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EPOXY RESIN CASTING OF DRY-TYPE HIGH-VOLTAGE TRANSFORMERS, BUSHINGS, AND POTHEADS

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Epoxy resins have been used in the indoor components to be described for several reasons. First in importance is the elimination of any air inclusions, which if present would lead to destructive corona. Secondly, the physical size of the units has been greatly reduced in proportion to their voltage-handling capabilities. Thirdly, the necessity for an insulating oil has been eliminated.

It will be noted that the height-to-diameter ratio of these epoxy units has been kept near unity. This has been impractical with ceramics, because of the limitation that thick sections cannot be cast in one piece.

In all epoxy units a buried ground electrode has been used to control the distribution of the surface gradient. (The epoxies have excellent properties of adhesion to metals.) The buried ground electrode cannot be incorporated in ceramic castings, owing to the high firing temperature. Figure 1 illustrates typical ceramic use of the buried ground electrode. This current transformer requires the use of three pieces of ceramic. A unit like this can be made in one pour of epoxy resin.

Attention is called to the fact that although there is only 2-5/8 inches separation between the high-voltage and ground electrodes, the current transformer in Fig. 1 has a flashover voltage of 65 kv rms 60 cycle. Yet a bushing was subsequently designed with only 1-3/4 inches' clearance between the electrodes. The design was accomplished through use of a field-plotting board to ascertain the correct flux distribution.

The field-plotting board makes use of conducting paper with a resistance of about 5000 ohms per square. The entire board is covered with one sheet of paper, which in the portions representing the air dielectric is equivalent to a dielectric constant of unity. The epoxy portion, which may be

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to some convenient scale, is represented by several thicknesses of the same paper. If the dielectric constant of the epoxy is 6, then five additional layers of paper are tacked down on the large sheet. A cross-sectional representation of the metallic portions of the assembly is painted on the conducting paper with a conducting silver paint. This paint has a resistivity of less than 3 ohms per square, and this can be made still less by the application of several coats. A voltage of 3 volts 60 cycles is applied between the simulated high-voltage and ground electrodes with a precision potentiometer in parallel. A vacuum-tube voltmeter is connected between the swinger of the potentiometer and a probe that is placed in contact with the conducting paper. The potentiometer is set to some ratio and the probe is moved around over the paper to find the null point. With this method the equipotential lines are plotted, usually in 10 per cent steps. (A photograph of a full-scale plot is shown in Fig. 7.) The epoxy and metallic dimensions are adjusted to give a uniform gradient along the surface where the epoxy will be in contact with the air. Figure 2-A shows the desired gradient distribution.

When the desired shape has been determined and a mold has been prepared, the epoxy is mixed with hardener and filler and is vacuum pumped before it is poured into the mold. After it is poured into the mold, the mix is again vacuum pumped to remove all included air and moisture. The mold is coated with a release agent, which also imparts a high-gloss finish to the epoxy.

The earlier epoxy units used no filling material, and were of an amber color with some transparency. This transparency was helpful in locating flaws or cracks. The material used at present has an added filler of glass beads 20 to 70 microns in size, and is opaque. It has a dielectric constant of 6, whereas the unfilled type had a dielectric constant of 4.

Figure 3 shows the various fabrication stages of a secondary coil for a filament transformer to be operated at high voltage. The diameter of the inner hole is 3 inches and is ample for the primary and core. The secondary coil consists of 10 turns of No. 10 B and S enamel wire and is rated at 5 volts 30 amperes 60 cycles. The surface of the epoxy surrounding the coil is painted with a conducting silver paint, which has good adherence and leaves no air voids. The silver is copper plated to give mechanical protection and to lower the resistance. This copper-plated shield is connected to ground, and being a short-circuited turn is slit as shown in Fig. 3-I. In the pilot model, the coil leads were brought out through a simple neck 3.5 inches long, similar to Fig. 3-E.

This unit was tested at 100kv d-c with no breakdown, but displayed surface corona streamers at 18kv rms 60 cycle. The neck was lengthened to 5 inches with little improvement. A plot of the surface gradient for this simple neck is shown in Fig. 2-B. This curve shows that 55 per cent of the surface gradient occurs on the first 10 per cent of the length and that the upper half has only 7 per cent of the total gradient. This latter condition indicates that there is almost no potential difference along this surface and that the neck could be shortened with little difference in the final result. The neck was turned down and two metal rings were installed as shown in Fig. 3-F. The upper ring is connected to one coil lead, and the lower ring is extended downward to the grounded metal. These two rings were then imbedded as shown and the casting was turned into a spherical shape. The unit now was tested, and flashover occurred at 100kv rms 60 cycles. Flashover occurs along and close to the curved surface, sometimes marking up the Epon surface. A plot of the surface gradient is shown in Fig. 2-C.

Later designs described here do not have the epoxy surface follow along a sparkover flux line. This secondary was tested at normal current, with 60kv rms 60 cycles between the winding and ground, for a period of 110 hours with no ill effects. Other secondary coils of the same physical size have been made with a 5-volt 70-ampere rating and a 115-volt 4.5-ampere rating. These units have the primary on another leg of the core. The 115-volt winding was enclosed in an inner electrostatic shield which was brought out coaxially around the coil leads.

