

X. PHYSICAL ACOUSTICS*

Prof. K. U. Ingard
Dr. L. W. Dean III
Dr. R. G. Chatterji

N. A. Ball
G. C. Maling, Jr.

E. J. Martens, Jr.
D. S. Wiley
H. L. Willke, Jr.

A. A LOW RESONANT FREQUENCY BARIUM TITANATE TRANSDUCER

A barium titanate slab with a resonant frequency of 1000 cps would be 2.5 meters thick. Therefore, if one wants a resonant transducer at lower frequencies, one must find some way to lower the resonant frequency of a piece of barium titanate of reasonable dimensions.

One approach to the problem is the configuration shown in Fig. X-1. Two strips of barium titanate are cemented together to form a bilaminate, which bends when a voltage is applied across the faces. The resonant frequency is lowered by the addition of masses to the ends. Transducers having resonant frequencies from 100 cps to 2000 cps were made from barium titanate bilaminates 6 cm long, 3 cm wide, and $1/3$ -1 cm thick by adding end masses of approximately 100-200 grams.

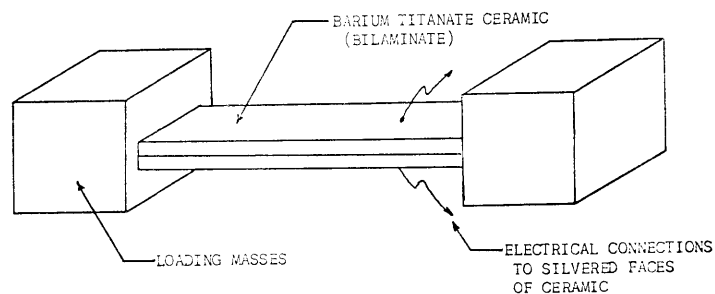


Fig. X-1. A mass-loaded bar.

Attempts to find a simple formula relating the resonant frequency to the transducer parameters have failed. However, by adding or subtracting mass from the ends, the device can be tuned to a particular frequency.

Since the transducer is physically much smaller than a wavelength of sound at its resonance, it does not make an efficient radiator. For such a device the radiation impedance of various media does not scale as ρc , where ρ is the density, and c the speed of sound, but as $\rho c \cdot (ka)^4$, where k is the wave number ($k=\omega/c$), and a is a characteristic dimension of the transducer. Thus this device is a less efficient radiator in water than it is in air. The radiation pattern, as expected, is that of a dipole, the axis

*This work was supported in part by the U. S. Navy (Office of Naval Research) under Contract Nonr-1841(42).

(X. PHYSICAL ACOUSTICS)

of which is perpendicular to the flat surface of the bilaminate.

Details of measurements of the electrical and mechanical parameters are given in N. A. Ball's thesis.¹

N. A. Ball, L. W. Dean III

References

1. N. A. Ball, Determination of Design Parameters for a Novel Electroacoustical Transducer, S.M. Thesis, Department of Electrical Engineering, M. I. T., June 1961.

B. THE DAMPING OF MECHANICAL OSCILLATORS BY FLOW

A low-speed wind tunnel has been constructed in order to make measurements on the damping of mass-spring oscillators by flow. The damping of an oscillator has been found to be a strong function of flow velocity. For example, the amplitude of an oscillator with a period of 1.04 seconds decreases to one-half of its original value with no flow in 6 minutes and 37 seconds. A flow velocity of 200 feet per minute past the mass causes this damping time to decrease to 1 minute and 27 seconds.

Results of this kind can be most easily interpreted by using the following analysis: The force on the mass is

$$F = K(V-u)^2, \quad (1)$$

where V is the air stream velocity, u is the velocity of the mass, and K is some proportionality factor. In practice, u can be made much less than V so that, apart from a steady force that shifts the equilibrium position slightly, the drag force may be written

$$F = 2KVu. \quad (2)$$

The drag force is therefore proportional to the oscillator velocity and should result in ordinary exponential damping. The dependence (if any) of K on oscillator frequency and flow speed can be found by measurement of the damping time. The experiments that have been performed, thus far, have not given particularly satisfactory results because disk-shaped weights were used to change the mass, and therefore the period of the oscillator. In the next series of experiments, the mass will be a sphere, and the period will be changed by changing the spring constant.

U. Ingard, G. C. Maling, Jr.

C. ACOUSTICS OF INHOMOGENEOUS MOVING MEDIA

Two problems that involve acoustic wave propagation in inhomogeneous media are being investigated. The first involves the effect of a plane boundary on the magnitude

of the fluctuations in sound pressure that occur when a slowly moving turbulent air stream is made to pass over the boundary.

This problem has been analyzed theoretically and an experiment is now being carried out in the anechoic chamber to study the problem further. Construction of the experimental apparatus has now been completed and data are being obtained.

Another aspect of the interaction of sound with moving air streams involves the influence of a heat source in a moving medium. Through the modulation of the heat transfer to the medium by the sound itself, the heat source acts as a scatterer of sound. The conditions for self-sustained oscillations (as in the Rijke tube) are being investigated with particular emphasis on the amplitude of the oscillations as a function of geometry, heat-source parameters, and so forth. The effect has been observed in a number of Rijke tubes of various sizes, but quantitative data have not yet been obtained because of difficulties involved in the construction of a heat source that will introduce heat into the medium at a known rate.

