THE GENERAL RADIO

EXPERIMENTER

VOLUME 35 No. 8 AUGUST, 1961

IN THIS ISSUE

New Sound-Level Meter

New Precision Capacitors

THE GENERAL RADIO

EXPERIMENTER

Published Monthly by the General Radio Company

VOLUME 35 · NUMBER 8 AUGUST, 1961

CONTENTS

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

GENERAL RADIO COMPANY

West Concord, Massachusetts

Telephone: (Concord) EMerson 9-4400; (Boston) MIssion 6-7400

NEW YORK: Broad Avenue at Linden, Ridgefield, New Jersey
Telephone — N. Y., WOrth 4-2722
N. J., WHitney 3-3140

CHICAGO: 6605 West North Avenue, Oak Park, Illinois
Telephone — VIllage 8-9400

PHILADELPHIA: 1150 York Road, Abington, Pennsylvania
Telephone — HAncock 4-7419

WASHINGTON: 8055 13th St., Silver Spring, Maryland
Telephone — JUniper 5-1088

LOS ANGELES: 1000 North Seward St., Los Angeles 38, Calif.
Telephone — HOllywood 9-6201

SAN FRANCISCO: 1186 Los Altos Ave., Los Altos, Calif.
Telephone — WHitecliff 8-8233

CANADA: 99 Floral Parkway, Toronto 15, Ontario
Telephone — CHerry 6-2171

REPAIR SERVICES

EAST COAST: General Radio Co., Service Dept., 22 Baker Avenue, West Concord, Mass.
Telephone — Concord, EMerson 9-4400
Boston, MIssion 6-7400

NEW YORK: General Radio Co., Service Dept., Broad Ave. at Linden, Ridgefield, New Jersey
Telephone — N. Y., WOrth 4-2722
N. J., WHitney 3-3140

MIDWEST: General Radio Co., Service Dept., 6605 West North Ave., Oak Park, Illinois
Telephone — VIllage 8-9400

WEST COAST: General Radio Co., Service Dept., 1000 North Seward Street, Los Angeles 38, Calif.
Telephone — HOllywood 9-6201

CANADA: Bayly Engineering, Ltd., First St., Ajax, Ontario
Telephone — Toronto EMpire 2-3741

COVER

Rotor and stator plates of the Type 1422 Precision Capacitors are individually aligned during assembly.

New Model Meets Both American and International Standards

TYPE 1551-C SOUND-LEVEL METER

The change in type number (TYPE 1551-B to TYPE 1551-C) designates two significant changes in the performance of the General Radio Sound-Level Meter.[1] A new and superior microphone is now supplied, and the frequency weighting characteristics have been modified to conform to the new American Standard Specifications for General-Purpose Sound-Level Meters. (ASA S1.4-1961.) Neither change is obvious at a glance, since the appearance of the instrument, except for a shift from B to C in the engraved type number on the panel, is unchanged.

[1] E. E. Gross, "Improved Performance Plus a New Look for the Sound-Level Meter," *General Radio Experimenter*, Vol. 32, No. 17, October 1958.

NEW MICROPHONE

The TYPE 1560-P3 Microphone* supplied with the TYPE 1551-C Sound-Level Meter is a PZT piezoelectric ceramic type developed expressly for sound-level meters. It replaces and is interchangeable with the older TYPE 1560-P1** Rochelle-salt crystal microphone. Its characteristics approach those of condenser microphones classed as laboratory standards. Unlike condenser microphones, however, the ceramic unit does not require a special preamplifier with a high dc polarizing-voltage sup-

*Identified by red insigne on face of microphone and Shure Brothers model no. 98108 on nameplate.

**Identified by blue insigne on face of microphone and Shure Brothers model no. 98B99 on nameplate.

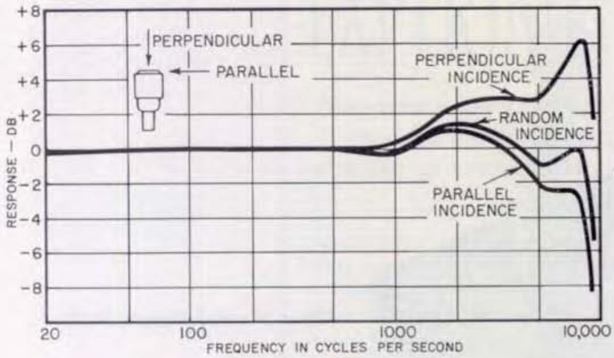


Figure 1. Response of the Type 1560-P3 Ceramic Microphone.

ply, and its impedance is an order of magnitude lower, so that leakage due to high humidity is less of a problem, and it can be used more readily at the end of a cable.

Several other features of this new microphone make it highly desirable for sound-level meter use:

1. Frequency Response. As shown in Figure 1, the microphone has a flat response to sounds of random incidence. Of the several hundred microphones we have measured to date, all match the curve shown to within ±.3 db from 20 cps to above 1000 cps, and most of the microphones match the curve to within ±1 db up to 8000 cps.

2. Sensitivity. The nominal sensitivity is the same (−60 db re 1 volt per microbar) as for Type 1560-P1 Rochelle-salt crystal microphone, which is unusually high for a small ceramic unit.

3. Temperature Coefficient of Sensitivity. The output voltage is practically constant with temperature. Our measurements indicate that the temperature coefficient of sensitivity is approximately −.01 db per degree Centigrade. This compares very favorably with that of laboratory standard microphones, such as the Western Electric Co. Type 640-AA.

4. Internal Impedance. The internal impedance of the new microphone is capacitive, and, although it is of the same order of magnitude as that of the

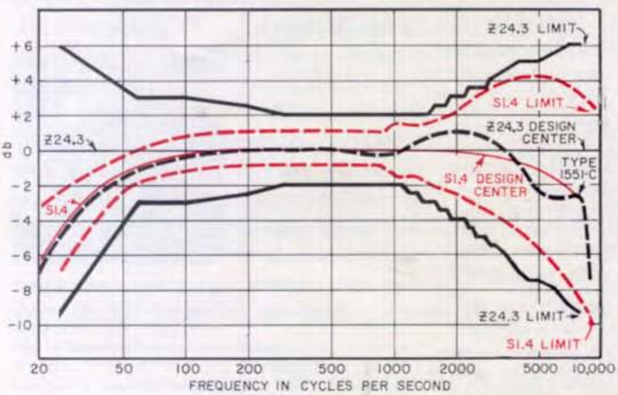


Figure 2. Design centers and limits for C-weighting characteristics, as specified by Z24.3 and S1.4 (red) standards together with acoustical response of the Type 1551-C Sound-Level Meter for C-weighting.

