THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also IN THIS ISSUE

THE NEW WAVE ANALYZER —SOME OF ITS FEATURES

● SINCE its announcement five years ago*, the Type 636-A Wave Analyzer has been applied to a wide variety of uses. While the majority of these heterodyne-type analyzers are used in the electrical communication field, industry in general has found them useful in analyzing noise and other mechanical vibrations. Specific uses range from the study of brain waves to the analysis of airplane vibrations. The experience of nearly five hundred users with the older model, plus considerable research work on circuits and circuit elements, has made it possible to design a new instrument, which not only makes the measurements that the older model made, but makes them so much more simply and smoothly that its performance is qualitatively entirely different.

The principle of the heterodyne analyzer is well known. As with the common superheterodyne type of radio receiver, tuning is accomplished by means of a

*L. B. Arguimbau, "Wave Analysis," *Experimenter*, June-July, 1933.

Figure 1. Panel view of the Type 736-A Wave Analyzer. The panel is standard 19-inch relay-rack width.

fixed-frequency filter and a frequency changer, as indicated in Figure 2. Since this principle of operation is used in both models, it is necessary to consider some of the essential details of the design in order to appreciate the degree of improvement obtained in the new instrument.

Perhaps the most important change is that made in the crystal filtering system. At the time the first analyzer was designed, little information was available on quartz crystal filters. It was known that crystals had satisfactory frequency and damping characteristics, but whether serious changes in these characteristics would occur with changing external conditions, such as humidity and age, was not certain.

When only a single crystal is used, slight changes in the characteristics are of little consequence, but with two crystals (which were necessary in the wave analyzer), any drift in frequency of one unit with respect to the other would be quite serious.

In order to avoid the effects of aging, the crystals were ground to have the same frequency, but one of the crystals was made to have a considerably higher damping than the other. Their combination resulted in an over-all characteristic which would be little changed if the crystals shifted by a fraction of a cycle in frequency or if the damping changed. Although this arrangement was adequate to eliminate the effects of aging, it resulted in a response curve which was unnecessarily sharp and which made tuning very critical; slight changes in frequency were sufficient to cause detuning.

Experience has shown that humidity is by far the most important factor affecting crystal stability. Vibration tests have shown the mountings to be less critical than had previously been believed. Consequently, the crystals, when hermetically sealed in their mountings, can be regarded as fixed elements.

With these results as a starting point, three crystals were combined in a flat-top filter. As a preliminary step, an exhaustive series of measurements was made of crystal transmission and band width as functions of terminal impedance*. From the results, the schematic circuit diagram of Figure 3 was determined. Accurate knowledge of these equivalent circuits led to a practical filter design in which the damping factors and frequencies of the crystals could be individually adjusted by trimmers and combined in a way which gives the flat-top curve of Figure 4.

For the user, this curve is of practical importance in several ways. In the first place, it is unnecessary to tune the oscillator for an exact maximum. The response is flat over a band of about four cycles, so that when the dial is adjusted for an approximate maximum, the deflection is very close to that corresponding to the true peak. When this has been done, the circuit remains in tune so that the effect of various circuit changes upon harmonic amplitudes can be studied without continuous ad-

*These measurements were described in detail before the June, 1938, Convention of the Institute of Radio Engineers.

FIGURE 2. Functional schematic diagram showing the principles of operation of the wave analyzer.

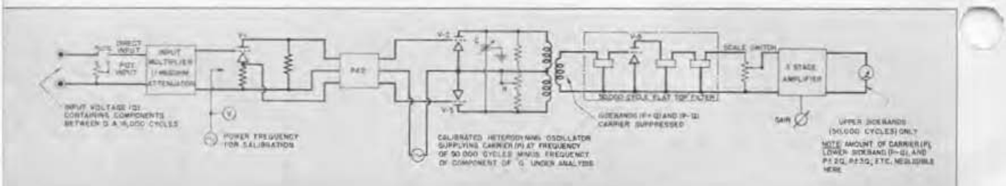
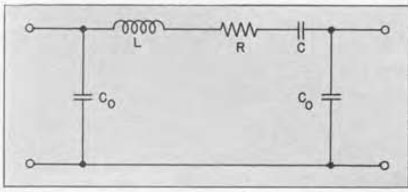


