The GENERAL RADIO

EXPERIMENTER

ELECTRICAL MEASUREMENTS TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

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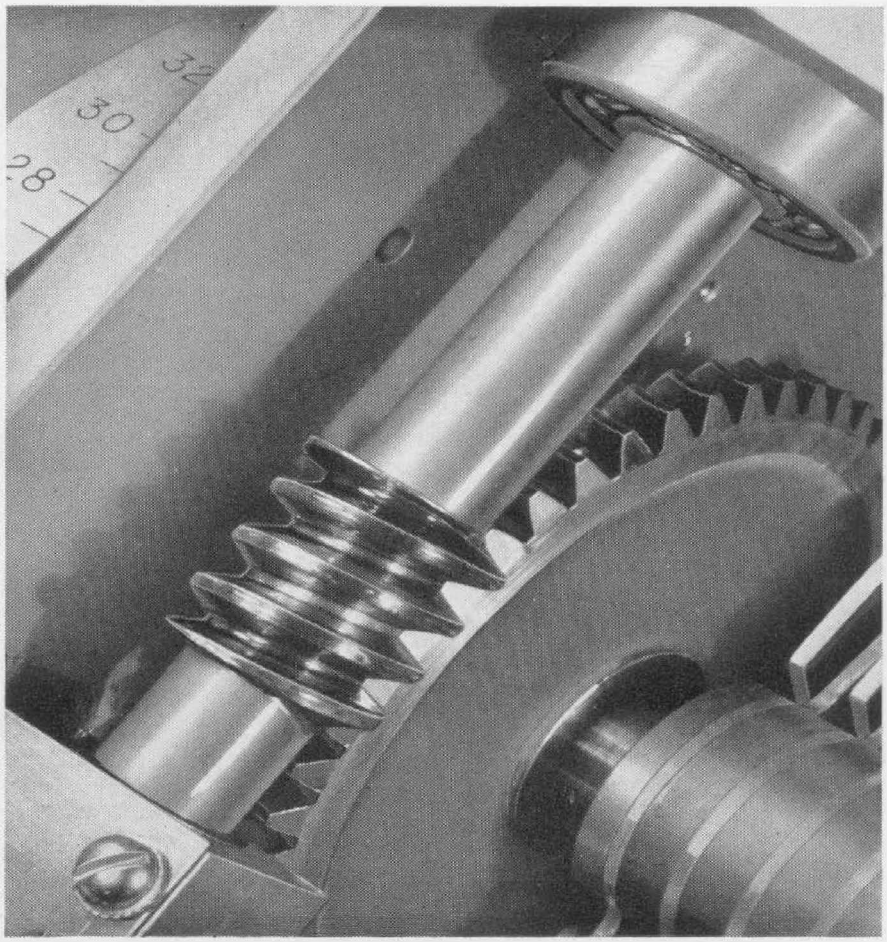
BUILDING PRECISION INTO AN AIR CONDENSER

● IN TECHNICAL FIELDS, universal acceptance for a product does not depend on ballyhoo, but can result only from recognized excellence. This quality has made General Radio precision condensers the standard of capacitance for the electrical-communications industry.

The life span of the well-known TYPE 222 Precision Condenser (1919-1936) is traceable directly to the excellence of the original design plus a full utilization of advances in materials and manufacturing methods. A good condenser in 1919 because it was well ahead of current practice, it was still a good condenser in 1936 because it had kept abreast of advances in the art. The end of research and experience, however, is not to carry this process to the point of putting V-8 motors under Model-T hoods, but to point the way through better fundamental design to better products. Hence the TYPE 722*, a better precision condenser than the best 222.

*A New Precision Condenser, *Experimenter*, Vol. X, No. 8, January, 1936.



ALSO IN THIS ISSUE:

A Diatonic Scale Disc

Price Change — Type 732-A Distortion and Noise Meter

FIGURE 1. Panel view of TYPE 722-D Precision Condenser

Design is the medium of the engineer. Materials and men produce the finished instrument. The engineer's story has already been told.* Here we present briefly the manufacturing side.

