OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

DEPARTMENT OF PHYSICS
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

TECHNICAL REPORT PTR-83-2

PROPAGATION OF SOUND THROUGH THE EARTH'S ATMOSPHERE

By

Roger W. Meredith

and

Jacob Becher, Principal Investigator

Final Report
For the period July 1, 1982 to May 31, 1983

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NAG1-234
Harlan K. Holmes, Technical Monitor
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Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508-0369

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By

Roger W. Meredith[1] and Jacob Becher[2]

SUMMARY

This report summarizes the work performed under research grant NAG1-234, during the period from June 1, 1982 to May 31, 1983, concerning the Measurement of Sound Absorption in Air.

DATA ACQUISITION

Table 1 summarizes the data collected at a pressure of one atmosphere for the different temperatures and relative humidities of the air-water vapor mixtures of this study. The dew point hygrometer used in these measurements did not give reliable results for dew points much above the ambient room temperature. For this reason measurements were not attempted at the higher temperatures and humidities.

Viscous wall losses in the resonant tube at 0° C so dominate the molecular relaxation of nitrogen, in the air-water vapor mixture, that reliable data could not be obtained using the free decay method in a resonant tube at one atmosphere. In an effort to obtain viable data at these temperatures, measurements were performed at a pressure of 10 atmospheres. Since the molecular relaxation peak is proportional to the pressure and the viscous losses are proportional to the inverse square root of the pressure the peak height should be measurable at the higher pressure. The tradeoff here is that at 10 atmospheres the highest relative humidity attainable is 10 percent. Table 2 summarizes the data collected at 10 atmospheres.

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Table 1. Data collected in air-water vapor mixtures at one atmosphere.

RELATIVE HUMIDITY %				
Temperature °C				
10° C	20° C	30° C	40° C	50° C
1.1%	0.604%	0.45%	0.36%	0.28%
5.3	9.1	13.8	9.4	6.2
11.6	17.0	24.2	16.5	17.4
	20.8	38.3	25.7	28.8
	28.3	46.1	32.9	
	35.6	52.1	47.9	
	45.8	65.4		
	55.3			
	65.4			
	66.5			
	73.4			
	87.6			
	91.2			

Table 2. Data collected in air-water vapor mixtures at 10 atmospheres.

RELATIVE HUMIDITY	
Temperature °C	
0° C	10° C
3.25%	1.25%
5.28%	4.76%

DATA EVALUATION

For the low frequency, straight line decay curves, the absorption is computed from the slope determined by the least squares best fit to a third degree polynomial. For the higher frequency, stair step decay curves, the absorption is computed from the average step depth.

The software and documentation has been completed and the data is currently being evaluated at NASA/Langley. Appendix A is a reprint of the manuscript describing the evaluation and acquisition in more detail.

APPENDIX A

DIGITAL DATA ACQUISITION SYSTEM FOR MEASURING THE FREE DECAY OF ACOUSTICAL STANDING WAVES IN A RESONANT TUBE

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INTRODUCTION

The widespread availability of powerful low-cost microcomputers in recent years has led to their increasing utilization in the control, acquisition, and processing of experimental data obtained in the laboratory. Such a system based on an 8-bit Apple II microcomputer has been designed to achieve on-line evaluation of sound absorption measurements in gases. The measurements are conducted in a resonant tube, whereby an acoustical standing wave is excited in the tube, the excitation removed, and the sound absorption evaluated from the free decay envelope. The response of a microphone to the sound pressure at one end of the tube is the source of the analog data. Following a brief review of the analog instrumentation, this paper will describe the digital hardware, software, and system performance. Some of the peculiarities of the free decay of standing waves in a resonant tube will be discussed, and measurements of sound absorption in air will be presented as an example. The digital data acquisition system can be used to evaluate the damping of any resonant system in which it is feasible to use the method of free decay.

