THE General Radio EXPERIMENTER

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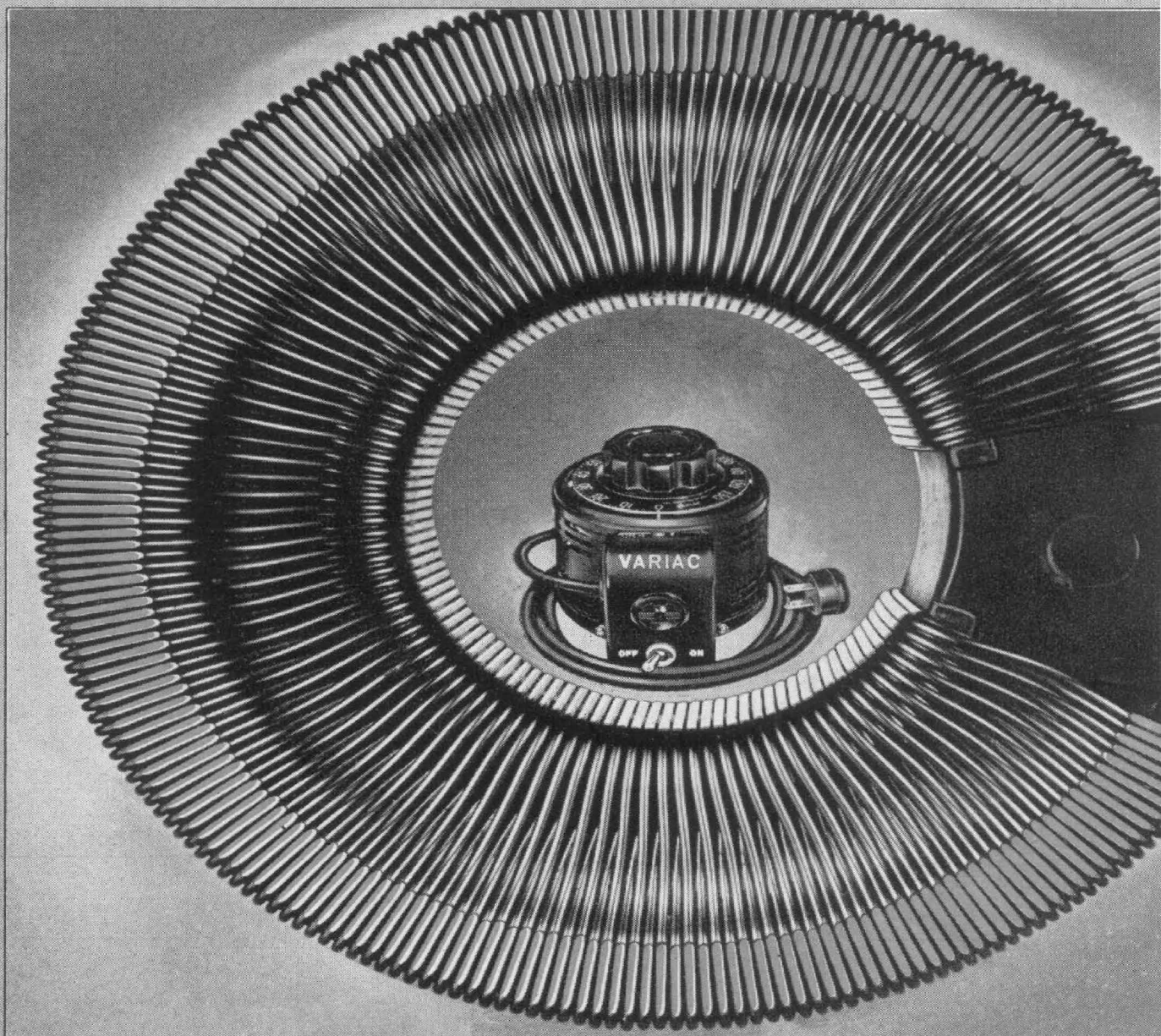
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS®



Duratrak, the new General Radio brush-track surface for VARIAC® autotransformers, is the most important advance since the original development of the variable autotransformer by General Radio twenty years ago. Today's VARIAC® autotransformer truly sets a new standard of reliability for the industry.