MATERIALS

Choice of materials is a function of the designer, their fabrication a matter of manufacturing. Any modern product, whether a laboratory instrument or a typewriter, is made up of a surprising variety of raw materials. The TYPE 722 Precision Condenser appears at a glance to be an aluminum condenser in a wood cabinet, and indeed these are the two major constituents. In all, however, a dozen different materials are used, the proportions of the major ones being shown in Figure 2. These materials are made into over eighty *different* parts, ranging from a casting weighing 1¾ pounds to a tiny phosphor bronze spring weighing a small fraction of an ounce.

MEN AND TOOLS

The precision condenser appears to be, and is, a simple instrument, but the manufacturing, although not complicated, embraces a wide variety of operations. Fabrication of the metal alone into parts involves some forty operations performed by thirty-two men. A single workman assembles the parts into the finished instrument. Most of these operations are carried on in our own plant. A few, however, are more conveniently done outside.

Although materials and men produce the finished condenser, tools play an important part. Specially-designed jigs, dies, and forming tools are used, as well as the standard types used on lathes and milling machines. The variable air condenser is an electrical device, but the manufacturing operations which produce it are entirely mechanical. All factors affecting its stability and, in fact, all its characteristics except accuracy of calibration depend solely on mechanical considerations. Because of this, manufacturing tolerances are extremely important.

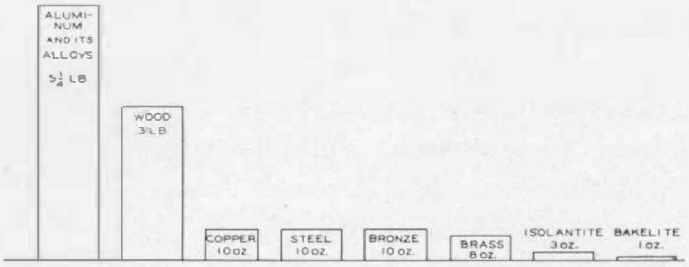


FIGURE 2. Approximate proportions of materials used in a TYPE 722-F Precision Condenser

TOLERANCES

Probably the most important of the desirable characteristics of a precision condenser are linearity, stability, and reset accuracy. Linearity of capacitance with scale setting depends on the shape and alignment of the plates, stability and reset accuracy upon freedom from both backlash and eccentricity in the moving parts. All three are a function of manufacturing tolerances. Backlash, eccentricity, and lack of alignment are matters of degree

*A New Precision Condenser, *Experimenter*, Vol. X, No. 8, January, 1936.

only, and the precision with which parts are machined to a given set of dimensions determines whether or not their magnitude is sufficient to be detected.

The accuracy with which many of the parts are machined is of the order of a few ten-thousandths of an inch. The main rotor shaft, for instance, is held to a radial tolerance of ± 0.0005 inch; its bearing surfaces to 0.0002 inch. The worm shaft, on which the worm is cut directly, has a tolerance of 0.0004 inch. The radial eccentricity of the gear is held to less than 0.002 inch. Accurate alignment of the moving parts is assured by machining and drilling the cast frame in a box jig. Even the dials receive individual attention. The main drum-type dial is engraved on a pantograph engraving machine, while the worm dial, the accuracy of which directly affects the linearity of the condenser, is engraved on a circular dividing engine to insure uniformity of its divisions.

A uniform calibration curve for the condenser requires accurate parallelism of both rotor and stator plates. These plates are stamped from full-hard aluminum and are carefully inspected for flatness and uniformity of thickness. Spacers must be cut to within 0.00025 inch.

ASSEMBLY

Care in assembly is fully as important as precision machining. No amount of precise specifications and workmanship in parts manufacture can compensate for faulty assembly. Production-line methods are not suitable; each condenser is individually assembled and adjusted by skillful, experienced workmen.

A preliminary assembly of the frame, shafts, and gears is driven by a motor for twenty minutes with the gears filled with grinding compound, after which these parts are thoroughly washed in gasoline to remove all traces of abrasive.

