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

X-75509

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.

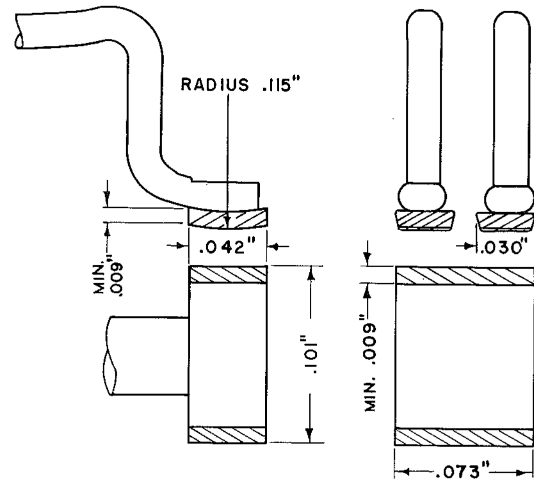

Fig. VI-1 - AF, AG, and AJ Relay Contacts

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.

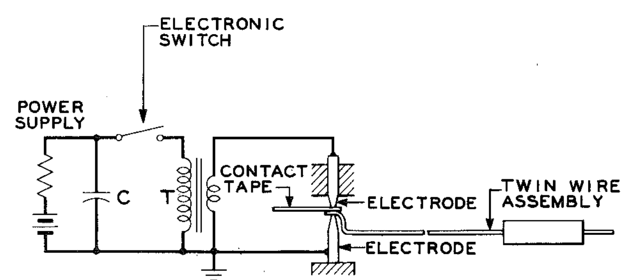

Fig. VI-2 - Welding Diagram - Twin Contacts

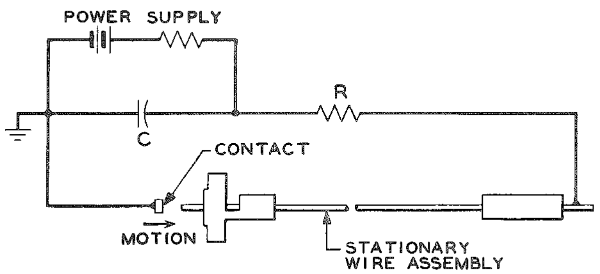

Fig. VI-3 - Welding Diagram - Single Contacts

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 moving and fixed 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.

