conditions where more than 12 make contacts are required. This relay can replace two relays, or can be used where a multicontact relay might otherwise be required.

The 24-make-contact relay uses four molded-wire blocks, two single- and two twin-wire blocks. The contacts are arranged in two vertical rows of 12 contacts each as shown in Fig. I-4.

AK Relay

The AK relay is essentially two relays which mount like a single relay. There is a single core plate, core and balancing spring, but two armatures and two actuating cards. The twin- and single-wire combs for the two relays are molded as single units. Fig. I-5 shows the general appearance of the relay.

The AK relay has a capacity of five contact sets on each half. Each contact set may be a make, break, break-make, or make-break. No preliminary contacts are used, since there are only two stages of armature travel.

Magnetic Structure

The magnetic structure of the AF, AG, and AJ relays (Fig. I-6) consists of a simple E-shaped core and a flat U-shaped armature, both 1 per cent silicon iron. Silicon iron is used for the armature and core in preference to magnetic iron because it has a higher resistivity which contributes to faster operating and releasing times and also has much less magnetic aging properties. The one-piece E-shaped core construction avoids welded or butt joints, common to many magnets. These are responsible for added reluctance and decreased magnetic sensitivity. The relatively wide spacing of the legs reduces the leakage and in turn increases the useful magnetic flux.

Two different armatures are provided; a short armature, 0.062 inch thick with legs 1/2 inch long for the AF relay and a long armature, 0.078 inch thick with legs 1-1/4 inch long for the AG and AJ relays. Both armatures are coined to a thickness of 0.058 inch at the front where they pass through the opening in the core plate so that the same core plate may be used regardless of the armature used. The AF and AJ relays are equipped with nonmagnetic separators, or stop discs, 0.006 inch, 0.014 inch, or 0.022 inch high. The stop discs vary -0.000 inch, +0.003 inch. The AG relay armature has a spherical embossing (Fig. I-3). The stop discs prevent an iron-to-iron contact between the armature and the core, and the embossing provides a more uniform reluctance between the armature and the core for the slow releasing AG relays. The armature is supported by a hinge attached to the two legs in a

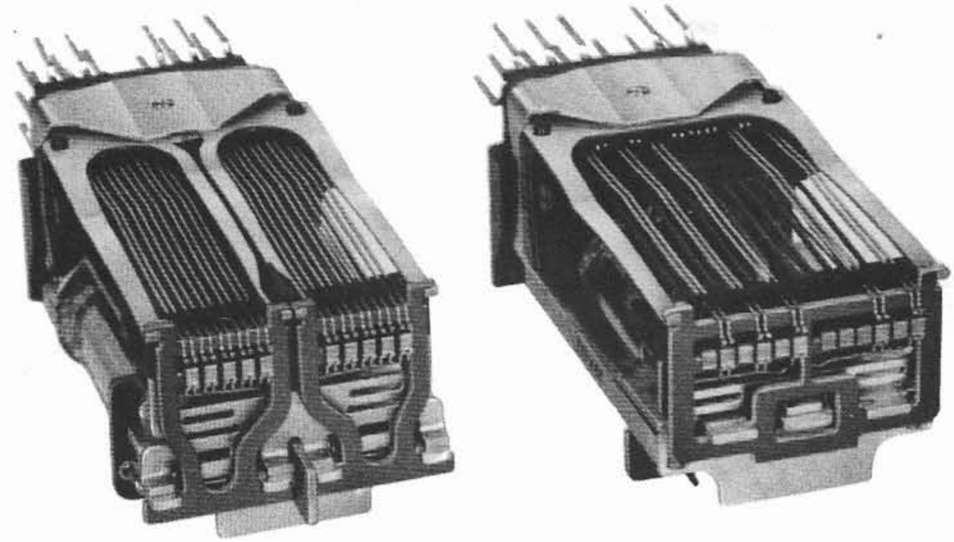


Fig. I-7 - AF and AK Relay Balancing Springs

X-75509

manner to produce a minimum rebound when the relay releases.

The armature is held against the backstop by a pretensioned U-shaped balancing spring. (Fig. I-7.) There are seven balancing springs of various thicknesses with different offsets, and the one used on any particular relay depends on the number of make contacts on the relay. These springs may be adjusted within certain limits to meet marginal circuit conditions.

The magnetic structure of the AK relay differs considerably from that of the other wire-spring relays. The core is U-shaped (Fig. I-8) and the coils are placed over the two legs. The U-shaped armature is replaced by a flat armature that has a double offset (see Fig. I-5) to fit around the coil. Only one stop-disc height, 0.005 inch, has been used. Where slow release times are required, a spherical embossing similar to that on the AG relay is used.

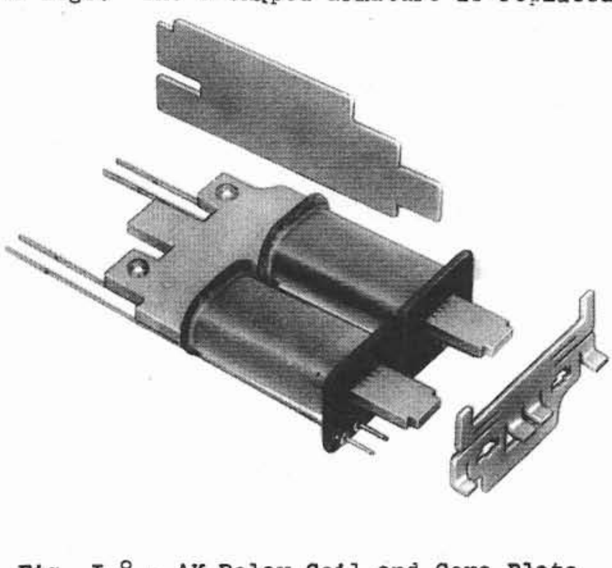


Fig. I-8 - AK Relay Coil and Core Plate

Each armature is held against its backstop by two arms of a balancing spring (Fig. I-7). There are two balancing springs and the one used depends on the number of make contacts on the relay.

Core Plate

AF, AG, and AJ Relays

After a cellulose acetate filled coil (see Section X) has been assembled to the center leg of the core, a core plate shown in Fig. I-9, is forced over the ends of the E-shaped core to hold the three legs in good alignment for proper mating with the armature. The speed and pull depend, to an important extent, on the alignment of the armature with respect to the three legs of the core. A clearance is required between the armature and the side legs to insure that the armature hits the stop discs, or dome, and not the side legs. On the other hand, if this side-gap clearance is too large, a loss of pull capability results. A lip on the core plate serves as a backstop for the armature. The core plate also provides a means of mass-adjusting the contacts. This can be done by inserting a screwdriver in the upper or lower adjusting slots and twisting the screwdriver. The lower slot controls contacts 1 through 6, and the upper slot controls contacts 7 through 12. The armature travel is

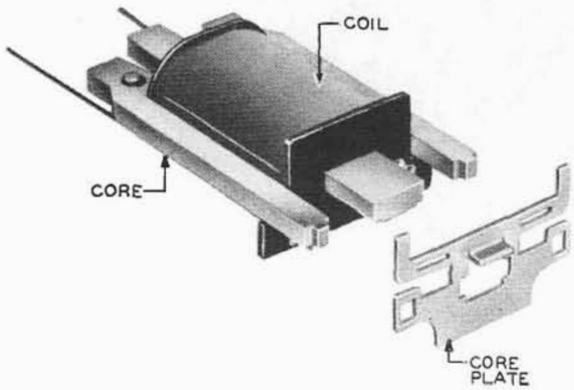


Fig. I-9 - AF, AG, or AJ Relay Coil and Core Plate

governed by the height of an opening in the core plate, the armature thickness, and the stop-disc height. Thus, a separate core plate is required for each of the three stop-disc heights and each armature travel stage.

AK Relay

A single core plate (Fig. I-8) fits over the cores of the two halves of the relay. It provides the same method of adjustment as that of the AF relay, except that the upper slot controls the adjustment of the top relay unit and the lower slot the bottom relay unit. The core plate has two lips, one serving as the backstop for each relay unit.

Spring Assemblies

One of the major features of the new relay is the use of molded spring assemblies. A number of wires are fed into a molding press, where a plastic block is molded around the wires to hold them in place. The molds are also shaped to provide dowel pins and holes in the molded blocks which facilitate the relay assembly and hold the parts in alignment. Fig. I-10 shows continuous ladders of molded wire spring sections before they are cut to length.

In general, three basic wire-spring assemblies, or combs, are required. Two of these carry twin wires of nickel-silver for make and break contacts and are identical except for some details in forming at the terminal end for convenience in wiring. The third comb consists of a group of 12 (ten on the AK relay) relatively heavy nickel-silver single wires molded in plastic sections, one a short distance behind the contacts and the other near the terminal end of the relay. These sections are rigidly supported in the relay structure. The twin-wire assemblies are mounted on either side

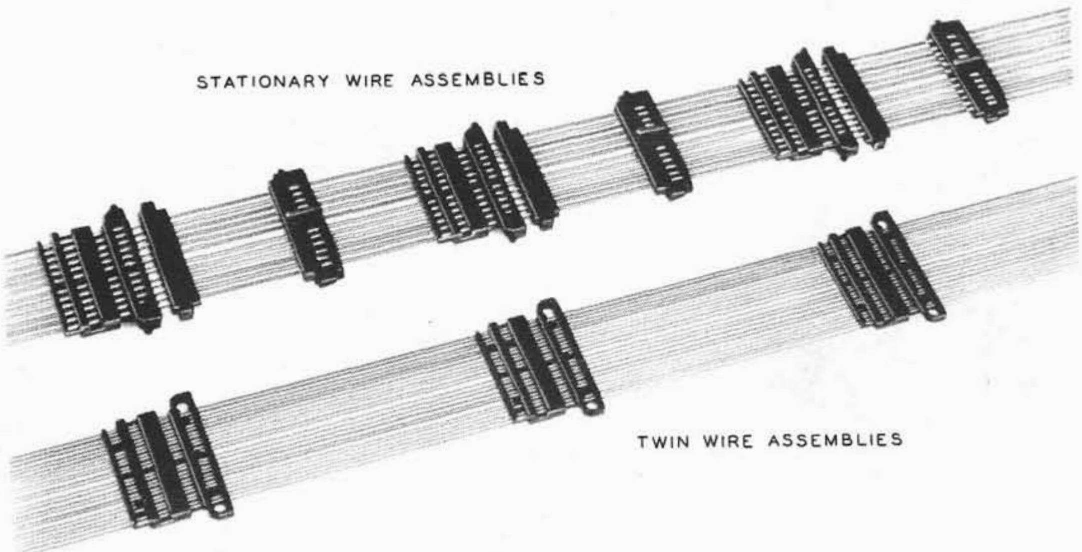


Fig. I-10 - Molded Spring Assemblies Before Cutting to Length

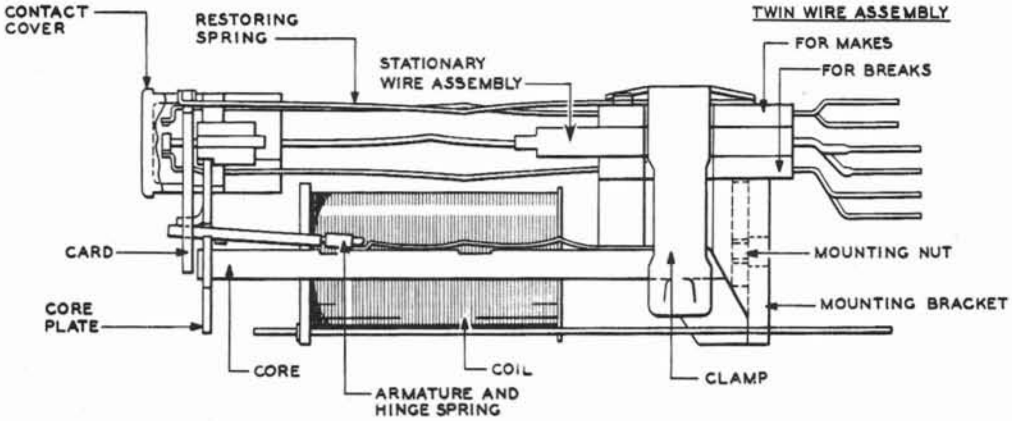


Fig. I-11 - Top View of AF Relay Showing Location of Parts

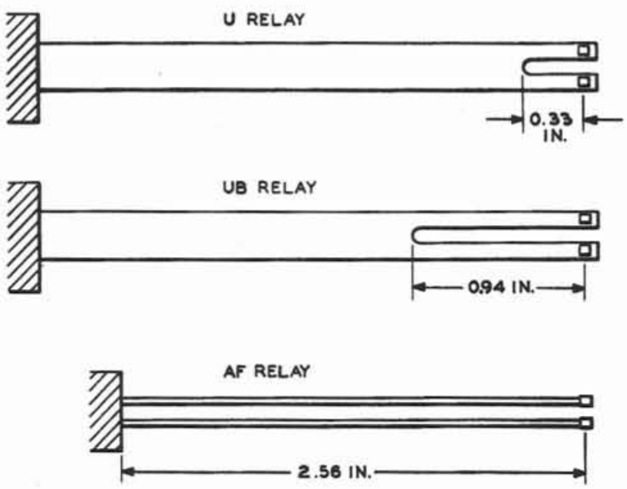


Fig. I-12 - U, UB, and AF Relay Springs

X-75509

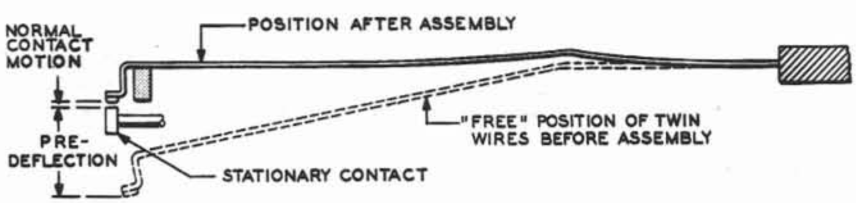


Fig. I-13 - Predeflection of Twin Wires

of the stationary single wires. Fig. I-11 shows a top view of the relay and the location of the parts.

Contacts on the movable twin wires are associated with the single fixed contact. The twin wires are held in good alignment with the single contacts by molded guide slots in the single-wire comb just behind the card. These slots are slightly wider than the wires so that the wires are free to move in the direction of the single wires but are restrained in the lateral movement. Fig. I-12 shows the independent action of the twin contacts compared with the limited action of the twin contacts on the U and UB relays. This contact arrangement assures contact reliability and reduction of open contacts in the presence of dirt.

Each group of twin wires is tensioned toward the stationary wires by means of large predeflections (approximately 1/2 inch) before assembly. The contact pressures are controlled by this predeflection as illustrated in Fig. I-13. When the twin-wire blocks are assembled in the relay, the twin wires are displaced from their free position by the single contacts or by the actuating card. The stiffness of the twin wires is such that this results in a contact pressure of about 12.5 grams for the twin pairs.

The twin wires are actuated by a single punched fiber card, which in turn is actuated by the armature. The tension of the twin wires is always in a direction to hold the contacts closed; therefore, the card must hold the make contacts open when the relay is unoperated, and the break contacts open when the relay is operated. The armature back tension is thus controlled by the back tension of the balancing spring minus the forward tension of the twin-wire moving springs of the make contacts.

The single-wire stationary combs are always provided with a full complement of wires in order to support the front molded section which is held against the core plate by the tension of these wires. Only the single wires mating with twin wires may be equipped with precious metal contacts. Thus, the single wire may be equipped with no contact metal, contact metal on both sides, or on either side only.

Actuating Card

The twin wires are actuated by a phenol fiber moving card (Fig. I-7) held against the armature by the tension of a flat balancing spring. The twin wires that form the make contacts are pretensioned against the outer edge of this card and toward the single mating contacts and the core. As the armature moves toward the core, the card allows the twin-wire springs to move forward to make contact with the single-wire contacts. As the armature movement continues, the card touches the break-twin wires which are tensioned against the single-wire contacts. As the armature continues to move further toward the core, the actuating card lifts the break-twin wires from the mating single-wire contacts and the break contacts open. The principle of operation is shown in Fig. I-14 for transfer contacts.

Contact Sequences

Contact sequences are obtained by controlling the contact so that it functions early or late in the armature stroke. The particular point at which contacts make or break depends mainly on the dimension of the card between the surface which bears against the armature and that which engages the twin wires. By providing recesses for early makes and shoulders for early breaks, any contact can be made to operate early or late in the armature stroke. Thus, a transfer is obtained by making the card dimension such that a break contact will open before its associated make contact closes. A continuity combination is obtained by controlling the card dimensions so that the make contact closes before its associated break opens. Fig. I-15 shows an early break-make (transfer), an early make-break (continuity), and a break-make (nonsequence transfer) side-by-side. Of the contacts shown, only two operate early and this is accomplished by means of the two steps in the actuating card. If no different sequences were required, the card would have two straight unbroken surfaces, one for the makes, and one for the breaks.

Combinations with sequences require a longer armature travel than those with no sequences. Three different travels or contact stages are provided. At the card, these travels are: 0.026 inch (short) for no sequences, 0.044 inch (intermediate) for one sequence, and 0.060 inch (long) for preliminary contacts which involve two stages or sequences. The 0.060-inch travel is not used on the AK relay.

Mounting

The relays are mounted with two screws which engage a clamp plate held in the rear assembly. The molded rear assembly is such that the relays are insulated from the mounting plate without the use of separate mounting plate insulators.

Generally, all relays mount on 2-inch vertical and 1-1/2-inch horizontal centers, except transmission relays requiring a magnetic shield, and the 24-make relay. In the case of transmission relays, 1-3/4-inch horizontal centers are required.

When mounted next to each other on 1-1/2-inch horizontal centers, the wire-spring relays nest in such a manner that there is a nominal clearance of 1/8 inch at the closest points. When mounted next

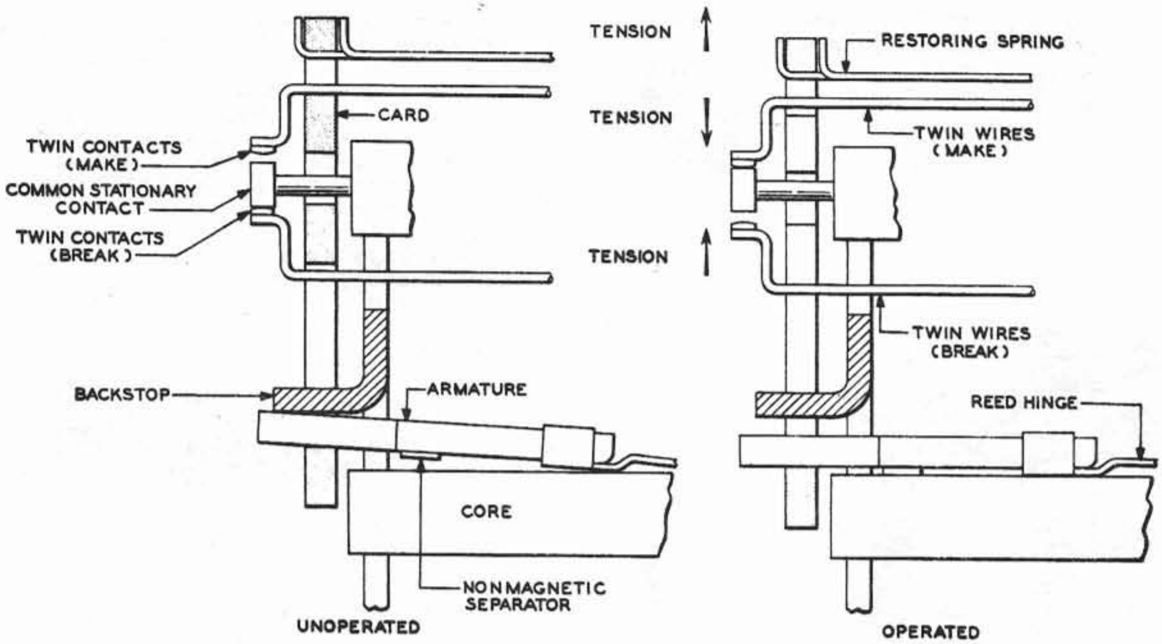


Fig. I-14 - Principle of Operation of Transfer Contacts

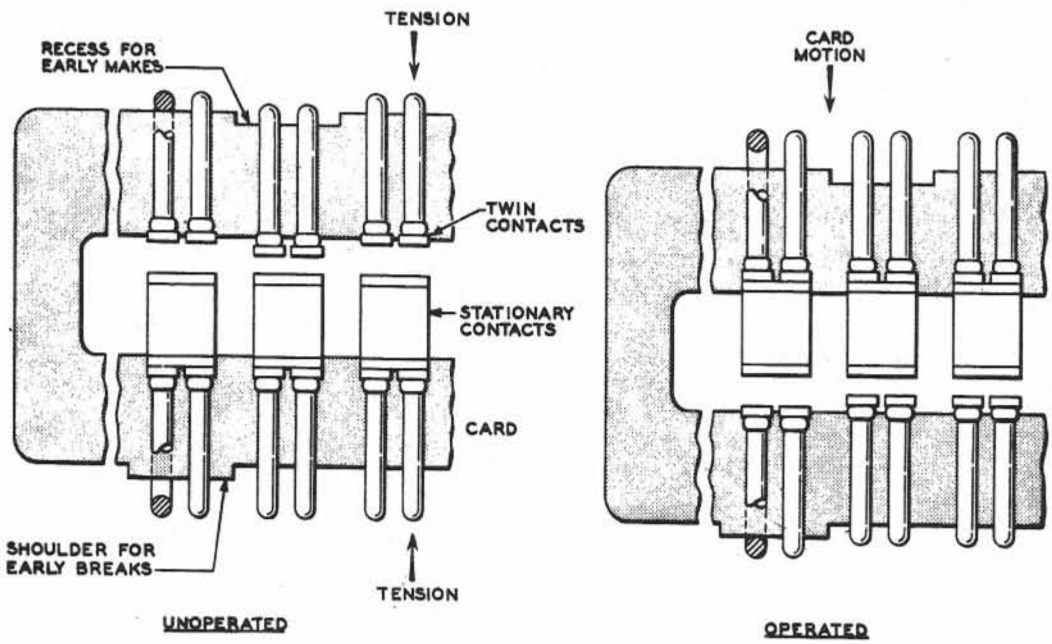


Fig. I-15 - Method of Obtaining Early Contacts

X-75509

to dissimilar apparatus, however, the adjacent apparatus seldom nests with the wire-spring relay and somewhat larger space must be allowed. Where no penalties in the number of mounting plates occur, the center-to-center dimension, between the wire-spring relay and the dissimilar apparatus, should

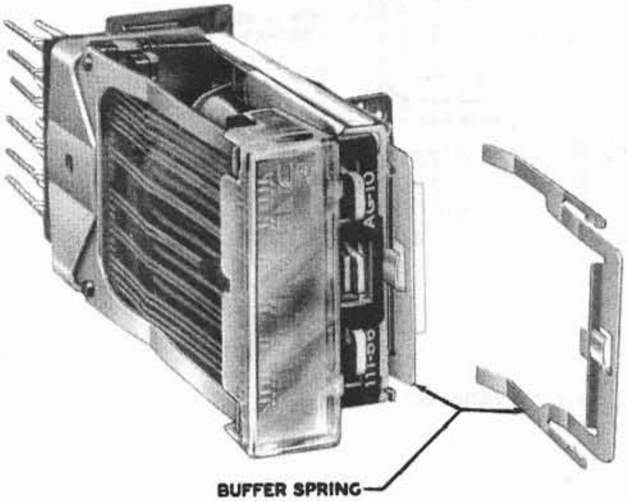


Fig. I-16 - Buffer Spring

be increased 1/8 inch. The AJ relay, equipped with a magnetic shield, is considered dissimilar apparatus since relays equipped with the boxlike shield will not nest.

Where the additional 1/8-inch allowance, due to dissimilar apparatus, will cause the use of an extra mounting plate, the following minimum mounting allowances may be used.

	AF,AG,AJ
Dissimilar apparatus on coil side of relay - all lengths	1.566 inches
Dissimilar apparatus on spring side of relay - 2-7/8 inches or less from mounting plate	1.566 inches
Dissimilar apparatus on spring side of relay - over 2-7/8 inches from mounting plate	1.634 inches

The 24-make relays may be mounted on 1-3/4-inch centers with respect to other 24-make relays, but the use of 2-1/2-inch mounting centers is recommended as a means of reducing the wiring congestion at the back of the relay. When a general purpose wire-spring relay is mounted on the spring side of a 24-make relay, the minimum 1-5/8-inch center-to-center spacing should be increased to 1-3/4 inches to obtain an adequate clearance between the outer row of terminals on the 24-make relay and the coil terminals of the general purpose relay. 24-make relays with more than one winding require a special layout of mounting holes and a minimum mounting center of 2 inches.

Assembly of Coded Parts

The design of the wire-spring relay permits considerable savings in assembly and adjusting cost. Major design features which contribute to low assembly cost are:

1. The use of molded spring subassemblies which avoid individual handling of the wire springs.

2. Clamping the relay pile-ups by means of a simple steel spring clamp. No screws are used in the relay except those that fasten it to the mounting plate.

3. A single, easily-mounted operating card.

A large variety of different relay codes are obtained by assembling parts which, for assembly purposes, are identical. Thus, the assembly operation is essentially the same for all codes. A buffer spring (Fig. I-16), which is used to obtain an increased load in the operated position without increasing the unoperated position load, can be placed on the relay (except the AK relay) after the assembly is completed. Fig. I-17 shows the part that is used in the assembly of the AF relay, and Fig. I-18 the AK relay.

While it is possible to have a great number of different molded spring combs, it is expected that a relatively small number will be adequate for all uses. Relatively few of the large number of actuating cards possible will be used. Only seven have been used on the AF, AG, and AJ relays and two on the AK relays up to the present time.

Contact Cover

Each relay is equipped with a molded methyl methacrylate cover which encloses only the front of the contacts and protects them from dirt. The cover also traps the twin wires in the individual guide slots to avoid displacement and crossing of these wires such as would occur during shipment and under pressure-cleaning conditions. It is important that the cover be kept in place at all times except for relay maintenance.

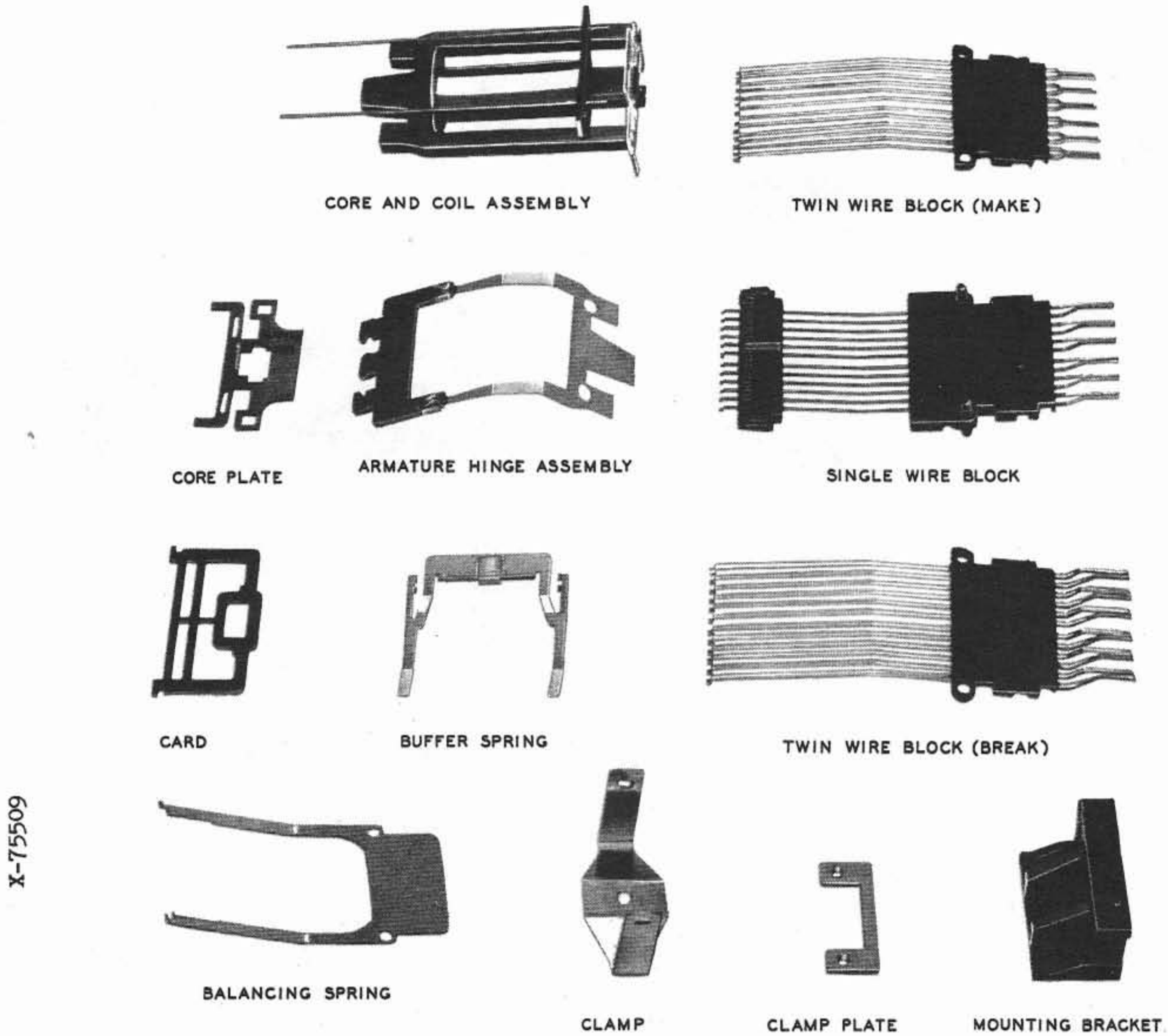


Fig. I-17 - AF Relay Parts

Life

It is expected that AF, AG, and AJ relays will have a life of 100 to 300 million operations depending on the coil resistance and spring combination. Where longer life is essential, special features can be used that will extend the life to approximately one billion operations. These special features consist of heavy chromium plate on the armature, core, and core-plate, stop discs of No. 1 contact metal, and stainless steel wear pads on the core legs in the region where the armature pivots

At present the AK relay has a life of about 25 million operations, but it is hoped that this can be extended to 50 or 60 million by contemplated design changes.

Contact Chatter and Rebound

Contact chatter in general purpose relays has several causes. For convenience in discussing the extent and characteristics of chatter on the wire-spring relays, chatter can be divided into four fundamental types characterized by their cause as follows:

1. Initial Chatter is chatter occurring immediately after contact closure. This is usually confined to a period of about 100 microseconds after closure. It is usually of high frequency and has been sometimes called fine chatter.

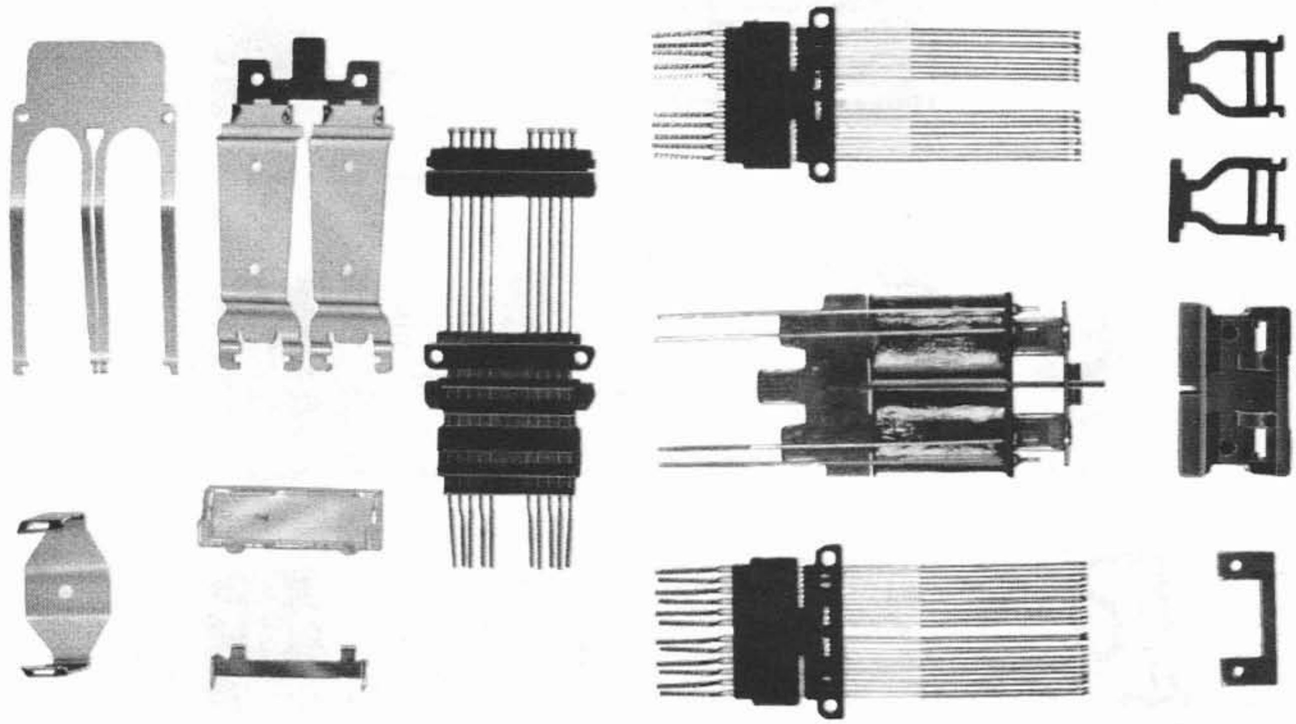


Fig. I-18 - AK Relay Parts

2. Shock Chatter is caused by vibration of the springs from the impact of the armature as it strikes the core or backstop on operate or release. This type of chatter usually starts from 1 to 3 milliseconds after the initial closure and is periodic in nature.

3. Hesitation Chatter is caused by hesitation of the armature during the operate or release stroke. Abrupt changes in load cause the armature to momentarily stop or even reverse its direction of motion before completing its stroke.

4. Rebound Chatter is caused by the bounce of the armature on striking the backstop.

Conditions under which the various kinds of chatter can be anticipated are shown in the following table.

	Type of Relay		
Chatter*	AF or AJ Controlled by		Slow**
	Mass	Load	
Initial	✓	✓	✓
Shock	✓		
Hesitation		✓	✓
Rebound - Short A T			✓
Rebound - Int & Long A T	✓	✓	✓

*Check marks indicate conditions where chatter can occur.

**AF, AG, or AJ relays with sleeves or shunts.

The wire-spring relays show substantial improvement in performance over older relays in all types of chatter except hesitation and rebound chatter.

Initial Chatter

This type of chatter may occur on any wire-spring relay contact, but will be found more often on the make contacts of fast-operate or lightly-loaded relays. Its occurrence and duration are so small that for most circuit applications it can be neglected. It has some adverse effect on contact erosion but the effect is included in the life estimates of contact performance.

Shock Chatter

This type of chatter is a function of the armature speed and does not occur on the operate of the slower relays or on the release of lightly-loaded or slow release relays. It will occur most frequently on the fast operating speed coils. Its occurrence and duration are so small that for most circuit applications it can be neglected.

Hesitation

X-75509

Hesitation is a temporary slowing down, stopping or reversal of the armature during its travel between the core and the backstop on either operate or release. This tends to increase the stagger time between contacts and prolong the operate or release time. Operate hesitation occurs when the spring load builds up faster than the armature pull, and usually occurs on the high-inductance coils or under marginal conditions. Operate hesitation is worse on relays with a large number of springs, which are picked up early in the armature travel with little dispersion of the contact pick-up points. A change in the adjusting requirements to prevent picking up the contacts too early has practically eliminated hesitation on coils of less than 700 ohms and reduced the tendency of hesitation on the higher resistance coils.

Hesitation may be reduced or eliminated by three methods.

1. Use more power on the coil.
2. Use an adjustment to guarantee a gradual or a late load pick-up. Adjusting the core plate tabs so that the single-wire comb is moved nearer to the core increases the distance that the armature travels before picking up the load. As a consequence, the armature is traveling faster and the pull is greater as the load is picked up, both of which reduce hesitation.
3. Use an AJ relay in place of an AF relay. The greater pull of the AJ relay, under the same circuit conditions, tends to reduce hesitation.

Release hesitation is encountered almost entirely on relays with buffer springs. When the buffer spring load is dropped, on the release of the relay, the armature may stop or momentarily reoperate some contacts before moving to the backstop. Since the hesitation is caused by the abrupt dropping of the heavy buffer spring load while there is still some flux in the delay, the remedy is to remove the buffer spring, if this can be done.

Rebound

Rebound is the bounce of the armature after it hits the backstop on release. On wire-spring relays with a short armature travel all the contacts may close at about the same time leaving no contact safe from rebound, if it occurs. On intermediate travel relays the late contacts are usually safe from closure on rebound.

The make contacts of continuity (EMB) springs are vulnerable to rebound on relays with intermediate travel. Where such springs are used to lock a relay, the locking circuit should not be re-enabled for at least 20 milliseconds after the relay has released in order that rebound will not cause the relay to lock falsely. This condition can sometimes be overcome by the use of a long travel relay whose preliminary contacts may absorb the rebound. Rebound can also be reduced by the use of a minimum 60 grams armature back tension. A flexible mounting, LP-19A890, can also be used to aid in reducing rebound, especially under pulsing conditions.

Rebound is aggravated by operation under a pulsing condition, a release from a short pulse closure and the use of a shunt, contact protector, or sleeve. The following table summarizes the results of a study of rebound on the wire-spring relay with contact protection but no sleeve or shunt. This table shows that relays with light spring loads (two to six contacts) should be free from rebound, except possibly under pulsing conditions. Rebound chatter increases with the use of the long armature, the number of springs, and an increase in the armature travel.

TABLE I-1

Estimate of Occurrence and Duration of Contact Operation Due to Rebound

Relay Type	Arm. Travel	No. of Contact Spring Pairs	Length of False Operation in Milliseconds
AF	Short	2 to 18	None
AF	Int	2 to 6	None
AF	Int	7 to 18	0 to 2
AJ	Short	2 to 6	None
AJ	Short	7 to 18	0 to 3
AJ	Short	19 to 24	1 to 4
AJ	Int	2 to 6	0 to 1
AJ	Int	7 to 18	0 to 4
AJ*	Int	19 to 24	2 to 6

*May have two or three false operations.

Long travel relays are not included in the table. They are worse than the intermediate travel relays. Lightly-loaded long travel relays may be liable to false closure of the preliminary contacts and heavily loaded relays may close both the preliminary and the early contacts.

Rebound is negligible on the AK relay if either half of the relay is operated or released while the other half of the relay is stationary. If both halves are released together, or within 50 milliseconds of each other, rebound chatter may occur.

Short Pulse Operation

The contacts of a relay can be caused to function on a pulse of current shorter than the actual operate time of the relay. This effect is due to the armature inertia and is aggravated by the use of a contact protection network. The actual operate time of a relay operating from a short pulse is longer than its operate time on a long steady closure.

Under the worst conditions, short travel mass controlled wire-spring relays may operate on a pulse equal to about 50 per cent of their actual operate time if protected by a 186A network, 60 per cent if protected by a 185A network, and 70 per cent if unprotected. Increasing the back tension, the armature travel or the contact gap tends to make the length of the pulse required to operate the relay approach the normal operate time.

Similarly, an interruption of the coil current, much shorter than the release time of the relay, may permit the armature to fall away from the core and open some of the closed contacts. In extreme cases, with no contact protection, an interruption of current as short as 40 per cent of the release time can release the relay. With contact protection the open interval to release the relay would vary from 50 to 75 per cent of the normal release time depending on the contact protection and relay coil.

Grounding Strap

The wire-spring relay is usually insulated from the mounting plate, but it is sometimes necessary to ground the relay core for shielding reasons in high-frequency circuits. A grounding strap, which is assembled in the relay behind the mounting bracket has been developed for this purpose and is specified as part of the relay code. There are a limited number of codes that have this grounding strap. Relays with the grounding strap are not recommended for general use and therefore should be used only where the grounded relay is required for circuit reasons.

SECTION II

CODE INFORMATION

General

This section contains code information for all AF, AG, AJ, and AK relays that have been coded on the date of issue. The information is arranged in a form to facilitate the selection of relays to meet particular circuit requirements.

The relay code information, that is, code number, spring combination, winding, and adjustment information is listed in Tables II-1, II-2, II-3, and II-4 according to the number of contacts on each code. The M, B, EM, EB, PM, and PB contact arrangements each count as one contact. The EMB, BM, and EBM contact arrangements each count as two contacts.

To locate the design information for a particular coded relay, lists of codes in numerical order are provided preceding Table II-1. These show the table number and the number of contacts where this information may be found.

X-75509

High-Operation Relays

Wire spring relays that are expected to operate several hundred million times in a 40-year life require the use of special long-life features to avoid the necessity of periodic readjustments to compensate for wear. These special features consist of heavy chromium plate on the armature, core, and core plate, No. 1 metal stop discs, and stainless steel wear pads on the core legs in the region where the armature pivots. The number of operations, in millions, for which relays with different coils are satisfactory without the use of the long-life features are:

	1 to 6 Contacts		Over 6 Contacts	
Res	S Travel	I Travel	S Travel	I Travel
16	150	100	200	150
270	250	200	300	250
400	300	200	300	300
700	350	300	400	350
Over700	400	350	400	350

Relays that operate in excess of these figures should be equipped with the long-life features. Relays with the long-life features are coded in a separate code series. These relays should not be used unnecessarily since the long-life features increase the price of the relay approximately 20 cents.

Code Numbers

The following blocks of code numbers have been established for the AF, AG, and AJ relays. There is only one code series for the AK relays.

Ordinary Relays

1 to 12 Contact Positions	24 Makes
AF1 to 499	None
AJ1 to 199	AJ200 to 299
AG1 to 199	None

Long-Life Relays

1 to 12 Contact Positions	24 Makes
AF500 and Up	None
AJ500 to 699	AJ700 to 799
AG	None Anticipated

Preferred Codes

The coded AF and AJ relays listed in the attached tables are marked with (P) when their use is preferred over other codes. The preferred codes are those with preferred windings and spring combinations which will be satisfactory for many circuit applications and consequently will have high production. Wherever possible, preferred codes should be used. In cases where the preferred code will not meet circuit requirements, or where its use is uneconomical because of the cost of extra springs or increased current drain, other codes should be used.

Relays with the long-life features are shown in the nonpreferred list since they cost more than the normal relay.

Spare Contacts

It is economical to use relays having spare contacts on the following basis before considering a new code with the exact number of contacts required.

Demand per 10,000 Lines	Permissible Spare Contacts
800 - 400	1
400 - 200	2
200 - 100	3
100 - 80	5
80 - 60	6
60 - 50	8
Less than 50	10

Procedure

Count the total number of required contacts (M, B, BM, EBM, etc). For AF and AJ relays, look in Table II-1 for single-wound or in Table II-2 for multiple-wound relays, starting with the total number of contacts required; for AG relays look in Table II-3, and for AK relays Table II-4. If the exact combination is not coded, then select the code available having the lowest number of contacts which will meet the requirements and determine if this design is economically satisfactory for the known demand.

If a satisfactory relay is not found in these tables, submit a wire-spring relay request in duplicate to the relay requirements group (Form E-973A).

Adjustments

The Western Electric Company adjusts all U, UA, and Y relays furnished on wired equipments in the wiring shop, and uses the current flow values shown in the circuit requirements table. With this program, the current flow values on the circuit requirements table do not necessarily have to be the same as the M specification.

With the introduction of the wire-spring relay, the Western Electric Company feels that it is more economical to adjust these relays in the relay assembly shop. This is due to the greater stability of the relay, the use of fewer adjustable features resulting from more preformed and pretensioned springs, the expectation of less adjusting effort, and the mass adjustment of the same code of relay. This program also permits the establishment of a single adjusting shop instead of one in the assembly shop and another in the wiring shop. The circuit requirement values must therefore be no more severe than the M specification values in order to avoid checking and readjusting effort in the wiring shop.

It will not be permissible to specify requirements on the circuit requirements table that are not a part of the M specification. Where a relay requires current flow values different from those in the M specification, it will be necessary to change the M specification or to issue a new code with the new adjustment. The choice of which procedure is to be followed will be determined by the economics of the situation. If the M specification is changed, the more expensive adjustment must be applied in the shop to all relays of that code, which might be uneconomical if there existed a high demand for the relay without the additional requirements. On the other hand, a new code for a relay with a small use would result in an increased over-all production cost by manufacturing more small-lot orders. The cost of the two methods must be compared to determine the most economical procedure. Section XI contains the data for making this comparison. On low-demand uses, a new code cannot be justified because the existing code has extra adjusting requirements.

Where a multiplicity of requirements are shown in Tables II-1, II-2, and II-4 for AF, AJ, and AK relays, all of them need not necessarily be shown on the circuit requirements table for every circuit application. Those requirements which do not apply to a particular circuit condition may be omitted. For instance, a nonoperate requirement should not be shown if there is no nonoperate condition in the circuit. Check adjustments on other windings are not considered as additional requirements, and therefore may be used on the circuits without affecting the M specification. For example, if a relay is adjusted with two windings series aiding, a check adjustment may be shown for either winding alone in a particular circuit requirements table even though it is not specified in the M specification.

The current flow requirements for the coded relays in Tables II-1, II-2, and II-4 are readjust requirements. The test requirements are 105 per cent of the operate and hold requirements and 95 per cent of the nonoperate and release requirements.

Both test and readjust current flow requirements are shown for AG relays in Table II-3. The margin between release test and readjust for these relays is on an ampere turn rather than a percentage basis to provide margin for wear. The margin between test and readjust is 5 per cent for operate, nonoperate, and hold requirements

For AG relays, always specify the soak, operate, hold, and release requirements.

Show "FS" in the "After Soak" column of the circuit requirements table when soak currents are given, provided the full soak obtained under the test condition is equal to, or greater than, the specified value. If the full soak exceeds 0.7 ampere, the specified soak should be used.

Armature Back Tension

Armature back tension other than standard - minimum 30 grams for AF, AJ, and AK relays, minimum 45 grams for relays with 24 makes, minimum 20 grams for AG relays - must be shown in the circuit requirements table.

Contact Gauging

Contact gauging values other than standard are shown in Tables II-1, II-2, II-3, and II-4 and must be shown in the circuit requirements table.

A visual check, without gauges, will be made for all EBM, EMB, PBEM, and PMEB spring units. No check is made for any other sequence unless the sequence is specified in the circuit requirements table.

Resistance Tolerances

Unless otherwise stated, the resistance variation of inductive windings is ±10 per cent and noninductive windings is ±5 per cent. All resistance values are based on 68F.

Contacts

Only palladium (No. 2 metal) contacts of one size are used on AF, AG, AJ, and AK relays. The twin-wire contacts have a thin gold overlay.

Battery Connection to Springs

Battery and ground shall not be connected to springs in adjacent positions, since these springs may be shorted by the contact burnisher.

Contact Pressure

The AF, AG, AJ, and AK relays are generally designed to provide a nominal 12.5-gram contact pressure. The sensitive relays are designed to provide a nominal 8-gram pressure. Since the contact pressure is nonadjustable, no reference will be made to it in the circuit requirements table.

X-75509

Armature Travel

The armature travel is nonadjustable and so will not be specified in the circuit requirements table. The nominal armature travels, measured at the card are:

	Travel Inch	Contact Sequence	Spring Combination Number
Short	0.026	1 Stage	1 to 199 and 500
Intermediate	0.044	2 Stage	200 to 399
Long	0.060	3 Stage	400 to 499

Operate and Release Times

The operate and release times for the AF, AJ, AG, and AK relays are shown in Tables II-5, II-6, II-7, and II-8. These times are based on local circuit operation, 45 to 50 volts and no contact protection. The operate times are not shown for relays which cannot be used in local circuit on 48 volts.

Circuit Preparation

Wire-spring relays may be blocked in the operated or the unoperated position, and their contacts may be insulated. When a make contact on the relay under test is insulated, the margin between the readjust and test operate should be increased to 10 per cent to compensate for the effect of the contact insulator on the operate current.

Winding terminals are extended to the front of the relay to provide connecting points for test purposes. The single-wire contacts may be used as connecting points for test purposes. This connection is made by a test prod that plugs into a 360 tool, as shown in Fig. VIII-1. Mechanical interference between 360 tools makes it impossible to pick up adjacent contacts without interference. At least two contact positions should be left between contacts to be picked up. As an exception, only one contact position need be left between connecting points straddling the center of the spring combination because of the wider space between contacts 6 and 7.

Maintenance Specifications

The following Bell System Practices cover the information for maintaining the wire-spring relays.

