E N G I N E E R I N G   R E F E R E N C E   D A T A

X-75509

WIRE SPRING RELAYS

AF-, AG-, AJ-, AK-, AL-, & AM-TYPES

Bell Telephone Laboratories
Research and Development Unit of the Bell System

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 Bell Laboratories. It is intended primarily for use by engineers of the Bell 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 nonassociate use. Codes rated Manufacture Discontinued are not included.

It is planned to bring this bulletin up to data periodically; however, the information contained herein may not be complete and the 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.

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SECTION I

GENERAL

General

The AF, AG, AJ, AK, AL, and AM relays constitute a class of relay characterized by card operation of pretensioned wire-spring subassemblies. The important characteristics that have been attained in these 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

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The various design and engineering characteristics of the wire-spring relays are presented in this bulletin. 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 to switching systems.

Description

The AF, AG, AJ, and AL 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 that 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 stationary single-wire block. The contacts are arranged in 12 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; the stages are commonly termed late, early, and preliminary.

The AK and AM relays are 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 contact operation, 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 six types of wire-spring relays: AF, AG, AJ, AK, AL, and AM.

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

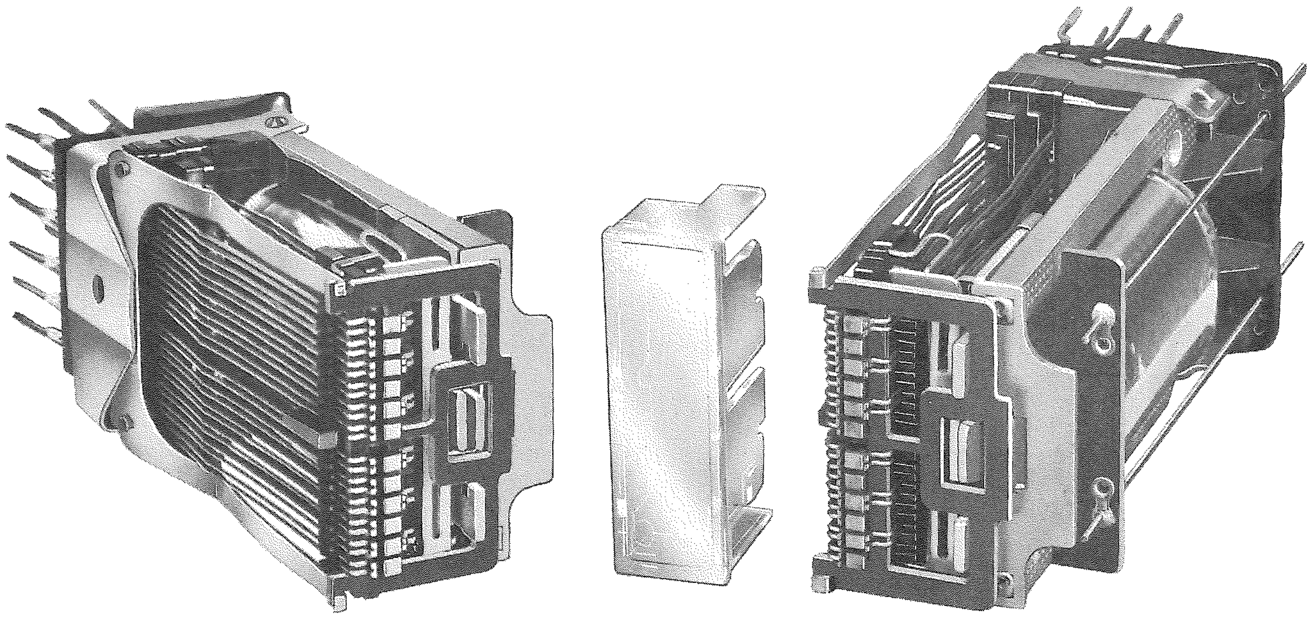

Fig. I-1 - AF Relay (Front View)

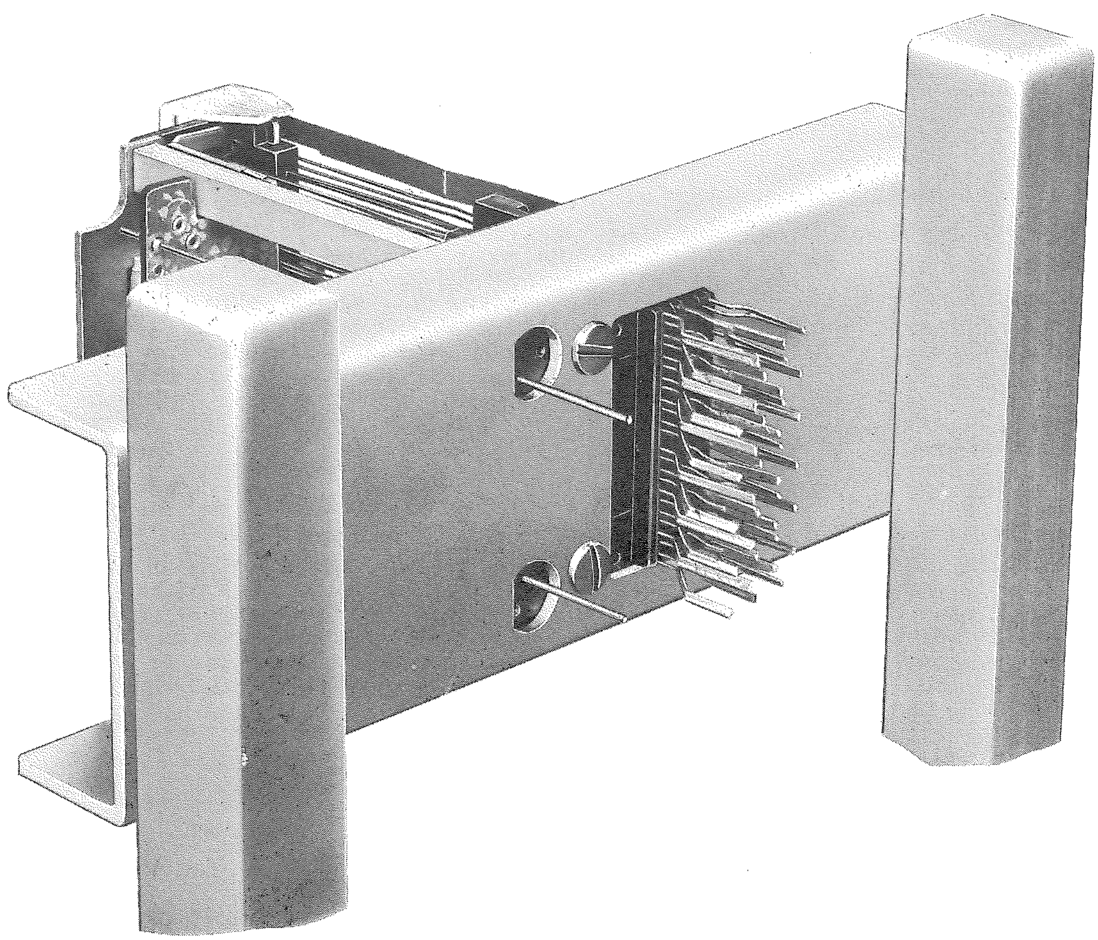

Fig. I-2 - AF Relay (Rear View)

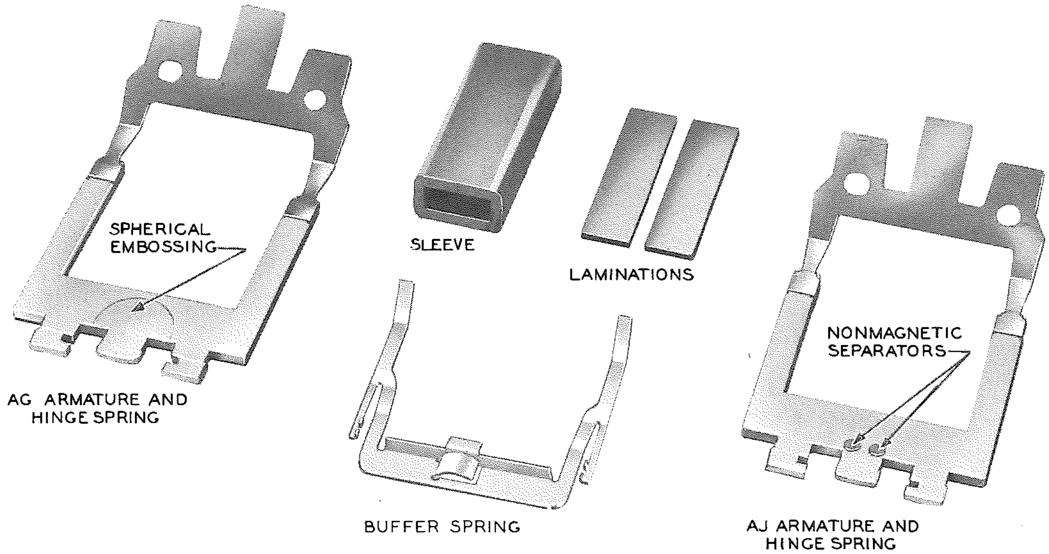

Fig. I-3 - Additional Parts for AG and AJ Relays

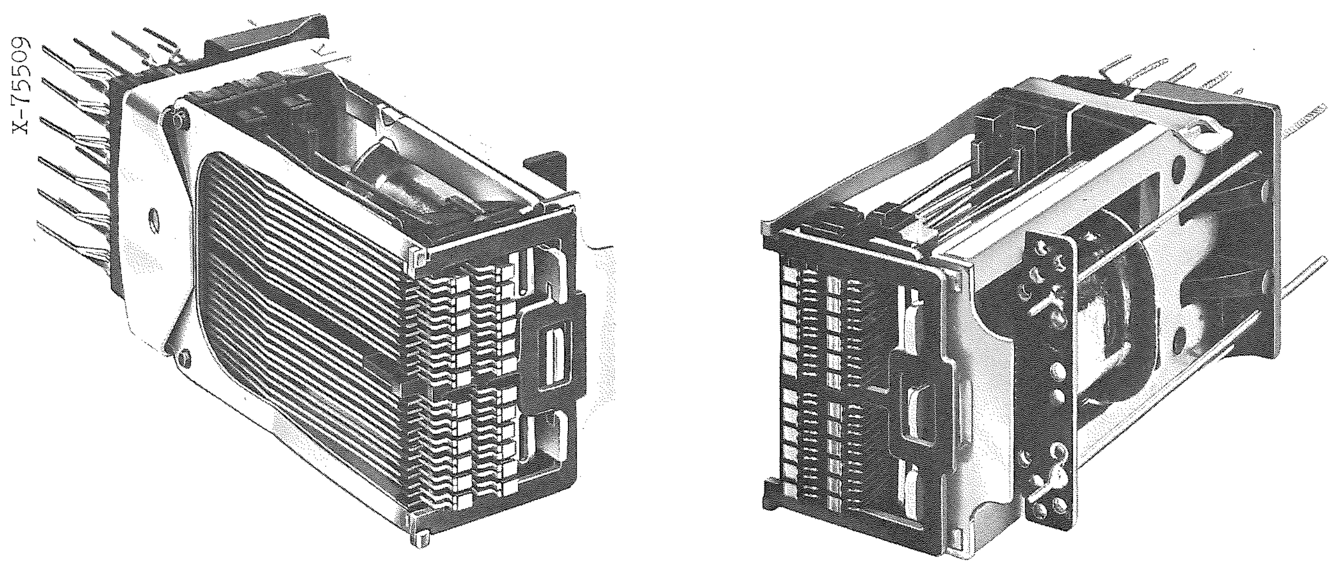

Fig. I-4 - 24 Make- and 24 Break- Contact Relay

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-, 0.014-, 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.

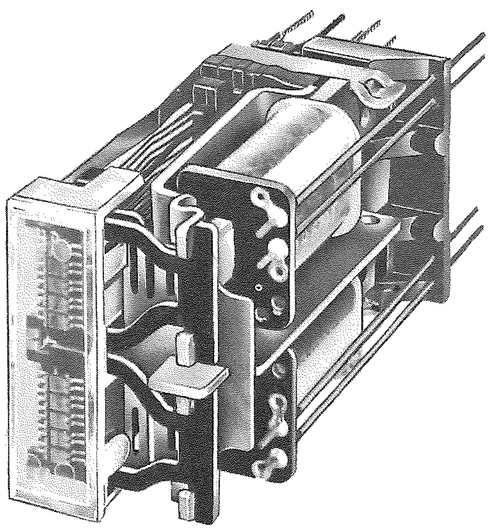

Fig. I-5 - AK and AM Relays

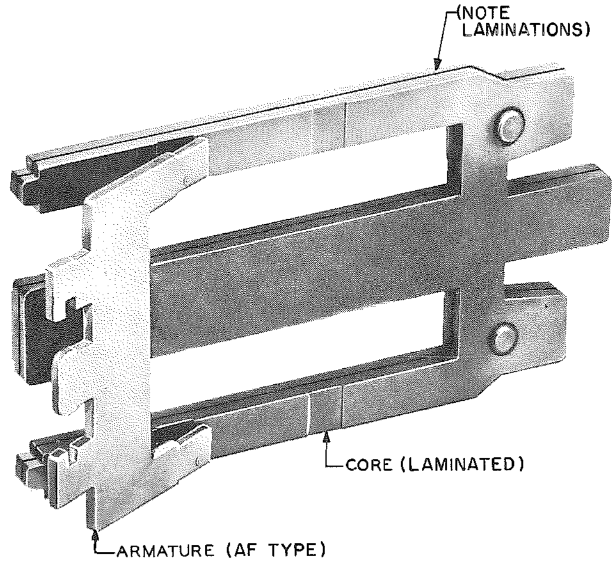

Fig. I-6 - AF Relay Magnetic Structure

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 may be satisfactorily used 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-wire blocks, and two twin-wire blocks. The contacts are arranged in two vertical rows of 12 contacts each, as shown in Fig. I-4.

24 Break-Contact Relay

A 24 break-contact version of the AJ relay is also available for use where more than 12 break-contacts are required. It is similar to the 24 make-contact relay in appearance and construction. 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 that 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, early break-make, or early make-break. No preliminary contacts are available, since there is no long-travel AK relay.

AL Relay

The AL relay is a magnetic latching variation of the general purpose type wire spring relay. It has been designed to (a) operate on relatively small amounts of power, (b) operate and release in times of extremely short duration, (c) remain latched (operated) with current removed, and (d) release only when a reverse current is applied. Contact arrangements currently available on AF-, AG-, and AJ-type relays may be obtained on the AL-type, also. In appearance, it is identical to the AF-type relay.

AM Relay

The AM relay is a magnetic latching version of the AK dual armature relay. The contact arrangements and coil resistances available are the same as for the AK. It has the same operating characteristics as the AL relay with regard to its magnetic latching features.

Magnetic Structure

The magnetic structure of the AF, AG, and AJ relays consists of a laminated E-shaped core and a flat U-shaped armature (Fig. I-6). Silicon iron is used for the armature 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 E-shaped core, originally of one-piece construction, is made of two pieces of 1010 low carbon steel, resulting in a slight improvement in mag-

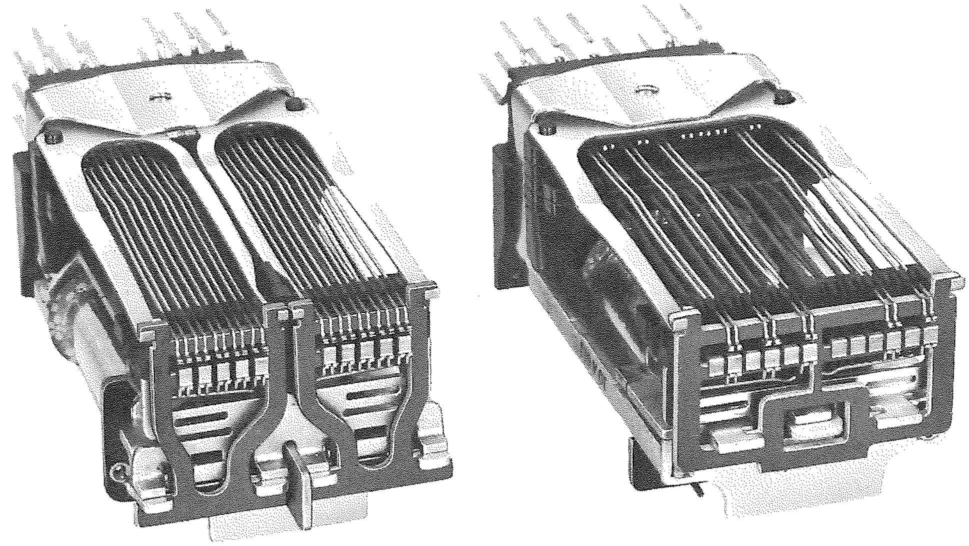

Fig. I-7 - AF and AK Relay Balance Springs and Cards

netic capability while materially reducing the cost. The relatively wide spacing of the core legs reduces the leakage, thus increasing the useful magnetic flux. The AL relay core is made from a single piece of 1045 medium carbon steel in order to obtain the desired magnetic latching characteristics.

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Two different armatures are provided: a short armature, 0.063-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 such a manner as to produce a minimum rebound when the relay releases.

The magnetic structure of the AK and AM relays differs considerably from that of the other wire spring relays. The core is U-shaped (Fig. I-5) and the coils are placed over the two legs. Both the AK and AM cores are of one-piece construction, differing only in the grade of steel used, and the method of heat-treating.

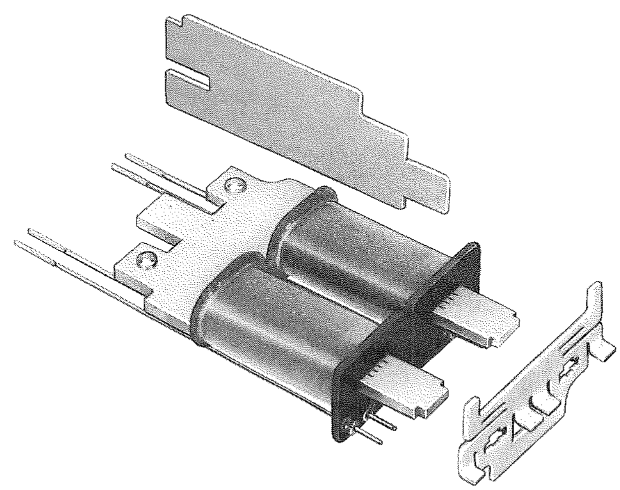

Fig. I-8 - AK Relay Coil Assembly and Core Plate

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.

Balance Spring

The armature of the AF, AG, AJ, and AL relays is held against the backstop by a pretensioned U-shaped balancing spring (Fig. I-7). There are eight balancing springs of various thicknesses with different offsets,

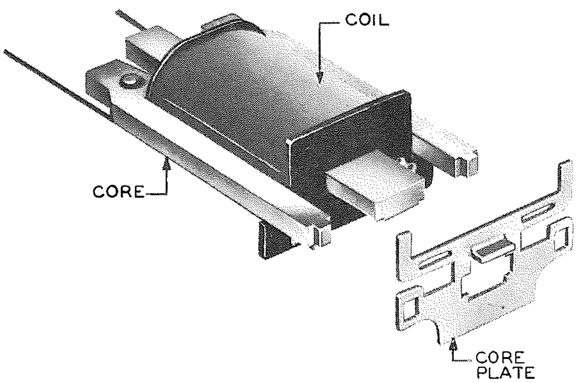

Fig. I-9 - AF, AG, or AJ Relay Coil Assembly and Core Plate

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.

Each armature of the AK and AM relays 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, AJ, and AL 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; the upper slot controls contacts 7 through 12. The armature travel is 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 and AM 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 relay is the use of molded spring assemblies.

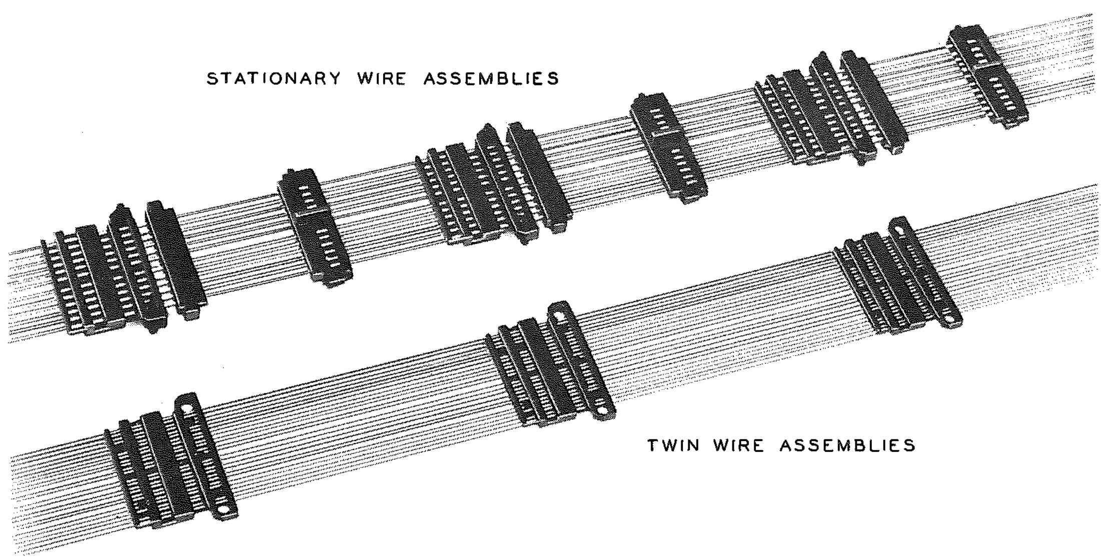

Fig. I-10 - Molded Spring Assemblies Before Cutting to Length

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 copper-nickel 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 and AM relays) relatively heavy copper-nickel 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

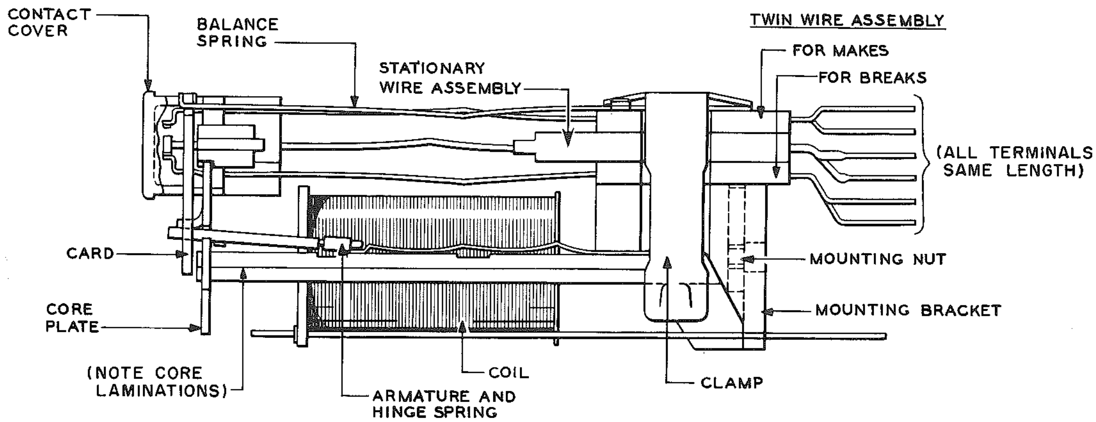

Fig. I-11 - Top View of AF Relay Showing Location of Parts

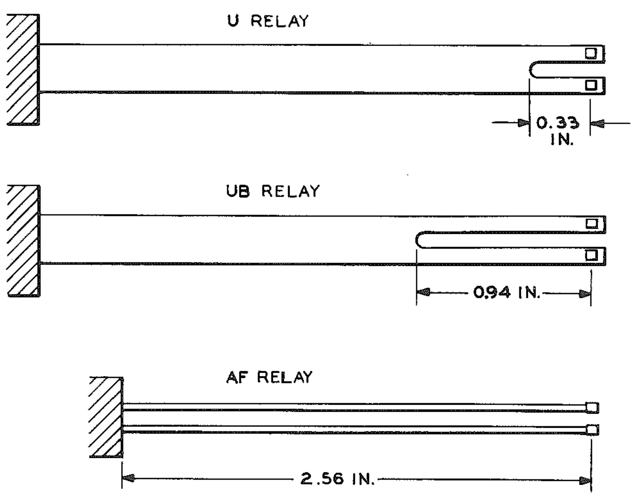

Fig. I-12 - U, UB, and AF Relay Springs

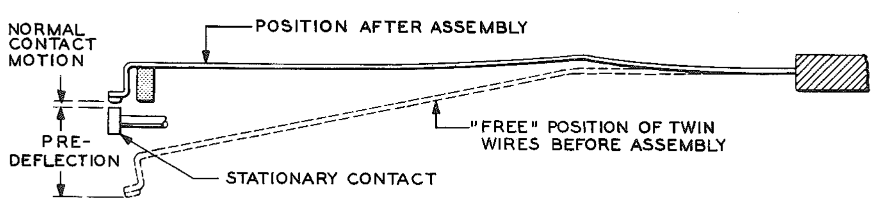

Fig. I-13 - Predeflection of Twin Wires

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assemblies are mounted on either side 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 forces 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 force of about 12.5 grams for each contact pair of a standard wire-block.

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 the sum of the restoring forces of the balance spring legs, minus the forward tension of the twin wire movable 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 to accommodate a make-contact or a break-contact only, a sequence contact, or no contact, depending on the arrangement.

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 towards 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-contact 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 that involve two stages or sequences. The 0.060-inch travel is not used on the AK and AM relays.

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 the 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

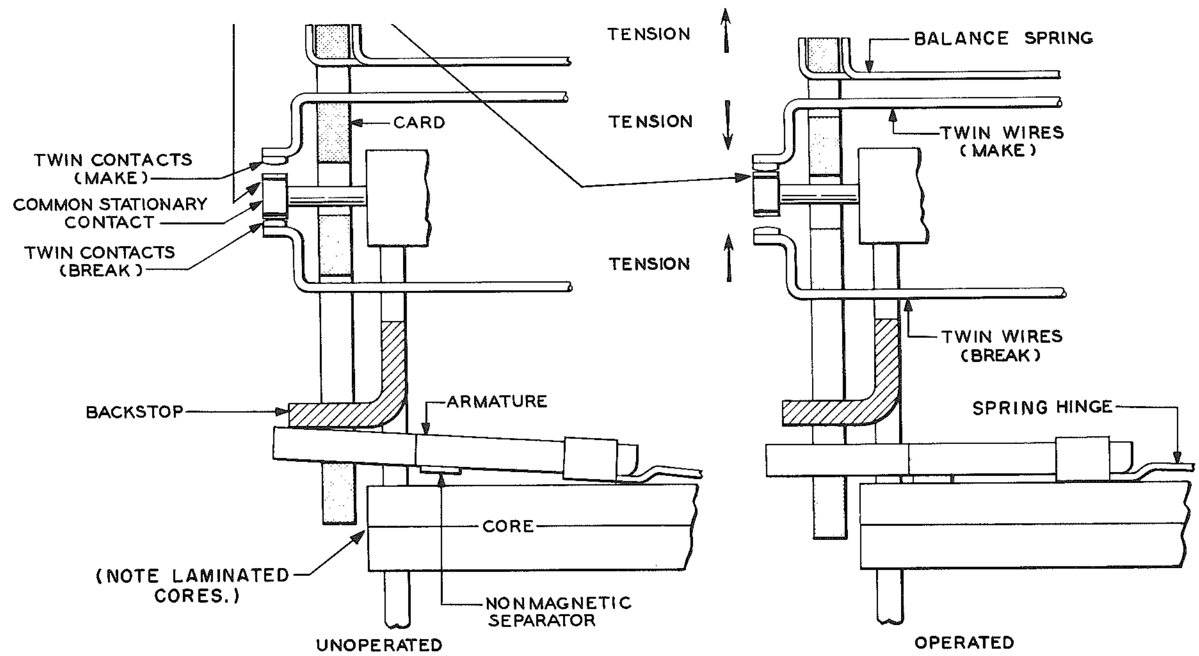

Fig. I-14 - Principle of Operation of Transfer Contacts

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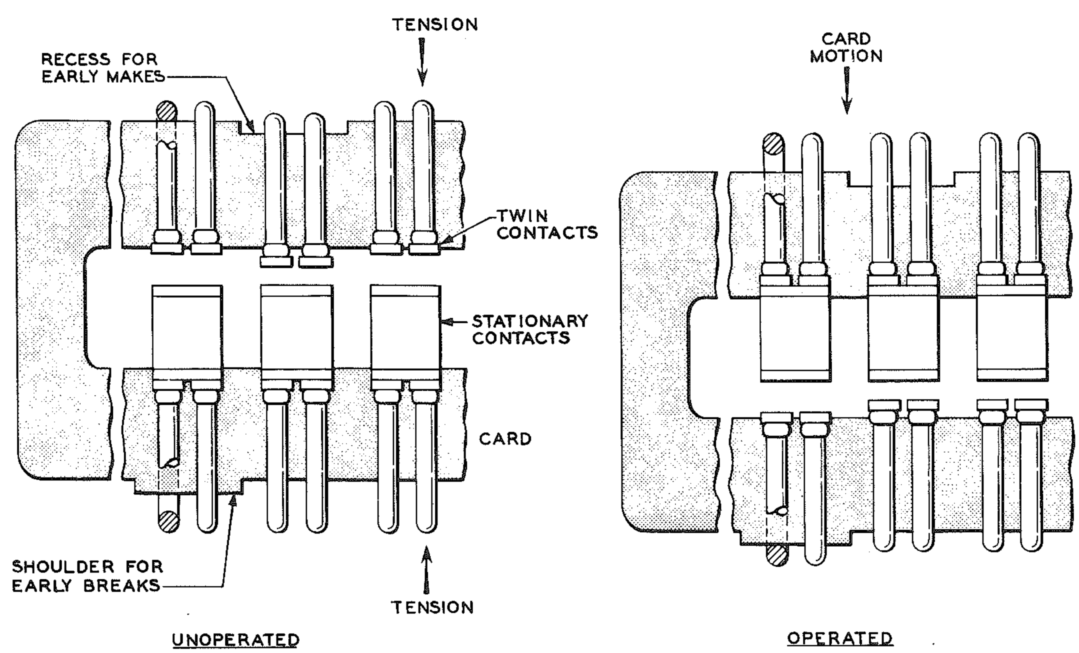

Fig. I-15 - Method of Obtaining Early Contacts to dissimilar apparatus, however, the adjacent apparatus seldom nests with the wire spring relay and somewhat larger space must be allowed. Where no penalties in the number of mounting plates occur, the center-to-center dimension, between the wire spring relay and the dissimilar apparatus, should

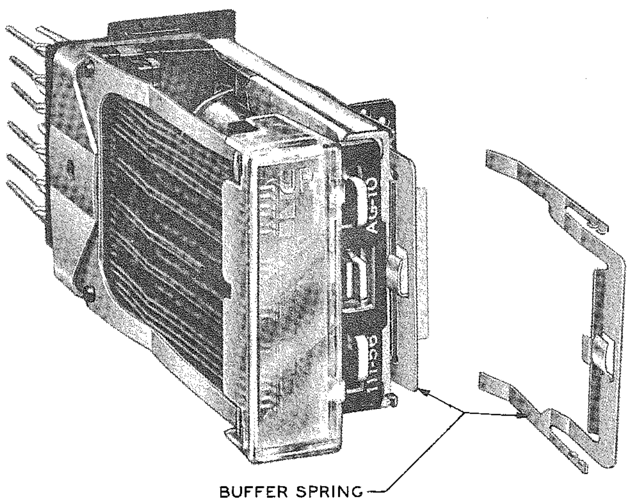

Fig. I-16 - Buffer Spring

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,AK, AL,AM
Dissimilar apparatus on coil side of relay - all lengths	0.033 inch
Dissimilar apparatus on spring side of relay - 2-7/8 inches or less from mounting plate	0.033 inch
Dissimilar apparatus on spring side of relay - over 2-7/8 inches from mounting plate	0.067 inch

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 inch 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 that 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 that, 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 or AM relay) after the assembly is completed. Fig. I-17 shows the parts that are 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 eight have been used on the AF, AG, AJ, and AL relays and four on the AK and AM relays up to the present time.

Contact Cover

Each relay is equipped with a molded styrene-acrylonitrile 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.

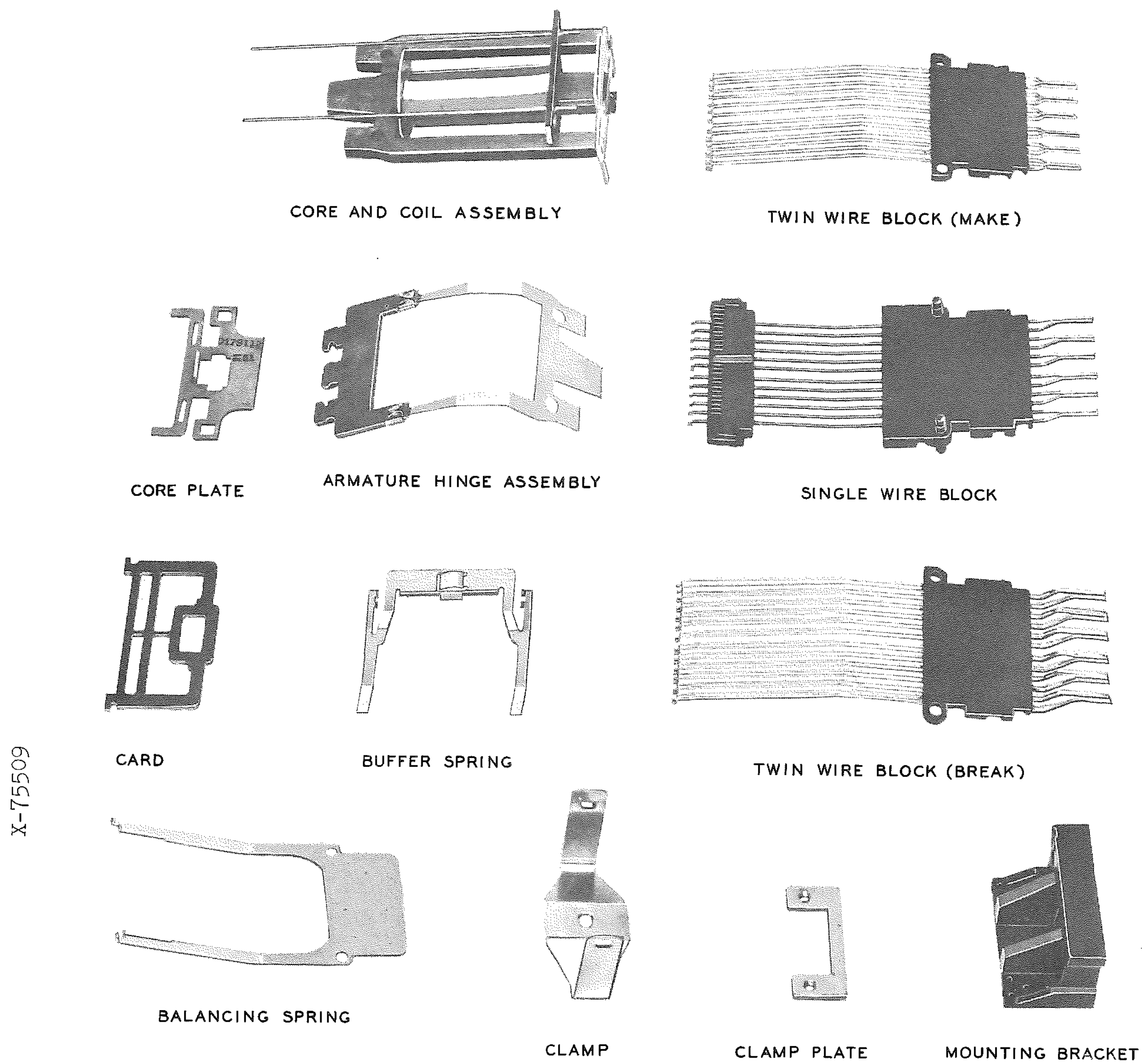

Fig. I-17 - AF Relay Parts

Life

It is expected that AF, AG, AJ, and AL 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.

The AK and AM relays have a life of about 40 million operations. When long life features, as noted above, are incorporated, these relays have a life expectancy of 100 million operations.

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 µsec after closure. It is usually of high frequency and has sometimes been called fine chatter.

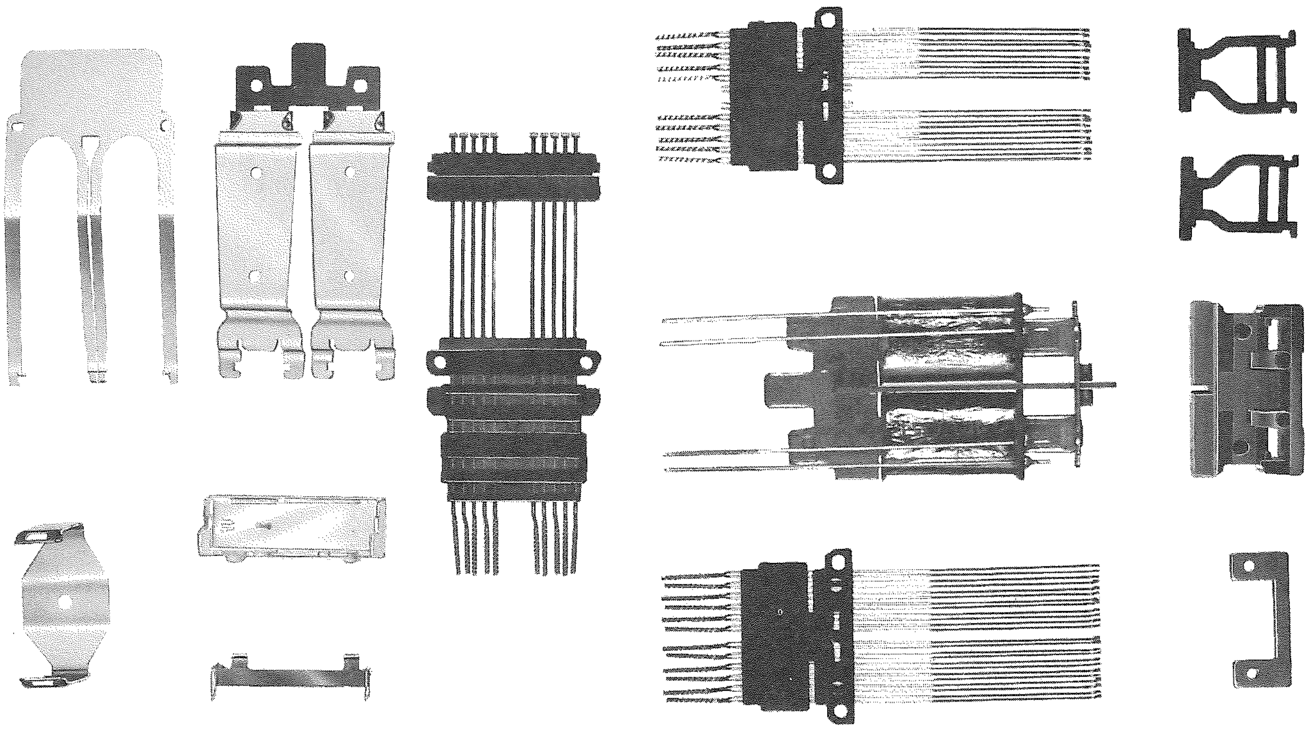

Fig. I-18 - AK Relay Parts

2. Shock Chatter is caused by vibration of the springs resulting 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 msec 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, on release.

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

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

* Checks (✓) 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 it 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

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. Hesitation chatter may also be induced by rebound of the armature under high pulse rate 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 pickup 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 late load pickup. 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 factors 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 relay, 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 msec 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-gram armature back tension. A flexible mounting, P-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. Table I-1 summarizes the results of a study of rebound on the wire spring relay with contact protection but no sleeve or shunt. It 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
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 Table I-1. They are worse than the intermediate travel relays. Lightly-loaded long travel relays may be liable to false closure of the preliminary contacts; 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 msec 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 percent of their actual operate time if protected by a 186A network, 60 percent if protected by a 185A network, and 70 percent if unprotected. When the back tension is increased, 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 percent of the release time can release the relay. With contact protection the open interval to release the relay would vary from 50 to 75 percent 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, P-15A868, which is assembled in the relay behind the mounting bracket, has been developed for this purpose. It must be specified as part of the relay code.

SECTION II

CODE INFORMATION

General

This section contains code information for all AF, AG, AJ, AK, AL, and AM 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, ie, 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. Each M, B, EM, EB, PM, and PB contact arrangement counts as one contact. Each EMB, BM, and EMB contact arrangement counts 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.

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:

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	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
Over 700	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 cost of the relay by approximately 15 cents.

Code Numbers

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

Ordinary Relays	
1 to 12 Contact Positions	24 Makes
AF1 to 499	None
AJ1 to 199	AJ200 to 299
AG1 to 199	None
AK1 to 499	None

Long-Life Relays	
1 to 12 Contact Positions	24 Makes
AF500 and up	None
AJ500 to 699	AJ700 to 799
AG None Anticipated	
AK500 and up	None

At the present time, there are 459 codes of wire spring relays being manufactured. This number includes all the basic types listed above and represents many combinations of winding resistances and contact arrangements. Special requirements, such as long-life features, or nonstandard adjustments, will result in a slight increase in price of the relay.

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, 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. AL relays are listed in Tables II-1A and II-2A and AM relays in Table II-4A. If the exact combination is not coded, then select the code available having the lowest number of contacts that 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).

TEST & READJUST CURRENT REQUIREMENTS

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 need not 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 requirements 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 overall 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 is 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 that 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 percent of the operate and hold requirements and 95 percent 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 percent 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 the standard (minimum 30 grams for AF, AJ, and AK relays; minimum 45 grams for relays with 24 makes or 24 breaks; 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 percent and noninductive windings is ±5 percent. All resistance values are based on 68° F.

Contacts

Only palladium (No. 2 metal) contacts of one size are used on AF, AG, AJ, AK, AL, and AM 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 Force

The AF, AG, AJ, AK, AL, and AM relays are generally designed to provide a nominal 12.5-gram contact force. The sensitive relays are designed to provide a nominal 8-gram force. A high contact force range is available that provides a minimum 15-gram force. Since the contact force is nonadjustable, no reference is made to it in the Circuit Requirements Table.

Armature Travel

The armature travel is nonadjustable and so should 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, 500,501
Intermediate	0.044	2 Stage	200 to 399
Long	0.060	3 Stage	400 to 499

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Operate and Release Times

The operate and release times for the AF, AG, AJ, and AK relays are shown in Table 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 the relays that cannot be used in local circuit on 48 volts.

AL and AM relays are normally pulse operated and, hence, their operate and release times are circuit-dependent. For this reason, timing values are not generally listed; instead, they are specified as manufacturing requirements, where appropriate.

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 percent 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. The physical size of the 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
040-505-501	Timing and Latching Force Tests Using J94735 Test Set
040-505-701	Requirements and Adjusting Procedures - AL and AM Relays
040-505-801	Piece Parts and Replacement - AL and AM Relays

AF RELAY CODES

Code	Contacts	Table	Code	Contacts	Table	Code	Contacts	Table
AF1	MD		AF56	2	1	AF111	15	1
AF2	MD		AF57	8	1	AF112	13	1
AF3	10	1	AF58	None		AF113	12	1
AF4	6	1	AF59	4	1	AF114	7	1
AF5	10	1	AF60	7	1	AF115	7	1
AF6	11	1	AF61	5	1	AF116	14	1
AF7	None		AF62	Replaced by AF115		AF117	10	1
AF8	10	2	AF63	7	1	AF118	7	1
AF9	12	1	AF64	18	1	AF119	11	1
AF10	9	1	AF65	None		AF120	12	1
AF11	8	2	AF66	6	2	AF121	16	1
AF12	11	2	AF67	6	1	AF122	12	1
AF13	11	1	AF68	3	2	AF123	12	2
AF14	None		AF69	Replaced by AF526		AF124	7	1
AF15	4	1	AF70	6	2	AF125	13	1
AF16	11	1	AF71	5	2	AF126	7	1
AF17	4	1	AF72	4	2	AF127	11	2
AF18	4	2	AF73	8	2	AF128	16	2
AF19	4	1	AF74	Replaced by AF500		AF129	16	1
AF20	14	1	AF75	Replaced by AF501		AF130	8	2
AF21	11	2	AF76	Replaced by AF502		AF131	11	1
AF22	6	1	AF77	12	2	AF132	14	1
AF23	12	1	AF78	None		AF133	3	2
AF24	12	1	AF79	14	1	AF134	15	1
AF25	6	1	AF80	Replaced by AF503		AF135	9	1
AF26	6	1	AF81	Replaced by AF525		AF136	11	1
AF27	6	1	AF82	15	1	AF137	6	1
AF28	8	1	AF83	12	1	AF138	1	1
AF29	Replaced by AF114		AF84	12	1	AF139	11	1
AF30	12	1	AF85	7	1	AF140	13	1
AF31	Replaced by AF512		AF86	6	1	AF141	6	2
AF32	12	1	AF87	8	1	AF142	10	1
AF33	12	1	AF88	14	1	AF143	15	1
AF34	10	1	AF89	4	1	AF144	5	1
AF35	9	1	AF90	6	1	AF145	8	1
AF36	Replaced by AF514		AF91	6	1	AF146	6	1
AF37	12	1	AF92	11	1	AF147	12	1
AF38	Replaced by AF515		AF93	Replaced by AF504		AF148	11	1
AF39	Replaced by AF516		AF94	12	2	AF149	2	1
AF40	10	1	AF95	14	1	AF150	10	1
AF41	Replaced by AF517		AF96	3	2	AF151	14	1
AF42	16	1	AF97	3	2	AF152	18	1
AF43	3	1	AF98	13	1	AF153	13	1
AF44	4	1	AF99	6	2	AF154	11	1
AF45	Replaced by AF519		AF100	16	1	AF155	13	1
AF46	Replaced by AF520		AF101	4	2	AF156	8	1
AF47	Replaced by AF521		AF102	3	2	AF157	12	1
AF48	16	1	AF103	3	2	AF158	8	1
AF49	13	1	AF104	3	2	AF159	8	1
AF50	6	1	AF105	7	1	AF160	9	1
AF51	4	1	AF106	3	1	AF161	14	1
AF52	11	1	AF107	MD		AF162	12	1
AF53	13	1	AF108	MD		AF163	12	1
AF54	12	1	AF109	7	2	AF164	9	1
AF55	16	1	AF110	9	1	AF165	14	1

AF AND AJ RELAY CODES

Code	Contacts	Table
AF166	10	1
AF167	8	1
AF168	3	1
AF169	9	1
AF170	12	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 AF524	
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
AF536	12	1
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

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Code	Contacts	Table
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
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

Code	Contacts	Table
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
AJ111	14	1
AJ112	10	1
AJ113	20	2
AJ114	9	2
AJ115	3	2
AJ116	16	2
AJ117	3	1
AJ118	1	1
AJ119	1	1
AJ120	16	2
AJ121	Replaced by AJ129	
AJ122	24	2
AJ123	12	1
AJ124	18	1
AJ125	24	1
AJ126	24	2
AJ127	16	1
AJ128	14	1
AJ129	9	1
AJ130	15	1

AJ, AG, AK, AL AND AM RELAY CODES

Code	Contacts	Table
AJ131	24	1
AJ132	11	2
AJ133	5	2
AJ134	3	2
AJ135	2	2
AJ136	3	2
AJ137	15	1
AJ138	7	2
AJ139	24	1
AJ140	4	2
AJ141	8	2
AJ142	11	2
AJ143	3	2
AJ200	24	1
AJ201	Replaced by AJ700	
AJ202	24	1
AJ203	24	1
AJ204	24	2
AJ205	24	1
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
AJ518	24	2
AJ519	3	2
AJ520	24	1
AJ521	13	2
AJ700	24	1
AJ701	MD	
AJ702	24	1
AJ703	24	2
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

Code	Contacts	Table
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
AG58	4	3
AG59	16	3
AG60	14	3
AG61	18	3
AK1	13	4
AK2	10	4
AK3	8	4
AK4	18	4
AK5	8	4

Code	Contacts	Table
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
AK39	15	4
AK40	9	4
AK41	18	4
AK42	12	4
AK43	9	4
AK44	20	4
AK45	14	4
AK46.	10	4
AK47	18	4
AK48	14	4
AK49	18	4
AK50	20	4
AK500	13	4
AK501	20	4
AL1	24	1a
AL2	24	2a
AM1	20	4a
AM2	20	4a
AM3	20	4a
AM4	20	4a

TABLE II-1

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 Note
							1 CONTACT							
1	-	-	-	-	-	1	AJ7	34900	9100	1.6			0.5	A,(AC),G, Z,(AY)
-	1	-	-	-	-	53	AJ25	3710	220	24	22			D,X,N
										(after minus 50 soak)				
-	1	-	-	-	-	53	AJ47	3710	220	23	21			D,X,N
										(after minus 50 soak)				
-	1	-	-	-	-	53B	AF138	3900	100	30	-	-	12.5	A
-	1	-	-	-	-	53	AJ118	3710	220	21	19			D,G,X
										(after minus 50 soak)				
-	1	-	-	-	-	53	AJ119	3710	220	18.5	16.5			D,G,X
										(after minus 50 soak)				
							2 CONTACTS							
-	-	-	1	-	-	209	AF56	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,(AY)
							3 CONTACTS							
1	-	1	-	-	-	17	AF43	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

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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-gram readjust, 15-gram test.
X. Equipped with one iron and two copper washers.
Z. Adjusted on light contact force.
(AC). Armature back tension minimum 18-gram readjust, 15-gram 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 (Cont)

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 Note
						4 CONTACTS								
2	-	-	-	1	-	216	AF15	19400	2500	6.7				
4	-	-	-	-	-	3	AF19	1580	16	64				
4	-	-	-	-	-	3	AF44	2110	270	48				
4	-	-	-	-	-	3	AF51	5150	700	19.5				
4	-	-	-	-	-	3	AF59	19400	2500	5.2				
2	2	-	-	-	-	41B	AF89	2260	34	45	29.5 (after soak 130)		17.5	
-	-	-	1	1	-	211	AF17	2110	270	62	46			
3	1	-	-	-	-	38	AJ80	8250	1050	11	7.9			C
						5 CONTACTS								
-	5	-	-	-	-	23	AF61	19400	2500	5.5	2.4			
1	-	-	-	2	-	258	AF144	5150	700	26				
4	1	-	-	-	-	71	AJ85	22200	3800	4.6	3			(AY)(RA)
1	-	2	-	-	-	74	AJ98	2260	34	70			30	B

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 percent.

TABLE II-1 (Cont)

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 Note
							6 CONTACTS							
2	-	2	-	-	-	18	AF4	3330	400	34.5				
2	-	2	-	-	-	18	AF50	5150	700	22	13.2			
2	-	2	-	-	-	18	AF527	3330	400	34.5				
2	-	2	-	-	-	18	AF522	5150	700	22				
-	-	-	2	1	-	207	AF22	2110	270	62				
-	-	-	2	1	-	207	AF67	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	2110	270	62				
2	4	-	-	-	-	43	AF91	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	19400	2500	8				T
							7 CONTACTS							
2	1	2	-	-	-	54	AF114	5150	700	23				
2	1	2	-	-	-	32	AF511	5150	700	23	10.9			
6	1	-	-	-	-	12	AF60	19400	2500	6.2				
2	1	-	2	-	-	274	AF115	19400	2500	6.7	5			
2	3	-	-	1	-	229	AF63	19400	2500	6.7				
1	-	-	2	-	2PM	401	AF85	6450	1000	34	23.5		10.5	A,C, (RA)
1	-	-	2	1	-	253	AF105	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	19400	2500	6.5		2.6		
-	1	3	-	-	-	69	AJ74	19400	2500	4.9			1.1	

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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-gram readjust, 60-gram test.
(AP). Maximum buffer spring gauging waived.
(RA). Resistance ±5 percent.

TABLE II-1 (Cont)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Oper	N.O.	Hold	Rls	See Note
							8 CONTACTS							
4	-	-	2	-	-	210	AF57	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	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	5150	700	25.5				
4	2	-	-	1	-	295	AF159	3950	200	33.5				
5	3	-	-	-	-	36	AF158	5575	550	23	12.2			C
-	-	-	4	-	-	203	AJ121	28000	6000	3.9				W
							9 CONTACTS							
3	1	-	1	1	1EM	214	AF10	19400	2500	7.2	4.5			
4	2	-	-	1	1EM	248	AF35	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	19400	2500	5.4				
6	1	1	-	-	-	73	AF160	3950	200	34				
5	-	-	1	1	-	319	AF164	5150	700	27				
1	-	-	4	-	-	335	AJ129	28000	6000	3.9				W
							10 CONTACTS							
6	2	-	-	1	-	329	AJ112	11850	950	10.9		5.6		
10	-	-	-	-	-	6	AF3	3330	400	42				
10	-	-	-	-	-	6	AF5	2110	270	66				
9	1	-	-	-	-	14	AF34	5150	700	26.5				
4	1	-	1	1	1EM	222	AF40	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				

Notes:

A. Equipped with 0.014-inch stop discs.
C. Equipped with 0.147-inch copper sleeve.
W. Armature back tension minimum 20-gram readjust; 15-gram test.
(AG). Armature back tension, maximum 60-gram.
(RA). Resistance ±5 percent.
(RB). Resistance ±15 percent.

TABLE II-1 (Cont)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGMENT								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Oper	N.O.	Hold	Rls	See Note
							11 CONTACTS							
7	2	1	-	-	-	29	AF6	1580	16	95				
4	2	-	1	1	1EM	215	AF13	19400	2500	12.4			4.2	A
4	1	-	3	-	-	204	AF16	5150	700	29 20.3V				
3	-	4	-	-	-	19	AF52	5150	700	28				
3	-	4	-	-	-	19	AF523	5150	700	28				
11	-	-	-	-	-	7	AF92	2110	270	69				
10	1	-	-	-	-	15	AF520	2110	270	69				
6	3	-	-	-	2EM	266	AF119	19400	2500	12	5.9		4.1	A
1	4	-	2	1	-	256	AJ30	5150	700	27	19			
3	-	4	-	-	-	19	AJ508	1580	16	71				
4	2	-	1	1	1EM	215	AJ36	2260	34	49				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	19400	2500	7.9 20V		4.5		
3	2	-	3	-	-	280	AF148	5625	180	39 7.1V	20	25.5	11.3	A
5	-	-	1	-	1EB,1PM 2PB	417	AF154	6700	275	22				W
5	-	-	2	-	2EB	331	AF169	6700	275	38				A,(AK)

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Notes:

A. Equipped with 0.014-inch stop discs.
W. Armature back tension minimum 20-gram readjust; 15-gram test.
(AK). Armature back tension, minimum 60-gram.

TABLE II-1 (Cont)

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 Note
							12 CONTACTS							
12	-	-	-	-	-	8	AF37	1580	16	135				A
12	-	-	-	-	-	8	AF24	5150	700	29				
12	-	-	-	-	-	8	AF83	19400	2500	7.8				
12	-	-	-	-	-	8	AF504	2110	270	72				
12	-	-	-	-	-	8	AF506	5150	700	29				
2	3	-	2	1	1EM	213	AF9	19400	2500	8.2 — 23V				
5	-	-	2	1	1EM	206	AF23	3330	400	69.5				A
-	-	-	6	-	-	217	AF30	19400	2500	8.2	5		1.8	
-	-	-	4	2	-	208	AF32	5150	700	30.5 — 21.4V				
-	-	-	4	2	-	208	AF513	5150	700	30.5				
10	2	-	-	-	-	16	AF33	11850	950	12.8 — 12.2V				
2	2	4	-	-	-	25	AF54	5150	700	29				
4	3	1	1	-	1EM	236	AF84	19400	2500	8.2				
6	1	-	1	1	1EM	223	AF517	2110	270	80				
-	4	-	4	-	-	273	AF113	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 — 14V				
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 — 8.5V				
5	-	-	1	-	1EB,1EM 1PM,2PB	423	AF535	2110	270	80				
6	-	-	-	-	6EM	333	AK123	15800	1625	14	6.1		2.1	(BD)
12	-	-	-	-	-	8	AF536	2110	270	80				(BD),(AK) (BE)
5	-	-	2	1	1EM	206	AF170	3330	400	69.5	24			A,(AH)

Notes:

A. Equipped with 0.014-inch stop discs.
E. Equipped with 0.046-inch copper sleeve.
T. Armature back tension minimum 65-gram readjust; 60-gram test.
(AH). Armature back tension maximum 80-gram readjust; 85-gram test.
(AK). Armature back tension minimum 60-gram.
(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-gram readjust, 50-gram test.
maximum 75-gram readjust, 80-gram test.
(BD). Adjusted on heavy contact force.
(BE). Contact make 4.5R, 3T; no make 8.5R, 10T (at S.D.).

TABLE II-1 (Cont)

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 Note
							13 CONTACTS							
3	1	-	3	1	1EM	212	AF49	3330	400	50.5	29			
1	4	4	-	-	-	24	AF53	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	5150	700	33.5				
1	4	-	3	1	-	245	AF125	8275	500	20				
5	4	1	-	-	2EM	304	AF140	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	19400	2500	6.5				
5	-	-	4	-	-	301	AJ84	10450	800	12.2	6.5			
							14 CONTACTS							
2	-	-	4	2	-	205	AF20	5150	700	34				
2	-	-	4	2	-	205	AF79	19400	2500	9.2	4.5			
4	6	2	-	-	-	42	AF88	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	5150	700	32.5				
-	3	2	2	-	2EM,1PM	411	AJ51	385	375	48.5	37.5		8.5	C,(RA) (AM)
-	-	2	1	4	-	238	AJ61	5150	700	30.5				
-	-	2	2	1	2PBEM	415	AF151	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				
6	2	-	2	1	-	334	AJ128	15800	1625	11.1			3.6	

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Notes:

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

TABLE II-1 (Cont)

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 Note
							15 CONTACTS							
8	-	-	2	1	1EM	235	AF82	5150	700	40.5				
9	-	3	-	-	-	21	AF521	2110	270	85				
7	1	-	2	1	1EM	270	AF111	5150	700	40.5				
9	-	3	-	-	-	21	AJ507	2110	270	95				A
8	-	-	2	1	1EM	235	AJ509	5150	700	31.5	13.6			
4	3	-	4	-	-	230	AF134	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	5150	700	27	19			
2	1	-	4	2	-	271	AJ91	3950	200	40				
1	2	1	2	1	1PBEM 1PMEB	424	AJ130	15800	1625	8.7				W
6	1	2	2	-	-	338	AJ137	3950	200	61.5				A
							16 CONTACTS							
4	1	-	2	2	3EB	313	AJ62	6450	1000	36	22.5			A,C
3	1	-	4	2	-	224	AF42	2110	270	95				
3	1	-	4	2	-	224	AF518	2110	270	95				
2	6	4	-	-	-	28	AF48	2110	270	90				
7	1	4	-	-	-	26	AF55	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	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	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	5150	700	32				
8	-	4	-	-	-	63	AJ95	11850	950	13.2				
4	-	-	4	2	-	252	AJ127	15800	1625	12.4			4.1	

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.
W. Armature back tension minimum 20-gram readjust; 15-gram test.
(RA). Resistance ±5 percent.
(RB). Resistance ±15 percent.

TABLE II-1 (Cont)

CODE INFORMATION

SINGLE-WOUND AF AND AJ RELAYS

CONTACT ARRANGEMENTS								WINDING		CURRENT FLOW REQTS				
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Oper	N.O.	Hold	Rls	See Note
							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	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				
6	-	4	-	2	-	219	AJ124	730	4.4	200	110			(RB)
							19 CONTACTS							
2	2	-	6	1	1EB	278	AJ69	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				
2	-	3	4	2	-	226	AJ16	8275	500	36				A
-	-	-	8	2	-	234	AJ9	5150	700	38				
-	-	-	8	2	-	234	AJ502	5150	700	38				
-	-	-	8	2	-	234	AJ22	5150	700	38	13.4			
-	-	-	8	1	2EM	259	AJ21	2110	270	95				
-	-	-	8	2	-	234	AJ37	1580	16	125				

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Notes:

A. Equipped with 0.014-inch stop discs.
W. Armature back tension minimum 20-gram readjust; 15-gram test.
(RB). Resistance ±15 percent.

TABLE II-1 (Cont)

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 Note
							24 CONTACTS							
24	-	-	-	-	-	500	AJ202	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	19400	2500	12.6				
-	-	-	12	-	-	220	AJ12	5150	700	40.5				
-	-	-	9	3	-	249	AJ15	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	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
-	24	-	-	-	-	501	AJ205	5150	700	45				
-	-	2	6	4	-	299	AJ125	19400	2500	10.3				
-	-	-	6	6	-	336	AJ131	5150	700	42				
-	-	-	6	6	-	336	AJ520	2670	395	75				
-	-	-	9	3	-	249	AJ139	8275	500	23		13.5	4.4	

Notes:

C. Equipped with 0.147-inch copper sleeve.

TABLE II-1A

CODE INFORMATION

SINGLE-WOUND AL RELAYS

CONTACT ARRANGEMENTS								WINDING		CURRENT FLOW REQTS						
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Soak	Oper	N.O.	Rls	Non-Rls	No Flux Rls	See Note
							24 CONTACTS									
-	-	2	6	4	-	299B	AL1	3900	100	-300	-80	-	+23	-	+43.5	BJ,BM BN,BO

Notes:

BJ. Winding arrangement No. 13.
BM. Soak current shall not flow for more than 5 seconds.
BN. Operate and nonoperate test after soak and no flux release.
BO. Release and nonrelease test after soak.

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 Note
								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			0.2	G,L,R, W,(AJ)
1	1	-	-	-	-	52L	AJ135	P.L5200 S.L5200	400 400	P/S (soak	6 20)			1.8	A,L,Z, G,(AJ)

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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-gram readjust, 15-gram test.
Y. Laminations next to core.
Z. Adjusted on light contact force.
(AB). Armature back tension minimum 23-gram readjust, 20-gram test.
(AJ). Contact break 5, no break 8.5, readjust; break 3.5, no break 10, test.

TABLE II-2 (Cont)

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 Note
								3 CONTACTS							
1	2	-	-	-	-	10	AF68	P.7975 S.13950	1000 2700	P S	12.3 7.4				K
3	-	-	-	-	-	46	AF96	P.1050 S.3770	8 850	P S	95 28	85			K,Z,(RC)
3	-	-	-	-	-	46	AF97	P.560 S.3020	2.7 690	P S	215 42	190			K,Z,(RB)
3	-	-	-	-	-	46	AF102	P.790 S.2950	10 400	P S	165 46.5	145			K,Z
3	-	-	-	-	-	46	AF104	P.560 S.3020	2.7 690	P S	205 40	180			K,Z,(RB)
3	-	-	-	-	-	46	AF103	P.1050 S.3770	8 850	P S	115 34	100			K,Z,(RC)
3	-	-	-	-	-	46B	AJ29	P.L5520 S.L5520	425 425	P/S	7.5 (soak 27)			3.8	A,L,R,Z, W,G,(AG)
3	-	-	-	-	-	46B	AJ34	P.L3235 S.L3235	200 200	P/S	14.3 (soak 100)		9.6	6.6	A,L,W,G, Y,Z,R, (AG)(AN)
3	-	-	-	-	-	46	AJ50	P.2660 S.2660	100 100	P/S	10	5.5			G,L,R,W
2	1	-	-	-	-	37	AF133	P.9125 S.9125	1175 1075	P S	10.8 11.4	7.3		1.9	K
2	1	-	-	-	-	37	AJ59	P.L5200 S.L5200	400 400	P/S	9.9			4.3	B,L,R,W
2	1	-	-	-	-	75	AJ102	P(L)3235 S(L)3235	200 200	P/S	14	-	-	6.1	A,G,L,R, W,Y,(AZ)
3	-	-	-	-	-	46	AJ115	P(L)5520 S(L)5520	425	P/S	7.5 (soak 27)	6.4	-	3.8	A,G,L,R, W,Z
1	2	-	-	-	-	10	AJ519	P.1010 S.1100	16 16	P S	90 90				K
2	1	-	-	-	-	75	AJ134	P(L)2660 S(L)2660	100 100	P/S	13.7				L,R,W
3	-	-	-	-	-	46	AJ136	P(L)3235 S(L)3235	200 200	P/S	14.2(R)	12.1(R)		6.6(R)	A,G,L,Y, Z,R,(AN)
2	1	-	-	-	-	75	AJ143	P(L)2660 S(L)2660	100 100	P/S	13.7				G,L,R,W

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.
R. P/S primary and secondary in series aiding.
W. Armature back tension minimum 20-gram readjust, 15-gram test.
Y. Laminations next to core.
Z. Adjusted to light contact force.
(AG). Armature back tension maximum 60-gram readjust, 65-gram 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 percent.
(RC). Secondary winding resistance ±15 percent.

TABLE II-2 (Cont)

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 Note
								4 CONTACTS							
-	-	-	2	-	-	201	AF18	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				
4	-	-	-	-	-	3	AJ140	P.3235	200	P/S	16.5	-	-	5.0	A,L
								S.3235	200						
								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
								S.2770	85	P/S	25.5				(RA)
2	1	1	-	-	-	55B	AJ26	P.L3235	200	P/S	15.5			6.8	A,L,R,W
								S.L3235	200						Y,Z
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
								S.L3235	200						Y,Z
-	3	-	1	-	-	315	AJ86	P.L3235	200	P/S	19.5			2.4	L,R,Y
								S.L3235	200		(after soak 31)				
3	2	-	-	-	-	39	AJ133	P(L)5520	425	P/S	7.8	6.4	-	3.8	A,L,R,W
								S(L)5520	425						Z,G,(AJ)

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Notes:

A. Equipped with 0.014-inch stop discs.
G. Contact make 5, no make 8.5 (R), make 3.5, no make 10 (T).
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-gram readjust, 15-gram test.
Y. Laminations next to core.
Z. Adjusted on light contact force.
(AJ). Contact break 5, no break 8.5 (R), break 3.5, no break 10 (T).
(RA). Resistance ±5 percent.
(RB). Resistance ±15 percent

TABLE II-2 (Cont)

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 Note
								6 CONTACTS							
2	-	-	1	1	-	225	AF66	P.2590	100	P	61.5	46			K
								S.9625	1100	S	17				
1	1	-	1	1	-	202	AF70	P.7975	1000	P	16.5				K
								S.13950	2700	S	9.9				
-	2	-	1	1	-	251	AF99	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	11.6			K,R
								S.3750	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				
2	3	1	-	-	-	56	AJ138	P(L)5200	400	P/S	12	-	-	5.5	A,L,R
								S(L)5200	400						

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-gram readjust, 65-gram test.

TABLE II-2 (Cont)

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 Note
								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.2590	100	P	61	25.5			R,K
								S.9625	1100	P/S	13.5				
4	-	-	2	-	-	210	AF130	P.2590	100	P	54	30.5			(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	17	-	7.1	A,L,R,Y
								S.L3235	200						
5	-	-	-	1	1EM	327	AF167	P.10500	950	P	13.1				K
								S.3450	450	S	38	-	-	8.4	
3	1	1	-	1	-	339	AJ141	P.4100	210	P	32.5	20			A,K
								S.8375	1000	P/S	10.8				
								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	(soak 31)		3.2	L,R,Y
								S.L3235	200						
1	4	-	2	-	-	293	AJ114	P.560	2.7	P	225	175			K,(RB),(RC)
								S.3020	690	S	47				
								10 CONTACTS							
2	2	-	2	1	-	200	AF8	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				

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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-gram readjust, 65-gram test.
(RB). Resistance variation ±15 percent.
(RC). Resistance variation on secondary winding ±15 percent.

TABLE II-2 (Cont)

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 Note
								11 CONTACTS							
2	1	-	2	1	1EPMB	425	AJ142	P.9100	800	P	22	-	14.3	6.7	A,K,(RA)
								S.5350	880	S	37.5				
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.7975	1000	P	18.5		10		K
								S.13950	2700	S	11.1				
4	2	-	1	1	1EM	215	AF127	P.L3930	335	P/S	27.5	14.5		8.1	A,L,R,(RA)
								S.L3930	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						
2	1	-	2	2	-	337	AJ132	P(L)4550	415	P/S	21.5	12.7	12	6.1	A,R,(BF) (RD)
								S(L)4550	415						
								Ter.U 5350	900	T	37	-	-	9.8	
								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.7975	1000	P	20				K
								S.13950	2700	S	12				
-	-	-	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				
								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				
7	-	-	3	-	-	26	AJ521	P.3170	390	P	47				K
								S.3120	390	S	49.5				

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.
S. P/S primary and secondary in parallel aiding.
W. Armature back tension minimum 20-gram readjust, 15-gram 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.
AS. Winding arrangement No. 7.
(RA). Resistance ±5 percent.
(BF). Winding arrangement No. 10.
(RD). Primary and secondary resistance ±5 percent; tertiary resistance ±10 percent.

TABLE II-2 (Cont)

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 Note
								16 CONTACTS							
7	-	-	3	1	1EM	330	AJ116	P.7975	1000	P	22	11.6			K
								S.13950	2700	S	11.8	6.9			
2	5	-	3	1	1EM	250	AJ14	P.7975	1000	P	21				K
								S.13950	2700	S	12.6				
5	-	-	4	1	1EM	257	AJ28	P.7975	1000	P	22	11.6			K
								S.13950	2700	S	11.8	6.9	7.1	2	
-	5	-	4	1	1EM	265	AJ20	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				
5	1	-	2	2	2EB	332	AJ120	P.7975	1000	P	17.5	12			K
								S.13950	2700	S	10.5				
								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	P	19.5				K
								S.13950	2700	S	10.6				
								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				
24	-	-	-	-	-	500	AJ703	P.3170	390	P	71				K, BD
								S.3120	390	S	75				
-	-	-	9	3	-	249	AJ122	P.7100	700	P	29.5	-	-	5	K
								S.7150	700	S	31				
-	-	-	9	3	-	249	AJ126	P.3200	300	P	65				K
								S.3550	300	S	62.5				
-	-	-	9	3	-	249	AJ518	P.7100	700	P	33.5				K
								S.7150	700	S	33.5				

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Notes:

K. Winding arrangement No. 2.
R. P/S primary and secondary series aiding.
W. Armature back tension minimum 20-gram readjust, 15-gram test.
AA. Winding arrangements No. 9.
AE. Resistance variation ±3 percent on secondary winding.
BD. Adjusted on heavy contact force.

TABLE II-2A

CODE INFORMATION

MULTIPLE-WOUND AL RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS						
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Test Wdg	Soak	Oper	N.O.	Rls	Non-Rls	No Flux Rls	See Note
24 CONTACTS																	
-	-	-	6	6	-	336B	AL2	P.5250	510	P	-75	-57.5	-36	-	-	+32	K,BN,BO
								S.2950	910	S	-	-	-	+32	+19	-	

Notes:

K. Winding arrangement No. 2.
BN. Operate and nonoperate test after soak and no flux release.
BO. Release and nonrelease test after soak.

Readjust Test

TABLE II-3

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Sleeve	Soak	Oper	Hold	Rls	Min msec	Max msec	See Note
										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	R 20 T 21	1.8 2.0	1.3 1.0	250	500	(AF)
3	1	-	-	-	-	38B	AG58	P.7100 S.7150	700 700	-	42	P(R) 13.8 P(T) 14.5 PNO(R) 7.3 PNO(T) 6.9 S(R) 14.5 S(T) 15.5	2.0 2.1	1.5 1.2			K
										5 CONTACTS							
3	2	-	-	-	-	39B	AG4	8250	1050	0.147	36	R 11.8 T 12.4	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	0.046CU	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.R 35 P.T 37 S.R 32 S.T 34	4.6 4.9	3.6 3.2	95	160	(AD), (AE), (AR)

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Notes:

K. Winding arrangement No. 2.
(AD). Requirements apply to primary winding with secondary winding short-circuited.
(AE). Resistance variation ±3 percent on secondary winding.
(AF). Armature back tension minimum 45-gram readjust, 40-gram test.
(AR). Winding arrangement No. 6.

TABLE II-3 (Cont)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Sleeve	Soak	Oper	Hold	Rls	Min msec	Max msec	See Note
								6 CONTACTS									
3	3	-	-	-	-	45B	AG14	P.3330 S.3440	400 210	-	90	P.R 30 P.T 31.5 S.R 30.5 S.T 32.5	4.4 4.7	3.6 3.3	85	137	(AD), (AE), (AH), (AR)
2	-	2	-	-	-	18B	AG24	8250	1050	0.147	36	R 13 T 13.7	1.5 1.6	1.0 0.7	300	620	Z
3	3	-	-	-	-	45B	AG27	P.3250 S.2430	198 80	-	95	P.R 32 P.T 34 S.R 45 S.T 47.5	4.5 4.8	3.4 2.7	103	206	K, (AD)
4	2	-	-	-	-	67B	AG35	P.3330 S.3440	400 210	-	90	P.R 30 P.T 31.5 S.R 30.5 S.T 32.5	4.4 4.7	3.6 3.3	85	137	(AD), (AE), (AH), (AR)
-	-	3	-	-	-	50	AG40	19400	2500	-	6.3	R 4.4 T 4.7	0.8 0.9	0.5 0.4			
								7 CONTACTS									
1	2	-	2	-	-	246B	AG9	15800	1625	-	19	R 8.9 T 9.4	1.1 1.2	0.9 0.8			
3	-	-	-	2	-	282B	AG21	P.3000 S.2540	450 57	-	100	P.R 46 P.T 48.5 S.R 57.5 S.T 60.5	5.7 6.0	4.6 3.9	136	267	K, (AD), (AH)
2	3	1	-	-	-	56B	AG22	P.3000 S.2540	450 57	-	100	P.R 34 P.T 36 S.R 42.5 S.T 45	5.3 5.6	4.2 3.5	144	288	K, (AD), (AH)
1	-	-	3	-	-	267B	AG30	8275	500	-	36	R 17 T 18	2.0 2.1	1.6 1.3	7.2	17	
2	-	-	2	-	1EM	325B	AG54	P.4800 S.13150	360 1900	-	65	P.R 29 P.T 30.5 S.R 11 S.T 11.7	3.6 3.8	2.6 2.2			K

Notes:

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

TABLE II-3 (Cont)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Sleeve	Soak	Oper	Hold	Rls	Min msec	Max msec	See Note
								8 CONTACTS									
5	3	-	-	-	-	36B	AG2	8250	1050	0.147	36	R 11.8 T 12.4	2.0 2.1	1.4 1.1	245	475	
2	2	-	2	-	-	233B	AG3	8250	1050	0.147	36	R 16.5 T 17.5	2.4 2.6	1.4 1.1	195	475	T
2	2	-	2	-	-	233B	AG16	8250	1050	0.147	36	R 16.5 T 17.5	2.1 2.3	1.4 1.1	225	475	
2	2	-	2	-	-	233	AG11	8250	1050	0.147	36	R 16.5 T 17.5	2.1 2.3	0.7 0.4	225	830	
3	-	-	1	1	1EM	221	AG15	7800	600	0.091	38	R 17.5 T 18.5	2.3 2.5	0.8 0.5	147	512	
2	2	-	2	-	-	286B	AG23	15800	1625	-	19	R 6.4 T 6.8	1.1 1.2	0.8 0.6			
1	-	-	1	2	1EB	297B	AG37	P.3000 S.2540	450 57	-	100	P.R46 P.T48.5 S.R57.5 S.T60.5	5.9 6.3	4.6 3.9	130	275	K,AD
3	3	-	-	1	-	296B	AG36	7800	600	0.091	38	R 14.7 T 15.5	2.3 2.5	1.8 1.5	150	280	(AG)
-	-	-	1	2	2EB	290B	AG47	P.3000 S.2540	450	-	100	P.R46 P.T48.5 S.R57.5 S.T60.5	5.9 6.3	4.6 3.9	130	275	K,AD
4	2	1	-	-	-	72B	AG51	23600	4000	-	10	R 4.2 T 4.5	0.7 0.8	0.5 0.4			(AY)
								9 CONTACTS									
8	1	-	-	-	-	48B	AG18	13500	2000	0.091	20	R 7.6 T 8.0	1.4 1.5	0.9 0.7	142	320	
2	3	-	2	-	-	264B	AG41	13500	2000	0.091	20	R 10.2 T 10.8	1.7 1.8	1.3 1.1	120	235	
3	2	2	-	-	-	76B	AG55	P.6525 S.2260	1000 42	-	46	P.R15 P.T16 S.R45.5 S.T48	2.7 2.9	1.9 1.6	136	307	K,AD

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Notes:

K. Winding arrangement No. 2.
T. Armature back tension minimum 65-gram readjust, 60-gram test.
(AD). Requirements apply to primary winding with secondary winding short-circuited.
(AG). Armature back tension maximum 60-gram readjust, 65-gram 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 (Cont)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Sleeve	Soak	Oper	Hold	Rls	Min msec	Max msec	See Note
10 CONTACTS																	
4	1	-	1	1	1EM	222B	AG26	5575	550	0.147	33	R 25 T 26.5	3.9 4.1	2.5 2.1	187	402	
3	3	-	-	2	-	279B	AG42	10050	875	0.046AL	30 26V	R 14 T 14.7 13V	1.9 2.1	0.7 0.5	46	175	
11 CONTACTS																	
7	-	2	-	-	-	20B	AG45	16050	2200	0.046AL	18	R 6.6 T 7	1.3 1.4	1.1 0.9	40	85	
7	-	2	-	-	-	20B	AG46	7975 13950	1000 2700	-	P38	PR12.8 PT13.5 SR 7.7 ST 8.1	2.7 2.9	1.7 1.4	5	16	K
12 CONTACTS																	
8	4	-	-	-	-	35B	AG1	8250	1050	0.147	36	R 12.1 T 12.8	2.5 2.7	1.6 1.3	190	425	
8	4	-	-	-	-	35B	AG10	10050	875	0.046AL	30	R 10.2 T 10.8	2.1 2.3	1.4 1.2	42	100	
2	3	-	2	1	1EM	213B	AG38	P.3000 S.2540	450 57	-	100	P.R47 P.T49.5 S.R58.5 S.T61.5 P NO 26.5R, 25T	7.9 8.4	6.0 5.2	96	210	K,(AD)
2	2	-	2	1	1EM 1PM	416B	AG49	P.3000 S.2540	450 57	-	100	P.R56 P.T59 S.R70 S.T74	8.0 8.4	6.6 5.9	95	195	K,(AD)
13 CONTACTS																	
7	-	-	3	-	-	268B	AG28	10050	875	0.046CU	20	R 14.5 T 15.5	2.3 2.5	1.3 1.1	61	145	
3	3	-	2	1	1EM	305B	AG33	10050	875	0.046AL	30	R 14 T 14.7	2.3 2.5	1.5 1.3	40	95	
3	-	-	5	-	-	307B	AG34	8250	1050	0.147	36	R 17 T 18	2.8 3.0	1.8 1.5	175	395	
7	-	-	3	-	-	268B	AG39	P.7975 S.13950	1000 2700	-	38	P.R17.5 P.T18.5 S.R10.5 S.T11.1	3.0 3.2	1.9 1.6	4.5	14	K

Notes:

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

TABLE II-3 (Cont)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Sleeve	Soak	Oper	Hold	Rls	Min msec	Max msec	See Note
								14 CONTACTS									
1	1	-	4	2	-	239B	AG6	16050	2200	0.046AL	18	R 8.8 T 9.3	1.5 1.6	1.0 0.8	37	95	
5	-	4	-	-	1EM	281B	AG44	6525 2260	1000 42	-	46	P.R21.5 P.T23 S.R65 S.T70	3.8 4.0	2.4 2.1	95	250	K (AD)
2	2	-	2	1	1PBEM 1PMEB	419B	AG60	8250	1050	0.147	36	R 20.5 T 21.5	3.1 3.3	2.0 1.7	156	355	
								15 CONTACTS									
7	-	-	4	-	-	241B	AG7	8250	1050	0.147	36	R 16.5 T 17.5	3.0 3.2	1.9 1.6	155	365	
2	1	-	4	2	-	271B	AG17	16050	2200	0.046CU	18	R 8.8 T 9.3	1.6 1.7	1.0 0.8	55	150	
5	-	-	3	2	-	262B	AG20	13500	2000	0.091	20	R 10.2 T 10.7	1.9 2.0	1.1 0.9	103	260	
4	3	-	4	-	-	230B	AG48	13500	2000	0.091	20	R 10.2 T 10.8	1.9 2.0	1.2 1.0	105	250	
								16 CONTACTS									
3	1	-	4	2	-	224B	AG32	P.7975 S.13950	1000 2700	-	38	P.R17.5 P.T18.5 P/SR6.6 P/ST7.0 PNO R9.2 PNO T8.7	3.5 3.7 1.4 1.5	2.0 1.7	3.7	13.5	K,R
-	-	2	2	4	-	318B	AG52	P.5750 S.17400	700 3300		50	P.R24 P.T25.5 S.R 8.3 S.T 8.9	4.5 4.8	2.8 2.5	4.0	13.0	K
-	-	8	-	-	-	70B	AG59	P.4350 S.4600	450 500	0.091CU	FS	P.R28 P.T29.5 S.R28 S.T29.5	5.8 6.1	4.7 4.3	115	180	K

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Notes:

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

TABLE II-3 (Cont)

CODE INFORMATION

AG RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS				RELEASE TIME		
															msec		
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Sleeve	Soak	Oper	Hold	Rls	Min	Max	See Note
								17 CONTACTS									
-	-	3	2	1	1EM 2PMEB	408B	AG29	7800	600	0.091CU	39	R 22 T 23.5	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	0.147CU	36	R 15.5 T 16.5	3.3 3.5	2.0 1.7	145	360	
2	-	3	5	-	-	314B	AG50	16050	2200	0.046CU	18	R 8.8 T 9.3	1.8 1.9	1.3 1.1	45	115	
6	-	-	6	-	-	343B	AG61	8250	1050	0.147CU	36	R 17 T 18	3.5 3.7	2.1 1.9	135	330	
								21 CONTACTS									
3	-	3	6	-	-	326	AG57	16050	2200	0.046CU	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 Note
							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				

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Notes:

(AV). Winding arrangement No. 8.

