The GENERAL RADIO EXPERIMENTER

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A REVIEW OF TWENTY YEARS OF PROGRESS IN COMMUNICATION - FREQUENCY MEASUREMENTS

INTRODUCTION

WATT must have been watching his teakettle at almost the same time that Franklin was flying his kite. These two incidents illustrate rather strikingly a difference which was present from the outset between the philosophies of steam engineering and electrical engineering.

Development of steam engineering was, until a late date, entirely empirical and outside of the scientific thought of the period. It was distinctly a method of procedure from application to theory. Nor could this type of development be ascribed to a complete lack of problems pressing for solution. In the 1840's Dickens approached an Ohio steamboat voyage with a degree of trepidation which indicates that these craft enjoyed an explosive reputation in England at that time. Steam engineering as a science did not appear until many years after the steam engine was extensively adopted, and even now has not entirely shaken off the teakettle tradition.

In Franklin's kite experiment we see scientific curiosity seeking to investigate the phenomenon of lightning and to correlate it with other scientific information. By its very nature electrical engineering requires procedure from theory to application. No one ever observed an electric conductor being repelled by a magnetic field until Faraday set up the experiment. The electric motor could not possibly have resulted from the intrusion of homely phenomena on a fireside daydream.

A corollary of the scientific method is a need of apparatus, and it is, therefore, not surprising to find Franklin importing Leyden jars and similar apparatus at about the time of the kite experiment. As the electrical engineering art developed there grew up with it an increasing demand, first for experimental, and later for measuring and testing equipment, until as early as the 1870's commercial companies were able to concentrate on electrical measuring equipment alone.

With this background in the older

branches of electrical engineering it was natural that a need for measuring equipment would be felt early in the development of frequencies used for communications. It was with this need in mind that Mr. Melville Eastham organized the General Radio Company in 1915. The Company was founded with a distinct field in view. It was desired to reduce measuring methods to practical commercial forms of a type suitable for use in everyday shop and commercial tests, —a field which may well be described as tool making for the electrical engineer. This issue of the EXPERIMENTER presents a group of articles which attempt to show some of the more important developments of the last twenty years.

DEVELOPMENT OF RECEIVER TESTING EQUIPMENT

WHILE testing methods for components and circuits were early developments, the quantitative testing of complete receivers is a comparatively recent growth. It must, in fact, have been as late as 1928 that the writer was told in all seriousness by the engineer of an important manufacturer that he believed it would be necessary to buy a wavemeter very soon because the plant was then running twenty-four hours a day, and it was difficult to find broadcast stations in operation during the early hours of the morning in order to check dial spreads.

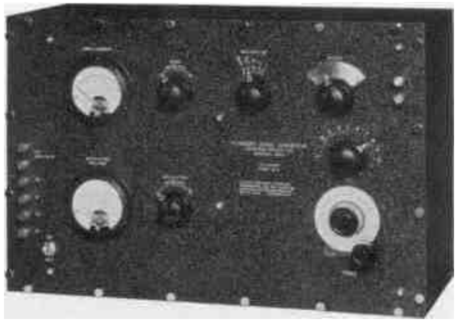
At this period tests of complete receivers were usually purely qualitative. The individual components were checked and circuits were matched carefully for tracking, but the completed receiver as a general rule received only a listening test.

A principal reason for the delay in the development of receiver-measurement methods which would permit a quantitative rating of the instrument was a lack of agreement as to the form the rating should take. The problem was rather unusual in that the radio receiver is a power converter, but one whose power efficiency gives no clue to its performance. The problem was complicated by the fact that the method of rating to be devised must not only be clear to the engineers, but must be such as to provide a fair and intelligible means of comparison between receivers by a public entirely unfamiliar with the aspects of the problem and even with the technical terms used.

Scientific popularizers were estimating receiver performance in terms of power expended by a fly crawling one foot up a window pane. While graphic, evaluation of receiver performance in fly power was insufficient to inform the purchaser as to the satisfaction he might obtain from a purchased receiver. The advertising departments were more explicit and rated their receivers, optimistically, in terms of distances from which signals could be received. There was sound technical precedent for this, since telephone equipment had been rated in terms of miles of standard—cable, but the difficulties of defining a standard radio-transmission medium prevented any standardization on such a basis. Furthermore, the world was too small to give proper play to the competitive advertising imagination.

The confusion was finally resolved in the Standardization Report of the Institute of Radio Engineers published in preliminary form in May of 1928. This report recognized the necessity of rating receivers in terms of three characteristics—sensitivity, selectivity, and fidelity—and set up standard methods of procedure to establish such values.

Measurement of sensitivity and selectivity required the setting up of an entirely new type of apparatus, since it involved the measurement of radio-frequency voltages of the order of a few microvolts. An approach to this problem had been made by Englund, Friis, and others several years earlier in connection with field-strength surveys. The method consisted of producing the radio-frequency voltage at a level which was readily measured with a high degree of accuracy, and then subdividing the known voltage through a suitable network sufficiently to obtain the required small voltages which then allowed the measurements to be made by direct substitution. Obviously, the method is subject to the objection that the standard low voltage can be no more accurate than the subdividing network. This objection underlies all receiver sensitivity measurements at the present time. Networks of quite different type incorporated into equipment of different manufacturers ' do, however, give fair agreement at voltages of a few microvolts, whence it may be reasonably assumed that these values are accurately known.



The first commercial Standard-Signal Generator, General Radio TYPE 403-A, November, 1928

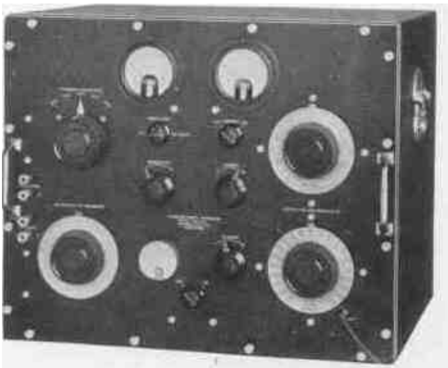
The problems of signal-generator development were centered in the attenuator. The General Radio Company selected the resistance type of attenuator as the most promising approach to the problem at broadcast frequencies, and development was rapidly pushed ahead during 1928 on a signal generator which would be suitable for the evaluation of receiver characteristics as defined by the Institute of Radio Engineers' Standards.