I. INSTRUMENTATION AND ACQUISITION SYSTEM

A block diagram of the analog instrumentation and the digital data acquisition system is shown in figure 1. A detailed description of the resonant tube and operating procedure has been given previously.[1] The excitation signal originates at the frequency synthesizer and passes through a relay and a power amplifier to a vibration exciter, which displaces a rigid piston inside the tube. The acoustical signal is received by a high-sensitivity piezoelectric quartz microphone, and amplified and filtered by the lock-in amplifier. The synthesizer provides the reference signal to the lock-in. The dc output of the lock-in is applied logarithmically to an analog-to-digital converter. Due to the exponential nature of the free decay envelope, the logarithmic converter is employed to distribute the digital sampling intervals equally per dB increment over the full range of the free decay. Thus, a given voltage drop corresponds uniformly to the same number of decibels independently of voltage level.

The 12-bit A/D converter provides a resolution of 1:4096 or 0.024%. It is a CMOS level device and requires the non-inverting hex buffers to make the A/D output TTL-compatible. The analog instrumentation, on the other hand, has a dynamic range of 40 dB.

After the acoustic standing wave is set up in the tube, a keyboard command calls a machine language program that controls the A/D converter. The timer is used to increase the start convert pulses to levels sufficient to trigger the A/D. On the 16th start convert pulse the counter causes the relay to open, shutting off the excitation, and allowing the remaining 240 samples to monitor the free decay. As a result, the reference level of the decay is well defined by the first 16 samples, and the sample number at the start of the decay is exactly known. The reset switch, which de-energizes the relay, and the on/off switch together permit manual control of the excitation.

II. PROGRAM CONTROL

The digital data acquisition is accomplished by a combination of machine language and BASIC programming. A flow chart for controlling the A/D converter and for acquiring the digital data is shown in figure 2. After initialization of the peripheral interface adapter, the computer sends the first start-convert pulse to the A/D converter. The duration of the timing loop--an input parameter assigned during initialization--affords software control of the digital sampling rate SR. Thus, the time between start convert pulses, i.e. the digital sampling period, can be varied from 2 milliseconds to 10 seconds. The results of the analog-to-digital conversion are stored in hexadecimal format in successive memory addresses in the computer. The process repeats itself until the 256th conversion, at which time the program returns to BASIC. The digital data is converted to decimal format by means of the PEEK command and stored in an array.

III. DECAY CURVE EVALUATION

A typical low frequency (9.592 Hz) decay curve appears in figure 3. The oscillographic trace shows the microphone response to the sound pressure level as the standing wave decays in time. The lower curve is the digital reproduction of the logarithmic envelope. The sound absorption coefficient is determined from the decay slope, which is computed from a linear regression analysis. Typically, 180 successive digital samples are used in the numerical evaluation. Correlation coefficients for these decay curves are usually greater than 0.9999.

Figure 4 shows an example of a high frequency (992 Hz) decay curve. Again, the oscillographic trace is the analog signal from the microphone and the lower plot is the digital reproduction of the logarithmic envelope. The stairstep phenomenon is inherent in the free decay of standing waves in continuous media. When the excitation is removed each cycle of the standing wave initially has the same amplitude as the others and undergoes the same attenuation while it travels from one endplate to the other. Thus, the microphone sees an interval of constant amplitude equal to the duration of the wave train, followed by a sudden amplitude drop corresponding to the round trip attenuation. The sound absorption coefficient is determined from the absorption per unit round trip time. For each interval of constant amplitude the average step depth with respect to the known reference level is computed to find the average absorption per round trip time. It should be noted that if the analog input saturates the A/D converter, an error will result in the value of the reference level.

