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RELAY INSULATION STUDIES

O. B. Rudolph

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O. B. Rudolph

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ABSTRACT

This report deals with the use of small hermetically sealed relays in a type of service where extremely high insulation resistance is necessary, the difficulties encountered, and corrective techniques employed.

RELAY INSULATION STUDIES

O. B. Rudolph

Generally speaking, to the electrically conscious person, the name "Relay" denotes a rather simple device with contacts and an operating electromagnet, by which electrical circuits can be opened or closed, turning on or off, lights, motors, etc., sometimes at remote locations and usually dispensing with the necessity of operating a switch manually. Usually about the only requirements that are in any way critical are that the contact size and spacing be consistent with the characteristics of the circuits in which they are to be used.

Occasionally, applications requiring the use of relays are encountered where the characteristic electrical standards that must be met are extremely critical. Such a case was recently encountered by the author. This paper deals with troubles that arose on a particular relay application, the underlying causes, and the measures taken to correct them. It is quite likely that the information obtained will be of value to others having need of somewhat similar relay applications.

The case in point was the use of a Baird Direct Reader in a spectrochemical analysis operation, where desired spectral lines of an element to be analyzed are focused on the cathodes of separate photomultiplier tubes and the resulting electron current from each tube stored in separate capacitors for a definite period of time. At the end of the integrating period the charge of each capacitor, in volts, is measured, whereby the relative line intensities are obtained and relative

abundance of the different elements is determined. Since photomultipliers have dark currents which feed the capacitor, along with the current resulting from the incident spectral light, accurate analysis necessitates some method of subtracting out the dark current. This is done by exposing the photomultiplier to the spectral light for a given length of time, then shutting off the light and reversing the capacitor for an equal length of time, resulting in a net charge on the capacitor, corresponding to the light current, at the end of the cycle. The capacitor reversal is done by the use of relays. In the Baird system a two second cycle is used (one second light and one second dark). The total exposure time in cycles is varied at the discretion of the operator to obtain best results. In a typical case an exposure time of 120 seconds and 120 capacitor reversals or 60 cycles was used. Other relays are also required in each channel, each of which are in the capacitor circuit, viz., one for switching the capacitor to either arc or spark circuit, one for switching from exposure to measure, and one for shorting out the capacitor at the end of the measure operation, making a total of four for each channel or capacitor. The type relay used is a hermetically sealed, D.P.D.T. plug-in type, with octal plug base, similar to advance relay spec. No. A-8902-9.

Very shortly after beginning use of the direct reader, inconsistent and erratic readings began to appear on different channels which could be corrected only by substituting new relays in the place of ones being used. Since it was evident some sort of testing device for relays was very necessary, one as shown in Figure 1 was built. This incorporates facilities (1) for resistance measurements from any one contact to all other contacts, coil, or case, (2) for coil continuity checks, and (3) for contact continuity checks. The tester is quite simple and the only