The stator unit is assembled in the casting with fixtures designed to preserve the parallelism of stator rods and rotor shaft Each air gap is then measured and individual plates are straight-

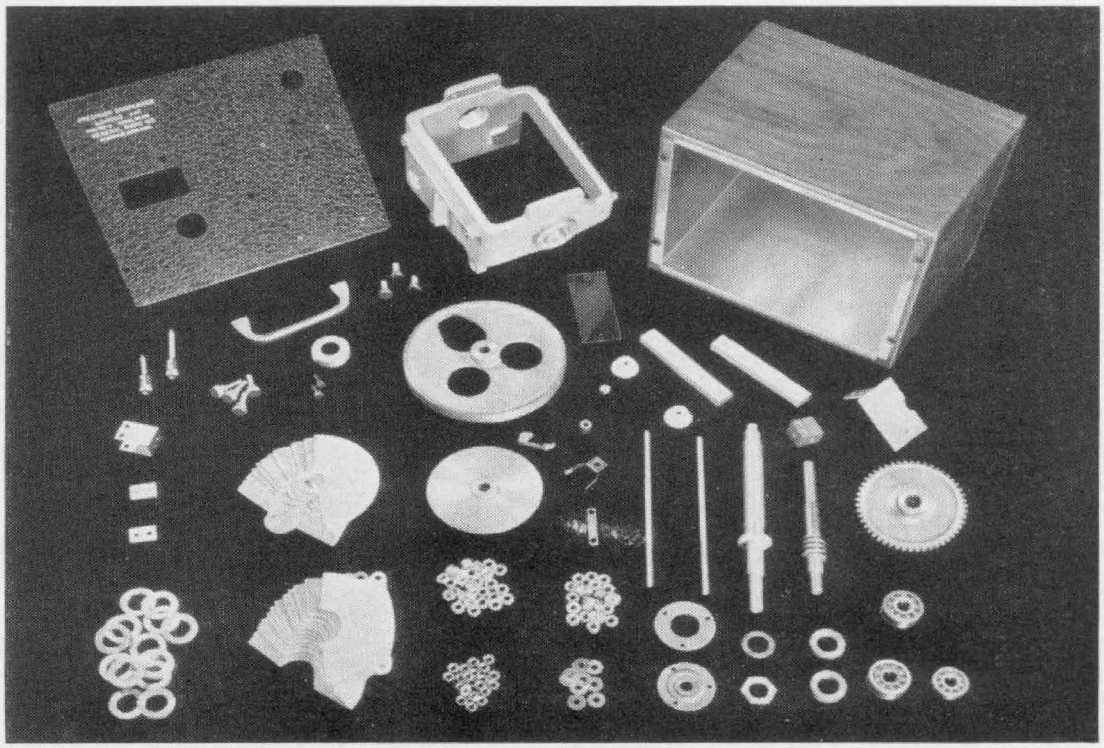


FIGURE 3. Major parts of a TYPE 722-F Precision Condenser

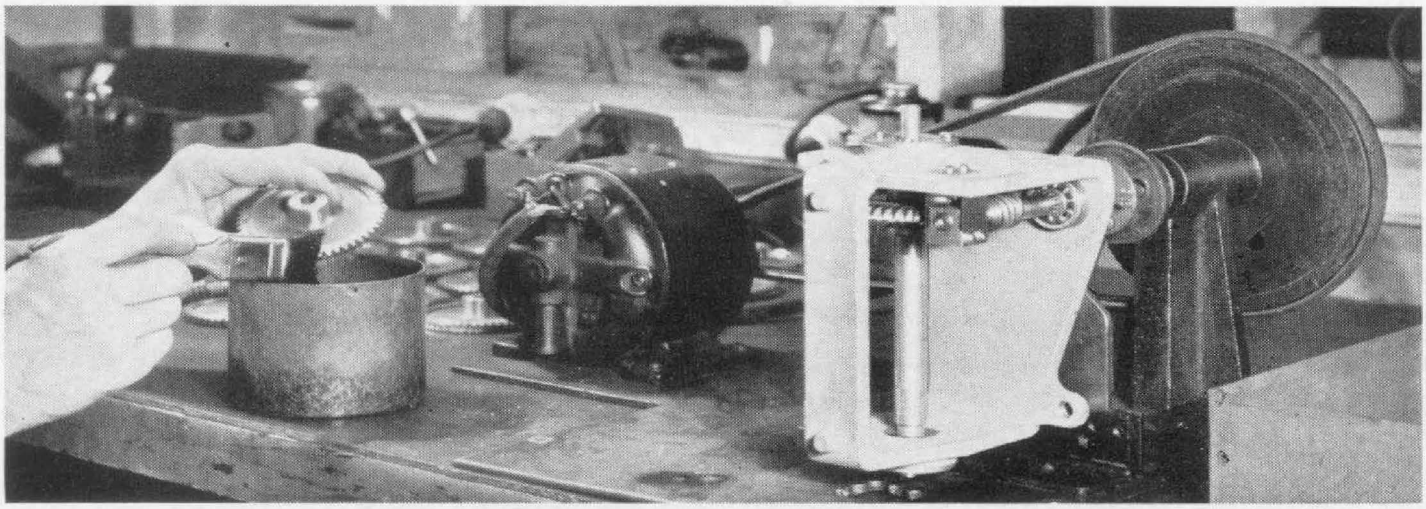


FIGURE 4. At the right is shown the motor-driven assembly for "wearing-in" the worm and gear. After this is finished, the gears must be washed in gasoline, as shown at the left, to remove the fine particles of grinding compound

ened to correct any lack of parallelism which may still exist. Straightening produces strains, and these are removed by a heating process which produces in a few hours the same amount of aging for which years would otherwise be required.

CALIBRATION

Calibration, besides converting a fine mechanical instrument into a usable standard of capacitance, places the seal of approval on all operations thus far performed. A few preliminary measure-

