# the GENERAL RADIO Experimenter

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The GENERAL RADIO EXPERIMENTER

VOL. IX. No. 8 JANUARY, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

# MONITORING OF BROADCASTING STATIONS

IN running a broadcasting station, it is essential to get the maximum signal strength with the minimum of interference and distortion. A transmitter differs from ordinary circuits in that, once the amplitude exceeds a certain value, the signal is very badly distorted. In well-designed transmitters which are properly maintained, very little distortion exists below this definite overload point. The more nearly the overload point can be approached, the greater will be the coverage of the station and the smaller will be the percentage interference with neighboring stations. On the other hand, if the modulation capability is exceeded, very serious distortion will occur and, even worse, there will be serious interference known as "monkey chatter" in neighboring channels. Thus the problem of monitoring a broadcasting station consists, on the one side, in getting the largest percentage modulation possible without distortion and, on the other side, in keeping the modulation down to a sufficiently low level to avoid overloading.

Most modern transmitters when new are surprisingly linear. Modulation of 90% can usually be obtained without objectionable distortion. On the other hand, when tubes age and push-pull stages of

## AND NOW FIDELITY

**ONE of the greatest contributions to better broadcasting in recent years was the clearing up of the conditions resulting from off-frequency operation of broadcasting stations. The General Radio Company's contribution to this improvement was the visual continuous indicating frequency monitor.**

**The present most pressing problem in broadcasting is that of maintenance of high fidelity without loss of station efficiency. This involves careful maintenance of modulation at all times. To this end we have developed a continuous indicating modulation meter. A companion piece is a distortion and noise-level measuring instrument, whose simplicity of operation encourages frequent checks on these quantities.**

amplification become unbalanced, the transmitter is likely to become very badly non-linear.

At present, it is the practice with most stations to monitor the programs at the studio, maintaining a certain input level to the line leading to the remote transmitter, the level being determined by a power-level indicator. Another power-level indicator is used at the transmitter to make certain that the transmission line has not changed sufficiently to make serious overloading possible. Except under abnormal conditions, no control is permitted at the transmitter itself. In the best present practice the input power level permissible for a given type of program is determined by tests on the transmitter which correlate percentage modulation and distortion with input level.

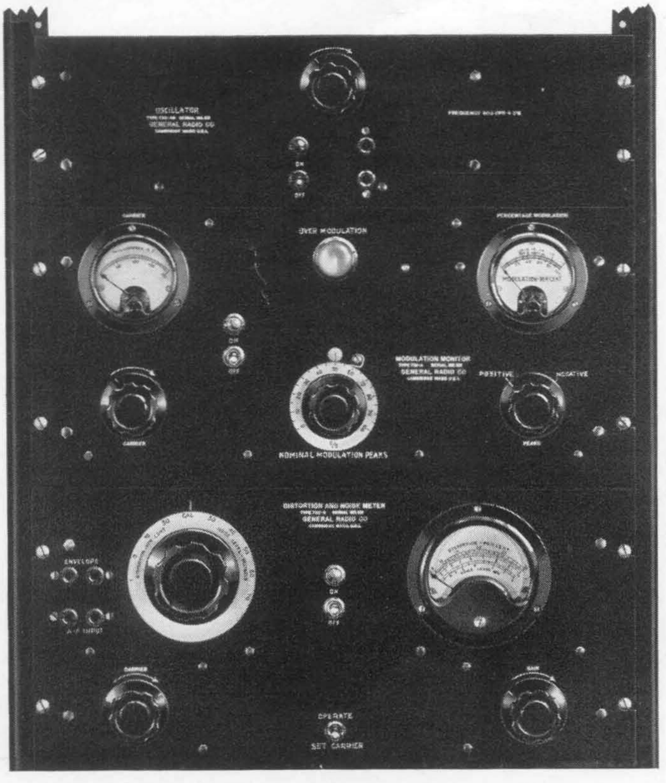
This whole system is very badly at fault in several small but important details. In the first place the volume-level indicators are not at all instantaneous in their action and the overmodulation peaks which are responsible for all of the trouble are seldom of sufficient duration to register on the monitoring meters. In addition to the fact that the meters are not instantaneous, it so happens that most of those at present in use are subject to resonance troubles so that they fail to give a proper idea of the mean power in a syllable as well as not following peaks. A pulse of given intensity may transiently give an indication 3 or 4 decibels higher than the true value. Such a condition can result in radically wrong monitoring; a change of 3 decibels in adjustment would result in halving efficiency. The full significance of these meter faults has not been generally realized.

There is a further difficulty in that at present the program is monitored at the input to the transmitter rather than at the output. This means that changes in the gain of any of the audio-frequency amplifiers or in the modulator efficiency are not taken into account except by comparatively infrequent periodic checks. This practice has resulted from the lack of equipment designed for continuous monitoring.

Previous equipment was fairly satisfactory so far as it went but did not lend itself readily to rapid experimental checks, and as a result it was sparingly used by the operating staffs, tests being made every week or so. For this reason it was necessary to provide too large a safety factor and to use an unnecessarily low peak modulation to be sure of satisfactory transmission. Conversely, stations which have not been allowing such safety factors have had unnecessarily high distortion.

With these conditions in mind, the General Radio Company has designed a group of instruments to reduce the monitoring of broadcasting stations to a very simple procedure which can be carried on continuously and accurately.

The Type 731-A Modulation Monitor is designed so that it can be coupled directly to the radio-frequency output of the transmitter. An automatic biasing arrangement used in conjunction with a thyratron flashes a light whenever the modulation instantaneously exceeds the value which is considered permissible with the particular transmitter. In addition, meters are provided to indicate carrier shift and percentage modulation. The per cent meter is direct reading on positive or negative peaks and is of the rapid movement type recently developed. While not instantaneous, it is free from resonance effects



CLASS 730-A Transmission-Monitoring Assembly. The assembly consists of three rack-mounting units. From bottom to top they are the TYPE 731-A Modulation Monitor, the TYPE 732-A Distortion and Noise Meter, and the TYPE 733-A Oscillator. The entire assembly occupies 22¾ inches of rack space

*(Licensed under patents of the American Telephone and Telegraph Company.)*

and follows a signal much more faithfully and rapidly than the previous instruments.

In addition to the modulation monitor, a new direct-reading distortion factor and noise meter (TYPE 732-A) has been provided for getting very rapid checks on noise and distortion. A filtered 400-cycle oscillator (TYPE 733-A) of good waveform has been provided for use in conjunction with the distortion meter. The distortion meter reads the noise level of the "unmodulated" signals directly in decibels with respect to the standard modulated signal. The operation of the instrument is so simple that it is possible to make checks on noise between announcements, if it is thought desirable to do so.

This frequent monitoring of noise makes it possible to keep constant checks on the balance of the rectifier equipment, assuring a minimum hum at all times. It also makes possible frequent checks on transmission lines to make certain that excessive interference is not present. The meter will give an accurate indication of noises down to 65 db below the completely modulated signal. This same instrument gives direct reading indication of distortion on a 400-cycle signal. A check of distortion at any one level should certainly take less than one minute and there is no reason why such a check should not be made immediately before and after the station is on the air so that it should always be possible to keep the station working at its optimum efficiency.

A technical discussion of all of these instruments will be given in next month's issue of the EXPERIMENTER. It is our belief that this group of instruments will prove a very definite economy to broadcasting stations in enabling them to operate at the highest possible level consistent with fidelity.

—L. B. ARGUIMBAU

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The CLASS 730-A Transmission-Monitoring Assembly was designed by L. B. Arguimbau. We were fortunate in having the close co-operation of the engineers of the Columbia Broadcasting System in the development and testing of the apparatus.

Every effort has been made to design the equipment to meet the actual conditions of present installations and methods of operation. The monitoring assembly consists of three units: Modulation meter with over-modulation indicator (TYPE 731-A), distortion and noise meter (TYPE 732-A), 400-cycle oscillator (TYPE 733-A). The equipment is capable of measuring:

1. Percentage modulation on both positive and negative peaks.
2. Program monitoring with high-speed volume indicator meter.
3. Carrier shift upon the application of modulation.
4. Carrier noise and hum level.
5. Combined audio-frequency harmonic distortion of modulation envelope.
6. Modulation peaks exceeding a predetermined, desired degree of modulation (*i.e.*, over-modulation indicator).
7. Combined audio-frequency harmonic distortion present in speech-input amplifier and other station equipment.
8. Noise and *hum* level of audio amplifiers and other station equipment, including wire lines to remote pickup points and to transmitter.

With the addition of a variable-frequency audio oscillator it is also possible to measure:

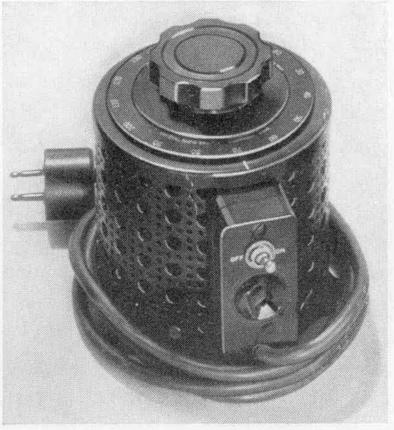
9. Transmitter audio-frequency response.
10. Audio amplifier and equipment frequency response.
11. Wire line frequency response.

No critical adjustments or balances are required. The quantities measured are read directly from the instrument and no calculations are involved. In the course of operating tests the equipment has been used to measure the characteristics of radio transmitters ranging from 50-watt portable remote pickup equipment to 50-kilowatt broadcast transmitters, as well as high-frequency transmitters operating at frequencies up to 15 megacycles. Checks on audio equipment have been made on everything from portable field amplifiers to program amplifiers and public-address equipment.

It has been found possible to make complete runs on a transmitter determining positive and negative modulation peaks, per cent distortion, hum and noise level throughout the range of audio input of the transmitter in less than ten minutes.

The entire monitoring assembly, CLASS 730-A, is priced at $462.00 (Code Word, EXILE). Delivery will start about February 28.

# VARIAC APPLICATIONS IN PHOTOGRAPHY



PHOTOGRAPHY enthusiasts have been finding a variety of applications for the Variac auto-transformer described in previous issues of the EXPERIMENTER. This unit, which combines the ease of control of a rheostat with the high efficiency of a transformer, is being substituted for resistance controls in all of the photographic processes where control of light intensity is required. Heretofore full advantage has not been taken of the possibilities of light control at the source of illumination as the equipment generally available has a number of limitations.

## PHOTOFLOOD LAMPS

Photoflood Lamps are being used by thousands of photographers, professional and amateur. The life of the No. 1 Photoflood Lamp is approximately two hours when operated on a 115-volt circuit. During the major portion of its life, however, the lamps could be operated at reduced voltage, while arranging subjects, getting correct light angles, focusing, and all the other operations preliminary to actual exposure. The Variac makes it possible to reduce the voltage on the Photoflood Lamp to any desired value, and then to "flash" the lamp at normal voltage during the comparatively brief exposure period, thereby prolonging the life of the lamps greatly.

The curve of Figure 1 shows the relation between lamp voltage and average lamp life, and lamp voltage and illumination of the No. 1 Photoflood Lamp. A voltage reduction of only 11

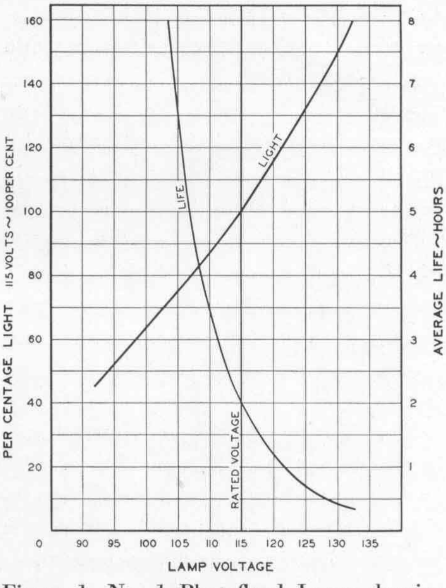



Figure 1. No. 1 Photoflood Lamp showing lamp voltage as a function of (a) probable life in hours and (b) percentage of light

volts, on the average, increases the lamp life by a factor of four, and the illumination from the lamp is still sufficient for most preliminary operations. When the lamp voltage is reduced by some 50%, the life of the Photoflood Lamps is comparable to that of a standard lamp operating at normal voltage.

Some photographers are operating Photoflood Lamps in groups of two, connecting them in series to secure half normal voltage during the preliminary adjustments, and in parallel for full illumination during the time of exposure. At half voltage the illumination is so low, comparatively, that it is difficult to predict the results when the lamps are operated at normal voltage. The Variac permits setting the voltage on the lamps at any value.

### PROJECTION PRINTERS

Photoflood Lamps are being used in projection printers so that enlargements may be made on chloride or chloro-bromide contact paper. Some control of the brilliancy of the light is essential as the heat generated by the Photoflood Lamp is sufficient, in many cases, to cause the negative to buckle before an exposure may be made. If used over prolonged periods at standard voltage, the Photoflood Lamp may damage the enlarging system, the reflector, or condensing lens, or the projection lens.

The Variac allows continuous adjustment of the brilliance of the lamp, to reduce it during the time the negative is being adjusted and masked, the picture "framed," and the paper adjusted. It also permits operating the Photoflood Lamps at reduced voltages when bromide papers are being enlarged upon.

In enlarging machines using standard electric lights, the several models of the Variac giving output voltages higher than line voltage are very useful in that the standard lamp may be flashed at voltages higher than normal when printing on extra dense negatives or making very large enlargements. The Variac, when used with an enlarger, also makes it possible to use a constant iris diaphragm setting, varying the degree of illumination to suit the density of the negative.

### CONTACT PRINTERS

In printing machines, particularly when used in commercial photo-finishing establishments, the use of a standard printing time on all negatives, varying the illumination from the lamps according to the negative density, is conducive to uniformity of results. Where it is desired to work to a standard illumination and control the printing by varying the time of exposure, the Variac models affording "above line" output voltages are used to compensate for changes in line voltages unfortunately met with in many localities.

### SAFELIGHTS

A control of the illumination from the safelamp is an exceedingly useful adjunct to the developing and printing room in that, when very sensitive emulsions or papers are being used, the safelamp may be operated at a voltage just great enough to allow the photographer to see his way around, yet it can be brought up to full brilliance momentarily to observe development progress. As the speed of emulsions varies, the amount of "safe" illumination varies also and hence the usefulness of a varying light source.

### STUDIO LIGHTING

In the photographic studio, amateur, portrait, or commercial, the lighting problem involves, in general, the control of both the intensity and the *direction* of the various light sources. Heretofore the intensity of illumination has been controlled by varying the distance between the subject and the light sources. This method is not entirely satisfactory; any change in the position of the lamp stands, to vary the *amount* of light, also affects the *angle* between the light source and the subject, requiring a readjustment of the light angles each time the stands are moved.

Many photographers work with well-defined and known light angles, merely varying the degree of illumination of the general, flood, and spot lights to secure the desired tone values and modeling. The Variac control offers an extremely flexible, simple, and economically operated method of controlling the illumination by varying the intensity of the light itself. When the Variac is used in the studio, the lamp stands are placed to secure the desired light angles and all modeling is accomplished electrically by adjusting the Variacs to change the intensity of each main light source.

## ADVANTAGES OF USING VARIAC CONTROL

The Variac has many advantages over the resistive control method. In the first place, up to the full load rating, the output of the Variac is essentially independent of load. One Variac can be used to control one or more lamps, replacing a number of resistive units. The power saving from use of the Variac is quite appreciable. Figure 2 shows the actual *saving* in watts when a Variac is used in place of a resistive control to vary the voltage on four No. 1 Photoflood Lamps.

## VARIAC RATINGS

The Type 200-B Variac (price $10.00) will control any lamp combination drawing not over 170 watts at 115 volts. It is ideal for controlling a single Photoflood Lamp. It supplies output voltages from zero to line.

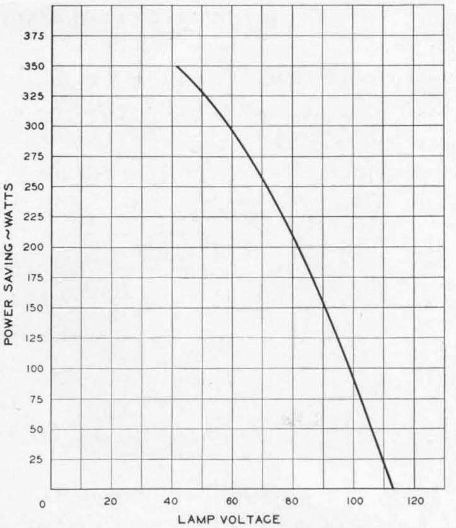



Figure 2. Actual power saved when using the Type 200-C Variac instead of a rheostat to control four No. 1 Photoflood Lamps

The Type 200-C Variac (Type 200-CM mounted and supplied with cord, plug, switch, and outlet, price $17.50) — Type 200-CU (unmounted and no wiring conveniences, price $14.00) will control 860 watts at 115 volts. It can be used to control from one to four No. 1 Photoflood Lamps. Its output voltages are continuously adjustable from zero to *135* volts, and is the model to use where voltages above line are required.

The Type 100 Variac (Type 100-K, for 115-volt circuits and Type 100-L, for 230-volt circuits, price $40.00) is rated at 2 kva at line voltage and will control any lamp combination consuming not over 2000 watts at line voltage. The Type 100-L Variac is supplied with a tap so that this unit may be operated on 115-volt circuits to give output voltages up to 230 volts. When so operated, the Type 100-L is rated at 1350 watts at output voltages from zero to 150, tapering to 900 watts at 230 volts.

# DIRECT-READING VARIABLE INDUCTORS

THE usefulness of any variable reactor or resistor is greatly increased if it is direct-reading. Reference to a calibration chart is always time-consuming and frequently leads to errors.

During recent years a number of direct-reading instruments have been announced by the General Radio Co. The five TYPE 107 Variable Inductors now join this continually lengthening list.

The general appearance of the calibrated dial is shown above. While the scale is not uniform, it is sufficiently linear to allow an accuracy of reading of 1% of the full scale reading.

The terminals of the rotor and stator coils are brought out separately to two pairs of posts on the upper left corner of the panel, which are distinct from the terminal posts on the upper right corner. The two coils may be placed either in series or in parallel by means of two links. The engraved plate at the top edge of the panel specifies the positions of these links. The scale marked on the dial is for the series connection of the coils, as indicated on the dial.

The inductance of the coils when connected in parallel is one-quarter that for the series connection to an accuracy of better than 0.1%. The existence of circulating currents in these coils for this connection has been minimized by making their separate inductances equal.

When the rotor and stator coils are at right angles, their mutual inductance is zero. The value of their self-inductance at which this occurs is given on the engraved plate in the lower left corner of the panel. For any other position of the coils their mutual inductance is one-half the difference between this zero mutual value and the scale reading. These formulae, together with the nominal d-c resistance and current-carrying capacity of the inductor, are also given on this plate.

There are five sizes of TYPE 107 Variable Inductors as shown in the following table.

| Type | *Self-Inductance* Series | *Self-Inductance* Parallel | *Mutual Inductance* |
|---|---|---|---|
| 107–J | 6– 50 μh | 1.5–12.5 μh | 0–12.5 μh |
| 107–K | 50–500 μh | 13–125 μh | 0–125 μh |
| 107–L | .5– 5 mh | .13–1.25 mh | 0–1.25 mh |
| 107–M | 5– 50 mh | 1.3–12.5 mh | 0–12.5 mh |
| 107–N | 50–500 mh | 13–125 mh | 0–125 mh |

The price of the three smallest inductors is $35.00, that of the two larger, $40.00.

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GENERAL RADIO COMPANY

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# The GENERAL RADIO EXPERIMENTER

VOL. IX. No. 9 — FEBRUARY, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

## MONITORING OF BROADCASTING STATIONS
### Part II

THOSE familiar with the TYPE 536-A Distortion-Factor Meter[1] and the TYPE 457-A Modulation Meter[2] will notice many points of similarity with the equipment described here. The older instruments were intended primarily for the experimental determination of the performance of transmitters, and experience over a period of four years has proved them to be entirely satisfactory on an electrical basis.

**LAST month's *Experimenter* discussed new methods of monitoring broadcasting station output and described the uses and capabilities of the CLASS 730-A Transmission Measuring Assembly. The present article discusses in more detail the instruments themselves and explains their operation.**

For continuous monitoring, however, equipment must be direct-reading, entirely self-contained, and must require a minimum of effort on the part of the operator. The CLASS 730-A Transmission Measuring Assembly has been designed to meet these requirements without sacrificing any of the accuracy obtainable with the older equipment.

#### TYPE 732-A DISTORTION AND NOISE METER

The Distortion and Noise Meter measures the harmonic distortion in the transmitter with 400-cycle modulation and the noise level in decibels below any given modulation level. Its operation is easily understood by referring to the diagram of Figure 1.

The carrier, modulated at 400 cycles, is applied to the input of the instrument. A capacitive attenuator is provided to adjust the carrier level to a convenient value. After a preliminary adjustment, this need not be changed. The carrier is rectified by a linear diode detector,[3] and the audio-frequency component of

[1] W. N. Tuttle, "Modulation Measurements on Broadcast Transmitters," General Radio *Experimenter*, Volume V, No. 10 (March, 1931).

[2] W. N. Tuttle, "Direct Measurements of Harmonic Distortion," General Radio *Experimenter*, Vol. VI, No. 6 (Nov., 1931).

[3] C. H. Sharp and E. D. Doyle, Crest Voltmeters, Trans. A.I.E.E., Volume 35, pp. 99-107, February, 1916.

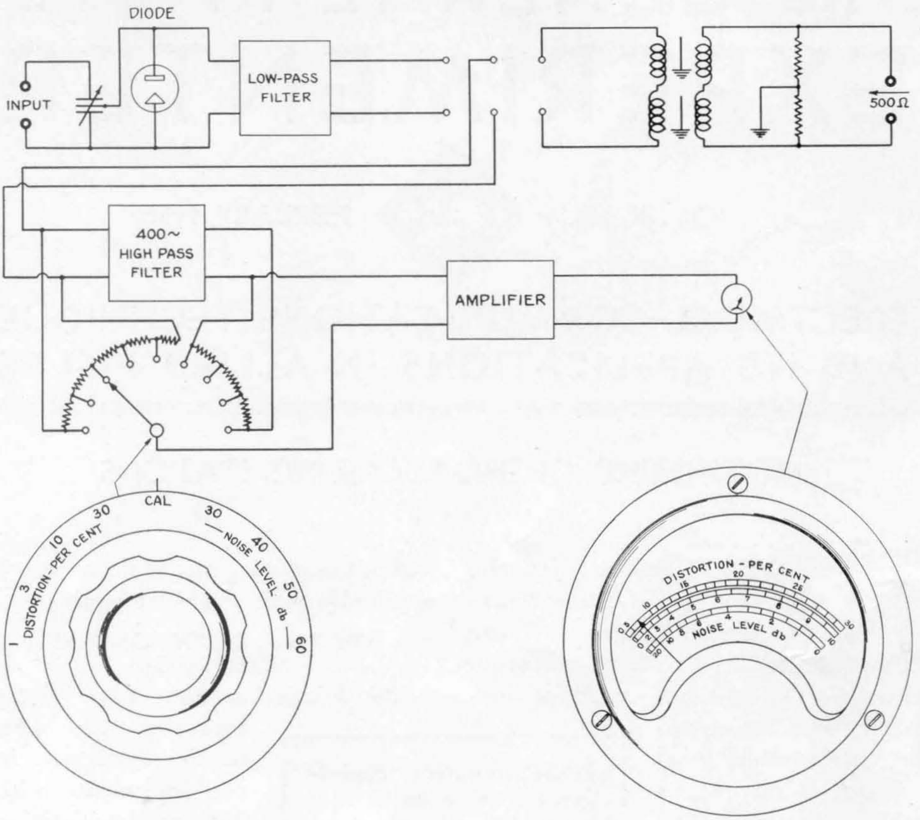



FIGURE 1. Functional schematic diagram of TYPE 732-A Distortion and Noise Meter

the envelope is applied to an attenuator and filter.

In order to standardize the direct-reading scales, a known fraction of the audio-frequency output is applied to the amplifier and the gain adjusted to give full scale deflection on the output meter. This is done at the CAL position of the attenuator.

To measure distortion, the 400-cycle component is then filtered from the signal, and a known fraction of the remaining harmonics is applied to the amplifier whose output meter is now direct reading in the distortion factor. Four scales are provided: 1%, 3%, 10%, and 30%. All are direct reading, as indicated in the drawing of the meter, which is a reduced reproduction of the actual scale.

In order to measure noise, the 400-cycle signal is applied to the transmitter and the amplifier gain adjusted as before. The modulation is then removed from the transmitter, and the residual audio components of the carrier envelope are applied to the amplifier. The ratio of noise to signal is given directly in decibels on a third meter scale. Full scale values of 30, 40, 50, and 60 db are provided, giving a total signal-to-noise ratio range of about 30-70 db.

As shown in the diagram, provision

is made for connecting the equipment directly to the carrier or to the audio system of the transmitter.

### TYPE 733-A OSCILLATOR

A 400-cycle filtered oscillator (TYPE 733-A) specially adaptable to the distortion meter has also been designed. The distortion factor of this oscillator as filtered is less than 0.2% under load and less than 0.1% on open circuit.

### TYPE 731-A MODULATION MONITOR

The modulation monitor consists of three essential elements: A linear diode rectifier which gives an instantaneous output voltage proportional to the carrier envelope, a peak voltmeter which measures the peak modulation, and a trigger circuit which flashes a light whenever the modulation momentarily exceeds a predetermined value. The output of the first diode is used as a measure of the carrier and is set at the start to 100, as shown in Figure 2. This meter will then indicate carrier shift as the station is modulated.

As shown in Figure 2, the audio frequency component of the carrier envelope in the desired phase for either positive or negative peak is applied to a peak voltmeter, which is specially de-

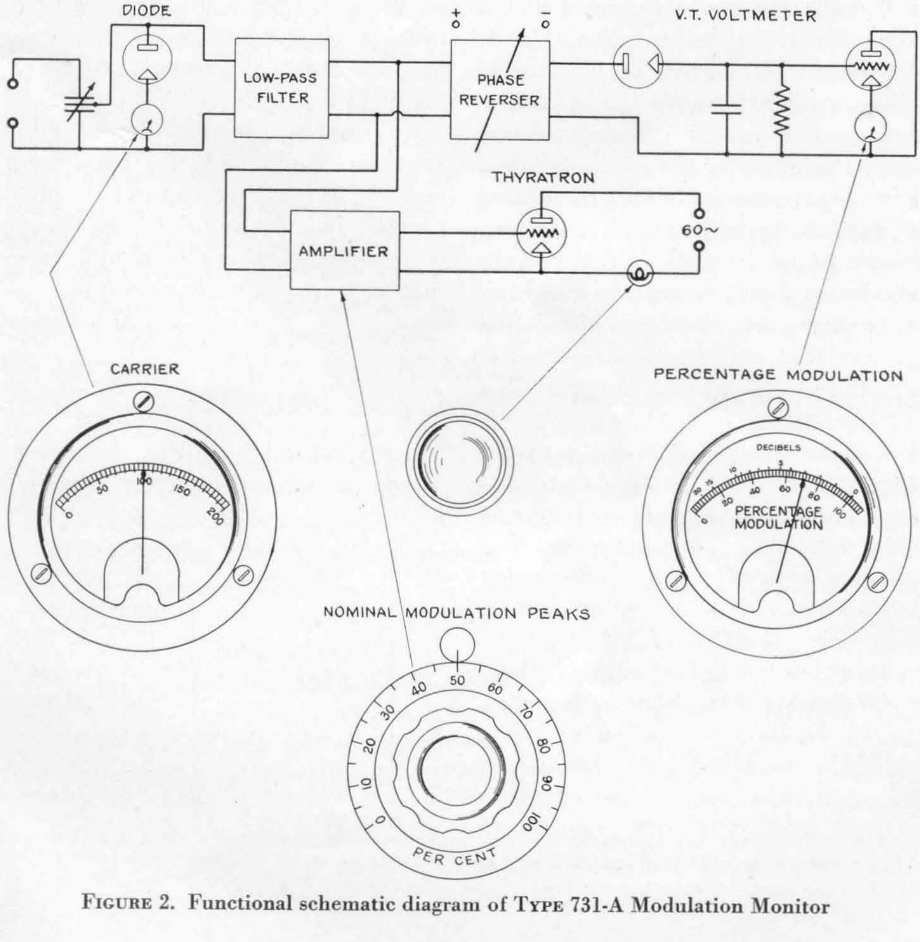



FIGURE 2. Functional schematic diagram of TYPE 731-A Modulation Monitor

signed to be highly independent of tube characteristics and to put an entirely negligible load on the first detector. This voltmeter circuit makes it possible to combine the accuracy of the older type of null method instrument[2] with a direct-reading, rapid-movement meter. The peak voltmeter reads directly in percentage modulation from 0 to 110% and has a superimposed decibel scale for monitoring purposes.

The meter movement is arranged to follow speech and music very rapidly. Over-all tests on the equipment show that a pulse lasting only 0.1 second will make the meter throw to within about 90% of the true value. This is the most rapid meter as yet commercially available, but it is not instantaneous and, even if it were, it would not be possible for the eye to follow it with any accuracy. In fact, in making dynamic tests on the meter, it was necessary to use screens to be sure of the maximum throw. In order to avoid this difficulty, a warning lamp circuit has been provided. After determining the permissible level of modulation by means of the distortion meter, a dial is set in the lamp circuit controlling the percentage modulation at which it will flash. An automatic biasing arrangement used in conjunction with a thyratron flashes a light whenever the percentage modulation exceeds the value at which the dial is set. This method is essentially an automatic null arrangement which requires no attention or adjustment.

A plug has been provided so that additional percentage meters and flashing lamps can be used externally. A connection is also made by this plug to provide an audio-frequency voltage proportional to the modulation for recording purposes.

