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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A VACUUM-TUBE-DRIVEN TUNING-FORK OSCILLATOR

Also IN THIS ISSUE

● **THE ELECTRO-MECHANICAL OSCILLATOR,** whose frequency is controlled by a tuning fork, has many uses in electrical communications. The Type 813 Oscillator and its predecessor the Type 213 have been used, for instance, as power sources for bridge measurements and for transmission measurements on lines and cables, as modulating sources for test oscillators and radio-beacon transmitters, and as test-tone sources for communication systems. For applications where a constant-frequency audio oscillator is needed for permanent installation in other equipment or circuits, the tuning-fork type is usually the most economical.

The Type 813 Oscillator, like its predecessor the Type 213, is a microphone-button-driven type. For some applications, in particular those requiring very low distortion, stability of output voltage, or a-c operation, vacuum-tube drive is more satisfactory. To meet these requirements, the new Type 723 Vacuum-Tube Fork, shown in Figure 1, has been designed. This instrument has extremely low distortion so that it can be used for distortion measurements without additional filters, and its output is much more stable

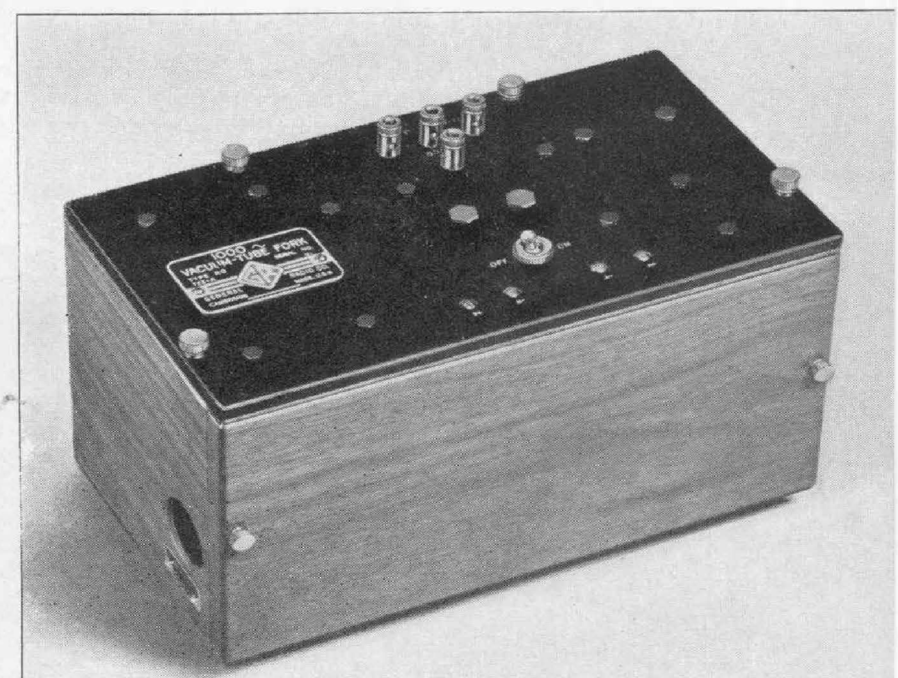


Figure 1. View of the Type 723 Vacuum-Tube Oscillator, showing the panel.

