Smaller and Better Condensers

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Telephone Apparatus Development

BECAUSE of their widespread employment in radio receivers during the last decade, condensers—formerly rather mysterious scientific toys to the man in the street—are now familiar pieces of apparatus. Long before the advent of radio broadcasting, however, they had lost all appearance of mystery to the telephone engineer, and had become commonplace elements of communication systems. They are, as a matter of fact, widely used in almost all electrical fields. From large power distribution systems, where they may be used for power factor improvement, to automobile ignition systems, their peculiar characteristics find useful application, but from the standpoint of quantity used the telephone industry probably ranks first. Not only are they required at all of the nineteen million subscribers' stations but in even greater quantity they find use in every central office of the country. Although for their varied uses they are made of a number of combinations of materials, condensers for most uses in the telephone plant consist of alternate layers of paper and metal foil rolled together.

In partial contrast to the American production slogan of "bigger and better," the objective of condenser development for telephone use has been "smaller and better." At subscribers' stations smallness is obviously desirable. The less bulky the subset, or bell-box as it is popularly called, the more readily can it be mounted in some inconspicuous location. In central offices, space—although perhaps not so obviously—is also of great importance. It is desirable to mount condensers along with relays and other apparatus, which places certain preferred limits to their length and width, and because of the very large

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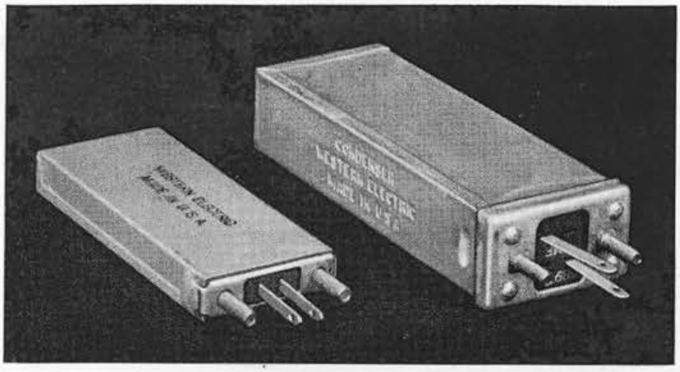

Fig. 1—The 141-A condenser has less than 1/3 the volume of its predecessor of the same capacity

numbers of them used, reductions in thickness also become of considerable value.

Size, however, is not the only consideration. Permanence of rating and reliability are of even greater importance. Although for all purposes it is desirable that there be no radical change in the capacity of a condenser with the passing of time, for certain purposes it is essential that it remain accurately constant. In addition to its ability to maintain a constant capacity, a condenser should not break down under possible abnormal voltages, nor lose its high resistance in the presence of unusual moisture. In efforts to obtain reduction in size these other characteristics, therefore, can never be entirely lost sight of.

Since the beginning of the telephone industry considerable reduction in size and improvement in quality has been obtained. By 1924 the commonly used 1 microfarad condenser was housed in a container only 4½ inches long by about 1⅝ inches wide and one inch thick—which seemed a very satisfactory attainment. The urge of "smaller and better" continued, however, and recent development work, both by the Laboratories and by the Western Electric Company, has reduced the 1 microfarad condenser to less than ⅓ of its 1924 size. Fundamental studies of the materials used leading to progressive improvement in their characteristics, with improved manufacturing methods superimposed, have been responsible for the achievement.

Two sheets of conducting material, separated by an insulating medium, form the essential elements of a condenser. The common practice for telephone condensers has been to use paper for the insulating medium, which allows multiple layers of foil and insulation to be built up to give comparatively large capacity with small bulk. A metal container is used to protect the condenser unit from mechanical damage.

Capacity is a function of the area of the conducting sheets and of the

Fig. 2—Two sheets of paper between adjacent layers of aluminum foil form the elements of a telephone condenser

thickness and nature of the insulating material. This nature of the material is measured by its dielectric constant, and capacity varies directly with dielectric constant and area, and inversely with distance of separation. To decrease size, therefore, it is necessary either to decrease the thickness of the insulation or to increase its dielectric constant, or both.