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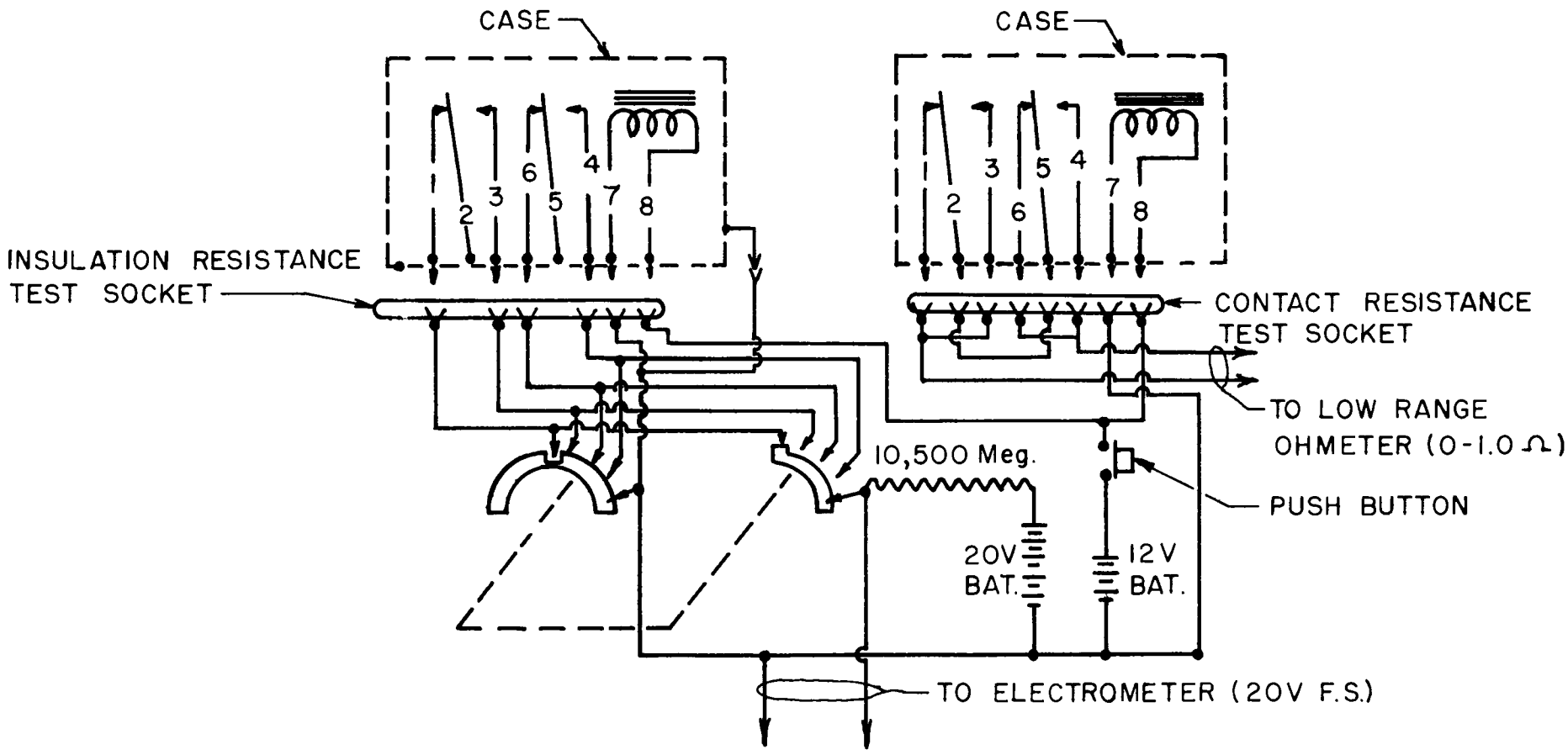

FIGURE 1. RELAY TEST CIRCUIT.

precaution necessary in its construction is the use of a well insulated selector switch and wiring. A ceramic insulated switch and plastic covered wire will do the job nicely.

By checking relays that were removed because of faulty or inaccurage readings it was found that if the insulation resistance at any one point in the relay was below 60,000 megohms it should be discarded. After a large number of rejects had accumulated it was decided to recheck them and the larger percentage of them tested "good". This, of course, pointed to some operating condition as being the cause of failure; naturally, the first thought was of operating temperature. This was checked and found to be approximately 35° C. Then all the rejects were heated in an electric oven to about 40° C. and again they all tested "bad". Naturally at this point all relays were suspected as being temperature sensitive so a number of new, unused ones were heated to about 40° C. and about 50 per cent showed an insulation resistance of 40,000 to 50,000 megohms, which was too low to permit their being used.