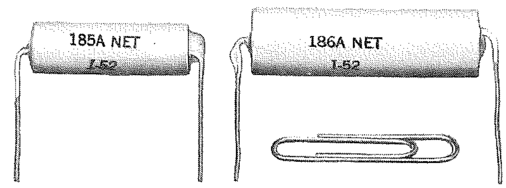

Fig. VI-4 - Protection Networks

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

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

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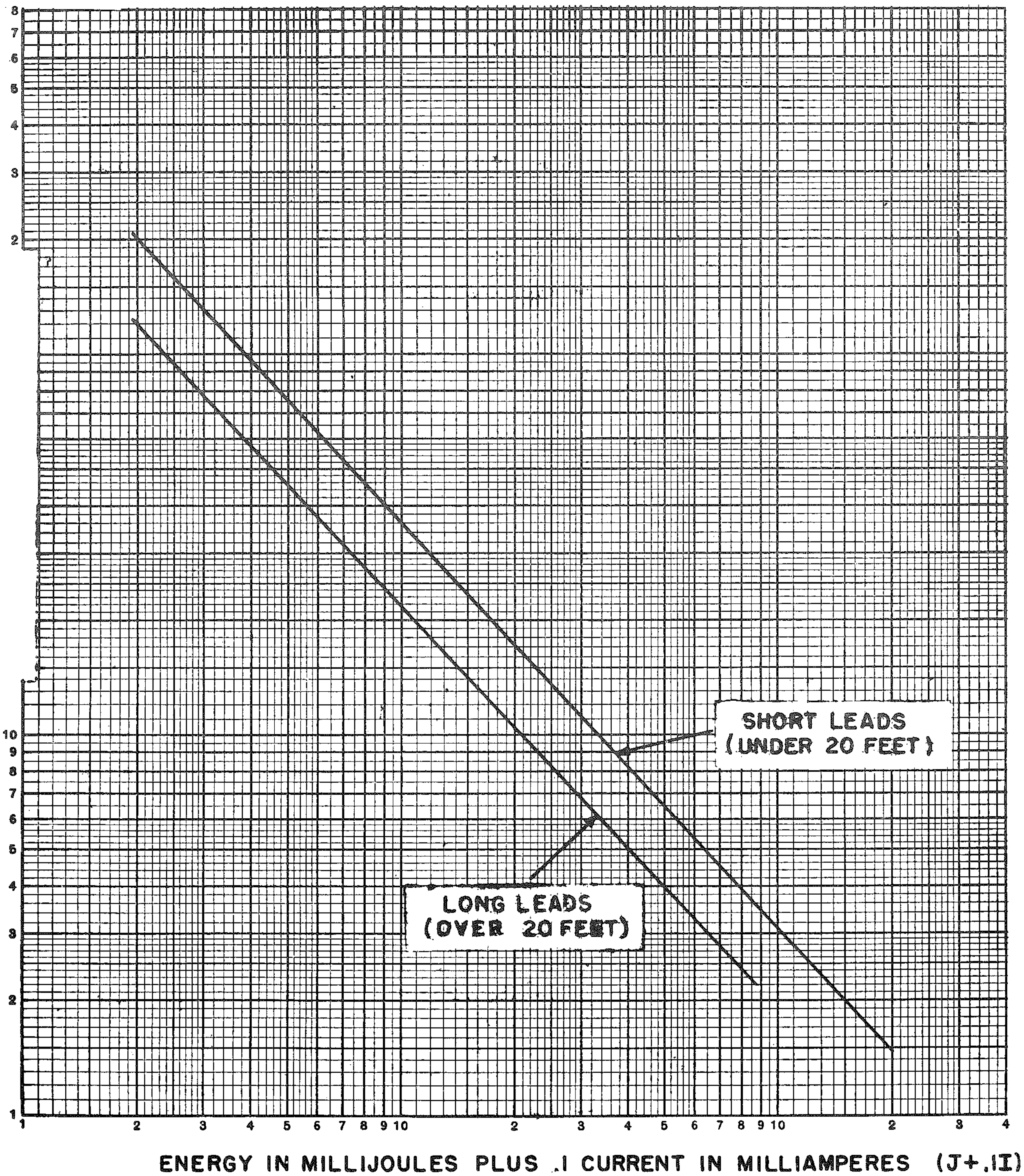