TABLE II-4 (Cont)

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 Note
							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				
							9 CONTACTS							
2	3	-	-	-	-	17	AK40	T 4000	145	29			6.9	(AV)
2	3	-	-	-	-			B 8600	640	13.5				
2	1	1	-	-	-	20	AK43	T 10300	960	10				(AV),W
3	1	-	-	-	-			B 2800	65	37				W
							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	18.2V			(AV)
-	1	2	-	-	-			B 15750	2450	7.4				
-	1	2	-	-	-	13	AK38	T 10300	960	11.3	10.9V	5.1		(AV)
-	1	2	-	-	-			B 10300	960	11.3		5.1		
3	2	-	-	-	-	19	AK46	T 5000	630	25	21.5(60 soak)		5	(AV)
3	2	-	-	-	-			B 5000	630	25	21.5(60 soak)		5	

Notes:

W. Armature back tension minimum 20-gram readjust; 15-gram test.
(AV). Winding arrangement No. 8.

TABLE II-4 (Cont)

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 Note
								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				
2	-	-	1	1	-	223	AK42	T 12300	1500	10				W, (AV)
2	-	-	1	1	-			B 12300	1500	10				W
								13 CONTACTS						
1	1	-	2	1	-	201	AK1	T 6900	410	24.5	10.1V 11.5V			(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)
1	3	1	-	-	-	15	AK500	T 8600	640	13.8				(AV)
2	1	2	-	-	-			B 8600	640	14.2				

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Notes:

W. Armature back tension minimum 20-gram readjust; 15-gram test.
(AT). Copper sleeve and domed armature on bottom unit.
(AV). Winding arrangement No. 8.
(BB). Domed armature on bottom unit.

TABLE II-4 (Cont)

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 Note
							14 CONTACTS							
2	-	-	1	1	1EM	204	AK8	T 15750	2450	8.7				(AV)
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				
2	-	-	1	1	1EM	204	AK45	T 15750	2450	10.4				(AV)
1	1	-	2	-	1EM			B 3400	100	48	32.5	18	-	
2	-	-	1	1	1EM	204	AK48	T 15750	2450	8.8	6.2	-	-	W, (AV)
1	1	-	2	-	1EM			B 15750	2450	10.4				
							15 CONTACTS							
4	-	1	-	-	-	7	AK10	T 15750	2450	7.4		1.5		(AV) (AU)
1	-	4	-	-	-			B 10300	960	15.5		2.6		
-	-	-	2	2	-	221	AK39	T 15750	2450	10.7	-	4.2		(AV)
1	-	-	1	2	-			B 10300	960	16				
							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-gram readjust; 15-gram test.
(AU). Domed armature on top and bottom units.
(AV). Winding arrangement No. 8.
(RB). Resistance variation on top winding ±15 percent.

TABLE II-4 (Cont)

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 Note
								18 CONTACTS						
1	-	-	2	2	-	202	AK4	T 15750	2450	11.3 — 22.8V				(AV)
1	-	-	2	2	-			B 15750	2450	11.3				
1	-	-	2	2	-	202	AK30	T 8600	640	22 — 14V				(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				
1	-	-	2	2	-	202	AK41	T 6250	680	30	(48 soak)	4.2		(AV),(BC)
1	-	-	2	2	-			B 6250	680	30	(48 soak)	4.2		
1	-	-	2	2	-	202	AK47	T 12300	1500	12.5 — 19V DON'T USE ON 24V!				W, (AV)
1	-	-	2	2	-			B 12300	1500	12.5				
1	-	-	1	3	-	224	AK49	T 15750	2450	11.3				(AV)
1	-	-	1	3	-			B 15750	2450	11.3				
								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 — 17V				(AV)
-	-	-	3	2	-			B 8600	640	26				
-	-	-	5	-	-	222	AK44	T 8600	640	26				(AV)
-	-	-	5	-	-			B 8600	640	26				
-	-	5	-	-	-	2	AK501	T 8600	640	27.5				(AV)
-	-	5	-	-	-			B 8600	640	27.5				
-	-	-	3	2	-	216	AK50	T (P) 6282	820	36				
								(S) 5024	682	45				(BH)
-	-	-	3	2	-			B (P) 6282	820	36				
								(S) 5024	682	45				

Notes:

W. Armature back tension minimum 20-gram readjust; 15-gram test.

(AT). Copper sleeve and domed armature on bottom unit.

(AV). Winding arrangement No. 8.

(BC). Copper sleeve and domed armature on top and bottom units.

(BH). Winding arrangement No. 12.

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TABLE II-4A

CODE INFORMATION

AM RELAYS

CONTACT ARRANGEMENT								WINDING			CURRENT FLOW REQTS					
M	B	BM	EBM	EMB	Other	Spg Comb.	Code	Turns	Res	Soak	Oper	N.O.	Rls	Non-Rls	No Flux Rls	See Note
								20 CONTACTS								
-	-	-	3	2	-	216	AM1	T 3400	100	-300	-100	-	+27	-	+32	BG, BK, BL,
-	-	-	3	2	-			B 3400	100	-300	-100	-	+27	-	+32	BM, BN, BO
-	-	-	5	-	-	222	AM2	T 3400	100	-300	-100	-	+27	-	+32	BG, BK, BL,
-	-	-	5	-	-			B 3400	100	-300	-100	-	+27	-	+32	BM, BN, BO
-	-	-	3	2	-	216	AM3	T 3400	100	-300	-150	-	+16.5	+7.4	+32	BG, BD, BK,
-	-	-	3	2	-			B 3400	100	-300	-150	-	+16.5	+7.4	+32	BL, BM, BN, BO
-	-	-	5	-	-	222	AM4	T 3400	100	-300	-150	-	+16.5	+7.4	+32	BG, BD, BK,
-	-	-	5	-	-			B 3400	100	-300	-150	-	+16.5	+7.4	+32	BL, BM, BN, BO

Notes:

BD. Adjusted on heavy contact force.
BG. Winding arrangement No. 11.
BK. Armature back tension minimum 40-gram readjust; 35-gram test.
BL. Armature back tension maximum 110-gram readjust; 115-gram test.
BM. Soak current shall not flow for more than 5 seconds.
BN. Operate and nonoperate test after soak and no flux release.
BO. Release and nonrelease test after soak.

TABLE II-5

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 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 90-ohm noninductive resistance.

TABLE II-5 (Cont)

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
AF46								
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

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TABLE II-5 (Cont)

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	Avg
AF91	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 90-ohm noninductive resistance.

TABLE II-5 (Cont)

OPERATE AND RELEASE TIMES

AF RELAYS

Code	Res	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	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	16.0	7.0	10.5	10.2	1.5	4.5
146	2500	207	50.0	15.0	29.0	10.5	1.7	4.7
147	2500	217	55.0	15.0	29.0	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
157	180	317	11.5	6.1	8.6	3.9	1.0	2.1
158	550	36	52.0	14.0	26.0	235.0	30.0	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
166	500	421B	22.0	9.0	13.7	4.0	1.0	1.7
167	P-950	327	22.0	8.5	14.7	10.7	1.3	4.1
	S-450		10.8	4.8	7.6	-	-	-
168	700	46	13.2	5.6	9.1	14.5	2.1	6.5
169	275	331	18.0	6.0	11.0	4.0	1.0	2.1
170	400	206	9.8	4.2	6.8	5.1	1.6	2.3

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* 24-volt operation

TABLE II-5 (Cont)

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			
535	270	423	9.8	4.1	6.7	9.0	1.1	3.5
536	270	8	5.6	2.8	4.2	5.9	1.0	3.2

* In series with 90-ohm 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	P200	2B	Supervisory Relay					
	S200							
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	P400	1	Supervisory Relay					
	S400							
9	700	234	12.0	5.1	8.3	9.1	1.3	4.2
10	P1800	39	15.5	8.6	12.0	14.5	2.6	8.0
	S85							
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	P1000	250	24.0	8.0	11.5	10.1	1.4	4.6
	S2700		54.5	12.0	26.5			
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	P300	41	7.4	3.5	5.6	16.7	3.3	8.6
	S300		7.7	3.8	6.0			
20	P1000	265	24.0	8.0	11.5	10.1	1.1	4.6
	S2700		54.5	12.0	26.5			
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	P200	1B	Supervisory Relay					
	S200							
24	P200	52B	Supervisory Relay					
	S200							
25	220	53	Ring Trip Relay					
26	P200	55B	Supervisory Relay					
	S200							
27	2200	213	84.0	28.0	50.0	56.0	7.8	30.0
28	P1000		24.0	8.2	12.0			
	S2700	257	60.0	14.5	26.5	10.1	1.4	4.6
29	P425	46B	Supervisory Relay					
	S425							
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	P200	46B	Supervisory Relay					
	S200							
35	16*	9	4.4	2.2	3.3	18.0	3.8	8.6

* In series with 90-ohm noninductive resistance

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TABLE II-6 (Cont)

OPERATE AND RELEASE TIMES

AJ RELAYS

Code	Res	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	Avg
AJ36	34	215				12.0	1.9	5.7
37	16*	234	6.1	2.7	4.3	9.1	1.3	4.2
38	P170	294B		Supervisory Relay				
	S140							
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	P61	66		Supervisory Relay				
	S61							
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	P1500	3	17.5	7.7	10.2	16.0	3.1	8.5
	S2950		23.0	11.0	18.5			
49	P220	302		Ring Trip Relay				
	S1150							
50	P100	46		Supervisory Relay				
	S100							
51	375	411	80.0	30.0	40.0	360.0	31.0	155.0
52	P400	303		Supervisory Relay				
	S400							
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	P5000	62	85.0	12.0	30.0	11.0	1.6	5.1
	S1000		21.5	5.6	10.0			
56	400	413	11.5	4.2	7.8	10.0	1.3	4.2
57	P200	237		Supervisory Relay				
	S200							
58	P220	308		Ring Trip Relay				
	S1150		49.0	10.0	22.0	115.0	17.5	55.0
59	P400	37		Supervisory Relay				
	S400							
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	P1000	283	23.1	8.0	11.5	9.7	1.4	4.4
	S2700		50.5	12.0	26.5			
71	P1000	250	24.0	8.0	11.5	10.1	1.4	4.6
	S2700		54.5	12.0	26.5			
72	P700	64	11.1	5.6	8.2	8.1	1.0	3.4
	S700		11.1	5.6	8.2			

* In series with 90-ohm noninductive resistance

TABLE II-6 (Cont)

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 73	P360	5	8.3	4.2	6.2	8.0	2.0	4.0
	S1900		24.5	8.0	15.5			
74	2500	69	29.5	10.0	20.0	14.1	2.4	6.7
75	2500	291	40.0	13.0	29.0	11.1	1.8	5.2
76	2500	292	40.0	13.0	29.0	14.2	2.4	6.9
77	P200	293	Supervisory Relay					
	S200							
78	P1000	278	23.0	8.0	11.5	9.1	1.5	4.2
	S2700		60.0	12.0	26.5			
79	1625	419	33.0	13.0	27.0	10.5	1.7	4.7
80	1050	38	49.0	19.0	28.0	305.0	85.0	175.0
81	500	220	25.0	7.0	11.0	8.5	1.0	3.5
82	500	300	21.0	10.0	14.5	5.6	1.7	3.2
83	2500	249	99.0	13.0	29.0	8.5	1.0	3.5
84	800	301	18.0	8.0	14.0	10.7	1.7	5.2
85	3800	71	35.0	14.0	18.5	14.0	2.7	6.7
86	P200	315	Supervisory Relay					
	S200							
87	P1200	316	24.0	8.2	13.4	10.1	1.4	4.6
	S6000							
88	P200	303	Supervisory Relay					
	S200							
89	270	238	7.9	3.6	5.6	11.1	1.8	5.2
90	16*	420	7.9	3.3	5.4	11.5	1.2	7.0
91	200†	271	25.0	3.8	13.0	10.5	1.5	4.8
92	200†	220	30.5	3.8	13.0	8.5	1.0	3.5
93	200†	278	30.0	3.8	13.0	9.1	1.3	4.2
94	700	320	12.0	5.1	8.3	10.1	1.4	4.6
95	950	63	28.0	8.0	12.0	11.1	1.5	5.0
96	34	8				11.5	1.5	5.3
97	P210	321	P-	-	-			
	S1000		S18	4.0	10.0	11.1	1.8	5.2
98	34	74	-	-	-	5.3	1.8	3.0
99	P200	322	Supervisory Relay					
	S200							
100	180	46	8.3	4.5	6.4	19.0	3.1	8.9
101	500	323	19.0	7.0	11.0	12.0	1.9	5.7
102	P200	75	Supervisory Relay					
	S200							
103	1050	299	29.0	10.0	14.0	190.0	15.0	84.0
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

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* In series with 90-ohm noninductive resistance
† 24-volt operation

TABLE II-6 (Cont)

OPERATE AND RELEASE TIMES

AJ RELAYS

Code	Res	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	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	26.0	9.2	13.7	10.5	1.5	4.8
	S2700		60.0	15.0	24.0	-	-	-
117	180	37	8.3	4.5	6.4	18.0	3.4	9.4
118	220	53	Ring Trip Relay					
119	220	53	Ring Trip Relay					
120	P1000	332	23.0	8.0	11.5	9.1	1.5	4.2
	S2700		60.0	12.0	26.5	-	-	-
121								
122	P700	249	14.6	6.4	10.2	7.1	1.0	3.5
	S700		14.8	6.6	10.4	-	-	-
123	1625	333	48.5	14.0	30.5	8.0	1.6	5.4
124	4.4	219	-	-	-	8.6	1.1	4.3
125	2500	299	61.0	13.0	33.0	7.4	1.0	3.5
126	P300	249	9.4	4.0	6.5	7.4	1.0	3.5
	S300		9.8	4.2	6.8	-	-	-
127	1625	252	40.4	13.0	26.4	5.7	1.6	2.4
128	1625	334	40.4	13.0	26.4	6.4	1.6	2.5
129	6000	335	69.0	15.0	29.0	12.5	1.7	6.2
130	1625	424	37.8	11.5	18.0	9.4	1.1	4.5
131	700	336	10.7	4.3	7.2	7.4	1.0	3.5
132	P415	337	Supervisory Relay					
	S415							
	T900							
133	P425	39	Supervisory Relay					
	S425							
134	P100	75	Supervisory Relay					
	S100							
135	P400	52	Supervisory Relay					
	S400							
136	P200	46	Supervisory Relay					
	S200							
137	200*	338	26.4	8.4	16.0	6.6	1.0	2.0
138	P400	56	Supervisory Relay					
	S400							
139	500	249	25.0	7.0	11.0	8.5	1.0	3.5
140	P200	3	Supervisory Relay					
	S200							
141	P210	339	-	-	-	7.6	1.6	3.3
	S1000		16.1	8.0	11.9	-	-	-
142	P800	425	24.5	15.0	21.0	6.5	1.6	2.8
	S880		23.6	12.0	16.5	-	-	-
143	P100	75	Supervisory Relay					
	S100							

* 24-volt operation

TABLE II-6 (Cont)

CODE INFORMATION

AJ RELAYS

Code	Res	Spg Comb.	OPERATE TIMES Max	OPERATE TIMES Min	OPERATE TIMES Avg	RELEASE TIMES Max	RELEASE TIMES Min	RELEASE TIMES Avg
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
205	700	501	22.0	5.1	11.5	11.0	1.0	3.7
500	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	P2.7	39						
	S690		19.2	4.8	8.6	11.5	1.8	5.2
511	P700	206	16.5	7.4	10.1	11.5	1.7	5.3
	S700		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	P700	227	23.0	5.6	9.4	9.0	1.2	4.0
	S700		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
517	P700	318	13.4	5.8	9.3	10.1	1.4	4.6
	S3300		53.0	13.0	34.0	-	-	-
518	P700	249	14.3	6.3	10.0	7.4	1.0	3.5
	S700		14.6	6.4	10.2	-	-	-
519	P16*	10	3.9	2.0	2.9	15.3	3.2	9.1
	S16*		4.0	2.0	3.0	-	-	-
520	395	336	21.5	5.2	8.4	8.5	1.0	3.6
521	P390	268	7.2	3.6	5.3	8.6	1.2	4.4
	S390		7.0	3.5	5.2	-	-	-
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
703	P390	500	7.2	3.6	5.3	5.6	1.0	2.8
	S390		7.0	3.5	5.2	-	-	-

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* In series with 90-ohm noninductive resistance

TABLE II-7

OPERATE AND RELEASE TIMES

AG RELAYS

			OPERATE TIMES			RELEASE TIMES	
Code	Res	Spg Comb.	Max	Min	Avg	Max	Min
AG1	1050	35B	64.0	10.5	29.0	425	190
2 5M,3B	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 13V	P-400 S-210 } 3M, 3B	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 22V	P-450 S-57 } 3M, 2EMB	282B	8.6	4.6	6.6	267*	136*
22	P-450 S-57 } 2M, 3B, 1BM	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 17V	P-198 S-80 } 3M, 3B	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 17V	P-450 S-200 } 5M	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 13V	P-400 S-120 } 4M, 2B	67B	9.8	3.5	6.8	137*	85*
36	600	296B	39.5	10.0	23.0	280	150
37 22V	P-450 S-57 } 1M, 1EBM, 2EMB, 1EB	297B	8.6	4.6	6.6	275*	130*
38	P-450	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 (Cont)

OPERATE AND RELEASE TIMES

AG RELAYS

				OPERATE TIMES			RELEASE TIMES	
Code		Res	Spg Comb.	Max	Min	Avg	Max	Min
AG43		1050	34B	75.0	11.0	29.0	360	145
44	23V	P-1000	281B	24.0	6.6	18.0	250*	95*
		S-42 5M, 4BM, 1EM						
45		2200	20B	45.0	8.5	20.5	85	40
46		P-1000	20B	17.0	5.6	8.6		
		S-2700		34.0	7.2	16.8	16	4.9
47	22V	P-450	290B	8.6	4.6	6.6	275*	130*
		S-57 1EBM, 2EMB, 2EB						
48		2000	230B	95.0	15.0	50.0	250	105
49	27V	P-450	416B	10.5	5.7	8.0	195*	95*
		S-57 2M, 2B, 2EBM, 1EMB, 1PM, 1EM						
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		
53	43V	P-450	249B	8.6	4.6	6.6	195*	57*
		S-57 9EBM, 3EMB						
54		P-360	325B	-	-	-	17	7
		S-1900		37.0	8.5	20.0		
55	16V	P-1000	76B	15.0	5.0	9.3	307*	136*
		S-42 3M, 2B, 2BM						
56	33V	P-450	413B	12.9	5.2	8.7	205*	74*
		S-57 4M, 2B, 1BM, 1EMB, 1EM, 1PBEM, 2 PMEB						
57		2200	326B	66.0	13.5	43.5	100	40
58		P-700	38B	12.1	6.0	9.0	17	11
		S-700		12.2	6.1	9.1		
59		P-450	70B	39.5	9.6	14.0	180	115
		S-500		45.5	10.7	16.0		
60		1050	419B	88.5	18.0	43.0	320	168
61		1050	343B	85.5	16.8	32.0	330	135

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* With secondary winding short-circuited

TABLE II-8

OPERATE AND RELEASE TIMES

AK RELAYS

Code	Res	Spg Comb.	OPERATE TIMES Max	Min	Avg	RELEASE TIMES Max	Min	Avg
AK1	T410 12V	201	-	-	-	8.7	1.0	3.6
	B315* 12V		-	-	-	175.0	60.0	-
2	T960	1	13.4	7.5	10.5	10.4	1.6	4.8
	B960		13.4	7.5	10.5	10.4	1.6	4.8
3	T185	3	-	-	-	11.0	1.8	5.4
	B280		-	-	-	11.0	1.8	5.4
4	T2450 24V	202	44.0	18.7	31.0	8.5	1.0	3.4
	B2450		44.0	18.7	31.0	8.5	1.0	3.4
5	T640	4	11.1	6.3	8.7	11.0	1.8	5.4
	B640		11.1	6.3	8.7	11.0	1.0	5.4
6	T640	2	11.1	6.3	8.7	8.5	1.0	3.4
	B640		11.1	6.3	8.7	8.5	1.0	3.4
7	T955	203	18.2	10.7	14.5	8.7	1.0	3.6
	B955		18.2	10.7	14.5	8.7	1.0	3.6
8	T2450	204	29.2	18.7	24.0	9.3	1.1	3.9
	B960		18.8	11.6	14.5	9.3	1.1	3.9
9	T2450	5	25.0	10.5	17.5	11.0	1.8	5.4
	B145		-	-	-	14.0	2.6	6.6
10	T2450†	7	25.0	10.5	17.5	22.5	4.5	16.5
	B960†		13.4	7.5	10.5	17.0	3.8	12.0
11	T960	206	18.8	11.6	14.5	11.3	1.7	5.0
	B960		18.8	11.6	14.5	11.3	1.7	5.0
12	T1500	8	18.2	8.2	13.0	14.0	2.6	6.6
	B1500		18.2	8.2	13.0	14.0	2.6	6.6
13	T640	203	16.2	10.5	13.4	8.7	1.0	3.6
	B640		16.2	10.5	13.4	8.7	1.0	3.6
14	T410	208	-	-	-	8.7	1.0	3.6
	B410		-	-	-	10.0	1.2	4.2
15	T640	9	11.1	6.3	8.7	11.6	2.1	5.9
	B960		13.4	7.5	10.5	8.8	1.2	4.1
16	T100	211	-	-	-	9.3	1.1	3.9
	B100		-	-	-	9.3	1.1	3.9
17	T210‡	212	20.7	9.6	15.2	9.3	1.1	3.9
	B210‡		20.7	9.6	15.2	9.3	1.1	3.9
18	T210‡	213	20.7	9.6	15.2	12.5	2.0	5.6
	B210‡		20.7	9.6	15.2	11.3	1.7	5.0
19	T210‡	214	20.7	9.6	15.2	10.0	1.2	4.2
	B210‡		20.7	9.6	15.2	10.0	1.2	4.2
20	T640	217	16.2	10.5	13.4	12.5	2.0	5.6
	B640		16.2	10.5	13.4	10.5	1.4	4.5
21	T640	215	16.2	10.5	13.4	10.0	1.2	4.2
	B640		16.2	10.5	13.4	10.0	1.2	4.2
22	T640 17V	216	16.2	10.5	13.4	8.7	1.0	3.6
	B640		16.2	10.5	13.4	8.7	1.0	3.6
23	T2450	3	25.0	9.1	15.2	11.0	1.8	5.4
	B2450		25.0	9.1	15.2	11.0	1.8	5.4
24	T2450	12	25.0	9.1	15.2	10.0	1.3	4.4
	B2450		25.0	9.1	15.2	10.0	1.3	4.4
25	T640	11	11.1	6.3	8.7	14.0	2.6	6.6
	B640		11.1	6.3	8.7	11.0	1.8	5.4

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

TABLE II-8 (Cont)

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
AK26	T640	10	11.1	6.3	8.7	10.0	1.3	4.4
	B640		11.1	6.3	8.7	8.8	1.2	4.1
27	T640	218	16.2	10.5	13.4	10.5	1.4	4.5
	B2450		40.0	18.7	29.0	10.5	1.4	4.5
28	T5.5	219	-	-	-	10.0	1.2	4.2
	B1500		28.0	15.0	21.5	8.7	1.0	3.6
29	T2450	13	25.0	9.1	15.2	10.4	1.6	4.8
	B2450		25.0	9.1	15.2	10.4	1.6	4.8
30	T640	202	16.2	10.5	13.4	8.5	1.0	3.4
	B640		16.2	10.5	13.4	8.5	1.0	3.4
31	T955	14	12.0	6.0	9.0	8.5	1.0	3.4
	B145		-	-	-	12.5	2.0	5.6
32	T210*	210	20.7	9.6	15.2	9.3	1.1	3.9
	B210*		20.7	9.6	15.2	9.3	1.1	3.9
33	T2450	209	40.0	18.7	29.0	7.0	2.1	4.5
	B2450		58.0	18.7	38.0	18.5	4.5	11.5
34	T640	15	11.1	6.3	8.7	10.0	1.3	4.4
	B640		11.1	6.3	8.7	8.8	1.2	4.1
35	T2450	202	49.0	18.7	33.9	8.5	1.0	3.4
	B680†		41.0	11.6	26.0	175.0	50.0	-
36	T16	16	-	-	-	8.0	1.0	3.4
	B1500		22.0	8.2	15.0	8.4	1.0	3.8
37	T1500	201	28.0	15.0	21.5	8.7	1.0	3.6
	B1100†		50.0	13.6	32.0	230.0	70.0	-
38	T960	13	13.4	7.5	10.5	10.4	1.6	4.8
	B960		13.4	7.5	10.5	10.4	1.6	4.8
39	T2450	221	40.0	18.7	29.0	8.7	1.0	3.6
	B960		18.8	11.6	14.5	9.3	1.1	3.9
40	T145	17	-	-	-	8.6	1.8	5.3
	B640		11.5	5.9	8.7	15.5	1.6	4.8
41	T680†	202	41.0	11.6	26.0	175.0	50.0	-
	B680†		41.0	11.6	26.0	175.0	50.0	-
42	T1500	223	21.6	13.0	17.3	8.7	1.0	3.6
	B1500		21.6	13.0	17.3	8.7	1.0	3.6
43	T960	20	13.4	7.5	10.5	10.4	1.6	4.8
	B65		-	-	-	18.0	1.8	5.3
44	T640	222	16.2	10.5	13.4	8.5	1.0	3.4
	B640		16.2	10.5	13.4	8.5	1.0	3.4
45	T2450	204	29.2	18.7	24.0	9.3	1.1	3.9
	B100		-	-	-	9.3	1.1	3.9
46	T630	19	8.0	5.0	6.5	9.5	1.6	4.9
	B630		8.0	5.0	6.5	9.5	1.6	4.9
47	T1500	202	26.8	13.0	18.0	7.1	1.0	3.7
	B1500		26.8	13.0	18.0	7.1	1.0	3.7
48	T2450	204	29.2	18.7	24.0	9.3	1.1	3.9
	B2450							
49	T2450	224	44.0	18.7	31.0	8.5	1.0	3.4
	B2450		44.0	18.7	31.0	8.5	1.0	3.4
50	T(P)820		16.4	9.6	13.0	6.2	1.0	3.2
	(S)682	216	14.8	8.5	11.6	6.2	1.0	3.2
	B(P)820		16.4	9.6	13.0	6.2	1.0	3.2
	(S)682		14.8	8.5	11.6	6.2	1.0	3.2
500	T640	15	11.1	6.3	8.7	10.0	1.3	4.4
	B640		11.1	6.3	8.7	8.8	1.2	4.1
501	T640	2	11.1	6.3	8.7	8.5	1.0	3.4
	B640		11.1	6.3	8.7	8.5	1.0	3.4

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

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SECTION III

SPRINGS

General

This section on spring combinations deals with:

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

The AF, AG, AJ, and AL 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 and AM relays have 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.

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

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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 pretensioned single wires is always supplied. This facilitates terminal numbering and provides sufficient tension to hold the fixed block 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 towards 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 of 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, AJ, and AL relays are designed to permit operating contacts in three stages, ie, 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 24 make-or 24 break-twin-wire contacts provided in each of the 24 positions. These positions are arranged in two vertical rows of 12 positions each. The contacts farthest from the core are positions 1 to 12 and those nearest the core are 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 and AM relays 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 as a part of 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 is 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 relays have been designed to operate various contact arrangements in positions 1 to 12 as shown in Table III-1a. 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 and AM relays are also shown in Table III-1b.

The actuating cards for the 24-spring relays are designed to provide only 24 make-contacts, or 24 break-contacts.

Contact Forces

The twin wires that form make- and break-contacts are pretensioned to provide nominal 12.5-gram contact force for each

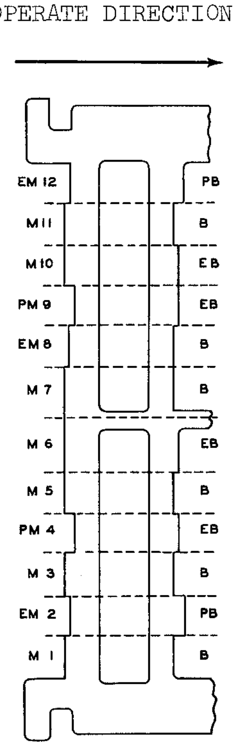

Fig. III-1 - Card Profile

contact pair. For special cases, the twin wires may be pretensioned to provide nominal 8-gram contact force (light contact force) or nominal 18-grams contact force (heavy contact force).

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 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, only when different spring positions are involved.

TABLE III-1a

CARDS
AF, AG, AJ, AND AL RELAYS

Contact Arrangements
Contact Position Number

Travel	1	2	3	4	5	6	7	8	9	10	11	12
Short P-19A130	M B	M B	M B	M B	M B	M B	M B	M B	M B	M B	M B	M B
Intermediate P-19A131	M B	M EB	M B	M EB	M B	M EB	M B	M EB	M B	M EB	M B	M EB
Intermediate P-19A132	M B	M EB	M B	M EB	M B	EM B	M B	M EB	M B	M EB	M B	EM B
Long P-19A133	M B	EM PB	M B	PM EB	M B	M EB	M B	EM B	PM EB	M EB	M B	EM PB
Intermediate P-19A134	M EB	M EB	M EB	M EB	M EB	M EB	M EB	M EB	M EB	M EB	M EB	M EB
Intermediate P-19A135	M EB	M EB	M EB	M EB	EM B	EM B	M EB	EM B	M EB	M EB	M EB	M EB
Intermediate P-19A136	EM B	M EB	EM B	M EB	M B	M EB	M B	M EB	EM B	M EB	EM B	M EB
Intermediate P-19A137	EM B	M EB	EM B	M EB	EM B	M EB	EM B	M EB	EM B	M EB	EM B	M EB

TABLE III-1b

CARDS
AK AND AM RELAYS

	1	2	3	4	5	8	9	10	11	12
Short P-10B701	M B	M B	M B	M B	M B					
Short P-10B702						M B	M B	M B	M B	M B
Intermediate P-10B699	M EB	M EB	M EB	EM B	EM B					
Intermediate P-10B700						EM B	EM B	M EB	M EB	M EB
Intermediate P-10B703	M EB	M EB	EM B	EM B	EM B					
Intermediate P-10B704						EM B	EM B	EM B	M EB	M EB
Intermediate P-10B705	M EB	M EB	M EB	M EB	M EB					
Intermediate P-10B706						M EB	M EB	M EB	M EB	M EB

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Spring Combination Numbers

AF, AG, AJ, and AL 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, and No. 501 to 24 break-contacts.

The spring combination numbers that 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 fewer 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 and AM 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 and AM relays 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 that have been assigned to date are given in Tables III-5 and III-6, which also indicate 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.

Balance Springs

The balance 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 balance springs is described in Section IX.

Buffer Spring (See Fig. I-16)

A removable U-shaped buffer spring is available; it may be attached to the AF, AG, AJ, and AL 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.

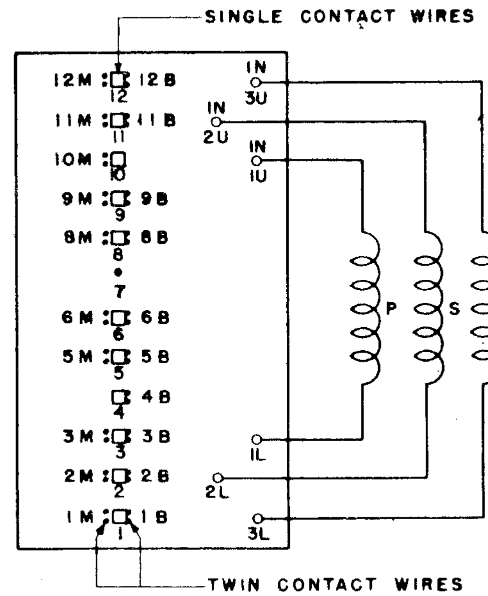
The pretensioned buffer spring is positioned between the spoolhead and outer legs of the core with a lip resting against the center leg of the core between the core plate and card. An adjustable tang, adjacent to the lip, controls the point at which the card engages the buffer spring as the relay operates.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

Terminals and Terminal Numbering

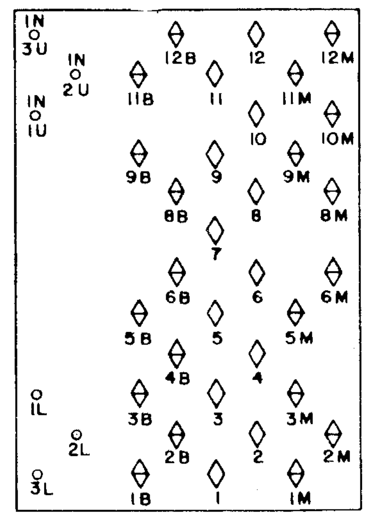
For test purposes, the winding terminals are extended to the front of the relay. The terminals for wiring are shaped to permit the use of solderless wrapped connections. The numbering for winding and contact terminals is shown in Fig. III-2 for the AF, AG, AJ, and AL relays and in Fig. III-3 for the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

Spring Combinations

In the circuit schematics, the wire spring relays are numbered by spring positions 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 AND CONTACT SPRING ARRANGEMENT AS VIEWED FROM THE FRONT (CONTACT SIDE) 12-POSITION AF, AG, AJ, AND AL RELAYS.



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

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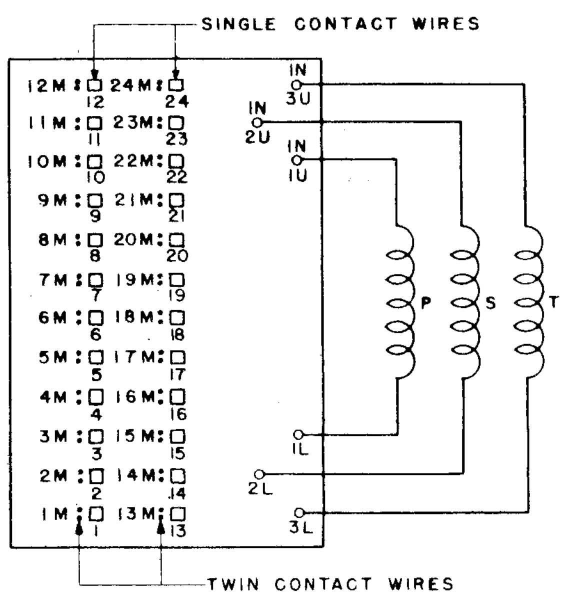
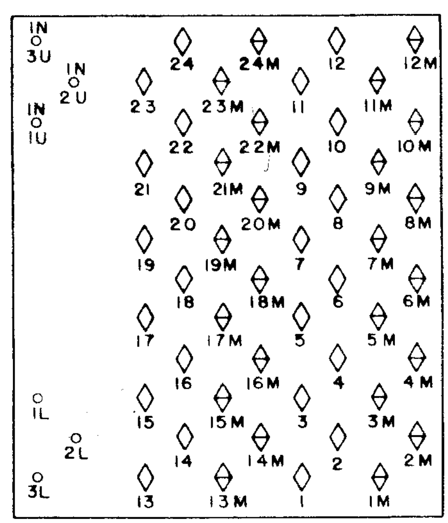


WINDING AND CONTACT SPRING ARRANGEMENT AS VIEWED FROM THE FRONT (CONTACT SIDE) 24-POSITION AJ RELAYS. THE 24-MAKE TYPE IS SHOWN; THE 24-BREAK TYPE IS NUMBERED IN THE SAME PATTERN.



WINDING AND TERMINAL ARRANGEMENT AS VIEWED FROM THE REAR (TERMINAL SIDE) 24-POSITION AJ RELAYS. THE 24-MAKE TYPE IS SHOWN; THE 24-BREAK TYPE IS NUMBERED IN THE SAME PATTERN.

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

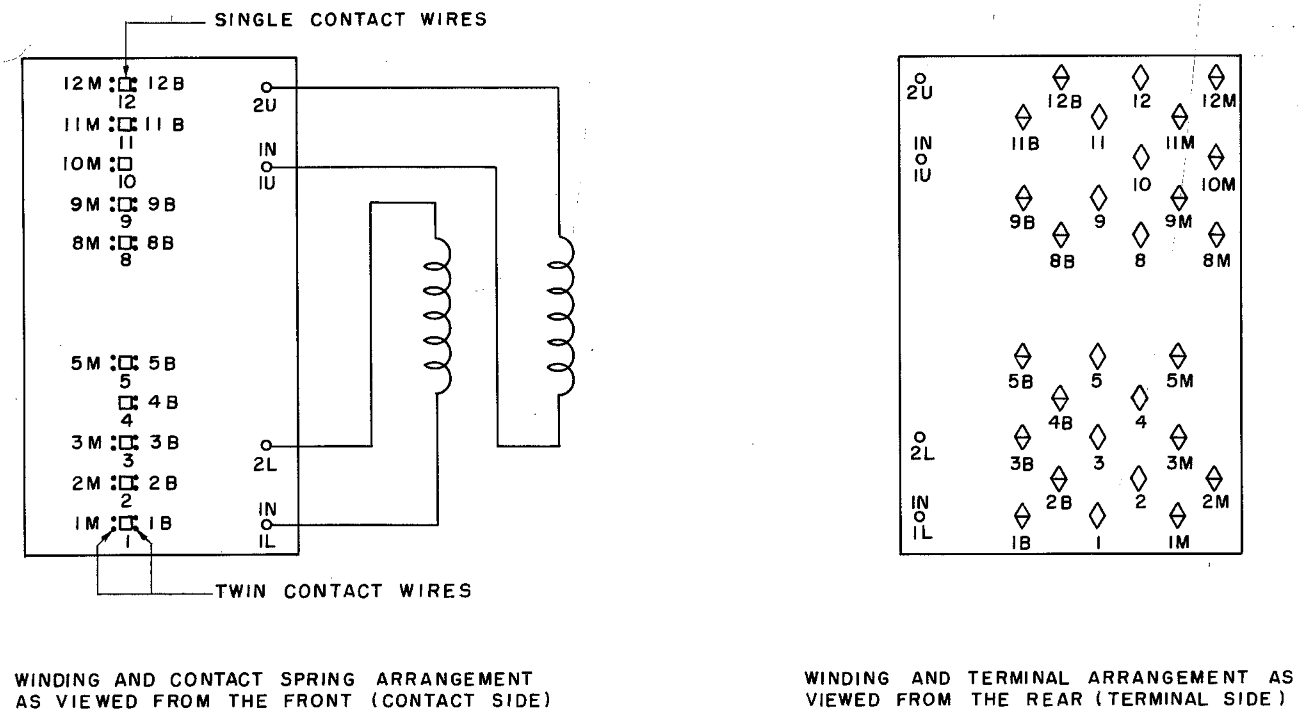


Fig. III-3 - AK and AM Relays - Terminal Arrangements

Notes

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).

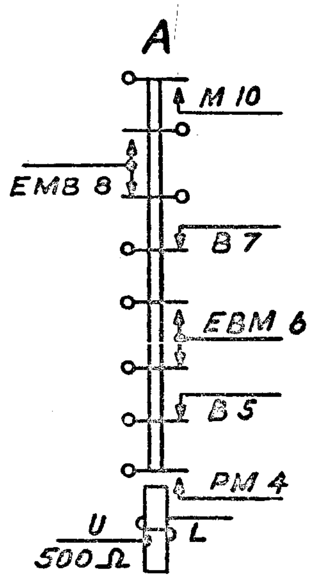


Fig. III-4 - Symbol for Use on Attached-Contact Type Schematic

TABLE III-2

SPRING COMBINATIONS
AF, AG, AJ, AND AL RELAYS

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	-	-	-	-

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TABLE III-2 (Cont)

SPRING COMBINATIONS
AF, AG, AJ, AND AL 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, AJ, AND AL RELAYS

Comb. No.	M	B	BM	EBM	EMB	Others	1	2	3	4	5	6	7	8	9	10	11	12
	Spring Combinations						Positions											
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
220	-	-	-	12	-	-	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM
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
249	-	-	-	9	3	-	EBM	EBM	EBM	EBM	EMB	EMB	EBM	EBM	EBM	EBM	EBM	EBM
250	2	5	-	3	1	1EM	M	M	B	EBM	B	EMB	B	EBM	B	EBM	B	EM

EMB

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TABLE III-3 (Cont)

SPRING COMBINATIONS
AF, AG, AJ, AND AL 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
AJ91- 271	2	1	-	4	2	-	M	EBM	-	EBM	-	EMB	B	EBM	-	EBM	M	EMB — AJ 91
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
ALL 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 (Cont)

SPRING COMBINATIONS
AF, AG, AJ, AND AL RELAYS

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Comb. No.	M	B	BM	EBM	EMB	Others	1	2	3	4	5	6	7	8	9	10	11	12
	Spring Combinations						Positions											
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
AJ101 – 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	1	1EM	M	M	M	EBM	M	EM	M	EBM	M	EBM	M	EMB
331	5	-	-	2	-	2EB	M	M	M	-	EB	EBM	EB	EBM	-	M	-	M
332	5	1	-	2	2	2EB	M	M	EBM	EBM	B	EMB	EB	EMB	EB	M	M	M
333	6	-	-	-	-	6EM	EM	M	EM	M	EM	M	EM	M	EM	M	EM	M
334	6	2	-	2	1	-	M	M	M	EBM	EMB	B	EBM	B	M	M	M	-
335	1	-	-	4	-	-	-	M	-	EBM	-	EBM	-	EBM	-	EBM	-	-
336	-	-	-	6	6	-	EMB	EBM	EMB	EBM	EMB	EBM	EMB	EBM	EMB	EBM	EMB	EBM
~~337~~	2	1	-	2	2	-	-	EBM	-	M	B	EMB	-	EBM	-	M	-	EMB
338	6	1	2	2	-	-	M	M	M	EBM	BM	-	B	EBM	BM	M	M	M
339	3	1	1	-	1	-	M	M	BM	-	B	-	-	-	-	M	-	EMB
340	-	-	-	-	-	6EM,6EB	EM	EB	EM	EB	EM	EB	EM	EB	EM	EB	EM	EB
341	-	-	-	-	-	6EM	EM	-	EM	-	EM	-	EM	-	EM	-	EM	-
342	-	-	-	-	-	6EB	EB	-	EB	-	EB	-	EB	-	EB	-	EB	-
343	6	-	-	6	-	-	M	EBM	M	EBM	M	EBM	M	EBM	M	EBM	M	EBM

TABLE III-4

SPRING COMBINATIONS
AF, AG, AJ, AND AL 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	-	1PMEB 3EM	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
424	1	2	1	2	1	-	-	1PBEM 1PMEB	M	PBEM	-	PMEB	B	EBM	B	EMB	-	EBM	BM	-
425	2	1	-	2	1	-	-	1EMPB	M	-	B	-	M	EBM	-	EMB	-	EBM	-	EMPB

Comb. No.	M	B	
500	24		Make in 24 positions
501	-	24	Break in 24 positions

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TABLE III-5
AK AND AM 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	-	-
19	6	4	-	M	M	M	B	B	B	B	M	M	M
20	5	2	1	-	B	M	M	M	M	M	BM	B	-

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TABLE III-6

AK AND AM 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	AK305
203	-	-	-	6	-	4	-	EBM	EBM	EBM	EM	EM	EM	EM	EBM	EBM	EBM	AK4
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	
221	1	-	-	3	4	-	-	M	EBM	-	EMB	EMB	EMB	EMB	-	EBM	EBM	
222	-	-	-	10	-	-	-	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	EBM	
223	4	-	-	2	2	-	-	M	M	EBM	-	EMB	EMB	-	EBM	M	M	

SECTION IV

HEATING DATA

General

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

Normal heating is the condition imposed on the 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 the condition to which the coil is subjected when the circuit ceases to function normally. Trouble condition may result from a continuous application of voltage (which normally is applied intermittently), or from a short circuit, cross, or false ground that 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 that has been subjected to a trouble condition will function satisfactorily thereafter. The coil, however, must withstand the trouble heating without creating a fire hazard. A coil meeting this trouble condition is said to be self-protecting.

Normal Operating Temperature Limits

Normal operating temperature limits are based on four factors:

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1. 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.

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

3. The possibility of injuries to personnel from bodily contact.

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

A normal mean winding temperature limit of 225° F has been in effect since 1919; relays and switching apparatus generally have been designed to withstand an average operating temperature of the coil of 225° F. 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 225° F 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 fire hazard will be reached. Such a fire hazard can 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 the establishment of 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.

Indefinite and 48-Hour Trouble Heating Limits

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 360° F, for cellulose-acetate-filled coils wound with thin-enameled wire per MS58364 was adopted. It was stipulated 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 360° F 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 MS58364 wire at 360° F for a cumulative time longer than 48 hours, the 250° F limit was retained for trouble heating periods of indefinite duration.

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 225° F 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 fractions of a second to several seconds on a call and is then de-energized 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 percent 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 1 second or for intervals up to 1 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 225° F, 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 1 second with any duty cycle, or 1 minute with 15-percent duty cycle, but introduces a substantial error for 50-percent 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.

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 relationship is $\rho = \rho_a + \rho_c = K_a A_a + \frac{1}{R_{c1} + \frac{1}{K_c A_c}}$

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 that would result from supplying 1 watt per square inch of radiating area; it 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.

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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 are shown in Table IV-3.

The allowable initial watts for any AF, AG, or AJ relay coil may be computed by 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, ie, 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 thermal conductance, the final temperature may be found in Fig. IV-2. The temperature coefficient for copper wire results in a rise of 1 percent for each 4.58° F increase in temperature. The hot resistance is therefore

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

To facilitate determining the hot resistance, the percent 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 is shown in the appendix. Conditions not covered herein should be referred to the relay requirement group.

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:

<u>Condition 1</u>

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

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

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

<u>Condition 2</u>

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

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

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

<u>Condition 3</u>

Watts $= 125\ \rho\ (225°\ F)$

Watts $= 150\ \rho\ (250°\ F)$

Watts $= 260\ \rho\ (360°\ F)$

Condition 4

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

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

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

Condition 5

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

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

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

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Condition 6

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

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

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

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

Condition 1

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

HEATING DATA

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 68° F.

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 WIRES

	Mean Winding Temperature Limit for Trouble Conditions			
	Cellulose-Acetate-Filled Coils		Spoolwound Coils	
Insulation	Indefinite	48 Hours*	Indefinite	48 Hours*
Enamel per MS58364	250° F	360° F	Not Recommended	
Enamel per MS58364	250° F	360° F	250° F	325° F
Heavy Formex per MS58371	360° F		360° F	
Single Nylon per LRM-6034,1N1; Double Nylon per LRM-6034,1N2; Single Nylon Plus Enamel (LRM-6034,2N1); Double Nylon Plus Enamel (LRM-6034,2N2)	360° F		360° F	
Cotton or Cotton Plus Enamel	360° F		360° F	

Notes:

1. For coils in which freedom from short-circuited turns is essential, or where inductance requirements are specified, enameled wire per MS58371, or nylon insulated wires per LRM-6034, should be used.

2. 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.

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

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

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PARALLEL, TWISTED, AND NONINDUCTIVE WINDINGS

Enameled wires, single nylon, or cotton should not be used. The insulation should be nylon per LRM-6034. Single cotton over MS58371 wire, or double cotton over MS58364, may also 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 225° F.

TABLE IV-2

HEATING LIMITS FOR AF, AG, AJ, AND AL RELAYS (Single-Wound Coils)

Res	Sleeve	Ther Cond	Allowable Wattage 225° F	250° F	360° F*
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
100		0.045	7.5	9.4	19.1
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 or cu	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	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
6000		0.046	7.6	9.6	19.6
9100		0.043	7.2	9.0	18.3

TABLE IV-2a

HEATING LIMITS FOR AF, AG, AJ, AND AL RELAYS (Multiple-Wound Coils)

Res	Sleeve	Ther Cond	Allowable Wattage† 225° F	250° F	360° F*
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 16		0.034	5.7	7.2	14.4
S 16		0.038	6.4	8.0	16.2
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

* 48-hour cumulative.
† Values listed should not be applied to winding simultaneously.

TABLE IV-2a (Cont)

HEATING LIMITS FOR AF, AG, AJ, AND AL RELAYS (Multiple-Wound Coils)

Res	Sleeve	Ther Cond	Allowable Wattage† 225° F	250° F	360° F*
P 170 S 140		0.033 0.043	5.6 7.2	7.0 9.0	14.1 18.3
P 198 S 90		0.034 0.041	5.7 6.9	7.2 8.7	14.5 17.5
P 200 S 200		0.044 0.040	7.4 6.7	9.2 8.4	18.7 17.0
P 210 S 1000		0.036 0.038	6.1 6.4	7.6 8.0	15.4 16.2
P 220 S 1150		0.040 0.043	7.4 7.2	9.2 9.0	18.7 18.3
P 300 S 300		0.034 0.040	5.7 6.7	7.2 8.4	14.5 17.0
P 335 S 335		0.039 0.036	6.6 6.1	8.2 7.6	16.6 15.3
P 360 S 1900		0.034 0.045	5.7 7.6	7.2 9.5	14.5 19.2
P 390 S 390		0.033 0.035	5.5 5.9	6.9 7.4	14.0 14.8
P 400 S 210		0.034 0.046	5.7 7.7	7.2 9.6	14.5 19.5
P 400 S 400		0.043 0.038	7.2 6.4	9.0 8.0	18.3 16.2
P 415 S 415 T 900		0.035 0.035 0.034	5.9 5.9 5.7	7.4 7.4 7.2	14.8 14.8 14.4
P 425 S 425		0.043 0.038	7.2 6.4	9.0 8.0	18.3 16.2
P 450 S 57		0.032 0.044	5.4 7.4	6.8 9.2	13.6 18.7
P 450 S 110		0.035 0.044	5.9 7.4	7.4 9.2	14.9 18.7
P 450 S 200		0.032 0.044	5.4 7.4	6.8 9.2	13.6 18.7
P 450 S 500	0.091 cu	0.038 0.045	6.4 7.6	8.0 9.5	16.2 19.2
P 540 P 540		0.033 0.036	5.6 6.1	7.0 7.6	14.1 15.3
P 550 S 550 T 525		0.033 0.037 0.041	5.6 6.2 6.9	7.0 7.8 8.7	14.1 15.8 17.5
P 700 S 700		0.034 0.043	5.7 7.2	7.2 9.0	14.5 18.3
P 700 S 3300		0.033 0.042	5.5 7.0	6.9 8.8	14.0 17.8
P 800 S 880		0.040 0.035	6.7 5.9	8.4 7.4	17.0 14.8
P 1000 S 42		0.033 0.045	5.6 7.6	7.0 9.5	14.1 19.2
P 1000 S 2700		0.034 0.043	5.7 7.2	7.2 9.0	14.5 18.3

* 48-hour cumulative.

† Values listed should not be applied to windings simultaneously.

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TABLE IV-2a (Cont)

HEATING LIMITS FOR AF, AG, AJ, AND AL RELAYS (Multiple-Wound Coils)

Res	Sleeve	Ther Cond	Allowable Wattage† 225° F	250° F	360° F*
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.
† Values listed should not be applied to windings simultaneously.

TABLE IV-3

HEATING LIMITS FOR AK AND AM RELAYS

	Ther Cond	Allowable Wattage 225° F	250° F	360° F*
One Coil Energized	0.031	5.1	6.5	13.2
Two Coils Energized	0.026	4.4†	5.5†	11.0†

* 48-hour cumulative
† Each Coil

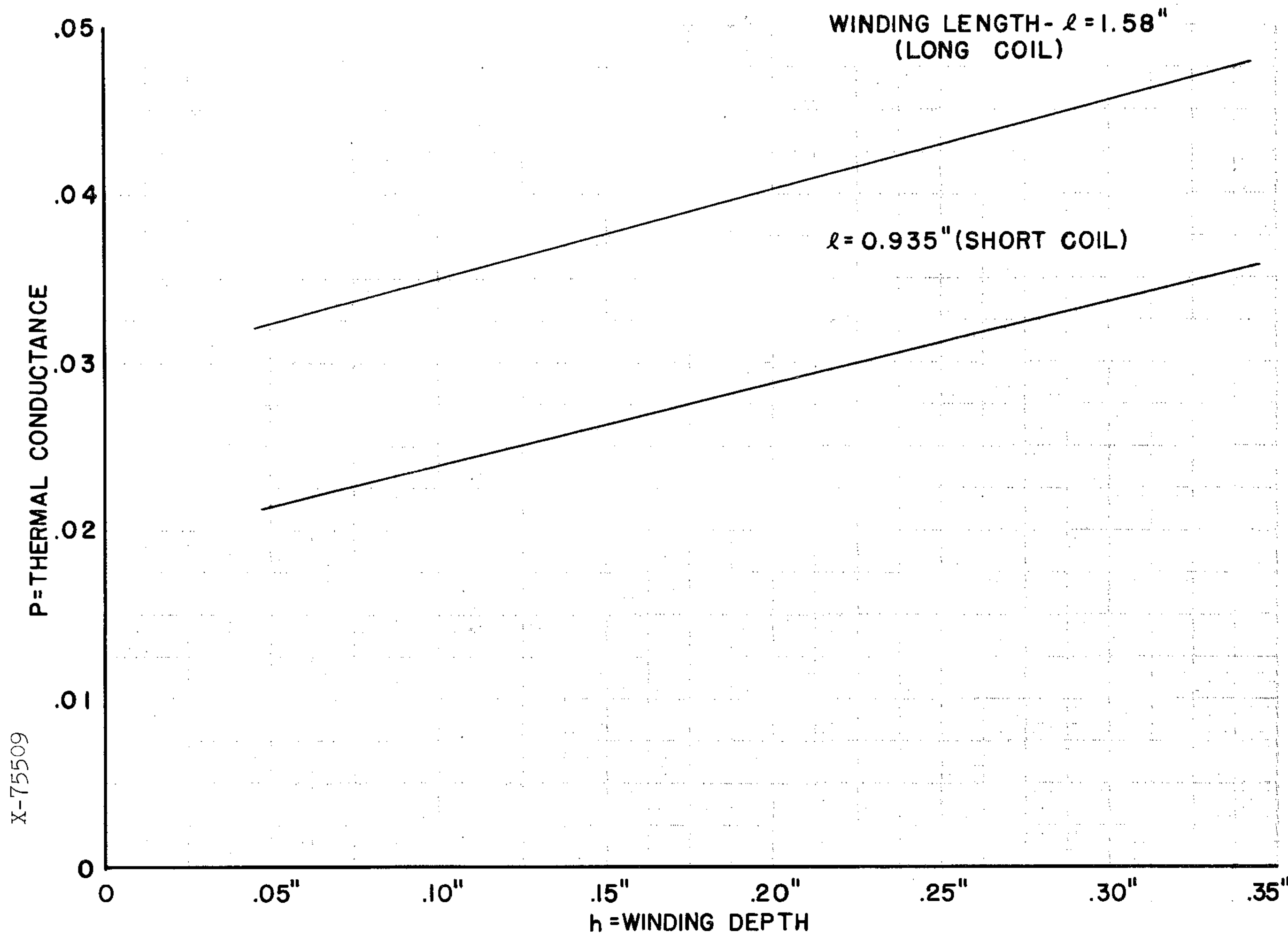

Fig. IV-1 - Thermal Conductance (ρ) for Various Winding Depths - AF, AG, and AJ Relays

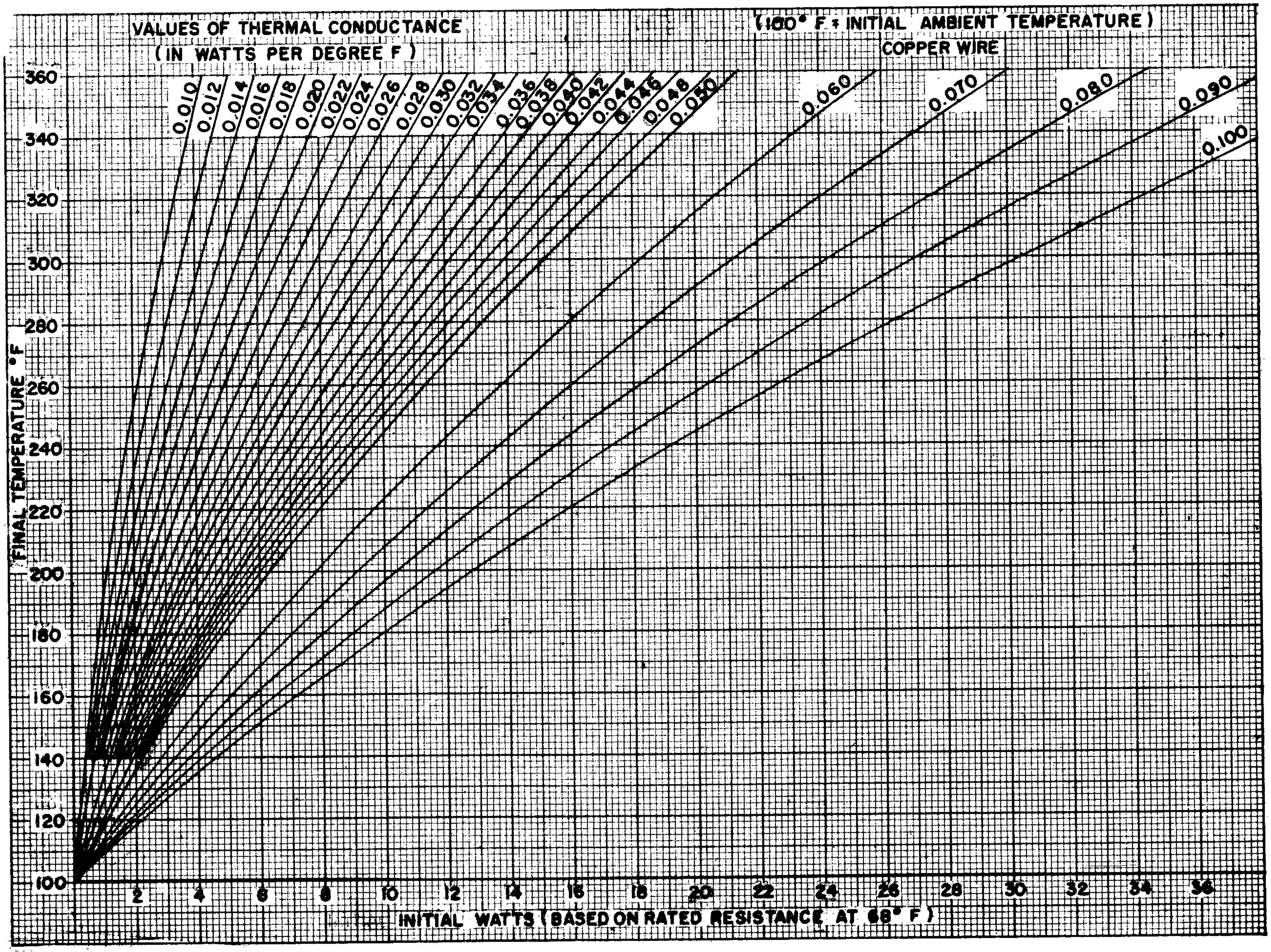

Fig. IV-2 - Constant Voltage Condition - Relation Between Initial Watts and Final Temperature

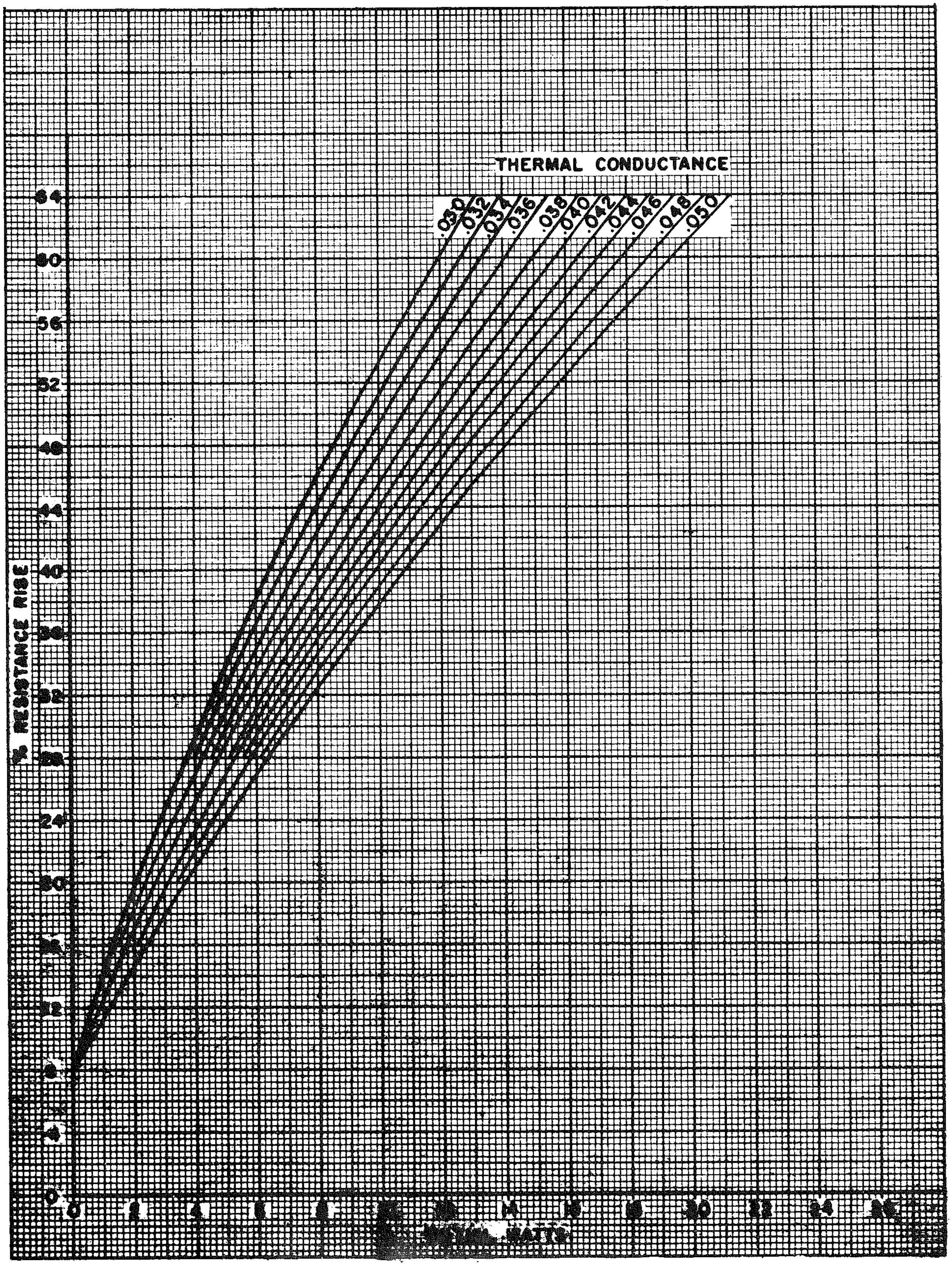

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Fig. IV-3 - Resistance Rise

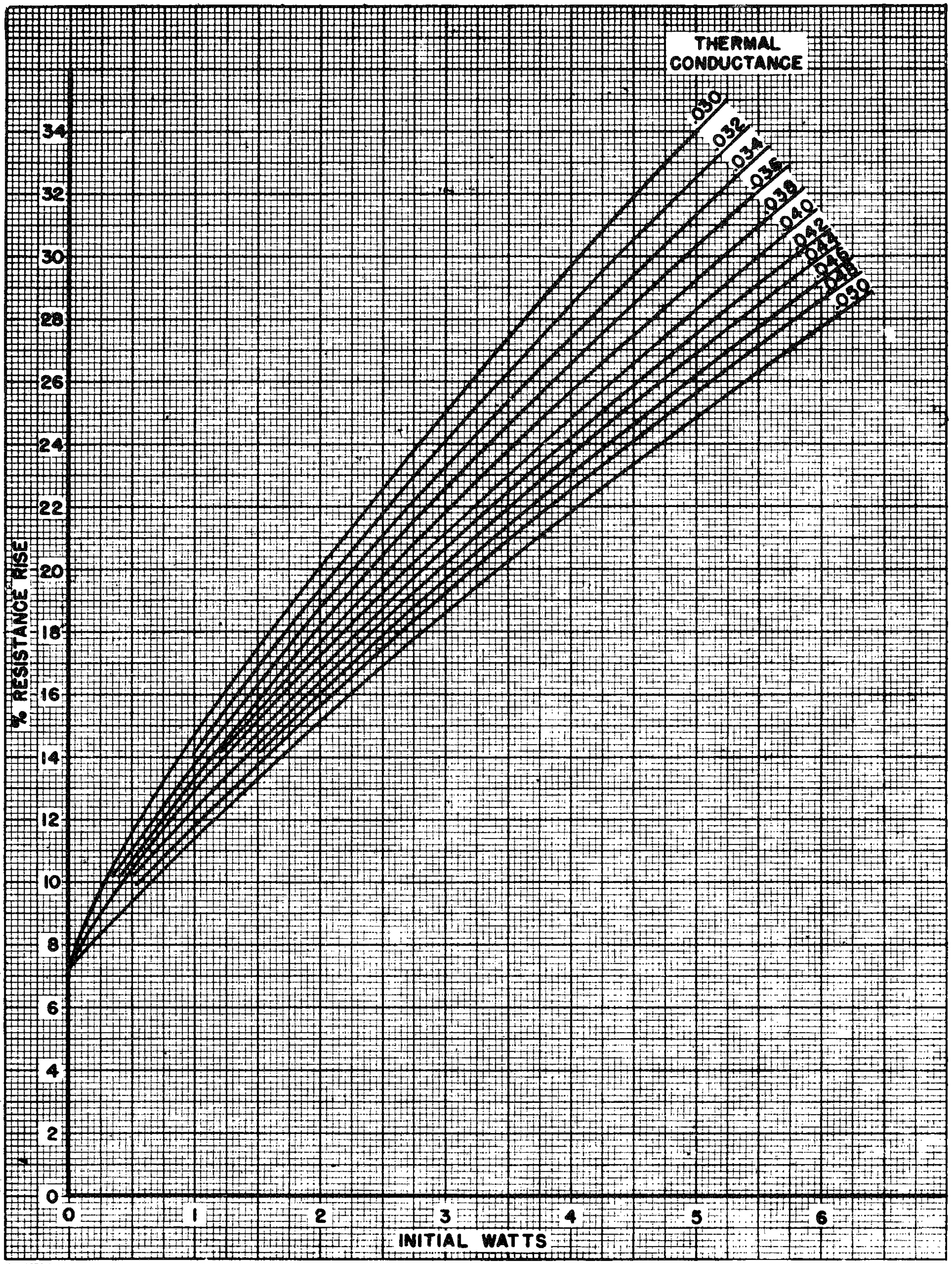

Fig. IV-4 - Resistance Rise

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:

1. The ampere turn energization and amount of leakage flux of the adjacent apparatus.
2. The function of the relay, ie, whether operate, nonoperate, hold, or release is involved.
3. The spacing between the relay and the interfering apparatus.
4. The amount and polarity of the leakage flux from the adjacent relays.
5. The extent to which the relay is affected by stray magnetic fields.
6. 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.

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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 inches horizontal

U relays 1-1/4 inches horizontal

U and AF relays 2 inches vertical

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, eg, 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: the effect on the adjustment of a relay when it is adjusted with adjacent relays energized, and 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 circuits or similar circuits in which a relay may be adjusted when relays in adjacent circuits are energized. Adjacent energized relays may be avoided by making the adjacent circuits busy or by 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.

Table V-1 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 percent, whereas with a U relay energized at 600-ampere turns above and below a Y relay, the maximum effect is 75 percent. 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 percent instead of 9.5 percent.

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 percent. With a U interfering relay above and below, the comparable effect on a stiff Y relay is above 25 percent.

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-percent margin between the hold readjust and test and 5-percent 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.

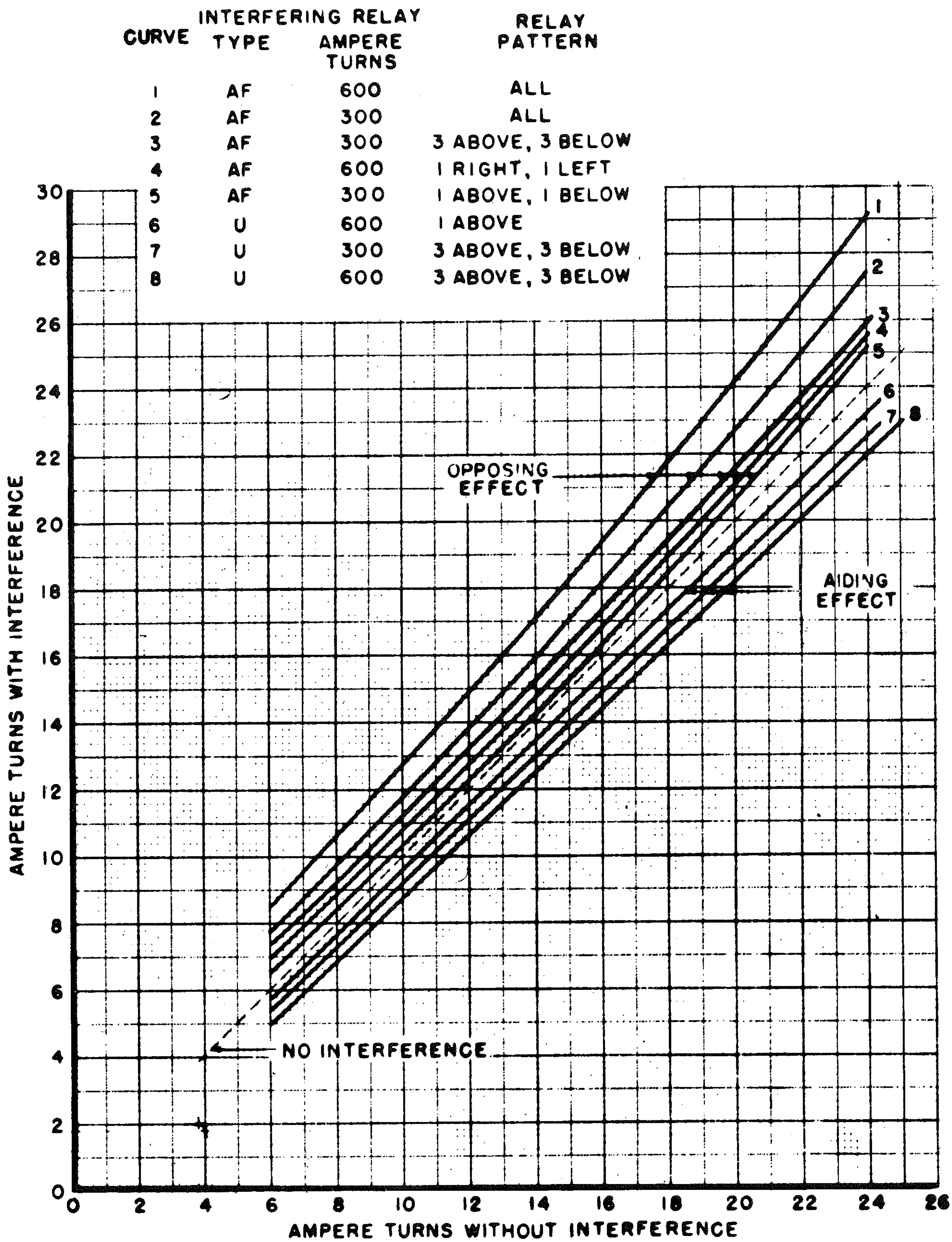
Effect on Performance of the Relay

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 percent 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 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.



CURVE	INTERFERING RELAY TYPE	INTERFERING RELAY AMPERE TURNS	RELAY PATTERN
1	AF	600	ALL
2	AF	300	ALL
3	AF	300	3 ABOVE, 3 BELOW
4	AF	600	1 RIGHT, 1 LEFT
5	AF	300	1 ABOVE, 1 BELOW
6	U	600	1 ABOVE
7	U	300	3 ABOVE, 3 BELOW
8	U	600	3 ABOVE, 3 BELOW

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

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 effect 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 relay 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 hold or release-ampere turns. The time can be obtained by reading these values on the minimum or maximum time curves.

Crosstalk

Another important effect of stray magnetic fields is crosstalk between

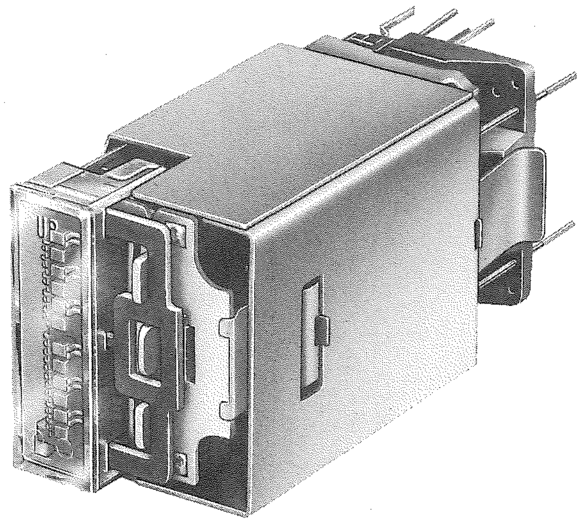

Fig. V-2 - AJ Relay with Shield

transmission relays of adjacent trunk circuits. The wire spring relay 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 No. 5 under test.
7	8	9	

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CONTACTS

General

The AF, AG, AJ, AK, AL, and AM relays are equipped with twin palladium contacts. A recent development has been the addition of a 0.001-inch gold overlay to this palladium surface. 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:

1. One size and kind of contact - palladium, with gold overlay
2. Lower contact force
3. Reduced open contacts
4. No contact locking
5. Lower rate of contact bridging
6. 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 overall 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 capacitor 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 contact reliability.

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 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 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.

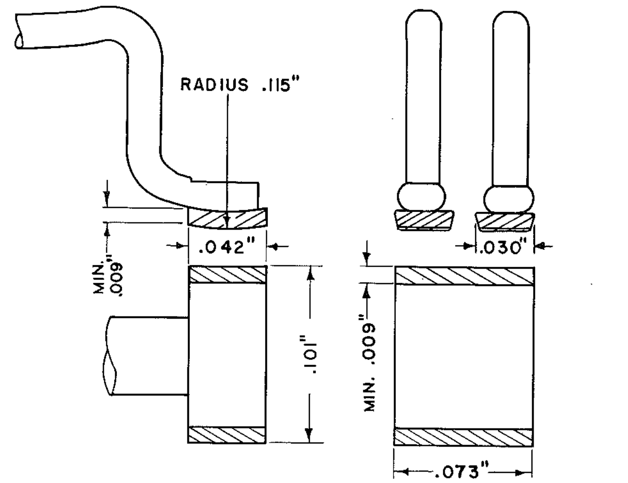

Fig. VI-1 - AF, AG, and AJ Relay Contacts

Fig. VI-3 shows the diagram of the percussive welding circuit. The capacitor C is charged by means of a direct current power supply, and the capacitor voltage also appears on the stationary single-contact wire. The other side of the capacitor is connected to the single contact. As the contact to be welded is moved toward the end of the wire, the capacitor 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 resistor R is used in series with the discharge circuit to limit the current and control the arcing period.

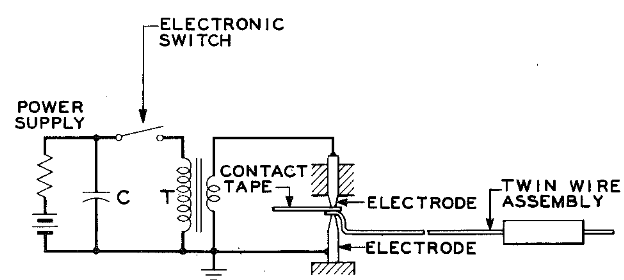

Fig. VI-2 - Welding Diagram - Twin Contacts

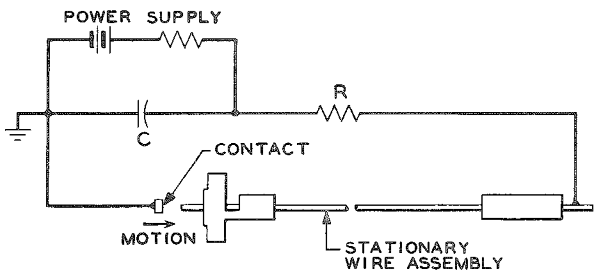

Fig. VI-3 - Welding Diagram - Single Contacts

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 to facilitate spot welding to a single wire. 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 fixed contacts and moving contacts.

Contact Dimensions

The dimensions of the wire spring relay contacts are:

	Twin contact	Single contact
	inch	
Width	0.030(ea)	0.073
Length	0.042	0.042
Thickness	0.009	0.009
Radius of Surface	0.115	

Contact Capability

General

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

1. Expected life from unprotected and protected contacts
2. Cost of metal and contact protection
3. Cost of replacing contacts having less than a 40-year life.

Consideration of the above 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 size of contact on the wire spring relay equals, at least, the capability of the 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 that 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 percent 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 buildups 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)
ohms	operations	
400 or less	2,000,000	500,000
over 400	2,000,000	2,000,000

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

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 No. 5 crossbar system and the 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.

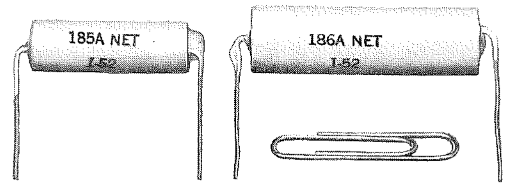

Fig. VI-4 - Protection Networks

The dimensions of the two networks are:

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

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-ohm 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 that 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 encountered on the wire spring relays, even with the lower contact forces.

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*	Short Leads†
AF, AJ Relays (0.006-inch 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-inch 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

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For relay loads with high stop discs, reduce above life estimates by 20 percent

Lamp Loads

One ampere steady state current.