Section	Contents
040-502-701	Maintenance and Adjustment - AF, AG, and AJ Relays
040-504-701	Maintenance and Adjustment - AK Relays
069-020-801	Blocking and Insulating
069-131-811	Test Connections
069-306-801	Contact Cleaning
069-310-803	Contact Replacement
040-502-801	Piece Parts and Replacement - AF, AG, and AJ Relays
040-504-801	Piece Parts and Replacement - AK Relays
005-120-103	Winding and Spring Designations
040-502-101	Educational Information AF, AG, and AJ Relays

AF RELAY CODES

Code	Contacts	Table	Code	Contacts	Table	Code	Contacts	Table
AF1	MD		AF51	4	1	AF101	4	2
AF2	MD		AF52	11	1	AF102	3	2
AF3	10	1	AF53	13	1	AF103	3	2
AF4	6	1	AF54	12	1	AF104	3	2
AF5	10	1	AF55	16	1	AF105	7	1
AF6	11	1	AF56	2	1	AF106	3	1
AF7	None		AF57	8	1	AF107	MD	
AF8	10	2	AF58	None		AF108	MD	
AF9	12	1	AF59	4	1	AF109	7	2
AF10	9	1	AF60	7	1	AF110	9	1
AF11	8	2	AF61	5	1	AF111	15	1
AF12	11	2	AF62	Replaced by AF115		AF112	13	1
AF13	11	1	AF63	7	1	AF113	12	1
AF14	None		AF64	18	1	AF114	7	1
AF15	4	1	AF65	None		AF115	7	1
AF16	11	1	AF66	6	2	AF116	14	1
AF17	4	1	AF67	6	1	AF117	10	1
AF18	4	2	AF68	3	2	AF118	7	1
AF19	4	1	AF69	Replaced by AF526		AF119	11	1
AF20	14	1	AF70	6	2	AF120	12	1
AF21	11	2	AF71	5	2	AF121	16	1
AF22	6	1	AF72	4	2	AF122	12	1
AF23	12	1	AF73	8	2	AF123	12	2
AF24	12	1	AF74	Replaced by AF500		AF124	7	1
AF25	6	1	AF75	Replaced by AF501		AF125	13	1
AF26	6	1	AF76	Replaced by AF502		AF126	7	1
AF27	6	1	AF77	12	2	AF127	11	2
AF28	8	1	AF78	None		AF128	16	2
AF29	Replaced by AF114		AF79	14	1	AF129	16	1
AF30	12	1	AF80	Replaced by AF503		AF130	8	2
AF31	Replaced by AF512		AF81	Replaced by AF525		AF131	11	1
AF32	12	1	AF82	15	1	AF132	14	1
AF33	12	1	AF83	12	1	AF133	3	2
AF34	10	1	AF84	12	1	AF134	15	1
AF35	9	1	AF85	7	1	AF135	9	1
AF36	Replaced by AF514		AF86	6	1	AF136	11	1
AF37	12	1	AF87	8	1	AF137	6	1
AF38	Replaced by AF515		AF88	14	1	AF138	1	1
AF39	Replaced by AF516		AF89	4	1	AF139	11	1
AF40	10	1	AF90	6	1	AF140	13	1
AF41	Replaced by AF517		AF91	6	1	AF141	6	2
AF42	16	1	AF92	11	1	AF142	10	1
AF43	3	1	AF93	Replaced by AF504		AF143	15	1
AF44	4	1	AF94	12	2	AF144	5	1
AF45	Replaced by AF519		AF95	14	1	AF145	8	1
AF46	Replaced by AF520		AF96	3	2	AF146	6	1
AF47	Replaced by AF521		AF97	3	2	AF147	12	1
AF48	16	1	AF98	13	1	AF148	11	1
AF49	13	1	AF99	6	2	AF149	2	1
AF50	6	1	AF100	16	1	AF150	10	1

AF AND AJ RELAY CODES

AF RELAY CODES

Code	Contacts	Table
AF151	14	1
AF152	18	1
AF153	13	1
AF154	11	1
AF155	13	1
AF156	8	1
AF157	12	1
AF158	8	1
AF159	8	1
AF160	9	1
AF161	14	1
AF162	12	1
AF163	12	1
AF164	9	1
AF165	14	1
AF166	10	1
AF167	8	2
AF168	3	1
AF169	9	1
AF500	8	1
AF501	18	1
AF502	16	1
AF503	MD	
AF504	12	1
AF505	6	1
AF506	12	1
AF507	16	1
AF508	6	1
AF509	18	1
AF510	1	2
AF511	7	1
AF512	6	1
AF513	12	1
AF514	6	1
AF515	16	1
AF516	8	1
AF517	12	1
AF518	16	1
AF519	9	1
AF520	11	1
AF521	15	1
AF522	6	1
AF523	11	1
AF524	8	1
AF525	10	2
AF526	Replaced by AF534	
AF527	6	1
AF528	6	2
AF529	13	2
AF530	12	2
AF531	8	1
AF532	11	2
AF533	9	2
AF534	4	2
AF535	12	1

AJ RELAY CODES

Code	Contacts	Table
AJ1	2	2
AJ2	Replaced by AJ24	
AJ3	20	1
AJ4	None	
AJ5	24	1
AJ6	None	
AJ7	1	1
AJ8	1	2
AJ9	20	1
AJ10	5	2
AJ11	2	1
AJ12	24	1
AJ13	Replaced by AJ503	
AJ14	16	2
AJ15	24	1
AJ16	20	1
AJ17	Replaced by AJ25	
AJ18	13	1
AJ19	4	2
AJ20	16	2
AJ21	20	1
AJ22	20	1
AJ23	1	2
AJ24	2	2
AJ25	1	1
AJ26	5	2
AJ27	12	1
AJ28	16	2
AJ29	3	2
AJ30	11	1
AJ31	8	1
AJ32	16	1
AJ33	6	1
AJ34	3	2
AJ35	2	1
AJ36	11	1
AJ37	20	1
AJ38	7	2
AJ39	24	1
AJ40	2	2
AJ41	12	1
AJ42	8	2
AJ43	24	1
AJ44	MD	
AJ45	24	1
AJ46	11	1
AJ47	1	1
AJ48	4	2
AJ49	7	2
AJ50	3	2
AJ51	14	1
AJ52	8	2
AJ53	16	1
AJ54	16	1
AJ55	13	2

X-75509

AJ RELAY CODES

AJ RELAY CODES

Code	Contacts	Table
AJ56	17	1
AJ57	6	2
AJ58	12	2
AJ59	3	2
AJ60	8	1
AJ61	14	1
AJ62	16	1
AJ63	9	1
AJ64	17	1
AJ65	18	1
AJ66	5	2
AJ67	MD	
AJ68	15	1
AJ69	19	1
AJ70	18	2
AJ71	16	2
AJ72	24	2
AJ73	6	2
AJ74	7	1
AJ75	13	1
AJ76	7	1
AJ77	9	2
AJ78	19	2
AJ79	14	1
AJ80	4	1
AJ81	24	1
AJ82	8	1
AJ83	24	1
AJ84	13	1
AJ85	5	1
AJ86	5	2
AJ87	17	2
AJ88	8	2
AJ89	14	1
AJ90	12	1
AJ91	15	1
AJ92	24	1
AJ93	19	1
AJ94	16	1
AJ95	16	1
AJ96	12	1
AJ97	13	2
AJ98	5	1
AJ99	11	2
AJ100	3	1
AJ101	12	1
AJ102	3	2
AJ103	24	1
AJ104	10	1
AJ105	14	1
AJ106	14	1
AJ107	20	1
AJ108	2	1
AJ109	16	2
AJ110	9	2

AJ RELAY CODES

Code	Contacts	Table
AJ111	14	1
AJ112	10	1
AJ113	20	2
AJ114	9	2
AJ115	3	2
AJ116	15	2
AJ117	3	1

AJ RELAY CODES

AJ RELAY CODES

Code	Contacts	Table
AJ200	24	
AJ201	Replaced by AJ700	
AJ202	24	1
AJ203	24	1
AJ204	24	2
AJ500	20	1
AJ501	24	1
AJ502	20	1
AJ503	24	1
AJ504	16	1
AJ505	8	1
AJ506	7	1
AJ507	15	1
AJ508	11	1
AJ509	15	1
AJ510	5	2
AJ511	12	2
AJ512	24	1
AJ513	24	1
AJ514	18	2
AJ515	16	1
AJ516	24	1
AJ517	16	2
AJ700	24	1
AJ701	MD	
AJ702	24	1

X-75509

AG RELAY CODES

Code	Contacts	Table
AG1	12	3
AG2	8	3
AG3	8	3
AG4	5	3
AG5	MD	
AG6	14	3
AG7	15	3
AG8	5	3
AG9	7	3
AG10	12	3
AG11	8	3
AG12	4	3
AG13	5	3
AG14	6	3
AG15	8	3
AG16	8	3
AG17	15	3
AG18	9	3
AG19	4	3
AG20	15	3
AG21	7	3
AG22	7	3
AG23	8	3
AG24	6	3
AG25	MD	
AG26	10	3
AG27	6	3
AG28	13	3
AG29	17	3
AG30	7	3
AG31	5	3
AG32	16	3
AG33	13	3
AG34	13	3
AG35	6	3
AG36	8	3
AG37	8	3
AG38	12	3
AG39	13	3
AG40	6	3
AG41	9	3
AG42	10	3
AG43	18	3
AG44	14	3
AG45	11	3
AG46	11	3
AG47	8	3
AG48	15	3
AG49	12	3
AG50	18	3
AG51	8	3
AG52	16	3
AG53	24	3
AG54	7	3
→ AG55	9	3
→ AG56	17	3
→ AG57	21	3

X-75509

This page is blank AK codes
are on other side.

AK RELAY CODES

AK RELAY CODES

Code	Contacts	Table
AK1	13	II-4
AK2	10	4
AK3	8	4
AK4	18	4
AK5	8	4
AK6	20	4
AK7	16	4
AK8	14	4
AK9	6	4
AK10	15	4
AK11	8	4
AK12	4	4
AK13	16	4
AK14	14	4
AK15	10	4
AK16	14	4
AK17	14	4
AK18	7	4
AK19	12	4
AK20	8	4
AK21	12	4
AK22	20	4
AK23	8	4
AK24	12	4
AK25	6	4
AK26	13	4
AK27	10	4
AK28	14	4
AK29	10	4
AK30	18	4
AK31	13	4
AK32	14	4
AK33	13	4
AK34	13	4
AK35	18	4
AK36	18	4
AK37	13	4
AK38	10	4

TABLE II-1

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

Readjust. pg II-2 Col 2

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							1 CONTACT							
1	-	-	-	-	-	1	AJ7	34900	9100	1.6			.5	A,(AC)G,Z,(AY)
-	1	-	-	-	-	53	AJ25	3710	220	24	22			D,X,N
										(after soak-50)				
-	1	-	-	-	-	53	AJ47	3710	220	23	21			D,X,N
										(after soak-50)				
-	1	-	-	-	-	53B	AF138	3900	100	30	-	-	12.5	A
							2 CONTACTS							
-	-	-	1	-	-	209	AF56(P)	5150	700	25.5				
2	-	-	-	-	-	2	AJ11	5625	180	15		9.3	5.1	A,G,W
										(after soak 45)				
1	1	-	-	-	-	9	AJ35	1580	16	60	54			
-	-	-	1	-	-	209	AF149	2260	34	71	58			
→ 2	-	-	-	-	-	2	AJ108	34900	9100	2.1				W
							3 CONTACTS							
1	-	1	-	-	-	17	AF43(P)	2110	270	46.5				
2	1	-	-	-	-	37	AF106	13500	2000	7.1	4.6			D
3	-	-	-	-	-	46	AJ100	5625	180	10	5.3			G,W
→ 3	-	-	-	-	-	46	AF168	5150	700	25	22			
→ 2	1	-	-	-	-	37	AJ117	5625	180	11.8				W

Notes:

A. Equipped with 0.014-inch stop discs.
D. Equipped with 0.091-inch copper sleeve.
G. Contact make 5, no make 8.5, readjust; make 3.5, no make 10, test.
N. Winding arrangement No. 5.
W. Armature back tension minimum 20 grams readjust, 15 grams test.
X. Equipped with one iron and two copper washers.
Z. Adjusted on light contact pressure.
(AC). Armature back tension minimum 18 grams readjust, 15 grams test.
(AY). The use of a protective network on the coil is required to limit the peak voltage to a safe value.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							4 CONTACTS							
2	-	-	-	1	-	216	AF15(P)	19400	2500	6.7				
4	-	-	-	-	-	3	AF19	1580	16	64				
4	-	-	-	-	-	3	AF44(P)	2110	270	48				
4	-	-	-	-	-	3	AF51(P)	5150	700	19.5				
4	-	-	-	-	-	3	AF59(P)	19400	2500	5.2				
2	2	-	-	-	-	41B	AF89	2260	34	45	29.5		17.5	
											(after soak		130)	
-	-	-	1	1	-	211	AF17(P)	2110	270	62	46			
3	1	-	-	-	-	38	AJ80	8250	1050	11	7.9			C
							5 CONTACTS							
-	5	-	-	-	-	23	AF61(P)	19400	2500	5.5	2.4			
1	-	-	-	2	-	258	AF144(P)	5150	700	26				
4	1	-	-	-	-	71	AJ85	22200	3800	4.6	3			(AY) (RA)
1	-	2	-	-	-	74	AJ98	2260	34	70			30	B

X-75509

Notes:

B. Equipped with 0.022-inch stop discs.
C. Equipped with 0.147-inch copper sleeve.
(AY) The use of a protective network on the coil is required to limit the peak voltage to a safe value.
(RA) Resistance ±5%.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							6 CONTACTS							
2	-	2	-	-	-	18	AF4	3330	400	34.5				
2	-	2	-	-	-	18	AF50(P)	5150	700	22	13.2			
2	-	2	-	-	-	18	AF527	3330	400	34.5				
2	-	2	-	-	-	18	AF522	5150	700	22				
-	-	-	2	1	-	207	AF22(P)	2110	270	62				
-	-	-	2	1	-	207	AF67(P)	19400	2500	6.8				
-	-	-	2	1	-	207	AF512	5150	700	25				
-	-	-	2	1	-	207	AF505	19400	2500	8.5				T
5	1	-	-	-	-	11	AF25	1580	16	72				
5	1	-	-	-	-	11	AF27	3330	400	34.5				
5	1	-	-	-	-	11	AF508	1580	16	72				
→6	-	-	-	-	-	5	AF26	11850	950	9.7				
6	-	-	-	-	-	5	AF514	2110	270	54.5				
2	-	-	2	-	-	237	AF86	8275	500	16	11.7		3.5	(RA)
2	2	-	1	-	-	242	AF90(P)	2110	270	62				
2	4	-	-	-	-	43	AF91(P)	2110	270	54				
6	-	-	-	-	-	5B	AJ33	5625	180	30	(soak 225)		18	A,G,(AP)
-	-	-	-	1	2PBEM	412	AF137	2110	270	85				T
-	-	-	2	1	-	207	AF146(P)	19400	2500	8				T
							7 CONTACTS							
2	1	2	-	-	-	54	AF114(P)	5150	700	23				
2	1	2	-	-	-	32	AF511	5150	700	23	10.9			
6	1	-	-	-	-	12	AF60(P)	19400	2500	6.2				
2	1	-	2	-	-	274	AF115(P)	19400	2500	6.7	5			
2	3	-	-	1	-	229	AF63(P)	19400	2500	6.7				
1	-	-	2	-	2PM	401	AF85	6450	1000	34	23.5		10.5	A,C,(RA)
1	-	-	2	1	-	253	AF105(P)	2110	270	62		34.5		
1	-	-	2	-	2PM	401	AF118	11850	950	13.3				
1	-	-	3	-	-	267	AJ506	1580	16	75				
2	-	-	-	2	1EM	287	AF124	8275	500	16				
3	-	-	1	1	-	288	AF126	3330	400	39				
→1	2	-	1	1	-	292	AJ76(P)	19400	2500	6.5		2.6		
→-	1	3	-	-	-	69	AJ74(P)	19400	2500	4.9			1.1	

Notes:

A. Equipped with 0.014-inch stop discs.
C. Equipped with 0.147-inch copper sleeve.
G. Contact make 5, no make 8.5, readjust; make 3.5, no make 10, test.
T. Armature back tension, minimum 65 grams readjust, 60 grams test.
(AP). Maximum buffer spring gauging waived.
(RA). Resistance ±5 per cent.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							8 CONTACTS							
4	-	-	2	-	-	210	AF57(P)	5150	700	25.5				
4	-	-	2	-	-	210	AF524	5150	700	25.5				
4	4	-	-	-	-	33	AF500	730	4.4	175				(RB)
1	2	-	1	1	1PM	400B	AF28	8275	500	26			10.9	A
-	-	-	1	2	1EM&1EB	240	AF87	10080	2550	13.6	9.5			C
3	-	-	1	1	1EM	221	AF516	2110	270	63				
5	3	-	-	-	-	36	AJ31	8275	500	13.7				
5	3	-	-	-	-	36	AJ505	1580	16	71				
-	-	-	4	-	-	203	AF531(P)	5150	700	36			12.6	A
-	-	-	4	-	-	203	AJ60	8275	500	20	-	-	6	A,(RA)
3	-	-	-	2	1EM	269	AF145	8275	500	16				(RA)
2	-	-	3	-	-	300	AJ82	8275	500	21	13.9			A
4	2	-	-	1	-	295	AF156(P)	5150	700	25.5				
4	2	-	-	1	-	295	AF159	3950	200	33.5				
5	3	-	-	-	-	36	AF158	5575	550	23	12.2			C ←
							9 CONTACTS							
3	1	-	1	1	1EM	214	AF10(P)	19400	2500	7.2	4.5			
4	2	-	-	1	1EM	248	AF35(P)	2110	270	66				
4	1	2	-	-	-	27	AF519	2110	270	69			17	
-	1	-	3	1	-	272	AF110	11850	950	15.5			5.6	A
1	3	-	1	1	1PM	409B	AF135	8275	500	26			10.9	A
6	3	-	-	-	-	68	AJ63(P)	19400	2500	5.4				
6	1	1	-	-	-	73	AF160	3950	200	34				
5	-	-	1	1	-	319	AF164(P)	5150	700	27				
3	-	-	2	-	2EB	331	AF169	6700	275	38				A,(AK) ←
							10 CONTACTS							
6	2	-	-	1	-	329	AJ112	11850	950	10.9		5.6		←
10	-	-	-	-	-	6	AF3	3330	400	42				
10	-	-	-	-	-	6	AF5(P)	2110	270	66				
9	1	-	-	-	-	14	AF34(P)	5150	700	26.5				
4	1	-	1	1	1EM	222	AF40(P)	2110	270	69.5				
4	1	-	1	1	1EM	222	AF117	5625	180	27	17		6	
3	5	-	-	-	1EM 1EB	310	AF142	5625	180	36.5	20	23.5	10.1	A,(AG)
7	-	-	-	-	3EM	289	AF150	5625	180	26	17		6.4	
1	3	-	1	1	1EM-1PM	421B	AF166	8275	500	28			10.9	A ←
-	-	-	4	1	-	324	AJ104	11850	950	12				

X-75509

Notes:

A. Equipped with 0.014-inch stop discs.
C. Equipped with 0.147-inch copper sleeve.
→ (AK). Armature back tension, minimum 60 grams
(AG). Armature back tension, maximum 60 grams.
(RA). Resistance ±5 per cent.
(RB). Resistance ±15 per cent.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							11 CONTACTS							
7	2	1	-	-	-	29	AF6	1580	16	95				
4	2	-	1	1	1EM	215	AF13(P)	19400	2500	12.4			4.2	A
4	1	-	3	-	-	204	AF16(P)	5150	700	29				
3	-	4	-	-	-	19	AF52(P)	5150	700	28				
3	-	4	-	-	-	19	AF523	5150	700	28				
11	-	-	-	-	-	7	AF92(P)	2110	270	69				
10	1	-	-	-	-	15	AF520	2110	270	69				
6	3	-	-	-	2EM	266	AF119(P)	19400	2500	12	5.9		4.1	A
1	4	-	2	1	-	256	AJ30(P)	5150	700	27	19			
3	-	4	-	-	-	19	AJ508	1580	16	71				
4	2	-	1	1	1EM	215	AJ36	2260	34	49.0				W
-	2	1	1	1	1EM 1PBEM	407	AF131	2110	270	80				
6	3	-	-	-	2EM	266	AJ46	11850	950	11.7				
3	1	-	1	1	1PB 1PBEM	410	AF136	5150	700	32				
1	4	-	2	1	-	256	AF139(P)	19400	2500	7.9		4.5		
3	2	-		-		280	AF148	5625	180	39	20.	25.5	11.3	A
→ 5	-	-	1	-	1EB,1PM 2PB	417	AF154	6700	275	22				W

Notes:

A. Equipped with 0.014-inch stop discs.
W. Armature back tension minimum 20 grams readjust,15 grams test.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							12 CONTACTS							
12	-	-	-	-	-	8	AF37	1580	16	135				A
12	-	-	-	-	-	8	AF24(P)	5150	700	29				
12	-	-	-	-	-	8	AF83(P)	19400	2500	7.8				
12	-	-	-	-	-	8	AF504	2110	270	72				
12	-	-	-	-	-	8	AF506	5150	700	29				
2	3	-	2	1	1EM	213	AF9(P)	19400	2500	8.2				
5	-	-	2	1	1EM	206	AF23	3330	400	69.5				A
-	-	-	6	-	-	217	AF30(P)	19400	2500	8.2	5		1.8	
-	-	-	4	2	-	208	AF32(P)	5150	700	30.5				
-	-	-	4	2	-	208	AF513	5150	700	30.5				
10	2	-	-	-	-	16	AF33	11850	950	12.8				
2	2	4	-	-	-	25	AF54(P)	5150	700	29				
4	3	1	1	-	1EM	236	AF84(P)	19400	2500	8.2				
6	1	-	1	1	1EM	223	AF517	2110	270	80				
-	4	-	4	-	-	273	AF113(P)	19400	2500	8.2	5			
2	3	-	2	1	1EM	213	AJ27	16050	2200	14.2	8.6			A,E
-	3	-	2	1	2EM 1PM	406	AF120	11850	950	19.5	14.5			
4	-	4	-	-	-	49	AF122	1580	16	95				
5	7	-	-	-	-	40	AJ41	19400	2500	5.6				
-	-	-	6	-	-	217	AF147	19400	2500	8.8				T
1	5	-	1	-	3EM 1PM	420	AJ90	1580	16	100		53		
12	-	-	-	-	-	8	AF162	3950	200	38				
5	-	-	2	1	1EM	206	AF163	3950	200	40				
12	-	-	-	-	-	8	AJ96	2260	34	51				
3	5	-	2	-	-	317	AF157	5625	180	44.5	20	26	12	A,(AW)(AX)
4	-	-	3	1	-	323	AJ101	8275	500	17				
5	-	-	1	-	1EB-1EM 1PM-2PB	423	AF535	2110	270	80				←

X-75509

Notes:

A. Equipped with 0.014-inch stop discs.
E. Equipped with 0.046-inch copper sleeve.
T. Armature back tension minimum 65 grams readjust, 60 grams test.
AW. Conts 2, 4 & 10 make 8 readjust, 7 test.
no make 12 readjust, 13.5 test.
Conts 1,3,5,7,9 break 8 readjust, 7 test.
no break 12 readjust, 13.5 test.
AX. Armature back tension minimum 55 grams readjust, 50 grams test.
maximum 75 grams readjust, 80 grams test.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Oper	N.O.	Hold	Rls	See Notes
							13 CONTACTS							
3	1	-	3	1	1EM	212	AF49	3330	400	50.5	29			
1	4	4	-	-	-	24	AF53(P)	5150	700	30				
1	4	-	3	1	-	245	AF98	11850	950	14.1				
4	1	-	4	-	-	263	AJ18	5625	180	26.5				
7	-	-	3	-	-	268	AF112(P)	5150	700	33.5				
1	4	-	3	1	-	245	AF125	8275	500	20				
5	4	1	-	-	2EM	304	AF140(P)	19400	2500	8.6				
7	2	-	2	-	-	261	AF153	6700	275	38			10	A
1	-	2	2	-	3EM, 1PM	418	AF155	19400	2500	9.3				
1	2	1	3	1	-	291	AJ75(P)	19400	2500	6.5				
5	-	-	4	-	-	301	AJ84	10450	800	12.2		6.5		
							14 CONTACTS							
2	-	-	4	2	-	205	AF20(P)	5150	700	34				
→ 2	-	-	4	2	-	205	AF79(P)	19400	2500	9.2	4.5			
4	6	2	-	-	-	42	AF88(P)	5150	700	31.5	12.9			
7	2	-	1	1	1EM	244	AF95	1580	16	115	43			
7	3	-	2	-	-	285	AF116	3330	400	55.5				
10	-	2	-	-	-	61	AF132(P)	5150	700	32.5				
-	3	2	2	-	2EM 1PM	411	AJ51	3850	375	48.5	37.5		8.5	C,(RA)
→ -	-	2	1	4	-	238	AJ61	5150	700	30.5				(AM)
-	-	2	2	1	2PBEM	415	AF151(P)	2110	270	90				
2	2	-	2	1	1PBEM 1PMEB	419	AJ79	15800	1625	8.7				W
→ -	-	2	1	4	-	238	AJ89	2110	270	75	45			(AM)
-	-	2	1	4	-	238	AJ106	1580	16	100				(AM)
10	-	2	-	-	-	61	AF161	3950	200	41.5				
10	-	2	-	-	-	61	AF165	11850	950	14.2				
1	5	-	1	-	3EM-1PM 1PMEB	422	AJ105	1580	16	105	-	58		
→ 4	-	-	4	1	-	328	AJ111	8275	500	18.5				

Notes:

A. Equipped with 0.014-inch stop discs.
C. Equipped with 0.147-inch copper sleeve.
W. Armature back tension minimum 20 grams readjust, 15 grams test.
(AM). Frame of relay grounded by mounting screws. Not recommended for general use.
(RA). Resistance ±5 per cent.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

X-75509

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							15 CONTACTS							
8	-	-	2	1	1EM	235	AF82(P)	5150	700	40.5				
9	-	3	-	-	-	21	AF521	2110	270	85				
7	1	-	2	1	1EM	270	AF111(P)	5150	700	40.5				
9	-	3	-	-	-	21	AJ507(P)	2110	270	95				A
8	-	-	2	1	1EM	235	AJ509(P)	5150	700	31.5	13.6			
4	3	-	4	-	-	230	AF134(P)	19400	2500	9.8	4.9			
1	1	-	5	1	1EB	311	AF143	6925	860	27	14	14.5	5.7	
3	5	1	1	1	1EM	277	AJ68(P)	5150	700	27	19			
2	1	-	4	2	-	271	AJ91	3950	200	40				
							16 CONTACTS							
4	1	-	2	2	3EB	313	AJ62	6450	1000	36	22.5			A,C
3	1	-	4	2	-	224	AF42(P)	2110	270	95				
3	1	-	4	2	-	224	AF518	2110	270	95				
2	6	4	-	-	-	28	AF48(P)	2110	270	90				
7	1	4	-	-	-	26	AF55(P)	5150	700	35				
7	1	4	-	-	-	26	AF507	5150	700	35				
6	2	-	4	-	-	231	AF502	2760	395	72		46.5		
4	-	-	4	2	-	252	AF100(P)	5150	700	39.5				
3	1	6	-	-	-	31	AF515	2110	270	90				
3	1	6	-	-	-	31	AF121	1580	16	120				
3	1	6	-	-	-	57	AJ504	16050	2200	11.2	7.1			F
2	6	4	-	-	-	28	AF129(P)	19400	2500	9.5				
-	-	-	6	2	-	254	AJ32	730	4.4	230	90			(RB)
8	-	-	4	-	-	298	AJ53	6450	1000	37	22.5			A,C,(RA)
3	4	-	3	1	1EM	306	AJ54	6450	1000	36	22.5			A,C,(RA)
8	-	4	-	-	-	63	AJ515	6700	275	35				A
3	3	1	3	-	2EM	320	AJ94(P)	5150	700	32				
8	-	4	-	-	-	63	AJ95	11850	950	13.2				

Notes:

A. Equipped with 0.014-inch stop discs.
C. Equipped with 0.147-inch copper sleeve.
F. Equipped with 0.046-inch aluminum sleeve.
(RA). Resistance ±5 per cent.
(RB). Resistance ±15 per cent.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							17 CONTACTS							
4	2	1	-	1	1EM 2PMEB 1PBEM	413	AJ56	3330	400	54.5				
1	-	-	6	1	2EB	275	AJ64	6925	860	27	14	12.2	5.2	
							18 CONTACTS							
6	-	6	-	-	-	34	AF501	2760	395	75		47		
6	-	4	-	2	-	219	AF64(P)	19400	2500	10.6				
6	-	4	-	2	-	219	AF509	19400	2500	10.6			2.2	
-	6	6	-	-	-	59	AJ65	11850	950	14.2				
6	-	6	-	-	-	34	AF152	15800	1625	13				
							19 CONTACTS							
2	2	-	6	1	1EB	278	AJ69(P)	5150	700	30.5	13.6			
2	2	-	6	1	1EB	278	AJ93	3950	200	45.5				
							20 CONTACTS							
2	-	3	4	2	-	226	AJ3	11850	950	17		8.1		
→2	-	3	4	2	-	226	AJ500	11850	950	17	8.1			
2	-	3	4	2	-	226	AJ16	8275	500	36				A
-	-	-	8	2	-	234	AJ9(P)	5150	700	38				
-	-	-	8	2	-	234	AJ502	5150	700	38				
-	-	-	8	2	-	234	AJ22(P)	5150	700	38	13.4			
-	-	-	8	1	2EM	259	AJ21(P)	2110	270	95				
-	-	-	8	2	-	234	AJ37	1580	16	125				
→ 2	-	3	4	2	-	226	AJ107	11850	950	12.7				W

Notes:

A. Equipped with 0.014-inch stop discs.

→ W. Armature back tension minimum 20 grams readjust, 15 grams test.

TABLE II-1 (Contd)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							24 CONTACTS							
24	-	-	-	-	-	500	AJ202(P)	5150	700	40.5				
24	-	-	-	-	-	500	AJ200	8275	500	28.5				
24	-	-	-	-	-	500	AJ203	6700	275	35				
24	-	-	-	-	-	500	AJ700	2110	270	85				
24	-	-	-	-	-	500	AJ702	5150	700	40.5				
-	-	-	12	-	-	220	AJ5(P)	19400	2500	12.6				
-	-	-	12	-	-	220	AJ12(P)	5150	700	40.5				
-	-	-	9	3	-	249	AJ15(P)	5150	700	40.5				
-	-	-	9	3	-	249	AJ503	2110	270	90				
-	-	-	9	3	-	249	AJ501	5150	700	40.5				
-	-	12	-	-	-	64	AJ512	2110	270	85				
-	-	-	12	-	-	220	AJ39	11850	950	17.5	8.1			
-	-	-	9	3	-	249	AJ43	8275	500	23				
-	-	-	9	3	-	249	AJ45	1580	16	120				
-		5	2	1	2PBEM 2PMEB	414	AJ513	2110	270	100				
-	-	-	12	-	-	220	AJ81	8275	500	23				
-	-	-	9	3	-	249	AJ83(P)	19400	2500	12.6				
-	-	2	6	4	-	299	AJ516	5150	700	39				
-	-	-	12	-	-	220	AJ92	3950	200	48				
-	-	2	6	4	-	299	AJ103	8250	1050	23.5	11.6			C

X-75509

Notes

C. Equipped with 0.147-inch copper sleeve.

TABLE II-2

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Test Wdg	Oper	N.O.	Hold	Rls	See Notes
								1 CONTACT							
1	-	-	-	-	-	1	AJ8	P.L5200 S.L5200	400 400	P/S (soak	6 20)			1.8	Z A,R, G,L (AB)
1	-	-	-	-	-	1	AF510	P.L5200 S.L5200	400 400	P S	19 19.5				L
1	-	-	-	-	-	1B	AJ23	P.L3235 S.L3235	200 200	P/S	13.5	10		6.5	B,Y, R,H, L,W,Z
								2 CONTACTS							
2	-	-	-	-	-	2B	AJ1	P.L3235 S.L3235	200 200	P/S (soak	19 31)			10.8	B,Y, R,H,L
→1	1	-	-	-	-	52B	AJ24	P.L3235 S.L3235	200 200	P/S (soak	19 31)			9.3	B,Y, R,L,
1	1	-	-	-	-	52	AJ40	P.L2070 S.L2070	61 61	P/S	16.5			.2	G,L, R,W, (AJ)

Notes:

A. Equipped with 0.014-inch stop discs.
B. Equipped with 0.022-inch stop discs.
G. Contact make 5, no make 8.5, readjust; make 3.5, no make 10, test.
H. Contact make 10, no make 14.5, readjust; make 8.5, no make 16, test.
L. Winding arrangement No. 3.
R. P/S Primary and secondary in series aiding.
W. Armature back tension, minimum 20 grams readjust, 15 grams test.
Y. Laminations next to core.
Z. Adjusted on light contact pressure.
(AB). Armature back tension minimum 23 grams readjust, 20 grams test.
(AJ). Contact break 5, no break 8.5, readjust; break 3.5, no break 10, test.

TABLE II-2 (Contd)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

X-75509

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Test Wdg	Oper	N.O.	Hold	Rls	See Notes
								3 CONTACTS							
1	2	-	-	-	-	10	AF68(P)	P.7975	1000	P	12.3				K
								S.13950	2700	S	7.4				
3	-	-	-	-	-	46	AF96	P.1050	8.0	P	95	85			K,(RC)Z
								S.3770	850	S	28				
3	-	-	-	-	-	46	AF97	P.560	2.7	P	215	190			K,(RB)Z
								S.3020	690	S	42				
3	-	-	-	-	-	46	AF102	P.790	10	P	165	145			K,Z
								S.2950	400	S	46.5				
3	-	-	-	-	-	46	AF104	P.560	2.7	P	205	180			K,(RB),Z
								S.3020	690	S	40				
3	-	-	-	-	-	46	AF103	P.1050	8.0	P	115	100			K,(RC),Z
								S.3770	850	S	34				
3	-	-	-	-	-	46B	AJ29	P.L5520	425	P/S	7.5			3.8	A,L,R,Z,
								S.L5520	425		(soak 27)				W,G,(AG)
3	-	-	-	-	-	46B	AJ34	P.L3235	200	P/S	14.3		9.6	6.6	A,L,W,G
								S.L3235	200		(soak 100)				(AG),(AN),Y,Z
3	-	-	-	-	-	46	AJ50	P.2660	100	P/S	10	5.5			G,L,R,W
								S.2660	100						
2	1	-	-	-	-	37	AF133	P.9125	1175	P	10.8			1.9	K
								S.9125	1075	S	11.4				
2	1	-	-	-	-	37	AJ59	P.L5200	400	P/S	9.9			4.3	B,L,R,
								S.L5200	400						W
2	1	-	-	-	-	75	AJ102	P(L)3235	200	P/S	14	-	-	6.1	A,G,L,R,
								S(L)3235	200						W,Y, (AZ)
3	-	-	-	-	-	46	AJ115	P(L)5520	425	P/S	7.5	6.4	-	3.8	A,G,L,R, ←
								S(L)5520	425		(27 soak)				W,Z

Notes:

A. Equipped with 0.014-inch stop discs.
B. Equipped with 0.022-inch stop discs.
G. Contact make 5, no make 8.5, readjust; make 3.5, no make 10, test.
K. Winding arrangement No. 2.
L. Winding arrangement No. 3. } See X-pg 4 & X-12 Chart
R. P/S primary and secondary in series aiding.
W. Armature back tension minimum 20 grams readjust, 15 grams test.
Y. Laminations next to core.
Z. Adjusted on light contact pressure.
(AG). Armature back tension maximum 60 grams readjust, 65 grams test.
(AN). With 4.5 gauge inserted between armature and backstop and the relay not energized, no contact shall make.
(AZ). Contact break 13 readjust, 11.5 test, no break 16.5 readjust, 18 test.
(RB). Resistance ±15 per cent.
(RC). Secondary winding resistance ±15 per cent.

TABLE II-2 (Contd)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Test Wdg	Oper	N.O.	Hold	Rls	See Notes
								4 CONTACTS							
-	-	-	2	-	-	201	AF18(P)	P.2590	100	P	50.5				K
								S.9625	1100	S	14.3				
-	-	-	2	-	-	201	AF534	P.7975	1000	P	20				A,K
								S.13950	2700	S	10.8		6.6		
→2	2	-	-	-	-	41	AF101	P.3200	300	P	41.5	30	18.5		K
								S.3550	300	S	37				
→2	2	-	-	-	-	41	AJ19	P.3200	300	P	28		12.6		K
								S.3550	300	S	26		11.7		
4	-	-	-	-	-	3	AJ48	P.9400	1500	P	8	6.5			K,W
								S.15400	2950	S	5.1				
-	-	-	2	-	-	201	AF72	P.9125	1175	P	14.3				K
								S.9125	1075	S	15				
								5 CONTACTS							
5	-	-	-	-	-	4	AF71	P.9125	1175	P	11.8				K
								S.9125	1075	S	12.4				
→3	2	-	-	-	-	39	AJ10	P.10900	1800	P	6.8	4.3			W,K,S,Z, (RA)
								S.2770	85	P/S	25.5				
2	1	1	-	-	-	55B	AJ26	P.L3235	200	P/S	15.5			6.8	A,L,R, W,Y,Z
								S.L3235	200						
3	2	-	-	-	-	39	AJ510	P.560	2.7	P	240	215			K,Z,(RB)
								S.3020	690	S	47				
1	2	1	-	-	-	58	AJ66	P.L3235	200	P/S	15.5			6.8	A,L,R, W,Y,Z
								S.L3235	200						
-	3	-	1	-	-	315	AJ86	P.L3235	200	P/S	19.5			2.4	L,R,Y
								S.L3235	200		After Soak 31				

Notes:

A. Equipped with 0.014-inch stop discs.
K. Winding arrangement No. 2.
L. Winding arrangement No. 3.
R. P/S Primary and secondary in series aiding.
S. P//S Primary and secondary in parallel aiding.
W. Armature back tension minimum 20 grams readjust, 15 grams test.
Y. Laminations next to core.
Z. Adjusted on light contact pressure.
(RA). Resistance ±5 per cent.
(RB). Resistance ±15 per cent.

TABLE II-2 (Contd)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

X-75509

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Test Wdg	Oper	N.O.	Hold	Rls	See Notes
								6 CONTACTS							
2	-	-	1	1	-	225	AF66(P)	P.2590	100	P	61.5	46			K
								S.9625	1100	S	17				
1	1	-	1	1	-	202	AF70(P)	P.7975	1000	P	16.5				K
								S.13950	2700	S	9.9				
-	2	-	1	1	-	251	AF99(P)	P.7975	1000	P	16.5				K
								S.13950	2700	S	9.9				
2	2	-	1	-	-	284	AF528	P.2590	100	P	62	36		21	A,K,(AG)
								S.9625	1100	S	17.5				
2	-	-	1	1	-	225	AF141	P.4550	540	P/S	16.0	11.6			K,R
								S.3730	540						
2	-	-	2	-	-	237	AJ57	P.L3235	200	P/S	19	10(Soak 31)		2.7	L,R,Y
								S.L3235	200						
6	-	-	-	-	-	5	AJ73	P.4800	360	P	26			6.6	A,K,R
								S.13150	1900	P/S	7				
								7 CONTACTS							
2	1	-	2	-	-	218	AF109	P.2590	100	P	50.5		27		K
								S.9625	1100	S	14.5				
3	-	-	2	-	-	294B	AJ38	P.2800	170	P	45	18.5		11.4	K
								S.3850	140	S	34.5			(soak 90)	
-	-	3	-	-	1EM	302	AJ49	P.4400	220	P	26.5	21.5			E,K
								S.6775	1150	S	18				

Notes:

A. Equipped with 0.014-inch stop discs.
E. Equipped with 0.046-inch copper sleeve.
K. Winding arrangement No. 2.
L. Winding arrangement No. 3.
R. P/S Primary and secondary in series aiding.
Y. Laminations next to core.
(AG). Armature back tension maximum 60 grams readjust, 65 grams test.

TABLE II-2 (Contd)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT						Spg		WINDING		Test	CURRENT FLOW REQTS				See
M	B	BM	EBM	EMB	Other	Comb.	Code	Turns	Res.	Wdg	Oper	N.O.	Hold	Rls	Notes
								8 CONTACTS							
2	-	-	1	2	-	303	AJ52	P.L5200	400	P/S	12.6	-	-	3.3	L,R
								S.L5200	400						
7	1	-	-	-	-	66	AJ42	P.2070	61	P/S	27.5				L,R
								S.2070	61						
6	2	-	-	-	-	13	AF11(P)	P.2590	100	P	61	25.5			R,K
								S.9625	1100	P/S	13.5				
4	-	-	2	-	-	210	AF130	P.2590	100	P	54				(AG),K
								S.9625	1100	S	15.5				
-	-	-	4	-	-	203	AF73	P.9125	1175	P	14.5				K
								S.9125	1075	S	15.5				
2	-	-	1	2	-	303	AJ88	P.L3235	200	P/S	25	-	-	7.1	A,L
								S.L3235	200						R,Y
→5	-	-	-	1	1EM	327	AF167	P.10500	950	P	13.1				
								S.3450	450	S	38	-	-	8.4	K
								9 CONTACTS							
8	1	-	-	-	-	48	AF533	P.3200	300	P	44.5	24			K
								S.3550	300	S	41.5				
1	4	-	2	-	-	293	AJ77	P.L3235	200	P/S	27	17.5			A,L,R,Y
								S.L3235	200						
→5	-	-	1	1	-	319	AJ110	P.L3235	200	P/S	19.5	(31 soak)		3.2	L,R,Y
								S.L3235	200						
→1	4	-	2	-	-	293	AJ114	P.560	2.7	P	225	175			K,RB,
								S.3020	690	S	47				RC
								10 CONTACTS							
2	2	-	2	1	-	200	AF8(P)	P.7975	1000	P	18.5	12			K
								S.13950	2700	S	11.1				
10	-	-	-	-	-	6	AF525	P.7100	700	P	20				K
								S.7150	700	S	21				

Notes:

A. Equipped with 0.014-inch stop discs.
K. Winding arrangement No. 2.
L. Winding arrangement No. 3.
R. P/S primary and secondary in series aiding.
Y. Laminations next to the core.
(AG). Armature back tension maximum 60 grams readjust, 65 grams test.
→ (RB). Resistance variation ±15%.
→ (RC). Resistance variation on secondary winding ±15%.

TABLE II-2 (Contd.)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

X-75509

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Test Wdg.	Oper	N.O.	Hold	Rls	See Notes
								11 CONTACTS							
3	4	-	1	1	-	228	AF21	P.9125	1175	P	19.5	8.9			K
								S.9125	1075	S	20.5				
7	-	2	-	-	-	20	AF12(P)	P.7975	1000	P	18.5		10		K
								S.13950	2700	S	11.1				
4	2	-	1	1	1EM	215	AF127	P.13930	335	P/S	27.5	14.5		8.1	A,L,R, (RA)
								S.13930	335						
4	1	-	3	-	-	204	AF532	P.7975	1000	P	20				K
								S.13950	2700	S	10.9	6.9			
2	4	-	-	2	1EB	322	AJ99	P.(L)3235	200	P/S	25.5			8	A,L,R,W,Y ←
								S.(L)3235	200						
								12 CONTACTS							
12	-	-	-	-	-	8	AF77	P.3200	300	P	46.5				K ←
								S.3550	300	S	41.5				←
4	1	-	2	1	1EM	243	AF94(P)	P.7975	1000	P	20	595 AT			K
								S.13950	2700	S	12	167 AT			
-	-	-	6	-	-	217	AF530	P.3200	300	P	49.5				K ←
								S.3550	300	S	46				←
-	-	-	6	-	-	217	AF123	P.9125	1175	P/S	8.8				K,R,(AM)
								S.9125	1075						
5	-	-	2	1	1EM	206	AJ511	P.7100	700	P	20		11.		K
								S.7150	700	S	21				
4	3	2	-	-	1EM	308	AJ58	P.4400	220	P	26.5	21.5			E,K,(AL)
								S.6775	1150	P	28				
										S	18				

Notes:

A. Equipped with 0.014-inch stop discs.
E. Equipped with 0.046-inch copper sleeve.
K. Winding arrangement No. 2.
L. Winding arrangement No. 3.
R. P/S primary and secondary in series aiding.
→ W. Armature back tension minimum 20 grams readjust, 15 grams test.
→ Y. Laminations next to core.
(AL). Only contacts in position 12 need make on 26.5 primary operate.
→ (AM). Frame of relay grounded by mounting screws. Not recommended for general use.
(RA). Resistance ±5 per cent.

TABLE II-2 (Contd)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Test Wdg	Oper	N.O.	Hold	Rls	See Notes
								13 CONTACTS							
6	1	-	3	-	-	247	AF529	P.3620	550	P	46.5				AS
								S.3620	550	S	49				
								T.3620	525	T	49				
5	-	4	-	-	-	62	AJ55	P.22600	5000	P	6.2				K
								S.6140	1000	S	24				
6	3	-	2	-	-	321	AJ97	P.4100	210	P//S	26				K,S,W
								S.8375	1000	S	14.2				
								15 CONTACTS							
→ 7	-	-	3	-	2EM	330	AJ116	P.7975	1000	P	22	11.6			
								S.13950	2700	S	11.8	6.9			K
								16 CONTACTS							
2	5	-	3	1	1EM	250	AJ14(P)	P.7975	1000	P	21				K
								S.13950	2700	S	12.6				
5	-	-	4	1	1EM	257	AJ28(P)	P.7975	1000	S	11.8	6.9	7.1	2	K
								S.13950	2700	P	22	11.6			
-	5	-	4	1	1EM	265	AJ20(P)	P.7975	1000	P	21				K
								S.13950	2700	S	12.6				
-	-	-	6	2	-	254	AF128	P.9125	1175	P	22				K
								S.9125	1075	S	23.5				
2	5	-	3	1	1EM	250	AJ71	P.7975	1000	P	21	12			K
								S.13950	2700	S	12.6				
-	-	2	2	4	-	318	AJ517	P.5750	700	P	28.5				K
								S.17400	3300	S	9.7				
→ 2	5	-	3	1	1EM	250	AJ109	P.2590	100	P	63.5	27			K
								S.9625	1100	S	18				
								17 CONTACTS							
4	-	-	4	2	1EB	316	AJ87	P.7550	1200	P/S	5.2		3.7		R,AA,AE
								S.19666	6000	P	19				
								18 CONTACTS							
5	1	-	6	-	-	227	AJ514	P.7100	700	P	25.5				K
								S.7150	700	S	26.5				
6	-	3	3	-	-	283	AJ70	P.7975	1000	S	10.6				K
								S.13950	2700	P	19.5				

Notes:

K. Winding arrangement No. 2
R. P/S Primary and secondary series aiding.
S. P//S primary and secondary in parallel aiding.
→ W. Armature back tension minimum 20 grams readjust, 15 grams test.
AA. Winding arrangement No. 9.
AE. Resistance variation ±3 per cent on secondary winding.
AR. Winding arrangement No. 6.
AS. Winding arrangement No. 7.

TABLE II-2 (Contd)

CODE INFORMATION

MULTIPLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Test Wdg	Oper	N.O.	Hold	Rls	See Notes
								19 CONTACTS							
2	2	-	6	1	1EB	278	AJ78	P.7975	1000	P	19.5	12			K
								S.13950	2700	S	11.7				
								20 CONTACTS							
4	-	8	-	-	-	77	AJ113	P.22600	5000	P	6.7				K
								S.6140	1000	S	26				
								24 CONTACTS							
-	-	12	-	-	-	64	AJ72	P.7100	700	P	32				K
								S.7150	700	S	33.5				
24	-	-	-	-	-	500	AJ204	P.7100	700	P	29.5				K
								S.7150	700	S	31				

Notes:

K. Winding arrangement No. 2.

TABLE II-3

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME-MS		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Notes
								4 CONTACTS									
3	1	-	-	-	-	38B	AG12	15800	1625	-	19	R 6.4 T 6.8	0.8 0.9	0.6 0.4			
-	-	-	1	-	PBEM	405B	AG19	8250	1050	0.147	36	R20 T21	1.8 2.0	1.3 1.0	250	500	(AF)
								5 CONTACTS									
3	2	-	-	-	-	39B	AG4	8250	1050	0.147	36	R11.8 T12.4	1.6 1.7	1.2 0.9	295	540	
2	1	1	-	-	-	44B	AG8	13500	2000	0.091	20	R 7.3 T 7.7	1.0 1.1	0.7 0.5	190	390	
-	-	-	2	-	1PM	402B	AG13	16050	2200	0.046 CU	18	R 7.8 T 8.2	1.0 1.1	0.7 0.5	90	235	
5	-	-	-	-	-	4B	AG31	P.3000 S.3460	450 200	-	90	P.R35 P.T37 S.R32 S.T34	4.6 4.9	3.6 3.2	95	160	(AD), (AE), (AR)

X-75509

Notes:

(AD). Requirements apply to primary winding with secondary winding short-circuited.
(AE). Resistance variation ±3 per cent on secondary winding.
(AF). Armature back tension minimum 45 grams readjust, 40 grams test.
(AR). Winding arrangement No. 6.

TABLE II-3 (Contd)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME-MS		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Notes
								6 CONTACTS									
→ 3	3	-	-	-	-	45B	AG14	P.3330 S.3440	400 210	-	90	P.R30 P.T31.5 S.R30.5 S.T32.5	4.4 4.7	3.6 3.3	85	137	(AD), (AE), (AH),(AR)
2	-	2	-	-	-	18B	AG24	8250	1050	.147	36	R13 T13.7	1.5 1.6	1.0 0.7	300	620	Z
3	3	-	-	-	-	45B	AG27	P.3250 S.2430	198 80	-	95	P.R32 P.T34 S.R45 S.T47.5	4.5 4.8	3.4 2.7	103	206	K,(AD)
4	2	-	-	-	-	67B	AG35	P.3330 S.3440	400 210	-	90	P.R30 P.T31.5 S.R30.5 S.T32.5	4.4 4.7	3.6 3.3	85	137	(AD), (AE), (AH), (AR)
-	-	3	-	-	-	50	AG40	19400	2500	-	6.3	R4.4 T4.7	0.8 0.9	0.5 0.4			
								7 CONTACTS									
1	2	-	2	-	-	246B	AG9	15800	1625	-	19	R8.9 T9.4	1.1 1.2	0.9 0.8			
3	-	-	-	2	-	282B	AG21	P.3000 S.2540	450 57	- -	100	P.R46 P.T48.5 S.R57.5 S.T60.5	5.7 6	4.6 3.9	136	267	K,(AD), (AH)
2	3	1	-	-	-	56B	AG22	P.3000 S.2540	450 57	- -	100	P.R34 P.T36 S.R42.5 S.T45	5.3 5.6	4.2 3.5	144	288	K,(AD), (AH)
1	-	-	3	-	-	267B	AG30	8275	500	-	36	R17 T18	2.0 2.1	1.6 1.3	7.2	17	
2	-	-	2	-	1EM	325B	AG54	P.4800 S.13150	360 1900	-	65	P.R29 P.T30.5 S.R11 S.T11.7	3.6 3.8	2.6 2.2			K

Notes:

K. Winding arrangement No. 2.
Z. Adjusted on light contact pressure.
(AD). Requirements apply to primary winding with secondary winding short-circuited.
(AE). Resistance variation ±3 per cent on secondary winding.
(AH). Armature back tension maximum 80 grams readjust, 85 grams test.
(AR). Winding arrangement No. 6.

TABLE II-3 (Contd)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME-MS		
M	B	BM	EBM	EMB	Other	Spg. Comb.	Code	Turns	Res.	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Notes
								8 CONTACTS									
5	3	-	-	-	-	36B	AG2	8250	1050	0.147	36	R11.8	2.0	1.4			
												T12.4	2.1	1.1	245	475	
2	2	-	2	-	-	233B	AG3	8250	1050	0.147	36	R16.5	2.4	1.4			
												T17.5	2.6	1.1	195	475	T
2	2	-	2	-	-	233B	AG16	8250	1050	0.147	36	R16.5	2.1	1.4			
												T17.5	2.3	1.1	225	475	
2	2	-	2	-	-	233	AG11	8250	1050	0.147	36	R16.5	2.1	0.7			
												T17.5	2.3	0.4	225	830	
3	-	-	1	1	1EM	221	AG15	7800	600	0.091	38	R17.5	2.3	0.8			
												T18.5	2.5	0.5	147	512	
2	2	-	2	-	-	286B	AG23	15800	1625	-	19	R 6.4	1.1	0.8			
												T 6.8	1.2	0.6			
1	-	-	1	2	1EB	297B	AG37	P.3000	450	-	100	P.R46	5.9	4.6			
								S.2540	57			P.T48.5	6.3	3.9	130	275	K,(AD)
												S.R57.5					
												S.T60.5					
3	3	-	-	1	-	296B	AG36	7800	600	0.091	38	R14.7	2.3	1.8			
												T15.5	2.5	1.5	150	280	(AG)
-	-	-	1	2	2EB	290B	AG47	P.3000	450	-	100	R.P46	5.9	4.6			
								S.2450	57			T.P48.5	6.3	3.9	130	275	K,(AD)
												R.S57.5					
												T.S60.5					
4	2	1	-	-	-	72B	AG51	23,600	4000	-	10	R. 4.2	.7	.5			(AY) ←
												T. 4.5	.8	.4			
								9 CONTACTS									
8	1	-	-	-	-	48B	AG18	13500	2000	0.091	20	R 7.6	1.4	0.9			
												T 8.0	1.5	0.7	142	320	
2	3	-	2	-	-	264B	AG41	13500	2000	0.091	20	R10.2	1.7	1.3			
												T10.8	1.8	1.1	120	235	
3	2	2	-	-	-	76B	AG55	P.6525	1000	-	46	P.R15	2.7	1.9			
								S.2260	42			P.T16	2.9	1.6	145	325	K,(AD) ←

X-75509

Notes:

K. Winding arrangement No. 2.
T. Armature back tension minimum 65 grams readjust, 60 grams test.
(AD). Requirements apply to primary winding with secondary winding short-circuited.
(AG). Armature back tension maximum 60 grams readjust, 65 grams test.
(AY). The use of a protective network on the coil is required to limit the peak voltage to a safe value.

TABLE II-3 (Contd)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME-MS		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Notes
								10 CONTACTS									
4	1	-	1	1	1EM	222B	AG26	5575	550	0.147	33	R25	3.9	2.5			
												T26.5	4.1	2.1	187	402	
3	3	-	-	2	-	279B	AG42	10050	875	0.046AL	30	R14	1.9	0.7			
												T14.7	2.1	0.5	46	175	
								11 CONTACTS									
7	-	2	-	-	-	20B	AG45	16050	2200	0.046AL	18	R6.6	1.3	1.1			
												T7	1.4	0.9	40	85	
→ 7	-	2	-	-	-	20B	AG46	7975	1000	-	P38	PR12.8	2.7	1.7			K
								13950	2700			PT13.5	2.9	1.4	5	16	
												SR7.7					
												ST8.1					
								12 CONTACTS									
8	4	-	-	-	-	35B	AG1	8250	1050	0.147	36	R12.1	2.5	1.6			
												T12.8	2.7	1.3	190	425	
8	4	-	-	-	-	35B	AG10	10050	875	0.046AL	30	R10.2	2.1	1.4			
												T10.8	2.3	1.2	42	100	
2	3	-	2	1	1EM	213B	AG38	P.3000	450	-	100	P.R47	7.9	6.0			
								S.2540	57			P.T49.5	8.4	5.2	96	210	K,(AD)
												S.R58.5					
												S.T61.5					
												P NO 26.5R,25T					
→ 2	2	-	2	1	1EM	416B	AG49	P.3000	450	-	100	P.R56	8.0	6.6			K,(AD)
					1PM			S.2540	57			P.T59	8.4	5.9	95	195	
												S.R70					
												S.T74					
								13 CONTACTS									
7	-	-	3	-	-	268B	AG28	10050	875	0.046CU	20	R14.5	2.8	1.3			
												T15.5	2.5	1.1	61	145	
3	3	-	2	1	1EM	305B	AG33	10050	875	0.046AL	30	R14	2.3	1.5			
												T14.7	2.5	1.3	40	95	
3	-	-	5	-	-	307B	AG34	8250	1050	0.147	36	R17	2.8	1.8			
												T18	3.0	1.5	175	395	
7	-	-	3	-	-	268B	AG39	P.7975	1000	-	38	P.R17.5	3.0	1.9			
								S.13950	2700			P.T18.5	3.2	1.6	4.5	14	K
												S.R10.5					
												S.T11.1					

Notes;

K. Winding arrangement No. 2.
(AD). Requirements apply to primary winding with secondary winding short-circuited.

TABLE II-3 (Contd)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME-MS		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Notes
								14 CONTACTS									
1	1	-	4	2	-	239B	AG6	16050	2200	0.046AL	18	R8.8	1.5	1.0			
												T9.3	1.6	0.8	37	95	
5	-	4	-	-	1EM	281B	AG44	6525	1000	-	46	P.R21.5	3.8	2.4			K
								2260	42			P.T23	4.0	2.1	95	250	(AD)
												S.R65					
												S.T70					
								15 CONTACTS									
7	-	-	4	-	-	241B	AG7	8250	1050	0.147	36	R16.5	3.0	1.9			
												T17.5	3.2	1.6	155	365	
2	1	-	4	2	-	271B	AG17	16050	2200	0.046CU	18	R8.8	1.6	1.0			
												T9.3	1.7	0.8	55	150	←
5	-	-	3	2	-	262B	AG20	13500	2000	0.091	20	R10.2	1.9	1.1			
												T10.7	2.0	0.9	103	260	
4	3	-	4	-	-	230B	AG48	13500	2000	0.091	20	R10.2	1.9	1.2			
												T10.8	2.0	1.0	105	250	
								16 CONTACTS									
3	1	-	4	2	-	224B	AG32	P.7975	1000	-	38	P.R17.5	3.5	2.0			K,R
								S.13950	2700			P.T18.5	3.7	1.7	3.7	13.5	
												P/SR6.6	1.4				
												P/ST7.0	1.5				
												P NO 9.2R, 8.7T					
-	-	2	2	4	-	318B	AG52	P.5750	700		50	P.R24	4.5	2.8			K
								S.17[illegible]00	3300	-		P.T25.5	4.8	2.5	4	13	
												S.R8.3					
												S.T8.9					

X-75509

Notes:

K. Winding arrangement No. 2.
R. P/S = Primary-secondary in series aiding.
(AD). Requirements apply to primary winding with secondary winding short-circuited.