FIGURE 3 (*below*). Simplified equivalent circuit of the three-electrode quartz crystal. Approximate circuit constants are

L = 1000 henrys R = 7000 Ω
C = 0.009 μμf C_o = 6 μμf
Q = 50,000 f_o = 50 kc



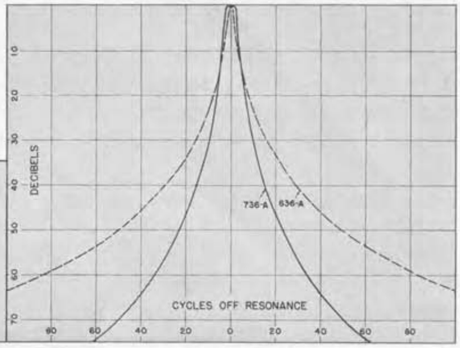


FIGURE 5 (*above, right*). Response curves of the old and new analyzers for frequencies outside the normal pass band. The discrimination to unwanted frequencies is greatly improved. At 60 cycles off resonance the response is 0.06% on the new unit, 0.2% on the old.

FIGURE 4 (*below*). Response curves near resonance for the old and new wave analyzers. The "flat-top" band of 3 or 4 cycles makes tuning much less critical.

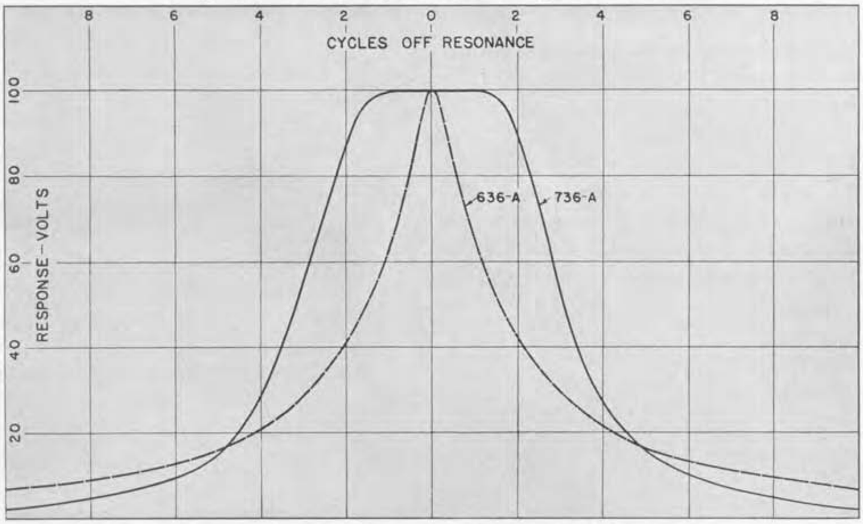
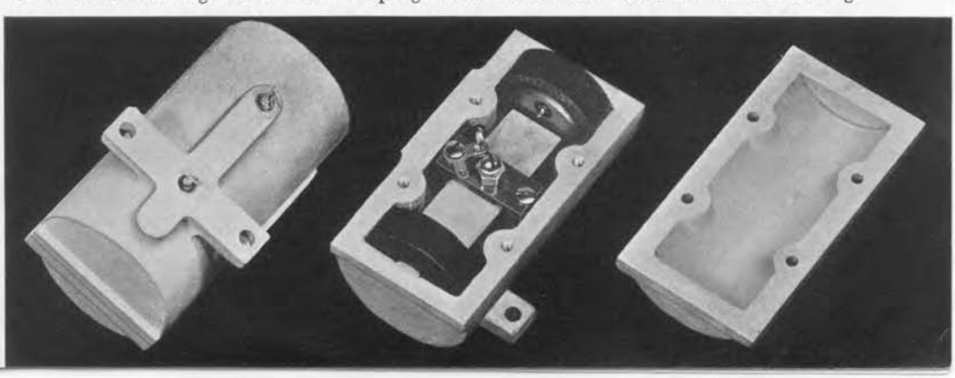


FIGURE 6 (*below*). Three-electrode quartz crystal filter elements. These quartz bars are plated with copper and gold to provide electrodes, and are mounted by felt in a cast aluminum frame which serves as a support and also provides acoustic baffles at the ends to prevent damping. The aluminum castings are mounted in sponge rubber within a sealed cast-aluminum housing.



justment of the tuning controls. In the measurement of disturbances which are not of completely constant pitch, this feature is particularly important.