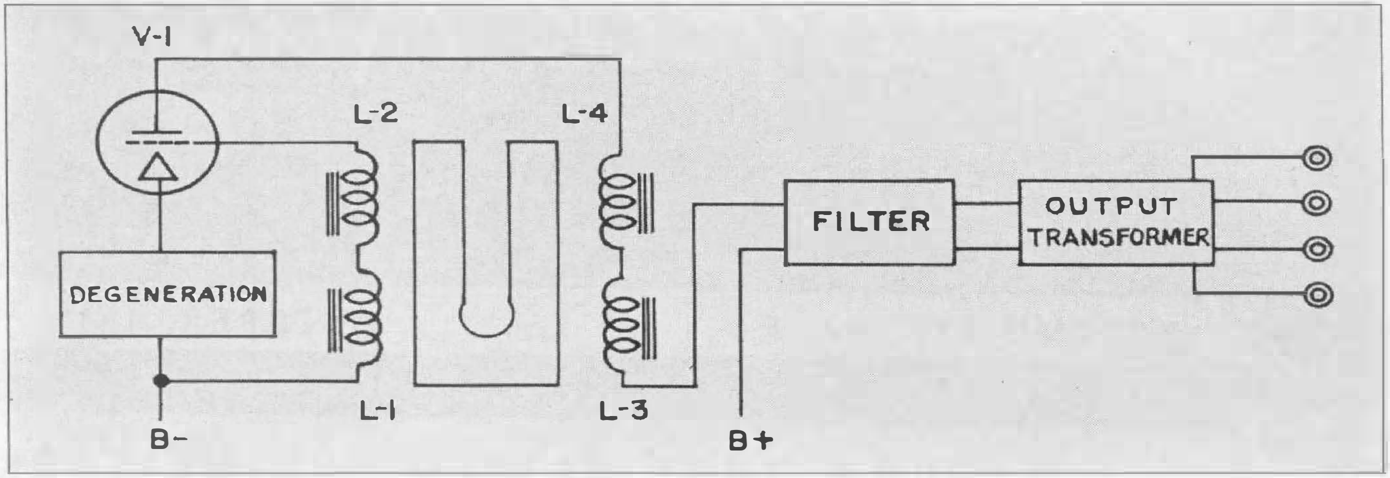


FIGURE 2. Functional circuit diagram of the TYPE 723 Vacuum-Tube Fork.

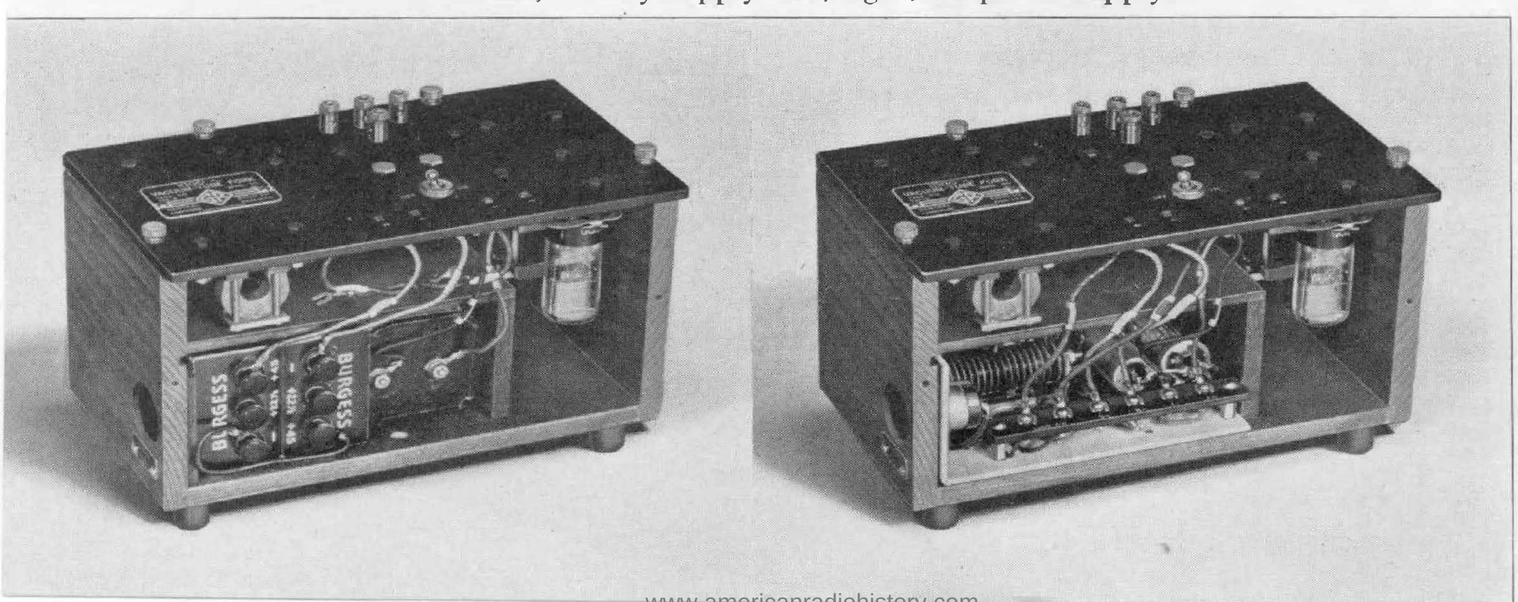
than that of the microphone-button type.

