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A Continuous-Film Camera for the Oscillograph

By Horatio W. Lamson *

An oscillograph, as the name implies, is a device which enables one to observe the waveform of an electrical current and to note any changes in this waveform with the passage of time. This is accomplished by converting the varying electrical current into mechanical vibrations which are a more or less perfect reproduction of the variations in the amplitude of current. A spot of light reflected from such a vibrating system, or the shadow of some portion of the system itself, focused to a point, will vibrate back and forth and will, accordingly, trace a straight line upon a viewing screen. The length of this line will be proportional to the amplitude of vibration but no indication of the waveform will appear on the viewing screen because the coördinate of time is lacking.

Figure 1. The new camera with its accessories and the General Radio string oscillograph

There are two methods whereby a proper time element, perpendicular to the direction of vibration, may be introduced. One of these consists of causing the vibrating shadow or spot of light to be reflected, before striking the viewing screen, from a single or multiple-sided plane mirror which is rotating about an axis parallel to the line of vibration of the spot. The shadow spot or light spot will then be given an additional displacement, proportional to time, at right angles to its vibration due to the amplitude variations in the electrical current, so that a waveform, that is, a trace showing the relation of amplitude and time, will appear on the viewing screen. If the current waveform is a repeated and sustained one and if the rotation of the mirror is synchronized at a proper speed, a stationary trace will appear on

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the screen. This method is used in the General Radio TYPE 338-L String Oscillograph* and in all other forms of oscillograph making use of the rotating-mirror principle.

If the screen upon which the vibrating line is traced is capable of retaining an instantaneous picture of the shadow spot or light spot, that is, if it is of the nature of a photographic film, then the second method of introducing the time axis may be employed. This consists merely of pulling along the screen continuously in a direction perpendicular to the line of vibration, thereby giving the required trace of amplitude versus time.

This method is employed in the new continuous-film camera which the General Radio Company has recently perfected to be used for obtaining permanent oscillographic records. Obviously, records obtained in this manner may show either sustained or transient phenomena.

This instrument, designated as the TYPE 408 Oscillograph Camera, was designed primarily to be used as an adjunct to the TYPE 338-L String Oscillograph, but with proper arrangements it may be adapted for use with other makes of oscillograph. The instrument is intended to use 100-foot reels of standard 35-millimeter perforated motion-picture film or paper, so that individual exposures of any length up to this amount may be made. If only a single copy of the record is required, Eastman No. 2 perforated recording paper may be purchased on 100-foot reels provided with leaders which permit loading of the camera in daylight. This paper, while quite sensitive, is much easier to handle than negative film stock and, if it is developed with Eastman x-ray developer, produces a contrasty and very satisfactory record.

The camera consists of a rectangular aluminum casting having three separate compartments. The lower compartment on one side serves as a magazine for the unexposed film or paper. This film passes over a driving sprocket and through a light-tight slit into the upper compartment, which serves as a magazine for the exposed film. A duplicate reel is provided herein which is driven through a slipping clutch and serves to wind up the exposed film properly. As the film passes up over the driving sprocket, it is momentarily exposed through a horizontal slit running transversely across the film. If the shadow spot or light spot is then made to vibrate in a horizontal plane to and fro along this slit, a white trace on a dark background or a dark trace on a white background, respectively, will be produced on the photographic paper.

Independent sliding shutters give access to these two camera compartments so that the exposed magazine may be opened without illuminating the other. If short records, under four feet only, are required, it is not necessary to use the reel in the exposed magazine since the paper will not curl up of its own accord as it is fed through.

The third compartment on the other side of the camera contains the various driving mechanisms. It need not be light-tight. The driving sprocket is rotated directly by a suitable hand crank, but provision may easily be made for substituting a motor drive if desired. The take-up reel with its slip clutch is driven through a chain and sprocket system. A resetable counter is provided for recording the amount of film that has been exposed.

In order to use this camera with the General Radio TYPE 338-L String Oscillograph, the TYPE 409 Camera

*In the General Radio TYPE 338-L String Oscillograph, the vibrating element consists of a single fine tungsten filament passing through a magnetic field supplied by a permanent magnet. The shadow image of the center portion of this string is thrown into the rotating-mirror viewing box or into the camera.