A NEW STANDARD OF RELIABILITY IN VARIABLE AUTOTRANSFORMERS VARIAC® WITH DURATRAK

The Variac® continuously adjustable autotransformer was first introduced by General Radio in 1933. It found ready and rapid acceptance as a laboratory instrument for the control of alternating voltages. For a given rating, it was more efficient, less cumbersome, cooler, and had better regulation than resistive controls previously employed for such service.

These same features proved to be equally attractive in the industrial field, and the Variac rapidly moved out of the laboratory and into the industrial plant. This trend was accelerated by the rapid expansion of the electronic and electrical control industries during and after World War II. Off came the "lab" coat and on went the overalls.

This new usage was vastly different from the original laboratory service. Variacs were expected to operate twenty-four hours a day, month after month — in some cases, year in and year out — often at some particular fixed setting. Ratings were pushed to the limit (and often beyond) in ambient temperatures and contaminating atmospheres that could not be tolerated in a laboratory but that are industrial commonplaces. As a result, Variacs were subjected to service conditions far more severe than those for which they were originally designed. The relatively few service failures under these conditions have been a continuing tribute to their inherently conservative design, and the prompt adjustment of these few failures by our Service Department has meant a minimum of inconvenience to our customers.

Service experience over the years has shown that perhaps 99% of the failures that do occur in continuously adjustable autotransformers are caused by overheating at the brush or, more specifically, at the winding underneath the brush, resulting in a cumulative deterioration of the brush track. This field experience checks well with what would be expected from the known design limitations of such devices.

This problem has now been solved as the result of an intensive development program started several years ago. General Radio's new *Duratrak* process makes the Variac as durable as a fixed-ratio transformer.

DESIGN CONSIDERATIONS

A Variac autotransformer is similar to a conventional autotransformer or two-winding power transformer in many respects. It is also similar to a motor in having a carbon brush, and a moving element and commutator. It differs from a motor, however, in two fundamental respects: (1) The brush is often left in a fixed position drawing full current for long periods of time, and (2) Variac brushes operate at current densi-

ALSO IN THIS ISSUE

ties many times those encountered in motor practice due to the dimensional limitations of a commutator formed from the winding itself, the segments of which are spanned by the brush. The heating that occurs at the brush-to-commutator interface is thus localized, whereas in a motor the heat is distributed uniformly about the periphery of the commutator.

This localized heating at the contact is inherent in the device. In fact, control of this heating was the key to making the Variac a practical commercial device. In continuously adjustable autotransformers, the brush makes contact with two or more adjacent turns. There is therefore a circulating current flowing through the brush, in addition to the load current. The problem is to minimize the net power loss by balancing power loss in the short-circuited turn against the power loss due to load current drawn out through the brush.[1] Analysis has shown that the proper design calls for a brush contact drop such that the power dissipated is equal approximately to the full load current multiplied by the volts per turn of the winding.

The actual temperature rise that results from the power dissipation can be reduced by proper radiator design but, because of the relatively low thermal conductivity of carbon materials, only a portion of the generated heat can flow into the radiator and the balance must flow into the copper winding.

Cumulative Deterioration

With proper design of brush and radiator structure, the temperature rise can be held to a reasonable value. Under severe load conditions, however, the exposed copper to which contact is made tends to oxidize if the brush is left at a fixed setting for a long period of time. The oxides of copper have relatively high resistance, and this causes a cumulative heating effect under conditions of fixed load. It is obvious that a potentially destructive cycle exists in this situation. Under certain adverse conditions (high ambient, high load, fixed brush setting, continuous operation, infrequent maintenance), a destructive cycle can be initiated which will ultimately lead to failure.