The TYPE 403-A Standard-Signal Generator was described in THE GENERAL RADIO EXPERIMENTER in November, 1928. This instrument, designed by Dr. Lewis Hull, was, we believe, the first standard-signal generator to be commercially available, and it opened up an entirely new field of receiver measurements.

The TYPE 403-A Standard-Signal Generator consisted of a radio-frequency oscillator with an audio-frequency modulator. The output of the oscillator was impressed across a resistance attenuator, permitting the reduction of the output voltage to small values and its adjustment over a wide range.

The increasing use of other than broadcast frequencies later dictated design changes in the earlier TYPE 403-A Generator. Higher frequencies and lower output voltages, as well as more severe demands for accuracy, were straining the possibilities of the original 403-A design rather seriously.

All of these factors led to the abandonment of the TYPE 403-A design and the introduction of the TYPE 603



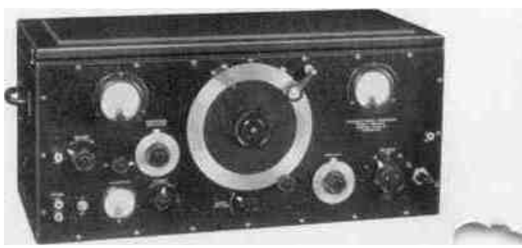
The second step, TYPE 600-A Standard-Signal Generator, for rapid measurements on broadcast receivers at selected frequencies, August, 1931

Signal Generator early in 1932. Announcement of the new instrument was carried in the May, 1932, issue of THE GENERAL RADIO EXPERIMENTER. The fundamental elements of the earlier signal generator were repeated with many refinements in design. In the attenuator especially an entirely new type of mechanical design was followed.

During this period a development of the ultra high-frequency bands similar to that earlier taking place in the broadcast bands was in progress. As development of these bands settled down to a commercial basis, a means of evaluating receiver performance

A simultaneous development for servicing and testing over a wide frequency range, the Type 601-A Standard-Signal Generator of July, 1931

in them was demanded. This was met in February, 1933, with the announcement of the TYPE 604-A Test-Signal Generator. This instrument did not replace the TYPE 603, hut merely supplemented it by covering frequency bands where the 603 could not possibly be used. It was recognized that performance measurements at ultra-high frequencies could not have a high precision at the present state of the art, and a rather simple and inexpensive type of instrument was, therefore, developed. The familiar design pattern of modulated oscillator and attenuator was, however, again fol-



The modern laboratory standard, the General Radio TYPE 603-A Standard-Signal Generator lowed. One important departure from previous practice was required. A condenser type of attenuator was found to give more satisfactory operation at frequencies above 20 megacycles than the resistance type used in the earlier signal generators, and this type of network was substituted.

While laboratory measurement technique was being worked out, a parallel development in factory inspection and test methods was required in order that the higher standards of performance could be translated into actual production performance. The testing and inspection set-up projected for the radio-receiver plant of the Victor Company (1929) at Camden was probably the earliest and certainly the *most* ambitious quality control set-up for that day. The receiver was broken down into radio-frequency and audio-frequency sections, and each portion was subjected to exhaustive tests which were, however, reduced to such simple terms that unskilled testing personnel could be trained to make the tests very quickly.

This test equipment, designed and built by General Radio, provided for a complete response test of each receiver. The test method was simple and rapid, and a comparatively small number of test panels were required to handle the production schedule of 2000 receivers per day.

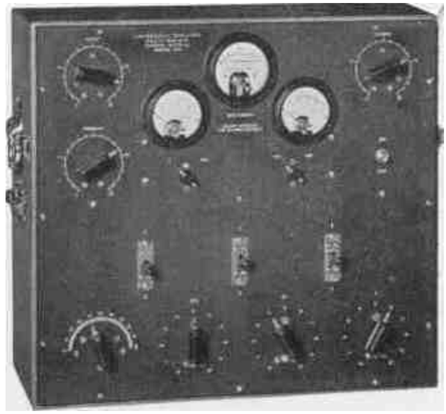
Measurement methods for tests of receiver fidelity have been gradually developed until a very complete evaluation of the frequency response and harmonic distortion of the entire receiver or of component parts can be made. One of the earliest fidelity testing instruments was the TYPE 355 Transformer Test Set which was designed for the measurement of individual audio transformers.

With an eye to the future, the TYPE 604-B Test-Signal Generator for ultra-high-frequency work

