THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A WIDE-FREQUENCY-RANGE BRIDGE OSCILLATOR

Also IN THIS ISSUE

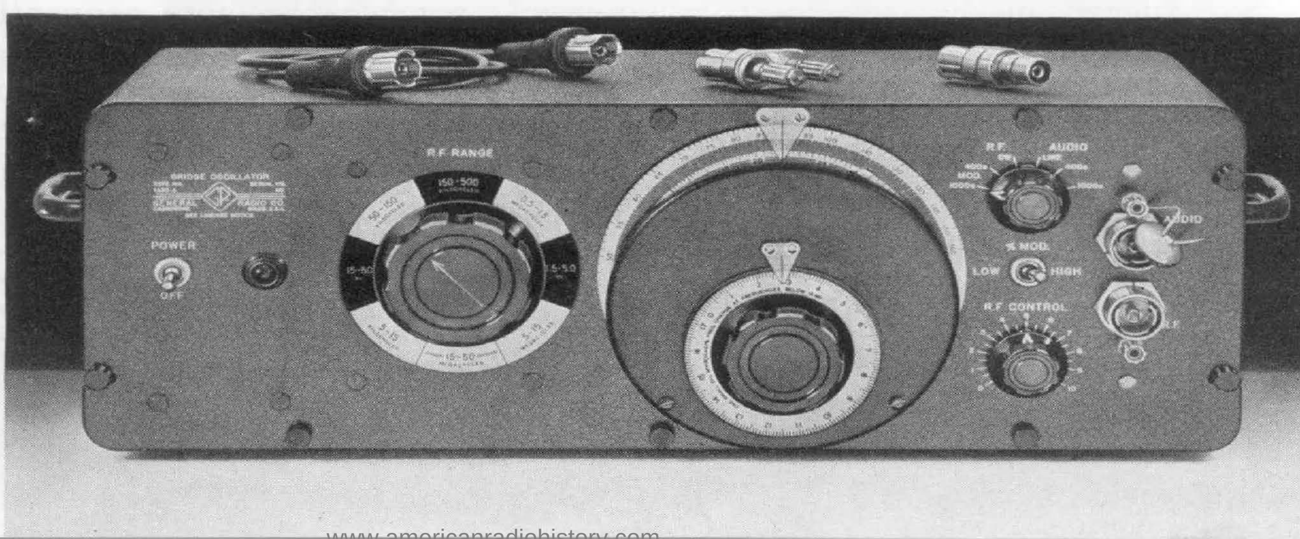
● **BRIDGE MEASUREMENTS,** antenna measurements, and many laboratory procedures require a stable, variable-frequency source of moderate power output. The standard-signal generator, while adequate for most purposes, is not an economical solution because its output is low and because it includes amplifiers, meters, attenuators, etc., which are essential to its proper function but are needless components in a laboratory signal source.

The Type 1330-A Bridge Oscillator was designed to provide a more satisfactory solution both technically and economically. This new oscillator is recommended for use with General Radio bridges such as the Type 716-C Capacitance Bridge, the Types 916-A and 916-AL Radio-Frequency Bridges, and the Type 821-A Twin T.

RANGE AND OUTPUT

The Type 1330-A Bridge Oscillator supplies three audio frequencies (power line frequency, 400 cycles, and 1000 cycles) and a wide continu-

Figure 1. Panel view of the Type 1330-A Bridge Oscillator.



ous range of radio frequencies (5 kilocycles to 50 megacycles), either modulated or unmodulated.

The output voltage is of the order of ten volts. The output power into a 50-ohm load is more than one watt over most of the frequency spectrum. Typical output performance is indicated in Figure 4.

MOUNTING AND SHIELDING

In view of its rugged construction, wide-frequency range and appreciable power output, the new bridge oscillator is surprisingly compact. The relay-rack-type panel is only seven inches high. The aluminum cabinet is about nine inches deep and provides double shielding which reduces the stray field at one megacycle to about 50 microvolts per meter two feet from the instrument. The instrument can be easily removed from its cabinet and mounted in a relay-rack. Since the radio-frequency circuits are completely enclosed in a shielding compartment, the stray-field level is still sufficiently low for most applications.

Type 874 Coaxial Output Jacks are provided; the coaxial cable and adaptors supplied with the instrument permit complete shielding from the oscillator to the measuring instrument.

