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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also IN THIS ISSUE

THE NOISE PRIMER

PART XII

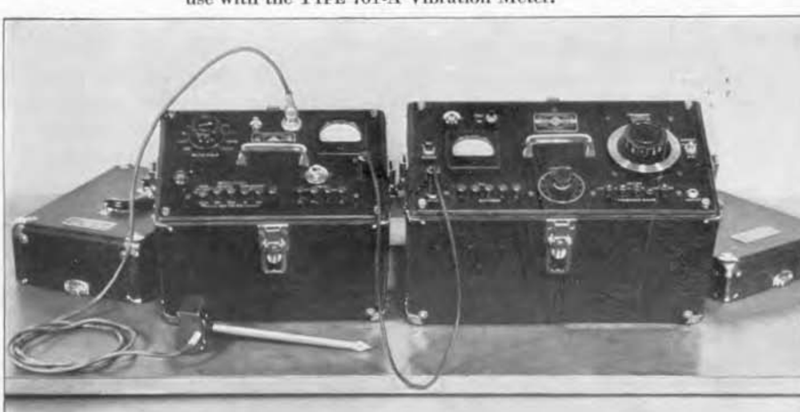
ANALYSIS OF VIBRATION

● **THE VIBRATION METER** measures the displacement, velocity, or acceleration of a vibration in terms of the r-m-s value of the waveform. Unless the waveform is substantially sinusoidal, however, the vibration meter by itself gives little information about the frequencies involved.[32] An analyzer, therefore, is desirable and in many cases a necessity. As with noise, the analysis of vibration provides clues to the sources of the various components and information necessary in the suppression of the vibration.

The general discussion of analysis and the classification of noises contained in Part VI (April *Experimenter*) applies equally well to vibration and need not be repeated here. Vibration, like noise, may be classified into two types — Class 1, or pitched, which consists mainly of harmonics or subharmonics of a fundamental frequency, all of which

[32]For sinusoidal vibrations, a measure of the frequency may be obtained by taking readings of displacement and velocity. As shown in Equations (5) and (6), the frequency will be: $f = \frac{v}{2\pi x}$. Displacement (x) and velocity (v) readings are better for this sort of frequency measurement than acceleration readings, since they are less affected by any harmonics that may be present in the waveform.

FIGURE 25. The TYPE 762-A Vibration Analyzer was designed particularly for use with the TYPE 761-A Vibration Meter.



will vary in frequency by the same percentage that the machine speed varies; and Class 2, or unpitched, which are caused by shock excitation and occur over bands of frequencies.

Analyzer Characteristics

The degenerative analyzer circuit as used in the TYPE 760-A Sound Analyzer (see Part VI) is even better suited to vibration problems, since its circuit is naturally adapted for use at very low frequencies. This type of analyzer does not require any inductances or transformers in its construction. Hence it is free from the usual difficulties encountered when iron cores are used at low frequencies with attendant distortion and pickup. For use in the frequency range above 25 cycles, the standard TYPE 760-A Sound Analyzer is satisfactory. For vibration problems involving lower frequencies, a special instrument has been developed.

The Type 762-A Vibration Analyzer

The TYPE 762-A Vibration Analyzer[33] covers the frequency range from 2.5 to 750 cycles per second (150 to 45,000 rpm), but otherwise is similar to the sound analyzer. The meter scale on the vibration analyzer is calibrated in linear units for reading displacement, velocity, and acceleration directly in terms of micro-inches, micro-inches per second, and inches per second per second, respectively, rather than decibels, thus matching that on the TYPE 761-A Vibration Meter. The selectivity characteristics are shown in Figure 26. It will be noted that the selectivity curve maintains the important constant shape in terms of percentage of the resonant frequency over the entire range, while operation of a conventional heterodyne analyzer in the low-frequency range becomes completely impractical. The degenerative circuit, so far as is known at the present time, provides the most satisfactory means for obtaining high selectivity at subaudible frequencies.

The general design features of the vibration analyzer are the same as for the sound analyzer.

[33]This analyzer was described in "An Analyzer for Sub-Audible Frequencies" by H. H. Scott, Journal of the Acoustical Society of America, Vol. XIII, No. 4, pages 360–362, April, 1942.