To sum up, the modulation meter provides a pointer which gives a direct reading, dynamic measure of the modulation and, in addition, provides a warning signal when the desirable modulation is momentarily exceeded.

—L. B. Arguimbau

## *ERRATA*

## PERFORMANCE SPECIFICATIONS FOR CATHODE-RAY TUBES

In the November-December, 1934, issue of the *Experimenter*, the values of d-c voltage sensitivity given for Type 528-B Cathode-Ray Tube were incorrect. The entire table is reprinted below:

| *Type* | *Screen Diam.* | *Fast or Slow* | *Accelerating Voltage* | *D-C Voltage Sensitivity** | *Maximum Spot Speed†* |
|---|---|---|---|---|---|
| **635-P2** | 3 in. | Slow | 1000 v | 0.013 in/v | 4,100 in/sec |
| **635-P3** | 3 in. | Fast | | | 11,000 in/sec |
| **687-P1** | 5 in. | Slow | 1500 v | 0.012 in/v | 6,400 in/sec |
| **687-P2** | 5 in. | Fast | | | 16,000 in/sec |
| **528-B** | 7 in. | Fast | 3000 v | 0.0083 in/v | 50,000 in/sec |
| | | | 1000 v | 0.025 in/v | . . . . . . . . . . . . . |
| | | | 500 v | 0.050 in/v | 300 in/sec |

* Average for both pairs of plates.

† These values are maximum workable spot speeds $S$ for Verichrome film, on the basis of a hypothetical aperture $f/1.0$ and with the screen at infinite distance from the lens. The maximum speed $S'$ for any other aperature $f/N$ and a ratio $k$ between length of trace on screen and on the camera plate is: $S' = \dfrac{S}{N^2\left(\dfrac{1+k}{k}\right)^2}$.

# SUPERSONIC SOUNDS IN NATURE*

*By* Elbert P. Little †

> **THE following article, curiously enough, shows the exact technique that would be employed to eliminate noise as the result of an industrial noise survey. The steps are, roughly, the location of the source, a frequency analysis of the disturbing sound, and a visual analysis of the mechanism parts having periods corresponding to the predominant frequencies in the disturbance spectrum.**
>
> **The stroboscope used was a General Radio Type 528-A Edgerton Stroboscope, the clock a Class C-21-H Standard Frequency Assembly.**
>
> **—The Editor**

Biologists have often speculated as to whether or not animals produce supersonic noises, namely, sounds above the range of human audibility. We are able to hear noises due to vibrations in the air up to 18,000 per second, but anyone who has watched a humming bird singing must have observed that, as a note rises higher and higher, suddenly it can no longer be heard, but the bird's mouth will still be open and he will look as if he were still singing. The obvious conclusion is that he is singing above the range of human audibility.

Until recently we have been unable to study supersonic phenomena because no adequate methods existed of detecting high sounds and determining their pitch. But in the Cruft Laboratory at Harvard apparatus has been developed making use of magnetostriction and piezo-electric controlled oscillators and detectors by means of which we are now equipped to listen to noises that have been heretofore inaudible. Certain crystals, when properly cut, have the ability to control the frequency of an oscillator to a remarkable degree. Quartz crystals cut in this manner have a very narrow response width — that is, they will receive or oscillate at frequencies only very close to some particular one. Rochelle salts, on the other hand, have a wide range of response.

In receiving sound, a Rochelle crystal is put into a parabolic horn that can be directed towards a noise. When a sound strikes it, it gives rise to a varying voltage across two metal plates holding it. This electric variation is amplified. The amplified vibration is then heterodyned or combined with a vibration of a different frequency. The result of superimposing these two vibrations, which are applied to a vacuum tube detector, is to produce an audible vibration in the loudspeaker. By analyzing this audible sound the nature of the inaudible sound is determined. The sound detector is so sensitive that it can pick up the song of a cricket 200 yards away. It is connected to the analyzer by a shielded wire and can be carried out into the field in the direction from which the song is loudest until the insect making the noise is found.

The noises that are made by crickets are now the main feature of this research on sounds in nature. Professor George W. Pierce (assisted by Dr. Noyes and Miss Prouty) has been

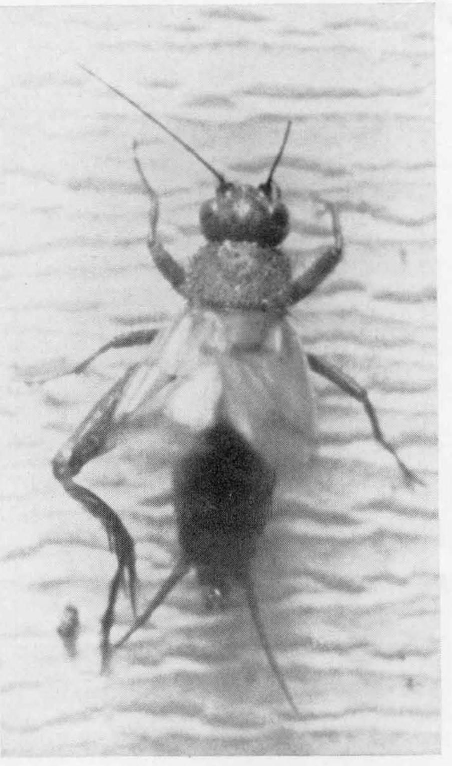
* Reprinted by permission from the *Harvard Alumni Bulletin* through the courtesy of Professor George W. Pierce and Miss Jane Prouty of the Cruft Laboratory where Harvard's work on Communication Engineering is done.

† *Harvard Alumni Bulletin.*

working with Nemobius Fasciatus, a small, dark-brown cricket that is very common in the fields. It is about one-third as long as the common house cricket. It sings at a frequency of 8000-11,000, whereas the house cricket sings at 4600 vibrations per second. Instead of discrete chirps, as with the house cricket, this small cricket emits unbroken trills, some of them lasting for over five minutes without a pause.

The study was started, and will be continued, in the country where many different insects can be taken up, and it is possible that some will be found which sing entirely above audibility. At the present time a number of crickets (Nemobius Fasciatus) are being kept in the Cruft Laboratory, and a detailed study of their singing mechanism is being made.

Insect noises are not produced vocally, but are produced by friction of one part of the body against another, by vibrations of the wings, by vibrations of a muscularly-controlled diaphragm, or by tapping the body on some external object. The cricket has small wing covers, or tegmina, which, according to biologists, are not adapted for flight. It is these wings which rub on one another to produce the "song." It is the male alone who "sings" or stridulates, the female possessing no stridulatory organs. Sometimes he sings alone with no female at hand, and at other times he sings while quite obviously trying to interest her, but she is at all times silent, appearing rather indifferent to his long trills. After a prolonged song of sometimes half an hour, the male is seen to perform a sort of dance, chirping excitedly, and the female, standing a short distance from him, will then execute back-and-forth



Stroboscopic picture of cricket with wings raised in "singing." Taken with a Leica Camera, exposure 5 seconds, stroboscope flash speed 16⅔ per second

motions. The stridulatory apparatus consists of a series of file-like teeth (148 per millimeter) located on the under side of each wing, and a hardened, raised portion on the upper inner edge of the tegmina which is used as a scraper. During the song the cricket raises his wings to an angle of 45 degrees and draws the scraper on one wing rapidly across the file on the other. This mechanism of stridulation has long been recognized by biologists, and the present investigations are principally concerned with the character of the sound. No such analysis has heretofore been made of this type of cricket, although the common house cricket and the

European field cricket have been studied.

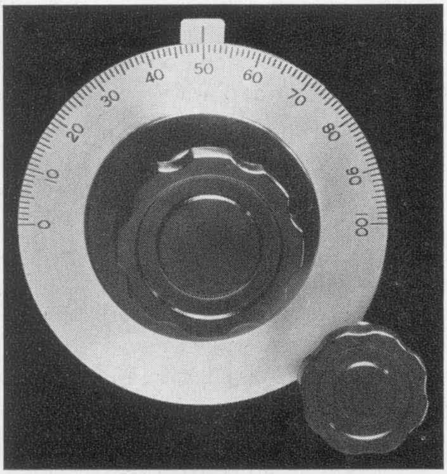
The main frequency of the note picked up by the detector was found to be about 8000 vibrations per second, or a note five octaves above middle C on the piano, but there are also strong vibrations at 16,000, 24,000, and 32,000 vibrations per second. If the signal in the amplifier is connected to a neon glow tube, the tube will flash every time sound is coming through the apparatus. The tube is attached to an arm and rotated once a second, and a photograph taken of the rotating light. A steady glow, indicating steady sound, will appear as a ring of light on the picture, whereas if the sound comes in pulsations separated by silence there will be spots of light separated by dark regions. The steady trill of Nemobius Fasciatus is seen to be made up of 16 pulsations of sound per second at room temperature, 70 degrees Fahrenheit; but if the cricket is heated up to the temperature of a hot summer evening, 94 degrees Fahrenheit, his song has 20 pulses a second. Each pulse is due to a single scraping of the wings, the pause between representing time required by the insect for changing the direction of the wing motion or going back to the start. In a previous investigation published by the American Museum of Natural History, Mr. Lutz and Mr. Hicks, working on the house cricket, concluded that this cricket did not have enough time in the .017 second pause between pulses to get his wings back to the center, so they assumed that he scraped in both directions.

The present investigators, in order to study the wing motion of Nemobius Fasciatus, set up a stroboscope beside the vivarium containing a cricket. The stroboscope is an instrument where a light can be made to flash on and off at any desired rate. If the cricket is singing, his wings are moving too fast to study. He is therefore put in the dark and the instrument is adjusted until the wings appear to stand still. Once during every cycle of the wing motion the light is flashing on for 1-100,000 second, the rest of the cycle occurring in the dark. The wings are therefore lighted every time they reach the same position. The stroboscope has a scale where the number of flashes per second can be read. The investigators found that they must adjust the speed to 16 1-3 flashes per second in order to make the wings appear stationary; hence there are 16 1-3 complete, back-and-forth wing flaps. As was stated above, at room temperature there are 16 pulses per second in the song. If stridulation was produced while the wings moved in both directions there would have to be 32 pulses per second; so in these crickets noise is produced while the wings move in one direction only.

This is, of course, only a preliminary study. Professor Pierce has listened to other noises, the song of newly-hatched robins, which is loudest at 15,000 vibrations per second, and the black pole warblers which sing at about 15,000. The ultimate object of this series is to study and classify the sounds in nature and if possible to determine whether they serve some purpose for communication. In addition to noises made by animals, Professor Pierce has found a large number of persistent supersonic noises, such as the vibrations emitted by leaves under the action of the wind, noises produced by air jets some of which are inaudible to the ear, the rubbing of clothing or of hands, noises made by the burning of a match when freshly ignited. The ticking of a watch may be heard at a distance of 30 feet or more by means of sounds of a frequency as high as 30,000 vibrations per second. The devices which are here employed in scientific study have also highly important practical applications in the production and detection of sounds under water, as a means of signaling between vessels or of finding the depth of the sea by timing echoes, or in detecting vessels by means of supersonic noises produced by the vibration of their hulls or propellers.

The vibrations produced by magnetostriction oscillators and piezo-electric crystal oscillators have a high constancy of frequency and are used in controlling the frequency of radio sending-stations and to provide time-keeping mechanisms for clocks of high precision. One such clock operated at the research laboratory, based on principles discovered by Professor Pierce and manufactured by the General Radio Co., keeps time so accurately that it changed in rate by less than 1-10 of a second per day in four months.

## NEW DIALS




As companions to the 2¾- and 4-inch dials used on much of our equipment and in the assembly of laboratory and experimental apparatus of others, two new General Radio dials having diameters of 3¼ inches are now available. The new dials are similar to the Types 702 and 710 Dials, except for the larger dial plates. The dials are nickel-silver finished, with photo-etched engraving, and are insulated from the shaft. The fluted knob is polished black bakelite with rounded edges. These dials are available for both ¼- and ⅜-inch shafts, with and without friction drive.

| Type | Dial Diam. | Dial Arc | Scale Div. | Diam. Shaft | Diam. Knob | Reduc. Ratio* | Code Word | Price |
|---|---|---|---|---|---|---|---|---|
| 712-A | 3¼ in. | 180° | 100 | ¼ in. | 1⅝ in. | .... | DIAPE | $1.25 |
| 712-F | 3¼ in. | 180° | 100 | ⅜ in. | 1⅝ in. | .... | DIFAR | 1.25 |
| 705-A | 3¼ in. | 180° | 100 | ¼ in. | 1⅝ in. | 1 : 4 | DIARK | 1.75 |
| 705-F | 3¼ in. | 180° | 100 | ⅜ in. | 1⅝ in. | 1 : 4 | DIFAL | 1.75 |

* Licensed under U. S. Patents Nos. 1,713,146 and 1,744,675.

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS


## WAVEFORM ERRORS IN THE MEASUREMENT OF FILTER CHARACTERISTICS

ENGINEERS whose work includes the design and manufacture of electric wave filters have often been concerned with the discrepancy that appears to exist between the calculated and actual performance. Given reasonably good data about the characteristics of the coils and condensers that are used, the frequency characteristics of a filter can usually be predicted fairly accurately, yet seemingly careful measurement often indicates a marked difference between the design data and the manufactured product.

While nearly all communication engineers are aware that waveform distortion in the power source will influence the measured characteristic of a filter, few take the trouble to make an actual calculation of how serious such errors may become.

Two of the usual circuits for observing filter characteristics are illustrated in Figure 1. With either method, the output voltage of the oscillator, which

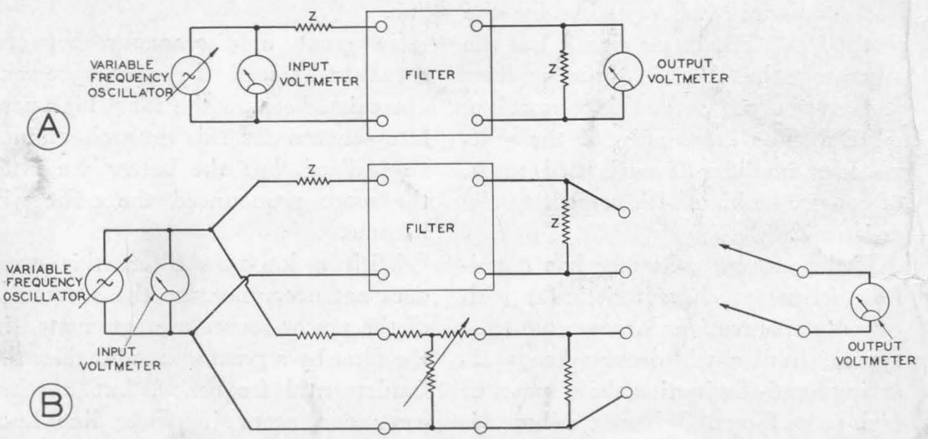



FIGURE 1. Schematic diagram of circuits for measuring wave filter characteristics

is usually kept constant, is applied to the filter through a resistance equal to the characteristic impedance of the filter. The filter is terminated in a second resistance of the same value, across which the output voltage is measured. Generally an amplifier preceding the output voltmeter is required, because the voltage after being attenuated by the filter is too low for direct measurement by voltmeters of ordinary

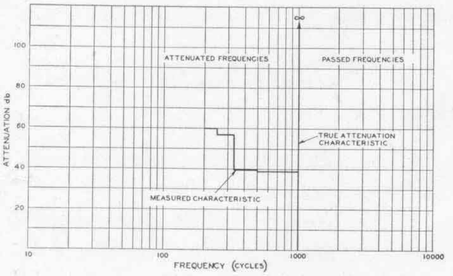



FIGURE 2. Error in measured characteristic of high-pass filter due to distortion in the power source

sensitivity. The loss is either read directly from the meter readings with the amplifier gain known, as in A, or a loss equal to the filter loss at the various frequencies is set up in a parallel variable attenuation network, and the losses balanced for equality by the method B. The latter circuit has the advantage that the gain of the amplifier need not be known for this comparison method. The impedance of the voltmeter or amplifier (if one is used) must, of course, be high with respect to the resistor Z.

If the output voltmeter has a uniform frequency characteristic (as with copper-oxide-rectifier or vacuum-tube types), trouble will occur when measuring band-elimination, band-pass, or high-pass filters. When a-c hum is present in the power source or is picked up in the circuit, even low-pass types may appear to possess characteristics which differ widely from those indicated by the calculated data.

A graphic illustration of the error of measurement of a high-pass filter is shown in Figure 2. An ideal high-pass filter with a cut-off at 1000 cycles is assumed. It eliminates entirely all frequencies below cut-off and passes without attenuation frequencies above cut-off. The power source in this case is a representative beat-frequency type of vacuum-tube oscillator which has relatively good waveform. The amplitudes of its harmonic components referred to the fundamental are as follows: second harmonic, 0.316% (–50 db), third harmonic, 1.0% (–40 db), fourth harmonic, 0.1% (–60 db), and fifth harmonic, 0.1% (–60 db) or a total distortion of about 1.06%.

At a measuring frequency of 200 cycles the fifth harmonic, or 1000 cycles, just falls in the passed band and is read on the output voltmeter. At 250 cycles the fourth appears, adding to the fifth, and so on up to the second, at 500 cycles. The result is the apparent attenuation curve shown by the heavy line.

So great a discrepancy between actual and measured performance cannot exist, because the ideal high-pass filter chosen for this example cannot be realized, but the better the filter the more pronounced the error will become.

With a low-pass filter, this error does not occur because the harmonics of the power source are attenuated in the filter by a greater amount than the fundamental frequency, but another error can occur if power line hum frequencies which lie below the cut-off frequency are present in the measuring circuit. For instance, when measuring a 1000-cycle, low-pass filter, one would expect a continually rising attenuation with increasing frequency above 1000 cycles. Actually, however, the attenuation would never exceed the r.m.s. level of the hum frequencies, all of which pass through the filter unattenuated. The discrepancy between actual and measured characteristics under such conditions can be very considerable. If the hum voltage amplitude is only one per cent of the amplitude of the power source, the measured attenuation cannot exceed a maximum of 40 db (one-hundredth of the amplitude of the measuring frequency). An r.m.s. output voltmeter has no means for distinguishing between measuring frequencies and extraneous hum.

Figure 3 is a comparison of the true characteristic of a band-pass filter with that obtained using the representative beat-frequency oscillator and r.m.s. output meter mentioned in the discussion of high-pass filter measurements. The accurate curve was obtained by a method described later, which eliminates the effects of the distorted waveform of the power source. The solid line represents the true attenuation curve, and the dotted curve is the indicated attenuation characteristic. The presence of the fifth harmonic, which is the highest one of any appreciable amplitude, shows up by the deviation of the measured from the true characteristic at a frequency of 200 cycles. The third harmonic has the greatest amplitude of all (1%). Thus at 333 cycles a big dip occurs in the measured characteristic as the third harmonic of 333 cycles falls in the passed band.

There are three methods that can be used to reduce the errors caused by power source harmonics:

(1) Improving the waveform of the a-c power source.

(2) Utilizing filters between the power source and the measuring circuit to reduce the harmonics to a negligible level.

(3) Using a tuned or selective output voltmeter, that is, one which responds to only *one* frequency at a time.

Vacuum-tube oscillators are universally used for the power source. The difficulty of reducing the harmonic content of their waveform below one, two, or three per cent is well known to anyone who has attempted it, therefore the method (1) above is impracticable. Of course, if the filter being examined has a maximum attenuation of only 20 db (10:1 ratio between

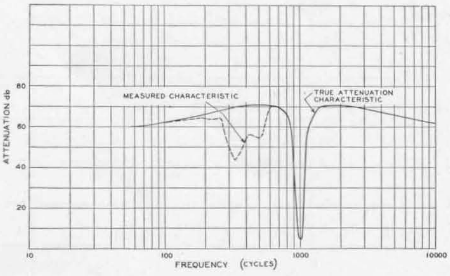



FIGURE 3. Error in measured characteristic of band-pass filter due to distortion in the power source

passed and cut-off frequencies), a three per cent harmonic will not bother the measurements seriously. Most wave filters, however, have a higher attenuation ratio than this, and too frequently vacuum-tube oscillators have much more than three per cent of harmonics.

Method (2), while often used, has

several practical disadvantages, principally that suitable filters for use with the power source are not always available, and, for a wide frequency range, they become too numerous and bulky to be handled conveniently.

Method (3) is, therefore, by far the most useful. If the measuring voltmeter is sufficiently sharply tuned so that it will respond only to the desired frequency, eliminating all others, and if its frequency response range is variable over wide limits, it will prevent the errors caused by harmonics and will still be flexible enough for making most audio-frequency measurements.

The Type 636-A Wave Analyzer* has these characteristics. Briefly, this instrument functions on the heterodyne principle. It has an internal variable-frequency oscillator covering the range from 34,000 to 50,000 cycles per second. The impressed voltage under measurement is heterodyned with the internal oscillator, which is set to the proper frequency so that the upper side band of the combined frequencies is 50,000 cycles. This fixed side-band frequency is passed through a two-stage quartz crystal filter of high selectivity. The internal or local oscillator is varied over its frequency range by means of a single large dial which is calibrated in terms of the frequency under measurement, *i.e.*, 16,000 to 0 cycles. The selectivity is so great that a frequency of only 30 cycles off resonance is attenuated by 40 db and one off 90 cycles is attenuated by 60 db. With such extreme selectivity, harmonics of the desired frequency do not produce a measurable reading, thus eliminating the errors from this cause; likewise hum frequency components that may cause errors in low-pass filter measurements are eliminated.

Our laboratories are frequently confronted with practical filter design

** General Radio Experimenter*, June-July, 1933, pp. 12-14.

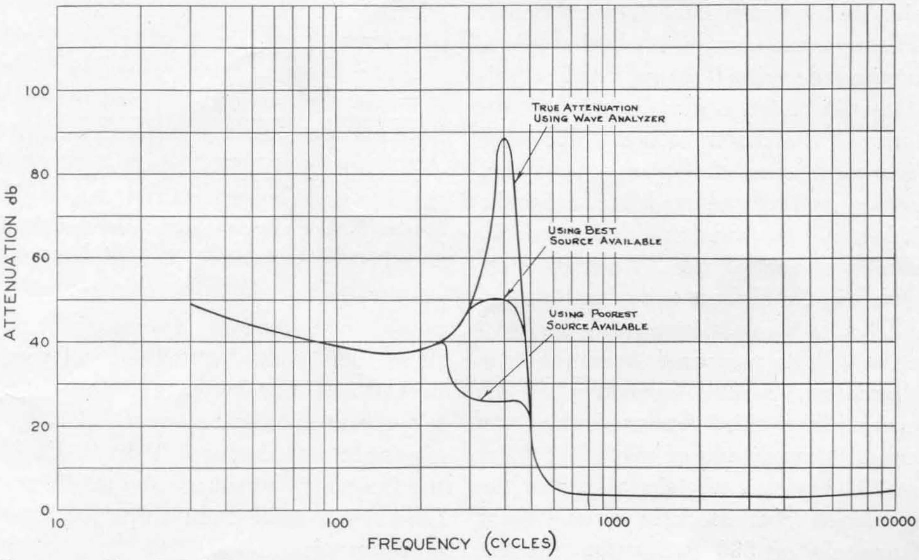



Figure 4. Results of three measurements on a band-elimination filter. The true attenuation characteristic is obtained when the Type 636-A Wave Analyzer is used as the detector. The two lower curves were taken using two different oscillators and a vacuum-tube voltmeter as the detector

problems requiring a careful measuring technique. For example, in two General Radio measuring instruments* a good combination high-pass and band-elimination filter is used to eliminate a 400-cycle fundamental frequency and pass only the harmonics of the impressed 400-cycle frequency, in order to measure the total residual harmonics in its waveform. The ratio of the amplitude of the total r.m.s. harmonic content to the fundamental amplitude is the "distortion factor," usually expressed as a percentage. Obviously the excellence of these instruments depends upon the use of a filter that will attenuate the 400-cycle fundamental frequency to such an extent that its amplitude after filtering will be entirely negligible compared to its harmonics. The frequencies below 400 cycles are also attenuated by the high-pass sections, so that errors due to extraneous noises, chiefly power line hum, will be eliminated.

Figure 4 shows the attenuation characteristic of this filter measured in three ways: First, an r.m.s. vacuum-tube voltmeter was used as the output meter, and an obsolete type of beat-frequency oscillator with high harmonic content was the power source. Instead of showing some attenuation at 400 cycles, the attenuation appeared actually to dip in the band-elimination region. Second, the best oscillator available was used with the same output meter. The new TYPE 713-A Beat-Frequency Oscillator was the power source in this case, which at 400 cycles had a harmonic content of only about 0.3% (–50 db). This time the attenuation curve showed a rising characteristic as it should, but its maximum was naturally limited to 50 db. For the third test a TYPE 636-A Wave Analyzer was substituted for the VT voltmeter. In addition to being highly selective, this has so great a sensitivity (one millivolt full-scale at its highest sensitivity) that the amplifier preceding the voltmeter in the two previous measurements was dispensed with. When the frequency selective wave analyzer was used, the true attenuation curve was obtained, showing, as it should, a maximum attenuation of 88 db. The curve obtained was practically the same, using *either* of the two oscillators for the power source.

—A. E. THIESSEN

*The TYPE 536-A Distortion-Factor Meter and the TYPE 732-A Distortion and Noise Meter.

## USES FOR GENERAL RADIO INSTRUMENTS

THIS issue of the *Experimenter* is devoted mainly to uses for General Radio equipment. The filter measurement article by Mr. Thiessen describes one of the many laboratory measurement applications of the TYPE 636-A Wave Analyzer, and the article reprinted from *Norge News* on pages 6 and 7 shows an interesting industrial application of the Edgerton Stroboscope. We shall be glad to receive from our readers information regarding other interesting applications of General Radio apparatus, particularly those which are unique or of more than ordinary interest. We plan to publish those which are of general interest to our readers and full credit will, of course, be given to the source of the information.

# THE STROBOSCOPE STOPS THE ROLLATOR

**THE following article is an excellent example of the use of the Edgerton Stroboscope in observing the operation of rapidly-moving mechanical systems to check the performance of the finished product against the design data.**

**Our readers are undoubtedly familiar with the descriptions of the Norge Rollator in the manufacturer's advertising. This article (reprinted from *Norge News* by permission of the Norge Corporation) shows how these design features can be observed in operation.**

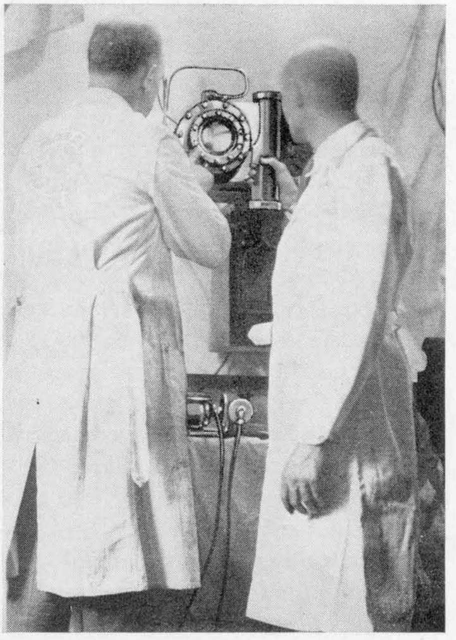
ABOUT a year ago the Norge Engineering Laboratory obtained one of the very latest model Edgerton Stroboscopes developed by the General Radio Company. With this instrument, any motion up to as high as 10,000 vibrations or cycles per minute, so long as it was repeated in a regular cycle, could be slowed down or even stopped so that the parts could be studied with the eye the same as if they were standing still. For instance, if the tip of a fan blade is suspected of vibrating and making a noise, it may be viewed with the aid of the Edgerton Stroboscope the same as if the rapidly revolving blades were actually standing still, and if there are any vibrations imposed upon the ordinary rotation of the fan, they may be instantly detected. This instrument took care of the rapid movement of the parts, but the Engineering Department was still faced with the problem of being able to see into the cylinder.

They had previously built Rollators with glass inserts in the dome, simply to observe the effect on the oil when a job was in operation. Therefore, they were able from past experience to design a dome with a very large glass insert, so that the whole interior of the compressor would be easily illuminated by the flash from the lamp of the Edgerton Stroboscope. The cylinder bearing plate, as it is amply strong to support the shaft bearing, could be cut away sufficiently to expose the cylinder end plate, especially since additional available space for opening holes in the cylinder bearing plate could be obtained by moving the discharge valve from the cylinder end plate on to the side of the cylinder itself. This still left the problem of making a cylinder end plate from some transparent material.

The cylinder end plate is the flat plate which closes the end of the cylinder, and it must be absolutely flat to preserve the proper clearance between itself and the end of the roller. It was thought by the Norge engineers that it might be possible to construct this cylinder end plate out of glass with sufficient accuracy so that it would function properly. This problem was turned over to the engineers of the Bausch & Lomb Optical Company, who, after several weeks of work, were able to produce two plates ground flat with a sufficient degree of accuracy so that the compressor would function as satisfactorily as it would with the very accurately ground cast iron cylinder end plates produced in the Rollator plant at Detroit. Producing these glass end plates was a very unusual and painstaking job because bolt holes had to be drilled through the end plates the same as are in the regular cast iron end plate. However, at quite an expense, this problem was finally solved, and very tenderly the compressor was assembled to avoid any chance of a strain that would crack the precious glass end plates. It was finally put in operation and has revealed some very interesting and instructive facts about the interior of the Norge Rollator.

One of the first things that was checked was to see whether or not the statement was true that the Rollator actually rolled around the inside of the cylinder and did not itself revolve at shaft speed. The actual speed of revolution of the roller inside of the cylinder was observed and it was found that, for all practical purposes, it is almost stationary. On two separate occasions the roller was observed over a period of two hours, during which time it did not make even one complete revolution. However, it did creep about 10 to 15 degrees, proving that its position changes sufficiently to equalize any possible tendency to wear.