CONSTRUCTION

Since frequency stability is very desirable in bridge measurements, the rugged mechanical construction used in the Type 1001-A Standard-Signal Generator[1] was adopted for the new oscillator. The tuning capacitor has preloaded ball bearings mounted in 3/16-inch end plates and the end-plate supports are ½-inch diameter rods. The entire oscillator assembly is mounted on a ¼-inch subpanel for complete rigidity. The radio-frequency range switch is taken bodily from the signal generator design to provide the eight coil turret positions. The r-f oscillator coils, however, are of different design, since the oscillator must deliver power directly to the load. For the same reason, the r-f oscillator tube is the higher-power type 6AQ5 miniature tube which has a rating of 12 watts plate dissipation.

The oscillator assembly plugs into a deep brass box and the double cover completes the shielding. Since the two leads entering the box are fully filtered and the four shafts extending from the box are enclosed in shielding sleeves, the leakage is at a minimum over the entire frequency range in spite of the high voltage level inside the box, necessitated by the power output requirements.

The power-supply, on a separate bracket, is mounted alongside the r-f compartment.

CIRCUIT

The radio-frequency oscillator is the Hartley type with its tapped coil and "floating" rotor and stator of the tuning capacitor. The higher-frequency components are quite conventional in design. At the lower radio frequencies, the plate and grid coils are mounted adjacent to each other to permit propor-

[1]A. G. Bousquet, "General Purpose A-M Standard-Signal Generator," *General Radio Experimenter*, September, 1949.

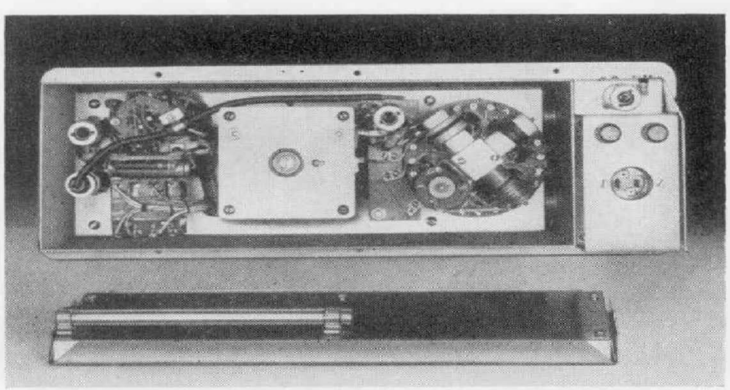


Figure 2. Rear view with shield removed. Power supply unit is at the right of the assembly.

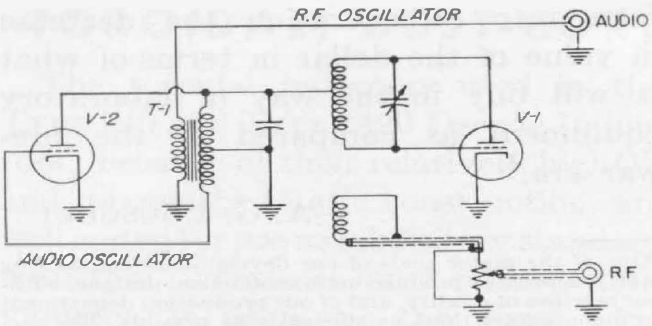


Figure 3. Elementary wiring diagram of Type 1330-A Bridge Oscillator.

tioning the coupling between the output coil and the plate and grid coils, for low carrier distortion.

Modulation of such a wide-frequency-range oscillator by the usual methods is not a simple matter. Since modulation is limited to two audio frequencies (400 and 1000 cycles), a novel and very effective method was devised for providing plate modulation. The plate-supply by-pass capacitor of the r-f oscillator is used as the tuning capacitor of the audio oscillator, thus dispensing with the modulating choke coils and r-f filters that inevitably cause dips in output at some frequency or other and upset the normal operating condition of the r-f oscillator. The method has resulted in excellent modulation characteristics over the 15 kc to 50 Mc span. The shape of the tube characteristic is fortunately such as to compensate for any distortion in the audio oscillator. As a consequence, even though the audio oscillator distortion is about 5%, the envelope distortion of the modulated carrier is usually less than 5%, and at many points is less than 1%. The modulation level is either 30% or 60% as selected by the toggle switch on the panel.