Fig. VI-5 - Wire Spring Relay Contacts Life Estimates

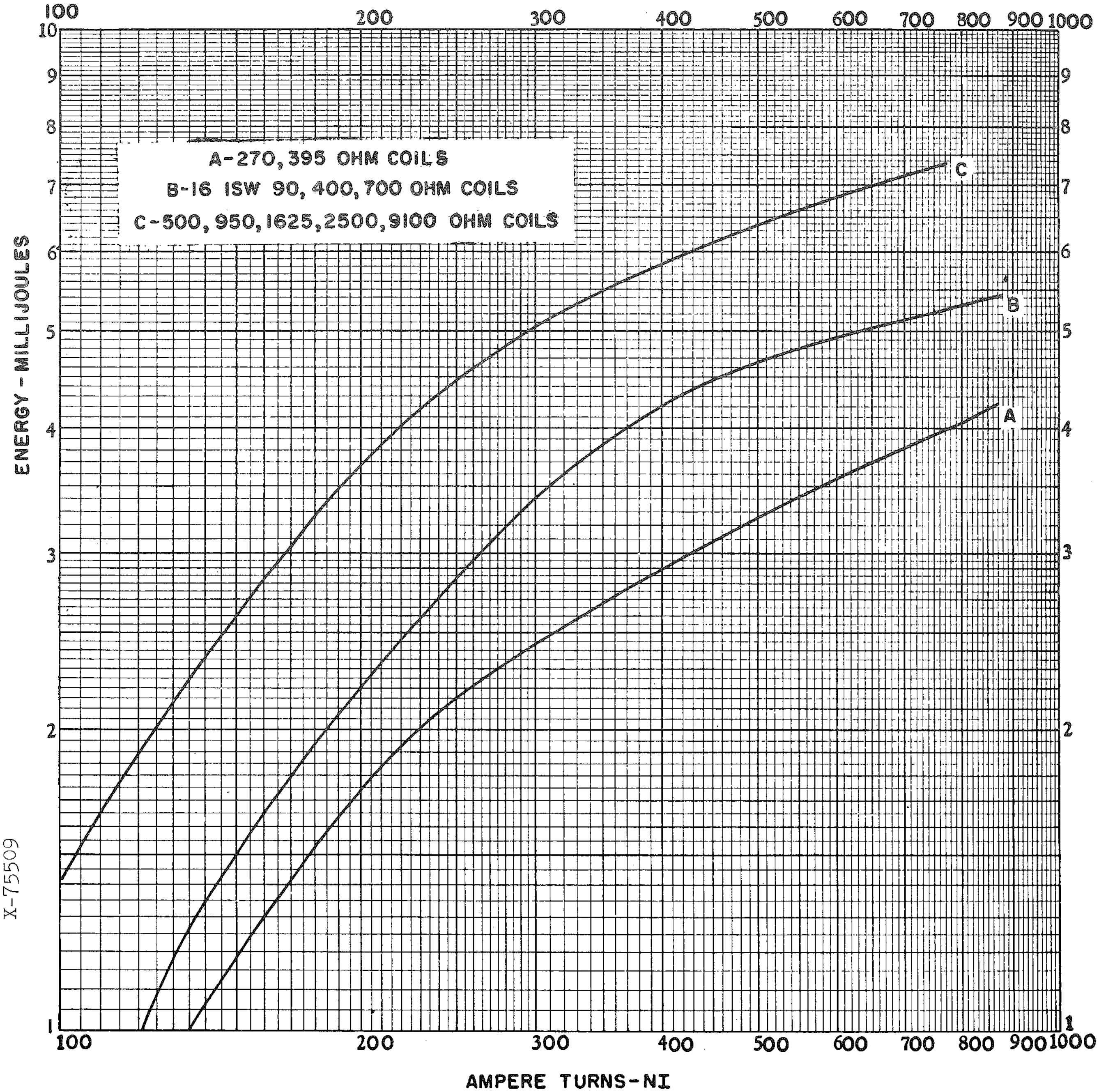

Fig. VI-6 - AF and AJ Relays - Energy Curves -
0.014-Inch or 0.002-Inch Stop Discs