There are now under way further intensive studies of the action of the blade and the oil inside of the compressor cylinder as they are revealed through the glass compressor. With the aid of this visibly operated machine, some very interesting and pertinent data are being obtained on the action of the oil in the cylinder, and especially the flow of the oil as it is forced past the ends of the roller and around the blade into the cylinder and out through the discharge valve.



Norge engineers viewing the operation of the Rollator by means of the Edgerton Stroboscope

Some studies also are to be made to see if there is any vibration of the blade during operation, and also of the action of the blade spring and the discharge valve under actual conditions of operation.

# A NEW REACTANCE CHART

THE June, 1934, issue of the General Radio *Experimenter* announced that a considerable quantity of reactance-computation charts were available for distribution to readers. So many requests were received that our supply was very quickly exhausted.

We have recently prepared a new and improved chart which has a number of advantages over the older one and we shall be glad to forward a copy to everyone who requests it.

# MODIFICATION OF BROADCAST FREQUENCY MONITORS FOR COMPLETE A-C OPERATION

FOR the benefit of those who are using frequency monitors composed of TYPE 575-D Piezo-Electric Oscillator and TYPE 581-A Frequency-Deviation Meter, the General Radio Company is prepared to rebuild this equipment for complete a-c operation. This service is being made available because most of the d-c monitors have been in continuous use for two or three years, and, in many cases, a general overhaul and readjustment may be desirable.


The modification of the piezo-electric oscillator into a TYPE 575-E includes installing a new panel and modification of the terminal strip, replacing the temperature control relay with an a-c unit, installing fusible protective links in the temperature-control circuit, replacement of the heat indicator lamp by one of the "bull's-eye" type, and such other minor changes as may be necessary.

The quartz plate will be readjusted to exact frequency, and bakelite bases will be replaced by isolantite.

The deviation meter, after modification, will be called TYPE 581-B and will supply the power for the TYPE 575-E Oscillator. The instrument will be given a complete overhauling and put in first-class electrical and operating condition.

The charge for the total modification is $125.00. The rebuilt instruments will carry the same guarantee as new equipment. The quoted price will include minor repairs not strictly a part of the reconditioning operation, but necessary major repairs will be subject to additional charge at a fair rate. The time required to do the work will be between ten days and two weeks.

The Federal Communications Commission will grant a permit to operate a broadcasting station for a period of three weeks without a visual monitor provided it is stated that the frequency monitoring equipment is being returned to the manufacturer for modification and calibration. It is, therefore, essential that the permit be granted before the equipment is returned to us.

Before returning instruments for this modification, write to the Service Department for shipping instructions.

—H. H. DAWES



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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

## USING THE NOISE METER WITH A VIBRATION PICKUP

IN industrial noise measurement, particularly when attempting to eliminate objectionable noise in machinery or to reduce sound transmission through walls, it is often useful to make a quantitative measurement of the comparative amplitudes of vibration of the surfaces producing or transmitting the sound. The use of a piezo-electric vibration pickup in conjunction with the TYPE 559-A Noise Meter is a convenient and simple method of measuring these relative amplitudes of vibration.

The piezo-electric vibration pickup transforms the motion of the surface into an alternating voltage of substantially identical waveform. The face of the vibration pickup is covered with a piece of felt, through the center of which a small plunger projects. This plunger bears on the surface against which the pickup is held, and transmits the motion of the surface directly to the piezo-electric crystal. The resultant variations in pressure on the surface of the crystal produce corresponding alternating voltages.

Figure 1 shows the method of coupling the pickup to the noise meter. The transformer is required in order to match the high impedance of the piezo-electric unit to the low impedance of the noise meter input circuit.

When comparing two vibrations of the same frequency, the readings will

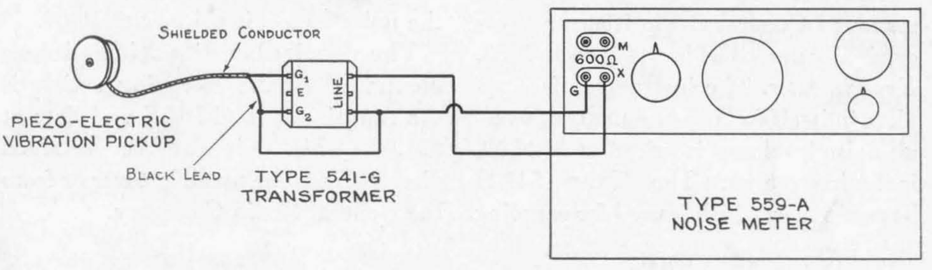


FIGURE 1. Equipment for measuring relative intensity of vibrations of surfaces

indicate directly in decibels the difference between the two vibrations. Relative measurements of this sort are extremely valuable when attempting to reduce the amplitude of a vibration or to trace its source.

Since the noise meter amplifies the various frequencies with a characteristic closely approaching that of the human ear, the readings of the meter, when used with a vibration pickup, are very good indications of the amount of audible noise which will be caused by the vibration being measured. When the equipment is used to compare two vibrations of different frequencies, not only the amplitudes but the frequencies are taken into account, so that the readings are closely related to the annoyance which the vibrations will cause to the average human being.

This equipment is being used by several large manufacturers of acoustic insulating material. Among these is the Seaman Paper Company of Detroit, manufacturers of "Seapak" and other well-known types of insulating materials. This company has used the noise meter both with and without the vibration pickup for extensive tests in the sound-proofing of automobiles, railroad cars, offices, etc. In one case, measurements made with the noise meter were the cause of the Seaman Company obtaining an order for sound-proofing a number of new air-conditioned passenger coaches for a large middle-western railroad.

The science of noise measurements as applied to industrial problems is comparatively new and its entrance into the industrial picture has been accompanied by so much misleading information that the possibilities of equipment of this type have been frequently over-rated. No noise-measuring equipment will tell a manufacturer all that is wrong with his product, but a good noise meter gives definite readings of noise level which show immediately whether constructional changes and adjustments result in an increase or a decrease in noise. This type of instrument is not excessively expensive and is the most satisfactory for industrial use. The use of a vibration pickup extends further the usefulness of the noise meter by allowing comparative measurements of surface vibrations which frequently enable the user to trace a disagreeable sound back to its source.

— H. H. SCOTT

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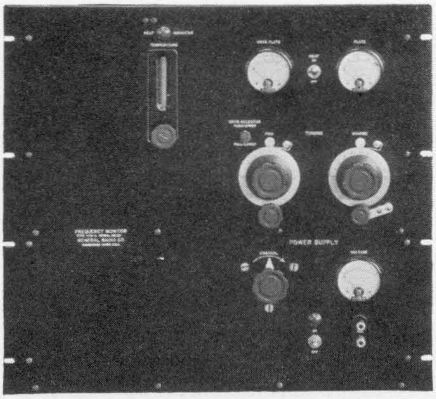
The TYPE 559-A Noise Meter is a standard General Radio item and was originally described in the March, 1933, *Experimenter*. The instrument is complete in itself for measurements of over-all noise level and is priced at $190.00, including tubes. The TYPE 541-G Transformer, which is used for coupling a high-impedance vibration pickup to the noise meter, is priced at $10.00.

The particular vibration pickup mentioned in the foregoing article is the Astatic TYPE C-104-S and lists at $21.00. This unit can be obtained directly from the manufacturer or from the General Radio Company.

# A FREQUENCY MONITOR FOR POLICE AND HIGHER FREQUENCIES

For limited service transmitters which operate, for the most part, at frequencies above the standard broadcast band, some positive means of determining the accuracy of the transmitter frequency is necessary. This is particularly true with police broadcast transmitters, where too marked a deviation from the assigned channel may produce sufficient interference to handicap seriously the reception in a nearby municipality operating on an adjacent channel.



Type 475-A Frequency Monitor

Although the tolerances specified by the Federal Communications Commission are not sufficiently narrow to require the 50-cycle type of visual deviation indicator that is used in the normal broadcast band, they do necessitate the use of an accurate type of frequency monitor. Heterodyne frequency meters and tuned-circuit instruments in general, unless of an expensive type, are not satisfactory from either the standpoint of accuracy or that of convenience.

The most acceptable instrument from all angles is the piezo-electric monitor. Its accuracy is in excess of that required at present and it is adequate to take care of more rigid tolerances in the future. It requires a minimum of attention on the part of the operator, whose total effort consists of listening to a beat tone whenever it is desired to check the transmitter frequency.

The Type 475-A Frequency Monitor has been designed with the requirements of police transmitters in mind. It consists of a temperature-controlled piezo-electric oscillator, a detector, an audio-frequency amplifier, and a built-in a-c power supply. Monitoring is accomplished by means of the beat frequency, or frequency difference, between the piezo-electric oscillator and the transmitter. Terminals are provided for connecting head telephones or a loudspeaker for listening to the beat tone. The presence of an audible tone in the loudspeaker is an indication that the transmitter has deviated from its assigned frequency by an amount equal, in cycles per second, to the beat frequency.

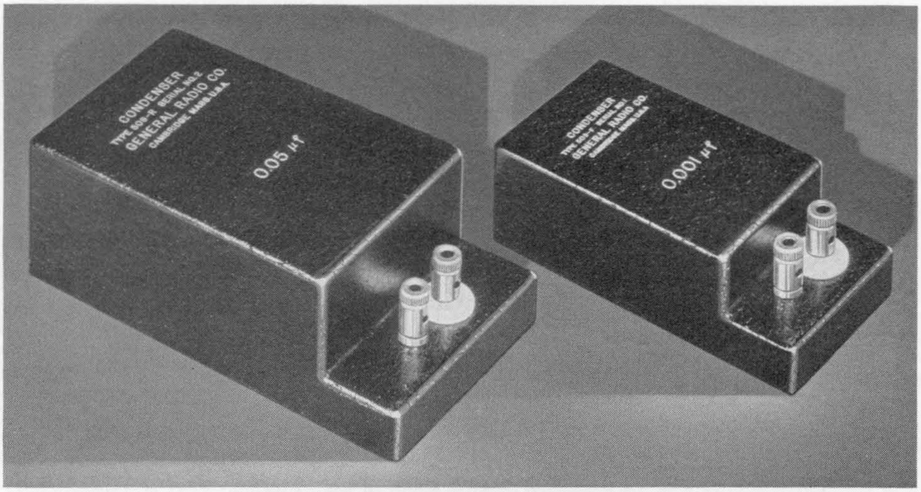
Present-day frequency tolerances on police transmitters are $\pm 0.04\%$. At a frequency of 1600 kc, this is equivalent to $\pm 640$ cycles. At 2450 kc the tolerance is 980 cycles. If the transmitter is adjusted until zero audible beat is reached or until a low tone is heard in the loudspeaker, the operator is assured that the station is operating well within the specified frequency tolerance.

This method of frequency monitoring is accurate, convenient, and comparatively inexpensive. For those police departments which continually receive from the Federal Communications Commission reports of off-frequency operation, the Type 475-A Frequency Monitor is the obvious remedy.

The Type 475-A Frequency Monitor is priced at $330.00 complete with vacuum tubes. In addition a Type 376-J Quartz Plate is required, priced at $85.00, making the price of the complete monitor $415.00, f.o.b. Cambridge. Deliveries can be made from stock. — C. E. Worthen

## MICA CONDENSERS FOR THE LABORATORY

For use in the laboratory, mica condensers, due to the wide range of possible capacitance values in units of small physical size, make excellent secondary standards. The General Radio Company now has available the Type 509 Mica Condensers, designed specifically for this purpose. Similar in general construction to the Type 505 Condensers,* their larger size permits much higher capacitance values, extending up to 1.0 $\mu$f.




Type 509 Mica Condensers

Type 509 Mica Condensers are carefully assembled and mounted to insure the stability that is necessary in a laboratory standard. After assembly, the condensers are put through an artificial aging process which removes most of the capacitance change which would otherwise occur due to natural aging. That which remains is so small as to be negligible over long periods of time. After aging, the capacitance is adjusted to be within 0.25% of its nominal value. The exact value of capacitance is measured to 0.1% and recorded on the calibration certificate.

The available sizes are so chosen that

*A. E. Thiessen: "Recent Developments in Mica Condensers," General Radio *Experimenter*, Vol. VII, No. 8, January, 1933.

a minimum of duplication is required to obtain all values in any one decade. The maximum safe voltage which can be applied is a function of frequency, as shown in the price list. These limits are imposed by the maximum power dissipation of the unit. At frequencies higher than those stated, the maximum safe voltage varies inversely as the square root of the frequency. All voltages are peak values.

The power factor is less than 0.05% for all sizes. The temperature coefficient of capacitance is less than 0.01% per degree Centigrade.

TYPE 509 Mica Condensers are mounted in two sizes of cast aluminum cases. The dimensions of the larger size are 6 x 3⅜ x 2⅜ inches, over-all; those of the smaller are 4⅞ x 2½ x 1⅞ inches, over-all. The net weights are 3½ and 2½ pounds respectively.

## TYPE 509 MICA CONDENSER

| *Type* | *Capacitance* | *Maximum Voltage* | *Maximum Frequency* | *Case* | *Code Word* | *Price* |
|---|---|---|---|---|---|---|
| 509-F | 0.001 μf | 1200 v | 440 kc | Small | GOODCONBOY | $12.50 |
| 509-G | 0.002 μf | 700 v | 640 kc | " | GOODCONBUG | 12.50 |
| 509-K | 0.005 μf | 700 v | 260 kc | " | GOODCONCAT | 12.50 |
| 509-L | 0.01 μf | 700 v | 130 kc | " | GOODCONDOG | 12.50 |
| 509-M | 0.02 μf | 700 v | 65 kc | " | GOODCONEYE | 15.00 |
| 509-R | 0.05 μf | 700 v | 60 kc | Large | GOODCONFIG | 18.00 |
| 509-T | 0.1 μf | 700 v | 30 kc | " | GOODCONROD | 22.00 |
| 509-U | 0.2 μf | 700 v | 16 kc | " | GOODCONSIN | 25.00 |
| 509-X | 0.5 μf | 500 v | 12 kc | " | GOODCONSUM | 32.00 |
| 509-Y | 1.0 μf | 500 v | 6 kc | " | GOODCONTOP | 48.00 |

# A NEW REACTANCE CHART

THE June, 1934, issue of the General Radio *Experimenter* announced that a considerable quantity of reactance-computation charts were available for distribution to readers. So many requests were received that our supply was very quickly exhausted.

We have recently prepared a new and improved chart which has a number of advantages over the older one and we shall be glad to forward a copy to everyone who requests it.

# 230-VOLT TYPE 200-C VARIACS


FIGURE 1. TYPE 200-CUH 230-Volt Variac, unmounted

IN many applications of the Variac adjustable transformers, models for use either on 230-volt circuits or on 115-volt lines for output voltages above 135 volts are required. To meet the many requests for units smaller than the 2-kva TYPE 100 Variac, there have been developed two models similar to the TYPE 200-C for the higher voltage circuits.

These new models are mechanically identical and interchangeable with the TYPE 200-CU or TYPE 200-CM Variacs. They are intended for the following uses: on 230-volt inputs to deliver output voltages continuously adjustable from 0 to 270 volts; on 230-volt input circuits to furnish output voltages from 0 to 230 volts with slightly higher wattage ratings; on 115-volt circuits to deliver output voltages from 0 to 270 volts.

Dials reading directly in output voltage with an accuracy of ±2% for the 270-volt output are furnished with each unit.

The mounted model, TYPE 200-CMH, is regularly supplied with cord and internal connections for these voltage ratings. By means of seven terminals which are provided and which are easily accessible, the other input-output voltage combinations are possible, with either the mounted or the unmounted models.

In the table below, the reference letter corresponds to a similar letter on the "Output Voltage-Continuous Output Current" curves of Figure 2.

| *Reference Letter* | *Input 50-60 Cycles* | *Output 50-60 Cycles* |
|---|---|---|
| A | 230 volts | 0-230 volts |
| B | 230 volts | 0-270 volts |
| C | 115 volts | 0-270 volts |

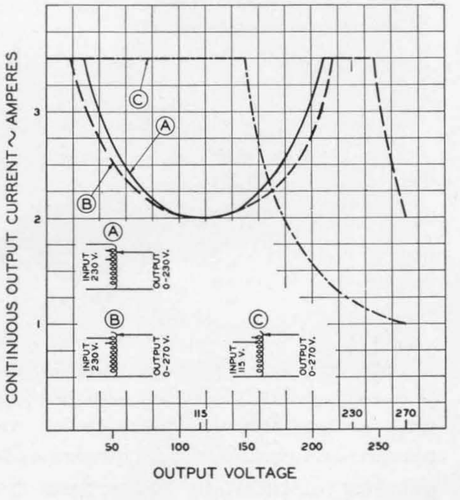



FIGURE 2. Continuous output current vs. output voltage for the three different connections of TYPE 200-CUH and TYPE 200-CMH Variacs

The current ratings shown in the curves are for *continuous* duty. Where the load is applied intermittently over comparatively short periods of time, these ratings may be exceeded materially without harm to the Variac.

TYPE 200-CMH Variac, mounted model, complete with calibrated dial, case cord and plug, switch, and convenience outlet (Code Word, BAIRN).

Net Weight: 10 pounds.

Price ........................ $21.50

TYPE 200-CUH Variac, identical with TYPE 200-CMH except intended primarily for behind panel mounting, and not supplied with case or wiring conveniences (Code Word, BAGUE).

Net Weight: 9 pounds.

Price ........................ $18.50

For detailed information concerning the construction and use of the Variac transformers, the reader is referred to the following General Radio publications, copies of which will be sent free of charge upon request: Bulletin 936 (Parts Catalog); General Radio *Experimenters:* June-July, 1933; July-August, 1934; January, 1935.

# A LARGE CAPACITANCE OIL CELL

THE TYPE 683-C Oil Cell has been designed for the measurement of the power factor and dielectric constant of oil when 1000 cc of the oil are available. This cell follows the design originated by Professor J. C. Balsbaugh[1] of the Massachusetts Institute of Technology. It is similar to the TYPE 683-A Oil Cell[2], but larger in all dimensions.

The general arrangement of its parts is shown in Figure 1, which is a photograph of the cell. The measuring electrodes are concentric polished-nickel cylinders. The inner cylinder is mounted on a central tubing of pyrex glass through nickel discs. The outer cylinder is supported on two pyrex rods fastened to two guard cylinders, which are mounted on the central tubing in the same manner as the inner

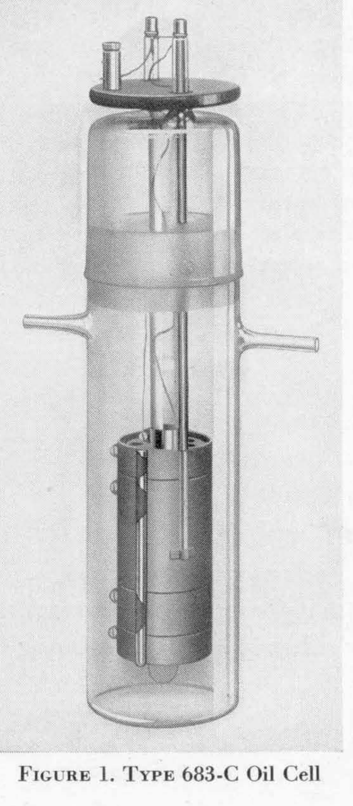


FIGURE 1. TYPE 683-C Oil Cell

[1] J. C. Balsbaugh and A. Herzenberg, "Comprehensive Theory of a Power-Factor Bridge," *Journal of the Franklin Institute*, Vol. 218, No. 1, July, 1934, pp. 49-97.

[2] R. F. Field, "Power-Factor Measurements in Oil Analysis," General Radio *Experimenter*, Vol. IX, No. 4 Sept. 1934, pp. 1-5.

cylinder. These mounting discs are punched with holes to allow circulation of the oil being measured and of the cleaning liquid used when the oil is changed.

This type of construction provides a three-terminal condenser in which there is no solid dielectric between the measuring electrodes. The direct capacitance of these electrodes has a practically zero power factor and a unity dielectric constant. An energy loss can occur only in the air between the plates and in the gas occluded on their surfaces. The latter loss is minimized by a heat treatment of the nickel tubing, in which the natural occluded gases are replaced by hydrogen.

The leads from the outer and guard cylinders are nickel wires, that from the former being shielded by nickel tubing connected to the guard. A flexible copper lead from the inner cylinder passes inside the central pyrex tubing, which is large enough to contain a thermometer for measuring the temperature of the oil.

The electrode structure is mounted in a pyrex glass container, having a ground joint and two tubulations. The cell may thus be operated in a vacuum or in an atmosphere other than air. The appearance of the mounted cell is shown in Figure 1. The over-all length is 18 inches and width across tubulations, 8 inches. The outside diameter of the glass container is 4 inches.

The direct capacitance of the measuring electrodes is 90 $\mu\mu$f with a spacing of .075 inch. The volumetric capacity of the container is 1000 cc.

This oil cell may be used only with a bridge having a Wagner ground or a suitable guard circuit. It must be placed in a metal shield which may be the container of the bath for temperature control. The liquid of this bath must be conducting or a close-fitting tin-foil jacket used so that the slight leakage over the outer glass surface may not introduce a loss in the capacitance of the measuring electrodes.

The price of the Type 683-C Oil Cell is $250.00, complete as shown in Figure 1. The price of the electrode structure alone, mounted on a 10-inch pyrex tubing and provided with 12-inch leads, is $215.00. —R. F. Field

*THE GENERAL RADIO COMPANY mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the*

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# The GENERAL RADIO EXPERIMENTER

VOL. IX. No. 12 — MAY, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS


## AN IMPROVED AUDIO OSCILLATOR

FOR a number of years the General Radio TYPE 213 Audio Oscillator has served in many laboratories as a tone source for bridge measurements and other purposes. This oscillator, which consists of a single-button microphone-driven tuning fork, has been widely used because of its simplicity, compactness, low cost, and ease of operation.

A redesign of this instrument, resulting in the TYPE 813 Audio Oscillator, has produced very definite improvements along the following lines: (1) more accurate calibration to any specified frequency value, (2) lower damping and greater frequency stability, (3) complete independence of output and fork driving circuits, (4) more reliable operation and self-starting characteristics, (5) much lower harmonic content in output, (6) fork enclosed and free from damage and dirt, (7) provision made for a small self-contained 4½-volt dry battery for intermittent operation; or, alternately, outside batteries for continuous service or greater power output, (8) a reduction of the sound in air produced by the oscillator.

These improvements have been accomplished by the use of a much more massive fork of unique design, by employing two microphones of an improved type symmetrically loading each tine, and by the use of an output filter which reduces the harmonics in the output.

The fork is cut from a rectangular bar of uniform cold rolled steel which is then cadmium plated to resist corrosion. Two rigid back microphones are mounted from the heel of the fork

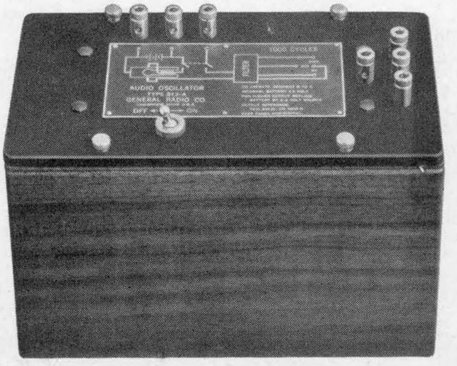



FIGURE 1. External view of 1000-cycle TYPE 813-A Oscillator

FIGURE 2. Internal view of 400-cycle oscillator, showing fork and method of mounting

and are located symmetrically on the tines at, or back of, the point where maximum flexure occurs. In this manner, the free vibration of the fork is influenced only to a very slight degree by the load of the microphones.

The fork is mounted rigidly at the heel above a small metallic base panel which carries the driving electromagnet located between the tines. The base panel is suspended internally with four resilient mountings beneath a bakelite panel, which carries the terminal posts and control switch and which serves as a cover for the walnut cabinet.

Since the output of the microphone button contains harmonics of considerable amplitude, a filter is provided to obtain good waveform. This filter attenuates the second harmonic by more than 40 decibels.

The wiring diagram (Figure 3) shows how one microphone, in series with the electromagnet and whatever battery is connected across the terminals *A* and *B*, drives the fork. The other microphone, in series with the filter and whatever battery is connected across the terminals *A* and *C*, independently supplies the electrical output of the oscillator. The switch controls both circuits simultaneously.

Output impedances of 50, 500, and 5000 ohms are provided. Four output terminals are so arranged that the Type 274-M Double Plug may be quickly attached to give any one of these three internal impedance values. The output circuit is completely isolated from the driving circuit, and there is no direct-current component in the output.

For intermittent operation with a moderate power output, an internal 4½-volt battery is connected across the terminals *A* and *B* and the terminal *C* is connected, externally, to the terminal *B*. The single battery thus energizes both the driving- and the output-microphone circuits. For greater output, or for continuous operation over extended periods, the internal battery may be replaced by an external battery of greater capacity or by some other low impedance direct-current source of 4½ volts to 8 volts, connected externally across the terminals *A* and *B*, with *C* joined to *B*.

The best frequency stability and the lowest harmonic content are obtained when the amplitude of fork vibration is small, corresponding to a driving battery voltage not greater than 4½ volts. Maximum power output consistent with these conditions is obtained with a total output battery voltage of 6 to 8 volts.

The operating characteristics of the Type 813 Oscillator are given below.

*Frequency:* The Type 813 Audio Oscillator is available in two models, 400 cycles and 1000 cycles. Other frequencies between 300 cycles and 1500 cycles can be obtained on special order.

The frequency is adjusted to within 0.5% of the specified value. The temperature coefficient is −0.007% per degree Fahrenheit and the change in frequency with driving voltage is less than 0.01% per volt. The frequency is entirely independent of load impedance.

*Waveform:* The total harmonic content of the output into a matched resistive load is less than 0.5% with

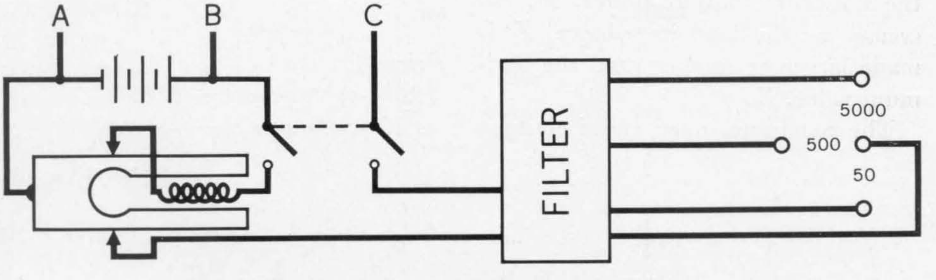



Figure 3. Circuit diagram of Type 813-A Oscillator

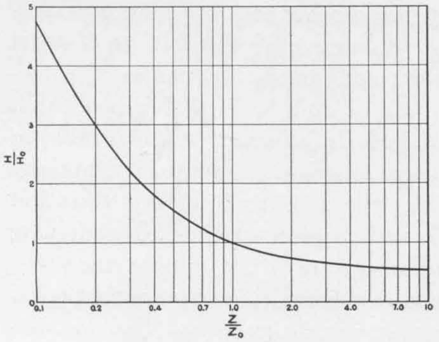
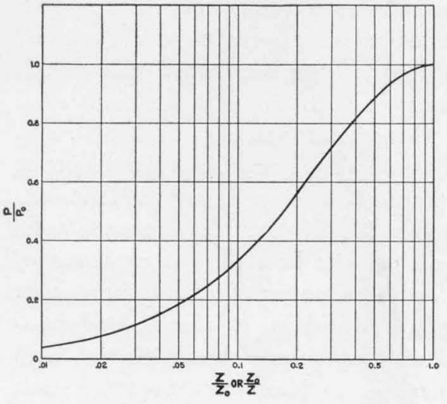



FIGURE 4 (left). Variation in harmonic content of output voltage as a function of the ratio of the load impedance, $Z$, to the matched load impedance $Z_0$. Note that the harmonic content is extremely small for high impedance loads. This makes it possible to work the oscillator into the grid circuit of a vacuum-tube amplifier to obtain higher power output with good waveform

FIGURE 5 (right). Ratio of power output, $P$, to the maximum power output, $P_0$, as a function of output impedance. The horizontal scale may be read as $\frac{Z}{Z_0}$ or $\frac{Z_0}{Z}$, depending upon whether the load impedance is larger or smaller than the matched value, $Z_0$




4½-volt drive and less than 0.8% with 6-volt drive. Figure 4 shows how the ratio of total harmonic content, $H$, to the harmonic content, $H_0$, with a matched load, varies with the ratio of load impedance, $Z$, to matched load impedance, $Z_0$.

*Output:* The output to a matched load impedance is 20 to 30 milliwatts with 6-volt drive and 10 to 15 milliwatts with 4½-volt drive. Figure 5 shows how the ratio of output power, $P$, to the maximum output power, $P_0$, decreases as the load impedance, $Z$, is made larger or smaller than the optimum value, $Z_0$.

The maximum open circuit output voltage is 20 to 24 volts with 6-volt drive and 14 to 17 volts with 4½-volt drive.

*Input Power:* The driving microphone draws about 25 milliamperes at 4½ volts and 30 milliamperes at 6 volts. The output microphone draws about 60 milliamperes at 4½ volts and 80 milliamperes at 6 volts. These values are subject to considerable variation.

*Dimensions:* Both models, (length) 9 x (width) 5 x (height) 6 inches, overall.

*Price:*

1000-cycle model — $34.00
400-cycle model — 36.00

— H. W. LAMSON

# THE ANALYSIS OF COMPLEX SOUNDS OF CONSTANT PITCH

One of the many uses of the Type 636-A Wave Analyzer is in the frequency analysis of sounds which have a constant pitch. The selectivity and ease of operation of the analyzer make it particularly useful for applications of this sort.

