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STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

AN IMPROVED SONIC APPARATUS FOR DETERMINING THE DYNAMIC MODULUS OF CONCRETE SPECIMENS

By

C. E. Goodell
Physical Research Engineer

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Testing and Research Division
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AN IMPROVED SONIC APPARATUS FOR DETERMINING
THE DYNAMIC MODULUS OF CONCRETE SPECIMENS

In recent years considerable emphasis has been placed on the theoretical aspects of the sonic method for testing materials and experience has proven it to be a satisfactory method for determining the dynamic modulus of a great many substances. Since it is a non-destructive and rapid method of testing, it's application and acceptance in the field of concrete testing has been widespread. Hornibrook[1] has shown this method to be ideally suited to freezing and thawing studies of concrete specimens where there exists a definite relationship between the decrease in modulus of elasticity and the modulus of rupture.

The Sonic Method

The sonic method of testing is primarily one of determining the fundamental or natural frequency of vibration of the specimen under consideration, the dynamic modulus being related to this frequency by the following simple formula:

$$E = \frac{N^2 4\pi^2 L^4 d^2}{m^4 k^2 g}$$

Where E = Young's modulus, pounds per sq. in.,

N = natural frequency, cycles per second,

L = length of specimen, inches,

d = weight per unit volume, pounds per cu. in.,

g = acceleration due to gravity, in. per sec. per sec.,

k = radius of gyration of a section about its axis, and

m = dimensional factor depending on mode of vibration and conditions of restraint.

Many excellent papers have appeared on the theory of sonic testing,1,2,3,4,5, therefore, the text of this paper will be confined to a discussion of the device developed to perform these tests.

All sonic test devices have the following basic units in common:

(a) Variable frequency audio oscillators;

(b) Specimen vibration mechanism, or driving unit;

(c) Pick-up device;

(d) Resonance indicator.

These units function according to the following plan: The oscillator actuates the driving mechanism at any desired frequency within the range of the apparatus. The driving mechanism vibrates the specimen. The signal generated by the oscillator is fed into the resonance indicator, and this results in a certain operating level indication on the resonance meter, or an amplitude indication on a cathode ray tube. Now the frequency at which the specimen is being vibrated is transmitted to the resonance indicator through a pick-up device, usually of the crystal type. This signal adds to the oscillator signal to raise the operating level of the resonance indicator. Since the electrical output of the pick-up increases with mechanical input to the crystal, and the mechanical input is maximum when a specimen is vibrating at its fundamental frequency, then the resonance indicating meter will give its greatest reading, or a cathode ray tube will register greatest amplitude, when the specimen is vibrating at its fundamental frequency.

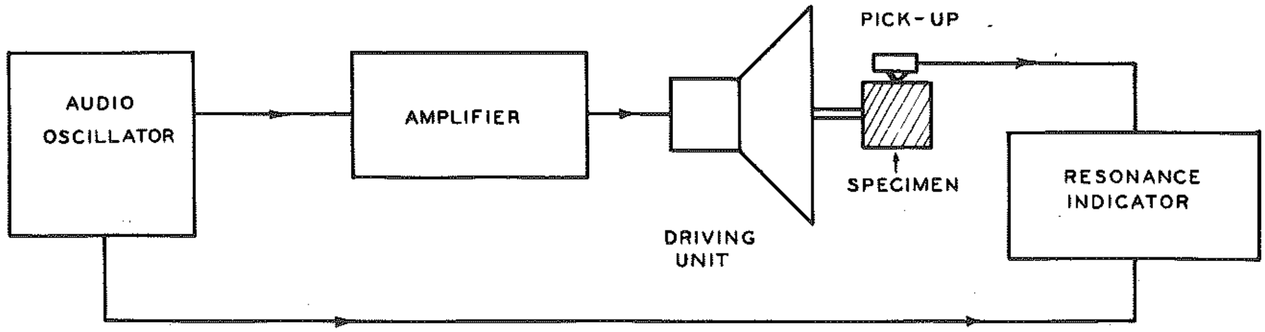
When the indicator incorporates a cathode ray tube, an additional and more reliable principle of determining resonance is used. The oscillator signal is fed to one set of plates on the tube, and the amplified pick-up signal to the other set of plates. When these signals are of the same frequency and in phase a Lissajous circle is seen on the tube screen.