One example is the analysis of the sound or vibration coming from rotating machinery, gasoline engines, etc. An airplane engine in flight is likely to vary by about ±0.5% in speed. This means that a frequency of 100 cycles will cover a band 1 cycle wide and so can be measured with perfect stability by the analyzer. A component having a frequency of 400 cycles will cover a band 4 cycles wide, and this can be observed with an accuracy of about 10%. Higher frequencies can be recognized, but their measurement is not accurate. With the older type of analyzer, frequencies as low as 70 cycles would give an unstable deflection under the same conditions.

In addition to the improvement in the crystal filter, the instrument has been made a-c operated. This was by no means a routine problem, since the detector tubes in the analyzer are peculiarly susceptible to hum. After much experimentation it was found necessary to supply the heaters of several of the tubes from rectified dc to avoid this difficulty. Similarly, the detectors followed by a high-gain amplifier and voltmeter tube made careful voltage regulation necessary to provide stability and to avoid power supply oscillations.

One innovation is the input circuit, which contains a degeneratively arranged phase-inverter tube to supply the balanced voltage needed for the detectors. This eliminates the transformer which in the older d-c operated analyzer was likely to introduce much more hum than is found in the present a-c unit.

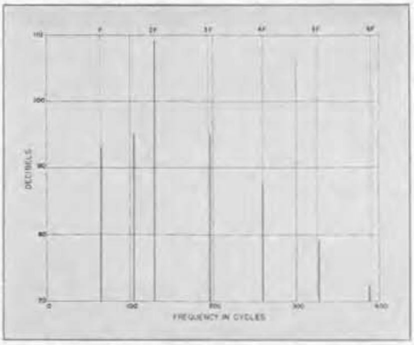


FIGURE 8. Results of measurements made with the TYPE 736-A Wave Analyzer on a phonograph record of airplane noise (courtesy Douglas Aircraft Company).

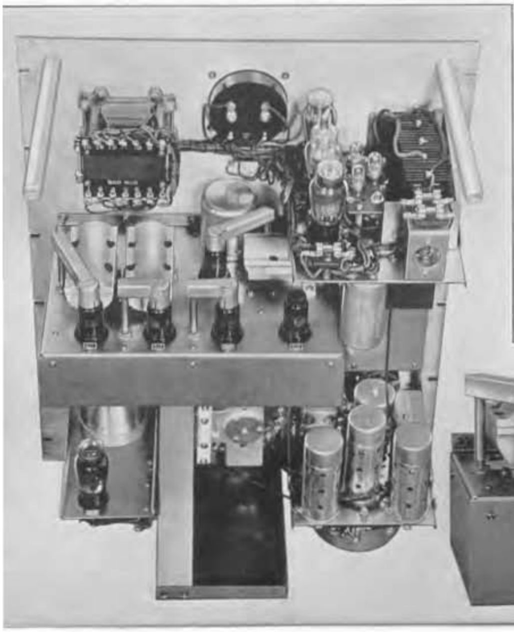


FIGURE 7. Internal view of analyzer showing the mechanical construction. The amplifier (shown also at the right) is of low-impedance aperiodic design; the older type inductive coupling and trimmers are notably absent. The parts are readily accessible. The oscillator is of much more rugged design, which minimizes frequency drifts previously troublesome.

Another improvement which will be appreciated by users of the older instrument is the virtual elimination of any necessity for accurate balancing of the detector circuits.

The General Radio calibration laboratory puts all new instruments through exaggeratedly severe tests in order to check their reliability under service conditions. In line with this policy, one of the new analyzers was packed in its shipping case and driven around for several days with particularly rough handling in a delivery truck. Upon its return to the laboratory it was unpacked and kept in a humidity chamber at 90° F. and 100% humidity for about eight hours. The instrument was then tested before it had a chance to dry out, and it was found that after a 10% readjustment of the gain control (which is a normal procedure in using the instrument) the operation was normal, and the crystal filter was not affected.