ACKNOWLEDGMENTS

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REFERENCE

1. A.J. Zuckerwar and W.A. Griffin, J. Acoust. Soc. Am. 68, 218-226 (1980).

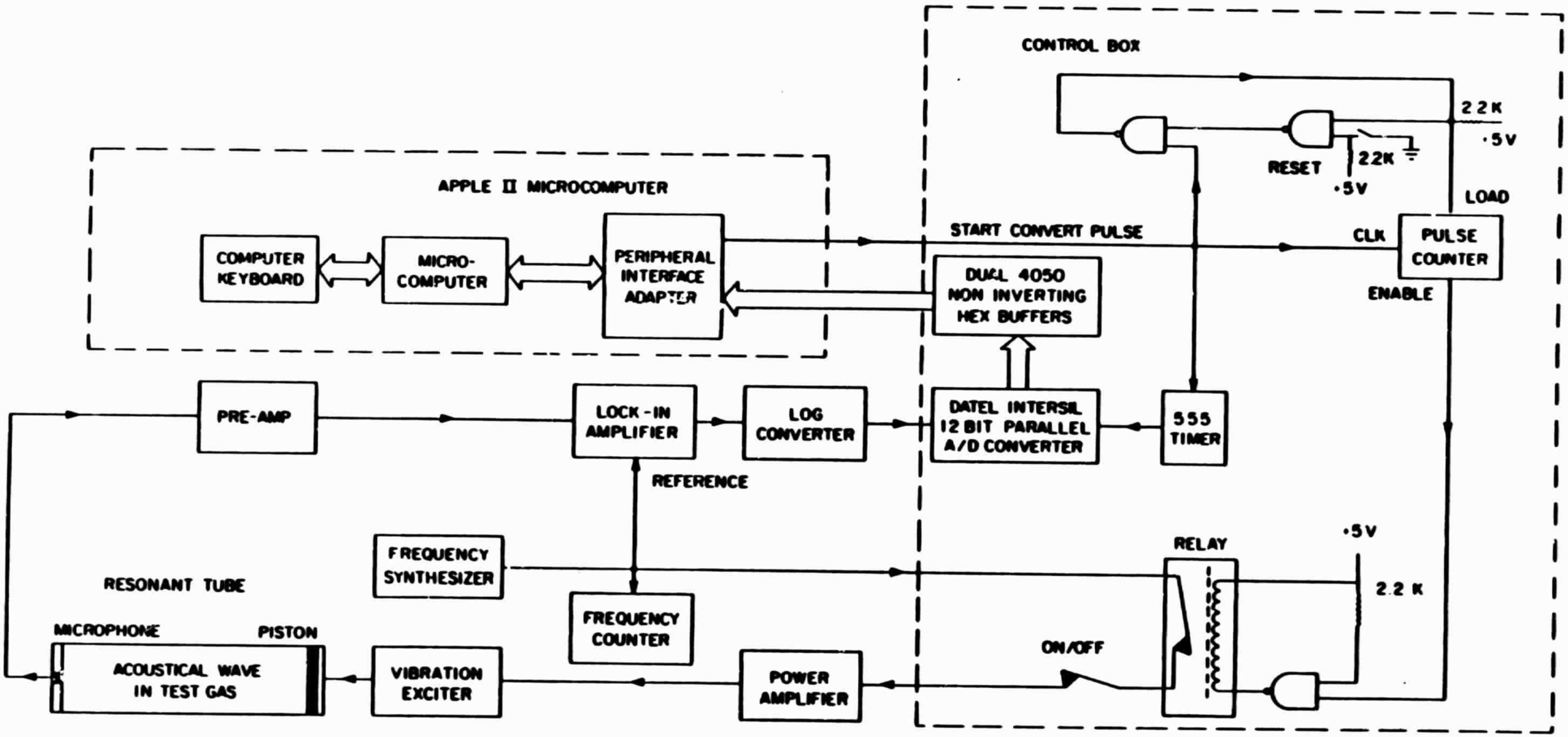

Figure 1. Block diagram of the analog instrumentation and digital data acquisition system.