* Leads over 20 feet
† Leads less than 20 feet
‡ In series with 90-ohm noninductive resistance
§ Nominal voltage 52
\# Effective turns

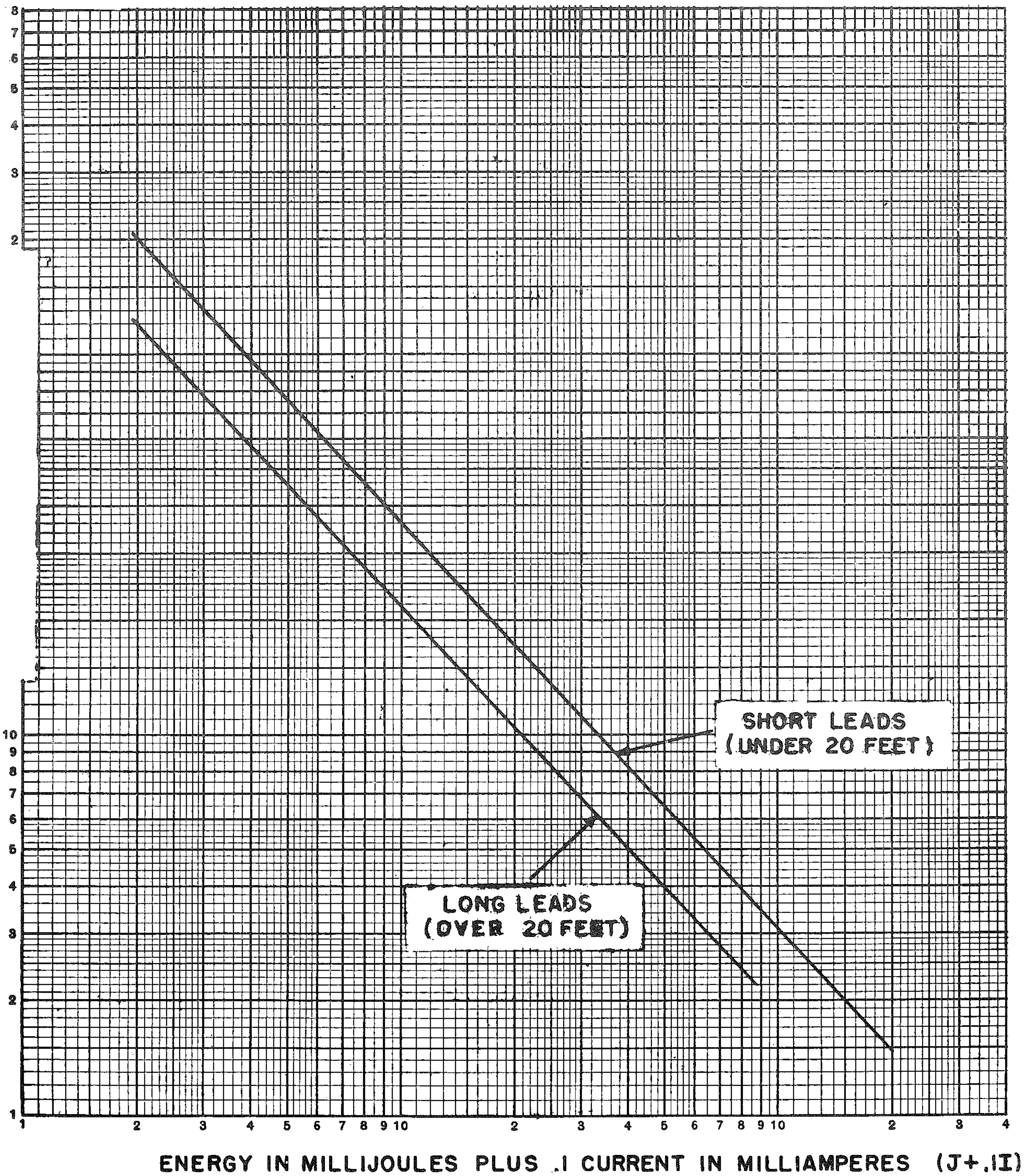

Fig. VI-5 - Wire Spring Relay Contacts Life Estimates

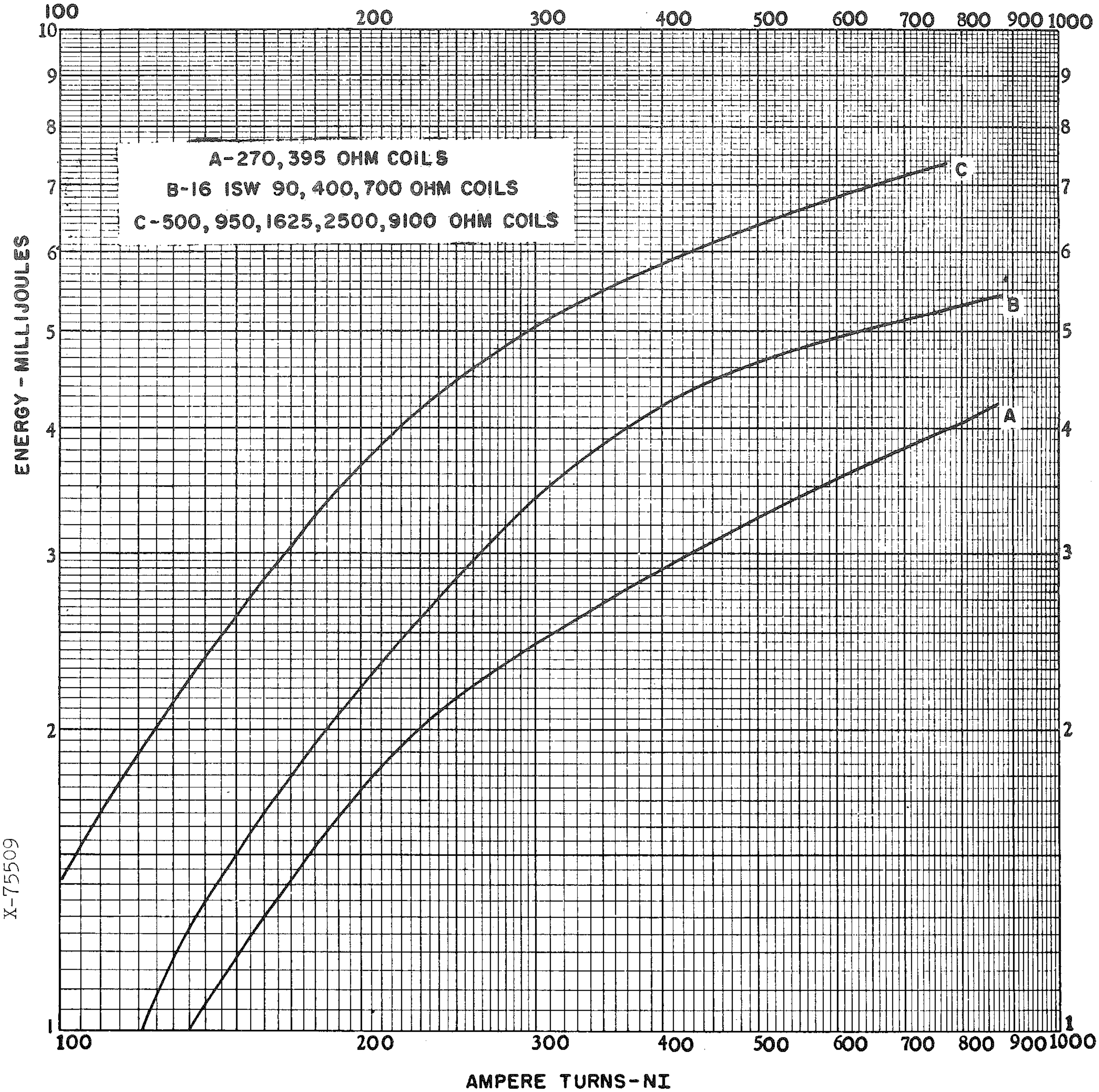

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Fig. VI-6 - AF and AJ Relays - Energy Curves -
0.014-Inch or 0.002-Inch Stop Discs

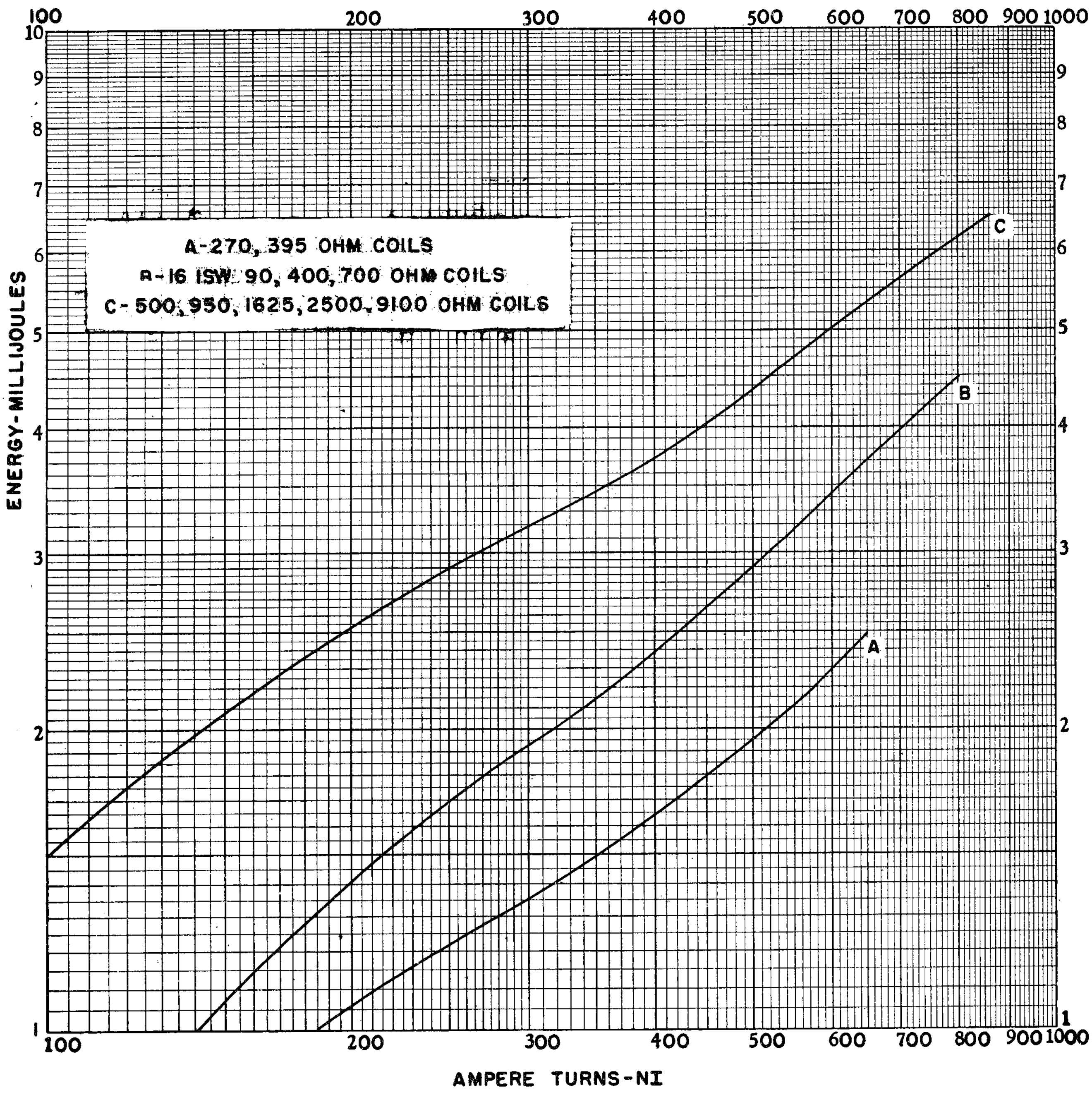

Fig. VI-7 - AF and AJ Relays - Energy Curves - 0.006-Inch Stop Discs

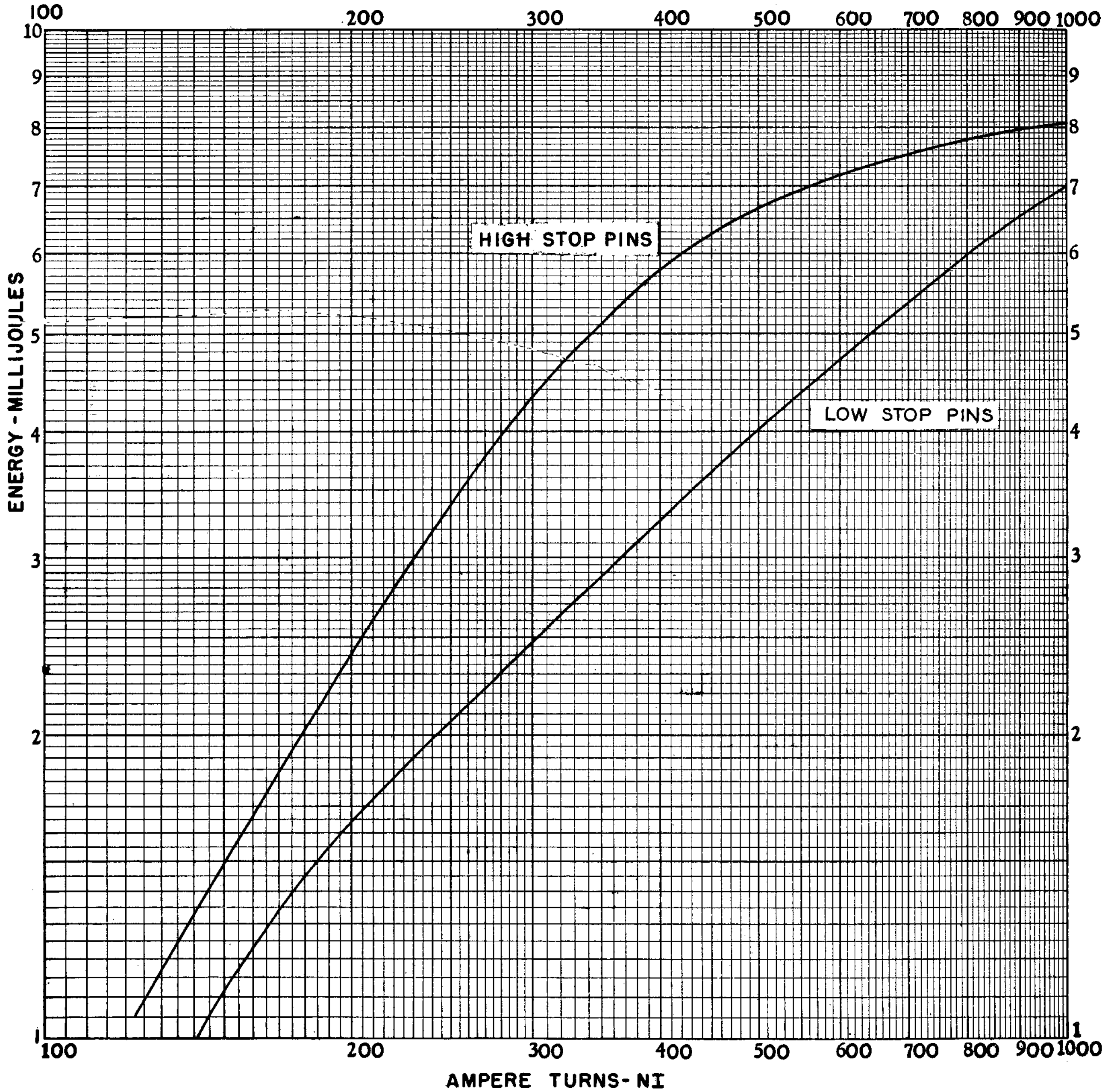

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Fig. VI-8 - U Relay - Energy Curves

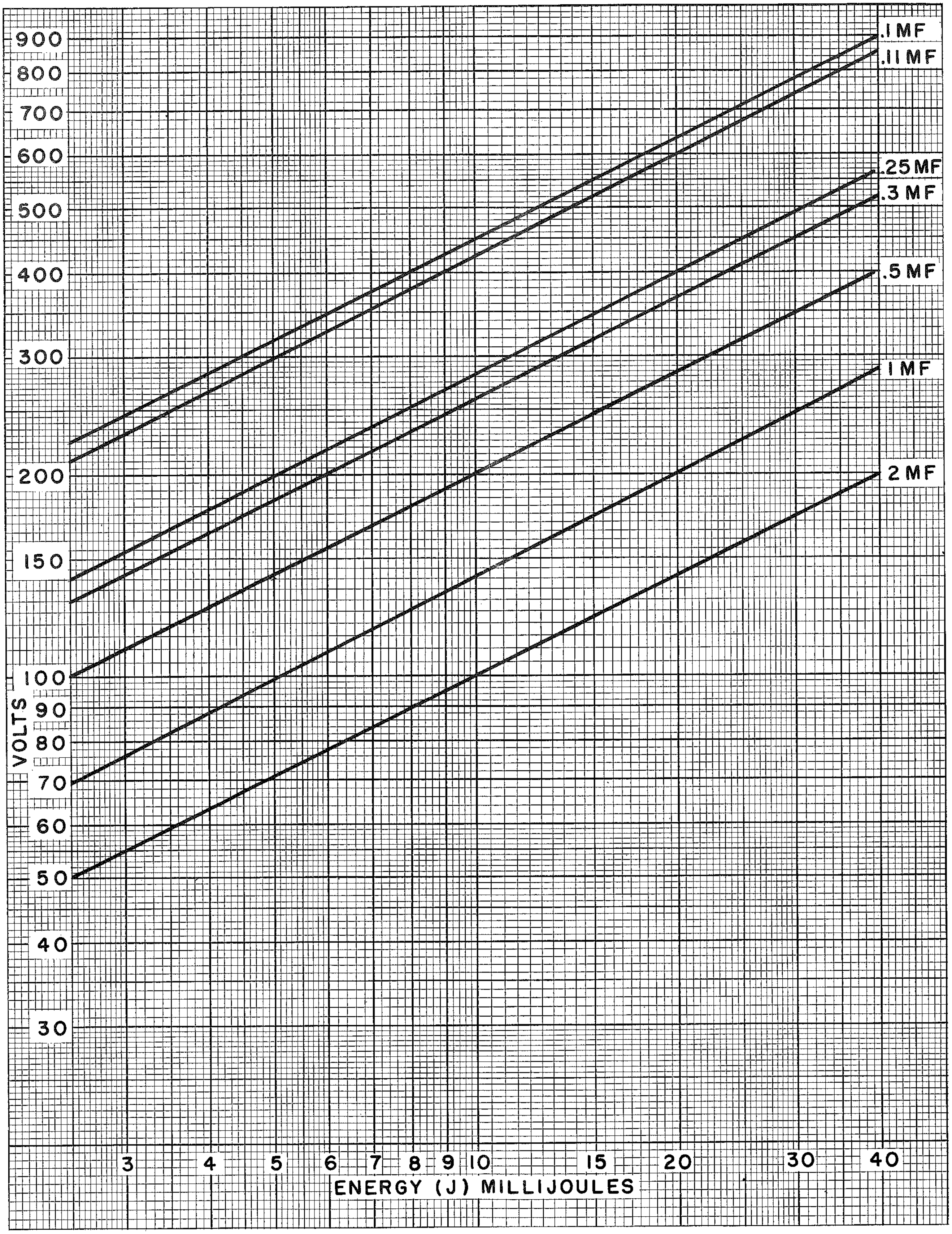

Fig. VI-9 - Protection Peak Voltages

SECTION VII

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 determining 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 that 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 that 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 time 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 time. 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 percent 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 buildup, 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"; 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 $= \frac{N^2}{R} \times 10^{-3}$

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 percent for the AG relay and 10 percent 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 sleeves.

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 multiplied 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; 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 msec) 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.

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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.

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

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

$$NI = 19{,}400 \text{x} 8.2 = 160$$

In Fig. VII-1, find the point corresponding to 2750 ohms and 19,400 turns (63 msec on horizontal scale). Project vertically along 63-msec line to intersection with NO SLEEVE curve (65 msec on vertical scale). Project horizontally along 65-msec line to intersection with 0.5 CURRENT RATIO line. Project vertically and read 48 msec on horizontal scale. For 160 NI on the AF curve, read 0.96 for a saturation correction factor. The operate time is therefore 48x0.96 = 46 msec.

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:

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

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 IV) 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:

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

The minimum operate time curve, Fig. VII-2, should be used. The operate time as read should be increased by 5 percent for the AF, 10 percent for the AJ, or 20 percent 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 msec.

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 ISW 90	270	395 or 400	700
	ohms			
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-gram 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 percent.

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 percent 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 msec, 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:

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

$$\text{Conductance} = \frac{(3330)^2}{400} = 27.2\text{x}10^3 \text{ mhos}$$

$$= 27.2 \text{ Kmhos}$$

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

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 percent variation.

For applications, such as the AMA Center, where the maximum operate times are specified for troubleshooting reasons, and where it is feasible to turn the relays to meet the specified operate time requirement, limits of ±20 percent 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, ie, 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:

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

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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 buildup time for the coil. To obtain the maximum operate time, a mechanical time of 1.3 msec for short armature travel and 2.7 msec 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 msec for short travel or 2 msec 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 percent 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 watts	Short Travel (msec)	Intermediate Travel (msec)
1	1.3	2.7
2	1.0	2.0
3	0.9	1.8
5	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 gram armature tension specified in the M specification. The operate time will be increased about 20 percent if the armature tension is raised from 45 to 90 grams. The operate time will be increased about 60 percent 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 buildup 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

Figure 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 90-ohm 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, r^C, 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 factor 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.

turns $= N'$

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

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

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

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

The release time consists of three parts:

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Electrical Time. The time necessary for the flux to decrease to a point that 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 msec for short travel and 1.5 msec for intermediate travel for relays releasing an 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 are 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 percent 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 percent 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-ohm) 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

Relays with a nonoperate requirement are figured in the same way 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 msec. 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 msec. 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 times 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 percent 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-percent 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 percent, and for soaks of 150-ampere turns or less by 5 percent.

Average Releasing Time

The average release time is obtained by taking 80 percent 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.

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 show 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 large sleeves, 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 capacitor and resistor in shunt with a relay winding, or across a contact that 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 capacitor 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 msec for short travel and 1.5 msec 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 times for the AJ relay. The list of the release time curves for protected relays:

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

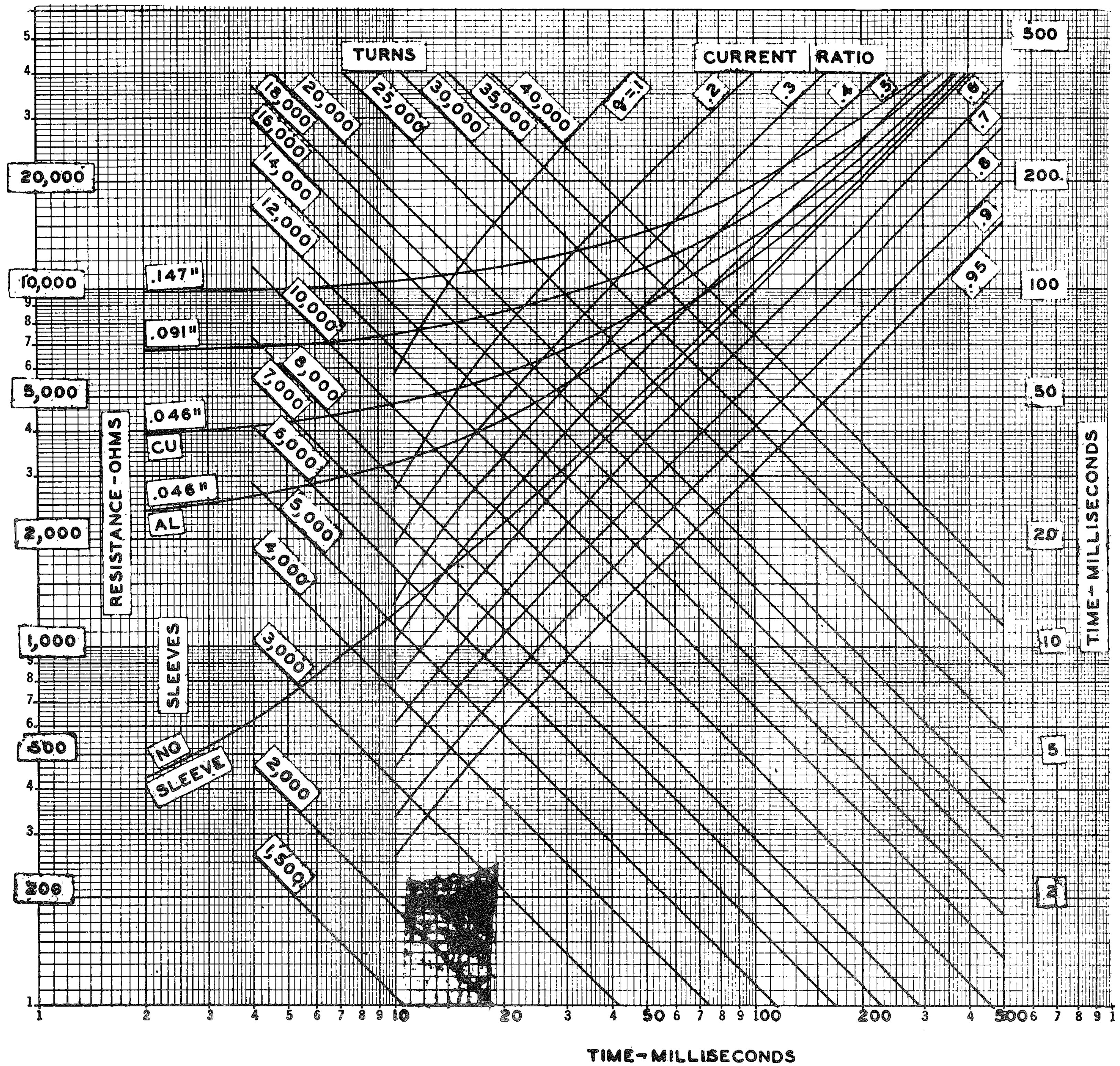
These curves apply to relays with all stop-disc heights since the release time of protected relays with the same ampere-turn release is independent of the stop-disc height. The release ampere turns, and therefore the release time, for the same spring load will vary with the stop-disc height.

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

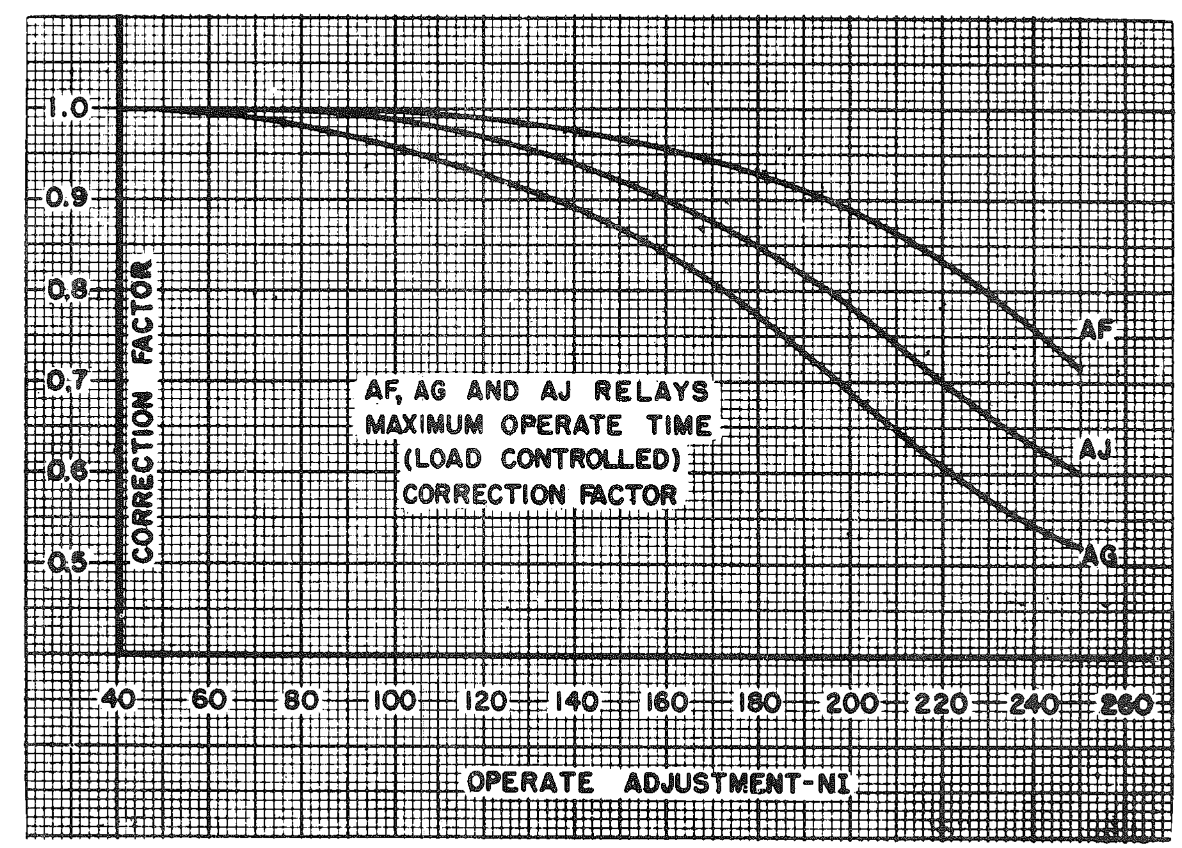
(THESE VALUES ARE INCLUDED IN q CURVES)

$L = .46\mu H$

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

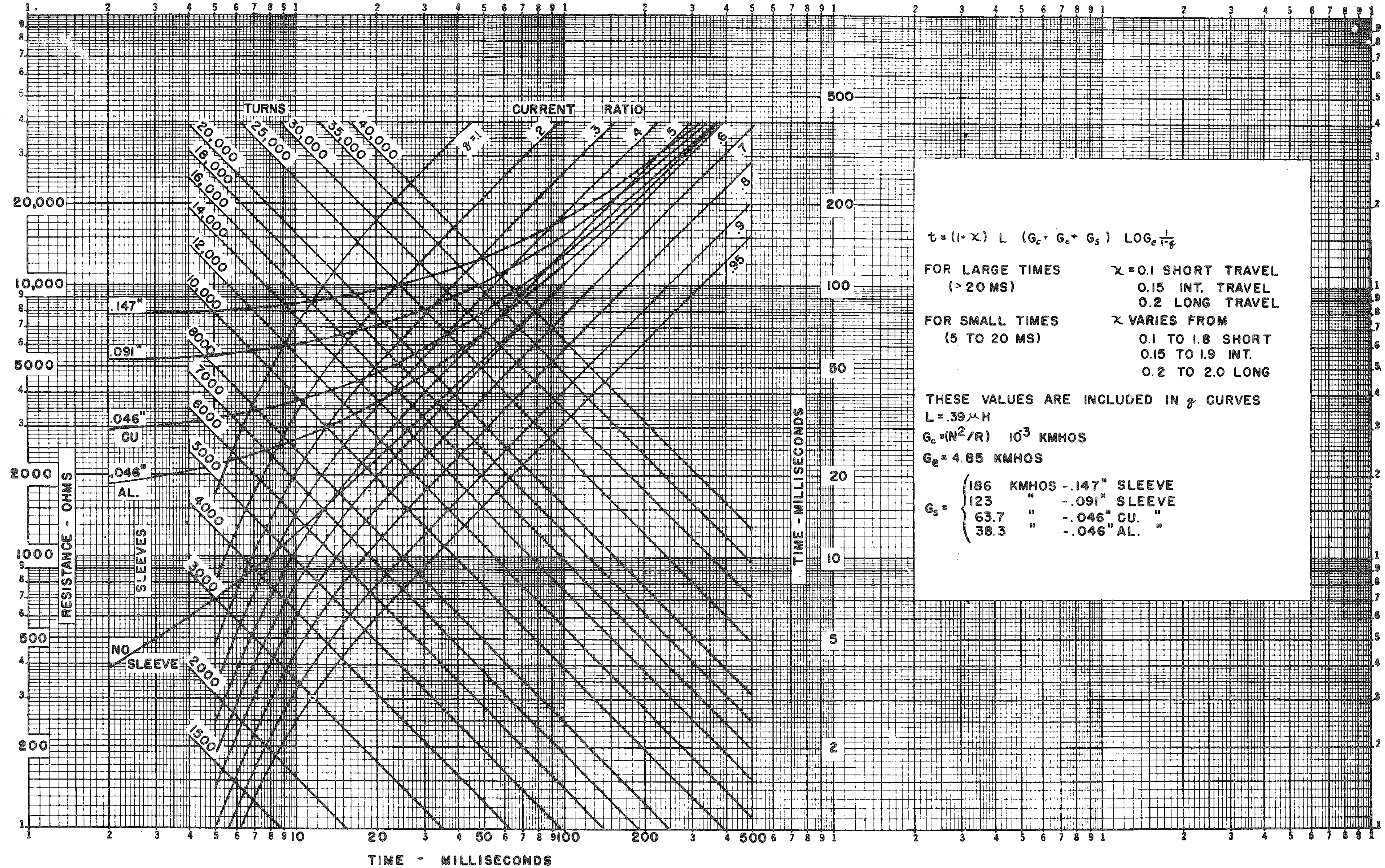
$G_e = 5$ KMHOS

$G_s = \begin{cases} 210", & .147" \text{ SLEEVE} \\ 144", & .091" \text{ SLEEVE} \\ 78", & .046" \text{ SLEEVE, CU.} \\ 44", & .046" \text{ SLEEVE. AL.} \end{cases}$



X-75509

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



X-75509

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

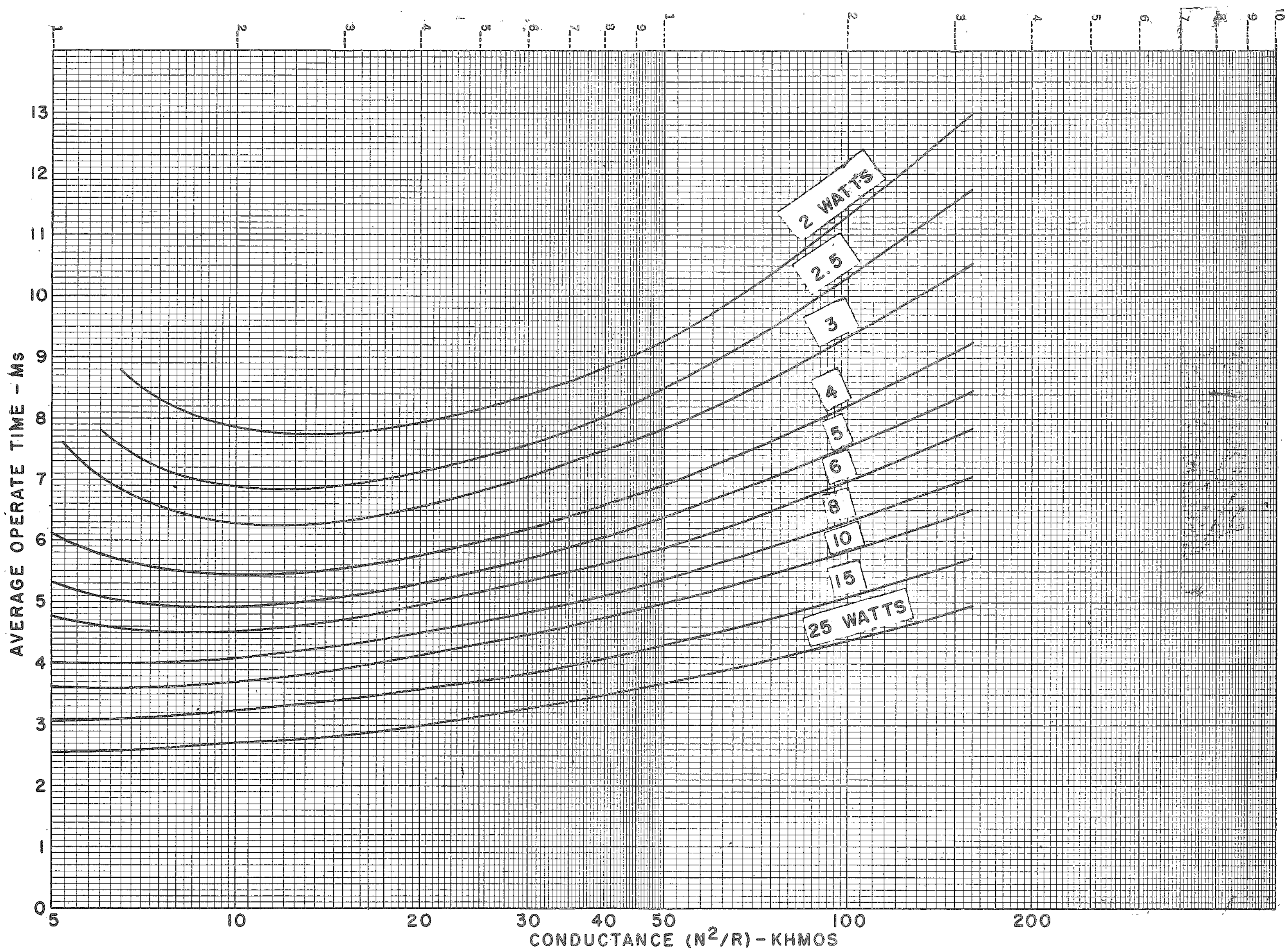


Fig. VII-3 - AF and AJ Relays - Short Armature Travel - Average Operate Time - Mass Controlled

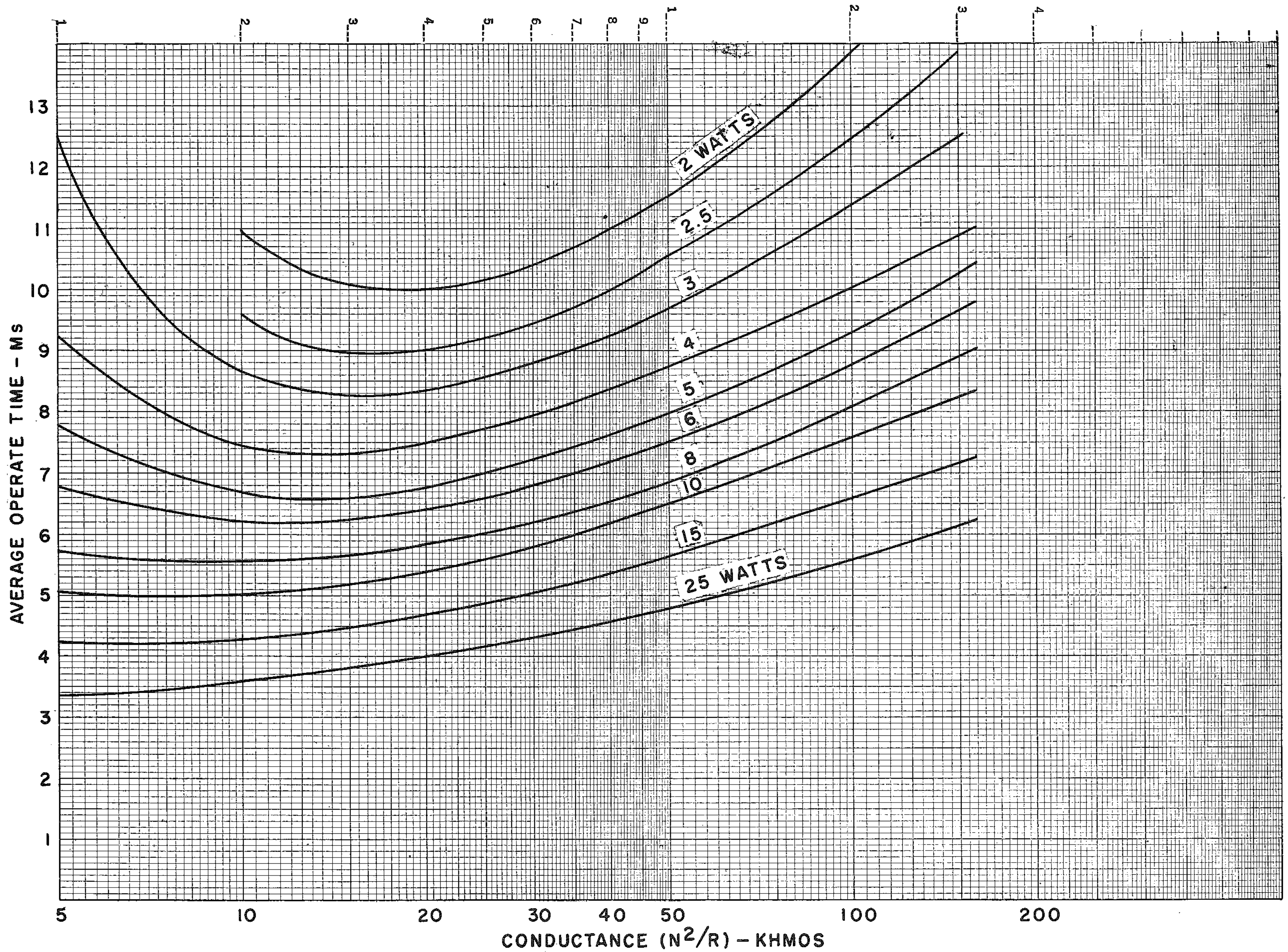


Fig. VII-4 - AF and AJ Relays - Intermediate Armature Travel - Average Operate Time - Mass Controlled

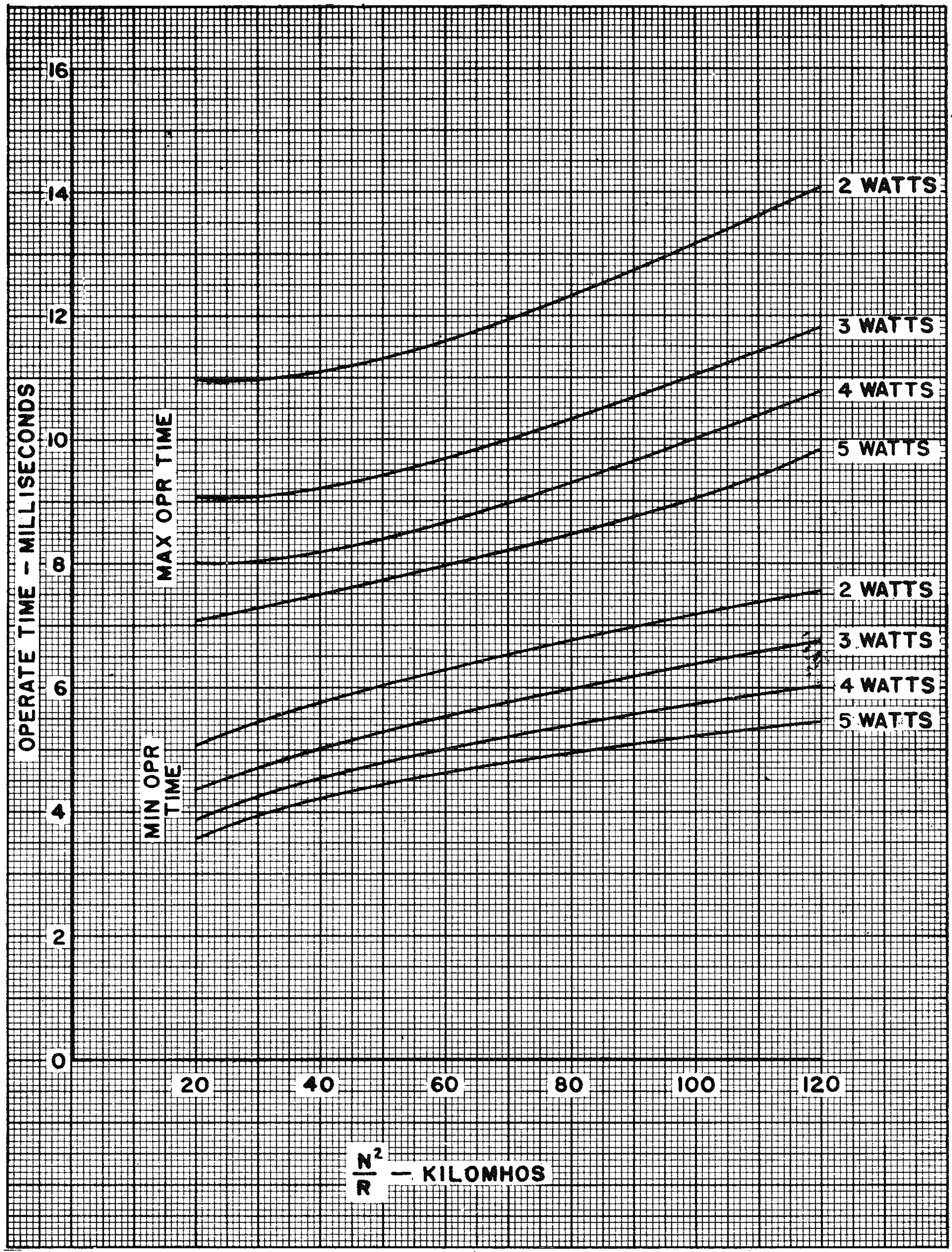


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Fig. VII-4A - AK Relay Operate Time - Short Travel

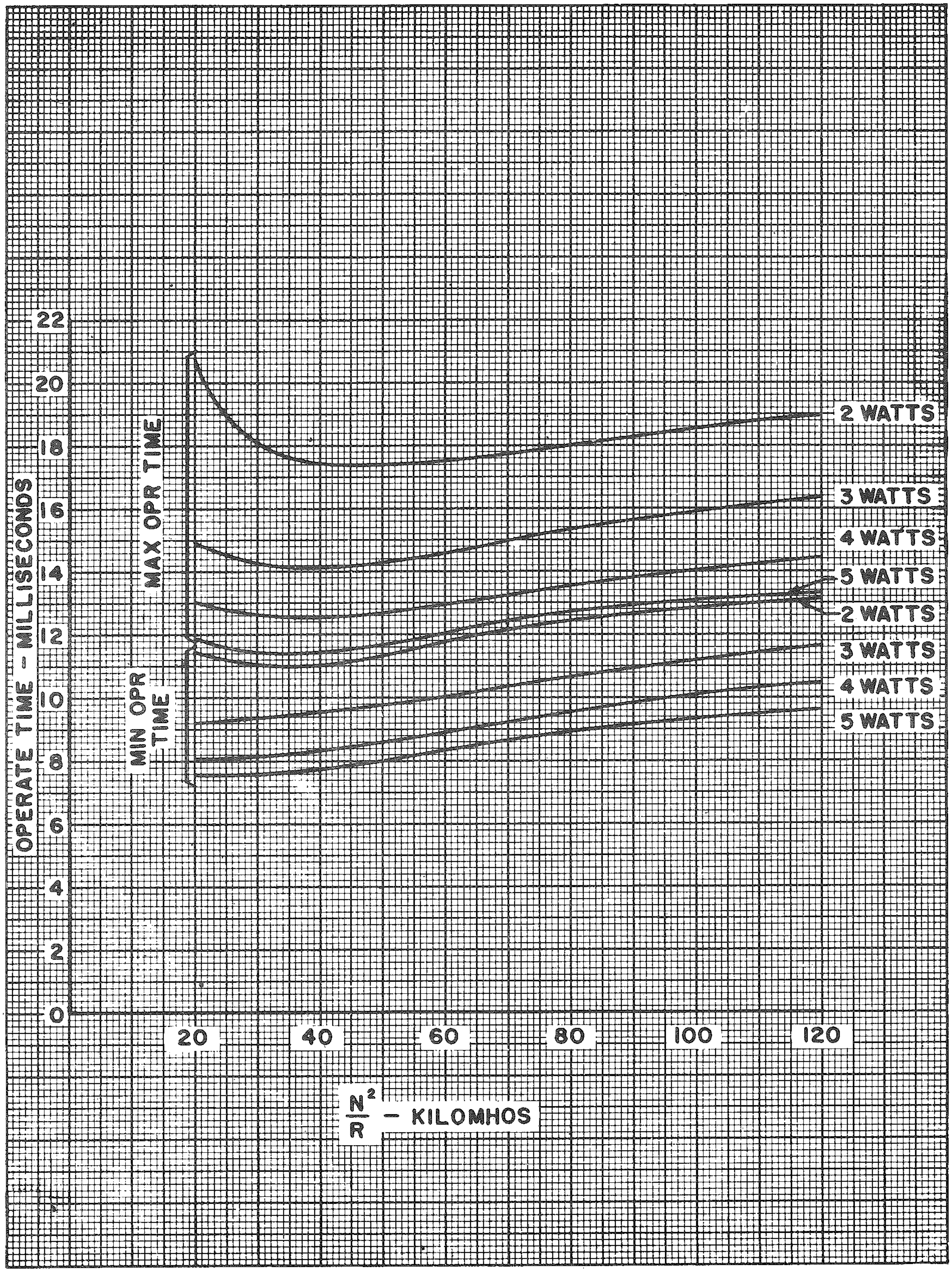

Fig. VII-4B - AK Relay Operate Time - Intermediate Travel

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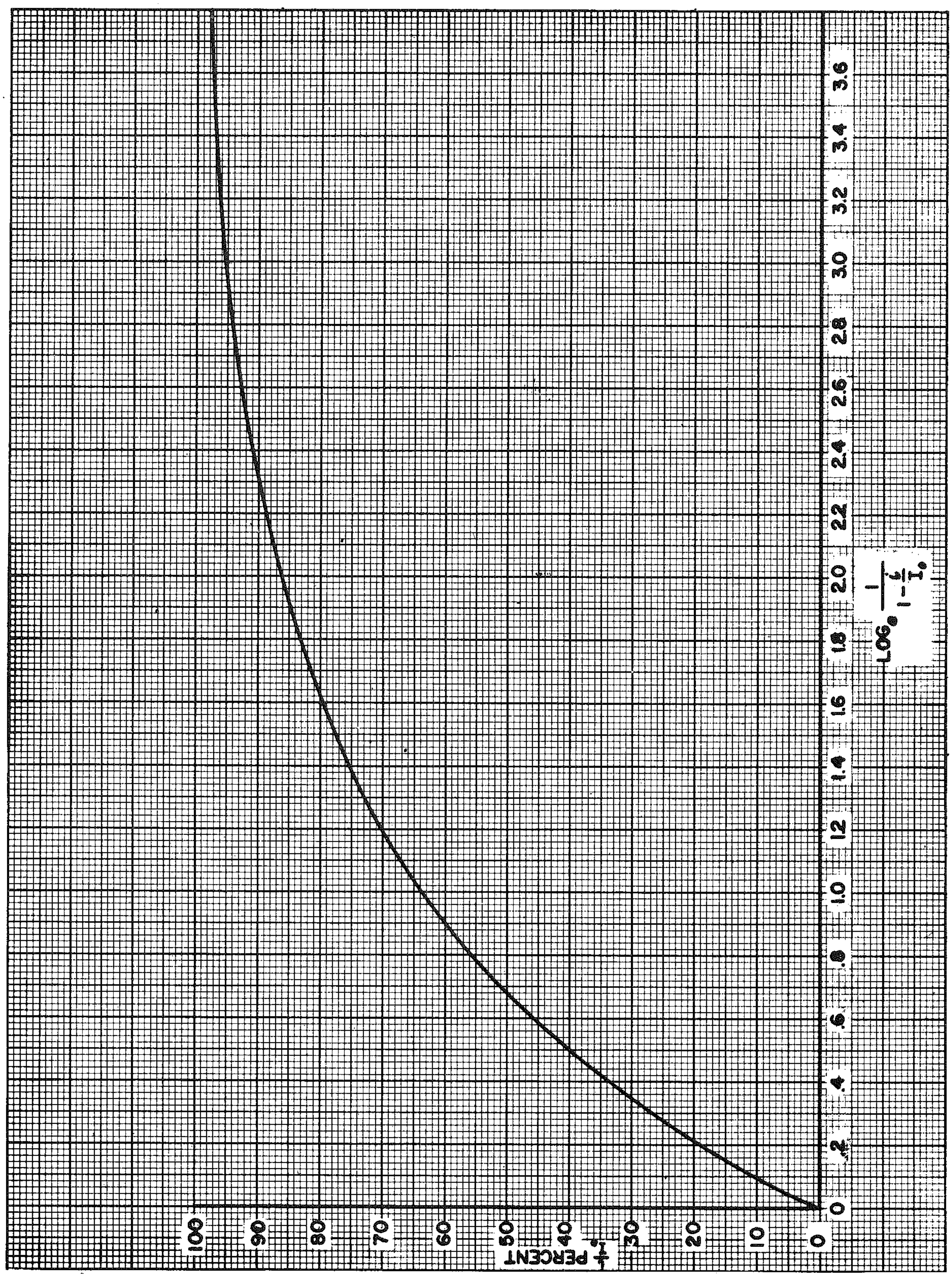

Fig. VII-4C - Time Constant Curve

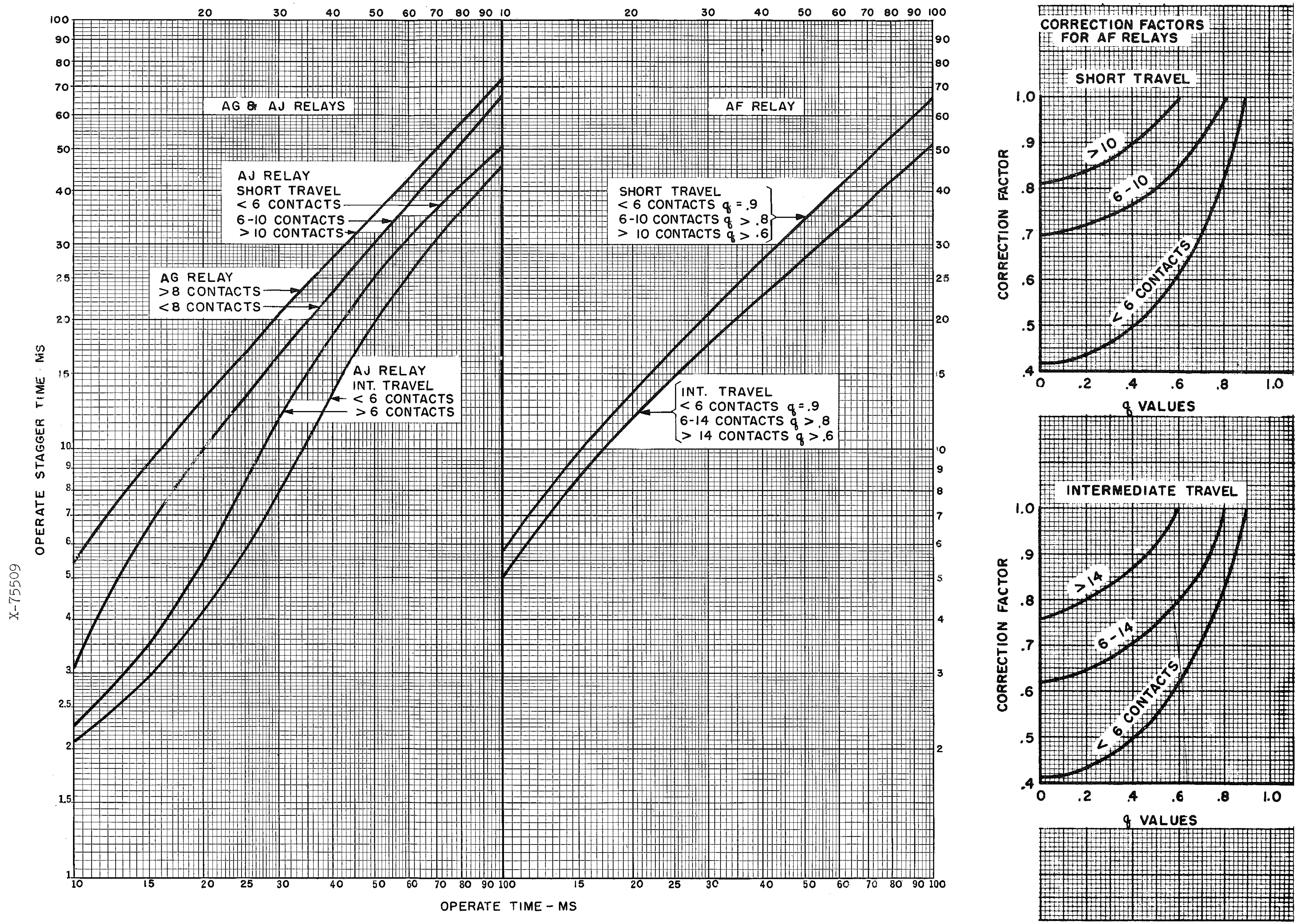

Fig. VII-5 - Load-Controlled Stagger Time

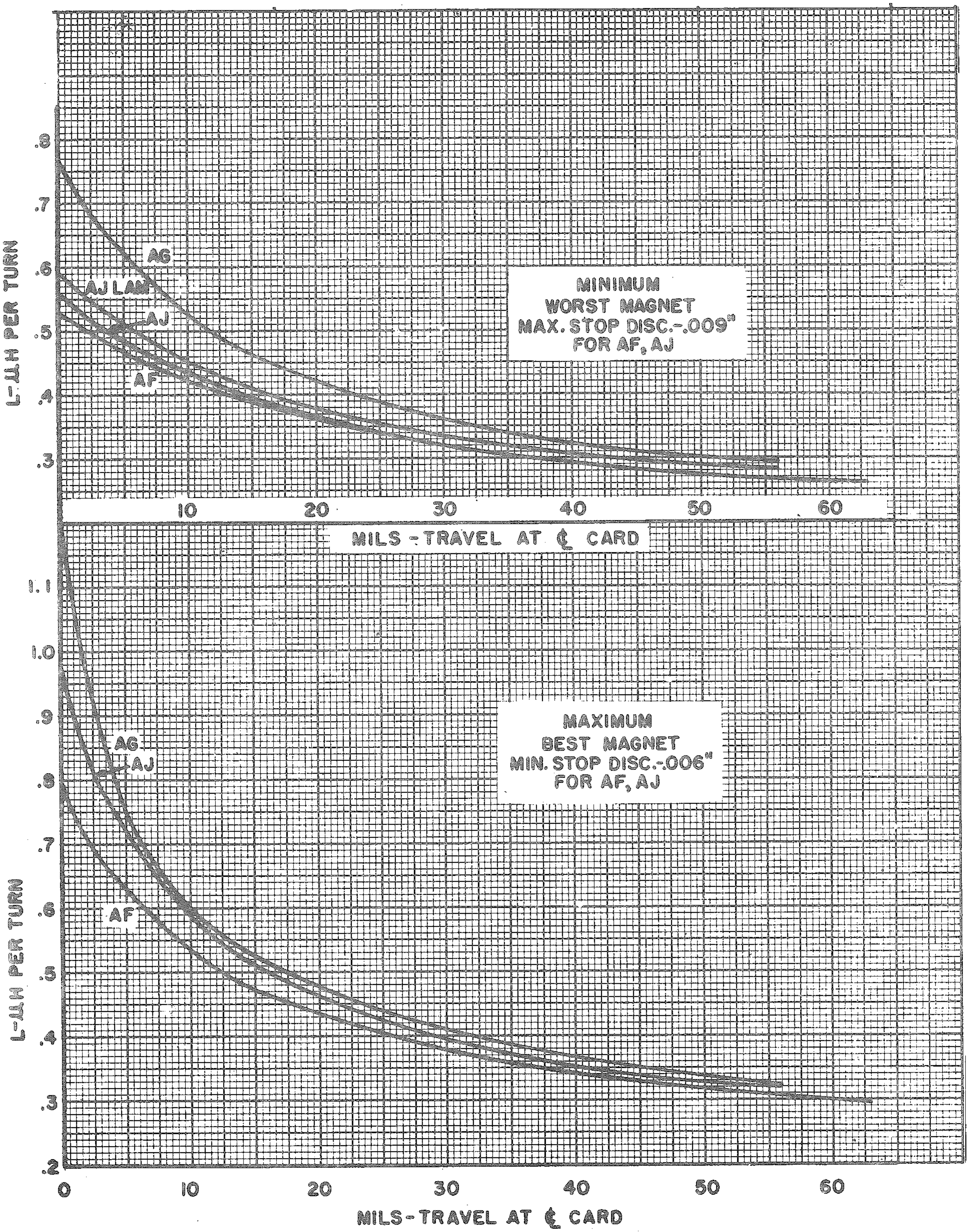

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Fig. VII-6 - AF, AG, and AJ Relays - Inductance Constant of One Turn

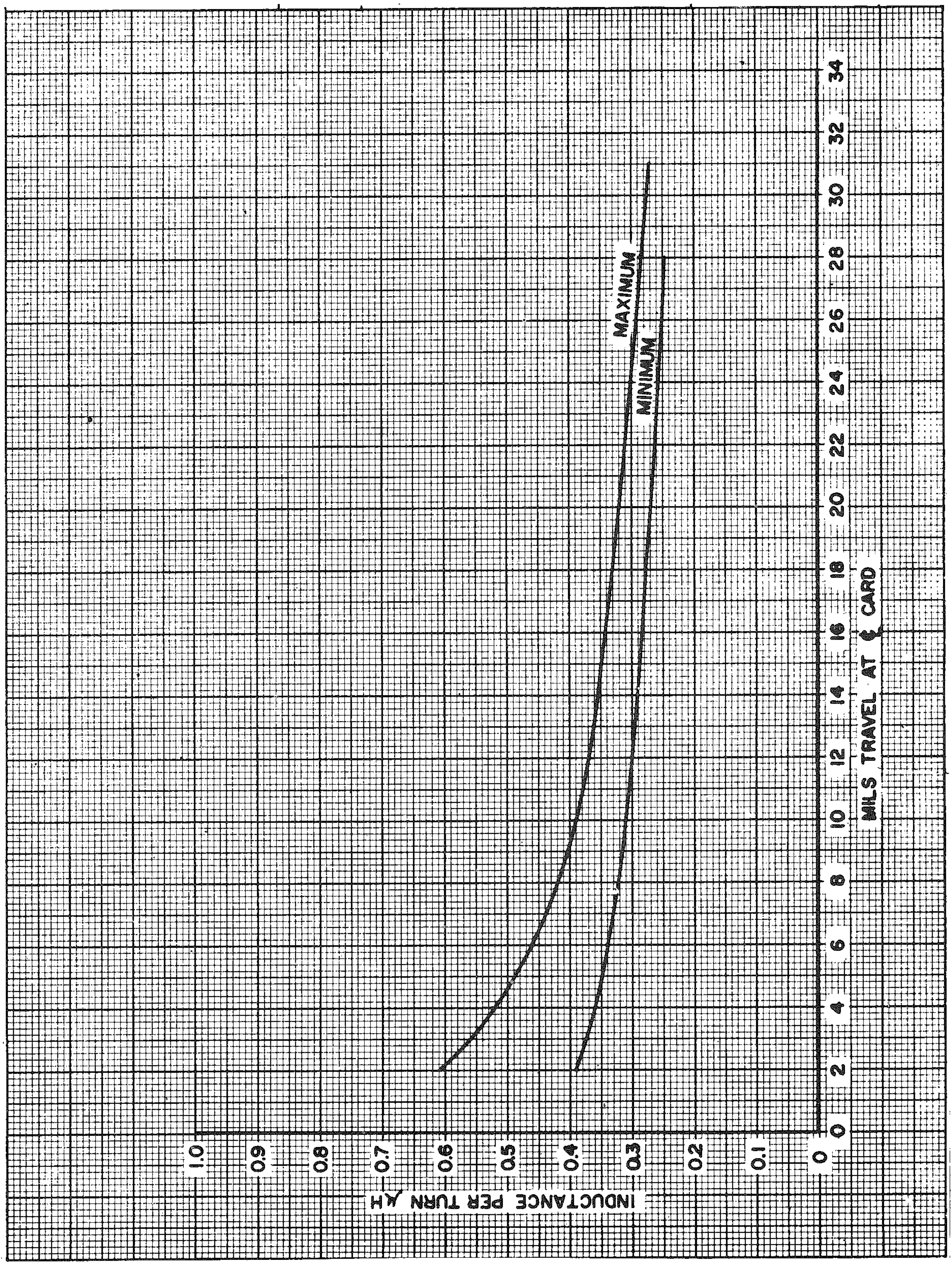
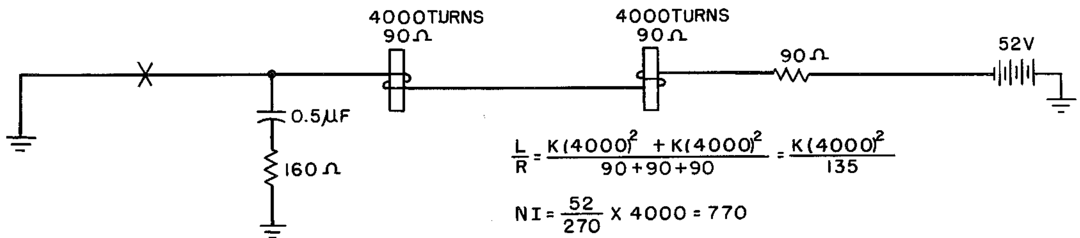


Fig. VII-6A - AK Relay - Inductance Constant of One Turn

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.

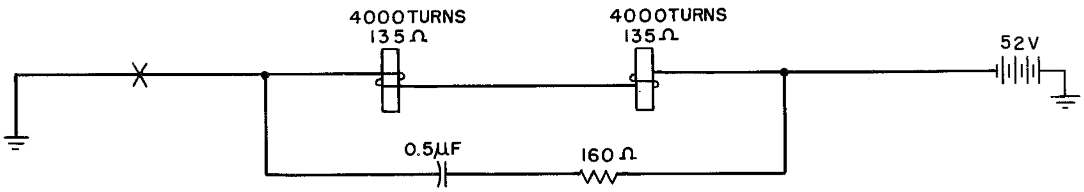


FIG. VII-7b

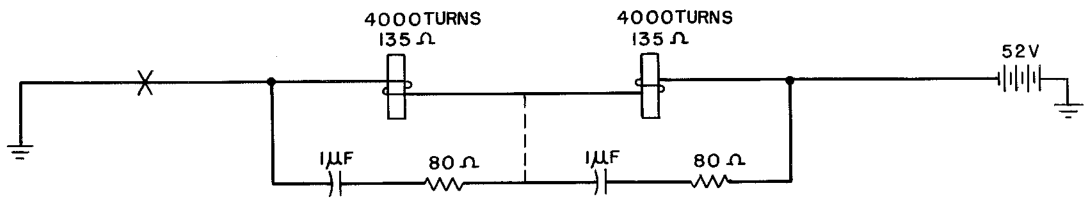
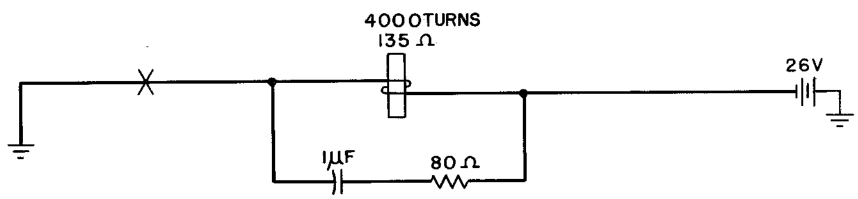


FIG. VII-7c



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

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

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

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

FIG. VII-7d

Fig. VII-7 - Equivalent Circuits

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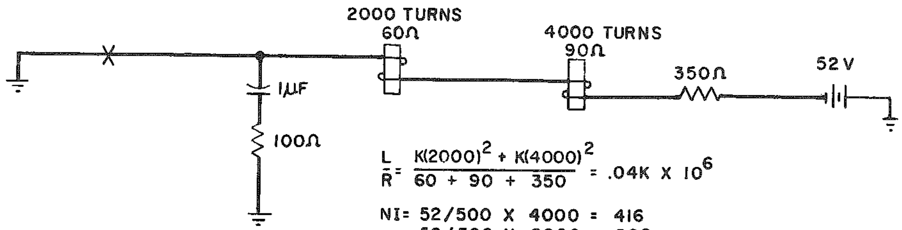
CIRCUIT TO BE SIMPLIFIED



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

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

$$= 52/500 \times 2000 = 208$$

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

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

FIGURE VII-8A

EQUIVALENT CIRCUITS

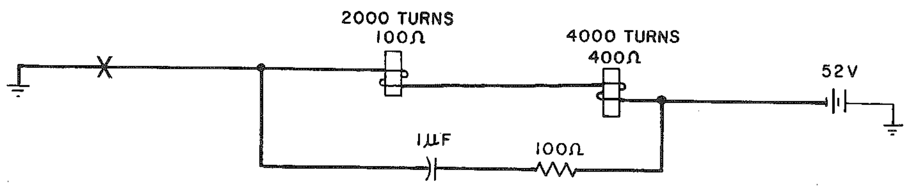


FIGURE VII-8B

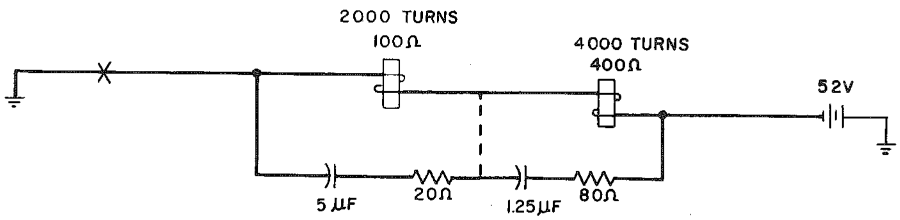


FIGURE VII-8C

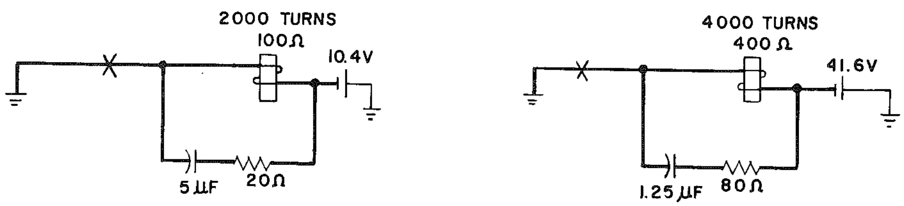


FIGURE VII-8D

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

$$NI = \frac{10.4}{100} \times 2000 = 208$$

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

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

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

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

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

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

Fig. VII-8 - Equivalent Circuits

CKT. TO BE SIMPLIFIED

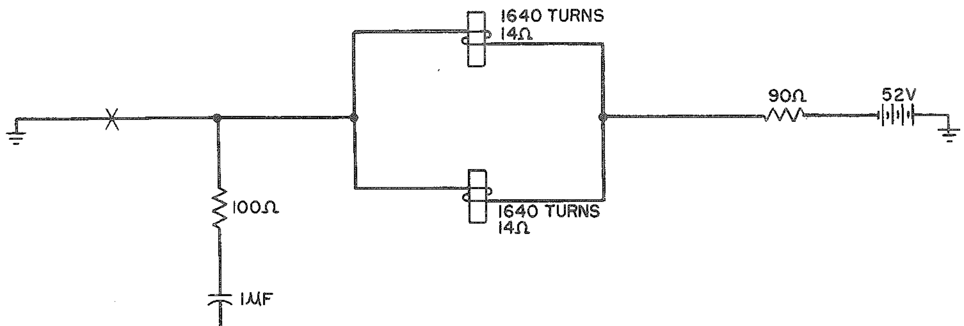


FIG. VII-9 a

EQUIVALENT CKTS.

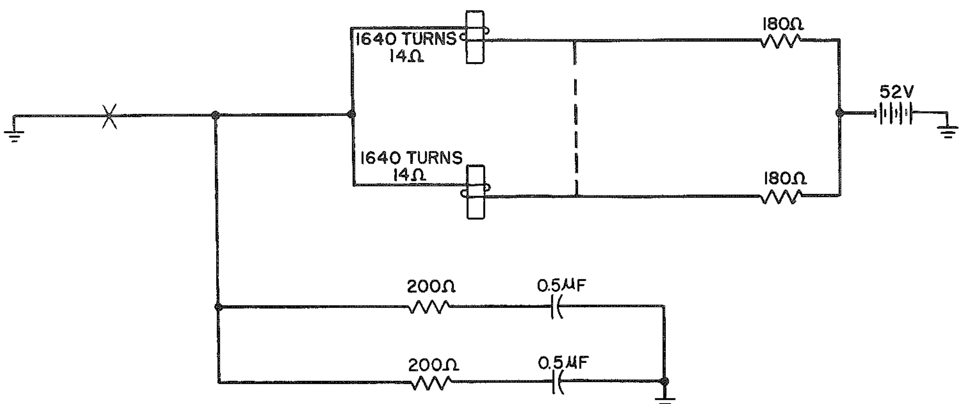


FIG. VII-9b

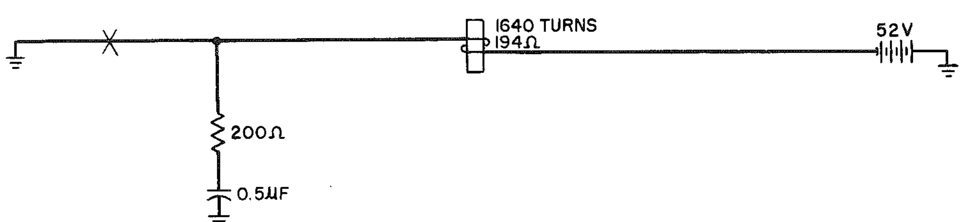


FIG. VII-9C

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Fig. VII-9 - Equivalent Circuits

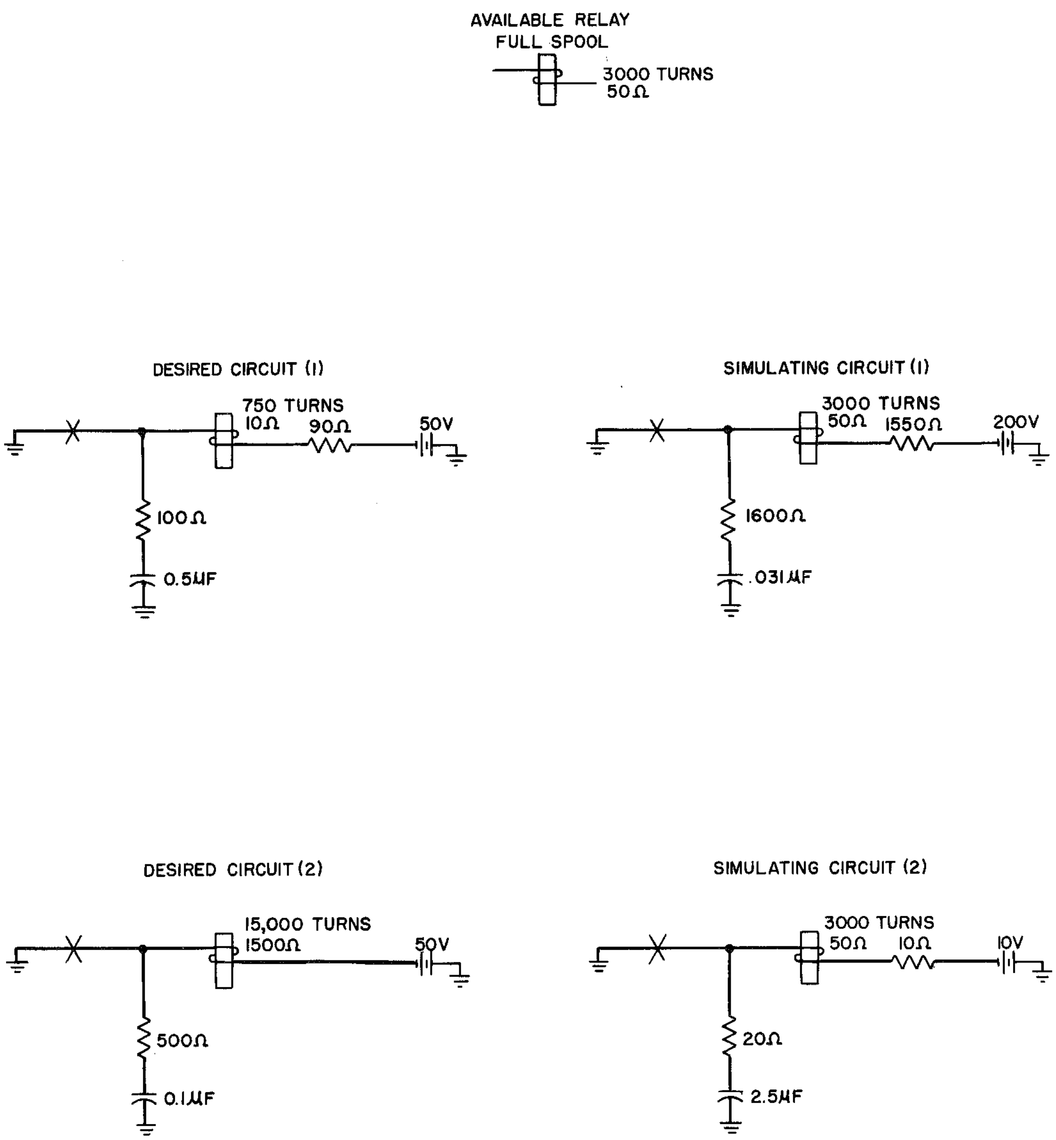


Fig. VII-10 - Equivalent Circuits

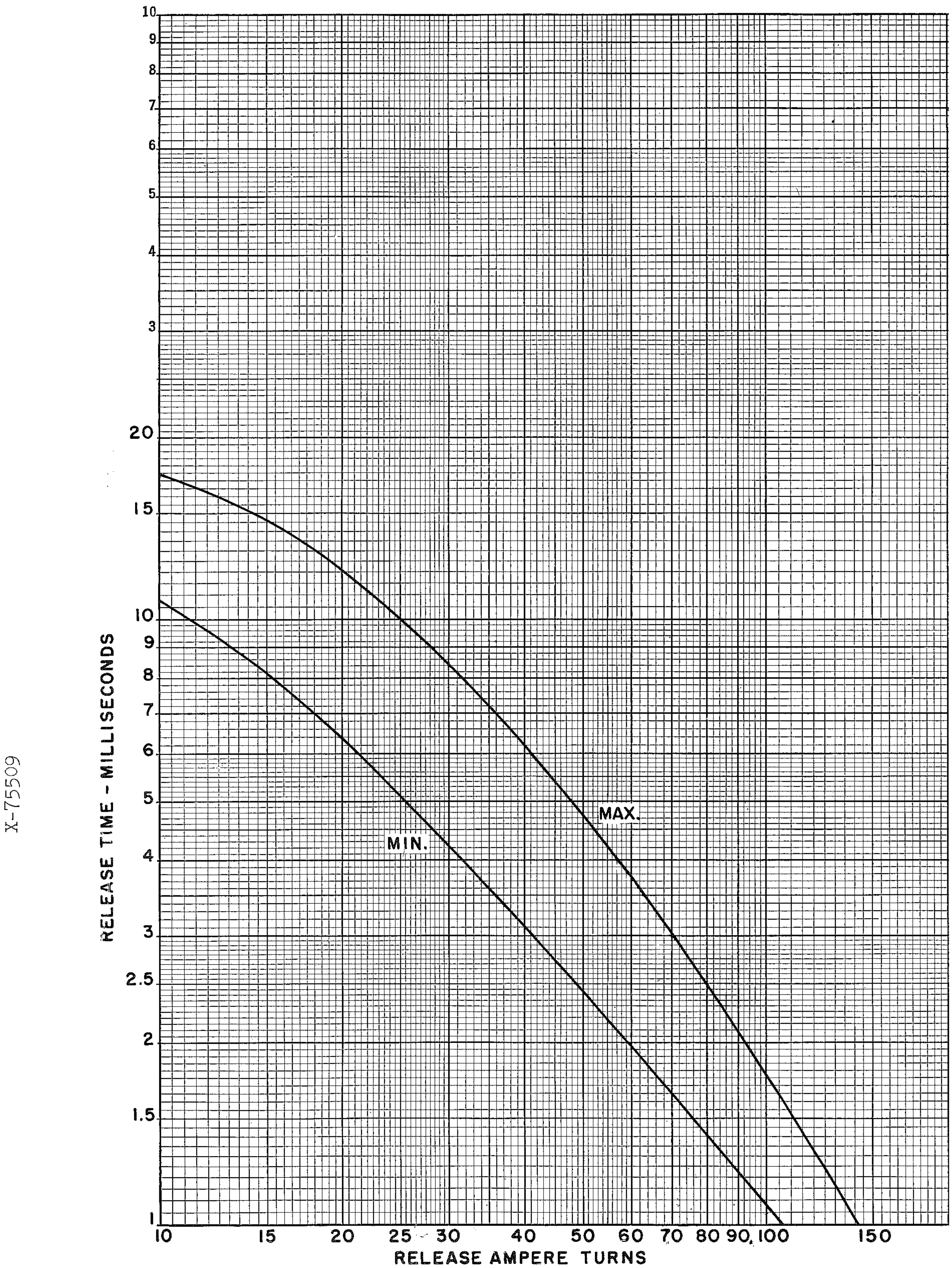


Fig. VII-11 - AF and AJ Relays - Open Circuit Release - No Sleeve or Contact Protection (0.006-Inch Stop Discs)

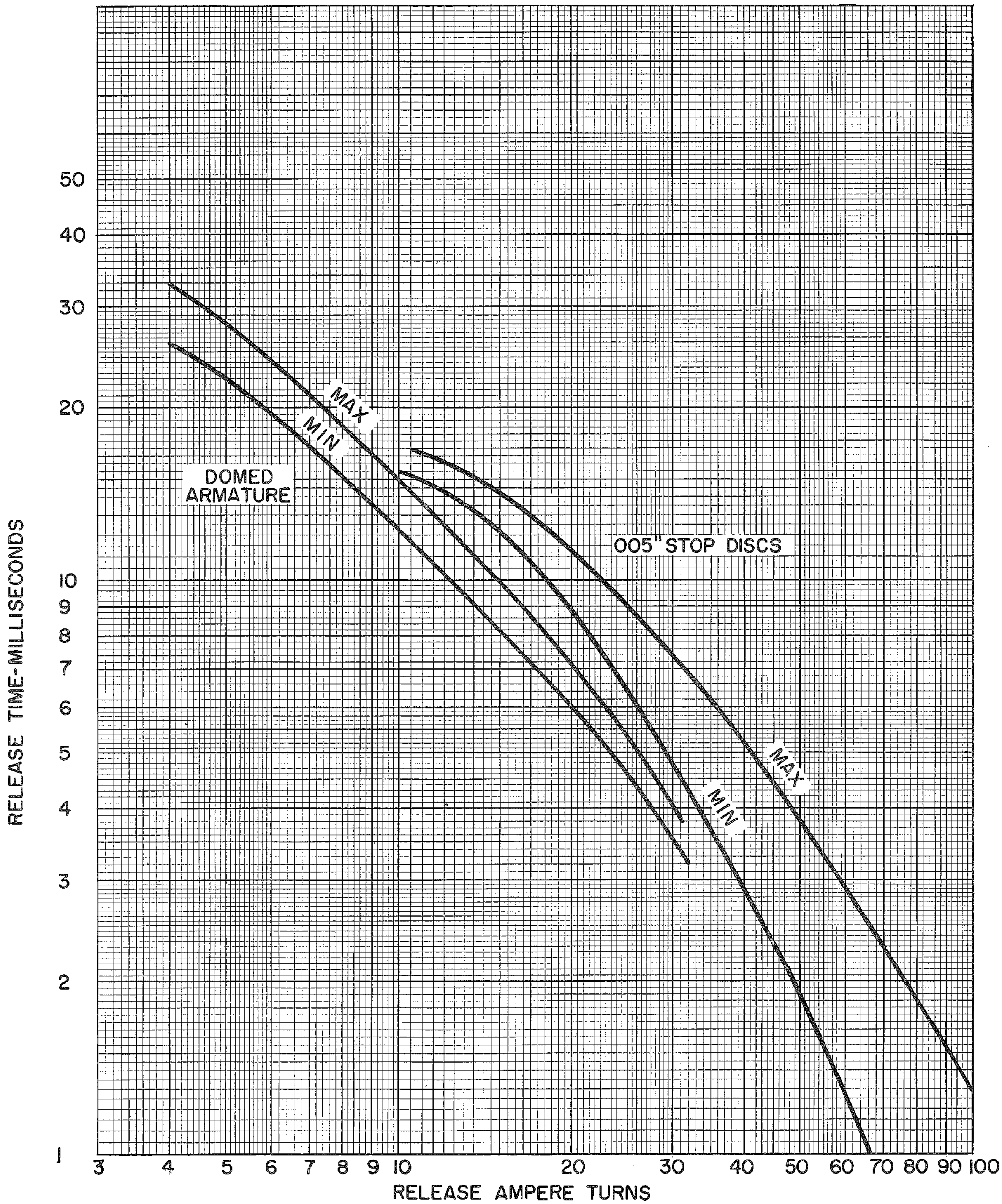
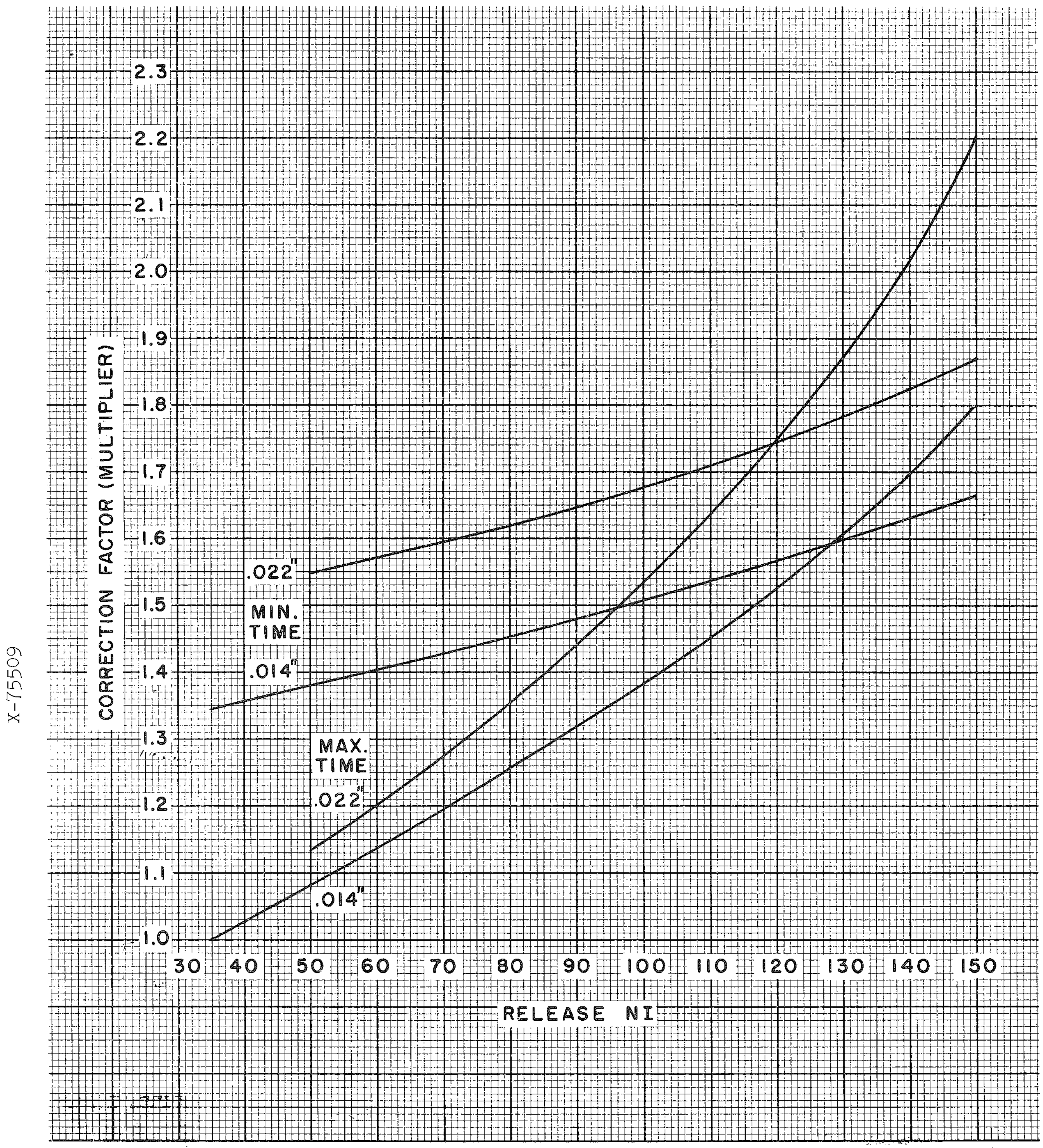


