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Magneto-Striction Oscillators

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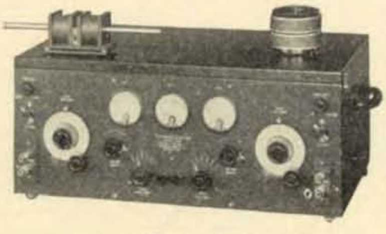
PART I

During the last three years Professor G. W. Pierce, director of Cruft Laboratory at Harvard University, has been conducting a series of interesting and valuable researches which have led to a new method of frequency standardization and control based on the phenomenon of magneto-striction.

Just as properly prepared quartz crystals expand and contract under the influence of a varying electrostatic field due to their piezo-electric properties, so also do rods of certain materials expand and contract under the action of varying magnetic fields by virtue of their magneto-strictive properties. Strangely enough, pure iron, and steels which are alloys of iron and carbon, although they are strongly magnetic, show only very feeble magneto-strictive effects. On the other hand, pure nickel, which is only slightly magnetic, gives a strong magneto-strictive response. Alloys of nickel and iron in certain proportions are active, especially those having about 36% nickel and 64% iron, which is the approximate composition of invar and stoic metal. Alloys of chromium, nickel and iron, exemplified by the metal nichrome, and monel metal, which is an alloy of nickel and copper, are among the most active materials which are easily obtained. Alloys of cobalt and iron are also strongly magneto-strictive. All of these materials are improved by annealing.



Type 489
Twin Magneto-Striction-Oscillator

Suppose now that we have a rod of some magneto-strictive material surrounded by a coil through which an alternating current is passing. At the peak of each half cycle the rod is magnetized and is thereby made to expand along its length, regardless of the polarity of the magnetization. Thus, the rod will expand and contract, that is, it will vibrate longitudinally, with a frequency which is twice that of the alternating current in the coil.

If, on the other hand, the rod is at the same time subjected also to a steady magnetizing force greater than the peaks of the alternating force, then the net magnetization will rise and fall with the a.c. wave but will never reverse its polarity. As a result, the rod will now vibrate with the same frequency as the alternating current. If this frequency falls within the range of audition these *forced* vibrations of the rod imparted to the surrounding air will, of course, be audible.

Instead of forcing the rod to vibrate in step with any impressed frequency, Professor Pierce discovered that, by the use of the circuit shown in full lines in the diagram, the rod could be made to control the oscillations of the hi-mu tube T_1 to a single frequency (and harmonics thereof) corresponding to the *natural frequency of vibration* of the rod, which is inversely proportional to its length. In this manner we have a controlled or standardized frequency closely analogous to the control of a vacuum tube oscillator by means of a piezo-electric crystal.

The two equal coils L_1 and L_2 are inserted respectively in the plate and grid circuits of the tube, while C is a variable condenser whereby the total reactance of these coils may be resonated to the natural frequency of the rod. The coils surround but do not touch the rod, which is balanced or clamped at its center point. The direction of winding of the coils is such that filament emission currents flowing in the plate and the grid circuits would magnetize the rod with the same polarity. This is exactly the opposite of the condition existing in the familiar Hartley oscillator circuit. That is to say, the magneto-striction oscillator with the rod removed is degenerative rather than regenerative in character.

A is a d.c. milliammeter giving an indication of resonant tuning of the circuit as C is varied. The dotted circuits show how, by virtue of a second tube, T_2, a stage of amplification may be added to the oscillator. The coupling condenser C_1 is of the