[1] Karplus and Tuttle, U. S. Patent No. 2,009,013.

Variacs are precision wound on toroidal winders of our own design and manufacture.

The Remedy, Duratrak — an Improved Commutator Surface

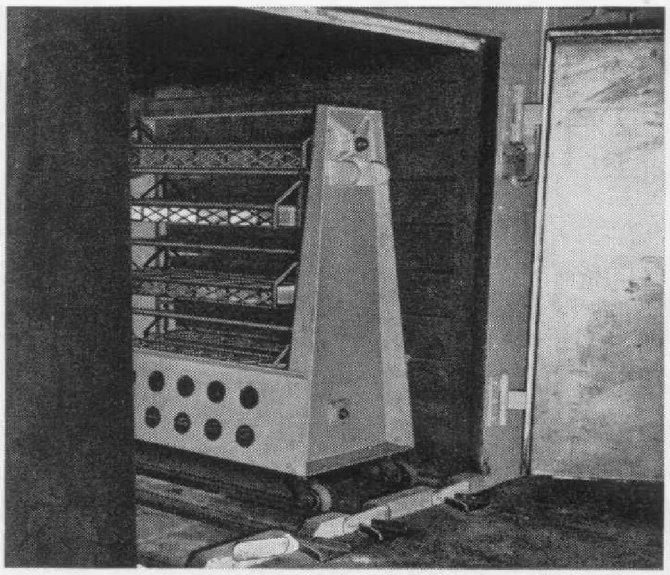
Intensive study of this problem led to the realization that the solution lay in developing a commutator surface whose contact resistance or voltage drop would remain relatively constant in the face of long-time exposures to elevated temperatures. A silver coating is, within the limits of our present knowledge, completely stable, and a method has now been developed of applying it to the brush track. In the course of the experi-

mental work, it was determined that a large number of alloys and noble metals met the requirement of stable contact resistance. It should be noted that the use of silver and precious metal alloy materials in general for electrical contact processes is as old as the electrical art itself. It is important to note, however, that in the usual application these materials are used for an entirely different reason. The usual objective is to obtain a low contact resistance, but in the Variac low resistance is of no help at all — the required resistance is prescribed by minimum loss considerations and must be high enough to limit circulating currents to safe values. A non-deteriorating surface is used to insure that the initial value of voltage drop is maintained even if, under heavy load, the brush is allowed to remain at a fixed setting.