Fig. VII-11A - AK Relay - Open Circuit Release Time -
No Sleeve or Contact Protection



STOP DISC CORRECTION
OPEN CIRCUIT OR SHUNT RELEASE

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

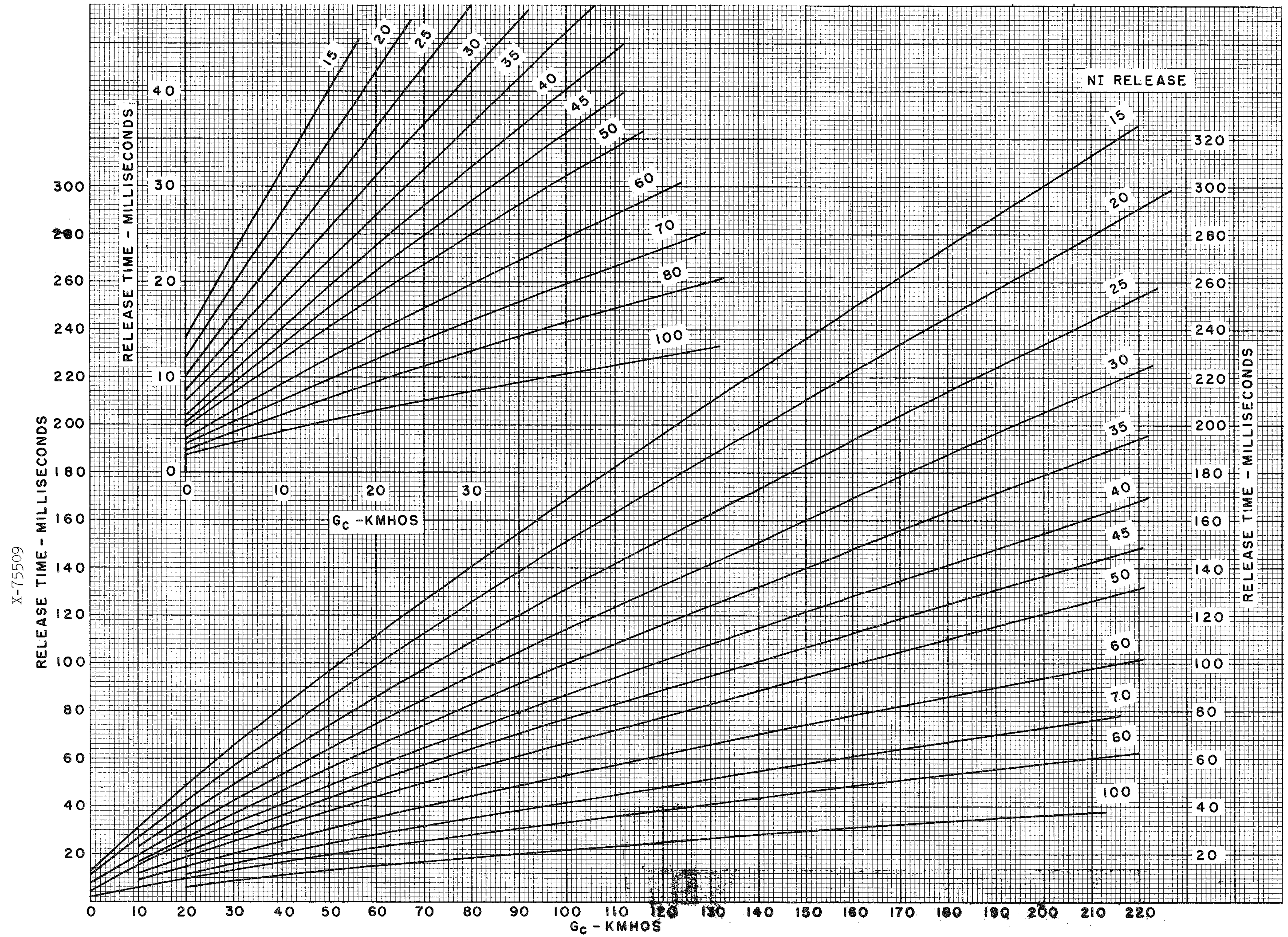


Fig. VII-13 - AF and AJ Relays - Maximum Release Time With Resistive Shunt

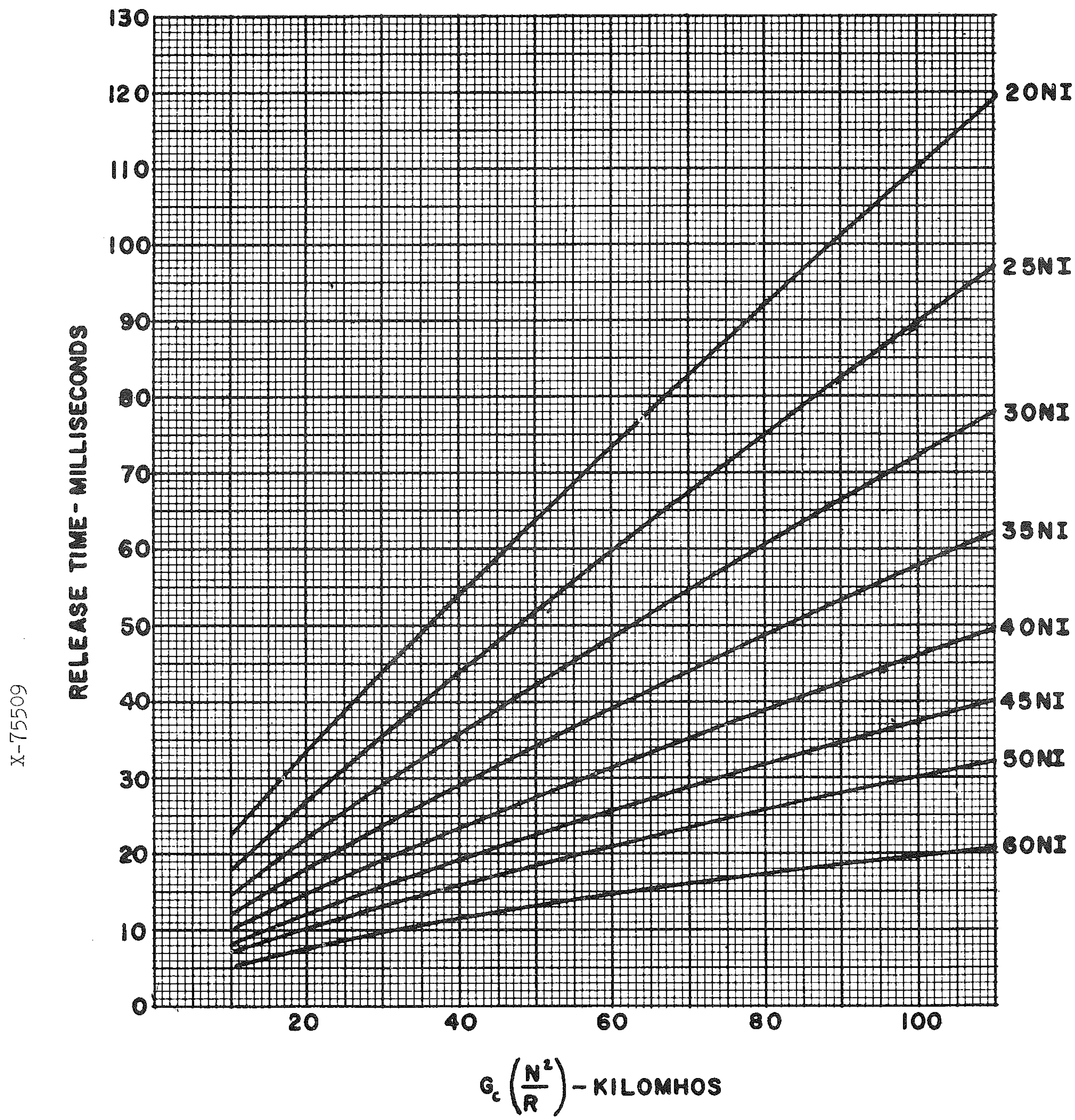


Fig. VII-13A - AK Relay - Maximum Release Time With Resistive Shunt

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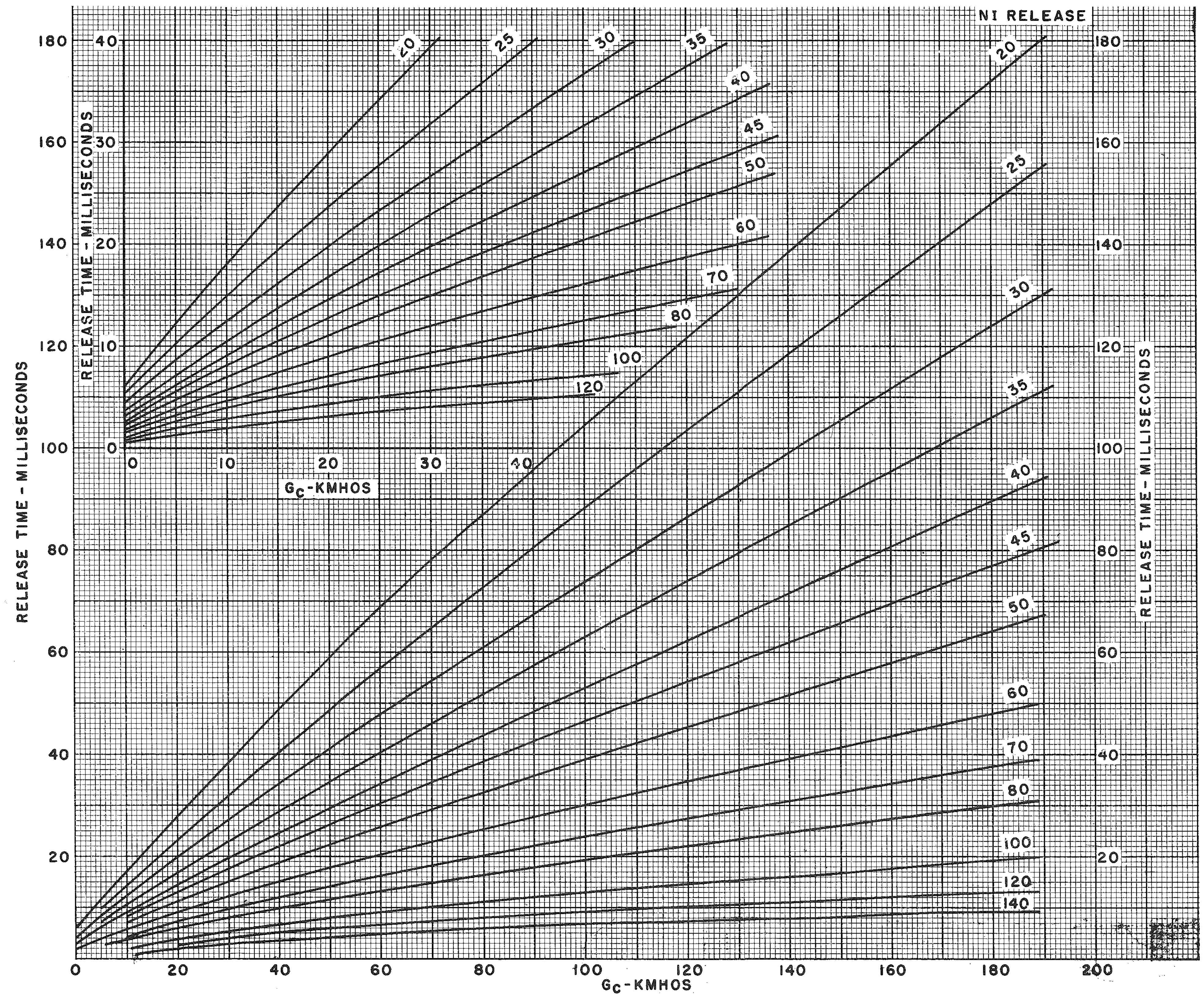

Fig. VII-14 - AF and AJ Relays - Minimum Release Time With Resistive Shunt

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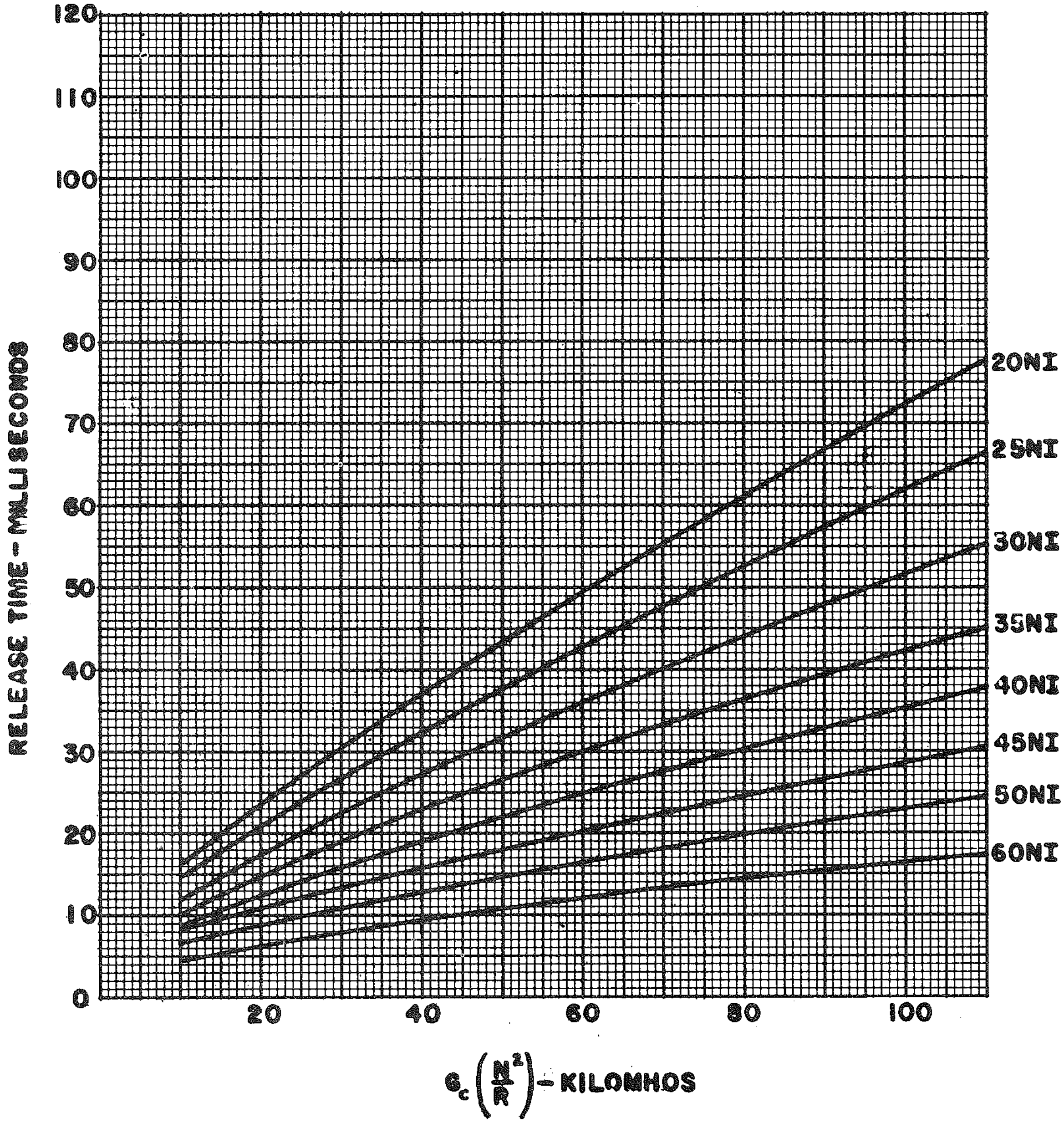

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Fig. VII-14A - AK Relay - Minimum Release Times With Resistive Shunt

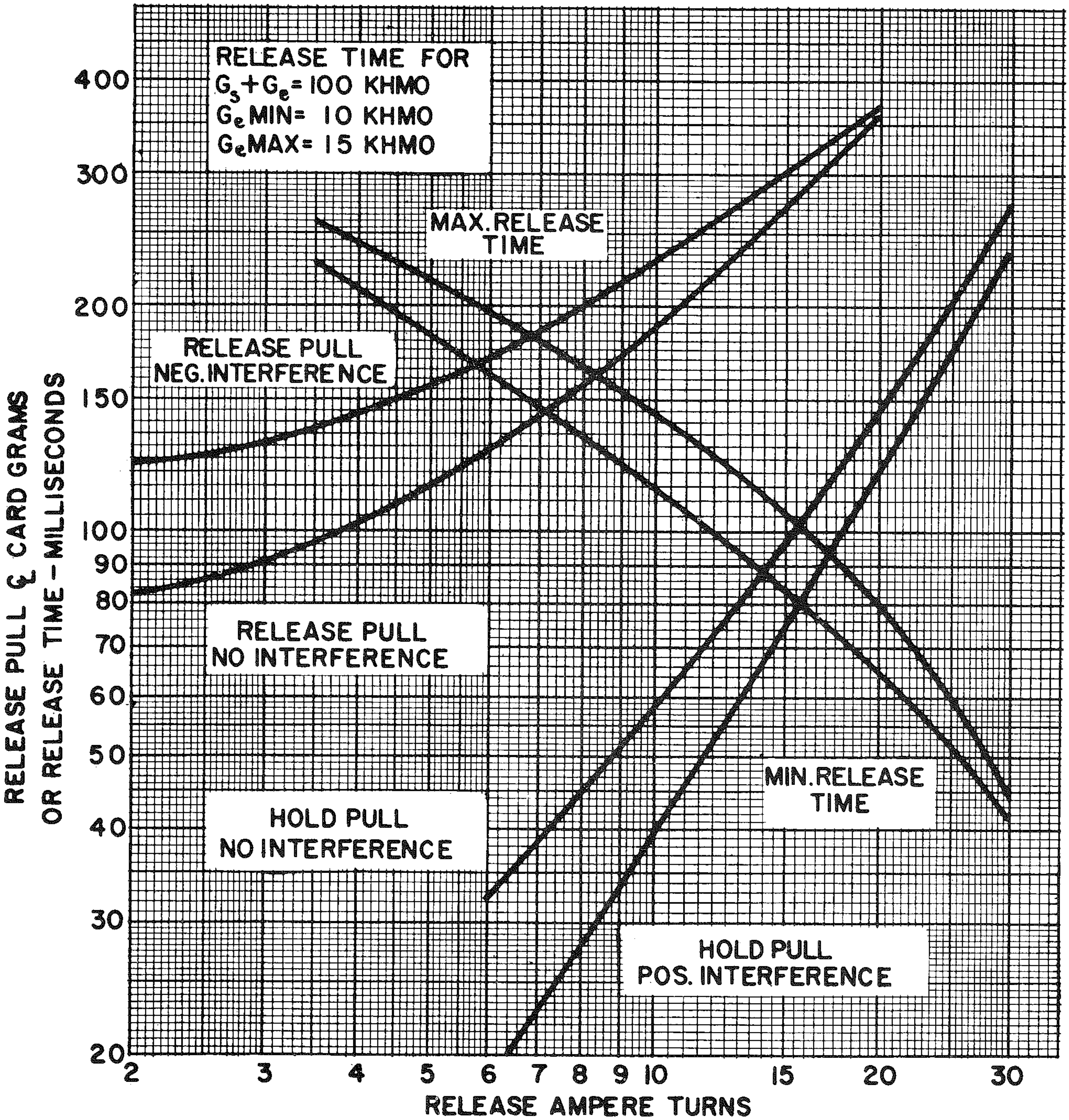

Fig. VII-14B - AK Relays - Release Time - Domed Armature With Shunt
Positive Interference: Both Coils Same Polarity
Negative Interference: Coils Oppositely Poled

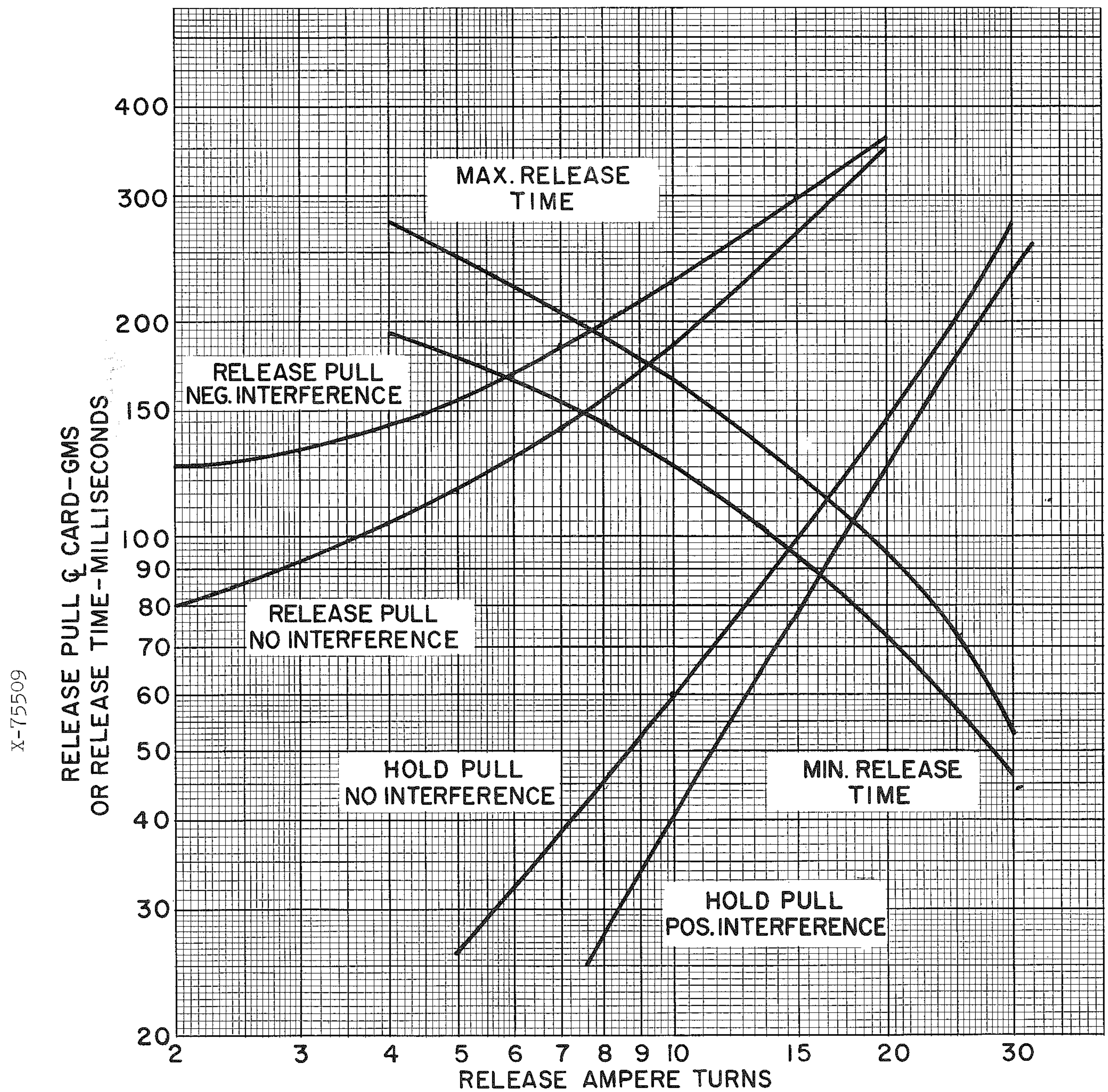

Fig. VII-14C - AK Relay - Slow Release - 0.069-Inch Copper Sleeve (Domed Armature)

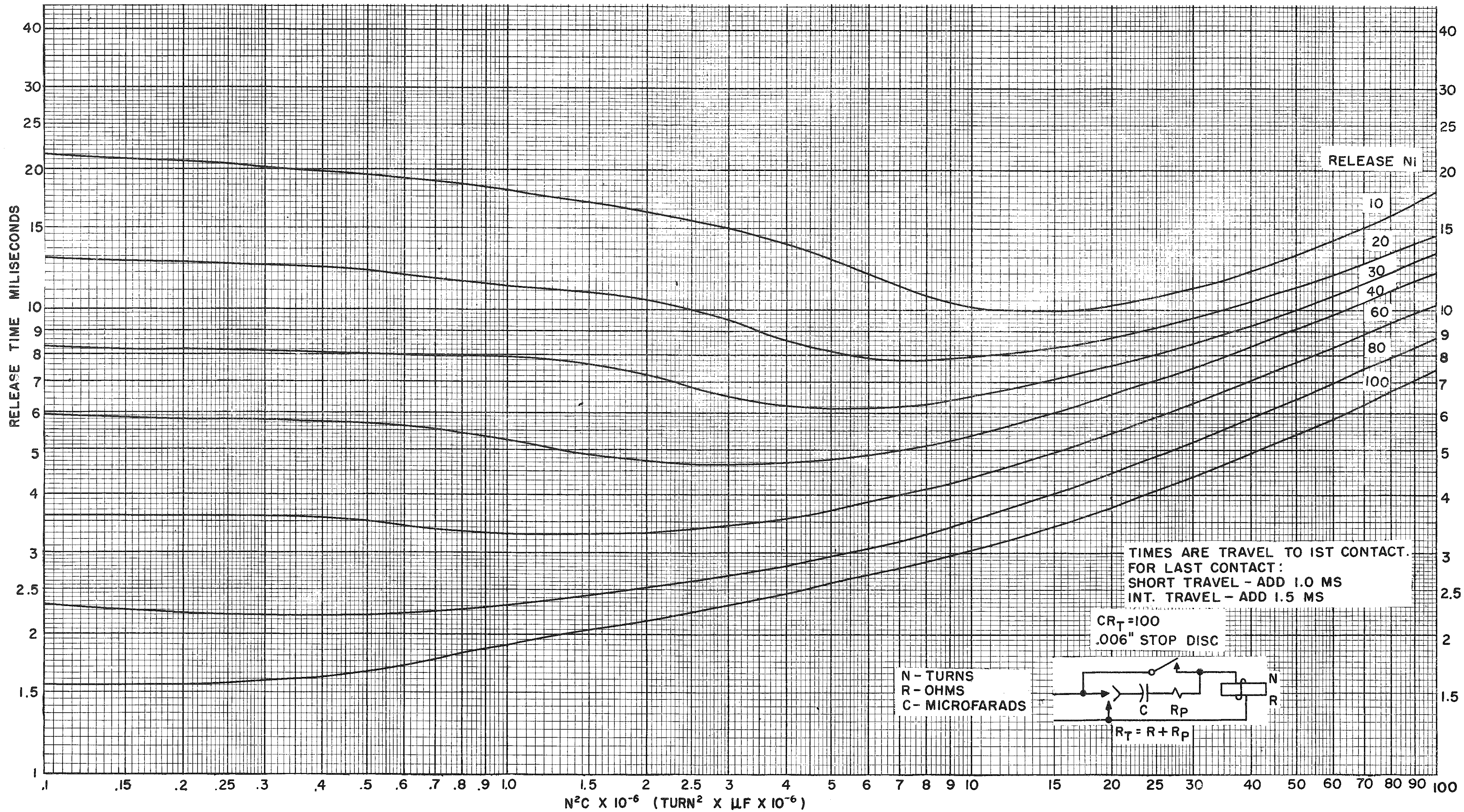

Fig. VII-15 - AF Relay - Maximum Release Time
With Contact Protection

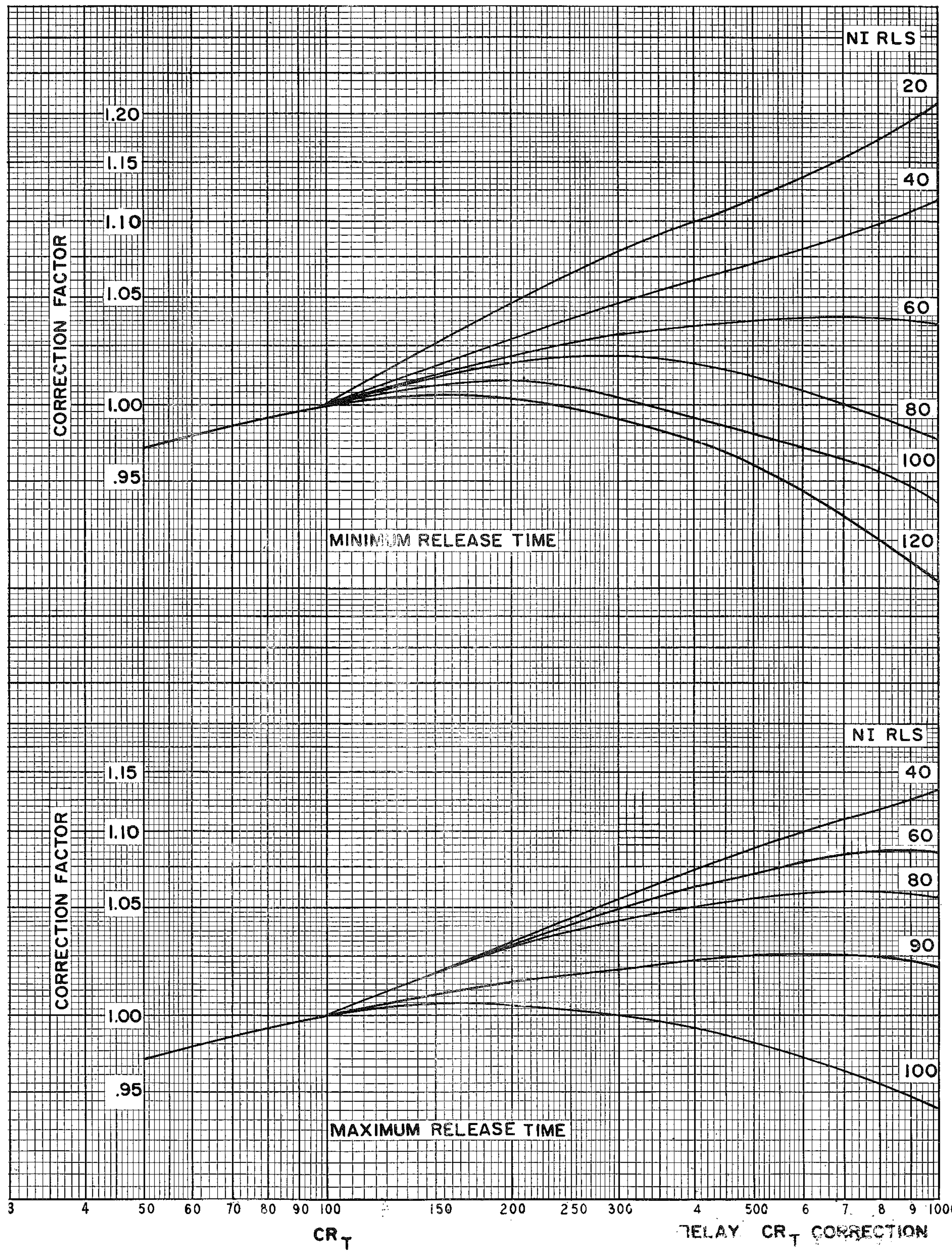

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Fig. VII-16 - AF Relay - Correction for Different Contact Protections

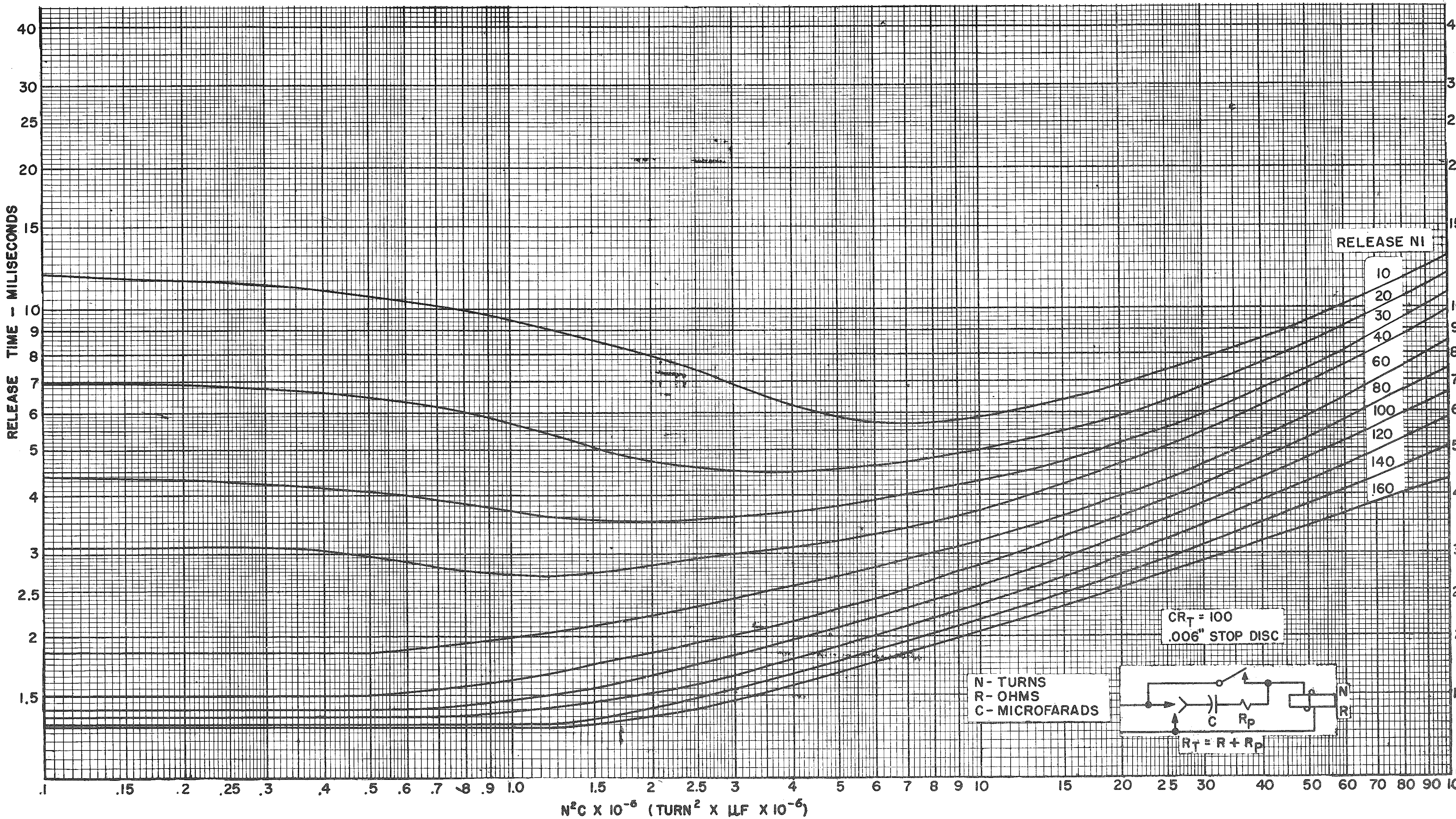

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Fig. VII-17 - AF Relay - Minimum Release Time
With Contact Protection

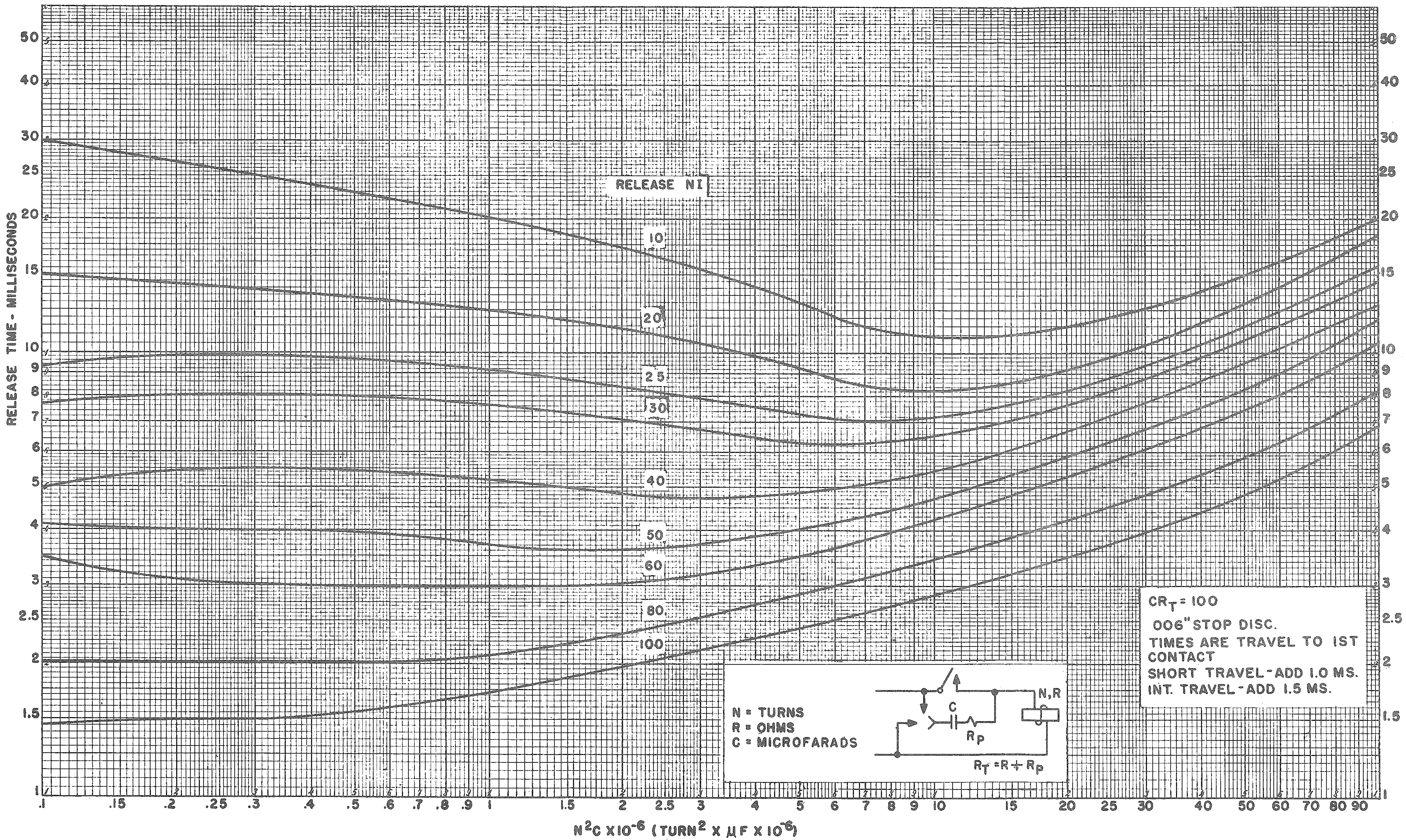

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Fig. VII-18 - AJ Relay - Maximum Release Time With Contact Protection

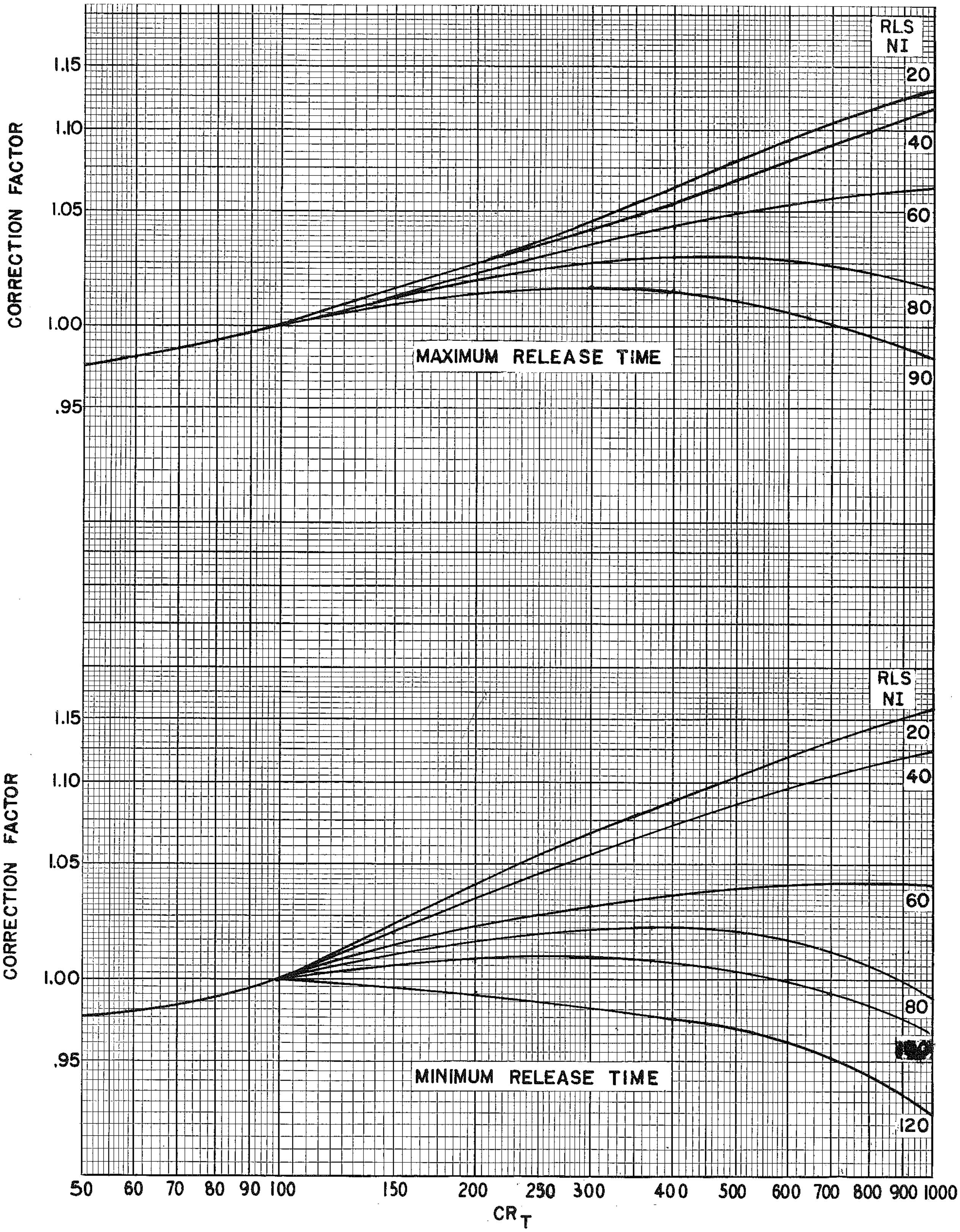

Fig. VII-19 - AJ Relay - Correction for Different Contact Protections

MECHANICAL REQUIREMENTS

General

This section describes the mechanical requirements of AF, AG, AJ, AK, AL, and AM relays to be applied in the shop and in the field. Due to the construction of these relays, the adjusting effort in the shop is much less than that required for the U and Y relays. The shop adjustment is mostly confined to a touch-up of the back tension by adding to, or subtracting from, the balancing spring pre-tension and a mass adjustment of the contacts to meet the contact gauging requirement. On relays with critical hold and release requirements, an adjustment of the buffer spring tension and point of pickup of this spring by the card may be necessary.

Due to the greater stability of these relays, and the improved contact performance, the necessity for readjustments in the field is considerably less than for the U relays.

In general, spring sequences required for proper circuit functioning must be specified in the Circuit Requirements Table, except for EBM, EMB, PBEM, or PMEB combinations, which are checked for the sequence in the position in which these combinations appear. Where the circuit function involves preliminary contacts operating in sequence, with late contacts, it may not be necessary to specify the sequence in the Circuit Requirements Table. These conditions should be discussed with the relay requirements group.

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The ratio of the gauging value applied at the card to that applied at the stop disc, or dome, is not the same for the AF, AG, AJ, AL, AK, and AM relays. The AF and AL relays have short armatures and the AG and AJ relays have a long armature, but the stop discs, or domes, are located the same distance from the front of the armature on all four relays. The armatures on the AK and AM relays are a different design from the AF, AJ, or AL relay. The stop discs or domes will, therefore, be at different distances from the hinge on the different armatures and consequently will travel different distances for the same travel at the card. The ratios for these motions are:

	AF,AL	AG,AJ	AK,AM
Stop disc, or dome, to card	0.718	0.845	0.912
Contact to card	1.065	1.065	1.065
Stop disc, or dome, to contact	0.675	0.793	0.885

The performance and stability of the wire spring relay is controlled mainly by the following features:

Contact Gauging
Armature Travel
Contact Force
Armature Back Tension
Buffer Spring Tension and Position
Stop Discs
Armature Leg Clearance

Some of the above features are specified in the shop mechanical requirements and are to be checked on the assembled relay Others are controlled by manufacturing tolerances on the component parts and no check is made after assembly.

Contact Gauging

Contact gauging values provide the minimum and the maximum points in the armature stroke at which the contacts may be actuated. The gauging requirements for these relays are shown in Table VIII-1. Some relays may have special contact gauging to facilitate meeting the current flow requirements; these special gauging values must be shown in the Circuit Requirements Table. All gauging values are relative to the center leg of the core on AF, AG, AJ, and AL relays.

It should be noted that, using the readjust values with adverse gauging limits, the interval that guarantees that a sequence is provided is small. With the test values, there is a negative sequence interval. The interval may refer to transfer or continuity contacts, which are in the same position on the relay, or it may refer to a contact in one position with respect to contacts in other positions, such as any early contact with respect to any late contacts. Different gauging values are specified in Table VIII-1 for different purposes as outlined in the following paragraphs. The contacts should not be actuated on the maximum values shown.

M Specification Gauging Values

These values are specified by the Apparatus Department for use in the shop. The gauging may be made either at the stop discs or at the card, using equivalent gauging values, depending on which is the most convenient. The gauging requirements guarantee a minimum interval of 2 mil inches, measured at the contacts (1.5 mil inches measured at the stop discs) between any contacts in different travel stages. Since the gauging requirements insure the sequences, no other check is made for the sequence.

Readjust Gauging Values

These are identical with the M specification values but are applied at the stop discs. When a relay has reached the end of its adjustment life, it may be readjusted to the original gauging values.

Wired Equipment Test Gauging Values

These values are used in the shop for wired equipment inspections and will be applied at the stop discs. They are uniformly 1.5 mils easier than the M specification values and result in a negative sequence interval of 1.5 mils. Consequently, a visual check for sequence will be made on all EBM, EMB, PBEM, and PMEB spring units with the armature operated manually. No check for other sequences will be made unless explicitly covered by notes in the Circuit Requirements Table.

Before Turnover Test Gauging Values

These are for the use of the installer prior to turnover and are identical with the wired equipment test values used in the shop.

Maintenance Test Gauging Values

These values are the "end of adjustment life" and are easier than the before turnover test values to allow for wear. The method of gauging for the "no make" point of the contact is different in that the gauge is inserted between the armature and the backstop with the relay de-energized. This method allows greater wear before rejection of relays with contacts worn in a direction to pick up the contact early in the stroke. The gauge applied between the armature and the backstop is large enough to allow for armature rebound.

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

If the deterioration in contact gauging is caused by excessive card wear, the contact sequences may be restored by replacing the actuating card in the field.

Armature Travel

The armature travel is not adjustable and is controlled by the core plate and stop discs used. The core plate in turn depends on the spring combination. There will be three standard armature travels corresponding to the three stages of contact spring sequence: short, intermediate, and long. The nominal armature travels measured at the card are:

	Travel (inch)	Contact Sequence	Spring Combination Number
	AF, AG, AJ, and AL Relays		
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
	AK and AM Relays		
Short	0.026	1 stage	1 to 199
Intermediate	0.044	2 stage	200 to 399

There are no specified variations in the armature travel, but the manufacturing limits on the component parts that control the travel show that they may vary ±0.005 inch.

These armature travels will not be shown in the Circuit Requirements Table, the BSP, or the manufacturing specifications. Some relays with critical adjustments, such as the AJ1 and AJ2 supervisory relays, may have special armature travels and contact gauging to aid in meeting the current flow requirements.

Contact Force

The contact force, measured at the contacts, will be nominal 12.5 grams, but for critical or sensitive relays a nominal 8-gram force may be used. A nominal 17.5-gram contact force may be used in cases where contact chatter is detrimental to circuit function. The contact force is obtained by the bend and large deflection of the twin-wire springs held in a molded block and is not adjustable once the relay is assembled. A relay, coded with a particular force adjustment, cannot be given another force adjustment as is done with older types of relays. Where any change in adjustment is required, a new code must be provided.

Armature Back Tension

The armature is held against the backstop of the core plate with a pressure of minimum 30 grams for the AF, AJ, and AK relays, minimum 45 grams for the 24-make AJ relay, and minimum 20 grams for the AG relay, unless otherwise specified on the individual relay code. A minimum of 20 grams back tension may be specified for the sensitive, marginal, or slow-releasing relays, where necessary to meet the current flow requirements. A maximum 60 grams back tension is specified in the manufacturing specification for the speed relays (4.4-, 16-, 270-, 395-, 400-, and 700-ohm coils) to prevent increased operating times due to excessive armature back tensions. The 60-gram back tension is increased to 80 grams where nonoperate or release requirements are specified. On the 24 make AJ relay, there is a maximum back tension of 100 grams on standard relays and maximum 80 grams on the speed relays of this type. The back tension is obtained from the balancing spring, the thickness of which is selected on the basis of the number of make-contacts. (See Section IX.) The tension and offset of the balancing spring may be changed to meet the armature back tension requirement, or a nonoperate, or release. AL and AM relays have special back tension values. Consult the relay applications group for specific details.

Buffer Spring Tension and Position

A buffer spring may be provided on the AF, AG, AJ, or AL relay to obtain an additional adjustable load in the operated position. This provides a better balance between the relay pull and the operated load and permits better control of the hold and release adjustments. Relay codes that may be equipped with a buffer spring (shown in Section I, Fig. I-16) are identified by the letter suffix B following the spring combination number. However, the buffer spring may or may not be provided on individual relays of these codes, depending on whether its use was required to meet initial electrical requirements.

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The point at which the buffer spring is picked up in the operation of a relay must be controlled. It is adjusted to the gauging values shown on Table VIII-1. If the buffer spring is picked up too soon, there is a possibility of a momentary open of make-contacts caused by a hesitation of the armature when the actuating card engages the buffer spring. If the buffer spring is picked up too late, the load of the buffer spring may be dropped, on the release of the relay before the armature is far enough away from the core to prevent reclosure of make-contacts when the buffer load is dropped.

Stop Discs

The AF and AJ relays are always equipped with stop discs 0.006-inch, 0.014-inch, or 0.022-inch high, with a tolerance of -0.000-inch +0.003-inch. The 0.006-inch stop disc is used for the general purpose functions, and the 0.014-inch or 0.022-inch stop discs are used to meet marginal operating conditions. The AG and AL relays have an embossing or dome on the armature to provide a uniform point of contact between the armature and core. This minimizes the effect of varying alignment of the armature and core on the releasing time. The AK relay is equipped with a stop disc 0.005-inch -0.000-inch, +0.003-inch high, or in special cases a dome for the slow-release relays. AM relays are equipped with a domed armature.

Armature Leg Clearance - AF, AG, AJ, and AL Relays

With the relay electrically operated, there shall be a clearance of minimum 0.002 inch between the outer legs of the core and the armature. This is to prevent an iron-to-iron contact between the armature and the core legs due to stop disc wear or cocking of the armature.

Coil Replacement

A tool kit (1014B) has been provided for replacement of the coil of the AF, AG, AJ, or AK relays in the field. It was designed for replacing defective coils and is not intended for the modification of relay codes. Replacement procedures are covered in Bell System Practices 040-502-801 and 040-504-801 for AF, AG, and AJ types and the AK type, respectively. No attempt should be made to replace the coil of either the AL or AM type latching relay in the field.

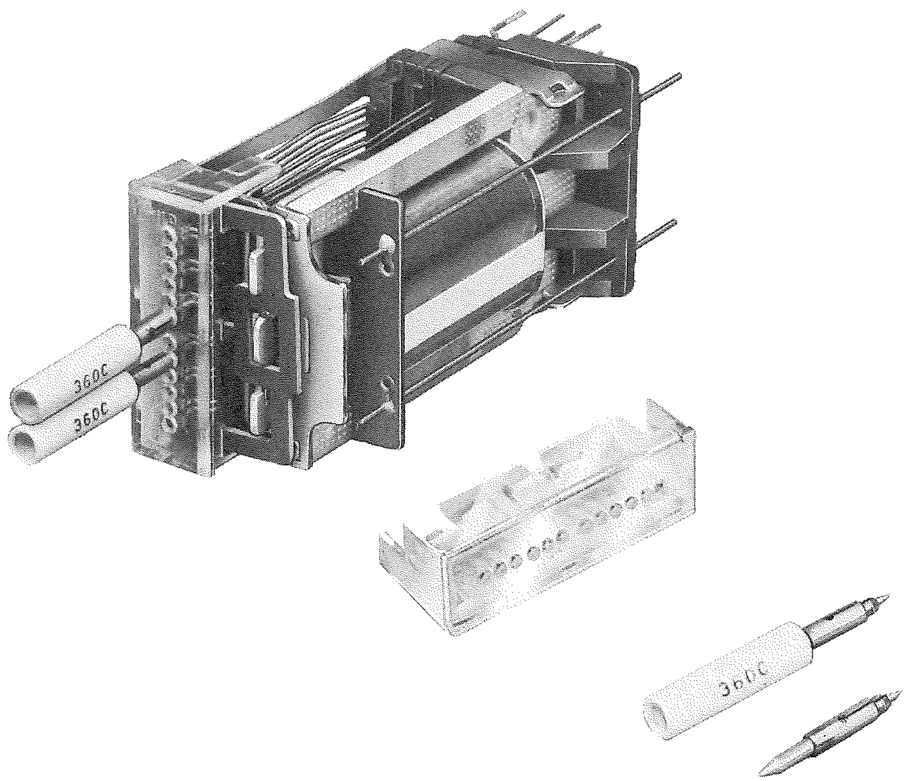

Fig. VIII-1 - Method of Connecting to Fixed Contacts

Adjusting Tools

A list of the adjusting tools required for field maintenance of the wire spring relay is shown below.

AF, AG, AJ, and AL Relays

1. Gram gauge for back tension and buffer tension (70D or 70J)

2. Armature blocking tool (No. 627A tool)

3. Contact insulator (KS-14737, List 1); tweezer to apply contact insulator (KS-8511)

4. Contact burnisher (266E) (Do not burnish contacts with gold overlay.)

5. Winding connector (624B tool)

6. Balance spring lifter (628A tool)

7. Balance spring adjuster (No. 534F, 534G, 534H spring adjusters)

8. Tools for adjusting buffer spring (No. 363 and 534E spring adjusters)

9. Tool for mass adjustment of contacts (H cabinet screwdriver)

10. Thickness gauges for contact operate point (171A)

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11. Tools for removing card
    - Spring holders (629A and 629B)
    - Spring holder and clamp (630A)
    - Spring holders (652A and 652B)
    - Insulator (656A)

12. Contact welding tools
    - Stripping pliers (2)
    - Welders (2)
    - Forming pliers

13. Tools for adjusting individual twin-contact wires (638A)

14. Tool to connect to fixed contacts (651B, 651C, or 651D and 639A) (Fig. VIII-1)

15. Cover wire bail adjuster (485A pliers)

16. Coil replacement tool kit (1014B) for AF, AG, and AJ relays only

AK and AM Relays

1. Gram gauge for back tension (70D)

2. Armature blocking tool (679A tool)

3. Contact insulator (KS-14737, List 1); tweezers to apply contact insulator (KS-8511)

4. Contact burnisher (266E) (Do not burnish contacts with gold overlay)

5. Winding connector (624B tool)

6. Balancing spring lifter (628A tool)

7. Balance spring adjuster (534F spring adjuster)

8. Tool for mass adjustment of contacts (H cabinet screwdriver)

9. Thickness gauge for contact operate point (184A)

10. Tools for removing card
    - Spring holders (675A, 675B)
    - Spring holders (688A, 688B)
    - Insulators (684A)

11. Contact welding tools
    - Stripping pliers (2)
    - Welders (2)
    - Forming pliers

12. Tool for adjusting individual twin-contact wires (638A)

13. Tool to connect to fixed contacts (651D and 639A)

14. Cover wire bail adjuster (485A pliers)

15. Coil replacement tool kit (1014B) for AK relays only

TABLE VIII-1

CONTACT GAUGING IN MILS

	M Spec or Readjust				Wired Equipment Test Or Before Turnover Test	
	At Card		At Stop Discs or Dome		At Stop Discs Or Dome	
	Min	Max	Min	Max	Min	Max
AF, AL						
M, B*	6.0	17.0	4.5	12.0	3.0	13.5†
EM, EB	19.0	30.0	13.5	21.5	12.0†	23.0
PM, PB	32.0	43.0	23.0	31.0	21.5	32.5
Buff. Spg	4.0	10.0	3.0	7.0	1.5	8.5
AG, AJ						
M, B*	6.0	17.0	5.0	14.5	3.5	16.0†
EM, EB	19.0	30.0	16.0	25.5	14.5†	27.0
PM, PB	32.0	43.0	27.0	36.5	25.5	38.0
Buff. Spg	4.0	10.0	3.5	8.5	1.5	10.0
AK, AM						
M, B	6.0	17.0	5.0	15.0	3.5	16.5†
EM, EB	19.0	30.0	16.5	26.5	15.0†	28.0
Specified in	M Spec		M Spec and BSP		BSP	

*Relays with seven or more springs and spring combinations, number 1 to 199 and 500, shall meet the following requirement: With a 0.007-inch gauge inserted between the armature and the armature backstop, the make-contacts shall not close and the break-contacts shall not break.

†Not to be checked on EBM or EMB spring combinations. A visual check for sequence is made instead. (See text.)

Armature Travel	Spring Comb. No.	Maintenance Test (Specified in BSP) At Stop Disc Min	At Backstop Min
AF, AG, AJ, AL			
Short (6 or less spring pairs)	1 to 199, and 500	1.5	4.5
Short (7 or more spring pairs)	1 to 199, and 500	1.5	7.0
Intermediate	200 to 399	1.5	7.0
Long	400 to 499	1.5	10.0
	Buffer Spring	1.5	-
AK, AM			
Short	1 to 199	1.5	4.5
Intermediate	200 to 399	1.5	7.0

SECTION IX

CAPABILITY DATA

Introduction

This section describes the method of determining the spring loads and current flow requirements for the wire spring relays. These loads have been tabulated for the AF, AJ, and AK relays. The AG relays are treated in more detail in Part II due to their precise release-time requirements.

Pull curves are provided from which the operate, nonoperate, hold, and release ampere turns may be obtained. The ampere turns required to operate various numbers of springs on the AF and AJ relays have been tabulated.

The following tables and pull curves form a part of this section.

Tables:

Pull Curves - Figures:

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PART I - AF, AJ, AND AK RELAYS

General

In considering ampere turn adjusting requirements for any spring combination, the following must be considered:

1. The magnetic capability of the relay, including the size, flatness, and quality of the magnetic parts;

2. The operated airgap, or stop-disc height;

3. The maximum airgap which, with the stop-disc height, determines the armature travel;

4. The gram loads at the critical points in the travel.

With such a large number of variables, it does not seem reasonable to assume all contributing factors at their extreme limits. The gram loads, therefore, have been taken as maximum and the airgaps as nominal. The nominal air gap values may be used in considering maximum critical loads because, for the small percentage of cases where the maximum loads are combined with minimum pull, maximum airgap, and unfavorable contact gauging, adjustments can be made. If the load at the backstop is too high, the armature travel cannot be changed to obtain a smaller airgap, but the back tension can be adjusted to compensate for this. Considering the critical load point, if there is a large spread between contact actuations, the critical load point will be toward the minimum anyway. If there is a small spread between contact actuations, a mass adjustment can be made to reduce the load point.

The construction of the relay is such that for any stage the break-contact loads may be picked up earlier than the make-contact loads. However, to provide a simple method of computing spring loads and operate ampere turns, no differentiation has been made between the pickup point of breaks and makes. The resulting error in the load is small and usually on the conservative side.

Contact Actuation

The wire spring relay uses a single card system with the single wires held in a fixed position. The twin wires are actuated by the moving card on the armature, either making or breaking contact with the single-wire contact.

Makes

The make twin wires are pretensioned toward the single contact, but held away from them by the tension of the balance spring against the moving card. Thus, they provide an opposing back tension tending to push the armature toward the core but counteracted by the balance spring. As the relay starts operating, the tension of the twin wires decreased in magnitude, resulting in an increasing balance spring load on the armature. This continues up to the pickup point where the twin wires just make contact with the single wire. During the next 0.8-mil travel, the make load is transferred from the card, or armature, to the single contact. At this critical load point, the make wire tension against the card becomes zero, resulting in further increased load on the armature. The make wire tension on the armature remains zero for the remainder of the armature travel as the moving card and twin wires separate. Fig. IX-1 shows how the load on the armature changes as the armature moves toward the core.

Breaks

In the unoperated position, the twin break wires rest against their mating single contact. The twin wires do not touch the card and no load is on the armature at this point; therefore, no build-up of load occurs as the gap between the card and the twin wires closes to the pickup point. During the next 0.8-mil travel, the load is transferred from the single contact to the card. From this critical load point, where the transfer is completed, to the end of the travel, the break spring load builds up at a small, but uniform, rate due to the buildup of the break spring wires, the balance spring, and the armature hinge.

The load on the armature from combined make and break loads is shown in Fig. IX-1. The armature is held against the backstop by the balance spring tension. This tension has two components, the assumed back tension, holding the armature against the backstop, and the twin make wire spring tension, tending to operate the armature. As the armature moves toward the core, the load builds up at a slow uniform rate due to the buildup of the balance spring, armature hinge, and the contact spring. When the actuating card touches the break spring, there is a rapid buildup of load until the break-contact opens, at which point the armature is carrying the full break spring contact pressure.

As the armature continues its movement, the make-contact closes. At this point there is another rapid buildup of load as the twin wire make-contact tension tending to operate the armature is transferred to the single contact. From this point on there is only the buildup due to the balance spring, armature hinge, and break-contact spring.

For multiple stage loads, the load would increase in a similar manner as later stage makes and breaks are picked up.

Critical Load Points

The critical load points are the points in the armature travel where a major load change takes place, such as picking up a break or a make twin contact spring. Fig. IX-2 shows a typical load buildup curve and pull curves indicating the way in which the critical load points control the ampere turns required to operate the relay.

The critical load airgaps have been computed for the different armature travels and stop discs and are shown on Table IX-1. The loads at the critical points for relays with 0.006-inch stop discs are shown on

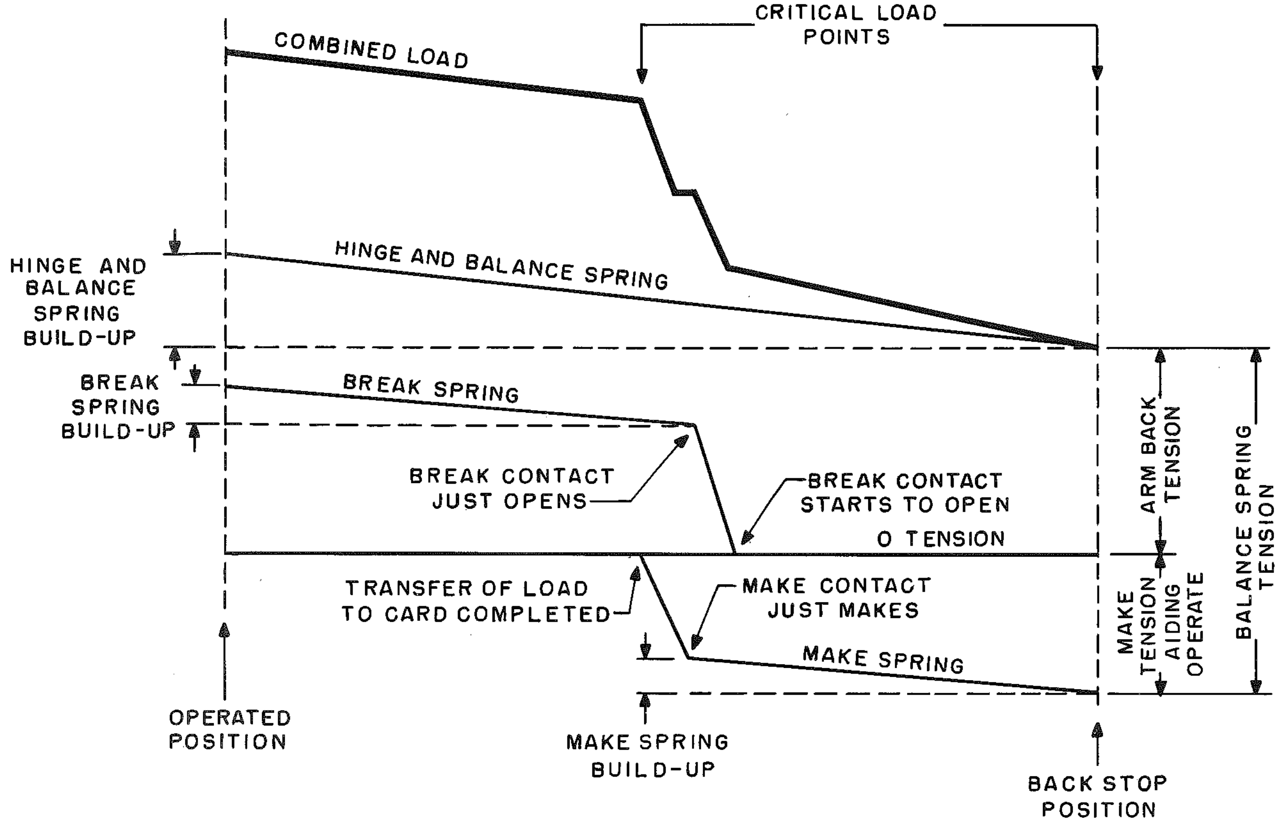

Fig. IX-1 - Single Stage Load Buildup

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Table IX-2. These loads assume that the last of all makes and breaks in each stage is picked up at this point.

When considering marginal or sensitive relays, the adjustment should be computed on a more exact basis. Fig. IX-4 shows the distribution of the contact pickup points for marginal or sensitive adjustments. This figure will be discussed in more detail in Appendix A.

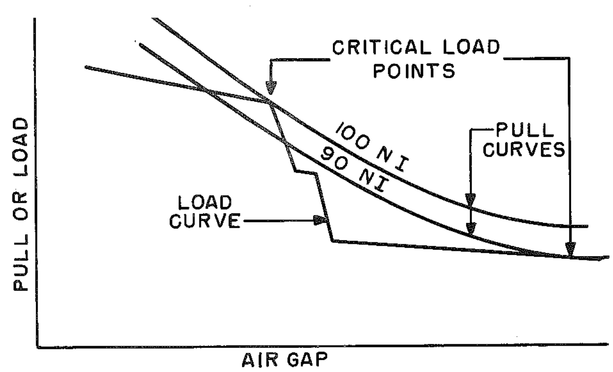

Fig. IX-2 - Typical Load and Pull Curve

Light Contact Forces

In relay applications requiring great sensitivity, an extremely slow release, etc, a lighter contact force has been used. The loads are figured the same as for the standard force except that the nominal contact load is reduced from 13.3 grams at the card to 8.6 grams.

Balance Spring, Armature Hinge, and Back Tension

The balance spring is pretensioned to provide an initial tension on the armature of minimum 30 grams above that required to counteract the tension of the make-contact springs. Critical or sensitive relays may be figured with a back tension of minimum 20 grams, and the lower tension is specified in the shop requirements and on the Circuit Requirements Table. The balance spring tension can be adjusted, if necessary, to meet the electrical requirements.

The thickness of the balance spring varies with the number of makes and armature travel in accordance with the following table.

No. of Makes	Travel* S	I	L	Balance Springs P Detail	Thickness inch	Buildup in Gm/Mil Travel Min	Nom	Max
				AF and AJ Relays				
0	x	x	x	15A220	0.014	0.090	0.107	0.127
1	x	x	x	15A221	0.016	0.134	0.159	0.189
2	x	x	x	15A221	0.016	0.134	0.159	0.189
3	x	x	x	15A226	0.018	0.189	0.225	0.267
4	x	x	x	15A226	0.018	0.189	0.225	0.267
5	x			15A226	0.018	0.189	0.225	0.267
5		x	x	15A222	0.020	0.258	0.307	0.364
6	x	x	x	15A222	0.020	0.258	0.307	0.364
7	x			15A222	0.020	0.258	0.307	0.364
7		x	x	15A223	0.022	0.338	0.403	0.478
8	x	x	x	15A223	0.022	0.338	0.403	0.478
9	x			15A223	0.022	0.338	0.403	0.478
9		x	x	15A224	0.025	0.494	0.588	0.697
10	x	x		15A224	0.025	0.494	0.588	0.697
10			x	15A225	0.025	0.494	0.588	0.697
11	x			15A224	0.025	0.494	0.588	0.697
11		x	x	15A225	0.025	0.494	0.588	0.697
12	x	x	x	15A225	0.025	0.494	0.588	0.697
24	x			15A334	0.032	1.030	1.230	1.460
24	x			11F880	0.036	1.452	1.696	1.977
				AK Relays				
0 to 2	x	x		10B698	0.018	0.175	0.209	0.249
3 to 5	x	x		10B697	0.020	0.234	0.278	0.330

*S = Short
I = Intermediate
L = Long

A thicker balance spring may be specified to facilitate meeting a nonoperate or release requirement.

The balance spring tension, plus a buildup of 1 gram per make-contact per stage, is added to the spring load at the critical points in computing the total gram loads. The 24-make relay requires an extra heavy balance spring which if figured as 24 grams per stage.

The armature hinge is assumed to have an initial load of zero grams and builds up at a uniform rate of 7 grams per stage for AF, AJ, and AK relays.

Buffer Springs

Buffer springs are provided to aid in meeting a release requirement. The buffer spring is provided on a code basis and is used normally in adjusting the relay if the specified release cannot be met without its use. This spring is picked up with a minimum 0.004-inch, maximum 0.010-inch gauge at the center line of the card.

The buffer spring load is thus picked up after the last critical load point. Normally, it should not affect the operate ampere turns, but the operate load where the buffer spring is picked up should be checked to be sure that the operate is not affected. The buffer spring tension is effective only with less than the maximum spring load and thus will not affect the hold ampere turns.

Determination of Airgaps

The backstop position is set by the core plate and the core, while the operated position is controlled by the stop disc height. The airgap with the armature at the backstop is dimension A of the core plate minus the 0.058-inch armature thickness. The height of the stop disc has no effect on this. The tolerances affecting the unoperated airgap total ±0.005 inch and are due to variations in the core plate dimension A, the armature flatness, and the armature thickness. Dimension A for the various travels and stop discs is shown on Table IX-1. A short travel relay with 0.006-inch stop discs will have a nominal unoperated airgap of 0.092 inch - 0.058 inch = 0.034 inch ±0.005 inch. The minimum airgap for a nonoperate would be 0.034 inch - 0.005 inch = 0.029 inch.

The armature stop discs set the operated position of the armature. With 0.006-inch stop discs, the armature is parallel to the core in the operated position and the gap at the center line of the card is the same as that at the stop disc. This is because the armature hinge holds the rear of the armature 0.006 inch away from the core. With larger stop discs, there is, effectively, a triangle on top of a rectangle as shown in Fig. IX-3. The triangular part, ie, the difference between the stop disc height and 0.006 inch, is converted to the center line of the card by dividing by the a/b ratio of Fig. IX-3. For example, with 0.022-inch stop discs (average 0.0235) on an AF relay, the average effective stop-disc height at the center line of the card is:

$$0.006 \text{ inch} + \frac{0.0235 \text{ inch} - 0.006 \text{ inch}}{0.718} = 0.030 \text{ inch}$$

Operate Ampere Turns - Simplified Method

The simplified method of computing the operate ampere turns is recommended for general use. The detailed method described later should be used for marginal or sensitive requirements where a more precise method may enable more difficult circuit

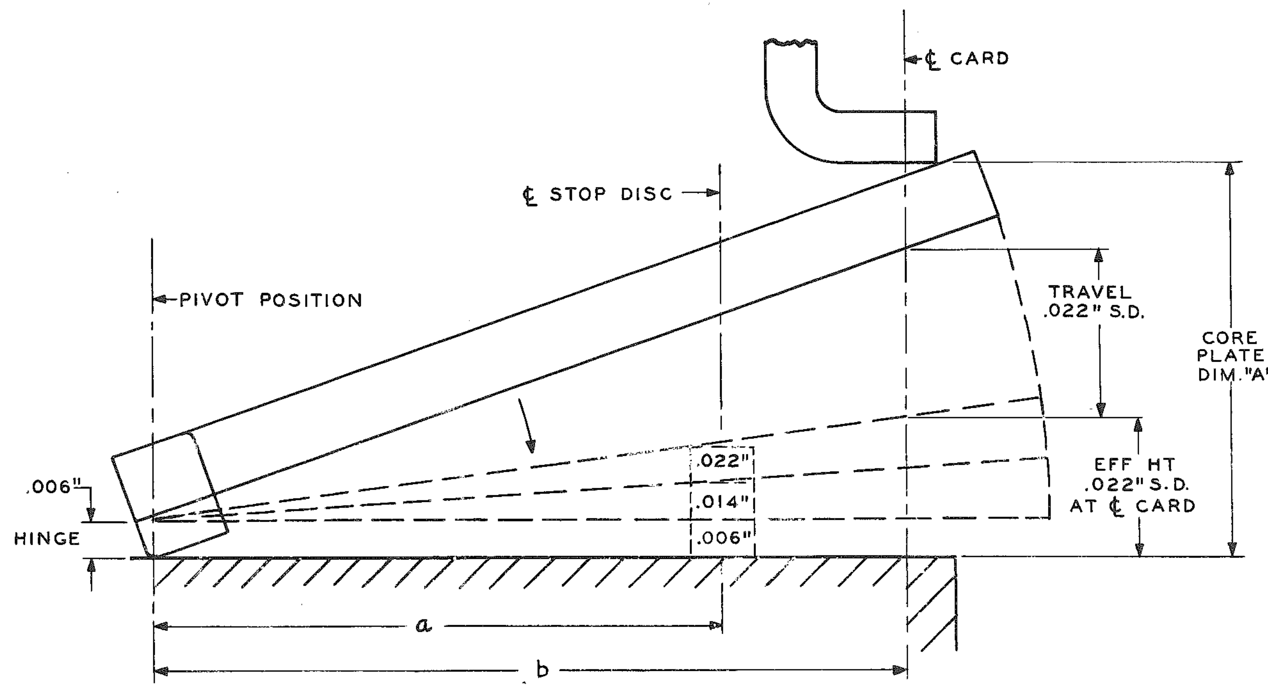

Fig. IX-3 - Airgap Relationship

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conditions to be met. The simplified method of computing the operate ampere turns for standard adjustments is shown on Table IX-1. This table also shows the airgap values for the different armature travels and stop discs. The critical load points and maximum operated loads computed in this manner are shown on Table IX-2. This table is calculated on the basis of 0.006-inch stop discs, but may be used for any stop disc by substituting the proper airgap from Table IX-1. The operate ampere turn values have been computed and are shown on Tables IX-3, IX-4, and IX-5 for the AF and AJ relays and the AJ relay with laminations.

Operate Ampere Turns - Detailed Method

This method of computing the operate ampere turns gives more accurate results than the simplified method. It is used on sensitive or marginal relays where the requirements figured in the normal manner fail to meet the circuit requirements.

Fig. IX-4 shows the maximum load curves from which the load buildup for any spring combination may be determined. This curve starts with an assumed back tension at the unoperated airgap; has a slight buildup to the point where the contacts make, or break; and then a rapid buildup occurs for a small travel interval. The make-contacts at the pickup point have a load of 13.3 grams ±25 percent. At the backstop, this tension will be 13.3 grams plus the buildup in tension from the pickup point to the backstop.

After contact actuation, there is a small buildup on break-contacts to the end of the travel. For intermediate travel, there are two stages of contact pickup; for long travel, three stages.

The buildups for the various thickness balance springs and the armature hinge are also shown.

The actual method of using the load buildup curve to determine the ampere turn operate is shown in Appendix A.

Nonoperate Ampere Turns

No load tables are needed for the nonoperate ampere turn values as the back

Travel	Stop Discs	Minimum Unoperated Airgap	Core Plate Dim. A	Core Plate P Number Ordinary Duty	Core Plate P Number Long Life
	Inch				
Short	0.006	0.029	0.092	15A212	15A215
Intermediate	0.006	0.047	0.110	15A213	15A216
Long	0.006	0.063	0.126	15A214	15A217
Short	0.014	0.040	0.103	15A280	15A279
Intermediate	0.014	0.058	0.121	15A277	15A281
Long	0.014	0.074	0.137	15A278	-
Short	0.022	0.047	0.110	15A213	15A216
Short (special)	0.006	0.020	0.083	15A282	-

tension, stop discs, and armature travel are the only significant factors. The nonoperate ampere turns are obtained by reading the back tension at the minimum unoperate airgap on the nonoperate pull curves Fig. IX-11, IX-17, IX-23, or IX-33. The minimum airgaps are tabulated above.

The back tension is usually taken as 30 grams, but this may be increased to 60 grams with no change in spring thickness, or to a maximum of 85 grams by using the next thicker balance spring. A still higher nonoperate may be obtained by using a balancing spring two sizes thicker. This allows a maximum back tension of 115 grams. Any increase in tension over 60 grams must be added to the critical load points. A higher nonoperate may also be obtained by using an airgap higher than that required for the spring combination. The speed coils (4.4-, 16-, 270-, 395-, 400-, and 700-ohm coils) have a maximum armature back tension of 60 grams specified in the M specification. Nonoperate or release requirements for these coils should not be figured on a back tension greater than 60 grams. The back tension requirement in the M specification for these relays with a nonoperate or release should be maximum 80 grams.

Where no nonoperate adjustment is specified and an equivalent nonoperate is desired for time studies, or for consideration in a marginal circuit, the equivalent nonoperate is assumed to correspond to 30 grams at the minimum unoperated airgap. This nonoperate should be met without readjustment and should be used, if possible, when adding a nonoperate requirement to existing relays.

Hold Ampere Turns

The maximum load in the operated position is the critical point for the hold ampere turns. These maximum loads are shown on Table IX-2 and read on the hold pull curve to determine the hold ampere turns. The operated airgap for hold is based on the maximum stop-pin height and corrected to the equivalent gap at the center line of the card. These operated position airgaps are shown on Table IX-1.

Release Ampere Turns

The procedure for obtaining the release ampere turns, together with the critical release loads, is shown on Table IX-6. The critical release loads shown on Table IX-6 are based on a back tension of 30 grams, but the nominal 60-gram tension may be used by increasing the release loads by 30 grams. This does not change the operate requirements. The 30-gram back tension gives a release requirement that can be met with the minimum amount of adjustment and should be used where it will meet the circuit conditions.

A relay may be tensioned up to an 85-gram back tension to meet a release circuit condition by using the next thicker balancing spring. This, however, requires that the operate loads at the critical points be increased by the amount the back tension is raised above 60 grams. Where critical release conditions are involved, a more exact release requirement may be computed using the minimum load buildup curve (Fig. IX-5). The method of using this figure is the same as shown in Appendix A for figuring the operate.

Current Flow Requirements

The current flow requirements are obtained by dividing the ampere turns by the specified turns. The operate and hold requirements must be increased and the nonoperate and release decreased, if necessary, to use values that are readable on the 35F relay test set.

The 35F relay test set has four scales with the nearest readable value as shown below:

Scale	Readable Tolerance
ma	
0-3	±0.02
3-15	±0.10
15-75	±0.50
75-750	±5.00

Check Adjustments

Multiple-wound relays may be used with the windings in series or with the windings in separate operating circuits. The current flow requirements for the first condition are computed the same as for a single winding equivalent to the sum of the turns of the two windings.

Where each winding has a different operating condition, readjust requirements are computed for one winding in the normal manner. Check adjustments are computed for the other winding, or windings, assuming a ±5 percent variation in turns on the windings. This is necessary in order to insure that any relay, adjusted on the winding that has the readjust requirements, will always meet the requirements on the check winding provided the check winding has the proper number of turns.

The method of computing the check readjust or test requirements is as follows, assuming that the primary winding is the adjusting winding.

$$\text{Operate} - \frac{\text{pri operate x pri turns x 105\%}}{\text{sec turns}}$$

$$\text{Hold} - \frac{\text{pri hold x pri turns x 105\%}}{\text{sec turns}}$$

$$\text{Nonoperate} - \frac{\text{pri nonoperate x pri turns}}{\text{sec turns x 105\%}}$$

$$\text{Release} - \frac{\text{pri release x pri turns}}{\text{sec turns x 105\%}}$$

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SECTION IX

CAPABILITY DATA

PART II - AG RELAYS AND SLOW RELEASE AK RELAYS

AG Relays

The AG relay is a slow release wire spring relay having a maximum capacity of 12 transfers. An AG relay with the lightest contact load is capable of providing a minimum release time of 0.380 second. The maximum release time is generally 2 to 2-1/2 times the minimum release time.

Instead of stop discs, which are provided on the AF and AJ relays, the AG relay has a dome embossing on the armature pole face. In the operated position of the armature, the dome touches the center leg of the core. This provides a relatively uniform point of contact between the armature and the core and thereby minimizes the effects of varying alignment of the armature and the core on the release times. The core of the AG relay is hydrogen annealed to obtain the permeability and coercive force required, so that the AG relay minimum to maximum release time spread is within the required limits.

Generally, the AG relay is provided with a short-circuited winding in the form of a sleeve over the center leg of the core. An aluminum sleeve of 0.046-inch wall thickness or a copper sleeve of 0.046-inch, 0.091-inch, or 0.147-inch wall thickness is furnished as required to obtain the desired release times. Most AG relays are equipped with a buffer spring which is adjustable to provide additional load in the operated position for reducing or controlling the maximum release time.

Relays having a copper or aluminum sleeve over the core are slower in operating than relays having only a single inductive winding. For this reason, where a fast operate, slow release relay is required, an AG relay may be used with a noninductive resistance in parallel with the inductive winding. The same arrangement may also be used where the required relay release times are less than those provided by the minimum size of sleeve. Instead of a sleeve, a short-circuited secondary winding may be provided. This is used only where the circuit conditions require that the variation in relay release times shall be less than those obtainable with a sleeve. Where fast operate time is required, the secondary winding is short-circuited by a make-contact of the relay.

Test and readjust hold and release current flow requirements are specified to control the releasing times of AG relays. The hold requirement determines the minimum release time and the release requirement determines the maximum release time. Current flow requirements are more convenient to apply than direct timing requirements and are unaffected by variations in copper resistance due to changes in ambient and relay winding temperatures. These hold and release requirements shall not be used to meet any circuit marginal hold or release current conditions. A circuit current release condition is not desirable for an AG relay and would require special consideration.

