the GENERAL RADIO Experimenter

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Since 1915 – Manufacturers of Electronic Apparatus for Science and Industry

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Also IN THIS ISSUE

The 40th birthday is a minor milestone, not calling forth the same fervor of festivity as the 25th or the 50th. Yet it has a unique significance. A man, lacking the dignity of a full half century, still hopes that he is not really old yet knows he is no longer young. He is old enough to have a past but young enough to have a future. It is the age where he longs to be young again, knowing what he knows now.

Unlike a man, a company is self-renewing and can face the future with the vigor of youth and the experience of maturity; so, as General Radio celebrates its 40th anniversary this month, we recall the past in its significance for the flowering of the present and the fruition of the future.

The electron was less in the public mind than the atom now is when the youthful Melville Eastham started a company intended to apply the com-

paratively new idea of industrial measurements to an industry hardly born.

This young man had another idea, even further from the general industrial mind of 1915 — the concept of a manufacturing company as a community of interest among stockholders, employees, management, and customers. (Two, and eventually three, of these interests became in fact merged because there were no outside stockholders, and the Company early became employee owned and has always been employee managed.) Growth would be slow, financed from earnings, and there would be no lay-offs or shutdowns. Profit-sharing and job security would be features of employment.

Industry would be supplied with the measuring tools required to support the technology of the new fields opened by the development of the electron tube and the exploitation of frequencies above the commercial power range. An adequate engineering staff would insure timely new products, and advanced manufacturing methods would produce prices below the prevailing range for laboratory instruments. Another important departure from prevailing practice, possibly the first in the manufacture of laboratory apparatus, would be the production in quantity (relatively) of a standard line of instruments, which would be maintained in stock to provide prompt fulfillment of customers' requirements. The saving in cost and the improvement in service would be great, for the common practice at the time was to build to a customer's order.

All of these aims have been realized, and through the years the policy that what is good for the employees is good for General Radio has produced a progressing series of employee benefits. Even in the bad time of the early 30's there were no lay-offs on account of lack of work. The first productive employee hired retired a few years ago.

Wavemeter of 1915.

A steady growth has brought employment to approximately 600. Our turnover is small, and lifetime employment is frequent. All this has built a force of highly skilled production workers. No women are employed in manufacturing departments. In assembly, the artisan rather than the mass-production system is used — that is, one man usually assembles a complete instrument working from prints.

Naturally in such a company, spending about 10 per cent of its annual sales in development engineering, an unusually large porportion of the total staff are engineers, and men with engineering background are found in many other positions. The policy has been to develop men within the organization so far as possible. Co-operative courses are carried on with Massachusetts Institute of Technology and with Northeastern University, and in the later years of the course students spend about half their time in the General Radio plant. This has become an important source of engineering talent.

The growth of instruments since those early years is marked by the difference between the 9 pages of 1915's Catalog A and the 258 pages of 1954's Catalog N. However, the modern reader of Catalog A is struck by the element of continuity in an art that has developed in as many directions as has electronics since 1915. The early instruments were the fundamental tools of their day, and modern instruments to perform the same functions are still found in Catalog N.

The variable air condenser was then as now a basic measurement tool. The bakelite insulation has given way to quartz and steatite, but the applications are roughly the same, and the General Radio capacitor of 1955 is, like the condenser of 1915, the best commercial device in its class. The function performed by the universal wavemeter of Catalog A (range of 150 meters to 900 meters) is met in Catalog N by a crystal frequency standard and an extensive array of auxiliary equipment. Closer relatives, wavemeters of the coil and condenser type, also appear in Catalog N. In some of them the condenser and coil have merged in a single unit, the high-frequency butterfly.

The "sensitive high-frequency meter" of the early catalogs is the remote ancestor of the vacuum-tube voltmeter. Standards of inductance and capacitance complete Catalog A's listings, all represented in Catalog N and one even carrying the same type number (107).

A single instrument in Catalog A represents a vanished function — the "Type 110-A Spark Indicator" with which "the regularity of the intensity and spacing of the separate sparks can be seen, thus allowing the user to form a correct idea of the tone value and spark of a set." This development could no doubt have been used as a stroboscope, so even it may be said to have a descendant of sorts in Catalog N.