TABLE II-3 (Contd)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME-MS		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Notes
								17 CONTACTS									
-	-	3	2	1	1EM 2PMEB	408B	AG29	7800	600	0.91CU	39	R22 T23.5	3.7 3.9	2.2 1.9	90	235	
→ 4	2	1	-	1	1EM 1PBEM 2PMEB	413B	AG56	P.3000 S.2540	450 57	-	100 100	P.R57 P.T60 S.R71 S.T75	9.7 10.2	6 5.3	74	205	K,(AD)
								18 CONTACTS									
6	-	6	-	-	-	34B	AG43	8250	1050	.147CU	36	R15.5 T16.5	3.3 3.5	2.0 1.7	145	360	
2	-	3	5	-	-	314B	AG50	16050	2200	.046CU	18	R8.8 T9.3	1.8 1.9	1.3 1.1	45	115	
								21 CONTACTS									
→ 3	-	3	6	-	-	326	AG57	16050	2200	.046CU	18	R.9.4 T.9.9	2.0 2.1	1.1 0.9	40	100	
								24 CONTACTS									
-	-	-	9	3	-	249B	AG53	3000 2540	450 57	-	100 100	P.R62 P.T65 S.R80 S.T85	11.4 12	6.6 5.9	57	195	K,(AD)

Notes:

K. Winding arrangement No. 2
(AD). Requirements apply to primary winding with secondary winding short-circuited.

TABLE II-4

CODE INFORMATION

AK RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS.				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
							4 CONTACTS							
2	-	-	-	-	-	8	AK12	T 12300	1500	9.5				(AV)
2	-	-	-	-	-			B 12300	1500	9.5				
							6 CONTACTS							
2	-	-	-	-	-	11	AK25	T 8600	640	13.5			2.	(AV)
4	-	-	-	-	-			B 8600	640	13.5			2.6	
1	1	1	-	-	-	5	AK9	T 15750	2450	7.3				(AV)
1	1	-	-	-	-			B 4000	145	24	12.5			
							7 CONTACTS							
3	-	-	-	-	-	213	AK18	T 4000	210	41				(AV)
-	1	-	1	-	1EM			B 4000	210	41				

X-75509

Notes:

(AV) Winding arrangement No. 8.

TABLE II-4 (Contd)

CODE INFORMATION

AK RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS.				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
								8 CONTACTS						
1	1	-	-	1	-	206	AK11	T 10300	960	16.5				(AV)
1	1	-	-	1	-			B 10300	960	16.5				
1	3	-	-	-	-	4	AK5	T 8600	640	15				(AV)
1	3	-	-	-	-			B 8600	640	15				
3	-	-	-	-	-	217	AK20	T 8600	640	19.5				(AV)
1	-	-	2	-	-			B 8600	640	19.5				
-	-	2	-	-	-	3	AK3	T 4820	185	31				(AV)
-	-	2	-	-	-			B 5825	280	26				
-	-	2	-	-	-	3	AK23	T 15750	2450	7.4				(AV)
-	-	2	-	-	-			B 15750	2450	7.4				
								10 CONTACTS						
2	1	-	-	-	-	9	AK15	T 8600	640	13.5		5.6		(AV)
1	-	3	-	-	-			B 10300	960	11.9				
3	-	-	-	1		218	AK27	T 8600	640	19.5				(AV)
1	1	-	-	1	1EB			B 15750	2450	10.5				
5	-	-	-	-	-	1	AK2	T 10300	960	11.5				(AV)
5	-	-	-	-	-			B 10300	960	11.5				
-	1	2	-	-	-	13	AK29	T 15750	2450	7.4				(AV)
-	1	2	-	-	-			B 15750	2450	7.4				
-	1	2	-	-	-	13	AK38	T 10300	960	11.3		5.1		(AV)
-	1	2	-	-	-			B 10300	960	11.3		5.1		

Notes:

(AV) Winding arrangement No. 8.

TABLE II-4 (Contd)

CODE INFORMATION

AK RELAYS

X-75509

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS.				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
								12 CONTACTS						
2	-	2	-	-	-	12	AK24	T 15750	2450	7.4				(AV)
2	-	2	-	-	-			B 15750	2450	7.4				
3	-	-	-	1	1EM	215	AK21	T 8600	640	19.5				(AV)
3	-	-	-	1	1EM			B 8600	640	19.5				
-	-	-	3	-	-	214	AK19	T 4000	210	41				(AV)
-	-	-	3	-	-			B 4000	210	41				
								13 CONTACTS						
1	1	-	2	1	-	201	AK1	T 6900	410	24.5				(AT)(AV)
1	2	-	1	-	-			B 4380	315	36.5	(46 Soak)	4.9		
2	2	1	-	-	-	10	AK26	T 8600	640	13.8				(AV)
2	1	2	-	-	-			B 8600	640	14.2				
-	-	5	-	-	-	14	AK31	T 8125	955	22.5				(AV)
2	1	-	-	-	-			B 4000	145	29				
3	2	-	-	-	-	209	AK33	T 15750	2450	10.4		3.5		(AV)
-	-	-	1	2	2EB			B 15750	2450	12.6		1.5		(BB)
1	3	1	-	-	-	15	AK34	T 8600	640	13.8				(AV)
2	1	2	-	-	-			B 8600	640	14.2				
1	1	-	2	1	-	201	AK37	T 12300	1500	13.5				(AV)
1	2	-	1	-	-			B 7600	1100	22	(35 Soak)	2.5		(AT)

Notes:

(AT) Copper sleeve and domed armature on bottom unit.
(AV) Winding arrangement No. 8.
(BB) Domed armature on bottom unit.

TABLE II-4 (Contd)

CODE INFORMATION

AK RELAYS

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS.				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
								14 CONTACTS						
2	-	-	1	1	1EM	204	AK8	T 15750	2450	8.7			1.8	(AV)(W)
1	1	-	2	-	1EM			B 10300	960	16				
2	-	-	1	1	1EM	212	AK17	T 4000	210	41				(AV)
2	-	-	1	1	1EM			B 4000	210	41				
3	-	-	-	1	1EM	219	AK28	T 725	5.5	230	110			(AV)(RB)
1	-	-	2	1	1EM			B 12300	1500	13.7				
3	-	-	-	2	-	211	AK16	T 3400	100	48.5	33			(AV)
3	-	-	-	2	-			B 3400	100	48.5	33			
-	2	-	3	-	-	208	AK14	T 6900	410	24				(AV)
-	-	-	3	-	-			B 6900	410	24				
2	-	-	-	2	1EM	210	AK32	T 4000	210	41				(AV)
2	-	-	-	2	1EM			B 4000	210	41				
								15 CONTACTS						
4	-	1	-	-	-	7	AK10	T 15750	2450	7.4		1.5		(AV)(AU)
1	-	4	-	-	-			B 10300	960	15.5		2.6		
								16 CONTACTS						
-	-	-	3	-	2EM	203	AK13	T 8600	640	23				(AV)
-	-	-	3	-	2EM			B 8600	640	23				
-	-	-	3	-	2EM	203	AK7	T 8125	955	25.5	11			(AV)
-	-	-	3	-	2EM			B 8125	955	25.5	11			

Notes:

(W) Armature back tension minimum 20 grams readjust, 15 grams test.
(AU) Domed armature on top and bottom units.
(AV) Winding arrangement No. 8.
(RB) Resistance variation on top winding ±15%.

TABLE II-4 (Contd)

CODE INFORMATION

AK RELAYS

X-75509

CONTACT ARRANGEMENT								WINDING		CURRENT FLOW REQTS.				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res.	Oper	N.O.	Hold	Rls	See Notes
								18 CONTACTS						
1	-	-	2	2	-	202	AK4	T 15750	2450	11.3				(AV)
1	-	-	2	2	-			B 15750	2450	11.3				
1	-	-	2	2	-	202	AK30	T 8600	640	22				(AV)
1	-	-	2	2	-			B 8600	640	22				
1	-	-	2	2	-	202	AK35	T 15750	2450	11.8				(AT)
1	-	-	2	2	-			B 6250	680	30	(48 Soak)	4.2		(AV)
-	-	5	-	-	-	16	AK36	T 1390	16	135				(AV)
-	2	3	-	-	-			B 12300	1500	11				
								20 CONTACTS						
-	-	5	-	-	-	2	AK6	T 8600	640	27.5				(AV)
-	-	5	-	-	-			B 8600	640	27.5				
-	-	-	3	2	-	216	AK22	T 8600	640	26				(AV)
-	-	-	3	2	-			B 8600	640	26				

Notes:

(AT) Copper sleeve and domed armature on bottom unit.
(AV) Winding arrangement No. 8. - Coil Tab pg X 12-D

TABLE II-5

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	Avg
AF 1								
2								
3	400	6	7.0	3.5	5.3	9.2	1.4	4.2
4	400	18	7.0	3.5	5.3	11.5	1.8	5.4
5	270	6	5.6	2.8	4.2	9.2	1.4	4.2
6	16*	29	4.4	2.2	3.3	8.8	1.4	4.1
7								
8	P-1000	200	20.5	10.0	13.7	9.3	1.3	4.1
	S-2700		48.0	16.0	27.5			
9	2500	213	48.0	13.0	29.0	8.5	1.2	3.4
10	2500	214	40.0	15.0	29.0	9.7	1.4	4.2
11	P-100	13						
	S-1100		23.7	7.9	11.0	10.2	1.6	4.8
12	P-1000	20	20.5	6.8	10.5	8.8	1.4	4.1
	S-2700		48.0	9.0	17.0			
13	2500	215	90.0	13.0	33.0	4.0	1.0	2.1
14								
15	2500	216	37.0	13.0	29.0	13.1	2.0	5.6
16	700	204	12.0	5.1	8.3	8.9	1.3	3.8
17	270	211	8.7	3.9	6.7	11.5	2.0	5.6
18	P-100	201						
	S-1100		21.5	9.0	16.0	13.1	2.0	5.6
19	16*	3	4.4	2.2	3.3	13.2	2.2	6.2
20	700	205	12.0	5.1	8.3	8.0	1.1	3.3
21	P-1175	228	25.8	9.2	15.0	8.9	1.3	3.8
	S-1075		25.0	8.7	15.0			
22	270	207	7.9	3.6	5.6	11.5	1.7	5.2
23	400	206	10.1	4.5	7.1	3.9	1.0	2.1
24	700	8	9.1	4.5	6.7	8.4	1.3	3.8
25	16*	11	4.4	2.2	3.3	11.5	1.8	5.4
26	950	5	19.0	8.0	12.0	11.5	1.8	5.4
27	400	11	7.0	3.5	5.3	11.5	1.8	5.4
28	500	400B	20.5	9.6	13.8	4.2	1.0	1.7
29								
30	2500	217	48.0	13.0	29.0	8.5	1.2	3.7
31								
32	700	208	12.0	5.1	8.3	8.5	1.2	3.7
33	950	16	26.0	8.0	12.0	8.4	1.3	3.8
34	700	14	9.1	4.5	6.7	9.2	1.4	4.2
35	270	248	7.9	3.6	5.6	9.7	1.4	4.2
36								
37	16*	8	4.7	2.4	3.5	4.0	1.0	2.3
38								
39								
40	270	222	7.9	3.6	5.6	9.3	1.3	4.1
41								
42	270	224	7.9	3.6	5.6	7.5	1.1	3.1
43	270	17	5.6	2.8	4.2	14.2	2.3	6.5
44	270	3	5.6	2.8	4.2	13.2	2.2	6.2
45								

*In series with 90ω noninductive resistance.

TABLE II-5 (Contd)

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res.	Spg Comb.	Operate Times Max	Operate Times Min	Operate Times Avg	Release Times Max	Release Times Min	Release Times Avg
AF 46								
47								
48	270	28	5.6	2.8	4.2	7.2	1.1	3.2
49	400	212	10.5	4.5	7.3	8.3	1.1	3.3
50	700	18	10.0	4.9	7.3	11.5	1.8	5.4
51	700	3	9.1	4.5	6.7	13.2	2.2	6.2
52	700	19	9.1	4.5	6.7	8.8	1.4	4.1
53	700	24	9.1	4.5	6.7	8.1	1.2	3.7
54	700	25	9.1	4.5	6.7	8.4	1.3	3.8
55	700	26	9.1	4.5	6.7	7.2	1.1	3.2
56	700	209	12.0	5.1	8.3	15.5	2.4	6.9
57	700	210	12.0	5.1	8.3	10.2	1.5	4.5
58								
59	2500	3	29.0	10.0	20.0	13.2	2.2	6.2
60	2500	12	34.0	10.0	20.0	10.7	1.7	4.5
61	2500	23	31.0	10.0	20.0	12.5	2.0	5.7
62								
63	2500	229	39.0	13.0	29.0	10.9	1.5	4.8
64	2500	219	74.0	13.0	29.0	7.0	1.0	2.8
65								
66	P-100	225						
	S-1100		26.5	10.0	16.0	11.5	1.7	5.2
67	2500	207	40.0	13.0	29.0	11.5	1.7	5.2
68	P-1000	10	13.0	6.8	10.5			
	S-2700		26.0	9.0	17.0	14.2	2.3	6.5
69								
70	P-1000	202	18.7	8.2	14.0			
	S-2700		42.5	12.0	25.5	11.5	1.7	5.2
71	P-1175	4	17.8	6.7	11.5	12.5	2.0	5.7
	S-1075		17.5	6.8	11.5			
72	P-1175	201	19.5	8.6	15.0	13.1	2.0	5.6
	S-1075		21.4	8.2	15.0			
73	P-1175	203	19.5	8.6	15.0	10.9	1.5	4.5
	S-1075		21.4	8.2	15.0			
74								
75								
76								
77	P-300	8	6.6	3.5	5.1	8.4	1.3	3.8
	S-300		7.0	3.8	5.4			
78								
79	2500	205	60.0	13.0	29.0	8.0	1.1	3.3
80								
81								
82	700	235	12.0	5.1	8.3	7.7	1.1	3.2
83	2500	8	46.0	10.0	20	8.4	1.3	3.8
84	2500	236	48.0	13.0	29.0	8.5	1.2	3.4
85	1000	401	175.0	50.0	97.0	86.0	17.5	55.0
86	500	237	16.0	9.0	13.7	11.5	1.7	5.2
87	2550	240	270.0	55.0	98	210.0	38.0	113.0
88	700	42	10.0	4.9	7.3	7.8	1.2	3.6
89	34	41B				7.0	1.9	5.5 ←
90	270	242	7.9	3.6	5.6	11.5	1.7	5.2

X-75509

TABLE II-5 (Contd)

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AF 91	270	43	5.6	2.8	4.2	11.5	1.8	5.4
92	270	7	5.6	2.8	4.2	8.8	1.4	4.1
93								
94	P-1000	243	22.0	8.2	14.0	8.5	1.2	3.4
	S-2700		60.0	12.0	25.0			
95	16*	244	6.1	2.7	4.3	8.0	1.1	3.3
96	P-8	46						
	S-850		8.5	4.5	6.5	14.0	2.0	6.0
97	P-2.7	46						
	S-690		7.6	4.0	5.8	14.0	2.0	6.0
98	950	245	28.0	10.0	17.5	8.3	1.1	3.3
99	P-1000	251	18.7	8.2	14.0			
	S-2700		42.5	12.0	25.0	11.5	1.7	5.2
100	700	252	12.0	5.1	8.3	7.5	1.1	3.1
101	P-300	41	7.4	3.5	5.6			
	S-300		7.7	3.8	6.0	13.2	2.2	6.2
102	P-10	46						
	S-400		10.5	4.4	6.7	14.0	2.0	6.0
103	P-8	46						
	S-850		15.7	5.0	8.4	14.0	2.0	6.0
104	P-2.7	46						
	S-690		12.5	4.0	8.6	14.0	2.0	6.0
105	270	253	7.9	3.6	5.6	10.9	1.5	4.8
106	2000	37	50.0	17.0	26.5	200.0	49.0	122
107								
108								
109	P-100	218						
	S-1100		21.5	9.0	16.0	10.9	1.5	4.8
110	950	272	32.0	10.5	14.5	4.2	1.0	1.6
111	700	270	12.0	5.1	8.3	7.7	1.1	3.2
112	700	268	12.0	5.1	8.3	8.3	1.1	3.3
113	2500	273	48.0	18.0	29.0	8.5	1.2	3.4
114	700	54	9.1	4.5	6.7	10.7	1.7	5.0
115	2500	274	39.0	13.0	29.0	10.9	1.5	4.8
116	400	285	9.6	4.2	6.7	8.0	1.1	3.3
117	180	222	10.4	5.6	8.0	9.3	1.3	4.1
118	950	401	26.5	12.0	18.0	10.4	1.3	4.0
119	2500	266	85.0	15.0	29.0	4.0	1.0	2.1
120	950	406	36.0	18.0	27.0	8.8	1.2	3.6
121	16*	31	4.4	2.2	3.3	7.2	1.1	3.2
122	16*	49	4.4	2.2	3.3	8.4	1.3	3.8
123	P-1175	217	24.5	8.6	15.0	8.5	1.2	3.4
	S-1075		25.0	8.2	15.0			
124	500	287	16.0	7.0	10.5	10.9	1.5	4.8
125	500	245	18.5	7.0	10.5	8.3	1.1	3.3
126	400	288	9.6	4.2	6.7	10.9	1.5	4.8
127	P-335	215	Supervisory Relay					
	S-335							
•128	P-1175		32.5	8.6	15.0			
	S-1075	254	27.5	8.2	15.0	7.2	1.1	3.2
129	2500	28	61.0	10.0	20.0	7.5	1.1	3.1

*In series with 90ω noninductive resistance.

TABLE II-5 (Contd)

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AF130	P-100	210						
	S-1100		23.0	9.0	16.0	10.9	1.5	4.8
131	270	407	9.8	4.1	6.7	9.0	1.3	3.7
132	700	61	9.1	4.5	6.7	7.8	1.1	3.6
133	P-1175	37	15.0	6.7	11.5	14.0	2.3	6.5
	S-1075		16.0	6.8	11.5			
134	2500	230	65.0	15.0	29.0	7.7	1.1	3.2
135	500	409B	21.5	9.0	13.7	4.0	1.0	1.7
136	700	410	15.0	5.9	10.0	9.0	1.2	3.7
137	270	412	10.9	4.5	7.6	9.6	1.6	4.0
138	100	53B				5.5	1.7	4.0
139	2500	256	46.0	13.0	29.0	8.9	1.3	3.8
140	2500	304	55.0	13.0	29.0	8.3	1.1	3.3
141	P-540	225		Line Relay		11.5	1.7	5.2
	S-540							
142	180	310	11.0	6.1	8.6	4.2	1.0	1.7
143	860	311	23.0	9.0	14.0	8.0	1.1	3.3
144	700	258	12.0	5.1	8.3	13.1	2.0	5.6
145	500	269	16	7	10.5	10.2	1.5	4.5
146	2500	207	50	15	29	10.5	1.7	4.7
147	2500	217	55	15	29	8.5	1.2	3.4
148	180	280	11.5	6.1	8.6	4.2	1.0	1.7
149	34	209				15.5	2.4	6.9
150	180	289	10.1	5.6	8.0	9.3	1.3	4.1
151	270	415	9.8	4.1	6.7	8.7	1.1	3.5
152	1625	34	45.0	9.5	16.0	6.9	1.1	3.2
153	275	261	20.0	7.0	10.4	3.9	1.0	2.1
154	275	417	14.5	8.0	10.4	9.0	1.3	3.7
155	2500	418	60.0	15.0	33.0	7.9	1.1	3.3
156	700	295	12.0	5.1	8.3	10.9	1.5	4.5
AF157	180	317	11.5	6.1	8.6	3.9	1.	2.1
158	550	36	52.0	14.	26.	235.0	30.	145.0
159	200**	295	20.0	3.8	12.4	10.2	1.5	4.5
160	200**	73	20.0	2.6	10.0	9.6	1.5	4.5
161	200**	61	26.5	2.6	10.0	7.8	1.1	3.6
162	200**	8	24.0	2.6	10.0	8.4	1.3	3.8
163	200**	206	25.0	3.8	12.4	8.5	1.2	3.4
164	700	319	12.0	5.1	8.3	9.7	1.4	4.2
165	950	61	28.0	8.0	12.0	7.8	1.1	3.6
AF166	500	421B	22.	9.	13.7	4.	1.	1.7
AF167	P-950	327	22.	8.5	14.7	10.7	1.3	4.1
	S-450		10.8	4.8	7.6	-	-	-
AF168	700	46	13.2	5.6	9.1	14.5	2.1	6.5
AF169	275	331	18	6	11	4	1	2.1

X-75509

**24-volt operation

TABLE II-5 (Contd)

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AF130	P-100	210						
	S-1100		23.0	9.0	16.0	10.9	1.5	4.8
131	270	407	9.8	4.1	6.7	9.0	1.3	3.7
132	700	61	9.1	4.5	6.7	7.8	1.1	3.6
133	P-1175	37	15.0	6.7	11.5	14.0	2.3	6.5
	S-1075		16.0	6.8	11.5			
134	2500	230	65.0	15.0	29.0	7.7	1.1	3.2
135	500	409B	21.5	9.0	13.7	4.0	1.0	1.7
136	700	410	15.0	5.9	10.0	9.0	1.2	3.7
137	270	412	10.9	4.5	7.6	9.6	1.6	4.0
138	100	53B				5.5	1.7	4.0
139	2500	256	46.0	13.0	29.0	8.9	1.3	3.8
140	2500	304	55.0	13.0	29.0	8.3	1.1	3.3
141	P-540	225		Line Relay		11.5	1.7	5.2
	S-540							
142	180	310	11.0	6.1	8.6	4.2	1.0	1.7
143	860	311	23.0	9.0	14.0	8.0	1.1	3.3
144	700	258	12.0	5.1	8.3	13.1	2.0	5.6
145	500	269	16	7	10.5	10.2	1.5	4.5
146	2500	207	50	15	29	10.5	1.7	4.7
147	2500	217	55	15	29	8.5	1.2	3.4
148	180	280	11.5	6.1	8.6	4.2	1.0	1.7
149	34	209				15.5	2.4	6.9
150	180	289	10.1	5.6	8.0	9.3	1.3	4.1
151	270	415	9.8	4.1	6.7	8.7	1.1	3.5
152	1625	34	45.0	9.5	16.0	6.9	1.1	3.2
153	275	261	20.0	7.0	10.4	3.9	1.0	2.1
154	275	417	14.5	8.0	10.4	9.0	1.3	3.7
155	2500	418	60.0	15.0	33.0	7.9	1.1	3.3
156	700	295	12.0	5.1	8.3	10.9	1.5	4.5
AF157	180	317	11.5	6.1	8.6	3.9	1.	2.1
158	550	36	52.0	14.	26.	235.0	30.	145.0
159	200**	295	20.0	3.8	12.4	10.2	1.5	4.5
160	200**	73	20.0	2.6	10.0	9.6	1.5	4.5
161	200**	61	26.5	2.6	10.0	7.8	1.1	3.6
162	200**	8	24.0	2.6	10.0	8.4	1.3	3.8
163	200**	206	25.0	3.8	12.4	8.5	1.2	3.4
164	700	319	12.0	5.1	8.3	9.7	1.4	4.2
165	950	61	28.0	8.0	12.0	7.8	1.1	3.6
AF166	500	421B	22.	9.	13.7	4.	1.	1.7
AF167	P-950	327	22.	8.5	14.7	10.7	1.3	4.1
	S-450		10.8	4.8	7.6	-	-	-
AF168	700	46	13.2	5.6	9.1	14.5	2.1	6.5
AF169	275	331	18	6	11	4	1	2.1

**24-volt operation

X-75509

TABLE II-5 (Contd)

OPERATE AND RELEASE TIMES

AF RELAYS (500 SERIES)

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AF500	4.4	33				10.2	1.6	4.8
501	395	34	6.6	3.3	4.9	6.9	1.1	3.2
502	395	231	9.2	4.0	6.4	7.5	1.1	3.1
503								
504	270	8	5.6	2.8	4.2	8.4	1.3	3.8
505	2500	207	53.0	15.0	29.0	10.5	1.7	4.7
506	700	8	9.1	4.5	6.7	8.4	1.3	3.8
507	700	26	9.1	4.5	6.7	7.2	1.1	3.2
508	16*	11	4.4	2.2	3.3	11.5	1.8	5.4
509	2500	219	74.0	13.0	29.0	7.0	1.0	2.8
510	P-400	1	10.5	4.8	8.4	16.5	2.4	7.0
	S-400		11.0	4.8	8.4			
511	700	32	9.1	4.8	6.7	10.7	1.7	5.0
512	700	207	12.0	5.1	8.3	11.5	1.7	5.2
513	700	208	12.0	5.1	8.3	8.5	1.2	3.4
514	270	5	5.6	2.8	4.2	11.5	1.8	5.4
515	270	31	5.6	2.8	4.2	7.2	1.1	3.2
516	270	221	7.9	3.6	5.6	10.2	1.5	4.5
517	270	223	7.9	3.6	5.6	8.5	1.2	3.4
518	270	224	7.9	3.6	5.6	7.5	1.1	3.1
519	270	27	6.1	2.8	4.6	9.6	1.5	4.5
520	270	15	5.6	2.8	4.2	8.8	1.4	4.1
521	270	21	5.6	2.8	4.2	7.5	1.2	3.5
522	700	18	9.1	4.5	6.7	11.5	1.8	5.4
523	700	19	9.1	4.5	6.7	8.8	1.4	4.1
524	700	210	12.0	5.1	8.3	10.2	1.5	4.5
525	P-700	6	16.5	5.6	9.4	9.2	1.4	4.2
	S-700		17.5	5.6	9.4			
526								
527	400	18	7.0	3.5	5.3	11.5	1.8	5.4
528	P-100	284						
	S-1100		26.5	7.8	10.5	4.5	1.4	2.8
529	P-550	247	10.7	4.8	7.5	8.3	1.1	3.3
	S-550		10.7	4.8	7.5			
	T-525		10.7	4.8	7.5			
530	P-300	217	9.2	4.3	6.6	8.5	1.2	3.4
	S-300		9.7	4.5	6.9			
531	700	203	12.0	5.1	8.3	5.6	1.4	2.6
532	P-1000	204	22.0	10.0	15.0	8.9	1.3	3.8
	S-2700		48.0	16.0	27.5			
533	P-300	48	7.4	3.5	5.6	9.6	1.5	4.5
	S-300		7.7	3.8	6.0			
534	P-1000	201	22.0	8.2	14.0	6.9	1.2	2.7
	S-2700		48.0	12.0	25.5			
→ AF535	270	423	9.8	4.1	6.7	9.	1.1	3.5

*In series with 90ω noninductive resistance.

TABLE II-6

OPERATE AND RELEASE TIMES

AJ RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AJ 1	P-200 S-200	2B	Supervisory Relay					
2								
3	950	226	40.0	10.0	18.0	9.1	1.3	4.2
4								
5	2500	220	99.0	13.5	31.0	8.5	1.0	3.5
6								
7	9100	1	37.5	14.0	23.5	11.0	2.3	5.5
8	P-400 S-400	1	Supervisory Relay					
9	700	234	12.0	5.1	8.3	9.1	1.3	4.2
10	P-1800 S-85	39	15.5	8.6	12.0	14.5	2.6	8.0
11	180	2	8.3	4.5	6.4	11.0	2.3	5.5
12	700	220	12.0	5.1	8.3	8.5	1.0	3.5
13								
14	P-1000 S-2700	250	24.0 54.5	8.0 12.0	11.5 26.5	10.1	1.4	4.6
15	700	249	12.0	5.1	8.3	8.5	1.0	3.5
16	500	226	30.0	8.0	14.5	9.1	1.3	4.2
17								
18	180	263	10.4	5.6	8.0	11.1	1.8	5.2
19	P-300 S-300	41	7.4 7.7	3.5 3.8	5.6 6.0	16.7	3.3	8.6
20	P-1000 S-2700	265	24.0 54.5	8.0 12.0	11.5 26.5	10.1	1.1	4.6
21	270	259	7.9	3.6	5.6	9.1	1.3	4.2
22	700	234	13.2	5.6	9.1	9.1	1.3	4.2
23	P-200 S-200	1B	Supervisory Relay					
24	P-200 S-200	52B	Supervisory Relay					
25	220	53	Ring Trip Relay					
26	P-200 S-200	55B	Supervisory Relay					
27	2200	213	84.0	28.0	50.0	56.0	7.8	30.0
28	P-1000 S-2700	257	24.0 60.0	8.2 14.5	12.0 26.5	10.1	1.4	4.6
29	425 425	46B	Supervisory Relay					
30	700	256	13.2	5.6	9.1	12.0	1.9	5.7
31	500	36	11.0	5.5	8.2	14.1	2.4	6.7
32	4.4	254				10.1	1.4	4.5
33	180	5B	9.8	5.2	7.5	8.0	2.0	4.0
34	P-200 S-200	46B	Supervisory Relay					
35	16*	9	4.4	2.2	3.3	18.0	3.8	8.6

*In series with 90ω noninductive resistance.

X-75509

TABLE II-6 (Contd)

OPERATE AND RELEASE TIMES

AJ RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	Avg
AJ 36	34	215				12.0	1.9	5.7
37	16*	234	6.1	2.7	4.3	9.1	1.3	4.2
38	P-170	294B		Supervisory Relay				
	S-140							
39	950	220	40.0	10.0	18.0	8.5	1.0	3.5
40	61	52		Supervisory Relay				
	61							
41	2500	40	36.0	10.0	21.0	11.3	1.9	5.4
42	P-61	66		Supervisory Relay				
	S-61							
43	500	249	25.0	7.0	11.0	8.5	1.0	3.5
44								
45	16*	249	6.1	2.7	4.3	8.5	1.0	3.5
46	950	266	27.0	10.0	18.0	12.0	1.9	5.7
47	220	53		Ring Trip Relay				
48	P-1500	3	17.5	7.7	10.2	16.0	3.1	8.5
	S-2950		23.0	11.0	18.5			
49	P-220	302		Ring Trip Relay				
	S-1150							
50	P-100	46		Supervisory Relay				
	S-100							
51	375	411	80.0	30.0	40.0	360.0	31.0	155.0
52	P-400	303		Supervisory Relay				
	S-400							
53	1000	298	215.0	50.0	75.0	95.0	16.0	70.0
54	1000	306	205.0	50.0	75.0	95.0	16.0	70.0
55	P-5000	62	85.0	12.0	30.0	11.0	1.6	5.1
	S-1000		21.5	5.6	10.0			
56	400	413	11.5	4.2	7.8	10.0	1.3	4.2
57	P-200	237		Supervisory Relay				
	S-200							
58	P-220	308		Ring Trip Relay				
	S-1150		49.0	10.0	22.0	115.0	17.5	55.0
59	P-400	37		Supervisory Relay				
	S-400							
60	500	203	19.5	10.0	14.5	6.0	1.7	3.2
61	700	238	12.0	5.1	8.3	11.1	1.8	5.2
62	1000	313	205.0	50.0	75.0	95.0	16.0	70.0
63	2500	68	29.0	10.0	20.0	9.2	1.4	4.2
64	860	275	26.0	9.0	14.0	9.1	1.3	4.2
65	950	59	35.0	8.0	12.0	10.5	1.5	4.8
66	P200	58						
	S200			Supervisory Relay				
67								
68	700	277	13.2	5.6	9.1	10.5	1.5	4.8
69	700	278	13.2	5.6	9.1	9.1	1.3	4.2
70	P-1000	283	23.1	8.0	11.5	9.7	1.4	4.4
	S-2700		50.5	12.0	26.5			
71	P-1000	250	24.0	8.0	11.5	10.1	1.4	4.6
	S-2700		54.5	12.0	26.5			
72	P-700	64	11.1	5.6	8.2	8.1	1.0	3.4
	S-700		11.1	5.6	8.2			

*In series with 90ω noninductive resistance.

TABLE II-6 (Contd)

OPERATE AND RELEASE TIMES

AJ RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	Avg
AJ73	P360	5	8.3	4.2	6.2	8.0	2.0	4.0
	S1900		24.5	8.0	15.5			
AJ74	2500	69	29.5	10.0	20.0	14.1	2.4	6.7
AJ75	2500	291	40.0	13.0	29.0	11.1	1.8	5.2
AJ76	2500	292	40.0	13.0	29.0	14.2	2.4	6.9
AJ77	P200	293	Supervisory Relay					
	S200							
AJ78	P1000	278	23.0	8.0	11.5	9.1	1.5	4.2
	S2700		60.0	12.0	26.5			
AJ79	1625	419	33.0	13.0	27.0	10.5	1.7	4.7
AJ80	1050	38	49.0	19.0	28.0	305.0	85.0	175.0
AJ81	500	220	25.0	7.0	11.0	8.5	1.0	3.5
AJ82	500	300	21.0	10.0	14.5	5.6	1.7	3.2
AJ83	2500	249	99.0	13.0	29.0	8.5	1.0	3.5
AJ84	800	301	18.0	8.0	14.0	10.7	1.7	5.2
AJ85	3800	71	35.0	14.0	18.5	14.0	2.7	6.7
AJ86	P200	315	Supervisory Relay					
	S200							
AJ87	P1200	316	24.0	8.2	13.4	10.1	1.4	4.6
	S6000							
AJ88	P200	303	Supervisory Relay					
	S200							
AJ89	270	238	7.9	3.6	5.6	11.1	1.8	5.2
AJ90	16*	420	7.9	3.3	5.4	11.5	1.2	7.
AJ91	200**	271	25.	3.8	13.	10.5	1.5	4.8
AJ92	200**	220	30.5	3.8	13.	8.5	1.	3.5
AJ93	200**	278	30.	3.8	13.	9.1	1.3	4.2
AJ94	700	320	12.	5.1	8.3	10.1	1.4	4.6
AJ95	950	63	28.	8.0	12.	11.1	1.5	5.
AJ96	34	8				11.5	1.5	5.3
AJ97	P210	321	P-	-	-			
	S1000		S18	4	10	11.1	1.8	5.2
98	34	74	-	-	-	5.3	1.8	3.
99	P200	322	Supervisory Relay					
	S200							
100	180	46	8.3	4.5	6.4	19.	3.1	8.9
101	500	323	19	7.0	11.0	12.0	1.9	5.7
102	P200	75	Supervisory Relay					
	S200							
103	1050	299	29.0	10.0	14.	190	15.	84.
104	950	324	25.0	10.0	18.0	12.4	2.0	5.9
105	16*	422	7.9	3.3	5.4	10.5	1.7	4.7
106	16*	238	6.1	2.7	4.3	11.1	1.8	5.2
107	950	226	27.0	10.0	18.0	9.1	1.3	4.2

X-75509

*In series with 900Ω noninductive resistance.
**24 volt operation.

TABLE II-6 (Contd)

OPERATE AND RELEASE TIMES

AJ RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AJ108	9100	2	44.0	13.0	33.0	19.5	2.9	8.8
109	P100	250	-	-	-	10.7	1.3	4.3
	S1100		27.0	8.4	15.5	-	-	-
110	P200	319	Supervisory Relay					
	S200							
111	500	328	20.0	4.2	13.0	11.5	1.4	4.6
112	950	329	24.0	6.2	17.5	13.0	1.7	5.5
113	P5000	77	95.0	11.5	27.0	9.4	1.1	4.1
	S1000		22.5	5.6	9.7	-	-	-
114	P2.7	293	-	-	-	13.5	1.9	5.7
	S690		8.2	4.0	6.0	-	-	-
115	P425	46	Supervisory Relay					
	S425							
116	P1000	330	26	9.2	13.7	10.5	1.5	4.8
	S2700		60	15	24	-	-	-
117	180	37	8.3	4.5	6.4	18	3.4	9.4
AJ200	500	500	11.3	5.8	8.5	8.1	1.0	3.4
201								
202	700	500	10.0	5.0	7.3	8.1	1.0	3.4
203	275	500	9.9	5.3	7.6	8.1	1.0	3.4
204	P700		11.1	5.6	8.2			
	S700	500	11.1	5.6	8.2	8.1	1.0	3.4
AJ500	950	226	40.0	10.0	18.0	9.1	1.3	4.2
501	700	249	12.0	5.1	8.3	8.5	1.0	3.5
502	700	234	12.0	5.1	8.3	9.1	1.3	4.2
503	270	249	7.9	3.6	5.6	8.5	1.0	3.5
504	2200	57	66.5	24.0	38.5	58.0	14.0	33.0
505	16*	36	4.4	2.2	3.3	14.1	2.4	6.7
506	16*	267	6.1	2.7	4.3	14.2	2.4	6.9
507	270	21	6.1	3.3	4.7	4.1	1.2	2.6
508	16*	19	4.4	2.2	3.3	12.4	2.0	5.9
509	700	235	13.2	5.6	9.1	10.5	1.5	4.8
510	P-2.7	39						
	S-690		19.2	4.8	8.6	11.5	1.8	5.2
511	P-700	200	16.5	7.4	10.1	11.5	1.7	5.3
	S-700		17.5	7.4	10.1			
512	270	64	5.6	2.8	4.2	8.1	1.0	3.4
513	270	414	9.9	4.1	6.7	8.0	1.0	3.3
514	P-700	227	23.0	5.6	9.4	9.0	1.2	4.0
	S-700		24.0	5.6	9.4			
515	275	63	9.9	5.3	7.6	4.1	1.2	2.6
516	700	299	12.0	5.1	8.3	8.5	1.0	3.5
AJ517	P700	318	13.4	5.8	9.3	10.1	1.4	4.6
	S3300		53.0	13.0	34.0			
AJ700	270	500	6.2	3.1	4.6	8.1	1.0	3.4
701								
702	700	500	10.0	5.0	7.3	8.1	1.0	3.4

*In series with 90ω noninductive resistance

TABLE II- 7

OPERATE AND RELEASE TIMES

AG RELAYS

X-75509

Code	Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min
AG 1	1050	35B	64.0	10.5	29.0	425	190
2	1050	36B	62.0	10.5	29.0	475	245
3	1050	233B	84.5	18.0	45.5	475	195
4	1050	39B	62.0	10.5	29.0	540	295
5							
6	2200	239B	59.0	12.0	33.5	95	37
7	1050	241B	84.5	15.5	45.5	365	155
8	2000	44B	61.5	11.0	30.0	390	190
9	1625	246B	37.0	10.0	23.0	22	6.5
10	875	35B	26.5	6.2	14.5	100	42
11	1050	233	84.5	15.5	45.5	830	225
12	1625	38B	28.5	6.0	15.5	26	9
13	2200	402B	63.5	18.0	45.5	235	90
14	P-400 S-210	45B	9.8	3.5	6.8	137*	85*
15	600	221	40.0	10.0	23.0	512	147
16	1050	233B	84.5	15.5	44.5	475	225
17	2200	271B	68.0	13.5	43.5	150	55
18	2000	48B	62.5	10.0	32.5	320	142
19	1050	405B	100.0	19.0	57.5	500	250
20	2000	262B	95.0	15.0	50.0	260	103
21	P-450 S-57	282B	8.6	4.6	6.6	267*	136*
22	P-450 S-57	56B	6.7	3.5	5.1	288*	144*
23	1625	286B	28.5	10.0	23.0	22	6.5
24	1050	18B	68.0	10.5	29.0	620	300
25							
26	550	222B	70.0	12.0	32.0	400	187
27	P-198 S-80	45B				206*	103*
28	875	268B	45.0	10.0	21.5	145	61
29	600	408B	47.0	12.0	28.5	235	90
30	500	267B	20.5	7.0	11.0	17	7
31	P-450 S-200	4B	7.0	3.5	5.3	160*	95*
32	P-1000 S-2700	224B	23.0 57.0	7.8 10.0	12.0 25.0	13.5	3.7
33	875	305B	37.0	8.0	19.0	95	40
34	1050	307B	84.5	15.5	45.5	395	175
35	P-400 S-210	67B	9.8	3.5	6.8	137*	85*
36	600	296B	39.5	10	23	280	150
37	P-450 S-57	297B	8.6	4.6	6.6	275*	130*
38	P-450 S-57	213B	8.6	4.6	6.6	210*	96*
39	P-1000 S-2700	268B	23.0 57.0	7.0 10.0	12.0 25.0	14	4.5
40	2500	50	30.0	8.0	18.0	20	8
41	2000	264B	95.0	15.0	50.0	235	120
42	875	279B	37.0	8.0	19.0	175	46

*With secondary winding short-circuited.

TABLE II-7 (Contd)

OPERATE AND RELEASE TIMES

AG RELAYS

Code	Res.	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIME Max	Min
AG 43	1050	34B	75.0	11.0	29.0	360	145
44	P1000 S42	281B	24.0	6.6	18.0	250*	95*
45	2200	20B	45.0	8.5	20.5	85	40
46	P1000	20B	17	5.6	8.6		
	S2700		34	7.2	16.8	16	4.9
47	P450 S57	290B	8.6	4.6	6.6	275*	130 *
48	2000	230B	95.0	15.0	50.0	250	105
49	P450 S57	416B	10.5	5.7	8.0	195*	95*
50	2200	314B	68.0	13.5	43.5	115	45
51	4000	72B	45.5	9.0	35.0	19	6.5
52	P-700	318B	13.7	6.1	9.6	13	4
	S-3300		50.5	11.0	30.0		
AG 53	P450 S57	249B	8.6	4.6	6.6	195*	57*
AG54	P360	325B	-	-	-	17	7
	S1900		37.	8.5	20		
AG55	P1000 S42	76B	15.	5.	9.3	300*	139*
AG56	P450 S57	413B	12.9	5.2	8.7	205*	74*
AG57	2200	326B	66.	13.5	43.5	100	40

*With secondary winding short circuited.

TABLE II-8

OPERATE AND RELEASE TIMES

AK RELAYS

Code		Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AK-1	T	410	201	-	-	-	8.7	1.0	3.6
	B	315*		-	-	-	175.0	60.0	-
AK-2	T	960	1	13.4	7.5	10.5	10.4	1.6	4.8
	B	960		13.4	7.5	10.5	10.4	1.6	4.8
AK-3	T	185	3	-	-	-	11.0	1.8	5.4
	B	280		-	-	-	11.0	1.8	5.4
AK-4	T	2450	202	44	18.7	31	8.5	1.0	3.4
	B	2450		44	18.7	31	8.5	1.0	3.4
AK-5	T	640	4	11.1	6.3	8.7	11.0	1.8	5.4
	B	640		11.1	6.3	8.7	11.0	1.0	5.4
AK-6	T	640	2	11.1	6.3	8.7	8.5	1.0	3.4
	B	640		11.1	6.3	8.7	8.5	1.0	3.4
AK-7	T	955	203	18.2	10.7	14.5	8.7	1.0	3.6
	B	955		18.2	10.7	14.5	8.7	1.0	3.6
AK-8	T	2450	204	29.2	18.7	24	9.3	1.1	3.9
	B	960		18.8	11.6	14.5	9.3	1.1	3.9
AK-9	T	2450	5	25	10.5	17.5	11.0	1.8	5.4
	B	145		-	-	-	14.0	2.6	6.6
AK-10	T	2450**	7	25	10.5	17.5	22.5	4.5	16.5
	B	960**		13.4	7.5	10.5	17.0	3.8	12.0
AK-11	T	960	206	18.8	11.6	14.5	11.3	1.7	5.0
	B	960	-	18.8	11.6	14.5	11.3	1.7	5.0
AK-12	T	1500	8	18.2	8.2	13.0	14.0	2.6	6.6
	B	1500		18.2	8.2	13.0	14.0	2.6	6.6
AK-13	T	640	203	16.2	10.5	13.4	8.7	1.0	3.6
	B	640		16.2	10.5	13.4	8.7	1.0	3.6
AK-14	T	410	208	-	-	-	8.7	1.0	3.6
	B	410		-	--	-	10.0	1.2	4.2
AK-15	T	640	9	11.1	6.3	8.7	11.6	2.1	5.9
	B	960		13.4	7.5	10.5	8.8	1.2	4.1
AK-16	T	100	211	-	--	-	9.3	1.1	3.9
	B	100		-	-	-	9.3	1.1	3.9
AK-17	T	210***	212	20.7	9.6	15.2	9.3	1.1	3.9
	B	210***		20.7	9.6	15.2	9.3	1.1	3.9
AK-18	T	210***	213	20.7	9.6	15.2	12.5	2.0	5.6
	B	210***		20.7	9.6	15.2	11.3	1.7	5.0
AK-19	T	210***	214	20.7	9.6	15.2	10.0	1.2	4.2
	B	210***		20.7	9.6	15.2	10.0	1.2	4.2
AK-20	T	640	217	16.2	10.5	13.4	12.5	2.0	5.6
	B	640		16.2	10.5	13.4	10.5	1.4	4.5
AK-21	T	640	215	16.2	10.5	13.4	10.0	1.2	4.2
	B	640		16.2	10.5	13.4	10.0	1.2	4.2
AK-22	T	640	216	16.2	10.5	13.4	8.7	1.0	3.6
	B	640		16.2	10.5	13.4	8.7	1.0	3.6
AK-23	T	2450	3	25	9.1	15.2	11.0	1.8	5.4
	B	2450		25	9.1	15.2	11.0	1.8	5.4
AK-24	T	2450	12	25	9.1	15.2	10.0	1.3	4.4
	B	2450		25	9.1	15.2	10.0	1.3	4.4
AK-25	T	640	11	11.1	6.3	8.7	14.0	2.6	6.6
	B	640		11.1	6.3	8.7	11.0	1.8	5.4
AK-26	T	640	10	11.1	6.3	8.7	10.0	1.3	4.4
	B	640		11.1	6.3	8.7	8.8	1.2	4.1
AK-27	T	640	218	16.2	10.5	13.4	10.5	1.4	4.5
	B	2450		40.0	18.7	29.0	10.5	1.4	4.5
AK-28	T	5.5	219	-	-	-	10.0	1.2	4.2
	B	1500		28.0	15.0	21.5	8.7	1.0	3.6

X-75509

TABLE II-8 (Contd)

OPERATE AND RELEASE TIMES

AK RELAYS

Code		Res.	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
AK-29	T	2450	13	25.0	9.1	15.2	10.4	1.6	4.8
	B	2450		25.0	9.1	15.2	10.4	1.6	4.8
AK-30	T	640	202	16.2	10.5	13.4	8.5	1.0	3.4
	B	640		16.2	10.5	13.4	8.5	1.0	3.4
AK-31	T	955	14	12.0	6.0	9.0	8.5	1.0	3.4
	B	145		-	--	-	12.5	2.0	5.6
AK-32	T	210***	210	20.7	9.6	15.2	9.3	1.1	3.9
	B	210***		20.7	9.6	15.2	9.3	1.1	3.9
AK-33	T	2450	209	40.0	18.7	29.0	7.0	2.1	4.5
	B	2450		58.0	18.7	38.0	18.5	4.5	11.5
AK-34	T	640	15	11.1	6.3	8.7	10.0	1.3	4.4
	B	640		11.1	6.3	8.7	8.8	1.2	4.1
AK-35	T	2450	202	49.0	18.7	14.0 ?	8.5	1.0	3.4
	B	680*		41.0	11.6	26.0	175.0	50.0	-
AK-36	T	16	16	-	-	-	8.0	1.0	3.4
	B	1500		22.0	8.2	15.0	8.4	1.0	3.8
AK-37	T	1500	201	28.0	15.0	21.5	8.7	1.0	3.6
	B	1100*		50.0	13.6	32.0	230.0	70.0	-
AK-38	T	960	13	13.4	7.5	10.5	10.4	1.6	4.8
	B	960		13.4	7.5	10.5	10.4	1.6	4.8

*Has copper sleeve and domed armature.
**Has domed armature.
***24-volt operation.

SPRINGS

General

This section on spring combinations deals with:

- Armature Travels
- Core Plate
- Contact Arrangements
- Actuating Cards
- Contact Pressures
- Contact Sequences
- Spring Combination Numbers
- Balancing Springs
- Buffer Spring
- Terminals
- Terminal Numbering

The AF, AG, and AJ relays are designed to provide single-wire contacts in 12 positions with provision for a make twin-wire contact and a break twin-wire contact in each or any of the 12 positions. The AK relay has single-wire contacts in ten positions with provision for a make twin-wire contact and a break twin-wire contact in each or any of the ten positions. The twin wires farthest from the core form make contacts, and those nearest the core form break contacts. The twin wires are held in alignment with the single wires by grooves molded in the single-wire comb near the front end. Twin wires are provided only as required by the spring combination.

X-75509

The twin wires are actuated by means of a moving card which is held against the armature by the tension of a flat balancing spring.

The single wires, molded in the middle block, are at all times stationary, being molded into fixed blocks at the front and rear end. A full complement of pre-tensioned single wires is always supplied. This facilitates terminal numbering and provides sufficient tension to hold the fixed card against the core plate, and prevents false closures or openings of contacts during relay operation or removal of the contact cover cap. Contact metal is provided only where make or break combinations are furnished.

The twin wires that form the make contacts are tensioned against the outer edge of the moving card and toward the single mating contacts and the core. This tension tends to close the make contacts and to move the armature toward the core. The balancing spring, however, which is also tensioned against the moving card at the outer edge, but away from the single contacts and the core, provides the armature back tension and a force to counteract the tension in the twin wires. Thus, the make contacts and armature are held in the unoperated position. As the relay operates, the armature pulls the moving card in the direction of the core, thereby permitting the twin-wire contacts to make contact with the single mating contacts. After the contacts make, the tension of the twin wire is transferred from the moving card, or armature, to the mating contact.

In the unoperated position, the break contacts are tensioned, by the formation of the twin wires, against the single mating contacts. The twin wires are held away from the moving card. As the relay operates, the card moves forward and lifts the twin wires off the single wires. Slightly after this pickup point, the back tension of the break contacts is transferred to the moving card, thereby increasing the load on the armature.

The AF, AG, and AJ relays are designed to permit operating contacts in three stages, that is, preliminary, early, and late-contact operation. The point in the armature stroke at which contacts are actuated is controlled by the cutting of the moving card. Using the card designed for 12 makes or 12 breaks as a base, the surfaces of the card in positions used for early and preliminary make contacts are recessed 0.013 inch and 0.026 inch respectively. The surfaces of the card in positions used for early and preliminary break contacts are extended 0.013 inch and 0.026 inch respectively. (See Fig. III-1).

An AJ relay has been designed to provide single-wire contacts in 24 positions with a make twin-wire contact provided in each of the 24 positions. These positions are arranged in two vertical rows of 12 positions each. The make contacts farthest from the core are in positions 1 to 12 and those nearest the core are in positions 13 to 24. The positions in each row are numbered from bottom to top.

The construction and actuation of the single and twin wires are the same as for the 12-position relays; however, in assembling these relays, a new clamping plate, core plate, and actuating card are required.

The AK relay contact action is like that of the AF relay except that only two stages of contact operation, early and late, are used.

Armature Travels - Core Plate (See Fig. I-9)

The stop-disc height and the core-plate dimensions primarily determine the armature travel. In general, single-stage (non-sequence contact) relays have short travel (0.026 inch ±0.005 inch), 2-stage (sequence contact) relays have intermediate travel (0.044 inch ±0.005 inch), and 3-stage (preliminary contact) relays have long travel (0.060 inch ±0.005 inch). Some marginal or sensitive relays may have a combination of stop disc and core plate that provides a travel differing from the standard travel. Armature travels will not be shown in the circuit requirements table.

A lip formed from the core plate, which is rigidly attached to the core, serves as a backstop for the armature.

Contact Arrangements

By proper selection of the actuating card and single- and twin-wire blocks, the more common contact arrangements shown below may be obtained.

- M - Make
- B - Break
- EM - Early Make
- EB - Early Break
- BM - Break-Make (Nonsequence Transfer)
- EBM - Early Break-Make (Sequence Transfer)
- EMB - Early Make-Break (Continuity)
- PM - Preliminary Make
- PB - Preliminary Break
- PMEB - Preliminary Make - Early Break (Preliminary continuity with respect to late contacts)
- PBEM - Preliminary Break - Early Make (Preliminary transfer with respect to late contacts)

If all possible combinations of the above were made available, an excessive number of twin-wire blocks and cards would be necessary. To keep the cost of these relays to a minimum, the number of twin-wire blocks and actuating cards are restricted to that which will provide the greatest number of combinations normally used in service. For the same reason, relays are frequently recommended with more contacts than required for a particular application.