An excellent example of this type of problem is the analysis of the tone produced by an automobile horn. Necessary equipment consists of a suitable microphone, an audio-frequency amplifier, and the wave analyzer, and should be arranged as shown in Figure 1. The microphone should have a reasonably good response over the range up to 10,000 cycles. In the analysis described here, a low-priced piezo-electric microphone was used. The amplifier is used to obtain a voltage of sufficient magnitude to operate the wave analyzer and should, of course, have a flat response over the frequency range in which measurements are to be made.

Three different automobile horns were analyzed with this equipment and the results are shown in Figures 2, 3, and 4. The scale of ordinates, *Sound Pressure in Percentage of Fundamental*, is proportional to the wave analyzer readings, since all elements in the system have essentially flat frequency response curves.

The horn in Figure 2 is a type used on low-priced automobiles and has a loud, piercing tone. An examination of its spectrum shows a resonance in the region of the tenth harmonic, which is nearly thirty times as strong as the fundamental. This accounts for the peculiar tone quality of this type of horn. The horns shown in Figures 3 and 4 are a pair which are intended to be sounded at the same time. Each has a rather pleasant tone, not greatly different from that of some musical instruments. The output of each horn contains harmonics of approximately equal amplitudes over a wide frequency range with no pronounced resonances.

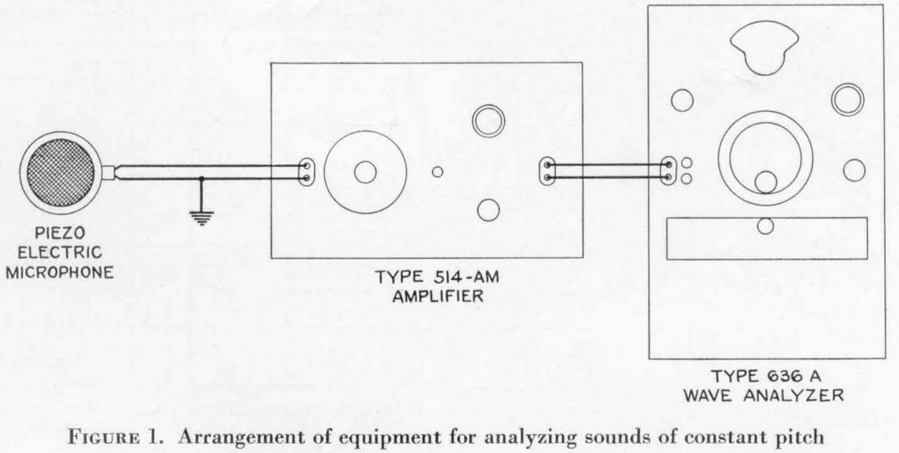



Figure 1. Arrangement of equipment for analyzing sounds of constant pitch

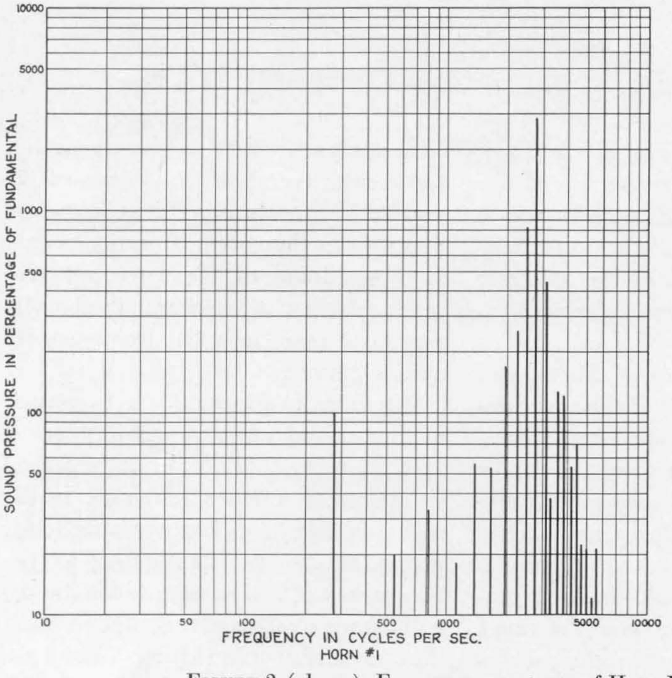
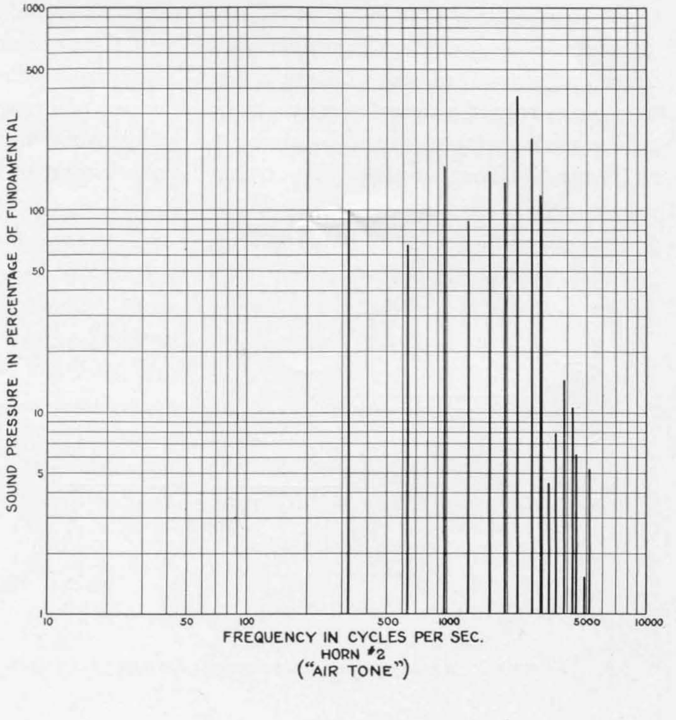



FIGURE 2 (above). Frequency spectrum of Horn No. 1
FIGURE 3 (below). Frequency spectrum of Horn No. 2



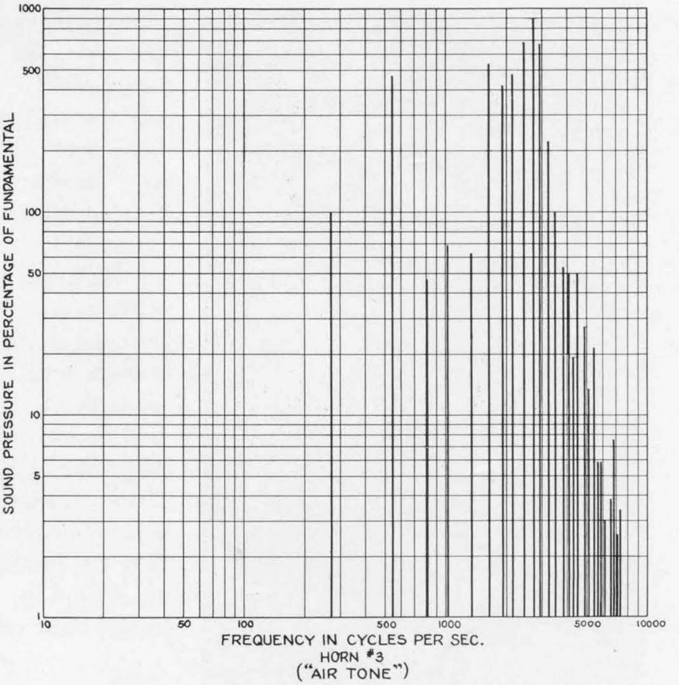



FIGURE 4. Frequency spectrum of Horn No. 3

A visual indication of the waveform, made by means of a cathode-ray oscillograph and sweep circuit, is often useful in interpreting the frequency analysis. A permanent record can be made by photographing the oscillograph pattern with a still-picture camera. The necessary equipment is shown in Figure 5 and consists of the piezo-electric microphone, an amplifier, a cathode-ray oscillograph with linear sweep circuit, and a hand camera.

To obtain sufficient deflecting voltage for the oscillograph, an amplifier with a high voltage output, such as the new General Radio TYPE 714-A Amplifier, is needed. The oscillograph (TYPE 687-A) has a self-contained sweep circuit and power supply. For making the photographs of Figure 6, a camera having an f/4.5 lens was used with Verichrome film. The exposure was 0.2 second.

The three oscillograms of Figure 6

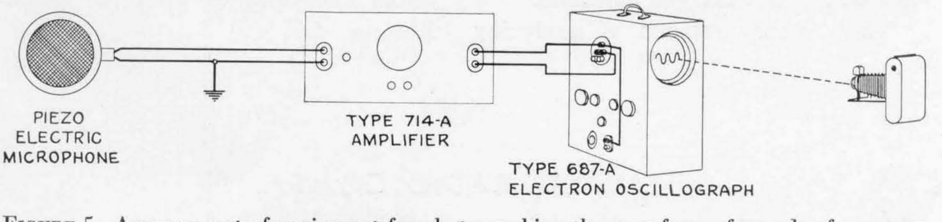



FIGURE 5. Arrangement of equipment for photographing the waveform of sounds of constant pitch

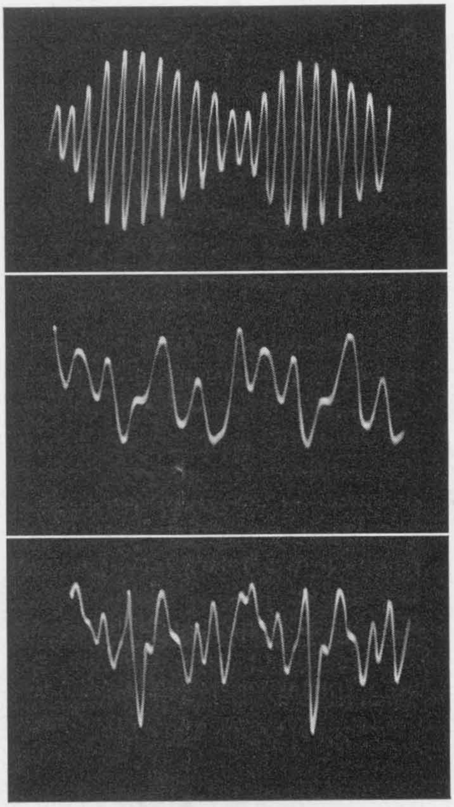


FIGURE 6. Oscillograms showing waveform of horns (top) No. 1, (center) No. 2, (bottom) No. 3

are, respectively, the waveforms of the horns of Figures 2, 3, and 4. In each oscillogram the sweeping frequency was equal to one-half the horn fundamental frequency. Note that Figure 6 shows that the fundamental of the horn of Figure 2 appears as a modulation of the tenth harmonic.

These same methods of analyzing and photographing sounds of constant pitch can, of course, be applied to a large number of problems. The noises of internal combustion engines, mufflers, and various types of electrical and mechanical equipment can be treated in the same manner as the horn tones. A harmonic analysis of a sound of this type will readily show up the frequencies at which resonant phenomena are taking place. In the case of a horn tone, proper treatment of the acoustic systems producing resonances will improve the quality of the sound. In other applications where it is desired to reduce the intensity or disagreeableness of a sound, as in a muffler, for instance, the resonances may be shifted, by proper design, to points where their effect is less noticeable.

— H. H. SCOTT

The General Radio equipment mentioned in the foregoing article is all standard catalog apparatus. The prices are as follows:

| | |
|---|---|
| TYPE 636-A Wave Analyzer | $490.00 |
| TYPE 514-AM Amplifier | 85.00 |
| TYPE 714-A Amplifier | 190.00 |
| TYPE 687-A Electron Oscillograph | 184.00 |

The microphone used for this particular work was an Astatic Type D104, which lists at $22.50. This microphone can be obtained from the General Radio Company or from the manufacturer.

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

## INTRODUCTION

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

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

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

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

With this background in the older

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

## DEVELOPMENT OF RECEIVER TESTING EQUIPMENT

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

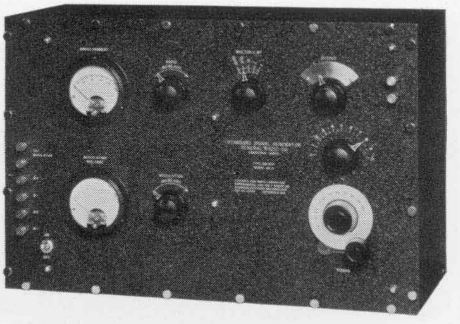
At this period tests of complete receivers were usually purely qualitative. The individual components were checked and circuits were matched carefully for tracking, but the completed receiver as a general rule received only a listening test.

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

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

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

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



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

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

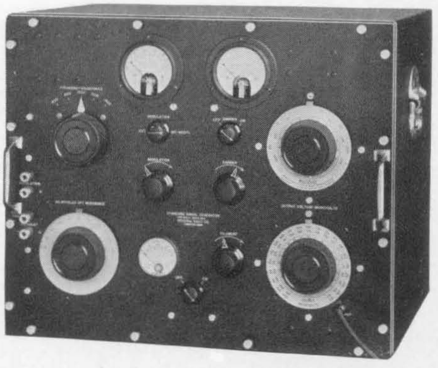
The TYPE 403-A Standard-Signal Generator was described in THE GENERAL RADIO EXPERIMENTER in November, 1928. This instrument, designed by Dr. Lewis Hull, was, we believe, the first standard-signal generator to be commercially available, and it opened up an entirely new field of receiver measurements.

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

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

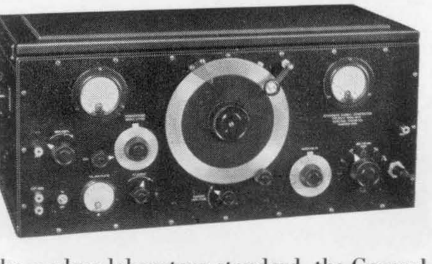
All of these factors led to the abandonment of the TYPE 403-A design and the introduction of the TYPE 603 Signal Generator early in 1932. Announcement of the new instrument was carried in the May, 1932, issue of THE GENERAL RADIO EXPERIMENTER. The fundamental elements of the earlier signal generator were repeated with many refinements in design. In the attenuator especially an entirely new type of mechanical design was followed.

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



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

During this period a development of the ultra high-frequency bands similar to that earlier taking place in the broadcast bands was in progress. As development of these bands settled down to a commercial basis, a means of evaluating receiver performance in them was demanded. This was met in February, 1933, with the announcement of the TYPE 604-A Test-Signal Generator. This instrument did not replace the TYPE 603, but merely supplemented it by covering frequency bands where the 603 could not possibly be used. It was recognized that performance measurements at ultra-high frequencies could not have a high precision at the present state of the art, and a rather simple and inexpensive type of instrument was, therefore, developed. The familiar design pattern of modulated oscillator and attenuator was, however, again fol-



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

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

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

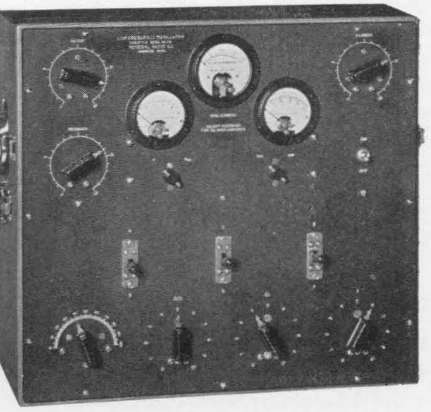
Measurement methods for tests of receiver fidelity have been gradually developed until a very complete evaluation of the frequency response and harmonic distortion of the entire receiver or of component parts can be made. One of the earliest fidelity testing instruments was the TYPE 355

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

Transformer Test Set which was designed for the measurement of individual audio transformers.

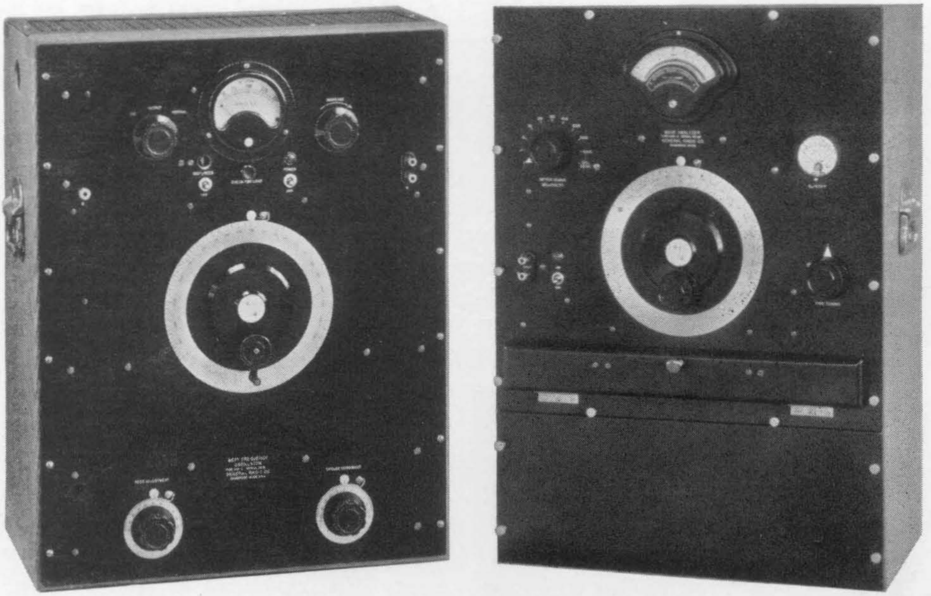
The development of vacuum-tube oscillators for audio frequencies was largely an outgrowth of the demand for better fidelity reproduction. Audio-frequency vacuum-tube oscillators are such a laboratory commonplace that it is easy to forget that as recently as ten years ago they were a comparative rarity.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

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



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

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



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

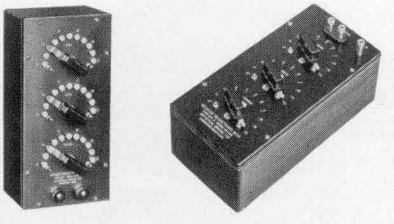
# ALTERNATING-CURRENT BRIDGES

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

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

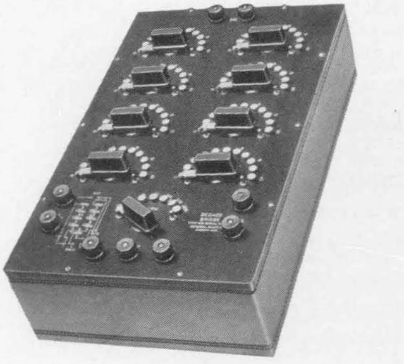
Marked emphasis is lent to the contrast between this conception and the then current view by the practice of a leading English manufacturer of laboratory equipment. As a deliberate policy, parts and instruments were made non-standard, screws were seperately cut on a screw-machine with differing threads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

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

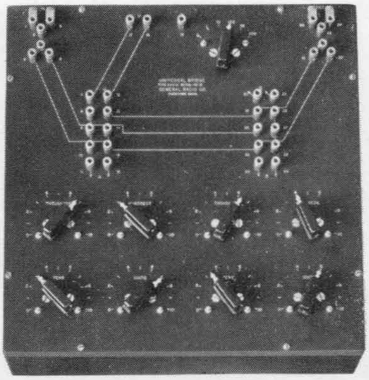


Even decade-resistance boxes improve. The latest TYPE 602 *right* is completely shielded, has better switches, contacts, terminals, wiring, and card construction than the older TYPE 102 *left*

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



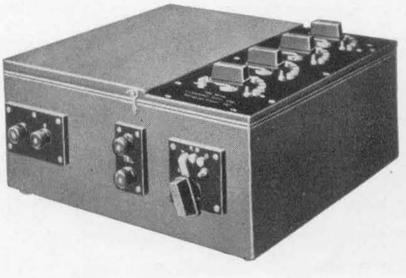
The TYPE 193 Decade Bridge, an intermediate stage in the extension of the decade bridge to alternating-current measurements

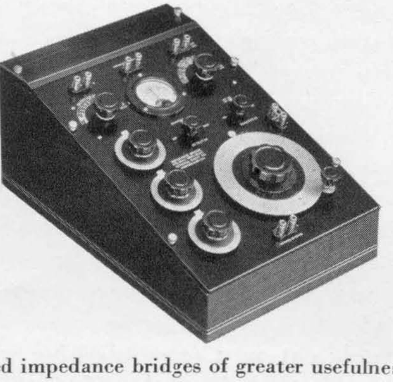


The TYPE 293 Universal Bridge has a greater flexibility of arrangement of the arms and the enclosed-contact construction

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

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

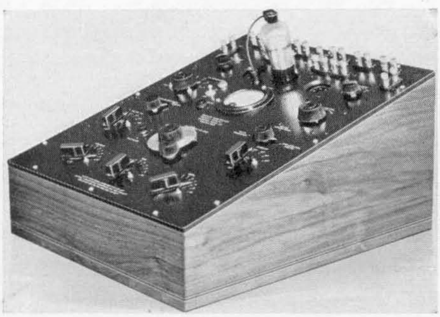




The refinement of decade bridges leads to specialized impedance bridges of greater usefulness in smaller fields, such as the TYPE 216 Capacity Bridge *left*, and the TYPE 650-A Impedance Bridge *right*

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

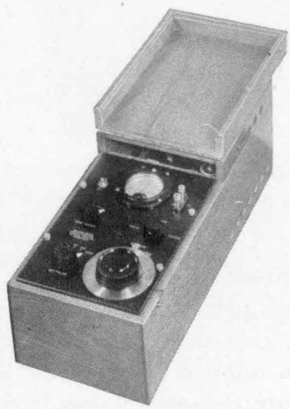
The measurement of vacuum-tube constants necessitated the development of another group of highly specialized bridges. The early TYPE 361 was made obsolete by the rapid developments of multi-element tubes



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

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

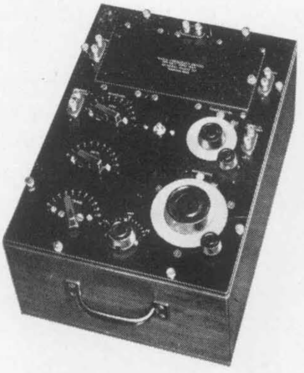
While rapid and continuous progress was made in the development of bridges for all types of 1000-cycle measurements, commercial apparatus for bridge measurements at radio fre-



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

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

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

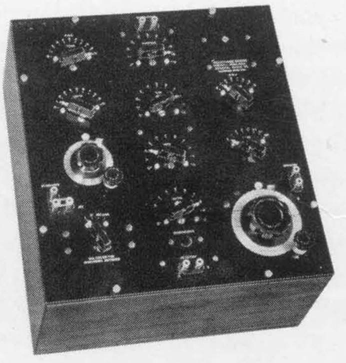


The TYPE 516-C Radio-Frequency Bridge measures impedances directly at frequencies up to 5 megacycles

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

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

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



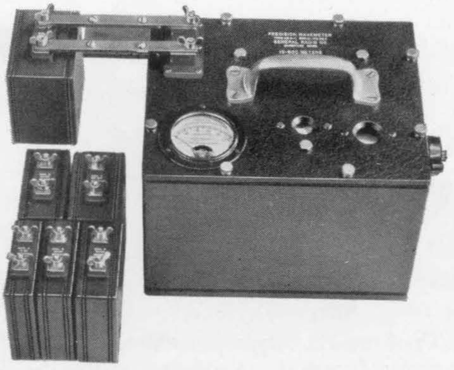
The latest development in measuring small inductances, the TYPE 667-A Inductance Bridge, June, 1935

## FREQUENCY MEASURING INSTRUMENTS

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

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

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



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

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

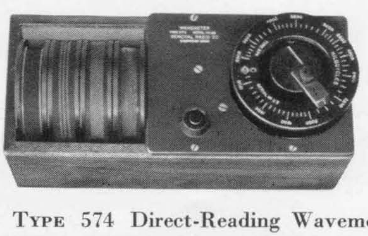
The TYPE 224 Wavemeter was one of the first commercial models (about 1920) incorporating the features of precision variable condenser construction and worm drive. The worm-drive condenser had a scale of 2500 readable divisions, an increase of ten times, or more, over contemporary models.

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

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

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

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



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

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

The first commercial piezo-electric

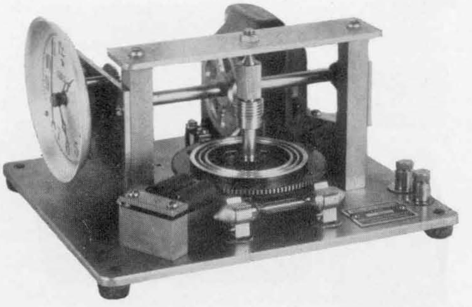
oscillator appeared in 1924, known as the TYPE 275. This instrument served as either a laboratory standard or as a frequency monitor. In the latter capacity it gave satisfactory performance down through the days of the 500-cycle tolerance in broadcasting. In this early work General Radio Company furnished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

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

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

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

Early experimental determinations of frequency in terms of time forecast



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

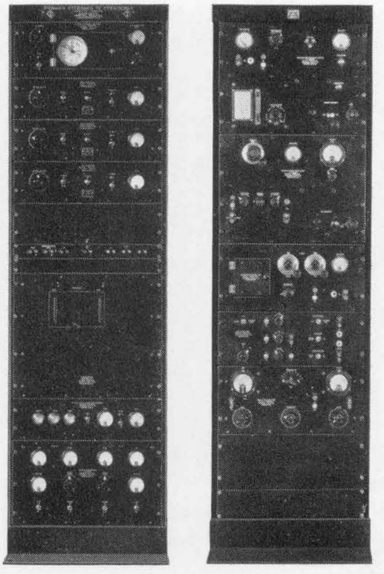
the development of the primary standard of frequency. In 1859 Fedderson used a rotating mirror to photograph a spark discharge and prove the oscillatory character of the discharge. By timing the rotation of the mirror, in terms of a tuning fork, Pierce was able to obtain a measure of the frequency of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

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

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

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

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



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

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

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

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

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

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

# ELECTRICAL MEASUREMENTS IN THE RADIO BROADCASTING STATION

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

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

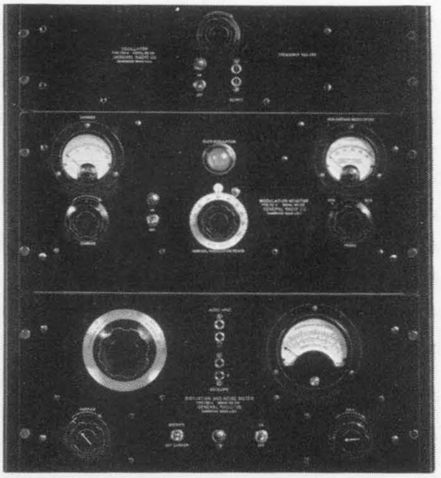
The two major assets of a radio broadcasting station are its operating license, which is granted by governmental authority, and its coverage, that is, the number of listeners which it can reach. To retain the former and to increase the latter are the two factors which mean the most, economically, to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

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

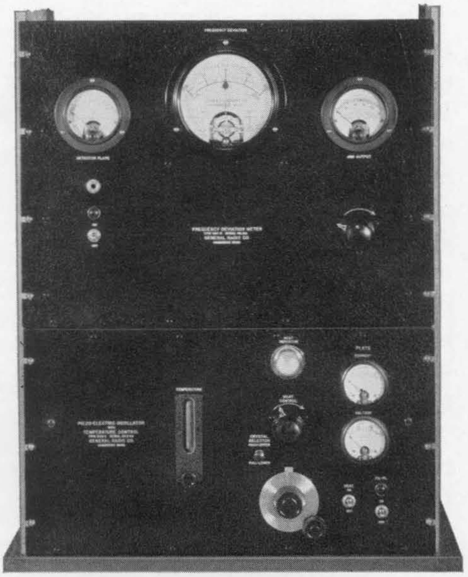
One of the primary rules prescribed by the Federal Communications Commission deals with the maintenance of the operating frequency of the transmitter within certain specified limits. These regulations have been responsible for the development of the present technique of frequency monitoring in broadcasting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

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

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



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



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

is required, to prevent heterodyne interference.

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

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

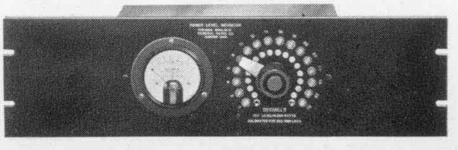
The Type 457 Modulation Meter gives laboratory measurement of percentage modulation on positive or negative peaks

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

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

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

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



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

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

## WHO'S WHO

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

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

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

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

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

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

The officers remain unchanged.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

GENERAL RADIO COMPANY

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The GENERAL RADIO EXPERIMENTER

VOL. X No. 2 JULY, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

## WIDE-RANGE TRANSFORMERS

BASED on original designs of the engineers of Wired Radio, Inc.,* the General Radio Company has developed a new line of transformers characterized by their extremely wide frequency range.

The characteristics of these three transformers are shown in Figure 1, Figure 2, and Figure 3. The TYPE 741-G Line-to-Grid Transformer has a flat frequency response within 2 decibels from 35 to 225,000 cycles. It will be noted from an examination of the curve that the characteristic does not deviate from a linear response anywhere below 200,000 cycles except for gradual falling off of the low frequency response below 100 cycles.

The TYPE 741-J Interstage Transformer is flat within 2 decibels from 70 to slightly over 200,000 cycles. This curve was taken with the transformer operating from the plates of 56-type tubes operating in push-pull and into the grids of the tubes in the following stage connected in push-pull. The same characteristic would be obtained when operating from tubes or any other balanced impedance of the order of 10,000 ohms. When operating from lower impedances than this, the low frequency characteristic is improved correspondingly. As might be expected, a uniform wide frequency response with these transformers is most difficult of achievement when the impedances between which they work are highest.

The TYPE 741-P Tube-to-Line Transformer has a flat frequency response from less than 20 cycles to about 200,000 cycles. The input circuit in this case is a pair of 56-type tubes in push-pull, and the terminating impedance 500 ohms, resistive.