Subsequent catalogs show a developing sophistication in these original models, and from time to time new basic instruments are added. By 1919 the 9 pages have become 32, and resistance boxes and bridges begin to appear.

In the mid-20's a new element appears — the great build-your-own broadcast-receiver boom was on, and General Radio entered into a major deviation. Radio parts (transformers, condensers, rheostats) became so numerous that by 1925 a separate parts catalog appeared. The line-operated receiver, too complicated for home construction, brought this period to a close, and by 1928 General Radio was again putting all its effort into instrument development and manufacturing. Indeed, this field had not been neglected, for during this period oscillographs, vacuum-tube oscillators, and crystal frequency standards appeared in the

1955's Frequency Standardizing Equipment in the General Radio Engineering Laboratories.

Since 1915, the radio-electronics industry has looked to General Radio for its laboratory standards. At the left is shown an early Type 107 Variable Inductor; at the right, today's direct-reading model.

Catalog, which had grown to 120 pages by 1930. The first cathode-ray oscillograph commercially available for general sale in the United States was introduced in 1931; the first standard-signal generator appeared even earlier, in 1928.

The decade of the 1930's saw a great development in the application of electronic techniques to industrial measurement problems. No longer was the radio industry the principal customer. The General Radio Company in fact became steadily more general and less radio. Firsts in all of these fields were numerous. These included the feedback-type R-C oscillator, the heterodyne wave analyzer, the electronic stroboscope, and noise-meters. The Variac® autotransformer, the first commercialization of an old idea, appeared in 1933.

The war years show a forced-draft expansion and some turning away from instrument development to the immediate requirements of national defense. A portion of our Engineering Department was in fact on leave and engaged in Government projects.

Plant facilities were expanded, and sub-contracting arrangements were entered into with neighboring plants. The booming requirements for electronic weapons produced a corresponding pressure for instruments to measure the performance not only in development but in use. General Radio was, in the early years of the war, the only source in the world outside of Germany for many of these essential tools, and even before the entry of the United States into the war, the expanded requirements of our future allies were being met. The war demands were so well met that the Company received five Army-Navy "E" Awards.

Following the war, an expanded Engineering Department redesigned many older instruments and produced new items at an accelerated tempo. Coaxial connectors and devices extended the frequency range of the Company's operations into the 5000 Mc. area. Motor speed controls appeared for the first time, expanding our interest in the industrial field, as did a voltage regulator. Both of these items were built around the Variac® autotransformer.

Television brought a station monitor, a companion to broadcast and F-M monitors long in the line, and, too new to be catalogued, at the 1955 Radio Engineering Show were displayed instruments for automatic curve tracing, a response to the current trend. Yet, among the elaborate newer instruments the old basic items are not forgotten, and among the most recent developments are found new standards of capacitance and inductance, and new types of impedance bridges.

Expansion in the field of customer service is shown also. The first catalogue listed only the factory address. During the 20's and early 30's, listings of foreign representatives appear covering, before the outbreak of hostilities, every portion of the world. District offices started by Company personnel appear first in New York in 1934, followed by Los Angeles, Chicago, Washington, and this month, Philadelphia.

No industrial reminiscences are complete without recalling the old works where everything started. General Radio, too, had its old plant, although it is doubtful if the founder ever stoked the furnace there. This building was abandoned by General Radio in 1927, and operations moved to a growing plant started nearby in 1924. This site, with additions to expand it fivefold through the years, was outgrown in 1950, and a branch plant was built in West Concord, Massachusetts, which now accommodates about one-half of the manufacturing operations.

This, then, is what we know now, the accumulated experience of 40 years. It is the foundation on which younger men are building — young men with more in their philosophies than an aging scribbler of memoirs has dreamed of.