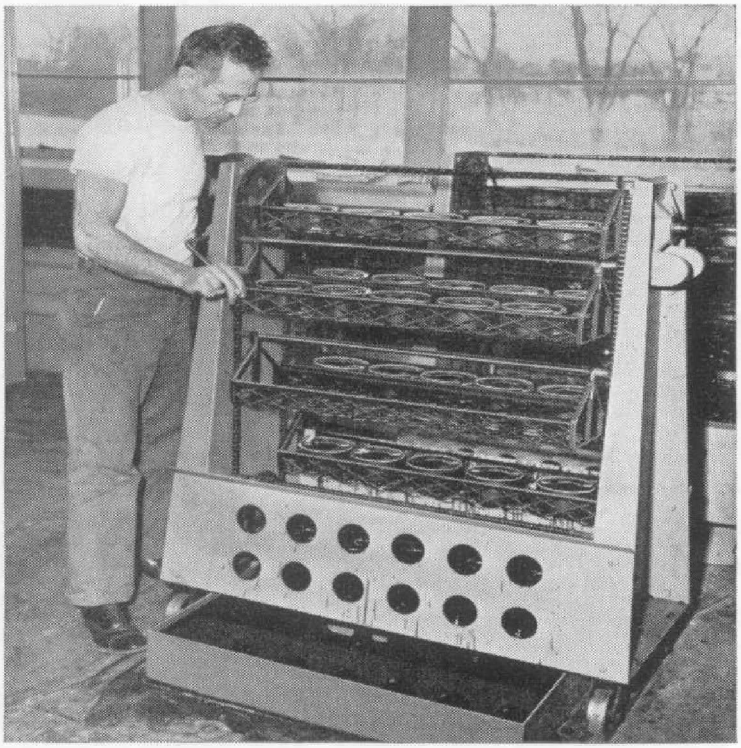
FIELD TESTS

For three years Variacs with the treated track surface have been under extensive and tortuous tests in General Radio laboratories. While controlled laboratory tests are important, every engineer concerned with industrial devices knows that field tests under a wide variety of conditions are even more important. Accordingly, these new Variacs have been extensively field tested in increasing numbers as our confidence in performance and method of manufacture has grown. Field tests have been conducted under conditions of unusually severe service where old-style Variacs had required an exorbitant amount of maintenance or had actually failed.

In contrast, not a single field failure has been reported to date with the several thousand Duratrak units in service.



Rack, with load of Variacs, then goes into an oven to bake the thermosetting varnish.



After winding, Variac coils are dipped in baking varnish in specially designed racks.

Lighting Control

One of the earliest uses of these new Variacs was in the new liners *S. S. Constitution* and *S. S. Independence*. Variacs are used to provide complete and flexible control of the lighting in salons and dining rooms of these luxurious ships. It is obvious that the nature of the service places a high premium on reliability. To

achieve the necessary reliability is particularly difficult because of the conditions of installation and use. High ambient temperature, salt air, enclosed mounting, and a minimum of maintenance combined with fixed settings and the high inrush currents of incandescent lamp loads conspired to make this service about as severe as anything that one would expect to encounter. Yet the installations are functioning satisfactorily after two years.

Laboratory Tests

Under laboratory test, the performance of the treated Variacs has been quite spectacular, and any user of adjustable autotransformers will recognize from the description of these tests the tremendous improvement that has been realized. He may also recognize that one of the tests was inadvertent.

In one instance a TYPE V-20 Variac, conventionally rated at 20 amperes, was subjected to a load current at mid-point setting of 30 amperes for a period of approximately one month. There was no visible damage to the Variac winding and, to make a more severe test, the unit was enclosed in a thoroughly insulated cubicle to simulate conditions of unusually poor ventilation or heat transfer. After several days at 30 amperes, the current was raised to 45 amperes and held there for a period of four days. The ambient temperature within the box under these conditions was about 55°C., and the temperature rise in the winding of the Variac estimated at the order of 175°C. Clearly, this temperature is well beyond the safe limits for Class A insulation, but the important point is that *no damage occurred to the brush track.* As a final test, *a current of 100 amperes* was drawn for a few minutes at a low voltage setting. The brush heating from this current was sufficient to cause the carbon to become *incandescent.* Failure of the Variac still did not occur, although, of course, the organic (Class A) insulation was very badly charred by the high temperatures developed. With this extreme test, a slight discoloration and damage of the brush track occurred, but not sufficient to have any serious effect on the performance of the unit.

Another startling comparison between the new Variacs and a conventional unit was obtained in the process of operating a new unit and an untreated unit on a "pump-back" test. In this connection, the circuit current is limited only by internal impedance of the two units, and the voltage difference between the two brushes must be kept small. In one instance the brush of one unit was rotated far enough to develop practically full line voltage in the low impedance circuit. The resulting circulating current burned out the untreated unit almost instantaneously. The treated unit was substantially undamaged.

The *Duratrak* process, which follows baking, coats the brush track with the silver surface shown on these partially assembled units.

Testing, which is continuous, has indicated to date a mechanical life of *many millions of brush traverses under severe overload without detectable deterioration*. Surge and inrush currents at least twice as great as before can be safely handled. While deliberate overload for extended periods gradually affects insulation condition (as with any transformer), there is no accelerated deterioration of the brush track, as invariably occurs with an unstabilized, copper brush track.

With this new development, the limitation of the brush and track has essentially been removed from the adjustable transformer, and the rating and use of such a device are therefore limited solely by the same considerations that control the use of any fixed ratio transformer, namely the temperature rating of the electrical insulation used therein.