Actuating Cards

Actuating cards for the 12-position relay have been designed to operate various contact arrangements in positions 1 to 12 as shown in Table III-1. Additional cards may be necessary for special spring combinations that may be requested in the future. These cards are removable and may be replaced without dismounting the relay. The actuating cards for the 10-position AK relay are also shown in Table III-1.

The actuating card for the 24-spring relay is designed to provide only 24-make contacts.

Contact Pressures

The twin wires that form make and break contacts are pretensioned to provide nominal 12.5-grams contact pressure for each contact pair. For special cases, the twin wires may be pretensioned to provide nominal 8-grams contact pressure.

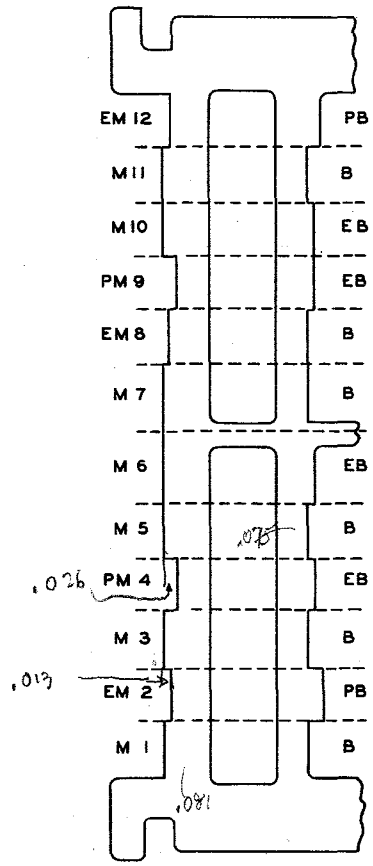


Fig. III-1 - Card Profile

Contact Sequences

Where the EBM or PBEM contacts are used, the break contacts will always open before their associated make contacts close. Where the EMB or PMEB contacts are used, the make contacts will close before their associated break contacts open.

Where circuit races are involved between contacts in different positions, it can be assumed that ordinarily all preliminary contacts function before the early contacts, and all early contacts function before all late contacts. These sequences are guaranteed by the M specification or readjust gauging requirements, but not by the test gauging requirements, or after a few milli-inches of adverse contact wear. The probability of the nonsequential contact action however, is low, and when it does occur, the false closure or open time will be small. For critical circuits where the sequence must be maintained to insure satisfactory performance, it is recommended that a special note be added to the circuit requirements table. Consult the relay requirements group on these critical conditions.

TABLE III-I

Contact Arrangements
Contact Position Number

Travel	1	2	3	4	5	6	7	8	9	10	11	12
Short	M	M	M	M	M	M	M	M	M	M	M	M
LP-19A130	B	B	B	B	B	B	B	B	B	B	B	B
Intermediate	M	M	M	M	M	M	M	M	M	M	M	M
LP-19A131	B	EB	B	EB	B	EB	B	EB	B	EB	B	EB
Intermediate	M	M	M	M	M	EM	M	M	M	M	M	EM
LP-19A132	B	EB	B	EB	B	B	B	EB	B	EB	B	B
Long	M	EM	M	PM	M	M	M	EM	PM	M	M	EM
LP-19A133	B	PB	B	EB	B	EB	B	B	EB	EB	B	PB
Intermediate	M	M	M	M	M	M	M	M	M	M	M	M
LP-19A134	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB
Intermediate	M	M	M	M	EM	EM	M	EM	M	M	M	M
LP-19A135	EB	EB	EB	EB	B	B	EB	B	EB	EB	EB	EB
Intermediate	EM	M	EM	M	M	M	M	M	EM	M	EM	M
LP-19A136	B	EB	B	EB	B	EB	B	EB	B	EB	B	EB
Short	M	M	M	M	M							
LP-10B701*	B	B	B	B	B							
Short								M	M	M	M	M
LP-10B702*								B	B	B	B	B
Intermediate	M	M	M	EM	EM							
LP-10B699*	EB	EB	EB	B	B							
Intermediate								EM	EM	M	M	M
LP-10B700*								B	B	EB	EB	EB
Intermediate	M	M	EM	EM	EM							
LP-10B703	EB	EB	B	B	B							
Intermediate								EM	EM	EM	M	M
LP-10B704*								B	B	B	EB	EB

X-75509

*Used on AK relays.

Spring Combination Numbers

AF, AG, and AJ Relays

Spring combination numbers from 1 to 199 are assigned to single-stage (short travel) relays, 200 to 399 to 2-stage intermediate travel) relays, and 400 to 499 to 3-stage (long travel) relays. Spring combination No. 500 has been assigned to 24- make contacts.

The spring combination numbers which have been assigned to date are given in Tables III-2, III-3, and III-4 which also indicate the positions in which the various contact arrangements are located.

On relays with six or less positions used, the springs should be located in the even-numbered positions if it can be done without a new actuating card. This permits the shop to speed up production by arranging the contact welders to skip the odd-numbered positions.

Where a relay is to be furnished with a buffer spring, the spring combination number will be followed by a letter "B".

AK Relays

Spring combination numbers from 1 to 199 are assigned to single-stage (short travel) relays and 200 to 399 to 2-stage (intermediate travel) relays. Since the twin-wire combs for the top and bottom parts of the AK relay are molded as one unit, the spring combination number assigned to a relay includes the springs in both the top and bottom relay units.

The spring combination numbers which have been assigned to date are given in Table III-5 which also indicates the positions in which the various contact arrangements are located. Positions 1 to 5 are the bottom relay unit and 8 to 12 the top relay unit.

Balancing Springs

The balancing spring used in any particular relay will depend upon the number of make contacts on the relay, its armature travel, and whether the relay is required to meet marginal conditions. The proper selection of balancing springs is described in Section IX.

Buffer Spring (See Fig. I-16)

A removable U-shaped buffer spring is available, and may be attached to the AF, AG, and AJ relays to provide an additional load on the armature to the operated position in order to obtain a high percentage release requirement, or to meet a specified maximum releasing time.

The pretensioned buffer spring is positioned between the spoolhead and outer legs of the core with a lip resting against the center leg of the core between the core plate and card. An adjustable tang, adjacent to the lip, controls the point at which the card engages the buffer spring as the relay operates. The tension of the spring is controlled by changing the offset in the spring.

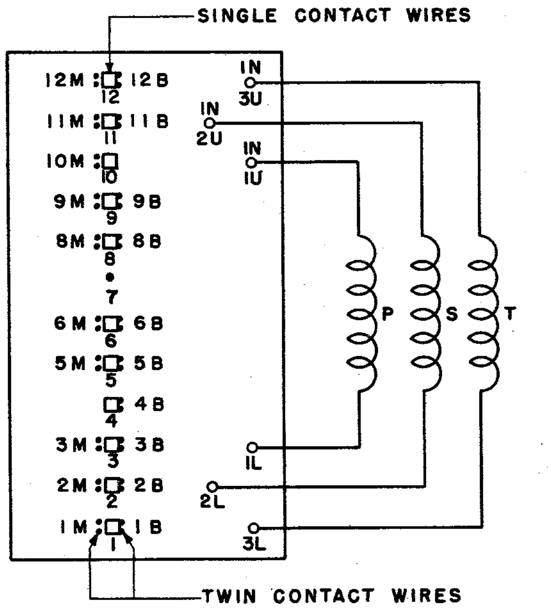
Terminals and Terminal Numbering

For test purposes, the winding terminals are extended to the front of the relay. The terminals for wiring are shaped to permit the use of solderless wrapped connections. The numbering for winding and contact terminals is shown in Fig. III-2 for the AF, AG, and AJ relays and in Fig. III-3 for the AK relays.

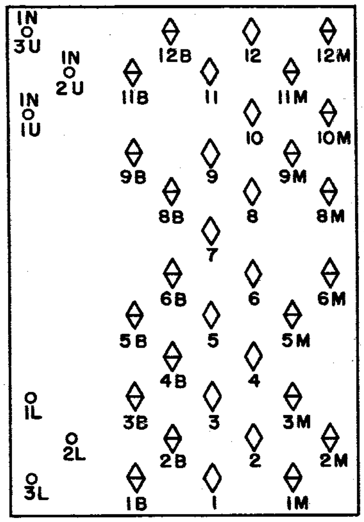
Spring Combinations

In the circuit schematics, the wire-spring relays are numbered by spring position and not individual spring numbers. As an example, an EBM in position 3 would be shown simply as 3 in the detached contact schematics and as EBM 3 in the attached contact schematics. Fig. III-4 shows the way the springs are shown on the attached contact schematics. When referring to a particular contact, as for purposes of insulating a contact of an EBM combination the M or B designation should be used. Insulate 3B would thus mean insulate the break contact in position 3.

Winding arrangements pg X12-C

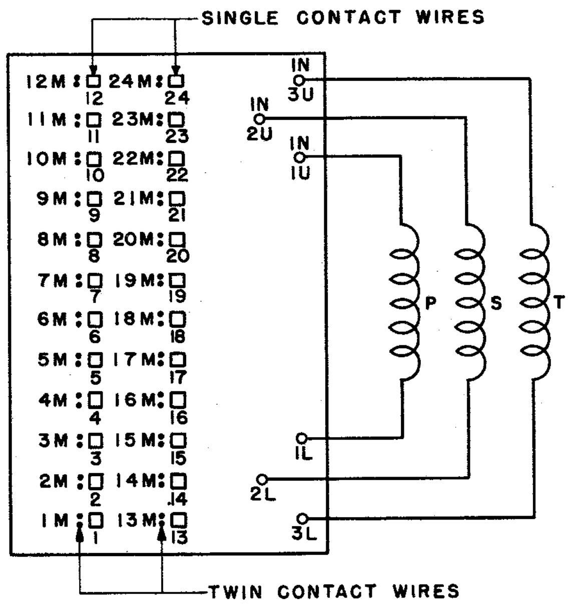


WINDING AND CONTACT SPRING ARRANGEMENT AS VIEWED FROM THE FRONT (CONTACT SIDE) 12-POSITION AF, AG AND AJ RELAYS.

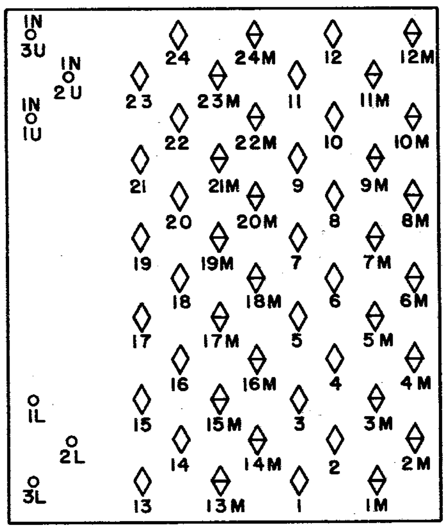


WINDING AND TERMINAL ARRANGEMENT AS VIEWED FROM THE REAR (TERMINAL SIDE) 12-POSITION AF, AG AND AJ RELAYS.

X-75509

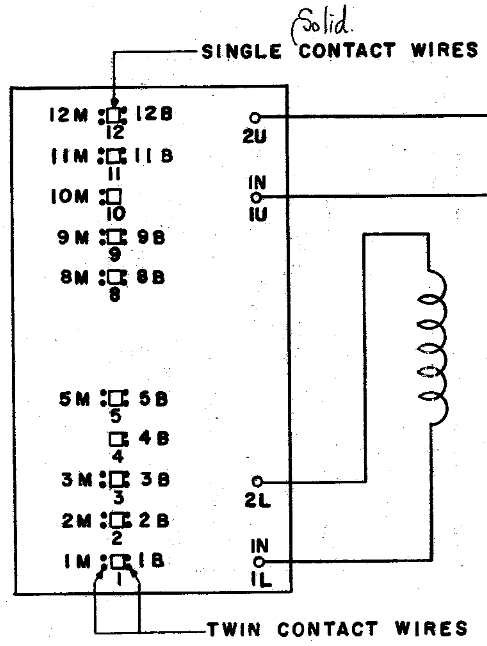


WINDING AND CONTACT SPRING ARRANGEMENT AS VIEWED FROM THE FRONT (CONTACT SIDE) 24-POSITION AJ RELAYS.

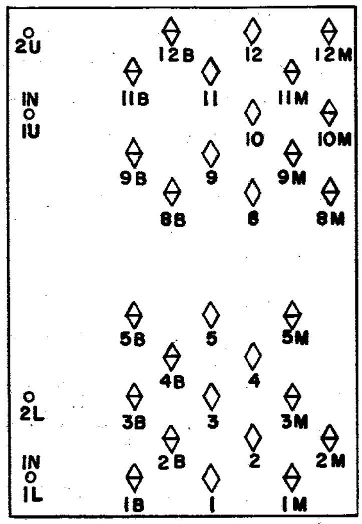


WINDING AND TERMINAL ARRANGEMENT AS VIEWED FROM THE REAR (TERMINAL SIDE) 24-POSITION AJ RELAYS.

Fig. III-2 - AF, AG, and AJ Relays - Terminal Arrangements

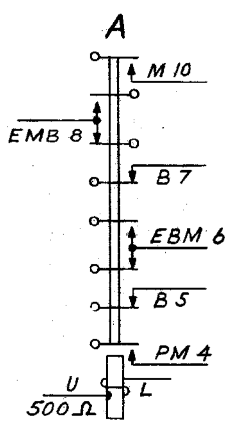


WINDING AND CONTACT SPRING ARRANGEMENT AS VIEWED FROM THE FRONT (CONTACT SIDE)



WINDING AND TERMINAL ARRANGEMENT AS VIEWED FROM THE REAR (TERMINAL SIDE)

Fig. III-3 - AK Relays - Terminal Arrangements



1. *SYMBOL ILLUSTRATED IS FOR AF28 RELAY.*
2. *IF RELAY CONTACTS ARE ALL OF SAME ARRANGEMENT (ALL MAKES, ETC.), OMIT THE ABBREVIATION (M, ETC.) FROM THE SYMBOL AND ADD A NOTE ADJACENT TO THE CORE AS FOLLOWS: ALL CONTACTS ARE M (ETC.).*

Fig. III-4 - Symbol for Use on Attached-Contact Type Schematic

TABLE III-2

SPRING COMBINATIONS
AF, AG, AND AJ RELAYS

All Comb 1-99 use Short Operating Card LP-19A130

Comb. No.	Spring Combinations M	B	BM	Positions 1	2	3	4	5	6	7	8	9	10	11	12
1	1	-	-	-	-	-	-	-	M	-	-	-	-	-	-
2	2	-	-	-	-	-	-	-	M	-	M	-	-	-	-
3	4	-	-	-	-	-	M	-	M	-	M	-	M	-	-
4	5	-	-	-	M	-	M	-	M	-	M	-	M	-	-
5	6	-	-	-	M	-	M	-	M	-	M	-	M	-	M
6	10	-	-	M	M	M	M	-	M	-	M	M	M	M	M
7	11	-	-	M	M	M	M	M	M	-	M	M	M	M	M
8	12	-	-	M	M	M	M	M	M	M	M	M	M	M	M
9	1	1	-	-	-	-	-	-	M	B	-	-	-	-	-
10	1	2	-	-	-	-	-	B	M	B	-	-	-	-	-
11	5	1	-	-	M	-	M	-	M	B	M	-	M	-	-
12	6	1	-	-	M	-	M	-	M	B	M	-	M	-	M
13	6	2	-	-	M	-	M	B	M	B	M	-	M	-	M
14	9	1	-	M	M	M	M	-	M	B	M	-	M	M	M
15	10	1	-	M	M	M	M	-	M	B	M	M	M	M	M
16	10	2	-	M	M	M	M	B	M	B	M	M	M	M	M
17	1	-	1	-	-	-	-	-	BM	-	M	-	-	-	-
18	2	-	2	-	-	-	M	-	BM	-	BM	-	M	-	-
19	3	-	4	M	M	-	BM	-	BM	-	BM	-	BM	-	M
20	7	-	2	M	M	M	M	-	BM	-	BM	-	M	M	M
21	9	-	3	M	M	M	BM	M	BM	M	BM	M	M	M	M
22	-	-	2	-	-	-	-	-	BM	-	BM	-	-	-	-
23	-	5	-	-	-	B	-	B	-	B	-	B	-	B	-
24	1	4	4	-	M	B	BM	B	BM	B	BM	B	BM	-	-
25	2	2	4	-	M	-	BM	B	BM	B	BM	-	BM	-	M
26	7	1	4	M	M	M	BM	M	BM	B	BM	M	BM	M	M
27	4	1	2	-	M	-	M	-	BM	B	BM	-	M	-	M
28	2	6	4	B	M	B	BM	B	BM	B	BM	B	BM	B	M
29	7	2	1	M	M	-	M	B	BM	B	M	-	M	M	M
30	5	2	1	-	M	-	M	B	BM	B	M	-	M	-	M
31	3	1	6	M	BM	M	BM	-	BM	B	BM	-	BM	M	BM
32	2	1	2	-	-	-	M	-	BM	B	BM	-	M	-	-
33	4	4	-	-	-	B	M	B	M	B	M	B	M	-	-
34	6	-	6	M	BM	M	BM	M	BM	M	BM	M	BM	M	BM
35	8	4	-	M	M	B	M	B	M	B	M	B	M	M	M
36	5	3	-	-	M	-	M	B	M	B	M	B	M	-	-
37	2	1	-	-	-	-	-	-	M	B	M	-	-	-	-
38	3	1	-	-	-	-	M	-	M	B	M	-	-	-	-
39	3	2	-	-	-	-	M	B	M	B	M	-	-	-	-
40	5	7	-	B	M	B	M	B	M	B	M	B	M	B	B
41	2	2	-	-	-	-	-	B	M	B	M	-	-	-	-
42	4	6	2	B	M	B	M	B	BM	B	BM	B	M	B	M
43	2	4	-	-	-	B	-	B	M	B	M	B	-	-	-
44	2	1	1	-	-	-	M	-	BM	B	M	-	-	-	-
45	3	3	-	-	-	-	M	B	M	B	M	B	-	-	-
46	3	-	-	-	-	-	M	-	M	-	M	-	-	-	-
47	-	1	-	-	-	-	-	-	-	B	-	-	-	-	-
48	8	1	-	M	M	-	M	-	M	B	M	-	M	M	M
49	4	-	4	M	M	-	BM	-	BM	-	BM	-	BM	M	M
50	-	-	3	-	-	-	BM	-	BM	-	BM	-	-	-	-

X-75509

TABLE III-2 (Contd)

SPRING COMBINATIONS
AF, AG, AND AJ RELAYS

Comb. No.	Spring Combinations M	B	BM	Positions 1	2	3	4	5	6	7	8	9	10	11	12
51	7	3	1	M	M	-	M	B	BM	B	M	B	M	M	M
52	1	1	-	-	-	-	-	-	M	-	-	-	B	-	-
53	-	1	-	-	-	-	-	-	B	-	-	-	-	-	-
54	2	1	2	-	B	-	M	-	BM	-	BM	-	M	-	-
55	2	1	1	-	-	-	M	-	BM	-	M	-	B	-	-
56	2	3	1	-	B	-	M	-	BM	-	M	-	B	-	B
57	3	1	6	BM	M	BM	M	BM	B	BM	-	BM	M	BM	-
58	1	2	1	-	BM	-	-	-	-	-	B	-	M	-	B
59	-	6	6	B	BM	B	BM	B	BM	B	BM	B	BM	B	BM
60	-	-	7	BM	-	BM	-	BM	BM	BM	-	BM	-	BM	-
61	10	-	2	M	M	M	M	M	BM	M	BM	M	M	M	M
62	5	-	4	M	M	M	BM	-	BM	-	BM	-	BM	M	M
63	8	-	4	M	M	M	BM	M	BM	M	BM	M	BM	M	M
64	-	-	12	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM
65	5	-	1	-	M	-	M	-	BM	-	M	-	M	-	M
66	7	1	-	M	M	-	M	-	M	B	M	-	M	-	M
67	4	2	-	-	M	-	M	-	B	-	B	-	M	-	M
68	6	3	-	-	M	-	M	B	M	B	M	B	M	-	M
69	-	1	3	-	-	-	BM	-	BM	-	BM	-	B	-	-
→ 70	-	-	8	BM	BM	-	BM	-	BM	-	BM	-	BM	BM	BM
71	4	1	-	-	M	-	M	-	B	-	M	-	M	-	-
72	4	2	1	-	M	-	M	B	BM	B	M	-	M	-	-
73	6	1	1	M	M	-	M	-	BM	B	M	-	M	-	M
74	1	-	2	-	-	-	M	-	BM	-	BM	-	-	-	-
75	2	1	-	M	M	-	-	-	-	-	-	-	-	-	B
→ 76	3	2	2	-	M	-	M	B	BM	B	BM	-	M	-	-
→ 77	4	-	8	BM	BM	M	BM	M	BM	M	BM	M	BM	BM	BM

TABLE III-3

SPRING COMBINATIONS
AF, AG, AND AJ RELAYS

Comb. No.	Spring Combinations: M	B	BM	EBM	EMB	Others	Positions: 1	2	3	4	5	6	7	8	9	10	11	12
200	2	2	-	2	1	-	-	M	-	EBM	B	EMB	B	EBM	-	M	-	-
201	-	-	-	2	-	-	-	-	-	-	-	EBM	-	EBM	-	-	-	-
202	1	1	-	1	1	-	-	-	-	M	-	EMB	B	EBM	-	-	-	-
203	-	-	-	4	-	-	-	-	-	EBM	-	EBM	-	EBM	-	EBM	-	-
204	4	1	-	3	-	-	M	M	-	EBM	-	EBM	B	EBM	-	M	-	M
205	2	-	-	4	2	-	M	EBM	-	EBM	-	EMB	-	EBM	-	EBM	M	EMB
206	5	-	-	2	1	1EM	M	M	M	EBM	-	EMB	-	EBM	-	M	M	EM
207	-	-	-	2	1	-	-	-	-	EBM	-	EMB	-	EBM	-	-	-	-
208	-	-	-	4	2	-	-	EBM	-	EBM	-	EMB	-	EBM	-	EBM	-	EMB
209	-	-	-	1	-	-	-	-	-	-	-	EBM	-	-	-	-	-	-
210	4	-	-	2	-	-	-	M	-	M	-	EBM	-	EBM	-	M	-	M
211	-	-	-	1	1	-	-	-	-	-	-	EMB	-	EBM	-	-	-	-
212	3	1	-	3	1	1EM	M	M	-	EBM	-	EMB	B	EBM	-	EBM	M	EM
213	2	3	-	2	1	1EM	-	M	-	EBM	B	EMB	B	EBM	B	M	-	EM
214	3	1	-	1	1	1EM	-	M	-	M	-	EMB	B	EBM	-	M	-	EM
215	4	2	-	1	1	1EM	M	M	-	M	B	EMB	B	EBM	-	M	-	EM
216	2	-	-	-	1	-	-	-	-	M	-	EMB	-	M	-	-	-	-
217	-	-	-	6	-	-	-	EBM	-	EBM	-	EBM	-	EBM	-	EBM	-	EBM
218	2	1	-	2	-	-	-	-	-	M	-	EBM	B	EBM	-	M	-	-
219	6	-	4	-	2	-	M	M	BM	M	BM	EMB	BM	M	BM	M	M	EMB
AJ12 — 220	-	-	-	12	-	-	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM
[illegible] — 221	3	-	-	1	1	1EM	-	M	-	M	-	EMB	-	EBM	-	M	-	EM
222	4	1	-	1	1	1EM	M	M	-	M	-	EMB	B	EBM	-	M	-	EM
223	6	1	-	1	1	1EM	M	M	M	M	-	EMB	B	EBM	-	M	M	EM
224	3	1	-	4	2	-	M	EBM	M	EBM	-	EMB	B	EBM	-	EBM	M	EMB
225	2	-	-	1	1	-	-	-	-	M	-	EMB	-	EBM	-	M	-	-
226	2	-	3	4	2	-	BM	EBM	BM	EBM	M	EMB	-	EBM	M	EBM	BM	EMB
227	5	1	-	6	-	-	M	EBM	M	EBM	M	EBM	B	EBM	M	EBM	M	EBM
228	3	4	-	1	1	-	-	M	B	M	B	EMB	B	EBM	B	M	-	-
229	2	3	-	-	1	-	-	-	-	M	B	EMB	B	M	B	-	-	-
230	4	3	-	4	-	-	M	M	-	EBM	B	EBM	B	EBM	B	EBM	M	M
231	6	2	-	4	-	-	M	M	M	EBM	B	EBM	B	EBM	M	EBM	M	M
232	4	-	-	-	1	-	-	M	-	M	-	EMB	-	M	-	M	-	-
233	2	2	-	2	-	-	-	-	-	M	B	EBM	B	EBM	-	M	-	-
234	-	-	-	8	2	-	EBM	EBM	EBM	EBM	-	EMB	-	EMB	EBM	EBM	EBM	EBM
235	8	-	-	2	1	1EM	M	M	M	EBM	M	EMB	M	EBM	M	M	M	EM
236	4	3	1	1	-	1EM	M	M	-	M	BM	B	B	EBM	B	M	-	EM
237	2	-	-	2	-	-	-	-	-	M	-	EBM	-	EBM	-	M	-	-
238	-	-	2	1	4	-	EMB	-	EMB	-	BM	EBM	BM	-	EMB	-	EMB	-
239	1	1	-	4	2	-	M	EBM	-	EBM	-	EMB	B	EBM	-	EBM	-	EMB
240	-	-	-	1	2	1EM& 1EB	-	-	-	EB	EM	EMB	-	EMB	-	EBM	-	-
241	7	-	-	4	-	-	M	M	M	EBM	M	EBM	-	EBM	M	EBM	M	M
242	2	2	-	1	-	-	-	-	-	M	B	EBM	B	M	-	-	-	-
243	4	1	-	2	1	1EM	M	M	-	EBM	-	EMB	B	EBM	-	M	M	EM
244	7	2	-	1	1	1EM	M	M	M	M	B	EMB	B	EBM	M	M	M	EM
245	1	4	-	3	1	-	-	M	B	EBM	B	EMB	B	EBM	B	EBM	-	-
246	1	2	-	2	-	-	-	-	-	M	B	EBM	B	EBM	-	-	-	-
247	6	1	-	3	-	-	M	M	M	EBM	-	EBM	B	EBM	-	M	M	M
248	4	2	-	-	1	1EM	-	M	-	M	B	EMB	B	M	-	M	-	EM
AJ15 — 249	-	-	-	9	3	-	EBM	EBM	EBM	EBM	EMB	EMB	EBM	EMB	EBM	EBM	EBM	EBM
250	2	5	-	3	1	1EM	M	M	B	EBM	B	EMB	B	EBM	B	EBM	B	EM

X-75509

TABLE III-3 (Contd)

SPRING COMBINATIONS
AF, AG, AND AJ RELAYS

Comb. No.	M	B	BM	EBM	EMB	Others	1	2	3	4	5	6	7	8	9	10	11	12
	Spring Combinations						Positions											
251	-	2	-	1	1	-	-	-	-	-	B	EMB	B	EBM	-	-	-	-
252	4	-	-	4	2	-	M	EBM	M	EBM	-	EMB	-	EBM	M	EBM	M	EMB
253	1	-	-	2	1	-	-	-	-	EBM	-	EMB	-	EBM	-	M	-	-
254	-	-	-	6	2	-	EBM	EBM	-	EBM	-	EMB	-	EMB	-	EBM	EBM	EBM
255	7	2	-	-	-	2EM	M	M	M	M	B	EM	B	M	-	M	M	EM
256	1	4	-	2	1	-	-	-	B	EBM	B	EMB	B	EBM	B	M	-	-
257	5	-	-	4	1	1EM	M	EBM	M	EBM	M	EMB	-	EBM	M	EBM	M	EM
258	1	-	-	-	2	-	-	-	-	M	-	EMB	-	EMB	-	-	-	-
259	-	-	-	8	1	2EM	EBM	EBM	EBM	EBM	EM	EMB	-	EM	EBM	EBM	EBM	EBM
260	1	1	-	-	2	2EB	-	-	-	M	B	EMB	EB	EMB	EB	-	-	-
261	7	2	-	2	-	-	M	M	M	M	B	EBM	B	EBM	-	M	M	M
262	5	-	-	3	2	-	M	EBM	M	EBM	-	EMB	-	EMB	M	EBM	M	M
263	4	1	-	4	-	-	M	M	-	EBM	-	EBM	B	EBM	-	EBM	M	M
→ 264	2	3	-	2	-	-	-	-	-	M	B	EBM	B	EBM	B	M	-	-
265	-	5	-	4	1	1EM	-	EBM	B	EBM	B	EMB	B	EBM	B	EBM	B	EM
266	6	3	-	-	-	2EM	M	M	-	M	B	EM	B	M	B	M	M	EM
267	1	-	-	3	-	-	-	-	-	EBM	-	EBM	-	EBM	-	M	-	-
268	7	-	-	3	-	-	M	M	M	EBM	-	EBM	-	EBM	M	M	M	M
269	3	-	-	-	2	1EM	-	M	-	-	EM	EMB	-	EMB	-	M	-	M
270	7	1	-	2	1	1EM	M	M	M	EBM	M	EMB	B	EBM	M	M	M	EM
271	2	1	-	4	2	-	M	EBM	-	EBM	-	EMB	B	EBM	-	EBM	M	EMB
272	-	1	-	3	1	-	-	-	-	EBM	-	EMB	-	EBM	-	EBM	-	B
273	-	4	-	4	-	-	-	-	B	EBM	B	EBM	B	EBM	B	EBM	-	-
274	2	1	-	2	-	-	-	EBM	-	M	-	B	-	EBM	-	M	-	-
275	1	-	-	6	1	2EB	EBM	EBM	EB	EBM	-	EMB	M	-	EB	EBM	EBM	EBM
276	1	2	-	3	2	-	B	EBM	B	M	-	EMB	-	EBM	-	EBM	-	EMB
277	3	5	1	1	1	1EM	BM	M	B	M	B	EMB	B	EBM	B	M	B	EM
278	2	2	-	6	1	1EB	EBM	EBM	EBM	M	EMB	B	M	B	EBM	EBM	EBM	EB
279	3	3	-	-	2	-	-	-	-	M	B	EMB	B	M	B	M	-	EMB
280	3	2	-	3	-	-	-	M	-	EBM	B	EBM	B	EBM	-	M	-	M
→ 281	5	-	4	-	-	1EM	M	M	BM	M	BM	-	BM	-	BM	M	M	EM
282	3	-	-	-	2	-	-	M	-	M	-	EMB	-	EMB	-	M	-	-
283	6	-	3	3	-	-	M	M	M	EBM	BM	EBM	BM	EBM	BM	M	M	M
284	2	2	-	1	-	-	-	M	-	EBM	-	B	-	B	-	M	-	-
285	7	3	-	2	-	-	M	M	M	M	B	EBM	B	EBM	B	M	M	M
286	2	2	-	2	-	-	-	M	-	EBM	-	B	-	B	-	EBM	-	M
287	2	-	-	-	2	1EM	-	M	-	-	EM	EMB	-	EMB	-	M	-	-
288	3	-	-	1	1	-	-	M	-	M	-	EMB	-	EBM	-	M	-	-
289	7	-	-	-	-	3EM	M	M	M	-	EM	EM	M	EM	-	M	M	M
290	-	-	-	1	2	2EB	-	-	-	EBM	-	EMB	-	EB	-	EB	-	EMB
→ 291	1	2	1	3	1		BM	EBM	B	-	-	EMB	-	EBM	-	EBM	M	B
→ 292	1	2	-	1	1	-	-	-	-	M	B	EMB	B	EBM	-	-	-	-
→ 293	1	4	-	2	-	-	-	-	B	M	B	EBM	B	EBM	B	-	-	-
294	3	-	-	2	-	-	-	M	-	M	-	EBM	-	EBM	-	M	-	-
→ 295	4	2	-	-	1	-	-	M	-	M	B	EMB	B	M	-	M	-	-
296	3	3	-	-	1	-	-	-	-	M	B	EMB	B	M	B	M	-	-
297	1	-	-	1	2	1EB	-	-	-	EBM	-	EMB	EB	EMB	-	M	-	-
298	8	-	-	4	-	-	M	M	M	EBM	M	EBM	M	EBM	M	EBM	M	M
→ 299	-	-	2	6	4	-	EMB	EBM	EMB	EBM	BM	EBM	BM	EBM	EMB	EBM	EMB	EBM
→ 300	2	-	-	3	-	-	-	M	-	EBM	-	EBM	-	EBM	-	M	-	-

TABLE III-3 (Contd)

SPRING COMBINATIONS
AF, AG, AND AJ RELAYS

Comb. No.	Spring Combinations M	B	BM	EBM	EMB	Others	Positions 1	2	3	4	5	6	7	8	9	10	11	12
301	5	-	-	4	-	-	-	M	M	EBM	M	EBM	M	EBM	M	EBM	-	-
302	-	-	3	-	-	1EM	-	-	-	-	BM	-	BM	-	BM	-	-	EM
303	2	-	-	1	2	-	-	M	-	EBM	-	EMB	-	EMB	-	M	-	-
304	5	4	1	-	-	2EM	M	M	B	M	B	EM	B	M	B	M	BM	EM
305	3	3	-	2	1	1EM	M	M	-	EBM	B	EMB	B	EBM	B	M	-	EM
306	3	4	-	3	1	1EM	M	M	B	EBM	B	EMB	B	EBM	B	EBM	M	EM
307	3	-	-	5	-	-	M	EBM	-	EBM	-	EBM	-	EBM	-	EBM	M	M
308	4	3	2	-	-	1EM	M	M	BM	M	B	-	B	-	BM	M	B	EM
309	3	3	1	2	-	1EM	M	M	-	EBM	BM	B	B	EBM	B	M	-	EM
310	3	5	-	-	-	1EM,1EB	-	M	B	M	B	B	B	EB	B	M	-	EM
311	1	1	-	5	1	1EB	EBM	EBM	EB	M	-	EMB	-	B	-	EBM	EBM	EBM
312	2	1	-	2	1	1EM	-	M	-	EBM	-	EMB	B	EBM	-	M	-	EM
313	4	1	-	2	2	3EB	M	M	EB	EBM	B	EMB	EB	EMB	EB	EBM	M	M
314	2	-	3	5	-	-	BM	EBM	BM	M	-	EBM	-	EBM	M	EBM	BM	EBM
315	-	3	-	1	-	-	-	-	-	-	B	EBM	B	-	B	-	-	-
316	4	-	-	4	2	1EB	M	EBM	M	EBM	-	EMB	EB	EMB	M	EBM	M	EBM
317	3	5	-	2	-	-	B	M	B	M	B	EBM	B	EBM	B	M	-	-
318	-	-	2	2	4	-	EMB	-	EMB	-	BM	EBM	BM	EBM	EMB	-	EMB	-
319	5	-	-	1	1	-	M	M	-	M	-	EMB	-	EBM	-	M	M	-
320	3	3	1	3	-	2EM	M	EBM	M	EBM	B	EM	B	EBM	B	M	BM	EM
321	6	3	-	2	-	-	M	M	B	M	B	EBM	B	EBM	-	M	M	M
322	2	4	-	-	2	1EB	EMB	M	B	-	B	EB	B	-	B	-	EMB	M
323	4	-	-	3	1	-	M	EBM	-	M	-	EMB	M	-	-	EBM	M	EBM
324	-	-	-	4	1	-	-	EBM	-	EBM	-	EMB	-	EBM	-	EBM	-	-
325	2	-	-	2	-	1EM	-	EBM	-	M	-	EM	-	M	-	EBM	-	-
326	3	-	3	6	-	-	BM	EBM	BM	EBM	M	EBM	M	EBM	M	EBM	BM	EBM
327	5	-	-	-	1	1EM	M	M	-	M	-	EMB	-	M	-	M	-	EM
328	4	-	-	4	1	-	-	EBM	M	EBM	M	EMB	M	EBM	M	EBM	-	-
329	6	2	-	-	1	-	M	M	-	M	B	EMB	B	M	-	M	M	-
330	7	-	-	3	-	2EM	M	M	M	EBM	M	EM	M	EBM	M	EBM	M	EM
331	5	-	-	2	-	2EB	M	M	M	-	EB	EBM	EB	EBM	-	M	-	M

X-75509

TABLE III-4
SPRING COMBINATIONS
AF, AG, AND AJ RELAYS

Comb. No.	Spring Combinations: M	B	BM	EBM	EMB	PM	PB	Others	Positions: 1	2	3	4	5	6	7	8	9	10	11	12
400	1	2	-	1	1	1	-		-	-	-	PM	B	EBM	B	EMB	-	M	-	-
401	1	-	-	2	-	2	-	-	-	-	M	PM	-	EBM	-	-	PM	EBM	-	-
402	-	-	-	2	-	1	-	-	-	-	-	PM	-	EBM	-	-	-	EBM	-	-
403	-	2	-	2	1	1	-	2EM	-	EM	-	PM	B	EBM	B	EMB	-	EBM	-	EM
405	-	-	-	1	-	-	-	1PBEM	-	PBEM	-	-	-	-	-	-	-	EBM	-	-
406	-	3	-	2	1	1	-	2EM	-	EM	B	PM	B	EBM	B	EMB	-	EBM	-	EM
407	-	2	1	1	1	-	-	1PBEM 1EM	B	EM	B	-	BM	EBM	-	EMB	-	-	-	PBEM
408	-	-	3	2	1	-	-	2PMEB 1EM	-	EM	BM	PMEB	BM	EBM	BM	EMB	PMEB	EBM	-	-
409	1	3	-	1	1	1	-	-	-	-	B	PM	B	EBM	B	EMB	-	M	-	-
410	3	1	-	1	1	-	1	1PBEM	M	PBEM	-	-	B	EBM	-	EMB	-	M	M	PB
411	-	3	2	2	-	1	-	2EM	BM	EM	B	PM	B	EBM	B	EM	-	EBM	BM	-
412	-	-	-	-	1	-	-	2PBEM	-	PBEM	-	-	-	-	-	EMB	-	-	-	PBEM
413	4	2	1	-	1	-	1EM	2PMEB 1PBEM	M	PBEM	M	PMEB	B	M	B	EMB	PMEB	M	BM	EM
414	-	-	5	2	1	-	-	2PBEM 2PMEB	BM	PBEM	BM	PMEB	BM	EBM	BM	EMB	PMEB	EBM	BM	PBEM
415	-	-	2	2	1			2PBEM	BM	PBEM	BM	-	-	EBM	-	EMB	-	EBM	-	PBEM
416	2	2	-	2	1	1		1EM	M	EM	-	PM	B	EBM	B	EMB	-	EBM	M	-
417	5	-	-	1	-	1	2	1EB	M	PB	M	-	M	EBM	M	-	PM	EB	M	PB
418	1	-	2	2	-	1	-	3EM	M	EM	BM	PM	-	EBM	-	EM	-	EBM	BM	EM
419	2	2	-	2	1	-	-	1PBEM 1PMEB	M	PBEM	-	PMEB	B	EBM	B	EMB	-	EBM	M	-
420	1	5	-	1	-	1	-	3EM	B	EM	B	PM	B	EBM	B	EM	-	M	B	EM
421	1	3	-	1	1	1	-	1EM	-	EM	B	PM	B	EBM	B	EMB	-	M	-	-
422	1	5	-	1	-	1	-	3EM) 1PMEB)	B	EM	B	PM	B	EBM	B	EM	PMEB	M	B	EM
→ 423	5	-	-	1	-	1	2	1EM-1EB	M	PB	M	-	M	EBM	M	EM	PM	EB	M	PB

500 24 Make in 24 positions

TABLE III-5

AK RELAYS

Comb. No.	Contact Arrangement M	B	BM	Positions 1	2	3	4	5	8	9	10	11	12
1	10	-	-	M	M	M	M	M	M	M	M	M	M
2	-	-	10	BM	BM	BM	BM	BM	BM	BM	BM	BM	BM
3	-	-	4	BM	BM	-	-	-	-	-	-	BM	BM
4	2	6	-	M	B	B	B	-	-	B	B	B	M
5	2	2	1	-	M	-	B	-	BM	-	B	-	M
6*	2	2	1	M	BM	B	-	-	-	-	-	B	M
7	5	-	5	BM	BM	BM	BM	M	M	M	M	M	BM
8	4	-	-	-	M	-	M	-	M	-	M	-	-
9	3	1	3	BM	BM	BM	M	-	-	-	M	M	B
10	4	3	3	M	BM	B	BM	M	M	B	BM	B	M
11	6	-	-	M	M	M	M	-	-	-	M	M	-
12	4	-	4	BM	BM	-	M	M	M	M	-	BM	BM
13	-	2	4	BM	BM	B	-	-	-	-	B	BM	BM
14	2	1	5	M	M	B	-	-	BM	BM	BM	BM	BM
15	3	4	3	M	BM	M	BM	B	B	B	M	BM	B
16	-	2	8	BM	BM	BM	B	B	BM	BM	BM	BM	BM
17	4	5	-	M	M	B	B	B	B	B	-	M	M
18	3	-	1	-	M	-	M	-	M	-	BM	-	-

X-75509

*Special for use on F-51877 only.

TABLE III-5 (Contd)

AK RELAYS

Comb. No.	Contact Arrangement M	B	BM	EBM	EMB	EM	EB	Positions 1	2	3	4	5	8	9	10	11	12
201	2	3	-	3	1	-	-	M	EBM	-	B	B	EMB	B	M	EBM	EBM
202	2	-	-	4	4	-	-	M	EBM	EBM	EMB	EMB	EMB	EMB	EBM	EBM	M
203	-	-	-	6	-	4	-	EBM	EBM	EBM	EM	EM	EM	EM	EBM	EBM	EBM
204	3	1	-	3	1	2	-	M	EBM	EBM	B	EM	EM	EMB	EBM	M	M
205	2	-	-	-	-	2	-	-	M	-	EM	-	EM	-	M	-	-
206	2	2	-	-	2	-	-	M	-	-	EMB	B	B	EMB	-	-	M
207	4	-	-	-	-	4	2	M	M	EB	EM	EM	EM	EM	EB	M	M
208	-	2	-	6	-	-	-	EBM	EBM	EBM	-	-	B	B	EBM	EBM	EBM
209	3	2	-	1	2	-	2	EBM	EB	EB	EMB	EMB	B	B	M	M	M
210	4	-	-	-	4	2	-	M	M	EMB	EM	EMB	EMB	EM	EMB	M	M
211	6	-	-	-	4	-	-	M	M	M	EMB	EMB	EMB	EMB	M	M	M
212	4	-	-	2	2	2	-	M	M	EBM	EM	EMB	EMB	EM	EBM	M	M
213	3	1	-	1	-	1	-	EBM	-	-	B	EM	-	-	M	M	M
214	-	-	-	6	-	-	-	EBM	EBM	EBM	-	-	-	-	EBM	EBM	EBM
215	6	-	-	-	2	2	-	M	M	M	EM	EMB	EMB	EM	M	M	M
216	-	-	-	6	4	-	-	EBM	EBM	EBM	EMB	EMB	EMB	EMB	EBM	EBM	EBM
217	4	-	-	2	-	-	-	M	EBM	EBM	-	-	-	-	M	M	M
218	4	1	-	-	2	-	1	EB	M	-	B	EMB	EMB	-	M	M	M
219	4	-	-	2	2	2	-	EBM	EBM	M	EM	EMB	EMB	EM	M	M	M
220	2	-	-	3	2	-	1	M	EBM	EBM	EMB	-	-	EMB	EBM	EB	M ←

HEATING DATA

General

The primary heating considerations in the design of coils for switching apparatus are: effects of temperature under normal operating conditions, and effects of temperature under trouble conditions.

Normal heating is considered to be the condition imposed on a coil, with respect to the wattage and duration of energization, when the circuit in which the coil is used is functioning in a normal manner.

Trouble heating is considered to be the condition to which a coil is subjected when the circuit ceases to function normally. Trouble conditions may result from a continuous application of voltage which normally is applied intermittently, or from a short circuit, cross, or false ground which causes a higher voltage than normal to be impressed on the coil. It is assumed that any increase in temperature above the normal operating temperature limit, whether caused by circuit failures or by maintenance activity, constitutes trouble heating. It is not guaranteed that apparatus which has been subjected to a trouble condition will function satisfactorily thereafter. The coil, however, must withstand the trouble heating without danger of creating a fire hazard. A coil meeting this trouble condition is said to be self-protecting.

X-75509

Normal Operating Temperature Limits

Normal operating temperature limits are based on four factors:

A. The ability of the coil to withstand the operating temperature for extended periods of continuous or intermittent operation without impairment of the electrical performance throughout the life of the relay.

B. The ability of other parts of the structure, such as separators and insulators, to withstand the temperature imposed without the adjustment being affected adversely.

C. The possibility of injury to personnel from bodily contact.

D. The possibility of contamination of apparatus and contacts by the volatile substances emitted.

A normal mean winding temperature limit of 225F has been in effect since 1919, and relays and switching apparatus generally have been designed to withstand an average operating temperature of the coil of 225F. Since, under conditions of normal operation, all the foregoing considerations are controlling, the normal operating temperature limit was established irrespective of the type of wire insulation. In a few special cases, after consideration of the factors involved, temperatures in excess of 225F have been permitted.

The normal heating is computed on the basis of the maximum initial watts and the maximum holding time per call, or the average holding time per busy hour, whichever is the greater.

Trouble Temperature Limits

The temperature of a magnet winding, placed across a battery, will rise by an amount depending on the values of the voltage and resistance and the heat dissipation characteristics of the magnet. The temperature of the winding will continue to rise until the point is reached where the power obtained from the battery is in equilibrium with the heat dissipated by the winding. The condition will stabilize at some elevated temperature provided this temperature is not high enough to cause a breakdown of the wire insulation. If this occurs, turns will become short-circuited, the magnet resistance will be lowered, more current will be drawn from the battery, and the temperature will rise further. Once started, the complete breakdown of the coil will proceed very rapidly, and during the period of disintegration, a very high temperature that may cause the magnet to become a possible fire hazard will be reached. Such a fire hazard may be avoided by insuring that the maximum temperature of the winding will never exceed that at which the wire insulation breaks down.

Various types of insulation have different heat-resisting properties and these characteristics are controlling in establishing trouble temperature limits. The trouble temperature limits for a particular type of wire insulation were determined by energizing coils with various amounts of energy corresponding to predetermined winding temperatures. A coil failure was detected by measurements of the inductance at 1000 cycles. The inductance at such frequency shows a marked change with only a few short-circuited turns. Table IV-1 shows the temperature limits that have been established for the various wire insulations.

48-hour Trouble Heating Limit

When the trouble temperature limits were established in 1919, the limit for each type of insulated wire was set on the basis of the temperature that the coil would withstand satisfactorily for an indefinite period. In 1941, it was considered advisable to include in the limits the temperature at which coils with enameled wire might be expected to function for a limited period without becoming a fire hazard. Accordingly, a restricted temperature limit of 360F, for cellulose-acetate-filled coils wound with LRM 70 wire, was adopted, with the stipulation that this limit applied only where trouble conditions would not occur, or recur, for a cumulative total of more than 48 hours during the 40-year life of the relay. The 360F temperature limit can be used only in circuit applications where it is feasible to administer the use of the coils to guarantee that trouble conditions would be detected within a very short time. Since a fire hazard might be involved in operating coils wound with LRM 70 wire at 360F for a cumulative time longer than 48 hours, the 250F limit was retained for trouble heating periods of indefinite duration. Formex wire, however, will withstand a 360F temperature indefinitely.

Maintenance Heating

It is a common practice, during installation and maintenance testing and trouble shooting, to block a circuit so that some relays are held energized for long periods of time. The heating, under this condition, should not exceed the normal limit if satisfactory performance is required subsequent to such maintenance activity. In a few special cases, such as the 270- and 400-ohm coils, where speed of operation is important, and after consideration of the factors involved, temperatures in excess of the normal limit have been permitted. While it is expected that no great risk is being taken with these two coils, based on experience with the 400-ohm U relay coil, it is not considered expedient to extend the maintenance heating limit above 225F until more information has been obtained.

Intermittent Heating

With respect to the way they are used in circuits, relays may be divided into two general groups: those energized during conversation, and those energized as the call is being established.

The first group of relays has coils that must meet the normal heating limit when energized continuously.

The second group of relays is energized for times varying from a fraction of a second to several seconds on a call and is then deenergized until the circuit is again seized on another call. The magnets are thus subjected to alternate periods of heating and cooling, generally called intermittent operation. With intermittent operation, the magnet temperature will rise during the heating, or "on" period, and drop during the cooling, or "off" period.

The percentage of the "on" period to the total period is called the per cent time energized, or duty cycle. The ultimate coil temperature that will be attained is dependent on both the duty cycle and the total cycle. The duty cycle cannot always be applied, but approximate limits have been established for which the duty cycle may be applied. Tests have shown that, for circuits like the marker, where the total cycle is approximately one second, or for intervals up to one minute with equal "on" and "off" periods, the duty cycle may be applied.

The maximum temperature to which the coil will rise is not the temperature that the coil would attain if energized continuously with the same initial wattage; therefore, with intermittent operation, an initial wattage higher than that which would cause a rise in temperature to the normal limit of 225F, with the magnet energized continuously, may be allowed.

The temperature rise, where the duty cycle is applicable, is based on a wattage equal to the initial wattage times the duty cycle. The allowable initial intermittent watts (W_I) is found from

$W_I = W_c \frac{a+b}{a}$ where W_c is the continuous watts, a is the "on" interval, and b the "off" interval. This method permits reasonably close results for short intervals in the order of one second with any duty cycle, or one minute with 50 per cent duty cycle, but introduces a substantial error for 50 per cent duty cycles in the order of 3 minutes.

Thermal Conductance

Most magnet coils are wound with copper wire which increases in resistance as its temperature is raised. Unless the energy supplied to the magnet is manipulated so as to remain constant as the temperature rises, there will be a change in energy consumption as the coil grows hotter. The temperature to which a magnet will rise bears a definite relationship to the electrical energy with which it is supplied. The quantity of heat which may be stored in a body is measured by its mass, its specific heat, and its increase in temperature.

Heat flows away from a coil principally through the core, by conduction, and through the outer surface of the coil by convection and radiation. The flow of thermal energy from a body resulting from its being at a higher temperature than its surroundings, and the energy lost by radiation to surrounding bodies depends on the thermal conductivity and dimensions of the body, and may be termed the thermal conductance ρ.

The thermal conductance will depend on the conductivity of heat through the core, the area of the winding adjacent to the core, and the outside area of the coil. An empirical equation expressing this relation is $\rho = \rho_a + \rho_c = K_a A_a + \cfrac{1}{R_{c1} + \cfrac{1}{K_c A_c}}$

Where ρ = total thermal conductance
ρ_a = thermal conductance to the air
ρ_c = thermal conductance to the core
K_a = coefficient for conductance to the air
K_c = coefficient for conductance to the core
A_a = coil area exposed to the air
A_c = coil area adjacent to the core
R_{c1} = thermal resistance to the core

K is a coefficient expressed as the temperature rise which would result from supplying 1 watt per square inch of radiating area, and is assumed to be independent of the gauge and insulation of the wire, but varying with the area (A).

The thermal resistance is defined as the reciprocal of the thermal conductance, or $\frac{1}{\rho}$.

The values of ρ have been determined as part of the fundamental design of the wire spring relay. These values have been plotted in Fig. IV-1, which shows the thermal conductance for different winding depths, and Fig. IV-2, which shows the final temperature for different values of initial watts and thermal conductance.

Allowable Heating

Since the thermal conductance increases with the winding depth, the allowable heating on a coil increases as the radiating area increases. The allowable initial wattage and thermal conductance for the AF, AG, and AJ relay coils are shown in Table IV-2. The wattage figures are valid only for coils wound with copper wire. The allowable initial wattage and thermal conductance for the AK relay is shown in Table IV-3.

The allowable initial watts for any AF, AG, or AJ relay coil may be computed finding the thermal conductance for the particular coil from Fig. IV-1 for the winding depth of the coil. The depth of the coil may be found from data in Section X. From Fig. IV-2, the allowable initial watts may be found from the thermal conductance and temperature limit. The initial watts should be computed from the maximum voltage and minimum resistance.

Resistance Rise

The resistance of a coil wound with copper wire, subjected to a constant voltage, rises to some value higher than that obtained at ambient room temperature. This rise is computed from the minimum initial watts, that is, minimum circuit voltage and maximum coil resistance. If short holding times are involved, the initial watts may be multiplied by the duty cycle to obtain the equivalent initial watts. Knowing the initial watts and the thermal conductance, the final temperature may be found in Fig. IV-2. The temperature coefficient for copper wire results in a rise of 1 per cent for each 4.58F increase in temperature. The hot resistance is therefore

$$R_H = R_{68}\left(1 + \frac{\text{Final temperature} - 68F}{458}\right).$$

To facilitate determining the hot resistance, the per cent resistance rise has been plotted against the initial watts for different thermal constants in Fig. IV-3 and IV-4.

Resistance wire has a zero temperature coefficient and therefore does not increase in resistance due to heating.

Heating Conditions

The allowable wattage in Table IV-2 and the resistance rise in Fig. IV-3 and IV-4 are based on a constant voltage across the coil. Service conditions sometimes arise in which other than a constant voltage is used across a magnet. A list of these conditions, together with the formulae for determining the allowable watts and final temperature, are shown in the appendix. Conditions not covered herein should be referred to the relay requirements group.