— C. T. Burke

NEW R-F BRIDGE FEATURES SMALL SIZE AND ADDED OPERATING CONVENIENCE

Since its introduction in 1942, the General Radio Type 916-A Radio-Frequency Bridge[1] has been the radio industry's standard for measurements on antennas, lines, networks and components in the frequency range between 400 Kc and 60 Mc. The widespread acceptance accorded this bridge is due largely to two important characteristics — accuracy of measurement and simplicity of operation. A new and improved version of this bridge has recently been developed, the Type 1606-A Radio-Frequency Bridge, which retains the desirable features of the older bridge and incorporates several new ones that contribute to increased ease and convenience of operation.

As in the older bridge, the resistive and reactive components of the unknown impedance are directly indicated on separate dials when the bridge is balanced to a null. The direct-reading resistance range is from 0 to 1000 ohms, and the direct-reading reactance range is from 0 to $\pm$ $5000/f_{Mc}$ ohms, where f_{Mc} is the frequency in megacycles. Higher impedances can be measured indirectly. A modified Schering bridge circuit, shown in Figure 2, is used, in which both the resistive and reactive components of the unknown impedance are measured in terms of capacitance,

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[1] Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Mc," *General Radio Experimenter*, XVII, 3, August, 1942.

and all balance adjustments are made by means of variable air capacitors.

Among the improvements in the new bridge are:

1. The volume occupied by the bridge has been halved.
2. A single bridge transformer replaces the two transformers used in the older bridge, thus eliminating the necessity of changing transformers at 3 megacycles.
3. New milled-plate variable air capacitors, which have very low losses, are used as reactance standards.
4. The resistor previously mounted in the lead used to connect the unknown to the bridge has been moved inside the bridge, which facilitates connections to the unknown.
5. The reactance dial is calibrated over a 330° arc rather than over a 165° arc, which permits more precise readings.
6. Teflon insulation is used to support the important bridge elements in order to keep losses low and to make operation possible over wide temperature ranges.
7. Dial locks are provided on the initial balance controls to prevent accidental movement.
8. A separate carrying case is made available as an accessory.

Bridge Transformer

Probably the most significant improvement in the bridge is the new broadband bridge transformer, which operates efficiently over the entire frequency range of the bridge. As shown in Figure 2, this transformer is the isolation network used to couple power from the generator into the bridge through junction points a and c.

The transformer must develop a voltage between points a and c which "floats" with respect to ground. That is, the relative potentials between point a and ground and between c and ground must be determined by the impedances in the bridge arms alone and not by stray couplings in the transformer. The transformer therefore should have only magnetic coupling between the primary and secondary, and all capacitive couplings between the windings themselves should be eliminated.

Figure 1. View of the Type 1606-A Radio-Frequency Bridge in its carrying case. Shielding is provided by the metal cabinet of the instrument, so that the bridge can be used either in or out of the carrying case.

In order to keep the stray capacitance coupling negligible, the primary and secondary windings are completely shielded, and an additional shield is used between the shielded primary and secondary, as shown in Figure 3. The fixed capacitance between the middle shield and the secondary shield causes no error since it appears in parallel with the capacitive arm of the bridge and can be included as part of the capacitance C_N. The details of construction are shown in Figures 3 and 4. Note that the individual shields are not complete turns around the core but are slotted to avoid the formation of short-circuited turns.

The wide frequency range is obtained through the use of a high-permeability ferrite core ($\mu = 850$) which forms a complete magnetic path around the windings. The low-reluctance magnetic circuit results in a high degree of coupling between the primary and secondary, and, since only two turns are required on both windings to produce an adequate primary inductance for satisfactory performance at the lowest frequencies, it also results in a high self-resonant frequency for the transformer.

All connections to the windings are made by means of coaxial cables in order to minimize possible capacitance couplings.

The performance of this new transformer is completely satisfactory. It covers the entire frequency range of the bridge and does not require any adjustment in order to balance out undesired couplings. Figure 5 is a graph showing the relative voltage developed across the bridge at balance as a function of frequency. The performance of the two transformers used in the older Type 916-A R-F Bridge is also shown. As is evident, the new transformer produces a substantially larger voltage across the bridge at practically all frequencies than do the older units.

Figure 3. View of the bridge transformer with component parts shown at left.