PART XIII

HOW TO USE THE VIBRATION ANALYZER

Relative Readings

All batteries for operating the vibration analyzer are contained within the case. Push buttons and a neon lamp on the panel indicate when the batteries should be replaced. The instructions mounted in the cover of the instrument should be followed.

Tuning is accomplished by the large knob and the push button range switch. The calibration is direct reading in cycles per second and may be converted to rpm by multiplying by 60.

A cord is provided to connect the input of the analyzer to the output of the vibration meter. For relative readings, the 0-to-120 scale is most convenient, and the sensitivity control on the vibration analyzer should be set so that for the strongest component of the vibration the reading is 100. This should be done with the vibration meter so adjusted that a normal indication is obtained on the indicating meter of that instrument.

The best procedure for setting the sensitivity control of the analyzer is as follows: Press range button A (2.5 to 7.5 cycles) and turn the main analyzer dial slowly, noting the deflections of the meter on the analyzer. Repeat, covering the entire range of the instrument by successively pressing buttons B, C, D, and E, and turning the dial around. The dial may be rotated continuously in one direction.

During this process the SENSITIVITY control on the analyzer should be turned down whenever a component is found which deflects the meter above 100, so that the meter reads 100 exactly. This sets the sensitivity such that the analyzer will read 100% on the strongest component in the vibration. *Do not change the setting of this control before the analysis is completed.*

The analyzer should then be tuned for maximum amplitude on each component (without resetting the sensitivity control) and the results recorded directly in terms of frequency and percentage of the amplitude of the strongest component. The procedure is exactly the same as for the sound analyzer. Because of the natural slow response of highly selective low-frequency circuits, a METER RETURN button is provided. When the operator has tuned the analyzer away from a component, pressing this button will return the meter reading quickly to zero.

The vacuum-tube voltmeter circuit included in the vibration analyzer provides a semilogarithmic scale on the indicating meter, so that the entire usable range of the instrument may be obtained without additional multipliers, etc. The controls of the vibration meter and the SENSITIVITY control of the vibration analyzer should not be readjusted during the analysis.

The analyzer is equipped with an output jack for operating a pair of phones which may be used for listening to the component being measured, if it is of audible frequency.[34]

Absolute Readings

For most purposes, relative readings are sufficient, but absolute readings may also be made with the vibration analyzer if desired. For absolute readings, the calibration procedure is as follows: Connect the vibration meter to the 60-cycle line as when adjusting its calibration. Connect the analyzer to the vibration meter in the normal manner. Depress the button marked CALI-

[34]Because of the a-v-c characteristics of the vacuum-tube voltmeter circuit, the output applied to the phones is not a pure sinusoid. Hence some output may be heard at very low frequencies which would normally be inaudible.

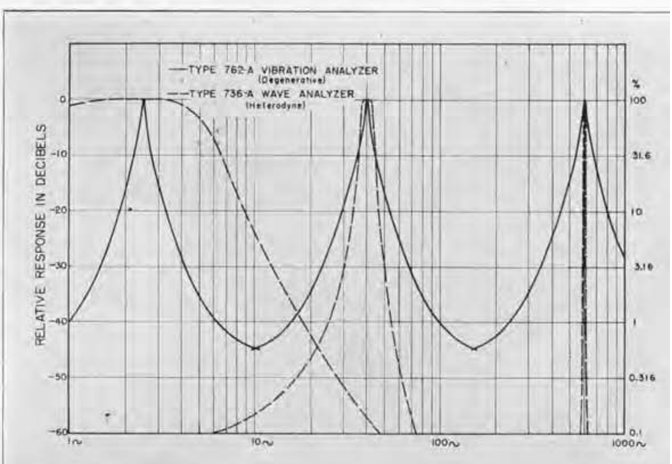
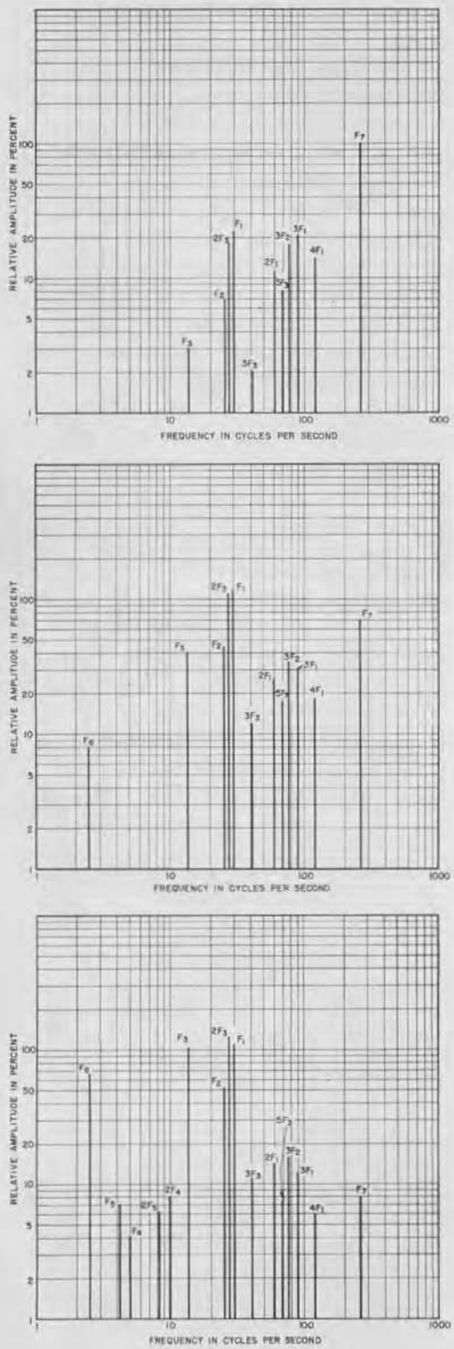