COMPARISON

It is interesting to compare the new instrument with the prewar Type 684-A Modulated Oscillator[2] that for many years was the standard bridge oscillator. The new instrument is eleven pounds lighter, consumes only half as much power, and has about half the volume, yet it covers a wider frequency range, is more rugged, and supplies about ten times the output power at a much lower impedance level.

All of these improvements have been achieved at a lower real price, when we

[2] "A Radio-Frequency Source for the Laboratory," *General Radio Experimenter*, November, 1937.

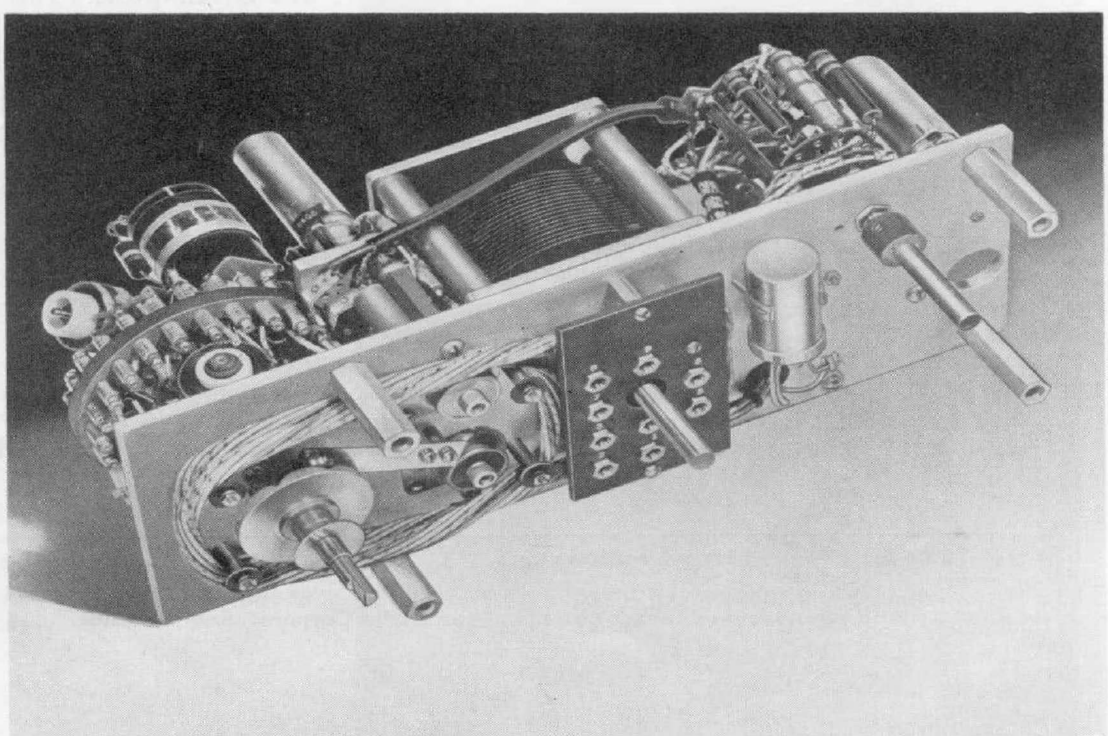


Figure 4. View of oscillator unit removed from cabinet. Servicing cable is shown coiled in its storage position.

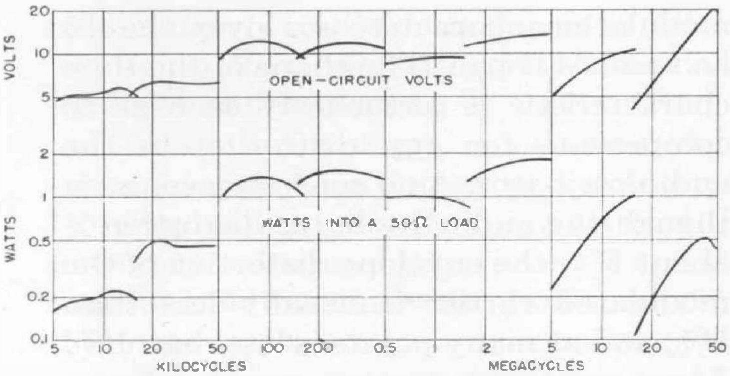


Figure 5. Output characteristics of the Type 1330-A Bridge Oscillator.

take into consideration the decrease in value of the dollar in terms of what it will buy in the way of laboratory equipment as compared to the pre-war era.[3]

—A. G. BOUSQUET

[3]One of the major goals of our development engineering staff has been to produce more economical designs, without sacrifice of quality, and of our production department to manufacture them as efficiently as possible. The success of this effort is attested to by the fact that General Radio prices have increased since 1939 by about 57%, as compared to an increase of over 84% in the general price index and over 100% in many other lines of durable goods.