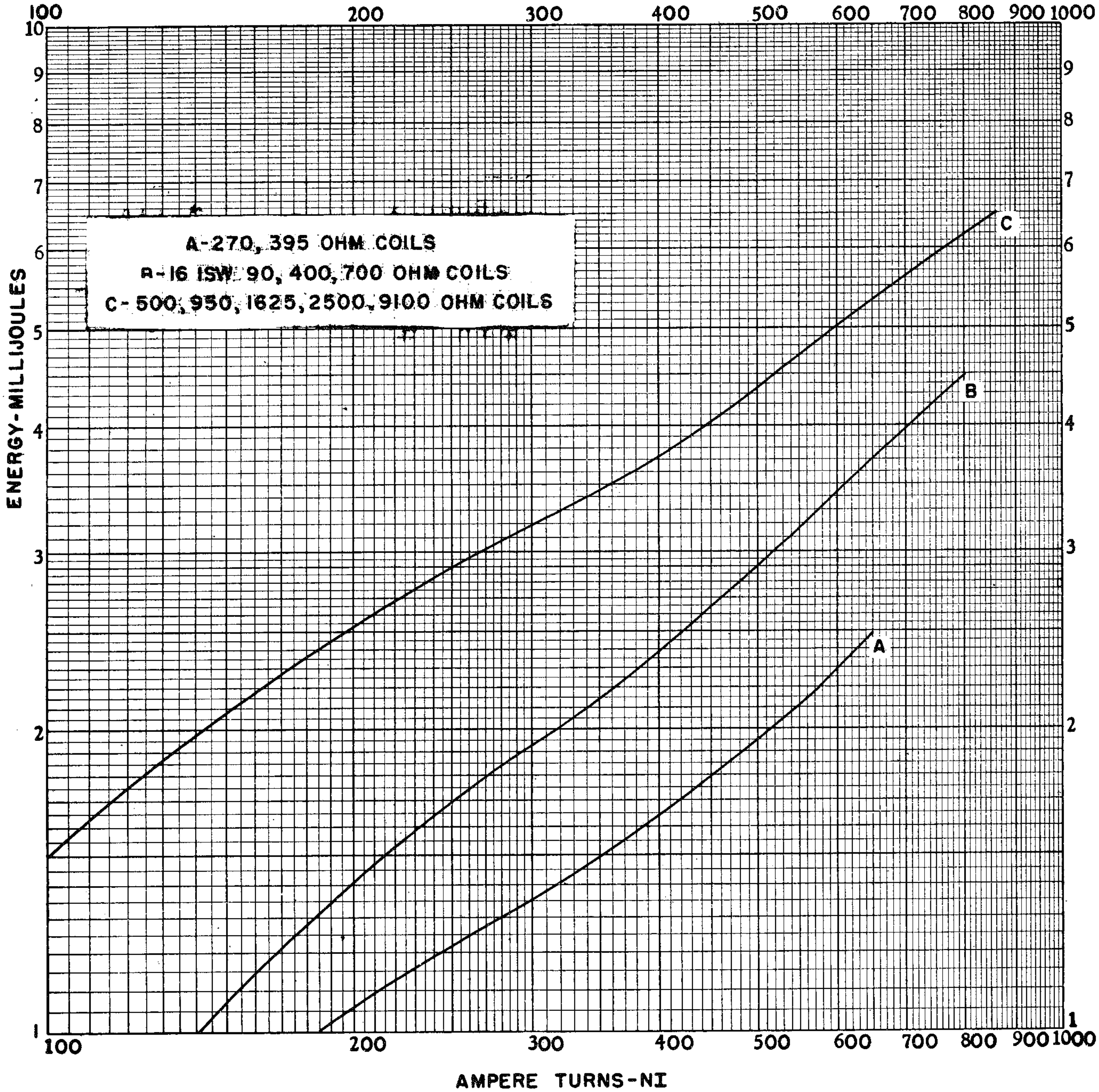

Fig. VI-7 - AF and AJ Relays - Energy Curves - 0.006-Inch Stop Discs

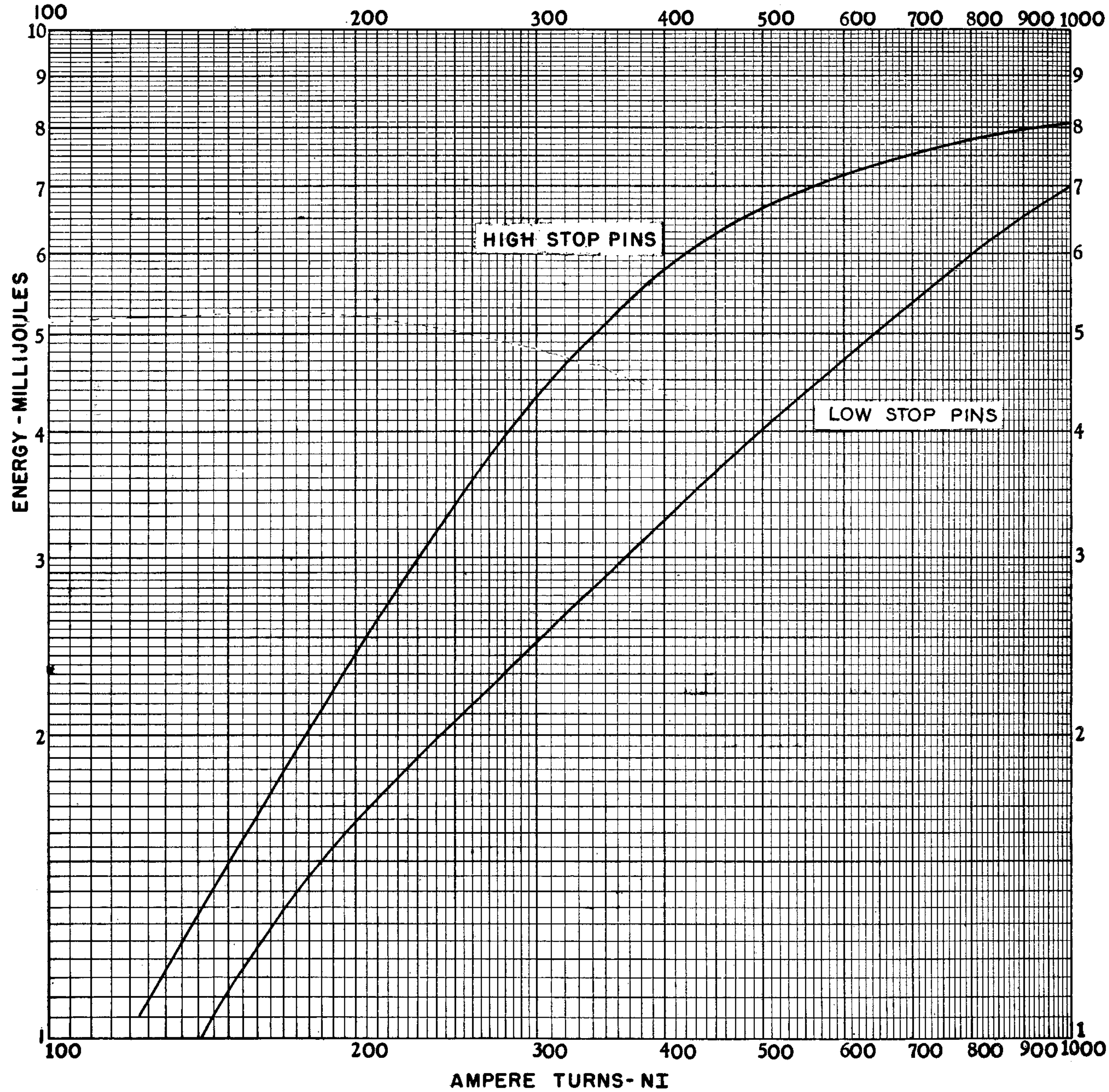

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Fig. VI-8 - U Relay - Energy Curves