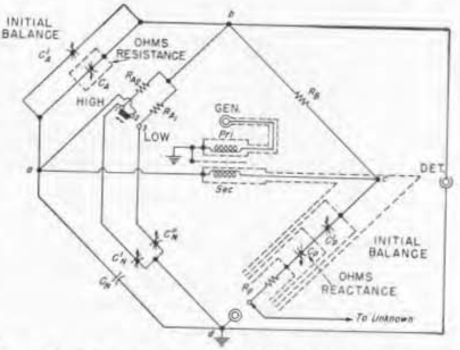
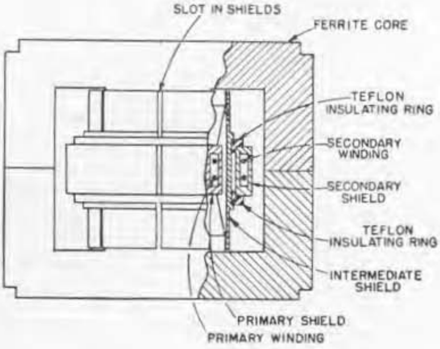


Figure 2. Schematic diagram of the bridge circuit.

As a matter of interest, the characteristics of the transformer alone working between a 50-ohm source and a 50-ohm load were measured and are plotted in Figure 6. As can be seen, the insertion loss is reasonably low over a very wide frequency range in spite of the large physical spacing necessitated by the shielding between the primary and secondary windings.

Figure 4. Cross section drawing of the bridge transformer.



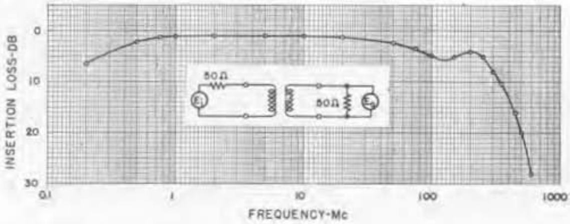


Figure 6. Insertion loss of the bridge transformer as a function of frequency, working between 50-ohm impedances.

Variable Capacitors

A new type of variable air capacitor is used for the reactance balances and the initial resistance balance. In this capacitor the complete rotor and stator sections are milled out of solid blocks of aluminum, a construction which avoids the losses at the joints between plates and spacers found in many conventional designs. Ball bearings mounted in high-temperature polystyrene-disk insulators support the glass-fiber shaft to which the rotor is clamped. Because their over-all losses are very low, capacitors of this type are excellent components for use in the bridge. Figure 7 is a view of a 220 $\mu\mu$f variable capacitor of the type used in the instrument.

Unknown Lead

In the older bridge the resistor, *Rp*, shown in Figure 2, used to make possible the initial resistance balance, is mounted external to the bridge in the lead used to connect the unknown to the circuit under test. As a result, special leads with the resistor mounted in them had to be used or an initial balance could not be obtained. In the new bridge the resistor is mounted inside the bridge, which permits much greater flexibility in the selection of connecting leads. In fact, components can often be most satisfactorily measured at high frequencies when connected directly across the unknown terminals by means of their own leads.

Carrying Case

The bridge is mounted in a sturdy aluminum cabinet, the inside of which is actually part of the bridge circuit. In field applications where some additional protection is desired, or in cases in which the instrument is transported frequently, a separate luggage-type case, shown in Figure 1, can be obtained as an accessory. The instrument can be operated while inside the case if desired.

Figure 5. Relative voltage developed across the bridge at balance as a function of frequency. Data for the older Type 916-A model are shown for comparison.

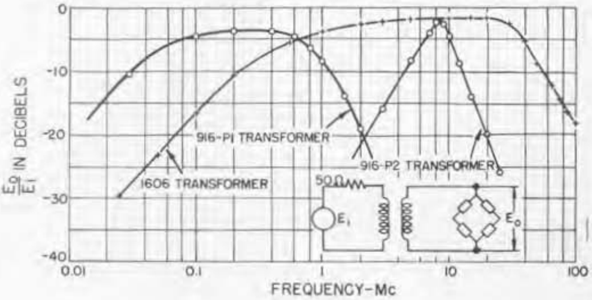


Figure 7. A variable air capacitor of the type used in the new r-f bridge.