The tuning fork itself is identical with that used in the TYPE 813 Oscillator. Figure 2 shows the electrical circuit. Driving coils L_3 and L_4, wound on U-shaped permanent magnets to give a constant polarization, are arranged along one tine of the fork, and similar coils L_1 and L_2, facing the other tine, serve as pickup coils. A 1A5G-type vacuum tube provides the necessary amplification between pickup and driving circuits. The output filter is in series with the driving coils and feeds an output transformer. A tapped secondary winding provides output impedances of 50, 500, and 5000 ohms.

The TYPE 723 Vacuum-Tube Fork is available in two models, 1000 cycles and 400 cycles, and with either of two types of power supply, batteries, or an a-c power pack. The a-c power unit uses selenium rectifiers and includes a voltage regulator tube to minimize the effect of line voltage fluctuations. The two power supplies are interchangeable mechanically and mount in the oscillator cabinet as shown in Figure 3.

Because magnetic drive and pickup impose comparatively little restraint upon the vibration of the fork, the frequency stability and waveform of this oscillator are considerably better than those of microphone-button-driven types, and the effective Q of the fork is higher. Another factor contributing to low distortion is the greater degree of linearity obtainable in the operation of a vacuum tube than in a microphone but-

FIGURE 3. Views showing the power-supply compartment.
Left, battery supply and, right, a-c power supply.



ton. The output filter further reduces the harmonic amplitudes, so that the total harmonic content is less than 0.5% when the oscillator is operated into a load equal to or greater than the nominal output impedance.

The rated output is 50 milliwatts into a matched resistive load. The fork, the tube, and the associated circuit elements are mounted on the under side of a bakelite panel. The walnut cabinet includes space for the power supply.

SPECIFICATIONS

Frequency: The Type 723 Vacuum-Tube Fork is supplied for two operating frequencies, 1000 cycles and 400 cycles. (See price list below.)

Frequency Stability: The temperature coefficient of frequency is approximately −0.008% per degree Fahrenheit. The frequency is entirely independent of load impedance. When the a-c power supply is used, an initial downward drift of frequency occurs as the temperature of the fork is affected by heat generated in the power-supply unit. The total frequency drift is of the order of .15% to .2%. Most of this drift, however, occurs in the first 30 minutes of operation.

Accuracy: The frequency is adjusted to within ±0.01% of its specified value, at 77° Fahrenheit, using battery power supply.

Output: The output to a matched load is approximately 50 milliwatts.

Internal Output Impedance: Output impedances of 50, 500, and 5000 ohms are provided.

Waveform and Hum Level: The total harmonic content is less than 0.5%. The hum is negligible.

Terminals: Binding posts for the output circuit are mounted on the panel. Battery terminals are brought out to sunken screw heads on the panel to permit measurements of the battery voltages.

Power Supply: The instrument is available for either battery operation or for operation from 105 to 125-volt, 50 to 60-cycle line. For battery operation one Burgess type 4FA (1½ volt) and two Burgess type Z30-N (45-volt) are required. The batteries and a-c power supply are interchangeable. The power supply, Type 723-P1, is available separately. (See price list.) The ON-OFF switch is arranged to control the a-c line or the battery current.

Vacuum Tubes:

For battery supply: 1 type 1A5G
For a-c supply: 1 type 1A5G
1 type VR-105-30

The necessary tubes are supplied.

Accessories Supplied: A seven-foot line connector cord is supplied with the a-c operated model.