SPECIFICATIONS

Frequency Range: Three fixed audio frequencies (power line frequency, 400 c, and 1000 c) and a continuous frequency spectrum from 5 kc to 50 Mc in eight direct-reading ranges as follows: 5 to 15 kc, 15 to 50 kc, 50 to 150 kc, 150 to 500 kc, 0.5 to 1.5 Mc, 1.5 to 5 Mc, 5 to 15 Mc, and 15 to 50 Mc.

Frequency Accuracy: ±5% for the 400- and 1000-cycle fixed frequencies, ±2% for the carrier frequencies above 150 kilocycles, and ±3% for the carrier frequencies below 150 kilocycles under no-load conditions. A 50-ohm resistive load may cause a frequency shift of as much as +5% at some of the lower carrier frequencies; above 150 kilocycles, the frequency shift due to a 50-ohm load is usually less than +1%. From 5 kilocycles to 15 Mc, the dial calibration is logarithmic.

Incremental-Frequency Dial: The slow-motion dial indicates frequency increments of 0.1% per division from 5 kc to 15 Mc.

Output Voltage and Power: The AUDIO output jack provides a fixed voltage output of about 12 volts open circuit, or a power output of about ¾ watt into a matching 50-ohm load; the output at the R-F jack is controlled by the R-F control, and supplies adjustable output for the 5 kc to 50 Mc range; over the mid-frequency range, the open circuit output voltage is about ten volts and the output power into a 50-ohm load (output control at maximum) is about one watt. The output falls off at the upper and lower ends of the frequency spectrum.

Output Impedance: 50 ohms at the AUDIO jack; between 20 and 80 ohms, depending on frequency, at the R-F jack when the 300-ohm output control is at maximum.

Modulation: The R-F range (15 kc to 50 Mc) can be internally amplitude-modulated at either 400 c or 1000 c at the two modulation levels of approximately 30% and 60%. There is no provision for external modulation.

Envelope Distortion: Between 1% and 6% at the 60% modulation level.

R-F Distortion: 3% over most of the range; at the lower radio frequencies it is about 6%.

Leakage: Stray fields at 1 Mc are about 50μv per meter at two feet from the oscillator. With the instrument out of its cabinet, the stray field may be greater by a factor of ten.

Controls: A switch for selecting between AUDIO (LINE, 400 c, or 1000 c) and R-F output (CW or MODULATED — 400 c or 1000 c); a switch for selecting between HIGH and LOW modulation; a voltage divider for controlling the R-F output; a range switch; a calibrated dial and a vernier dial for setting the radio frequency; a power switch.

Accessories Supplied: TYPE 874-R21 3-foot Coaxial Cable, TYPE 874-Q2 Adaptor, TYPE 874-Q7Adaptor, TYPE TO-44 Adjustment Tool, and a power cord.

Mounting: Aluminum panel finished in black-crackle lacquer. Aluminum cabinet is finished in black wrinkle and is provided with carrying handles. Cabinet can be removed for relay-rack mounting.

Power Supply: 115 (or 230) volts at 40 to 60 cycles. The power input is about 30 watts.

Tubes: Supplied with the instrument: Two 6AQ5-type tubes and one 6X4-type tube.

Terminals: TYPE 874 Coaxial Terminals are provided for both the AUDIO output and the R-F output.

Dimensions: (Height) 7½ x (width) 21¾ x (depth) 11¼ inches overall.

Net Weight: 36½ pounds.

Type		*Code Word*	*Price*
1330-A	**Bridge Oscillator**	ACORN	**$525.00***

*U. S. Patent No. 2,125,816.
Patent applied for. Licensed under patents of the Radio Corporation of America.