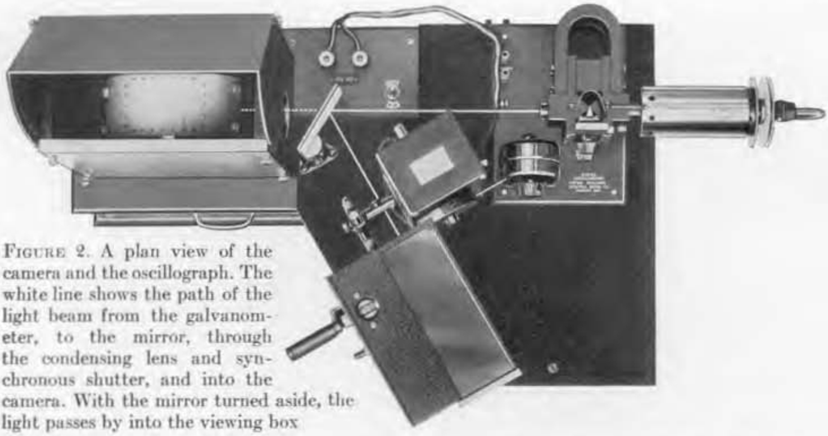


Figure 2. A plan view of the camera and the oscillograph. The white line shows the path of the light beam from the galvanometer, to the mirror, through the condensing lens and synchronous shutter, and into the camera. With the mirror turned aside, the light passes by into the viewing box

Shelf is required. This aluminum shelf is properly drilled for aligning the several parts. It is easily attached to the oscillograph underneath the galvanometer. As a part of the shelf is supplied a two-position plane mirror and mounting. This operates similar in principle to a Graflex camera, a turn of the wrist serving to throw the image of the vibrating element from the rotating-mirror viewing box into the camera, and vice versa. Simultaneous visual observations and photographic records are not possible, but one may closely follow the other.

Another part of the shelf equipment consists of a mounting carrying a cylindrical lens having a horizontal axis. This lens is for the purpose of condensing the pencil of light rays from the galvanometer into a narrow horizontal beam focused along the slit, thereby increasing the intensity of illumination many fold.

The Type 338-L String Oscillograph is designed to be operated from 110-volt, 60-cps. current. In the majority of cases the frequency of such a source of current is carefully stabilized so that it may be used to drive synchronous clocks. It is frequently desirable to utilize this regulated 60-cps. power supply as a reference scale of time on the oscillograph records. For this purpose, the Type 407 Synchronous Shutter serves to provide transverse time lines across the film. The shutter consists of an enclosed synchronous motor driven by the 60-cps., 110-volt current. The shaft of this motor, and the spoked wheel carried thereon, rotate at an exact speed of ten revolutions per second. This motor is not self-starting but is easily brought up to synchronous speed by rotating the shaft with the fingers. The shutter is so mounted on the camera shelf that, as the spokes come into a horizontal position on one side, they momentarily cast a shadow along the slit, thus giving a transverse line on the film.

A five-spoke wheel is provided which will, of course, mark the film in 0.02-second intervals with one spoke shortened to identify 0.1-second intervals. Models carrying a ten-spoke wheel have been provided to mark the film in 0.01-second intervals, likewise identifying the 0.1-second intervals. The former is to be recommended except for timing very high speed films. Through a reduction gear system a separate spoke marks the film along one edge at one-second intervals. This is advantageous in timing long exposures.