Up to this time relays from only two different manufacturers had been used which we will call Manufacturer A and Manufacturer B. Both appeared to have about the same temperature-resistance characteristics, and developed about the same percentage of failures in operation, but our stock consisted of a much greater number of those from A than from B. At about this juncture a new type of trouble began to appear which would cause erroneous readings and by test was found not to be due to low relay insulation resistance. Since it appeared only when relays from both A and B were used in the same channel it was evident some form of incompatability existed. Various characteristics of both makes were compared and it developed that there was a marked difference in reaction time, or the time required to operate

the contacts after the operating voltage was applied to the relay operating coil, between the relays from the two different manufacturers. This was because of the difference in coil resistance; B having only about 50 per cent of that of A. This was not thought of at first since both were supposed to have the same electrical characteristics and to be interchangeable. Relay response or reaction time is an important factor in Baird direct reader operation, since split-second sequential operation is absolutely necessary between certain points in the capacitor circuit. The two different types could be used simultaneously if properly placed as to circuit position, but to simplify things, since only a few of type B were on hand, they were discarded.

To some it might seem that such exacting requirements and hair-splitting accuracy are unnecessary; however, the following are some of the reasons why they are important in our application of the Baird system. Light intensities in our work are often very low and a charge of only a very few volts will be stored in the capacitor; it must be accumulated, the capacitor reversed every second, then switched to the measure circuit, all without loss or extraneous build-up if accurate readings are to be obtained. The most common trouble maker is leakage to ground in the capacitor circuit which usually is found in the contact insulators or lead insulation in one or more of the relays. Figure 2 shows the construction details of the relay type used.

Another frequently observed cause of error is a rapid change of capacitor voltage at the exact instant of the operation of some one or more of the relays in the capacitor circuit. This is usually caused by low insulation resistance between the high side of the relay operating coil and one or more of the relay contacts, and results from the inductive "kick" of the coil. Despite the fact

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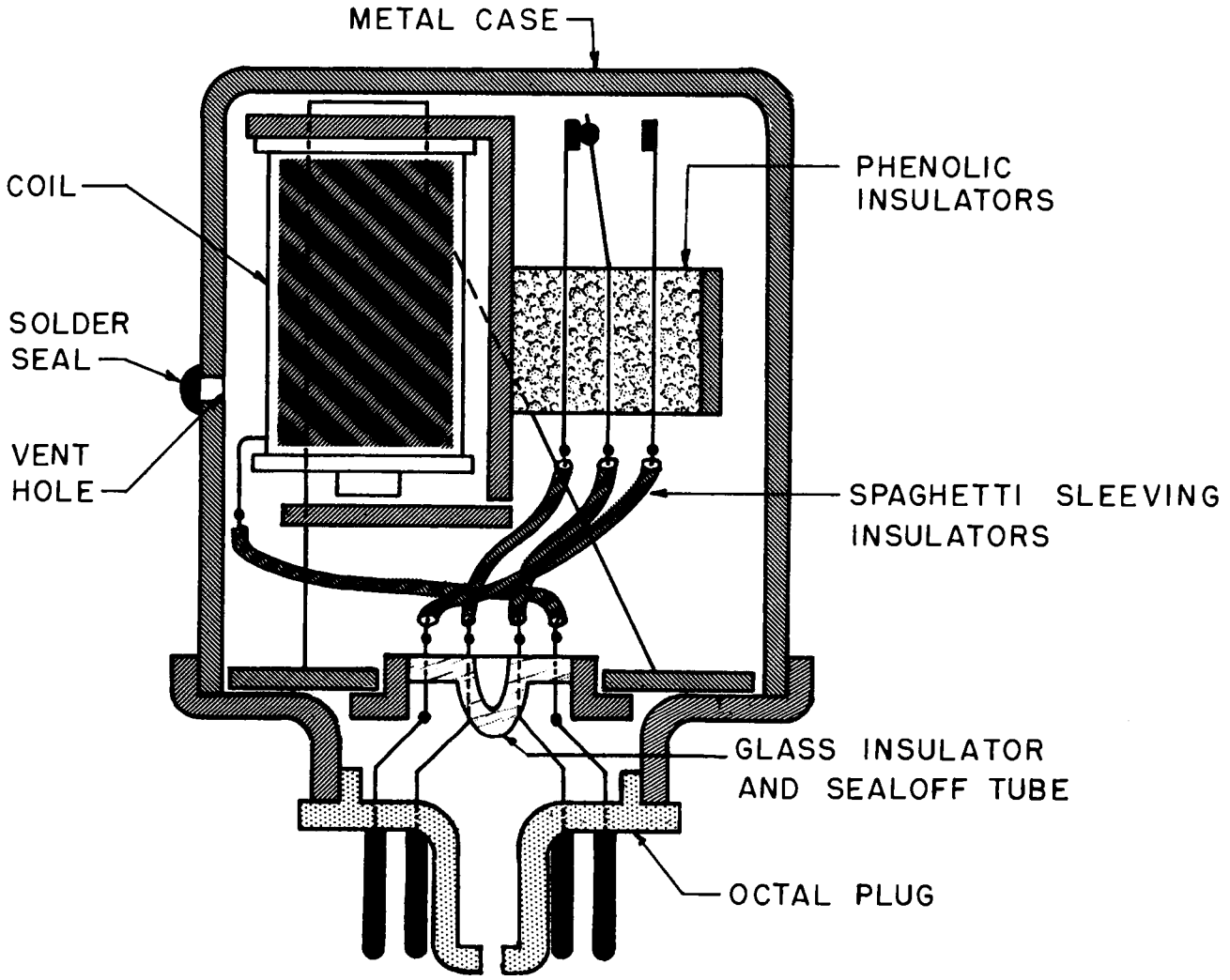