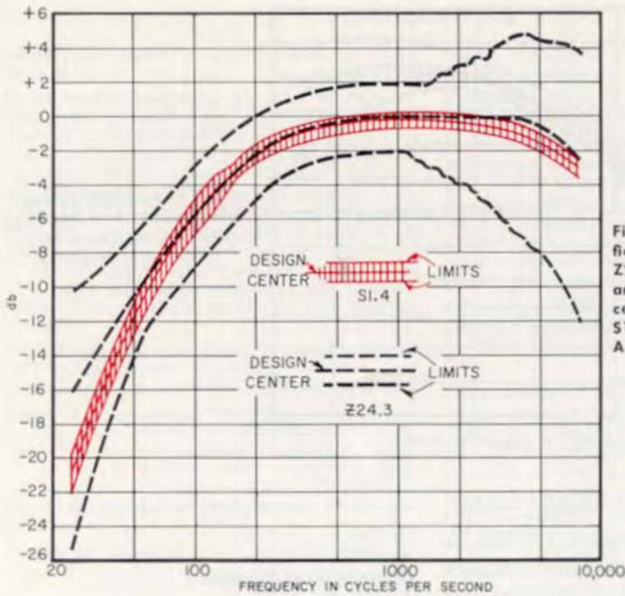


Figure 3. B-weighting specifications of S1.4 (red) and old Z24.3 standards. S1.4 standard shown assumes design-center, C-weighting, since S1.4 characteristic for both A- and B-weighting is specified with respect to C.

Rochelle-salt crystal, it is much more nearly constant. The capacitance is 475 pf at 25C and varies from 445 pf to 510 pf over a temperature range of 0 to 50C. The Rochelle-salt unit, for comparison, has a nominal capacitance of 1100 pf, at 25C, which drops to 650 pf at 10 and 30C.

This high stability of internal impedance results in greatly improved operation when the microphone is used with a long extension cable; the cable loss no longer varies widely as a function of the temperature at the microphone.

5. Directivity. The new microphone, since it is the same physical size and is similar in construction, maintains the good directional characteristics of the Type 1560-P1. Up to 1000 cps the variation in output with angle of sound incidence is very small. Above 1000 cps diffraction causes the microphone to respond more to sounds arriving normal to the diaphragm axis (0-degrees or perpendicular incidence) than to sounds from other directions. Figure 1 shows the extent of the variation in sensitivity as a function of the direction of sound incidence.

6. Ruggedness. Designed to be durable and dependable, this microphone will withstand, without damage, temperatures of −30 to +95C and relative humidities of 0 to 100%.

CIRCUIT CHANGES

New ASA Standard

The older Type 1551-B Sound-Level Meter[1] was designed to meet the requirements of the then current standard, ASA-Z24.3-1944.

The new Type 1551-C has been modified to conform to the weighting requirements of the newly announced standard (ASA S1.4 1961). The changes in response are not large, but an instrument matching the design center curves of ASA Z24.3 1944 will not fall within the tolerance allowed in ASA S1.4 1961.

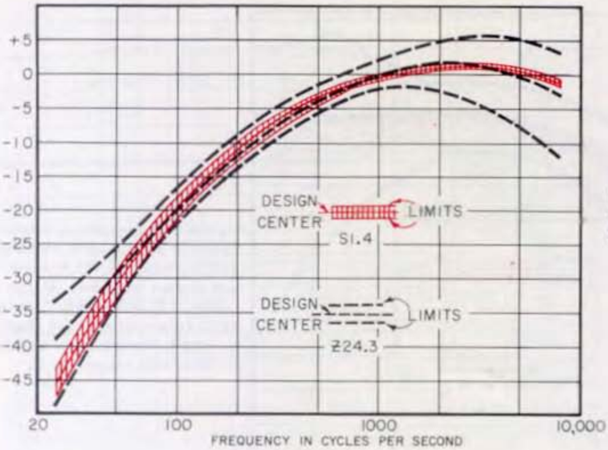


Figure 4. A-weighting specifications of S1.4 and old Z24.3 standards, assuming design-center C-weighting.

Figure 2 shows the design center, C-weighting, and tolerances allowed by both standards, plus the actual response of the new TYPE 1551-C Sound-Level Meter to sounds of random incidence. Design center curves differ only at high and low frequencies, while the new tolerances reduce the possible differences between sound-level meters of different manufacture, particularly at low frequencies.

Figures 3 and 4 compare the new and old B and A weighting characteristics respectively. The old weighting curves are specified as drawn. The new weighting curves (ASA S1.4 1961) are specified with respect to the C weighting characteristics. They are shown here as they would be in an instrument that matches the C-weighting design center. Here again the aim is to insure that instruments of different manufacture will have very similar characteristics.

In addition to the new weighting characteristics, the TYPE 1551-C has a flat response (20 kc position of the weighting switch) from 20 cps to 20 kc for sound-pressure measurements with wide range microphones. The output signal is unweighted and suitable for spectrum analysis.

International Standard

This sound-level meter also conforms to the new international standards. The requirements of the International Recommendation for Sound-Level Meters (IEC Publication 123, 1961) are, in most respects, similar to those of ASA S1.4 1961. The TYPE 1551-C readily meets all of the electrical requirements. The free-field acoustical response requirement is met when the microphone post is set at an angle of 55° with respect to the panel of the instrument. The swivel microphone post can be supplied with a detent at this preferred angle. In the near future all TYPE 1551-C Sound-Level Meters will be supplied with a properly detented microphone post for this application.

This new sound-level meter, with its stable, high-performance ceramic microphone and its conformance to both American and International Standards represents a significant advance in the accuracy and reliability of sound measurement devices.

— E. E. GROSS

SPECIFICATIONS

Sound-Level Range: From 24 to 150 db (re .0002 microbar).

Frequency Characteristics: Any one of four response characteristics, A, B, C, or 20 kc, can be selected by a panel switch.

The A, B, and C weighting positions are in accordance with American Standard Association specifications on sound-level meters.

The 20-kc position allows the use of the complete frequency response of the sound-level meter's amplifier, which is flat from 20 cps to 20 kc, so that complete use can be made of wide-range microphones such as the General Radio TYPE 1551-P1 Condenser Microphone Systems.