Another approach to the high-voltage dry-type transformer is made through the use of a mica-insulated, vacuum-impregnated transformer, potted in asphalt and with the high-voltage leads brought through the tank cover by means of an epoxy bushing. The development of this bushing started by suspending a metal "hat" as shown in Fig. 4-B, three inches above a ground plate. Various configurations were tried until one was found that just sparked over at 100kv rms 60 cycle. This shape was then put on the plotting board and the epoxy size as well as the placement of the buried ground shield adjusted until a good surface-gradient distribution was obtained. The final curve is shown in Fig. 2-D. Figure 4 shows the mold, metal parts, and a finished bushing. This bushing flashes over at 100kv rms 60 cycle, and along a flux line which is about 3/4 inch from the epoxy surface at the 50 per cent point. These bushings are made in one pour in the inverted position. The overpour is lathe-turned off and the lower metal ring is swaged on the central metal tube. Transformer leads are carried through the metal tube, with a metallic connection at the top between the "hat" and one of the coil leads.

Figure 5 shows this 100-kv bushing with a scaled-down 75-kv model and a scaled-down 62-kv model. A scaled-up 150-kv model is now in process.

Coaxial cables of the x-ray and RG types are capable of withstanding high voltages, but the termination is always the weak place. The buried ground shield technique has been used by piling up a tape ball, carrying the shield out on the ball by means of foil, and then piling on more tape. The epoxy type termination for an RG 19/U cable is shown in Fig. 6. This unit is slipped over the end of the cable and the shield is carried off on the tapered extension. A Zerk fitting is provided, and silicone grease is forced into the small void between the cable and the epoxy and ground support. This unit is operating at 235 kv d-c.

A full-scale plot on a 500-kv cable pothead is shown in Fig. 7. The metal parts are shown in Fig. 8 and the completed bushing in Fig. 9.

The diameter of the epoxy at the center is 12 inches, and the unit was made in five pours. The center metal mold rod has not been completely removed in these photos, being left in for handling and shipping purposes. No voltage breakdown test has been made on this pothead. Two of these units are now being installed.

CONCLUSION

The epoxy units that have been described have been used on electrical equipment to supply power to particle accelerators. Some of the applications appear at first to be of a d-c nature, but owing to the sparking nature of the accelerator loads, require an a-c design. Other units which appear at first to be in d-c application, such as voltage-doubler filament transformers, have to be designed for a-c service.

Plotting on the plane surface of the field-plotting board appears to be inexact, but the results obtained indicate that this method is sufficiently accurate for the purpose.

This work was performed under the auspices of the U. S. Atomic Energy Commission.

REFERENCES

Epoxy Resin Casting of Dry Type Current Transformers, W. C. Farneth and George Gallousis, AIEE Power Apparatus and Systems, April 1955, p. 194.

Theory of Dielectrics, Schwaiger and Sorensen. John Wiley and Sons, 1932.