Figure 1 illustrates, in block diagram form, the essential elements, and their interconnections, for use in testing concrete specimens.

A Discussion of Apparatus

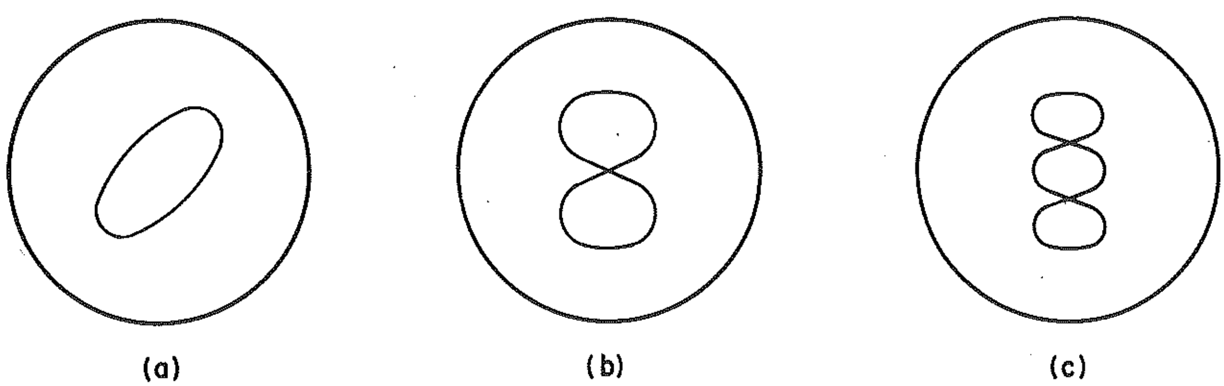
Most commercial audio oscillators are of the beat frequency or R-C Type, neither of which is particularily well suited to the method of sonic testing. If the oscillator is of the beat-frequency type it is subject to wide frequency drifts with variations of time and temperature and must be continually recalibrated if accurate results are to be expected. If the oscillator is of the R-C or Wein Bridge type it is less subject to frequency variations but the scale, in general, is too crowded to permit an accurate determination of the frequency setting. This objection can be overcome by the use of commercial interpolation oscillators but their added expense can seldom be justified.

The resonance indicator can be a very simple vacuum tube meter or a commercial cathode ray oscilloscope. If a vacuum tube voltmeter is employed the resonant point is apt to be determined less accurately than with a cathode ray oscilloscope and in addition it is extremely difficult to differentiate between the fundamental resonant frequency and one of the many harmonics that are present. By means of Lissajous figures on the cathode ray oscilloscope this latter objection can be eliminated, but the purchase of a commercial oscilloscope can hardly be justified to perform this one simple task.