Performance

The bridge is well suited to the accurate measurement of components, antennas, and other circuits having relatively low impedances over a frequency range from below 400 kc to 60 Mc. Figure 9 shows the results of a series of measurements made over a frequency range from 100 kc to 60 Mc on a length of transmission line terminated in a resistor and a capacitor connected in series.

At very low frequencies, that is below about 400 Kc, the resistance balance becomes progressively less sensitive than the reactance balance and as a result it becomes more difficult to measure very small resistances accurately. Since the reactance range is inversely proportional to frequency, it also becomes increasingly more difficult to measure very small reactances as the difference in dial settings for a given reactance is also inversely proportional to frequency, and in extreme cases the resolving power of the dial is approached or exceeded.

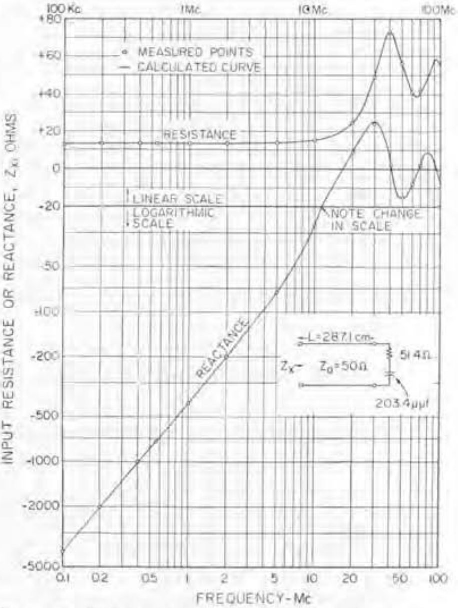


Figure 8. Resistance and reactance of a loaded transmission line as measured on the bridge (circles) and as calculated (curve).

The improvements outlined in the previous paragraphs will make this bridge even more useful than was the previous model. The broadcast engineer measuring antennas and the research worker in the field will both find new features which will simplify their work.

— R. A. Soderman

SPECIFICATIONS

Frequency Range: 400 Kc to 60 Mc.

Reactance Range: ±5000Ω at 1 Mc. This range varies inversely as the frequency; and at other frequencies the dial reading must be divided by the frequency in megacycles.

Resistance Range: 0 to 1000Ω.

Accuracy: For reactance at frequencies up to 50 Mc, $\pm(2\% + 1\Omega + 0.0008 \times R \times f)$, where R is the measured resistance in ohms and f is the frequency in Mc.

For resistance, at frequencies up to 50 Mc,

$$\pm\left[1\% + 0.0024 f^2 \left(1 + \frac{R}{1000}\right)\% \pm \frac{10^{-4} X}{f}\Omega + 0.1\Omega\right]$$

subject to correction for residual parameters. R is the measured resistance in ohms, X is the measured reactance in ohms, and f is the frequency in Mc. At high frequencies, the correction depends upon the frequency and magnitude of the unknown resistance component. A chart from which the correction can be determined is given in the instruction book supplied with the bridge.

Satisfactory operation can be obtained at frequencies as low as 100 Kc and somewhat above 60 Mc with not quite as good accuracy as indicated above. The f^2 term is important only at frequencies above 10 Mc. The $1/f$ term is important only at very low frequencies when the resistance of a high-reactance, low-loss capacitor is measured.

Accessories Supplied: Two leads of different lengths for connecting the unknown impedance to the bridge terminals, two Type 874-R22 Coaxial Cables for connecting the generator and detector, and one Type 874-PB58 Panel Connector.

Other Accessories Required: Radio-frequency generator and detector. The Type 1330-A Bridge Oscillator and the Type 1211-A Unit Oscillator are satisfactory generators, as are the Type 1001-A and the Type 805-C Standard-Signal Generators. At frequencies above 50Mc a Type 1215-A Unit Oscillator or a Type 1021-AV Standard-Signal Generator is recommended.