G. C. Maling, Jr.

D. BIFURCATION INSTABILITY OF A LIQUID CONDUCTOR IN AN AXIAL MAGNETIC FIELD*

During the past year, an extensive series of experiments has been performed to study the instability of a mercury current filament moving in an axial constant magnetic

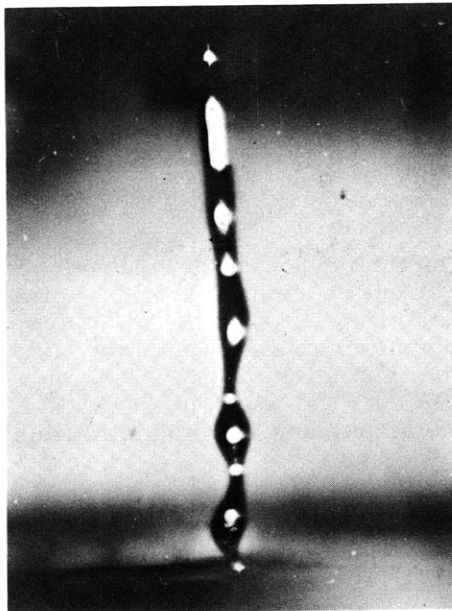


Fig. 2. Illustration of self-pinch of a mercury column falling freely under gravity, and carrying a current of 180 amp. The diameter of the mercury column is 0.3 cm.

*This work was supported in part by the National Science Foundation under Grant G-9330.

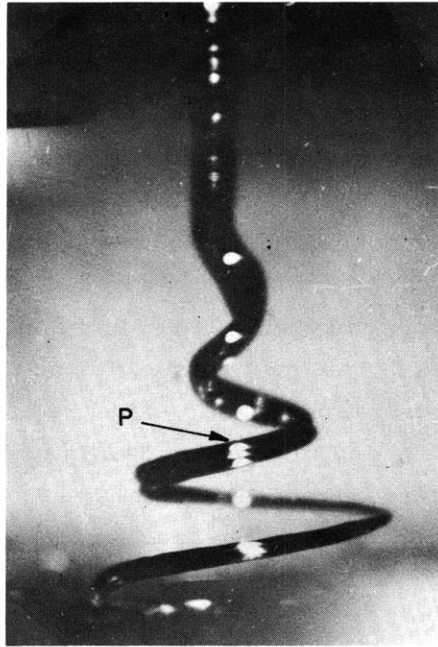


Fig. X-3. Illustration of spiral instability of a mercury column falling under gravity in an axial magnetic field. The diameter of the mercury column is 0.5 cm; the electrical current through it, 80 amps; and the axial magnetic field, 2200 gauss. Notice that the cross section of the mercury column is deformed as it spirals and that there is an indication of bifurcation. Actually, judging from the reflected light pattern at point P, two indentations seem to be present in the stream.



Fig. X-4. Illustration of a fully developed bifurcation resulting from spiral instability in a mercury column moving in an axial magnetic field. The diameter of the column is 0.5 cm; the current through it, 260 amps; and the magnetic field, 3600 gauss.

field. The pinch instability of this mercury filament (with no magnetic field present), and the spiral instability, have been studied and photographed by means of high-speed photography. A typical example of pictures showing pinch and spiral instabilities is shown in Figs. X-2 and X-3. During the course of these studies a new type of instability was found which might be referred to as a "bifurcation instability," and is illustrated in the photograph in Fig. X-4. At sufficiently large magnetic fields it was found that the mercury stream divides in two, continuing to spiral about the magnetic field. This bifurcation results presumably from the fact that when the mercury column bends, its cross section changes from circular to elliptical, and this distortion of the cross section continues until the stream divides in two. A detailed account of these experiments is being prepared for publication.

D. S. Wiley, U. Ingard

E. SEARCH FOR A STABLE PINCH IN A HORIZONTAL MERCURY COLUMN*

In the first published account¹ of the pinch phenomenon in a liquid conductor, and in a later systematic study of this phenomenon,² it was indicated that a stable pinch can be obtained in a horizontal mercury column that is carrying an electric current. This pinch, which formed a V-shaped indentation on the free surface of the mercury, was claimed to be stable and to increase in depth with the current. A theoretical study of this problem has been undertaken, and it has been shown that, at least for an infinitely long horizontal mercury column, a pinch cannot be explained. Experiments have been performed to study this phenomenon by using a mercury column in a vertical tray consisting of lucite plates. The thickness of the column was approximately 0.5 inch, the length was approximately 10 inches, and the height was varied from 0.5 inch to 3 inches. Currents up to 2000 amps were used. No pinches were found. Pinchlike deformations of the free surface of the mercury could be obtained, however, if the electric leads to the column were asymmetrical and hence produced asymmetry in the magnetic field, and it is clear that in experiments of this type special care should be taken to avoid inhomogeneities in the magnetic field. When such inhomogeneities are produced intentionally by ferromagnetic materials placed above the mercury columns, steady deformations of the free-mercury surface are readily produced.

U. Ingard, D. S. Wiley

References

1. C. Hering, A practical limitation of resistance furnaces, the Pinch Phenomenon, *Trans. Am. Electrochem. Soc.*, Vol. XI, p. 329, 1907.

*This work was supported in part by the National Science Foundation under Grant G-9330.

(X. PHYSICAL ACOUSTICS)

2. E. E. Northrup, Some newly observed manifestations of forces in the interior of an electric conductor, Phys. Rev. 24, 474 (1907).

F. OSCILLATION OF A FERROMAGNETIC BODY INSIDE A LIQUID CONDUCTOR*

In the course of our studies of instabilities of a mercury column, an amusing effect was found by floating a piece of metal on the surface of a horizontal mercury column. When a current (of approximately 1000 amps) was sent through the column, the piece of iron was pulled into the mercury and set into vertical oscillations approximately about the center of the mercury column. At the center of the column the magnetic field is clearly zero and the vertical field gradients on either side are directed toward the center line, thereby producing a linear restoring force on the piece of iron.

U. Ingard, D. S. Wiley

*This work was supported in part by the National Science Foundation under Grant G-9330.