FIGURE 2. RELAY CROSS SECTION

that the coil operating voltage is 12 to 15 volts the "kick" when the coil circuit is broken has been observed to reach a surge value greater than 200 volts. This surge may either be aiding or opposing to the stored capacitor charge, depending on conditions existing at that particular instant, often changing the value of the capacitor voltage ten per cent or more. The least frequent cause of inaccurate readings was improper sequential relay operation which in one case observed resulted in the standard capacitor being connected in series aiding with the standard cell for a split second resulting in a small change in capacitor voltage before the measure cycle began. This was caused by having relays of different coil resistance values in the same channel, or a weakening of a relay spring, either of which changed the relay response time. It is quite obvious that other types of relay failure, either singly or in combination, could cause trouble, but these listed are the most commonly observed, and will serve to illustrate the need for strict testing and evaluating procedure where relays are to be employed in similar applications.

Due to the high relay failure rate, the cost, and the amount of time required to obtain new replacements of the necessary quality, it became necessary to attempt to reclaim a few of our rejects, if possible, to insure continuous operation. The results of the attempt were very gratifying and it is felt that the procedures followed and the information and results obtained will doubtless be of considerable value to others who are faced with similar difficulties. Each step in the procedure is described sequentially as carried out and results noted. It will be seen that some of the individual steps produced no justifiable results except to disprove some one theory as to probable contributing causes of relay failure.

First in order, each relay was heated to 70° C. in a thermostatically controlled electric oven, and insulation resistance noted. Then while still hot the solder seal, Figure 2, was melted and the relay enclosure evacuated for one hour or more, reheated to 70° C. and the resistance checked again. A special clamp fitting was designed, Figure 3, to facilitate connection to the vacuum system. A few of the relays showed an appreciable improvement in resistance after evacuation.

The next step was to inject a wash liquid into the case, shake it violently, and then pump it out. Liquids used were alcohol, carbon tetrachloride, and chloroform. Inspection after dismantling showed that chloroform dissolved the insulating varnish on the operating coil and left it distributed in a gummy deposit over the entire assembly so its use was discontinued. Washing with the other two liquids showed negligible improvement. Always after each operation the relays were evacuated, reheated, tested, and results tabulated. Another operation was to unsolder and remove the relay cover and wash the entire internal assembly with either alcohol, or carbon tetrachloride, reheating to 70° C. until thoroughly dry, and rechecking resistance as before. (Extreme care should be exercised in applying heat to unsolder cover as the glass-to-metal seal may be damaged preventing resealing hermetically.)