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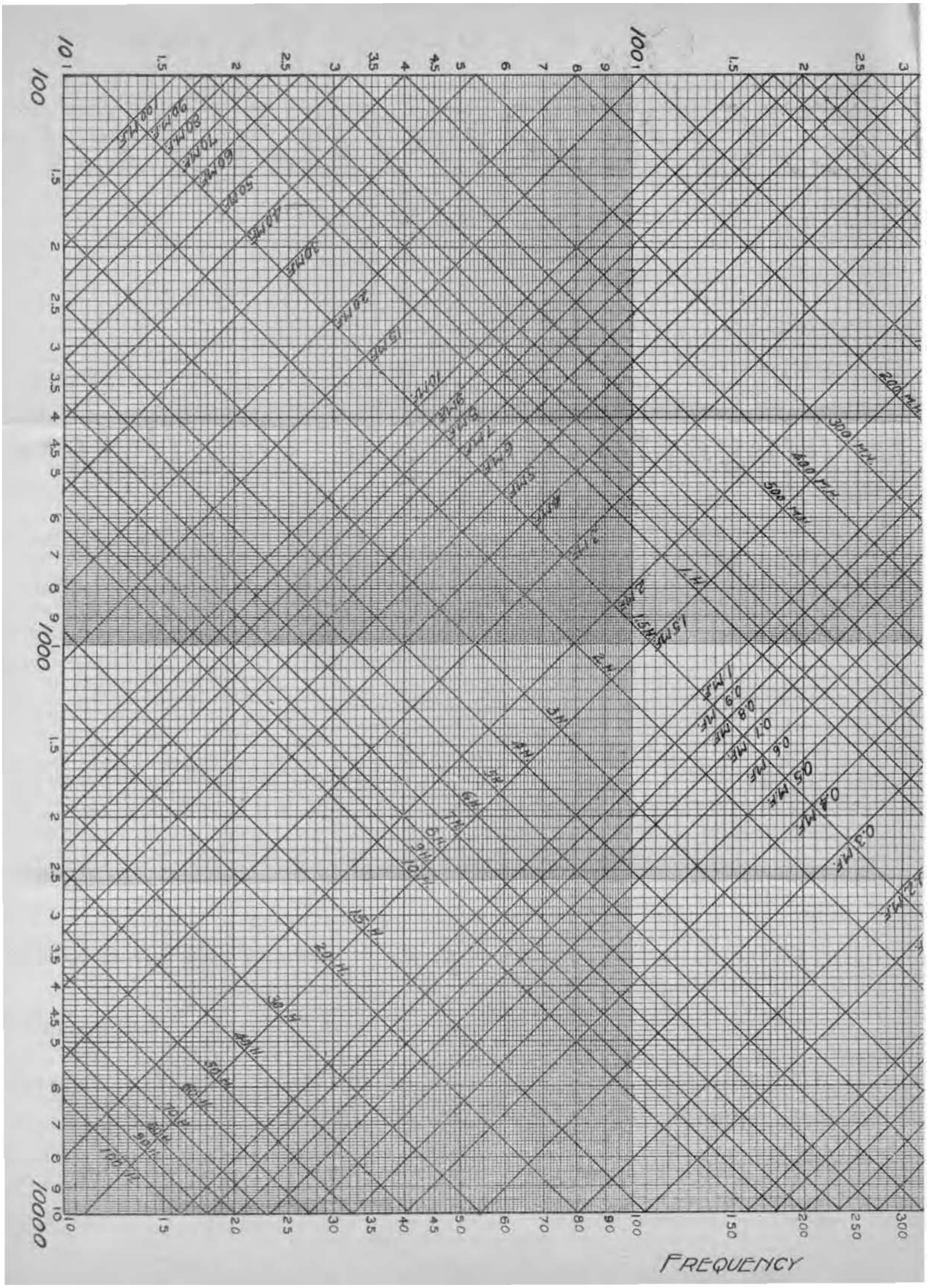
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8 H
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15 H
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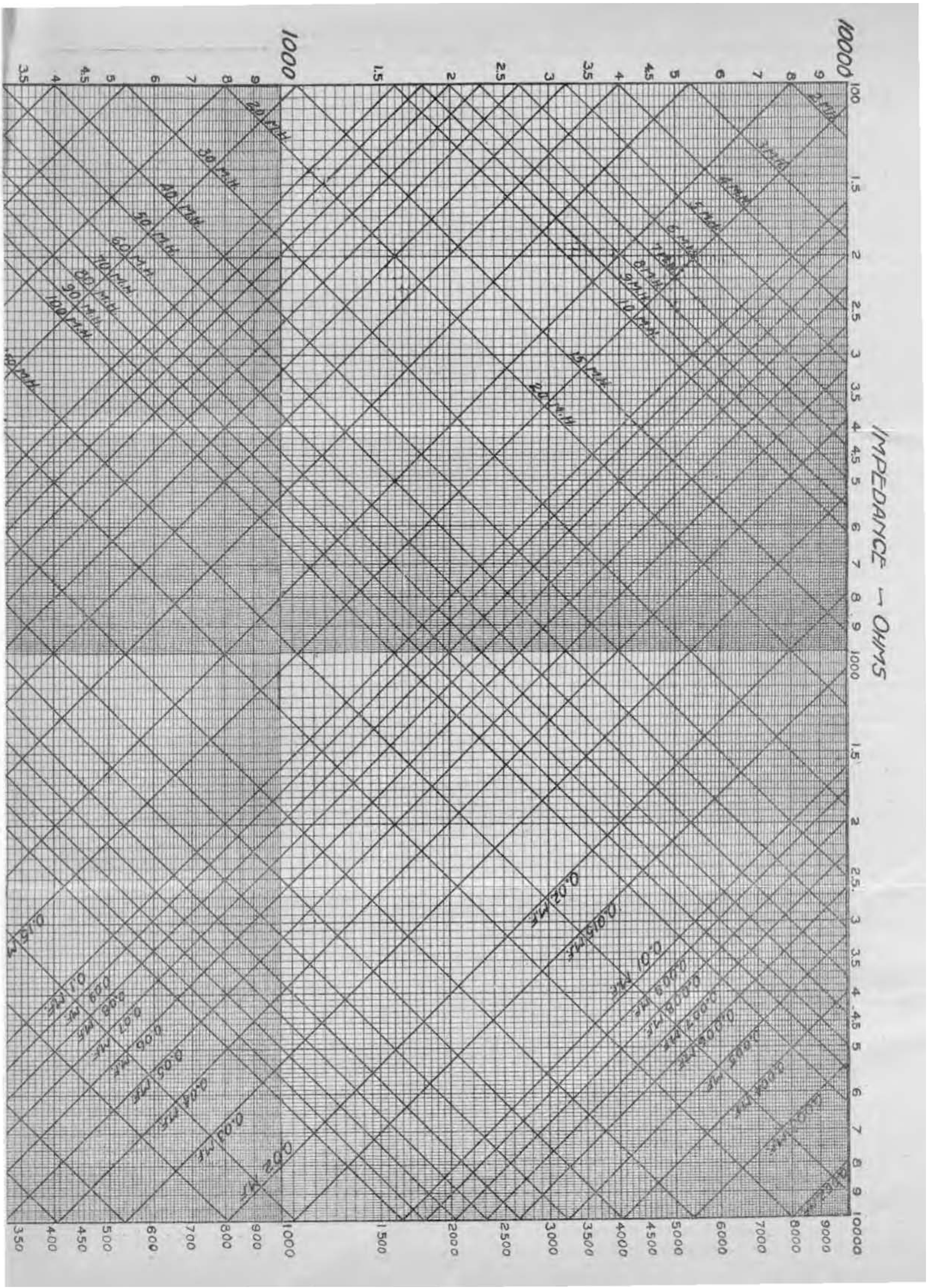
30 H
40 H
50 H
60 H
70 H
80 H
90 H
100 H
200 MMF
300 MMF
400 MMF
500 MMF
2 MF
1.5 MF
1 MF
0.9 MF
0.8 MF
0.7 MF
0.6 MF
0.5 MF
0.4 MF
0.3 MF
0.2 MF