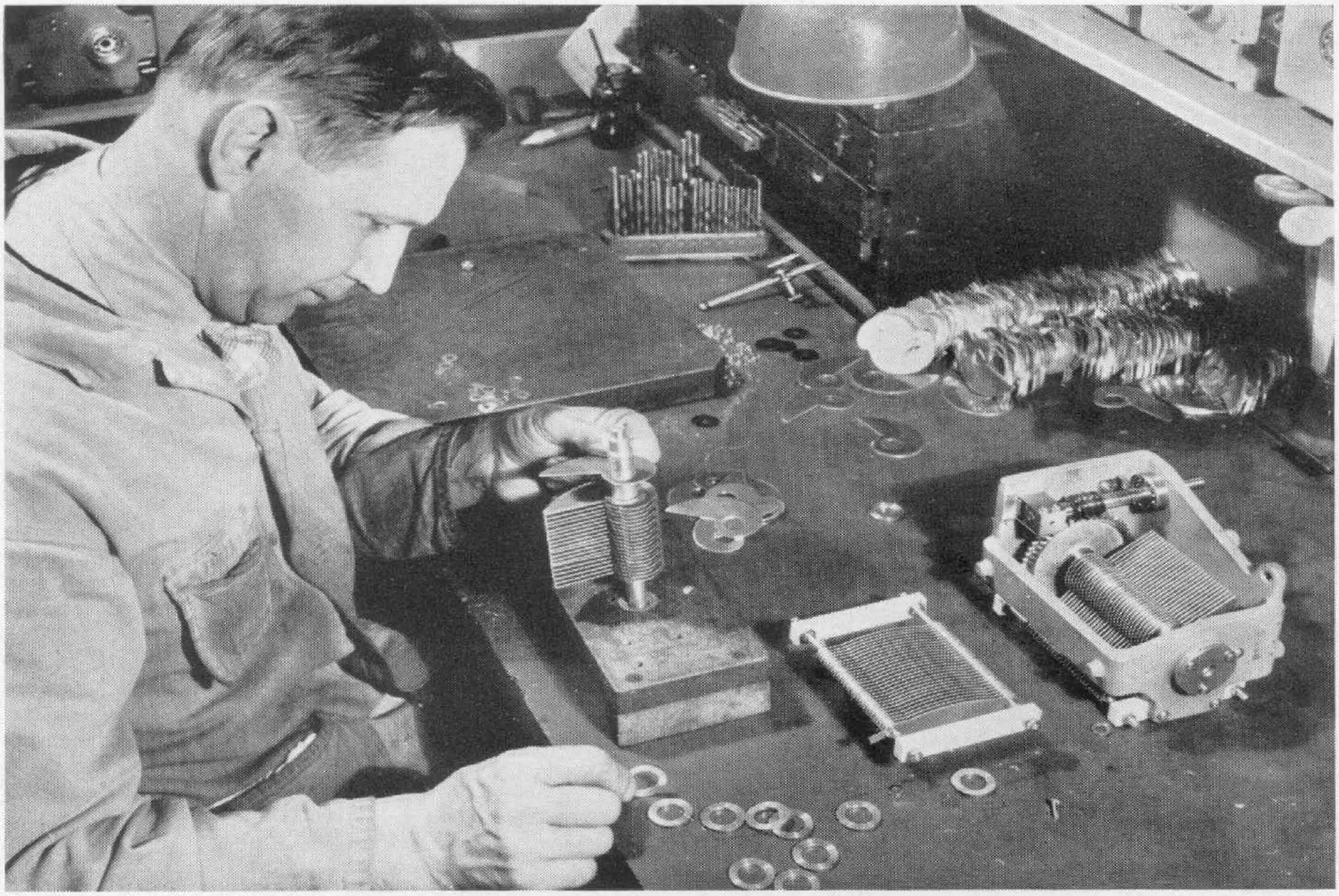


FIGURE 5. Assembling the rotor plates on the shaft. At the right may be seen a stator assembly and a completed condenser