X-75509

APPENDIX

Service conditions sometimes arise in which other than a constant voltage is used across a magnet. The conditions under which a magnet may be subjected to a temperature rise are:

1. Constant voltage.
2. Constant current condition. If the magnet is used in series with an external resistance of zero temperature coefficient, and the resistance of the magnet is a small part of the total circuit resistance, the current will not decrease materially as the magnet resistance increases due to the temperature rise.
3. Constant power. The circuit constants may change to maintain the wattage on the magnet constant.
4. Constant voltage with a copper winding in parallel with a resistance winding of zero temperature coefficient.
5. Constant voltage with a copper winding in series with a resistance winding of zero temperature coefficient.
6. Constant voltage with a copper winding in series with an external resistance of zero temperature coefficient.

Temperature formulae have been developed giving the maximum initial watts that will prevent an electromagnet from rising above given temperature limits. These formulae for conditions 1 to 6 above and the temperature limits are:

Condition 1

Initial watts $\left(\frac{E^2}{R_{68}}\right) = 168\ \rho$ (225F)

Initial watts $\left(\frac{E^2}{R_{68}}\right) = 210\ \rho$ (250F)

Initial watts $\left(\frac{E^2}{R_{68}}\right) = 426\ \rho$ (360F)

Condition 2

Initial watts $(I^2\ R_{68}) = 93.1\ \rho$ (225F)

Initial watts $(I^2\ R_{68}) = 107.3\ \rho$ (250F)

Initial watts $(I^2\ R_{68}) = 158.8\ \rho$ (360F)

Condition 3

Watts = $125\ \rho$ (225F)

Watts = $150\ \rho$ (250F)

Watts = $260\ \rho$ (360F)

Condition 4

$$\frac{\text{Initial watts on cu wdg } \left(\frac{E^2}{R_{68}}\right)}{1.343} + \text{watts on res wdg } \left(\frac{E^2}{r}\right) = 125\ \rho \quad (225F)$$

$$\frac{\text{Initial watts on cu wdg } \left(\frac{E^2}{R_{68}}\right)}{1.397} + \text{watts on res wdg } \left(\frac{E^2}{r}\right) = 150\ \rho \quad (250F)$$

$$\frac{\text{Initial watts on cu wdg } \left(\frac{E^2}{R_{68}}\right)}{1.638} + \text{watts on res wdg } \left(\frac{E^2}{r}\right) = 260\ \rho \quad (360F)$$

Condition 5

$$\frac{E^2}{1.343\ R_{68} + r} = 125\ \rho \quad (225F)$$

$$\frac{E^2}{1.397\ R_{68} + r} = 150\ \rho \quad (250F)$$

$$\frac{E^2}{1.638\ R_{68} + r} = 260\ \rho \quad (360F)$$

X-75509

Condition 6

Series res. (r) not less than $- 1.343\ R_{68} + \sqrt{\frac{E^2\ R_{68}}{93.1\rho}}$ (225F)

Series res. (r) not less than $- 1.397\ R_{68} + \sqrt{\frac{E^2\ R_{68}}{107.3\rho}}$ (250F)

Series res. (r) not less than $- 1.638\ R_{68} + \sqrt{\frac{E^2\ R_{68}}{158.8\rho}}$ (360F)

The final temperature of a magnet for the different heating conditions listed previously may be calculated as shown below.

Condition 1

$$T = -145 + \sqrt{60{,}000 + \frac{458\ E^2}{R_{68\rho}}}$$

Condition 2

$$T = \frac{490}{\frac{458\rho}{I^2 R_{68}} - 1} + 100$$

Condition 3

$$T = \frac{W}{\rho} + 100$$

Condition 5

$$T = -145 - \frac{229r}{R_{68}} + \frac{229}{R_{68}} \sqrt{(1.07 R_{68} + r)^2 + \frac{E^2 R_{68}}{114.5\rho}}$$

Heating conditions other than shown should be referred to the relay requirements group.

In the foregoing formulae:

E = Voltage in volts.

R_{68} = Resistance of the copper winding at 68F.

r = Resistance of zero temperature coefficient winding.

ρ = Thermal conductance (from Fig. IV-1).

TABLE IV-1

RECOMMENDED TEMPERATURE LIMITS FOR ELECTROMAGNETS CONCENTRIC WINDINGS, INCLUDING WINDINGS WITH SERIES TURNS OF RESISTANCE WIRE

Insulation	Mean Winding Temperature Limit for Trouble Conditions			
	Cellulose-acetate-filled coils		Spoolwound Coils	
	Indefinite	48 Hours**	Indefinite	48 Hours**
Enamel Per LRM-70	250F	360F	Not Recommended	
Enamel Per LRM-159	250F	360F	250F	325F
Heavv Formex Per LRM-222	360F		360F	
Single Nylon Per LRM-6002)				
Double Nylon Per LRM-6003)				
Single Nylon Plus Enamel (LRM-6004))*	360F		360F	
Double Nylon Plus Enamel (LRM-6005))				
Cotton or Cotton Plus Enamel	360F		360F	

*Formerly Silk Insulation.
**Coils should not be used in circuits where the cumulative hours of operation under trouble conditions may exceed 48 hours.

Notes:

For coils in which freedom from short-circuited turns is essential, or where inductance requirements are specified, enameled wire per LRM-222, or nylon insulated wires per LRM-6003, LRM-6004, and LRM-6005 should be used.

Where series resistance wire is used, the turns should be spread over as much of the coil length as possible. The hot-spot temperature should not exceed the recommended maximum mean winding temperature for the type of insulation employed.

Coil temperatures are based on operation at 100F ambient temperature.

X-75509

Parallel, Twisted, and Noninductive Windings

Enameled wires, single nylon, or cotton should not be used. The insulation should be nylon per LRM-6003, LRM-6004, or LRM-6005. Single cotton over LRM-222 wire, or double cotton over LRM-159 wire also may be used. The trouble temperature limits are the same as those for concentric windings.

Note: For all types of insulation and windings, the maximum mean winding temperature for normal operation should not exceed 225F.

TABLE IV-2

Heating Limits for AF, AG, and AJ Relays

Res	Sleeve	Ther Cond	Allowable Wattage 225°	250°	360°*
4.4		0.043	7.2	9.0	18.3
16		0.044	7.4	9.2	18.7
34		0.040	6.7	8.4	17.0
180		0.043	7.2	9.0	18.3
→200		0.035	5.9	7.4	14.9
220	0.091 cu	0.033	5.6	7.0	14.1
270		0.048	8.0	10.0	20.6
275		0.043	7.2	9.0	18.3
395		0.043	7.2	9.0	18.3
400		0.033	5.6	7.0	14.1
500		0.040	6.7	8.4	17.0
550	0.147 cu	0.044	7.4	9.2	18.7
600	0.091 cu	0.044	7.4	9.2	18.7
700		0.026	4.4	5.5	11.1
→800		0.041	6.9	8.7	17.5
860		0.034	5.7	7.2	14.5
875	0.046AL	0.043	7.2	9.0	18.3
950		0.042	7.1	8.8	18.0
1000	0.147 cu	0.041	6.9	8.7	17.5
1050	0.147 cu	0.044	7.4	9.2	18.7
1625		0.043	7.2	9.0	18.3
2000	0.091 cu	0.043	7.2	9.0	18.3
2200	0.046AL or cu	0.043	7.2	9.0	18.3
2500		0.043	7.2	9.0	18.3
2550	0.147 cu	0.041	6.9	8.7	17.5
→3800		0.045	7.6	9.5	19.2
4000		0.045	7.6	9.5	19.2
9100		0.043	7.2	9.0	18.3

*48 hour cumulative

TABLE IV-2 (Contd)

Heating Limits for AF, AG, and AJ Relays

Res	Sleeve	Ther Cond	Allowable Wattage 225°	250°	360°*
P 2.7		0.041	6.9	8.7	17.5
S 690		0.043	7.2	9.0	18.3
P 8		0.041	6.9	8.7	17.5
S 850		0.043	7.2	9.0	18.3
P 10		0.036	6.1	7.6	15.3
S 400		0.040	6.7	8.4	17.0
P 61		0.042	7.1	8.8	18.0
S 61		0.037	6.2	7.8	15.8
P 100		0.043	7.2	9.0	18.3
S 100		0.039	6.6	8.2	16.6
P 100		0.033	5.6	7.0	14.1
S 1100		0.043	7.2	9.0	18.3
P 170		0.033	5.6	7.0	14.1
S 140		0.043	7.2	9.0	18.3
P 198		0.034	5.7	7.2	14.5
S 90		0.041	6.9	8.7	17.5
P 200		0.044	7.4	9.2	18.7
S 200		0.040	6.7	8.4	17.0
P 220		0.040	7.4	9.2	18.7
S 1150		0.043	7.2	9.0	18.3
P 300		0.034	5.7	7.2	14.5
S 300		0.040	6.7	8.4	17.0
P 335		0.039	6.6	8.2	16.6
S 335		0.036	6.1	7.6	15.3
P 360		0.034	5.7	7.2	14.5
S 1900		0.045	7.6	9.5	19.2
P 400		0.034	5.7	7.2	14.5
S 210		0.046	7.7	9.6	19.5
P 400		0.043	7.2	9.0	18.3
S 400		0.038	6.4	8.0	16.2
P 425		0.043	7.2	9.0	18.3
S 425		0.038	6.4	8.0	16.2
P 450		0.032	5.4	6.8	13.6
S 57		0.044	7.4	9.2	18.7
P 450		0.035	5.9	7.4	14.9
S 110		0.044	7.4	9.2	18.7
P 450		0.032	5.4	6.8	13.6
S 200		0.044	7.4	9.2	18.7
P 450	0.091	0.038	6.4	8.0	16.2
S 500		0.045	7.6	9.5	19.2
P 540		0.033	5.6	7.0	14.1
S 540		0.036	6.1	7.6	15.3
P 550		0.033	5.6	7.0	14.1
S 550		0.037	6.2	7.8	15.8
T 525		0.041	6.9	8.7	17.5
P 700		0.034	5.7	7.2	14.5
S 700		0.043	7.2	9.0	18.3
P 1000		0.033	5.6	7.0	14.1
S 42		0.045	7.6	9.5	19.2

*48 hour cumulative

X-75509

TABLE IV-2 (Contd)

Heating Limits for AF, AG, and AJ Relays

Res	Sleeve	Ther Cond	Allowable Wattage 225°	250°	360°*
P 1000		0.034	5.7	7.2	14.5
S 2700		0.043	7.2	9.0	18.3
P 1175		0.034	5.7	7.2	14.5
S 1075		0.043	7.2	9.0	18.3
P 1200		0.032	5.4	6.8	13.6
S 6000		0.045	7.6	9.5	19.2
P 1500		0.035	5.9	7.4	14.9
S 2950		0.044	7.4	9.2	18.7
P 1800		0.034	5.7	7.2	14.5
S 85		0.044	7.4	9.2	18.7
P 5000		0.040	6.7	8.4	17.0
S 1000		0.044	7.4	9.2	18.7

*48 hour cumulative

TABLE IV-3

Heating Limits for AK Relays

	Ther Cond	Allowable Wattage 225°	250°	360°*
One Coil Energized	0.031	5.1	6.5	13.2
Two Coils Energized	0.026	4.4	5.5	11.0(Each coil)

*48 hour cumulative

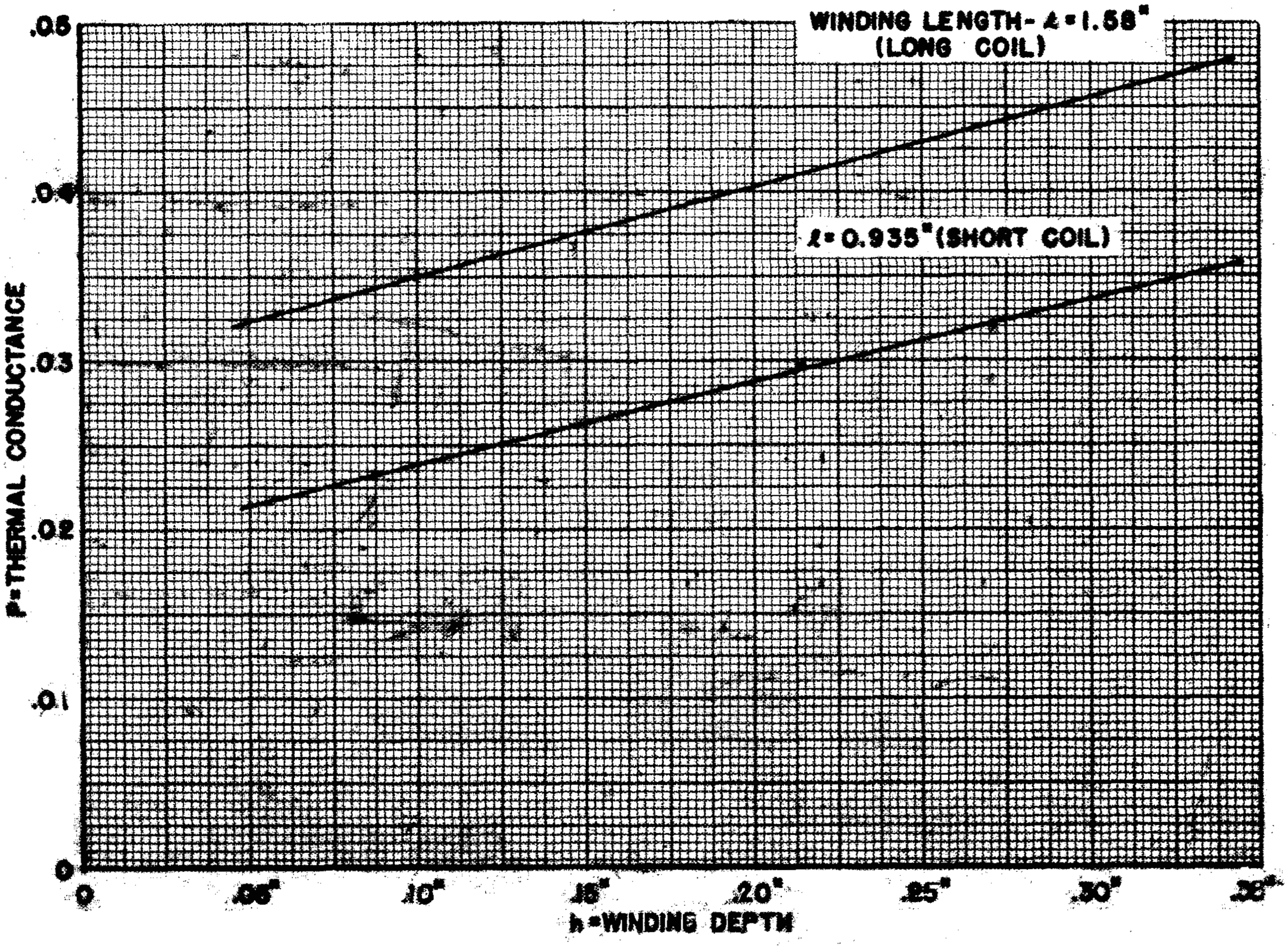


Fig. IV-1 - Thermal Conductance (p) for Various Winding Depths - AF, AG, and AJ Relays

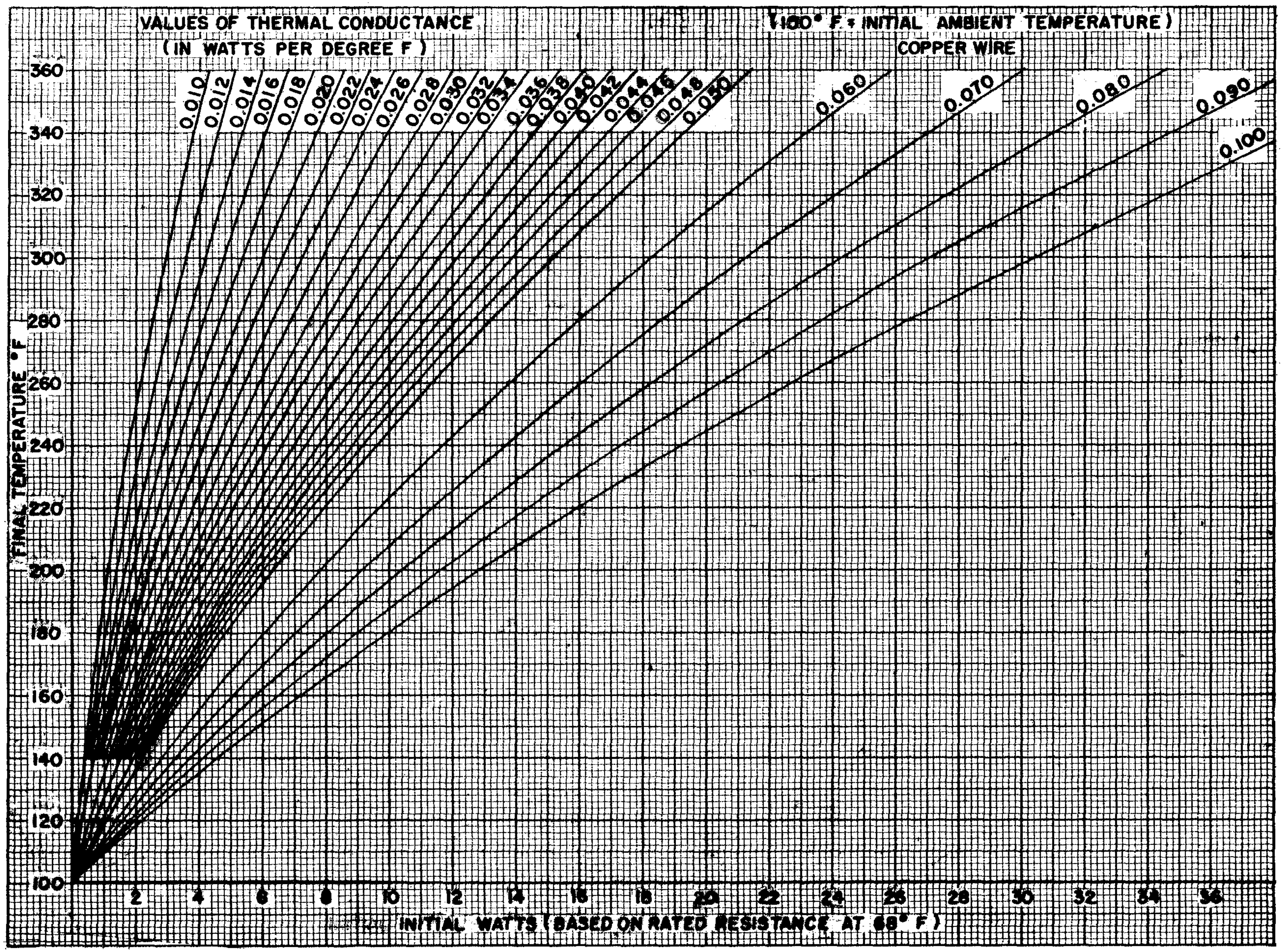


Fig. IV-2 - Constant Voltage Condition - Relation Between Initial Watts and Final Temperature

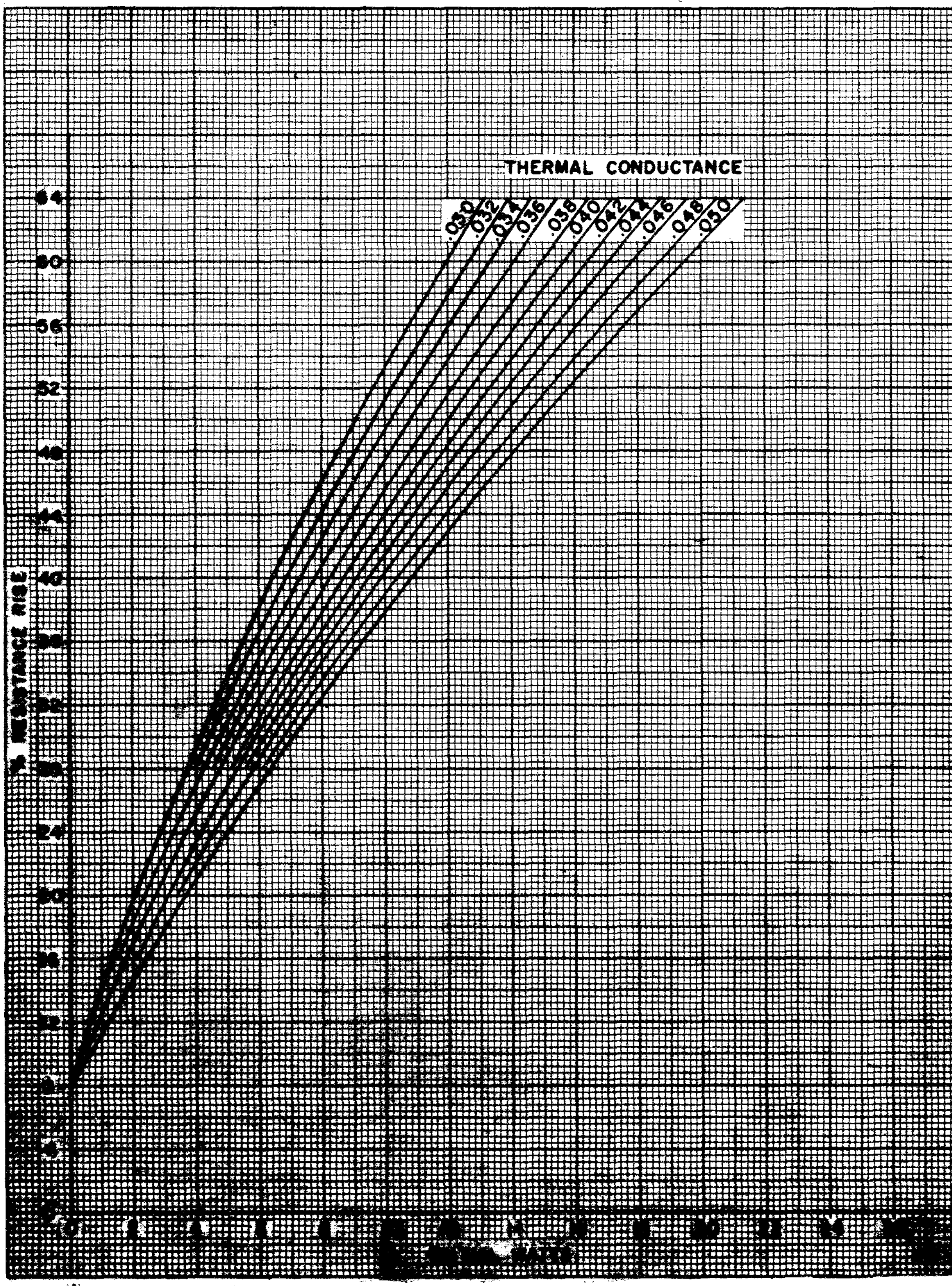


Fig. IV-3 - Resistance Rise

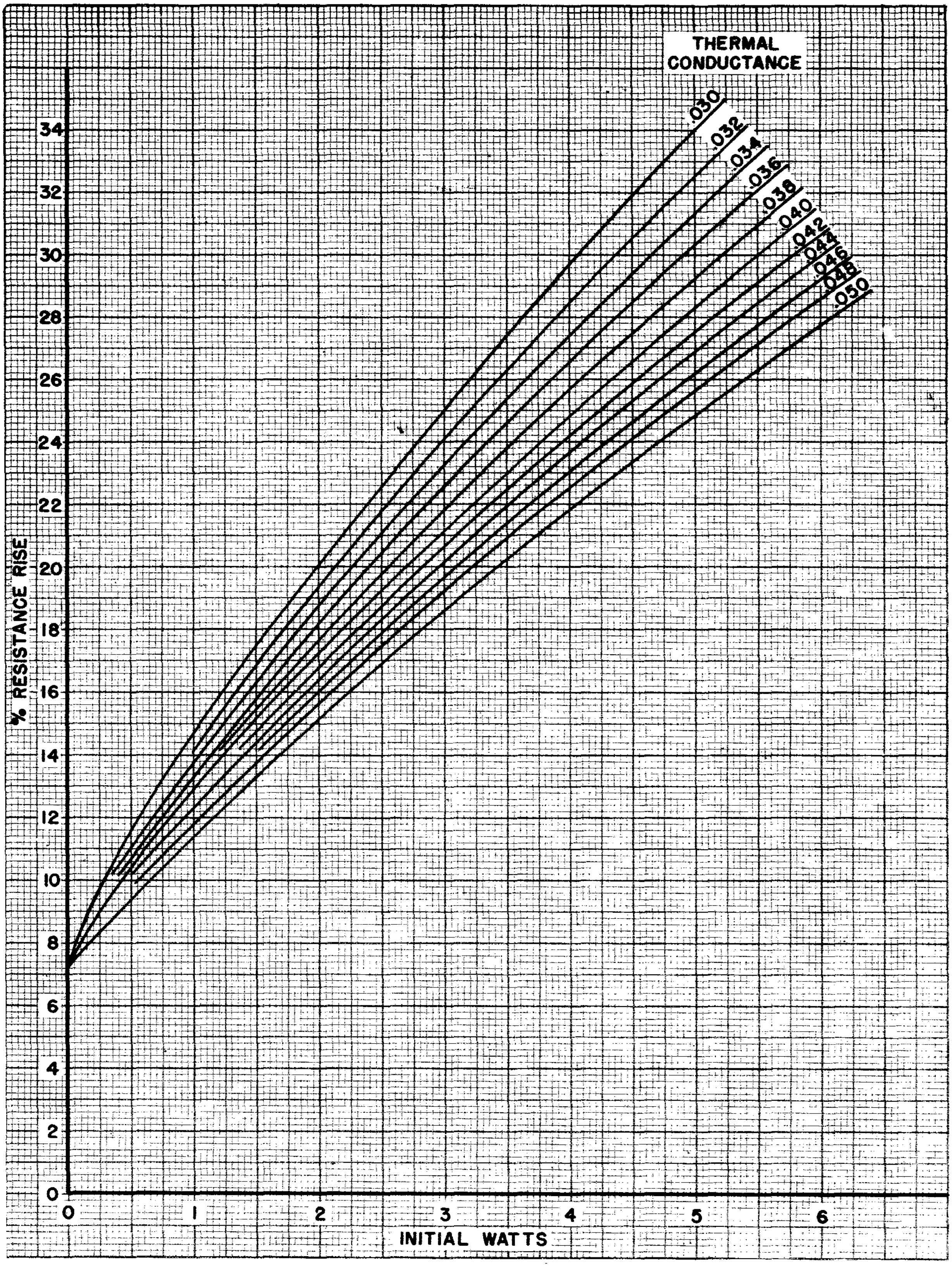


Fig. IV-4 - Resistance Rise

X-75509

MAGNETIC INTERFERENCE

General

The performance of a relay, or the adjustment applied to a relay, may be affected by the leakage or stray flux from adjacent energized apparatus. The magnitude of the effect on the relay performance or operation depends on:

A. The ampere turn energization and amount of leakage flux of the adjacent apparatus.

B. The function of the relay, that is, whether operate, nonoperate, hold, or release is involved.

C. The spacing between the relay and the interfering apparatus.

D. The amount and polarity of the leakage flux from the adjacent relays.

E. The extent to which the relay is affected by stray magnetic fields.

F. The use of covers on the interfering, or interfered with, apparatus.

The stray field from a relay varies with its ampere turn energization, increasing as the ampere turns are increased, up to the saturation point of the relay. The effect of the stray field on a relay will vary with the adjusting ampere turns. Thus, hold or release values of slow releasing AG relays, which are relatively low ampere turns, will be affected more on a percentage basis than the operate or nonoperate.

Only the adjacent relays 1, 2, 3, 4, 6, 7, 8, and 9, in the interference pattern shown below, will significantly affect relay No. 5, which is the one under consideration.

Interference Pattern

1	2	3
4	5	6
7	8	9

The mounting centers for the relays in the interference pattern are:

AF relays 1-1/2 in. Hor.

U relays 1-1/4 in. Hor.

U&AF relays 2 in. Vert.

Relays outside the interference pattern are 2-1/2 inches or more away and their field has no effect on the relay in position No. 5. Thus, magnetic interference may (if necessary) be eliminated by a suitable location of the energized relays. This method generally involves no penalty in circuits with a large number of mounting plates, like senders or registers, but may involve space penalties for trunk circuits. Trunk circuits may have only one or two mounting plates, in which case the adjacent relays may not be readily controlled as they may be in other circuits.

There are two effects of magnetic interference: (1) the effect on the adjustment of a relay when it is adjusted with adjacent relays energized, and (2) the effect on the performance of the relay.

Effect on the Relay Adjustment

This effect on the adjustment would be noted when the relay is adjusted with or without the interfering relays energized, and then checked, using approximately the same current flow values, with the opposite interfering condition. This effect will occur generally in trunk, or similar circuits in which a relay may be adjusted when relays in adjacent circuits are energized. Adjacent energized relays may be avoided by (1) making the adjacent circuits busy or (2) locating the critical relays on the middle plate of a 3-plate 2- or 3-trunk unit. The first method is undesirable since it may require making a trunk busy at another office. The latter method imposes restrictions on the equipment design and may waste space. The latter method was used in the No. 5 crossbar trunks using U and Y relays. The interference in these circuits was so great that it could not be ignored.

This interference effect is present on all adjustments of AF, AG, and AJ relays; operate, nonoperate, hold and release; however, the effect is so small on all adjustments, except the hold and release of the AG relay, that the interference effect can be ignored. Table V-1 shows the effect of interference from adjacent AF and U relays on the operate or nonoperate of AF, AG, and AJ relays and on the hold or release of AF and AJ relays.

X-75509

This table shows that the U relay has a negative or aiding effect on the wire spring relay instead of a positive or opposing effect. When U and wire spring relays are energized with ground on the inner end of the winding, in accordance with the standard wiring practice, the U relay is poled opposite to the wire spring relay. The U and wire spring relay coils are wound in the same direction, and the winding leads are terminated at the same end of the coil; however, the U relay coil is assembled on the core so that the terminals are brought out at the rear spoolhead, and the wire spring relay coil is assembled so that the terminals appear at the front spoolhead. This means that the direction of the magnetism of the wire spring relay is opposite to that of the U relay. Thus, the interference from surrounding AF or AJ relays has an opposing effect, whereas that from surrounding U relays has an aiding effect on the adjustment and performance of the wire spring relays.

The effect of AF and U interfering relays on the hold or release of the AG relay is shown in Fig. V-1. This effect, although small in comparison to Y relays, requires some consideration. The comparison in the effect on the release with one relay above and one relay below, energized at 600-ampere turns, for the AG relay with AF interfering relays and the Y relay with U interfering relays is:

NI Release With No Interference	Interference Effect On AG	Interference Effect On Y
6.3	9.5%	75%
18.7	5.0%	27%
24	4.0%	23%

It can be noted from the above that the effect on AG relays is considerably less than it is on the Y relays. For example, with one AF relay energized at 600-ampere turns, above and below an AG relay, the maximum interference effect is 9.5 per cent, whereas with a U relay energized at 600-ampere turns above and below a Y relay, the maximum effect is 75 per cent. Actually, very few AF relays can be energized at 600-ampere turns, but several U relay coils can be. With 300-ampere turns on the interfering relays, the maximum effect on the AG relay is 6.4 per cent instead of 9.5 per cent.

The minimum interference effect occurs with a weak adjustment or at the release end of the hold-release adjustment band. With a stiff adjustment, or at the hold end of the adjustment band, the interference effect on an AG relay with one AF relay above and one below energized at 300-ampere turns is not over 5 per cent. With a U interfering relay above and below, the comparable effect on a stiff Y relay is about 25 per cent.

In view of the marked reduction in the interference effect for the AG relay, as compared with the Y relay, it has been agreed that magnetic interference considerations should not impose any penalties on the equipment design of wire spring relay trunk circuits.

It has also been agreed not to recommend in the BSP that adjacent circuits be made busy when readjusting or testing AG relays. There is a small risk in these agreements, but it is believed that the risk is justified on the basis that (1) a marginal adjustment is rare, (2) there is a 5 per cent margin between the hold readjust and test and 5 per cent or more margin between the release readjust and test, and (3) the interference generally will not exceed that from one relay above and below. Actually, as long as there is any interference effect, it cannot be safeguarded for successive checks with and without interference, using the same test current; however, it is believed that relays will meet the test requirements with interference if they have been adjusted to the readjust requirements without interference. It is also believed that the adjustment trouble caused by interference that was experienced with the Y relay was aggravated by the aging of the magnetic iron that was used prior to the introduction of hydrogen-annealed iron.

Effect on Performance of the Relay

The effects of magnetic interference on the performance of wire spring relay circuits is generally insignificant. Since more ampere turns may be required to operate a relay under the influence of magnetic interference from relays poled alike, the normal margin between the test and the worst circuit operate may be reduced. In no case is this sufficient to impair the operating margin of the wire spring relay. The reduced operating margin has the effect of increasing the maximum operating time, but in no case is this increase significant.

The releasing times of the slow-releasing AG relays may be either increased or decreased depending on whether the interference comes from surrounding AF or U relays. The minimum releasing time of an AG relay with three AF relays above and below may be decreased in the order of 10 per cent which, usually, is not serious. The worst effect of U interfering relays is an increase in the maximum releasing time which, ordinarily, is not critical. If both AF and U relays create interference, the effects tend to neutralize each other.

In critical cases, such as the slow release (RA) relay in the originating

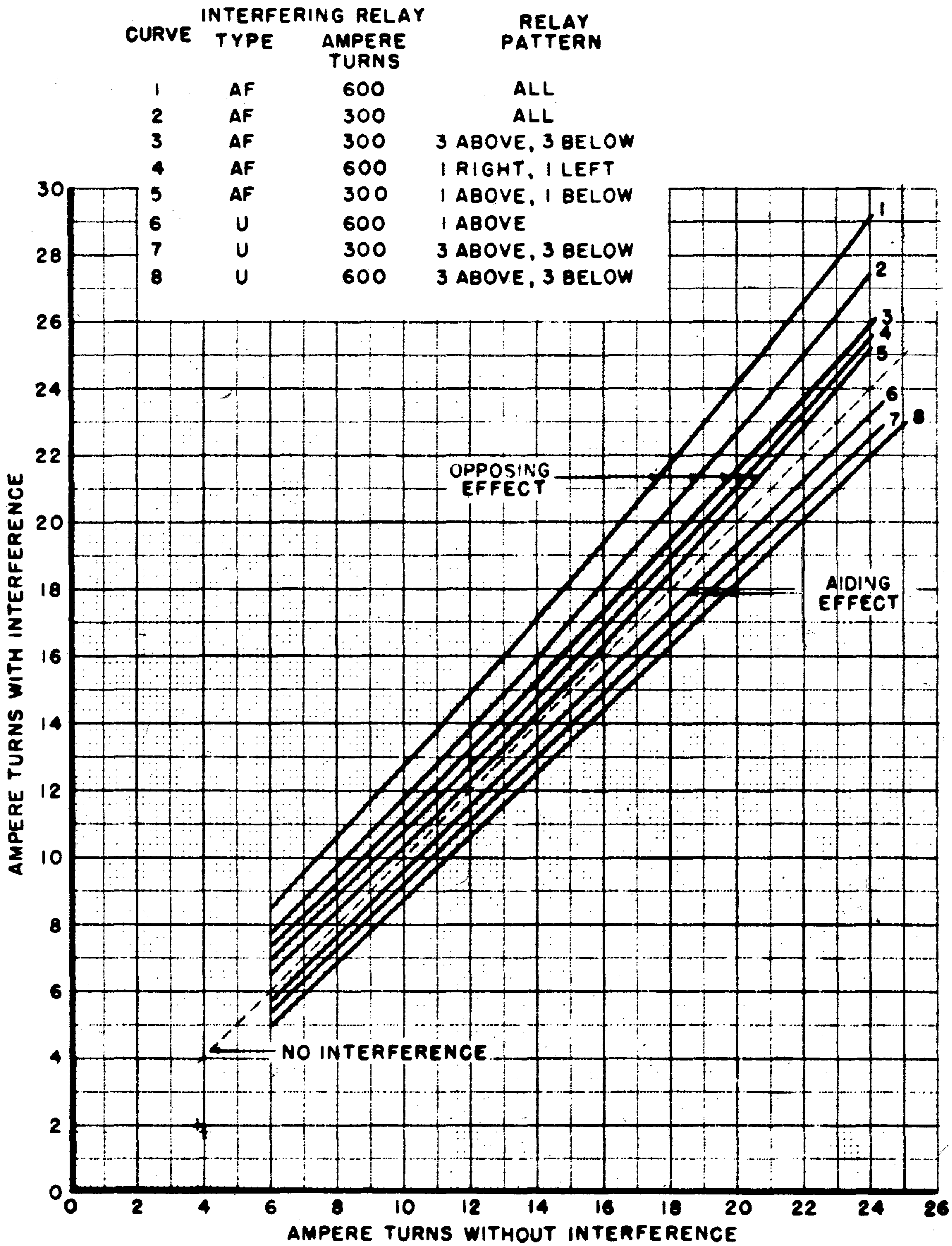


Fig. V-1 - AG Relay - Magnetic Interference Effect on Hold or Release

X-75509

register circuit, it may be found desirable to locate noninterfering apparatus adjacent to an AG relay. These cases should not occur very often.

The effect of magnetic interference on the releasing time of AG relays may be found from the release time curve in Section IX by reading the release time corresponding to (1) the release-ampere turns without interference, and (2) the release-ampere turns with interference. The release-ampere turns with interference are obtained from Fig. V-1

Effect on AK Relays

Magnetic interference on the AK relay must be considered from two aspects; that from surrounding relays and that from one coil of the relay on the other coil. The first condition, interference from surrounding relays, is negligible. Magnetic interference between two coils of an individual relay, equipped with stop discs, may be as much as ±10 ampere-turns on the operate and -5 ampere-turns on the release where both coils are poled in the same direction. The leakage flux from the interfering coil reduces the pull above the knee of the operate pull curve and increases the pull below the knee. Since most of the relays have the operate point near the knee of the pull curve, approximately 150 ampere-turns, the interference affect on the operate is usually much less than the maximum of 10 ampere-turns and can be neglected. The -5 ampere-turns interference effect on the release applies at high values of release ampere-turns and becomes less at lower values of release, so it has practically no effect on the relay performance.

Magnetic interference of either half of an AK on the other half of the relay, if equipped with a domed armature, may be appreciable and should be taken into consideration when figuring release times. This effect is shown in Fig. VII-14B and VII-14C. The relay adjustment should not be affected since one half of the relay should be adjusted with the other half de-energized. In Fig. VII-14B and VII-14C, positive interference assumes both coils poled in the same direction and negative interference the coils poled in the opposite direction. To obtain the release time with interference, read the hold or release gram loads on the hold or release pull curve with interference and obtain the holder or release-ampere turns. The time can be obtained by reading these values on the minimum or the maximum time curves.

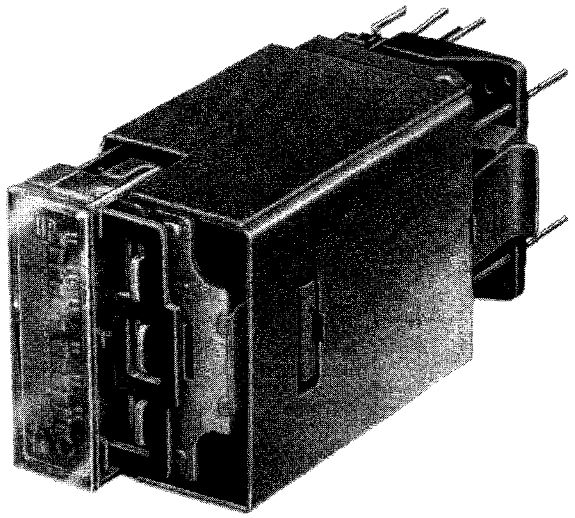


Fig. V-2 - AJ Relay With Shield

Crosstalk LP19A14-6

Another important effect of stray magnetic fields is crosstalk between transmission relays of adjacent trunk circuits. The wire spring is about 5 db better than the UA relay. This is not sufficient to permit mounting transmission relays in different circuits on 2-inch vertical centers, but will permit 4-1/2- instead of 6-inch mounting centers. Where the transmission relays of different circuits are closer than 4-1/2 inches, the relays are equipped with magnetic shields. Fig. V-2 shows the shields which may be used on the AF, AG, or AJ relays.

The crosstalk with wire-spring relays equipped with shields is approximately the same as that of UA relays equipped with crosstalk covers.

Where there are wire-spring transmission relays in the same circuit, crosstalk is neutralized to some extent and battery noises suppressed by mounting the relays side by side. They are connected to the tip and ring of the trunk or subscriber line with the battery winding of one relay and the ground winding of the other relay connected to the same side of the trunk or line.

TABLE V-1

Interference Effect on the
AF, AG, and AJ Relays

Effect on Operate or Nonoperate of AF, AG, and AJ Relays

Operate or Nonoperate NI Without Interference	50	120	170
AF Interfering Relays (600 NI)			
1, 2, 3, 4, 6, 7, 8, 9	4.4%	4.0%	3.3%
2, 4, 6, 8	2.0%	1.8%	1.0%
U Interfering Relays (600 NI)			
1, 2, 3	-1.7%	-1.6%	-1.5%
2	-1.5%	-1.1%	-1.0%

Effect on Hold or Release of AF and AJ Relays

Hold or Release NI Without Interference	16	57	90
AF Interfering Relays			
1, 2, 3, 4, 6, 7, 8, 9 (300 NI)	4.4%	2.5%	2.5%
1, 2, 3, 4, 6, 7, 8, 9 (600 NI)	6.3%	5.1%	4.1%
U Interfering Relays			
1, 2, 3 (300 NI)	-3.7%	-1.8%	-1.8%
1, 2, 3 (600 NI)	-5.0%	-2.0%	-2.0%
2 (300 NI)	-1.9%	-1.1%	-1.0%
2 (600 NI)	-2.5%	-1.6%	-1.3%

A negative sign indicates an aiding effect.

Test Pattern

1	2	3	
4	5	6	Relay #5 under test.
7	8	9	

X-75509

CONTACTS

General

The AF, AG, AJ, and AK relays are equipped with twin palladium contacts. The actuation of the contacts has been designed to provide long life and reliable performance. The design objectives that have been attained are as follows:

- One size and kind of contact - palladium
- Lower contact force
- Reduced open contacts
- No contact locking
- Lower rate of contact bridging
- Reduced contact erosion because of:
  - (a) faster opening of contacts
  - (b) decreased contact chatter
  - (c) less contact activation from organic vapors, because of individual contact covers and the elimination of frame covers

The objective has been to obtain minimum annual over-all charges, taking into account first cost and annual maintenance charges. A considerable reduction in the first cost of contacts and contact protection has been attained.

Contacts and Contact Welding

Fig. VI-1 shows the construction of the contacts. The twin-wire contacts consist of a palladium tape, 0.009-inch thick, spot-welded to the tips of the twin wires. The twin-wire contacts have a thin 22K gold overlay to reduce the development of polymer on the contacts. The diagram of the welding circuit is shown in Fig. VI-2. The condenser C is charged by a power supply to a predetermined voltage and then discharged through the primary of the welding transformer T. This causes a low-voltage surge which produces the weld. The contacts are sheared to length and then formed to a cylindrical shape to provide greater reliability from opens.

The stationary single-wire contact is made of duplex or triplex tape, consisting of a nickel silver strip with a 0.009-inch thick strip of palladium welded to either or both sides of the nickel silver. The single contact is equipped with the palladium strip only on the side where a mating twin-wire contact is provided. The single contact is butt-welded to the end of the single wire by a new process called percussive welding. Spot welding did not appear to be the best method of welding the contact to the end of the single wire, due to the need to grip the wires with heavy welding electrodes in the limited space directly behind the contacts. The percussive welding process permits one

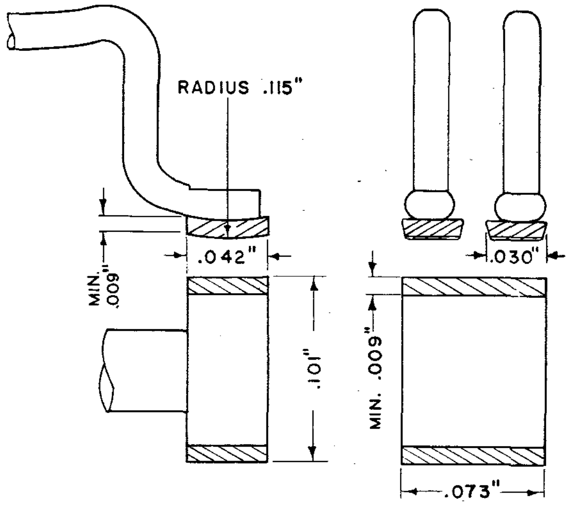


Fig. VI-1 - AF, AG, and AJ Relay Contacts

of the electrodes to be placed near the wiring end of the wire spring without developing excessive heating in the wire. It also permits the accurate positioning of the contacts needed to control the point of contact closure on the assembled relay.

Fig. VI-3 shows the diagram of the percussive welding circuit. The condenser C is charged by means of a direct-current power supply and the condenser voltage also appears on the stationary single-contact wire. The other side of the condenser is connected to the single contact. As the contact to be welded is moved toward the end of the wire, the condenser discharges, forming an arc which melts the abutting surfaces of the contact and wire. The parts are held together during a brief cooling period as the weld is completed. A small resistance R is used in series with the discharge circuit to limit the current and control the arcing period.

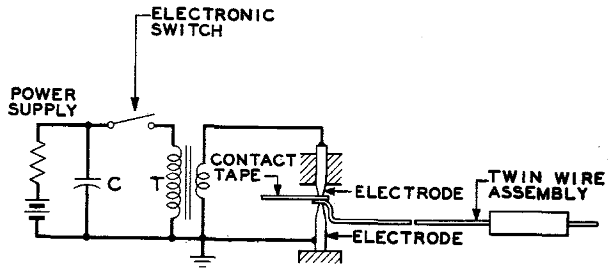


Fig. VI-2 - Welding Diagram - Twin Contacts

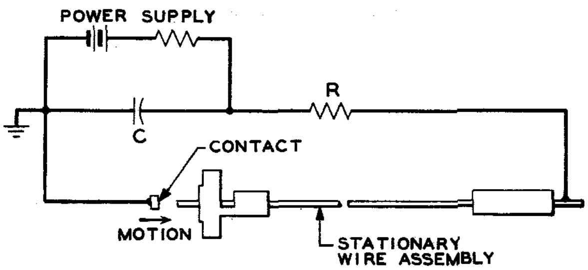


Fig. VI-3 - Welding Diagram - Single Contacts

Although percussive welding is more suitable for the single-wire contacts welded in the factory, the necessary replacement of both single and twin contacts in the field is made by spot welding using the standard field welding equipment provided with suitable electrodes. A special shaped palladium contact with a gold overlay will be used to facilitate spot welding to the single wire, and individual contact adjustment for the final position of the contacts may be necessary.

Contact Actuation

The "lift-off" type of contact actuation is used. With this type of actuation, which is also used on the UB relay, the moving springs are at all times in tension, exerting a force either against the single contact or the moving card. For both make and break contacts, the contact is opened by "lifting off" a moving contact from a stationary contact by the moving card. The chief advantage of this type of actuation is that a common card force is available for use in opening any contact tending to lock. It also has a secondary advantage in that the reduced vibration of the moving wires causes a reduction in contact chatter. The "lift-off" type of contact actuation results in a small amount of contact slide or relative motion between the moving and fixed contacts.

Contact Dimensions

The dimensions of the wire-spring relay contacts are:

	Twin contact	Single contact
Width	0.030 in.	0.073 in.
Length	0.042 in.	0.042 in.
Thickness	0.009 in.	0.009 in.
Radius of Surface	0.115 in.	

Contact Capability

General

The size of the contacts for the wire-spring relays was determined by the following factors.

Expected life from unprotected and protected contacts.

Cost of metal and contact protection.

Cost of replacing contacts having less than a 40-year life.

Consideration of these factors led to the adoption of a contact with an average erodible volume of about 20×10^{-6} cubic inches, and with a total volume of 56×10^{-6} cubic inches. This contact has an erodible volume about one half that of the present bimetal palladium contact of the U relay. Tests have indicated that the proposed size of contact on the wire-spring relay will equal, at least, the capability of the present bimetal U relay contact because of the reduced chatter and greater speed of contact opening.

Unprotected Contacts

Table VI-1 shows, in terms of permissible number of operations, the capability of unprotected wire-spring relay contacts for a range of typical wire spring, U, UB, and multicontact relay loads with short and long leads where the contact breaks, or both makes and breaks the contact load. Contacts which only make the load do not require contact protection, because there is so little contact chatter on closure. The estimates in this table are for load relays with low stop discs only. Load relays with high stop discs dissipate a somewhat greater energy on the contacts which control such loads. The estimates in Table VI-1 should be reduced by 20 per cent in the case of load relays with the higher stop discs.

The estimates in Table VI-1 are based on the capability curves for U relay contacts (erodible volume of 42×10^{-6} cubic inches), because limited tests indicate that the erosion rate on wire-spring relay contacts is about one half that of U relay contacts.

Contact bridging has been observed on unprotected wire-spring contact tests. It occurs when contact build-ups become large enough to bridge the contact gap.

Where trouble-free contact operation is necessary and contact bridging must be avoided for any particular circuit application, contact protection should be specified when relay operations exceed the following limits, except for make contacts which only close the circuit.

Load Resistance	Normally Open Contacts (Makes)	Normally Closed Contacts (Breaks)
400 ohms or less	2,000,000 oper	500,000 oper
over 400 ohms	2,000,000 oper	2,000,000 oper

When trouble-free operation is not required, protection should be provided only when the relay operations exceed those on Table VI-1.

In general, load currents should not exceed 0.5 ampere on unprotected contacts.

Protected Contacts

Contact protection should be provided under the following conditions:

1. When the number of operations on a particular circuit application exceeds the limits of unprotected contacts.

2. When circuit conditions require trouble-free operation from contact bridging under conditions described in the preceding paragraph.

In general, load currents should not exceed 0.5 ampere on protected contacts.

Contact Protection

X-75509

The contact life of a protected contact, with a steady state current of not more than 0.5 ampere, has been assumed to be 1.5 billion operations.

Two different contact protection networks have been standardized for use in the new No. 5 crossbar system and the new AMA system. They are:

185A network	0.11 mf	in series with	470ω
186A network	0.3 mf	in series with	120ω

Under extremes of aging, heating, etc., the resistances may vary through ranges of 335 to 605 ohms for the 470-ohm resistor and 93 to 147 ohms for the 120-ohm resistor.

Fig. VI-4 illustrates these networks. Ordinarily, the networks will be mounted by their leads behind the load relay on the wiring side of the frame. They consist of a capacitor, wound with a newly developed plastic dielectric, and a carbon composition resistor connected in series. The capacitor is wound over a metal tube which serves as a housing for the resistor and as a connection between one end of the capacitor and one end of the resistor. The capacitor is connected to the screw end of the unit. The networks are coated with an insulating finish obtained by dipping in gray lacquer.

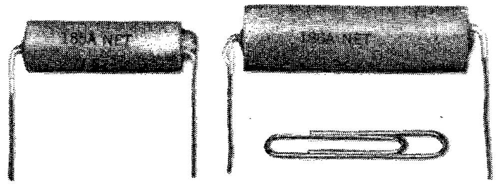


Fig. VI-4 - Protection Networks

The dimensions of the two networks are:

	185A	186A
Length	1-3/8 in.	1-7/8 in.
Diameter	7/16 in.	17/32 in.

The 185A and 186A networks were designed primarily for use with single relay loads. Both units are rated at a maximum working voltage of 350 volts.

The 185A network is intended for use on single-load relays with a resistance of 270 ohms and higher. In general, single relay loads of less than 270-ohms resistance, or multiple relay loads, require the use of the 186A network. Particularly heavy loads may require the use of a network with a higher capacity.

Method of Determining the Life of Unprotected Contacts

Engineering of contacts for wire spring relays involves first, the determination of whether a particular load and the number of required operations are within the capability of unprotected contacts, and second, the determination of a contact protection when the contact requirements exceed the capability of the unprotected contacts.

Table VI-1 gives life estimates, in millions of operations, for a range of AF, AJ, and U or UB relay loads where the contact breaks or makes and breaks the load. Fig. VI-5, from which the estimates were obtained, shows the capability of wire spring relay contacts in terms of operations plotted as a function of energy and current of the contact load (J+.1I). The abscissa of this figure is the arithmetical sum of the energy in millijoules and one tenth of the current in milliamperes. The ordinate scale shows the life in millions of operations. The two curves, for short and long leads, are based on the results of laboratory tests of a number of various loads. In evaluating the results of the life tests, it has been found that by combining the current factor with the energy factor, and plotting this combined factor against the life estimates, a relatively smooth curve is obtained. Plotting these data on log-log paper results in two straight lines, giving life estimates for short and long leads. (Less than 20 and more than 20 feet.)