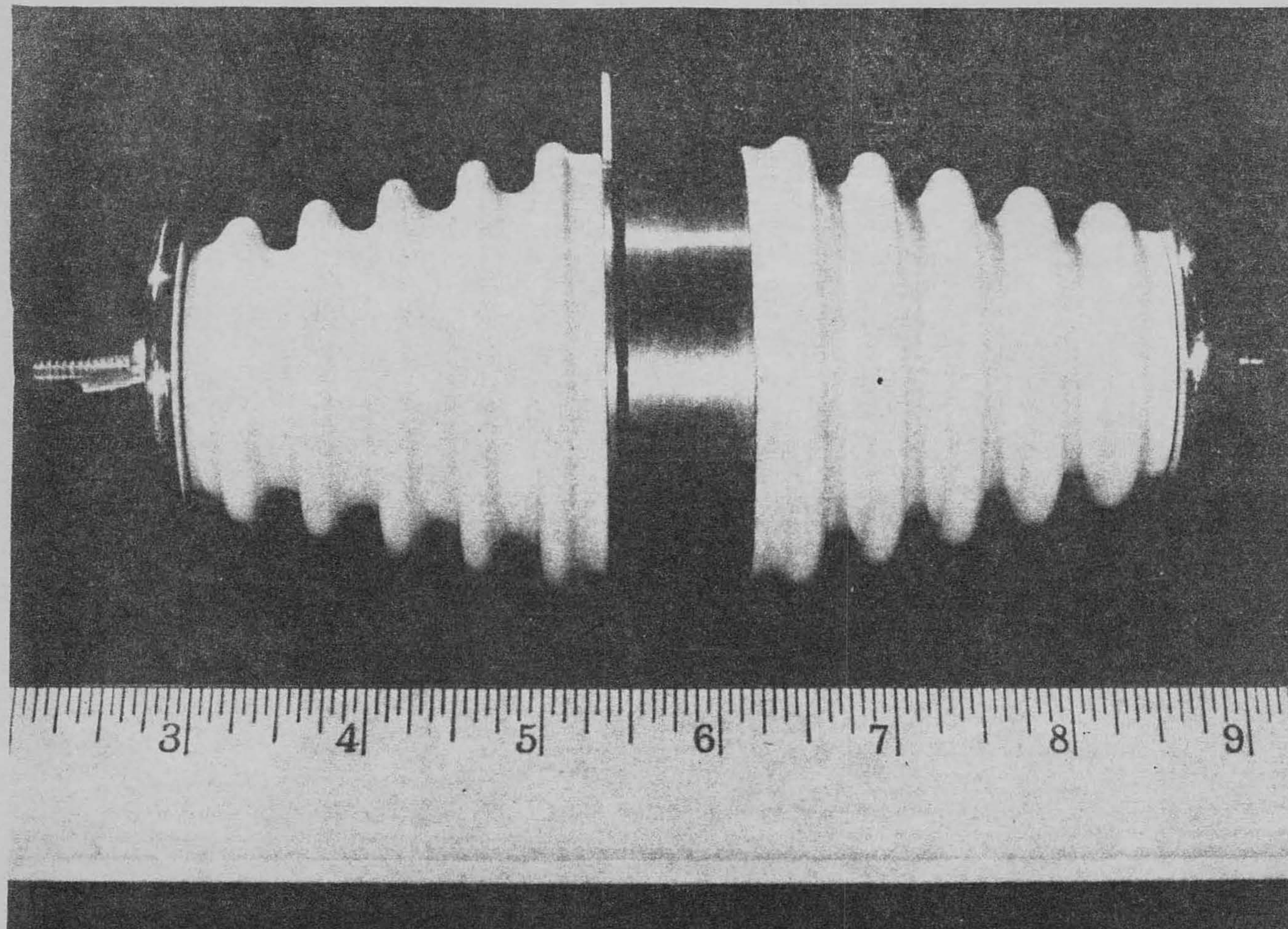

Fig. 1. Current transformer (flashover 65 kv rms 60 cycle); this typical use of buried ground electrode requires three pieces of ceramic, whereas a similar unit can be made in one pour of epoxy resin.

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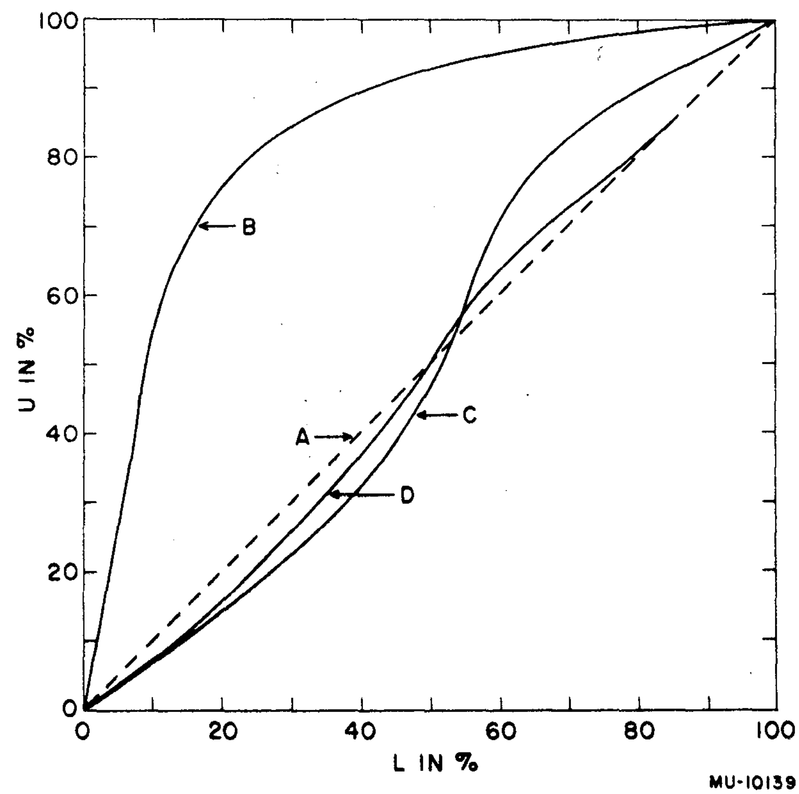

Fig. 2. Gradient distributions for various components; A shows a desirably uniform gradient; B indicates that the component should be reshaped.