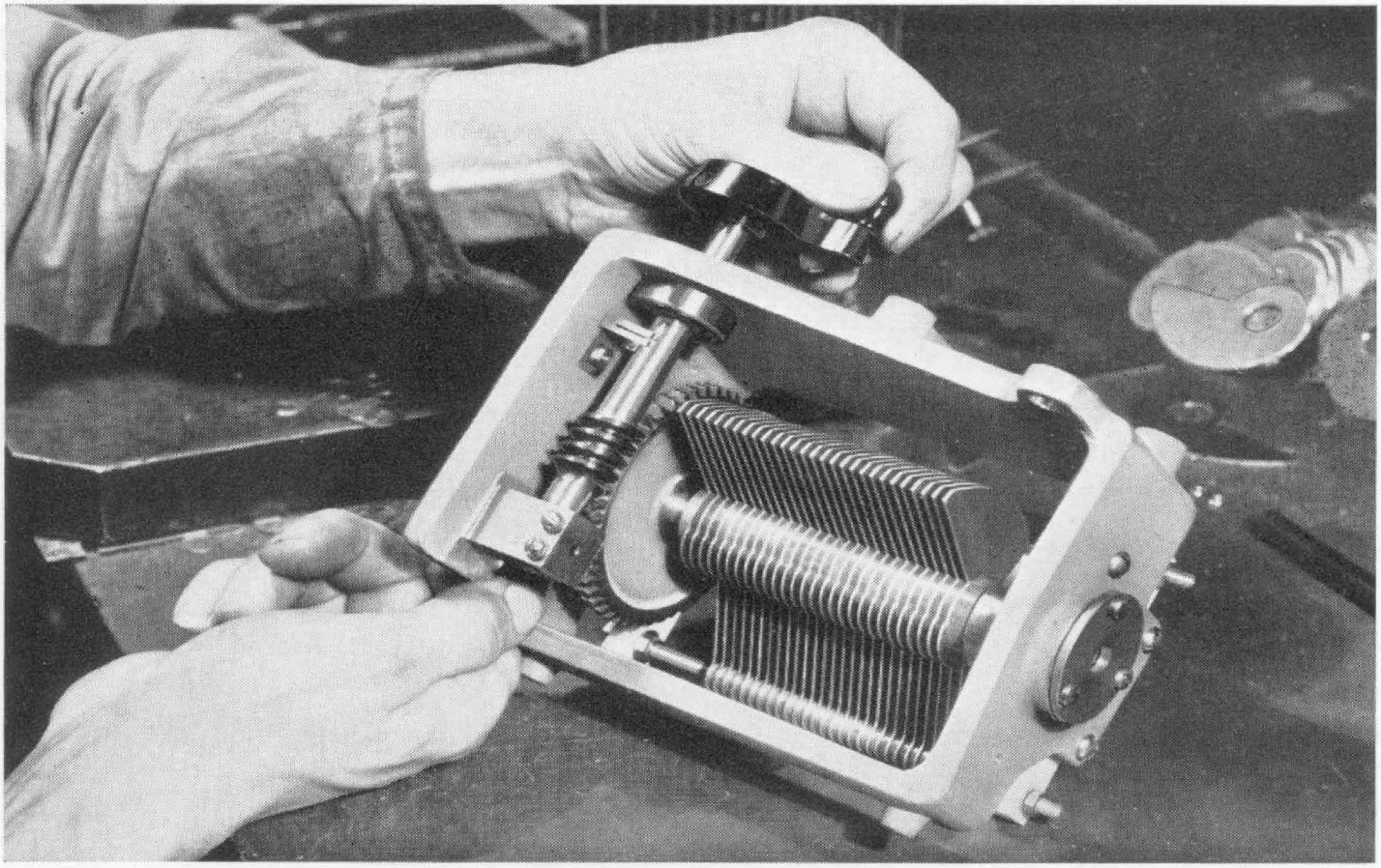


FIGURE 6. Inspecting the assembled condenser for accurate alignment of plates and smooth action of worm drive