—L. B. ARGUIMBAU

SPECIFICATIONS

Frequency Range: 20 to 16,000 cycles.

Selectivity: Approximately 4 cycles "flat top" band width. The response is down 15 db at 5 cycles, 30 db at 10 cycles, 60 db at 30 cycles from the peak. The selectivity is constant over the frequency range.

Voltage Range: 300 microvolts to 300 volts full scale. The lowest division on the meter corresponds to 10 μv. The over-all range is divided into four major ranges: 300 μv–300 mv, 3 mv–3 v, 30 mv–30 v, .3 v–300 v. Each of these ranges is divided into seven scale ranges; for example, the .3 v–300 v range has the following full-scale ranges: 0.3 v, 1 v, 3 v, 10 v, 30 v, 100 v, 300 v.

Direct-reading decibel scales are also provided.

Voltage Accuracy: Within ±5% on all ranges. Spurious voltages from higher order modulation products introduced by the detector are suppressed by at least 70 db. Hum is suppressed by at least 75 db.

Input Impedance: One megohm when used for direct voltage measurements. When used with the input potentiometer it is approximately 100,000 ohms.

Accuracy of Frequency Calibration: ±2%.

Vacuum Tubes Required:

3—Type 6C6	1—Type 6C5
2—Type 6K6G	1—Type 6X5G
3—Type 6J7	1—Type 6F5G
1—Type 6B8	3—Type T-4½ neon lamps

These are supplied with the instrument.

Power Supply: 115-volt, 40- to 60-cycle, vacuum-tube voltage regulator included. A change in the power transformer connection permits the use of 230 volts, 40- to 60-cycles.

Mounting: Shielded oak cabinet.

Dimensions: (Width) 19½ x (height) 25⅛ x (depth) 10⅞ inches, over-all.

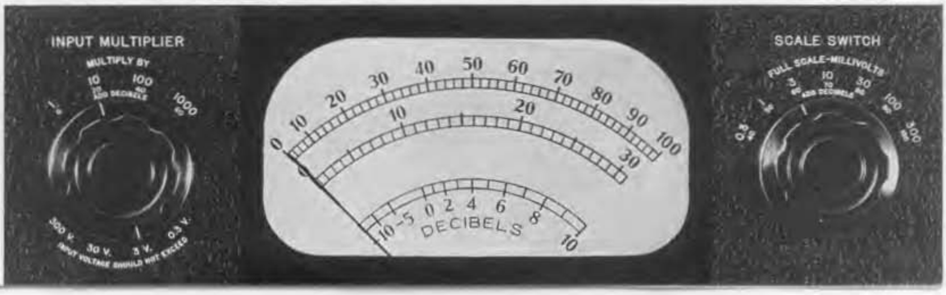
Net Weight: 85 pounds.

Type	*Code Word*	*Price*
736-A	ASKEW	$640.00

This instrument is manufactured and sold under the following United States Patents and license agreements:
1. 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, including industrial and engineering fields.
2. Patent No. 1,542,995.
3. Patent No. 1,967,185.

FIGURE 9. The input system has been designed to provide a wide voltage range. Full-scale ranges are from 300 microvolts to 300 volts. The smallest meter division corresponds to 10 microvolts. The over-all range is divided into four parts, selected by means of the switch shown at the left. Each of these major ranges is divided into seven scale ranges by means of the switch at the right. For example, the 0.3 v — 300 v range has the following full-scale ranges: 0.3 v, 1 v, 3 v, 10 v, 30 v, 100 v, 300 v.

The newly developed Weston TYPE 801 Meter with illuminated scale is used. The main scales are linear, but a direct-reading decibel scale is also provided. An alternate input circuit consisting of a 100,000 Ω potentiometer is provided for direct-reading percentage measurements.



HIGHER MODULATION LEVELS FOR THE TYPE 605-B STANDARD-SIGNAL GENERATOR

● **MODULATION** up to 80% is possible with the latest Type 605-B Standard-Signal Generators. Current models are equipped for internal modulation at 400 cycles or for external modulation between 30 and 15,000 cycles, up to 80%.