Many uses for such transformers are immediately suggested. With the cathode-ray tube available as an accurate oscillograph, voltmeter, or

* Mr. R. D. Duncan, Chief Engineer, Mr. H. R. Butler, Engineer, Wired Radio, Inc., Ampere, New Jersey. Patent No. 1,983,657; December 11, 1934.

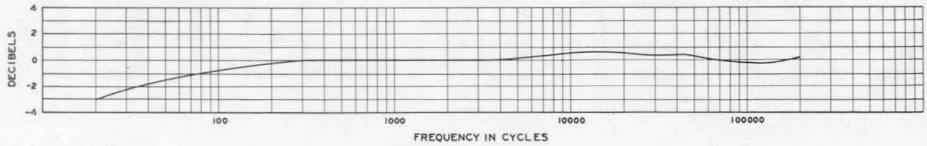



FIGURE 1. Frequency characteristic TYPE 741–G Line-to-Grid Transformer. Voltage step-up ratio 1 : 6.4

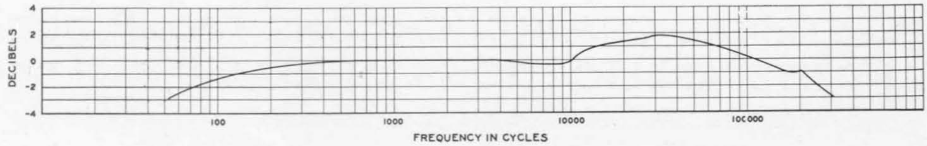



FIGURE 2. Frequency characteristic TYPE 741–J Interstage Transformer. Voltage ratio 1 : 1

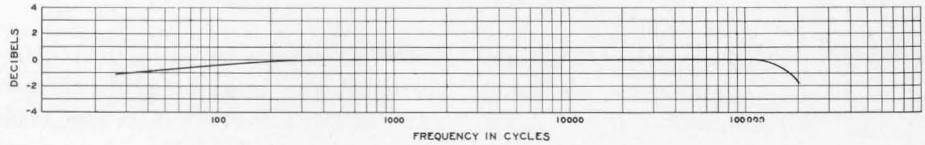



FIGURE 3. Frequency characteristic TYPE 741–P Plate-to-Line Transformer. Voltage step-down ratio 6.35 : 1

ammeter for the high-frequency ranges, the investigation of superaudible or low radio-frequency phenomena is greatly facilitated by the use of these transformers in amplifiers for the operation of cathode-ray tubes.

These transformers faithfully reproduce without attenuation all the frequencies of a wide frequency spectrum. With more and more interest constantly developing in high-quality sound reproduction, these transformers fill an important need in wide-range audio systems.

In experimental television applications, an acceptable picture can be transmitted over a 200,000-cycle band width. This band is frequently adequate for fair pictures and particularly for experimental investigation. Many other applications will suggest themselves to engineers and experimenters carrying on investigations which require the amplification of a wide band of frequencies including the audio spectrum.

A high-permeability nickel-iron alloy is used for the core material. Similar alloys have been considerably used for core material where their high permeability is helpful in obtaining wide frequency-response transformers. It, however, has one characteristic which makes it necessary to handle it carefully in the usual vacuum-tube circuits — that is, that magnetic saturation of the core occurs at very low values of ampere-turns. One of the important reasons

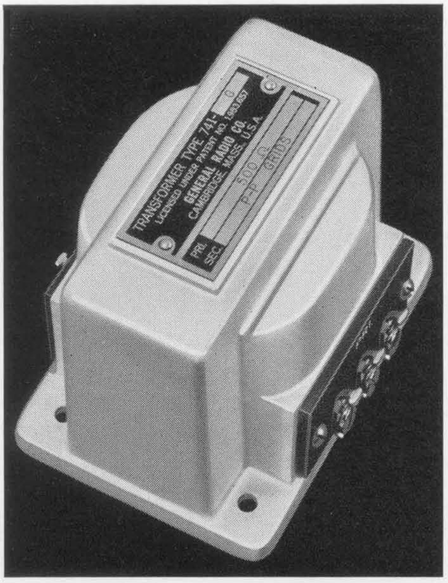



Figure 4. Type 741-G Transformer. The same size cast-aluminum case is used for all three models

why these wide-range transformers must be used in push-pull circuits is to cancel any direct current flowing in the plate circuits of tubes from which the transformers are operated. A current unbalance between tubes of 1 or 2 milliamperes will not affect the magnetic characteristics, but it is essential that the unbalance plate current does not exceed this value.

The principal feature of these new transformers and that which requires much attention in their design is the structure of the coil and the core so that leakage reactance and distributed capacitance are reduced to the lowest possible values. The question of the electrical balance between the various sections of the winding is important, and that is a second reason why it is necessary, in order to obtain the best possible frequency characteristic, that the transformers be worked in balanced or push-pull circuits.

As described above, three standard models are now available:

(1) Type 741-G, 500-600-ohm line to push-pull grids

(2) Type 741-J, interstage push-pull plates to push-pull grids

(3) Type 741-P, push-pull plates to 500-600-ohm line.

One of the completed transformers is illustrated in Figure 4. All models are housed in cast-aluminum cases. The cases provide excellent shielding for frequencies above 1000 cycles and are particularly useful in reducing inductive feed-back which may cause "singing." The cases are also excellent shields against other high-frequency disturbances such as the usual laboratory noises caused by circuit breakers, switches, etc., all of which are bothersome, particularly when a wide frequency range is being used. Cast iron is a somewhat more effective shield at 40-180 cycles than is aluminum. Such cases can be provided on special order, but generally it has been found that power-line hum interference is less serious than that produced by other sources.

—Arthur E. Thiessen

| *Type* | *Code Word* | *Use* | *Net Weight* | *Price* |
|---|---|---|---|---|
| 741-G | WIDTRANANT | L to G | 2½ pounds | $22.50 |
| 741-J | WIDTRANBOY | Interstage | 2½ pounds | 22.50 |
| 741-P | WIDTRANCAT | P to L | 2½ pounds | 22.50 |

# BEAT-FREQUENCY OSCILLATORS

**Among the new instruments recently announced is a beat-frequency oscillator (TYPE 713) which replaces the TYPE 513. The development of new types of tubes has made possible an oscillator of improved characteristics. The outstanding characteristic of the new oscillator is its power output, two watts, combined with excellent waveform. The power, adequate for all usual laboratory needs without amplification, has, we believe, never before been available in a laboratory oscillator.**

**The design of an oscillator of this beat-frequency type always presents many problems. In the following article Mr. Arguimbau, the designer, describes some of the interesting features of the new instrument.**

THE general characteristics of beat-frequency oscillators are well known. The outputs of two oscillators of high frequency are mixed in a modulator, and the difference frequency, after being filtered, is amplified and used as a source of alternating current. The system has two important advantages: the difference frequency can be controlled over a wide range by a single control without the use of large inductors and condensers and the output is approximately constant as the frequency is varied. On the other hand, certain drawbacks of such a system will appear upon examination. Among the troublesome factors which have contributed to make the beat-frequency oscillator one of the most difficult of design problems are: distortion introduced by the detectors, the presence of miscellaneous high-frequency products in the output, and the difficulty of getting a 10-cycle output when a change of 0.1% in the oscillator frequency makes a change of 200 cycles in the output.

As has been pointed out, the frequency stability of both oscillators is of primary importance in the design, since the output frequency is necessarily far less stable than that of the component oscillators, and yet stability of the output frequency is an essential characteristic of the instrument.

One of the chief difficulties which have been experienced in making stable oscillators has been the flow of grid current in the oscillator circuit. While circuits can be made stable where grid current is present by properly arranging the tuned circuit, the use of a pentode circuit which is entirely free from grid current has so simplified the problem that frequency stability becomes purely a question of the mechanical permanence of the circuit as influenced by temperature and aging.

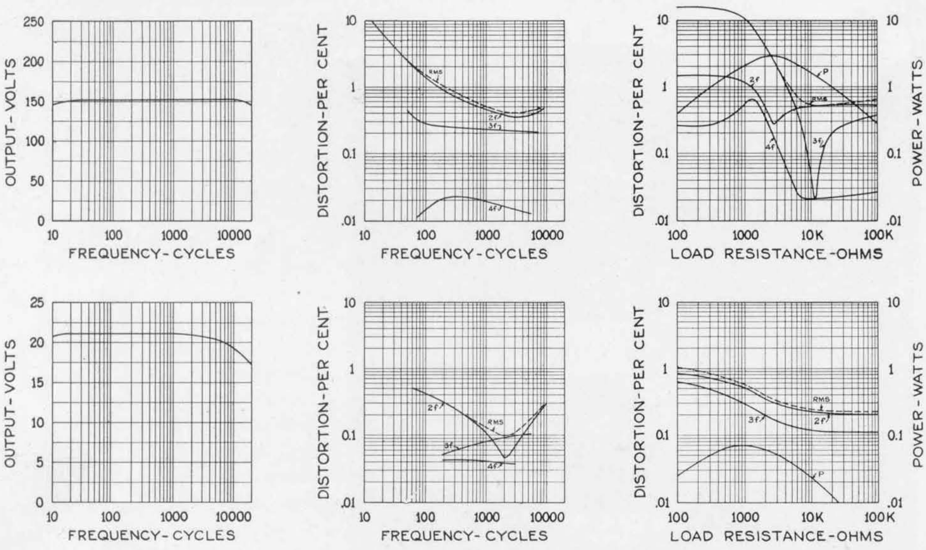
To reduce temperature variation, the two tuned circuits have been symmetrically placed and mounted on a heavy aluminum slab which is thermally insulated from all heated portions of the circuit, including the oscillator tubes themselves, reducing the temperature variations

The TYPE 713-A Beat-Frequency Oscillator. A new a-c operated oscillator with undistorted output of 2 watts. The frequency range is 10 cycles to 16,000 cycles.

due to heating within the oscillator to a somewhat lower order than normal room temperature fluctuations.

In addition to having a stable frequency, the oscillator should be of good waveform. Two superimposed waves of nearly equal frequency can be thought of as the vector sum of two signals differing in phase at the angular velocity of the difference frequency. The envelope generated by this is similar to the result of a connecting rod motion and contains a large second harmonic.

The use of a balanced push-pull detector circuit eliminates this second harmonic, and from this point on the problem is a routine matter of amplifier, filter, and transformer design. The filter and transformer arrangement has been made of substantially uniform gain from 10 cycles to 20,000 cycles. It was found impossible to pass the full 10-cycle output of two watts through any transformer of practical size without serious distortion. Partly for this reason a switch has been provided so that the input to the detector can be reduced and with it the level throughout the instrument. At the reduced output level, the distortion remains at less than 1% down to 10 cycles. While no measuring arrangements were available for accurate tests, the waveform as viewed on a




Performance characteristic of a typical TYPE 713-A Beat-Frequency Oscillator. The upper set of curves represents normal output conditions; the lower group conditions at 1/10 normal output. A considerable improvement of waveform at low frequencies will be noted under the latter conditions

cathode-ray oscillograph when beating against another oscillator appears sinusoidal at 2 cycles.

The push-pull detector circuit has the additional advantage of decreasing the coupling between the two oscillator circuits. The currents from the parallel branch divide equally through the coils of the grid-to-grid (variable) oscillator so that the resultant coupling is balanced to zero. The buffer stage in the parallel branch has been added to isolate the detector plate current of the fixed oscillator frequency (along with its second harmonic) which flows in this branch from the output. The detector balance along with the reduced coupling on the low output range makes interaction between the oscillators very small.

The power frequency components have been kept to about 1% on the low output range, to 0.1% on the high range. Most of this hum is introduced by the filaments of the last stage and the amplitude control must, therefore, be at the output of the final high-level stage. Otherwise, amplitude would be decreased without decrease in hum, *i.e.*, with increase in hum percentage. Realizing this situation, it was felt that for a general-purpose instrument it would be best to use a grounded output circuit. For most measuring purposes such a circuit is much less likely to cause trouble than a balanced circuit. In case the instrument is to be used in a carefully balanced circuit, a transformer is ordinarily necessary.

Many psychological laboratories have used an "incremental pitch" condenser* in conjunction with the

* A. E. Thiessen, April-May, 1933, General Radio *Experimenter*, Vol. VII, Nos. 11 and 12.

TYPE 613-B d-c operated beat oscillator for tone tests. This type of condenser with direct-reading scale of ±50 cycles has been included on the TYPE 713-A Oscillator. This dial permits resonance curves to be taken as well as permitting the auditory tests. Additional use has been made of this dial by engraving a line at least every 100 cycles on the main scale, thereby effectively providing a calibration point *for every cycle throughout the scale.* This does not mean that the oscillator should be used as a frequency standard, but the added feature should prove useful if it is desired to duplicate settings accurately.

— L. B. ARGUIMBAU

The TYPE 713-A Oscillator is licensed under patents of the American Telephone and Telegraph Company

## NETWORKS AT REDUCED PRICES

THE following attenuation networks (one each) are available at a large price reduction. They have been used for demonstration and display but are in perfect condition.

| *Type* | *Range* | *Impedance* | *Section* |
|---|---|---|---|
| **329-K** | 55 db steps of 0.5 | 6000 ohms | H |
| **329-N** | 22 db steps of 0.2 | 600 ohms | Bal. H |
| **329-R** | 22 db steps of 0.2 | 6000 ohms | H |
| **329-P** | 22 db steps of 0.2 | 6000 ohms | Bal. H |
| **429-R** | 22 db steps of 0.2 | 6000 ohms | T |

Price—all types **$50.00**

## VOLUME CONTROLS

A FEW of the TYPE 552 Master Gain Controls (discontinued) are still available (former price $28.00). All are L sections. Range 30 db in 1.5-db steps.

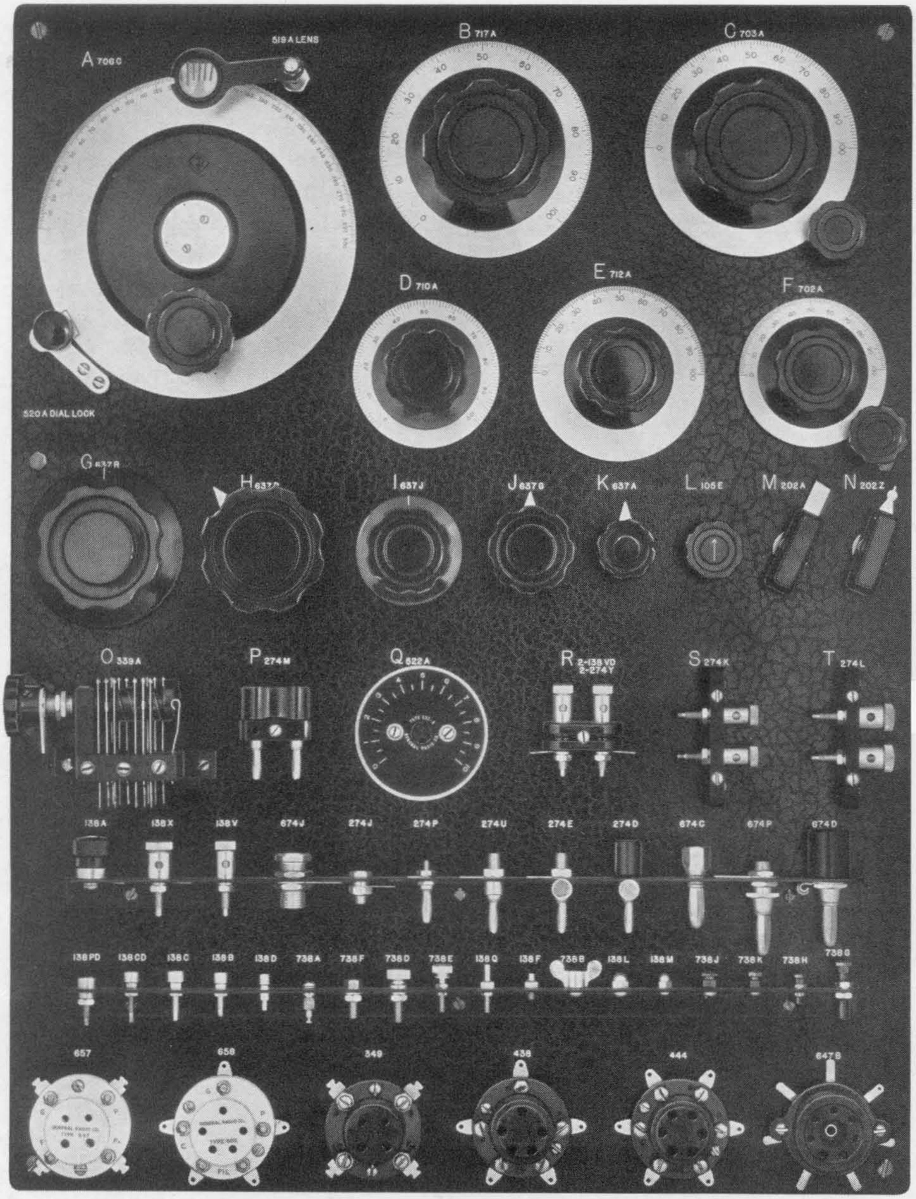
| *Type* | *Impedance* |
|---|---|
| **552-LA** | 50 ohms |
| **552-LB** | 200 ohms |
| **552-LC** | 500 ohms |

Price—all types **$10.00**

## ERRATA NOTICE
## TYPE 200-CUH VARIAC

WE regret that the curves showing the ratings for the TYPES 200-CUH Variacs shown in the April *Experimenter* were in error, showing a considerably higher rating at the ends of the winding than can be relied upon in practice.

The flat portions of Curves A and B should be at 2.5 amperes instead of 3.5 amperes as shown, and the flat portion of Curve C should be 2.0 amperes between 0 and 150 volts instead of 3.5 amperes as shown.




PARTS AND ACCESSORIES — A full-size reproduction of the parts and accessories panel illustrated above, approximately 19½ x 28 inches in size, is available for free distribution to engineers and draftsmen interested in securing a copy. Since all of the parts appear in full scale, this condensed parts catalog is of considerable assistance to persons having to design equipment. To secure a reproduction of the parts and accessories panel, readers of the *Experimenter* should ask for a copy of Form 339-B

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

# The GENERAL RADIO EXPERIMENTER

VOL. X No. 3 AUGUST, 1935

TWENTY YEARS OF GENERAL RADIO COMPANY 1915 1935 ELECTRICAL APPARATUS MANUFACTURE

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS


## In This Issue



## A NEW STROBOSCOPE FOR SPEED MEASUREMENTS

THE ability of the stroboscope* to slow down or stop motion has found many applications in industry, and one of these, the measurement of speed, has justified the design of a small unit especially adapted to it. Speed is measured with the stroboscope by adjusting the flash rate until the rotating object appears stationary, and reading the flash rate off a scale which may be calibrated directly in r.p.m.

Of the common industrial processes none is more dependent on accurate speed maintenance than the spinning operations in all kinds of textiles. Uniformity and high quality in the finished product depend directly on the maintenance of uniform spindle speed. Policing of spindles has not been convenient, owing to the difficulty of making contact to the end of the shafts, and to the large number of spindles involved. With the small stroboscope (strobotac) the problem disappears. The first spindle on a row is set at the proper speed, and the operative walks down the frame, leaving the strobotac speed setting unchanged. As the spot light strikes each spindle in turn it will appear to revolve slowly either forward or backward. Belts are quickly adjusted to make the spindle appear stationary, and the operative moves on. In this manner constant speed checks can be maintained on a large number of spindles by a single operative.

Stroboscopic methods for the measurement of speed of reciprocating or

*General Radio *Experimenter*, December, 1932.

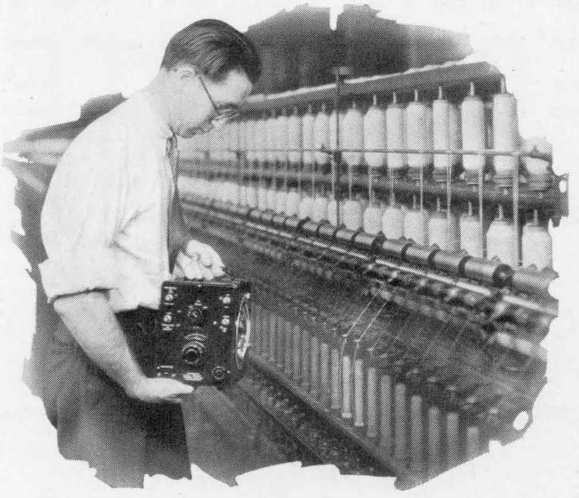


FIGURE 1
Spindle speed is quickly checked with the strobotac. When it is set for the right speed properly adjusted spindles will appear stationary

rotating machinery have numerous important advantages. Since no mechanical contact is required with the mechanism being studied and no power whatsoever is absorbed from that mechanism, the making of the measurement does not in any way alter the performance of the machine. This is frequently of great importance. For instance, in many types of machinery it is difficult or impossible to attach a mechanical or dynamometer tachometer to the moving shaft. In fact, it is frequently impossible even to approach the moving parts within several feet and, of course, ordinary tachometers cannot be used at all with reciprocating parts. Furthermore, in the case of many small and delicate mechanisms, any of the ordinary types of tachometer may cause a reduction in speed or may actually stall the equipment.

For such applications, a stroboscopic tachometer is invaluable. It requires no contact with the moving parts of the machine and may, in fact, be held some distance away. The General Radio Company is now announcing an instrument designed primarily for this type of work. The TYPE 631-A Strobotac is small and light and all parts are contained in a single case, including the lamp, triggering oscillator, etc. The strobotac is provided with a direct-reading, illuminated, revolutions-per-minute scale and provision is also made for control at the line frequency or by an external contactor, so that the instrument may also be used for the same purposes as other stroboscopes.

The TYPE 631-A Strobotac has a flashing range extending from 600 flashes per minute to over 12,000. The calibration is adjusted by means of a vibrating reed which is controlled by the alternating line voltage. Setting of the trimmer adjustments so that the reed appears to stand still when the strobotac dial is set at 900 and 3600 adjusts the whole calibration so that the unit is then direct reading. This check is easily and quickly made and compensates for drifts in line voltage, aging of tubes, and other factors which might otherwise impair the calibration.


FIGURE 2. TYPE 631-A Strobotac

The strobotac may also be used to obtain highly accurate measurements of the slip of induction motors. For this purpose, the strobotac is controlled by the power-line frequency and the slip of the motor may be counted directly. A similar method can be used to observe hunting and transients in synchronous motors.

While the intensity of illumination available is, of course, much less than is obtained from the TYPE 548-A Stroboscope, sufficient light is obtained for the stroboscopic observation of small mechanisms. The light is concentrated on the object being studied by means of a parabolic reflector. Among the many things which can be observed are such phenomena as vibration in valve springs, failure of a roller to follow a cam, etc.

The strobotac is illustrated in Figure 1. When it is held before the operative so that the reflector points forward, all controls are on the right side of the instrument, which results in maximum convenience of operation. The instrument is equipped with a handle and provision is made for fastening a tripod socket to the bottom.

The strobotac may be triggered off in three different manners. In the first place, it can be controlled by the knob on the panel which reads directly in r.p.m. and which is used for speed measurements. In the second place, the equipment can be controlled by an external contactor to provide absolute synchronism with the observed mechanism. This method of control also adapts the stroboscope for the adjustment of clocks, etc. The instrument may also be controlled by the power-line frequency. The various methods of control are made immediately available by merely snapping the toggle switches on the panel of the instrument. Only a source of 115-volt, 60-cycle alternating current is required to operate the strobotac.

— H. H. SCOTT

The TYPE 631-A Strobotac is a joint development of Harold S. Wilkins, of the Engineering Department of the General Radio Company, and Dr. Harold E. Edgerton and Kenneth Germeshausen of the Massachusetts Institute of Technology.

The price of the strobotac is $92.50 net, including tubes.

## CATALOG DATA

**Speed Range:** 600—4000 r.p.m.
2400—16,000 r.p.m.
**Accuracy:** ±2%.
**Weight:** 12 pounds.
**Dimensions:** 6½ inches by 9 inches by 10 inches.
**Operates:** From 115-volt 60-cycle mains.
**Power Required:** 25 watts.
**Price:** $92.50.
**Code Word:** BRAVO.

# COLOR COMPARATOR

THE problem of color matching has been of increasing urgency in industry for a number of years. Not only are new correlations between color and other qualities of materials being discovered, but color is being more extensively used in manufacturing, especially of consumer goods, and the problems of quantity production require accurate maintenance of color for large batches of goods and between successive batches. The use of color as an indication of condition in cooking is familiar, but industrial applications of the same sort are growing more numerous. These apply not only to processing, but to grading of materials and, even in some instances, to medical diagnosis.

Increasing use of colored materials in industry creates a great need for a quantitative method of reproducing colors. Under mass-production methods all of the upholstery of a car may not be made from the same lot of material. Successive lots, therefore, must match closely. Similarly, the sleeves and fronts of a lot of shirts might be made from different shipments of cloth, and there have been instances when the mismatch was not discovered until the shirts had been made up. The opportunities for financial loss and impairment of good will between fabricators and suppliers in such a situation are obvious.

Color matching in most industrial plants still depends upon the skill and the color judgment of an experienced operative unassisted by instrumentation. This method of matching is open to rather serious objections. In cases of disagreement there is no impartial basis for a decision, and the nature of the problem offers many opportunities for disagreement. The effect of the nature of the lighting on apparent color is familiar. Differences of weave and finish also introduce difficulties in matching, even to the trained observer.


FIGURE 1. TYPE 725-A Color Comparator. Color intensity is indicated as a meter reading. Filters are shifted by means of the knob at the upper left. The pilot lamp indicates which filter is in position

The complexity of the problem results from the fact that color stimulus reaching the eye is a summation of many factors which the eye has no power to differentiate. There are hundreds of widely different stimuli which would be described identically if seen separately. When samples are observed side by side, reasonably small differences can be distinguished, but the limitations of such matching are sufficient to represent a serious industrial problem.

Three factors combine to make up the complete psychological impression of color which the eye perceives. Most obvious of these is hue, that is, the position of the predominant response in the visible spectrum. Brilliance is the eye's estimate of the total reflection from the object. It is a measure of the "darkness" of the color, and if the object reflected all colors equally—that is, were white—the scale of brilliance would run from white to black. The third factor, saturation, is a measure of the intensity of the hue. A white object, having no predominant color, would have a zero saturation. An absolutely pure primary color would have maximum saturation.

The experienced eye unconsciously evaluates all of these factors within limits, but an objective method which would be independent of lighting, fatigue, and individuality possesses obvious advantages. The problem of color measurement is in many ways analogous to that of wave analysis. The color stimulus represents a complex waveform containing many components over a wide spectrum. The problem consists of measuring the relative intensity of these various components. Such a measurement takes into consideration all three subjective characteristics—hue, brilliance, and saturation.

The most complete and scientifically satisfactory method of color analysis which has been developed is concededly the Hardy Analyzer manufactured by the General Electric Company. This instrument surveys the entire visible spectrum with a highly selective optical filter, consisting of a prism and an optical slit, and measures the intensity of each frequency in the complex waveform in the same manner as wave analyzers are used at low frequencies. The construction of the instrument is, of course, essentially different in detail, although functionally similar. For example, where, in the examination of voltage, its magnetic effect is used to deflect a meter, in color analyzers the intensity of reflection is gauged by means of a light sensitive surface.

The complete analysis of color, while essential for standardization and for precise measurements, suffers a disadvantage on the score of cost and complication of operation when considered as a shop instrument.

The engineering firm of Barss, Knobel & Young have evolved a simplification of the analyzer principle in color measurement which rests on the fact, attested by the majority of color physicists, that any gradation of color can be exactly reproduced by recombination from three primary colors—red, green, and blue. The application of this principle has made colored moving pictures feasible, and all color effects obtained in modern chromo-cinema technique are founded on this principle.

In the Barss, Knobel & Young Color Comparator, which the General Radio Company is manufacturing, reflection is measured in three frequency bands selected from the complex waveform by filters. This results in a compact and easily operated instrument in which the sample is placed over the viewing aperture and the reading of a meter noted as the filters are successively moved into place. In examining any color three meter readings will be obtained corresponding to the red, blue, and green regions, respectively. When these readings are identical for two samples, the samples are identical in hue, saturation, and brilliance—that is, will appear to match under any conditions of lighting when viewed by reflected light.

Importance of the method of lighting a color sample is generally recognized, and a uniform lighting source is an essential beginning for such an instrument. When all samples are viewed by the same light the differences due to lighting are, of course, eliminated. It is also essential that the light intensity be constant at all times. In an alternating-current operated instrument this means that a precise voltage regulator must be included in the instrument.

Since light is reflected from material in somewhat different ways, depending upon its direction of incidence in relation to the weave direction, large errors may be incurred if this factor is not provided for in the design of the instrument. In the Type 725-A Comparator an optical system has been devised which eliminates this error entirely and makes the reading of the instrument substantially independent of the way in which the sample is laid on the viewing aperture.

The optical system has also been laid out so as to avoid errors due to glare in the reflection from the sample. This is accomplished by focussing the light slightly beyond the sample so that it is subjected to a diffuse illumination.

Functionally then, the instrument consists of a light source, a series of filters, a light sensitive surface, and a meter. The light sensitive material used has sufficient output so that a meter can be used directly without amplifiers. Light is directed through a lens system and the filter to the sample, which it strikes as monochromatic light, and is reflected to a photocell system so constructed as to integrate precisely the reflection from all directions, making the response entirely independent of the character of the surface.

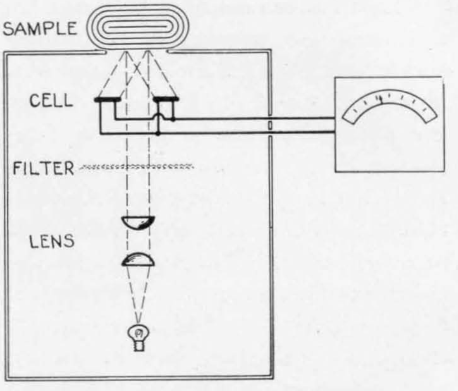



Figure 2. Light reflected from the sample to the photocell is transformed into electrical energy and indicated on the meter

In operation, the instrument is set up and calibrated with a magnesium-oxide sample over the viewing aperture. The shunts controlled by the knobs at the right are set to give the standard meter deflection for each filter. The sample is then placed over the aperture and the meter read with each filter successively in position. The three meter readings resulting completely describe the color.