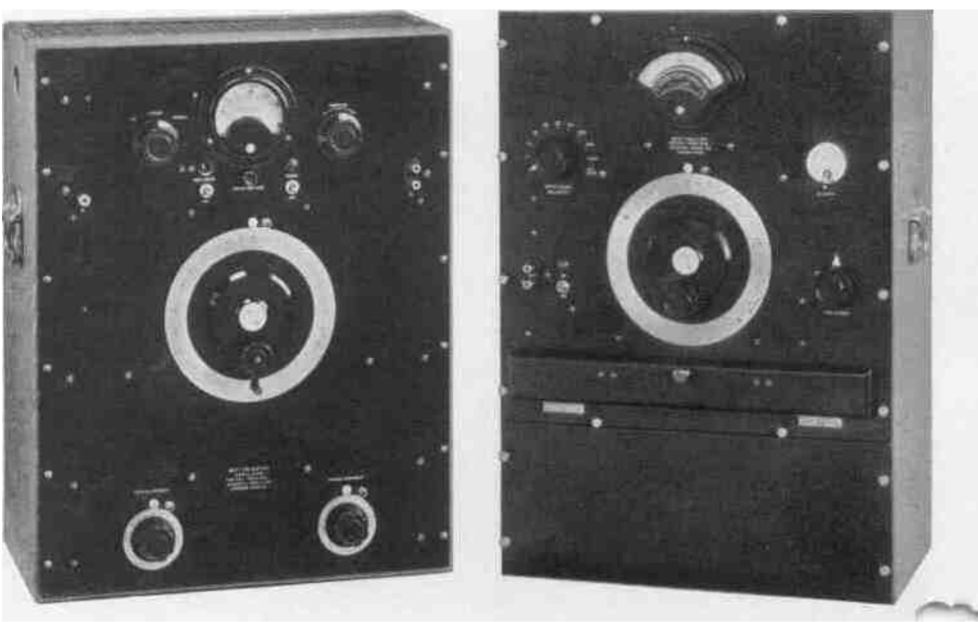
The development of vacuum-tube oscillators for audio frequencies was largely an outgrowth of the demand for better fidelity reproduction. Audio-frequency vacuum-tube oscillators are such a laboratory commonplace that it is easy to forget that as recently as ten years ago they were a comparative rarity. The first commercial vacuum-tube audio-frequency oscillator available for general laboratory use in this country was the TYPE 377 placed on the market by General Radio Company in 1925. Previous to that time such makeshifts as phonic wheels driven by variable-speed motors were the only source of variable audio frequency available. The development and improvement of audio-frequency apparatus induced a decided demand for oscillators capable of frequency variation over this range, and the beat-frequency type of oscillator offered the obvious advantage of single control for rapid adjustment over wide ranges.

The Type 713 Beat-Frequency Oscillator just being announced is the culmination of a series of beat oscillators reaching back about eight years. It is remarkable in the high voltage and power output for this type of oscillator, as well as for an unusually fine waveform.

Fidelity and gain measurements led into many ramifications of apparatus. An interest in wave distortion—that is, harmonic generation—in tubes and amplifiers has been a comparatively recent development. The cathode-ray oscillograph has been of great value in rough measurements of this kind, but the Type 636 Wave Analyzer produces a complete and accurate analysis of a distorted waveform, showing harmonics of magnitude far too small to be detected in an oscillogram. This instrument is probably the most specialized and highly developed in our line, and well serves as a tangible monument to our twenty years.



The TYPE 377-B Low-Frequency Oscillator generates audio and carrier frequencies up to seventy kilocycles



A perfect combination for audio-frequency measurements. On the *left* the newest Beat-frequency oscillator. General Radio TYPE 713-A, and on the right the TYPE 636-A Wave Analyzer for harmonic analysis

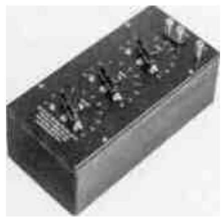
ALTERNATING-CURRENT BRIDGES

THE development of bridge circuits constitutes a particularly good illustration of the working out of the objectives of the General Radio Company. At the time of the founding of the Company the fundamental bridge circuits were well known. The Wheatstone Bridge was, in fact, first described in 1833. Standardized commercial bridges were, however, not extensively available at low prices. In fact, there seems to have been no American manufacturer of alternating-current bridges at that period, although English and Continental firms were listing them.

The purpose of the General Radio Company was to make commercially available established types of measuring equipment which would be manufactured on a standardized basis applying, so far as possible, mass-production principles in this field. The purpose was to place the burden of thought and planning on the designer and manufacturer, leaving the user of the equipment free to devote his full attention to the main objectives of his investigation undistracted by the necessity of coddling his equipment, and to remove accurate laboratory and shop measuring equipment from the luxury class.

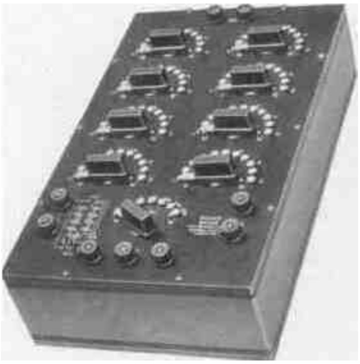
Marked emphasis is lent to the contrast between this conception and the then current view by the practice of a leading English manufacturer of laboratory equipment. As a deliberate policy, parts and instruments were made non-standard, screws were separately cut on a screw-machine with differing threads so that if any part were lost or broken the instrument would have to be sent back to the manufacturer for hand-fitting of new parts.

The bridges of the period were mostly of the once familiar type, displaying panels studded with large, highly polished brass blocks, connections being made by the insertion of tapered plugs between the blocks, although the dial-decade type of bridge had been introduced and was available in a direct-current bridge (the well-known TYPE K Test Set) manufactured by Leeds and Northrup.

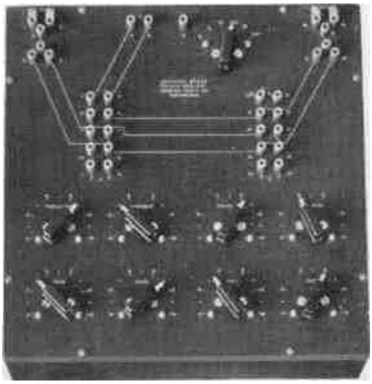


Even decade-resistance boxes improve. The latest TYPE 602 right is completely shielded, has better switches, contacts, terminals, wiring, and card construction than the older TYPE 102 *left*

Most of the bridges offered for measurement of inductors and capacitors operated on pulsating rather than alternating current. A basic requirement for a satisfactory bridge to operate at 1000 cycles or at higher audio frequencies is a type of resistance which can be used in the ratio arms without introducing frequency errors. The earlier alternating-current bridges were of the slide-wire type using a straight resistance wire with a slider as the ratio arms of the bridge. The Ayrton-Perry type of winding, which is nonreactive at audio frequen-