Mounting: The oscillator assembly is mounted on a bakelite panel and is enclosed in a walnut cabinet.

Dimensions: (Length) 10⅝ × (width) 6¼ × (height) 7¾ inches, over-all.

Net Weight: 11¼ pounds, including batteries; 8 pounds 14 ounces, with a-c supply; a-c power supply alone, 1¼ pounds.

Type	*Frequency*	*Power Supply*	*Code Word*	*Price*
723-A	1000 cycles	Batteries	SNAKE	$70.00
723-C	1000 cycles	105 to 125 volts, 50 to 60 cycles	SOLID	90.00
723-B	400 cycles	Batteries	STORY	70.00
723-D	400 cycles	105 to 125 volts, 50 to 60 cycles	SULKY	90.00
723-P1	A-C Operated Power Supply Only		SNAKEYBATT	22.00
723-P2	Set of Replacement Batteries		SNAKEYPACK	2.00

NOTE TO EXPEDITERS

To insure an early reply to follow-up inquiries on undelivered orders, please state in your inquiry the order number, the date of the order, and, if space permits, the material ordered. This information will assist us materially in locating and tracing your order.

IMPEDANCE BRIDGES ASSEMBLED FROM LABORATORY PARTS

PART IV—TRANSFORMER ERRORS

THE IDEAL SHIELDED TRANSFORMER interposed between a generator and bridge would provide complete isolation between the two windings, except for the desired inductive coupling. Even in a carefully designed and constructed transformer, however, there will be some small residual electrostatic and leakage coupling between the windings, which will introduce extraneous voltages into the bridge circuit. This type of error may best be analyzed by considering the effect of introducing (across any arm of a bridge) an external voltage E' in series with an impedance Z_T, as illustrated in Figure 1. The equation of balance for this network is

$$Z_P = \frac{Z_B}{Z_A} \frac{Z_N\left(\frac{Z_T}{\beta}\right)}{Z_N + \left(\frac{Z_T}{\beta}\right)} * \qquad (1)$$

The parameter β is given by

$$\beta = 1 \pm \alpha\left(1 + \frac{Z_B}{Z_A}\right) *$$

where $\alpha = \frac{E'}{E_O}$.

*These equations are strictly true only for the case of a zero-impedance generator. For a generator of finite impedance, Equation (1) may still be used, but the expression for β becomes more complicated.

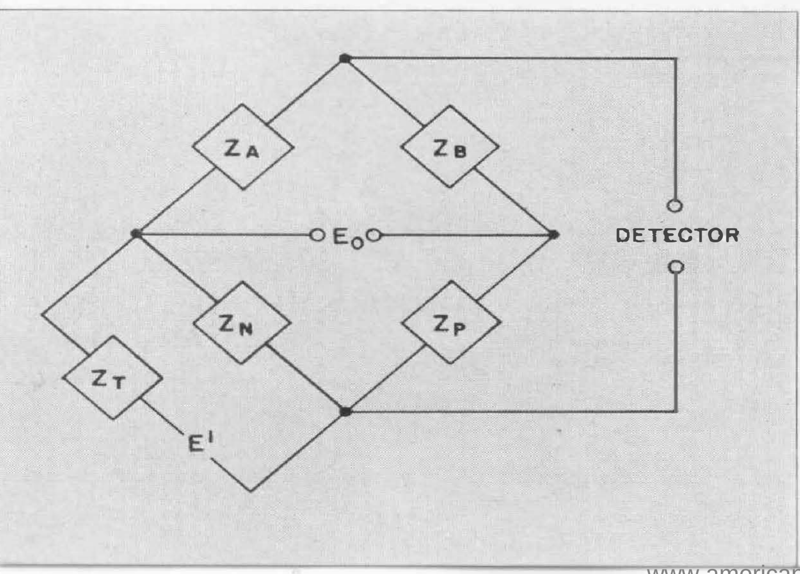


FIGURE 1. Showing an external voltage connected across a bridge arm through an impedance Z_T.