IMPEDANCE – OHMS
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70 MH
80 MH
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100 MH
0.02 MF
0.015 MF
0.01 MF
0.009 MF
0.008 MF
0.007 MF
0.006 MF
0.005 MF
0.004 MF
0.003 MF
0.002 MF
0.1 MF
0.09 MF
0.08 MF
0.07 MF
0.06 MF
0.05 MF
0.04 MF
0.03 MF

Inductance-Capacity-Frequency-Impedance Chart

There is very frequent occasion in communication work to compute the reactance of an inductance or capacitance at some frequency, or to determine the inductance required to give a desired reactance. The values of inductance and capacitance required for resonance at various frequencies are also frequently required. A chart is of invaluable assistance for routine calculations of this sort and the one shown herewith performs all the calculations mentioned. If frequency and impedance are taken as abcissae and ordinates on log-log graph paper constant capacitance lines will be straight lines at 45° with the co-ordinate axis. A series of such lines will give the relations between capacitance, frequency and reactance for the range covered. A similar set of constant inductance lines will also be straight lines, at 45° with the co-ordinates and 90° with the capacity lines. These lines give the relations between frequency, inductance, and impedance.

An inductance and a capacity resonate at the frequency where their reactances are equal. The point of crossing of a capacitance and an inductance line is therefore the resonant frequency for that combination.