Determining the life for a given load from the capability curves requires the determination of three factors: the required number of operations, the steady-state current of the load, and the amount of energy. The first two factors are readily available, but the energy factor is not, and requires a separate determination. The amount of energy (J) is determined indirectly from peak-voltage measurements obtained from the discharge of the load inductance into a large parallel capacity. After obtaining peak-voltage values for a given type of apparatus, for varying amounts of current through the load, the energy is calculated from the formula $J=0.5CV^2$. The results are then plotted in terms of ampere turns of the load against the corresponding energy in millijoules. The curve so obtained can be applied to any load with the same magnetic characteristics; however, variations in stop-disc height, fullness of the coil, and the use of permalloy affect the magnitude of the dissipated energy and therefore result in a different set of curves for the same type of apparatus. As an example, Fig. VI-6 and VI-7 show the energy curves for wire-spring relays for high and low stop discs and for coils of various degrees of fullness. The top curves on each drawing are for coils with a high number of turns, while the lower curves are for coils with a low number of turns. Fig. VI-8 shows the energy curves for U relays.

The energy for various relay loads has been calculated and is shown in Table VI-1.

Method of Determining Contact Protection

In designing contact protections the values of the capacitance and the series resistance must be determined. The function of the capacitance is to limit the rate of voltage rise across the contact as it opens to a value which will insure no breakdown of the contact gap. This requirement will be met, in the case of the wire-spring relay, if the ratio of $\frac{I}{C}$ is less than 2, I being the steady state current of the load relay in amperes and C the capacitance of the protection condenser in microfarads. The capacitance must also be large enough to limit the peak voltage to 300 volts to prevent air breakdown. It is also necessary to limit the peak voltage in order not to exceed the voltage limits of capacitors used in protection networks. The 185 and 186 networks are satisfactory up to 350 volts and the 177 networks up to 300 volts.

The peak voltage for any given load condition of known energy (J) is determined from $J=0.5CV^2$, solving for the value of C with V limited to 300 volts. Peak voltages for a number of commonly used values of capacitance have been plotted against the energy in millijoules in Fig. VI-9. The use of this graph permits direct reading of the peak voltages for a given value of energy with various values of capacitance. The use of the graph will determine the choice of a suitable network, or the choice of an adequate capacitor where the use of a separate capacitor and a series resistance becomes necessary.

Usually, adequate protection is obtained by the use of 185A or 186A networks around each individual relay load. In the case of parallel loads, however, substantial design economies can be achieved by using a single protection for combined loads. This can be either a single network or a single capacitor in series with a resistance. For instance, the 186A network offers adequate protection for any combination of loads with a total energy up to 12 millijoules; therefore, the 186A network will be satisfactory for a parallel combination of 3-wire-spring or U relays as long as their combined resistance is at least 100 ohms and the combined energy 12 millijoules or less. The 185A network is satisfactory for parallel loads with a total energy of 5 millijoules or less.

The choice of the resistance in series with the capacitance is governed by initial voltage limitations on the break of the contacts and by the requirement of keeping the condenser discharge current to a minimum on contact closure. For these reasons, the series resistance should ordinarily be chosen to be approximately equal to the resistance of the load.

The resistance requirement is closely followed for currents approaching or exceeding 0.5 ampere. For currents in the order of 0.1 ampere or less, the resistance is standardized at 470 ohms.

Contact Reliability of Wire-Spring Relays

Wire-spring relays are equipped with independent spring actuation thereby providing true twin-contact action. Detachable covers, which enclose only the contact end of the spring assembly, protect the contacts effectively from external dust.

Fewer contact opens, due to dust, are anticipated on the wire-spring relays, even with the lower contact pressures.

TABLE VI-1

Wire Spring Relay Contacts
Life Estimates in Millions of Operations
for Unprotected Loads on 50 Volts

Contact Load	Number of Turns on Coil	Energy in Millijoules	J & .1I	Contact Life in Millions of Operations: Long Leads (1)	Contact Life in Millions of Operations: Short Leads (2)
AF, AJ Relays (0.006-in. stop discs)					
16ω*	1580	4.2	52.2	4	6
270ω	2110	1.6	20	10	17
395ω**	2760***	2.2	15.3	14	23
400ω	3330	2.5	15	14	23
500ω	8275	6.3	16.3	13	21
700ω	5050	2.3	9.5	23	39
950ω	11850	5.3	10.5	21	34
1625ω	15800	4.3	7.4	29	49
2500ω	19400	3.6	5.7	40	67
9100ω	34900	2.5	3.2	73	125
U and UB Relays (0.005-in. stop discs)					
400ω	5600	5	17.5	12	20
700ω	9500	4.8	12	18	30
950ω	9000	3.7	9	25	40
1000ω	12350	4.5	9.5	23	39
1500ω	14600	3.8	7.1	32	52
2500ω	18800	3	5	46	75
Multicontact Relay (263 type)					
275ω	5380	17.2	35	6	10
120ω	3460	24	65	3	5
Multicontact Relay (286 and 287 types)					
275ω	2740	9.2	27	7	12
180ω	1920	8.5	35.4	6	9
120ω	1320	7	47.4	4	6
Hold Magnets					
1570ω	15600	5.5	8.5	26	41
1480ω	13900	5.3	8.5	26	41
1250ω	14000	5.8	9.7	22	36
330ω	7500	8.6	25.1	8	14
Select Magnets					
600ω	11000	9.5	17.5	12	20
240ω	6700	25.6	45.6	4	7
43ω*	2570	19.6	58.6	3	5

For relay loads with high stop discs, reduce above life estimates by 20 per cent.

Lamp Loads

One ampere steady state current.

(1) Leads over 20 feet.
(2) Leads less than 20 feet.

* In series with 90-ohms noninductive resistance.
** Nominal voltage 52.
*** Effective turns.

X-75509

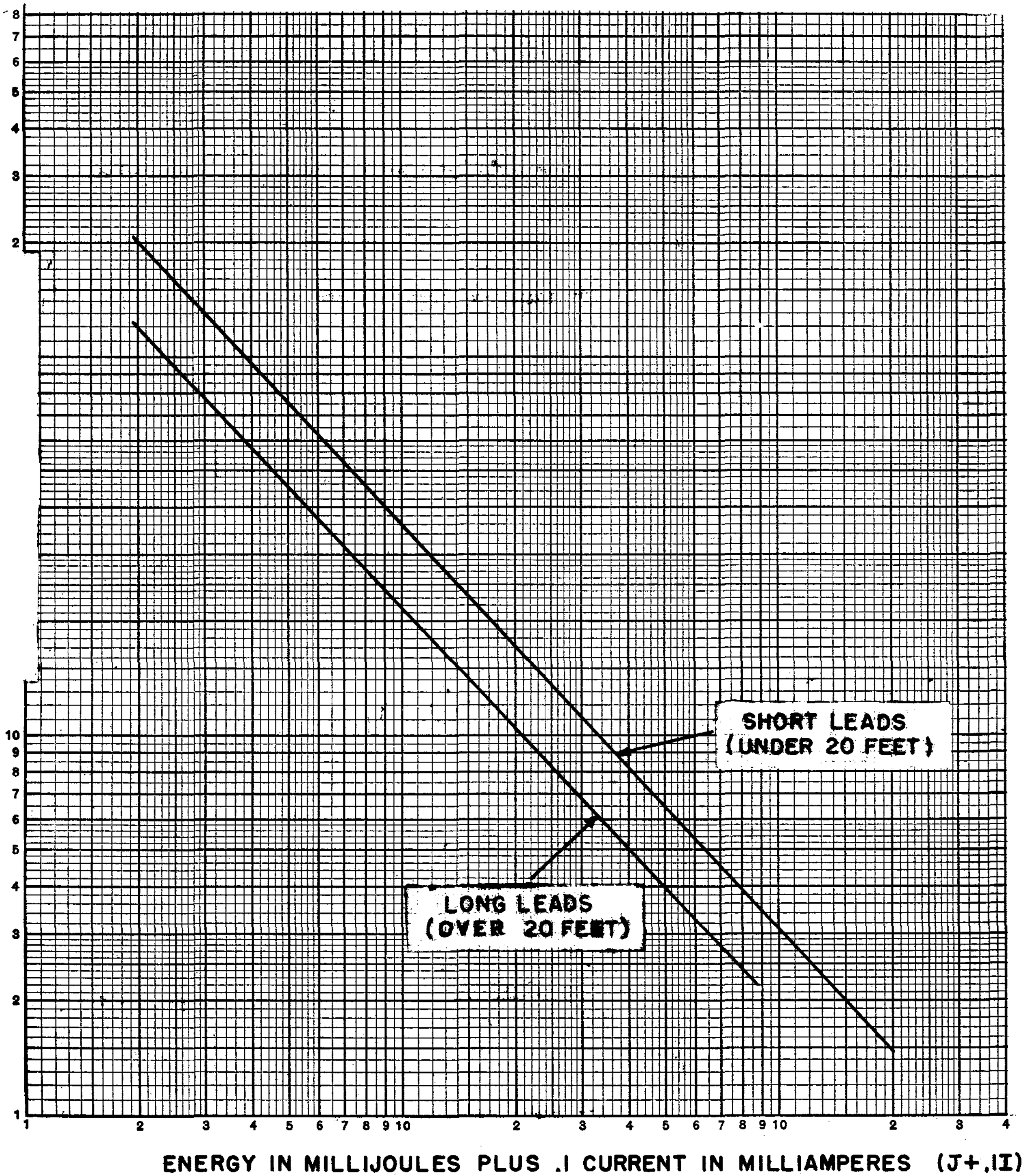
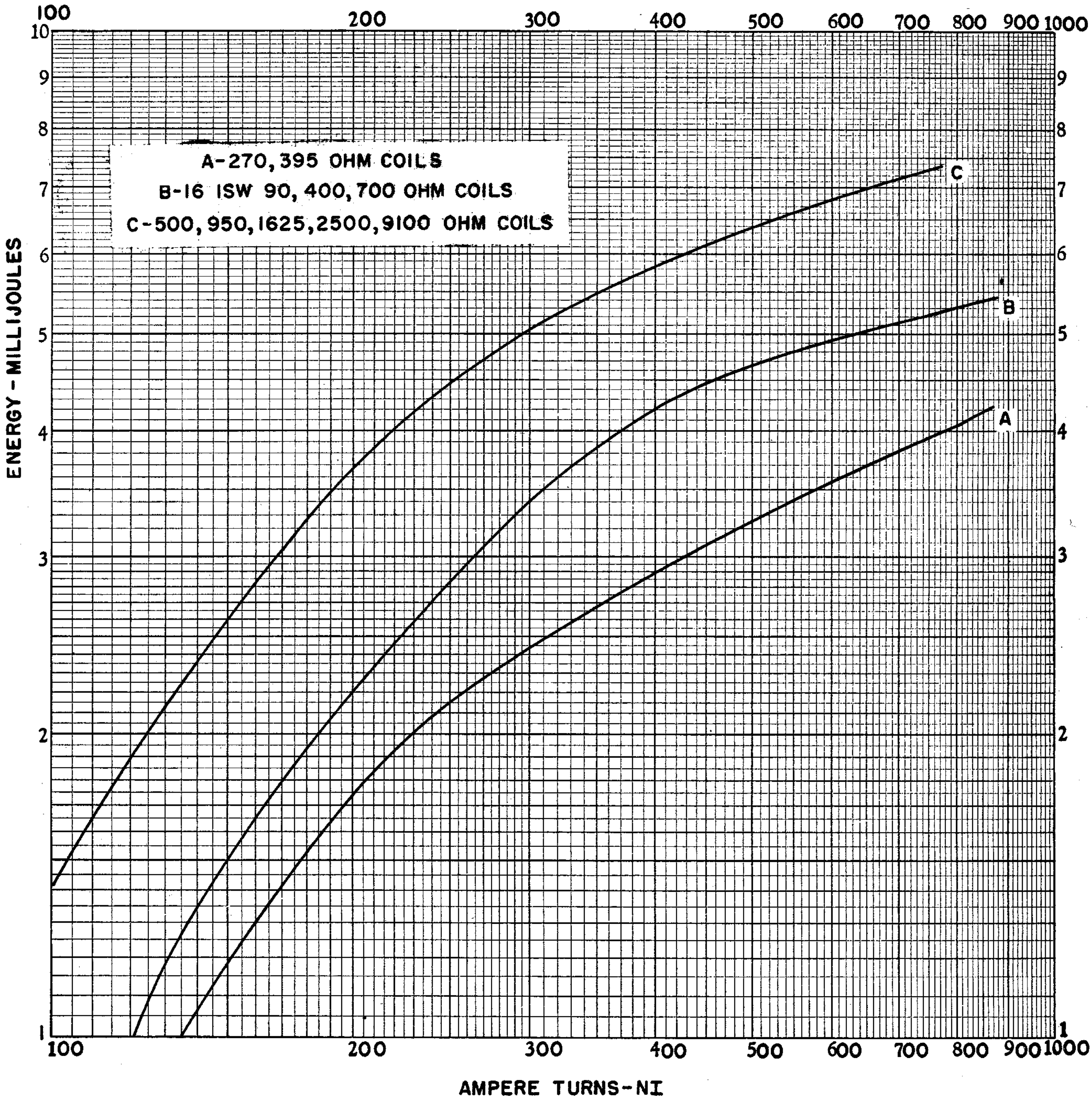


Fig. VI-5 - Wire-spring-relay Contacts Life Estimates



X-75509

Fig. VI-6 - AF and AJ Relays - Energy Curves - 0.014-inch or 0.022-inch Stop Discs

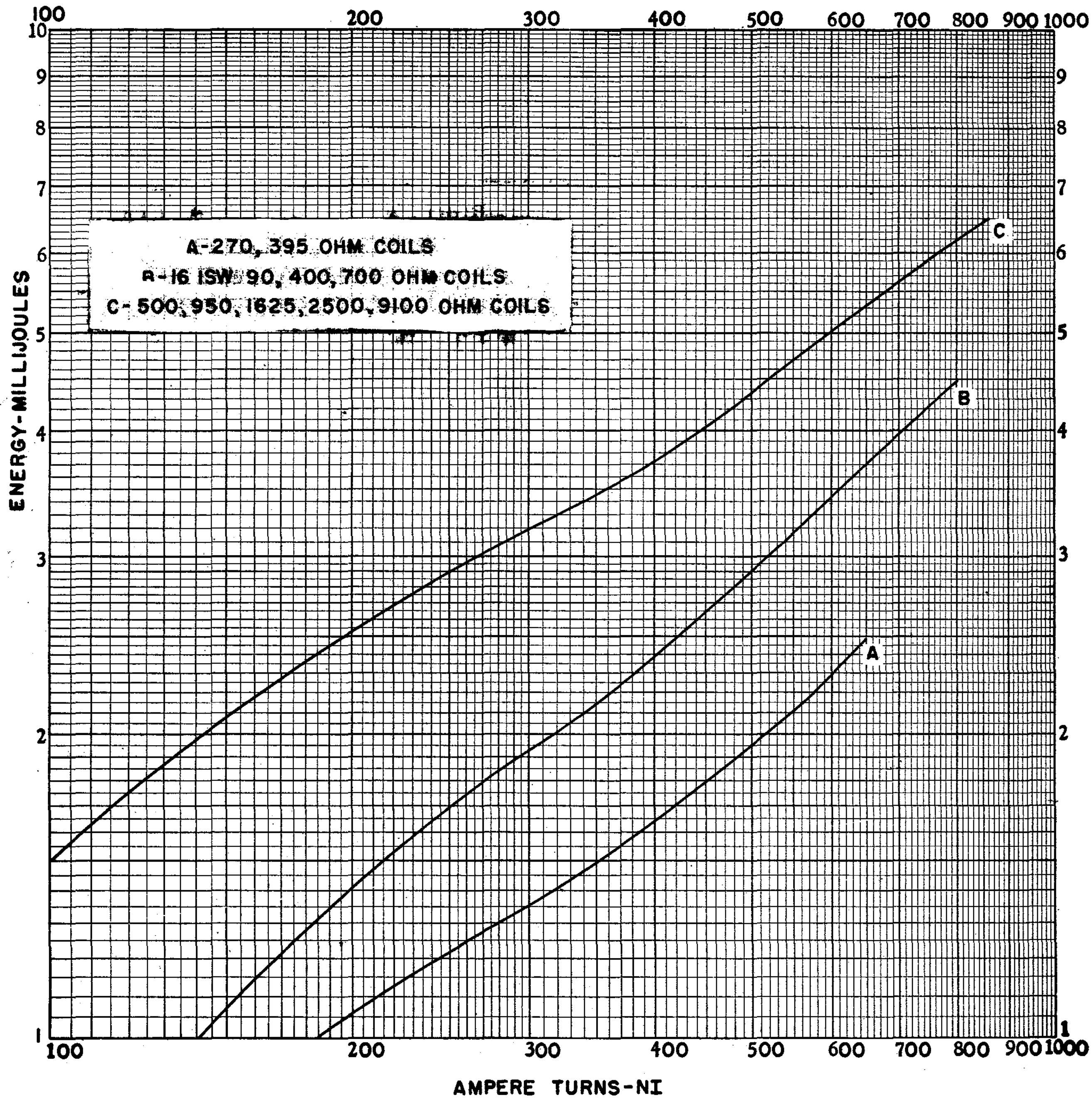


Fig. VI-7 - AF and AJ Relays- Energy Curves - 0.006-inch Stop Discs

X-75509

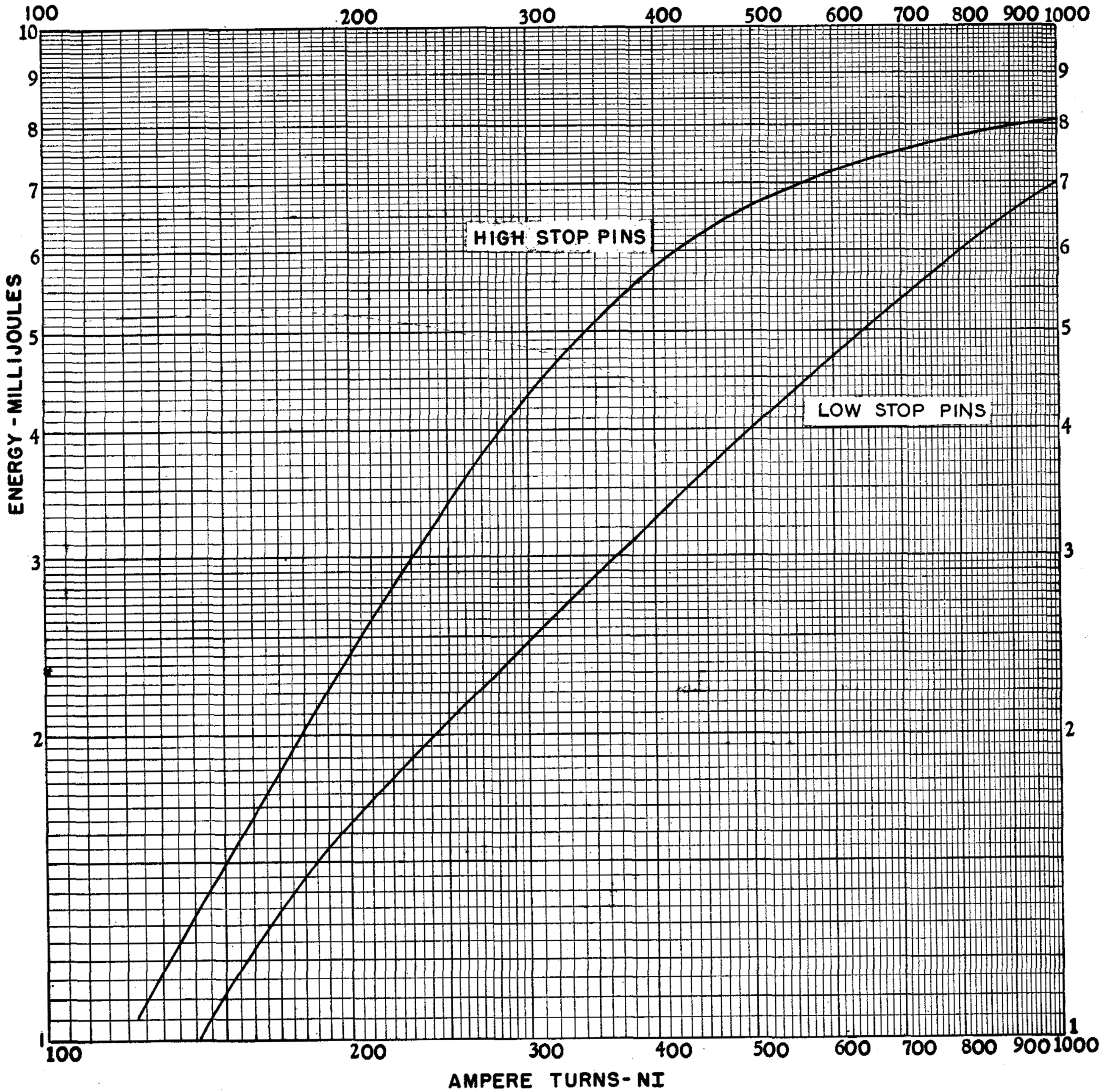


Fig. VI-8 - U Relay - Energy Curves

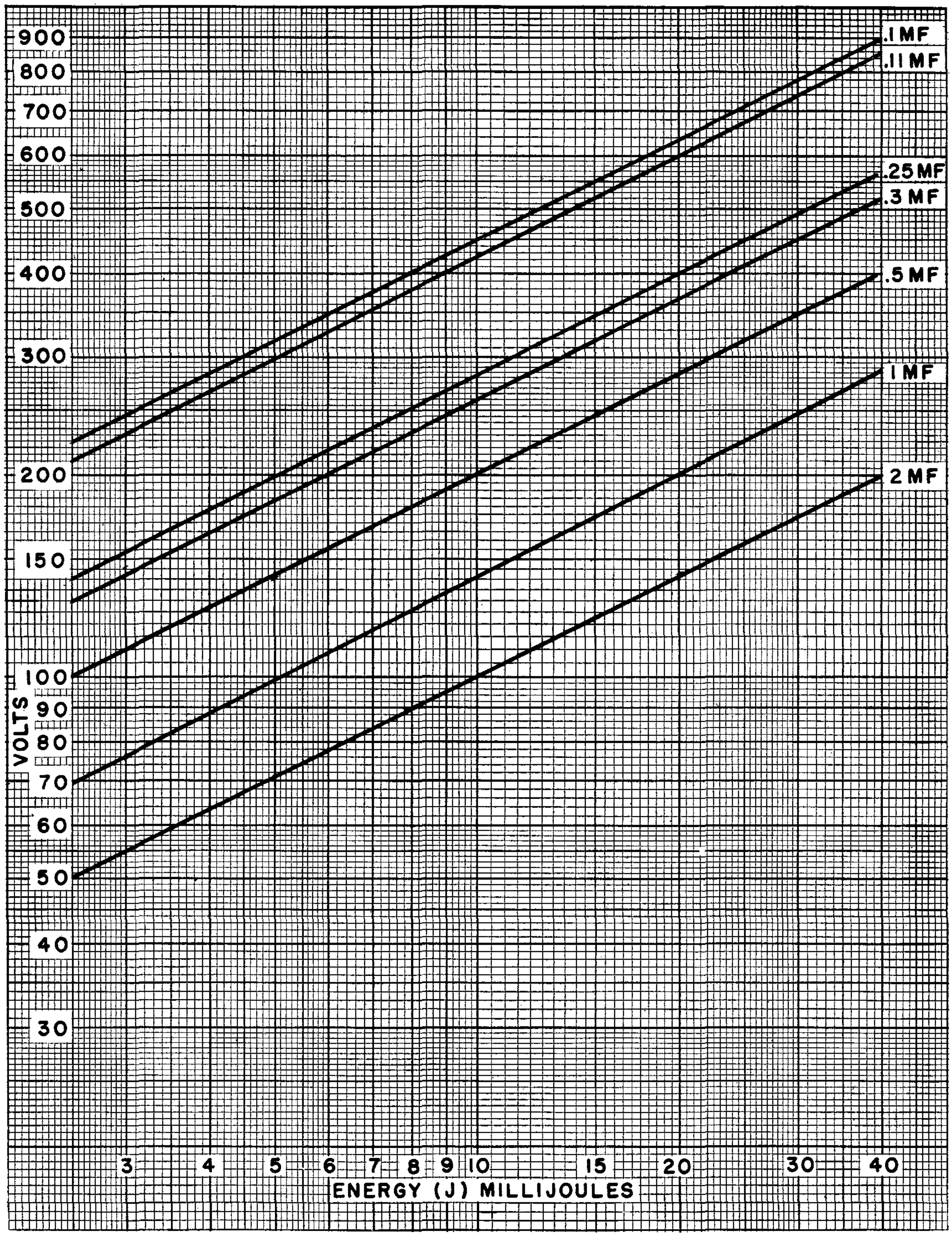


Fig. VI-9 - Protection Peak Voltages

OPERATE AND RELEASE TIMES

PART I - OPERATE TIMES

Listed Operate Times

Telephone relays are most commonly operated in local circuit on 48 volts. Since 48-**volt** applications are so common, the minimum, maximum, and average operate time values for each code on this voltage will be found in the code section (Section II). Some minor limitations on the use of these listed times are discussed later. It is expected that these listed times will greatly facilitate the computation of relay races for circuit analysis purposes.

For those cases where the operate times are not listed, or where the circuit conditions are not 48 volts, or where the circuit operation is not local circuit, it will be necessary to use the graphical solutions outlined in the following paragraphs.

Types of Problems

The most common problem that arises in relay application work in connection with relay operate time is to determine the operate time of a given code of relay operating in local circuit. This problem is considered separately because it is so common and the solution is relatively simple.

A less common type of problem exists where the relay and circuit parameters are all, or in part, subject to the engineer's selection or design. This problem occurs, for example, when a new coil is designed, or where a 48-**volt** coil is used in a 130-volt circuit, assuming, of course, that an optimum design from a speed standpoint is needed. Under such conditions, it is possible to design for optimum speed in a straightforward manner. Furthermore, it is practicable, where compromises have been made with optima, to determine the penalty paid for the deviation from optimum design. The problem is considered separately, mainly because it is less often needed and its complexity justifies separate treatment.

Another type of problem arises where a relay is required to operate in series parallel arrangements of circuit elements involving inductances and capacitances. The solutions to the more general cases are usually so involved as to be impractical. However, in a great many cases, the problem can be simplified either by considerations of symmetry or by the use of simplifying assumptions. The method of handling some typical cases is covered in Appendix A.

A type of problem, of importance mainly to the relay engineer, involves the simulation of one relay circuit by another relay circuit which happens to be available. For example, assuming that an extreme capability relay is available, it is possible to use a single full winding on the structure and obtain complete data on relay operate times for all relay coils without rewinding the coil. In effect, the operate times are obtained in circuits which are mathematically similar, the difference being only in impedance level. Such translations are exact and yield very satisfactory data. The method is set down in Appendix B.

Definition of Minimum, Maximum, and Average Times

In most relay operate time problems the average, maximum, or minimum operate times may be required. The average time is, of course, obtained when all variables are average. It is not so obvious what the variables will be for minimum or maximum times. If the number of contributing variables is large, it may be uneconomical to consider all variables to be at their maximum adverse values. Furthermore, it may be physically impossible for two particular contributing factors to be simultaneously adverse because one variable is a function of the other; therefore, in stating the minimum or maximum operate times it is important that the conditions and assumptions be defined.

The maximum and minimum operate times listed in the code sections of this manual were obtained by means of the methods and data to be described later. In these data, allowances have been made for the probability that all variables will not be simultaneously extreme. Allowances have also been made where a variable is dependent upon some other variable, both of which cannot be simultaneously adverse. For example, the size of the airgap and the magnitude of the inductance are interrelated in such a way that when the airgap is increased, the inductance is decreased.

The minimum operate times listed in the code sections were obtained with minimum resistance and the maximum times with maximum resistance. The maximum resistance was taken to be the cold value on the assumption that no appreciable heating occurred during circuit operation. Actually, the maximum operate time for the relay when hot will be increased only about 5 per cent for practically all local circuit relays.

The minimum operate times listed in the code sections were obtained at 50 volts and the maximum times at 45 volts. Since the voltages cannot be simultaneously adverse in a particular circuit relay race, a margin results to help balance the heating effect that tends to raise the maximum times as noted above. It is therefore concluded that a fair circuit analysis can be made of relay races by using the listed operate times and ignoring the effect of heating due to circuit operation.

Load-controlled Versus Mass-controlled Solutions

The complete solution for the operate time of a relay requires consideration not only of the time required to build the magnetic field up to the value needed to pull the load, but also the time required to move the armature system up to the relay contacts. The former time is commonly called electrical time and the latter time is called mechanical or travel time.

A complete mathematical solution involving both mechanical and electrical considerations is too complex for practical use and in fact has never been obtained. It is usually found to be adequate to determine the operate time on the assumption that either the flux build-up, without armature motion, or the armature movement, is the more controlling factor in the operate time. Where the flux rise time is more controlling, the relay operate time is referred to as "load-controlled" and where the armature movement is more controlling the operate time is referred to as "mass-controlled."

This should not be taken to mean that in the load-controlled solution the mass effect is neglected, or that in the mass-controlled solution the load effect is neglected. As will be seen, the mass-controlled solution includes the waiting time of the armature at the backstop and the load-controlled solution includes a factor to allow for the travel time of the armature.

Choice of Mass-controlled or Load-controlled Method

In general, the load-controlled solution will be needed on the AF, AG, and AJ relays when the applied power is less than 2 watts and the mass-controlled solution when the power is above 2 watts. For cases in the vicinity of 2 watts, the mass-controlled solution should be tried first. If the time exceeds 0.010 second, average, the load-controlled solution should be used. The AK relay, due to the mass of the armature, is mass-controlled to about the 2-watt power level.

The following paragraphs explain the methods used for calculating the operate time.

Calculation of Load-controlled Operate Time - AF, AG, and AJ Relays

The operate time is the time required to build up the magnetic field to the operate value plus an allowance for travel time:

$$t = (1 + X)\, L\, (G_s + G_e + G_c) \log_e \frac{1}{1-q}$$

X = allowance for travel time

t = time in milliseconds

L = inductance for one turn in microhenries

G_s = sleeve conductance in kilomhos

G_e = eddy current conductance in kilomhos

G_c = coil conductance in kilomhos = $\frac{N^2 \times 10^{-3}}{R}$

N = turns

R = resistance in ohms

q = i/I

i = just operate current in milliamperes

I = steady state current in milliamperes

Some of the above constants have various values depending on whether a minimum or maximum time is desired and whether the structure is an AF, AG, or AJ relay.

The maximum operate times for the AF relay are computed from Fig. VII-1. To compute the maximum operate times for the AG and AJ relays, Fig. VII-1 should also be used and the times as read should be increased by 20 per cent for the AG relay and 10 per cent for the AJ relay to correct for the higher inductance of these structures.

The minimum operate times for the AF, AG, and AJ relays are computed from Fig. VII-2 directly with no correction needed for the AG and AJ relays. This is because the minimum time curves are based on high airgaps where there is little difference in inductance for the three relay types.

The curves are based on unsaturated relays. When the operate adjustment extends into the saturation range, a correction is necessary when figuring the maximum operating time to allow for the decreased inductance. The correction for saturation effect is shown in Fig. VII-1. This correction is needed only on the more heavily loaded relays, as described later.

The computation for average time is covered later.

Construction of Curves

The graphs of Fig. VII-1 and VII-2 are constructed as follows: The left vertical scale is the resistance in ohms; the horizontal scale and the right vertical scale are time or time constant in milliseconds. The lines slanting downward from left to right represent the turns of the winding. The lines slanting upward from left to right represent the current ratio i/I or q, where i is the just operate current and I is the steady state circuit current. The curve designated "NO SLEEVE" represents the effect on the operating time of the eddy currents induced in the magnetic material. The curves designated 0.147 inch, 0.091 inch, and 0.46 inch cu for the copper sleeves and the 0.046 inch al for the aluminum sleeve represent the combined time constants of the eddy-current paths in the magnetic material and the various sleeve.

The insert graph of Fig. VII-1 shows the effect of saturation in reducing the electrical operate time. The maximum operate time as determined from Fig. VII-1 should be multipled by the percentage read from the correction curve of Fig. VII-1 for the particular value of operate ampere turns in order to read the actual operating time.

Use of Fig. VII-1 To Obtain Maximum Operate Time

The maximum electrical operating time of a relay is determined as follows: Using the turns and the maximum resistance of the energizing winding, determine the point of intersection of the "TURNS" and "RESISTANCE" curves and projecting this point vertically downward read the time constant of the energizing winding on the horizontal scale. If the relay has no sleeve, project the time constant of the energizing winding vertically upward to the "NO SLEEVE" curve and then horizontally to the right to read the sum of the time constant of the winding and the eddy current time constant (2 ms) of the magnetic material. Project this total time constant horizontally until it intersects the line representing the ratio i/I and then vertically downward to read the maximum operating time of the relay. If the relay has a copper sleeve, the procedure is the same except that instead of projecting the time constant of the energizing winding vertically upward to the "NO SLEEVE" curve it is projected upward to the proper sleeve curve and then horizontally to the right to read the sum of time constants of the energizing winding, the sleeve, and the magnetic material. The mechanical time is included in the q curves as drawn.

X-75509

In determining maximum electrical operating times the operating current i should be the maximum or operate test requirement and the circuit current I should be the minimum or hot worst circuit current.

The rated turns and the maximum resistance should be used in determining the time constant of the energizing winding.

As an example, suppose it is required to find the maximum operate time of a 2500-ohm AF relay having 19,400 turns and operating in local circuit on 45-50 volts. The test operate current is 8.2 ma.

$$I = \frac{45}{2500 \times 1.1} = 16.4 \text{ ma.}$$

$$q = i/I = \frac{8.2}{16.4} = 0.5$$

$$NI = 19,400 \times 8.2 = 160$$

In Fig. VII-1, find the point corresponding to 2750 ohms and 19,400 turns (63 ms on horizontal scale). Project vertically along 63 ms line to intersection with "NO SLEEVE" curve (65 ms on vertical scale). Project horizontally along 65 ms line to intersection with 0.5 "CURRENT RATIO" line. Project vertically and read 48 ms on horizontal scale. For 160 NI on the AF curve, read 0.96 for a saturation correction factor. The operate time is therefore 48 x 0.96 = 46 ms.

If the relay has appreciable heating during normal circuit operation, the relay resistance should be taken to be the maximum value when hot. It will be noted that if the current flow margin is good, the effect on the operate time will be insignificant.

Use of Fig. VII-2 To Obtain Minimum Operate Time

The procedure for determining minimum electrical operating times from Fig. VII-2 is the same as the procedure for maximum operating times except as described below.

In determining the minimum electrical operating times, the operating current should be the minimum or equal to the nonoperate test current flow requirement and the circuit current I should be the maximum based on maximum voltage and minimum resistance. If no nonoperate requirement is specified, then the equivalent nonoperate ampere-turn value should be read from the nonoperate capability curves for minimum tension and minimum armature gap (see Section IX for capability data). For AF and

AJ relays with 6-mil stop discs and for the AG relay, these ampere turn values are:

AG (20 Gms)	AF, AJ (30 Gms)	Arm. Travel
32 NI	48 NI	short
53 NI	69 NI	intermediate
71 NI	88 NI	long

The rated turns and the minimum resistance should be used in determining the time constant of the energizing winding.

Use of Fig. VII-2 To Obtain Average Operate Time

The average operate time is obtained with all constants taken at the average, or nominal value. The average operate current flow of the relay should be taken as the average of the operate and nonoperate readjust values. Where no nonoperate value is specified, the average operate value can be obtained by averaging the ampere turns obtained from the operate and nonoperate ampere turn capability curves (Section IX) for a load of 70 grams and nominal airgap. For AF and AJ relays with 6-mil stop discs and for the AG relay, these values are:

AG	AF, AJ	Arm. Travel
76 NI	93 NI	short
112 NI	127 NI	intermediate
135 NI	156 NI	long

The minimum operate time curve, Fig. VII-2, should be used. The operate time as read should be increased by 5 per cent for the AF, 10 per cent for the AJ, or 20 per cent for the AG to allow for the greater inductance of the average structure in each case.

Calculation of Mass-controlled Operate Time Using Fig. VII-3 or VII-4 - AF, AG, and AJ Relays

The operate time is the waiting time of the armature plus the time to move the armature from the backstop to the contacts. The method applies only where the rate of flux rise is so great that the contact load is insignificant in delaying the armature motion. This assumption is justified when the average operate time is less than 10 ms.

The operate time is obtained from Fig. VII-3 and VII-4 which have been obtained from test data. The data are given for the average conditions and provide the average operate time to close the average contact. The average time to the first or the last contact is found by subtracting from, or adding to, the average operate time, the following travel allowances.

	Coil Resistance			
Arm. Travel	16 I.S.W. 90ω	270ω	395 or 400ω	700ω
Short	0.1	0.1	0.2	0.3
Intermediate	0.4	0.5	0.7	1.0

The data in Fig. VII-3 and VII-4 apply only to relays with maximum 60-grams armature back tension. This includes all the 4.4-, 16-, 270-, 395-, 400-, and 700-ohm coils except those with nonoperate or release requirements. Relays with nonoperate or release requirements have a maximum 85-gram armature back tension. This increases the operate time about 10 per cent.

Relays using the short coil have an operate time faster than the values in Fig. VII-3 and VII-4. To obtain the short coil operate time take 95 per cent of the values from Fig. VII-3 or VII-4.

Average Operate Time

Determine the watts expended in the relay and series resistance, if any, using average voltage and average resistance. Also calculate the conductance, N^2/R, using specified turns and average resistance including any series resistance. Using the graph of Fig. VII-3 for short travel or Fig. VII-4 for intermediate travel, read the average operate time in milliseconds, interpolating between the power curves as necessary.

As an example suppose it is required to find the average operate time of a 400-ohm AF relay having 3330 turns short armature travel and operating in local circuit on 48 volts.

$$\text{Avg power} = \frac{48.5^2}{400} = 5.9 \text{ watts}$$

$$\text{Conductance} = \frac{330^2}{400} = 27.8 \times 10^{-3}$$

$$= 27.8 \text{ kmohos}$$

In Fig. VII-3, for short armature travel, the average operate time is found to be 5.3 milliseconds.

Minimum and Maximum Times

The minimum and maximum times are determined by finding the average time to the first or last contact and allowing ±30 per cent variation.

For applications, such as the AMA Center, where the maximum operate times are specified for trouble-shooting reasons, and where it is feasible to turn the relays to meet the specified operate time requirement, limits of ±20 per cent from the average may be specified.

Calculation of Operate Time - AK Relays

Both the short and the intermediate travel AK relays operating with an applied power of 2 watts or more are essentially mass-controlled and the contact load has practically no effect on the operate time. The minimum and the maximum operate time for short and intermediate armature travel is shown for the mass-controlled condition on Fig. VII-4A and VII-4B.

Since these figures are plotted for the minimum and the maximum operate times, the resistance and voltage used in computing the power and coil constant $\frac{N^2}{R}$ should be the limiting values that is minimum voltage and maximum resistance for the maximum operate and the reverse values for the minimum operate time. The average operate time is the mean of the maximum and the minimum time.

The operate time curves include a factor for contact stagger and therefore, the minimum time curves are the time to the first contact to function and the maximum times are to the last contact.

The maximum operate time for relays operating on less than 2 watts, based on average resistance and voltage, should be computed by means of the following expression for load-controlled operate time

X-75509

$$t = L(G_c + G_s + G_e) \log_e \frac{1}{1-\frac{i}{I_o}}$$

where t = relay operate time in seconds

L = inductance per turn as shown in Fig. VII-6A

G_c = coil conductance $\frac{N^2}{R}$ in mhos

G_s = sleeve conductance (if sleeve is used)

G_e = core conductance = 10,000 mhos

i = test operate or test nonoperate current

I_o = circuit current

The value of L should be taken for a travel value of one half the armature travel of the relay in question (0.015 inch for short travel and 0.022 inch for intermediate travel.) The values of the expression $\log_e \frac{1}{1-\frac{i}{I_o}}$ may be obtained from Fig. VII-4C which shows this expression plotted for values of the current ratio $\frac{i}{I_o}$

The above expression gives the electrical build-up time for the coil. To obtain the maximum operate time, a mechanical time of 1.3 milliseconds for short armature travel and 2.7 for intermediate travel should be added to the electrical time computed. The minimum operate time for all relays should be computed from the mass-controlled condition Fig. VII-4A or VII-4B.

Calculation of Maximum Contact Stagger Time

AF, AG, and AJ Relays

Where the operate time is mass-controlled, the stagger time will not exceed 1 millisecond for short travel or 2 milliseconds for intermediate travel.

Where the operate time is load-controlled, compute the maximum operate time using the load-controlled method, as explained previously. In Fig. VII-5, using 80 per cent of the computed maximum operate time, read the maximum stagger time. The data for the AF relay is for a particular q value (ratio of test operate to worst circuit operate) and must be corrected for other q values as shown in Fig. VII-5. This curve is a composite curve; it does not imply that the maximum stagger is obtained on the stiffest relay.

AK Relays

The stagger times for the AK relay are given in the following table.

Power	Short Travel	Intermediate Travel
1 watt	1.3 ms	2.7 ms
2 watts	1.0	2.0
3 watts	0.9	1.8
5 watts	0.8	1.6

Design for Highest Speed

The preferred coils, designed for speed use, provide highest speed for 48-volt operation. For highest speed design at other voltages and for series circuits, the following rules should be followed:

1. Use maximum power: The allowable power is usually limited by considerations of heating, power drain, contact current, and tube life.

2. Use minimum armature travel: It is advisable to examine the circuit to determine if sequences are necessary. The penalty for increased armature travel is evident in Fig. VII-3 and VII-4.

3. Use restricted armature tension: All relays using the 4.4-, 16-, 270-, 395-, 400-, and the 700-ohm coils have 45 ±15 grams armature tension specified in the M-spec. The operate time will be increased about 20 per cent if the armature tension is raised from 45 to 90 grams. The operate time will be increased about 60 per cent if the armature tension is raised from 45 to 180 grams.

4. Use optimum turns: If the relay has too few turns, it will be slow because of poor margins. If it has too many turns, it will be slow because of a large winding time constant. For each case there will be an optimum value of turns depending on the power input and the armature travel. Any deviation from optimum should always be on the high side to insure positive operation of the relay.

   For mass-controlled cases, the optimum turns will be evident from Fig. VII-3, VII-4, or X-13.

   For load-controlled cases, without copper sleeves, the optimum turns are approximately twice the turns needed to just operate the relay load.

   For copper sleeve relays, the optimum turns are greater than twice the turns needed to just operate the relay. Winding space limitations usually preclude the achievement of the optimum value.

Inductance Curves

Inductance values, as a function of the airgap are shown in Fig. VII-6 for the AF, AG, and AJ relays and Fig. VII-6A for the AK relay. Appropriate values of inductance taken from these curves have been used in the methods set down in the preceding paragraphs. It should be understood that these curves show the build-up inductance of the relay obtained from the slope of the magnetization curve with, as the name implies, increasing flux.

The curves will supply the inductance constant for use in computing the operate time under some conditions. For example, if the operate time of a series relay or switch of another type is needed, and the AF, AG, or AJ relay is a series or shunt element in the operating circuit, the inductance constant for the AF, AG, or AJ relay may be needed to make the computation.

The inductance constant shown in Fig. VII-6 and VII-6A is for one turn. For a structure of N turns the inductance will be obtained by multiplying the inductance constant by N^2.

Appendix A

Equivalent Simple Circuits For Series or Parallel Relay Circuits

General

The engineering data provided earlier in this section applies to a relay operating in local circuit or in series with a resistance and releasing with a contact protection network. In practice, relays often operate in series or parallel with one or more other relays and resistances. The contact protection network may be across the operating contact, the entire series circuit, or the parallel circuit.

These more complex circuit configurations do not seriously complicate the estimation of the operate and release time for the relay. For a great many of the cases it is possible to reduce the circuit to a simple equivalent for which the data presented earlier in this section will apply.

For the purpose of computing operate and release times, the equivalent circuit may be defined as one in which the ampere-turn transient, during operate or release, is not altered. This unchanged ampere-turn transient in the equivalent circuit is guaranteed provided the factors L/R, r^C, LC, and NI remain unchanged where L is the inductance of the operate path, R is the resistance of the operate path, C is the protection capacitance, r is the resistance in series with the protection capacitance, N is the turns on the relay, and I is the steady-state current when operated. In practice, the factor rC is found to have very little effect on the computed times so that for practical equivalence only the factors L/R, LC, and NI must be equivalent in order to guarantee equivalent operate and release times.

Applications of Equivalent Circuit Theory

Fig. VII-7a shows a relay circuit of the type commonly used in the AMA circuits. Because the relays are in series and because the contact protection is not per relay, the data and curves cannot be directly applied. It is desired to reduce this circuit to a simple equivalent involving only one relay and an equivalent contact protection. This case is simple and the equivalent can be drawn almost directly and then the factors L/R, r_C, LC, and NI checked to show equivalence.

In Fig. VII-7b, the contact protection has been connected to battery instead of ground which does not alter the transient at all. Also the 90ω external resistance is distributed equally between the two series relays. In Fig. VII-7c the protection network has been distributed equally between the two relays. The dotted line connects points of equal potential and may therefore be added or discarded without affecting the transient. Fig. VII-7d assumes the dotted connector in place and the battery divided equally between two equal circuit sections. The equivalent in this case has been derived in a simple manner because of the symmetry of the parts of the circuit. Fig. VII-7a and VII-7d are shown to be equivalent by noting that the factors L/R, NI, rC, and LC are unchanged.

Although the circuit of Fig. VII-7 is typical, the theory is not limited to such simple cases. In Fig. VII-8a a circuit is assumed in which the series relays have different windings. Here the total series resistance of the operate path must be distributed in proportion to the factor N^2 so as to make the time constant L/R (proportional to N^2/R) equal in each relay. This has been done in Fig. VII-8b and the protection connected to battery as before. In Fig. VII-8c, the protection capacitance has been divided into series components inversely proportional to N^2 so as to make the factor LC (proportional to N^2C) equal in each relay section. Also, in Fig. VII-8c the resistance in series with the protection capacitance has been distributed in proportion to the factor N^2 so as to keep the factor rC equal in each relay section. The dotted line connects points of equal potential throughout the transient and therefore may be added or removed, as required, without changing the current distribution. Finally the voltage has been divided into series components (proportional to N^2) in order to keep the factor NI unchanged in each relay and the circuit has been split, as shown in Fig. VII-8d. The factors L/R, NI, rC, and LC are calculated in Fig. VII-8a and VII-8d for a recheck of the equivalence between the original and final equivalent relay circuits.

In Fig. VII-9a, a parallel circuit is considered. The steps to arrive at the equivalent in Fig. VII-9c are almost obvious. The method can be extended to any number of relays in parallel, not necessarily of the same resistance, as long as the time constant for each relay is the same, which is practically true for all full wound relays on a given structure.

Appendix B

Simulated Relay Circuits

In compiling data for operate and release times of relays, particularly of new designs, it is often necessary to test a number of samples having various windings. Furthermore, if an extreme capability relay structure is available, it may be desirable to rewind the relay or remove turns to simulate the winding desired. This complication can be avoided by using a single winding on the extreme capability relay and changing all other circuit constants in such a way that the ampere-turn transient in the relay, during operate and release is unaltered thereby resulting in unchanged operate and release times.

The rule for such equivalent circuits is as follows:

It is desired to test a relay circuit for operate and release times. The desired circuit is made up of a total series resistance in the operate path of R ohms, a relay with N turns, and a battery of E volts. The contact protection consists of a capacitance of C mf and a resistance of r ohms. The available structure has N' turns. The required circuit can be simulated insofar as operate and release times are concerned by using the following equivalents.

$$\text{turns} = N'$$

$$\text{resistance} = \left(\frac{N'}{N}\right)^2 R$$

$$\text{voltage} = \left(\frac{N'}{N}\right) E$$

$$\text{protection capacitance} = \left(\frac{N}{N'}\right)^2 C$$

$$\text{protection resistance} = \left(\frac{N'}{N}\right)^2 r$$

A check for equivalence between the desired and the simulating circuit can be obtained by noting that the factors L/R, NI, LC, and rC are unchanged. Typical examples are given in Fig. VII-10.

A limitation of the simulating circuit is that no visible spark should occur on the actuating contact during release since the voltage of the simulating circuit may exceed the sparking potential of air. It is therefore recommended that the test structure be wound with 3000 turns since this value will allow equivalents as low as 750 turns without exceeding 200 volts in the test battery. It is also recommended that the actuating contact be a fast opening contact to further reduce the possibility of sparkover and that the protection capacitor be capable of the resulting peak voltages.

PART II - RELEASE TIMES

General

The minimum, maximum, and average releasing times for the various coded relays, on 45 to 50 volts, local circuit, and without contact protection, are listed in the code section (Section II). For those cases where contact protection is used, it will be necessary to compute the release times as outlined later in this section. This section covers AF, AJ, and AK relays only, as the AG slow-release relays require special treatment and are covered in Section IX.

Definition of Minimum, Maximum, and Average Times

Release time is that interval from the time the relay winding circuit is opened to the instant that a contact is actuated. This would be the first contact to be actuated in the case of minimum release time, the average contact for average release time, and the last contact for maximum release time.

The data shown is for relays without contact protection unless the data specifically states that contact protection is used.

X-75509

The release time consists of three parts:

Electrical Time - The time necessary for the flux to decrease to a point which will allow the release of the armature from the core.

Travel Time - The time necessary for the armature to move sufficiently to actuate the nearest contact.

Stagger Time - The time necessary for the armature to move from the nearest to the farthest contact. For AF, AJ, and AK relays the maximum stagger is 1 millisecond for short travel and 1.5 millisecond for intermediate travel for relays releasing on open circuit. Relays releasing under shunt conditions, or relays with copper sleeves, may have an appreciable stagger time, and will require special consideration.

Factors Controlling Release Time

The release time (t) of a relay is given by the equation $t=G\left[\frac{\varphi''-\varphi_o}{NI}\left(\frac{\log z}{z-1}-\frac{1}{z}\right)\right]$ where

t = electrical time

G = conductance

NI = release ampere turns

$$z = \frac{\varphi''-\varphi_o}{\varphi-\varphi_o}$$

φ'' = soak flux

φ_o = residual flux

φ = flux corresponding to the release ampere turns

The term $\frac{\log z}{z-1} - \frac{1}{z}$ is substantially a constant in the normal range of release ampere turns for the AF, AJ, and AK relays. The release time for any given load will, therefore, be proportional to G.

The conductance term G is made up of three parts; the coil conductance (G_c), the sleeve conductance (G_s), and the eddy-current conductance of the core of the relay (G_e). The eddy-current conductance is always present, but the coil conductance is present only when the relay releases from a short circuit or with a resistance in parallel with the winding, and the sleeve conductance is present only when a sleeve is provided on the relay.

The coil conductance may be determined from the relay winding data. $G_c = \frac{N^2}{R} \times 10^{-3}$ kilomhos where N is the turns on the coil and R is the total circuit resistance including any resistance in series or in parallel with the relay coil. If the relay is releasing on open circuit with no contact protection or shunt resistance there is no closed circuit for the coil and G_c is zero.

The sleeve conductance is also in the form of $\frac{N^2}{R}$ but $N^2 = 1$ since the sleeve is considered a single short-circuited turn. The problem therefore reduces to the determination of the resistance of the sleeve. The values of sleeve conductance for the sleeves used on the wire spring relays are:

Sleeve	Max G_s	Min G_s
AF,AG, and AJ Relays		
0.046 in. aluminum	44.0 kmhos	38.3 kmhos
0.046 in. copper	73.6 kmhos	65.6 kmhos
0.091 in. copper	135.5 kmhos	125.0 kmhos
0.147 in. copper	200.5 kmhos	189.0 kmhos
AK Relays		
0.069 in. copper	112.0 kmhos	100.0 kmhos

The core conductance has been measured and found to be 5 kilomhos for the AF, AG, and AJ relays and 10 kilomhos for the AK relay. It is simpler and more accurate to use a measured value than to estimate a value from the relay constants.

The release time curves are based on the just hold, or the just release ampere turns of the relay. These release ampere turns are determined as outlined in the following paragraphs.

Release Ampere Turns (NI) for Maximum Release Time

The data for maximum release time is based on the test release ampere turns of the relay. The release ampere turns are obtained by determining the readjust release value as shown below and multiplying by 95 per cent to obtain the test value. A release requirement offers the best method of controlling the maximum release time in order to obtain the lowest maximum release time for a particular relay.

Relays With Operate Requirement Only

The release ampere turns are found by reading the operated load grams of Table IX-6 on the release curve for 300-ampere turn soak and the proper stop-disc height in Fig. IX-13, IX-19, IX-25, or IX-35 depending on whether an AF, AJ, AJ relay with laminations or AK relay is being considered. If the relay has a specified minimum armature back tension of less than 30 grams, the operated load should be reduced by an amount equal to the difference between the specified back tension and 30 grams.

Relays With Nonoperate Requirement

The operated gram loads in Table IX-6 are based on a 30-gram armature back tension. Relays with a nonoperate requirement may have a back tension in excess of 30 grams as read on the nonoperate curve, which is based on a good magnet. If the nonoperate ampere turns were read on the operate pull curve, which is based on a poor magnet, a back tension in the order of 30 grams would result. Thus the nonoperate may not increase the back tension above 30 grams in the limiting case of a poor magnet and maximum unoperated airgap. Relays with a nonoperate should, therefore, be treated the same as relays with only an operate requirement.