BLOCK DIAGRAM OF SONIC APPARATUS

FIGURE 1



CHARACTERISTIC LISSAJOUS FIGURES

FIGURE 3

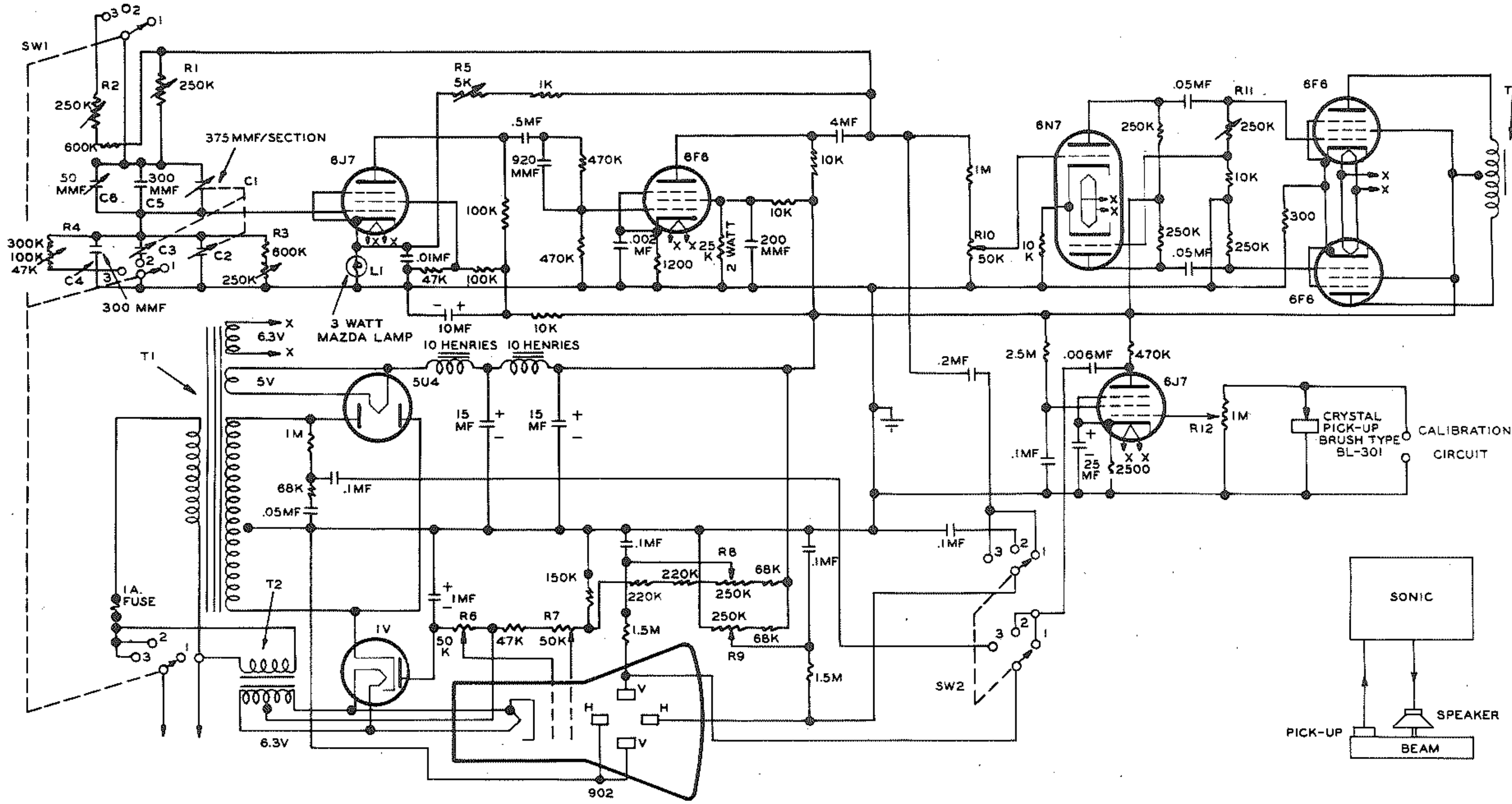
An Improved Compact Unit

The sonic apparatus developed for the Michigan State Highway Department combines all of these basic units into a compact unit that is simple enough in operation for the most unskilled worker, reliable, and of sufficient accuracy for the most critical tests. In addition, it possesses certain technical advantages unobtainable with the standard line of commercial equipment.

Figure 2 shows the circuit diagram of the sonic apparatus that has been developed to combine all of the best features possible and to eliminate the primary objections of most commercially available equipment.

The band spread on the frequency dial is at least twice that of the ordinary oscillator, yet the oscillator stability is remarkably good. Tests with this apparatus have shown that the frequency drift is less than 0.5 percent per hour, after the first ten minutes of operation. The output wave shape shows very little distortion and the amplitude is practically constant over the entire frequency range for any one setting of the amplitude control.