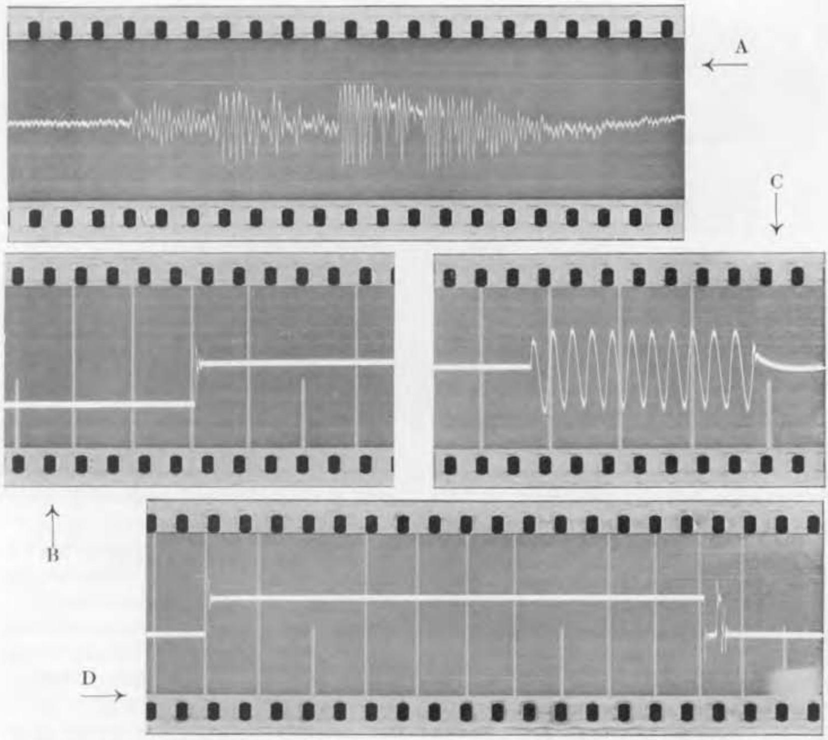


FIGURE 3. Typical records taken with the string oscillograph and camera. The vertical timing lines and the white spot (lower right corner of *D*) were marked at 1/50th-second and 1-second intervals by a synchronous shutter. *A* is the record of a watch tick; *B* and *D* show the operation of a relay; *C* shows the starting and stopping of a vacuum-tube oscillator. Time increases from left to right

The accuracy of these time markings is, of course, the accuracy with which the alternating-current supply is maintained at 60 cps. The addition of the synchronous shutter, which affords accurately timed small-interval indications on the film, makes the whole equipment a very accurate and useful form of chronograph even though the film speed of the hand-driven camera may vary slightly. It is readily possible thereby to time intervals to 0.002 second and with care to 0.001 second. Obviously, any other regulated source of current may be used to drive this synchronous shutter, as, for example, an electrically-driven tuning fork.

FIGURE 4. The TYPE 408 Oscillograph Camera

With the No. 2 paper, the optical system of the oscillograph provides sufficient illumination for satisfactory photography at any speed up to about 30 inches per second, which is about as fast as the crank may be turned by hand. The camera and oscillograph may readily be used in open daylight, the condensed illumination from the galvanometer lamp being sufficiently intense compared with ordinary illumination. It is best, however, not to have a strong light shining directly into the camera.

The many uses of the camera oscillograph which will suggest themselves to the experimenter may in general be grouped into two classes: first, applications wherein a record of sustained or transient waveforms is desired; and, second, chronographic tests involving the accurate measurement or comparison of time intervals. Double-string records showing two independent phenomena may, of course, be made as readily as single-string records by substituting the double string-holder in the galvanometer.

As examples of the former class may be cited records showing the sound impulses produced by small moving mechanisms such as clocks and watches, records of the sounds produced by heart beats, and records showing the making and breaking action of relay contacts, etc. As examples of the latter class may be cited the timing of seismic waves in geophysical researches pertaining to the location of oil, the accurate comparison of two clocks, and numerous other time-measuring problems. Actual records showing some of these applications are shown in the accompanying illustrations.