FIGURE 26. Selectivity characteristics of the TYPE 762-A Vibration Analyzer as compared with a typical (TYPE 736-A) heterodyne type of wave analyzer. Of utmost importance is the selectivity curve of the vibration analyzer, which maintains a satisfactory width and shape at both low and high vibration frequencies.



BRATE 1 on the vibration meter and tune the analyzer to maximum response at the power-line frequency. Adjust the analyzer sensitivity control so that the meter on the analyzer reads the same as the one on the vibration meter.[35] It is desirable to mark this calibration point on the sensitivity dial of the analyzer with a pencil so that it can be returned to if the control is accidentally shifted. The control should be left at this point and not readjusted during an analysis.

After the analyzer sensitivity is set, the vibration meter should be disconnected from the power line and adjusted for normal reading on the vibration to be analyzed. The analyzer may then be tuned to the various components of the vibration, the meter of the analyzer being read in exactly the same way as the meter of the vibration meter, using the readings of the METER SCALE knob and the multiplier factors of the push buttons on the vibration meter. The METER SCALE knob on the vibration analyzer also should not be readjusted, but should be left at the setting which gives a deflection on the upper part of the meter scale on that instrument.

The red scale on the analyzer should be used when the METER SCALE knob of the vibration meter is set at a red point and the black scale when the knob is set at an uncolored point. The

[35]On recent-production vibration analyzers the red and black scales track the same as on the vibration meter. On earlier models the scales are slightly displaced. With these analyzers two positions of the sensitivity control should be determined, one for the red scale and one for the black, if maximum possible accuracy is desirable. Otherwise an average setting is satisfactory.

FIGURE 27. Typical analyses of machinery vibration, showing (top) displacement, (center) velocity, and (bottom) acceleration measurements as made on a single machine under the same conditions. These illustrate the complexity of the vibrations which can be analyzed with the vibration analyzer, also the differences in the importance of the various components in measurements of displacement, velocity, and acceleration.

analysis will then be in terms of the same absolute values as the vibration meter reading[36] and the same multiplying factors will apply.

Displacement, Velocity, and Acceleration

The analysis will be made in terms of displacement, velocity, or acceleration, depending upon the setting of the vibration meter. Choice among these different characteristics should be based upon the same considerations as when measuring vibration, as described in Part XI.

Figure 27 shows typical machinery vibration analyses as made with the TYPE 761-A Vibration Meter and the TYPE 762-A Vibration Analyzer for (a) displacement, (b) velocity, and (c) acceleration. The change in the relative amplitudes of the various components for the different types of measurements will be noted.