If a condenser were built up solely of tin foil and paper, the actual insulating material would be partly paper and partly air since the paper itself includes air and in addition there are interstices between the layers of paper and foil which also contain air. The effective dielectric constant of the insulating medium of a wound paper condenser is small due to the large effect of the air present. To raise this constant it has been customary to impregnate the condenser unit with a substance having a higher dielectric constant than air. Until recently paraffin has been used for this purpose. The decrease in size has thus required a double development: an improvement in paper to permit thinner insulation, and an improvement of the impregnating substance to increase the effective dielectric constant.

The search for a thinner paper runs back over a number of years. The best paper obtainable in this country until the last few years has been .5 mil thick (1 mil = .001 inch). It was possible to obtain .4 mil paper abroad but a local source is desirable for an assured supply. To secure a satisfactory supply of .4 mil paper in this country has required sustained cooperation with the paper manufacturers. The procedure has been to authorize a definite number of condensers to be made up from some specified paper, and then to test the product under service conditions. As a result of a long sequence of such trials, interspersed with recommendations to the paper manufacturers, an assured and adequate source of paper of .4 mil thickness has finally been obtained. With the attainment of this objective one of the essential factors of reduction in size of the condenser was gained.

Efforts to obtain an impregnating compound which gives a higher effective dielectric constant in the finished condenser have also been carried on for a considerable period. Some years ago a material became available which seemed very promising. It was a chlorinated naphthalene known commercially as halowax. As then produced, however, it had certain undesirable ingredients, and only after many years of development have manufacturing methods been improved sufficiently to yield a product which warrants commercial use in condensers.

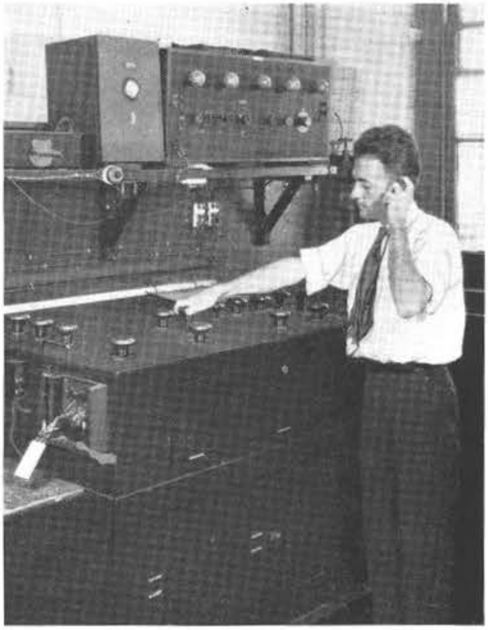

Fig. 3—J. A. Kater making a capacity measurement on a 141-A condenser

Even with a satisfactory .4 mil paper and an improved impregnating compound the entire gain would not have been possible without improved manufacturing methods. The actual process consists in rolling two sheets of tin foil and four of paper so that the completed unit will have two layers of paper between adjacent sheets of tin foil. After the winding step the unit is pressed into a compact shape, thoroughly dried in vacuum ovens, and then—while still in a high vacuum—is impregnated with the halowax. Following this the unit is pressed to the required size, which forces out all excess wax, and the soldering lugs are fastened to the metal contact strips that, at the beginning of winding, were laid in contact with the sheets of tin foil. The unit is then ready for potting in the rectangular tin plate containers. These are partially filled with a sealing compound which, when the condenser units are inserted, completely fills the container and seals the condenser against all entrance of moisture.

Manufacturing methods for all these steps have been improved by the Western Electric Company and have contributed no small share to the great overall improvement. Another change has been the substitution of aluminum foil for tin. This does not decrease the size—the tendency is slightly in the opposite direction—but it does reduce the cost.

These new designs and manufacturing methods have been approved only after thorough trials. From the results of an extensive field survey of atmospheric conditions in a number of cities, accelerated laboratory tests were devised which simulated from fifteen to twenty years of actual service. In carrying out these tests large numbers of condensers were subjected over considerable periods of time to severe conditions of continuously applied voltage, high humidity, high temperature, and of mechanical abuse. Also before final approval was given, several trial lots of many thousand condensers were made up by actual manufacturing methods and tried under operating conditions. The new condensers are now being placed in service, and are not only smaller than the old but are expected to bring about appreciable savings in initial cost.

The Morris Liebmann Memorial Prize has been awarded by the Institute of Radio Engineers to

Edwin Bruce

"for his theoretical investigations and field developments in the domain of directive antennas."