Relays With Release Requirement

Multiply the release current flow value specified by the number of turns to obtain the readjust ampere turns.

Release Ampere Turns for Minimum Release Time

The release ampere turns for the minimum release time are based on the test hold ampere turns. These are found by determining the readjust hold value as shown below and multiplying by 105 per cent to obtain the test value. The hold is used since the relay may release on a value just below the hold value.

Relays With Operate Requirement Only

The load used is the maximum operated gram load in Table IX-2. These loads are based on a 60-gram armature back tension. The speed coils (4.4, 16, 270, 395, 400, or 700 ohms) have a maximum 60-gram back tension specified in the manufacturing requirements, but the other coils have no limit on the back tension as long as they meet the operate requirement. With the exception of the relays using the speed coils listed above, the operated gram loads of Table IX-2 should be increased by 30 grams to allow for the actual back tension that is likely to be encountered on the relays. The ampere turns on which the relay will just release are found by reading the maximum operated gram load on the hold pull curve for 300-ampere turn soak and the proper stop-disc height of Fig. IX-12, IX-18, IX-24, or IX-34 depending on the type of relay being considered.

Relays With Hold Requirement

Multiply the hold current flow value specified by the number of turns to obtain the readjust ampere turns.

Relays With Nonoperate Requirement

These relays are figured the same as those with only an operate requirement.

Release Time on Open Circuit With No Shunt

The release times of the ordinary AF, AJ, or AK relay are in the range of 1 to 15 milliseconds. When adjusted on the same release ampere turns, the AF and AJ relays have essentially the same release time where no contact protection is used. The constants controlling the rate of flux decay are small unless a time delay sleeve or shunt is provided. This may increase the minimum time to about 50 milliseconds. Minimum release times greater than this require the use of the AG relay which has special design features to provide longer release times. Faster release times can be obtained by using 0.014-inch or 0.022-inch stop discs on the AF or AJ relays and heavy spring loads.

Fig. VII-11 and VII-11A show the maximum and the minimum release time for relays releasing on open circuit with no shunt, sleeve, or protection. These are the times to the first contact for relays with 0.006-inch stop discs. If the stop disc is other than 0.006 inch the release times should be corrected by the factors shown in Fig. VII-12. This may be an important correction and should not be overlooked. The stagger time should be added to the maximum time obtained from the release time curves.

The release times shown in Fig. VII-11 and VII-11A are based on a 300-ampere turn soak. Although the times may vary as much as 10 per cent for the extremes of high soak and high release ampere turns it does not appear necessary to complicate the figuring of release times by introducing a correction for high soak values. The maximum effect of the soak on the releasing time is obtained at high release ampere turns, which indicates a stiff relay and therefore fast release times, and the use of a coil developing about 500-ampere turns. Very few coils will develop 500-ampere turns and the 10 per cent effect on the release times at the high release ampere turns is only a fraction of a millisecond. It is concluded therefore that the effect of soak values of 250 or more ampere turns can be neglected. For soak values of 200-ampere turns, reduce the release times by 3 per cent, and for soaks of 150-ampere turns or less by 5 per cent.

Average Releasing Time

The average release time is obtained by taking 80 per cent of the maximum operated gram load from Table IX-2 and reading the release ampere turns for this load on both the hold and release pull curves. Read the release time for the hold ampere turns on the minimum release time curve and the release time for the release ampere turns on the maximum release time curve. The average of these two readings is the average release time.

X-75509

Release Time With Resistance Shunt

Under this condition G_c will be something greater than zero and will be found from $G_c = \frac{N^2}{R_1+R_2}$ where

N = number of turns in coil

R_1 = resistance of coil

R_2 = resistance of shunt

Fig. VII-13 shows the maximum release time of the AF and AJ relays plotted against the conductance in kilomhos for different ampere-turn release values and 0.006-inch stop discs. Fig. VII-14 shows the minimum release time for the same conditions. Fig. VII-13A and VII-14A shows the corresponding values for the AK relay. The release times are found by reading the previously determined release ampere turns for the value G_c determined from the coil constants. Although the curves are plotted for the coil and/or sleeve conductance only, the effect of the eddy-current conductance of the core (G_e) is also included in the release time curves. For open circuit release with no sleeve or shunt, $G_c + G_s$ is zero. The release time for AF or AJ relays with other than 0.006-inch stop discs is found by obtaining the time for the 0.006-inch stop discs and applying the correction factors from Fig. VII-12. The stagger time may be long and will require special consideration if it affects the circuit operation.

Release Time With Sleeves

In the release time of relays with sleeves, particularly those with the large sleeve, the major portion of the release time is due to the slow flux decay. These relays are treated the same as a relay with the resistive shunt, using a G_s corresponding to that shown previously for the size of sleeve used on the relay.

Release Time With Contact Protection

Contact life requirements frequently require the use of a condenser and resistance in shunt with a relay winding, or across a contact which is in series with the relay winding. This changes the rate and character of the flux decay and consequently the release time. The effect is the same whether the protection is in parallel with the relay winding or across the series contacts. In either case, the opening of the circuit starts the collapse of the flux in the relay and causes a flow of current in the condenser circuit. This current may or may not be oscillatory, depending on the coil turns, coil resistance, and the values of the protective network. The effect of protection on the operate time is minor and can be neglected.

The maximum release time for the AF relay with different ampere turn release values has been plotted for $N^2C \times 10^{-6}$ in Fig. VII-15. These values are for a value of $CR_T = 100$ where C is the protective capacity in microfarads and R_T is the sum of the coil and protective resistances. These times are for the travel to the first contact. For the time to the last contact, add the stagger time of 1 millisecond for short travel and 1.5 millisecond for intermediate travel. The release times must be adjusted if the value of CR_T is other than 100. This correction is shown in Fig. VII-16.

Other curves show the minimum release time for the AF relay and the maximum and minimum release time for the AJ relay. The list of the release time curves for protected relays is:

Maximum release AF relays	Fig. VII-15
Minimum release AF relays	Fig. VII-17
CR_T correction	Fig. VII-16
Maximum release AJ relays	Fig. VII-18
Minimum release AJ relays	Fig. VII-20
CR_T correction	Fig. VII-19

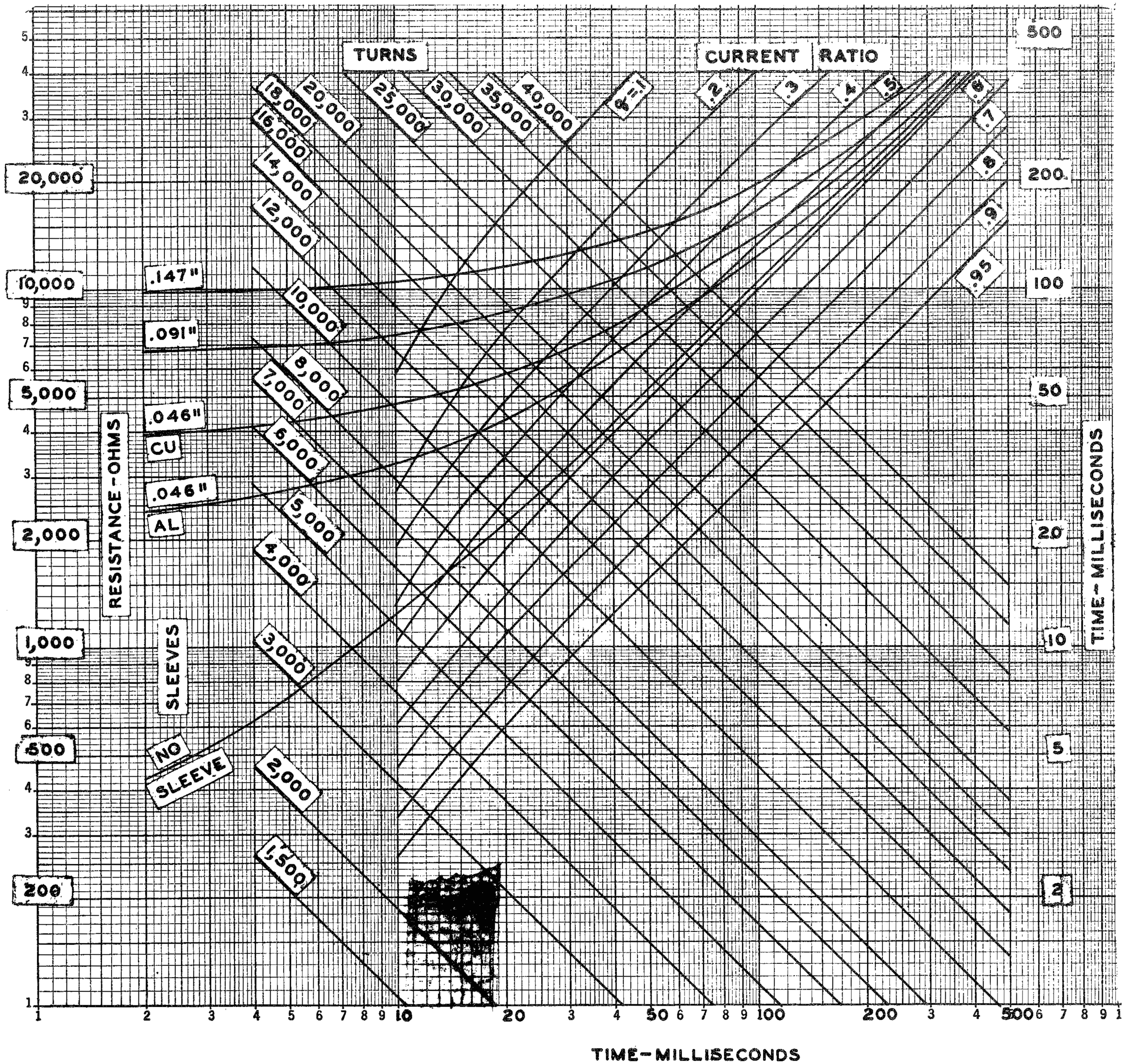
These curves apply to relays with all stop-disc heights since the release time of protected relays with the same ampere-turn release is independent of the stop-disc height. The release ampere turns, and therefore the release time, for the same spring load will vary with the stop-disc height.

AK Release With Copper Sleeve and Domed Armature

The AK relay may be equipped with a domed armature and a copper sleeve to obtain a slow release time. The minimum release time is obtained by computing the hold-ampere turns from data in Section IX and reading the release time from Fig. VII-14B or VII-14C. The maximum release time is obtained in a similar manner using the release value.

Release Time Under Shunt-down Condition

In case a relay is released by shunting the relay down and the shunt is not of zero resistance, a current will flow in the energizing winding during the releasing period. The releasing time of such a relay can be estimated from the data in this section. The procedure is to determine the coil constant, $G_c = \frac{N^2}{R}$, as described previously. The effect of the current in the short-circuited winding is to increase the release time. This influence can be accounted for by subtracting the ampere turns in the energizing winding during the releasing period from the release ampere turns determined from the hold or release pull curves and using the resulting release ampere turns to determine the release time.



FOR AF RELAYS: - USE CURVE AS SHOWN

FOR AG RELAYS: - ADD 20% TO FINAL READINGS

FOR AJ RELAYS: - ADD 10% TO FINAL READINGS

$$t = (1 + X)L(G_c + G_e + G_s)\log_e \frac{1}{1-q}$$

FOR LARGE TIMES (>30 MS.) X = 0.1

FOR SMALL TIMES (10 TO 30 MS.) X VARIES FROM 0.1 TO 0.5

(THESE VALUES ARE INCLUDED IN q CURVES)

$L = .46\mu H$

$G_c = \frac{N^2}{R} 10^{-3}$ KMHOS

$G_e = 5$ KMHOS

$G_s =$ (210", .147" SLEEVE
(144", .091" SLEEVE
(78", .046" SLEEVE, CU.
(44", .046" SLEEVE. AL.

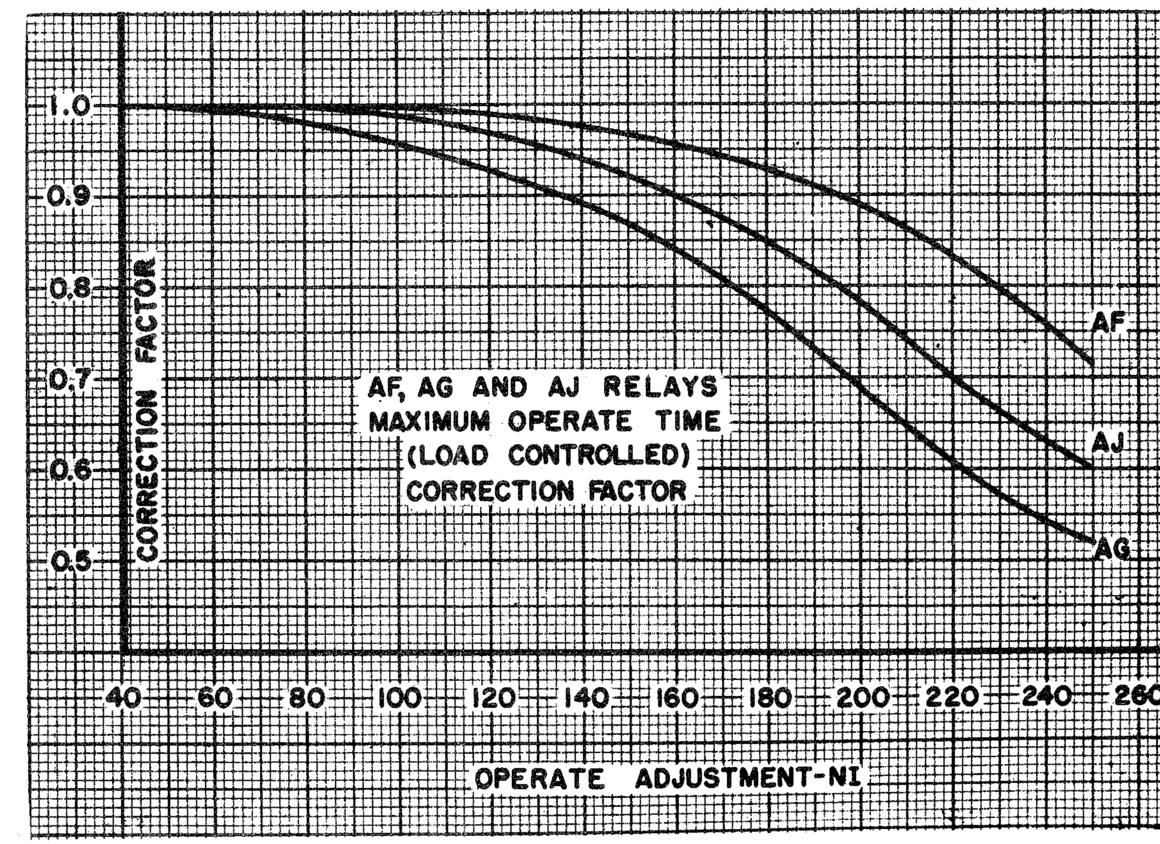


Fig. VII-1 - AF, AG, and AJ Relays - Maximum Operate Time - Load Controlled

A-75509

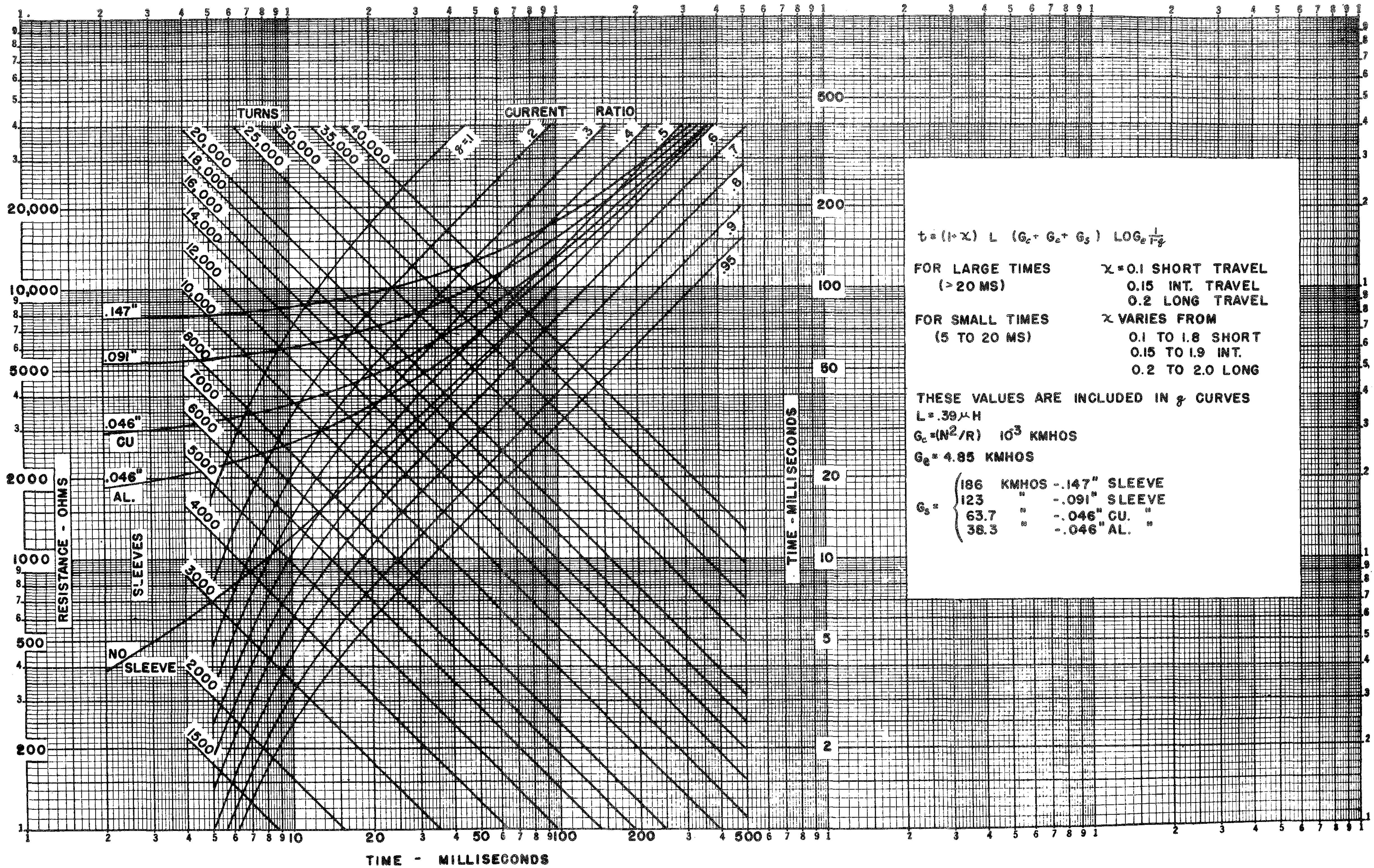


Fig. VII-2 - AF, AG, and AJ Relays - Minimum Operate Time - Load Controlled

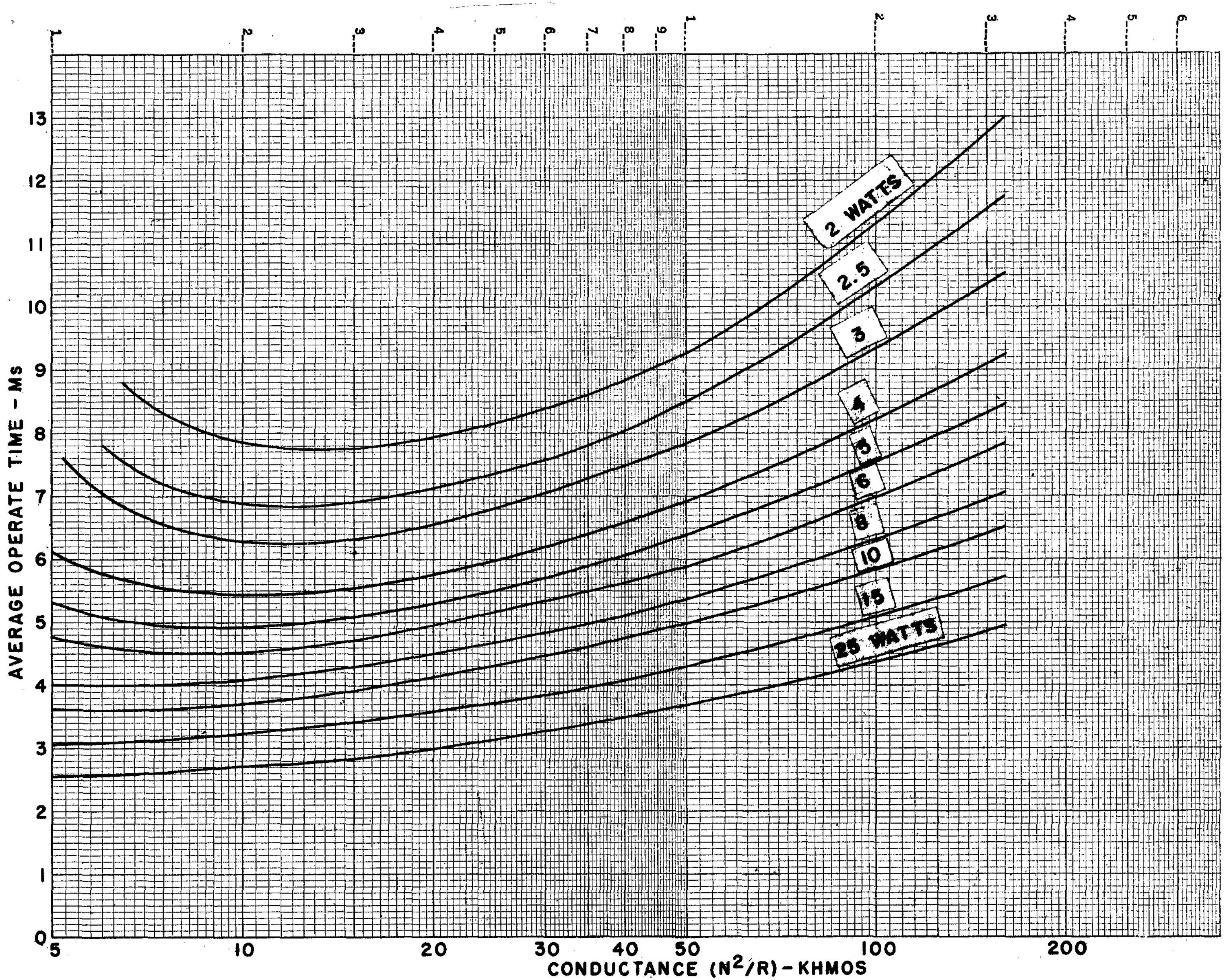


Fig. VII-3 - AF and AJ Relays - Short Armature Travel - Average Operate Time

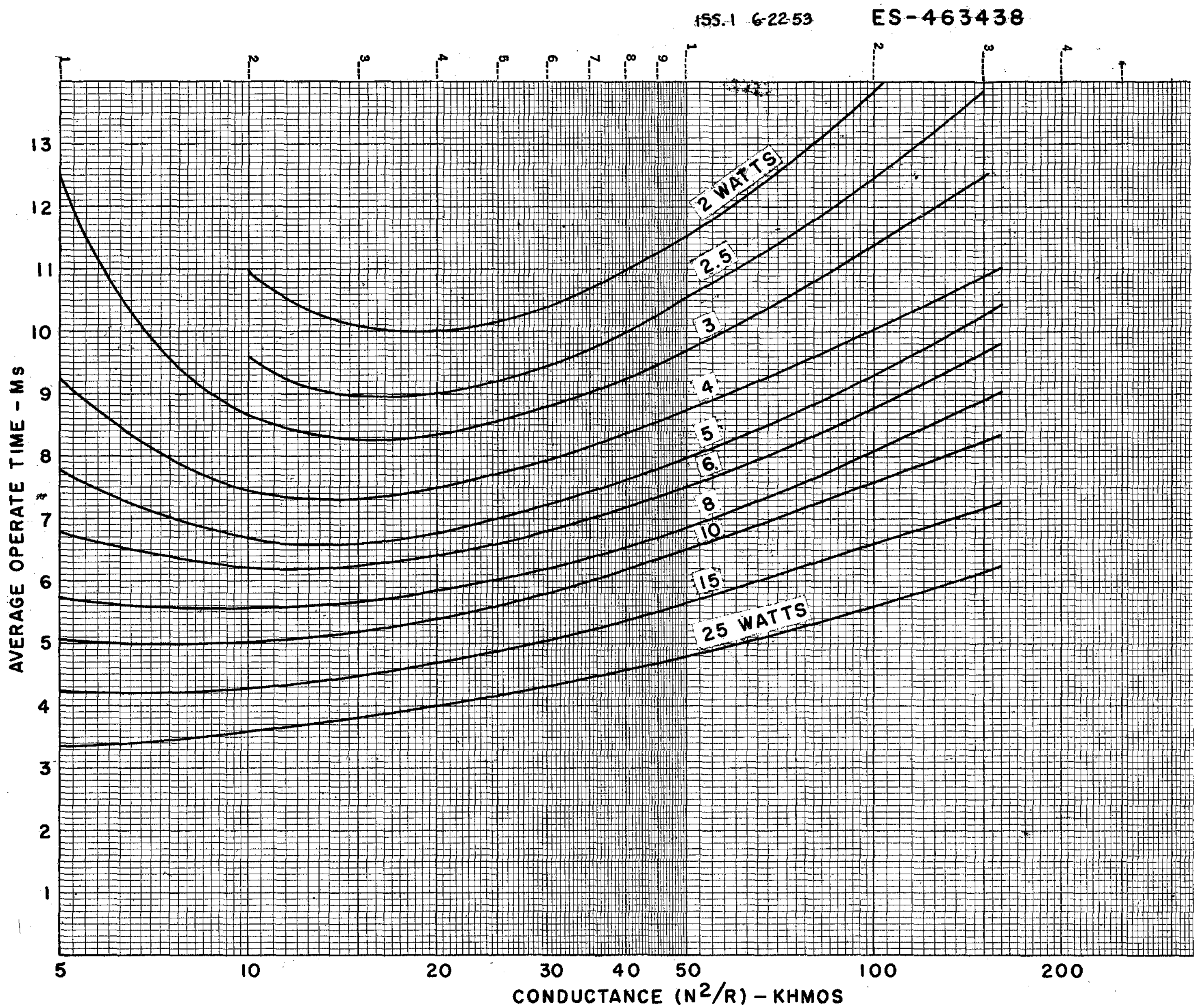
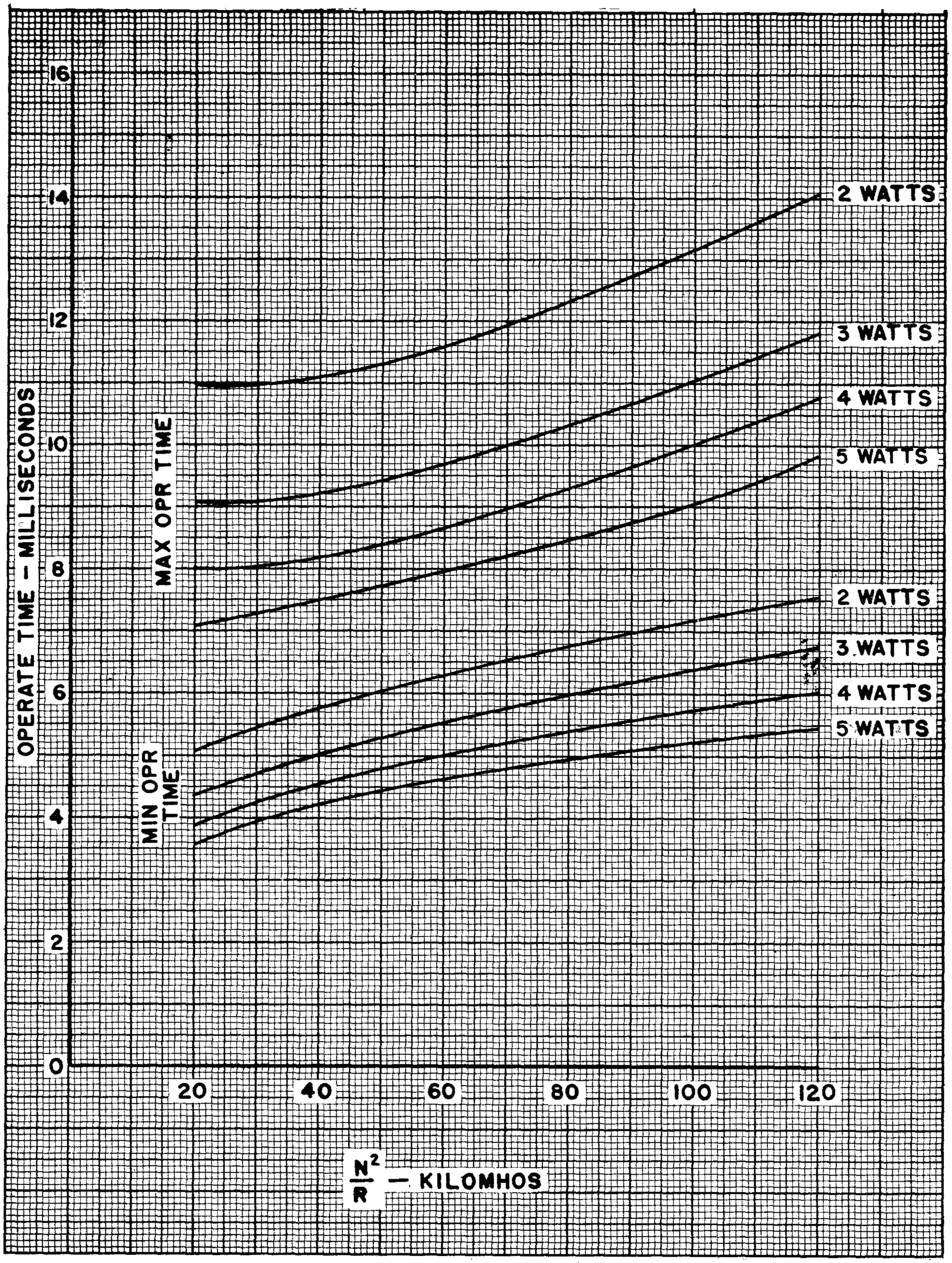


Fig. VII-4 - AF and AJ Relays - Intermediate Armature Travel - Average Operate Time



X-75509

Fig. VII-4A - AK Relay Operate Time Short Travel

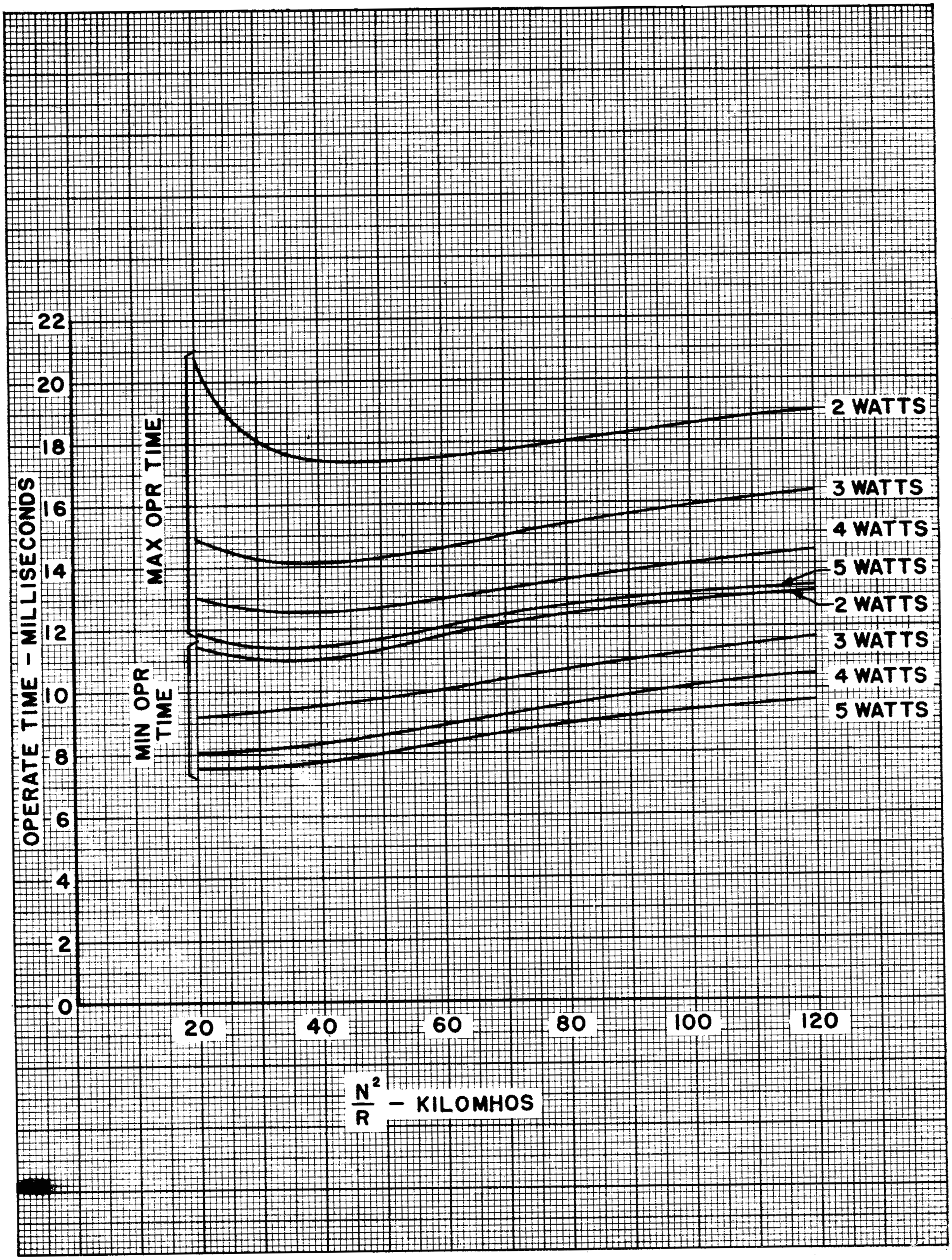


Fig. VII-4B - AK Relay Operate Time Intermediate Travel

X-75509

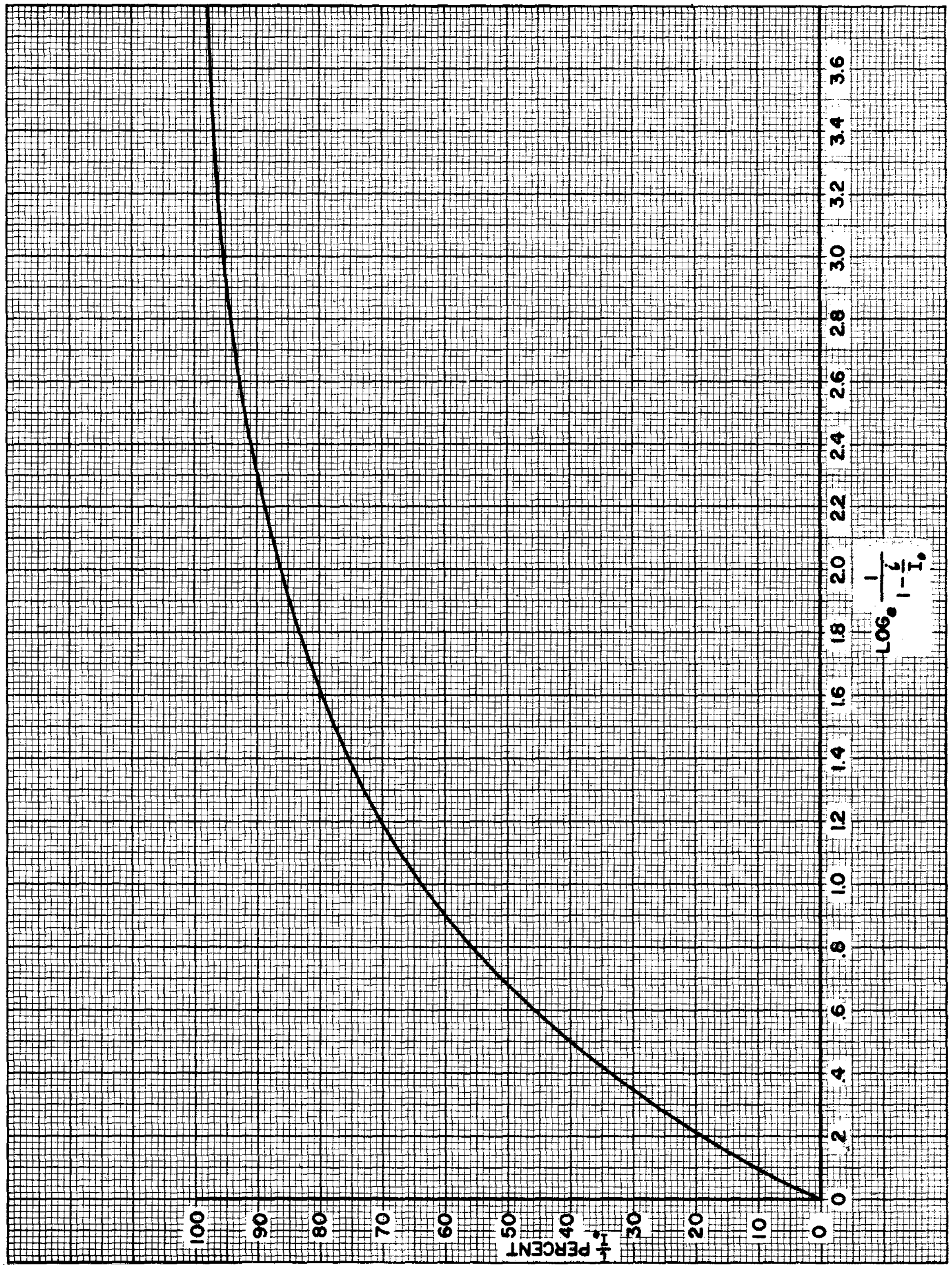


Fig. VII-4C - Time Constant Curve

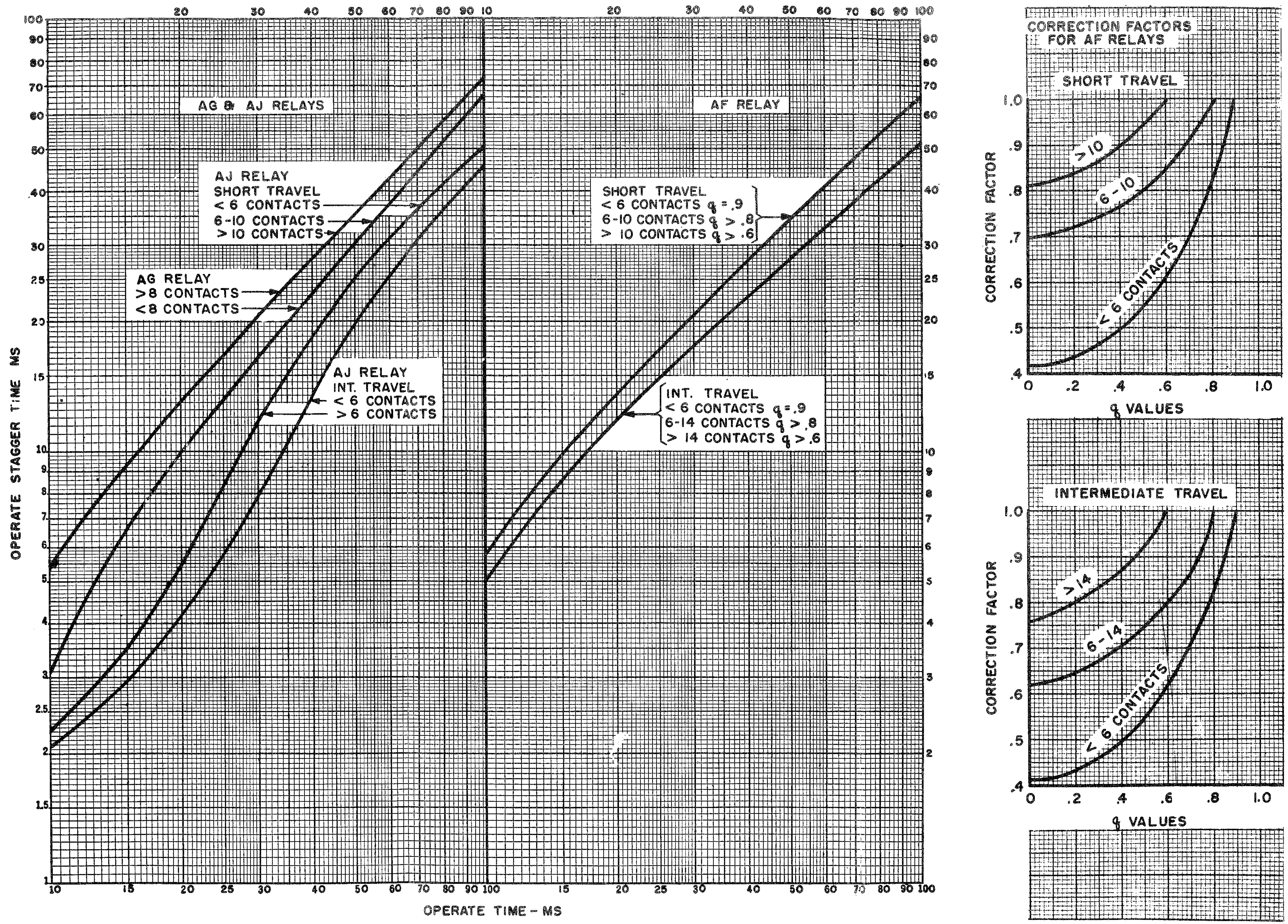
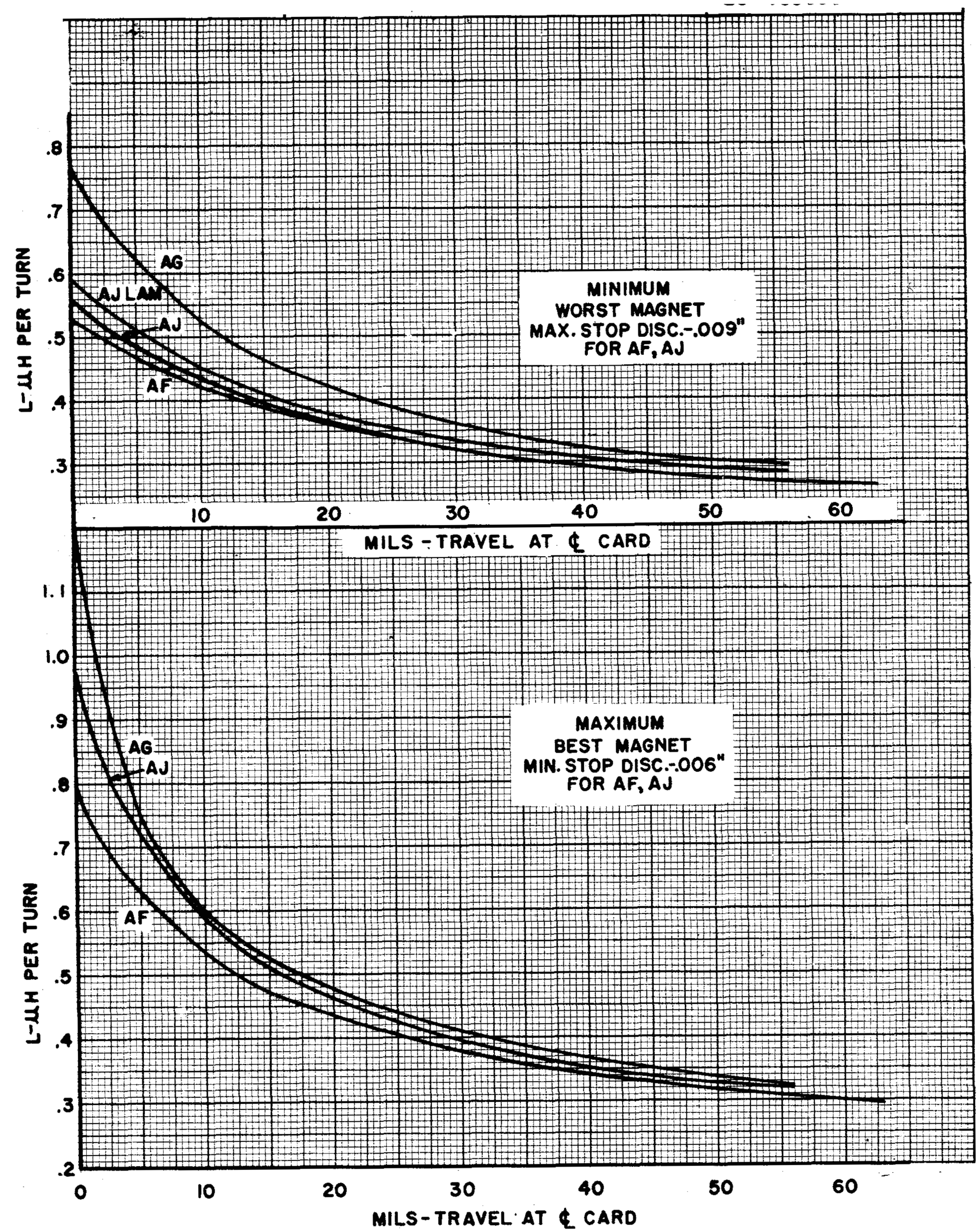


Fig. VII-5 - Load-controlled Stagger Time



X-75509

Fig. VII-6 - AF, AG, and AJ Relays - Inductance Constant of One Turn

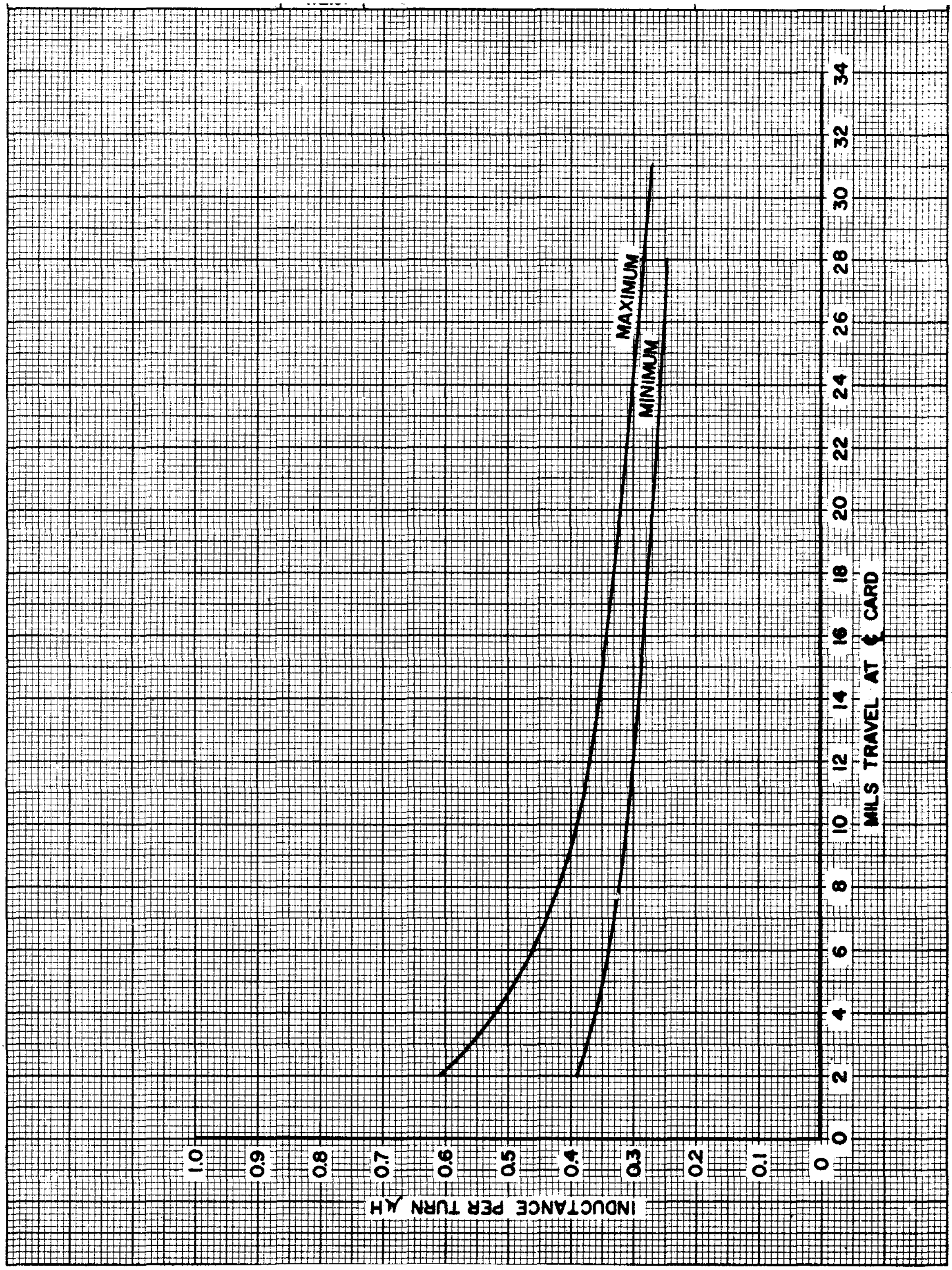
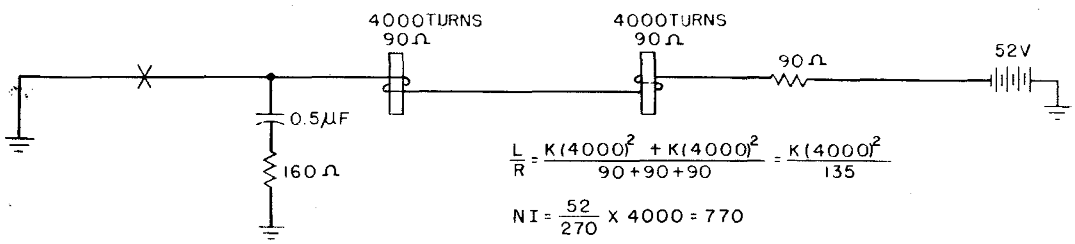


Fig. VII-6A - AK Relay-Inductance Constant of One Turn

CKT. TO BE SIMPLIFIED



$$\frac{L}{R} = \frac{K(4000)^2 + K(4000)^2}{90+90+90} = \frac{K(4000)^2}{135}$$

$$NI = \frac{52}{270} \times 4000 = 770$$

$$rC = 0.5 \times 10^{-6} \times 160 = 80 \times 10^{-6}$$

$$LC = 2 \times K(4000)^2 \times 0.5 \times 10^{-6} = K(4000)^2 \times 10^{-6}$$

FIG. VII-7a

EQUIVALENT CKTS.