Ratings, which are conservatively based on accepted (NEMA, AIEE) standards of temperature rise, remain unchanged. We leave for time and even more extended field experience the determination of practical overload or short-term, high-temperature ratings.

Prior to shipment, all Variacs must pass a series of rigid electrical tests to assure conformance to specifications.

We sincerely believe that this new development is the most significant advance in the adjustable autotransformer art since the conception of the Variac itself some twenty years ago. General Radio is proud to offer these new units, which are already establishing new high standards of reliability and durability.

—GILBERT SMILEY
IVAN G. EASTON

The authors wish to extend their thanks and credit to the members of the General Radio Company staff, without whose cooperation this development could not have been brought to fruition. Particular credit is due to:

MR. HAROLD S. WILKINS for patient, step-by-step testing of materials and methods in the development of production techniques.

MR. HAROLD M. WILSON for the design of materials handling equipment to put the process on an economic basis.

MR. CHARLES A. TASHJIAN for his cooperation and supervision in adapting the pilot-plant techniques to full-scale manufacture.

EXPANDED REPAIR SERVICES

Since the opening of our new branch plant in West Concord, Massachusetts, in April, 1952, a considerable number of our instruments are being manufactured and repaired there. Because of this, it is important that our customers write to the Service Department, 275 Massachusetts Avenue, Cambridge 39, Massachusetts, giving the type and serial number of their instrument, before returning it for reconditioning, recalibration, or for any other reason. A return material tag will then be mailed with shipping instructions for the return of the equipment to either our repair facilities in Cambridge or our West Concord

plant, depending upon the type of instrument involved. If this procedure is followed, the time consumed in handling can be held to a minimum.

Customers in Canada should write to Bayly Engineering Limited, 5 First Street, Ajax, Ontario, or phone WAverly 6866 through the Toronto exchange. This firm is our authorized repair service and is equipped to give prompt and competent attention to all General Radio instruments.

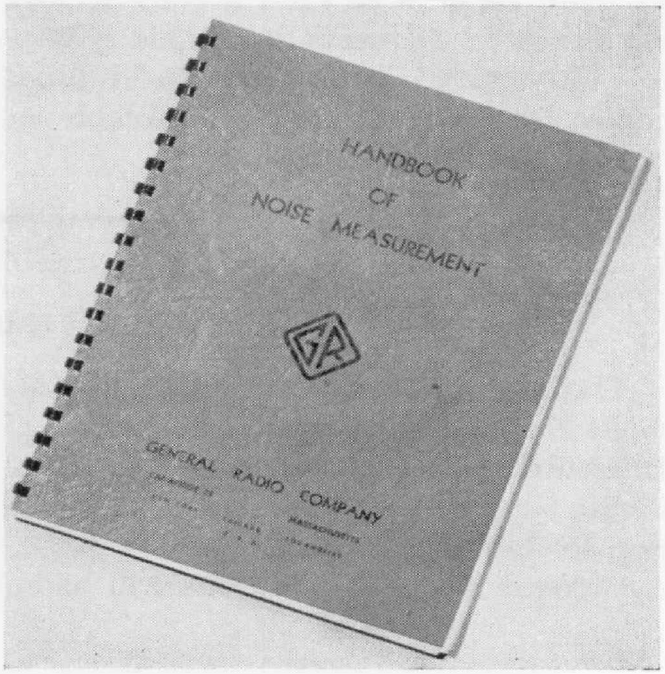
West Coast users of General Radio instruments can have their equipment repaired and recalibrated in California by writing to the Western Instrument Company, 826 North Victory Boulevard, Burbank, California, or phoning ROckwell 9-3013. This firm is also an authorized repair service for General Radio products.

Each of these companies has a well-equipped shop and laboratory, and can give prompt and satisfactory repair service on all General Radio instruments. The repairs and calibrations are made to the same specifications and standards as are used at our own repair facilities.