In the manufacturing specification for an AG relay, minimum and maximum release times, based on the readjust hold and release current requirements, are specified. In the shop, the relays are adjusted to the readjust hold and release current requirements, and the release time requirements provide a check of the dimensional and magnetic characteristics of the parts and their proper assembly in the relay. This assures that the relays as manufactured are capable of providing the required release times.

Slow Release AK Relay

The AK relay can be made slow release by using an embossing on the armature, similar to that of the AG relay, and a copper or aluminum sleeve over the core. It is not necessary that both units on the AK relay be made slow release, since one unit can have the embossed armature and the other unit the standard stop discs. Requirements similar to those of the AG relay are usually specified for the slow release AK relay, except the release requirements are not as effective in controlling the maximum release time since buffer springs are not provided on the AK relays.

Selection of Coded Relay

List of Codes

Section II of this specification provides a list of coded AG and AK relays according to the number of contacts. When the selection of a relay code is made, spare contacts may be tolerated, depending on the demand, as outlined in Section II, page 1.

Release Times

The minimum and maximum test release times are given in Section II for each relay code, except where the relay does not have a sleeve. These are the release time limits that the relay will not exceed with the relay adjusted within the test hold and release current requirements. These release times, although they are not specified in the circuit requirements table, are listed here for information purposes when selecting a suitable coded relay. The effect of heating or magnetic interference on the release times will be considered later in this section.

Requirements for Circuit Requirements Table

The current flow requirements given in Section II are the test and readjust operate, hold, and release requirements that shall be specified in the Circuit Requirements Table. With AG relays, as well as with AF and AJ relays, it is impractical from a manufacturing consideration to have more than one adjustment for a relay code. This is because all wire spring relays are adjusted in the relay assembly shop in accordance with the M specification requirements. Accordingly, current flow requirements other than those shown in Table II-3 cannot be specified without changing the M specification requirements.

A full soak (FS) requirement shall be specified in the soak column of the Circuit Requirements Table before all current flow requirements. The current flow soak shown in Section II corresponds to 300-ampere turns saturation and is specified in the manufacturing specification as we have no control of the voltage used in the shop adjustment. The difference between the effect of FS and 300-ampere turns soak on the release time is negligible.

Soak Effect

The release times for AG relays are based on releasing after a 300-ampere turn soak. If the soak is less than 300-ampere turns, the releasing time will decrease by the following amounts.

250 NI soak - 1.0%
200 NI soak - 2.0%
150 NI soak - 4.0%

The circuit current should be applied to an AG relay for a period of time somewhat longer than the actual operate time of the relay to insure that the full releasing time will be obtained. The minimum circuit closure should be 0.3 second for the 0.147-inch sleeve, and 0.2 second for the 0.091- and 0.046-inch sleeves.

Effect of Heating on Release Times

Where a slow release relay has a long circuit holding time, an appreciable increase in winding resistance results, due to the temperature rise of the relay coil. A corresponding increase in the resistances of the sleeve and the core, or equivalent decrease in the sleeve and the core conductance results. The effect is to reduce the minimum release times shown in Table II-3, which were determined on the basis of the relay at an ambient temperature of 80° F.

The final winding temperature is obtainable from the information provided in Section IV. For the relay winding at final temperature T, the minimum release time is equal to the minimum release time at room temperature multiplied by $\dfrac{1}{1 + \dfrac{(0.9T - 80)}{458}}$. The 0.9 factor allows for the sleeve and the core being at a lower temperature than the average winding temperature T.

Effect of Magnetic Interference

The effect of magnetic interference on the requirements and performance of AG and AK relays is covered in Section V.

Operate Times

Operate times may be determined from the data contained in Section VII, Part I. In general, operate times of AG relays are considered to be load-controlled. This is due to the time constant of the AG relay coil, including a sleeve where provided, being of such length as to result in an average operate time greater than 0.010 second.

General Design Information

In determining the adjusting requirements for slow releasing relays, the same factors are involved that are described in Part I of this section for the AF and AJ relays under the headings "General" and "Contact Actuation." There are, however, some differences because of the dome embossing on the armature of the AG relay and some AK relays, as compared with stop discs on the armature of the AF and AJ relays. These differences are:

1. The operated airgap is zero, since the dome embossing on the armature touches the core. For this reason, the airgap is the same as the armature travel at all critical load points.

2. The critical load airgaps for determining operate and nonoperate requirements for AG relays and AK relays with the domed armature have been computed and are shown in Tables IX-7 and IX-8.

3. For light contact force, the loads are figured the same as for the heavy contact force, except that the nominal contact load is reduced by 5 grams for each contact pair.

The general procedure for designing an AG relay is as follows:

1. Determine the maximum operated load.

2. Determine the corresponding readjust and test hold ampere turn and current flow requirements.

3. Select a sleeve so that the minimum release time required of the relay is met with the test hold requirement.

4. Determine the minimum operated load, and add the buffer spring load that is to be used (generally 160 grams).

5. Determine the corresponding readjust and test release ampere turn and current flow requirements.

6. Determine the maximum test and readjust release times.

7. Determine the operate readjust and test requirements.

Details of this procedure are covered in subsequent pages of this section and in Appendixes B and C. The design of an AG relay with a sleeve is covered in Appendix B, and the design of an AG relay with the winding in parallel with a noninductive resistance is shown in Appendix C.

Balance Spring, Armature Hinge, and Back Tension

Balance springs are pretensioned and are used to provide back tension to position the armature against the backstop. With make-contacts in the spring combination, the balance spring must also overcome the forward tension of the twin wire make-contact springs in keeping the contacts open in the unoperated position. For AG relays, the net back tension of 85 grams is used in determining the operate and release loads and 20 grams in determining the nonoperate and hold loads. The balance spring tension and the buildup of the balance spring at the critical load points are included in the spring load data in Tables IX-9 to IX-11, inclusive.

Balance Spring for AG Relays

No. of Makes	Travel* S	Travel* I	Travel* L	P Detail	Thickness inch	Buildup in Gm/Mil Travel Min	Buildup in Gm/Mil Travel Nom	Buildup in Gm/Mil Travel Max
0	√			15A220	0.014	0.090	0.107	0.127
0		√	√	15A221	0.016	0.134	0.159	0.189
1	√	√		15A221	0.016	0.134	0.159	0.189
1			√	15A226	0.018	0.189	0.225	0.267
2	√	√		15A226	0.018	0.189	0.225	0.267
2			√	15A222	0.020	0.258	0.307	0.364
3	√	√		15A226	0.018	0.189	0.225	0.267
3			√	15A222	0.020	0.258	0.307	0.364
4	√	√	√	15A222	0.020	0.258	0.307	0.364
5	√			15A222	0.020	0.258	0.307	0.364
5		√	√	15A223	0.022	0.338	0.403	0.478
6	√	√	√	15A223	0.022	0.338	0.403	0.478
7	√	√		15A223	0.022	0.338	0.403	0.478
7			√	15A224	0.025	0.494	0.588	0.697
8	√			15A223	0.022	0.338	0.403	0.478
8		√	√	15A224	0.025	0.494	0.588	0.697
9	√	√		15A224	0.025	0.494	0.588	0.697
9			√	15A225	0.025	0.494	0.588	0.697
10	√			15A224	0.025	0.494	0.588	0.697
10		√	√	15A225	0.025	0.494	0.588	0.697
11	√	√	√	15A225	0.025	0.494	0.588	0.697
12	√	√	√	15A225	0.025	0.494	0.588	0.697

*S = Short
I = Intermediate
L = Long

The required thickness of the balance spring depends on the number of make-contacts used and the armature travel, as shown in the foregoing table. For the same spring combinations, balance springs for AG relays are generally thicker than those for AF and AJ relays because the back tension for AF and AJ relays is considered to be 60 grams instead of 85 grams in computing the operate and release requirements. The greater back tension for AG relays allows for a wider range of operated load adjustment.

The armature hinge is assumed to have zero load in the unoperated position. As the armature moves to the operated position, there is an additional load because of the stress in the armature hinge. At each critical load point, the increase in hinge tension is added to the contact load. This buildup of armature hinge tension is approximately 1 gram per stage for operate and hold, and 0.5 gram per stage for release.

Buffer Spring

AG relays are generally provided with a buffer spring which is effective after most or all contacts have been actuated.

The buffer spring is adjustable and provides for increasing the release load without materially affecting the operate ampere turns. The buffer spring load is adjusted as required, to take care of variations in release characteristics of AG relays as manufactured. Where a particular relay has a coercive force greater than average (poor anneal), the buffer spring is adjusted so that the release requirement is met. On the other hand, where a relay has a coercive force less than average (good anneal), the hold requirement is controlling and the release requirement can be met without any buffer spring load. By this means, a smaller difference between the hold and release adjusting ampere turn requirements is obtainable, and this reduces the spread between minimum and maximum release times.

AG relays require the buffer spring where the balancing spring and contact springs do not provide the release load that is necessary for a 6-ampere turn readjust release requirement. This is the lowest readjust release recommended for AG relays in order to provide adequate margin for adjustment deterioration.

Originally, only a 0.012-inch buffer spring was provided. Later a 0.016-inch buffer spring was made available. The use of either the 0.012-inch or the 0.016-inch thick buffer spring is optional with the shop depending on which spring they find most desirable in meeting the release requirement of the relay being adjusted. The 0.012-inch buffer spring is capable of being adjusted to a maximum of 160-gram load at the center line of the card, and 0.016-inch buffer spring to 280 grams.

Before the 0.016-inch buffer spring was made available, it was the general practice to use the full 160-gram buffer spring load in calculating the readjust release requirement. This gives the least spread in release times and often makes the relay suitable for many circuit applications, thereby reducing the number of codes. For future AG relay designs, the use of 160-gram buffer spring load will be continued as the standard; however, with the availability of the thicker buffer spring, the buffer spring load may be increased to a maximum of 280 grams, if required.

Minimum Release Time

A particular AG or AK relay design meets the minimum release time required for circuit application by means of the specified hold requirement and the size of the sleeve. These are determined as outlined briefly in the following paragraphs and as covered in greater detail in Appendixes B and C.

The readjust hold ampere turn requirement is determined by the maximum operated load with the minimum armature back tension of 20 grams for the AG relay and 30 grams for the AK relay. The maximum operated loads are shown for the various spring combinations in Table IX-10. The maximum operated load read on the hold pull curve of Fig. IX-6 or IX-35 gives the readjust hold ampere turn requirement. All AG relays have a readjust hold of not less than 9-ampere turns and generally a minimum of 3-ampere turns difference between the hold and release readjust requirement. The 3-ampere turns provide a suitable adjustment range so that the relays are adjustable with normal adjusting effort. The test hold shall be 5 percent, but not less than 1-ampere turn greater than the readjust hold.

The minimum release time is obtained from Fig. IX-6 or IX-35. The test and readjust hold ampere turns are referred to the minimum time curve for the specified size of sleeve, and the minimum test and readjust release times are read on the ordinate scale.

Maximum Release Time

The specified release requirement and the size of sleeve selected for the relay determine the maximum release time. These are determined as outlined briefly in the following paragraphs and as covered in greater detail in Appendixes B and C.

The minimum operated load, with an armature back tension of 85 grams for the AG or 60 grams for the AK relay, is used to obtain the readjust release ampere turn requirement. This load can be determined, for any particular spring combination, from the data in Table IX-11. The minimum operated load is applied to the release pull curve of Fig. IX-6 or IX-35 to obtain the readjust release ampere turn requirement. When a buffer spring is provided on the AG relay, an additional load of 160 grams is generally added to the minimum operated load and the readjust release ampere turn requirement is determined for this total operated load. With the introduction of the thicker 0.016-inch buffer spring, a maximum of 280-gram buffer spring load may be added. In most cases, however, the 160-gram added buffer spring load is sufficient to provide the required readjust release requirement and maximum release time.

The minimum readjust release requirement permissible for the AG relay is 6-ampere turns. The minimum difference between the readjust hold and release ampere turns shall be 3-ampere turns. Where the relay has a light contact load, the buffer spring must be provided in order to obtain at least 6 ampere turns readjust release. The test release is 2 ampere turns less than the readjust release. A test release below 4 ampere turns is undesirable because an adjustment range is approached where release performance becomes unreliable due to small differences in operated load causing large differences in release ampere turns and release times.

The margin provided between test and readjust requirements is greater for release than for the hold because (1) the maximum release time is generally not as critical as the minimum release time and so greater release requirement margin is permissible and (2) the tendency is for the release time to increase due to wear. It is desirable to make allowance for this effect so that maintenance is not excessive and therefore, a 2-ampere turn spread between test and readjust release is generally provided.

The maximum release time is obtained from Fig. IX-6 or IX-35. The test and readjust release ampere turns are referred to the maximum release time curve for the proper sleeve from which the maximum test and readjust release times are obtained.

Operate Ampere Turns

AG Relay

The operate ampere turn requirement is based upon maximum loads, maximum armature travel, and average contact gauging. The loads and the airgaps are at the center line of the card. The load at the backstop and at each critical load point is determined from the data shown in Table IX-9. These loads include the balance spring load. The operate ampere turns are read for the various loads at their respective airgap on curves of Fig. IX-7. Since a buffer spring is generally provided, a critical operate load occurs at the buffer spring pickup point, which is at the 0.007-inch airgap. This load is obtainable from the data shown in Table IX-9, and the operate ampere turns for this load are determined from Fig. IX-7. The greatest of the operate ampere turns for the various critical load points is specified as the readjust operate requirement. For many of the AG relay designs the critical load in determining the operate ampere turns is the 85-gram back tension load at the unoperated airgap (armature against the backstop).

AK Relay

The operate ampere turn requirement for the AK relay with the embossed armature is figured as shown in Part I for the relay with the standard stop disc.

Nonoperate Ampere Turns

A nonoperate requirement is specified only where there is a nonoperate circuit condition or a minimum operate time requirement. A margin of 15 percent shall be provided between the readjust nonoperate and the maximum circuit nonoperate current. Nonoperate requirements are not recommended on the slow releasing AK relays due to the difficulty of adjusting the balancing spring.

The nonoperate readjust ampere turn requirement for the AG relay is determined by the minimum back tension of 20 grams at the minimum unoperated airgap which is shown in Table IX-8. The readjust nonoperate ampere turn requirement is read on curves shown in Fig. IX-8.

If the 20-gram back tension is insufficient to provide a suitable readjust nonoperate requirement, greater back tension may be used. The added back tension must also be considered when determining the hold requirement. A thicker balance spring may be required and shall be in accordance with the recommendation of the switching apparatus group responsible for the AG relay. Another method for increasing the nonoperate requirement is to use a core plate that is associated with a larger armature travel, which provides a greater unoperated airgap.

Check Adjustments

Check adjustments required for plural winding AG relays shall be determined in the same manner as outlined for AF and AJ relays.

SECTION IX

CAPABILITY DATA

PART III - AL AND AM RELAYS

For AL and AM relays the adjustments of the relay that are implied by the current flow requirements are verified in the same way as the requirements of other wire spring relays. However, the technique for making current flow tests is different since the core of the relay can retain a magnetic bias and in some cases this significantly affects the outcome of current flow tests. The added steps in making current flow tests on magnetic latching relays are necessary to insure that the proper magnetic state has been obtained before each relay characteristic is tested.

The operate and nonoperate (if specified) current flow values are applied when the magnetic structure of the relay is in its zero flux state (demagnetized state). To obtain the zero flux state, the specified soak current is applied followed by the specified NF release (no flux release) current. These currents are applied in a manner that causes the NF release flux to be in the opposite direction from the soak flux. Single-wound coils require current reversal. The soak current, specified with a negative (-) sign, will be in the same direction as the operate current, which also has a negative sign. All release currents will be specified with a positive sign indicating that these currents must flow in an opposite direction to the operate, nonoperate, and soak currents. Double-wound coils are basically the same as single-wound coils except that the operate and soak currents will generally be specified for the secondary winding. Some exceptions to these general rules will occur, usually because the secondary resistance may be so high that nonoperate and/or NF release currents cannot flow from the standard central office battery. The same sign convention will be used on both single- and double-wound coils.

The release, nonrelease, and NF release current flow values are applied when the magnetic structure of the relay is in its saturated flux state (latched state). To obtain the saturated state, the specified soak current is applied. The specified release, nonrelease, and NF release currents are applied in such a manner that the release flux is in the opposite direction from the soak (saturate) flux. Single-wound coils require current reversal. The release, nonrelease, and NF release current will be specified as a positive current. Double-wound coils are basically the same as single-wound coils and it is intended that the flux resulting from release currents be opposite to the soak and operate flux. The release, nonrelease, and NF release current generally will be specified on the secondary winding except as noted previously.

The AL and AM magnetic latching relays are not polar relays, ie, there is no preferred operate direction. However, the magnetic structure does exhibit a hysteresis effect such that the previous coil current affects relay performance when the next current is applied. Therefore, current flow testing results depend on the technique that is used to perform the test. The following sequence is recommended:

	Step	Omit these steps when:
1.	Soak current	
2.	NF release current	
3.	Operate current flow test	
4.	Soak current	Nonoperate is not specified
5.	NF release current	
6.	Nonoperate current flow test	
7.	Soak current	Nonrelease is not specified
8.	Nonrelease current flow test	
9.	Soak current	
10.	Release current flow test	
11.	Soak current	
12.	NF release current	Relay is to be left operated

Note: If there is no circuit specification that the relay be left operated after it is tested, it should be returned to its released state.

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Appendix A

Gram Load Determination Using the Maximum Load Curve - Fig. IX-4

A brief description of the curves in Fig. IX-4 will be helpful in describing its use. The gram load curves have several diagonal lines starting at the right side of the sheet. The meaning of the different lines is marked and needs no further explanation. These lines represent the negative buildup of the springs resting against the armature. They continue in a uniform manner until the make-contacts close, at which time there is a rapid change of tension to zero, where it remains until the end of the travel. Just before the make load is picked up, there is a rapid buildup of the break-contact load for a few mils travel. The break buildup then continues at a low, uniform rate until the end of the travel.

The numbers under TRAVEL at the right top of the sheet (Fig. IX-4) have the following significance.

P	Preliminary contacts
E	Early contacts
L	Late contacts
LONG L	Starting point for late contact on long travel relay
LONG E	Starting point for early contact on long travel relay
INT L	Starting point for late contact on intermediate travel relay
LONG P	Starting point for preliminary contact on long travel relay
INT E	Starting point for early contact on intermediate travel relay
SHORT L	Starting point for late contact on short travel relay

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The four horizontal scales are for the following purposes.

The top scale (P) is for preliminary contacts, the next (E) is for early contacts, the third (L) is for late contacts, and the lower scale (L SPL) is for contacts on a relay with a special travel. Thus, an early contact on a long travel relay would start on the E scale under LONG E, and on an intermediate travel relay on the E scale under INT E. A special travel relay is one that has a core plate that does not provide for the full contact gauging, such as a core plate for a 0.006-inch stop disc on a relay equipped with 0.014-inch stop discs.

Assume that it is desired to determine the maximum gram load for a relay having a spring combination consisting of 2EBM, 2EMB, 4M, and 2B.

<u>Step 1</u>: Examine the spring combination to determine:

Types of contacts. There are EB, EM, M, and B contacts.

Number of each type of contact. This is 2EB, 2EM, 6M, and 4B.

Whether makes or breaks are predominant. Makes are predominant. Use curve 2.

Balance spring required. 8 makes requires 0.022-inch spring.

Armature travel: Intermediate.

<u>Step 2</u>: From curve find travel points for backstop, pickup, and critical load points (CLP). These are:

Backstop travel point for intermediate travel: (INT E) - 50 mils.

Early pickup: first EB (break curve A, E scale) - 30.8 mils.

Critical load point: second EM (make curve B, E scale) - 28.2 mils.

Late pickup: first B (break curve A, L scale) - 17.8 mils.

Late critical load point: sixth M (make curve D, L scale) - 13.2 mils.

<u>Step 3</u>: Find loads for each type of contact plus balance spring and armature at backstop, pickup, and critical load points for late and early contacts and zero airgap. Multiply the loads for each type of contact by the number of contacts of that type. These are shown on the following table for the combination assumed.

Travel	Backstop (CLP) 50	Early Contact Pickup 30.8	Early Contact (CLP) 28.2	Late Contact Pickup 17.8	Late Contact (CLP) 13.2	Oper Pos 0
2EB	0	0	29.6	30.6	31.2	32.4
2EM	- 35	- 33.2	0	0	0	0
4B	0	0	0	0	60	62.4
6M	-108	-104.6	-102	-99.6	0	0
Bal Spg	0	9.5	11	16	18	23.5
Armtr	0	7	8	11	12.6	16
Step 4						
Bal Spg Tension	203	203	203	203	203	203
Step 5						
Total Load	60	81.7	149.6	161	324.8	337.3
Airgap	57	37.8	35.2	24.8	20.2	7
NI Reqd	140	118	158	130	185	118

The balance spring tension selected in step 4 is a plus load that will exceed the make contact load at the backstop by an amount equal to the chosen armature back tension. In the example above, the armature back tension is 60 grams. The same value is added to all gaps. The make-contact load at the backstop is an aiding load since it is a tension tending to operate the relay and must be counteracted by the balancing spring tension. When the make-contacts close, the negative make-contact load against the armature becomes zero, and, in effect, a positive make-contact load is picked up by the armature.

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These loads are read on the operate pull curves for the particular type of relay under consideration and at the airgaps corresponding to the travel points plus the effective stop-disc height. The effective stop-disc heights are:

Stop Disc	Average Effective Stop Disc at Card AF (inch)	Average Effective Stop Disc at Card AJ (inch)
0.006	0.007	0.007
0.014	0.019	0.017
0.022	0.030	0.027

The loads, computed as shown above, may be used in conjunction with the marginal capability data for the AJ relay, with 0.014-inch or 0.022-inch stop disc (Fig. 28 to 31). A typical use of these figures is in the design of the line supervisory relays.

SECTION IX

CAPABILITY DATA

Appendix B

AG or AK Relay With Sleeve

The hold and release requirements and the minimum and maximum release times are determined in the following manner. Since the circuit minimum release time is generally of greater importance than the maximum release, the hold requirements and minimum release times are determined first.

1. Determine the maximum operated load in grams, for the particular contact arrangement, from Table IX-10.

2. Read the readjust hold ampere turns, corresponding to the maximum operated load, on the hold pull curve of Fig. IX-6 or IX-35.

3. Obtain readjust hold current in milliamperes by dividing readjust hold ampere turns by the winding (U) turns.

4. The test hold current = 1.05 x readjust hold current. The test hold current multiplied by the winding (U) turns gives the test hold ampere turns, which shall be at least 1 ampere turn greater than the readjust hold ampere turns. If necessary, increase the test hold current to provide the 1-ampere turn difference.

5. The test hold ampere turns are referred to the minimum release time curves in Fig. IX-6 or IX-35. A sleeve is selected that will provide an adequate minimum release time as read on the ordinate scale. The release time obtained is the minimum test release time.

6. The readjust hold ampere turns are referred to the minimum time curve of the sleeve selected in Fig. IX-6 or IX-35. The release time as read on the ordinate scale is the minimum readjust release time.

7. Determine the minimum operated load in grams for the particular contact combination, from Table IX-11. To this load is added the buffer spring load (AG relays only), which is generally considered 160 grams. This is the maximum for a 0.012-inch buffer spring, but values up to 280 grams may be used for the 0.016-inch buffer spring.

8. On the release pull curve of Fig. IX-6 or IX-35, read the readjust release ampere turns corresponding to the gram load (Item 7). The readjust release ampere turns shall be at least 6 ampere turns. A minimum difference of 3 ampere turns between the readjust release and hold ampere turns is a design objective; however, in special cases where the required release times make a smaller difference necessary, a smaller difference is allowable, but the difficulty and cost of adjustment will be increased.

9. Obtain the readjust release current in milliamperes by dividing the readjust release ampere turns by the winding (U) turns.

10. The test release current = 0.95 x readjust release current. The test release current multiplied by the winding (U) turns gives the test release ampere turns. A minimum difference of 2 ampere turns between the readjust and test release ampere turns is preferred. A smaller difference is allowable where required by the release time limits.

11. The readjust release ampere turns are referred to the maximum time curve of the sleeve selected in Fig. IX-6 or IX-35. The release time as read on the ordinate scale is the maximum readjust release time.

12. The test release ampere turns are referred to the maximum time curve of the sleeve selected in Fig. IX-6 or IX-35. The release time as read on the ordinate scale is the maximum test release time.

Appendix C

AG Relay - Release in Parallel with An External Resistor

The hold and release requirements, the value of the shunt resistor, and the minimum and maximum release times are determined in the following manner. Since the circuit minimum release time is generally of greater importance than the maximum release, the hold requirements and minimum release times are determined first.

1. Determine the maximum operated load in grams for the particular contact arrangement, from Table IX-10.

2. Read the readjust hold ampere turns, corresponding to the maximum operated load, on the hold pull curve of Fig. IX-9.

3. Obtain readjust hold current in milliamperes by dividing readjust hold ampere turns by the winding (U) turns.

4. The test hold current = 1.05 x readjust hold current. The test hold current multiplied by the winding (U) turns gives the test hold ampere turns which shall be at least 1 ampere turn greater than the readjust hold ampere turns. If necessary, increase the test hold current to provide the 1-ampere turn difference.

5. The test hold ampere turns referred to the minimum release time curve in Fig. IX-9 gives the minimum test release time in milliseconds for a core conductance plus relay coil conductance of 100 kilomhos.

6. The minimum total conductance required with the resistor shunt is

$$G_c = \left(\frac{\text{required min rel time}}{\text{test rel time (Item 5)}}\right) 100 \text{ Kmhos}$$

7. The minimum core conductance G_e at the test hold ampere turns is read on the minimum G_e curve of Fig. IX-9.

8. The minimum conductance of the shorted winding G_c is equal to the conductance (Item 6 minus Item 7).

9. The maximum total resistance of the relay winding and the external shunt resistor in ohms is

$$R_t = \frac{[\text{winding (U) turns}]^2}{[\text{conductance (Item 8)}]10^3}$$

10. The external resistor maximum value is the difference between maximum resistance (Item 9) and the maximum winding resistance. A suitable coded resistor shall be selected with resistance variation limits as required by the time conditions.

11. The minimum conductance in kilomhos of the coil with the selected resistor in parallel =

$$\frac{[\text{winding (U) turns}]^2}{(\text{coil max res + resistor max res})10^3}$$

12. The minimum test release time in milliseconds = test release time (Item 5) x

$$\frac{\text{conductance (Item 11 + Item 7)}}{100 \text{ kilomhos}}$$

13. The readjust hold ampere turns referred to the minimum release time curve of Fig. IX-9 gives the minimum readjust release time in milliseconds for core conductance plus a relay coil conductance of 100 kilomhos.

14. The minimum core conductance at the readjust hold ampere turns is read on the minimum G_e curve of Fig. IX-9. This value is usually close to that for Item 7.

15. The minimum readjust release time in milliseconds = readjust release time (Item 13) x

$$\frac{\text{Conductance (Item 11 + Item 14)}}{100 \text{ kilomhos}}$$

16. Determine the minimum operated load in grams for the particular contact combination, from Table IX-11. To this load is added the buffer spring load, which is generally considered 160 grams. This is the maximum for a 0.012-inch buffer spring, but values up to 280 grams may be used for the 0.016-inch buffer spring.

17. Read the readjust release ampere turns, corresponding to the gram load (Item 16), on the release pull curve of Fig. IX-9. A minimum difference of 3 ampere turns between the readjust hold and release ampere

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turns is preferred; however, where the required release times make a smaller difference necessary, a smaller difference is allowable but the difficulty and cost of adjustment will be increased.

18. Obtain readjust release current in milliamperes by dividing readjust release ampere turns by winding (U) turns.

19. The test release current = 0.95 x readjust release current. The test release current multiplied by the winding (U) turns gives the test release ampere turns. A minimum difference of 2 ampere turns between the readjust and test release ampere turns is preferred. A smaller difference is allowable where required by the release time limits.

20. The readjust release ampere turns referred to the maximum release time curve in Fig. IX-9 gives the maximum readjust release time in milliseconds for a core conductance plus relay coil conductance of 100 kilomhos total.

21. The maximum conductance in kilomhos of the relay coil with the resistor shunt =

$$\frac{[\text{winding (U) turns}] + 50)^2}{(\text{coil min res} + \text{resistor min res})10^3}$$

22. The maximum core conductance at the readjust release ampere turns is read on the maximum G_e curve of Fig. IX-9.

23. The maximum readjust release time in milliseconds = readjust release time (Item 20) x

$$\frac{\text{conductance (Item 21 + Item 22)}}{\text{100 kilomhos}}$$

24. The test release ampere turns referred to the maximum release time curve in Fig. IX-9 gives the maximum test release time in milliseconds for a relay coil conductance of 100 kilomhos.

25. The maximum core conductance at the test release ampere turns is read on the maximum G_e curve of Fig. IX-9.

26. The maximum test release time in milliseconds = test release time (Item 24) x

$$\frac{\text{conductance (Item 21 + Item 25)}}{\text{100 kilomhos}}$$

TABLE IX-1

Airgap Values					Airgap (Center Line of Card)				
							Critical Load Point		
Relay Type	Stop Discs	Core Plate Dim. A	Nom Travel	Gauging	Backstop	Opr Pos	Late	Early	Prel
AF,AJ	0.006	0.092	0.026	Std	0.034	0.010	0.019	-	-
AF,AJ	0.006	0.110	0.044	Std	0.052	0.010	0.019	0.032	-
AF,AJ	0.006	0.126	0.060	Std	0.068	0.010	0.019	0.032	0.045
AJ	0.014	0.103	0.028	Std	0.045	0.019	0.028	-	-
AJ	0.014	0.092	0.017	Spl	0.034	0.019	0.0245	-	-
AF	0.014	0.103	0.026	Std	0.045	0.021	0.030	-	-
AF	0.014	0.121	0.044	Std	0.063	0.021	0.030	0.043	-
AF	0.014	0.137	0.060	Std	0.079	0.021	0.030	0.043	0.056
AJ	0.022	0.110	0.025	Std	0.052	0.0285	0.038	-	-
AJ	0.014	0.121	0.046	Std	0.063	0.019	0.028	0.045	-
AJ	0.006	0.083	0.017	Spl	0.025	0.010	0.015	-	-
AK	0.005	0.105	0.026	Std	0.032	0.007	0.015	-	-
AK	0.005	0.087	0.044	Std	0.050	0.007	0.015	0.027	-

Note: The above airgap values (all given in inches) are to be used for general purpose relays only. For marginal relays, use Fig. IX-4.

Procedure for Obtaining Operate and Hold Ampere Turns for AF, AJ, and AK Relays

Load Buildup

The critical loads shall be determined using the following assumptions.

1. The back tension, including friction, shall be 60 grams, except that this may be adjusted in extreme cases to 30 grams to permit 18 contact pairs on the AF relay.

2. Buildup of the armature spring shall be 7 grams per stage starting at the backstop.

3. Buildup of the balance spring shall be 1 gram per contact per stage, starting at the backstop, with a maximum of 12 grams per stage. The one exception to the 12 gram maximum is the 24 make relay with 24 grams per stage buildup.

4. Contact force at the center line of the card due to contact pickup shall be 11 grams for light, 16 grams for standard, and 21 grams for heavy contact force relays.

5. Contact spring tension buildup shall be 1/2 gram per contact per stage, starting at the contact pickup point.

Airgap Values

1. For airgap at the backstop, nominal travel and stop-disc heights are assumed.

2. For critical load points, nominal gauging values and stop-disc heights are assumed.

The airgap values at the backstop and at the critical load points for the coded AF, AJ, and AK relays are as shown above.

Operate Ampere Turns

Using the load and airgap values described above and shown in Table IX-2, the operate ampere turns are obtained from the operate capability curves which are as follows:

AF Relay	Figure IX-10
AJ Relay	Figure IX-16
AJ Relay with laminations	Figure IX-22
AK Relay	Figure IX-32

Procedure for Obtaining Hold Ampere Turns for AF, AJ, and AK Relays

For hold, maximum loads in the operated position are critical. Thus loads are built up as for the operate, then continued one further stage, following the same rules, to operate the operated loads. These maximum operated loads are shown in Table IX-2.

To determine the ampere turns required to hold, use the maximum load with Fig. IX-12, IX-18, IX-24, or IX-34 selecting the appropriate number of contacts, armature travel, relay type, stop discs, and soak ampere turns.

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TABLE IX-2

AF, AJ, AND AK RELAYS

CRITICAL LOAD POINTS AND MAXIMUM OPERATED LOADS

	For Use in Figuring Operate									For Use in Figuring Hold		
	Critical Load - Grams									Max Operated Load - Grams		
	Travel and Airgap											
	Short		Intermediate			Long						
No. Cont	Late 19	BS 34	Late 19	Early 32	BS 52	Late 19	Early 32	Prel 45	BS 68	Short Travel	Inter-mediate Travel	Long Travel
1	84	60	-	84	60	-	-	84	60	93	-	-
2	101	60	110	101	60	-	110	101	60	111	120	-
3	118	60	128	118	60	138	128	118	60	130	140	150
4	135	60	147	135	60	158	147	135	60	148	160	171
5	152	60	165	152	60	178	165	152	60	166	180	192
6	169	60	184	169	60	197	183	169	60	185	200	213
7	186	60	202	186	60	216	202	186	60	204	219	234
8	203	60	220	203	60	236	220	203	60	222	239	255
9	220	60	238	220	60	255	238		60	240	258	276
10	237	60	256	237	60	274	256		60	259	278	297
11	254	60	274	254	60	294	274		60	278	298	318
12	271	60	293	271	60	314	293		60	296	318	339
13	287	60	309		60	330	309		60	312	334	356
14	303	60	326		60	346	326		60	329	352	372
15	319	60	342		60	362	342		60	346	368	388
16	335	60	358		60	377	358		60	362	385	404
17	351	60	374		60	396			60	378	402	424
18	367	60	390		60	411			60	395	418	439
19	383	60	406		60	428			60	412	435	456
20	399	60	423		60	444			60	428	452	473
21	415	60	439		60	460			60	444	468	490
22	431	60	456		60	477			60	461	486	507
23	447	60	472		60	493			60	478	502	524
24	463	60	488		60	510			60	494	519	541
24 makes	475	60								506		

The airgap values apply only for the relays with 0.006-inch stop discs (0.005 for the AK relay). The critical loads apply with any stop discs, but for light contact force, subtract 5 grams per contact. Standard gauging values apply in all cases.

The maximum load values assume 60 grams back tension. If this is changed, the operated load is changed by the same amount.

For AJ relays with 20 or more springs, the load may be assumed to be somewhat dispersed and the critical load gap may be reduced by 0.003 inch if necessary.

TABLE IX-3

AF RELAY

OPERATE AMPERE TURNS

No. Contacts	Short Travel	Intermediate Travel		Long Travel		
		L+E	E	L+E+P	E+P	P
1	98	-	130	-	-	157
2	98	130	130	-	157	157
3	98	130	132	157	157	167
4	101	130	141	157	157	178
5	107	130	151	157	157	192
6	114	130	160	157	169	207
7	120	130	169	157	180	222
8	127	132	181	157	191	241
9	133	139	192	157	204	
10	139	146	203	157	218	
11	145	152	218	160	237	
12	151	159	233	169	258	
13	157	167		179	279	
14	164	177		190	315	
15	172	187		205		
16	183	199		206§		
17	195	206†				
18	206	206‡				
19	206*					

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* Assumes back tension adjustment 40 grams
† Assumes back tension adjustment 50 grams
‡ Assumes back tension adjustment 35 grams
§ Assumes back tension adjustment 45 grams

Note: This table is for use only for relays with 0.006-inch stop discs. When other stop discs are used, use Table IX-1 and Table IX-2 with operate capability curve, Fig. IX-10. For marginal relays, use Fig. IX-4 with operate capability curve.

Example:

Assume the operate is desired for a relay with a spring combination consisting of 2EBM, 2EMB, 3M, and 2B. Armature travel - intermediate.

The spring combination has a total of 13 contacts, 4 early and 9 late. Under intermediate travel, 4 contacts in column E requires 141 ampere turns and in column L+E, 13 contacts requires 167 ampere turns. Thus 167 ampere turns is required for the spring combination assumed.

TABLE IX-4

AJ RELAY

OPERATE AMPERE TURNS

No. Contacts	Short Travel	Intermediate Travel		Long Travel		
		L+E	E	L+E+P	E+P	P
1	91	-	126	-	-	157
2	91	126	126	-	157	157
3	91	126	126	157	157	160
4	91	126	133	157	157	173
5	96	126	142	157	157	186
6	101	126	151	157	159	199
7	107	126	160	157	168	212
8	113	126	169	157	178	229
9	118	126	179	157	189	
10	123	129	188	157	200	
11	128	135	199	157	213	
12	134	141	211	157	227	
13	139	147		157	240	
14	145	153		160	256	
15	150	159		167	275	
16	156	164		173	298	
17	162	172		181		
18	168	180		191		
19	176	188		200		
20	184	198		211		
21	193	207		222		
22	202	220		236		
23	213	233		251		
24	227	245		267		
24 makes	235					

Note: This table is to be used only for relays with 0.006-inch stop discs. When other stop discs are used, use Table IX-1 and Table IX-2 with operate capability curve, Fig. IX-22. For marginal relays, use Fig. IX-4 with capability curve.

TABLE IX-5

AJ RELAY WITH LAMINATIONS

OPERATE AMPERE TURNS

No. Contacts	Short Travel	Intermediate Travel		Long Travel		
		L+E	E	L+E+P	E+P	P
1	91	-	126	-	-	157
2	91	126	126	-	157	157
3	91	126	126	157	157	159
4	91	126	131	157	157	171
5	96	126	139	157	157	182
6	101	126	147	157	157	193
7	106	126	154	157	162	203
8	112	126	162	157	171	217
9	117	126	171	157	180	
10	122	127	180	157	189	
11	127	133	189	157	199	
12	132	138	197	157	209	
13	137	143		157	218	
14	142	148		157	227	
15	146	153		159	237	
16	151	158		164	247	
17	156	163		169		
18	161	168		175		
19	166	174		180		
20	171	179		187		
21	176	184		193		
22	182	190		199		
23	187	196		206		
24	193	202		212		
24 makes	200					

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Note: This table is to be used only for relays with 0.006-inch stop discs. When other stop discs are used, use Table IX-1 and Table IX-2, with operate capability curve, Fig. IX-16. For marginal relays, use Fig. IX-4 with operate capability curve.

TABLE IX-6

AF, AJ, AND AK RELAYS

PROCEDURE FOR OBTAINING RELEASE AMPERE TURNS
CRITICAL RELEASE LOADS

Short			Intermediate				Long Travel			
Total No. Contacts	Opr Load	Load at Pickup	Total No. Contacts	Opr Load	No. Early Contacts	Load at Late PU	Total No. Contacts	Opr Load	No. E+P Contacts	Load at Late PU
1	47	33	1	-	1	69*	1	-	1	-
2	59	34	2	64	2	80*	2	-	2	94*
3	73	35	3	78	3	91*	3	83	3	105*
4	86	36	4	92	4	102*	4	98	4	116*
5	99	37	5	106	5	113*	5	113	5	127*
6	112	38	6	120	6	124	6	128	6	138*
7	125	39	7	134	7	135	7	143	7	149*
8	138	40	8	148	8	146	8	158	8	160
9	151	41	9	162	9	157	9	173	9	171
10	164	42	10	176	10	168	10	188	10	182
11	177	43	11	190	11	179	11	203	11	193
12	190	44	12	204	12	190	12	218	12	204
13	201	44	13	215			13	229		
14	212	44	14	226			14	240		
15	223	44	15	237			15	251		
16	234	44	16	248			16	262		
17	245	44	17	259			17	273		
18	256	44	18	270			18	284		
19	267	44	19	281			19	295		
20	278	44	20	292			20	306		
21	289	44	21	303			21	317		
22	300	44	22	314			22	328		
23	311	44	23	325			23	339		
24	322	44	24	336			24	350		
24 makes	334	56	24 makes	360			24 makes	386		

* These values assume a total of 12 contacts. If total number of contacts is less than 12, subtract 2 grams for each contact less than 12.

Release

For release, minimum loads in the operated or late pickup positions are critical. The following rules apply:

1. The back tension shall be 30 grams.
2. Buildup of the combined balance spring and contact spring shall be 1 gram per contact per stage, starting at the backstop (maximum 12 grams per stage).
3. Buildup of the armature spring shall be 2 grams per stage.
4. Tension at the center line of the card due to contact pickup shall be 6 grams per contact for light, 11 grams for standard, and 16 grams for heavy contact force relays.
5. These load values assume 30 grams back tension. If the back tension is changed, the load is changed by the same amount.
6. To determine release ampere turns, use critical release loads with the release curves, selecting the applicable number of contacts, armature travel, relay type, stop discs, and soak ampere turns. Check the release for the operated position, Fig. IX-13, IX-19, IX-25, or IX-34 and for the AF and AJ relays at the late pickup position also (0.012-inch gauging), Fig. IX-14, IX-20, or IX-26.

Note: This procedure applies for general purpose relays only. For marginal relays use Fig. IX-4 for hold, Fig. IX-5 for release. Fig. IX-15, IX-21, and IX-27 show the release pull for use with special gauging values.

TABLE IX-7

AG RELAYS

PROCEDURE FOR OBTAINING OPERATE AND HOLD AMPERE TURNS

Loads - Maximum Loads Used (maximum pickup and buildup)

Operate: Compute loads at backstop and all contact points. These are called critical operate loads. Assume back tension is adjusted to 85 grams as for the release case (see Table IX-8), since both cases are essentially the same magnet (poor anneal), and the release is more important than the operate on most AG relays.

Hold: Compute loads at operated position only. Assume the back tension is adjusted as low as permitted by rebound (20-grams back tension). These are called maximum operated loads. (See Table IX-10.)

Assumptions for Computing Loads:

1. Back tension is adjusted to 85 grams for operate, 20 grams for hold.

2. Buildup of the armature spring is 1 gram per stage.

3. Contact force at the center line of the card due to contact pickup shall be 11 grams for light, 16 grams for standard, and 21 grams for heavy contact force relays.

4. Balance springs used and their buildups are as follows:

Spring Thickness mils	No. of Makes on Relay: Short Travel	Inter Travel	Long Travel	Stiff-ness Max gm/mil Travel
14	0	-	-	0.133
16	1	0-1	0	0.196
18	2-3	2-3	1	0.280
20	4-5	4	2-4	0.380
22	6-8	5-7	5-6	0.508
25	9-12	8-12	7-12	0.735

5. Contact spring build-up is 0.043-gram/mil travel/contact starting at the contact pickup point.

6. A contact consists of the pair of twin contacts that mate with one face of a single fixed contact.

7. Total buildup for all springs from buffer pickup to operated position is 30 grams (approx).

Airgap Values for Computing Loads and Comparing Pull

1. Unoperated airgaps (at card center line), assuming maximum travel and minimum dome height:

Short travel relay	32 mils
Intermediate travel relay	50 mils
Long travel relay	66 mils

2. Nominal gauging values are used as critical gaps, assuming that critical load points can be adjusted into these gaps, if necessary. These are:

BUFF = Buffer pickup	7.0 mils
L = late contacts	11.5 mils
E = early contacts	24.5 mils
P = preliminary contacts	37.5 mils

Ampere Turns

Operate: Using critical loads on Table IX-9 computed from above rules, obtain operate ampere turns (for above gaps) from operate capability pull in Fig. IX-7.

Hold: Using maximum operated loads on Table IX-10 computed from above rules, obtain hold ampere turns from hold capability pull in Fig. IX-6. Tolerance on load adjustment requires that the specified hold ampere turns shall be at least 3 ampere turns above the specified release ampere turns.

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TABLE IX-8

AG RELAYS

PROCEDURE FOR OBTAINING
NONOPERATE AND RELEASE AMPERE TURNS

Loads - Minimum Loads Used (minimum pickup and buildup)

Nonoperate: Load at backstop must be controlling. Assume back tension is adjusted to 20 grams as for the hold case (see Table IX-7) since both cases are essentially the same magnet (excellent anneal) and hold is more important than the nonoperate on most AG relays. Back tension up to 85 grams may be used to increase the nonoperate ampere turns, if required. This also increases the maximum operated loads on Table IX-10, increases the hold ampere turns, and reduces the minimum release time.

Release: Compute load at operated position only. Assume back tension adjusted to maximum permitted by stress in balance spring (85 grams). These are called minimum operated loads (see Table IX-11). Buffer spring loads must be added to these values per Note E on Table IX-11.

Assumptions for Computing Loads:

1. Back tension is adjusted to 20 grams for nonoperate and 85 grams for release.

2. Buildup of the armature spring is 0.5 gram per stage.

3. Contact force at the center line of the card due to contact pickup shall be 6 grams for light, 11 grams for standard, and 16 grams for heavy contact force relays.

4. Balance springs used, and their buildups are as follows:

Spring Thickness mils	No. of Makes on Relay: Short Travel	Inter Travel	Long Travel	Stiffness Min gm/mil Travel
14	0	-	-	0.094
16	1	0-1	0	0.142
18	2-3	2-3	1	0.201
20	4-5	4	2-4	0.279
22	6-8	5-7	5-6	0.369
25	9-12	8-12	7-12	0.552

5. Contact spring buildup is 0.036-gram/mil travel/contact, starting at the contact pickup point.

6. A contact consists of the pair of twin contacts that mate with one face of a single fixed contact.

Airgap Values

1. Unoperated airgaps (at card center line), assuming minimum travel and maximum dome height:

Short travel relay	20 mils
Intermediate travel relay	38 mils
Long travel relay	54 mils

2. Nominal gauging values and nominal buffer spring pickup are used as the critical gaps, assuming that the critical load points and buffer pickup can be adjusted out to these gaps, if necessary. These gaps are:

BUFF = Buffer pickup	7.0 mils
L = late contacts	11.5 mils
E = early contacts	24.5 mils
P = preliminary contacts	37.5 mils

Ampere Turns

Nonoperate: Using load above (for nonoperate) obtain nonoperate ampere turns (for above unoperated gaps) from nonoperate capability pull in Fig. IX-8.

Release: Using minimum operated loads on Table IX-11 (including buffer springs if on relay) which were computed from the above rules, obtain release ampere turns from release capability pull in Fig. IX-6. Tolerance on load adjustment requires that the specified release ampere turns shall be at least 3 ampere turns below the specified hold ampere turns. To insure release however, it shall not be less than 6 ampere turns readjust.

TABLE IX-9

AG RELAYS

CRITICAL OPERATE LOADS
(To Be Used In Establishing Operate
Ampere Turn Requirements)

At Stage	Gap	No. of Actuated Contacts	Using Table IX-	Load gm
Backstop	66	-	-	85
Preliminary	37.5	N = 2PM = 2 M = 2PM + 7M = 9	9A 9B 9A & 9B (total)	124 26 150
Early	24.5	N = 2PM + 3EB = 5 M = 2PM + 7M = 9	9A 9B 9A & 9B (total)	175 39 214
Late	11.5	N = 2PM + 3EB + 7M = 12 M = 2PM + 7M = 9	9A 9B 9A & 9B (total)	291 50 341
BUFF	7.0		Load required for release (see Table IX-11) minus buildup (Note 4) total	392 -30 362

Notes

1. N = number of contacts actuated at given stage or an earlier stage. Table IX-9A inculdes loads per Table IX-7, Items 1, 2, 3, and item 4 for 0 make contacts.
2. M = total M, EM, and PM contacts on relay. Table IX-9B approximates loads per Table IX-7, Item 5, and the additional buildup per Item 4 above that for 0 makes.
3. The above loads are for back tension of 85 grams (see Table IX-7 for reason).
4. For relays with buffer spring, critical operate load at buffer pickup is total operated load (including buffer) required for release (see Table IX-11) minus 30 grams. (per Table IX-7, Item 7).
5. For light contact force relays, reduce values in Table IX-9A by 5 grams per contact, ie, 5 x N (grams). For heavy contact force relays, increase values in Table IX-9A by 5 grams.

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USE OF TABLES

Example (Same relay as on Table IX-11):

Long travel relay 2PM, 3EB, 7M, with 16-mil buffer spring.

TABLE IX-9 (Cont)

AG RELAYS

CRITICAL OPERATE LOADS
(To Be Used In Establishing Operate
Ampere Turns Requirements)

TABLE IX-9A (see Note 1)

Loads - For 85-Gram Back Tension

Relay Travel Stage	Short		Inter.			Long			
Airgap (mils)	L	BS	L	E	BS	L	E	P	BS
N = No. Cont.	11.5	32	11.5	24.5	50	11.5	24.5	37.5	66
1	105	85	111	107	85	115	111	108	85
2	121	85	127	123	85	131	127	124	85
3	137	85	143	139	85	147	143	140	85
4	153	85	159	155	85	163	159	156	85
5	169	85	175	171	85	179	175	172	85
6	185	85	191	187	85	195	191	188	85
7	201	85	207	203	85	211	207	204	85
8	217	85	223	219	85	227	223	220	85
9	233	85	239	235	85	243	239	236	85
10	249	85	255	251	85	259	255	252	85
11	265	85	271	267	85	275	271	268	85
12	281	85	287	283	85	291	287	284	85
13	297	85	303	299	85	307	303		85
14	313	85	319	315	85	323	319		85
15	329	85	335	331	85	339	335		85
16	345	85	351	347	85	355	351		85
17	361	85	367	363	85	371			85
18	377	85	383	379	85	387			85
19	393	85	399	395	85	403			85
20	409	85	415	411	85	419			85
21	425	85	431		85	435			85
22	441	85	447		85	451			85
23	457	85	463		85	467			85
24	473	85	479		85	483			85

TABLE IX-9B (see Note 2)

M = No. Makes	Short L 11.5	Short BS 32	Inter. L 11.5	Inter. E 24.5	Inter. BS 50	Long L 11.5	Long E 24.5	Long P 37.5	Long BS 66
1	2		1	1		7	5	3	
2	5		6	4		14	11	7	
3	5		8	5		17	13	9	
4	8		13	9		19	15	10	
5	9		20	14		28	22	15	
6	13		21	15		31	24	16	
7	14		23	16		45	35	23	
8	14		34	23		48	37	25	
9	20		35	24		50	39	26	
10	21		37	25		52	40	27	
11	22		39	26		55	42	28	
12	23		40	27		57	44	30	

TABLE IX-10

AG OR SLOW RELEASE AK RELAYS

MAXIMUM OPERATED LOADS
(To Be Used In Establishing Hold Ampere Turn Requirements)

TABLE IX-10A (See Notes 1 and 5)
Loads - For 20-Gram Back Tension

N = No. Cont	Short Travel	Inter. Travel	Long Travel
1	43	-	-
2	59	67	-
3	76	84	88
4	92	101	105
5	109	118	122
6	125	135	139
7	142	152	156
8	158	169	173
9	175	186	190
10	191	203	207
11	208	220	224
12	224	237	241
13	241	254	258
14	257	271	275
15	274	288	292
16	290	305	309
17	307	322	326
18	323	339	343
19	340	356	360
20	356	373	377
21	373	390	394
22	389	407	411
23	406	424	428
24	422	441	445

TABLE IX-10B (See Note 2)

M = No. Makes	Short Travel	Inter. Travel	Long Travel
1	3	0	7
2	6	4	14
3	7	4	15
4	10	9	16
5	11	15	26
6	15	15	27
7	16	15	43
8	16	15	44
9	25	27	45
10	25	27	46
11	26	27	47
12	26	27	48

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NOTES

1. N = total number of contacts on relay. Table IX-10A includes loads per Table IX-7, Items 1, 2, 3, Item 4 for 0 makes, and Item 5 (approx).
2. M = total M, EM, and PM contacts on relay. Table IX-10B approximated additional build-up per Table IX-7, Items 4 and 5, above that for 0 makes.
3. The above are maximum loads adjusted as low as permitted by rebound requirements (20-gram back tension). For higher back tension, increase values in Table IX-10A by the increase in the back tension. This will also increase the nonoperate ampere turn value (see Table IX-8).
4. For light contact force relays, reduce values in Table IX-10A by 5 grams per contact, ie, 5xN (grams). For heavy contact force relays, increase values in Table IX-10A by 5 grams per contact.
5. For AK relays, add 10 grams to each of the loads in Table IX-10A as the AK relay is adjusted on minimum 30-gram back tension and the load data is based on 20-gram back tension.

USE OF TABLES

Example: Long travel relay 2PM, 3EB, 7M

N = 2PM + 3EB + 7M = 12; from Table IX-10A, load = 241
M = 2PM + 7M = 9; from Table IX-10B, load = 45
Total 286 grams

TABLE IX-11

AG OR SLOW RELEASE AK RELAYS

MINIMUM OPERATED LOADS
(To Be Used In Establishing Release Ampere Turns)

TABLE IX-11A (See Notes 1 and 6)

Loads - For 85-Gram Back Tension

N = No. Cont	Short Travel	Inter. Travel	Long Travel
1	99	104	-
2	111	115	118
3	122	127	130
4	134	138	141
5	145	150	153
6	156	161	165
7	168	173	176
8	179	184	188
9	191	196	199
10	202	207	211
11	213	219	223
12	225	230	234
13	236	242	246
14	248	253	257
15	259	265	269
16	270	276	281
17	282	288	292
18	293	299	304
19	305	311	315
20	316	322	327
21	327	334	339
22	339	345	350
23	350	357	362
24	362	368	373

TABLE IX-11B (See Note 2)

M = No. Makes	Short Travel	Inter. Travel	Long Travel
1	1	1	4
2	2	3	9
3	2	4	10
4	4	7	10
5	4	11	16
6	6	12	17
7	6	12	27
8	6	20	28
9	9	20	28
10	9	21	29
11	9	21	30
12	9	22	31

NOTES

1. N = total number of contacts on relay. Table IX-11A includes loads per Table IX-8, Items 1, 2, 3, and approximately Items 4 and 5 for 0 makes.
2. M = total M, EM, and PM contacts on relay. Table IX-11B approximates additional buildup per Table IX-8, Items 4 and 5, above that for 0 makes.
3. The above are minimum loads adjusted as high as permitted by stress in balance spring (85 grams). For lower back tension, reduce values in Table IX-11A by the reduction in back tension.
4. For light contact force relays, reduce values on Table IX-11A by 5 grams per contact, ie, 5 x N (grams). For heavy contact force relays, increase values in Table IX-11A by 5 grams per contact.
5. For relays equipped with buffer springs, the highest load permitted by stress in the springs is 160 grams for the 12-mil buffer used on the early relays and 280 grams for the standard 16-mil buffer. The load added with the buffer, however, should be kept as low as possible.
6. For AK relays, reduce the loads in Table IX-11A by 25 grams as the AK relay is adjusted on 60-gram back tension instead of 85 grams on which the loads in the table are figured.

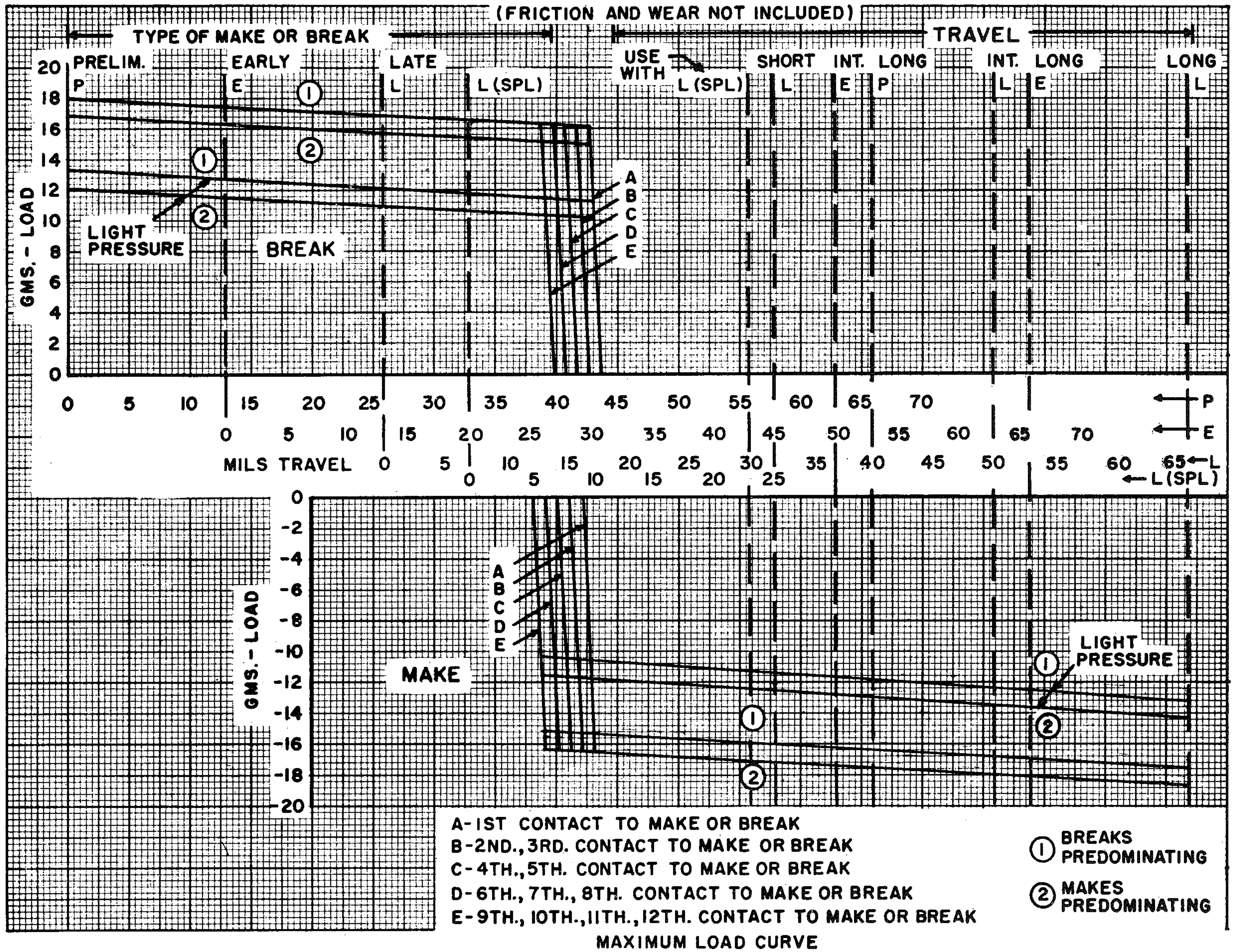
USE OF TABLES

Example: Long travel relay 2PM, 3EB, 7M with 16-mil buffer

N = 2PM + 3EB + 7M = 12; from Table IX-11A, load = 234
M = 2PM + 7M = 9; from Table IX-11B, load = 28
Add with buffer* = 130
Total 392 grams

* Assuming desired release ampere turns requires 392 grams total.

X-75509



Part of Fig. IX-4

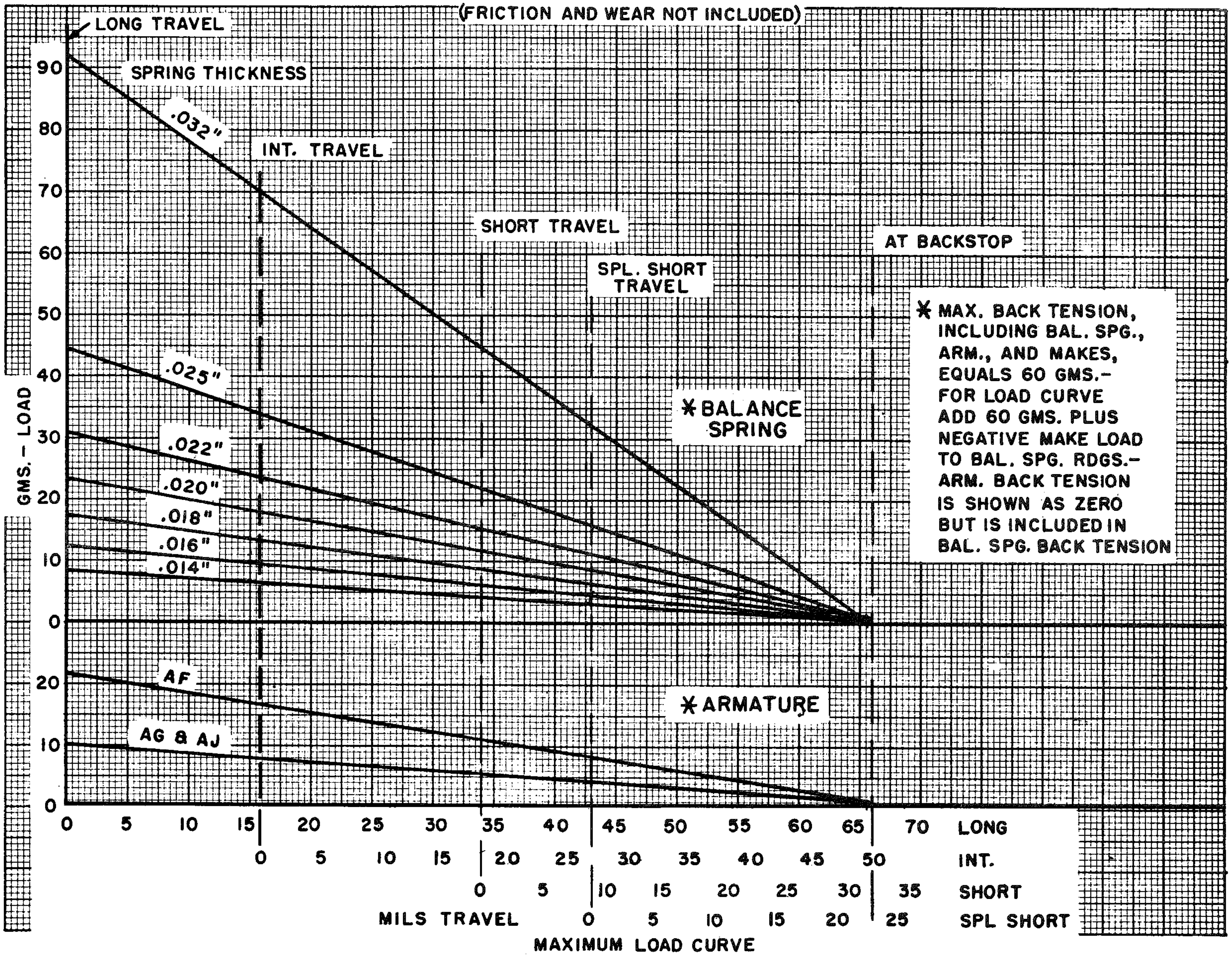
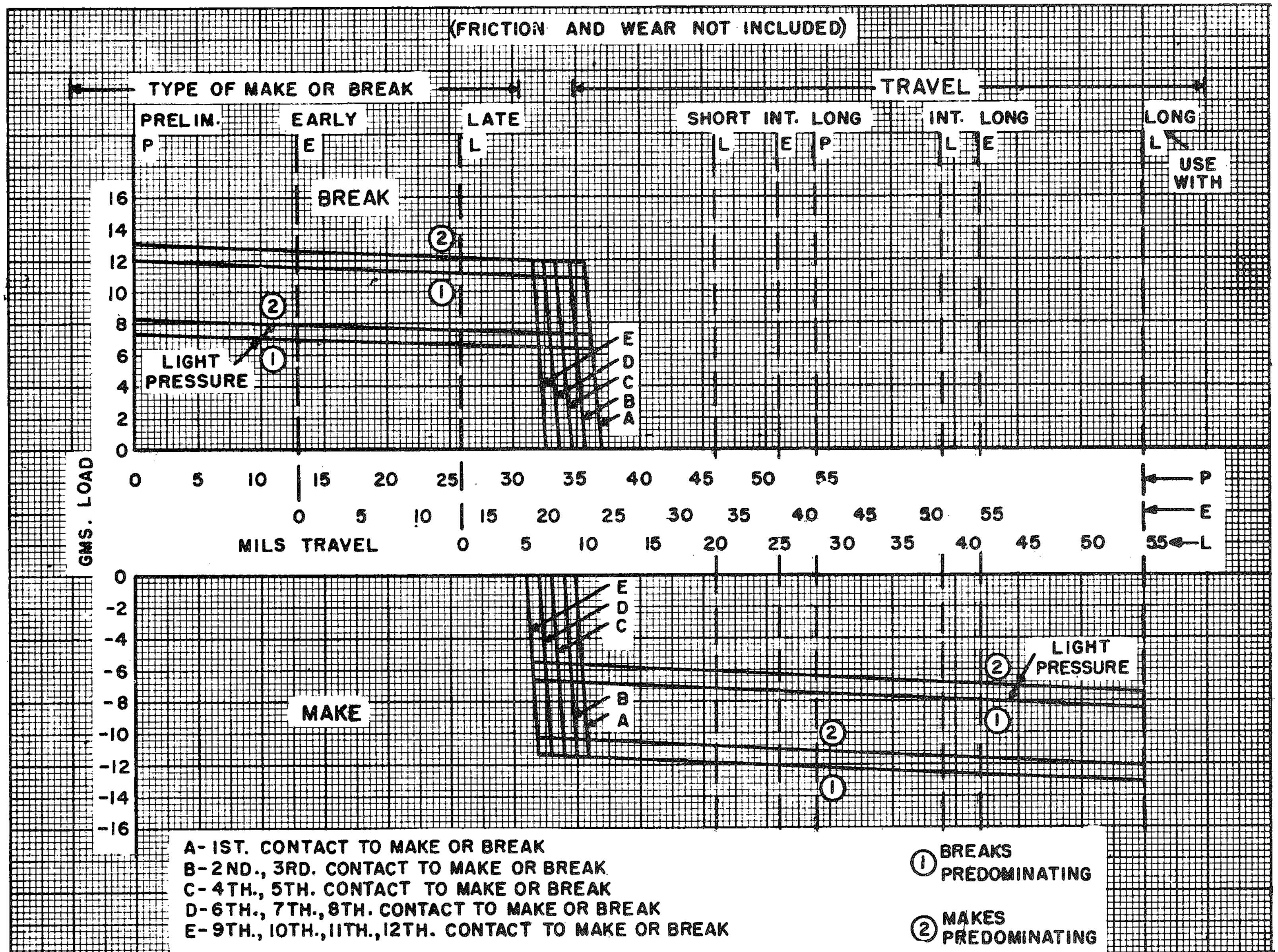


Fig. IX-4 - Maximum Load Buildup

X-75509



MINIMUM LOAD CURVE

Part of Fig. IX-5

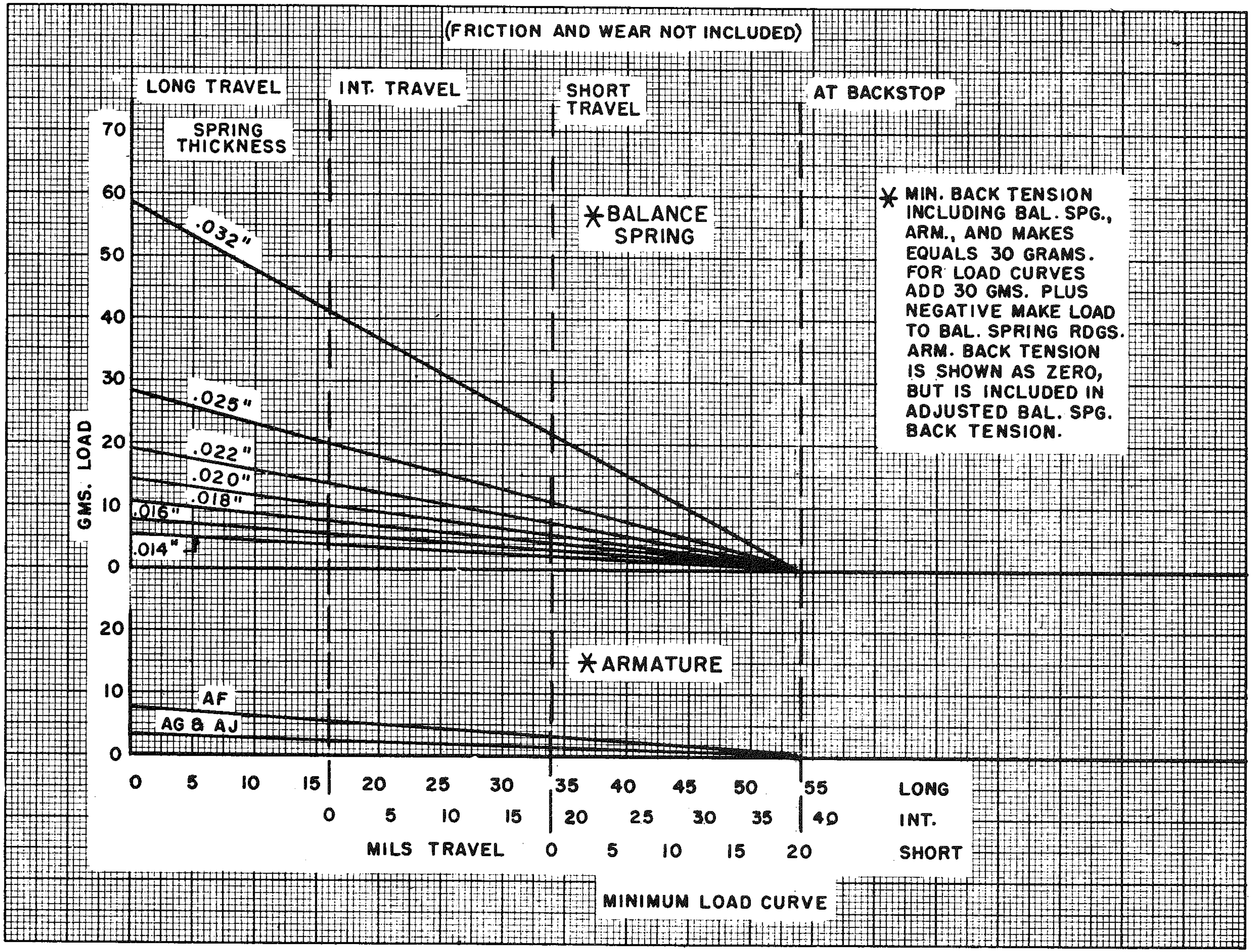


Fig. IX-5 - Minimum Load Buildup

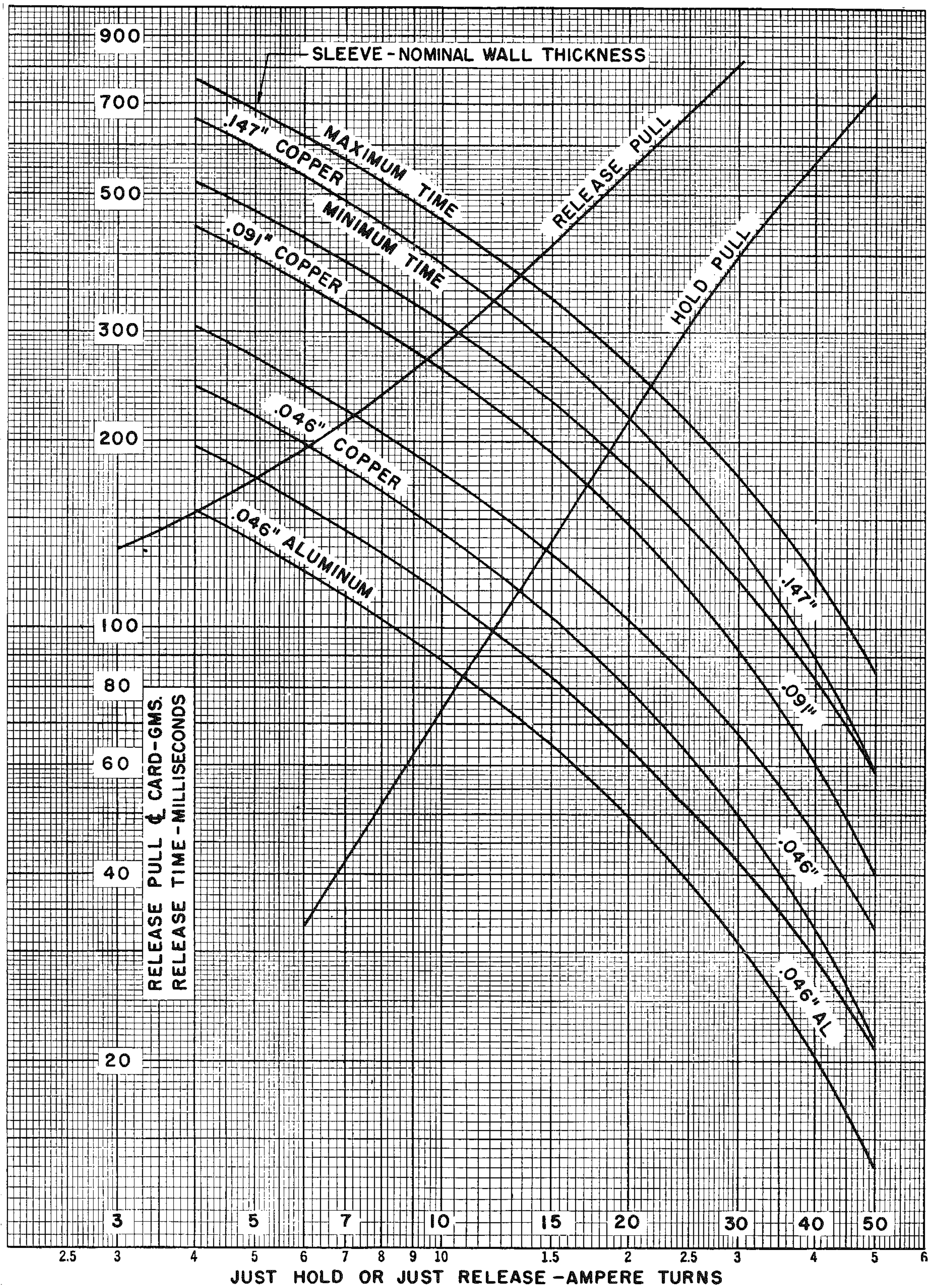


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Fig. IX-6 - AG Relay - Hold and Release Ampere Turns and Time