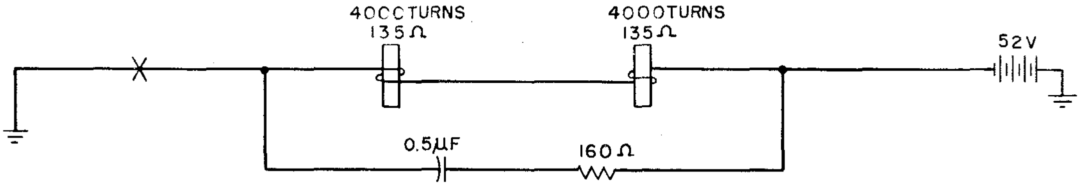


FIG. VII-7b

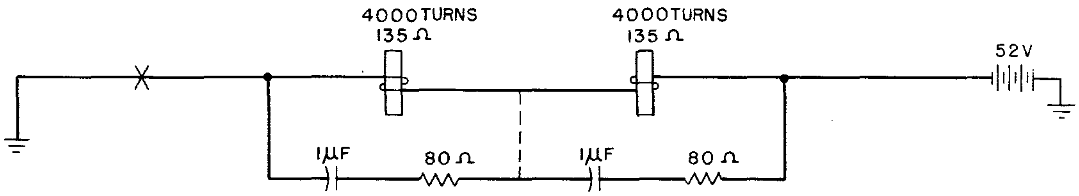
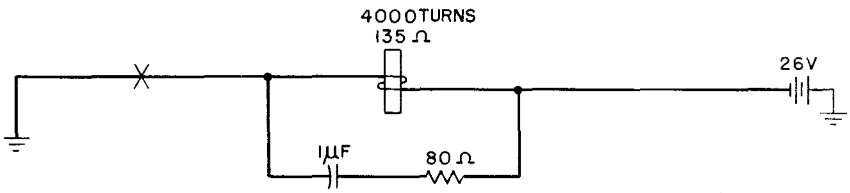


FIG. VII-7c



$$\frac{L}{R} = \frac{K(4000)^2}{135}$$

$$NI = \frac{26}{135} \times 4000 = 770$$

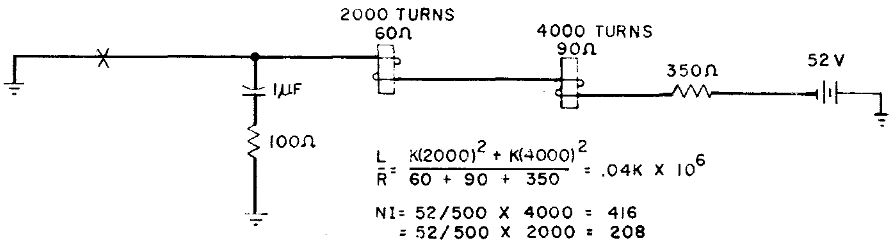
$$rC = 1 \times 10^{-6} \times 80 = 80 \times 10^{-6}$$

$$LC = K(4000)^2 \times 10^{-6}$$

FIG. VII-7d

Fig. VII-7 - Equivalent Circuits

CIRCUIT TO BE SIMPLIFIED



$$\frac{L}{R} = \frac{K(2000)^2 + K(4000)^2}{60 + 90 + 350} = .04K \times 10^6$$

$NI = 52/500 \times 4000 = 416$
$= 52/500 \times 2000 = 208$

$rC = 100 \times 1 \times 10^{-6} = 100 \times 10^{-6}$

$LC = (K(2000)^2 + K(4000)^2) \times 1 \times 10^{-6} = 20K$

FIGURE VII - 8A

EQUIVALENT CIRCUITS

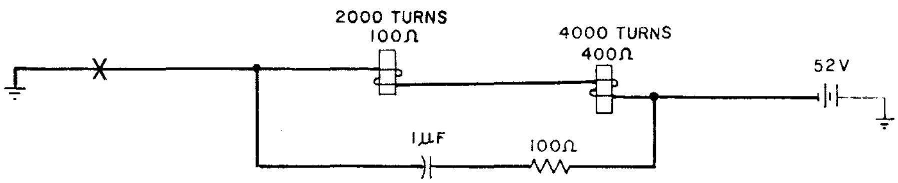


FIGURE VII - 8B

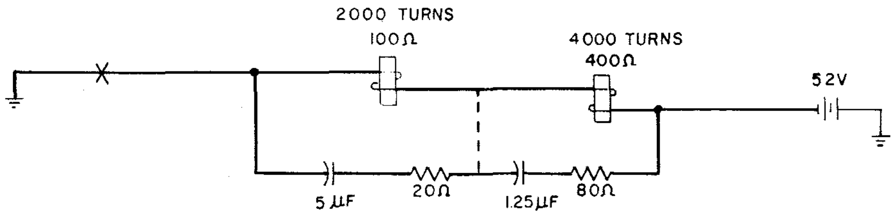
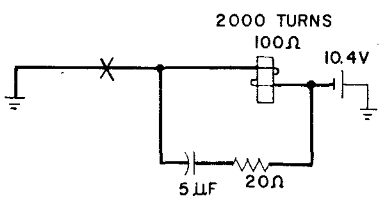


FIGURE VII - 8C



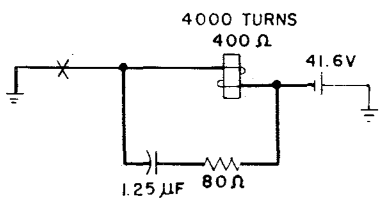


FIGURE VII - 8D

$\frac{L}{R} = \frac{K(2000)^2}{100} = .04K \times 10^6$

$NI = \frac{1.04}{100} \times 2000 = 208$

$rC = 5 \times 10^{-6} \times 20 = 100 \times 10^{-6}$

$LC = K(2000)^2 \times 5 \times 10^{-6} = 20K$

$\frac{L}{R} = \frac{K(4000)^2}{400} = .04K \times 10^6$

$NI = \frac{41.6}{400} \times 4000 = 416$

$rC = 1.25 \times 10^{-6} \times 80 = 100 \times 10^{-6}$

$LC = K(4000)^2 \times 1.25 \times 10^{-6} = 20K$

Fig. VII-8 - Equivalent Circuits

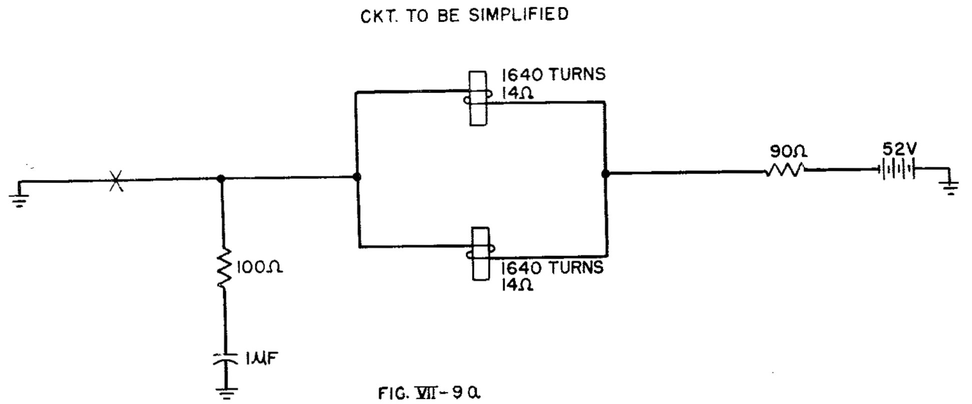


FIG. VII-9a

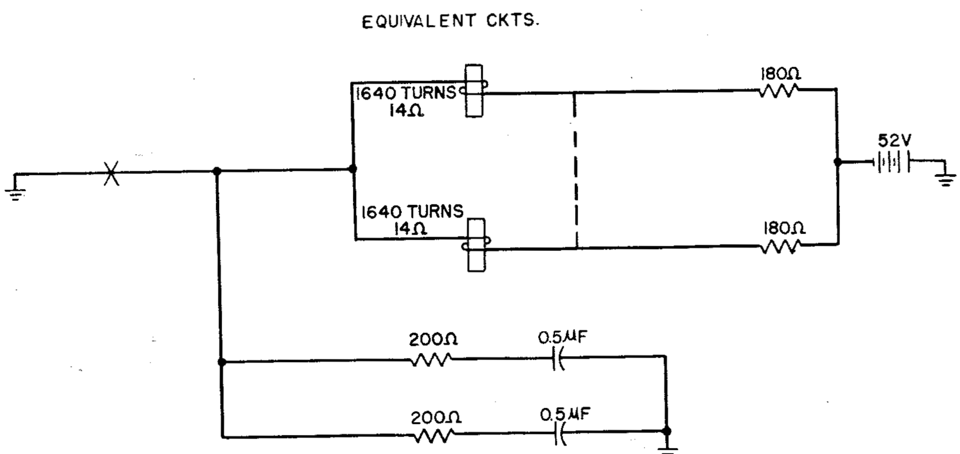


FIG. VII-9b

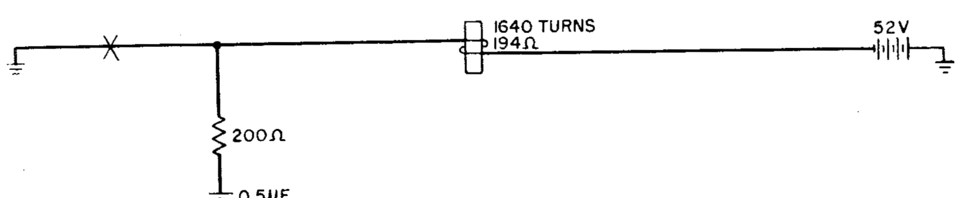


FIG. VII-9C

X-75509

Fig. VII-9 - Equivalent Circuits

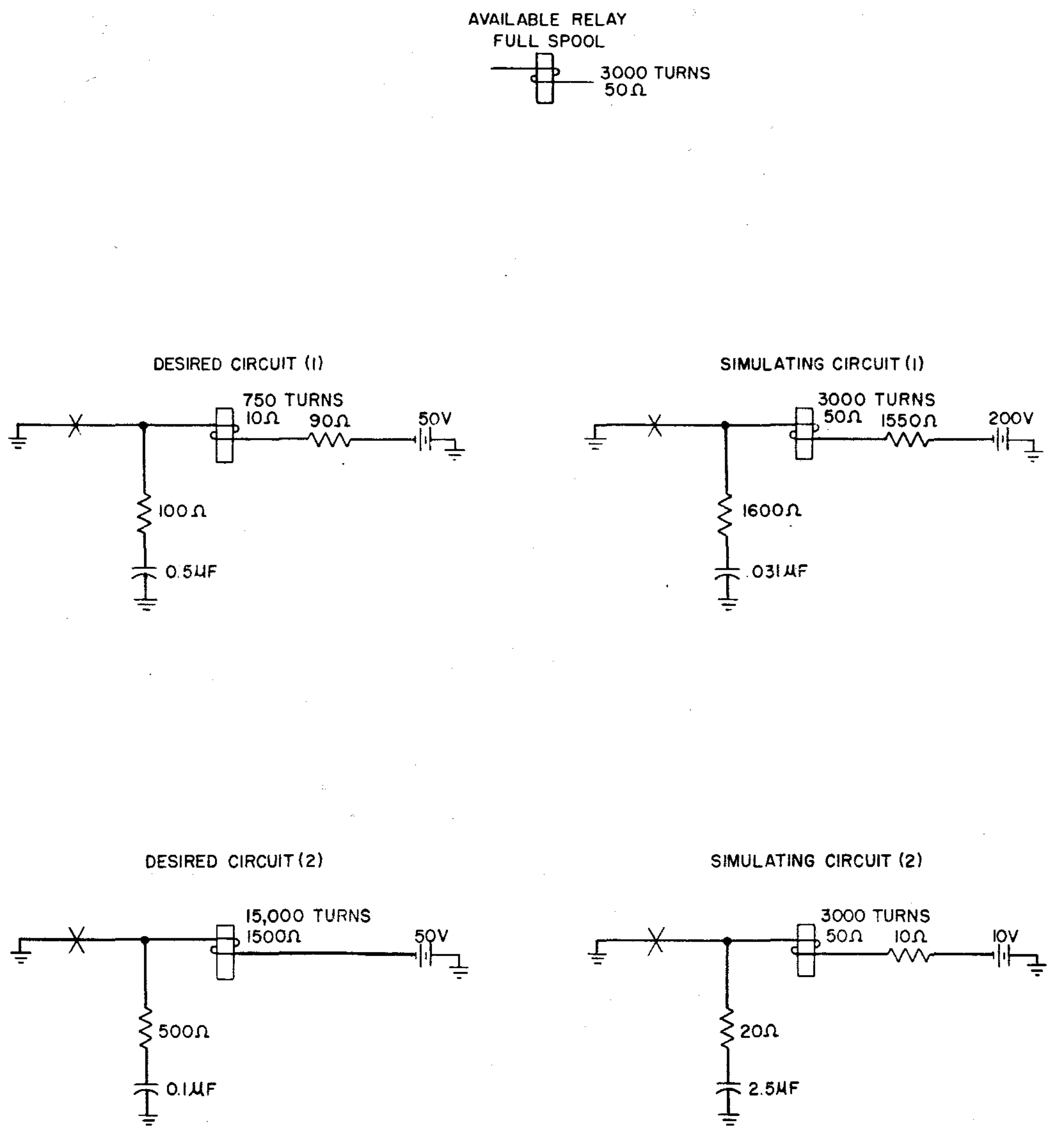


Fig. VII-10 - Equivalent Circuits

X-75509

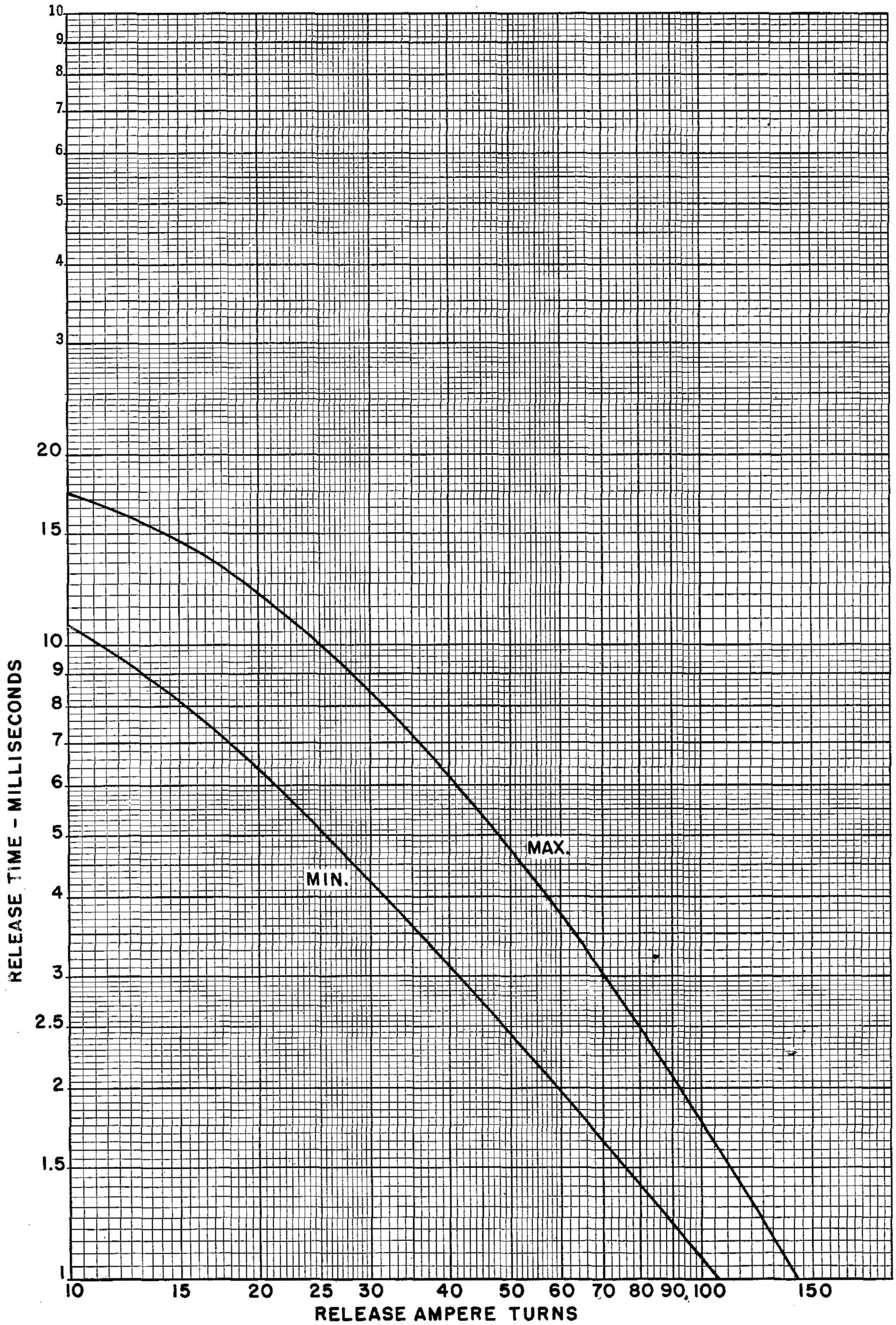


Fig. VII-11 - AF and AJ Relays - Open Circuit Release -
No Sleeve or Contact Protection

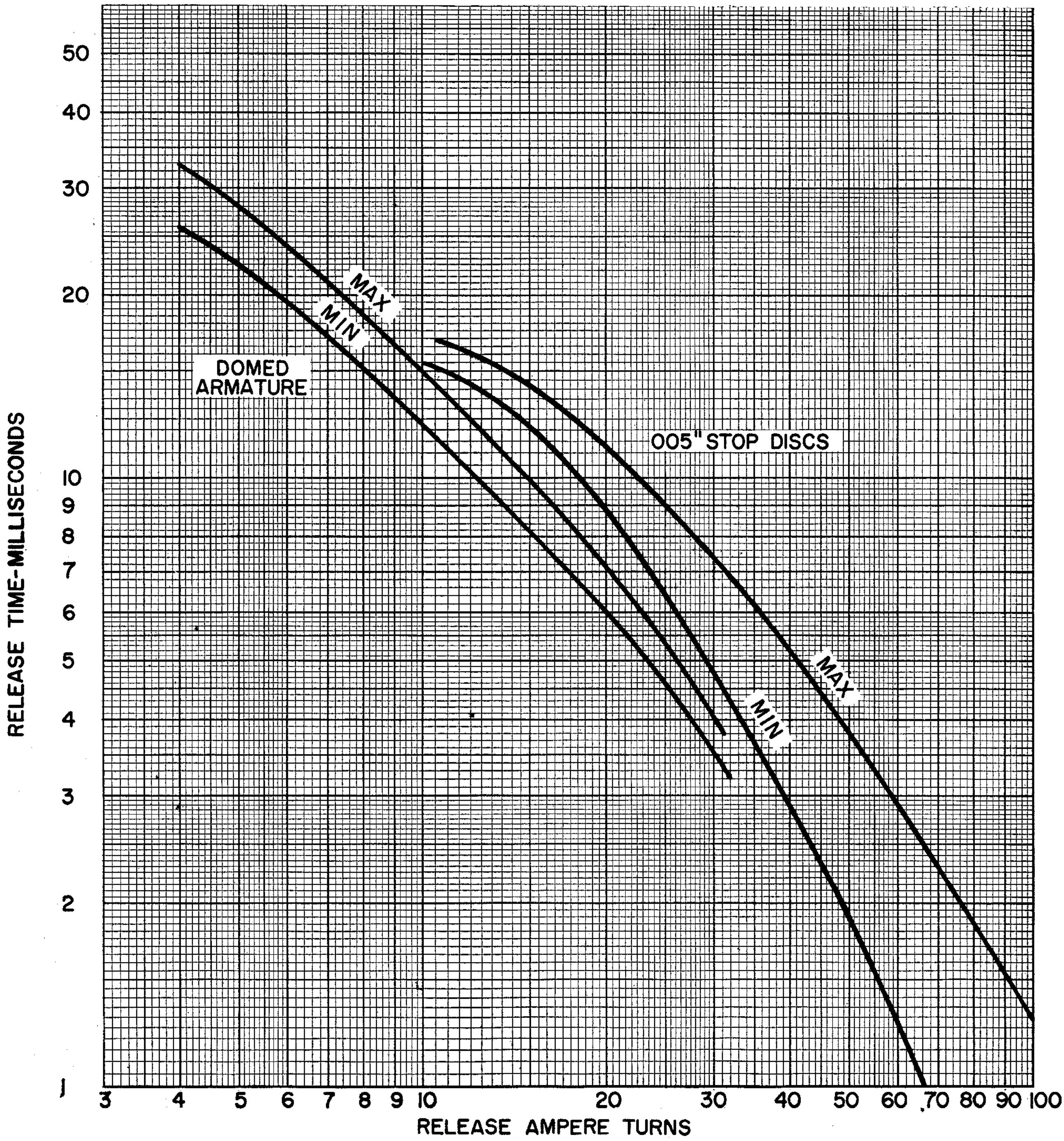
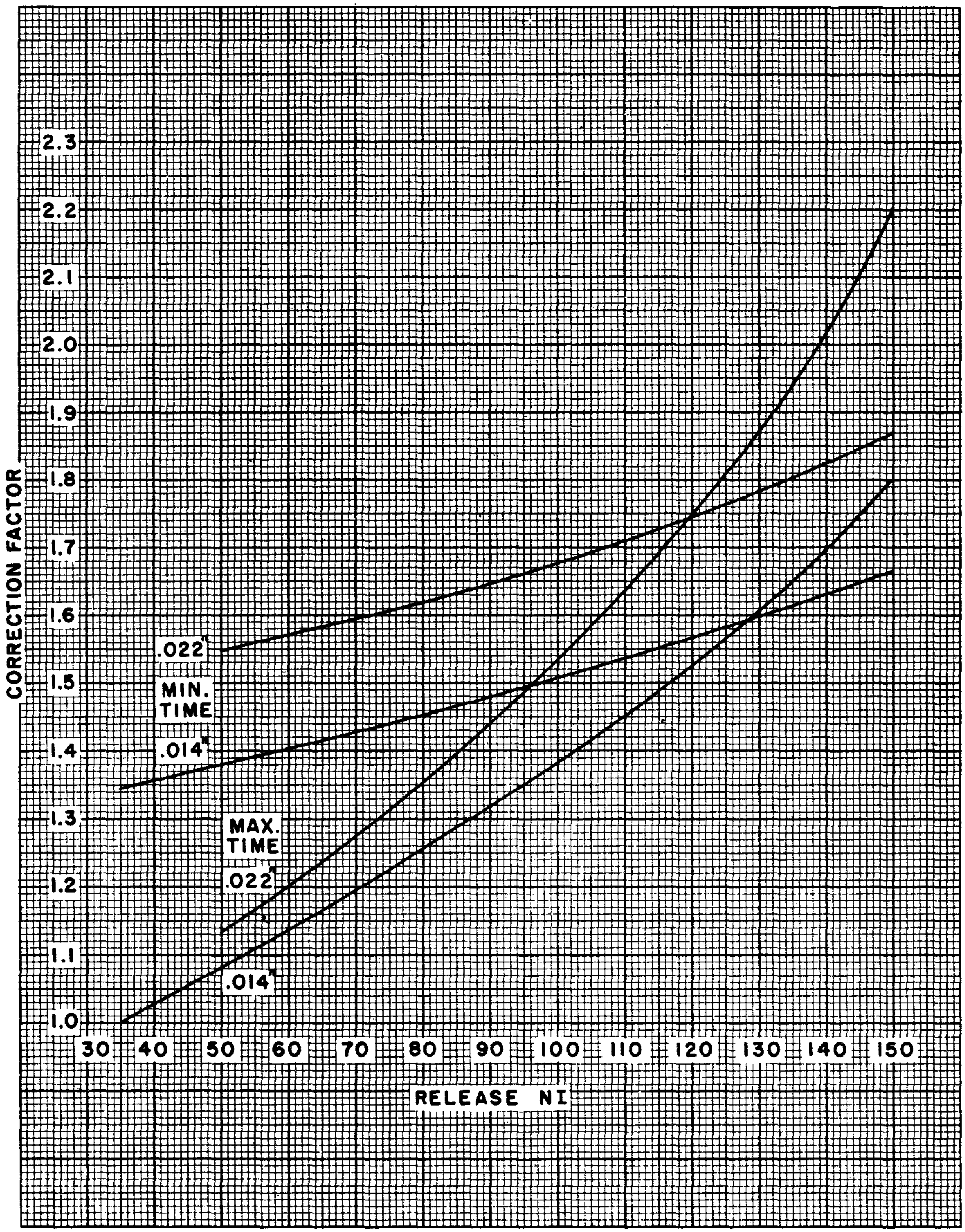


Fig. VII-11A - AK Relay - Open Circuit Release Time -
No Sleeve or Contact Protection



STOP DISC CORRECTION
OPEN CIRCUIT OR SHUNT RELEASE

X-75509

Fig. VII-12 - Stop Disc Correction - No Contact Protection

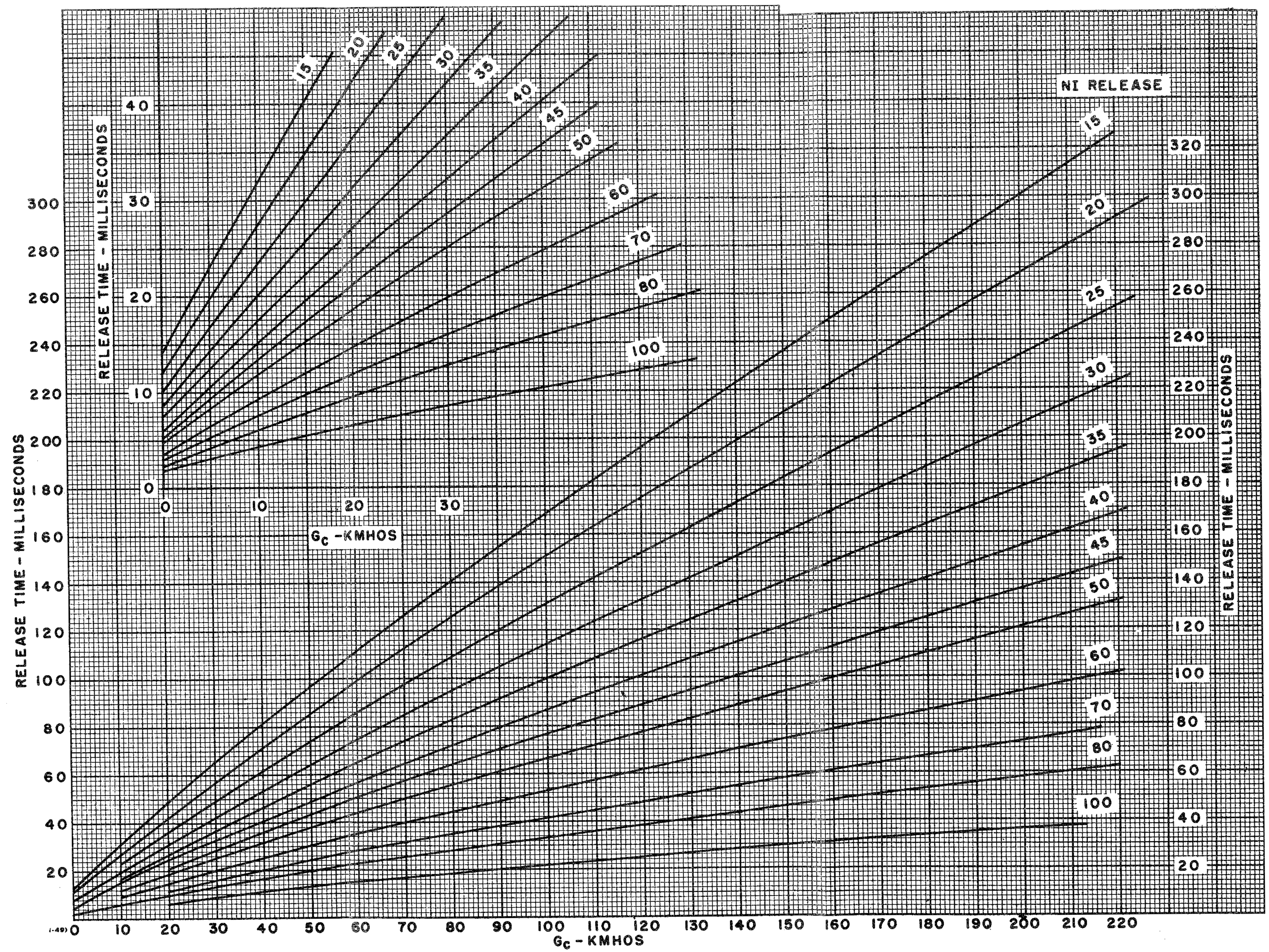


Fig. VII-13 - AF and AJ Relays - Maximum Release Time With Resistive Shunt

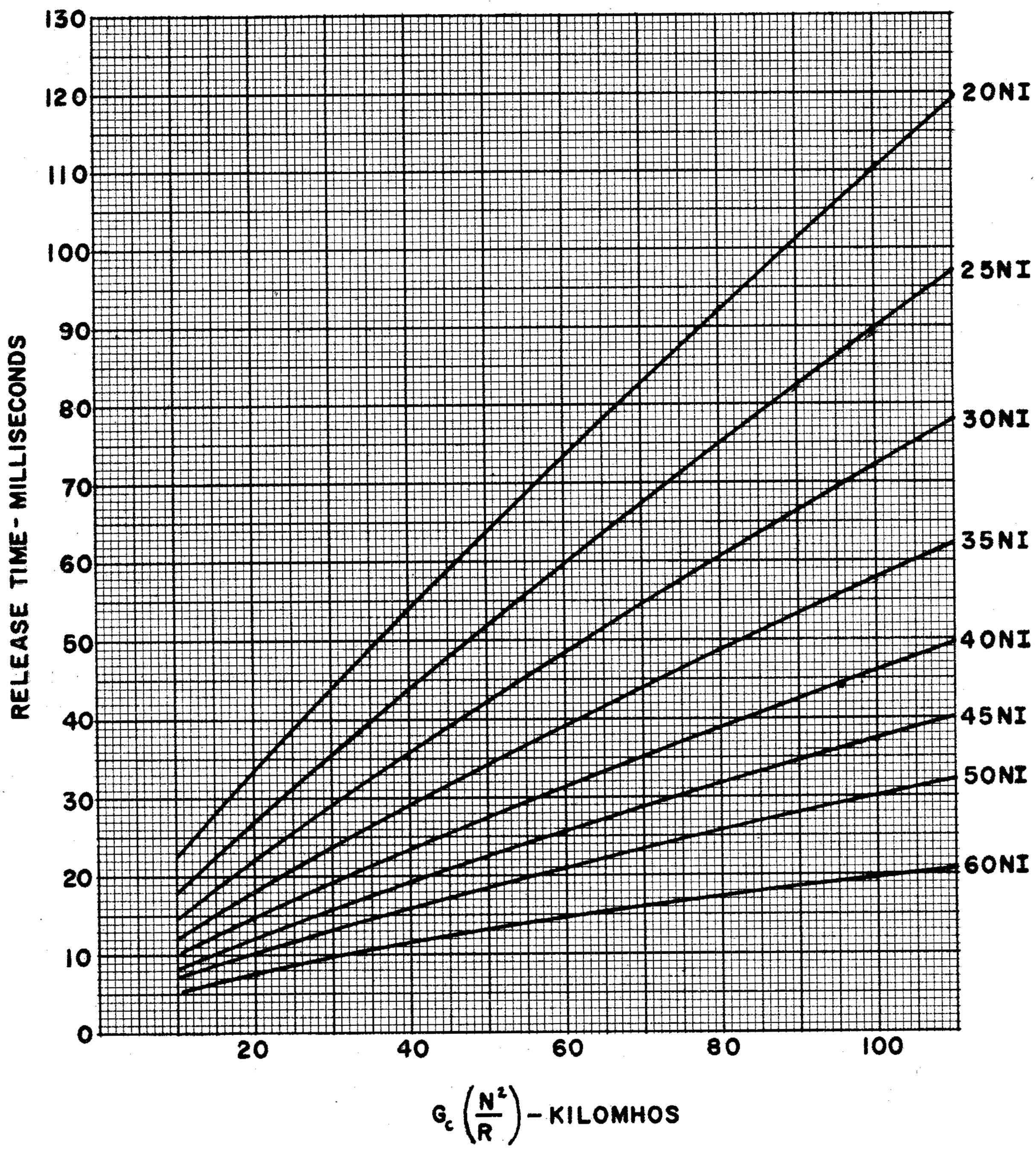


Fig. VIII-13A - AK Relay - Maximum Release Time With Resistive Shunt

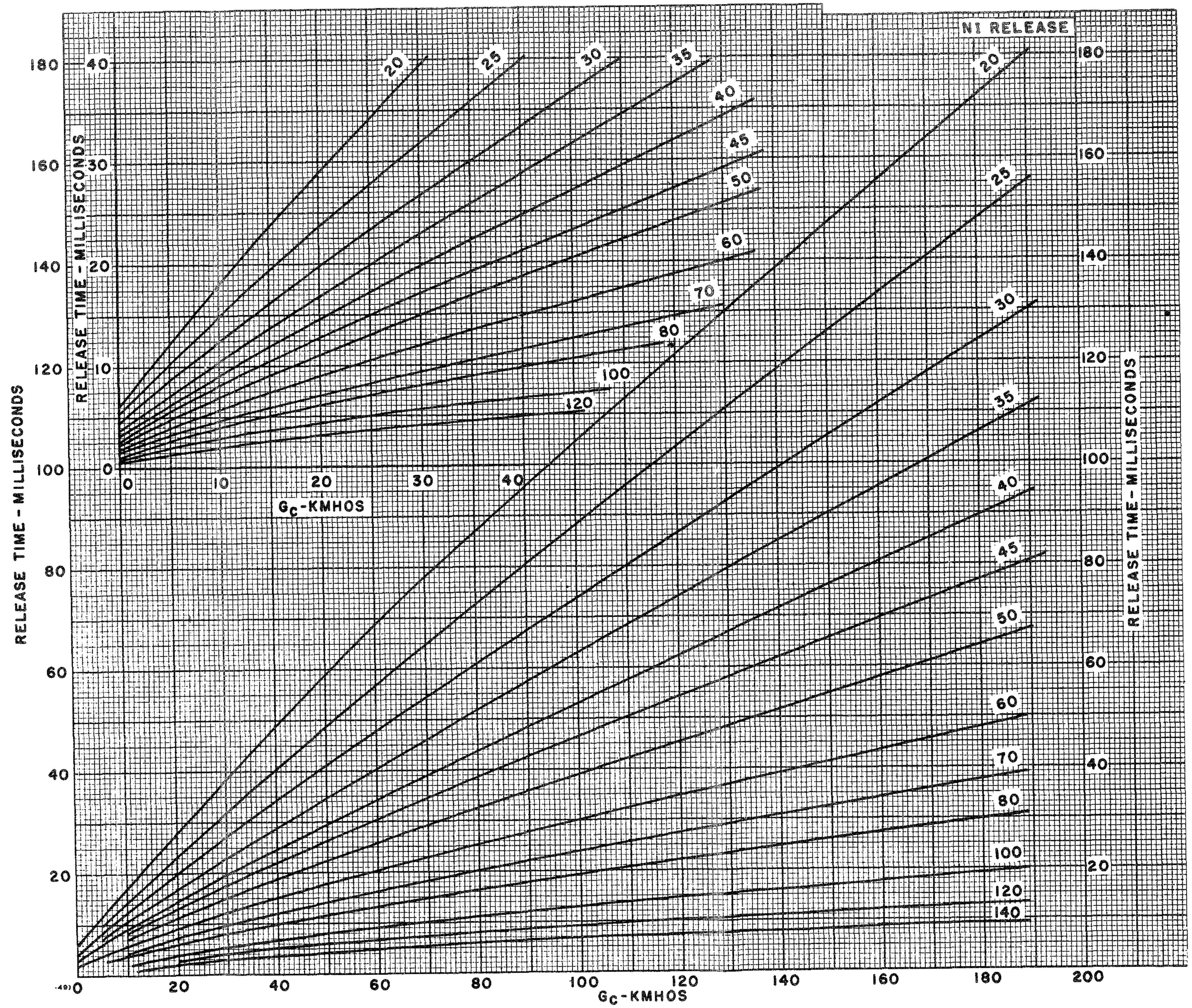


Fig. VII-14 - AF and AJ Relays - Minimum Release Time With Resistive Shunt

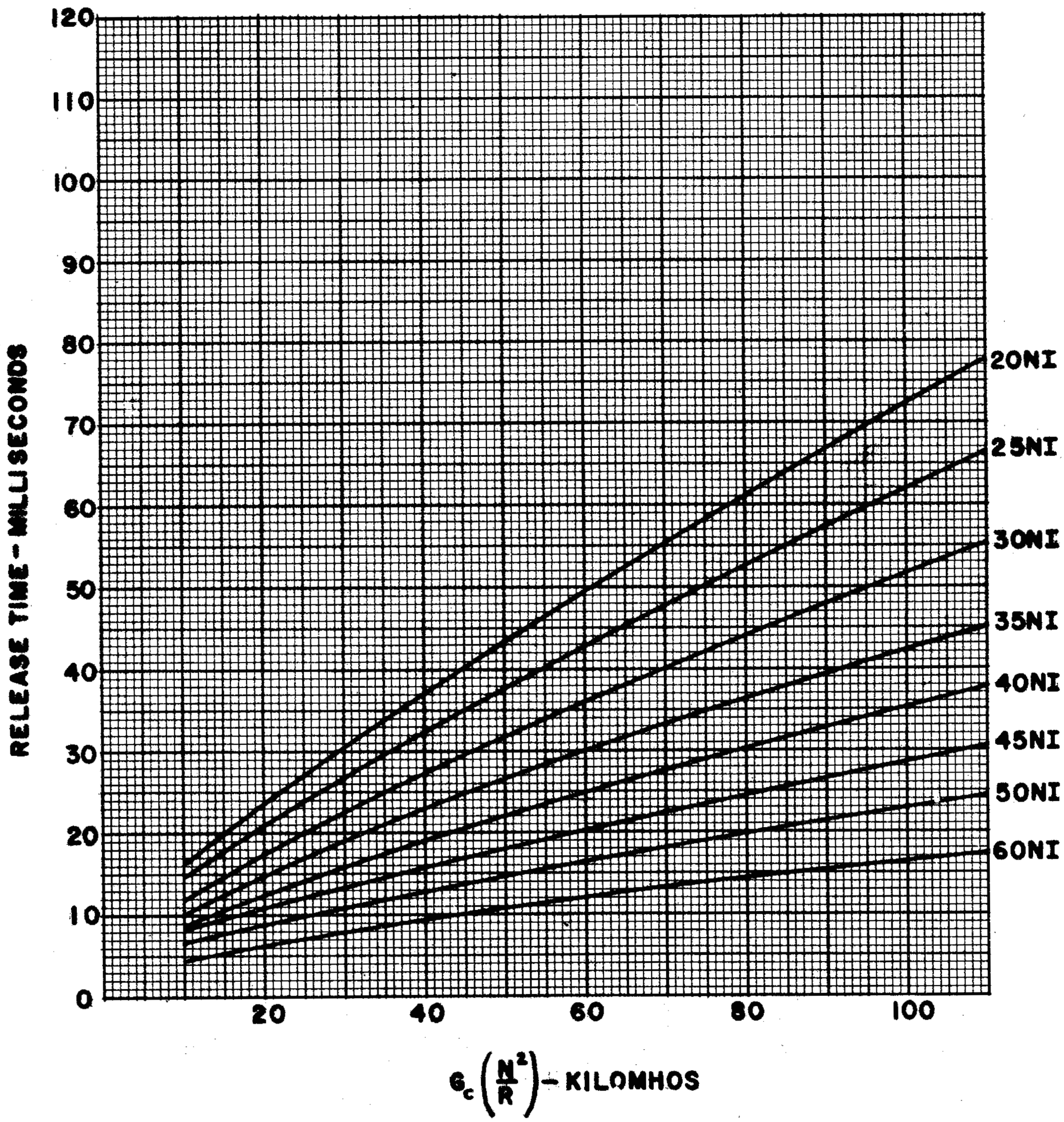


Fig. VIII-14A - AK Relay - Minimum Release Time With Resistive Shunt

X-75509

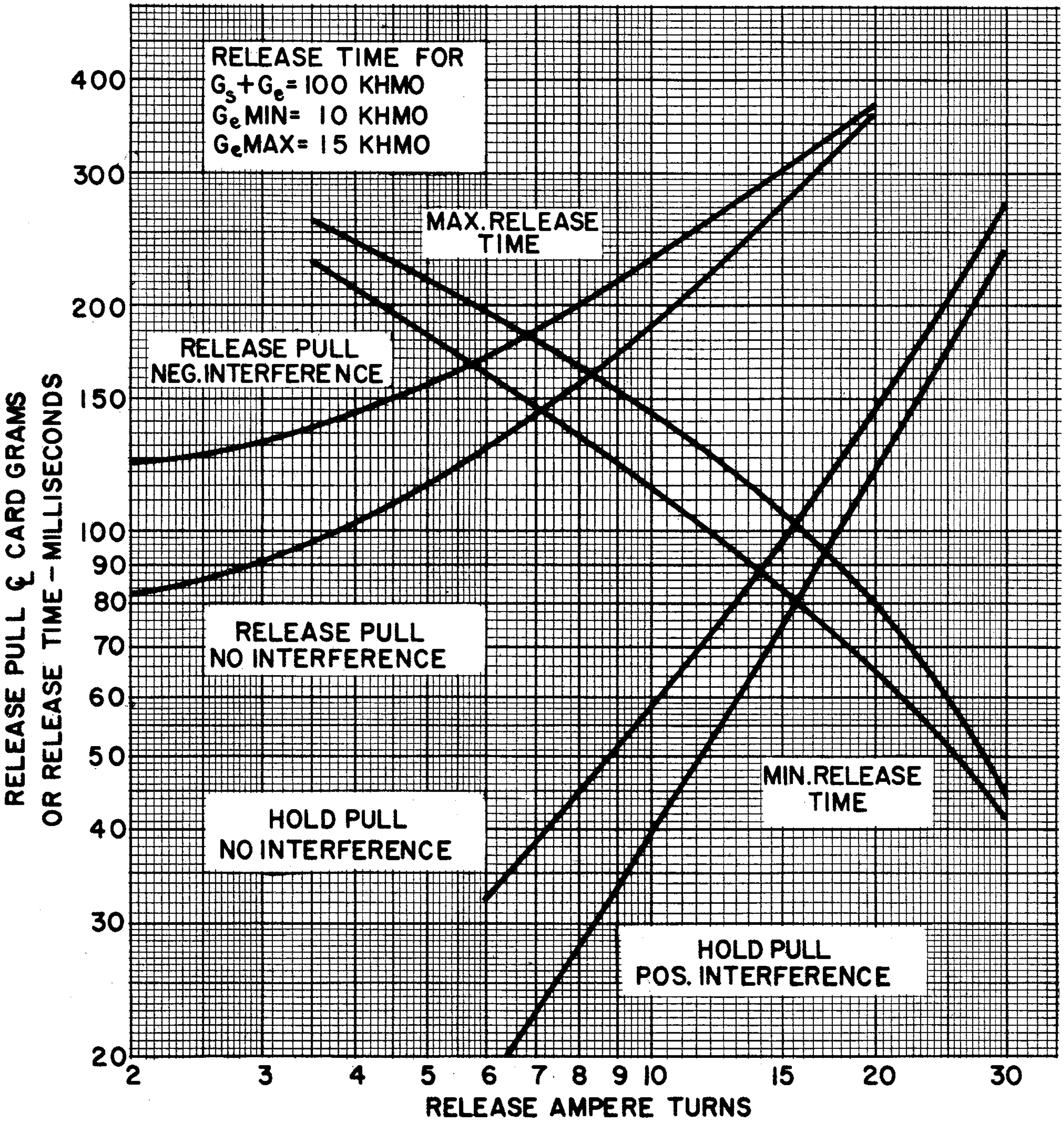


Fig. VII-14B - AK Relays - Release Time Domed Armature With Shunt

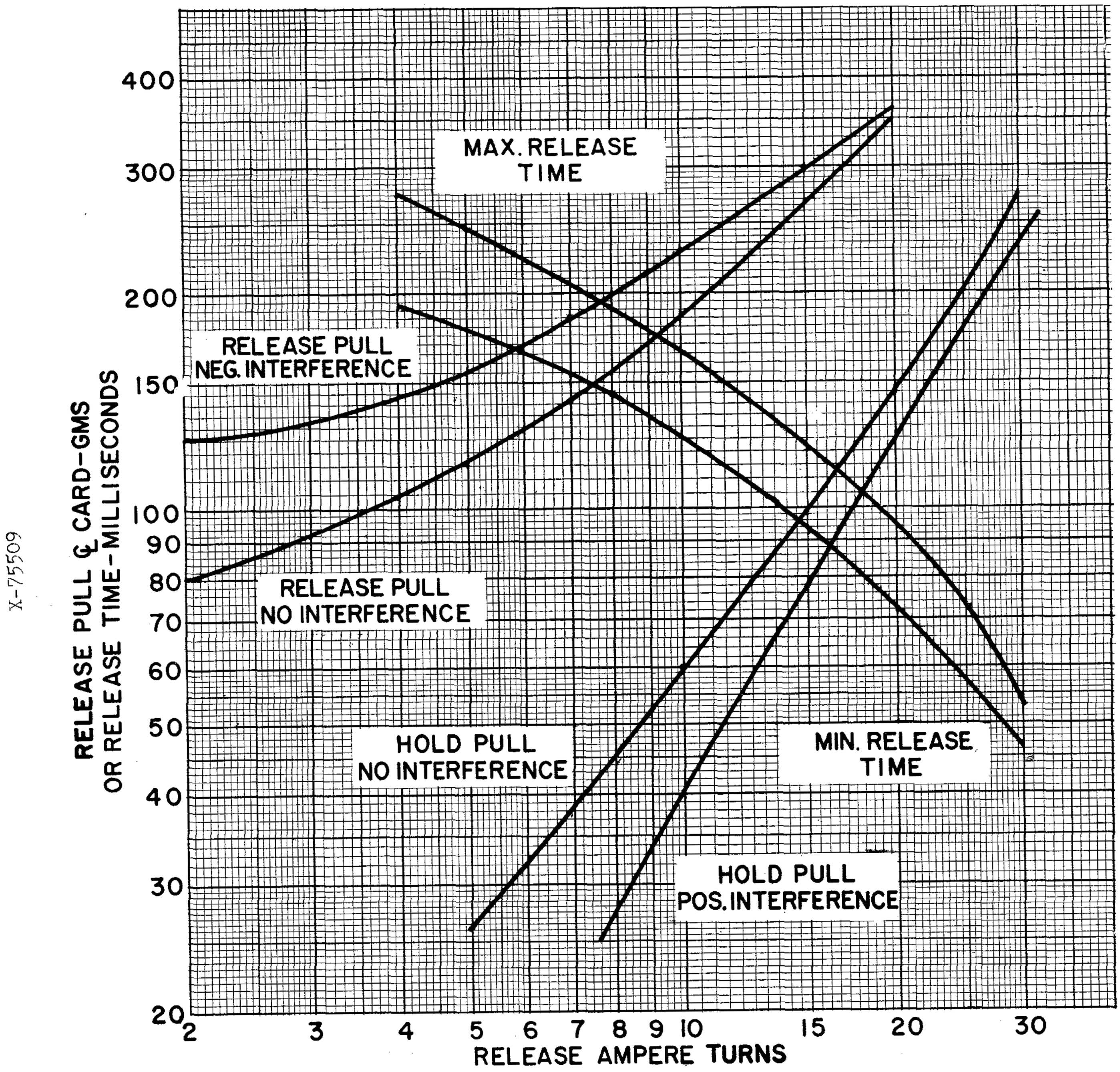


Fig. VII-14C - AK Relay - Slow Release - .069-inch Copper Sleeve

X-75509

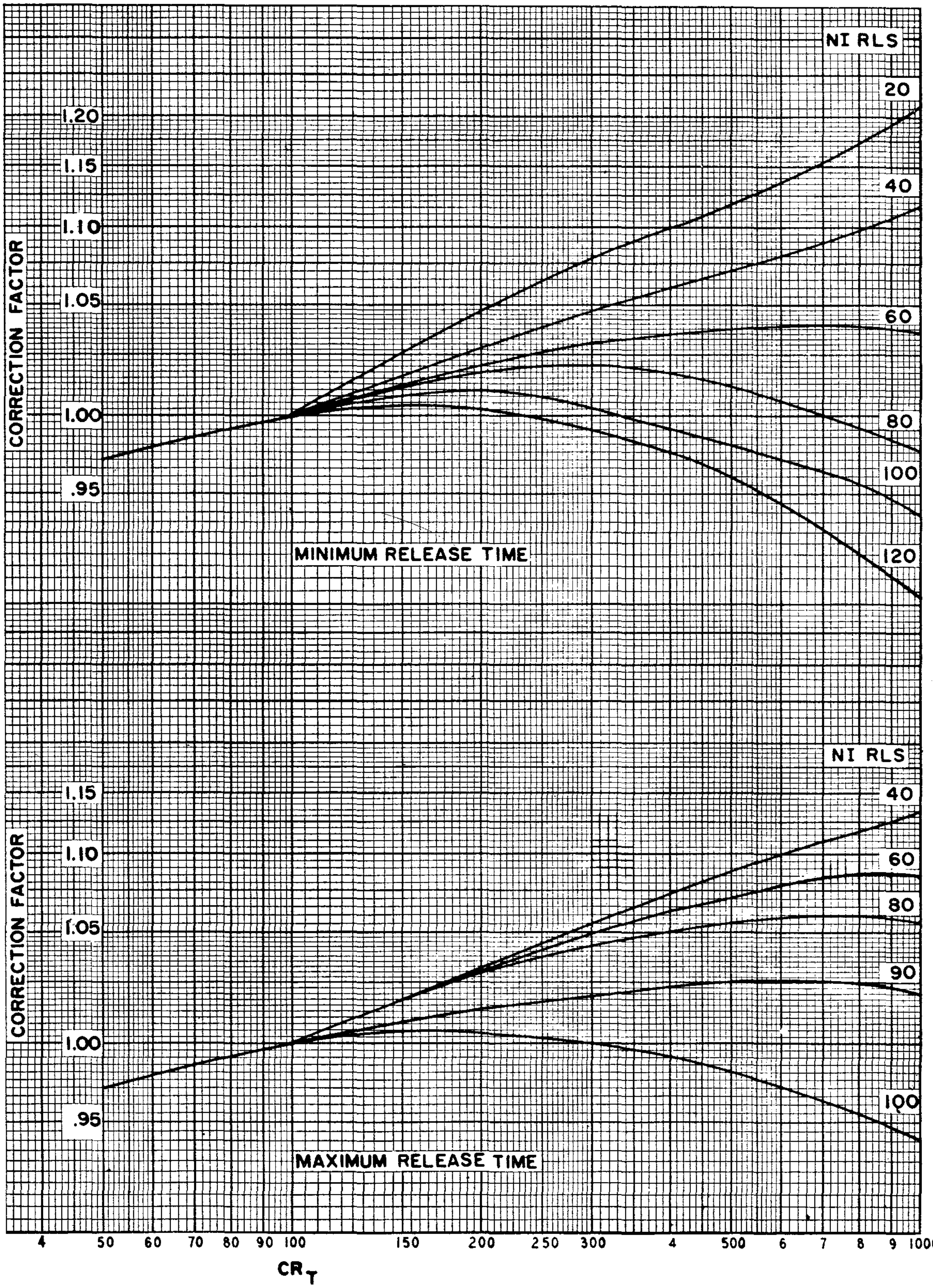
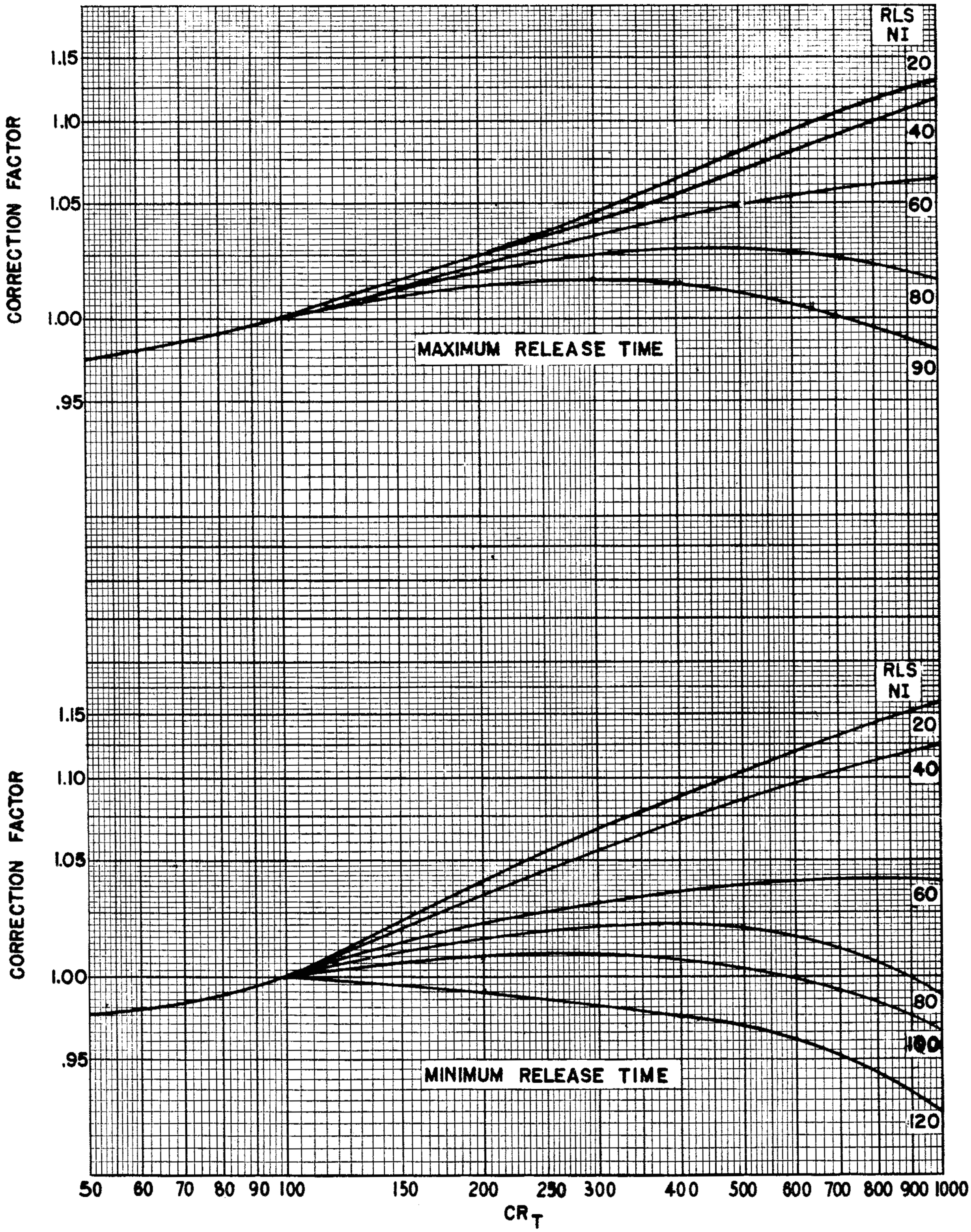


Fig. VII-16 - AF Relay - Correction for Different Contact Protections



X-75509

Fig. VII-19 - AJ Relay - Correction for Different Contact Protections