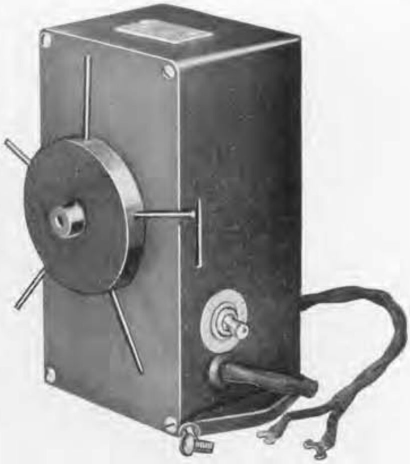
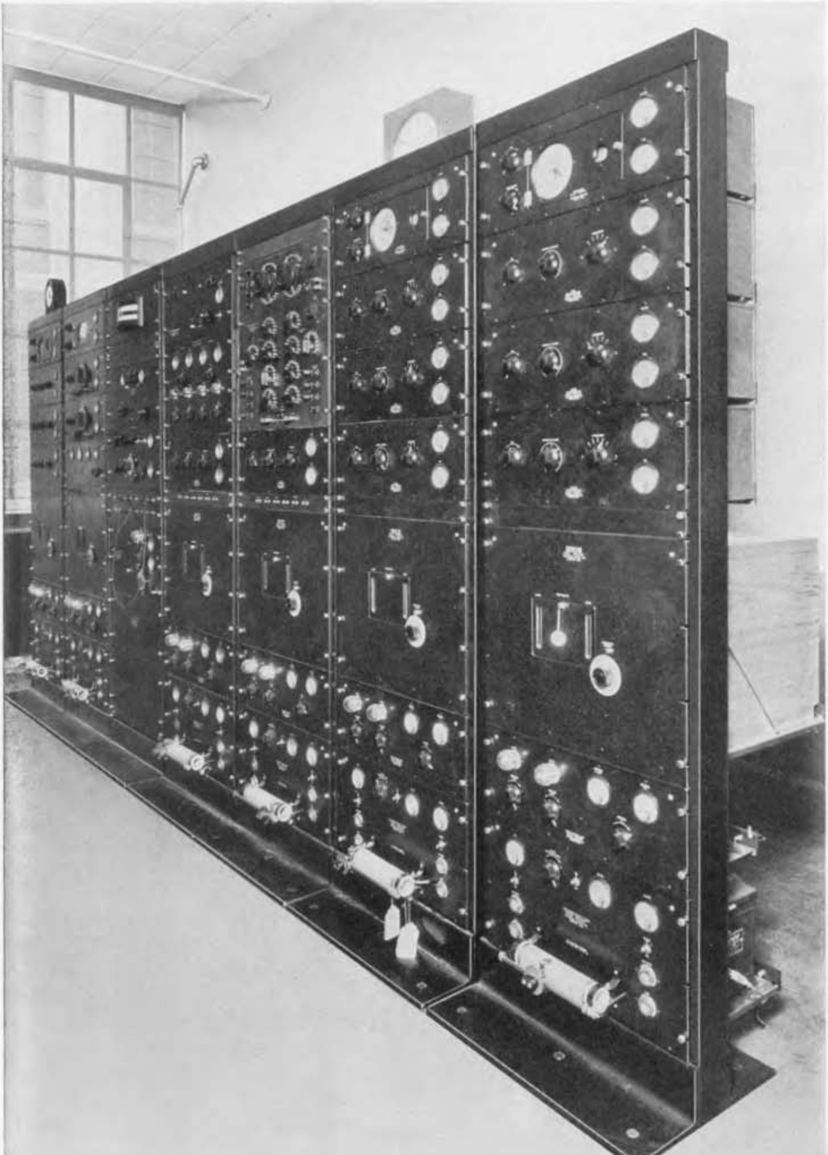


Figure 5. The Type 407 Synchronous Shutter



The General Radio Company's frequency-standards room. At the extreme left is a relay rack carrying the standard-frequency assembly we use for our own frequency measurements, and at the extreme right are two assemblies being tested before shipment to purchasers. The remainder is experimental equipment

A Useful Secondary Frequency Standard

By John D. Crawford *

CURRENT radio literature places a great deal of emphasis upon the truly remarkable degree of precision in frequency measurements which one can obtain with a primary standard like the ones shown on the opposite page. For a great many purposes, however, a good secondary standard yields all the necessary accuracy. In many college laboratories, in radio transmitter monitoring rooms, and in broadcasting stations, for example, a secondary standard is usually sufficient, especially when used with multivibrators for extending the range.