The increased band spread has been obtained by properly proportioning the amount of fixed and variable capacitances in the frequency-determining network consisting of $R_1, R_3, C_1, C_2, C_4, C_5, C_6$ for the low frequency range and $R_1, R_2, R_3, R_4, C_1, C_2, C_3, C_4, C_5, C_6$ for the high frequency range. (See Figure 2).



R1,R3– LOW FREQ. CALIB. CONTROLS
R2,R4– HIGH FREQ. CALIB. CONTROLS
R5– FEEDBACK CONTROL
R6– C.R.O. INTENSITY CONTROL
R7– C.R.O. FOCUS CONTROL
R8– C.R.O. VERTICAL CENTERING
R9– C.R.O. HORIZONTAL CENTERING
R10– VOLUME CONTROL
R11– PHASE INVERTER BALANCE
R12– SENSITIVITY CONTROL

SW1

POS. NO. 1– OFF
POS. NO. 2– LOW FREQ. SCALE, 600-1500 CPS.
POS. NO. 3– HIGH FREQ. SCALE, 1400-3000 CPS.

SW2

POS. NO. 1– LISSAJOUS RESONANCE INDICATOR
POS. NO. 2– AMPLITUDE OF BEAM VIBRATION
POS. NO. 3– OSCILLATOR CALIBRATION

T1– THORDARSON POWER TRANS. T22R07
700V CT., 200MA, 5V AT 3A, 6.3V AT 6A.
T2– THORDARSON FILAMENT TRANS. T21F10
6.3V CT. AT 3A.
T3– THORDARSON OUTPUT TRANS. T22S64
PRIMARY-10,000 Ω CT., SECONDARY-
3.2-4, 6-8, 15, 250, 500 OHMS.

FIGURE 2

SONIC APPARATUS *for* DETERMINING *the* DYNAMIC MODULUS *of* CONCRETE SPECIMENS

Frequency drift is inherently low in a Wein Bridge type of oscillator since the frequency-determining elements are required to pass only very minute currents and the power dissipated by these elements is, therefore, correspondingly small. Thus changes in circuit element values are caused almost entirely by changes in ambient temperature. With proper ventilation and placement of parts the frequency drift can be made very small.

Constant amplitude and low distortion of the oscillator output wave is accomplished by the negative feedback path consisting of elements R_5, L_1. The 3-watt Mazda Lamp L_1 serves as a non-linear circuit element which automatically adjusts the feedback and amplitude to the proper level.

The two-inch cathode ray tube serves three purposes. It is used for checking the calibration of the oscillator, the 60-cycle power frequency being used as a standard. It is also used as a resonance indicator, making use of Lissajous figures to ascertain the fundamental frequency, and in addition it is used to indicate the amplitude of the resonant peak when comparative tests are required.

Figure 3 illustrates typical Lissajous figures that may be observed on the cathode ray tube during the testing of a specimen. Figure 3 (a) represents the case where the frequency of vibration of the bar is equal to the applied frequency; and Figures 3 (b) and 3(c) illustrate the case when the frequencies of vibration of the specimen are two and three times, respectively, the applied frequency. Figure 4 shows an actual photograph of the Lissajous figure observed during the testing of a specimen.

Calibration controls for the oscillator are included within the cabinet to permit recalibration of the oscillator in the event that changes in the electrical components should alter the frequency scales. In addition, the usual centering, focusing, and intensity controls are included for the cathode ray tube. These controls are adjusted and then locked, as further adjustment is not necessary unless the tube is replaced.

Figure 5 shows a photograph of the sonic apparatus together with the specimen support and driving mechanism. The specimen is supported on knife edges at the nodal points of the bar and the entire assembly mounted upon a moveable carriage. By means of the hand wheel the carriage, support and specimen can be moved until the specimen makes the proper contact with the driving unit. The crystal acceleration type pick-up is spring suspended from a moveable rod that can be rotated so as to place the pick-up on the specimen during test, or rotated out of the field while changing specimens. The entire operation of specimen testing can be made in the matter of 30 to 60 seconds by a skilled operator.