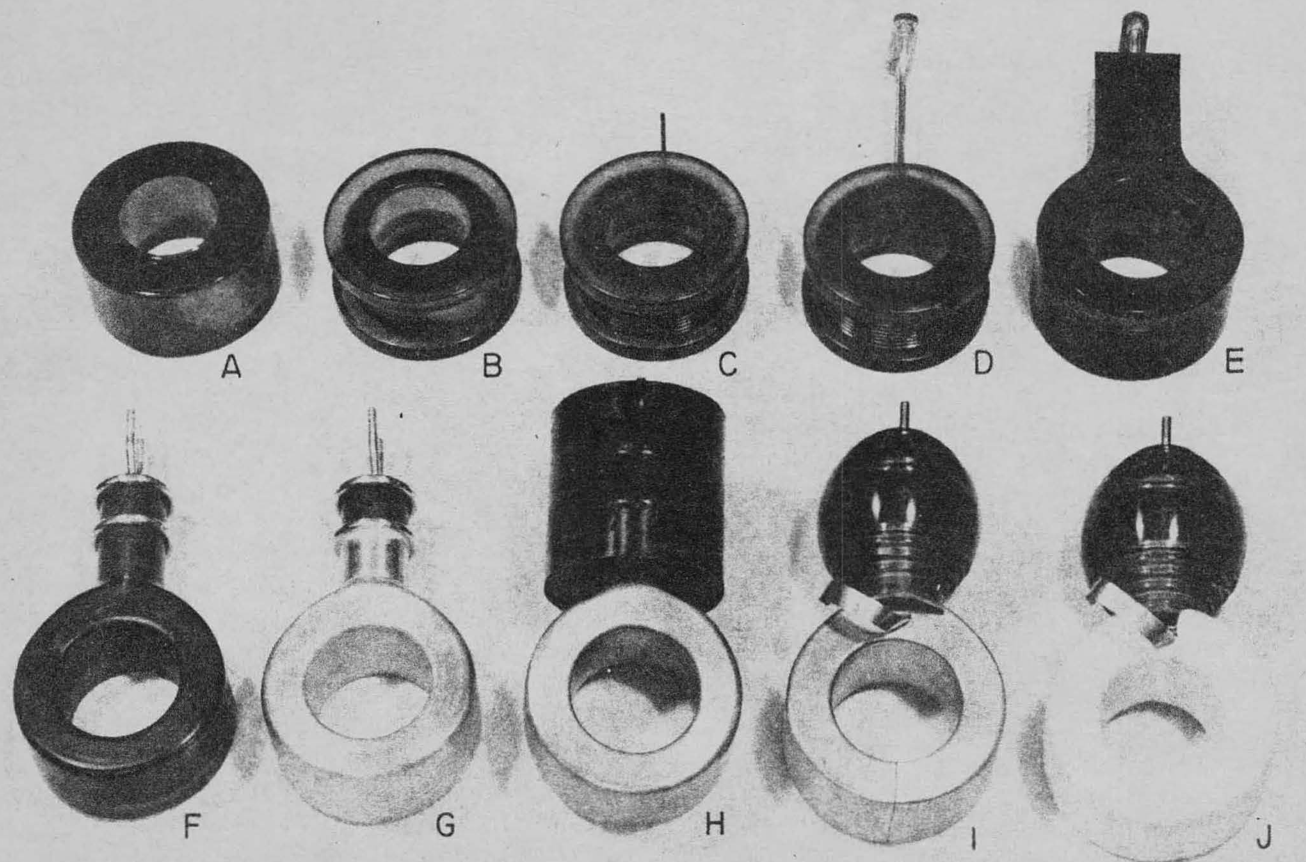

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Fig. 3. Stages in fabrication of secondary for a filament transformer for high-voltage operation.