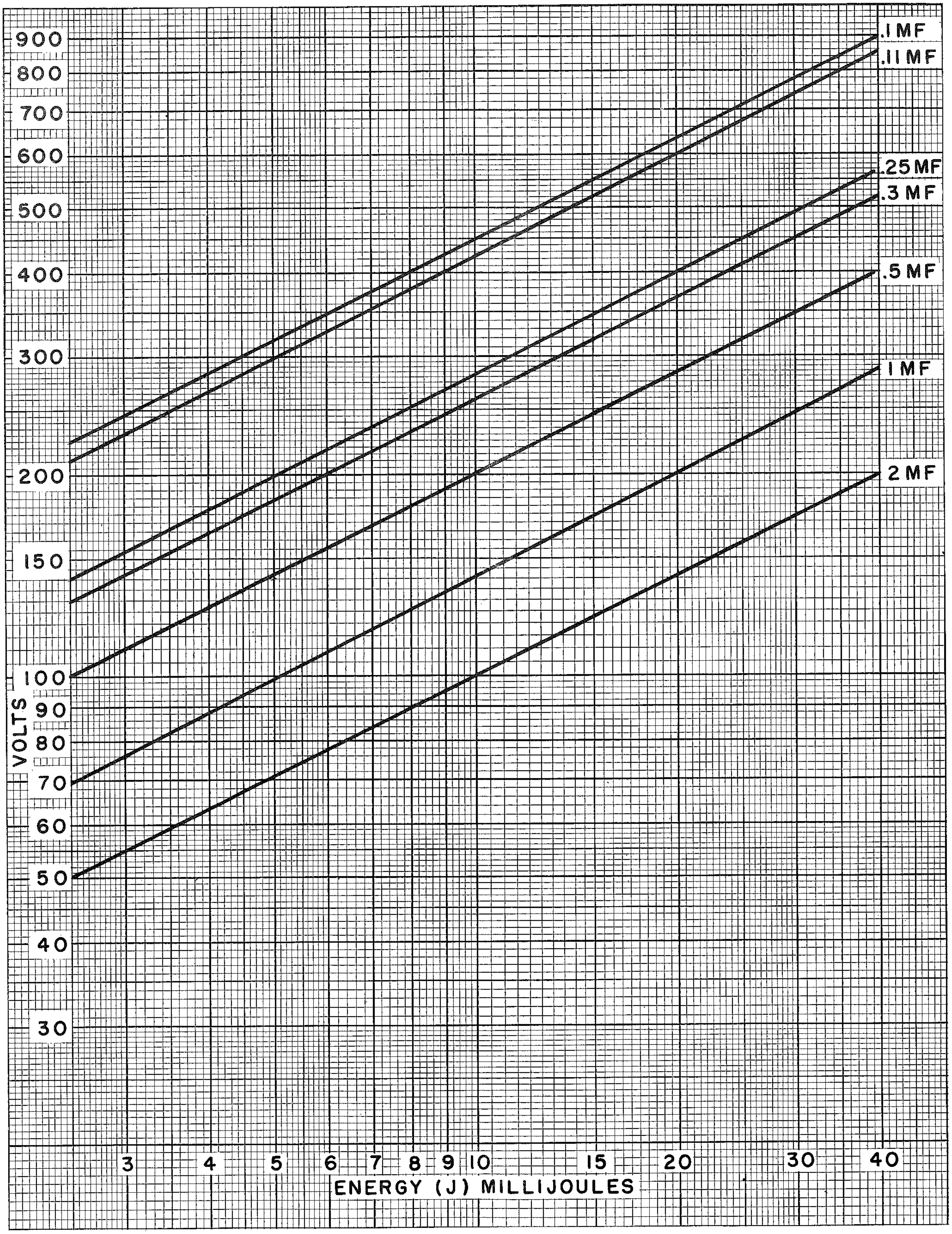

Fig. VI-9 - Protection Peak Voltages