When the 400-cycle internal oscillator is used, the total envelope distortion is less than 3% up to 50% modulation, and between 5% and 10% at 80% modulation.

Provision is also made for obtaining modulation percentages of 90% and 100%, although, at these higher levels, distortion may be serious.

The internal impedance at the external modulation terminals is 4000 ohms. Approximately 4 volts are required for 30% modulation and 12 volts for 80%.

Older Type 605-A or Type 605-B Standard-Signal Generators can be converted for these higher modulation levels at a charge of $40. This includes the necessary changes in the audio oscillator, the external modulation filter, and the audio-frequency vacuum-tube voltmeter, as well as the installation of a new scale on the percentage modulation meter.

When only external modulation is to be used at levels above 50%, it is possible for the user to install a new scale on the percentage modulation meter and recalibrate the audio-frequency vacuum-tube voltmeter, following directions given in the instruction manual. After this is done, external modulation can be used over the same range as in the new instruments. The internal 400-cycle oscillator, however, will not supply sufficient power for modulation above 50% without the extensive modification specified above. The new meter scale can be supplied for 65 cents. No change is necessary in the meter movement itself.

Listed below are all the changes which can be made on older models of Type 605-A or Type 605-B Standard-Signal Generators.

Type	*Change*	*Price*
605-A	(1) Addition of 1-volt output jack	$10.00
605-A	(2) New ball-bearing condenser and gear-drive dial	60.00
605-A or 605-B	(3) 80% Modulation	40.00

When changes (2) and (3) are made, at the same time, the price is $90.00 for the combination.

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

VISUAL-TYPE FREQUENCY MONITORS

MODERNIZATION OF BATTERY MODELS

● **EFFECTIVE** December 15, the price for converting battery-operated broadcast frequency monitors (TYPES 575-D and 581-A) for a-c operation will be $210. This increase in price is based on actual costs of modernizing these instruments during the past two years. The increased age of the monitors necessitates more minor repairs and replacement of small parts than were contemplated when the former price* was set. In addition, extensive changes made in the instruments by operating personnel have made complete disassembly a necessary part of the reconditioning operation, as have the heavy deposits of dust resulting from lack of proper maintenance.

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.

When, in addition to this work, a new TYPE 376-L, low-temperature-coefficient, quartz plate is installed, the total price is $270.

The Federal Communications Commission will grant a permit to operate a broadcasting station for a period of 30 days 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

* *Experimenter*, April, 1937.

MISCELLANY

● **WHEN** meteors suddenly leave wiggly trails on the photographic record of their course, that's headline news to the astronomical world. But Dr. Frederick Whipple of the Harvard Observatory, who noticed the phenomenon in a series of new photographs he had taken, held up the startling announcement while he checked his camera with a General Radio Strobotac. If the motion recorded on the film were real, the meteors 100 miles away were sidestepping about fifteen feet. But meteors have always gone about their business in a more orderly way. Dr. Whipple suspected his equipment. By placing a white dot on the camera box and flashing it with the Strobotac, he discovered that the camera, not the meteor, was oscillating at a rate of sixteen times a second. The dif-

ficulty was traced to the motor in the camera set-up. Again the Strobotac to the rescue of science.

That's not the end of the story, for Dr. Whipple realized that the distance between the wiggles was an accurate meteor speedometer. The speed with which meteors arrive gives the only precise measure of upper air resistance and may be used to trace meteoric paths back to interstellar space. The astronomers used their misfortune to double the number of timed meteor trails previously known in all the observatories of the world. And that *is* headline news.

● **RECENT** visitors to the General Radio plant include: Dr. Giacomo Segre, Chief Engineer of the General Electric Company of Milan; Major E. H. Armstrong of Columbia University; and Mr. Harry Sadenwater of R.C.A. Manufacturing Company.

● **A NOVEL USE** of the General Radio Type 759-A Sound-Level Meter has been in judging the noise produced by the various fraternity floats in the annual Noise Parade during the Homecoming Celebration at Oregon State College. This year the first three entries produced levels of 110, 106, and 103 decibels, respectively. These intensities were taken 40 feet from the source. Pneumatic hammers pounding on large circular saws won first prize. The meter was also used to judge the applause at the Midnight Matinee.

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