Microphone: The microphone is a highly stable PZT ceramic type. Condenser and dynamic microphones are available as accessories.

Sound-Level Indication: Sound level is indicated by the sum of the meter and attenuator readings. The clearly marked, open-scale meter covers a span of 16 db with calibration from −6 to 10 db. The attenuator is calibrated in 10-db steps from 30 to 140 db above the standard reference level.

Output: An output of 1 volt across 20,000 ohms (when the panel meter is at full scale) is available at an output jack. The output can be used to drive frequency analyzers, recorders, and oscilloscopes. A phone-plug-to-TYPE 274 connecting cable (TYPE 1560-P95) is available.

Input Impedance: 25 megohms in parallel with 50 pf.

Output Impedance: 7000 ohms.

Meter Damping: The panel meter has two different damping characteristics, either FAST or SLOW response being selected by a panel switch. The meter ballistics agree with current ASA standards.

Calibration: Built-in calibration circuit standardizes the sensitivity of the electrical circuits in the sound-level meter.

Calibration Accuracy: After standardization, sound-level measurements are within ±1 db at 400 cps, as specified in ASA standards. The TYPE 1552-B Sound-Level Calibrator is available for making periodic acoustic checks on the over-all calibration, including microphone.

Temperature and Humidity Effects: Readings are independent (within 1 db) of temperature and humidity over normal ranges of room conditions.

Power Supply: Two 1½-volt size D flashlight cells (Rayovac 2LP or equivalent) and one 67½-volt battery (Burgess XX-45 or equivalent) are supplied. A 115-volt ac power supply, the TYPE 1262-B, is available.

Tube and Transistor Complement: Four CK512-AX, two CK6418, one 2N1372 transistor.

Accessories Supplied: Telephone plug.

Accessories Available: TYPE 1551-P2 Leather Case, which permits operation of the instrument without taking it from the case. TYPE 1560-P95 Connecting Cable, for connecting output to TYPE 1521-A Graphic Level Recorder.

Cabinet: Aluminum, finished in gray crackle.

Dimensions: Height 9¼, width 7¼, depth 6⅛ inches (235 by 185 by 160 mm), over-all.

Net Weight: 7¾ lb (3.5 kg) with batteries; 9¾ lb (4.4 kg) including leather case.

Type		*Code Word*	*Price*
1551-C	Sound-Level Meter	MIMIC	$415.00
1262-B	Power Supply	MAYOR	95.00
	Set of Replacement Batteries	MIMICADBAT	3.90
1551-P2	Leather Carrying Case	CALYX	24.50
1560-P95	Connecting Cable	CONEC	3.00

NEW DYNAMIC MICROPHONE SYSTEM

The TYPE 1560-P12 Dynamic Microphone System replaces the older TYPE 759-P25 Dynamic Microphone and Accessories[1] as a high-quality acoustic pickup system for sound-level meters, analyzers, graphic level recorders or tape recorders. This new microphone system, illustrated in Figure 1, includes the TYPE 1560-P2 Dynamic Microphone, the TYPE 1560-P22 Microphone Transformer, the TYPE 1560-P72 25-foot cable and the TYPE 1560-P32 Tripod.

[1] "A Dynamic Microphone for the Sound-Level Meter," *General Radio Experimenter*, Vol. XXV, No. 11, April 1951.

Microphone Characteristics

The older TYPE 759-P25 Dynamic Microphone was a special Altec Lansing TYPE 633-A. The TYPE 1560-P2 Dynamic Microphone is also manufactured by Altec Lansing and is a special version

Figure 1. View of the Dynamic Microphone System with the Sound-Level Meter.

of their Type 661-A Microphone modified to meet the requirements of the American Standard Specifications for General-Purpose Sound-Level Meters (ASA S1.4-1961). The Type 661-A uses the same basic moving coil system of the Type 633-A, but it is housed in a smaller diameter shell which decreases diffraction effects at high frequencies. It has a sintered bronze face plate, in place of a silk cloth screen, which provides excellent protection from dust and other particles, a very worthwhile feature when the microphone is used in industrial areas and subjected to atmospheres containing tiny iron particles resulting from machining and grinding operations.

The low-frequency response, as illustrated in Figure 2, remains essentially flat down to 25 cps. In addition to the Microphone System response to sound of perpendicular incidence (0°) and sounds of random incidence, Figure 2 shows the over-all response of the Type 1551-C Sound-Level Meter (C weighting) and the Type 1560-P12 Dynamic Microphone System to sounds of random incidence. (See Figure 3 in accompanying article on Type 1551-C Sound-Level Meter for ASA S1.4 1961 requirements for C-weighting specifications.)

Use with Acoustic Calibrator

As shown in Figure 3, a step has been machined in the face of the microphone so that it can be readily calibrated with the Type 1552-B Sound-Level Calibrator. With 2.0 volts at 400 cps applied to the calibrator and the calibrator mounted as shown, the sound pressure level developed at the Type 1560-P2 Microphone is 119 db re 0.0002 microbar.

Transformer

The response curves shown in Figure 2 are for the complete dynamic micro-

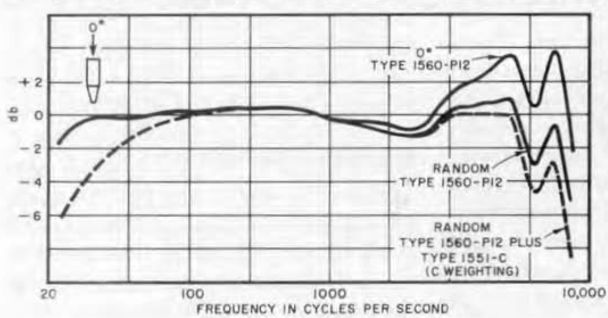


Figure 2. Free-field response characteristics of the Type 1560-P12 Dynamic Microphone System for 0° and random incidence, and for the Dynamic Microphone System plus the Type 1551-C Sound-Level Meter for random incidence.

phone system and include the TYPE 1560-P22 Dynamic Microphone Transformer, which has a very small effect on the frequency response of the system between 25 cps and 10 kc. This transformer steps up the output of the microphone from −90 db to −60 db re 1 volt per μbar so that the TYPE 1551-C Sound-Level Meter still reads directly in db re 0.0002 microbar when connected to the dynamic microphone system. The transformer is very well shielded to minimize the effects of stray magnetic fields. As shown in Figure 1, a strap that is part of the transformer case provides a convenient means to attach the transformer to the sound-level meter cabinet.