Two other operations proved about equally effective in restoring the necessary insulation resistance, so were performed alternately in sequence in an effort to ascertain which was more effective in producing the desired results. They were (1) removing spaghetti tubing on lead wires from contacts to glass seal, and (2) removing phenolic contact separator-insulators, boiling them in paraffine and

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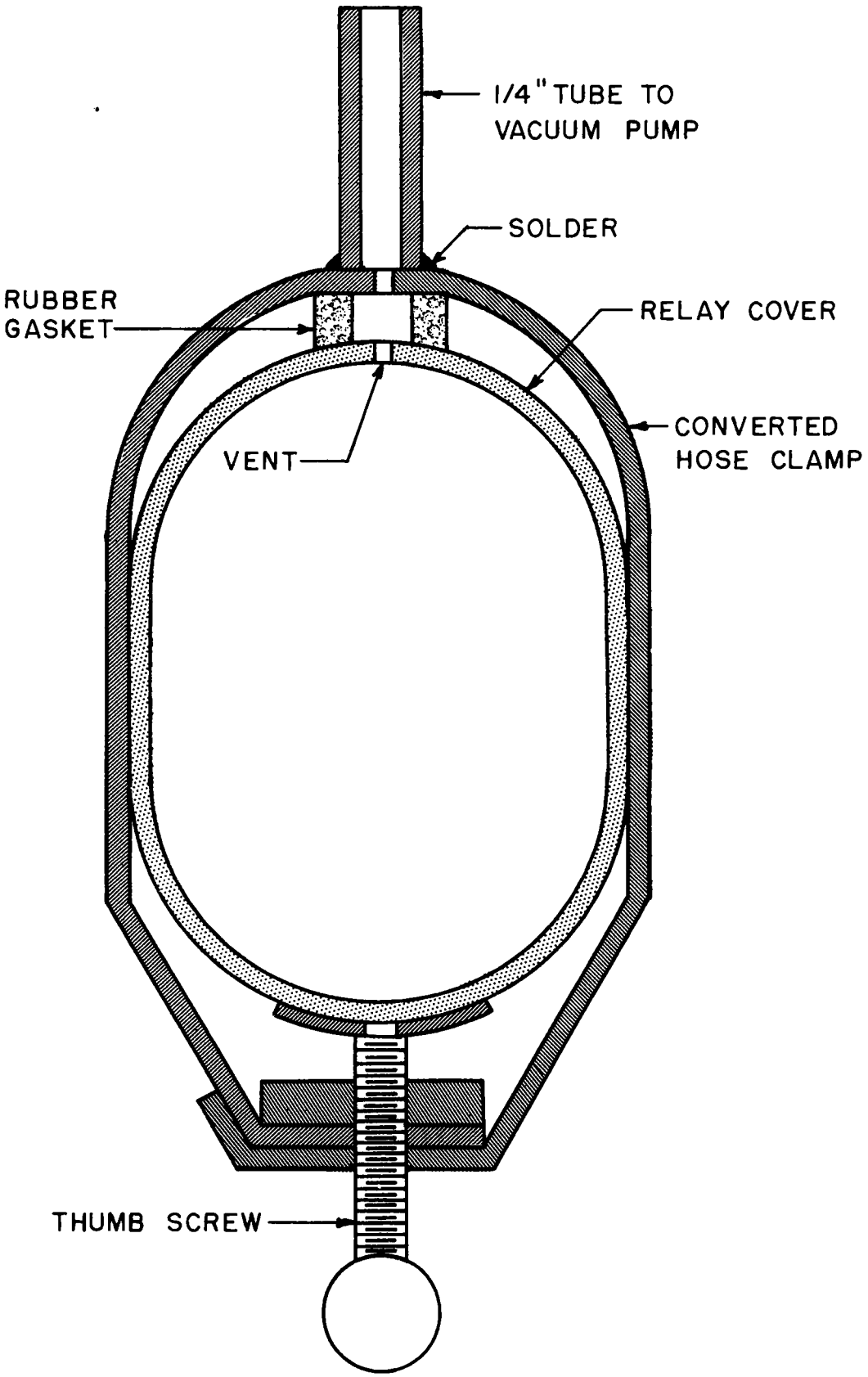