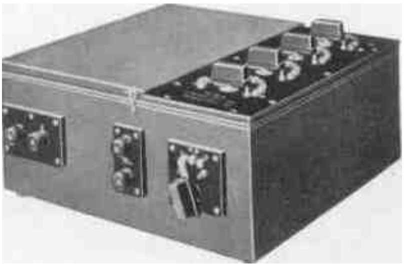
The TYPE 193 Decade Bridge, an intermediate stage in the extension of the decade bridge to alternating-current measurements

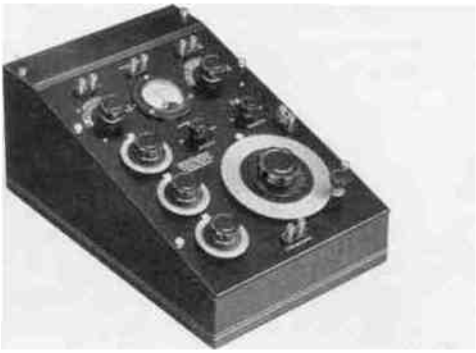


The TYPE 293 Universal Bridge has a greater flexibility of arrangement of the arms and the enclosed-contact construction

cies, was first introduced in General Radio resistance boxes in our familiar TYPE 102. With this type of winding it was possible to build up non-reactive resistors of large values, greatly extending the possible range and flexibility of bridges over the slide-wire type. This was very quickly followed by an impedance bridge which consisted of ratio arms and a power-factor arm with provision for connecting unknown and standards. A redesign of this bridge became the TYPE 193 with which many commercial and educational laboratories were equipped. It gave way a few years ago to the TYPE 293, a bridge of similar general characteristics but so designed that all impedances would terminate on the panel so that all types of standard bridge circuits. could be set up.

Measurement of power factor of insulating materials was another of the problems which was approached in the early years of the Company. The TYPE 216 Bridge was evolved for this purpose and has been the standard method of precise power-factor determinations for many years.

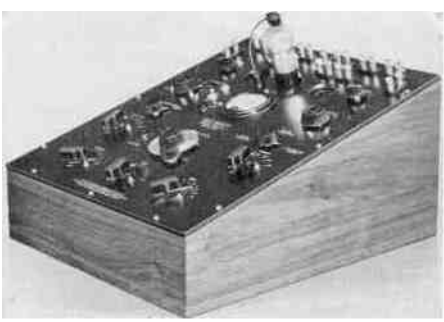




The refinement of decade bridges leads to specialized impedance bridges of greater usefulness in smaller fields, s uch as the Type 216 Capacity Bridge *left*, and the Type 650-A Impedance Bridge *right*

Particular measurement problems have called forth a number of bridges of special design to meet them. These have included bridges for the direct measurement of capacitance, for trimming gang condensers, and for measurement of electrolytic condensers. The latest development of this type of instrument is the TYPE 650-A Impedance Bridge, which comprises in a single unit bridge elements and standards for measurements of inductance, capacitance, and resistance over wide ranges. This instrument is the culmination of a long effort in the simplification of bridge measurements.

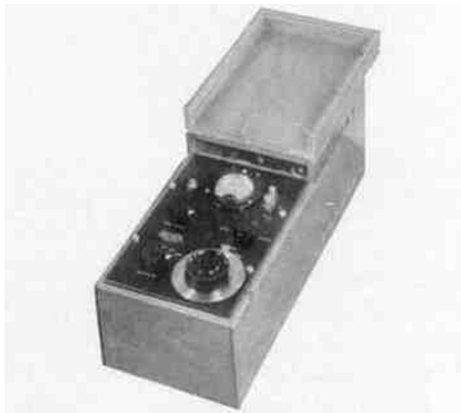
The measurement of vacuum-tube constants necessitated the development of another group of highly specialized bridges. The early TYPE 361 was made obsolete by the rapid developments of multi-element tubes



The Type 561 Vacuum Tube Bridge has adequately survived all tube developments since its introduction in May, 1932

beginning in 1930. The TYPE 561 Vacuum-Tube Bridge, which supplemented it, was designed with the object of providing for all possible tube development for a long time to come. So far it has accomplished this. Even the new metal tubes can be taken care of by means of a simple adapter.

While rapid and continuous progress was made in the development of bridges for all types of 1000-cycle measurements, commercial apparatus for bridge measurements at radio fre-



Ten thousand megohms on a bridge! — by means of the vacuum tube used in the TYPE 544 Megohm Meter

quencies proved a more difficult problem. Just as the Ayrton-Perry resistance-winding development cleared the way to the 1000-cycle bridges, compensated decades eventually made possible bridges for use at radio frequencies. In these resistance units the small residual inductance, which the most careful design could not eliminate from the standard type of card, is held constant regardless of dial setting and can be eliminated in a bridge circuit bv a preliminary balance.

The use of the compensated cards, together with other refinements of bridge technique, made possible the TYPE 516 Radio-Frequency Bridge, which was announced in 1933. Prior to this time bridge methods had not been developed to a point where they could be trusted at radio frequencies.

The TYPE 516-C Radio-Frequency Bridge measures impedances directly at frequencies up to 5 megacycles

Substitution and voltammeter methods had persisted in this high-frequency region long after they had been abandoned elsewhere.

The compensated resistor also made possible the construction of a bridge (TYPE 667) for another particularly difficult problem, the measurement of a small inductance associated with a comparatively large resistance. This is characteristic of radio-frequency coils measured at audio frequencies.

Although the commercial developments of bridge circuits briefly sketched here have made available an extensive line of reliable, easily operated equipment, the increasingly severe requirements of industrial measurements indicate that bridge development must be continuously carried forward, and it is, in fact, at this time one of our most active programs.