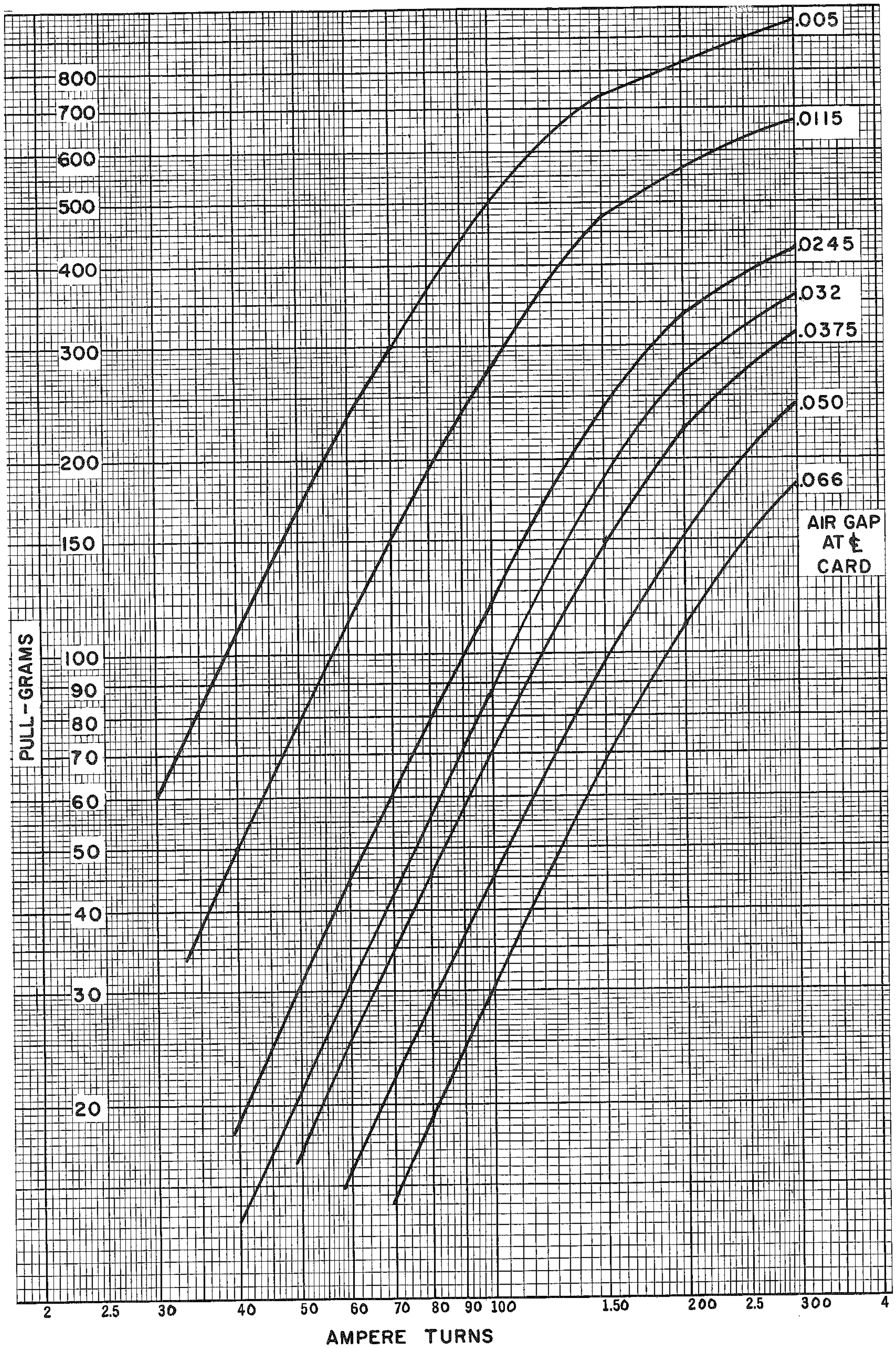

Fig. IX-7 - AG Relay - Operate

X-75509

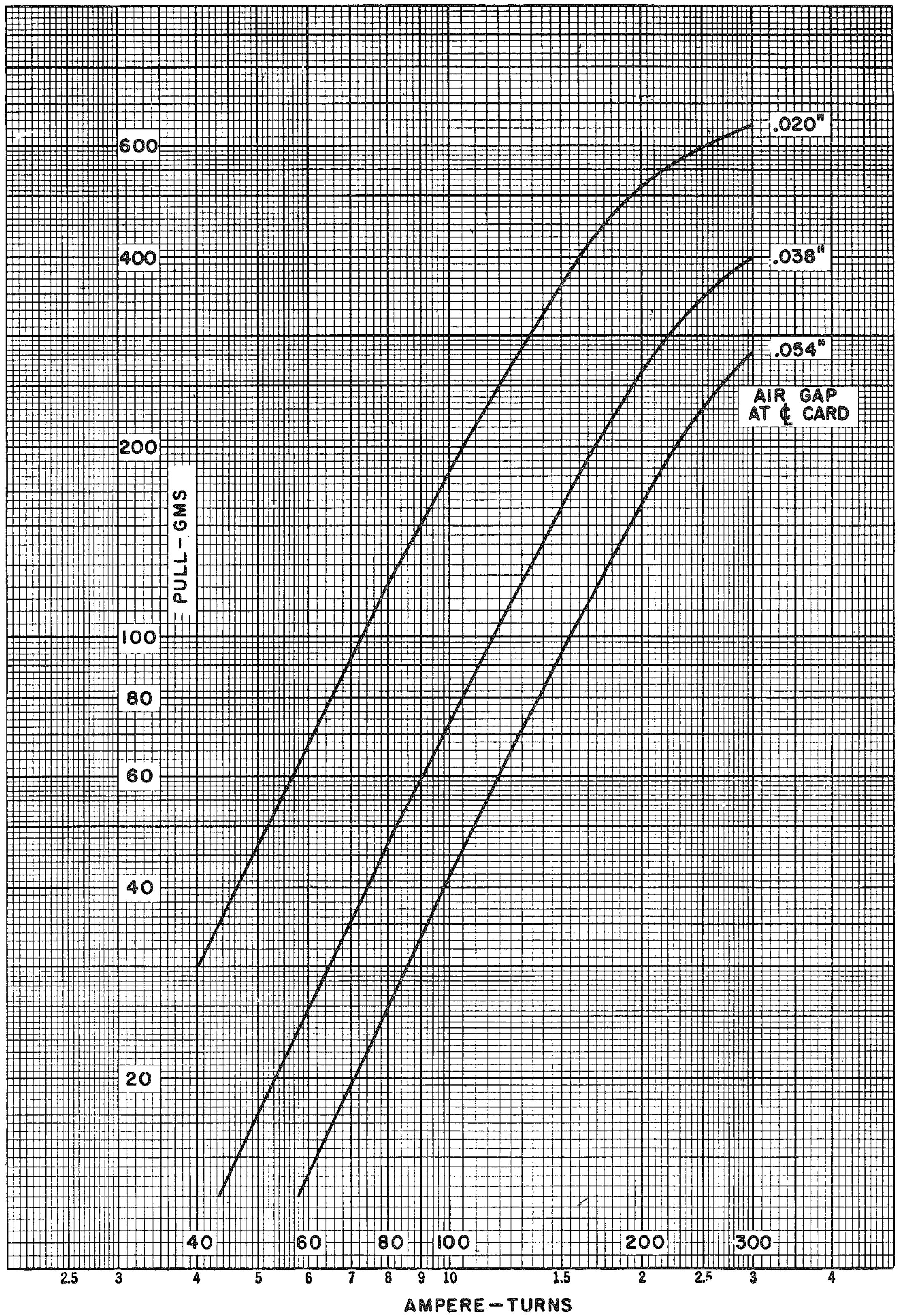

Fig. IX-8 - AG Relay - Nonoperate

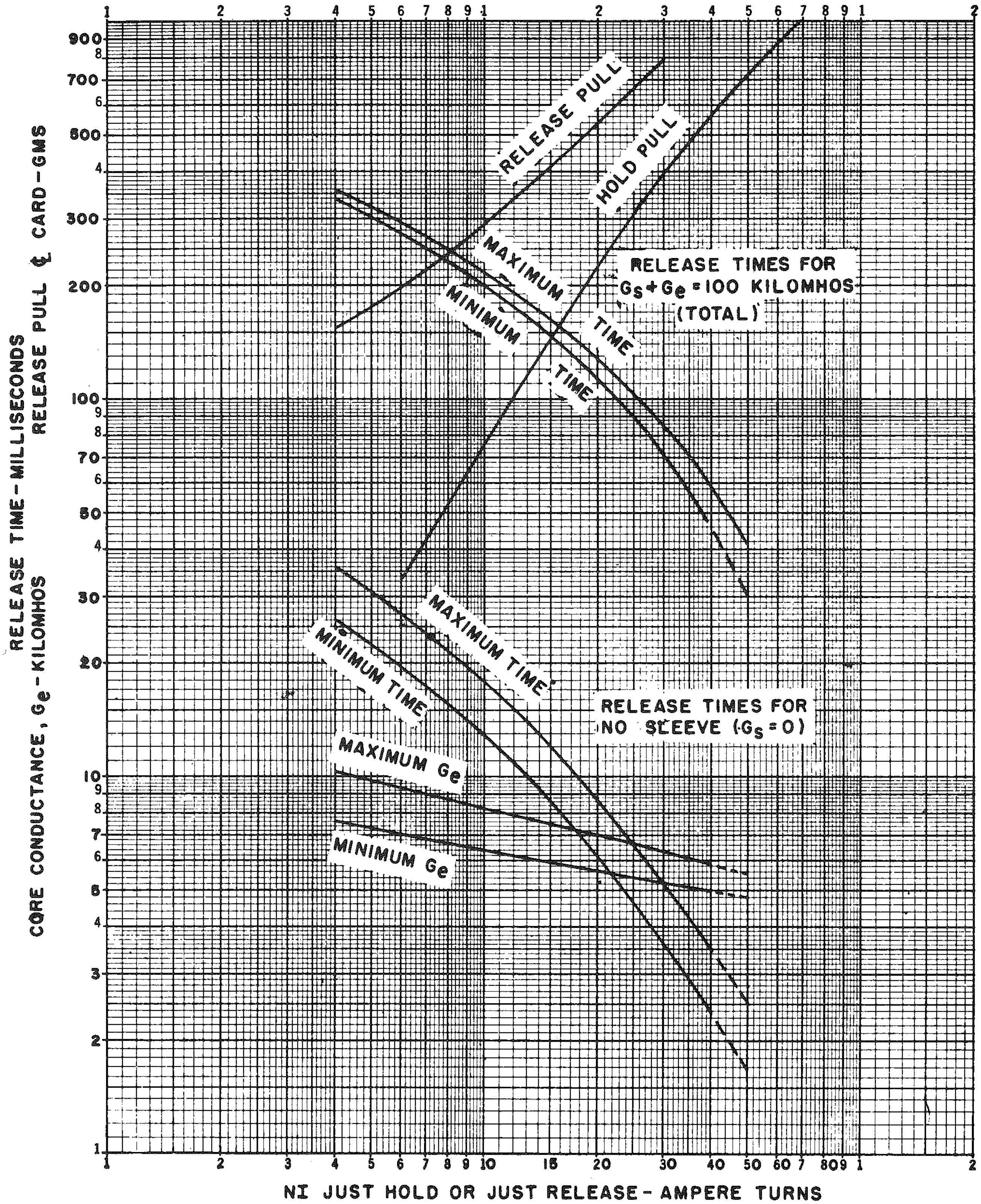

Fig. IX-9 - AG Relay - Release Times With Shunt

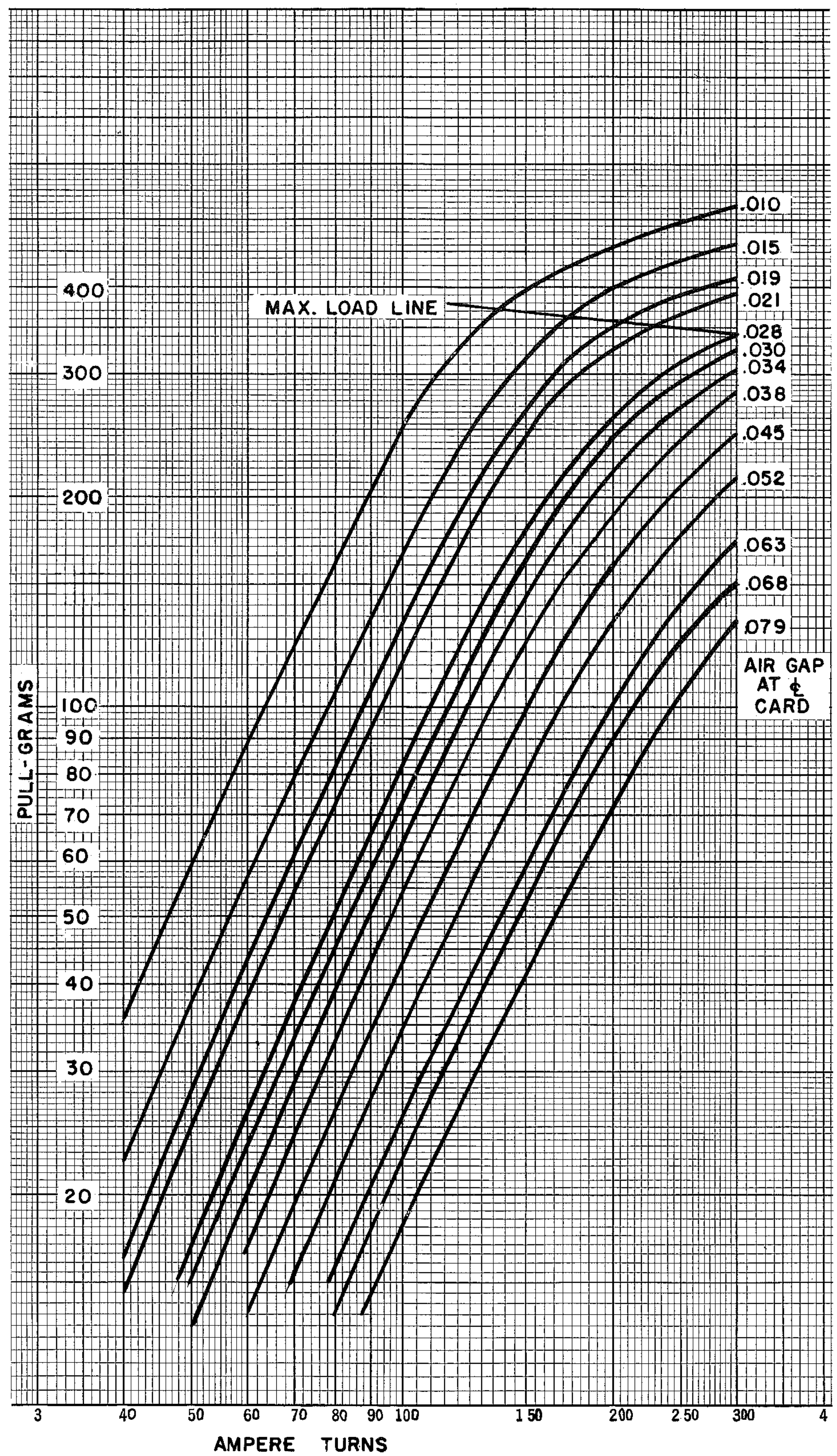

Fig. IX-10 - AF Relay - Operate

X-75509

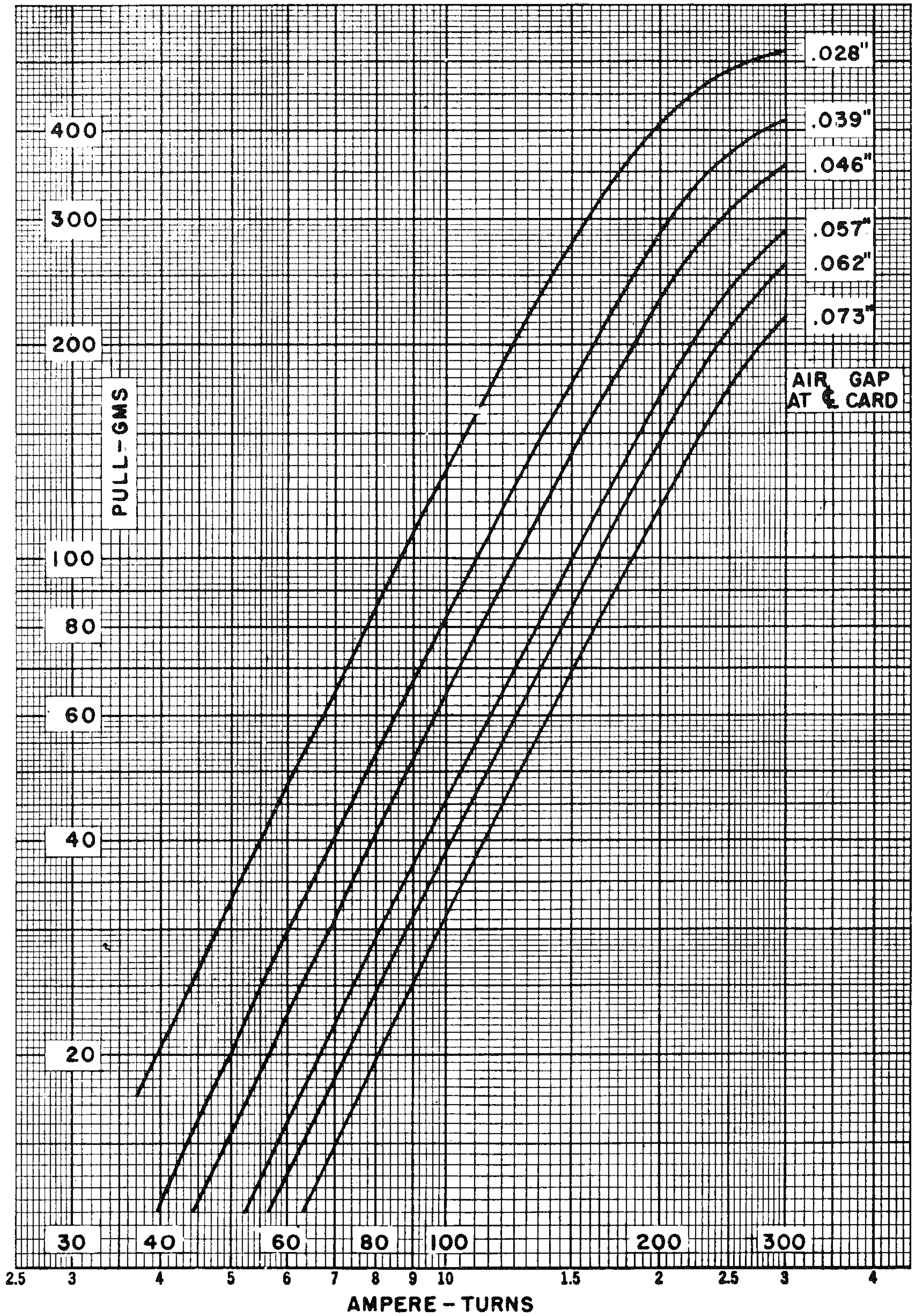

Fig. IX-11 - AF Relay - Nonoperate

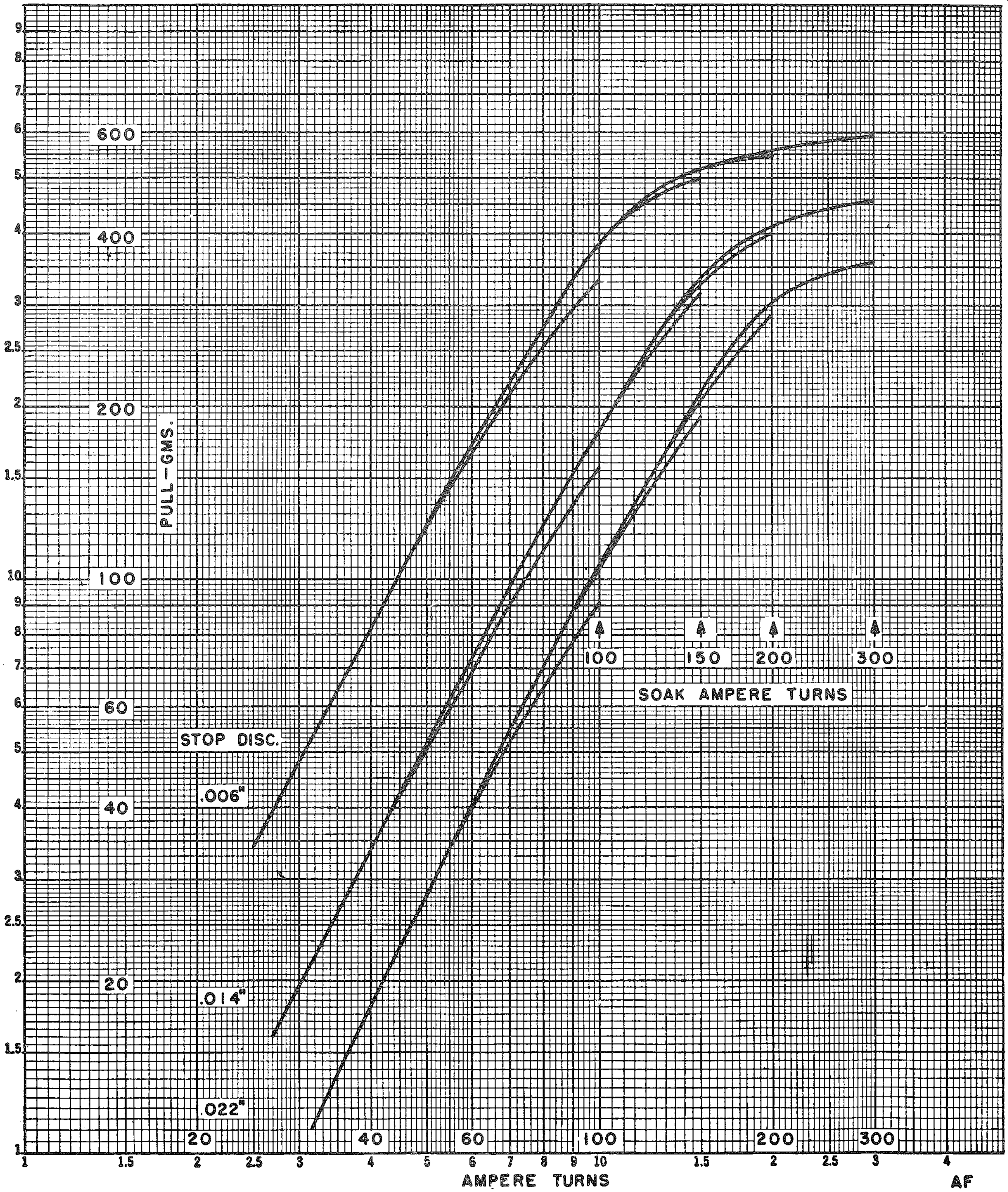

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Fig. IX-12 - AF Relay - Hold

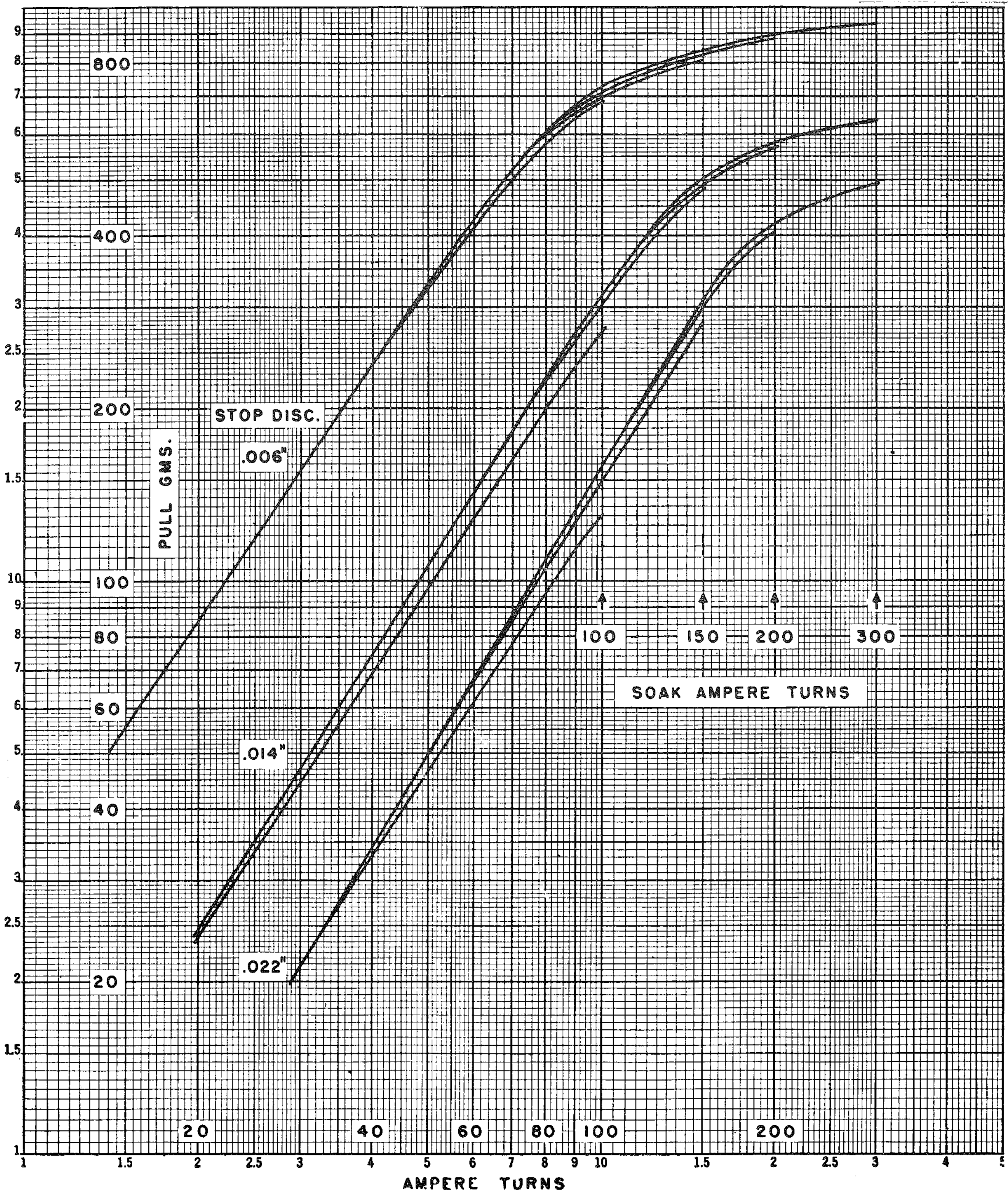

Fig. IX-13 - AF Relay - Release From Operated Position

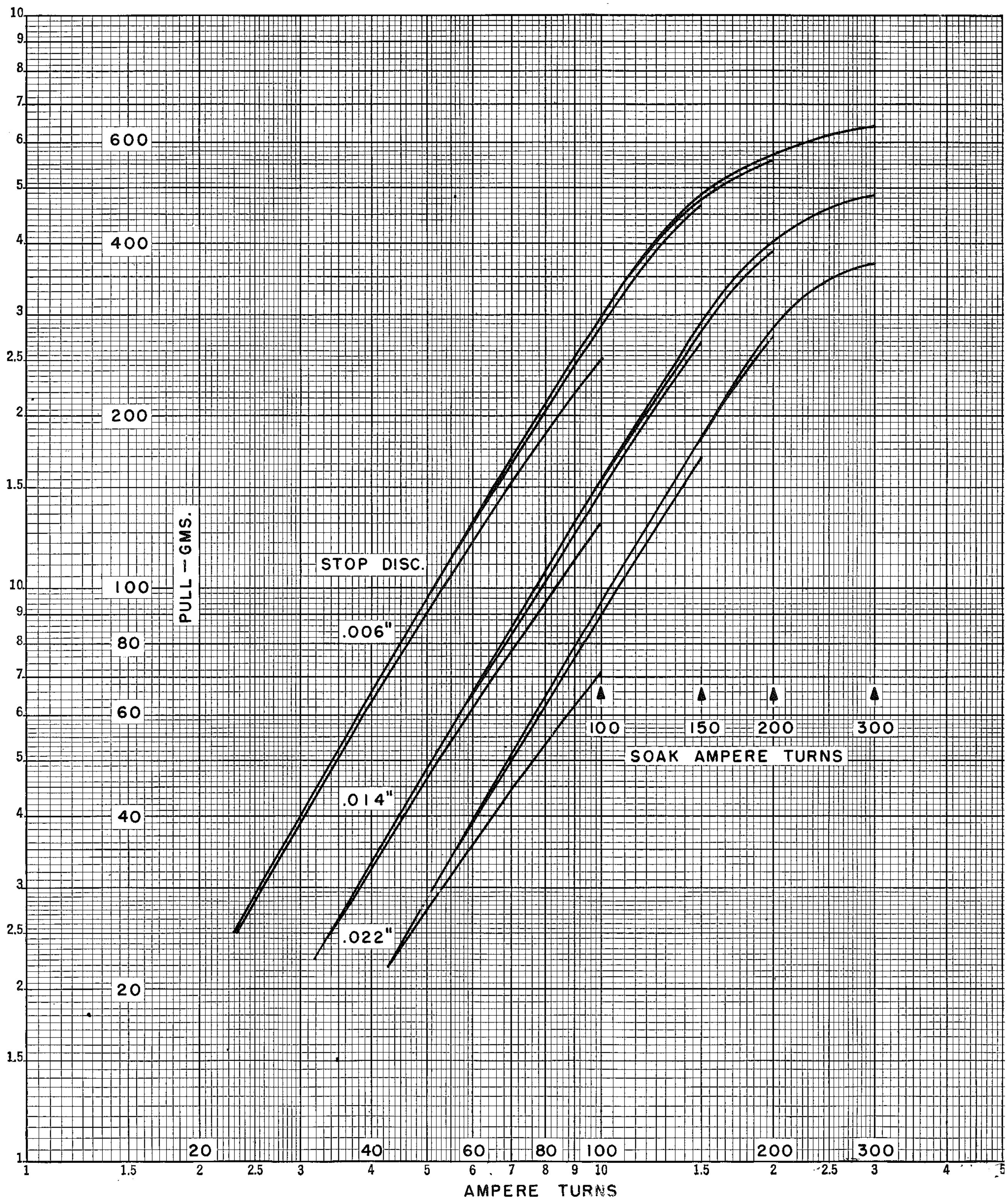

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Fig. IX-14 - AF Relay - Release From Pickup Position

X-75509

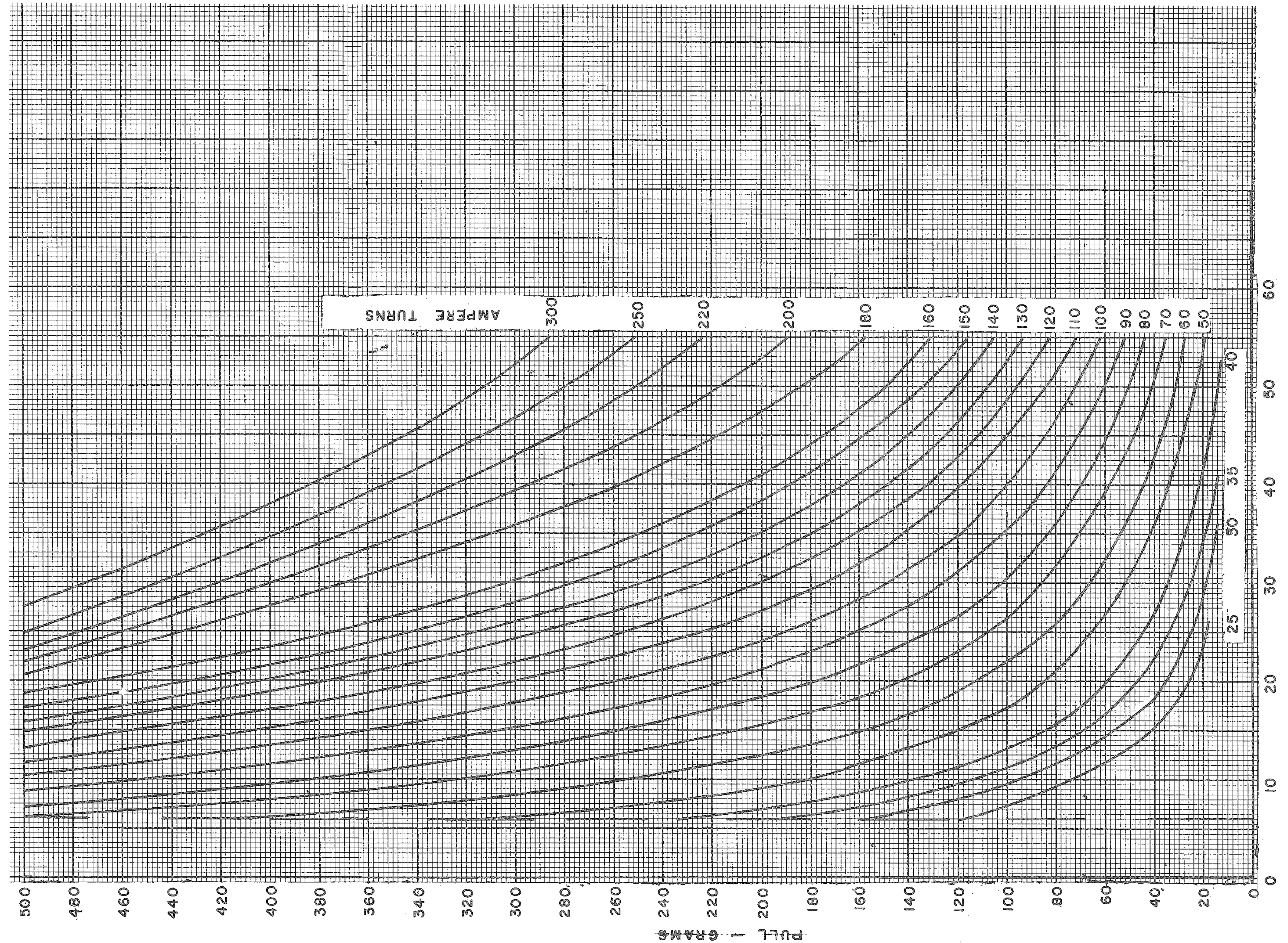

Fig. IX-15 - AF Relay - Release With Special Gauging

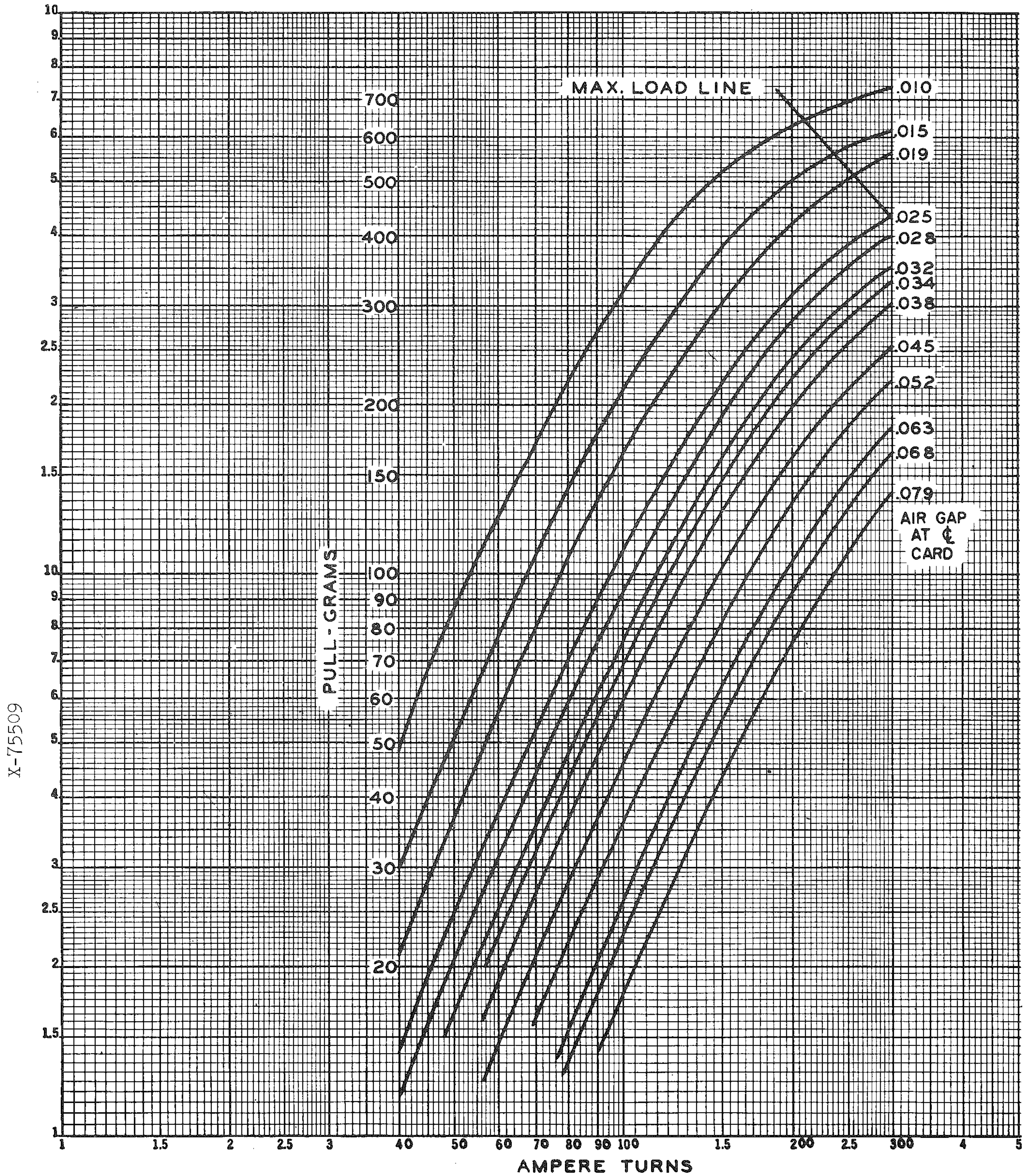

Fig. IX-16 - AJ Relay - Operate

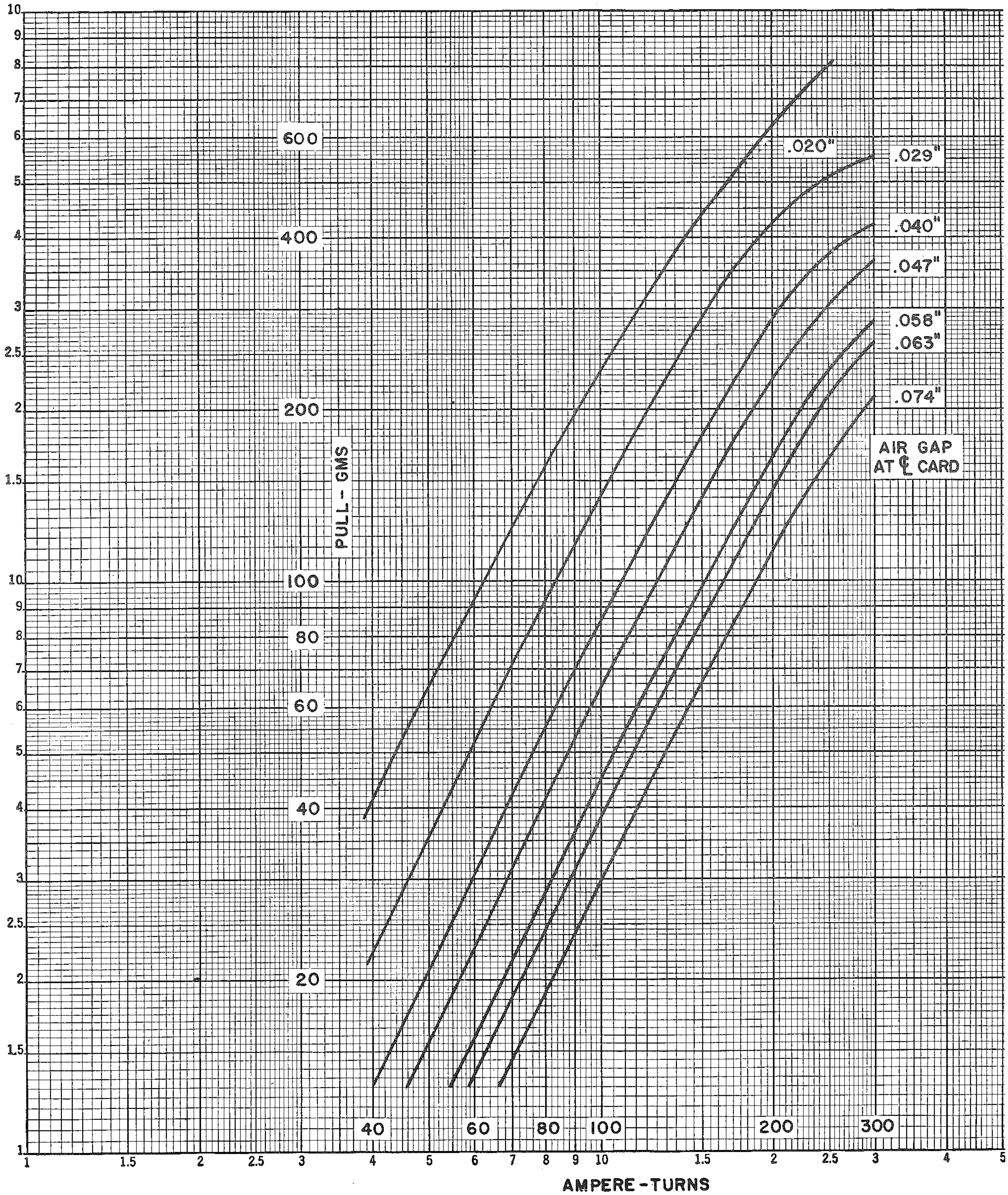

Fig. IX-17 - AJ Relay - Nonoperate

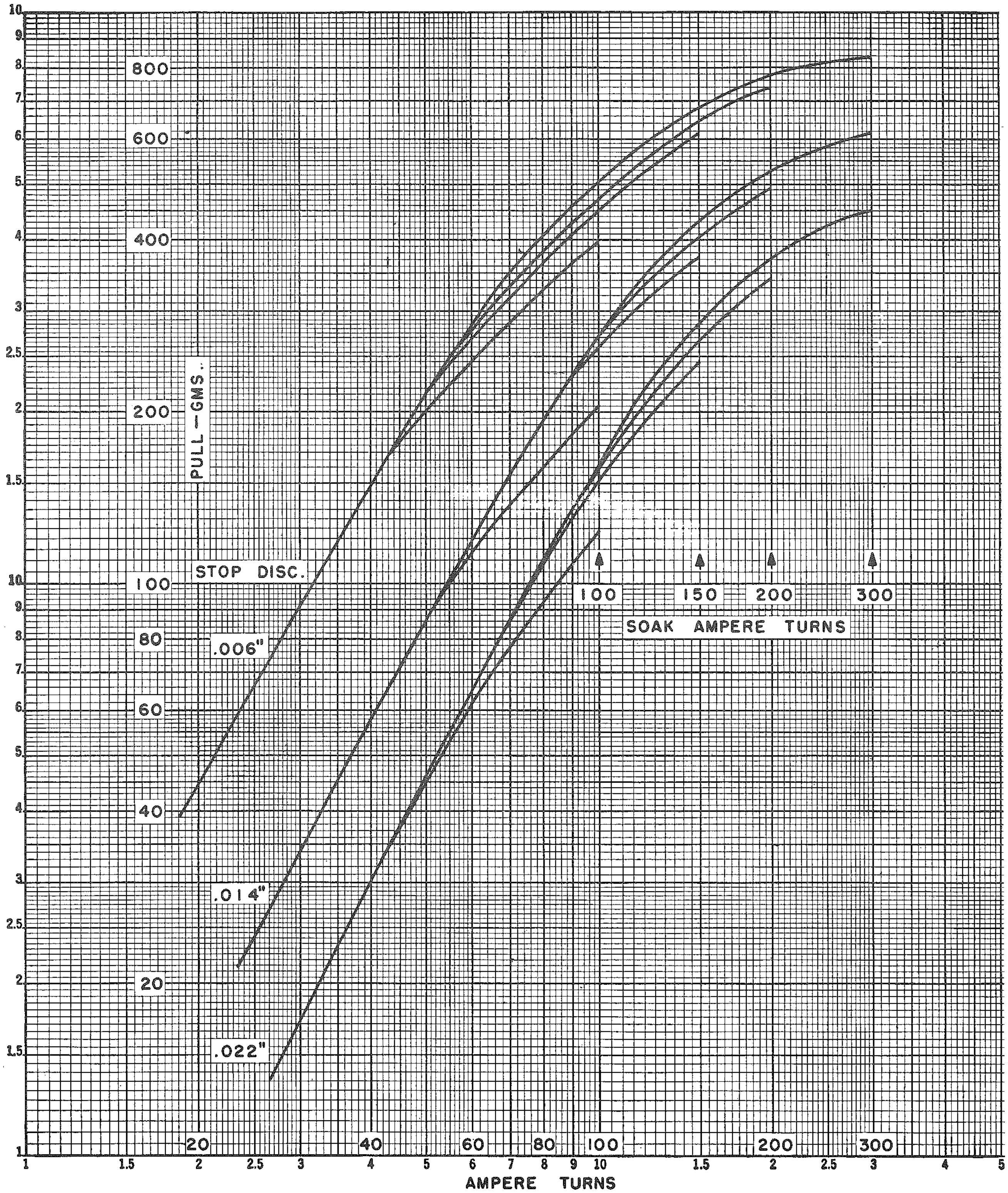

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Fig. IX-18 - AJ Relay - Hold

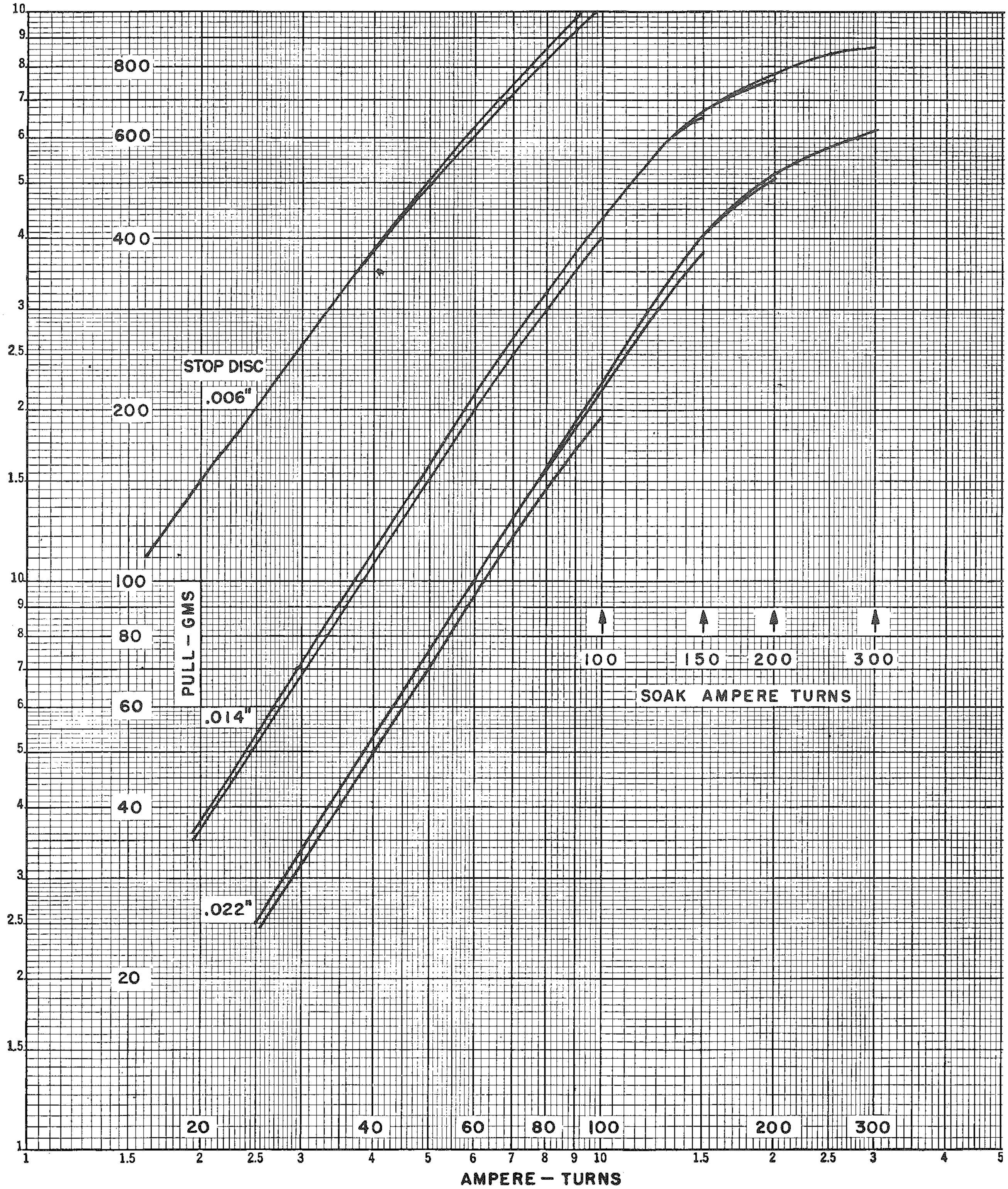

Fig. IX-19 - AJ Relay - Release From Operated Position

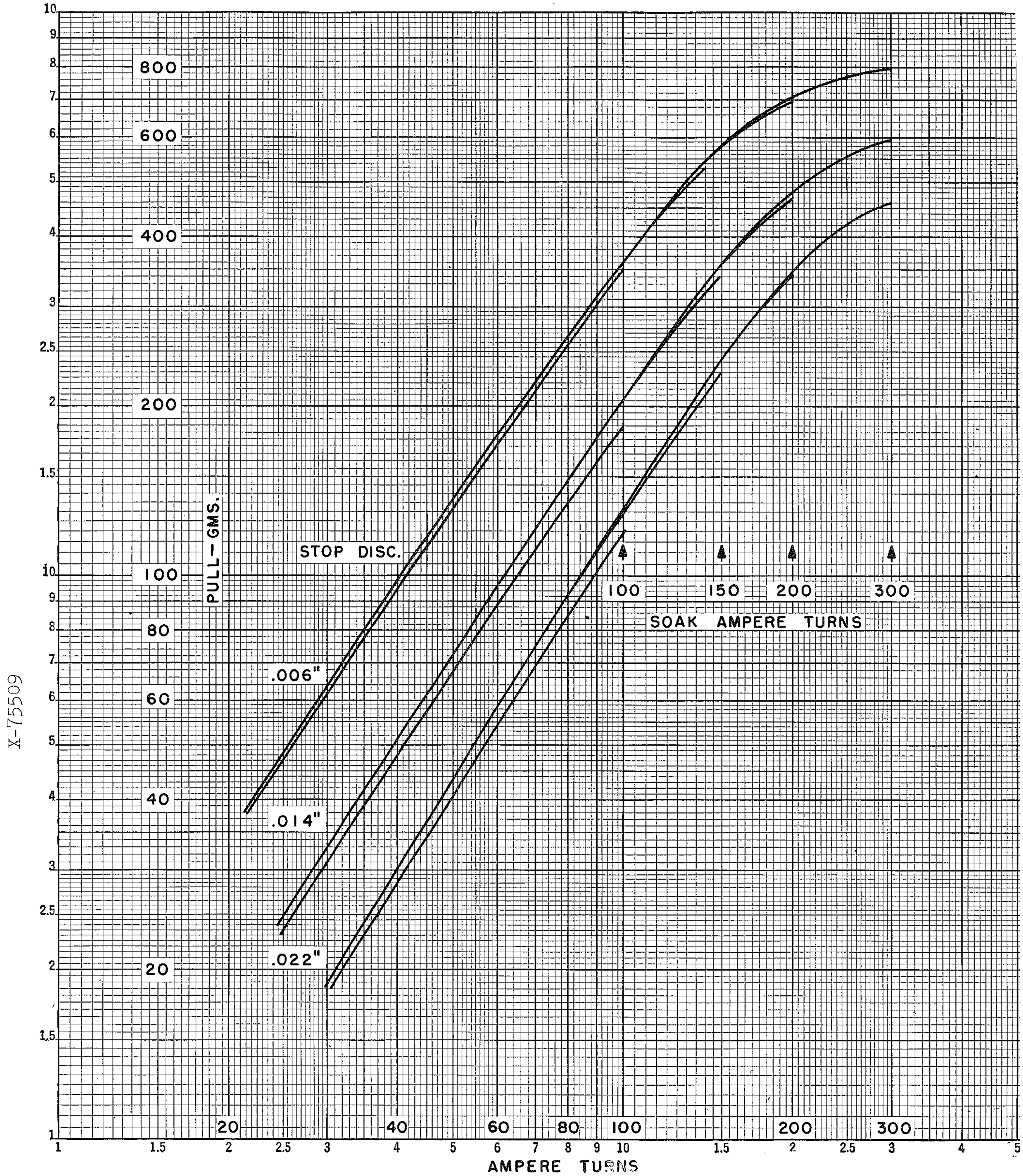

Fig. IX-20 - AJ Relay - Release From Pickup Position

X-75509

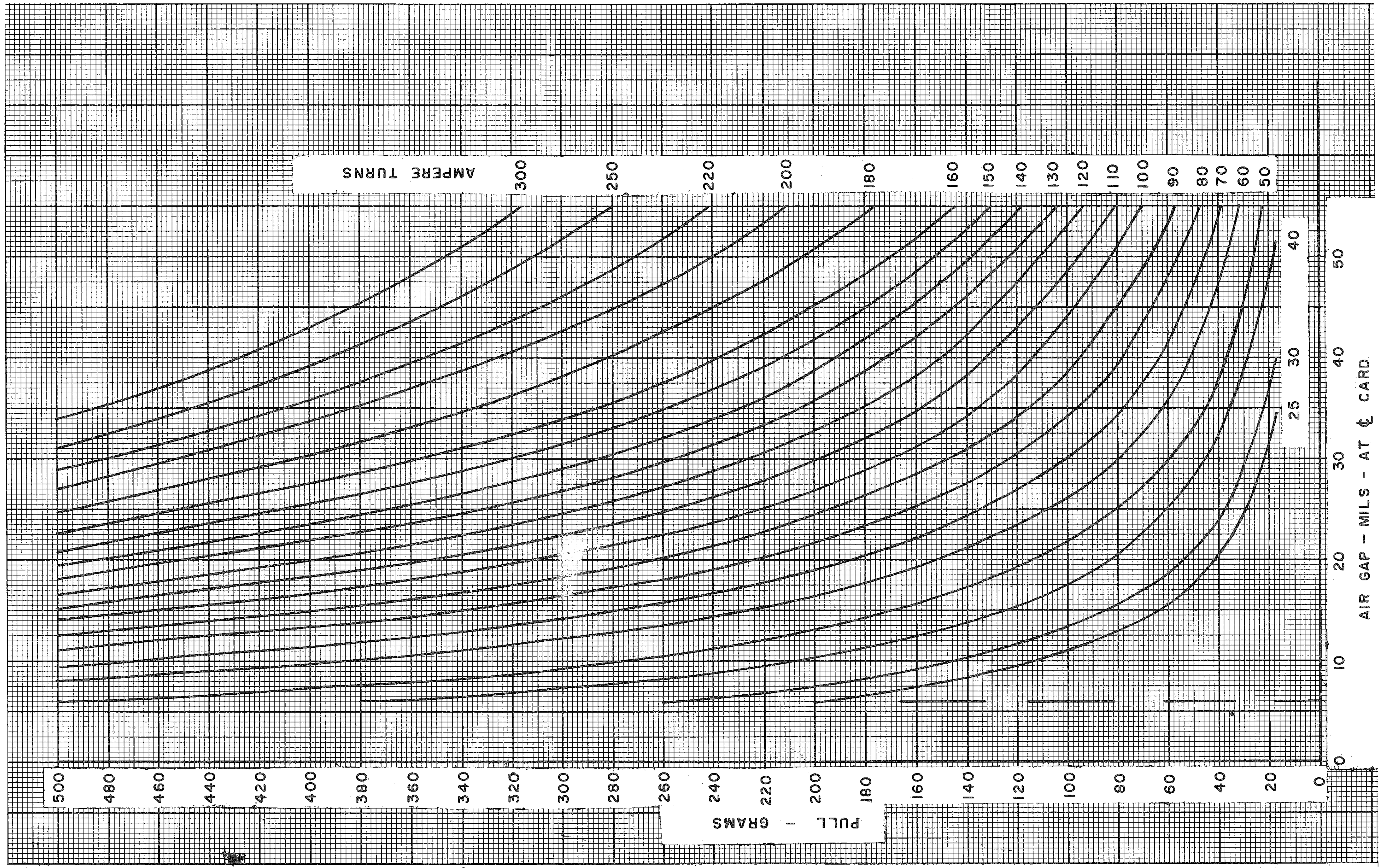

Fig. IX-21 - AJ Relay - Release With Special Gauging

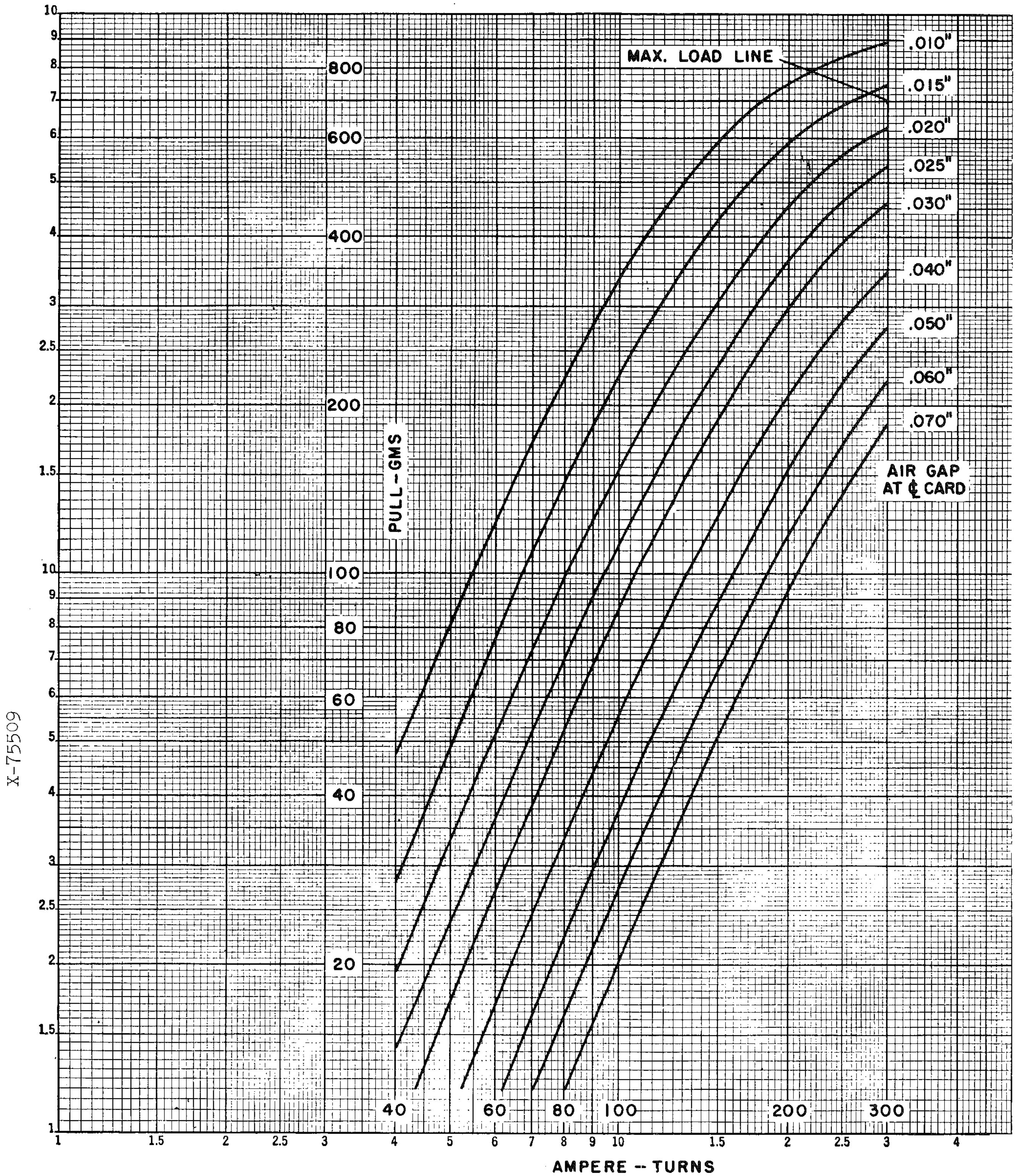

Fig. IX-22 - AJ Relay With Laminations - Operate

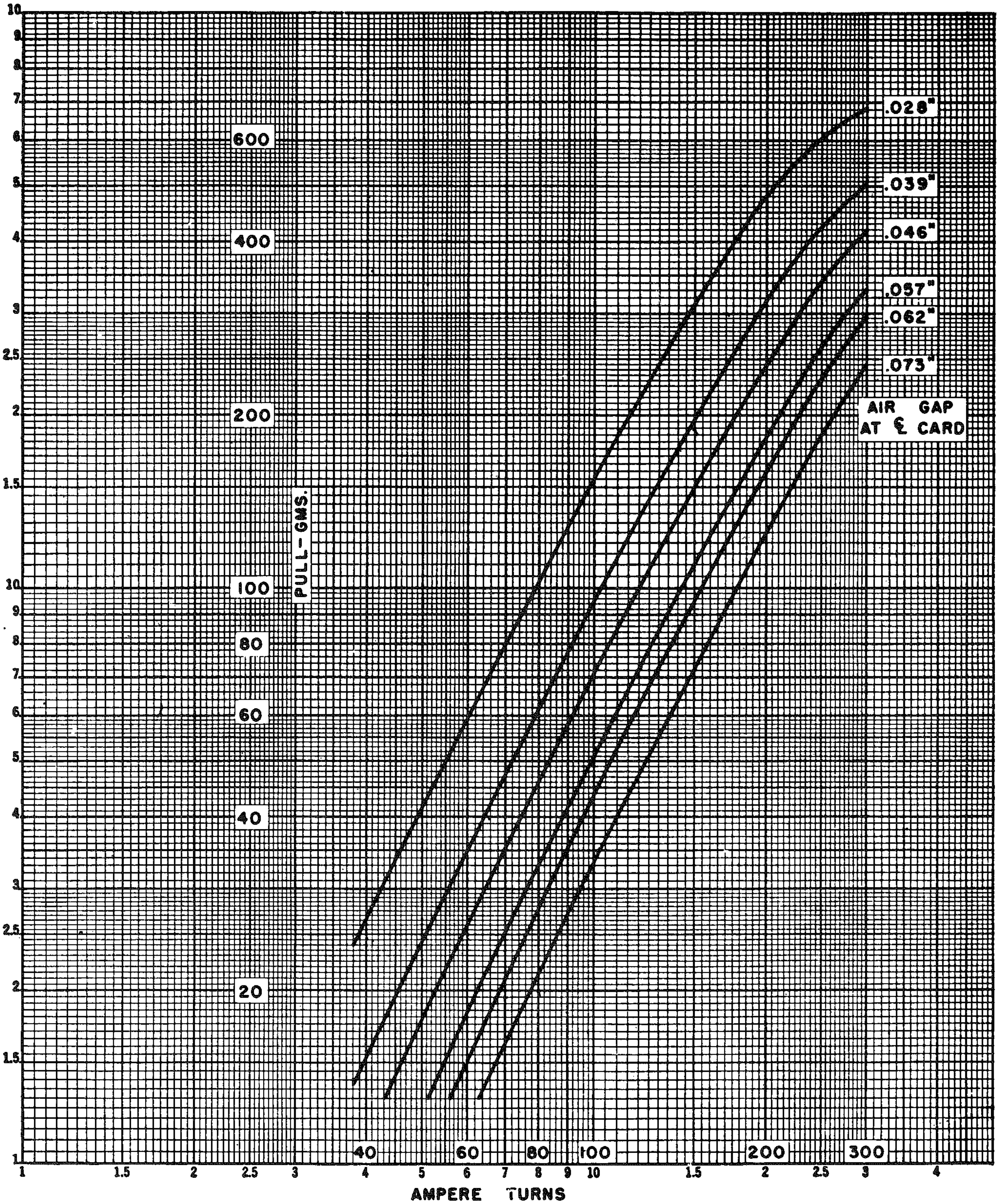

Fig. IX-23 - AJ Relay With Laminations - Nonoperate

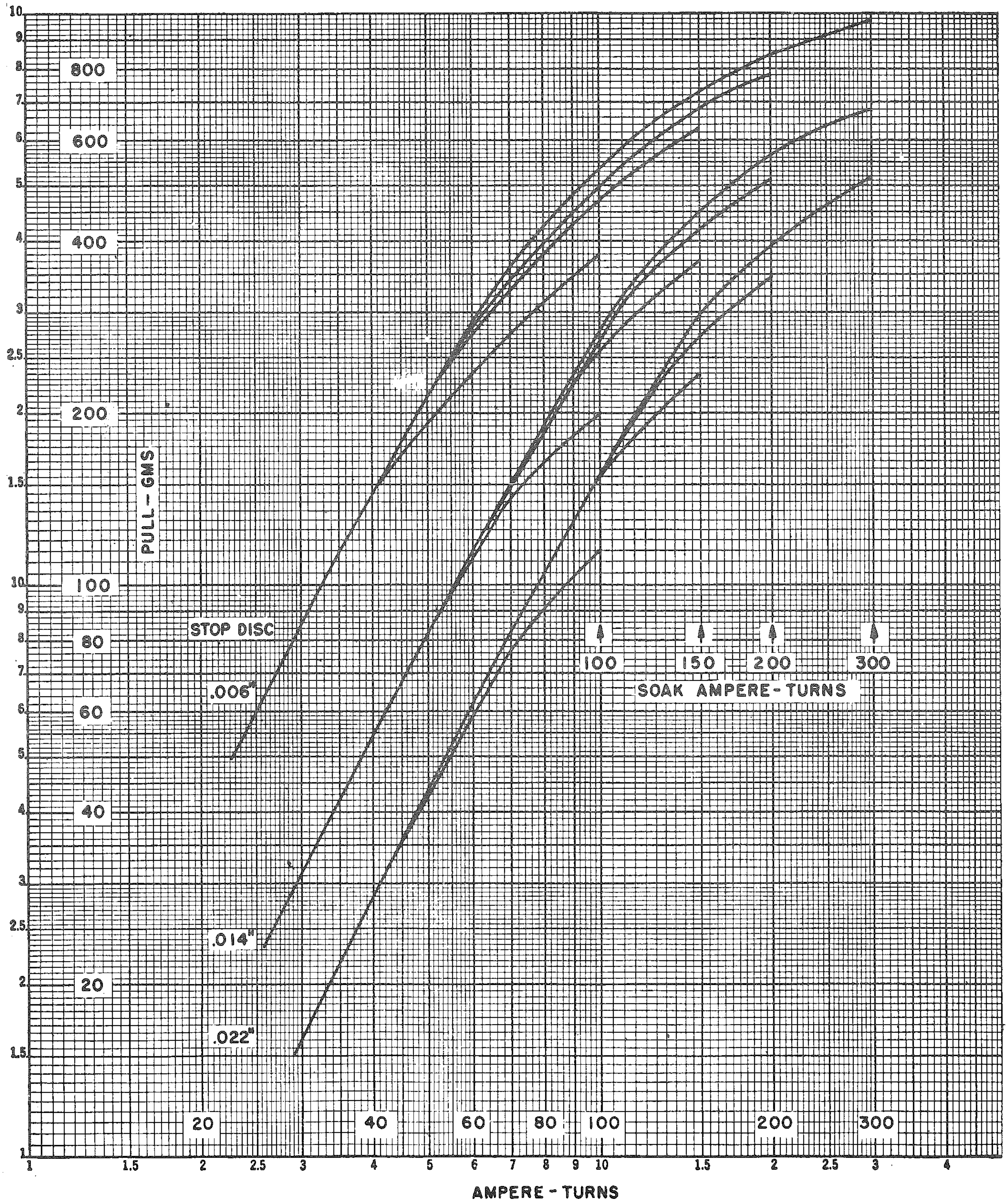

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Fig. IX-24 - AJ Relay With Laminations - Hold

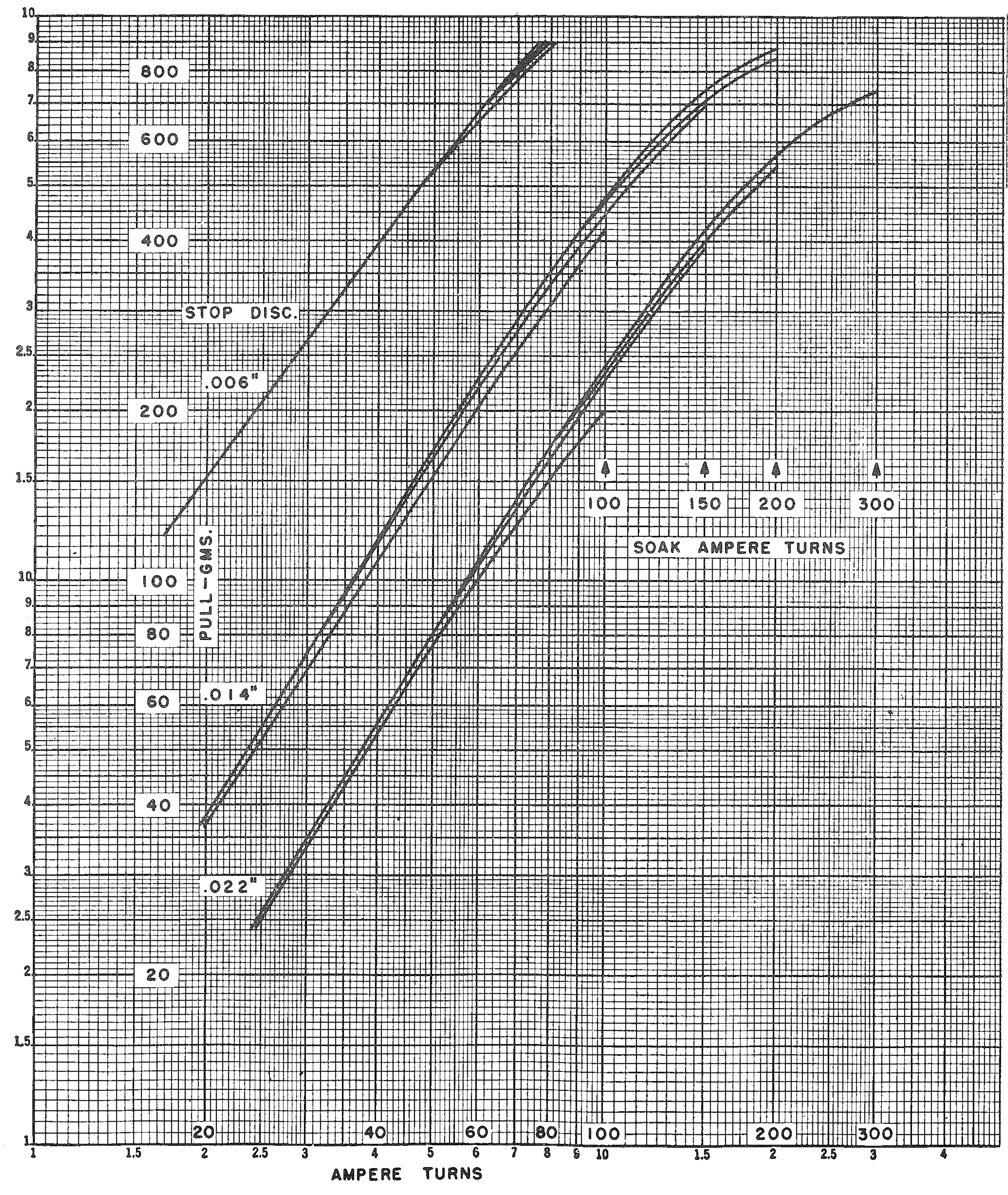

Fig. IX-25 - AJ Relay With Laminations - Release
From Operated Position

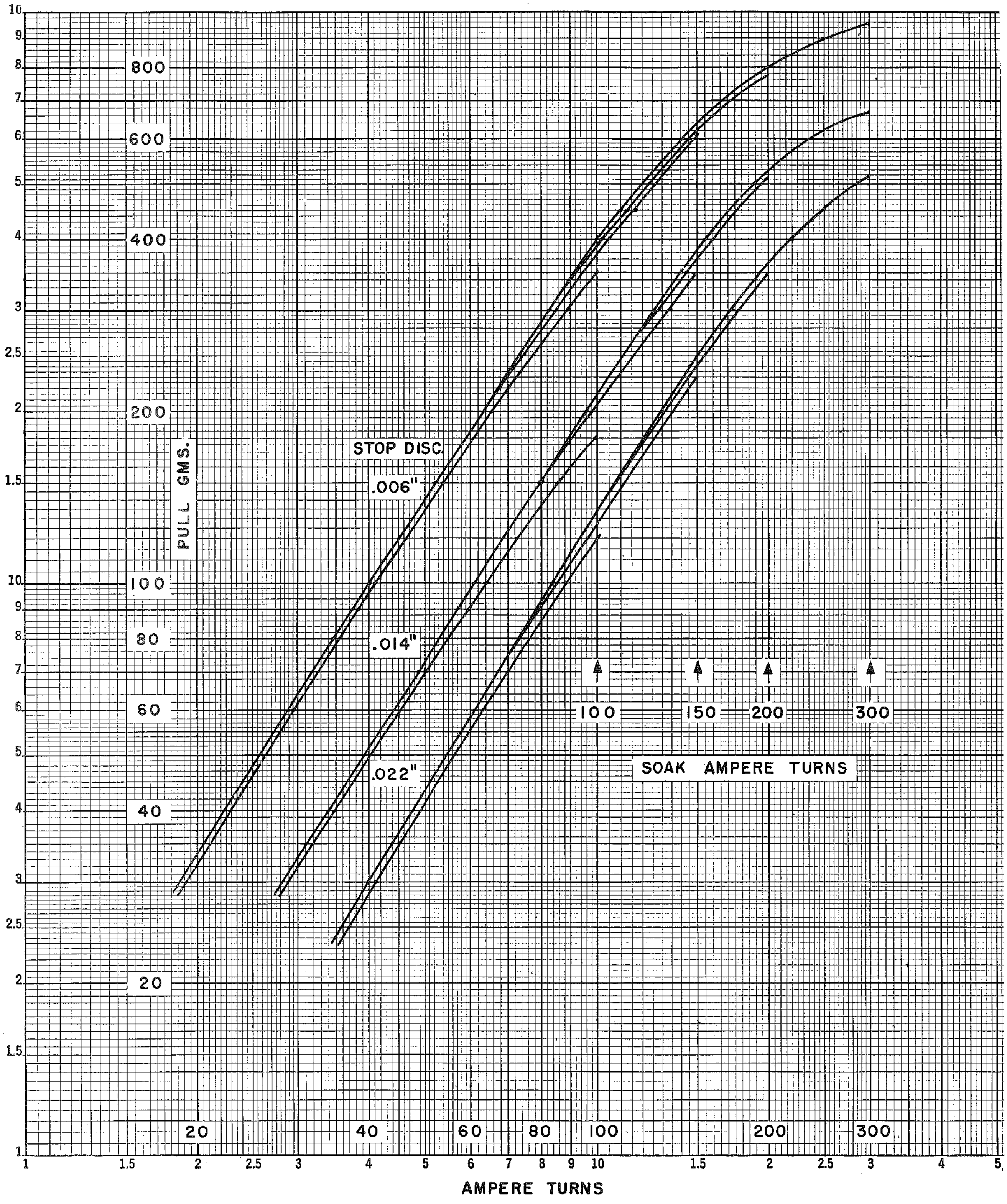

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Fig. IX-26 - AJ Relay With Laminations - Release From Pickup Position

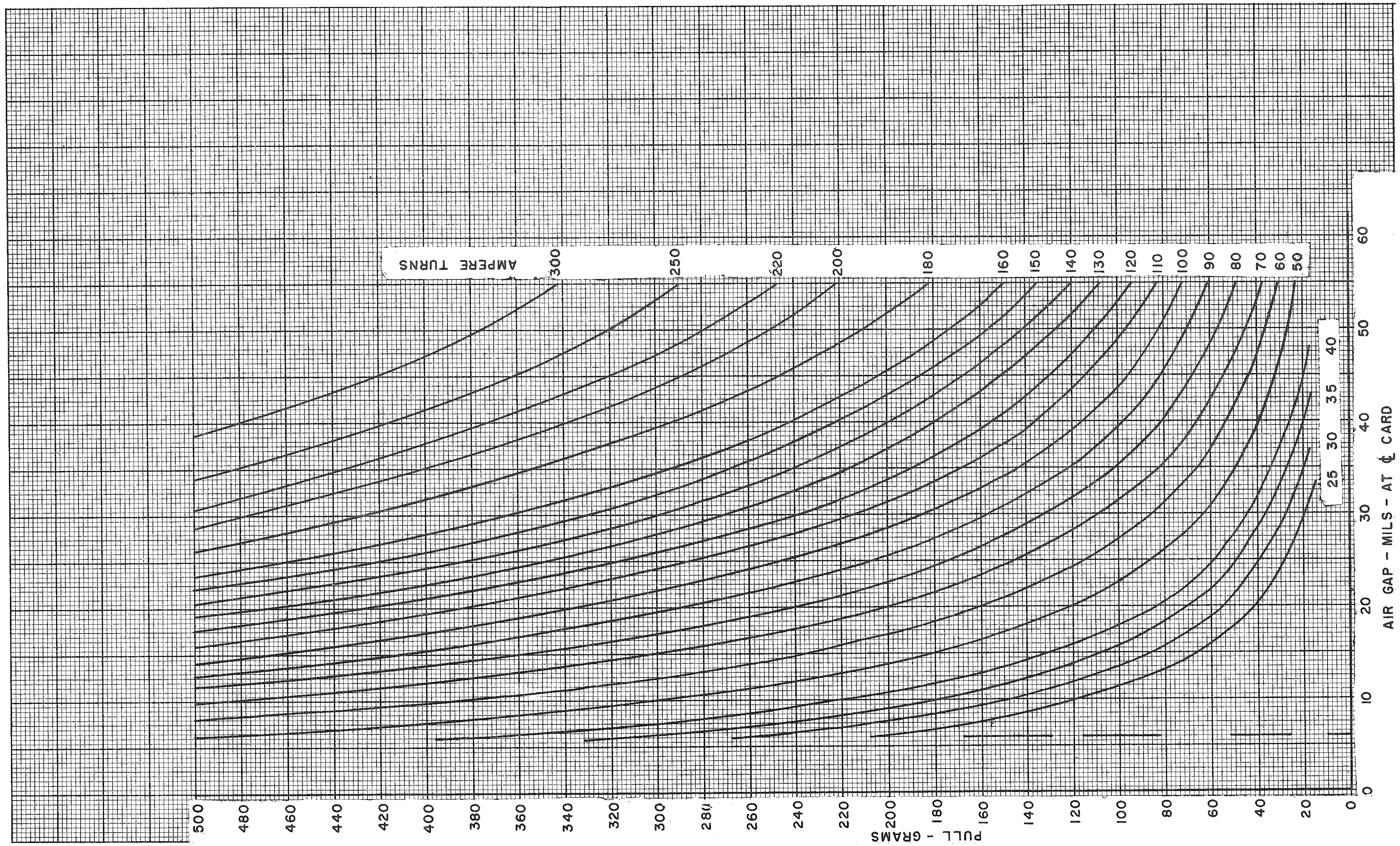

Fig. IX-27 - AJ Relay With Laminations - Release With Special Gauging

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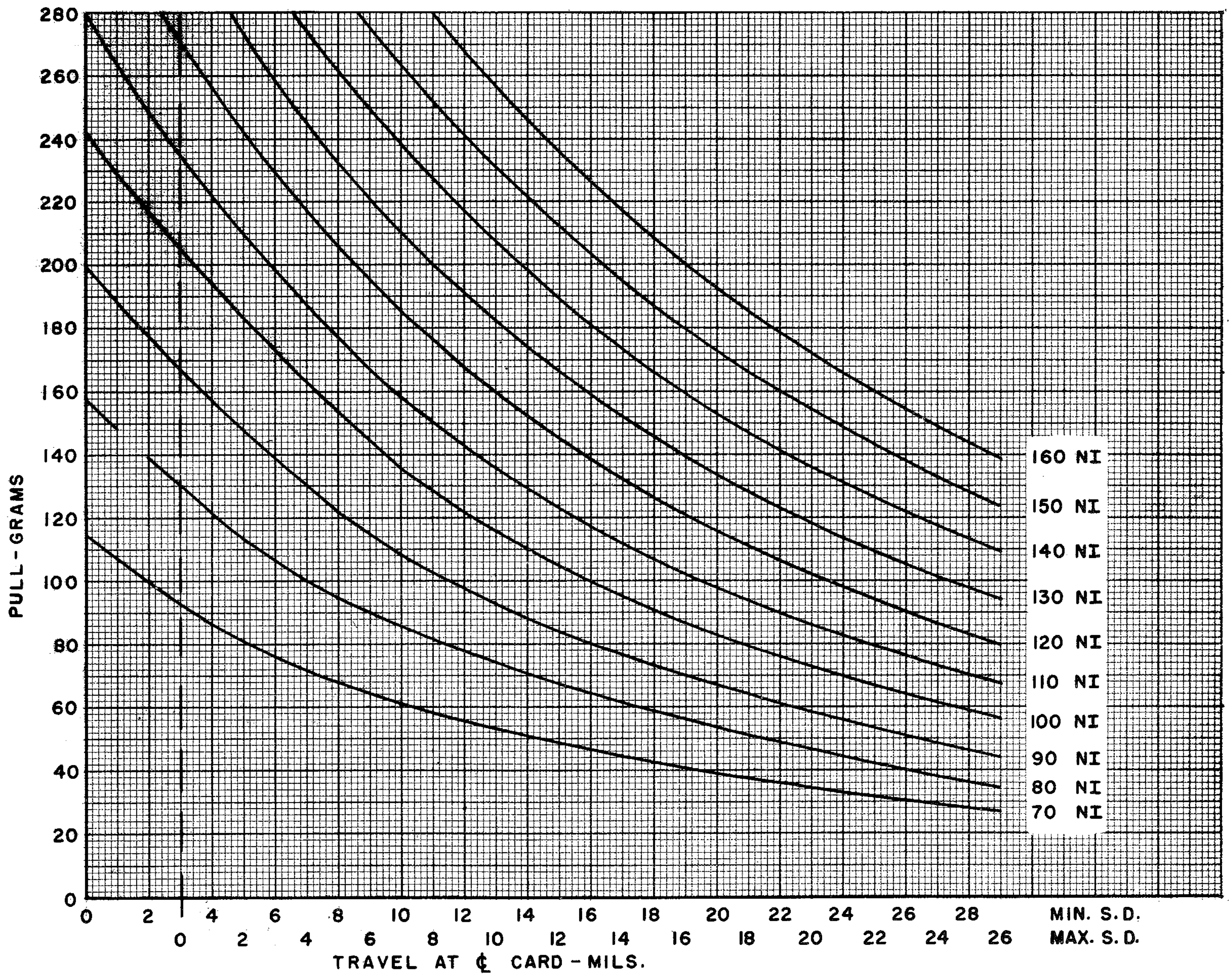

Fig. IX-28 - AJ Relay - With or Without Laminations 0.014-Inch Stop Discs - Marginal Operate Data

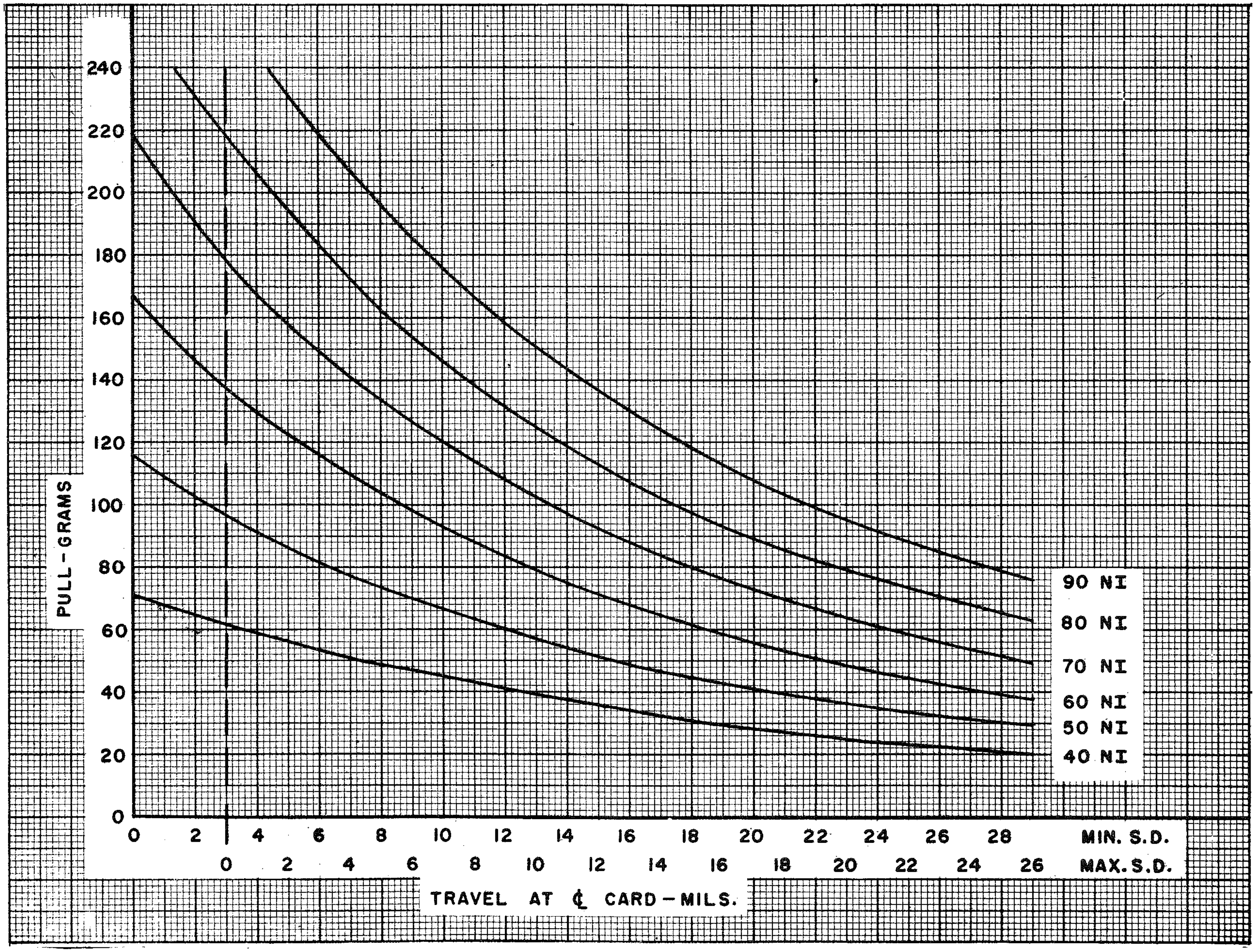

Fig. IX-29 - AJ Relay - With or Without Laminations 0.014-Inch Stop Discs - Marginal Release Data

X-75509

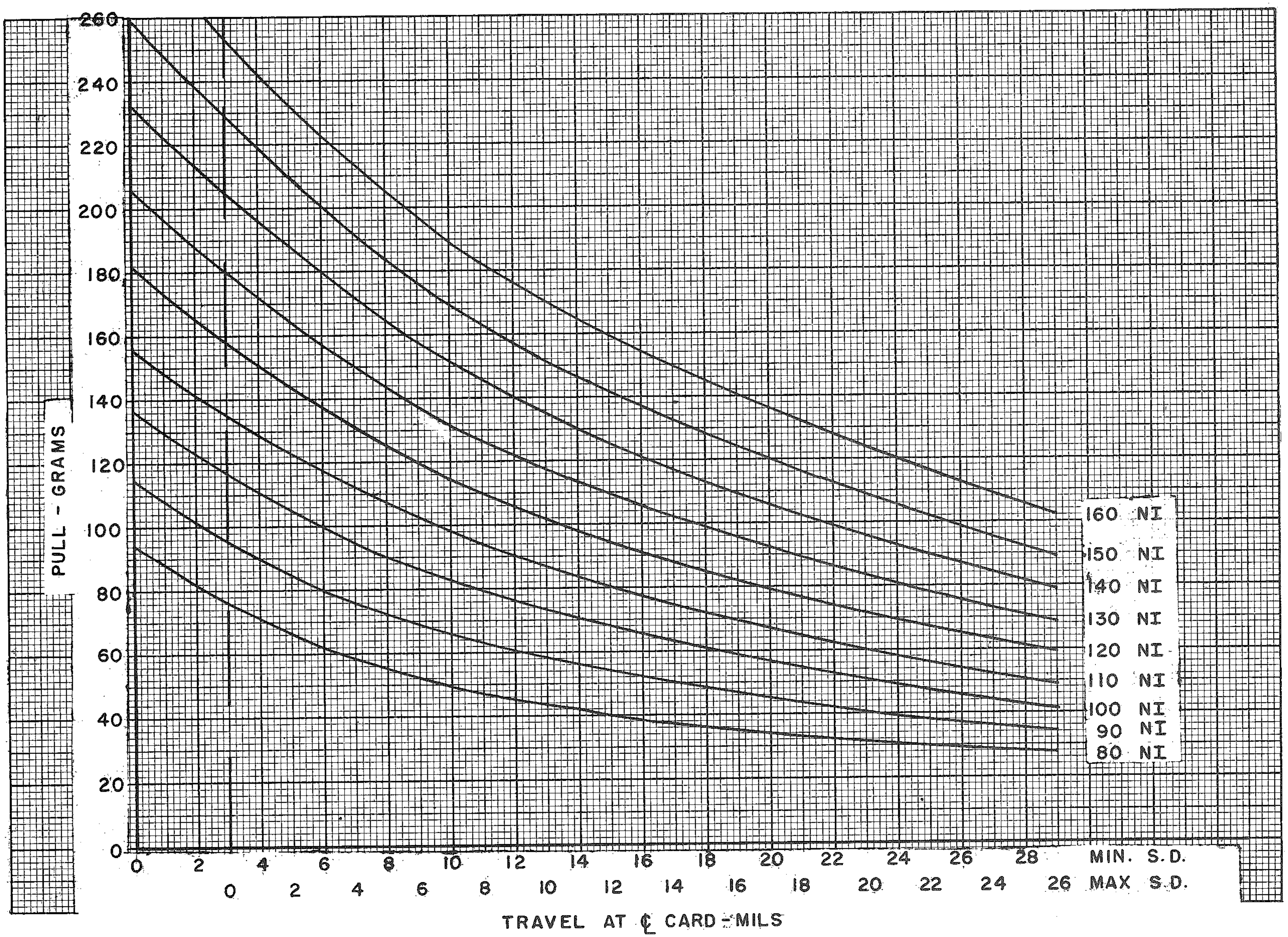

Fig. IX-30 - AJ Relay - With or Without Laminations
0.022-Inch Stop Discs - Marginal Operate Data