TOROIDAL, DUST-CORE STANDARD INDUCTORS

The toroidal inductors used in the Type 940 and Type 1490 Decade Inductors[1], because of their relatively high Q's and inherently astatic construction, are well suited for use as laboratory standard inductors. They are now offered individually, in cases, as the Type 1481 Standard Inductors.

They complement, rather than supersede, the air-core Type 106 Standard Inductors, and each type has its advantages for particular applications. As compared to the air-core type, the Type 1481 Standard Inductor has higher Q values, and the maximum Q occurs at lower frequencies. The ohmic resistance is less for a given value of inductance, and Q remains greater than unity down to a frequency of six cycles per second or lower. They have a somewhat smaller temperature coefficient of inductance at room temperatures. They are inherently much more astatic, so that coupling between adjacent units and to external fields is completely negligible, and they can be electrostatically shielded.

On the other hand, accuracy of adjustment is limited to the change produced by a single turn of the winding, which is one per cent for the smaller units. Since they are wound on ferromagnetic cores, the inductance changes somewhat with voltage or current while that of air-core coil does not.

Summarizing, the Type 1481 Standard Inductors are smaller in size for a given inductance, have higher Q's, and are much more astatic than are the Type 106 Standard Inductors, but they have a somewhat lower stability of inductance and cannot be adjusted as precisely.

[1] Horatio W. Lamson, "A New Decade Inductor," *General Radio Experimenter*, Vol. XXIV, No. 2, July, 1949.

Figure 1 is a view of the Type 1481 Standard Inductor. The impregnated toroid is clamped between two felt washers in a rectangular aluminum case, which is finished in black crackle and affords an electrostatic shield for the inductor element. One terminal is permanently grounded to the case so that, between the two terminals, we have a definite impedance value with resistive and reactive components which are independent of its environs, an advantageous feature. These specific components can then be measured with any desired precision. The nominal value of inductance is engraved on the case together with the precision limits within which its absolute *initial* value L_o (corresponding to a vanishingly small a-c excitation) at essentially zero frequency was calibrated. The case also carries a legend indicating the r-m-s a-c current which will produce a 0.25% increase in the initial inductance. This value, listed as I_1 in the table, corresponds to the

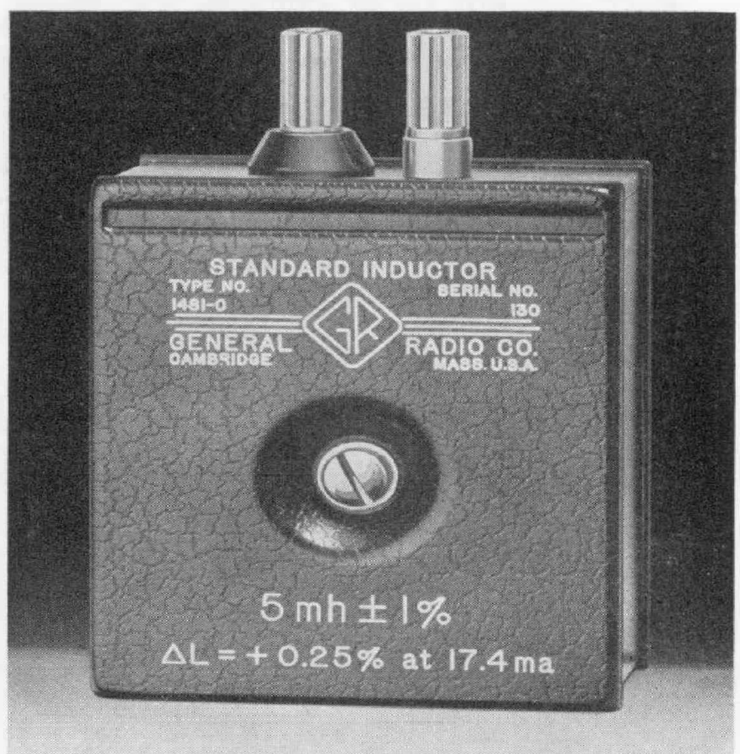


Figure 1. Assembled view of Type 1481 Standard Inductor. Note that one terminal is grounded to the case.