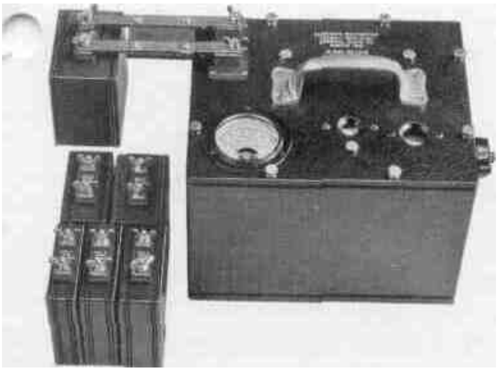
The latest development in measuring small inductances, the TYPE 667-A Inductance Bridge, June, 1935

FREQUENCY MEASURING INSTRUMENTS

IN 1915, the standard frequency-measuring device was the tuned-circuit wavemeter. The parallel-wire systems used by Hertz, Marconi, Lecher, and others had, with the introduction of longer and longer wavelengths, been displaced by various types of coil and condenser combinations, either or both elements of which were adjustable. General Radio has brought out over twenty different wavemeter models, of which a few may be mentioned as of interest here.

One of the earliest was the TYPE 105, brought out late in 1917, which included plug-in coils, buzzer, crystal detector, and telephones. Provision also was made for the use of a thermocouple and galvanometer, or a neon tube as the resonance indicator.

The Kolster Decremeter was one of the first commercial instruments fitted with a variable condenser having specially shaped plates to obtain a desired relationship between frequency (wavelength) and scale read-



Still modern after fifteen years, the current demand for the TYPE 224 Precision Wavemeter pays tribute to the excellence of the original design

ing. With the widespread use of continuous wave transmitters, the decremeter has fallen into disuse.

The TYPE 224 Wavemeter was one of the first commercial models (about 1920) incorporating the features of precision variable condenser construction and worm drive. The worm-drive condenser had a scale of 2500 readable divisions, an increase of ten times, or more, over contemporary models.

The TYPE 574 Direct-Reading Wavemeter incorporated the novel arrangement of using plug-in coils, each carrying its direct-reading calibration engraved on the coil form. The possibility of making an error in reading is greatly reduced, since there is but one scale in place of the usual arrangement of several in direct-reading multi-range instruments.

Practically all of these earlier instruments were calibrated by reference to some other instrument of the same or similar type, whose calibration had been in turn determined by reference to some other instrument, and so on, ad infinitum. What with the defects of design, errors arising from shipment, aging, temperature changes, and so forth, it is not surprising that there was a disappointing lack of agreement among various instruments.

Early in the 1920's standard frequencies were transmitted by the U. S. Bureau of Standards based on their standard wavemeter. Such transmissions had the great advantage of bringing the frequency standard, so to speak, into the laboratory of the user, and, further, brought a considerable improvement in the uniformity of results, since workers in many locations were able to make use of a single standard.

It was only when the standard wavemeter was replaced by oscillators of relatively high frequency stability, with means for determining the frequency directly in terms of time, that the precision of frequency measurements began to make rapid progress toward the high accuracies now possible.

The TYPE 574 Direct-Reading Wavemeter combines accuracy with rapidity of setting

Thus the use of piezo-electric quartz crystals for the frequency stabilization of radio-frequency oscillators in the early 1920's marks an important milestone in frequency measurements.

The first commercial piezo-electric

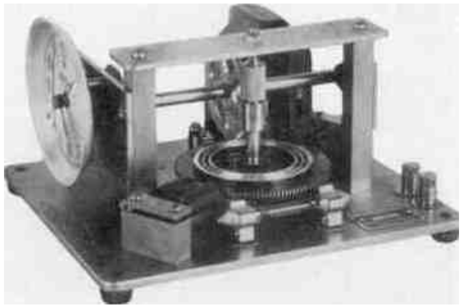
oscillator appeared in 1924, known as the TYPE 275. This instrument served as either a laboratory standard or as a frequency monitor. In the latter capacity it gave satisfactory performance down through the days of the 500-cycle tolerance in broadcasting. In this early work General Radio Company furnished the first quartz crystals to be used in controlling the frequency of a broadcast station (WEAF, 1923) and the first crystals used in commercial radio transmitters (RCA, 1923).

With demand for higher accuracies, the shortcomings of the early piezo-electric oscillators were overcome by progressive improvements

The early Type 275 Piezo-Electric Oscillator made no provision for temperature control of the Quartz Plate

in the cutting of the quartz plates, in the mountings and circuits, and in temperature control. As a result the accuracy was improved from 0.1% to 0.001%, and simultaneously the convenient improvement of a-c operation was included.

Early experimental determinations of frequency in terms of time forecast



The TYPE 411 Synchronous Motor integrated applied frequencies to give an absolute evaluation in terms of standard time

the development of the primary standard of frequency. In 1859 Fedderson used a rotating mirror to photograph a spark discharge and prove the oscillatory character of the discharge. By timing the rotation of the mirror, in terms of a tuning fork, Pierce was able to obtain a measure of the frequency of the spark oscillations, in 1915. By photographing the oscillations of an oscillator operating at a submultiple of the frequency of a quartz crystal oscillator and superimposing a timing record of pulses obtained from a chronometer. Pierce obtained a measure of the frequency in terms of time (about 1923) by counting the number of cycles per unit time and multiplying by the number of the harmonic of the oscillator controlled by the crystal.

In 1919 Abraham and Block described the "multivibrator," a type of relaxation oscillator having an output "rich in harmonics." This device was used to multiply frequencies by harmonic methods to obtain low and medium radio frequencies from an audio-frequency standard oscillator, such as a tuning fork. A little later, Dye incorporated such a standardizing equipment in a heterodyne frequency meter. Later it was found* that the multivibrator lent itself particularly well to the division of frequencies. That is, on the introduction of a voltage from a piezo-electric oscillator, the frequency of the multivibrator could be stabilized by the piezo-electric oscillator, even though the frequency of the piezo-electric oscillator was several times higher than the fundamental frequency of the multivibrator.