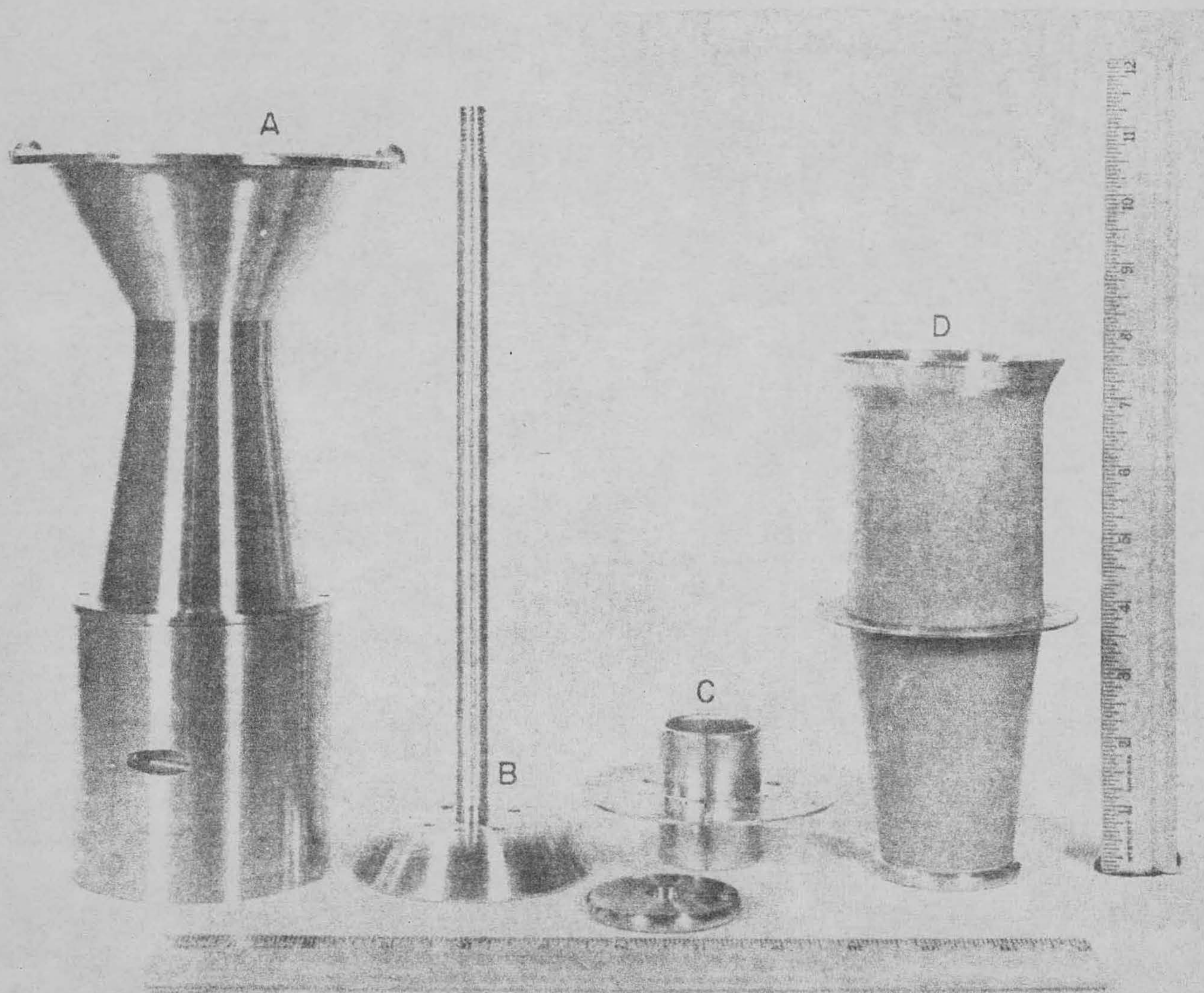

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Fig. 4. Mold, metal parts, and a finished bushing made in one pour of epoxy resin.

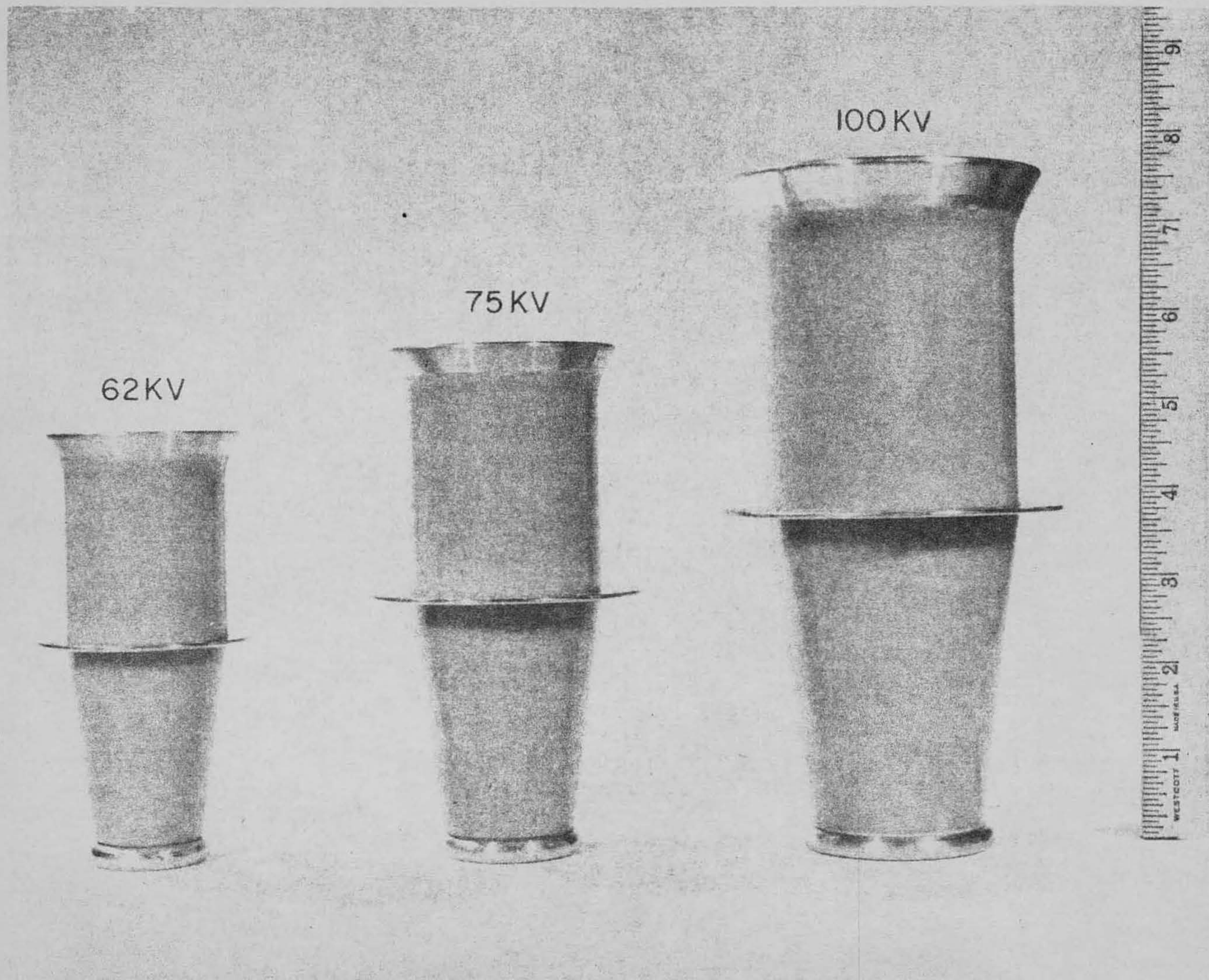

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Fig. 5. Bushings for transformer leads with 62-kv, 75-kv, and 100-kv flashover.