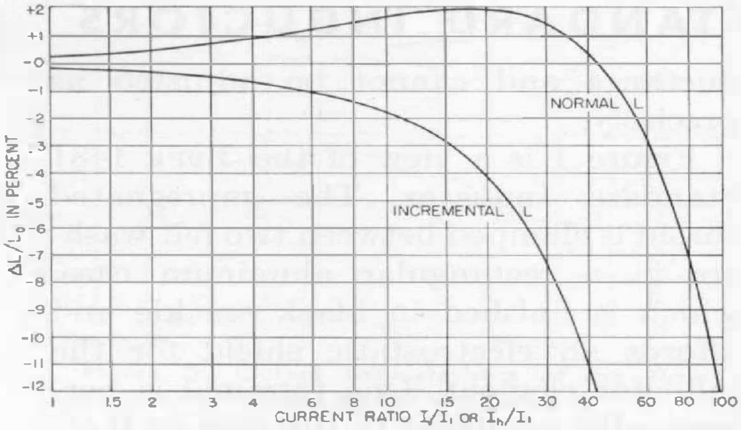


Figure 2. Per cent change in normal and incremental inductance with a-c and bias current. Incremental curve is limited to an a-c excitation less than I_1.

ampere turns which define the upper limit of the Rayleigh range, within which the increase of inductance above its individual initial value is directly proportional to the current.

VARIATION IN INDUCTANCE WITH APPLIED A–C AND WITH D–C BIAS

In the description of the decade inductors, previously published,[2] the changes in inductance with current and the incremental inductance resulting from d-c bias were discussed. Figure 2 shows the magnitude of both of these changes as a function of the ratio of either the normal r-m-s a-c exciting current I, or the d-c biasing current I_b, to I_1, the a-c current which produces the low level linear 0.25% rise in inductance. For the incremental curve the normal signal is considered to be less than I_1.

[2] Lamson, loc. cit.

DISSIPATION FACTOR

Figure 3 shows the variation of the dissipation factor, D (reciprocal of Q), as a function of frequency, computed at zero level so that hysteresis loss is nil. As analyzed in the *Experimenter* for July, 1949[1], D is the sum of three core or magnetic components and three winding components. The core components are (1) residual loss, D_r, a value independent of frequency; (2) hysteresis loss, D_h, likewise independent of frequency and the only component dependent upon the operating level; and (3) *core eddy current* loss, D_e, which is directly proportional to f. The winding components of D are (4) *copper ohmic* loss, D_c, which is inversely proportional to f and evaluated from the d-c resistance; (5) *dielectric* loss, D_d, which is proportional to f^2; and (6) *copper eddy current* loss, D_s, which is proportional to f. When plotted on log-log paper, each component is represented by a straight line having an appropriate slope. The resultant composite curves are shown in Figure 3.

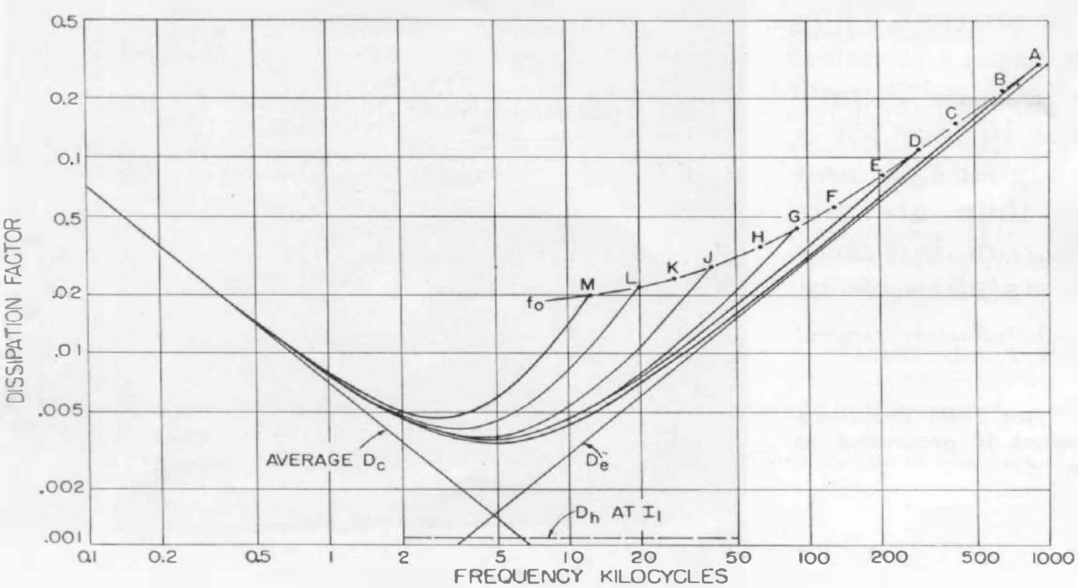


Figure 3. Initial D versus f curves ($D_h = 0$) for typical units. See Specification: Storage Factor.