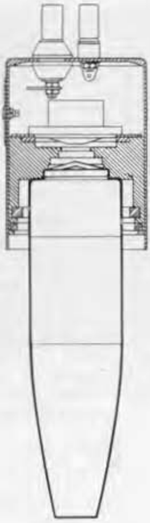


Figure 3. Sketch showing how the GR acoustic Calibrator fits firmly on the dynamic microphone to assure definite and reproducible calibration conditions.

Use

A number of noise-measurement codes require the use of a dynamic microphone, and noise-control situations continually arise where the dynamic microphone is required or where its use simplifies the measurement problem as when measurements must be made at the end of a long cable. Because of its low internal impedance, the dynamic microphone can drive very long cables with no loss in output voltage and consequently requires no cable corrections.

The combination of the dynamic microphone system and the TYPE 1551-C Sound-Level Meter meets the requirements of ASA S1.4 1961.

SPECIFICATIONS

Sensitivity: Open-circuit output of typical microphone is 90 db below one volt per microbar, and of microphone plus transformer is 60 db below one volt per microbar. The sensitivity is satisfactory for direct reading of sound-pressure level by the TYPE 1551-C, TYPE 1551-B, TYPE 1551-A,* and TYPE 759-B* Sound-Level Meters.

Direct Use with Analyzers: Microphone output can be supplied directly to the TYPE 1550-A† Octave-Band Noise Analyzer provided the level of the measured components is above 70 db (re 0.0002 microbar) or to the TYPE 1554-A† Sound and Vibration Analyzer, provided the level of measured components is above 50 db. (A TYPE 1552-B Sound-Level Calibrator is necessary to obtain absolute level.)

Maximum Safe Sound-Pressure Level: Sound-pressure levels above 140 db can damage the microphone.

Calibration: Output level is checked in our laboratories at several frequencies against a standard microphone that is calibrated periodically. The level at 400 cps is stated.

Cable Correction: No correction is necessary for the 25-foot cable supplied or the TYPE 1560-P72B 100-foot cable.

Components: TYPE 1560-P2 Dynamic Microphone, TYPE 1560-P22 Transformer Assembly, TYPE 1560-P72 Cable, TYPE 1560-P32 Tripod.

Net Weight: 5¼ pounds (2.4 kg); microphone only, 8½ oz (250 g).

*Type 1560-P92 Adaptor required.
†Type 1560-P93 Adaptor required.

Type		*Code Word*	*Price*
1560-P12	**Dynamic Microphone System**	DYNAM	**$210.00**
1560-P72B	**Extra 100-foot cable**	ADAPTORWAY	**30.00**
1560-P92	**Adaptor Assembly**	ADAPTORBUG	**12.50**
1560-P93	**Adaptor Assembly**	ADAPTORCOP	**12.50**

A NEW AND IMPROVED PRECISION CAPACITOR

Figure 1. Panel view of the new Type 1422 Precision Capacitor. Note the large, transparent flange on the control knob, which greatly facilitates precise setting.

There are many readers of the *Experimenter* who will have no difficulty in recalling, in a nostalgic moment, the consistent proud contention of the makers of the Dodge automobile in the 1920's that they made "no yearly models, only continuous improvements." Such a description might with equal truth be applied to the history of precision worm-driven capacitors at General Radio. Until the appearance of the new Type 1422 Capacitor in our current catalog, there had been only two distinctively different catalogued designs in forty years of continuous manufacture, the Types 222 and 722. Yet, these two designs throughout their useful lives were being constantly improved as new methods or materials became available, or when field reports indicated the desirability of modifications. Eventually, of course, the improvements that seemed desirable got beyond the capabilities of the existing design, and then a fresh start had to be made. A review of precision-capacitor manufacture and design (including some specialized designs never catalogued) will help to make more significant the improved features that have been incorporated into the new Type 1422.

Type 222 First Design

When the writer arrived at General Radio in the summer of 1921, the Type 222 Capacitor, then known as a condenser, was already a well-established product of the six-year-old firm (Figure 2).

It was massively and heavily constructed, using cast brass end plates spaced apart by three hexagonal brass posts. Bearings were conical, steel shaft against bronze insert. Only the rotor and stator plates were aluminum. The worm and wheel were stock articles of commerce made available to all and sundry through the commercial foresight of the Boston Gear Works.

To illustrate the care exerted to reduce backlash, from the very beginning the worm, taper-pinned to its shaft, was spring-pressed into engagement with the worm wheel to control backlash as much as could then be done. The worm shaft was journaled in a long hinged brass casting, as can be clearly seen in Figure 2. After assembly and before calibration, each capacitor was subjected to a running-in period to make the worm and wheel fit more closely to one another. At the same time a similar effect was produced on the conical bearings at the two ends of the main shaft.

The insulation at first was laminated phenolic, at that time the novel material called Bakelite. Even though its losses were appreciably higher than those of hard rubber (the popular good insulation of the day), it was preferred because it was much more stable mechanically.

Improvements

Almost immediately began a long series of changes and improvements.

Stator insulation progressed from phenolic to porcelain and then to steatite. The floating, spring-pressed, worm and wheel arrangement went through at least four successive designs, each an advance over its predecessors.

Direct-reading scales first appeared on the TYPE 222-M, a capacitor designed for parallel substitution measurements, direct reading in "capacitance removed."

Throughout this process of improvement the deficiencies in the 222 design were being recognized, and, when in 1936 the TYPE 722 was introduced,[1] a number of basic improvements were made. The composite structure of end

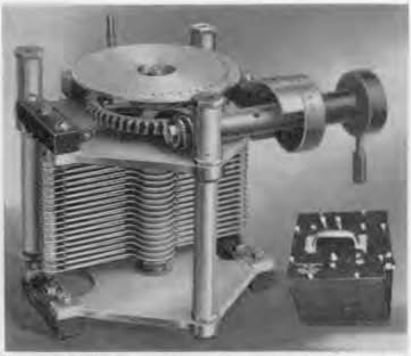


Figure 2. Interior view of an early Type 222 Precision Capacitor, grandfather of all present types. Inset shows cabinet.

plates and spacer rods was replaced by an aluminum frame cast in one piece, with a consequent increase in rigidity and mechanical stability. The conical bearings on the main shaft gave way to ball bearings, and the worm drive was again improved, still further reducing the backlash. Finally, all metal parts directly affecting the capacitance were made of aluminum or aluminum alloy to give a low and uniform temperature coefficient of capacitance. Additional capacitance-removed (double-section), high-frequency, and low-capacitance models were listed, and direct-reading scales were used throughout. Linearity over 21, rather than 20, worm turns was achieved, providing small overlap beyond nominal decimal maximum ΔC's.