HANDBOOK OF NOISE MEASUREMENT

A new publication, the "Handbook of Noise Measurement," is now available, replacing the old "Noise Primer." This new book, consisting of over 100 pages, covers thoroughly the measurement of noise and other airborne sounds, including definitions, standards, measuring equipment, measurement procedures, and interpretation of results. The authors, Dr. A. P. G. Peterson of the General Radio Engineering Staff and Dr. Leo L. Beranek of M.I.T., are well known in the field of acoustic measurement, and their treatment of the subject of noise measurement is based on many years' experience.

Copies of this handbook are available from the General Radio Company at a price of $1.00 each postpaid.



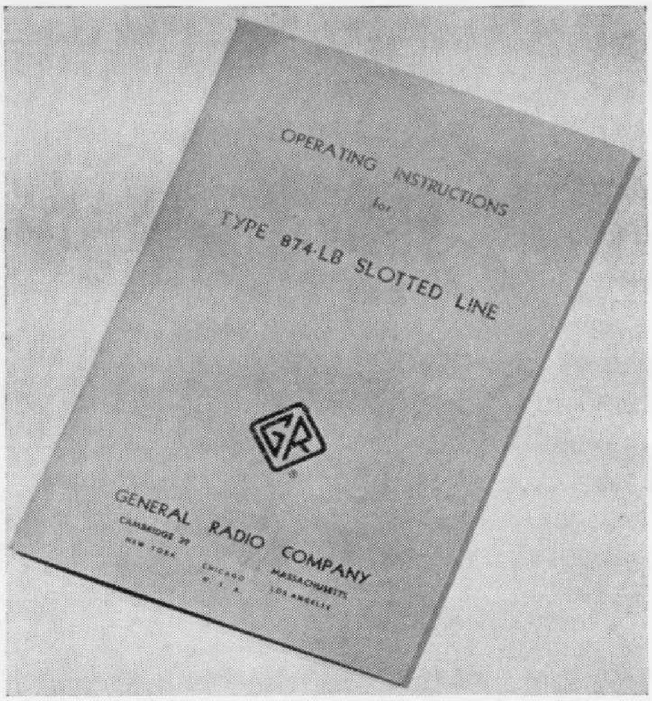
RECENT VISITORS TO GENERAL RADIO

Mr. Erland Cossel, Instructor, Department of Theoretical Electrical Engineering, University of Stockholm, Sweden; Dr. Ing. Agostino Belotti, of Ing. S. Belotti and Co., of Milan, our exclusive representatives for Italy; Mr. Harald Molinari, Engineer, Seyffer and Co., Zurich, our exclusive representatives for Switzerland; Dr. Toyohiko Okabe, of Tokyo Shibarua Electric Co., Ltd., Tokyo, Japan; and Dr. Shigeru Nakajima, Japan Radio Co., Tokyo.

NEW INSTRUCTION MANUAL FOR SLOTTED LINE

Users of the TYPE 874-LB Slotted Line will be glad to learn that the complete instruction book for that instrument is now available. Copies have been sent to all who returned the cards that were enclosed with slotted lines already shipped. If you are using the General Radio Slotted Line and have not yet received a copy of the instruction book, please request it on your company letterhead.

This book is a more comprehensive operating manual on slotted-line measurements than any other that we have seen. It should be very useful for classroom and laboratory instruction, and we shall be glad to send a copy to any teacher who requests it on his college or university letterhead. Additional copies for student use are available at a nominal price to cover the cost of printing.



RESEARCH EQUIPMENT EXHIBIT

The Third Annual Research Equipment Exhibit, sponsored by the National Institute of Health, will be held April 27-30, 1953, at the Clinical Center Building, Bethesda, Maryland.

General Radio instruments will be on display at Booth 56, and General Radio sales engineers will be on hand to discuss your measurement problems and to answer your questions. A cordial invitation to visit this display is extended to all our readers in the Washington area.

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