SAFE OPERATING LIMITS

The maximum safe operating level at which these inductors can be energized is limited by whichever of two specifications is first applicable.

(1) The terminal voltage $(= I\omega L)$ should not exceed 500 volts rms.

(2) The r-m-s current should be limited to 70 times the listed I_1 values.

This limitation produces about 0.3 watt copper loss and, from Figure 2, reduces the initial inductance by about five per cent, so that the units are no longer precise inductance standards.

—Horatio W. Lamson

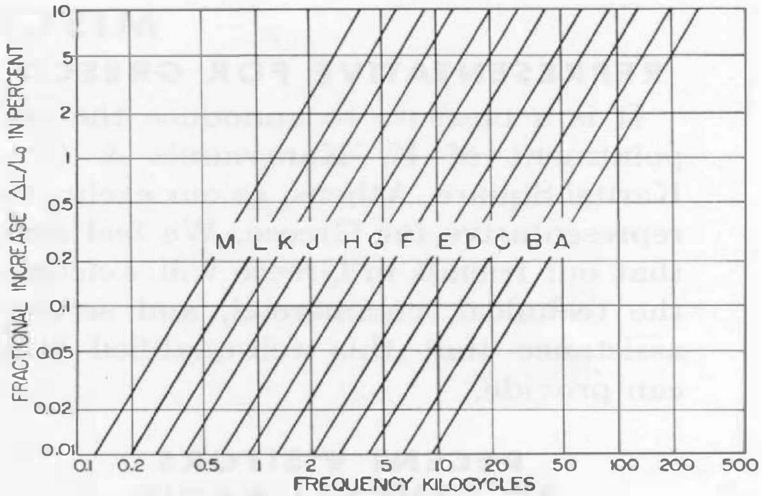


Figure 4. Per cent increase in L_o with frequency. For a 0.1% increase f varies between 400 cps for 5 h and 30 kc for 1 mh.

SPECIFICATIONS

Accuracy of Adjustment: See table below. Accuracy of adjustment is limited to the change produced by a single turn of the winding.

Storage Factor, Q: Maximum initial Q is between 230 and 300. Figure 3 shows the variation of dissipation factor $(D = \frac{1}{Q})$ as a function of frequency for zero level, i.e., with no hysteresis loss. For an r-m-s current I, the plotted D values must be increased by $D_h = 0.00107(\frac{I}{I_1})$.

Current Coefficient of Inductance: Per cent change in inductance as a function of $\frac{I}{I_1}$ is given in Figure 2, where I is the operating current and I_1 the current that would produce a 0.25% linear increase in L_o.

Incremental Inductance: D-C bias will reduce the initial inductance as shown in Figure 2.

Frequency Characteristics: Effective inductance at any frequency f below resonance can be computed from the expression $L = \frac{L_o}{1 - \left(\frac{f}{f_r}\right)^2}$, where L_o is the initial inductance and f_r is the listed resonant frequency. Per cent change in inductance with frequency is plotted in Figure 4. Variation in dissipation factor, D, with frequency is shown in Figure 3.

Temperature Coefficient of Inductance: Stabilized to be approximately −24 parts in 10^6 per degree C., between 16° and 32°C.

Safe Operating Limits: (1) Maximum terminal voltage, 500 volts rms, or (2) Maximum r-m-s current = 70 I_1, whichever limit is pertinent.

Distributed Capacitance: Between 28 $\mu\mu$f for the 1 millihenry and 33 $\mu\mu$f for the 5 henry inductor.

Dimensions: Case, (height) 3⅝ x (width) 3⅛ x (depth) 1⅝ inches; over-all height, including terminals, 4⅝ inches.

Net Weight: 14 ounces.