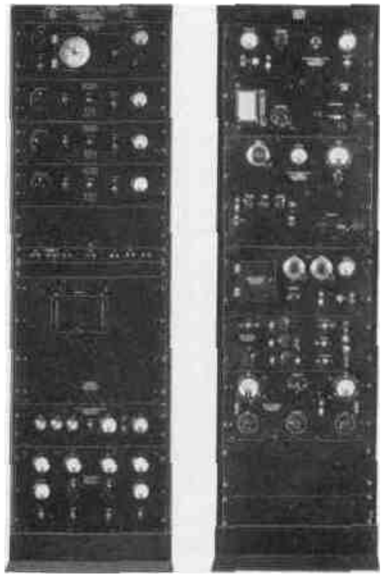
The TYPE 411 Synchronous-Motor Clock was brought out in 1926 and an early model was used by Marrison* in his work with the precision tuning fork standard at the Bell Laboratories.

The elements of the primary frequency standard were by now at hand: The piezo-electric oscillator of high frequency stability as the standard; the multivibrator as a frequency divider, to bring the radio frequency standard down to frequencies suitable for use in synchronous motors of the impulse type, and the synchronous-motor clock for counting the number of oscillations executed by the piezo-electric oscillator in a given time interval.

The first commercial primary frequency standard was the CLASS C-21-H brought out by General Radio Company in 1928. This laboratory frequency standard had an accuracy of one part in a million (0.0001 per cent), furnished hundreds of standard frequencies throughout the radio-frequency spectrum for measurement

* "Universal Frequency Standardization from a Sinple-Frequenry Source," J. K. Clapp, Journal of the Optical Society of America and Review of Scientific Instruments, July, 1927.

* "Precision Determination of Frequency," J. W. Horton and W. A. Marrison, Proc. I.R.E., February, 1928.



The final development, the Primary Standard of Frequency, accurate to within 5 parts in 10 million, *left,* and its auxiliary frequency-measuring equipment, *right*

use, and provided means for comparing the time of the crystal controlled clock with time signals to within 0.01 second. Later models yield an accuracy of a few parts in ten million.

Interpolation instruments for measuring frequencies in terms of harmonics supplied by the primary standard have been developed, by means of which frequencies from a few kilocycles to several megacycles can be measured with an accuracy of a few parts in one million.

Equipment of this type has been widely used in government and commercial services all over the world. Interesting applications, in addition to the normal uses for frequency measurements, have been in the measurement of bullet velocities, the measurement of velocity of light, and as precise standards of time.

ELECTRICAL MEASUREMENTS IN THE RADIO BROADCASTING STATION

IT is significant that the two portions of the radio industry which are most important from the economic standpoint (radio broadcasting and radio receiver manufacture) have been responsible for a major portion of the technical advances and instrument design in communication-frequency measurements during the last ten years. The radio broadcasting industry, in particular, affords an outstanding example of the way in which technical developments are conditioned and even forced by economic factors.

The operation of a modern radio broadcasting station involves, as a matter of routine, the measurement of many electrical quantities such as audio-frequency and carrier power levels, frequency, modulation level, noise level, and harmonic distortion, as well as the measurement of all operating voltages and currents in vacuum tube circuits. The design of equipment for broadcasting station use has tended always toward automatic or direct-reading instruments which require a minimum of attention on the part of the operator.

The two major assets of a radio broadcasting station are its operating license, which is granted by governmental authority, and its coverage, that is, the number of listeners which it can reach. To retain the former and to increase the latter are the two factors which mean the most, economically, to the station.

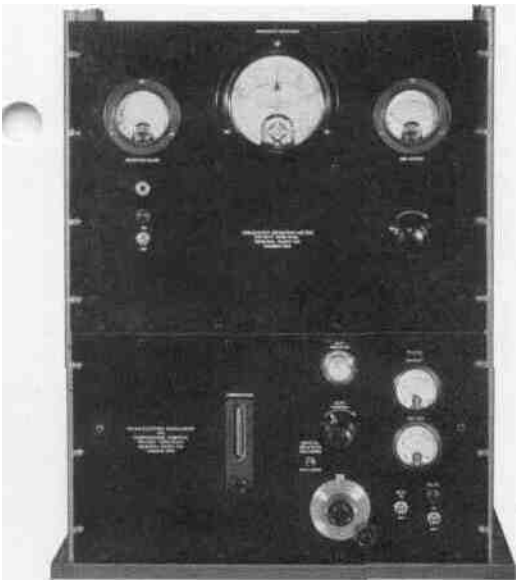
The granting of an operating license to the broadcasting station is contingent upon the observance of certain rules and regulations governing frequency, output level, quality of output, and operating procedure, specified (in this country) by the Federal Communications Commission. Operating within these specified limits, particularly at a specified carrier power level, the station which can operate with the highest percentage modulation, the minimum distortion, and the best radiating system is the one which, in terms of monetary return, makes the best success as a going concern.

One of the primary rules prescribed by the Federal Communications Commission deals with the maintenance of the operating frequency of the transmitter within certain specified limits. These regulations have been responsible for the development of the present technique of frequency monitoring in broadcasting stations, culminating in the visual-type, direct-reading, frequency monitor. The constant narrowing of frequency tolerances in the standard broadcast-

TYPE 375 Station Piezo-Electric Oscillator, the broadcast-station frequency monitor of 1926

frequency band has resulted from the continually increasing number of broadcasting stations. With only a few stations, it is not of primary importance whether or not the transmitter frequency wanders over a considerable range. As the number of stations increases, until one station is operating on each available channel, some type of crystal frequency monitor is required to prevent stations on adjacent channels from interfering. As the industry develops still further, several stations operate on a single channel, and the tolerances are narrowed to the point where a direct-reading narrow range indicator

The CLASS 730-A Transmission Monitoring Assembly, introduced January, 1935, permits rapid routine measurement of modulation, distortion, and carrier noise



Visual indication of frequency deviation arrived in 1932 in the TYPE 581 Frequency-Deviation Meter

is required, to prevent heterodyne interference.