A well-shielded communication receiver covering the desired frequency range makes a satisfactory detector. It is recommended that the receiver be fitted with the Type 874-PB58 Panel Connector or other coaxial connector to avoid leakage at the input connection.

Mounting: Welded aluminum cabinet supplied. A luggage-type carrying case is available separately and is recommended if the bridge is to be used as a portable field instrument.

Dimensions: 12½ x 9½ x 10¼ inches, over-all.

Net Weight: 23 pounds without carrying case; 29 pounds with carrying case.

Type		*Code Word*	*Price*
1606-A	**Radio Frequency Bridge***	CIGAR	**$535.00**
1606-P 1	**Luggage-type Carrying Case**	BILLY	**$15.00**

*U. S. Patents Nos. 2,125,816; 2,548,457; and 2,376,394

AN IMPROVED SOUND-LEVEL CALIBRATOR

The Type 1552-A Sound-Level Calibrator[1] has had an unexpectedly wide acceptance and use by those working with noise-measuring systems. With the combination of this calibrator and the Type 1307-A Transistor Oscillator,[2] over-all acoustic calibrations of noise-measuring systems are as simply and easily performed as electrical tests on the amplifiers and meters.

The use of this calibrator in noisy environments is limited by its 85 db maximum output level imposed by distortion in the transducer. For successful operation, therefore, the maximum background noise level is 75 db. While this is satisfactory for a majority of uses, it may be difficult or inconvenient in industrial noise surveys to find background levels as low as 75 db. A further complication results from the acoustic resonances within the calibrator, which may amplify frequencies present in the background, so that an actual background level of only 75 db may be effectively increased as much as 10 db.

To effect an improvement it was necessary to find a small transducer unit as rugged and stable as the one being used and yet capable of producing much higher sound levels without distortion. Long-period tests were conducted on a number of different types, and the unit finally chosen is a modification of the Shure Brothers Model R-5 Controlled-Reluctance Microphone Cartridge.[3] This transducer, which can produce levels in excess of 100 db with no greater input than that required by

Figure 1. View of the Type 1552-B Sound-Level Calibrator, installed on the Type 1551-A Sound-Level Meter and driven by the Type 1307-A Transistor Oscillator.

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[1] E. E. Gross, "An Acoustic Calibrator for the Sound Level Meter," *General Radio Experimenter*, December, 1949.

[2] Arnold Peterson, "A Pocket-size Transistor Oscillator for Audio Frequency Testing," *General Radio Experimenter*, August, 1954.

[3] B. B. Bauer, U. S. Patent 2,454,425, Nov., 1948.

its predecessor, has been incorporated in the new Type 1552-B Sound-Level Calibrator. The view of Figure 1 shows the new calibrator, which is quite similar in external appearance to the previous model. The interior mechanical and acoustical system, however, has been completely redesigned to obtain a better frequency characteristic. This, together with the higher output from the new calibrator, is shown in Figure 2.

A minor annoyance that has been eliminated in the design of the new calibrator is the frequency shift in the Type 1307-A Transistor Oscillator caused by the reactive input impedance of the old Type 1552-A.

The new calibrator can be used on all the usual sound-level meter microphones and on a number of supplementary microphones, without the need for special adaptors. Table 1 is a list of these microphones.

On all microphones in Table 1 except the BA-120 as installed in the Type 1555-A Sound Survey Meter and the now obsolete BR2S, the calibrator makes a good acoustic seal so that the background level is actually attenuated when a calibration is made. This feature coupled with the high level produced by the calibrator insures that a good

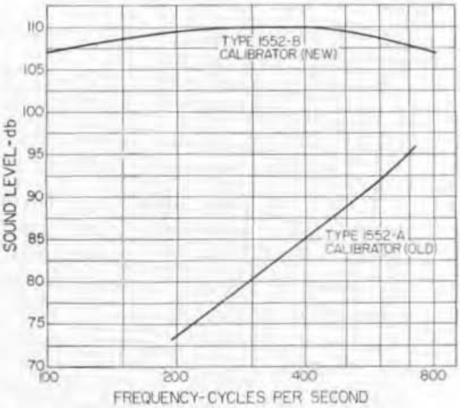

Figure 2. Output characteristics of the new and old models of the calibrator.