The color comparator has other applications than the measurement of colors. It can be used to measure the opacity of paper by measuring the difference in reflection between the paper with a white backing and with a black backing. Brightness also can be measured by the color meter. In this measurement the definition and method of the Institute of Paper Chemists is followed.

The complete color comparator is shown in Figure 1. Although no amplifiers are required, a meter of relatively low current sensitivity and, consequently, of considerable ruggedness is used. The meter scale is wide and open, permitting easy reading for the determination of small color differences. A voltage regulator is built into the instrument insuring constancy of the light source. Rapid calibration against a standard is provided for. The comparator is entirely operated from the alternating current mains.

— C. T. Burke

### CATALOG DATA

**Power Supply:** 115-volt, 50-60 cycle a-c line. A voltage regulator is included for holding the illumination to a constant value. Adequate fuse protection is provided. The total power consumption is 75 watts.

**Dimensions:** (Length) 16 inches by (width) 12 inches by (height) 12 inches, over-all.

**Net Weight:** 40 pounds.

| *Type* | *Code Word* | *Price* |
|---|---|---|
| **725-A** | SABER | **$550.00** |

## IT'S NOT THE HEAT, IT'S THE HUMIDITY

At this time of year we receive many letters recounting difficulties — high power factor, low leakage resistance — which are directly due to the prevailing high humidity. Since it's the weather, not much can be done about it, unfortunately.

Even though direct absorption of moisture is negligible, the formation of a film on the surface lowers the insulation resistance and, when subjected to alternating potentials, introduces a material loss. Among insulators there are great differences in moisture effect due to surface characteristics. Roughness or pores at molecular dimensions are the important factors. Such ceramics as isolantite are coated to reduce absorption. An insulating material which water does not wet is usually only slightly affected by surface moisture because the water collects in discrete drops and does not cover the whole surface. The yellow bakelite, XN-262 Natural, used in the cases of our Types 505 and 509 Condensers and in many other places where high insulation resistance and low dielectric loss are desired, owes its remarkable freedom from the effects of surface moisture to this property.

Unfortunately, some of the best dry materials show the worst absorption characteristics. Mica and quartz, both crystalline and fused, show larger decreases in their insulation resistance with moisture than many other insulators having much lower volume resistivities. This characteristic serves to decrease the difference between these insulators and others of lower volume resistivity as the humidity of the surrounding air is increased. In fact, it is quite possible, under the effects of high humidity, for quartz insulation to have a lower resistance and larger power factor than many ordinary ceramics.

The Type 222 Precision Condensers are now available with fused quartz insulation. In an atmosphere of low relative humidity, such a condenser has a figure of merit, $R^{\omega}C^2$, of 0.003 x $10^{-12}$ as compared with about 0.04 x $10^{-12}$ for isolantite. Its insulation resistance is about 100 megamegohms for quartz insulation and about 1 megamegohm for isolantite. Under the action of high humidity, a quartz insulated condenser may become poorer in respect to both insulation resistance and power factor than one with isolantite insulation, their insulation resistances reducing to perhaps 1000 megohms, while their figures of merit increase to perhaps 0.1 x $10^{-12}$. There appears to be no specific remedy for this effect of humidity on insulation except local heating or air conditioning. The extent to which such a conducting film forms is dependent both upon the temperature of the insulator with respect to the ambient temperature and upon the characteristics of the surface itself. An insulator which is maintained only a few degrees above room temperature will be very little affected by even a high degree of relative humidity. On the other hand, large amounts of moisture will collect upon insulators which are a few degrees lower than the surrounding temperature.

## TYPE 107 DIRECT-READING VARIABLE INDUCTORS

The table below supersedes the ranges given for the Type 107 Inductors in the January, 1935, *Experimenter*. These inductors are now fitted with a direct-reading calibration on the dial. The accuracy of reading is 1% of full scale.

| | *Self-Inductance* | | *Mutual* |
|---|---|---|---|
| *Type* | *Series* | *Parallel* | *Inductance* |
| 107–J | 7– 50 μh | 1.7–12.5 μh | 0–10.8 μh |
| 107–K | 60–500 μh | 15–125 μh | 0–110 μh |
| 107–L | 0.6– 5 mh | 0.15–1.25 mh | 0–1.1 mh |
| 107–M | 6– 50 mh | 1.5–12.5 mh | 0–11 mh |
| 107–N | 60–500 mh | 15–125 mh | 0–110 mh |

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VOL. X No. 4 SEPTEMBER, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

## In This Issue



# AN A-C OPERATED RESISTANCE-COUPLED VOLTAGE AMPLIFIER

RESISTANCE-COUPLED amplifiers have been used for such a long time that at first glance there seems little to be said about them. Actually, however, tube developments in recent years have so changed design considerations as to introduce the paradox, startling to one whose amplifier designing stopped five years ago, that interstage transformers *reduce* the amplifier gain.

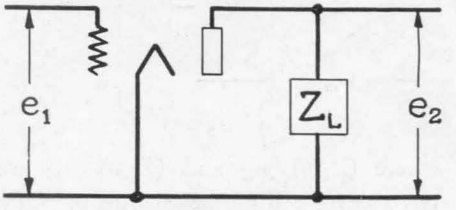



FIGURE 1. Schematic diagram of a vacuum-tube amplifier

The introduction of screen-grid tubes has made the question of maximum gain per stage of no importance. It happens that nearly all commercial tubes have approximately the same mutual conductance. A little arithmetic shows that in a resistance-coupled amplifier the voltage gain per stage is equal to the product of the mutual conductance and the equivalent parallel impedance of the tube plate circuit (which is the internal resistance and capacity of the tube in parallel with the impedance of the load circuit). Lumping the tube capacity in $Z_L$, as shown schematically in Figure 1,

$$\frac{e_2}{e_1} = \mu \frac{Z_L}{Z_L + R_P} = \frac{\mu}{R_P} \frac{Z_L R_P}{Z_L + R_P}$$

$$\frac{e_2}{e_1} = G_m Z_{L,P} \qquad (1)$$

where $\mu$ is the amplification constant, $Rp$ is the internal plate resistance, and *Gm* is the transconductance of the vacuum tube.

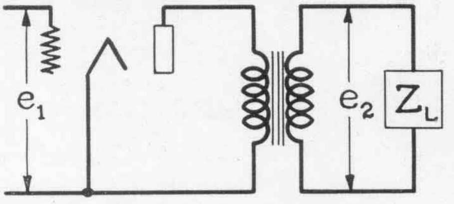



FIGURE 2. Schematic diagram of a single stage of transformer-coupled amplification

In an amplifier coupled by ideal transformers, as shown in Figure 2,

$$\frac{e_2}{e_1} = \mu \frac{Z_L \left(\frac{n_1}{n_2}\right)^2}{R_P + Z_L \frac{(n_1)^2}{n_2}} \frac{n_2}{n_1}$$

$$= G_m \frac{Z_L \left(\frac{n_1}{n_2}\right)^2 R_P}{R_P + Z_L \frac{(n_1)^2}{n_2}} \frac{n_2}{n_1}$$

$$= G_m (Z_{L,P})\ _{PRI} \frac{n_2}{n_1}$$

$$\frac{e_2}{e_1} = G_m \frac{(Z_{L,P})\ _{SEC}}{\frac{n_2}{n_1}} \qquad (2)$$

where $(Z_{L,P})\ _{PRI}$ and $(Z_{L,P})\ _{SEC}$ are the effective impedance due to plate and load as seen from the primary and secondary respectively.

Equation (1) shows that the gain of a resistance-coupled amplifier may be thought of as proportional to the effective impedance built up in the plate circuit; equation (2) shows that the gain of a transformer-coupled amplifier is proportional to the effective impedance built up in the secondary circuit *but is reduced by the step-up ratio of the transformer*. Before the introduction of high-impedance tubes, transformers were desirable, since the internal plate impedance was the true limiting factor. At that time a transformer could profitably be used to step up this impedance even at the expense of the enormously increased shunting capacities and the loss in voltage amplification (as compared with the later ideal cases) due to the transformer step-up ratio. In addition to the other limitations, the older amplifiers were very much bothered by grid-to-plate capacitive regeneration.

At present the situation is entirely different since the early limitations of tube design have been overcome and we are now limited in gain almost solely by the shunt capacities.

The new problem consists in effecting a compromise between the gain per stage and the frequency characteristic; in other words the total impedance-to-ground must be chosen at a value sufficiently low to make the effect of the shunt capacity negligible at the required high frequency limit. In this connection, it is worth mentioning that designers of television amplifiers have gone a step further and partially neutralized the shunt capacities by means of series inductors in the load circuits and by regenerative schemes.

One practical drawback is present with resistance-coupled amplifiers; due to the voltage drop in the load resistors, higher supply voltages are necessary and if batteries are used the whole amplifier becomes a bit unwieldy. This is particularly true if high output voltages are required. When a rectifier is used for plate supply, difficulty is experienced due to coupling between the various stages through the impedance of the supply and if no consideration is given to

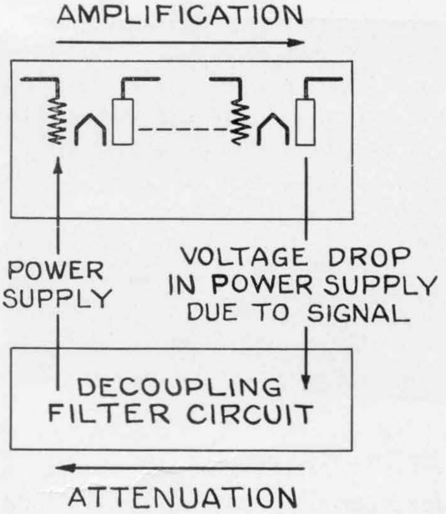



FIGURE 3. Block diagram showing how self-oscillation occurs in amplifiers

this, low-frequency oscillations can and do occur, the so-called "motor-boating." How this comes about is readily seen by reference to Figure 3.

If the voltage introduced into the early stages of an amplifier due to coupling with the last stages through the supply is equal at any frequency to the input signal required to produce that voltage, oscillation can occur. To prevent this, the attenuation of the supply circuit at all frequencies must be greater than the amplification. Figure 4 shows this condition graphically.

This means that the amplification at low frequencies must be limited to the attenuation possible at those frequencies with the condenser-resistance circuits that are economically available. In other words, in practice the lower end of the frequency scale is not at all limited by the availability of large grid coupling condensers and resistors but by the values which may be required to isolate the power-supply circuits. To avoid this limitation, it would be necessary to use several separate power supplies for the different stages.

There is still another limitation to the amplification which can be used at low frequency, that is, the presence of fluctuations in the commercial power lines. Such fluctuations appearing at the output of the rectifier may be considered as a low-frequency spectrum which must be attenuated by the filter circuit in such a way that the resultant voltage applied to the amplifier will not have components of sufficiently high amplitude and frequency to be amplified to an objectionable degree.

The foregoing discussion has been given to outline the problems which have been dealt with in designing the TYPE 714-A Amplifier which has recently been announced by the General Radio Company. This amplifier is intended as a commercial compromise between all of the foregoing factors and the amount of equipment required.

It has been built of three stages, all

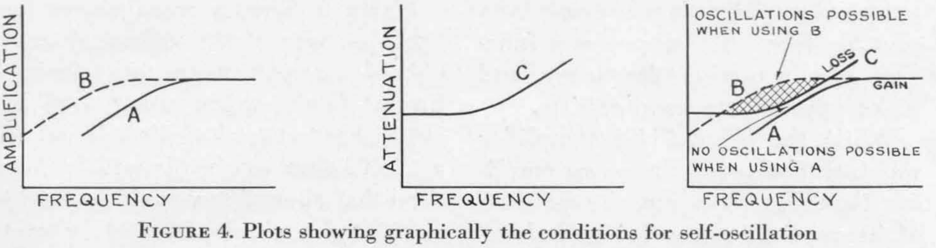



FIGURE 4. Plots showing graphically the conditions for self-oscillation

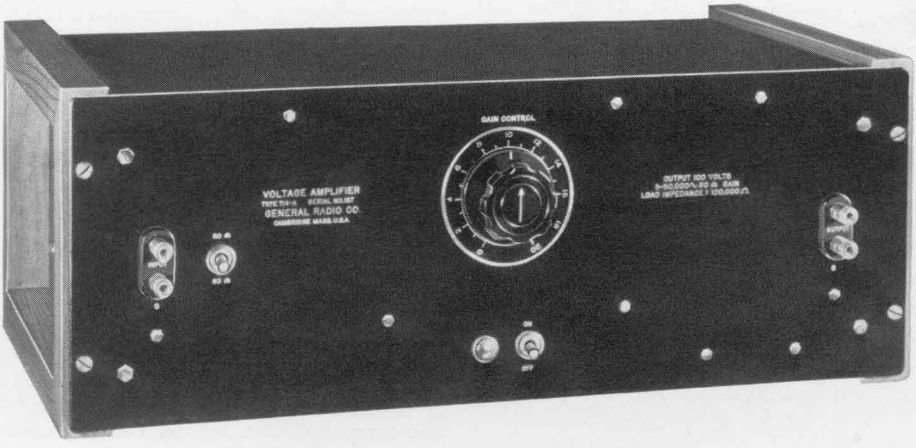



FIGURE 5. Panel view of the TYPE 714-A Amplifier

pentodes, and the gain has been kept to about 27 db per stage, giving a total gain between 80 and 90 db. By carefully keeping wiring capacities at a minimum, this gain was achieved with a drop of only 3 db at 50,000 cycles without using neutralization.

In order to obtain an undistorted output of 100 volts rms for use with cathode-ray oscillographs, it was found desirable to use a plate supply of 600 volts. With this supply and proper use of the 43 $\mu$f which was available for the filter unit it was found possible to extend the range of the amplifier downward to 5 cycles with a drop of only 3 db at this frequency. The effect of line voltage variations was studied with the assistance of a motor-driven *VARIAC* with varying-speed voltage fluctuations to exaggerate dynamic line voltage changes. Thus it was possible to plot *low*-frequency output as a function of fluctuation frequency and make appropriate compromises.

While the TYPE 714-A Amplifier was intended primarily as an amplifier for cathode-ray use, the question of its application for bridge balancing naturally comes up. Is the hum sufficiently large so that headphone use is prohibited?

The residual power supply hum has been found to be equivalent to approximately 10 $\mu$v on the grid of the first tube. Tests with a wave analyzer show that this arises partly from mutual inductance between the power transformer and the circuit wiring. (This is mainly 180 cycles rather than 60 cycles.) The remainder is due to the heater of the first tube and varies considerably from tube to tube so that some little selection is desirable.

The indirectly-heated-cathode tubes are much less microphonic than most filament-type tubes so that the a-c operated amplifier is actually somewhat quieter than the usual battery-operated type of equal gain.

Figure 6 shows average curves for two observers of the voltage threshold of hearing in a quiet room. Curve *A* was taken using a W.E. 509-W headset worked directly out of a 20,000-ohm source. It will be noticed that about 20 $\mu$v could be heard at 900 cycles whereas 300,000 $\mu$v were

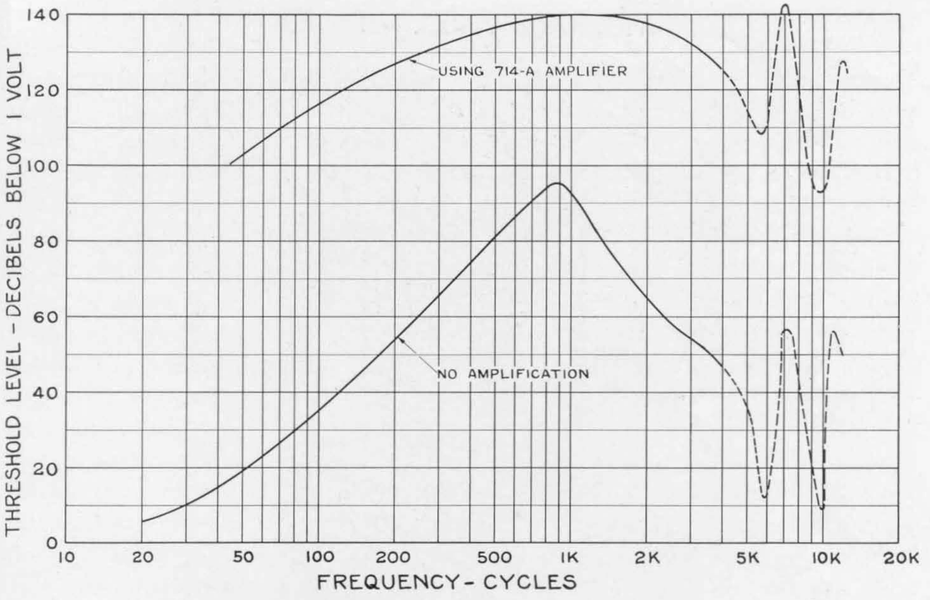



FIGURE 6. Plots showing how TYPE 714-A Amplifier improves the frequency characteristic in bridge measurements

required at 40 cycles and at 10 kilocycles. Curve *B* shows the corresponding curve taken with the amplifier inserted between the source and telephones. At 40 cycles the full gain is effective; at 1000 cycles acoustic masking cuts the gain to 50 db; at 10,000 the full gain is again available. From similar curves taken on other amplifiers it looks as though a signal (if above the threshold of hearing) can be heard if, and only if, it has higher energy than the continuous spectrum in the neighborhood which is sensibly indistinguishable in pitch from it. This would account for the broadening of the telephone response curve when the amplifier is inserted. It will be noticed that the effective acoustic gain of the amplifier is at least 50 db over the spectrum so that no amplifier of lower gain can be as satisfactory.

— L. B. ARGUIMBAU

SPECIFICATIONS

**Gain:** 80 db maximum, continuously adjustable between 20 db and 80 db.

**Frequency Characteristic:** Within 3 db between 5 cycles and 50 kc.

**Output Voltage:** 140 volts maximum peak (100 volts rms on sinusoidal wave).

**Load Impedance:** 100,000 ohms or greater (one terminal grounded).

**Input Resistance:** Over one megohm (one terminal grounded).

**Power Supply:** 115 volts, 40-60 cycles.

**Tubes:** Two 6*C*6, one 89, one 80 (all supplied with instrument).

**Dimensions:** (Length) 19 x (height) 7 x (depth) 10½ inches, over-all.

**Net Weight:** 40 pounds.

**Code Word:** AURAL.

**Price:** $190.00.

This instrument is licensed under patents of the American Telephone and Telegraph Company solely for utilization in research, investigation, measurement, testing, instruction, and development work in pure and applied science.

# McGRAW PRIZE WINNER

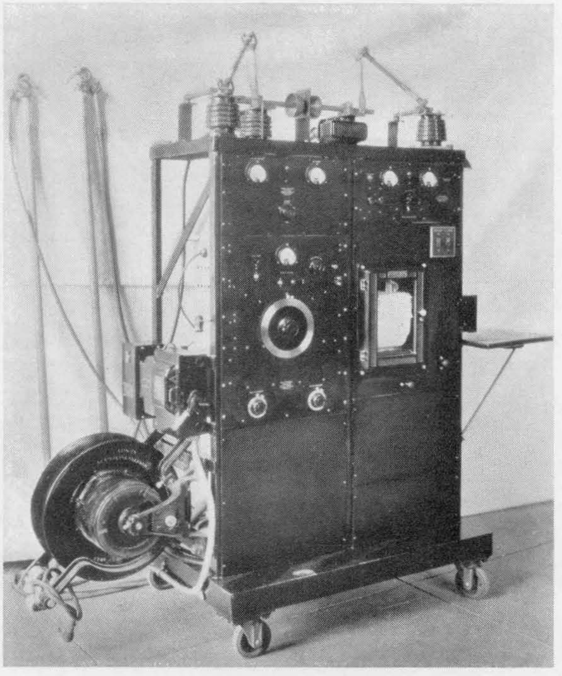


FIGURE 1. Panel view of the fault-locating equipment, showing the beat-frequency oscillator, power amplifier, and recorder

THE above illustration shows an interesting application of General Radio equipment. This assembly is used for locating faults, such as shorts, grounds, or open circuits, in overhead power transmission lines by a method developed by J. E. Allen and C. J. Gross of the Pennsylvania Water and Power Company, Baltimore, Maryland. The equipment consists of a high-powered, high-frequency, beat-frequency oscillator and power amplifier designed and manufactured by the General Radio Company to meet the specifications of the Pennsylvania Water and Power Company. Also included in the assembly are a recording rectifier-galvanometer, various protective and coupling devices, and a motor drive arrangement for operating the recorder and the oscillator control simultaneously.

The beat oscillator covers the range from 100 to 100,000 cycles per second with a substantially constant output of four watts. This drives a power amplifier containing two 203-A type tubes which may be operated either Class A or Class B. A-C operated power supply equipment provides all necessary operating voltages and is controlled by an automatic time switch which allows the filaments to heat before any plate voltage is applied.

In operation the equipment is coupled to the transmission line which is to be tested and the motor drives the oscillator and the recorder throughout the oscillator frequency range. The recording galvanometer draws a curve showing the current into the transmission line versus frequency. This curve will be a series of peaks separated by equal increments of frequency. The frequency increment between successive peaks is inversely proportional to the length of the line. Accordingly, it is only necessary to measure this frequency increment for the various transmission lines in normal operating conditions to determine the line constants. Then when a fault occurs (effecting a new termination of the line) its location can be immediately determined by measuring the frequency increments on the defective line. The same method is valid for a shorted or grounded line. Under some conditions the locations of the peaks in the curve are shifted, but the frequency increments remain the same.

With this equipment it is possible to locate in a few minutes a fault on a three-phase transmission line which it might otherwise take many hours to find. The arrangement works equally well for opens, short-circuits, or grounds in the line and no communication is needed with the line patrolmen or with any other station on the line. The apparatus can be operated by the regular station attendants and the accuracy of location is 2% or better. It can be used on lines up to 100 miles in length.

It is of interest to note that a paper by Messrs. Allen and Gross describing this equipment was awarded first prize last March in the McGraw prize competition of the Edison Electric Institute as the most meritorious paper on an engineering or technical subject relating to the electric light and power industry.*

The apparatus described is not commercially available as a complete installation. A beat-frequency oscillator of characteristics similar to that used can, however, be built to order by the General Radio Company.

—H. H. Scott

* *E.E.I. Bulletin*, Aug., 1935; *Electrical World*, July 20, 1935.

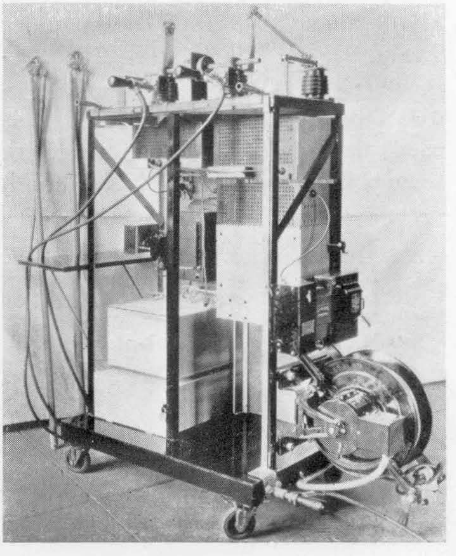


FIGURE 2. Rear view of the equipment, showing the type of construction used. The beat-frequency oscillator and power amplifier were designed and manufactured by the General Radio Company. The recording equipment, motor drive, and the protective and coupling devices were built by the Pennsylvania Water and Power Company

# NEW DECADE CONDENSER UNITS

TYPE 380 Decade Condenser Units are now furnished with a new type of cam switch which is more stable mechanically than that previously used. An all-mica 1.0 μf decade (in steps of 0.1 μf), TYPE 380-F, is now available and is made up of TYPE 505 Condensers. TYPES 380-L, 380-M, and 380-N listed below, replace the older TYPES 380-A, 380-B, and 380-C, respectively.

Electrical specifications are listed below. The maximum voltage listed holds for frequencies below those specified. For higher frequencies, the maximum safe voltage decreases and is inversely proportional to frequency.

| *Type* | *Capacitance* | *Accuracy* | *Dielectric* | *Power Factor* | *Maximum Voltage at Frequency* | |
|---|---|---|---|---|---|---|
| 380-F | 1.0 μf in 0.1 μf steps | 1% | Mica | 0.05% | 500 | 4 kc |
| 380-L | 1.0 μf in 0.1 μf steps | 2% | Paper | 1.0% | 300 | 1 kc |
| 380-M | 0.1 μf in 0.01 μf steps | 1% | Mica | 0.1% | 300 | 100 kc |
| 380-N | 0.01 μf in 0.001 μf steps | 1% | Mica | 0.2% | 300 | 1000 kc |

**Dimensions:** TYPE 380-F, panel space, 4 7/32 x 4 21/31 inches; behind panel, 3 15/16 inches. TYPES 380-L, 380-M, and 380-N, panel space, 3 5/10 x 2 13/16 inches; behind panel, 4 1/16 inches.

**Net Weight:** TYPE 380-F, 3⅝ pounds; TYPES 380-L and 380-M, 1½ pounds; TYPE 380-N, 1⅜ pounds.

| *Type* | *Code Word* | *Price* |
|---|---|---|
| **380-F** | ACUTE | **$58.00** |
| **380-L** | ADAGE | **10.00** |
| **380-M** | ADDER | **12.00** |
| **380-N** | ADDLE | **10.00** |

## TYPE 219 DECADE CONDENSER

New models of TYPE 219 Decade Condensers are now available, using the TYPE 380 Decade Condenser Units described above. TYPES 219-L 219-M, and 219-N replace the older TYPES 219-F, 219-G, and 219-J, respectively. TYPE 219-K is a new three-dial box in which mica dielectric is used throughout. All cabinets are lined with copper, effectively shielding the condensers from external fields.

**Dimensions:** TYPES 219-K and 219-M, 13¾ x 5 13/16 x 5½ inches, over-all; TYPES 219-L and 219-N, 10⅝ x 5 13/16 x 5½ inches, over-all.

**Net Weight:** TYPE 219-K, 10¾ pounds; TYPE 219-L, 6½ pounds; TYPE 219-M, 8⅝ pounds; TYPE 219-N, 6⅜ pounds.

| *Type* | *Capacitance* | *No. of Dials* | *Type 380 Decades Used* | *Code Word* | *Price* |
|---|---|---|---|---|---|
| **219-K** | 1.110 μf in 0.001 μf steps | 3 | F, M, N | CROSS | **$90.00** |
| **219-L** | 1.10 μf in 0.01 μf steps | 2 | L, M | COVER | **35.00** |
| **219-M** | 1.110 μf in 0.001 μf steps | 3 | L, M, N | BRIER | **45.00** |
| **219-N** | 0.110 μf in 0.001 μf steps | 2 | M, N | CRONY | **35.00** |

The GENERAL RADIO EXPERIMENTER

VOL. X. No. 5 OCTOBER, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

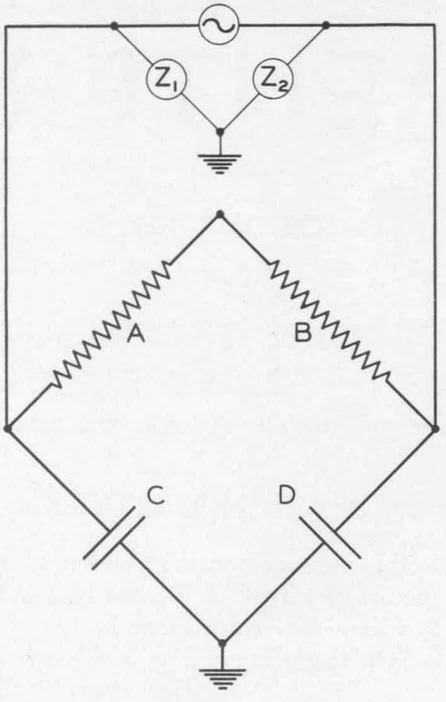
# SHIELDED TRANSFORMERS FOR IMPEDANCE BRIDGES

WHEN making direct impedance measurements with any kind of bridge, a shielded transformer is ordinarily used to connect either the generator or the detector to the bridge. The purpose of the transformer is to reduce or eliminate the errors in measurement which result from stray impedances between the terminals of the generator (or the detector) and ground. Although in the substitution method these errors generally cancel out of the simple bridge equations, it is desirable to make them as small as possible in order to minimize second order effects. Another less important use is the matching of impedances between the bridge and the external circuits to obtain maximum power transfer.

To illustrate the general application of shielded transformers in bridge measurements, let us consider the bridge circuit of Figures 1, 2, and 3, where the transformer is used to couple the generator to a grounded bridge. Figure 1 shows the generator connected directly to the bridge. Under this condition, the terminal impedances ($Z_1$ and $Z_2$) of the generator to ground are placed directly across the bridge arms *C* and *D*. These impedances are usually capacitive and have an extremely poor power factor. The resulting error in measurements of capacitance and power factor is large, since these terminal capacitances amount to several hundred micromicrofarads when an a-c operated oscillator is used, and, in addition, they are seldom balanced to ground.