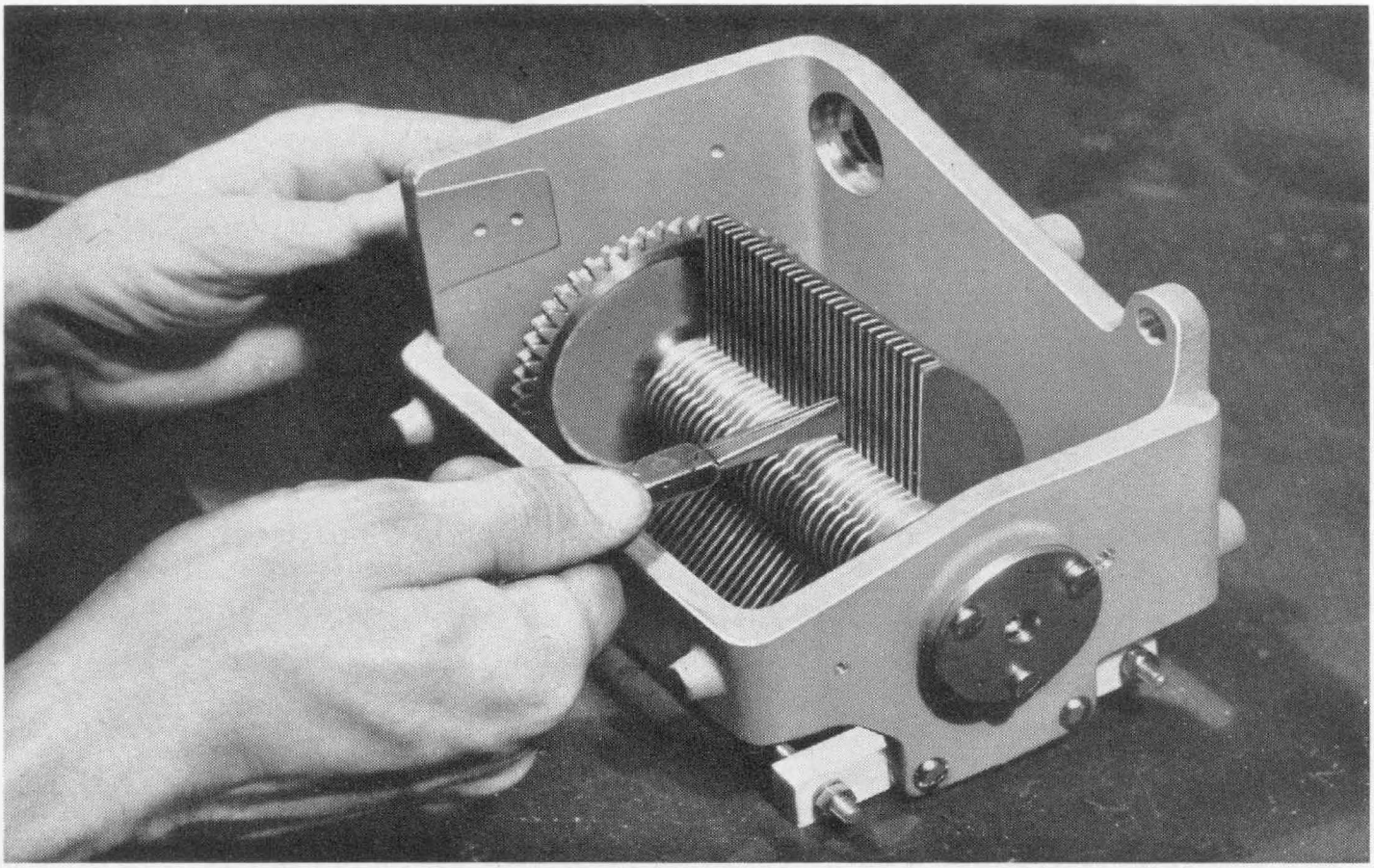


FIGURE 7. Straightening rotor plates after assembly. All plates must be parallel and all air gaps equal

ments serve to show up any lack of plate alignment or faulty manufacture which might exist. A rigid set of specifications must be completely met, or the condenser is rejected.

Calibration for the TYPE 722-F Precision Condenser consists of measurements at each of the main scale divisions. These data are supplied to the customer in the form of a table. TYPES 722-M and 722-D, being direct-reading models, require considerably more attention. Here, compensating plates are adjusted until the scale is direct reading to an accuracy considerably better than that indicated by catalog specifications. Since these adjustments require some bending of the adjusting plates, further heat treatment is necessary.

Each condenser receives at least one additional aging cycle, more if necessary. The criterion of complete aging is that the measured capacitance before and after aging shall be the same within 0.1 $\mu\mu$f.

As in the manufacturing process itself, men plus methods are necessary to produce the desired result. Calibrations are made by trained technicians, many of them engineering graduates. Methods are the result of many years' experience and a careful program of standardization. — C. E. W.

FIGURE 8. Calibrating a TYPE 722-F Precision Condenser

PRICE CHANGE—TYPE 732-A DISTORTION AND NOISE METER

● **EFFECTIVE** March 15, the price of TYPE 732-A Distortion and Noise Meter is $220.00. This makes the price of the complete Class 730-A Transmission Monitoring Assembly $477.00.

A DIATONIC SCALE DISC

● **THE STROBOSCOPIC DISC** shown in the illustration makes it possible to standardize the major tones of the diatonic scale in terms of A440, the pitch which is now accepted as standard. The disc is intended to be rotated at eleven revolutions per second, under which conditions ring A will be stationary when illuminated by a lamp flashing 440 times per second, and the other rings when illuminated at their respective frequencies.

Standardization in terms of any other pitch assigned to A can obviously be accomplished by changing the driving speed by the ratio of the new pitch to 440.