It will be observed that the balance Equation (2) is identical to that which would be obtained if a passive impedance equal to $\frac{Z_T}{\beta}$ were connected in parallel with Z_N. This fact makes it possible to estimate readily the effect of stray coupling from the voltage source to the bridge.

By properly choosing the magnitude and polarity of E' the expression for β can be reduced to zero (for a given value of the ratio $\frac{Z_B}{Z_A}$). Under this condition no error will be caused by the presence of Z_T, as it will effectively appear as an infinite impedance across Z_N. In Figure 3 is presented an experimental verification of this fact. The observed change in power-factor reading of a TYPE 716-A Capacitance Bridge is plotted against the computed value of the parameter β for various values of E'. Theoretically, this plot should be a straight line, passing through the origin, of slope equal to the coupling resistance R_T. The agreement obtained is well within the limit of experimental error.

In the practical case where E' is the voltage source supplying the bridge, the ratio α is the effective voltage ratio of the bridge transformer. Thus from the point of view of reducing the effect of residual interwinding coupling, there is an optimum turns ratio for any given bridge. In general, of course, other considera-

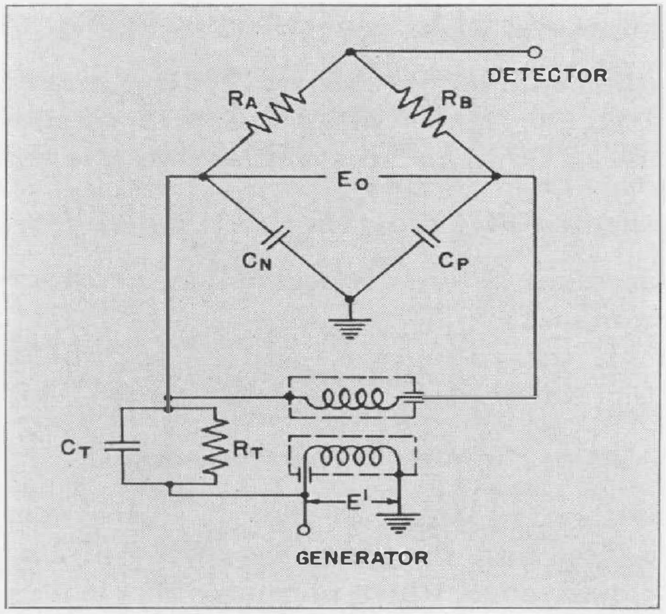


FIGURE 2. Showing how an impedance between windings of a TYPE 578-A Shielded Transformer gives rise to the situation shown in Figure 1.

tions dictate the choice of turns ratio, but it is well to keep in mind that there is a best choice of *polarity*.

Using the TYPE 578-A Shielded Transformer in the bridge arrangements previously described, the residual coupling between windings effectively places a small capacitance (βC_T) in parallel with large resistance $\frac{R_T}{\beta}$ across one of the *capacitance* arms of the bridge.

This can be seen by comparing Figures 1 and 2. With the bridge grounded at the junction of the capacitance arms, the oscillator voltage E', in series with C_T, R_T, is placed across the N arm. Although there is some coupling from the high side of the primary to either secondary terminal, the only path shown is to that terminal which is connected to the secondary shield. The other is negligible in comparison.

The capacitance C_T is of the order of a few tenths of a micromicrofarad, while the d-c leakage resistance is of the order of 10,000 megohms or greater. In addition to the d-c leakage, there is a component of resistance contributed by the dielectric losses associated with C_T. At 1000 cycles this component is roughly of the same magnitude as the leakage resistance. At frequencies much below this, the latter component is more important, while at higher frequencies the dielectric losses in C_T become the significant component.

In the previously suggested arrangement of the Schering circuit the impedance $\frac{Z_T}{\beta}$ is placed across P, or unknown arm of the bridge, and becomes part of the zero capacitance and dissipation factor of that arm. Since β varies with the setting of the ratio arms, however, this component is not constant, and the value of C_{SG}† and D_{SG}† will not be the same for all settings of the ratio arms. For large values of $\frac{A}{B}$ a fairly large capacitance is added, but in this case the unknown (C_P) is large and the error remains negligible.