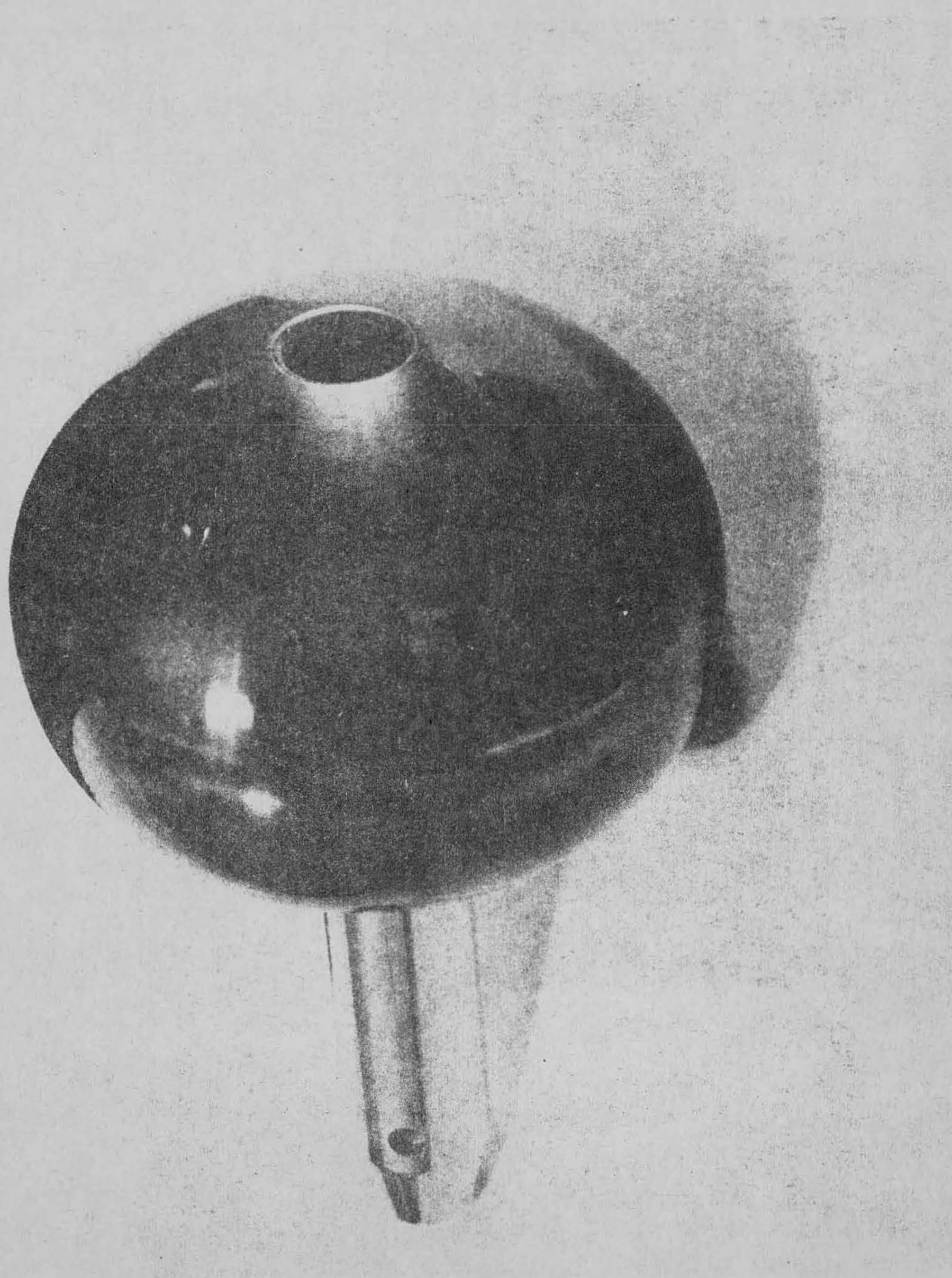

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Fig. 6. Epoxy type termination for RG 19/U cable.