Three-Terminal Types

Meanwhile, by the early 1950's, a number of developments in both military and commercial measuring techniques, and demands for high measurement accuracy made it apparent that three-terminal (or insulated-rotor) capacitors should be made available on a catalog basis. Although these were available at first only in high-capacitance models (50-to-1100 pf), the need for

[1] "A New Precision Condenser," *General Radio Experimenter*, 10, 8, January 1936.

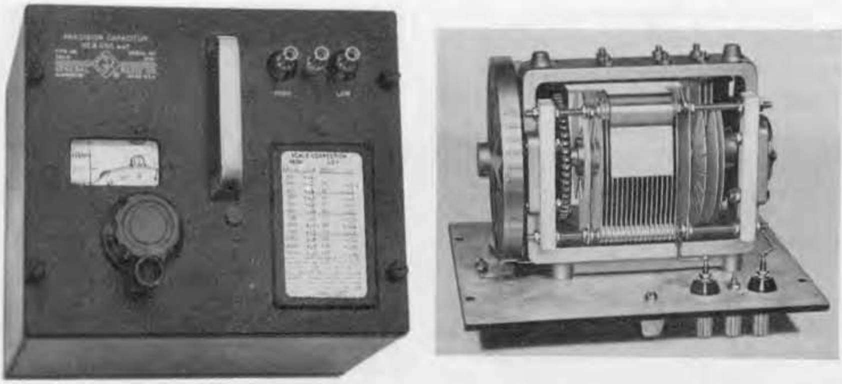


Figure 3. Panel and interior views of the Type 722-D Precision Capacitor, successor to the Type 222.

standardization at lower capacitance magnitudes, where three-terminal construction is mandatory, dictated the design of units with capacitance (ΔC) as low as 1.1 pf.

Special Types of Precision Capacitors

Although it was planned to keep in stock versions of the Type 722 for which there was a solid continuing demand, some 150 special variations have been made in the 25 years of its life, a few of them eventually becoming stock items (e.g., Type 722-CB).[2] As an example of special designs, several Type 722-CE's have been made having two linear capacitance ranges, respectively 0.05 to 1.1 and 0.005 to 0.11 pf.

However, requirements have arisen with which the Type 722 structure was unable to cope.

Figure 4 illustrates a Type 622 Capacitor having many special features. The rugged 5-sided casting was made to secure rigidity because of the very high frequency-stability requirements for the oscillator which this capacitor tuned. It was used in an instrument for the Navy which at sea would be subject to violent tilting as the ship pitched and rolled in bad weather. The rotor plates yielded an end-corrected narrow-range straight-line frequency performance. The extra shaft near the assembler's thumb in Figure 4 actuates a simple computer which averages two readings without calculation.

Figure 5 illustrates small precision worm-driven capacitors, Type 779, which fulfill a requirement for a capacitor of only 210 pf ΔC to occupy appreciably smaller volume than does the Type 722 and are used in an aircraft fuel-gage calibrator.

Type 1422 Introduced

While the Type 722 was far from obsolete, its design *was* 25 years old. Most of the improvements that could be made within the framework of the original design had been made. If further progress was to be realized, it would require starting afresh, but retaining the many demonstrated sound features of both the Type 722 and the Type 222, and borrowing from other of the mentioned designs. This has been done in the new Type 1422. Seven dif-

[2] Ivan G. Easton, "A Three-Terminal Precision Condenser," *General Radio Experimenter*, 23, 4, October 1958.

ferent models are listed, the analogues of the Type 722's previously offered. Figures 1 and 6 illustrate external views respectively of typical two-terminal and three-terminal models, while Figures 7 through 11 are internal views. A number of new features and improvements will be enumerated and described in connection with the illustrations:

1. The cases have been changed to aluminum instead of wood. This gives ¾ inch more stack room on the shaft with the same case length and a narrower box than the Type 722. The sides of the case are made from a heavy aluminum extrusion embodying decorative flutings (Figures 1 and 6).

2. For many years users have requested a slow-motion drive for greater ease in fine setting of the worm dial, not that accuracy of reading may be improved but that bridge balancing may be facilitated. Providing the speed reduction is very difficult to do with the spring-pressed worm arrangement. However, the large transparent skirt for the spinner knob (shown in Figures 1 and 6) gives about a 3-to-1 increase in diameter versus the fluted portion of the knob. There is even greater improvement in setting ease since one can rest a thumb against both the panel and the edge of the skirt and roll the thumb for fine control.

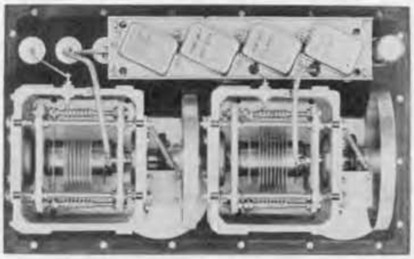


Figure 5. View of a small precision capacitor, designed for use in fuel gauge calibrator.

Figure 4. Final adjustments on a Type 622 "bathtub" capacitor, a special model designed for mechanical stability under extreme conditions.

3. Figure 6 illustrates the use of the new locking Type 874 Connectors on three-terminal capacitors. This feature makes it possible to lock connecting cables in place or to fit the capacitor semipermanently and inexpensively with other types of common coaxial connectors. The customer need merely purchase and attach two locking adaptors to have a capacitor with rigidly fastened coaxial connectors of the type desired.

4. Although there were no obvious places of entry, dust in the cabinet has occasionally been a problem in the past. To control this, the hole in the cabinet for the worm shaft has a minimal clearance, the transparent skirt catches the dust when the panel is in the usual horizontal operating position, and the window through which the scales are read has been changed to gasketed triplex safety glass.

5. To improve the rigidity and stability with time of the small section of a

Figure 6. Panel view of the new Type 1422-CB Precision Capacitor, an insulated rotor, 3-terminal model, with a capacitance range of 50 to 110 pf.

Figure 7. Interior view of the CB-model. Note the shielding washers at the extreme left, which prevent the direct electrostatic flux from traversing the solid insulation.

two-section capacitor, an additional support for each stator rod is provided by the crescent-shaped aluminum piece, shown in Figure 8, and mounted from an added bridge which is part of the main casting.