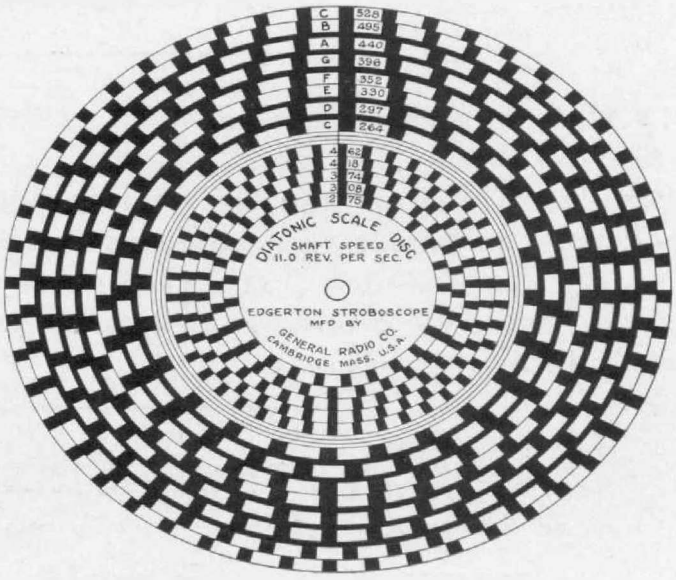
These discs may be found useful for purposes of instruction and demonstration, and we shall be glad to send copies to those interested.

The standard speed can be obtained in a number of ways. For precise standardization, a TYPE 611 Syncro-Clock driven from a 440-cycle standard-frequency source* could be used. A frequency controlled power line and synchronous motor form another possible system. If an 1800 rpm motor is available, it can be fitted with a 30:11 gear train to obtain 11 rps. When using a standard pitch, whether 440 cycles or some other value, the disc can be driven from a variable-speed motor and the speed adjusted until the A ring is stationary.

The disc can be illuminated by means of a neon lamp connected to the output of a vacuum-tube amplifier. A d-c bias on the lamp is usually required to prevent flashing at double frequency. When the pitch to be measured is produced by a musical instrument, a microphone is necessary as well.

In using this disc, it should be remembered that it represents the intervals of the diatonic scale only, and not those of the tempered scale used on a piano. The tones of the latter scale are not integrally related, and cannot, therefore, be standardized on a single speed disc.

* H. W. Lamson, "A Simple and Precise Standard of Musical Pitch," *Journal of the Acoustical Society of America*, Vol. VII, No. 1, July, 1935.



MISCELLANY

● **MR. J. V. ARGYLE,** Technical Representative of the Canadian Marconi Company of Montreal, was a recent visitor at Cambridge. In addition to going over numerous general policy problems, Mr. Argyle discussed various technical points pertaining to our equipment that he thought would be of interest to Canadian customers. The Canadian Marconi Company is the General Radio representative for all Canada and the distribution of our products is one of the special activities of Mr. Argyle's department.

● **OTHER VISITORS** to our plant and laboratories include:

Mr. V. G. Dubenetsky and Mr. Levitin of the Central Industrial Radio Laboratory, Glavesprom, Gorki, U.S.S.R.; Mr. Jyo Yamaguchi, Engineer of the Tokyo Electric Company, Tokyo, Japan; and Mr. W. E. Moser and Mr. Edwards of the Southampton Station of Mackay Radio and Telegraph Company.

● **MR. A. E. THIESSEN** of our engineering staff leaves February 22 for a few weeks on the Pacific Coast. En route he will speak before the Physics Club of Chicago, February 23, on Stroboscopes and their applications. He also plans to present papers before the Los Angeles and San Francisco sections of the Institute of Radio Engineers. While in California, Mr. Thiessen can be reached at our 1050 Howard Street, San Francisco, or 555 So. Flower Street, Los Angeles, offices.

● **DR. W. N. TUTTLE** of our engineering staff, and Chairman of our Development Committee, sailed with Mrs. Tuttle from New York on the *S. S. Europa* on January 22 for a skiing vacation in the Austrian Alps. While on the continent, Dr. Tuttle expects to visit our French representative, Radiophon of Paris, and our Italian representative, Ing. S. Belotti & C. of Milan. Dr. Tuttle is expected to return about the middle of March.

● **A REMINDER** — Post cards to correct the *Experimenter* mailing list were mailed to *Experimenter* readers during the latter part of January. If you haven't filled in your card and mailed it, please do so immediately as the revised list is now being made up from the cards returned.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company name, company address, type of business company is engaged in, and title or position of individual.

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