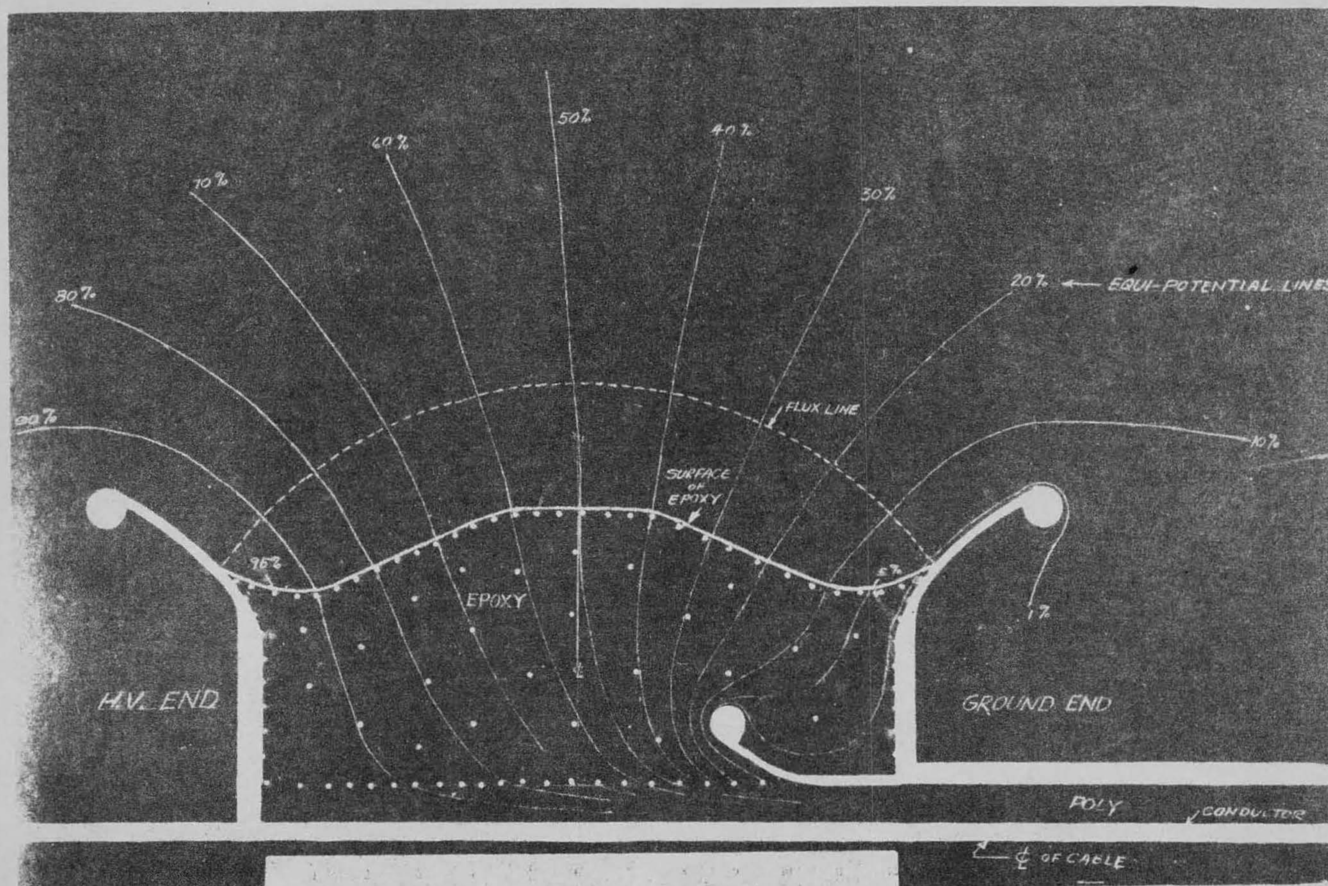

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Fig. 7. Illustrating use of a field-plotting board for determining optimum shape of epoxy portion of cable pothead shown in Fig. 9.