6. Once the small section is no longer cantilever supported, its weight may be safely increased. Thus, more plates more widely spaced are used for the small section common to the TYPES 1422-D and -MD.

7. The bridge which supports the small section also serves to make the main casting more rigid. This rigidity is further improved by adding the ribbing on the bottom and filleting the inside corners of the casting.

8. Stator rods have been increased from $\frac{3}{16}$ to $\frac{1}{4}$ inch in diameter to stiffen the structure and to reduce the difference in capacitance between horizontal and vertical panel positions.

9. The adding of the bridge gives the opportunity for a third foot on the bottom, so that the capacitor, when out of its cabinet during manufacture, may be set stably on a flat surface without abrasion of the drum dial.

10. Improvement in the ball-bearing arrangements was desirable to improve the backlash situation and stability with time. When the ball-bearing manufacturers recently made available oppositely disposed pairs of ball bearings with any desired preload, the answer to both problems was at hand. The main shaft has a pair of these at each end. At the drum-dial end the outer races are firmly clamped to the main casting and the inner races to a shoulder on the shaft. At the rear end (visible in Figures 8 and 9) the inner races of the two bearings are clamped tightly to a shaft shoulder by the $\frac{1}{4}$-28 Philips head screw to be seen there. The outer races float in the close-fitting, precision-bored hole through the boss at the end of the main casting. This arrangement prevents the "climbing" which occurs even in a ball bearing, smaller than that which occurs with a cone bearing, but still observable. Backlash now, if it is detectable, is generally no larger than the width of the engraved line on the dial.

11. It is just as important to give the worm shaft similar preferred treatment to reduce backlash and eliminate non-uniformities of motion that would disturb the linearity of capacitance change. Note that any axial shake in the

worm shaft can appear as backlash. To reduce this the new design incorporates a smaller preloaded ball-bearing pair, the outer races of which are tightly clamped within the round housing to be seen in Figures 7 and 10. The inner races are tightly clamped by a nut to a shoulder on the worm shaft. The round housing is supported with sidewise flexibility, but longitudinal integrity by a thin U-shaped beryllium copper member fastened to the housing by four screws and clamped to the main casting. This structure locates the shaft axially. The U-shaped beryllium copper piece provides free parallelogram-type floating motion for the worm shaft. The spring pressure to produce this motion is exerted by a spring-loaded bearing ball contained within the hex-headed housing going through the solid bracket just to the right of the ball-bearing mount. The self-aligning bearing at the dial end of the worm shaft fits nicely over a shaft shoulder and floats without shake within the precision-bored hole in the main casting. The shake inherent in the bearing is taken up by a partially compressed six-fingered Z-washer often used with ball bearings, which bears only against the outer race.

12. The nature and disposition of the insulators are greatly different from those of the Type 722. The insulators, instead of being long bars, are short buttons or washers having one face flat and the other spherical in contour. They mate with spherically counterbored holes in the casting or in an aluminum bar. One obvious advantage is that these insulators are self-aligning. Another is that they offer a minimum of disturbance to the "all-aluminum" nature of the structure. In the Type 722 the stator plates would, with an increase in capacitor temperature, push the stator rods farther apart than would the steatite insulators (see Figure 3), thus putting a bow in the rods. Thermal behavior with the present design is much more predictable.

13. Since the insulators are made of Rexolite 1422 (the identity of the numbers is pure coincidence), many advantages accrue. Rexolite 1422 is a cross-linked, thermo-setting, modified polystyrene which acquires heat stability as a result of chemical modification without the serious impairment of dielectric

Figure 8. Interior view of the Type 1422-ME, a dual-range unit, calibrated in capacitance removed, 0 to 10.5 and 0 to 105 pf.

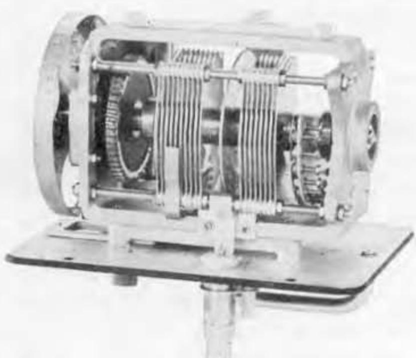


Figure 9. Interior of the Type 1422-N, a high-frequency model whose rotor connection is made through brushes bearing on a disk at the center of the stack in order to reduce residual inductance. Note the low-inductance lead to the terminal.

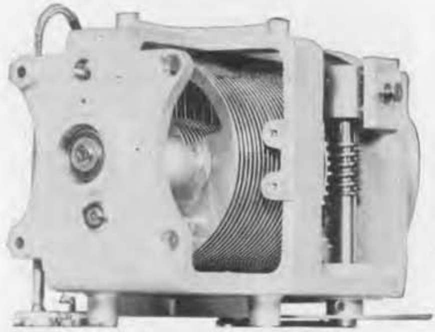


Figure 10. Interior of the 3-terminal Type 1422-CC Precision Capacitor, in which a window in the rotor plate is rotated between two oppositely poled stator plates to give a range of 5 to 110 pf.

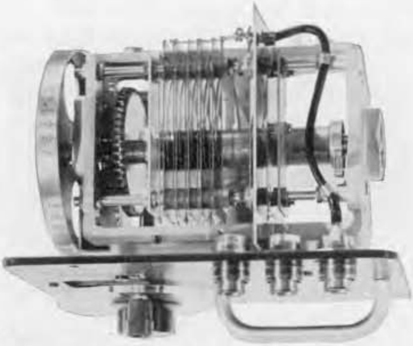


Figure 11. Interior view of the 3-terminal Type 1422-CD, another window type with two ranges, 0.5 to 11 and 0.05 to 1.1 pf.

properties usually accompanying such tampering. The dielectric loss of Rexolite 1422 is essentially comparable to that of fused quartz and along toward one order of magnitude better than that of steatite. Further, its surface is comparably hydrophobic to that of silicone-coated fused quartz. That is, it is moisture resistant and maintains high leakage resistance without the hazard of the possible disappearance of the silicone. Therefore, there is no need any longer to provide quartz-insulated capacitors for either ac or dc uses.

14. As usual, an advantage has its cost. A small price has been paid for the use of Rexolite 1422 insulating buttons. The zero capacitance of each capacitor section is somewhat larger in the Type 1422 than in the Type 722. This difference causes no trouble except in the case of the small section of the Type 1422-D, which is now linear down to only 35 pf versus the 25 pf of the Type 722.