Other government rules deal with such factors as power output, percentage modulation, and harmonic distortion. The measurement of output power, in one method at least, involves a knowledge of the constants of the antenna system. In the measurements of these constants, particularly the resistance, older methods have been used for some time. The need for portable and direct-reading equipment, however, has been an important factor in the development of the radio-frequency bridge and various types of specialized measuring sets using substitution methods.

The regulations which deal with percentage modulation specify only a lower limit for the maximum modulation level which the transmitter shall be capable of delivering. Here, however, the station coverage can be materially increased if a high percentage modulation is possible without materially increasing harmonic distortion. Laboratory instruments for the measurement of percentage modulation and harmonic distortion were developed and used in most broadcasting stations. With the increasing demand for high-quality transmission, however, automatic and direct-reading equipment became necessary, and instruments of the type shown on page 15 represent the latest developments in this particular field. With equipment currently available, it is possible to make a complete check on the quality of the output of a radio transmitter, consisting of measurements of modulation level, harmonic distortion, and noise level, in a few minutes. In addition, the output level can be continuously monitored, giving the operator, at a glance, a complete check on the operation of his transmitter at all times.

The Type 457 Modulation Meter gives laboratory measurement of percentage modulation on positive or negative peaks

Instruments for the measurement of the quality of the output of a radio transmitter, while showing the operating condition, must, of course, be supplemented by adjustments and measurements in the various portions of the transmitter itself in order to locate and eliminate sources of improper operation. That section of the transmitter which has received the most attention is the audio-frequency portion, consisting of microphone pickups and amplifiers, speech input equipment, and speech amplifiers.

The Type 536 Distortion-Factor Meter measures the 400-cycle distortion in an audio-frequency system

To minimize distortion in the audio-frequency system, it is necessary that the audio-frequency power level be continuously monitored at various points in the system. The demand for moderately-priced and compact direct-reading instruments was an important factor in the development of the copper-oxide-rectifier type of power-level indicator which is now almost universally used in the broadcasting and sound motion picture industries.

Since the beginning of commercial radio broadcasting. General Radio has supplied a large portion of the measuring tools of the broadcast station engineer. One or more General

The TYPE 586 Power-Level Indicator program monitors the audio-frequency level fed to the transmitter

Radio instruments, ranging from the inexpensive microphone mixer control to the direct-reading transmission monitoring equipment, are in use today in practically all the broadcasting stations of the United States. Many of these instruments have been distinct advances in the technique of a-c electrical measurements, but it is to the broadcasting industry, as the originator of the demand for the application of the advantages of direct-reading instruments to precision methods of measurement, that the radio art owes much of its progress in the past decade.

WHO'S WHO

WHY all this review of the art of electrical measurements in the field of audio and radio frequencies? The purpose is to point out that, new as this field is, the General Radio Company is one of the oldest companies in it. On June fourteenth we complete the second decade of our existence.

Five years ago on the occasion of the celebration of our fifteenth birthday we devoted an issue of THE GENERAL RADIO EXPERIMENTER to describing the history of the Company and to portraying by word and by picture some of the personnel who make up the organization. When recently we contemplated repeating this procedure, our printer looked over the pictures of our staff as shown in that issue of five years ago and remarked, "The depression certainly has left its mark on some of you!" So great was the shock to those of us who have been priding ourselves on retaining our youthfulness that we decided it might be better not to let our readers see how old and decrepit we had become.

Consequently, the 1935 edition of "Who's Who at General Radio" follows the traditional form of such publications and contains no pictures. Because we are fundamentally an engineering organization, and because the EXPERIMENTER readers are largely engineers, our word portraits will be limited principally to members of the engineering group.

We are most happy to state that all of those listed in the issue of five years ago are still living and, with the exception of J. W. Horton, are still with us. Mr. Horton has given up his executive work to devote his time entirely to research and is now a research associate at the Massachusetts Institute of Technology, doing a most promising piece of work in the field of bio-physics, on which problem this Company is co-operating.

We are also glad to say that Knut A. Johnson, the first employee of the Company, is still with us.

Although the Company has no definite unemployment plan, it has long had such a problem in mind in the maintenance of reserves, which have made it possible during the past five years to keep the entire organization together. Only for a brief period of time did the employment hours drop to 60% of normal, and, except for a few workers taken on in 1929, no employee was dropped because of declining business.

The officers remain unchanged.

Henry S. Shaw continues as Chairman of the Board of Directors. Although he does not take part in the active details of management, Mr. Shaw is at the Company offices several days each week and, in addition to maintaining a keen interest in apparatus development, particularly in the field of ultra-high frequencies, has through his personal generosity made possible the establishment of a fund available for the general welfare of employees and their families.

The General Radio Company owes its very existence to its President, Melville Eastham. It was he who founded it, and it is he who has led it through the varied transitions of the past twenty years. No more apt description of his duties can be found than by repeating what was written of him five years ago: "His activities . . . , however, are not properly described by his title, for he is rarely found at his presidential desk. His interests are almost exclusively in engineering work, and he may usually be found in his research laboratory, except during the summer, when he takes a long vacation, generally on the Pacific Coast or in Europe." That the remarks of the printer may not be taken too seriously, let it be recorded here that both the Chairman of the Board and the President have just arrived at that ripe old age of half a century.

In charge of all manufacturing and plant operations is Vice-President E. H. Locke. On him is placed all blame when deliveries are slow, and his good work is too easily forgotten when the Commercial Department finds itself overstocked. Seventeen years of association with the Company, fifteen of which have been in charge of manufacturing, have, however, done much to reconcile him to the small amount of help and of appreciation he may ever expect from those responsible for customer contacts.