In the series-resistance bridge as de-

†See August and September, 1941, *Experimenters.*

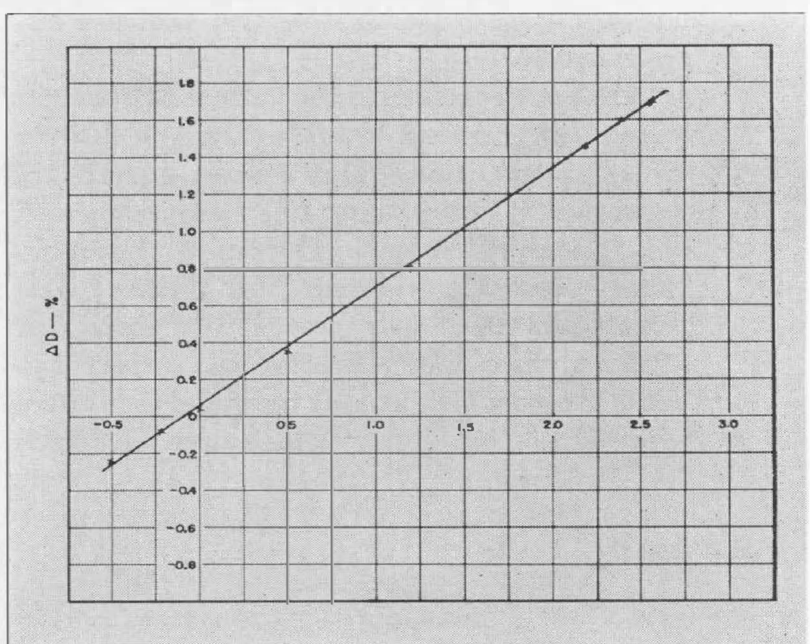


FIGURE 3. Plot of observed change in dissipation factor as a function of β. The slope corresponds to a resistance of 226 megohms. The measured d-c value of the coupling resistance used was 221 megohms.

scribed, $\frac{Z_T}{\beta}$ is placed across the N, or standard arm of the bridge, where it is completely negligible if β remains reasonably small, since $C_N = 10{,}000\ \mu\mu f$. In the extreme case, however, of $\frac{B}{A}$ equal to 1000, a capacitance of the order of 25 $\mu\mu f$ will be placed across C_N, i.e., $\beta = 1 \pm \frac{1}{4}(1 + 1000)$. Although small compared to 10,000 $\mu\mu f$, this value is not negligible. But a value of $\frac{B}{A}$ equal to 1000 corresponds to a capacitance in the P arm of only 10 $\mu\mu f$. Thus the error of 25 parts in 10,000 introduced corresponds to only a few hundredths of a micromicrofarad in the determination of the unknown capacitance.

Similar arguments will show that the effect of $\frac{R_T}{\beta}$ is generally negligible to other sources of error, at 1000 cycles. For extreme values of bridge arm impedances, however, it is well to estimate the effect of βC_T and $\frac{R_T}{\beta}$ for any given measurement before a statement of accuracy is made.

If the voltages E' and E_O are not in (or 180° out of) phase the ratio α becomes complex. The impedance $\frac{Z_T}{\beta}$ is then no longer of the same character as Z_T, and the presence of a coupling capacitance, which normally affects only the capacitance balance, will produce a shift in dissipation factor balance. Similarly, a resistance coupling will affect the capacitance balance. This can occur at higher frequencies, where the leakage reactance of the transformer becomes appreciable, producing a phase shift between input and output voltages.

— IVAN G. EASTON

MORE INFORMATION, PLEASE!

● **TIME**--a particularly valuable commodity to defense industries — can frequently be saved when equipment is returned for repairs if an effort is made to supply our Service Department with detailed information on the trouble experienced.

Often instruments have been returned with no greater trouble than a blown fuse or deteriorated vacuum tube. Occasionally equipment has been returned in first-class condition because the operating instructions supplied with it had not been followed, or possibly were not fully understood. Frequently what appears to be unsatisfactory performance can be traced to the external circuit with which the instrument is being used.