15. Adjustment of the serrated plates for linearizing the capacitance-rotation curve is accomplished by advancing or retracting hex-head screws against the serrations of a spring-tempered phosphor-bronze plate. This method yields many advantages over the prior use of hand-bending serrated aluminum plates with pliers. Access to the adjusting screws is through large clearance holes in the ends of the casting.

16. Level-adjusting plates have been moved from the rear to the front cross-bar of the main casting so that their adjusting screws may be made accessible through the front panel. This facilitates making that adjustment with the capacitor inside rather than outside its case.

17. In the design of the Type 1422-CB Capacitor, extra shielding has been provided (either cups or washers or both) to keep stray rotor-to-stator field from traversing any of the solid insulation, despite its excellence. Thus the dielectric losses in the Type 1422-CB, as well as in the -CC and -CD, between the two hot electrodes should be only those losses in air and at the air-plate interfaces.

18. An examination of the accuracy specifications for the Type 1422 Capacitors will reveal major differences in format, philosophy, and the specification numbers actually used. Better control of

dimensions achieved through changes in mechanical design and improved tooling yield better linearity or initial adjustment figures in some cases. Better Bureau of Standards certifications and more certainty of the precision of our own measurements enable us to give better accuracy figures for calibrations given on the panel charts and on the special 106-point calibrations, which are more significant and useful successors to what used to be called worm-correction calibrations.

Thus the TYPE 1422 Precision Variable Capacitors are ready to give the user improved service over the fine record of the predecessor TYPE 722's. They represent significant improvements in a number of important areas. There is no intention to suggest that they represent the ultimate in precision capacitors, and work is still under way to the end that this latest design of precision capacitor shall be the beneficiary of the "continuous improvements" that have made its predecessors the standard of the industry.

— P. K. McElroy

SPECIFICATIONS

Accuracy: See table. The errors tabulated are possible errors, i.e., the sum of error contributions from setting, stability, adjustment, calibration, interpolation, and standards. The probable errors are almost always smaller. The accuracy is increased when the readings are corrected using the 10 or more calibrated values of capacitance given on the correction chart on the capacitor panel and interpolating linearly between calibrated points. The highest accuracy can be obtained from a precision calibration of approximately 100 points on the capacitor dial, which permits correction for slight residual eccentricities of the worm drive and requires interpolation over only short intervals. This precision calibration is available for all models at an extra charge listed below. A mounted certificate of calibration is supplied, giving corrections to one more figure than the tabulated accuracy.

Calibration: The measured values are obtained by comparison, to a precision better than ±(.01% + .00001 pf), with working standards whose absolute values are known to an accuracy typically ±.02%, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

The measured values of total capacitance of the two-terminal capacitors are the capacitances added when the TYPE 1422 Capacitor is plugged into a TYPE 874-Q9 Adaptor. The uncertainty of this method of connection is approximately ±.03 pf. Calibration of total capacitance with the fine-wire connection method* used for the TYPE 722 Capacitors results in measured values approximately 0.45 pf lower than those obtained with the TYPE 874-Q9 Adaptor.

Resolution: The dial can be read and set without difficulty to 1/5 division.

The backlash is less than one-fifth division, corresponding to .004% of full-scale value. If the desired setting is always approached in the direction of increasing scale reading, no error from this cause will result.

Insulation Resistance: Under standard conditions (23 C, less than 50% RH), greater than 10^{12} ohms.

Maximum Voltage: All models, 1000 volts, peak.

Terminals: Jack-top binding posts are provided on 2-terminal models; standard ¾-inch spacing is used. The rotor terminal is connected to the panel and shield. Locking TYPE 874 Coaxial Connectors are used on 3-terminal models.

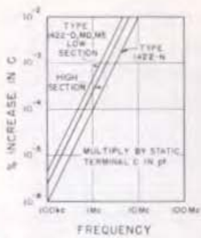
Accessories Supplied: 2 TYPE 874-C58 Cable Connectors with all three-terminal models.

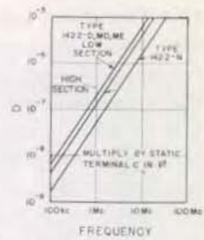
Accessories Available: TYPE 874-Q9 Adaptor.

Mounting: The capacitor is mounted on an aluminum panel finished in crackle and enclosed in a dust-tight ⅛-inch-thick aluminum case.

Dimensions: Panel, 7 by 9½ inches; depth 8⅛ inches, (180 by 240 by 205 mm) over-all.

*John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, 33, 7, July 1959.





Variation with frequency of effective capacitance and D per pf of capacitance for Type 1422 two-terminal Precision Capacitors.

Temperature Coefficient: Approximately ±.002% per degree Centigrade, for small temperature changes.

Residual Parameters: See table. The series resistance varies as the square root of the frequency above 100 kc. Its effect is negligible below this frequency.

Frequency Characteristic: See plots above, for two-terminal models. The resonance frequency for the -CB and -CC models is approximately 20 Mc; for the -CD model, 60 Mc for each section.

Dissipation Factor: The losses in the two-terminal capacitors are primarily in the stator supports, which are of low-loss polystyrene (DC = .01 − 10^{-12}).

The very small dissipation factor of the direct capacitance of the three-terminal capacitors is difficult to measure and is estimated to be not greater than 20 × 10^{-6} for -CB, 10 × 10^{-6} for -CC, -CD.