Like Messrs. Shaw and Locke, H. B. Richmond, the Company's Treasurer, joined Mr. Eastham when the years of the Company were still being counted on the fingers of one hand. It seems to be a habit of officers of the General Radio Company, regardless of title, to be closely associated with engineering, thus Mr. Richmond, in addition to his usual duties as Treasurer, watches over those phases of engineering pertaining directly to customer relationships, which, in our organization, is just a long way or saying sales.

Before apparatus can be manufactured it must be designed. After agreement among a conference group, at which specifications and other important limiting factors, including probable price, are agreed upon, the development and actual design are carried out by an engineering group known as Development Engineering. This group is headed by Mr. Eastham, assisted by Eduard Karplus, who received his Dipl. Eng. from the Technische Hochschule, at Vienna. The work carried on by the various engineers in this group is too varied to attempt to give any details of their specific activities. It perhaps is sufficient to state that most of the new items listed in our newly published Catalog H are the product of the engineers in this group, which includes: L. B. Arguimbau, S.B., Harvard; A. G. Bousquet, B.E.E., Tufts; J. D. Crawford, S.B., Massachusetts Institute of Technology; H. W. Lamson, S.B., Massachusetts Institute of Technology, A.M., Harvard; and W. N. Tuttle, Ph.D.. Harvard.

Oftentimes a standard item is the result of work which originated in connection with some customer problem. For this reason a considerable number of our instruments have been developed by members of a second engineering group, known as the General Engineering Department. While this group is under the general direction of Mr. Richmond, its administration is actively carried out by C. T. Burke, S.M., Massachusetts Institute of Technology, whose title is that of Engineering Manager. As many EXPERIMENTER readers know members of this group through personal contact or through correspondence, it seems appropriate to note the particular functions of the various engineers within this group.

A. E. Thiessen, B.E., Johns Hopkins, is the engineer in charge of Government activities and, in general, quantity special-problem items. He, too, has supervised the development of some items that have found their way into the catalog.

R. F. Field, A.M., Brown and Harvard, is familiar to many EXPERIMENTER readers for his work in bridge measurements and allied subjects. Nearly all the new bridges and associated equipment appearing in our recent catalog have been developed under Mr. Field's direction.

No one at General Radio can think of frequency standardization without thinking of it in terms of J. K. Clapp, S.M., Massachusetts Institute of Technology. A very considerable number of the broadcast stations in the United States have frequency-monitoring equipment developed by him, and it is the boast of the Company that the sun never sets on Mr. Clapp's primary-frequency standards, so worldwide is their distribution.

How much is it going to cost? That answer usually comes from P. K. McElroy, A. M., Harvard. Nearly all items of special manufacture and changes from standard design have their costs estimated by Mr. McElroy. To him also falls the lot of directing the final engineering design of much of Mr. Thiessen's special contract work.

If it must be made in a hurry, it goes to H. S. Wilkins, S.B., Massachusetts Institute of Technology, and his model shop. Not only does Mr. Wilkins handle individual customer problems, but nearly all our own first models are produced in his group.

Who publishes the EXPERIMENTER? C. E. Worthen, S.B., Massachusetts Institute of Technology, and he does a whole lot of other things, too, that make it easier for General Radio customers to know what we make and, after a purchase, how to make the apparatus work.

If your name is not correctly listed in our mailing files, blame J. M. Clayton, of Cornell. If you do not like our advertisements, tell Mr. Clayton, because he is responsible for the preparation of most of them as well.

Joining our staff only a year ago is Frank L. Tucker, B.S., University of Texas; M.B.A., Harvard Business

School. Mr. Tucker devotes his time to a statistical analysis of all costs, devoting particular attention to those pertaining to all forms of engineering in order that they may be properly allocated to their respective instruments.

Jnst a year ago it seemed advisable to have a New York engineering office to assist our metropolitan customers in the solution of technical problems involving our equipment. For this important post M. T. Smith, S.M., Massachusetts Institute of Technology, was selected, and he is already familiar to many General Radio friends in the New York district.

Others in the General Engineering Department who are devoting their time to helping customers in their engineering problems and who also are watching out for methods of improving our product are H. H. Scott, S.M., Massachusetts Institute of Technology; W. G. Webster, S.M., Massachusetts Institute of Technology; and F. Ireland, A.B., Harvard.

Also under the nominal supervision of Mr. Richmond but actively and ably administered by its chief, C. E. Hills, Jr., B.E.E., Northeastern, with title of Commercial Manager, is the Commercial Department. From the customers' viewpoint this is one of our most important groups, because here takes place the handling of all orders and the accounting associated with them. Directly handling the orders is H. P. Hokanson, and when exchange or servicing is necessary this work comes to the attention of H. H. Dawes. The accuracy of the accounts is the responsibility of A. W. Lufkin.

This Company has long taken great pride in the packing of its apparatus for shipment. This work has been ably directed for more than three quarters of the Company's existence by F. W. Beck.

Associated with Mr. Locke on production problems is a competent staff, some of whom, too, have likewise received an engineering training. The nature of their work is, however, ao interrelated that it will not be detailed here.

Labor turnover continues to be very small. In spite of the fact that during the past year there was an increase in employment of 14% from the average level of the preceding four years, 81% of the entire organization have been with the Company over five years. In fact, 41% have over ten years of service to their credit.

The Company has been operating under the Scientific Apparatus Makers' Code, but its own conditions regarding hours and rates of pay had long anticipated code requirements. In fact, a five-day week with full pay on holidays, and with time-and-one-half pay for overtime, has been in force for nearly sixteen years. Every employee who has been with the Company one year receives two weeks' vacation with pay each summer. Free medical consulting service and aid in the event of unusual illness are also provided. The employees have their own Mutual Benefit Association and operate their own Credit Union.

GENERAL RADIO COMPANY

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