The shielded transformer of Figure 2 completely eliminates these generator impedances but substitutes

## IN THIS ISSUE



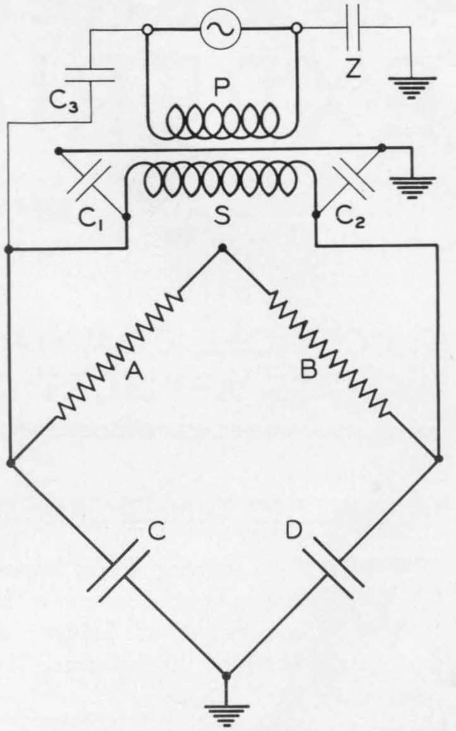




FIGURE 1 (left). Schematic circuit of a grounded bridge supplied by a generator having two unequal terminal impedances to ground

FIGURE 2 (right). Schematic diagram showing the use of a singly-shielded transformer between generator and bridge. The impedance $Z$ represents the equivalent terminal impedance between one side of the generator and ground. For convenience in analyzing the problem, this impedance is assumed to be associated entirely with one generator terminal

in their place the terminal capacitances $C_1$ and $C_2$ of the secondary winding of the transformer to the shield. While these capacitances can be made equal, they are usually quite large, amounting to several hundred micromicrofarads and, for this reason, the singly-shielded transformer is seldom used. For equal-arm bridges the resulting error is negligible only if the terminal capacitances are equal and, in unequal-arm bridges, only when their ratio is the same as that of the ratio arms. Since it is impossible to vary the ratio of terminal capacitances as the ratio arms are changed, a doubly-shielded transformer offers the best solution to the problem.

An additional error is introduced by the presence of the capacitance $C_3$ between primary and secondary windings. If $C_3$ is appreciable compared with the impedance in the bridge arm $C$, a fraction of the generator voltage is applied across this arm, proportional to the ratio $\frac{C_3}{C}$, since the impedance of the power source to ground is usually much smaller than that of $C_3$.

Figure 3 shows the doubly-shielded transformer connected to a bridge.

Here the bridge is isolated from the load by the series combination $C_5$ (or $C_6$) and $C_4$ and, if $C_4$ is made small, the effective terminal capacitance is kept at a low value.

The requirements for a good doubly-shielded transformer are met by the TYPE 578 Transformer, originally described in the *Experimenter* for April, 1934.*

This transformer, which is shown schematically in Figure 3, is designed to reduce both the terminal capacitance shown in Figure 1 and the direct capacitance $C_3$ of Figure 2. When used with a conventional type of impedance bridge, the shield on the generator side is grounded to prevent the to-ground impedance of the generator from introducing errors into the measurement. The terminal capacitances for the winding on the bridge side then consist of $C_5$ (or $C_6$) in series with one-half the series-parallel network $C_4$, $C_7$, $C_8$. Each terminal capacitance is then 28 $\mu\mu$f. If the case is grounded, thus short-circuiting $C_7$, the terminal capacitance is increased to 40 $\mu\mu$f.

These values are sufficiently low, compared to the usual figure of several hundred micromicrofarads, to be negligible when measuring directly large capacitances or when using a substitution method with the bridge. Under other conditions, allowance can be made in the result for any error which they may cause. Since they are equal, their effect is usually negligible in equal-arm bridges.

The capacitance $C_3$ is only 0.2 $\mu\mu$f.

TYPE 578 Transformers are made in three models covering a total frequency range of from 20 cycles per second to 500 kc. The turns ratio for each model is 4:1, giving an impedance transfer of 16:1. Exact impe-

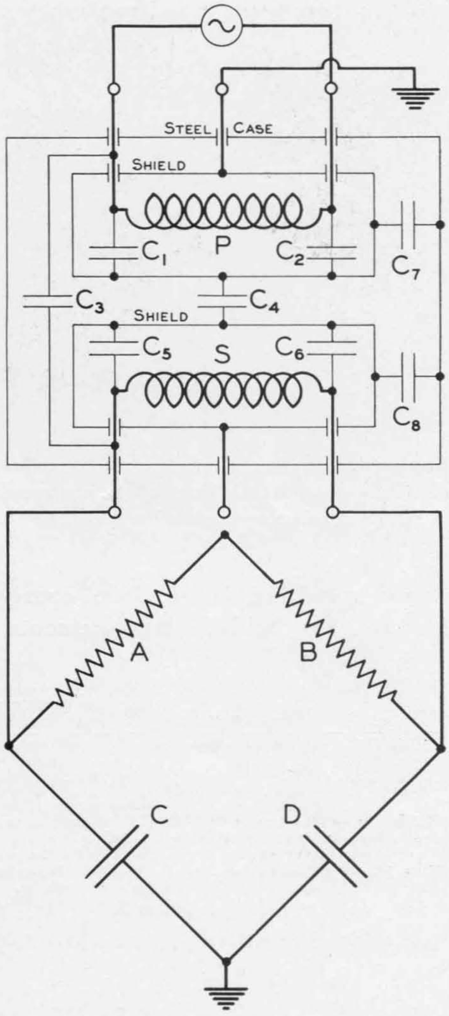



FIGURE 3. The grounded bridge supplied through a doubly-shielded transformer. Average values of the transformer capacitances for TYPE 578 Transformer are as follows:

| | |
|---|---|
| $C_1$, $C_2$, $C_5$, $C_6$ | each 200 $\mu\mu$f |
| $C_3$ | 0.2 $\mu\mu$f |
| $C_7$, $C_8$ | each 70 $\mu\mu$f |
| $C_4$ | 30 $\mu\mu$f |

*R. F. Field, "A Shielded Transformer for Bridge Use," General Radio *Experimenter*, April, 1934.

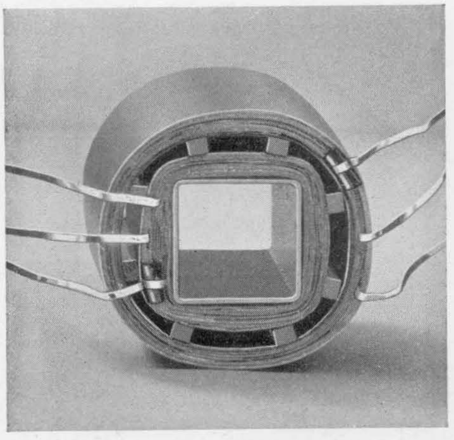


FIGURE 4. The air space between the two individually-shielded windings is the important factor in reducing terminal capacitance

dance matching is of little consequence in bridge measurements, since losses are easily compensated for by increasing either generator power or detector gain. The TYPE 578 Transformers are suitable for all impedance ratios between 1 to 16 and 16 to 1, a sufficiently wide range to cover all ordinary bridge-circuit requirements.

TYPE 578 Transformers can be used with the TYPE 293-A Impedance Bridge and, if mounted on a suitable plug-type base, in the TYPE 516-C Radio-Frequency Bridge. The range of the radio-frequency bridge can in this way be extended down to audio frequencies.

The A- and B-types can be used to step-down the 110-volt, 60-cycle, line voltage to supply a TYPE 650 Impedance Bridge.

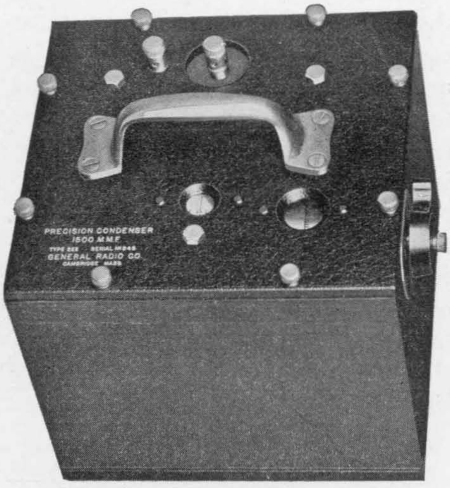
| | | *Impedance Range** | | | |
|---|---|---|---|---|---|
| *Type* | *Frequency Range** | *Primary*† | *Secondary*† | *Code Word* | *Price*‡ |
| 578-A | 50 cycles to 10 kc | 50 Ω to 5K Ω | 1K Ω to 100K Ω | TABLE | $15.00 |
| 578-B | 20 cycles to 5 kc | 60 Ω to 6K Ω | 1K Ω to 120K Ω | TENOR | 15.00 |
| 578-C | 2 kc to 500 kc | 20 Ω to 2K Ω | 4K Ω to 40K Ω | TEPID | 15.00 |

*Range for voltage transfer within 6 db of maximum value. At extreme ends of both impedance and frequency ranges, the combined loss may be 12 db.
†The low impedance winding is considered to be the primary.
‡TYPE 578 Transformers mounted on plug-type bases for use in TYPE 516-C Radio-Frequency Bridge can be supplied at an increase of $5.00 over the prices shown.

## REACTANCE CHARTS

WE have available for distribution a limited number of small-scale reproductions of the reactance chart mentioned in the March, 1935, issue of the *Experimenter*. These are our standard catalog page size, 10 x 6⅝ inches, suitable for use in loose-leaf notebooks. We shall be glad to send copies to any who request them.

# INCREASED ACCURACY WITH THE PRECISION CONDENSER




EXTENSIVE investigations of the stability of the TYPE 222 Precision Condenser have shown that the condenser is capable of holding a calibration made with a greater precision than has hitherto been considered feasible. The scale is sufficiently open on all models to permit settings to a considerably greater precision than is necessary for the calibration usually supplied.

The TYPE 222-L Precision Condenser is provided with a worm and 50-tooth gear, so that 25 turns of the worm are required for the 180° of rotation which lie between minimum and maximum capacitance. The drum mounted on the worm shaft has 100 divisions, each of which is about 1/16 inch long. There are then 2500 divisions, into which the capacitance increment may be divided. By estimating tenths of these divisions, the total scale length may be read to one part in 25,000. Over the middle 20 turns of the worm, the capacitance increment per turn is about 60 $\mu\mu$f, so that one worm division equals 0.6 $\mu\mu$f and 0.1 division equals 0.06 $\mu\mu$f.

The calibration chart regularly provided with each condenser gives the capacitance for each turn of the worm to an accuracy of 1 $\mu\mu$f or 0.1%, whichever is the greater. The limit of 1 $\mu\mu$f is set by the lack of a standardized technique in connecting the condenser into a measuring circuit, while the limit of 0.1% is determined by uncertainty in the value of the micromicrofarad. These two limits are equivalent for a capacitance of 1000 $\mu\mu$f. Since the stability of the condenser when carefully handled is at least one part in 10,000, a calibration to an accuracy of 0.1 $\mu\mu$f or 0.1%, whichever is the greater, is of considerable value because it allows capacitance differences to be measured to an equal accuracy. The fact that the absolute capacitance is known only to 1 $\mu\mu$f is no detriment, because all precise bridge measurements of capacitance are made by a substitution method in which the standard is not disconnected from the circuit.

To realize this accuracy, the setting of the worm must be read to 1/5 of a worm division and the effects of backlash avoided by always approaching a setting from the same direction. Because of a slight eccentricity in the worm itself and minute irregularities in the bearings of the worm shaft, the capacitance change is not exactly linear throughout each turn of the worm. An approximately sinusoidal variation usually appears which, expressed as a capacitance, may amount to a divergence from linearity of 0.3 μμf. This worm variation repeats itself for each turn of the worm throughout the linear capacitance range. It is expressed as a correction which is to be applied to the value of capacitance obtained from the calibration chart by linear interpolation.

As an illustration of the use of such a calibration chart and worm correction, let it be desired to find the capacitance corresponding to a reading of 1646.8 divisions. The calibration chart in the vicinity of this setting reads as follows:

| *Scale Setting* | *Capacitance in μμf* | *Capacitance Increment in μμf* |
|---|---|---|
| 1400 | 812.2 | 59.3 |
| 1500 | 871.5 | 59.2 |
| 1600 | 930.7 | 59.2 |
| 1700 | 989.9 | 59.0 |
| 1800 | 1048.9 | |

The worm correction is:

| *Worm Divisions* | *Correction in μμf* |
|---|---|
| 0 | 0 |
| 10 | —.1 |
| 20 | —.2 |
| 30 | —.2 |
| 40 | —.1 |
| 50 | —.1 |
| 60 | 0 |
| 70 | 0 |
| 80 | 0 |
| 90 | 0 |
| 100 | 0 |

The calibration chart gives the capacitance at 1600 divisions as 930.7 μμf, at 1700 divisions as 989.9 μμf, the corresponding capacitance increment as 59.2 μμf, the worm correction at 40 divisions as —0.1 μμf, and at 50 divisions as —0.1 μμf. Linear interpolation gives a value of 958.4 μμf for a given dial setting. Adding the worm correction of —0.1 μμf gives the final capacitance value of 958.3 μμf.

The capacitance calibration obtainable from such a calibration chart is internally consistent to an accuracy of 0.1 μμf or 0.1%, whichever is the greater, hence capacitance differences may be obtained to an accuracy of 0.2 μμf or 0.1%, whichever is the greater.

Similar calibrations may be made on other types of precision condensers with the same limits of accuracy. In the case of the Type 222-M Precision Condenser, which is already adjusted to be direct reading in capacitance difference to 1 μμf, the calibration takes the form of a single correction chart which gives the correction to be applied to the direct reading of the dial at every ten worm divisions.

This calibration to 0.1 μμf may be made at the time of purchase of a new condenser or on any precision condenser returned to our factory. In the latter case, it is advisable to have the bearings of the condenser readjusted before attempting the accurate calibration. The cost of such readjustment is usually between $5.00 and $10.00, dependent upon the amount of work necessary. Condensers made a number of years ago have only a single bearing for the worm shaft. It is not generally advisable to calibrate such condensers to 0.1 μμf because of their inferior stability. The price of the complete calibration for either new or old condensers is $35.00.

—Robert F. Field

# RESIDUAL IMPEDANCES IN THE PRECISION CONDENSER

WHEN using a variable air condenser as a capacitance standard at radio frequencies, it is important to know the variation in effective capacitance and power factor as a function of frequency. These variations result from the presence of residual impedance and can, if neglected, cause very appreciable errors in measurements in the radio-frequency range.

The variation in effective capacitance is caused by the inductance of the condenser structure and leads. This inductance is practically constant with frequency and increases the effective capacitance of the condenser by an amount equal to $\omega^2LC^2$.

Measurements made by means of the TYPE 516-C Radio-Frequency Bridge on TYPE 222 Precision Condensers indicate that the effective inductance of the condenser is approximately 0.06 $\mu$h. Figure 1 shows the increase in effective capacitance which this inductance causes at frequencies up to 6 megacycles. The inductance is nearly all in the supports and stator rods of the condenser and does not vary appreciably with dial setting.

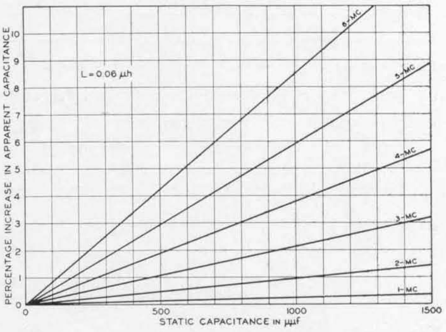



FIGURE 1. Increase in effective capacitance of a precision condenser caused by an equivalent inductance of 0.06 $\mu$h

At low frequencies the dielectric loss is constant with scale setting for condensers in which the field through the solid dielectric is independent of rotor position. Since the equivalent resistance varies with both frequency and scale setting and the power factor, while constant with frequency, varies with setting, a "figure of merit," $R\omega C^2$, is ordinarily used to express the magnitude of dielectric losses. This quantity is constant with both frequency and scale setting.

In addition to the dielectric loss, there is an ohmic loss in the resistance of the metallic structure. At radio frequencies the ohmic resistance may be the controlling factor, since it increases with frequency while the dielectric-loss resistance decreases. This metallic resistance

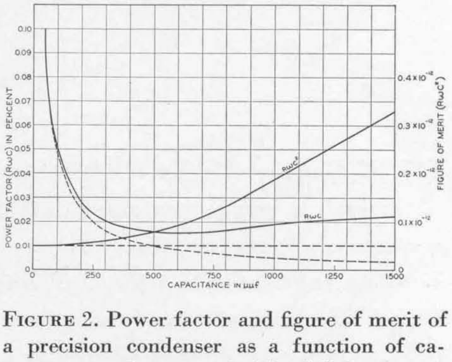



FIGURE 2. Power factor and figure of merit of a precision condenser as a function of capacitance at 1 megacycle. The full line curves are the true values obtained when dielectric loss and ohmic loss are combined. The dotted curves show these quantities when only dielectric loss is considered

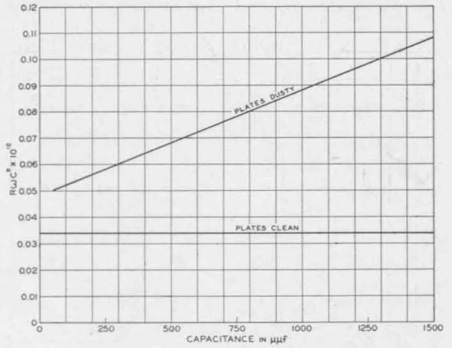



**Figure 3.** The variation in $R\omega C^2$ resulting from an accumulation of dust on the plates. The curve showing the effects of dust does not reach the "plates clean" plot at zero capacitance, because dust was removed from the solid dielectric as well as from the plates

can be measured by means of the radio-frequency bridge and is approximately 0.02 ohms at 1 megacycle. Figure 2 shows the power factor of the condenser and also $R\omega C^2$ plotted as a function of capacitance setting when both losses are combined. As a reference, plots are also given of these quantities when the metallic loss is neglected. An inspection of these curves shows that errors up to 50% may occur if the metallic loss is neglected in the measurement of the power factor of a condenser in the range below power factors of 0.05%, when the parallel substitution is used at radio frequencies. When measuring condensers of small physical size where the capacitance to ground is small, it is often possible to avoid the power factor error by using a series substitution method.

Another residual impedance, not chargeable to the condenser itself, exists if dust accumulates on the plates. The dust coating produces a loss varying with capacitance which is particularly serious when the condenser is used as the standard for measurements by the substitution method. Losses which vary with setting in either the standard or the unknown will yield erroneous results for the loss component of the unknown condenser. Figure 3 shows the variation in $R\omega C^2$ for a Type 222 Condenser resulting from dusty plates.

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

## WAVEFORM ERRORS IN THE MEASUREMENT OF POWER TRANSFORMER LOSSES

> **HARMONIC distortion is a phenomenon constantly dealt with by the communications engineer. It is by means of distortion in non-linear circuit elements that modulation, demodulation, and frequency multiplication are made possible. On the other hand, distortion is one of the most easily neglected sources of error in electrical measurements at communication frequencies. *Experimenter* readers will recall Mr. Thiessen's discussion of waveform errors in filter measurement published in the March, 1935, *Experimenter*. The present article discusses a similar type of error in power transformer measurements.**

ALTHOUGH nearly every communications engineer has, at one time or another, been concerned with the design of power-supply equipment, he seldom considers the results of harmonic distortion at commercial power frequencies. Iron-core circuit elements, however, are non-linear, and, while either voltage or current may be sinusoidal, both quantities never are.

In the design of power transformers one of the factors which must be taken into consideration is the magnitude of the no-load losses. These are commonly determined by measurement with a wattmeter as a function of the voltage applied to an experimental winding on the type of core which is to be used in the final product. From these measurements the voltage per turn at the desirable operating point can be calculated, yielding a basis for determining the final winding data.

It is necessary that the performance of this experimental winding be determined with a sinusoidal voltage impressed on the coil, since the final design will be used on a circuit of essentially sinusoidal voltage.

Figure 1 (a) shows a simple circuit for measuring the no-load losses by means of a wattmeter and a series rheostat to reduce the line voltage. The results of a series of measurements made with this circuit on a

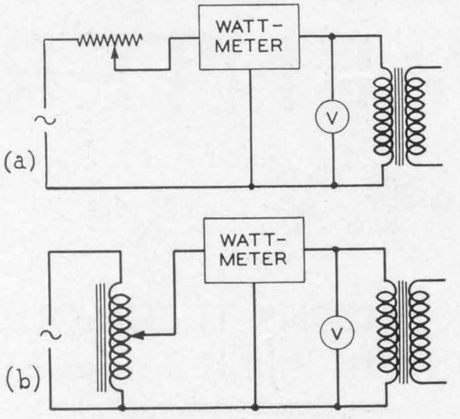



FIGURE 1. (a) Circuit for measuring the no-load loss of a power transformer using a series rheostat to vary line voltage. (b) Similar circuit using the *VARIAC*

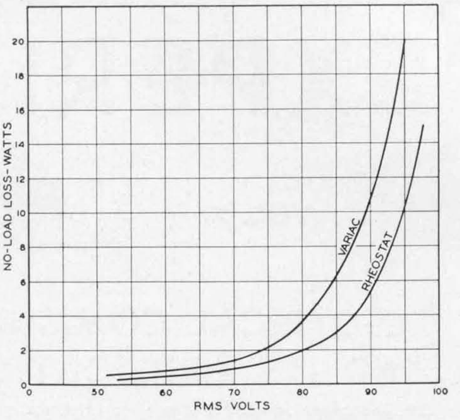



FIGURE 2. Power loss curves obtained by measurement using the circuits of Figure 1. Note that the results differ by 50%

sample winding yielded the lower of the two curves shown in Figure 2. When, however, a *VARIAC*, connected as indicated in Figure 1(b), was used to reduce the line voltage, the upper curve of Figure 2 resulted. Since the losses as measured when using the rheostat were some 50% lower than those obtained using the *VARIAC*, the waveforms of current and voltages in the two circuits were examined in order to determine which (if either) of the curves was correct.

To do this the circuit of Figure 3 was set up. With the *VARIAC* and the rheostat adjusted to give the same r-m-s voltage as read on the voltmeter *V*, the oscillograms of Figure 4 and Figure 5 were obtained. Figure 4 shows the voltage and current when the *VARIAC* was used. It will be noted that the voltage is sinusoidal and the current, as a result of the non-linearity of the magnetization curve of the iron, is highly distorted, containing a large third harmonic. Similar oscillograms for the rheostat circuit (shown in Figure 5) indicate that both the current and voltage are non-sinusoidal.

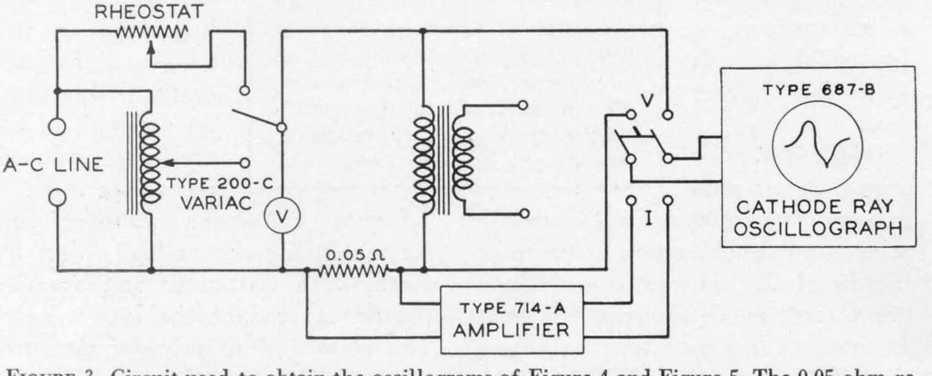



FIGURE 3. Circuit used to obtain the oscillograms of Figure 4 and Figure 5. The 0.05-ohm resistor supplies a voltage drop which is amplified to obtain the current wave shape

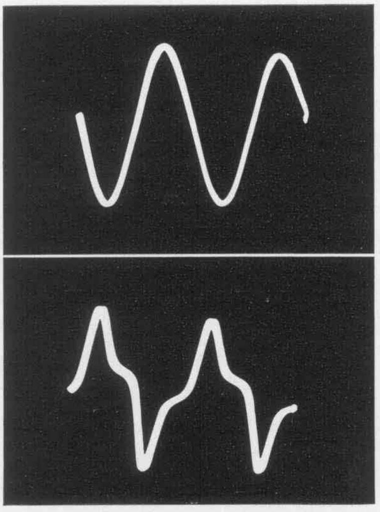


FIGURE 4. Voltage (upper) and current (lower) in the transformer primary when the *VARIAC* is used. The voltage is sinusoidal and the current distorted

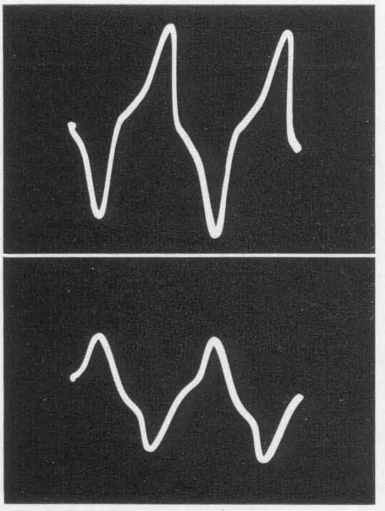


FIGURE 5. Voltage (upper) and current (lower) when the rheostat is used. Both curves are non-sinusoidal and the current is lower than in Figure 5

The reason for this is obvious upon further consideration of the circuit. The non-sinusoidal current produces an *IR* drop of similar waveform in the rheostat *I.* Since the voltage impressed on the transformer is the difference of the sinusoidal line voltage and the distorted *IR* drop, this voltage must also be distorted.

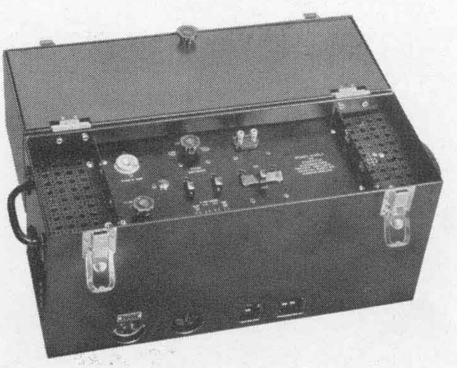
The net result as seen by the oscillograms is a considerably lower current when the rheostat is used. Both core loss and copper loss depend upon current, and the power consumed is therefore less than in the *VARIAC* arrangement.

The *VARIAC*, since it duplicates the desired operating condition of sinusoidal line voltage, gives the correct result.

## A NEW MODEL OF THE EDGERTON STROBOSCOPE

A REDESIGN of the TYPE 548-A Edgerton Stroboscope has recently been made in order to incorporate certain improvements and to utilize a more modern rectifier tube, the 83-type. Chief result of the redesign is a greater range of flash speeds. The new model, TYPE 548-B, can be used reliably at speeds slightly in excess of 200 per second.

Other specifications are unchanged and the price remains at $290.00.



# THE EDGERTON STROBOSCOPE

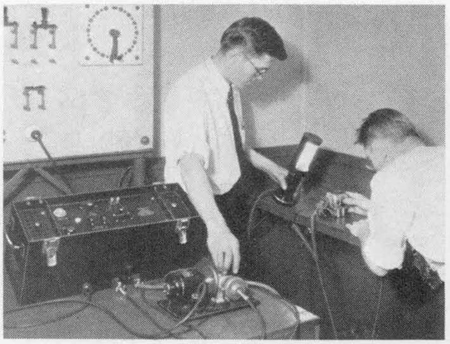
**STROBOSCOPY in the industrial field has reached its present state of excellence largely through the efforts of Professor Harold E. Edgerton of Massachusetts Institute of Technology. Professor Edgerton and Mr. Kenneth Germeshausen are responsible for the fundamental development underlying the three types of General Radio stroboscopes.**

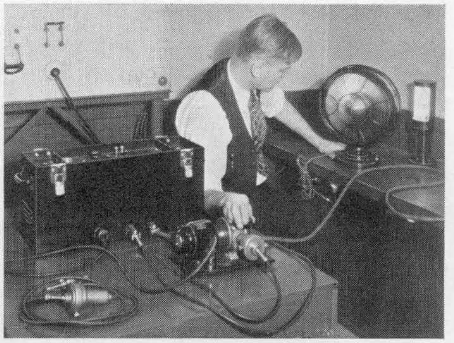
**In addition to the Type 548-B Stroboscope described herewith, the General Radio Company manufactures the Type 631-A Strobotac, a neon-lamp instrument intended primarily for speed measurements, and the Type 621 Edgerton Power Stroboscope, a high-power instrument suitable for taking high-speed motion pictures in conjunction with the Type 651-A Camera.**

THE TYPE 548-A Edgerton Stroboscope, now approaching its third birthday, has already achieved a position of some importance in the industrial scene.

The study of high-speed motion which the design and maintenance of modern machinery requires can be satisfactorily made only by the stroboscopic method. The Edgerton Stroboscope, because of its brilliant, short flash, has readily found its way into fields where older types of stroboscopes were not acceptable, and it is used today in some part of the design or manufacture of machines, automobiles, engines, instruments, cameras, electric motors, metal products, and textiles. The fact that some twenty engineering schools and universities are users of this instrument is further evidence of its utility in mechanical and electrical engineering.

The accompanying photographs, taken in the laboratories of the Emerson Electric Manufacturing Company, makers of motors, fans, and electrical specialties, are an excellent example of the use of the stroboscope in industry. For manufacturers of this type of product, the stroboscope is not only a means of laboratory testing on new products but is also the key to better design and more satisfactory performance. Emerson engineers have found it the only satisfactory method of determining the vibration and distortion of fan blades and hubs.





*Photographs, Courtesy Emerson Manufacturing Company*

# TYPE 559-B NOISE METER

**ALTHOUGH heralded by ballyhoo which might have ruined a less hardy child, the cause of "noise abatement," joint offspring of the social and the physical sciences, continues to flourish and shows distinct promise of a long and useful career.**

**In the factory, the office, and the store, noise reduction receives more and more attention as employers realize that noise takes its share of nervous energy with a consequent reduction in efficiency. Far less attention would be paid to critics of the machine age if its identifying characteristic were not the clatter and din of machinery.**

FOR industrial noise measurement and noise-level surveys, the noise meter is the most convenient instrument to use. It combines a reasonable accuracy with low cost, rugged construction, and portability.