TYPE 1422		TWO-TERMINAL							THREE-TERMINAL			
				RF	READS CAPACITANCE REMOVED							
		-D		-N	-MD		-ME		-CB	-CC	-CD	
CAPACITANCE RANGE, pf:	Min	100	35	100	0	0	0	0	50	5	0.5	.05
	Max	1150	115	1150	1050	105	105	10.5	1100	110	11	1.1
SCALE, pf Division:		0.2	.02	0.2	0.2	.02	.02	.002	0.2	0.02	.002	.0002
ACCURACY: ± Picofarads listed below or ± .03%, whichever is greater												
Direct-Reading (Adjustment):												
Total Capacitance		0.6†	0.1†	0.6†	Differences from Zero				0.6	0.15	.04	.008
Capacitance Difference		1.2	0.2	1.2	1	0.2	0.2	.05	1.2	0.3	.08	.061
With Corrections from Calibration Chart (supplied):												
Total Capacitance		0.3†	.04†	0.3†					0.3	.04	.01	.002
Capacitance Difference‡		0.6	.08	0.6	0.6	.08	.08	.02	0.6	.08	.02	.004
With Corrections from Precision Calibration (extra charge):												
Total Capacitance		0.1†	.01†	0.1†					0.1	.01	.001	.0002
Capacitance Difference‡		0.2	.02	0.2	0.2	.02	.02	.004	0.2	.02	.002	.0004
STABILITY: Capacitance change per year not greater than 1 scale division												
RESIDUALS (typical values):												
Series Inductance, μh		.06	0.10	.024	.06	0.10	.06	0.10	0.14	0.17	0.17	0.17
Series Resistance, ohms at 1 Mc		.02	.03	.008	.02	.03	.02	.03	0.1			
Terminal Capacitances, pf:			high terminal to case				min scale		20	560	74	23
							max scale		20	850	98	25
			low terminal to case				min scale		33	600	92	93
							max scale		36	920	117	115
Capacitance at Zero Scale Setting, pf:					1140	135	145	35				

†Total capacitance is the capacitance added when the capacitor is plugged into a Type 874-Q9 Adaptor.

‡Divide error by 2 when one setting is made at a calibrated point.

Type		*Net Weight Pounds*	*Net Weight KG*	*Code Word*	*Price*	*Additional Price for Precision Calibration†*
1422-D	Precision Capacitor	11¼	5.1	RAPID	$265.00	$ 90.00
1422-MD	Precision Capacitor	11	5	RAVEL	265.00	90.00
1422-ME	Precision Capacitor	10½	4.8	RAZOR	255.00	110.00
1422-N	Precision Capacitor	10¾	4.9	READY	250.00	50.00
1422-CB	Precision Capacitor	10¾	4.9	REBUS	250.00	55.00
1422-CC	Precision Capacitor	12½	5.7	RECUR	280.00	55.00
1422-CD	Precision Capacitor	11	5	REDAN	280.00	165.00

†When ordering capacitor with precision calibration, add P to the type number, and add WORMY to capacitor code word.

IMPROVEMENTS IN THE VACUUM-TUBE BRIDGE

The TYPE 1661 Vacuum-Tube Bridge is used primarily for highly accurate measurements of the low-frequency dynamic coefficients of vacuum tubes. It can also measure directly the short-circuit conductance parameters and the hybrid parameters of transistors.

The TYPE 1661-B now supersedes the TYPE 1661-A. This latest model permits greater flexibility in the measurement of two-section tubes, such as triode-pentodes.

These can now be measured sequentially without the necessity of reconnecting the patch cords. While the dynamic coefficients of one section are being measured, the grid, cathode, screen-grid, and plate of the other section may be grounded, open, or connected directly to their individual power supplies, as determined by the selector switch setting. This last position permits measurement of static tube characteristics with no voltage drops because of bridge transformers. A central switch position permits measurement of the static characteristics of both sections simultaneously. There is also provision for measuring the dc voltage at the "plate" of the section whose dynamic coefficient is being measured. This feature is particularly useful in the measurement of transistors or high-plate-current tubes where the voltage drop across the 34-ohm primary of the output transformer may be significant.

The terminal arrangement for connecting power supplies now provides for two grid, two screen-grid, and two plate supplies. Two pairs of terminals permit connecting individual cathode resistors for the two tube sections. Panel plugs are provided for paralleling heater leads when the tube is designed for both 12.6- and 6.3-volt heater operation.

A Nuvistor socket is now supplied to permit testing this new line of tubes.

The price remains unchanged at $1100.00.

LOCAL EXHIBITS — SYRACUSE TO WASHINGTON, D. C.

Convenient, comprehensive, competent, and concise. These words describe the second annual Electronic Instrument Manufacturers Exhibit (EIME), co-sponsored by seven leading instrument manufacturers. If you are between Syracuse and Washington, you can reach an exhibit location easily. Many new instruments to solve your measurement problems will be demonstrated by factory engineers. You can discuss your interests in unhurried detail.

The sponsors are General Radio Company, Lambda Electronics Inc., Non-Linear Systems Inc., Panoramic Electronics Inc., Sensitive Research Inc., Tektronix Inc., and Trio Laboratories Inc. The schedule of exhibits is:

Syracuse, New York, Sheraton Inn, September 21, Thursday, 12:00 – 7:00 P.M.

Norwalk, Connecticut, Norwalk Motor Inn, September 25, Monday, 12:00 – 7:00 P.M.

Roosevelt Field, L. I., New York, Sagamore Room, September 27 and 28, Wednesday and Thursday, 12:00 – 8:00 P.M.

Cedar Grove, New Jersey, The Towers, October 2, Monday, 12:00 – 7:00 P.M.

Philadelphia, Pennsylvania, Bellevue Stratford Hotel, October 3 and 4, Tuesday and Wednesday, 12:00 – 8:00 P.M.

Watchung, New Jersey, Wally's, October 9, Monday, 12:00 – 7:00 P.M.

Washington, D. C., Marriott Motel, October 11, Wednesday, 2:00 – 9:00 P.M.

General Radio will be operating its newest frequency instruments: the Type 1130 series of digital counting instruments, the Type 1142-A Frequency Meter and F-M Discriminator, and the Type 1120-A Frequency Standard. Among other new instruments, see the Type 1232-A Tuned Amplifier and Null Detector, the Type 1553-A Vibration Meter, and the Type 1264-A Modulating Power Supply.

BARGAIN SALE

TYPE 650-P1 OSCILLATOR-AMPLIFIER

Experimenter readers who are still using Type 650-A Impedance Bridge (which has now been replaced by the Type 1650-A) may be interested in acquiring a Type 650-P1 Oscillator-Amplifier which converts the bridge to an ac-operated instrument, provides a 1000 cycle generator and a dc supply for resistance measurements, and includes an amplifier tuned to 1000 cycles for the detector circuit. This instrument, originally priced at $155, is now available at $87.50, while they last.

TYPE 1262-A POWER SUPPLY

This power supply is an ac power pack, which converts the discontinued Type 1551-A Sound-Level Meter to ac operation. Originally priced at $70 for the 115 volt model and $85 for the 230 volt model, it is now available to those interested at the reduced price of $25. For 115 volt supply order Type 1262-A; for 230 volt supply order Type 1262-AQ18. Both models operate from power line frequencies of 50-60 cps.

General Radio Company

PRINTED IN U.S.A.