[36]Referring to Note 25a (June issue), which gives general equations for Class 1 (pitched) vibrations, the readings of the analyzer on displacement will correspond to $\frac{1}{\sqrt{2}}A_1, \frac{1}{\sqrt{2}}A_2, \frac{1}{\sqrt{2}}A_3$, etc., on velocity to $\frac{1}{\sqrt{2}}\omega_1 A_1, \frac{1}{\sqrt{2}}2\omega_1 A_2, \frac{1}{\sqrt{2}}3\omega_1 A_3$, etc., and on acceleration to $\frac{1}{\sqrt{2}}\omega_1^2 A_1, \frac{1}{\sqrt{2}}4\omega_1^2 A_2, \frac{1}{\sqrt{2}}9\omega_1^2 A_3$, etc. The corresponding total levels indicated by the vibration meter are given in Note 25b. In general, the equations for Class 2 (unpitched) vibrations will be the same, excepting that the components are not necessarily harmonically related.

The use of the TYPE 762-A Vibration Analyzer is not limited to the analysis of the output of the TYPE 761-A Vibration Meter. It can be used with any vibration meter for measuring either linear or torsional vibrations.

* * *

This is the end of The Noise Primer. Whether it has been too long or too short, too technical or too popular are matters we are not in a position to judge. It is hoped at some future date to reprint the series, with whatever modifications may prove desirable, in the form of a booklet to succeed Bulletins 20 and 30 ("The Technique of Noise Measurement" and "The Technique of Noise Analysis," respectively).

If you have any suggestions concerning such a booklet, please write to us. Also, we shall be glad to answer any other questions in regard to the measurement or analysis of noise and vibration, so far as we are able. We do not run a consulting service, neither is it our intention to write a textbook. We are, however, anxious to provide the best information possible to users of our equipment in order that they may secure a maximum benefit from its use. Your suggestions, therefore, are very important.

— H. H. SCOTT

400-CYCLE OPERATION OF 60-CYCLE INSTRUMENTS

● THE FLIGHT TESTING of airplanes often involves a variety of electrical measurements, many of which are not easily handled by an automatic radio recording system. Many standard laboratory measuring instruments, designed for 60-cycle power supply, can be used directly on the 400-cycle supply available in planes. In particular, instruments whose voltage regulating systems are not frequency sensitive, and in which slight increases in background hum are not serious, may give quite satisfactory performance.

A number of General Radio instruments have recently been tested on the

500-cycle power supply available in our laboratories. The results of these tests are listed below.

Type 631-B Strobotac

The operation of this instrument was normal in all respects. However, since the reed provided for checking the calibration is tuned to 60 cycles, it could not be used at the higher frequency. This should not be a serious drawback, because the periods of operation at 400 cycles would presumably be short, and the instrument could be standardized at 60 cycles before and after the test flight.

Type 804-B UHF Signal Generator

The performance obtained was quite satisfactory, although appreciable power supply hum appeared at the r-f output terminals. With the generator unmodulated, however, this should be of no consequence.

Type 620-A Heterodyne Frequency Meter and Calibrator

Except for a noticeable hum in the audio-frequency output, operation was quite satisfactory. The only effect of the increased hum is to reduce the effective sensitivity so that very weak beat tones are not as easily detected.

Type 700-A Beat-Frequency Oscillator

The operation of this instrument was normal, with a barely audible hum in the head telephones connected to the output terminals.

Type 736-A Wave Analyzer and Type 834-B Electronic Frequency Meter

Neither of these instruments could be made to operate properly. They cannot be used at frequencies of the order of 400 or 500 cycles with their present power supply.

INSTRUMENTS DISCONTINUED SINCE THE PUBLICATION OF CATALOG K— 1939 EDITION

● SINCE THE PUBLICATION OF CATALOG K, 1939 edition, the items in the following list have been discontinued in order that we might use our facilities more efficiently for the production of items urgently needed for the war effort. Some of these are small items for which no appreciable war demand exists. Others have been made obsolete by advances in the art. Also included are instruments for which satisfactory substitutes can be obtained from other manufacturers.