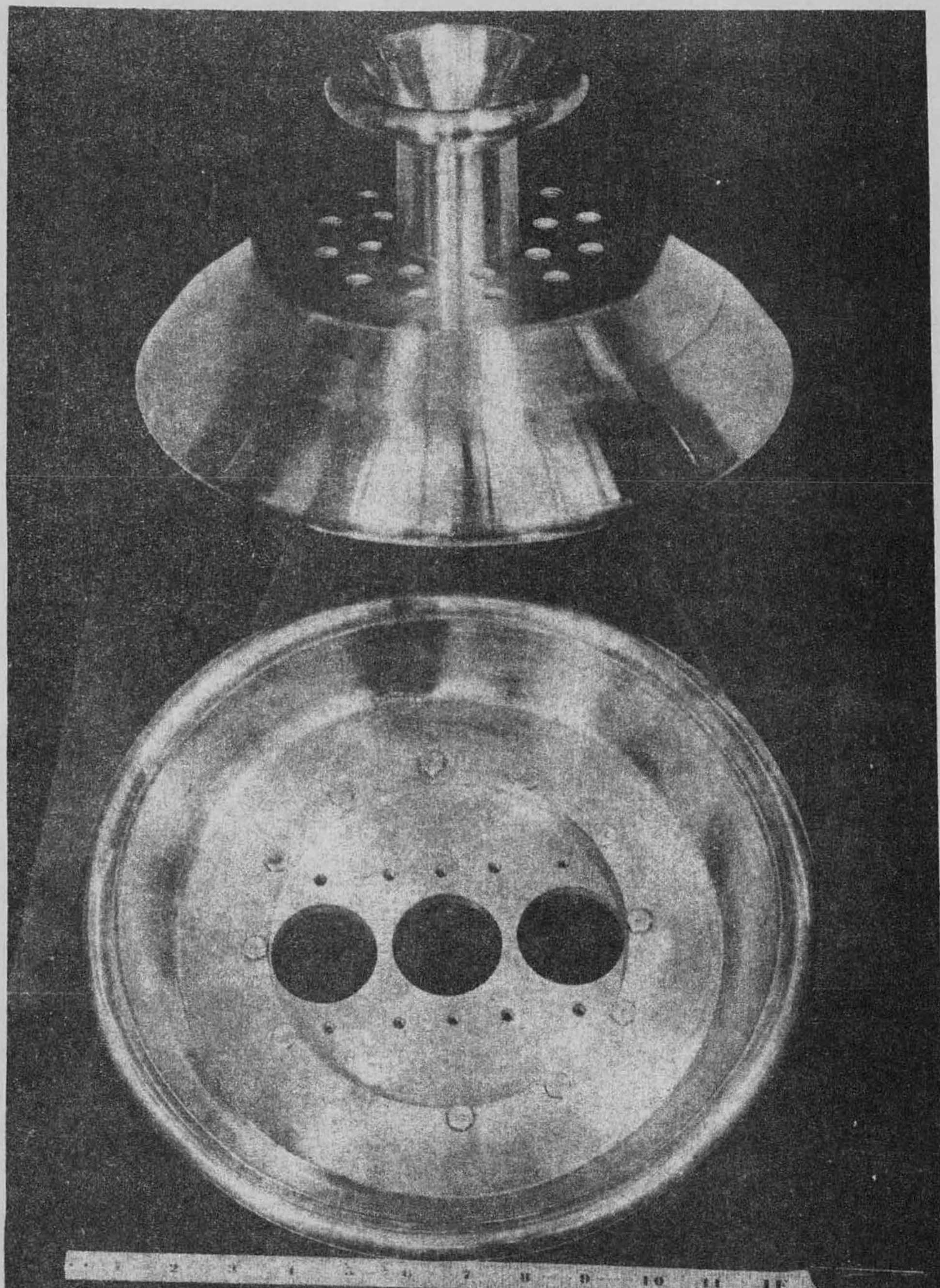

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Fig. 8. Metal parts for cable pothead shown in Fig. 9.

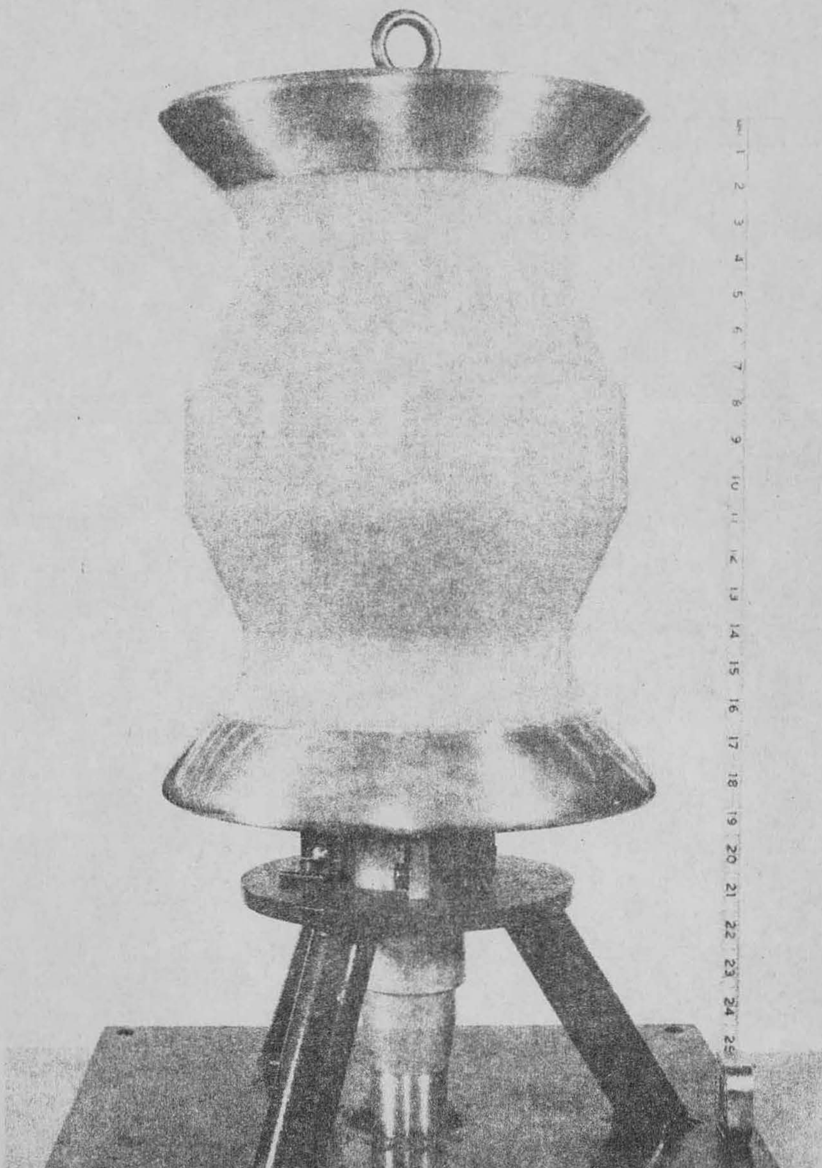

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Fig. 9. Completed bushing for cable pothead.