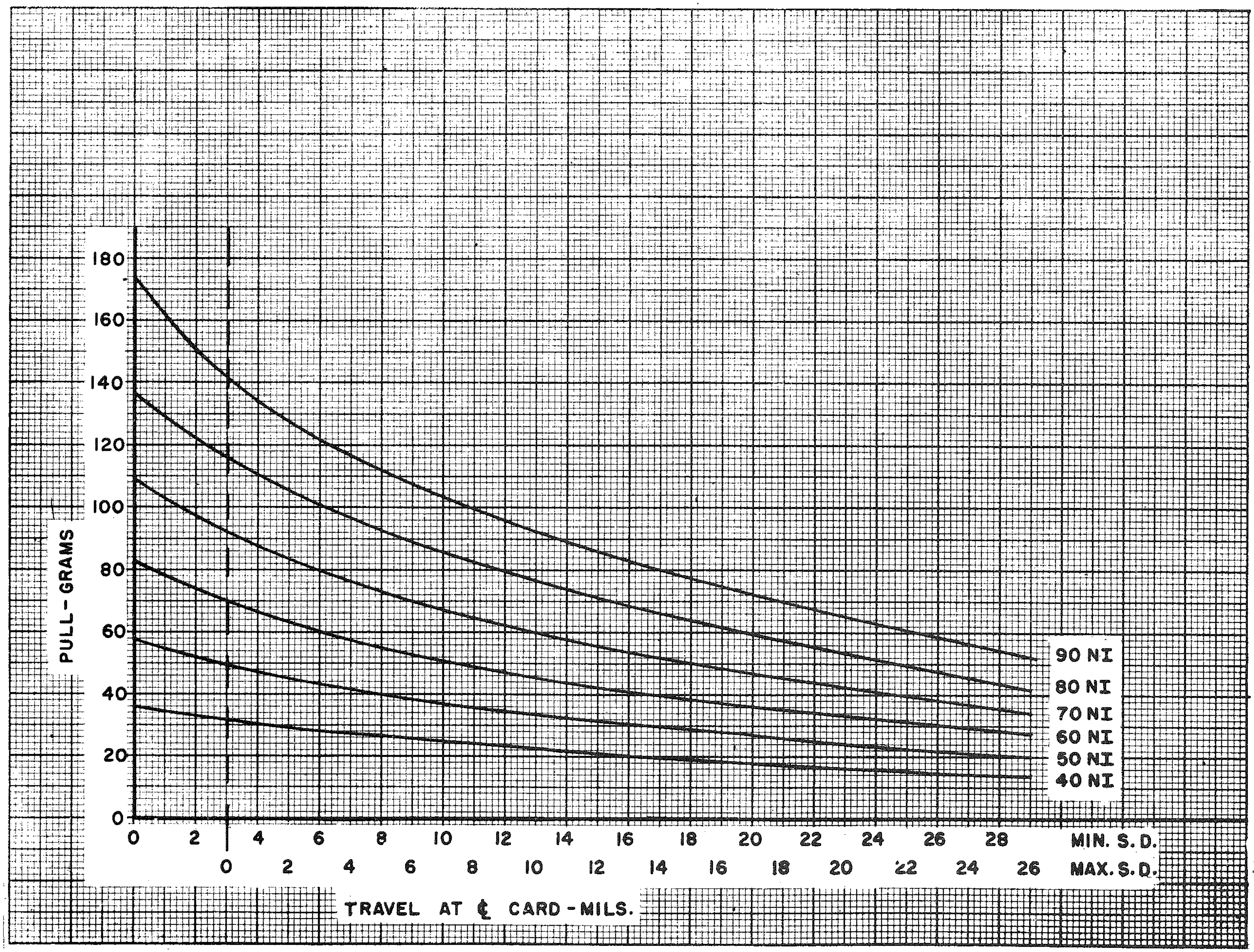

Fig. IX-31 - AJ Relay - With or Without Laminations 0.022-Inch
Stop Discs - Marginal Release Data

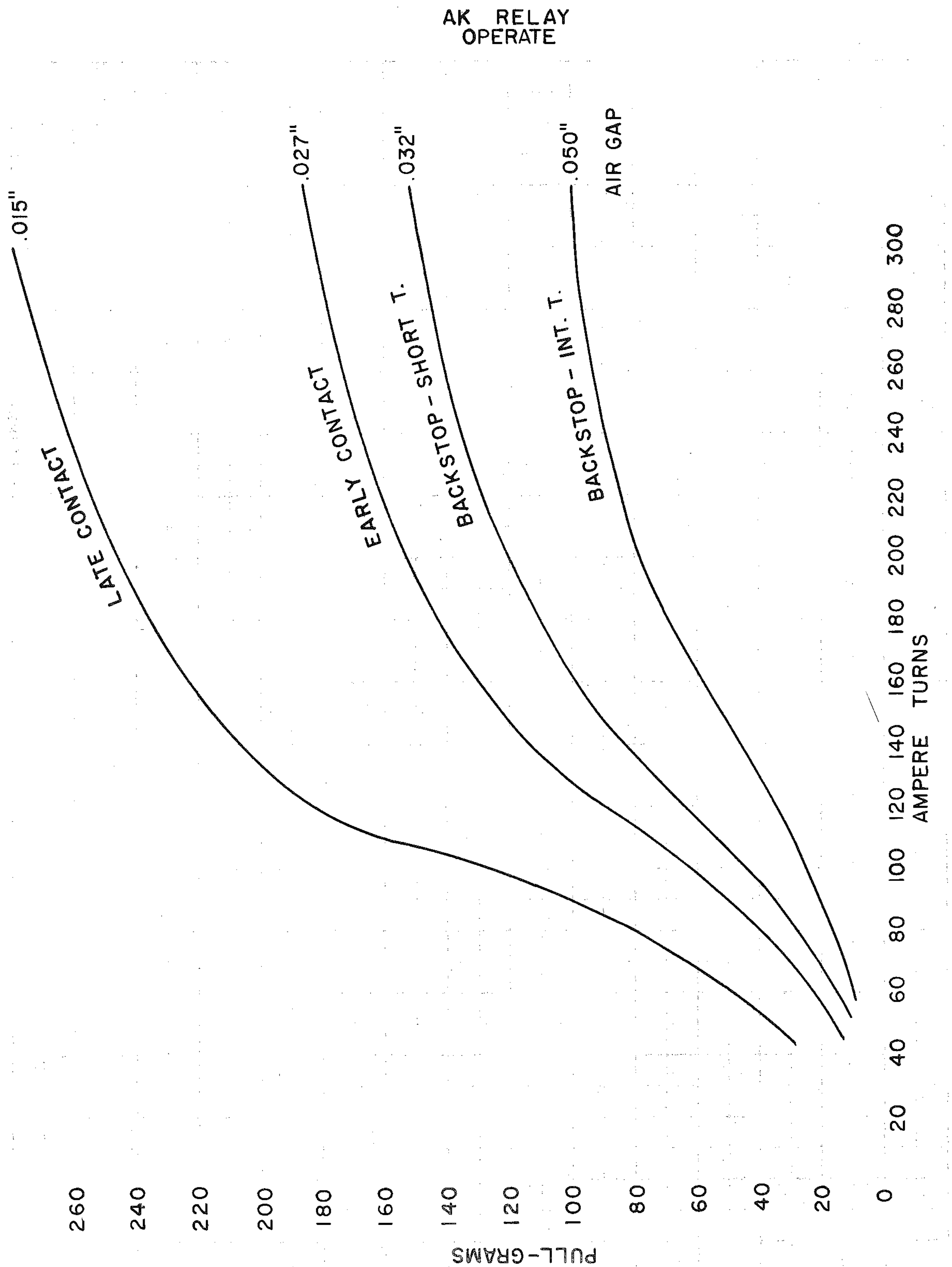

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Fig. IX-32 - AK Relay - Operate

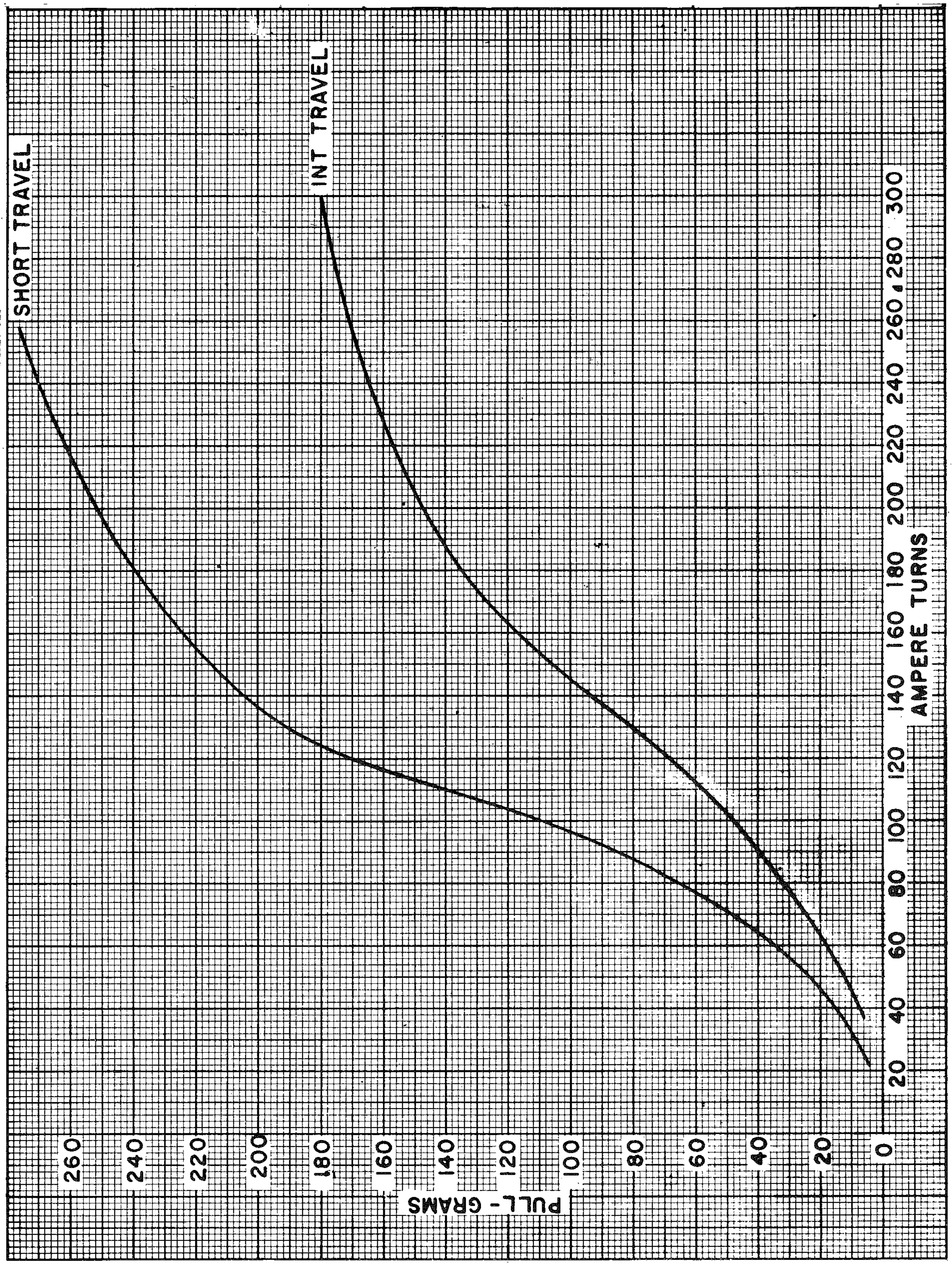

Fig. IX-33 - AK Relay - Nonoperate

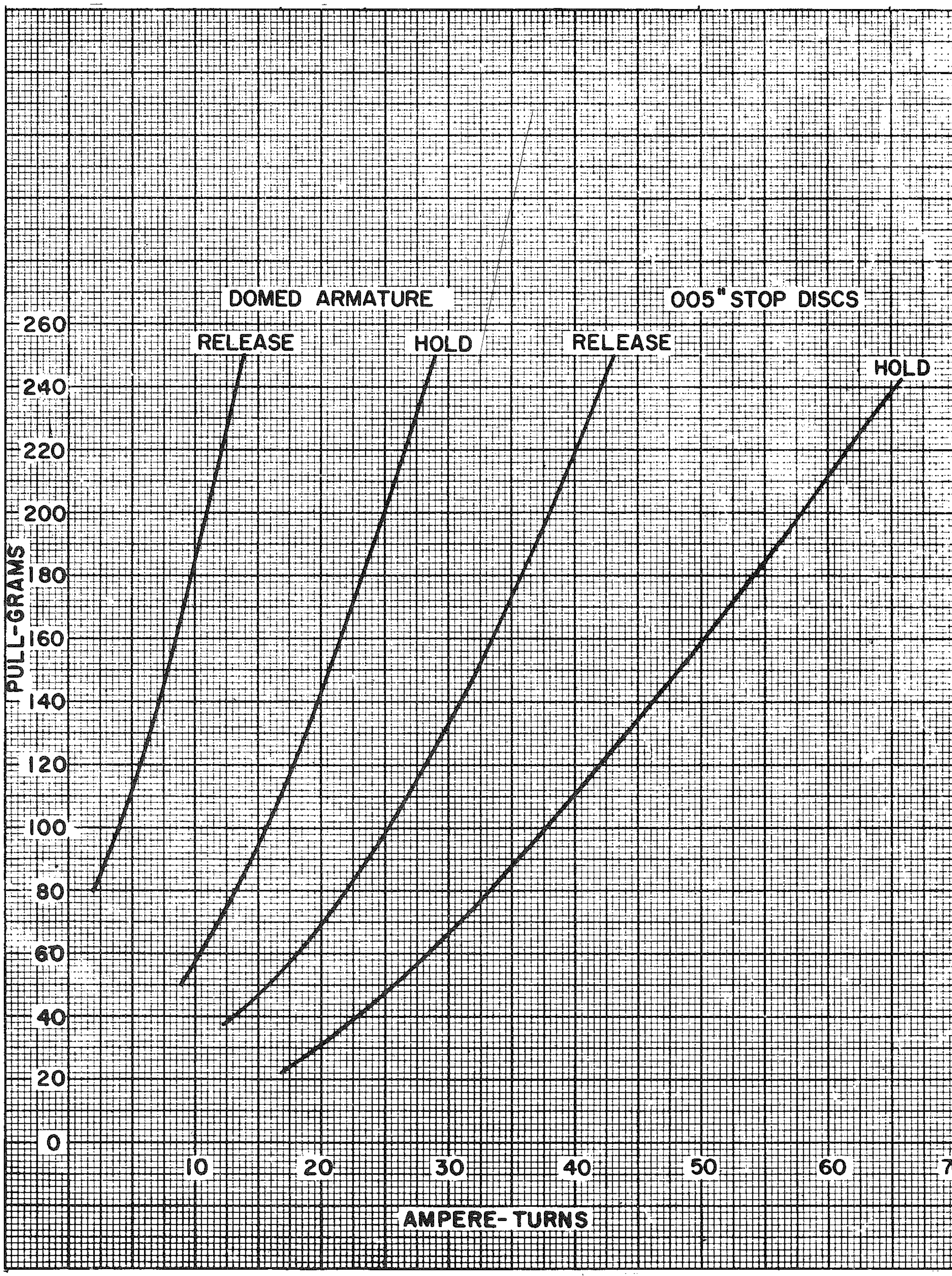

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Fig. IX-34 - AK Relay - Hold and Release

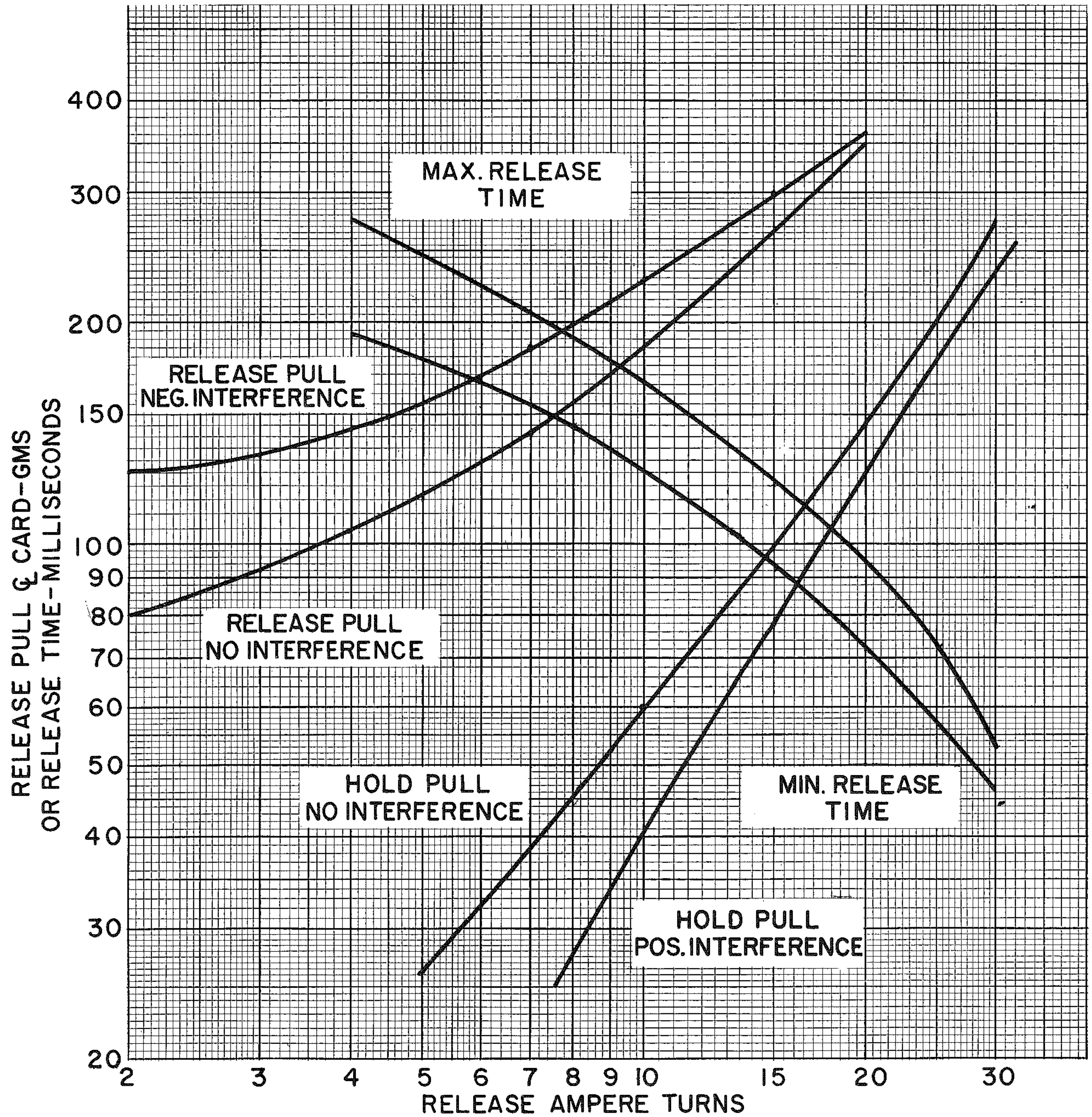

Fig. IX-35 - AK Relay - Slow Release - 0.069-Inch Copper Sleeve
(Data for Domed Armature)

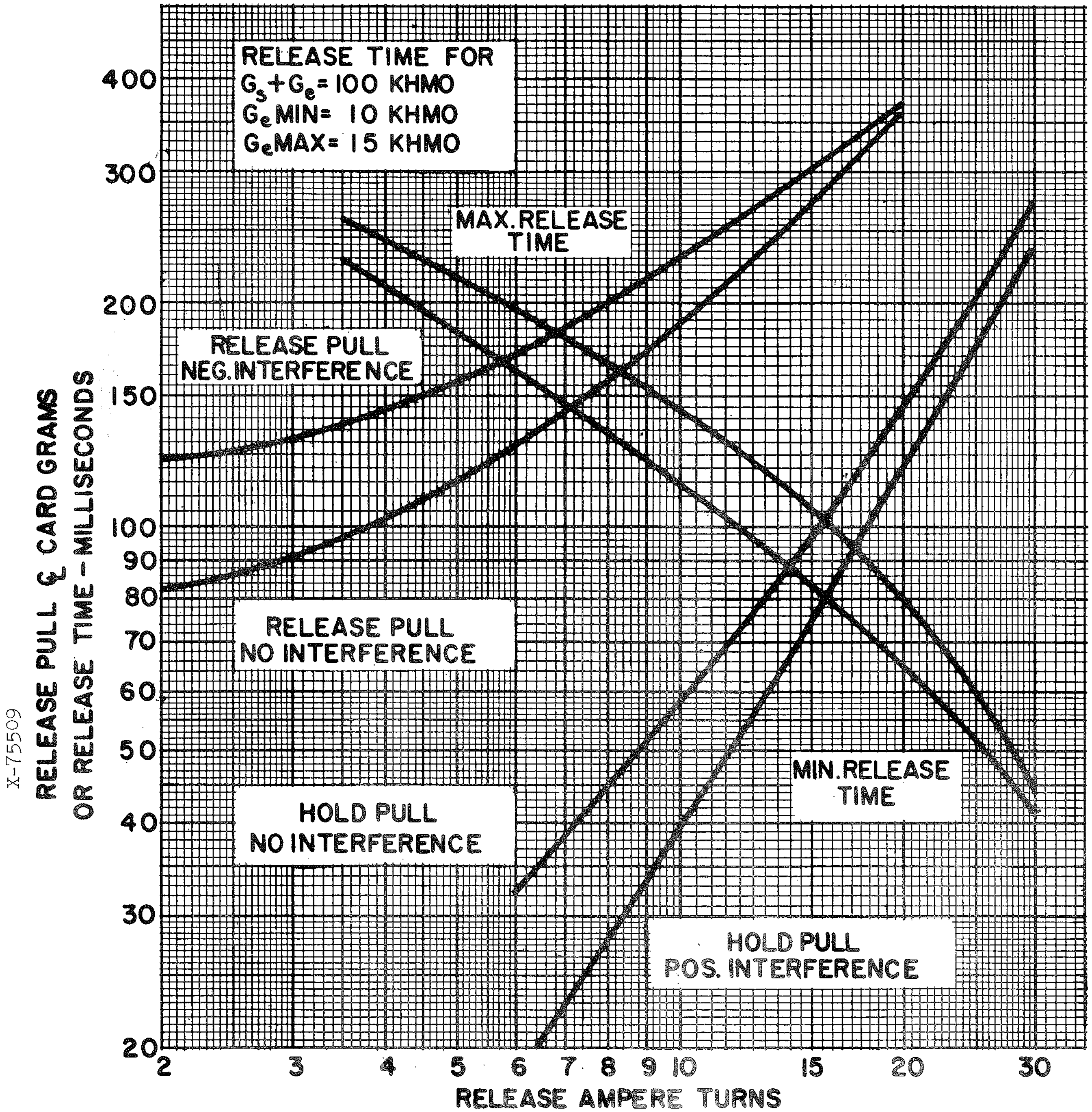

Fig. IX-36 - AK Relays - Release Time Domed Armature With Shunt

COILS

General

The wire spring relays use the cellulose-acetate-filled coil. This construction introduces a sheet of thin cellulose acetate between each layer of wire.

The multiple winding machine used in the manufacture of the filled coils employs round mandrels up to 15-3/4 inches long, on which are wound sticks of eight to twelve individual coils per mandrel. Wire is wound simultaneously from supply spools through wire guides spaced uniformly along the length of the mandrel. The coils are spaced 3/16 inch apart to provide insulation at the ends of the coils and space to permit cutting the stick into individual self-supporting coils.

During the winding operation, as the mandrel rotates, the winding mechanism moves along the mandrel and reverses direction at the completion of each layer of wire. As a layer is completed, and before the next one is wound, a sheet of cellulose interleaving is automatically cut to the required length and injected into the winding to cover the completed layer. In this manner, the layers of wire are interleaved with cellulose acetate.

When the required number of layers have been wound, a cellulose acetate cover is applied over the stick. The stick is then removed from the machine, the mandrel is withdrawn, and the coils are shaped to fit the rectangular wire spring relay core. The stick is cut into individual coils by means of a rotary multiple saw. Fig. X-1 shows the construction of the filled coil.

Normally, the interleaving is 0.0007 inch thick, but for wire sizes from 24 through 28, interleaving 0.002 inch thick is used in order to obtain a better bond to the spoolhead and to improve insulating the coil and leadout wires. Also, coils using wire

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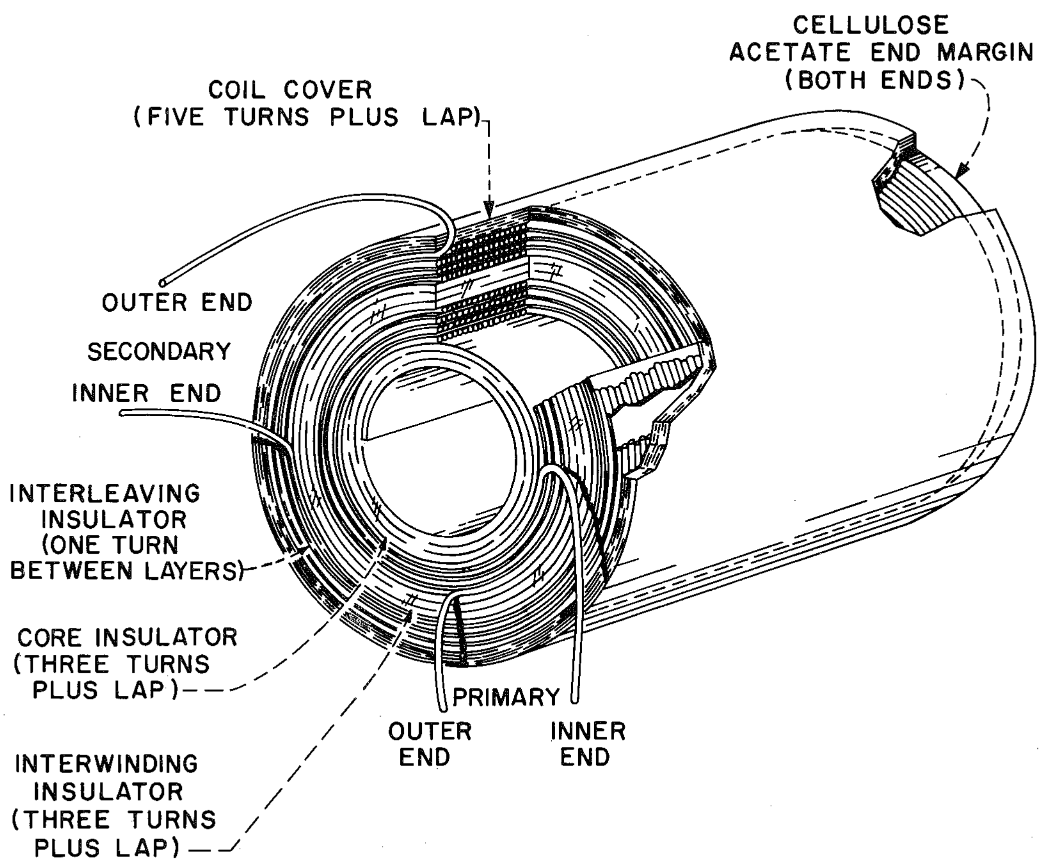
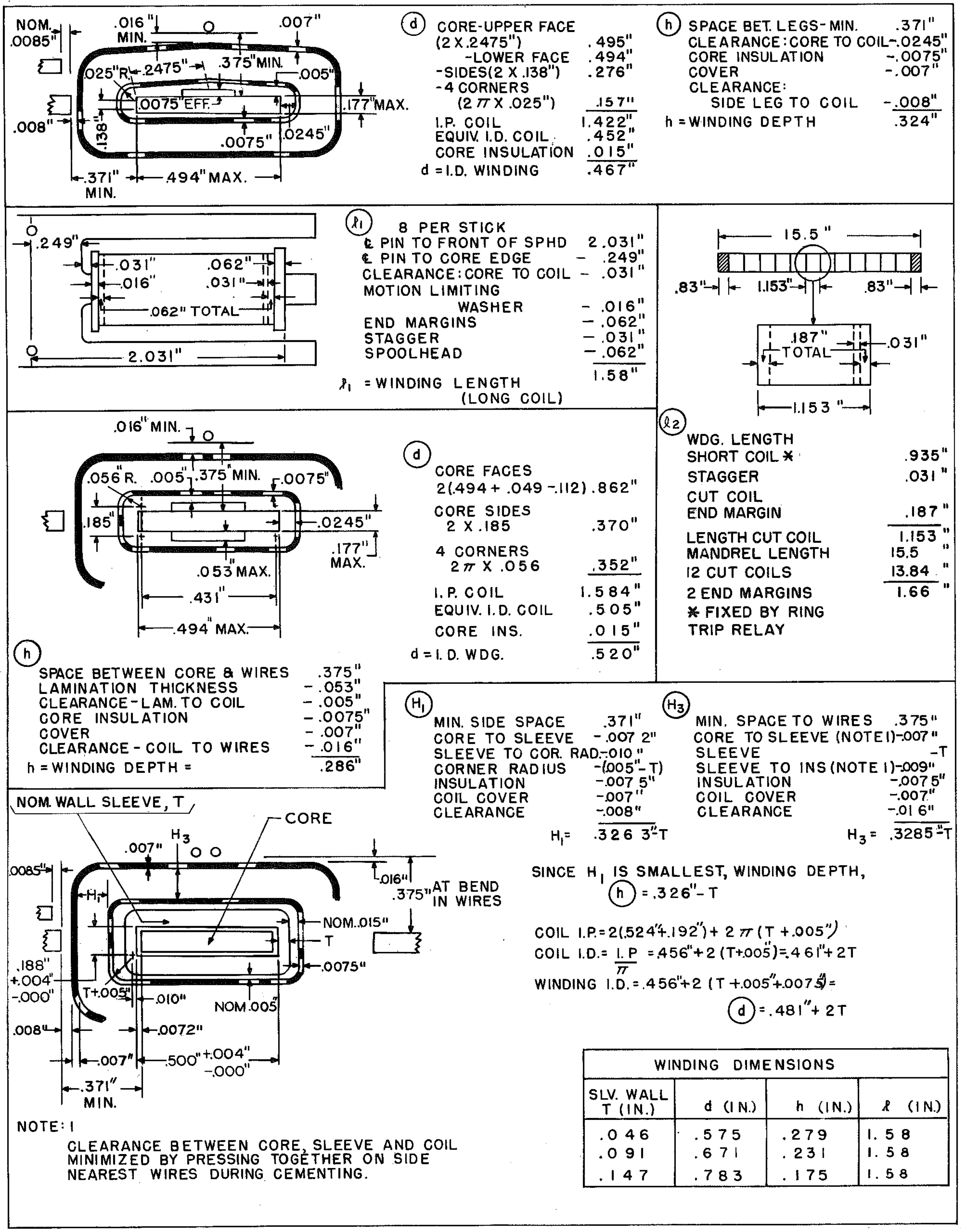


Fig. X-1 - Construction of a Cellulose-Acetate-Filled Coil



WINDING DIMENSIONS

SLV. WALL T (IN.)	d (IN.)	h (IN.)	ℓ (IN.)
.046	.575	.279	1.58
.091	.671	.231	1.58
.147	.783	.175	1.58

Fig. X-2 - AF, AG, and AJ Relays - Coil Dimensions gauges finer than 28 may use the 0.002-inch interleaving to increase the coil fullness and improve the thermal conductance or heat dissipation characteristic.

Secondary windings are wound over the primary windings before the shaping process, and the two windings together are then shaped to fit the rectangular core. Primary windings for relays with laminations or sleeves are wound on round arbors, with an equivalent diameter based on the circumference of the outer side of the laminations or sleeve, and then shaped to fit over the lamination or sleeve.

While noninductive windings may be wound on the wire spring relays, the use of these windings is not recommended as a general practice due to the added cost penalty imposed on the coil, especially for uses that do not require the extra resistance.

Filled coils are generally wound with enamel-covered wire per MS58364. This is a wire that is passed through the coating bath four times, resulting in a thinner enamel-coated wire than that used on spool-wound coils, which is passed through the coating bath eight times. Coils wound with 27 or heavier gauge wire should use MS58371 (heavy insulation) to protect against short-circuited turns caused by breaks in the MS58364 insulation during the shaping operation. The coils must meet a 500-volt ac breakdown test between the winding and any part of the frame. Spool-wound coils, which do not have the benefit of interleaving between adjacent layers of wire, must use wire with a heavier enamel coating than MS58364.

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In the process of assemblying the relay structure, the coil is first coalesced by holding the ends against a hot plate to seal the end of the coil and to adjust the length. A motion-limiting washer is slipped on the center leg of the core, followed by the coil and the front spoolhead. The leadout wires are threaded through the eyelets in the front spoolhead. The front spoolhead is pressed into position where it is held by a tight fit over a knurled portion of the core. The motion-limiting washer is held against the rear end of the coil, and this end is dipped into acetone to bond the washer to the coil. The coil is then pressed up against the front spoolhead and the front end of the coil dipped in acetone to bond the spoolhead to the coil. The leadout wires are soldered to the eyelets to complete the assembly.

The AF and AJ relays may be provided with either a long (full length) or a short coil, the short coil providing a reduction in winding cost where such coils will meet the circuit operating conditions. The short coils can be wound twelve at a time as contrasted with eight for a long coil. The AG relays are normally used where the full winding space is desired to obtain slow action; therefore, the short coil will not be used on the AG relay.

Available Coils

In the past, certain coils were preferred in order to minimize the number of coils. This practice has been discontinued because of improved manufacturing techniques, although the cost of a particular coil should remain a factor in its selection. In a few cases, however, it will not be possible to use an available coil due to the resistance limits imposed by connecting circuits and marginal or speed conditions. Special coils will be designed for these conditions when warranted. Table X-1 lists the coils that have been provided to date.

Winding Dimensions

The method of computing the winding dimensions is shown in Fig. X-2, and a photograph of the core structure is shown in Fig. X-3. The winding dimensions, in inches, for the wire spring relay coils are:

Type of Coil	Winding Depth (h)	Inner Diameter (d)	Length(ℓ) Long Coil	Short Coil
AF, AG, and AJ Relays				
General Use	0.324	0.467	1.58	0.935
Laminated Core	0.286	0.520	1.58	
0.046 Sleeve	0.279	0.575	1.58	
0.091 Sleeve	0.231	0.671	1.58	
0.147 Sleeve	0.195	0.783	1.58	
AK Relays				
General Use	0.202	0.363	1.31	0.935
0.069 Sleeve	0.128	0.531	1.31	

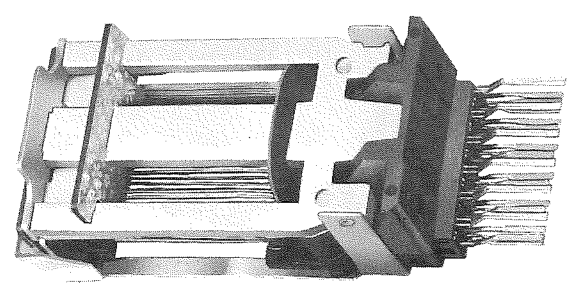


Fig. X-3 - Core Structure

Laminations and Sleeves

Laminated cores consist of a thin strip of metal, 0.050-inch thick and slightly narrower than the core, fastened to each side of the core. Laminations are used to obtain a high impedance for transmission circuits and to provide a better pull capability. Fig. X-4 shows the lamination used on each side of the core.

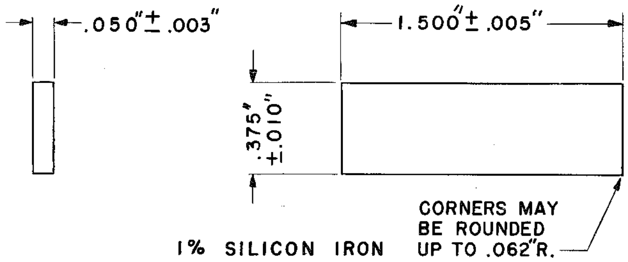
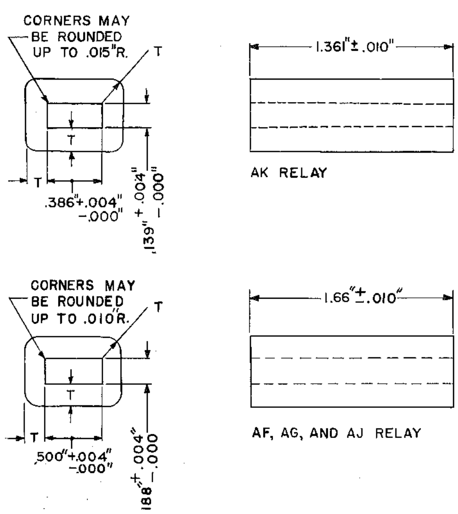


Fig. X-4 - Lamination

Copper or aluminum sleeves are provided on the wire spring relays to obtain slow operate or slow release times. The sleeves consist of seamless rectangular tubing with rounded outer corners and different wall thicknesses. The combination of metal and wall thickness is used to obtain different operating and releasing times. Fig. X-5 shows the dimensions of the various sleeves.



PIECE	DIM "T"	MATERIAL	USED ON
LP10A591	.0435"±.0035"	ALUMINUM	AF, AG, AJ RELAY
LP10A592	.0435"±.0035"	COPPER	AF, AG, AJ RELAY
LP10A593	.090"±.005"		
LP10A594	.145"±.006"		
LP10B988	.0695"±.005"	COPPER	AK RELAY

Fig. X-5 - Sleeve

Winding Arrangements

Arrangements are provided to bring out a maximum of six winding terminals on the AF, AG, AJ, and AL relays and three terminals on each half of the AK and AM relays. Fig. X-6 (parts 1, 2, and 3) shows the winding arrangements that have been used on the relays coded to date.

Coil Design

A coil design usually starts from one of three considerations:

1. Full-spool design for power saving or sensitivity.
2. A specific resistance required for a particular circuit condition.
3. Speed requirement.

The main difference in the design of coils to meet condition 1, 2, or 3 is the method of determining the number of layers and the size of the wire to be used. Once these factors have been determined, the design of a coil for any of the above conditions follows the same general method.

Full-Spool or Specific Resistance

A full-spool coil provides the best economic design for a relay with a long holding time. The first step is an estimate of the size of wire that should be used to provide a resistance of the desired value with a full spool. This estimate can be obtained from the curves shown in Fig. X-7 to X-10. These figures show the number of layers of any size wire required to provide a particular coil depth or resistance for different coil lengths and interleaving. These figures cannot be used directly for secondary windings or windings wound over laminations or sleeves.

Once the size of the wire has been chosen, the number of layers that may be wound on the spool must be determined. This may be obtained from Fig. X-7 to X-10, or may be determined as follows: No. of layers $(N_2) = \frac{h}{C_{max}}$ where h is the winding depth or radial space available for wire, in inches, and C_{max} is the maximum effective depth of one layer of wire and the interleaving, in inches. If the number of layers so calculated results in an odd number of layers, it must always be reduced to the next lower even number of layers. Tables X-2 and X-3 give the wire constants for thin enamel (MS 58364) wire for 0.0007-inch and 0.002-inch interleaving paper. Tables X-4 and X-5 give the wire constants for single and heavy formex wire with 0.002-inch interleaving paper.

Table X-6 lists the diameters over the insulation for the wires usually used in filled coil relays. The wire constants for filled coil design can be obtained from this table and the following relations:

$$B = 1.01 \text{ g max}$$

For 0.0007-inch interleaving paper:

$$C_{av} = 0.936\ (g_{av} + 0.00109)$$
$$C_{max} = 0.976\ (g_{max} + 0.00114)$$

For 0.0002-inch interleaving paper:

$$C_{av} = 0.978\ (g_{av} + 0.0026)$$
$$C_{max} = 1.010\ (g_{max} + 0.00317)$$

The maximum number of turns that may be wound on a layer is found from: turns per layer $(N_1) = \frac{\ell}{B}$ where ℓ is the length of the coil and B is the effective diameter of one turn of wire, in inches. The maximum number of turns is the product of the number of layers and the number of turns per layer. Some turns, however, will be lost in pulling out the leadout wires; by accidental breakages within the coil during winding (which could not be spliced until the machine was stopped); and by slight variations in the braking action as the winding machine is stopped. An allowance of 15 percent of one layer is allowed for these factors. The number of turns (N) that should be used for resistance calculations is therefore not more than the maximum number of turns that can be wound on the relay less 15 percent of one layer.

To simplify the withdrawal of the coil leadout wires after the coil has been cut from the stick, it is desirable that the winding should stop at the end of the coil rather than at any random point along the coil. All coils, therefore, should be wound to full layers, and to even numbers of layers so that all the wires will terminate at the same end of the coil.

Adjustments of the coil winding machine permit the pitch of the winding (turns per unit length of coil) to be set very accurately. This means that the maximum number of turns wound on a layer (100-percent pitch) can be reduced to permit adjusting the total turns to obtain an even number of full layers, or to adjust the resistance to the desired value by adjusting the total number of turns. The pitch is specified for the coil, and, for manufacturing reasons, should not be less than 85 percent.

The winding resistance is:

$$R = NA\left[N_2(C_{Av}) + d\right] \quad \text{where}$$

R = winding resistance ±10 percent

N = number of turns

A = a constant based on the resistivity of the wire

N_2 = number of layers

C_{Av} = average effective depth of one layer of wire

d = equivalent diameter of core (inner diameter) including any laminations, sleeves, or prior windings

The calculated resistance is specified to the nearest value as follows:

Calculated Resistance (ohms)	Specify to Nearest
10 - 20	0.2
21 - 50	0.5
51 - 100	1.0
101 - 200	2.0
201 - 500	5.0
501 - 1000	10.0
over - 1000	25.0

The number of turns (N), less one fifth of a layer allowance for stopping the machine and resistance adjustments, is rounded out in accordance with the following table:

Total Turns	Specify to Nearest
500 - 1000	5 turns
1001 - 5000	10 turns
5001 - 10000	25 turns
over - 10000	50 turns

These turns are specified as U (unlimited) turns. U turns are considered as varying one fifth of a layer from the specified number of turns.

The number of turns that should be wound on a layer are found from

$$N_1 = \frac{N}{N_2} \quad \text{where}$$

N_1 = the turns per layer

N_2 = the number of layers

N = the number of turns used in the resistance calculations rather than the specified number of turns.

Secondary windings are calculated the same as the primary windings, except that the diameter (d) is increased by twice the average depth of the primary winding. The insulation between the primary and secondary windings adds 0.012 inch to the depth of the primary winding. In computing coil fullness, the winding depth is based on the maximum depth of the primary winding plus the 0.012-inch insulation, plus the maximum depth of the secondary winding.

Slow releasing, or transmission relays, are designed like secondary windings on general purpose relays, except that it is not necessary to add the 0.012-inch interwinding insulation between the primary winding and the sleeve or laminations. Slow-releasing relays are normally designed to develop at least 300 ampere turns in order to saturate the core and provide the full releasing time.

Resistance Variation

The resistance variation is ordinarily ±10 percent. Single windings of 5 ohms or less vary ±15 percent and secondary windings wound over primary windings of less than 10 ohms vary ±15 percent. Relay windings can, in special cases, be held to

±5 percent. Where a ±5 percent resistance variation is to be specified, the winding resistance should be computed in the normal manner, the resistance increased 5 percent, and this value specified with a ±5 percent variation.

Fast Operate Coils

In the design of coils for fast operation, heating is an important consideration where circuit operating conditions do not limit the resistance; therefore, for the fastest operation, a relay should have the lowest coil resistance that will meet the heating requirements. The allowable temperatures and heating considerations are discussed more fully in Section IV, and only a reference to the method of using the heating data will be used herein.

The winding design starts with a determination of the probable resistance that will meet the heating requirements, considering the length of time that the relay will be energized. As an example of the method, assume the design of a fast-operating local-circuit relay for common use with a resistance of 400 ohms, and intermediate travel. Assume that the relay has a 50-percent duty cycle (see Section IV), ie, the operation is intermittent with the ratio of the on interval to the sum of the off and on intervals 0.5. For trouble condition, 100-percent duty, the maximum temperature should not exceed 250° F.

The extreme heating would result from the maximum voltage and minimum resistance. For maximum heating, the initial watts

$W_o = \frac{E^2}{R} = \frac{50^2}{360} = 6.95$. The relation between

the initial watts and the final temperature is shown in Fig. X-11. From this figure, a maximum temperature of 250° F with 6.95 initial watts requires that the thermal conductance (ρ) be 0.33 or greater, assuming no adjacent relays operated.

The winding depth is plotted against the thermal conductance in Fig. X-12 for various lengths of coils. From this figure, a thermal conductance of 0.033 requires a winding depth of 0.28 inch or more for the short coil (ℓ = 0.935 inch) but any winding depth over 0.06 inch is permissible for the long coil (ℓ = 1.58 inch).

The optimum number of turns to be used is that number of turns that, with a given resistance, will provide the least operate time for the relay spring load and armature travel. A greater number of turns will increase the initial inductance and the operating time. This is discussed more fully in Section VII covering operating times. Fast-operating relays should be designed as near the optimum number of turns as practical. The optimum turns are chosen using the nominal voltage and nominal hot operating resistance. For 50-percent duty cycle the nominal initial watts are:

$W_o = \frac{48^2}{400} = \frac{5.76}{2} = 2.88$ watts. From

Fig. X-11, with a thermal conductance of 0.033, the hot temperature will be 176° F.

The hot resistance is found by using

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

$$R_H = 400 \left(1 + \frac{176-68}{458}\right) = 495$$

The optimum number of turns for a particular resistance is shown in Fig. X-13, and the effect on the operate time with a divergence from these turns is shown in Fig. X-14. From Fig. X-13, the optimum number of turns for a resistance of 495 ohms is 2800, assuming intermediate travel.

Fig. X-10 shows the number of layers of any size wire necessary to obtain a particular winding resistance for a given winding depth using 0.002-inch interleaving and a short coil. Fig. X-9 shows the same thing for 0.0007-inch interleaving. From Fig. X-10, 32 layers of 36E wire will provide a minimum winding depth of 0.25 inch and a resistance of approximately 400 ohms.

The number of turns of 36E wire that can be wound on a layer is

$N_1 = \frac{\ell}{B} = \frac{0.935}{0.00566} = 165$ turns. The total

number of turns for 32 layers would be 32 x 165 or 5300 turns, which is considerably above the optimum of 2800 turns. This means that the long coil is more advantageous since the short coil, to meet heating requirements, must have a winding depth that requires many more than the optimum number of turns.

From Fig. X-8 for the long coil with 0.002-inch interleaving, the smallest number of turns to provide 400 ohms is ten layers of 39E. This coil, using ten layers of 39E, computed as shown in the foregoing description of the design of a full-spool winding, would be the 3330 turns 39E, 400 ±10 percent.

With the coil design set, the actual performance data can be obtained. From Fig. X-8, ten layers of 39E give a winding depth of 0.06 inch. The thermal conductance, from Fig. X-12, is 0.033. With 6.95 initial watts, Fig. X-11 shows a final temperature of 246° F.

The minimum ampere turns are found as follows: The wattage developed would be

$\frac{45^2}{440} = 4.6$ watts for 100-percent duty or

2.3 watts for 50-percent duty. From Fig. X-11, with a thermal conductance of 0.033, and 2.3 watts, the final temperature is 158° F. The hot resistance

$R_H = 440 \left(1 + \frac{158-68}{458}\right) = 525$. The ampere turns are $\frac{45}{525} \cdot 3330 = 285$ NI. The actual method of computing the operating time is shown in Section VII.

Coil Cost

The coil cost can be compared using the cost per turn of winding the wire on the coil; the cost per ohm for the size of wire used; the cost of sleeves or laminations; and the cost of bringing out additional winding terminals. The cost for the coils used to date is shown in Table X-1. The method of computing the coil cost is shown in Section XI. The cost of power is also shown in Section XI.

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TABLE X-1

LIST OF COILS

AF, AG, AJ, AND AL RELAYS

Single-Wound Coils

Res	T/L	Turns	Wire Size	Coil Cost (cents)	Remarks
4.4	76	730	25E (MS58371)	14.5	0.002-inch interleaving. Fast operate in series with printer magnet. Resistance ±15 percent.
16	100	1580	27E (MS58371)	21.5	0.002-inch interleaving. Fast operate with 90 ohms. Must also operate in series with 525 ohms.
34	128	2260	29E	15.2	Marginal; tandem and toll trunks.
100	140	3900	31E	17.9	
180	177	5625	32E	18.6	Line relay to operate on high-voltage cross.
200	250	3950	35E	9.8	Fast operate on 24 volts.
270	212	2110	37E	18.1	0.002-inch interleaving. Fast operate; local circuit; intermittent heating. Epoxy resin-filled coil to meet heating conditions.
275	189	6700	33E	18.7	Required to operate in parallel with multicontact relay in marker double-connection check.
395	231	2670	40E	4.8	Fast operate; local circuit heating on 53.5 volts. Used where four relays are operated in parallel. Special for AMA center. 0.002-inch interleaving.
400	340	3330	39E	5.0	0.002-inch interleaving. Fast operate in local circuit where circuit conditions do not permit use of 27-ohm relay.
500	246	8275	35E	15.2	No. 1 switchboard sleeve relay with ±5 percent resistance. For use in other circuits with ±10 percent resistance.
700	190	5150	39E	5.5	Short coil 0.0007-inch interleaving. General use for fast operate.
800	277	10450	36E	16.3	PBX marginal sleeve condition.
860	392	6925	39E	7.5	Low wattage, fast operate coil.
950	270	11850	36E	18.9	To meet cross-detection requirements of series relay. Must work with existing relays.
1625	306	15800	37E	22.3	No sleeve; slow release obtained by external noninductive resistance shunt.
2500	335	19400	38E	22.6	General use. Low-current drain.
3800*	385	22200	39E	30.6	PBX marginal sleeve condition.
4000*	370	23600	39E	24.9	High resistance to limit current drain on rectifier of limited capacity.
6000	420	28000	40E	26.9	
9100*	474	34900	41E	31.1	Light spring loads in high-resistance circuit.

* These relays require the use of contact protection to limit the peak voltage to a safe value.

TABLE X-1 (Cont)

Slow-Acting Coils

	Res	T/L	Turns	Wire Size	Coil Cost (cents)	Remarks
	220	134	3710	34E	-	Short coil 0.091-inch copper sleeve; one iron and two copper washers. Ring trip relay.
Pri	220	225	4400	34E	26.6	0.046-inch copper sleeve. Ring-up relay.
Sec	1150	345	6775	38E		
	375	244	3850	36E	26.4	0.147-inch copper sleeve. Resistance ±5 percent. Must meet resistance limits of present pad control circuits.
Pri	450	279	4350	37E	19.7	0.091-inch copper sleeve. Slow release, double wound.
Sec	500	262	4600	36E		
	550	256	5575	36E	13.9	0.147-inch copper sleeve. Fast operate; slow release to hold over dial pulses.
	600	244	7800	35E	18.4	0.091-inch copper sleeve; fast saturation.
	875	265	10050	36E	17.7	0.046-inch aluminum sleeve.
	875	265	10050	36E	17.7	0.046-inch copper sleeve.
	1000	335	6450	38E	10.5	±5 percent resistance 0.147-inch copper sleeve. Limited by pad control circuit in No. 3C switchboard.
	1050	297	8250	37E	14.8	0.147-inch copper sleeve.
	2000	337	13500	38E	18.1	0.091-inch copper sleeve. Low-current drain; slow operate.
	2200	336	16050	38E	22.3	0.046-inch aluminum sleeve.
	2200	336	16050	38E	19.9	0.046-inch copper sleeve.
	2550	423	10080	40E	11.8	0.147-inch copper sleeve. Low-current drain.

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TABLE X-1 (Cont)

Double-Wound Coils

	Res	T/L	Turns	Wire Size	Coil Cost (cents)	Remarks
Pri	2.7	58	560	24E (MS58371)	20.4	0.002-inch interleaving on primary. Marker cross-detecting relay. Resistance ±15 percent.
Sec	690	391	3020	39E		
Pri	8	90	1050	26E (MS58371)	24.5	0.002-inch interleaving on primary. Marker cross-detecting relay. Secondary winding resistance ±15 percent.
Sec	850	391	3770	39E		
Pri	10	101	790	29E	19.4	0.002-inch interleaving on primary. Marker cross-detecting relay.
Sec	400	301	2950	38E		
Pri	16	130	1010	30E		0.0007-inch interleaving on primary. 0.002-inch interleaving on secondary.
Sec	16	114	1100	28E		
Pri	61*	189-139	2070	33E,31E	21.4	Limited turns. +15 -0 on pri A and pri B, +30 -0 on sec. Pri A and pri B connected in series. Battery feed on 24 volts.
Sec	61	177	2070	32E		
Pri	100*	184-164	2660	34E,32E	30.7	Limited turns. +15 -0 on pri A and pri B, +30 -0 on sec. Pri A and pri B connected in series. Battery feed on 24 volts.
Sec	100	194	2660	33E		
Pri	100	219	2590	34E	27.4	Differential marginal coil.
Sec	1100	303	9625	37E		
Pri	170	241	2800	36E	22.2	Fast operate on 20 volts.
Sec	140	178	3850	32E		
Pri	198	279	3250	36E	17.0	Fast operate, slow release with short-circuited secondary on 20 volts.
Sec	80	178	2430	32E		
Pri	200*	80-195	3235	36E,34E	20.6	Limited turns. +15 -0 on pri A and pri B, +30 -0 on sec Laminations on core. Pri A and pri B connected in series. Subscriber supervision and battery feed.
Sec	200	232	3235	35E		
Pri	210	231	4100	35E	23.5	
Sec	1000	301	8375	37E		
Pri	300	336	3250	38E	17.7	Fast operate. MS58371 single insulation.
Sec	300	269	3670	36E		
Pri	335*	348-340	3930	38E,36E	18.1	Limited turns. +15 -0 on pri A and pri B, +30 -0 on sec. Pri A and pri B connected in series. Balanced bridge relay for toll trunks.
Sec	335	283	3930	37E		
Pri	360	306	4800	37E	24.7	To work with existing relay in CAMA senders.
Sec	1900	348	13150	38E		
Pri	390	324	3170	39E		ESS No. 1 network control circuit. 0.002-inch interleaving.
Sec	390	265	3120	38E (MS58371)		
Pri	400	340	3330	39E	35.0	Register (RA) relay. 0.002-inch interleaving. Secondary winding ±3 percent resistance.
Sec	210	194	3440	33E		
Pri	400*	250-230	5200	37E,35E	26.9	Limited turns. +10 -0 on pri A and pri B, +20 -0 on sec. Pri A and pri B connected in series. Trunk supervision.
Sec	400	261	5200	36E		
Pri	415	310-269	4550	38TE,36TE	38.1	Limited turns. +15 -0 on pri A and pri B, +30 -0 on sec. Pri and sec winding resistance ±5 percent. Pri A and pri B connected in series. Trunk supervision.
Sec	415	285	4550	37TE		
Ter	900	335	5350	38TE		
Pri	425*	278-237	5520	37E,35E	28.0	Limited turns. +10 -0 on pri A and pri B, +20 -0 on sec. Pri A and pri B connected in series. Trunk Supervision.
Sec	425	277	5520	36E		

* Half of the primary wound under the secondary and half over the secondary

TABLE X-1 (Cont)

Double-Wound Coils

	Res	T/L	Turns	Wire Size	Coil Cost (cents)	Remarks
Pri	450	392	3000	40E	18.5	0.002-inch interleaving. Has function in trunk circuit similar to RA in register.
Sec	57	143	2540	40E		
Pri	450	389	3740	39E	39.3	Used in by-link trunks for function similar to register RA relay. 0.002-inch interleaving
Sec	110	178	3140	32E		
Pri	450	392	3000	40E	42.5	RA relay for panel and No. 1 crossbar. 0.002-inch interleaving. Secondary ±3 percent resistance.
Sec	200	176	3460	32E		
Pri	540	391	4550	39E	10.4	756 PBX line relay.
Sec	540	379	3730	39E		
Pri	550	369	3620	40E	19.9	0.002-inch interleaving. Marker class check relay.
Sec	550	369	3620	39E		
Ter	525	307	3620	38E		
Pri	700	325	7100	38E	23.3	Fast operate; short holding time.
Sec	700	277	7150	36E		
Pri	700	366	5750	39E	26.3	
Sec	3300	380	17400	39E		
Pri	800	267	9100	37E		Limited turns. +30 -0 on pri and sec. Pri and sec winding resistance ±5 percent.
Sec	880	297	5350	38E		
Pri	1000	417	6525	40E	21.6	Slow release, fast operate for ANI trunks.
Sec	42	128	2260	29E		
Pri	1000	366	7975	39E	24.0	Low drain.
Sec	2700	370	13950	39E		
Pri	1175	383	9125	39E	24.3	General use.
Sec	1075	306	9125	37E		
Pri	1200	425	7550	40E	53.3	Sleeve relay for CAMA trunk.
Sec	6000	426	19500	40E		
		1Sh	166	40ERW		
Pri	1500	434	9400	40E	26.3	Ring-up, lock-up relay.
Sec	2950	389	15400	39E		
Pri	1700	418	10300	40E	41.9	High resistance double-wound relay.
Sec	1700	337	11300	38E		
Pri	1800	425	11000	40E	23.2	No. 3C switchboard sleeve relay. Resistance ±5 percent.
Sec	85	156	2770	31E		
Pri	5000	475	22600	41E	28.1	Double-wound high resistance marginal relay.
Sec	1000	348	6140	38E		

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TABLE X-1a

LIST OF COILS
AK AND AM RELAYS

Single-Wound Coils

Res	T/L	Turns	Wire Size	Coil Cost (cents)	Remarks
5.5	74	725	222H		Resistance ±15 percent.
16	101	1390	29E		
65	148	2800	32E		
100	157	3400	33E	8.6	
145	186	4000	34E		
185	188	4820	34E	10.6	
210	226	4000	36E	7.4	
280	210	5825	35E	12.2	
410	234	6900	36E	10.6	
630	313	5000	40E		
640	255	8600	37E	11.7	
955	228	8125	39E	9.6	
960	289	10300	38E		
1500	310	12300	39E	11.2	
2450	360	15750	40E	14.3	

Double-Wound Coils

	Res	T/L	Turns	Wire Size
Pri	820	349	6282	40E
Sec	682	314	5024	39E

Coils With Copper Sleeve (0.069 inch)

Res	T/L	Turns	Wire Size	Coil Cost (cents)
315	221	4380	36E	10.6
680	286	6250	38E	
1100	320	7600	39E	

TABLE X-2

WINDING DESIGN TABLE FOR FILLED COILS
Thin Enameled Copper Wire (MS58364) - Standard 0.0007-Inch Interleaving (Preferred)

Wire Size AWG	For Max Turns and Fullness B (in.)	C Max (in.)	For Resistance and Wire Size A	C Avg (in.)	K (sq in.)	A/K	Copper Effi-ciency e	Wire Size AWG
29	0.0123	0.0130	0.0213	0.0122	0.000150	142	0.669	29
30	0.0110	0.0117	0.0272	0.0110	0.000121	225	0.649	30
31	0.00980	0.0105	0.0343	0.00983	0.0000963	356	0.646	31
32	0.00889	0.00970	0.0424	0.00902	0.0000802	529	0.627	32
33	0.00788	0.00873	0.0538	0.00809	0.0000637	845	0.622	33
34	0.00697	0.00785	0.0684	0.00729	0.0000508	1,350	0.614	34
35	0.00626	0.00716	0.0867	0.00664	0.0000416	2,080	0.591	35
36	0.00566	0.00658	0.109	0.00607	0.0000344	3,170	0.570	36
37	0.00515	0.00609	0.134	0.00561	0.0000289	4,640	0.550	37
38	0.00454	0.00550	0.169	0.00504	0.0000229	7,380	0.550	38
39	0.00404	0.00502	0.222	0.00458	0.0000185	12,000	0.519	39
40	0.00364	0.00463	0.284	0.00420	0.0000153	18,600	0.490	40
41	0.00333	0.00433	0.344	0.00392	0.0000130	26,500	0.477	41
42	0.00303	0.00404	0.435	0.00364	0.0000110	39,500	0.445	42

TABLE X-3

WINDING DESIGN TABLE FOR FILLED COILS
Thin Enameled Copper Wire (MS58364) - Special 0.002-Inch Interleaving

Wire* Size AWG	For Max Turns and Fullness B (in.)	C Max (in.)	For Resistance and Wire Size A	C Avg (in.)	K (sq in.)	A/K	Copper Effi-ciency e	Wire Size AWG
24	0.0231	0.0264	0.00672	0.0244	0.000564	11.9	0.572	24
25	0.0208	0.024	0.00848	0.0222	0.000462	18.3	0.544	25
26	0.0187	0.0219	0.0107	0.0201	0.000376	28.5	0.528	26
27	0.0167	0.0199	0.0135	0.0183	0.000305	44.2	0.519	27
28	0.0136	0.0168	0.0171	0.0155	0.000211	81	0.592	28
29	0.0123	0.0155	0.0213	0.0142	0.000175	122	0.574	29
30	0.0110	0.0142	0.0272	0.0130	0.000143	190	0.549	30
31	0.00980	0.0130	0.0343	0.0118	0.000116	296	0.536	31
32	0.00889	0.0121	0.0424	0.0110	0.0000978	434	0.514	32
33	0.00788	0.0111	0.0538	0.00998	0.0000787	684	0.503	33
34	0.00697	0.0102	0.0684	0.00914	0.0000637	1,070	0.490	34
35	0.00626	0.00946	0.0867	0.00845	0.0000529	1,640	0.465	35
36	0.00566	0.00886	0.109	0.00787	0.0000446	2,440	0.440	36
37	0.00515	0.00835	0.134	0.00738	0.0000380	3,520	0.419	37
38	0.00454	0.00775	0.169	0.00680	0.0000309	5,470	0.408	38
39	0.00404	0.00724	0.222	0.00630	0.0000254	8,740	0.378	39
40	0.00364	0.00684	0.284	0.00592	0.0000216	13,100	0.347	40
41	0.00333	0.00653	0.344	0.00562	0.0000187	18,400	0.332	41
42	0.00303	0.00623	0.435	0.00532	0.0000161	27,000	0.304	42

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* Wire gauges 24 to 27 inclusive use formex insulation (MS58371).

TABLE X-4

WINDING DESIGN TABLE FOR FILLED COILS
Single Formex Wire (MS58371) - 0.002-Inch Interleaving

Wire Size AWG	For Max Turns and Fullness B (in.)	C Max (in.)	For Resistance and Wire Size A	C Avg (in.)	K (sq in.)	A/K	Copper Efficiency e	Wire Size AWG
24	0.0220	0.0258	0.0067	0.0241	0.000531	12.7	0.598	24
25	0.0197	0.0234	0.0085	0.0218	0.000429	19.8	0.586	25
26	0.0176	0.0211	0.0107	0.0197	0.000346	30.9	0.574	26
27	0.0158	0.0192	0.0135	0.0179	0.000283	47.7	0.559	27
28	0.0140	0.0174	0.0171	0.0162	0.000227	75.2	0.548	28
29	0.0127	0.0161	0.0213	0.0149	0.000189	112.9	0.531	29
30	0.0113	0.0146	0.0272	0.0134	0.000152	179.4	0.518	30
31	0.0102	0.0134	0.0343	0.0123	0.000125	273.5	0.496	31
32	0.0092	0.0124	0.0424	0.0113	0.000104	407.7	0.483	32
33	0.0083	0.0114	0.0538	0.0104	0.0000863	623.4	0.458	33
34	0.0074	0.0105	0.0684	0.0095	0.0000705	970.2	0.442	34
35	0.0066	0.0096	0.0867	0.0087	0.0000574	1,510.5	0.429	35
36	0.00596	0.00899	0.109	0.0081	0.0000482	2,261.4	0.407	36
37	0.0054	0.0084	0.134	0.0075	0.0000403	3,325.0	0.394	37
38	0.0048	0.0077	0.169	0.0069	0.0000328	5,152.0	0.383	38
39	0.0042	0.0072	0.222	0.0064	0.0000269	8,259.0	0.358	39
40	0.0038	0.0068	0.284	0.00599	0.0000228	12,456.0	0.331	40
41	0.0034	0.0064	0.344	0.0056	0.000019	18,134.0	0.324	41
42	0.0030	0.0059	0.435	0.0052	0.0000157	27,700.0	0.313	42

TABLE X-5

WINDING DESIGN TABLE FOR FILLED COILS
Heavy Formex Wire (MS58371) - 0.002-inch Interleaving

Wire Size AWG	For Max Turns and Fullness B (in.)	C Max (in.)	For Resistance and Wire Size A	C Avg (in.)	K (sq in.)	A/K	Copper Effi-ciency e	Wire Size AWG
24	0.0231	0.0269	0.0067	0.0252	0.00058	11.55	0.545	24
25	0.0208	0.0245	0.0085	0.0229	0.00048	17.85	0.530	25
26	0.0187	0.0223	0.0107	0.0207	0.000387	27.6	0.513	26
27	0.0167	0.0202	0.0135	0.0188	0.000314	42.99	0.504	27
28	0.0149	0.0184	0.0171	0.0171	0.000254	67.3	0.491	28
29	0.0135	0.0169	0.0213	0.0156	0.000211	101.1	0.476	29
30	0.0121	0.0154	0.0272	0.0142	0.000172	158.2	0.457	30
31	0.0109	0.0142	0.0343	0.013	0.000142	242.1	0.439	31
32	0.00999	0.0132	0.0424	0.012	0.00012	353.7	0.424	32
33	0.00889	0.0121	0.0538	0.011	0.0000974	552.4	0.417	33
34	0.0079	0.0110	0.0684	0.00999	0.0000789	866.9	0.395	24
25	0.0071	0.0102	0.0867	0.0092	0.000065	1,333.0	0.378	35
36	0.0062	0.0092	0.109	0.0084	0.0000518	2,105.5	0.364	36
37	0.0058	0.0088	0.134	0.0079	0.0000458	2,928.0	0.347	37
38	0.0052	0.0082	0.169	0.0073	0.0000378	4,470.0	0.332	38
39	0.0045	0.0075	0.222	0.0067	0.0000300	7,407.0	0.321	39
40	0.0040	0.007	0.284	0.0062	0.0000251	11,340.0	0.301	40
41	0.0036	0.0066	0.344	0.0058	0.0000208	16,540.0	0.296	41
42	0.0032	0.0062	0.435	0.0054	0.0000172	25,300.0	0.285	42

TABLE X-6

WIRE TABLE
DIAMETER OVER INSULATION (g) IN MIL INCHES

Wire Size AWG	Thin Enamel (MS58364)			Single Formex			Heavy Formex			Enamel Nylon		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
20				32.7	33.4	34.1	33.9	34.6	35.3	34.3	35.4	36.5
21				29.2	29.9	30.6	30.3	31.0	31.7	30.7	31.75	32.8
22				26.0	26.65	27.3	27.0	27.7	28.4	27.4	28.45	29.5
23				23.3	23.85	24.4	24.3	24.9	25.5	24.7	25.65	26.6
24	20.4	20.8	21.2	20.8	21.3	21.8	21.8	22.35	22.9	22.1	23.05	24.0
25	18.2	18.6	19.0	18.6	19.05	19.5	19.5	20.05	20.6	19.9	20.8	21.7
26	16.1	16.5	16.9	16.5	16.95	17.4	17.4	17.95	18.5	17.8	18.7	19.6
27	14.5	14.8	15.1	14.9	15.25	15.6	15.7	16.10	16.5	16.2	16.95	17.7
28	12.9	13.2	13.5	13.2	13.55	13.9	14.0	14.4	14.8	14.6	15.3	16.0
29	11.6	11.9	12.2	11.9	12.25	12.6	12.6	13.0	13.4	13.2	13.9	14.6
30	10.3	10.6	10.9	10.5	10.85	11.2	11.2	11.6	12.0	11.9	12.6	13.3
31	9.2	9.45	9.7	9.4	9.75	10.1	10.1	10.45	10.8	10.7	11.4	12.1
32	8.3	8.55	8.8	8.5	8.8	9.1	9.1	9.45	9.8	9.8	10.5	11.2
33	7.3	7.55	7.8	7.6	7.9	8.2	8.1	8.45	8.8	8.8	9.5	10.2
34	6.5	6.7	6.9	6.8	7.05	7.3	7.2	7.5	7.8	8.0	8.7	9.4
35	5.8	6.0	6.2	6.0	6.25	6.5	6.4	6.7	7.0	7.2	7.9	8.6
36	5.2	5.4	5.6	5.4	5.65	5.9	5.7	6.0	6.3	6.6	7.3	8.0
37	4.7	4.9	5.1	4.9	5.1	5.3	5.2	5.45	5.7	6.0	6.7	7.4
38	4.1	4.3	4.5	4.3	4.5	4.7	4.6	4.85	5.1	5.5	6.2	6.9
39	3.6	3.8	4.0	3.8	4.0	4.2	4.0	4.25	4.5	4.9	5.6	6.3
40	3.2	3.4	3.6	3.4	3.6	3.8	3.6	3.8	4.0	4.5	5.2	5.9
41	2.9	3.1	3.3	3.0	3.2	3.4	3.2	3.4	3.6	4.1	4.8	5.5
42	2.6	2.8	3.0	2.6	2.8	3.0	2.8	3.0	3.2	3.8	4.5	5.2

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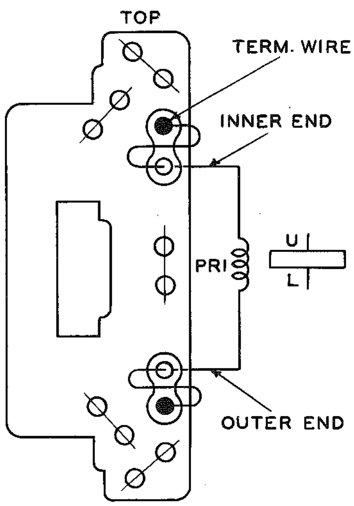

FIG. 1
SINGLE WINDING
SINGLE ARMATURE
TYPE

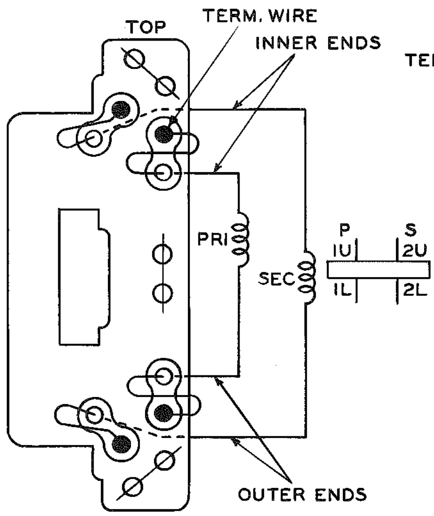

FIG. 2
DOUBLE WINDING
SINGLE ARMATURE
TYPE

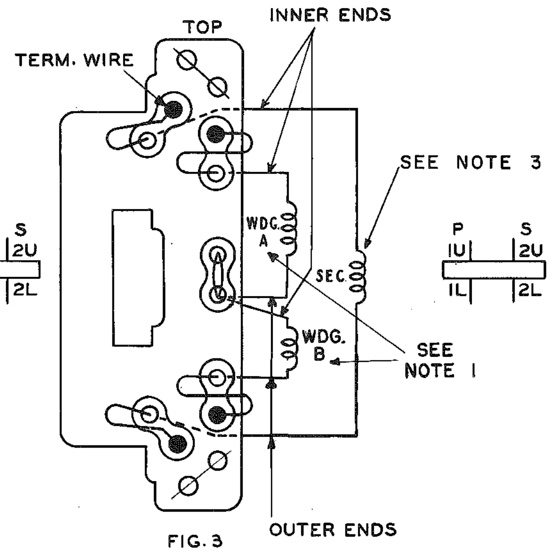

FIG. 3
DOUBLE WINDING
SINGLE ARMATURE
TYPE

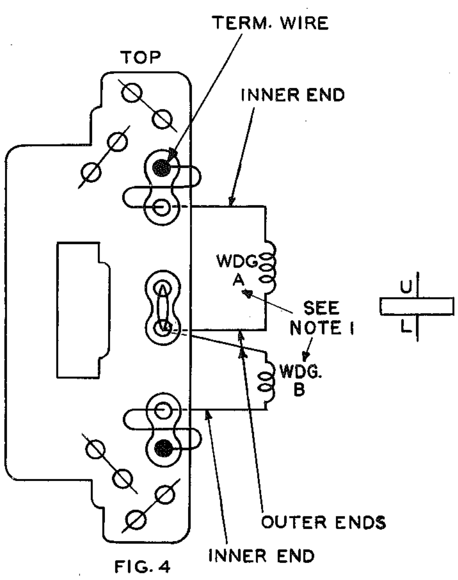

FIG. 4
SINGLE WINDING
SINGLE ARMATURE
TYPE

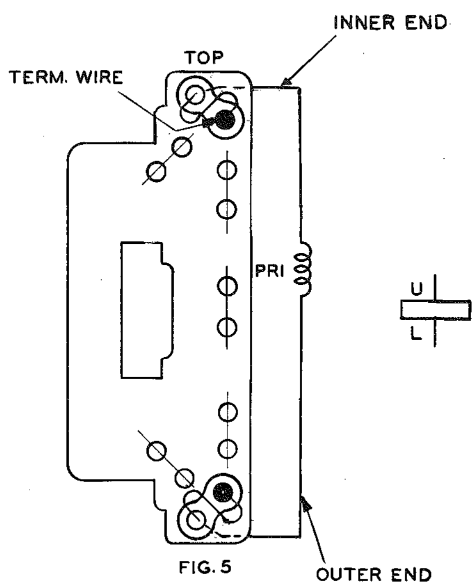

FIG. 5
SINGLE WINDING
SINGLE ARMATURE
TYPE

NOTES:

1. WINDINGS A AND B FORM PRIMARY.
2. WINDINGS A AND B FORM SECONDARY.
3. SECONDARY WINDING IS WOUND BETWEEN A AND B WINDINGS.
4. WINDING B IS NONINDUCTIVELY WOUND WITH RESISTANCE WIRE.
5. WINDING B IS INDUCTIVELY WOUND WITH RESISTANCE WIRE.

Fig. X-6 (Part 1) - AF, AG, AJ, AK, AL, and AM Relays - Winding Arrangements

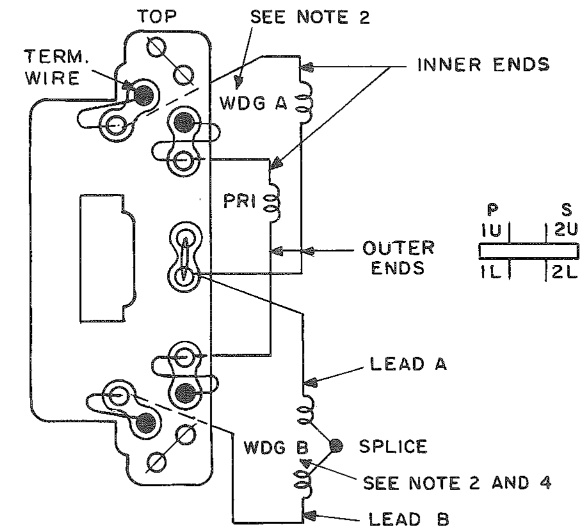

FIG. 6
DOUBLE WINDING
SECONDARY WITH NONINDUCTIVE SPLICE
SINGLE ARMATURE
TYPE

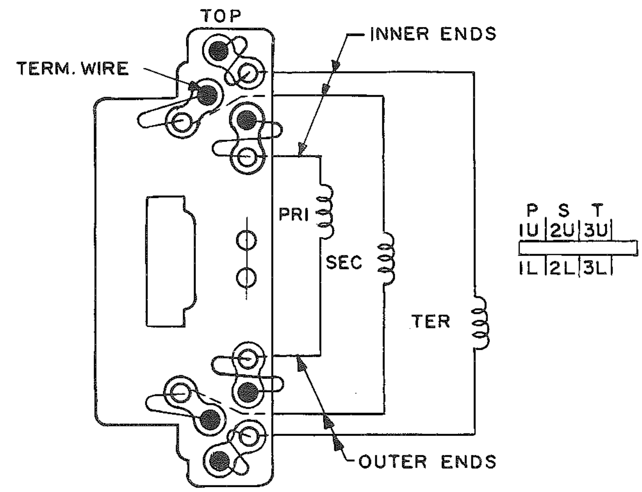

FIG. 7
TRIPLE WINDING
SINGLE ARMATURE
TYPE

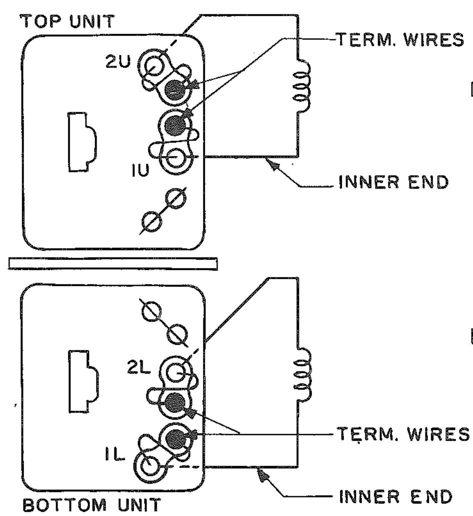

FIG. 8
SINGLE WINDING
DOUBLE ARMATURE
TYPE

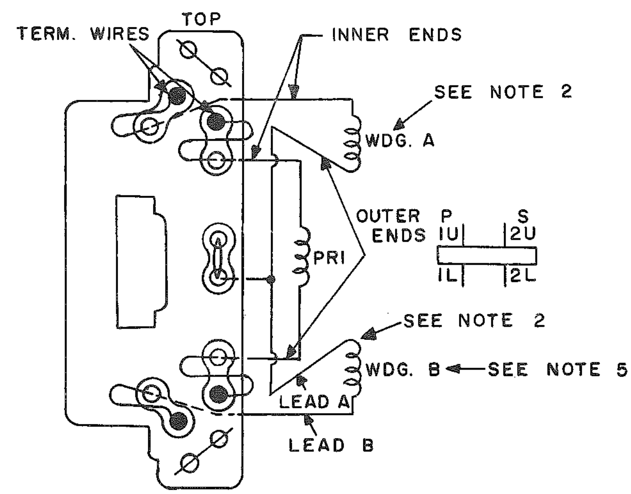

FIG. 9
DOUBLE WINDING
SECONDARY WITH INDUCTIVE WINDING
SINGLE ARMATURE
TYPE

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NOTES:
1. WINDINGS A AND B FORM PRIMARY.
2. WINDINGS A AND B FORM SECONDARY.
3. SECONDARY WINDING IS WOUND BETWEEN A AND B WINDINGS.
4. WINDING B IS NONINDUCTIVELY WOUND WITH RESISTANCE WIRE.
5. WINDING B IS INDUCTIVELY WOUND WITH RESISTANCE WIRE.

Fig. X-6 (Part 2) - AF, AG, AJ, AK, AL, and AM Relays - Winding Arrangements

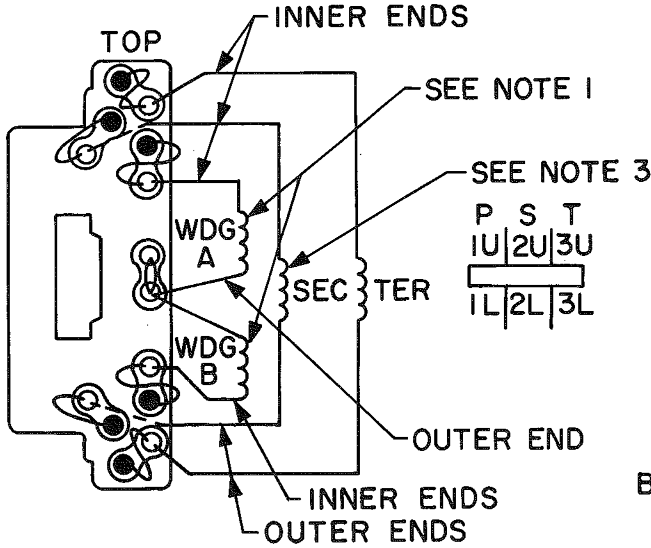

FIG. 10
TRIPLE WINDING-SINGLE ARMATURE TYPE

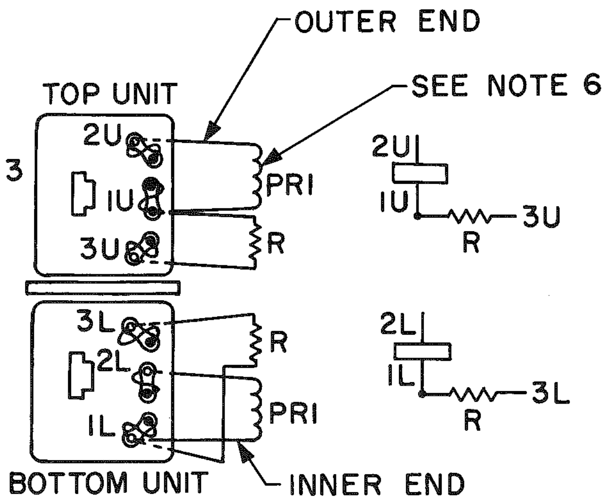

FIG. 11
SINGLE WINDING WITH SERIES RESISTANCE-DOUBLE ARMATURE TYPE

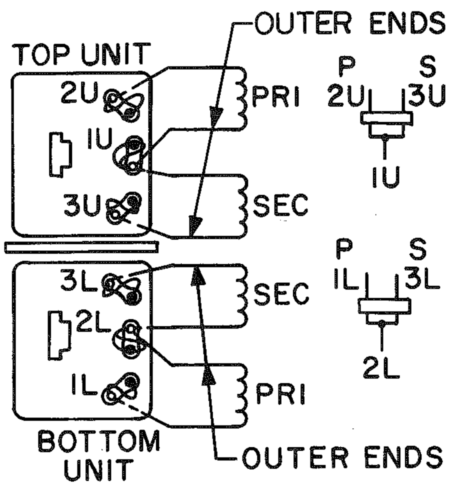

FIG. 12
DOUBLE WINDING-DOUBLE ARMATURE TYPE

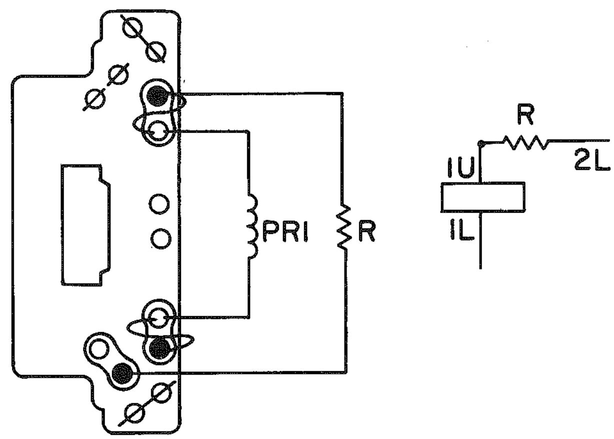

FIG. 13
SINGLE WINDING WITH SERIES RESISTANCE-SINGLE ARMATURE TYPE

NOTES:
1. WINDINGS A AND B FORM PRIMARY.
2. WINDINGS A AND B FORM SECONDARY.
3. SECONDARY WINDING IS WOUND BETWEEN A AND B WINDINGS.
4. WINDING B IS NON-INDUCTIVELY WOUND WITH RESISTANCE WIRE.
5. WINDING B IS INDUCTIVELY WOUND WITH RESISTANCE WIRE.
6. THE COIL OF THE TOP UNIT IS WOUND IN A COUNTERCLOCKWISE DIRECTION.