Type	*Description*
25-A	Frequency Monitor
70	Variacs
80	Variacs
90-B	Variac
138-A	Binding Post
138-D	Switch Contact

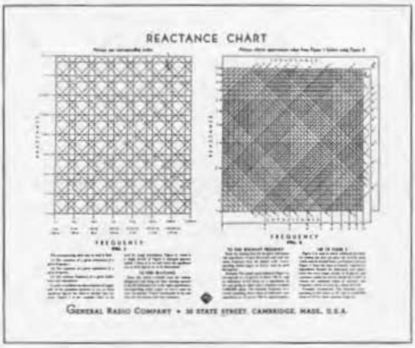
Type	Description
154	Voltage Dividers
202-A,-B	Switch
202-Y,-Z	Switch Knob
219-L,-N	Decade Condensers
246	Variable Air Condensers
247	Variable Air Condensers
274-K,-L	Binding Post Assembly
274-ML	Double Plug
293-A	Universal Bridge
329-J	Attenuation Box
333-A	Rheostat Potentiometer
334	Variable Air Condensers
335	Variable Air Condensers
358	Wavemeter
410-A	Rheostat Potentiometers
419-A	Rectifier-Type Wavemeter (replaced by TYPE 758-A)
433-A	Rheostat-Potentiometer
434-B	Audio Frequency Meter
449-A	Adjustable Attenuator
476-A	Quartz Bar
480-A, B	Relay Racks
493	Thermocouples
505-T, U, R, X	Mica Condensers
509-F, G, K, L	Standard Condensers
516-C	Radio-Frequency Bridge (replaced by TYPE 916-A and TYPE 821-A)
516-P2, P3, P4, P5, P6, P7, P10	Accessories
525	Resistors
526	Mounted Rheostat Potentiometers
530-C	Band-Pass Filter
533-A	Rheostat Potentiometer
539-P, X	Variable Air Condenser
544-P2	A-C Power Supply, 90 volts
574	Wavemeter (replaced by TYPE 566-A)
578-AR, BR, CR, AT, BT, CT	Shielded Transformer
586	Power-Level Indicators
588-AM	Direct-Current Meter
602-E	Decade Resistance Box
611-C	Syncro Clock
613-B	Beat-Frequency Oscillator (replaced by TYPE 913-A)
613-P1	A-C Power Supply
620-AM	Heterodyne Frequency Meter and Calibrator, Cabinet Model (the relay-rack model, TYPE 620-AR, is still available)

Type	Description
625-A	Bridge
625-P1	Condenser
641	Audio Transformers
642-D	Volume Control
646-A	Logarithmic Resistor
653	Volume Controls
664-A	Thermocouple
666-A	Variable Transformer
669-A, R	Compensated Slide Wire Resistor
670-BW, FW	Compensated Decade Resistor
672-A	Power Supply
673-A	Power Supply
677	Coil Forms
678	Coil Bases
682-B	Frequency Deviation Meter
684-A	Modulated Oscillator
686-A	Power Level Indicator
707-A	Cathode-Ray Null Detector
707-P	Accessories
713-BM, BR	Beat-Frequency Oscillator (replaced by TYPE 913-A)
714-A	Amplifier
716-P2	Guard Circuit
721-A	Coil Comparator
722-FU	Precision Condenser
731-A	Modulation Monitor
732-B	Distortion and Noise Meter
733-A	Oscillator
739-A, B	Logarithmic Condenser
741	Audio Transformers
755-A	Condenser
759-P21	Extension Cable and Tripod
769-A	Square-Wave Generator
774-R1, R2	Patch Cords
813-B	Oscillator, 400 cycles (the 1000-cycle model is still available)
815-C	100-cycle Precision Fork (still available on special order)

Not included in the above are redesigned instruments for which only the type letter was changed, keeping the same type number as, for instance, the replacement of TYPE 716-A Capacitance Bridge by TYPE 716-B.

REACTANCE CHART NOW AVAILABLE IN 8½ x 11 SIZE

● A NUMBER OF "EXPERIMENTER" readers have recently requested copies of the General Radio reactance chart suitable for laboratory notebook use. We are glad to announce that these are now available with standard 3-hole punching for binding in an 8½ x 11-inch ring binder. A copy will be sent on request. The larger size for wall mounting is also still available.



● THOUSANDS OF GENERAL RADIO SIGNAL GENERATORS are working overtime in plants manufacturing military radio equipment. In some plants, we are informed, generators have been operating for months without being turned off.

This photograph, published through the courtesy of FM Magazine, shows Signal Corps inspector E. P. Mayer testing receivers with a TYPE 605-B Standard-Signal Generator in a final inspection cage at the Hammarlund Manufacturing Company.

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