This sonic apparatus has superseded an earlier device used for sonic testing and the present indications are that it is far superior in every respect.

Figure 4. Lissajous figure obtained during test when beam is vibrating at its fundamental frequency.

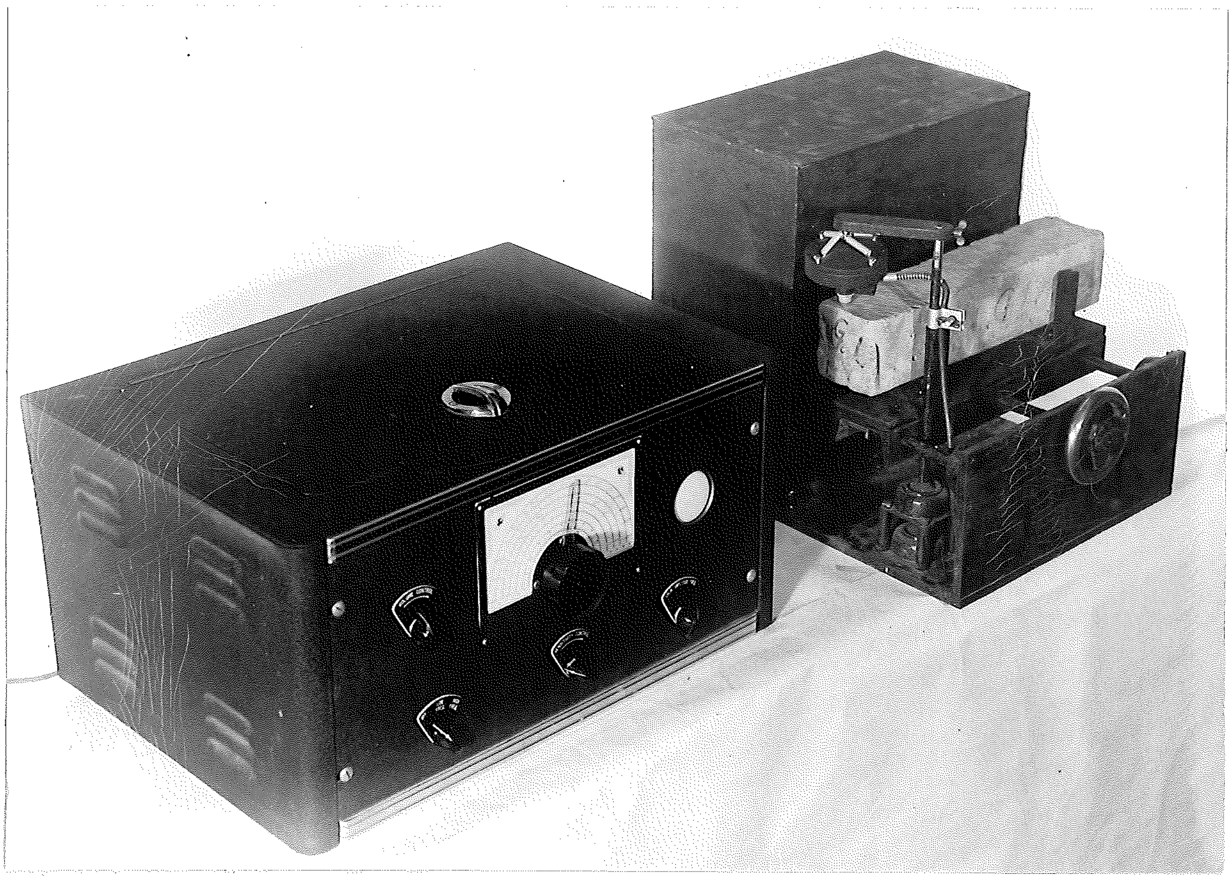


Figure 5. Sonic apparatus ready for test with beam mounted on nodal supports and crystal pick-up in position.

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