TABLE 1

Microphone	*Where Used*
Shure Brothers Type 9898	(G R Type 759-310 supplied on Type 1551-A Sound Level Meter & 759-B Sound Level Meter)
Brush Type BA-120	(As used in G R Type 1555-A Sound Survey Meter)
Brush Type BR2S	(Used on early G R Type 759-A Sound Level Meter)
Altec Type 633-A	(Supplied with G R Type 759-P25 Dynamic Microphone Assembly)
Shure Brothers Type 98B99	(New-type crystal microphone. Not yet available in production quantities [4])
Altec 21-BR Types	(Type 21-BR-150 and Type 21-BR-180 supplied with G R Type 1551-P1L and Type 1551-P1-H Condenser Microphone Systems [5])
Western Electric Type 640-AA	(Laboratory Standard Condenser Microphone [6])
Kellogg Microphone	(Laboratory Standard Condenser Microphone [7])
Massa Type M-141-B	(High Level Crystal Microphone [5])

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[4] John Meddill, "A Miniature Piezo Electric Microphone." *Transactions of the I.R.E. Professional Group on Audio*, Vol. AU 1, No. 6, November-December, 1953, pp. 7-10.

[5] Arnold Peterson, "Sound Measurements at Very High Levels," *General Radio Experimenter*, September, 1954.

[6] M. S. Hawley, "The Condenser Microphone as an Acoustic Standard," *Bell Laboratories Record*, Vol. XXXIII, No. 1, January, 1955, pp. 6-10.

[7] J. F. Houdek, Jr., "A Stable Laboratory Standard Condenser Microphone," *Journal of the Audio Engineering Society*, Vol. 2, No. 4, October, 1954, pp. 234-237.

calibration check can be made even in very noisy environments.

Variations in the acoustic impedance of the microphone will result in variations in the acoustic level produced by the calibrator. For the small newer microphones and condenser microphones, these variations are small, but on the older crystal microphones which are larger in diameter, they become appreciable. Consequently, the absolute level produced by the calibrator on any of these microphones cannot be specified closer than ±1 db. Tests indicate that the stability of the calibrator is excellent, and so whatever level is produced at a given microphone should be reproduced within a few tenths of a db over long periods of time.

The calibrator has been designed to fit laboratory standard condenser microphones,[6, 7] and hence its accuracy can be checked against these standards. In addition, it can be used as a transfer device between the laboratory standard and a group of less stable working microphones.

Whether used as a working standard or as a stable transfer device in connection with a standard microphone, the new TYPE 1552-B Sound-Level Calibrator, because of its higher level, its flatter frequency response, and its adaptability to a number of different microphones, is a valuable aid to standardization in acoustic measurements.

— E. E. GROSS

SPECIFICATIONS

Input: 2.0 volts, 400 cycles; total harmonics must not exceed 5%.

Output: When in position on the 9898-type microphone used on TYPES 1551-A and 759-B Sound-Level Meters, the calibrator produces a sound pressure of 110±1 db (above a reference level of 0.0002 microbar) at the microphone diaphragm for rated input as specified above.

Terminals: TYPE 938-W Binding Posts.

Accessories Required: 400-cycle source, with output control and voltmeter. The TYPE 1307-A Transistor Oscillator is recommended.

Dimensions: (Length) 4½ x (diameter) 2½ inches, over-all.

Net Weight: 14 ounces.

Type		*Code Word*	*Price*
1552-B	**Sound-Level Calibrator............................**	NATTY	**$45.00**

SUMMER CLOSING

During the weeks of July 25 and August 1, our Manufacturing Departments will be closed for vacation.

There will be business as usual in the Sales Engineering and Commercial Departments. Inquiries, including requests for technical and sales information, will receive our usual prompt attention.

Our Service Department requests that, because of absences in the manufacturing and repair groups, shipments of material be scheduled to reach us either well before or delayed until after the vacation period.

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