Fig. X-6 (Part 3) - AF, AG, AJ, AK, AL, and AM Relays - Winding Arrangements

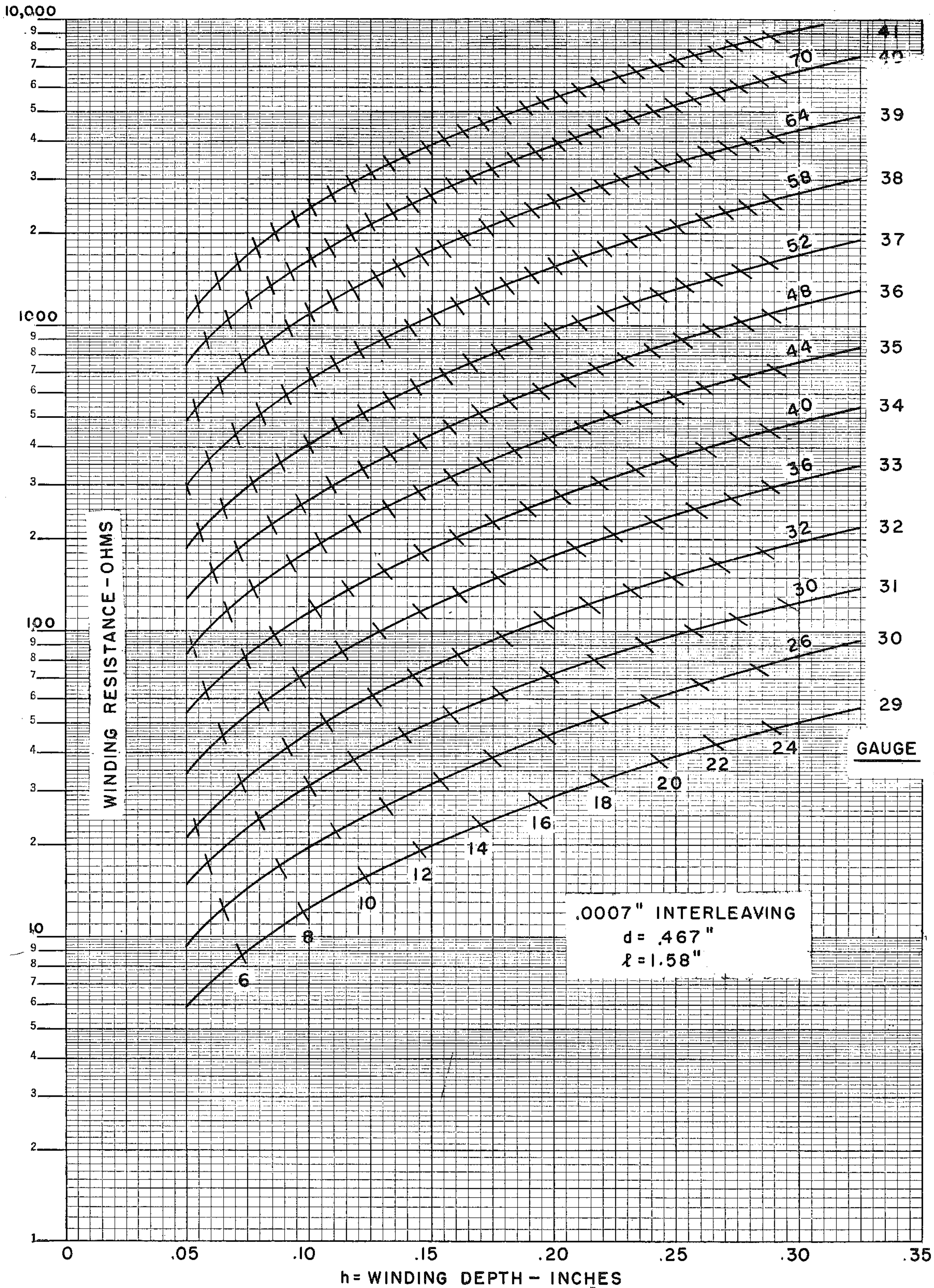

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Fig. X-7 - Coil Resistance Versus Winding Depth AF Relays - Long Coil - 0.0007-Inch Interleaving

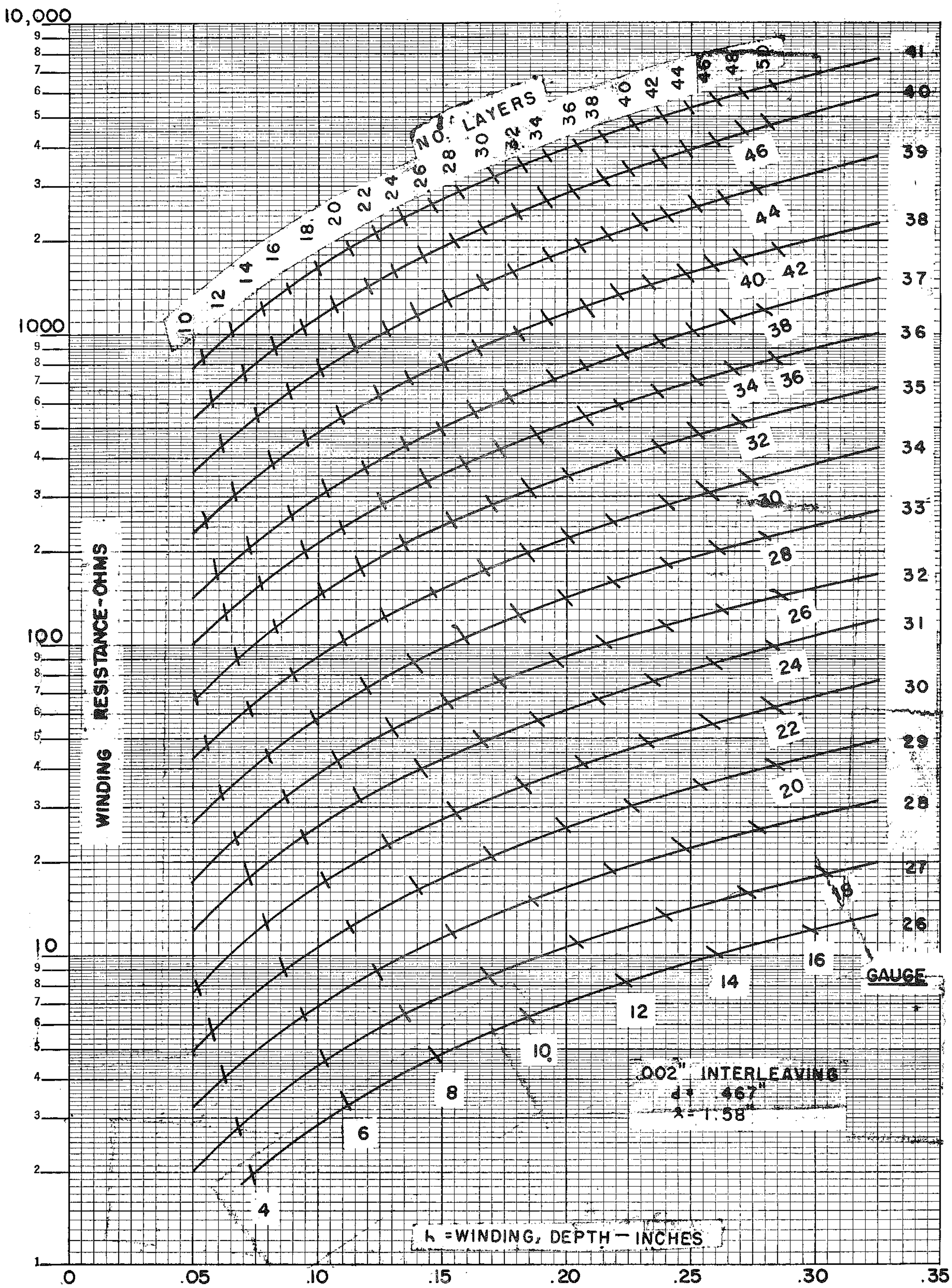

Fig. X-8 - Coil Resistance Versus Winding Depth AF Relays - Long Coil - 0.0002-Inch Interleaving

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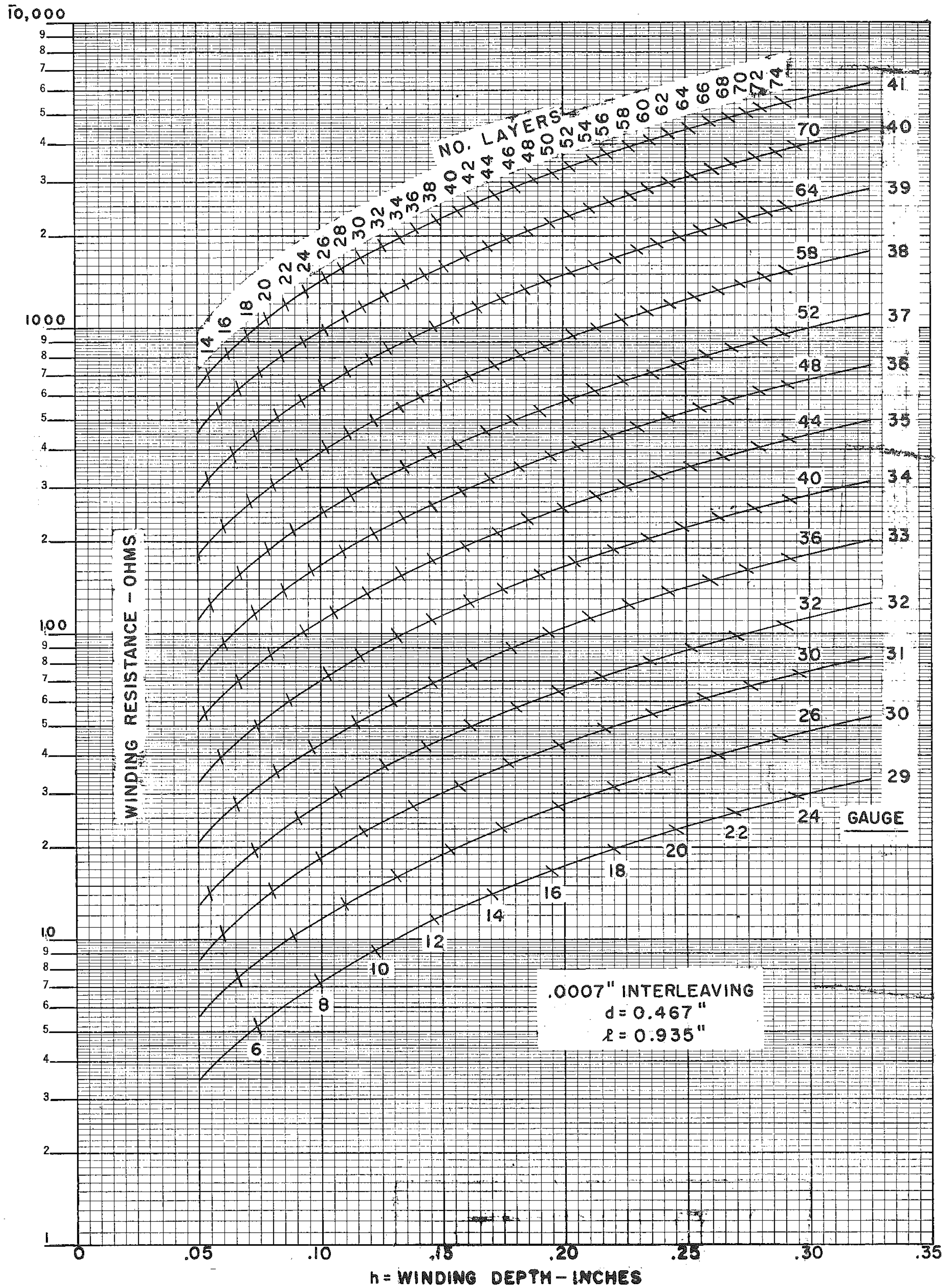

Fig. X-9 - Coil Resistance Versus Winding Depth AF Relays - Short Coil - 0.0007-Inch Interleaving

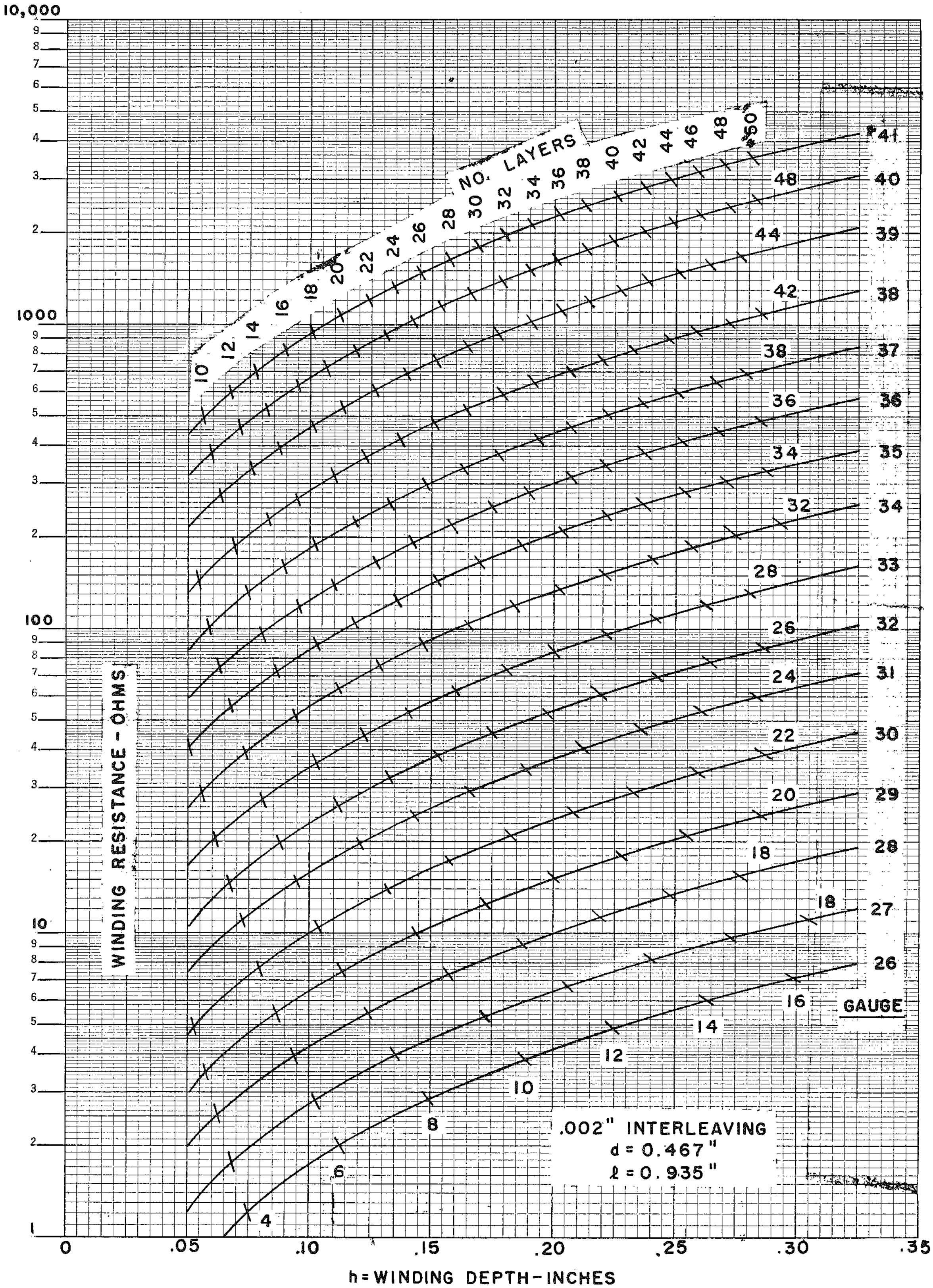

Fig. X-10 - Coil Resistance Versus Winding Depth AF Relays - Short Coil - 0.0002-Inch Interleaving

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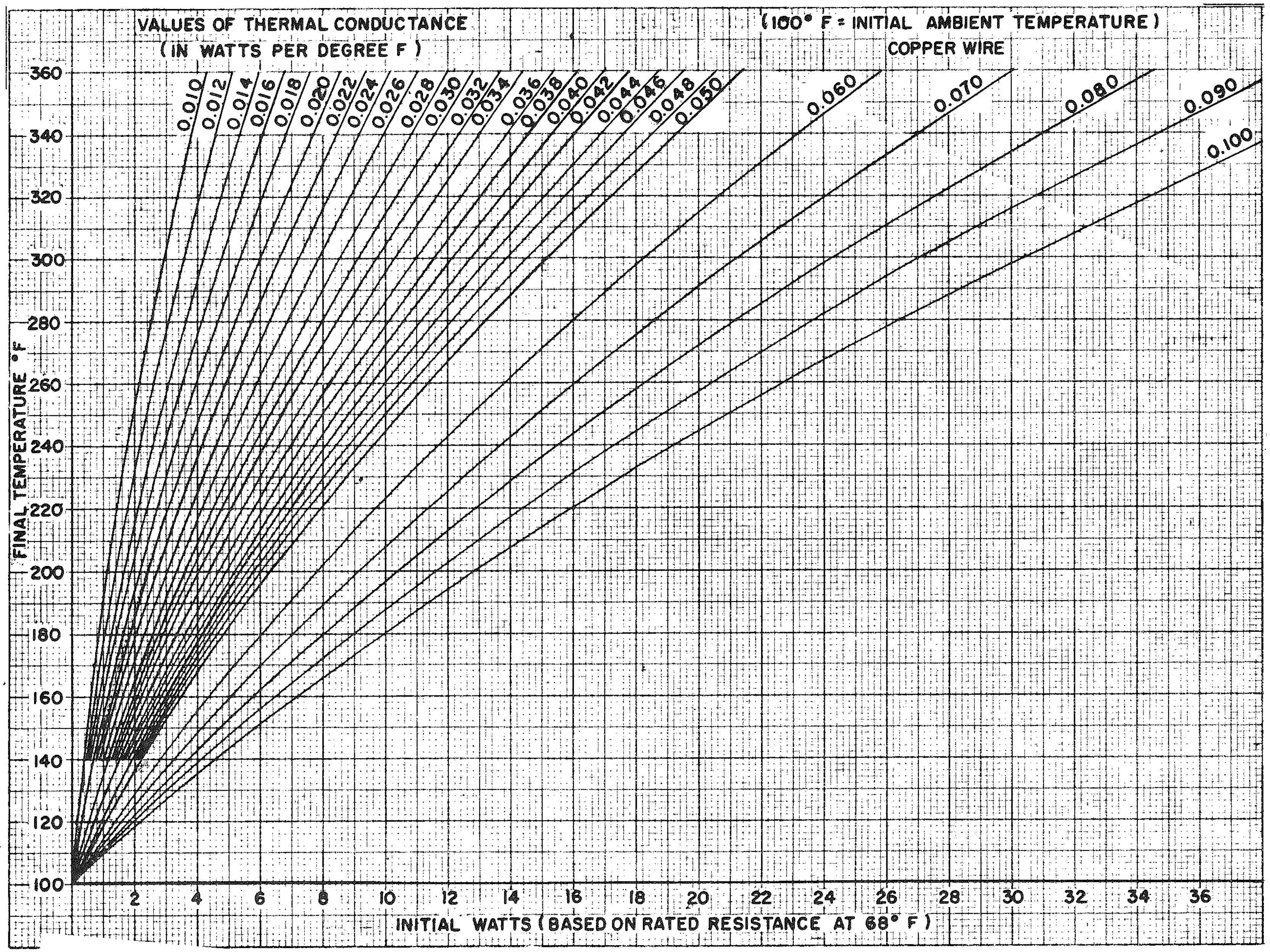

Fig. X-11 - Values of Thermal Conductance - In Watts per Degree F

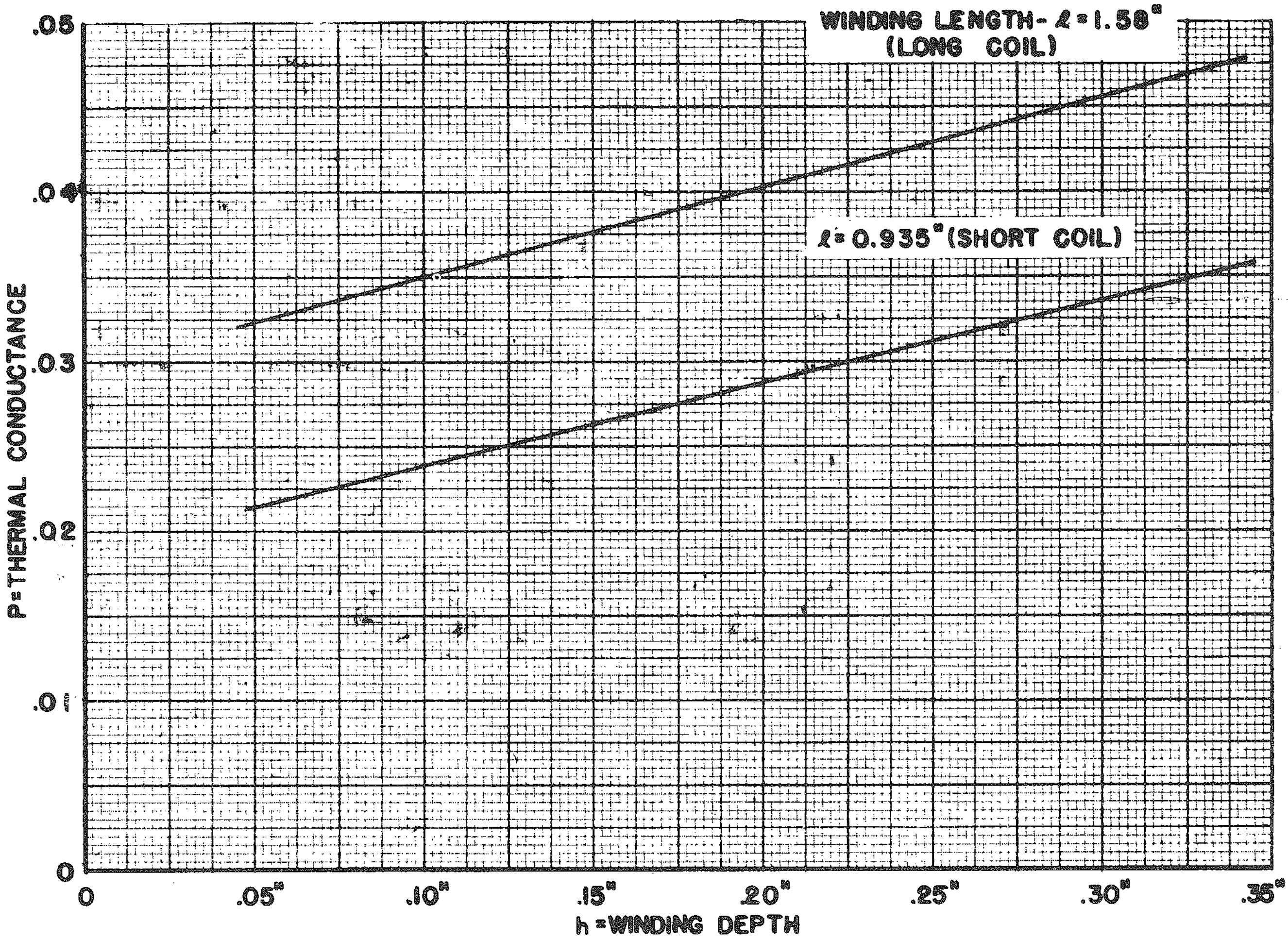

Fig. X-12 - Thermal Conductance (ρ) for Various Winding Depths - AF, AG, and AD Relays

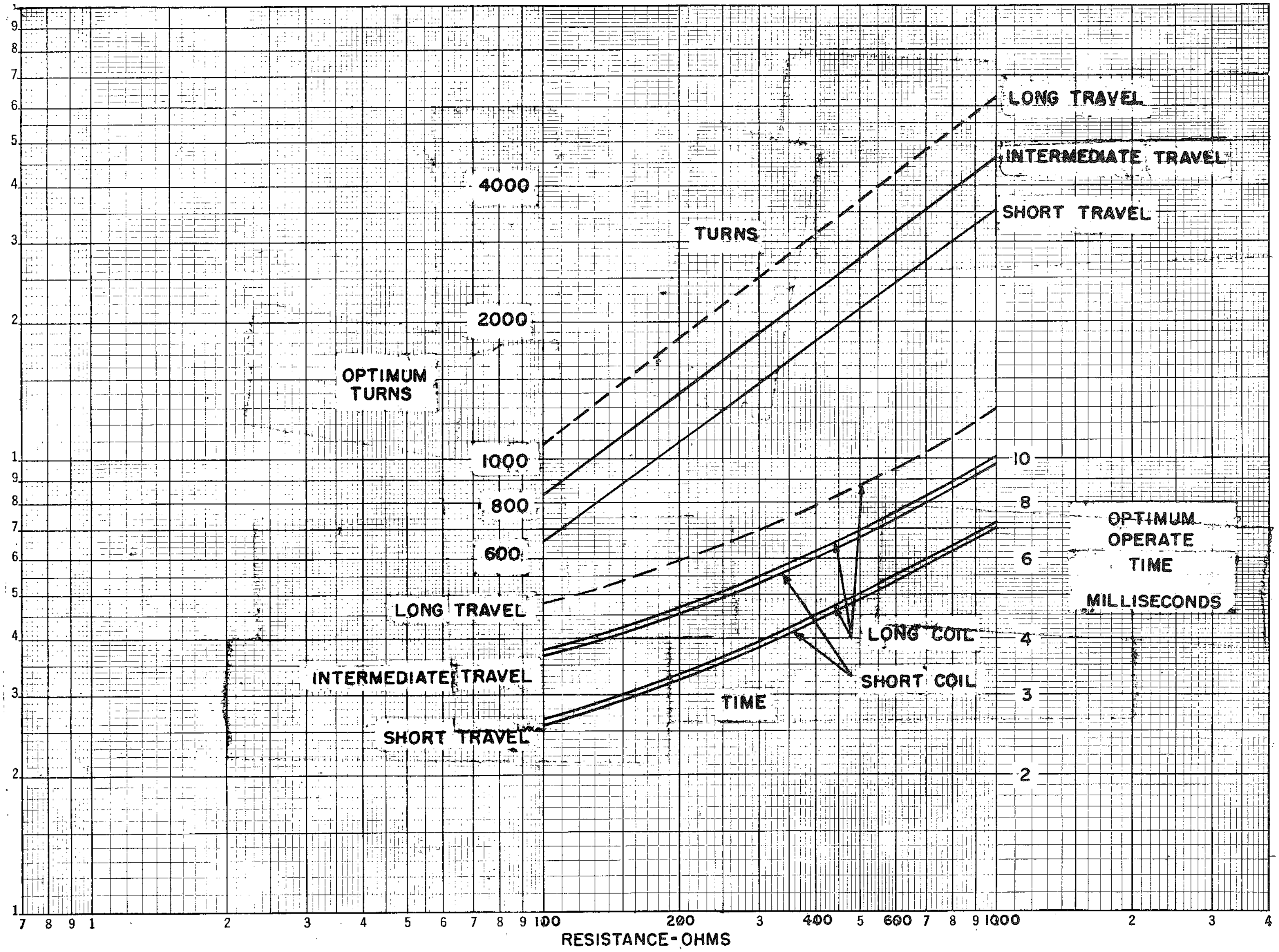

Fig. X-13 - AF Relay Speed Coils - Optimum Turns and Operate Time

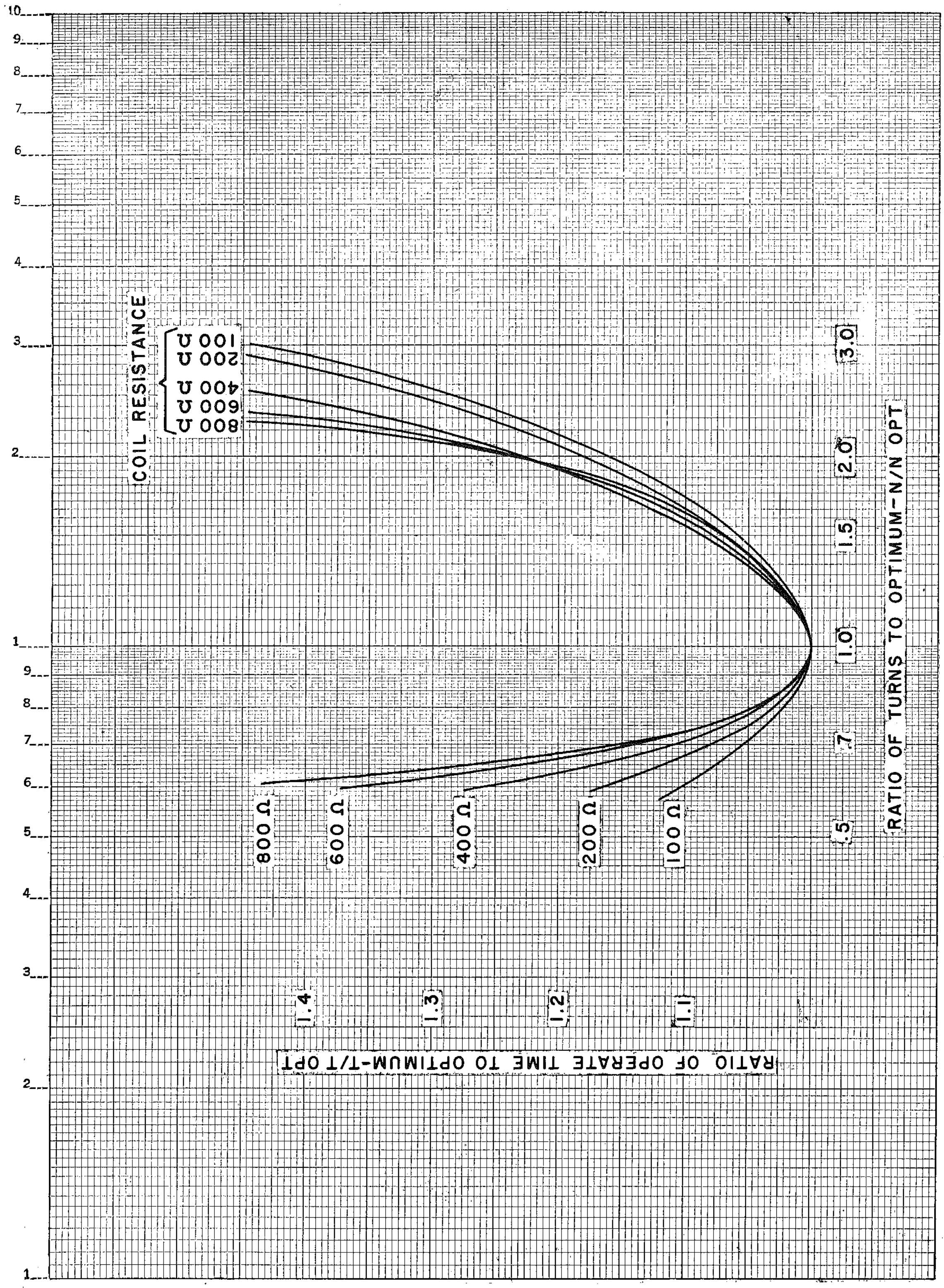

Fig. X-14 - Ratio of Optimum Turns and Operate Time

ECONOMICS

Introduction

This section deals with the economics of relay design for specific applications in switching systems. The subject is quite involved, with many of the factors obscure and difficult to price without some broad assumptions. It is assumed that the relay structure has been standardized and consequently this section deals in changes in variable relay design details only. No attempt will be made herein to include all of the steps and assumptions that were made in arriving at cost factors, but the conclusions reached will be used as the basis for establishing the cost figures and economic design data shown in this section. The problems will be discussed in general terms.

The subject may be broadly divided into the following parts:

A. When to Code a New Relay
B. Economic Selection of Coils
C. Cost of Power
D. Economics of Standardization

Part A provides the necessary data to determine whether to code a new relay or to use an existing relay for a specific circuit application. Parts B, C, and D provide a brief background of the problems involved.

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A. When To Code a New Relay

For each relay structure there is a winding depth that results in the lowest overall relay and power cost. For example: a low-turn winding is best for speed applications; a partially full winding is best for local circuit use where the holding time, and consequently the power cost, is low; a full winding is best where sensitivity is paramount; and a full, high-resistance winding would be chosen for long holding times where the power cost would be high.

For all such conditions, it is possible to evaluate each individual design by considering the variable winding costs and the cost of speed and of consumed power in terms of the equivalent relay first cost. The resulting net first-cost value of the relay winding is then the primary figure for comparison with other designs and can be used to estimate whether to create a new code or to use one of the existing designs.

In selecting a relay for a circuit condition where a relay exactly meeting the conditions is not available, two courses of action are open: Plan A (no new code) or Plan B (new code).

Plan A would use an existing relay that most nearly meets the circuit requirements. It would have the cost advantage of existing production but the disadvantage of too many contacts, or higher power drain, or too slow action, etc. Each of these extra items can be evaluated.

Plan B would have a new code, which, though it might have the possible disadvantage of an additional code with relatively low production, would satisfy the circuit conditions and thus have no performance penalties. The effect of a low demand is felt in two ways: the new code is more costly to manufacture, due to the low demand and the relays of the code that might be used with Plan A are more costly to manufacture because their demand was not increased. Both of these costs must be charged against the new code. These effects have been evaluated and are shown as the cost penalty in Fig. XI-1.

The cost figures to be used in determining the cost of extra features on a relay for the purpose of deciding whether or not to code a new relay are:

Additional combination	17.6¢
Extra spring pairs	2.2¢
Buffer spring	3.9¢
Extra features associated with long life	12.5¢
Extra adjustments	
Nonoperate	0.9¢
Release or hold (no buffer spring)	0.9¢
Hold (with buffer spring)	4.4¢
Release (with buffer spring)	4.4¢
Soak	0.4¢
Intermediate armature travel	0.7¢
Long armature travel	1.6¢
Max 60-gram back tension*	1.5¢
Sleeves	
0.046-in. Aluminum	5.6¢
0.046-in. Copper	9.1¢
0.091-in. Copper	11.5¢
0.147-in. Copper	18.1¢
Laminations	5.2¢
Long armature (AG and AJ relays)	2.0¢
Coil comparison costs	
Wire cost	Fig. XI-2
Winding on turns	Fig. XI-3
Additional winding connections	9.2¢
Pri A & pri B	9.2¢
Power per KWH (C_p)	40.0¢ (Fig. XI-4B)
Cost per millisecond of marker holding time	\$38.50 (Fig. XI-5)

$$KWH = \frac{E^2 t}{1000\ R}$$ where t = hours per year that the relay is energized.

*This applies to all 4.4-, 16-, 270-, 395-, 400-, and 700-ohm coils.

If the costs of the extra features exceed the amount determined from Fig. XI-1, a new code should be used instead of the existing code.

The following examples show the method of determining whether or not to code a relay.

Example 1

Required: a local circuit relay with 3M and 3B springs with a holding time of 360 seconds per busy hour. Demand 50 per 10,000 lines. No speed requirements. With 3000 busy hours per year, the yearly holding time is

$$3000 \times \frac{360}{3600} = 300 \text{ hours per year.}$$

Available relay - 700ω - 5050 turns 39E
Springs 4M, 3B - total 7
Short travel
700ω coil has max 60-gram armature back tension

New design - 2500ω - 19400 turns 38E
Springs - 3M, 3B - total 6
Short travel

Costs - available relay		
700ω 39E -	2.9¢	
5050 turns, short coil	3.0¢	
One extra spring	2.2¢	
60-gram back tension	1.5¢	
Total relay cost	9.6¢	

$$\text{Power cost} = \frac{E^2 t}{1000R} C_p$$

$$= \frac{48^2 x300}{1000x700} \times 0.40 = \quad 39.5¢$$

Total power + relay cost	49.1¢	49.1¢
Costs - new design		
2500ω 38E	14.0¢	
19400 turns, long coil	6.1¢	
Total relay cost	20.1¢	

Power cost

$$\frac{48^2 x300}{1000x2500} \times 0.40 = \quad 11.0¢$$

Total power + relay cost	31.1¢	31.1¢
Cost difference		18.0¢

From Fig. XI-1, a demand of 50 per 10,000 lines shows a cost penalty of 8.3 cents; therefore, a new code is justified since the existing relay will cost 18.0 cents more than the new relay and only 8.3 cents can be justified before coding a new relay.

Example 2

Required: a local circuit relay with 4M, 3EBM, and 1EM springs with a holding time of 100 seconds per busy hour. Demand 100 per 10,000 lines. No speed requirements.

The yearly holding time is

$$3000 \times \frac{100}{3600} = 83 \text{ hours.}$$

Available relay - 950ω - 11850 turns 36E
Springs - 5M, 3EBM, 1EMB - total 13

New design - 2500ω - 19400 turns 38E
Springs - 4M, 3EBM, 1EM - total 11

Costs - available relay		
950ω 36E	10.2¢	
11850 turns, long coil	4.3¢	
2 extra springs	4.4¢	
Total relay cost	18.9¢	

$$\text{Power cost} - \frac{E^2 t}{1000R} \times C_p$$

$$= \frac{48^2 x83}{1000x950} \times 0.40 = \quad 8.0¢$$

Total power + relay cost	26.9¢	26.9¢
Costs - new design		
2500ω 38E	14.0¢	
19400 turns, long coil	6.1¢	
Total relay cost	20.1¢	

Power cost

$$\frac{48^2 x83}{1000x2500} \times 0.40 = \quad 3.1¢$$

Total power + relay cost	23.2¢	23.2¢
Cost difference		3.7¢

From Fig. XI-1, a demand of 100 per 10,000 lines shows a cost penalty of 4.6 cents. A new code is not justified since the existing relay costs only 3.7 cents more than a new code and 4.6 cents can be spent before a new code is justified. The same procedure as shown in the two examples can be used to find the cheaper of two existing relays.

B. Economic Selection of Coils

Basically, the selection of a relay for any specific circuit application involves the following steps:

1. Establish the work requirements imposed by the desired contact functions (spring combination load).
2. Choose a favorable magnet structure that is capable of delivering the necessary amount or kind of work (select type of relay, ie, AF, AG, or AJ relay).

3. Select a coil to match the characteristics of the previous page to the desired circuit application, taking account of voltage, speed, heating, economy, and other special problems.

In service, relay operation must be assured even when the battery is minimum, the resistance is maximum, and all other possible conditions are adverse; thus it is necessary to build the relay so that it will function on a current considerably less than that obtained with average circuit constants. The usual variations requiring consideration, assuming local circuit operation of the relay but neglecting any resistance rise due to heat dissipation in the relay winding, are:

Office battery	±5%
Coil resistance	±10%
Resistance rise due to change from rated value at 68° F to that at ambient 100° F.	+7%
Deterioration from test operate to worst circuit	+5%
Deterioration from the readjust operate to the test	+5%

For the relay to operate under all adverse conditions, it must be capable of operating on 72 percent of the current that may pass through its circuit on nominal conditions.

When comparing various coil designs, certain common operations such as soldering the leads on the primary winding, attaching spoolheads, dipping, etc, are common to all coils; consequently, only the difference due to the varying amount of copper, which is paid for by the pound (or for any particular size by the ohm), the cost of sleeves or laminations, the cost of additional winding terminals, the cost of winding on the turns, etc, must be considered. The cost per ohm and the cost of winding the turns for the various wire gauges are shown in Fig. XI-2 and XI-3. To find the variable portion of the cost of any coil, it is only necessary to find the cost of the wire and the cost of winding on the turns (using the proper curve of Fig. XI-3 for the coil being considered) and add a factor for any extras such as sleeves and extra windings. The costs of these additional factors have been shown in the paragraphs on When to Code a New Relay. For any particular resistance, it is obvious that the cheapest coil results when the finest size wire that will provide the desired resistance and required minimum number of turns is used. For any given resistance, each change of one wire gauge changes the variable part of the coil cost between 20 and 30 percent.

The most common use of relays is in circuits where they are required simply to operate their contact load and then remain operated, consuming power for a specific holding time. In such cases, the actual cost is made up of two factors: the first cost of the coil, and the cost of the power consumed. The first cost of the coil decreases as the coil resistance decreases, but the power cost increases. There is an optimum point where the sum of the two costs is the lowest, and that is the point to strive for, other considerations permitting. Factors affecting the cost of power will be discussed later in this section.

There will be many cases in practice where the optimum resistance for sensitivity and power will not be used for such reasons as standardization of coil resistances, need for speed, or insufficient winding space. The cost penalty for deviations from the optimum may be found by comparing the costs for the coil used and the optimum resistance coil.

Fig. XI-6 shows the cost of power for the commonly used single-wound coils with different holding times and also the combined cost of power plus the coil cost for wire spring relays. From this figure, the cheapest coil for any holding time can easily be determined. For example, the 700-ohm coil is cheaper than the 2500-ohm coil up to 200 seconds holding time per busy hour, and cheaper than the 950-ohm coil up to 350 seconds per busy hour. The most economical coil use, ignoring all other circuit considerations, would be the use of the 700-ohm coil up to 200 seconds per busy hour holding time and the 2500-ohm coil above this value. Circuit operating conditions and the economics of coding a new relay where a relay with the best coil is not available can sometimes make the use of the most economical coil undesirable from an overall cost standpoint.

The speed of operation of a relay is a function of the power applied to the relay, the circuit resistance, and the relay inductance. For the fastest operation, there is an optimum number of turns for each value of coil resistance. The speed may be increased by increasing the power supplied to the relay, but, where faster action is obtained at the expense of more power consumption, there evidently must be some point for which the cost of power and the worth of the speed are economically optimum.

The worth of a saving in operating time is greatest in a common control circuit where the holding time of the circuit per call is very short and the cost of the circuit is high. The marker of crossbar systems is an outstanding example of such a circuit. The value of time saved is important only insofar as it saves marker holding time.

The value of a millisecond of marker holding time is not a simple figure to obtain. The fractional part of a marker that must be provided per line per millisecond of work time is almost directly proportional to the holding time of the marker. The value of a millisecond of marker work time will therefore vary with the holding time as well as the cost of the marker. The shorter the marker holding time, the more valuable a millisecond becomes since it becomes a greater percentage of the total time. Assuming a $17,000.00 marker with a holding time of 300 msec, the value of a millisecond of marker time is equivalent to a relay first cost of $38.50. With a holding time of 500 msec, the value drops to $24.00. Fig. XI-5 shows how the value of a millisecond of marker holding time varies with marker work time and cost.

C. Cost of Power

For every relay in the telephone switching system, one must allocate a small portion of the cost of the power plant and the building to house it. These, together with the cost of power purchased from the power companies, represent concrete costs which it may be possible to minimize by suitable design of the relay to consume less power.

The problem of power cost must be considered in two parts:

1. For a major systems development involving new apparatus where the design of the relay may exert a large influence on the size of the power plant required.

2. Where only a small change in the amount of power consumed is involved.

Equivalent First Cost of Power Plant

The price of a power plant will vary in two ways as shown in Fig. XI-7:

1. In fairly large steps as the basic plant size is changed.

2. In a fairly uniform manner as any particular basic plant size varies within its lower and upper limits.

If a major systems development permits a reduction in power consumption, such that the size of the plant can be reduced to the next lower basic size, an appreciable saving may be realized, whereas if the plant must stay within the same basic size, the savings are materially reduced.

If it is assumed that by the magnet design a given fraction (P) of the power may be saved, then for any particular range of power, a power plant operating near the top of its range will save a larger quantity of plant capacity than one operating near the bottom of its range. On the other hand, the one operating near the bottom of its range may be converted into the next cheaper range, thus realizing a base-price saving. The net-price saving per kilowatt of power saved has been found by determining the dollar value of the plant saved and dividing by the total amount of power saved. This saving was then averaged for all plants in the range. The results for each range were then weighted on the assumption that telephone power-plant sizes were uniformly distributed between 30 and 200 kilowatts. Fig. XI-4A shows a plot of the results for different percentages of power saved. Studies show that the power plant price-saving per kilowatt of savable power varies from $1420.00 for small percentages of power saved to a maximum of $1900.00. Even though the precise amount of power to be saved may not be accurately known, the resulting power plant price-savings per kilowatt of power saved will not vary widely from a value somewhere around $1700.00 in most practical cases.

The distribution of power used to operate magnets in a No. 5 crossbar office is approximately as follows:

Use	Percent of Power	
Talking channels, transmission	18	Power largely unaffected by relay design (24 percent)
Speed relays	6	
Nontransmission relays energized during conversation	20	Available for design changes to reduce power costs (76 percent)
Nontransmission hold magnets energized during conversation	29	
Relays	27	

thus, about three-fourths of the power in the office is subject to reduction by relay and switch design.

The annual power may be found from the busy-hour power. The daily load in an office has been broken down as follows:

Hours per Day	Percent of Busy-Hour Load	Total Load Hours
2	100	200
4	78	312
6	65	390
3	27	81
9	2	18
Total 24		1001

Thus, one busy hour accounts for 10 percent of the power drain. Assuming 10 busy hours per day and 300 days per year, the annual power taken by any particular unit will be 3000 times the power consumption in one busy hour.

Cost of Power Per Kilowatt Supplied

The installed power plant price per kilowatt, together with the annual charges, have been translated into equivalent first costs in terms of relay costs for different percentages of power saved and are shown in Fig. XI-4B.

The same figures have also been translated into the equivalent price of power supplied, and this is shown in Fig. XI-4C, also on the basis of the percentage of the power saved.

The cost per kilowatt hour is shown for two conditions: new equipment and additions. The figures for new equipments would apply only when new apparatus developments cause a major change in the size of the power plant installed. For comparisons between the costs of different relay coils, the more realistic approach is to use the figures for additions and consider that the percentage of power saved is practically zero. The equivalent first cost of a kilowatt hour of power in terms of relay first cost is thus $0.40 (Fig. XI-4B). The $0.40 figure results from the fact that the 8.2-cent price per KWH is an annual charge on the initial investment and the cost of ac power supplied. The price of power is an annual charge and should be related to the relay charge which is a first cost. The comparable cost of a KWH of power, therefore, should be an amount which when amortized over a period of years, will result in an annual cost of 5.6 cents $\left(\frac{\text{8.2-cent price}}{1.456}\right)$. This results in the first cost for power of $0.40 per KWH.

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D. Economics of Standardization

If enough information were available to the circuit engineer, he should be able to choose a relay for any particular application by considering:

1. The penalties due to standardization, ie, the penalties in performance and cost resulting from having only a certain limited number of available relay combinations as against sufficient combinations for complete flexibility.

2. The penalties due to not standardizing, ie, the penalties in first cost resulting from many variations of a basic type, as compared with a limited number of combinations.

By weighing both the penalties and the advantages of standardization in each case, it should be possible to maintain them in approximate balance and to obtain an economical number of codes. The cost penalties of standardization involve, mainly, factors such as value of speed, power consumption, kinds of contact metal, use of extra springs. The penalties of not standardizing involve extra costs due to a large number of codes and production in small-size lots.

What appear to be major ways in which the number of codes affect relay costs are:

1. Administration effort in maintaining information on each code and

2. Manufacture by more small lots.

Administration Costs

Administration costs for relay codes have been taken to be those costs that are incurred each year on the relay type in question. Such costs result from design activity on the relay type and are almost entirely due to the issuance of change orders, mainly at Bell Laboratories, but also in the Western Electric Company. Some of the change orders are to improve the product, or to effect cost savings so that the administration costs are to some extent self-supporting. There are, of course, some general change orders that affect all relays of a type, and the amount of work involved depends on the number of codes of that type of relay; thus, administration costs would be less if there were fewer codes.

Various forms of expense enter into the full administration costs; those incurred at Bell Laboratories and in Hawthorne Merchandise which are recovered in the pricing markup above the bulletin costs, and those incurred in the Hawthorne E of M organization which would affect the bulletin cost. The objective is to develop cost figures in terms of bulletin costs which then can be compared with similarly developed figures for the worth of power, operate time, windings, contacts, etc. For this reason, it has been concluded that Bell Laboratories and Hawthorne Merchandise figures should not be included in the administration cost figures.

During the early part of 1951, a comprehensive review of coding costs of the U relay was made by the Hawthorne engineers. It was concluded that a cost of $127.00 per-code-per-year would give a fairly accurate picture of the "bulletin cost" administration expense. This study also resulted in a figure of $90.00 as the cost of introducing a new code.

Assuming a code life (not relay life) of fifteen years, the $90.00 cost converts to an annuity value of $10.00, based on 7-percent interest.

It is believed that the wire spring relay, with its unitized components, would require considerably less attention per code than other types of relays. A 25-percent reduction seemed reasonable to the

Western Electric Company engineers. A cost of 75 percent of $127.00 + $10.00 annual coding cost, or $105.00, per-code-per-year has, therefore, been suggested for the administration cost of the wire-spring relay.

Manufacturing Costs as Affected by Lot Size

If only one kind of relay were needed, it could be built continuously in the same way, with no time lost for change-over to other parts, no special bookkeeping necessary to control the proper flow of different parts, and with more automatic and conveyor-type action. This would represent the height of manufacturing economy, but unfortunately this cannot be realized in the current relay programs.

There are three major phases of relay manufacture affecting the lot-size costs, each involving separate treatment; they are:

Assembly of the complete relay

Winding and assembly of the coil

Molding and welding of the spring blocks.

There are many codes of a basic type required to fill circuit needs, and the codes are not built in large quantities but only as ordered on a periodic basis. The periodic ordering is used to maintain a smooth flow of apparatus into the wiring department, where an even load is also assured by planning on a periodic basis. If relays were to be made in large quantities and then stored until they were needed, it would build up a large inventory investment, which is considered uneconomical. It appears that certain codes are made on an average of once in two weeks, while the more active ones are made on a daily or a weekly basis.

There are three methods of assembly for the U relay. Given in descending order of productivity they are progressive conveyor method, assemble complete method, and bench method. The wire spring relay, however, was designed with the specific objective of building complete molded assemblies of the spring blocks and thus greatly simplifying the final relay assembly compared to the U relay assembly. As now planned, only two assembly methods will be used for the wire spring relay: a conveyor assembly line for relays produced at a rate in excess of 12,000 annually, and a bench assembly method for relays produced at annual rates of less than 12,000.

Filled coils may be wound by two processes: by having either one or two winding machines under control of one operator. The loading rates for the two methods will be different since the operator controlling one machine is working on low turn coils and must of necessity spend more time in setting up the machine for different coils.

The choice of which method is to be used is summarized, approximately, by the following rules:

Method A

Two machines, one operator	For single windings only, when the turns >9000.

Method B

One machine, one operator	For all double windings and single windings where the turns are <9000.

The contact spring arrangement for the wire spring relay is different from any of the existing types of relays in that the spring assembly is molded in a block. For any change in molding, it will be necessary to shut down the molding machines for about 6 hours. To reduce the number of machine stoppages, the spring blocks will probably be molded with a full complement of wires and the extra twin wires clipped off in the finishing operation. The single-wire blocks always have a full complement of wires.

It is planned to complete the molded spring blocks in a separate line where the blocks will be fed into a machine and progressively stepped along while the finishing operations are performed. Since these operations will include clipping off the surplus wires and welding contacts, any change in the spring block will require stopping the machine. There will be flexibility within the machine for rapid changes from one condition to another. Some changes, however, may cause machine stops of as much as 45 minutes. This emphasizes the desirability of keeping the number of spring combinations to a minimum in order to minimize machine time loss.

Relation of Cost Penalty to Total Number of Codes

A picture of the cost penalty due to having more than one code averaged over the entire product can be gained if the distribution of demand for each code is known. Such information has been compiled for a particular type of No. 5 crossbar office. The number of codes and the quantity of each code were known, which was easily translated into an annual demand for each code. With the annual demand for each code, the cost penalty was found from a chart similar to Fig. XI-1. All such penalties were added and divided by the number of relays to give the average penalty per relay for the number of codes involved. By a process of combining codes and demands, a series of points were obtained showing how the cost penalty varied with the number of codes.

Figures were obtained in a similar manner for the number of coils used. These penalties were comparatively small, indicating that there is no great disadvantage in a moderate number of coils, except as they may increase the number of codes. Where a new code is required for some circuit condition, a new coil which offers some circuit advantage would not appreciably affect the average relay cost.

Choice of Number of Codes

The previous paragraphs discussed the cost penalty of diversifying the design as compared with the ideal of manufacturing only one design. As more and more codes are introduced, it is possible to estimate the effect on the cost. There is a point at which no more codes would be added, representing the condition where all circuit conditions are ideally satisfied. Any fewer codes cause performance penalties in one form or another, such as extra power drain, extra springs, slower operation, etc. As more and more codes are consolidated into smaller groups of codes, the sum of the cost penalties, averaged over all the relays in the office, will steadily increase. These can be stated in terms of first cost of the apparatus and will be called the performance, or standardization, cost penalty. The total cost penalty of a certain number of codes will be the sum of the coding cost penalty and the performance cost penalty at this point. One cost increases with the number of codes and the other decreases so that a minimum cost may be expected to result corresponding to some most favorable number of codes.

The difference in cost penalty with deviations from the optimum number of codes does not vary greatly. This indicates that the optimum number of codes is not very critical. It appears that the best procedure is to design so as to minimize the number of codes so that as much economy as possible can be realized in times of low output by manufacturing fewer varieties of relays without sacrificing more than a fraction of a cent in periods of large volume production. With this in mind, Fig. XI-1 has been prepared showing the amount that can be spent on an existing code before taking out a new code.

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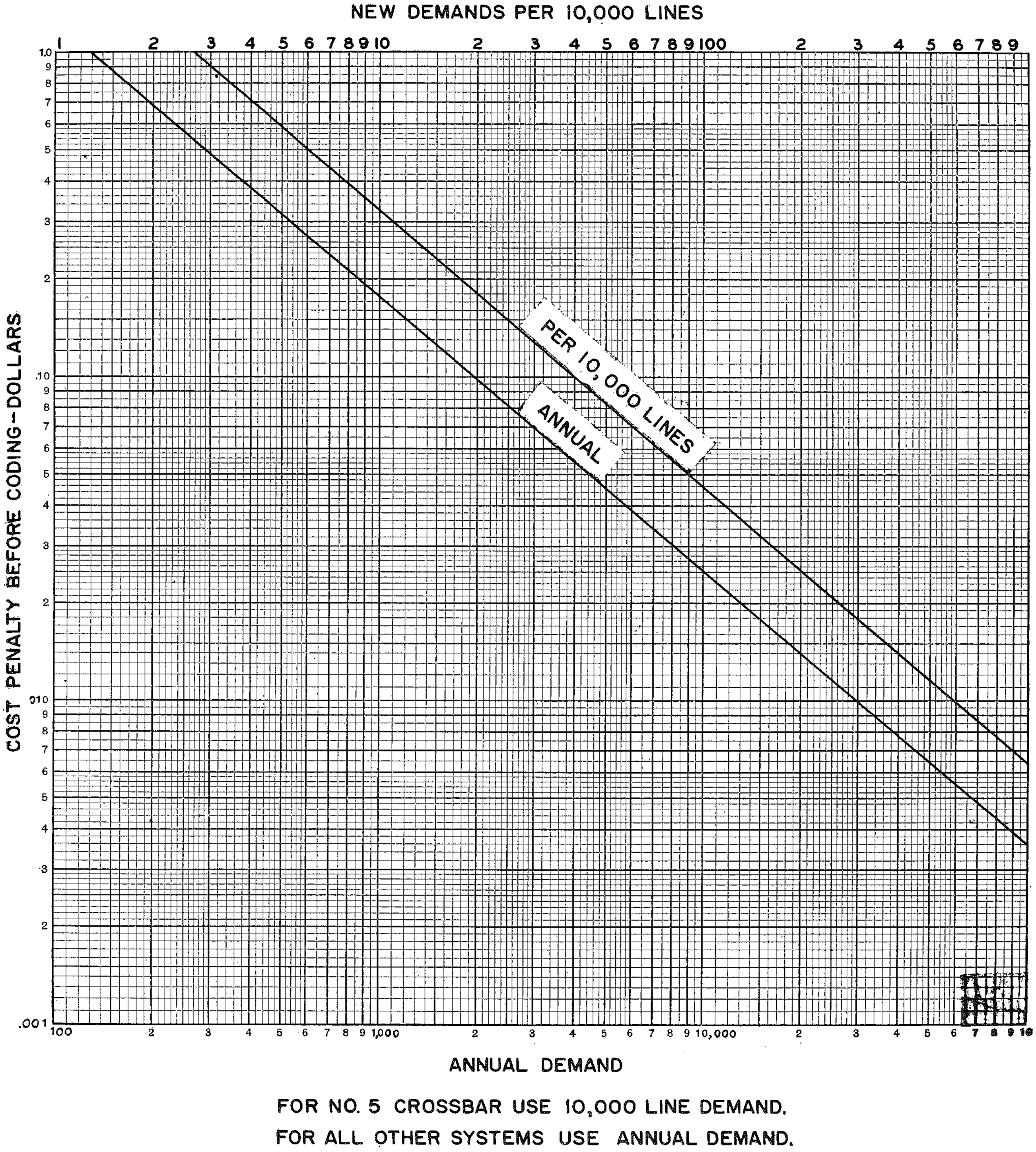

Fig. XI-1 - Coding Cost Penalty

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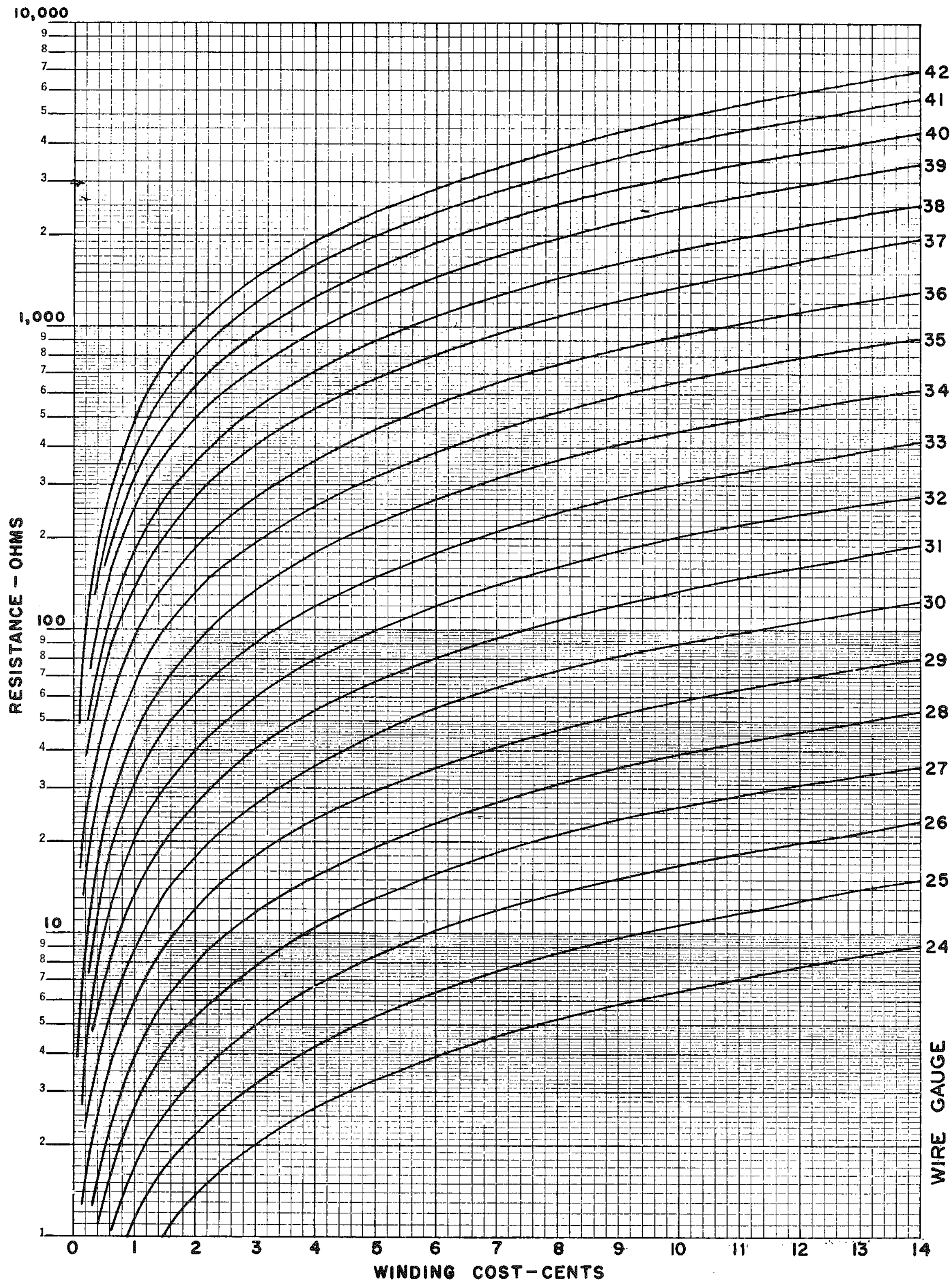

Fig. XI-2 - Wire Cost

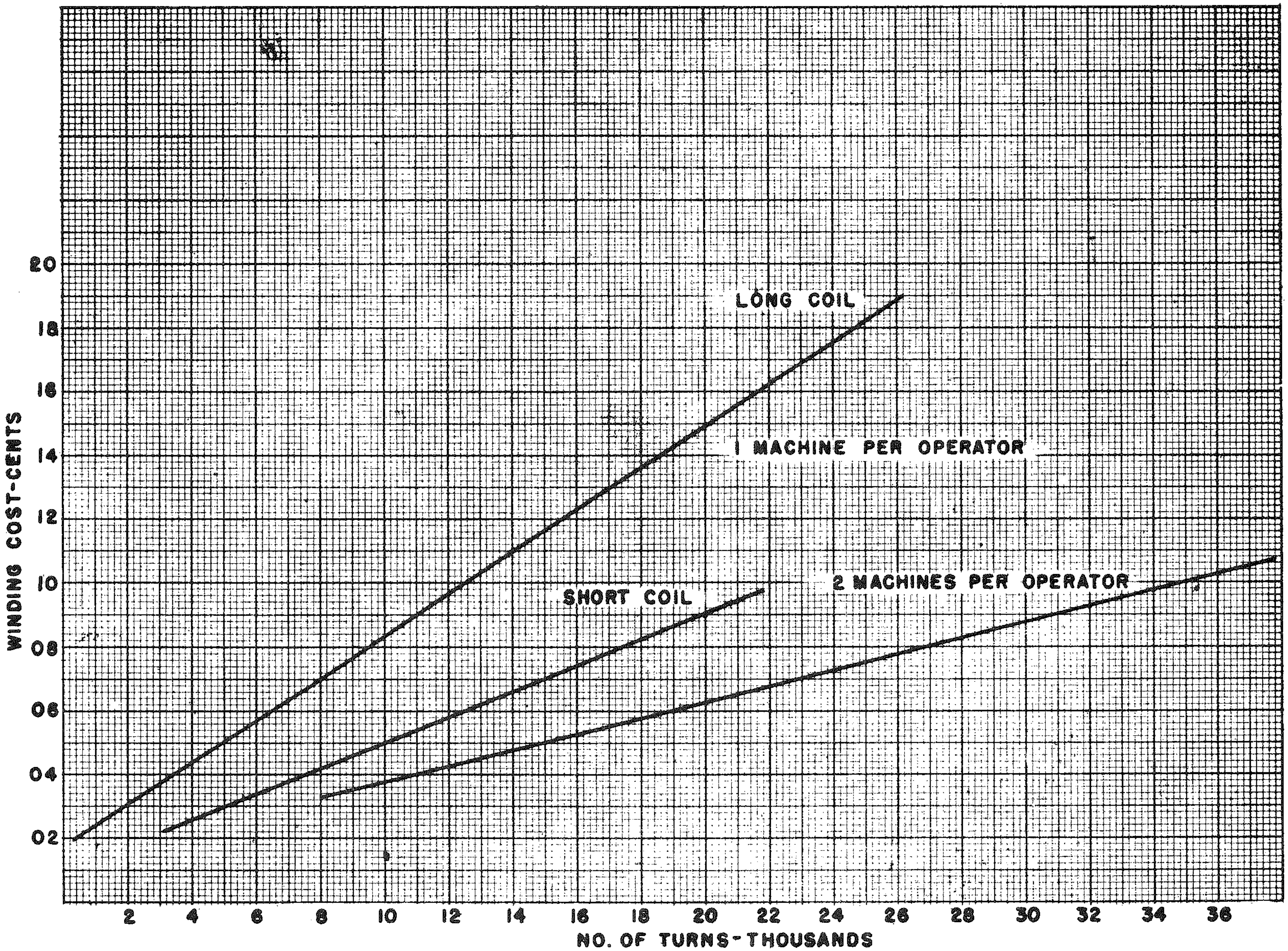

Fig. XI-3 - Coil Winding Cost

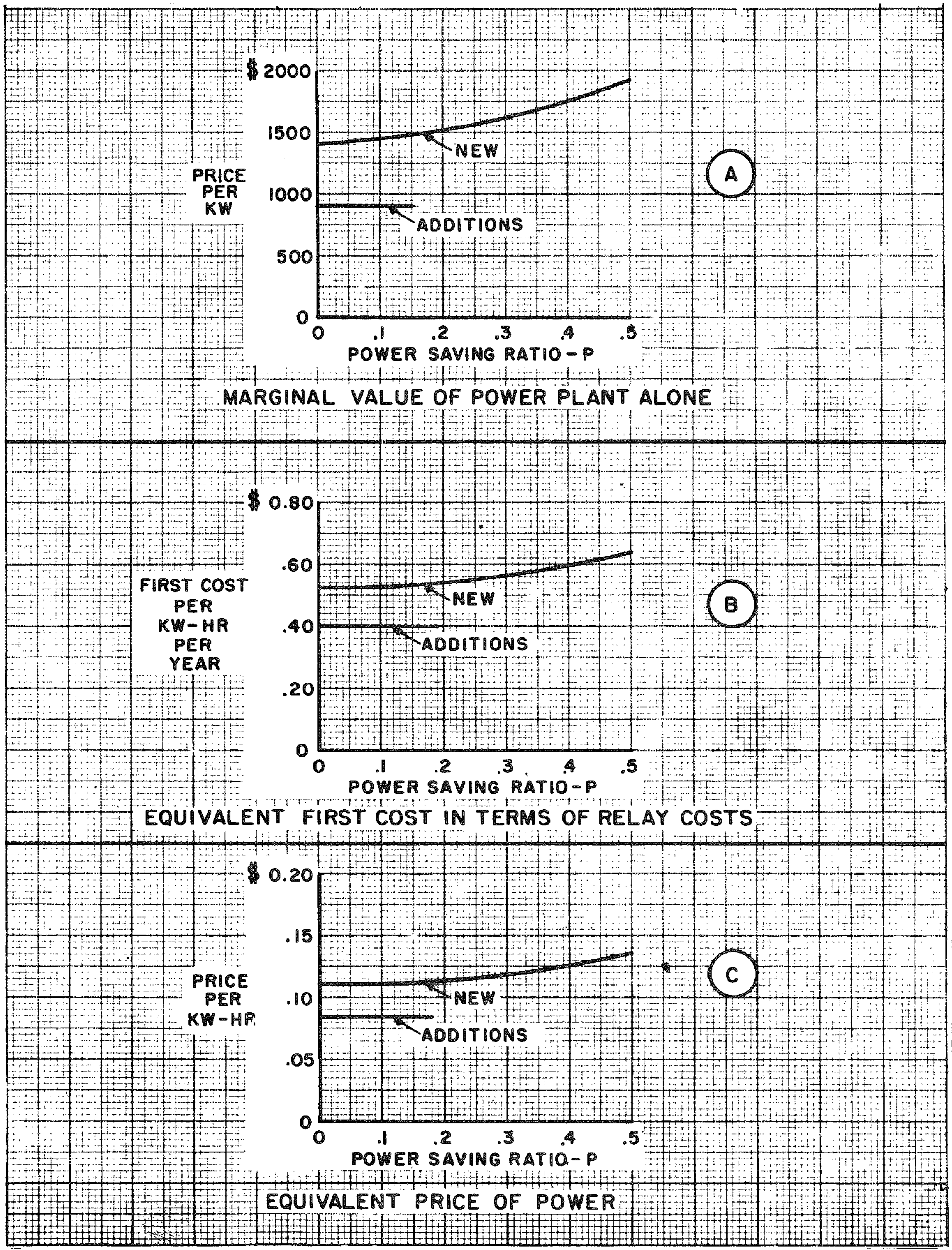

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Fig. XI-4 - Power Cost

WORK TIME IN SECS.	MKRS. PER LINE	$25000 MARKER PRICE			$17000 MARKER PRICE			$10000 MARKER PRICE		
		PER LINE (MKR. COST)	PER LINE PER M.S.	PER MKR. PER M.S.	PER LINE (MKR. COST)	PER LINE PER M.S.	PER MKR. PER M.S.	PER LINE (MKR. COST)	PER LINE PER M.S.	PER MKR. PER M.S.
0.5	.001	$25.0	$.050	$50.0	$17.0	$.034	$34.0	$10.0	$.020	$20.0
0.4	.0008	20.0	.050	62.5	13.6	.034	42.5	8.0	.020	25.0
0.3	.0006	15.0	.050	83.3	10.2	.034	56.7	6.0	.020	33.4
0.2	.0004	10.0	.050	125.0	6.8	.034	85.0	4.0	.020	50.0
0.1	.0002	5.0	.050	250.0	3.4	.034	170.0	2.0	.020	100.0

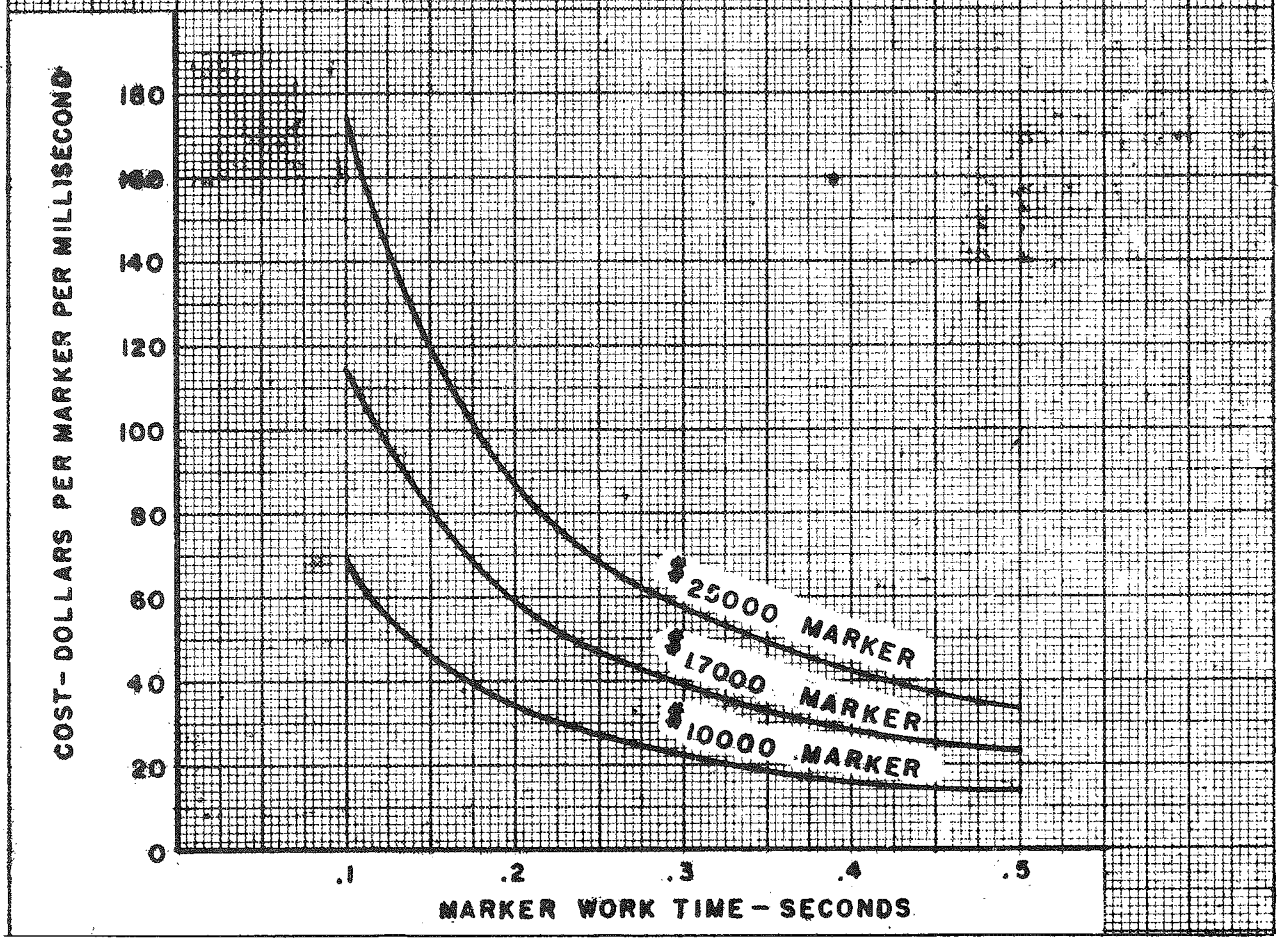

Fig. XI-5 - Cost of Marker Holding Time

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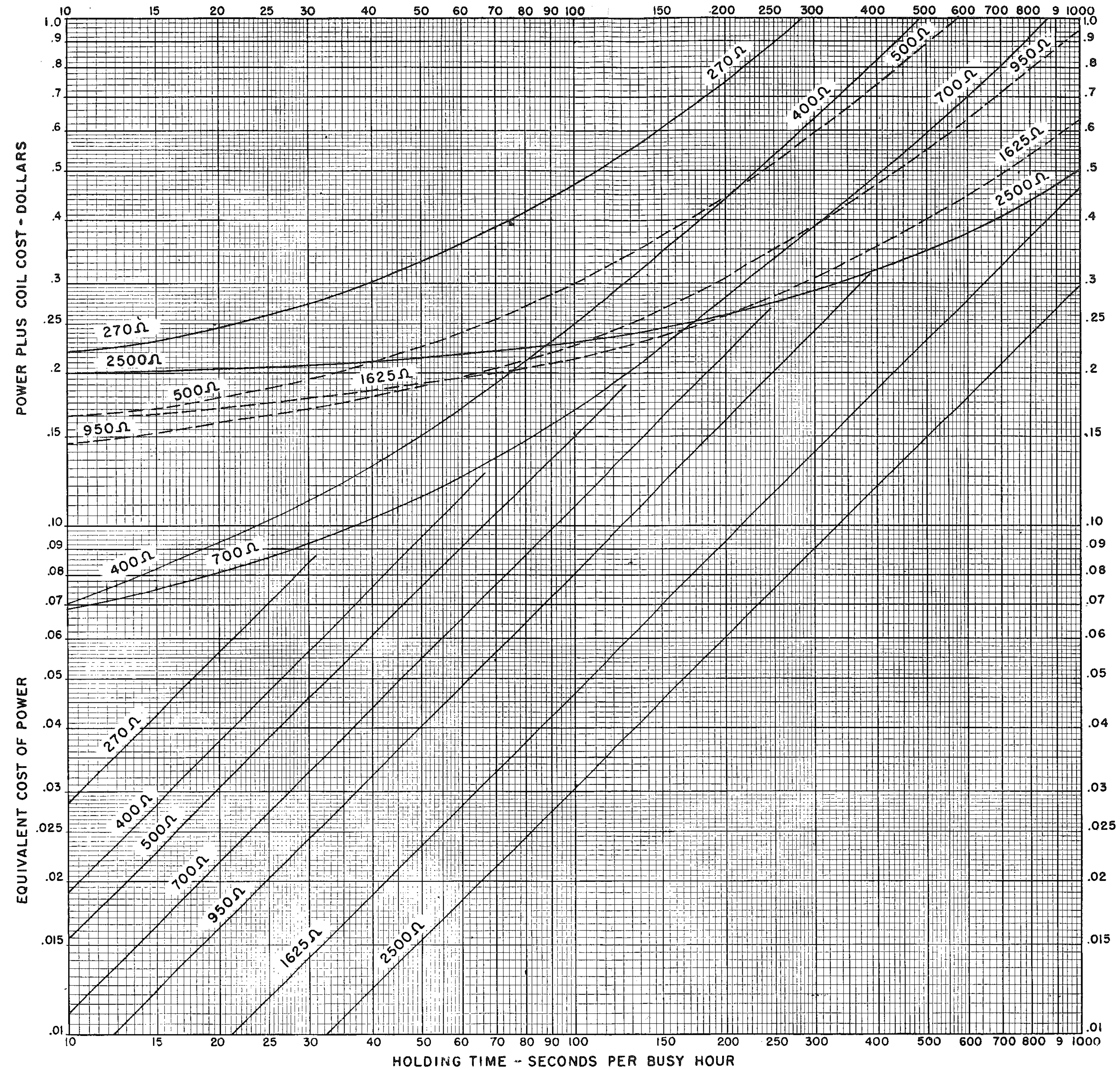
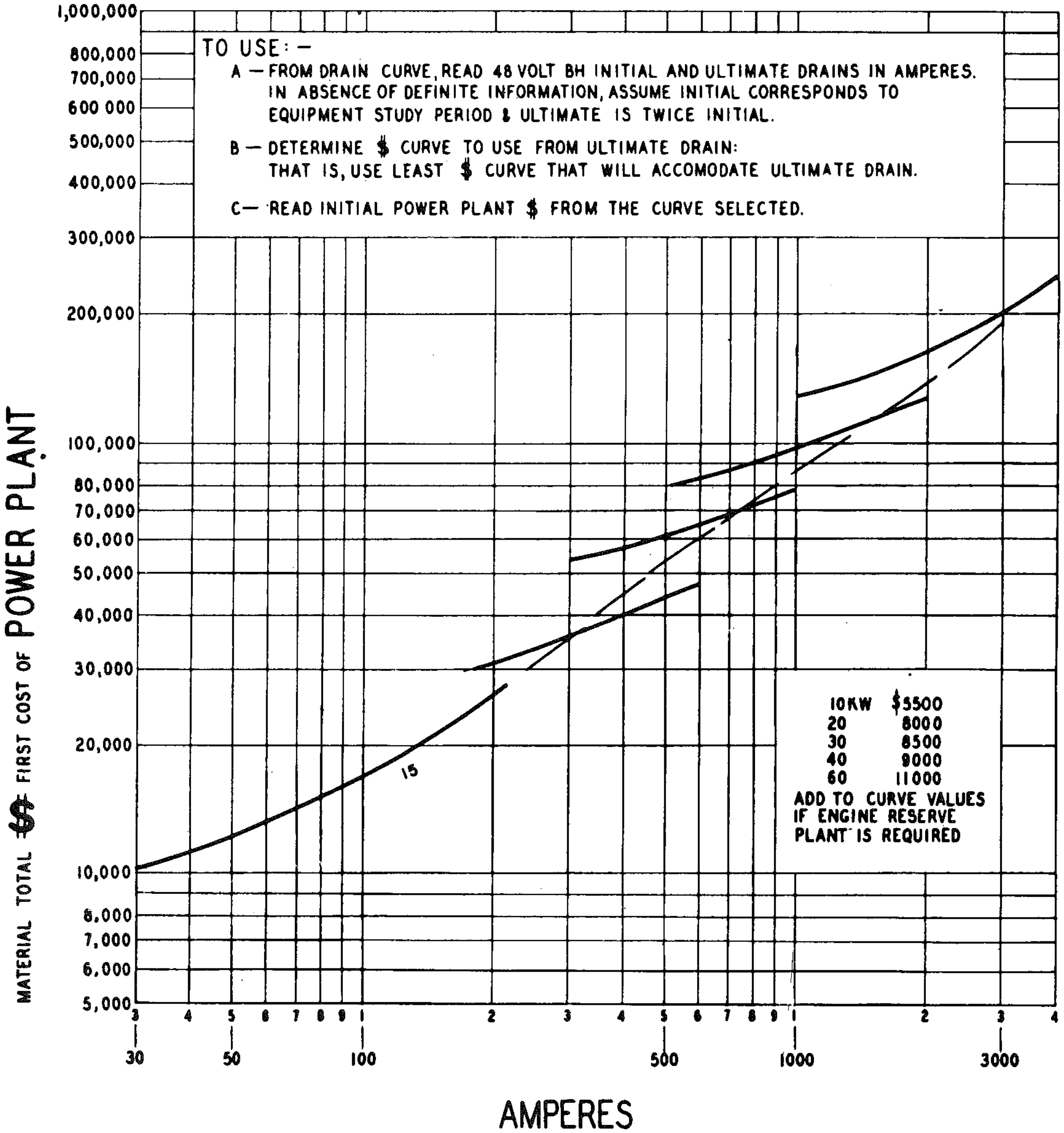


Fig. XI-6 - Power and Coil Costs

POWER PLANT



NOTE VALUES ARE FOR NEW STANDARD POWER PLANTS IN MEDIUM SIZE BUILDINGS AND ARE INTENDED TO REFLECT AVERAGE CONDITIONS, THEY TEND TO UNDERSTATE THE PROBABLE PRICE WHERE:

PBX DEVELOPMENT IS LARGE; BATTERY RESERVES ARE OVER 4 BUSY HOURS; THE POWER PLANT ALSO SERVES REPEATERS, LARGE TOLL BOARDS, CENTRAL "A" BOARDS, TEST CENTERS, ETC.; THE BUILDING IS LARGE WITH LONG AC SERVICE LEADS, LONG DC DISTRIBUTION, ETC.

VALUES TEND TO OVERSTATE THE PROBABLE PRICE WHERE:

PBX DEVELOPMENT IS SMALL; BATTERY RESERVES ARE UNDER 4 BUSY HOURS: SWITCHBOARD IS NOT SERVED BY THE POWER PLANT; MANUAL CONTROL IS TO BE USED; GROWTH OF LESS THAN 2 OFFICES IS TO BE PROVIDED FOR.

PRICING FOR POWER PLANTS DEVIATING FROM STANDARD, AND FOR ADDITIONS, REQUIRES MODIFICATIONS AND ADJUSTMENTS TO RECOGNIZE THESE DEPARTURES.

Fig. XI-7 - Power Plant Cost

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