FIGURE 3. CLAMP VACUUM FITTING

reassembling. Both appeared about equally effective and in most cases both were required to obtain the necessary high insulation resistance.

After running the gamut outlined above and passing the final test the relays were returned to our service stock under a number of different conditions. Some were hermetically sealed, others not, while some were filled with different gases at atmospheric pressure. Since none of them have shown any change in insulation resistance since being returned to service it is very evident that they are better than when purchased. Until there are failures, if any, no conclusions can be drawn as to the effects of the atmosphere in which they operate, except, of course, that an unsealed relay operating in a humid or corrosive atmosphere would naturally be expected to develop leakages very quickly.

Table I shows the sequence of service operations performed, and resulting insulation resistance after each operation. The values given in the table are the minimum resistances between any two points in the relay at the time of checking.

Very recently 21 new relays were obtained from a third manufacturer which are exact replacements electrically of type "A", but of slightly different physical construction, as seen externally. The internal construction is not known as there has been no occasion to remove the cover from any of them. They were all heated to 70° C. and tested when received. They all tested 95,000 megohms or over while hot, but have not as yet been placed in service so no information as to how they will stand up in operation will be available for some time.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance of Mr. G. K. Werner in the development of the relay tester.

TABLE I

INSULATION RESISTANCE AT 70° C.

Relay No.	Initial	After Each Operation in Sequence							
		1		2		3		4	
		OP.*	Resistance	OP.	Resistance	OP.	Resistance	OP.	Resistance
14	10,500 Meg.	a	15,750 Meg.	f	20,000 Meg.	e	200,000 Meg.		
23	24,000 "	a	24,000 "	f	50,000 "	e	199,000 "		
21	3,000 "	a	3,000 "	b	3,000 "	f	3,000 "	e	199,500 Meg.
9	10,000 "	a	10,000 "	b	10,000 "	e	199,500 "		
16	3,000 "	a	3,000 "	c	3,000 "	f	30,000 "	e	199,000 "
29	30,000 "	a	19,000 "	d	59,000 "	b	199,000 "		
32	550 OHM	a	3,300 "	c	5,600 "	f	95,000 "	e	199,500 "
15	10,500 Meg.	a	19,000 "	c	7,000 "	d	2,000 "	c	190,000 "
13	1,400 "	a	9,000 "	f	60,000 "	e	200,000 "		
36	24,000 "	a	31,000 "	e	50,000 "	f	200,000 "		
17	4,000 "	a	7,000 "	c	12,000 "	f	140,000 "	e	199,500 "
20	1,400 "	a	6,000 "	f	31,000 "	e	200,000 "		
5	500 OHM	a	4,000 "	c	19,500 "	e	24,500 "	f	200,000 "
37	1,100 Meg.	a	5,000 "	c	10,500 "	f	200,000 "		
38	24,000 "	a	50,000 "	f	199,000 "				
39	24,000 "	b	30,000 "	c	30,000 "	f	199,000 "		
35	400 OHM	a	50,000 "	f	94,000 "	e	200,000 "		
4	300 "	a	5,000 "	f	60,000 "	e	190,000 "		

* OP. (Operation)
- a = Evacuate
- b = Internal wash - alcohol
- c = Internal wash - carbon tetrachloride
- d = Internal wash - chloroform
- e = Remove phenolic insulators and boil in paraffine
- f = Remove spaghetti sleeving