The TYPE 559-A Noise Meter, announced in March, 1933,* was one of the first low-priced noise-measuring instruments available. Its reference level was the average threshold of hearing at 1000 cycles, since this level was used by many investigators at that time. It is only recently, however, that there has been any degree of standardization in this respect, and at present the tendency seems to be to favor a reference level approximately 7 db lower, which represents the threshold of hearing for a person whose hearing is unusually acute. This new reference level, as recommended by the American Standards Association, is $10^{-16}$ watts per square centimeter at 1000 cycles.

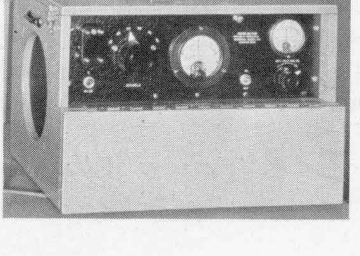
*"Commercial Noise Measurement," H. H. Scott, *General Radio Experimenter*, March, 1933.

The actual reference level of a noise meter is not particularly important, since the readings may be referred to any desired level by merely adding or subtracting a fixed number of decibels, but standardization is desirable since it eliminates the necessity of corrections between different instruments.

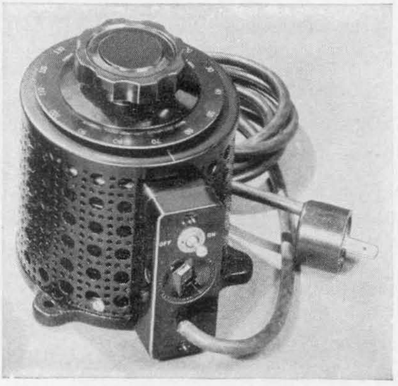
In order to promote standardization in noise measurements, the General Radio Company is announcing a modified noise meter, known as TYPE 559-B. This differs from the earlier model mainly in that the new reference level is used, with the result that, on any given sound, the new meter reads 7 db higher than the old one. The over-all sensitivity has also been increased to the extent of 3 db. Accordingly, the new noise meter covers the range from 34 db to 150 db above $10^{-16}$ watts per square centimeter at 1000 cycles. Users of the TYPE 559-A Noise Meter can, of course, compare their readings with the new reference level by merely adding 7 db.

—H. H. SCOTT

The description of the TYPE 559-A Noise Meter published in our current catalog applies, in all particulars except reference level and range, to the new model. The price remains unchanged at $190.00.



# USES OF THE VARIAC



To determine the market and applications of the *VARIAC*, we recently made a survey of a small group of customers. In the belief that they will be of interest to our readers, we are publishing the results of this analysis. In view of the wide variety of uses reported, present owners may find suggestions for increasing the usefulness of the *VARIACS* they already have, and others, not acquainted with the versatility of the *VARIAC*, may find a convenient solution to problems involving the control of voltage.

As a sample, a group of 100 invoices for the *VARIAC* representing the latest 100 orders were taken from our files in chronological sequence, with no attempt at selection. A letter was sent to each purchaser asking what use was made of the *VARIAC*. To these 100 letters, 70 replies were received. All but 2 of these indicated, at least in general terms, what use was being made of the instrument, and all but 7 listed specific applications. An analysis of these letters yields some 24 classes of users and 12 classifications of use. Actually, 96 applications were listed, but many of them were listed by more than one customer. These tabulations are given below.

## USERS

| | | |
|---|---|---|
| Electrical Manufacturing | | 24 |
| Meters | 2 | |
| Appliances | 2 | |
| Motors | 1 | |
| Controllers | 2 | |
| Transformers | 1 | |
| Condensers, Resistors | 4 | |
| Lamps and Vacuum Tubes | 7 | |
| Radio Receivers | 2 | |
| Radio Transmitters | 3 | |
| Other Manufacturing | | 23 |
| Instruments | 8 | |
| Machinery | 4 | |
| Glass | 1 | |
| Dental | 1 | |
| Chemical and Metallurgical | 6 | |
| Petroleum Products | 3 | |
| Educational Institutions | | 4 |
| Radio Broadcasting Stations | | 3 |
| Photo Supply Dealers | | 3 |
| Electric Power Companies | | 2 |
| Photographers | | 2 |
| Research Laboratories | | 5 |
| Radio Service | | 1 |
| Operating Communication Companies | | 1 |
| Motion Pictures | | 2 |
| Total | | 70 |

## USES

(1) Voltage control for testing electrical equipment .......................20
(Overload, over-voltage, and under-voltage tests on relays, switches, appliances, radio transmitters, radio receivers, electrical instruments, etc.)

(2) Power-supply control for testing ....12
(The *VARIAC* is used in the primary of a high-voltage transformer.)

(3) Voltage adjustment on vacuum-tube equipment .......................14
(Adjustment of grid bias, filament voltage, plate voltage on radio transmitters, rectifiers, etc., also exhausting equipment in vacuum-tube manufacturing.)

(4) Voltage control in manufacturing processes other than vacuum tube ... 4

(5) Heat control in electric furnaces, oil baths, electric heaters, etc. .........12

(6) Illumination control in photography. 7
(Used to adjust voltage supplied to enlargers, flood lights, etc.)

(7) General laboratory use ........... 7
(8) Manual adjustment of line voltage to constant value and to boost low voltage........................ 3
(9) Electric lamp life tests and demonstrations........................ 4
(10) To obtain a wide range of 60-cycle calibrating voltage ............... 4
(11) Motor speed control ............. 3
(12) Miscellaneous ................... 6
- *a*. Demagnetizing iron.
- *b*. Avoid overload in experimental circuits by increasing voltage gradually.
- *c*. Soldering iron—quick heating.
- *d*. Modulating voltage for transmitter tests.
- *e*. Regulate output of electro-therapeutic equipment.
- *f*. Motion picture exciter lamp control.

Total ........................96

The users' classification shows that some 33% of these 70 customers are engaged in electrical manufacturing and 31% in other branches of manufacturing.

The use classification tells us what these 64% do with the *VARIAC*. Items (1) and (2), amounting to 33% of the total uses submitted, are in electrical testing, nearly all by manufacturers. Items (4), (5), (11), and a portion of (3) are a part of manufacturing processes, totaling 22%.

Nearly every electrical product, whether intended for industrial or consumer use, must be tested above and below its normal operating voltage, and accordingly we find that the largest individual item is (1) which covers this field.

The most important single use of the *VARIAC* in the manufacturing process itself is the control of heat. Item (5), which covers both manufacturing and laboratory heaters, is 13% of the total.

Grouping these items in another way, in 70% of the uses, the primary object is the control of voltage; in 30% some other quantity, such as heat, illumination, or speed, is controlled by means of voltage.

A third grouping can be made by separating the total into two main classes. In the first, the primary object is to vary voltage, in the second, to hold it constant by manual adjustment. While it is difficult to make an exact analysis from the data in the USES table, it appears that in about 75% of the uses the voltage is varied, and in 25% it is held constant.

While it is not evident from either of the above classifications, one additional grouping might be made, a division between those used by the purchaser and those built into equipment for resale. A large number of the *VARIACS* used in radio transmitters and electrical controllers are used as an integral part of larger assemblies and resold.

One of the most interesting aspects of the analysis was the diversity of use reported. Although the *VARIAC* has been on the market a relatively short time—our patent* on the principle having just recently been issued—the number of uses listed exceeds appreciably the number of replies received to our questionnaire. In other words, the average number of applications per user reporting was approximately 1.4. Generalizations drawn from limited data are, of course, not conclusive, but the ready acceptance and wide range of usefulness of the *VARIAC*, as indicated by the survey, undoubtedly predicts for the *VARIAC* an industrial career of considerable importance.

*U. S. Patent No. 2,009,013.

# RELAY-RACK MOUNTING FOR THE ELECTRON OSCILLOGRAPH

**FOR the three branches of electrical engineering — education, manufacturing, and research — the cathode-ray oscillograph has been a tool of inestimable value. Although the merit of its high-impedance and practically inertia-less element has long been recognized by the research workers, it is only in the last few years that modern vacuum tube production and the simplified design of linear-time-axis circuits have made it a serious competitor of the vibrating-element oscillograph. Recent papers on multi-element operation by means of commutation point the way to a still wider use at commercial power frequencies, as well as in the communication field.**

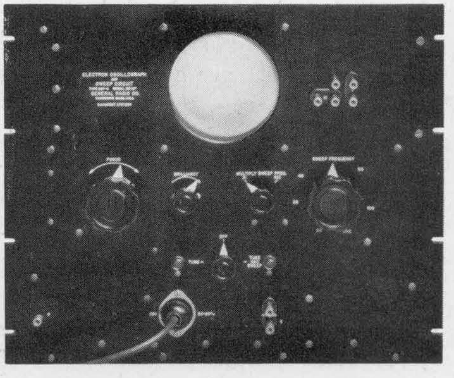
**To the fields invaded by the electron oscillograph, advertising must now be added. Although Braun would undoubtedly have had difficulty in visualizing any connection between his discovery and the manly art of shaving, the cathode-ray oscillograph appears as a research tool in the current advertising of the Gillette Safety Razor Company.**

IN the broadcasting station and the test laboratory, in fact in all permanent installations, relay-rack-mounted equipment is widely used. This type of mounting provides maximum accessibility in a minimum space and permits rear-of-panel interconnections.

Many General Radio instruments are supplied for relay-rack mounting; others can be converted for rack mounting if desired. The TYPE 687-A Cathode-Ray Oscillograph, not heretofore available in rack mounting, has recently been redesigned to facilitate this conversion.

The new models, TYPE 687-BM and TYPE 687-BR are identical in their electrical characteristics and specifications with the TYPE 687-A instrument, and the changes consist mainly of a mechanical rearrangement of parts. The relay-rack model is not carried in stock as such, but a cabinet model can be converted to rack mounting at the customer's request.

The prices given below are for standard models with fast-screen tubes.



| *Type* | | *Code Word* | *Price* |
|---|---|---|---|
| 687-BM | Cabinet Model | CRISP | $184.00 |
| 687-BR | Rack Model | CALIF | 224.00 |

# The GENERAL RADIO EXPERIMENTER

VOL. X. No. 7 — DECEMBER, 1935

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS


## THE NEW MODULATION MONITORS

**THE recent amendment of Rule 139 by the Broadcast Division of the Federal Communications Commission is of vital interest to everyone connected with radio broadcasting. This article discusses the specifications covered by Section (d) of Rule 139 from the viewpoint of the broadcasting station engineer and operator.**

THE Federal Communications Commission, recognizing the importance both to broadcasters and to the public of operating every broadcast channel at a high efficiency, has for several years required that all transmitters be capable of satisfactory operation at a modulation level of at least 75%. By a recent amendment to Rule 139 the Commission now requires that transmitters shall be capable of the still higher efficiency possible with the recent advances in design, and that means shall be available for continuously checking the modulation percentage. The amended Rule 139 says in effect:

(a) That all broadcasting transmitters shall be capable of delivering authorized power with a modulation of at least 85%; and that the total audio-frequency distortion generated by the transmitter at this level shall be not over 10%.

(b) That all stations shall have an approved modulation monitor.

According to the Commission's specifications, approved monitors must include a means by which the percentage of modulation can be continuously and easily read at all times, and must be equipped with an over-modulation alarm signal.

The purpose and usefulness of the monitor are immediately apparent. By its use station operators can maintain the highest possible modulation consistent with good broadcast practice, and, when modulation exceeds the capability of the transmitter, the alarm flashes a warning. A reasonable balance between inefficient under-modulation and distorted over-modulation is thus made possible. These characteristics are discussed more in detail later in this article.

Early in 1931 the General Radio Company placed on the market one of the first commercial modulation meters, the TYPE 457. This instrument was accurate, simple to operate and for the first time provided a means for easily determining modulation percentage without elaborate testing equipment. It was, however, a balance-operated device, not direct reading, and good only for steady-state conditions of modulation. The present need is for a direct-reading instrument which will follow accurately the rapid fluctuations resulting from voice or music modulation of the broadcast transmitter. The TYPE 731-A Modulation Monitor* has been developed to meet this need.

The first considerable number was installed in April, 1935, in the owned and affiliated stations of the Columbia Broadcasting System as a part of the complete CLASS 730-A Transmission Monitoring Assembly. The field trials thus obtained were of great assistance in determining how these instruments, and particularly the modulation monitors, worked out in practice in representative stations.

The transmission monitoring assembly not only provides the means for maintaining a continuous monitor of modulation percentage, but also for measuring the total harmonic distortion and the residual noise level of the transmitters. The modulation monitor is, of course, entirely self-contained and not dependent upon the other units in the assembly.

* Monitoring of Broadcasting Stations, L. B. Arguimbau, General Radio *Experimenter*, IX, 8 and 9, January and February, 1935.

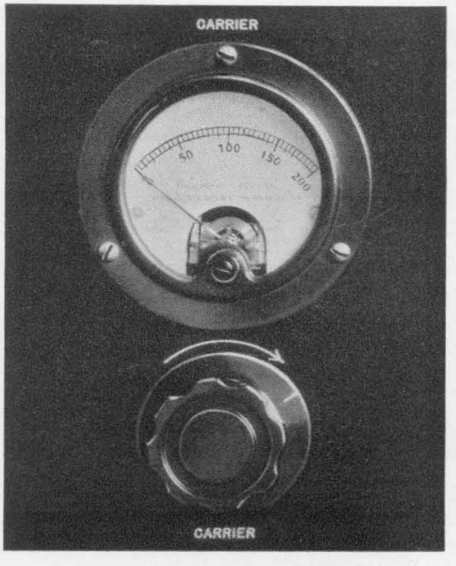
The Federal Communications Commission has specified in detail the electrical requirements of a suitable monitor. These requirements are met exactly by the General Radio TYPE 731-A Modulation Monitor.

The specifications are the result of a long study of the problem. In order to obtain the various viewpoints, the Commission held several conferences which were attended by engineering representatives of many operating companies and manufacturers. As a result of this study of the monitoring requirements of the broadcasting station, the final specifications were drawn, taking into consideration that the monitor as an instrument had to be simple in operation, accurate, and not expensive.

The important features which the monitor must provide are:

(1) A d-c meter for setting the average rectified carrier.

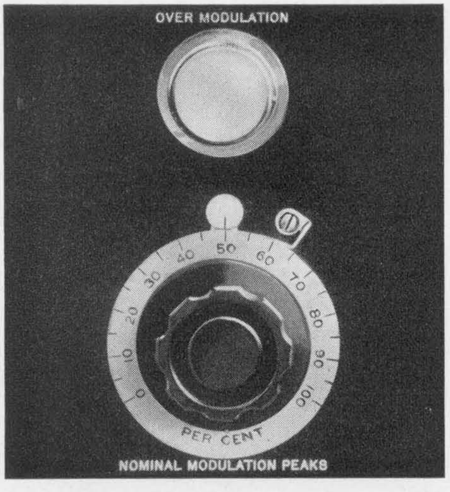
(2) A peak indicating light which flashes on all peaks exceeding a predetermined value set at will by operator.



(3) A meter indicating continuously the percentage modulation.

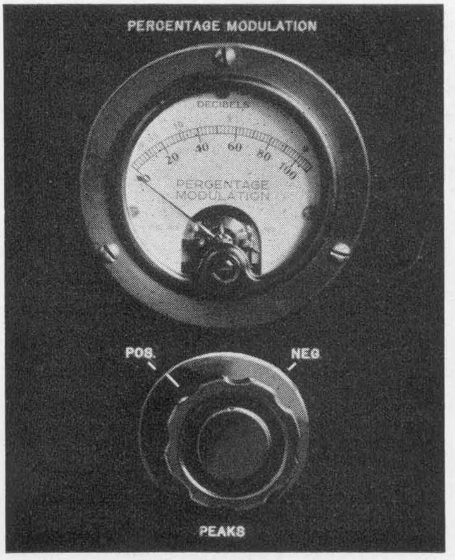
The d-c meter has two functions: first, it provides a means for indicating the reference carrier level at which the monitor is to operate and, second, it shows carrier shift during modulation, which is a warning of inequalities in positive and negative peaks, with the resulting probability of distortion.

The flashing light operates when the modulation exceeds any percentage that has been pre-set by the operator. The setting of the level of modulation above which the lamp flashes is determined by the modulation capability of the transmitter and by the type of program. It is set to flash with moder-




ate frequency while things are functioning normally. This is usually at a level of about 85% or higher. After a little experience, the normal rate of flash to be expected from any particular class of program material becomes familiar to the operators.

When used at first in conjunction with a monitoring loudspeaker, a surprising facility of modulation level




maintenance is developed by the use of the light alone. If, without a change in program, the rhythm of the flashes is markedly changed, the operator is immediately warned that something is wrong. If the flash rate slows down or stops, the modulation level has dropped too low, and if the light flashes continuously or not in synchronism with the loudspeaker monitor, trouble has developed in the transmitter. Since the light is visible at some distance, close attention to the monitor is not required. An electrical counter may be attached to provide a record of the number of over-modulation flashes occurring in a given period.

The third requirement is a meter which reads the actual percentage of modulation at all times. It can be switched to read either the positive or the negative modulation percentage. The meter has the new high-speed movement and is about critically damped. It reaches full-scale deflection in about 100 milliseconds with almost no overswing, and returns to zero in about the same time. If used directly on voice or music programs this high-speed movement would follow the rapidly changing levels faithfully, but its speed is so great that accurate monitoring would be difficult, and it would be rather tiring to watch it for any length of time, especially for those who are used to the lazy movement of the older volume indicator meters.

To avoid this it has been specified that the circuits of the monitor must be arranged so that, when a pulse of modulation between 40 and 90 milliseconds in duration occurs, it is stored electrically until the meter can reach 90% of its steady-state deflection. It is not desirable that shorter pulses show so prominently on the meter as these short bursts do not contain enough energy to be bothersome in case of over-modulation. The electrical circuit stores the pulse and then discharges rather slowly, the time for the meter to return from full scale to 10% of full scale being specified as between 500 and 800 milliseconds (it is 700 milliseconds in the Type 731-A Modulation Monitor). The result is a meter action which goes up extremely rapidly with modulation peaks and returns relatively slowly. This action has been selected for several reasons:

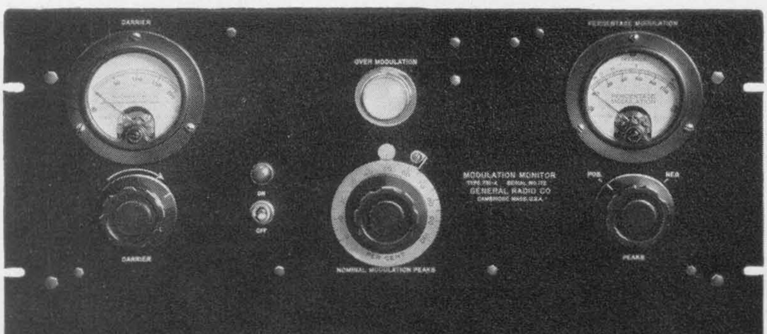
(a) A high-speed meter movement without the retarded return speed is rather difficult to follow by eye and soon results in fatigue, as mentioned previously.

(b) Monitoring is greatly facilitated when the meter stays at its top reading for a short time so that the peaks can be read.

(c) There is the feeling by observers that the meter reading corresponds with the sound heard by ear. This is a psychological effect and, although not of great importance, assists in monitoring. The dual-speed action (fast-up, slow-return) gives the impression that the monitor is following the peaks of the envelope of the modulation, and, in fact, it is registering faithfully the important modulation peaks as they occur, and the "floating" reading makes monitoring relatively a simple matter.

An additional requirement specifies that the monitor must have an extremely good audio-frequency characteristic (± 0.5 db from 30 to 10,000 cycles). This permits accurate measurements to be made of the over-all frequency response of a transmitter.

The foregoing paragraphs discuss the principal features of the specifications for modulation monitors as pub-



Panel view of Type 731-A Modulation Monitor lished by the Federal Communications Commission in a letter dated October 29, 1935, supplementing the new amended Rule 139.

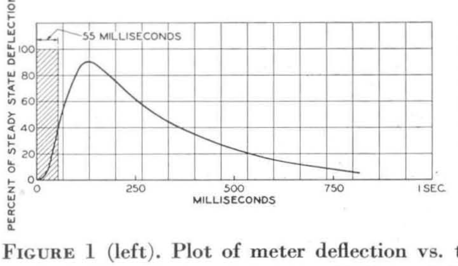
All monitors to be approved by the Commission are first carefully checked by the Bureau of Standards. At the time of our going to press the Bureau was not prepared to begin these tests, but, when the test set-ups are ready, a stock model of the General Radio modulation monitor will be submitted for test in order to obtain formal approval. —ARTHUR E. THIESSEN



# A NOTE ON THE MEASUREMENT OF METER SPEEDS

THE measurement of meter speed in the new modulation monitor presents an interesting problem. Photographing the action of the meter with a high-speed camera and a stroboscopic light source is a satisfactory method.

The plots of Figure 1 and Figure 2 were made from data obtained from this type of motion picture record. In order to compare accurately the motion of the pointer with the duration of the pulse, the modulation meter and



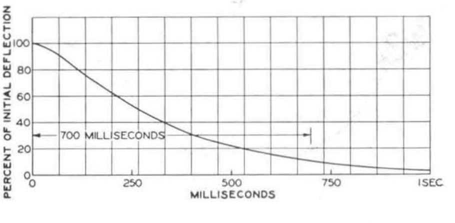




FIGURE 1 (left). Plot of meter deflection vs. time when a pulse of 55 milliseconds duration is applied. The pulse length is just sufficient to bring the meter to 90% of its steady-state reading on a pulse of the same amplitude. Note that the meter does not reach its maximum deflection until after the end of the pulse

FIGURE 2 (right). Deflection vs. time plot showing the meter returning to zero. The time required for the meter to return to 10% of its initial reading is 700 milliseconds a cathode-ray oscillograph were set up side by side, and the pulse applied to the meter was used to deflect the oscillograph beam. Flashing the stroboscope lamp at a speed of 60 per second gave a sufficiently complete record. From Figure 3, which shows a section of film, it will be noted that the trace on the cathode-ray tube is recorded continuously, while the meter is photographed at intervals of 1/60th second.

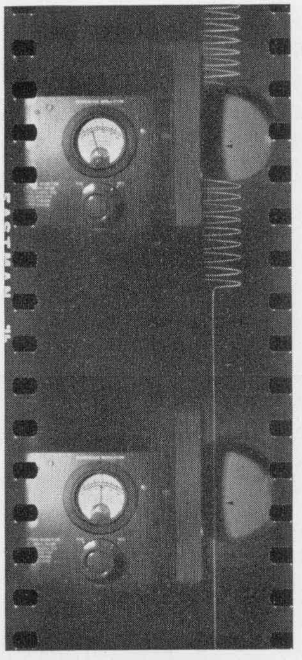
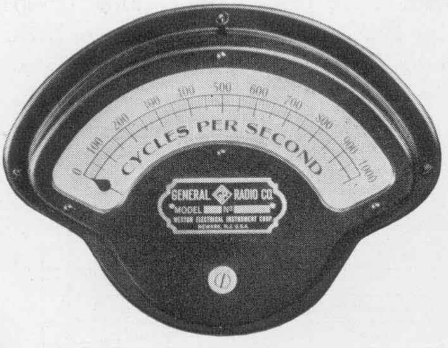


FIGURE 3. A section showing two frames of the motion picture record. The order of progression is from top to bottom. The oscillogram is recorded continuously while the meter is photographed at intervals of 1/60th second by means of the stroboscopic flash. The index mark was placed opposite the spot on the cathode-ray tube and indicates the position of the spot at the instant each photograph is taken. When the oscillogram becomes a straight line, showing the end of the pulse, the meter has not yet reached its maximum reading. This is shown graphically in Figure 1. In this photograph the oscillogram has been retouched to make it suitable for halftone reproduction

## A DIRECT-INDICATING AUDIO-FREQUENCY METER




A DIRECT-INDICATING audio-frequency meter is a great convenience in many laboratory measurements, or in production and testing operations where a large number of measurements must be quickly made. In some cases, a continuous indication of the value of a varying frequency is required. To meet these requirements, the TYPE 834-A Electronic Frequency Meter has been developed. This instrument is of radically new design, is direct reading from zero to 5000 cycles per second, and operates from the a-c line.

The meter consists, essentially, of an amplifier, a gas-discharge-tube counter, and an indicator. The fundamental circuit design of the instrument was devised by Dr. F. V. Hunt.*

Figure 1 is a schematic diagram showing the important circuit elements. A detailed explanation of the operation of the circuit will be found in a recent

* Cruft Laboratory, Harvard University.

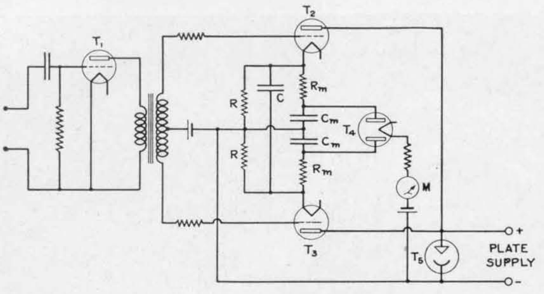



FIGURE 1. Schematic circuit diagram of the electronic frequency meter. For convenience, batteries are shown supplying the grid and meter biases. $T_1$ is an amplifier, $T_2$ and $T_3$ are gas-discharge tubes; $T_4$ is a double diode, and $T_5$ a voltage regulator. The circuits $R$, $C$, control the voltage on the grids of the gas-discharge tubes; the circuits $R_m$, $C_m$, control the action of the double diode

article† by Dr. Hunt published in the Review of Scientific Instruments.

The principle of operation is, briefly, as follows: On the application of an alternating voltage to the grids of the gas-discharge tubes, the tubes become alternately conducting and non-conducting. At each *transition* of the current from one tube to the other, a single, short current pulse is sent through the indicator circuit. As the successive current pulses are identical, the meter reading will depend only on the number of pulses per second, or the frequency.

The instrument includes a one-stage amplifier, the gas-discharge-tube counter circuit, diode switching tube, frequency-indicating meter and power supply (with rectifier and voltage regulator).

The amplifier provides for satisfactory operation on signal inputs of three volts or less, and also provides a high impedance input circuit (one megohm). By the arrangement of the amplifier circuit, provision is made for satisfactory operation over a wide range of signal input voltages, up to 200 volts, with no change in indication of frequency.

Five ranges are provided, each starting at zero and extending to 200, 500, 1000, 2000, and 5000 cycles. The desired range is selected by means of a multiplier switch mounted on the panel. Individual adjustments are provided for making the indication agree with the scale of the meter on each range. These adjustments are made at the factory, but, if necessary, readjustment may be made in the field. All adjustments are accessible from the panel, which is intended for mounting in a 19-inch relay rack.

The TYPE 834-A Electronic Frequency Meter is a time-saving aid in frequency measurements, such as the routine checking of a large number of radio transmitters. Generally, in such cases, the first question to be answered is: "Is the station frequency within the allowed tolerance?" and second, "How much does the station frequency deviate from the assigned value?" Both questions may be answered by the meter, but, having answered the first, often no further attention need be given to those stations falling well within the allowed tolerance.

In crystal grinding and similar adjustment operations, the indications of the frequency meter provide a continuous check on the progress of the adjustment — indicating when coarse adjustment is safe and also indicating when fine adjustments must be made to obtain the final desired

† A Direct-Reading Frequency Meter Suitable for High-Speed Recording, *Review of Scientific Instruments*, 6, 2, January, 1935.

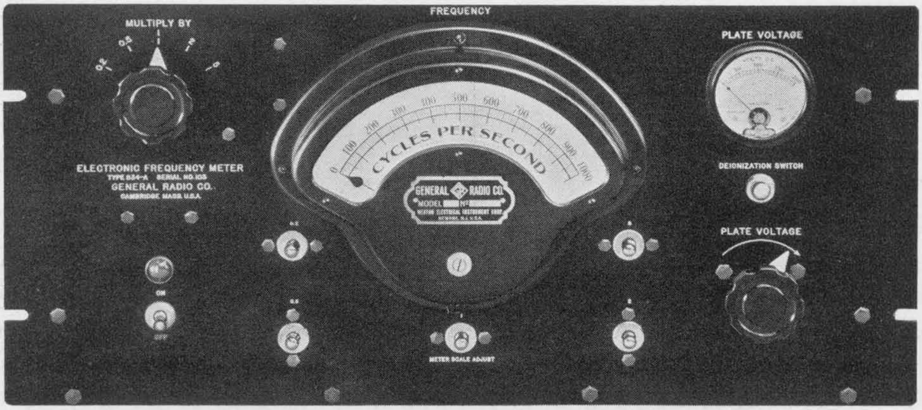



FIGURE 2. Panel view of TYPE 834-A Electronic Frequency Meter

value. Another example of this use is in tuning motor horns, chimes, and similar devices, where the continuous indication of the frequency is invaluable during the progress of adjustment.

When utilized with a sound or vibration pickup, the frequency meter is valuable in analyzing vibrations in machinery.

A simplified model of the electronic frequency meter will shortly be available for use in monitoring radio transmitters. This instrument, the TYPE 682-A Frequency-Deviation Meter, is intended to operate in conjunction with the TYPE 475-A Frequency Monitor which furnishes the power supply for the frequency meter, as well as the audio-frequency beat tone on which the meter operates. —J. K. CLAPP

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The TYPE 834-A Electronic Frequency Meter is available for immediate delivery. This instrument is manufactured and sold under the following U. S. Patents and license agreements:

Designs and patent applications of Dr. F. V. Hunt.

Patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.

| *Type* | | *Code Word* | *Price* |
|---|---|---|---|
| 834-A | Electronic Frequency Meter . . . | MUCUS | $250.00 |

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

GENERAL RADIO COMPANY

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