The unfortunate aspect of such cases is that our Standardizing Laboratory must spend considerable time in checking these returned instruments to make sure that there are no other sources of difficulty and no intermittent troubles which may be lying dormant only to reappear at the customer's laboratory. If these checks reveal no evidence of faulty operation we must then write the customer for information which might better have been furnished earlier and might even have eliminated the necessity for returning the equipment, thereby saving time, inconvenience, and expense.

Even when equipment is actually in

need of repairs, a detailed statement of the trouble may be very helpful. Analysis of this information sometimes shows that the trouble is caused by a single defective component which can be easily replaced. Where time is important, this part can be supplied to the customer with instructions for its installation in the instrument. If, on the other hand, the equipment must be returned, our laboratory will at least know what condition needs correction, and no time will be lost in making extra preliminary checks. Since repair charges depend upon the cost of the labor and material involved, a considerable saving can thus be made in the repair charge.

A further advantage of the detailed report is that it eliminates the possibility of our overlooking an intermittent fault while some other defect is discovered and corrected.

The following procedure is recommended when trouble apparently develops in General Radio equipment:

(1) Study the instruction book carefully.

(2) Check all fuses.

(3) Check all batteries under normal load. Replace if they show less than rated voltages. If batteries are old, it is advisable to try a new set, because the internal resistance may be high enough to cause trouble without showing a serious drop in voltage.

(4) Check all tubes.

(5) Check carefully the external circuit with which it is being used, particularly if the circuit is a new one.

If the source of trouble cannot be located, write our Service Department, giving the type and serial number of the instrument, a description of the exact nature of the defect, telling whether it developed suddenly or over a period of time, and a diagram of the circuit connected to it showing component values and locations of grounds. When measuring instruments, such as bridges or meters, give inaccurate readings, a sheet of sample data and a description of the method of measurement should be given. When the instruction book gives several paragraphs under the titles of INSTALLATION and OPERATION, it is especially helpful to describe the observed effects of carrying out the consecutive steps in each paragraph.

Upon the receipt of this information the Service Department will be in a position to render prompt assistance and can advise you at once how your service problem can best be handled.

When repairs are to be made on instruments needed in the execution of a National Defense contract, the work can be greatly facilitated if the preference rating is mentioned in the repair order.

— Kipling Adams

FREQUENCY MODULATION

● **BY NOW** almost everyone has felt the impact of the National Defense Program in one way or another. For many manufacturers, including the General Radio Company, it has meant a complete rearrangement and expansion of manufacturing facilities. Most of our plans for new equipment, especially for non-defense material, have been completely changed, and we are putting our maximum effort into the production of urgently required defense supplies.

One of the non-defense activities that we have been especially loath to postpone is the production of instruments for broadcast frequency modulation.

Designs had been completed and production was well under way for a modulation monitor for FM transmitters and for a standard-signal generator for FM broadcast receiver testing. We believe that both of these instruments are designed to cover adequately the requirements of their special fields, and under ordinary circumstances they would have been on the market some time ago. The manufacture of them has had to be put aside, at least temporarily, but we are glad to say that we are able still to continue engineering development of improved circuits and methods; in the end, of course, we intend that the instruments shall be up to the minute when they are finally released.

Another instrument that is being developed in the laboratory is a frequency monitor for FM, and this work will be continued up to the point of production so that we can start it immediately when production facilities are again available.

These are examples of the work that is continuously going on in our laboratories. Many of our engineers are working on instruments directly connected with the defense program, but a part of the staff is continuing the development of more generally useful equipment. As has happened before in a situation of this kind, the great concentrated effort on military equipment will result in a big step forward for the communications art in general, and all lines of radio development will eventually receive the benefits of the things that are being learned in doing the defense job.

— A. E. Thiessen

ABOUT THAT SHOTGUN SHELL

We have received a number of comments from readers about Figure 3 of the article on the Microflash appearing in last month's *Experimenter*. The caption is undoubtedly incorrect, and the shell was fired from the *right* of the picture.

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.

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