Last fall, J. K. Clapp, a General Radio engineer, published data[1] showing that under normal conditions, a General Radio Type 376 Quartz Plate operating in the broadcast band, would maintain its frequency to within ±10 parts per million, when used in the new Type 575 Piezo-Electric Oscillator. He has continued the work with other kinds of plates and finds that a group of specially mounted 100-kc. plates[2] can be relied upon to within ± 4 parts per million. I hope to be able to publish his results in an early issue of the *Experimenter*. It is sufficient for present purposes, however, to realize that a frequency stability of from four to ten parts per million can be expected from commercially available secondary standards.

If a multivibrator is connected to a 100-kc. piezo-electric oscillator, a long series of harmonic frequencies can be made available over a wide band of frequencies. Suppose that — and this is usually the most convenient arrangement — the multivibrator is made to operate at a fundamental frequency of 10 kc., its tenth harmonic being under the control of the 100-kc. oscillator. There will then appear in the multivibrator output circuit harmonics of 10 kc. all the way to the 300th. In other words, the piezo-electric oscillator and the multivibrator yield radio frequencies at 10-kc. intervals from 10 kc. to about 3000 kc., and the frequency of each is known with the same percentage accuracy as the frequency of the 100-kc. oscillator is known; in other words, to within four to ten parts per million.

The importance of a system of harmonics, evenly spaced at 10-kc. intervals, cannot be overemphasized. To the broadcaster it means that he can monitor the frequency of his own or of any other station and, if the Radio Commission shifts his frequency assignment to another channel, there is no need for buying another set of monitoring crystals. To the radio inspector it means that he can measure the frequency of any station which he can hear. To the radio laboratory it means that a reliable source of standard frequencies is available for calibration and frequency measurements work.

There is another feature of this system which is now important and which will become increasingly so as the art of frequency standardization makes progress. By tying in another multivibrator with a fundamental frequency of 100 kc. it is possible to derive a frequency of 5000 kc. which may be checked against the weekly standard-frequency transmission of the U. S. Bureau of Standards. The same scheme is used by Mr. Clapp in the General Radio frequency laboratory for comparing primary standards with WWV, the results of which were described in the last *Experimenter*.

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* Editor, *General Radio Experimenter*.

[1] James K. Clapp, "The Frequency Stability of Piezo-Electric Monitors," *General Radio Experimenter*, V, October and November, 1930.

[2] As soon as a number of minor details are arranged, the new 100-kc. quartz plate will be formally announced and cataloged.

GENERAL ORDER 106

By CHARLES T. BURKE*

A RECENT General Order (106), of the Federal Radio Commission dealing with the maintenance of a station log, requires checking and recording of the transmitter frequency at 30-minute intervals. The purpose of this measurement is presumably to reveal large changes in frequency, due to loss of control in the case of piezo-control transmitters, or failure to maintain the transmitter frequency when a monitor is being used, or changes due to such contingencies as failure of the temperature-control devices.

While the General Radio TYPE 532 Station Frequency Meter is not suited for use as a secondary standard in present-day practice, it is very well suited to the measurement of small frequency drifts since it may be read to about 20 cycles, that is, frequency differences of 20 cycles may be observed, although the instrument will not retain calibration of this order over any great period of time.

The frequency meter should be checked at intervals against the piezo oscillator (master oscillator or monitor) when the piezo oscillator is known to be operating under standard conditions. It will then constitute an excellent means of observing drifts in the transmitter from the monitor frequency or loss of control in a master-oscillator system.

The TYPE 532 Station Frequency Meter consists of the usual resonance-circuit type of wavemeter with some additional features. A large fixed condenser is shunted across the variable, so that the entire scale of the meter covers only 0.3% of the station frequency, with the station frequency in the center. There are ten scale divisions per kilocycle. In addition to the spread scale, another feature contributes to the accuracy of setting of the TYPE 532 Station Frequency Meter. A small auxiliary condenser may be

TYPE 532 Station Frequency Meter

connected across the main condenser by depressing a push button. The capacitance of this condenser is sufficient to shift the resonant frequency of the meter from one side of the transmitter peak to the other. The frequency meter is adjusted until the galvanometer reading is unchanged when the button is depressed. This method of locating the center or peak of the resonance curve is much more accurate than attempting to set to the top of the curve by observing maximum galvanometer deflection.

The price of the TYPE 532 Station Frequency Meter is $130.00.

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