Type Inductor	*Nominal Inductance L*	*Calibrated within*	*R-M-S Current, I_1, for 0.25% increase in L_o*	*Resonant Frequency f_r*	*Approx. D-C Resistance*	*Code Word*	*Price*
1481-A	1 mh	±1 %	39 ma	940 kc	0.043 Ω	INDUCTOSAP	**$24.50**
1481-B	2 mh	±1 %	28 ma	660 kc	0.15 Ω	INDUCTOSET	**24.50**
1481-C	5 mh	±1 %	17 ma	420 kc	0.25 Ω	INDUCTOSIG	**24.50**
1481-D	10 mh	±0.5 %	12 ma	300 kc	0.44 Ω	INDUCTOSOT	**24.50**
1481-E	20 mh	±0.5 %	8.7 ma	210 kc	0.95 Ω	INDUCTOSUM	**24.50**
1481-F	50 mh	±0.5 %	5.5 ma	130 kc	2.31 Ω	INDUCTOPAL	**24.50**
1481-G	100 mh	±0.25%	3.9 ma	91 kc	4.3 Ω	INDUCTOPEG	**24.50**
1481-H	200 mh	±0.25%	2.8 ma	64 kc	7.2 Ω	INDUCTOPIT	**24.50**
1481-J	500 mh	±0.25%	1.7 ma	40 kc	22 Ω	INDUCTOPOD	**24.50**
1481-K	1 h	±0.25%	1.2 ma	28 kc	40 Ω	INDUCTOPUB	**24.50**
1481-L	2 h	±0.25%	0.87 ma	20 kc	91 Ω	INDUCTORAM	**24.50**
1481-M	5 h	±0.25%	0.55 ma	12.5 kc	230 Ω	INDUCTORED	**27.50**

MISCELLANY

REPRESENTATIVE FOR GREECE

It is a pleasure to announce the appointment of K. Karayannis & Co., Karitsi Square, Athens, as our exclusive representative for Greece. We feel sure that our friends in Greece will welcome the technical, commercial, and service assistance that this well-qualified firm can provide.

RECENT VISITORS TO GENERAL RADIO

From France (Paris) — Mr. L. Simon, Director, SOTELEC; Mr. M. Leduc, Director, Lignes Telegraphiques and Telephoniques; Mr. E. H. Jensen, Consulting Engineer, Société Anonyme de Telecommunications; and Mr. A. Pagès, Technical General Secretary, Société Alsacienne de Constructions Mécaniques.

From the Netherlands — Mr. H. J. Lindenhovius, N. V. Philips Gloeilampenfabrieken, Eindhoven.

From Netherlands East Indies — Professor G. J. Levenbach, Faculty of Technology, University of Indonesia, Bandung.

From Norway — Mr. Arve Rambol, Royal Norwegian Council for Scientific and Industrial Research, Oslo.

From Switzerland — Mr. Jurg Keller, Seyffer and Co., Zurich, Representatives for General Radio in Switzerland.

From Italy — Dr. Emilio Montruschi and Dr. Roberto Nicoli, Ministero della Difesa-Aeronautica, Rome.

From Japan — Mr. Keizo Nishimura, President, and Dr. Keizo Ikada, Plant Manager, Furukawa Electric Co., Ltd., Tokyo; Dr. P. Uenishi, Shimadzu Seisakusho, Ltd., Kyoto; Professor Yosushi Watanabe, Department of Electrical Engineering, Tohuku University, Sendai; Professor Nobuyoshi Kato, Department of Electrical Engineering, Kyoto University, Kyoto; and Professor Yoshihiro Asami, Department of Electrical Engineering, Hokkaido University, Sapporo.

ELECTED — Kipling Adams, Manager of the General Radio Chicago Engineering Office, to the presidency of the Radio Engineers Club, of Chicago.

HIGH-FREQUENCY MEASUREMENTS CONFERENCE

The second high-frequency measurements conference sponsored by the A.I.E.E., the I.R.E., and the National Bureau of Standards will be held in Washington, D. C., on January 10, 11, and 12, 1951. Conference headquarters will be at the Hotel Statler, and technical sessions will be held in the auditorium of the Department of the Interior.

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

TELEPHONE: TRowbridge 6-4400

BRANCH ENGINEERING OFFICES

NEW YORK 6, NEW YORK
90 WEST STREET
TEL.—WOrth 2-5837

LOS ANGELES 38, CALIFORNIA
1000 NORTH SEWARD STREET
TEL.—HOllywood 9-6201

CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
TEL.—WAbash 2-3820

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