The horizontal lines on the chart are constant frequency lines and the vertical lines constant impedance. The capacity lines run downward to the right and the inductance lines upward to the right. The frequency range covered is 10 to 10,000 cycles. The impedance scale runs from 100 to 10,000 ohms, the capacity scale from 0.002 to 100 MF, and the inductance scale from 2 millihenries to 100 henries. All scales are logarithmic.

The chart may be shifted to cover the radio frequency range as follows. Multiply frequency by 1000, i. e. use Kilocycle instead of cycles. Retain the same impedance scale, and divide both capacity and inductance scales by one thousand, i. e. the capacity scale will now run from 20 MMF to .1 MF, and the inductance scale from .002 MH to 100 MH. A shift in the impedance scale may be made by multiplying the inductance scale and dividing the capacity scale by the "shift factor." A few examples will illustrate the use of the chart.

1. Find the impedance at 60 cycles of a transformer primary of 20 henries inductance. Following across from the frequency scale at 60 cycles to its intersection with the 20 H line, project downward to the impedance scale (impedance—7500 ohms).

2. At what frequency will 0.3 M.F. and 400 millihenries resonate? Locate the intersection of the 0.3 MF and the 400 MH lines and read the frequency scale (460 cycles).

3. What capacitance is required for resonance with 100 millihenries at 5000 cycles? Follow the 5000 cycle line to its intersection with the 100 MH line. Estimate the capacity line that would intersect the 100 MH line at this point (about 0.01 MF).

(Continued from page 1)

order of 0.1 MF. The choke and 2 MF condenser, C_2, in the plate circuit of the amplifying tube constitute the familiar "speaker-filter" for removing a.d.c. polarization from the output terminals. The grid leak is of the order of 50,000 ohms.

When such a circuit is tuned by means of C until resonance with the natural frequency of the rod is approached, the reading of A rises sharply to a maximum as the rod goes into strong vibration. When this optimum point is reached the condenser may be increased or decreased by a considerable amount while the frequency of the oscillations remains unchanged. That is to say, the circuit is stabilized at the natural frequency of the rod.

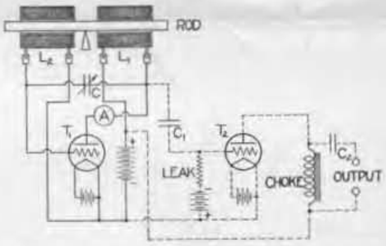
Various types of tubes may be used at T_1, the plate voltage may be changed from 67 to 135, or the filament voltage may vary from practically zero emission to destruction of the filament with a resultant change of less than one part in 30,000 in the stabilizing frequency of the circuit. A reasonable control of these variables gives, of course, a much more precise standardization of the frequency.

The relation between the length and natural frequency of a rod is given by the simple equation:

$$V = 2 LF$$

Where F is the frequency in cycles per second, L the length of the rod, and V the velocity of sound in the rod expressed in corresponding units. For a given material V is a constant essentially independent of L and F.

Knowing then the value of V, the length of rod having any desired frequency may readily be computed. In this way a whole series of rods of definite frequencies are easily prepared. Dr. Pierce has made such a series having fundamental frequencies varying over a wide range from a few hundred to 300,000 cycles per second. Harmonics of these frequencies up to several millions are readily detected. Since great difficulty is encountered in obtaining large enough piezo crystals to give fundamental frequencies below 25 kilocycles, the lower range of frequency standardization has been greatly increased by the invention of the magneto-striction oscillator. Magneto-striction rods are calibrated with much greater ease than are piezo-electric crystals, since the rods remain continually active and are not subject to the disappointing vagaries of crystals.



As the length of the rod is shortened and its frequency increased, greater efficiency of stabilization is attained by occasionally reducing the inductance of the two exciting coils. This is readily accomplished by having three or four different pairs of coils mounted on jack-plugs for easy substitution in the oscillatory circuit.

Under license to patents pending of Professor Pierce, the General Radio Company has developed a magneto-striction oscillator embodying the circuits shown in the diagram. This is known as the Type 389 Pierce Magneto-Striction Oscillator. For greater convenience in frequency calibration, the Type 489 Pierce Twin Magneto-Striction Oscillator, shown in the illustration, has been developed. This consists of two separate oscillators and amplifiers mounted in a single unit with provisions for a variable coupling between them. One of these oscillators may be controlled by a rod, while the other takes the form of a variable Hartley oscillator, to be used as described above, or both circuits may be rod controlled and definite fixed beats between them obtained. Prices and particulars, together with data on calibrated rods, may be had on application.