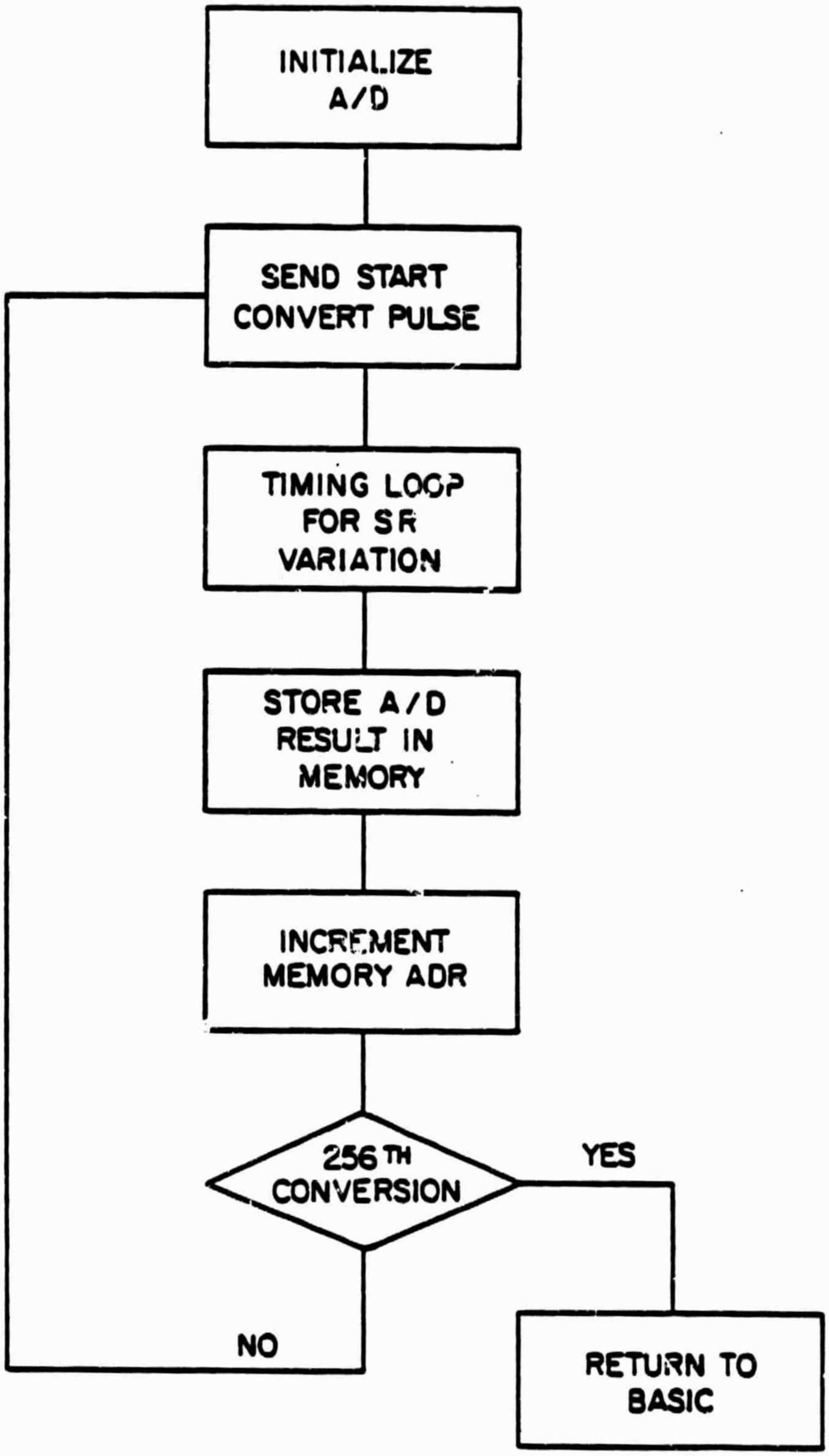

Figure 2. Machine language flow chart for digital data acquisition.

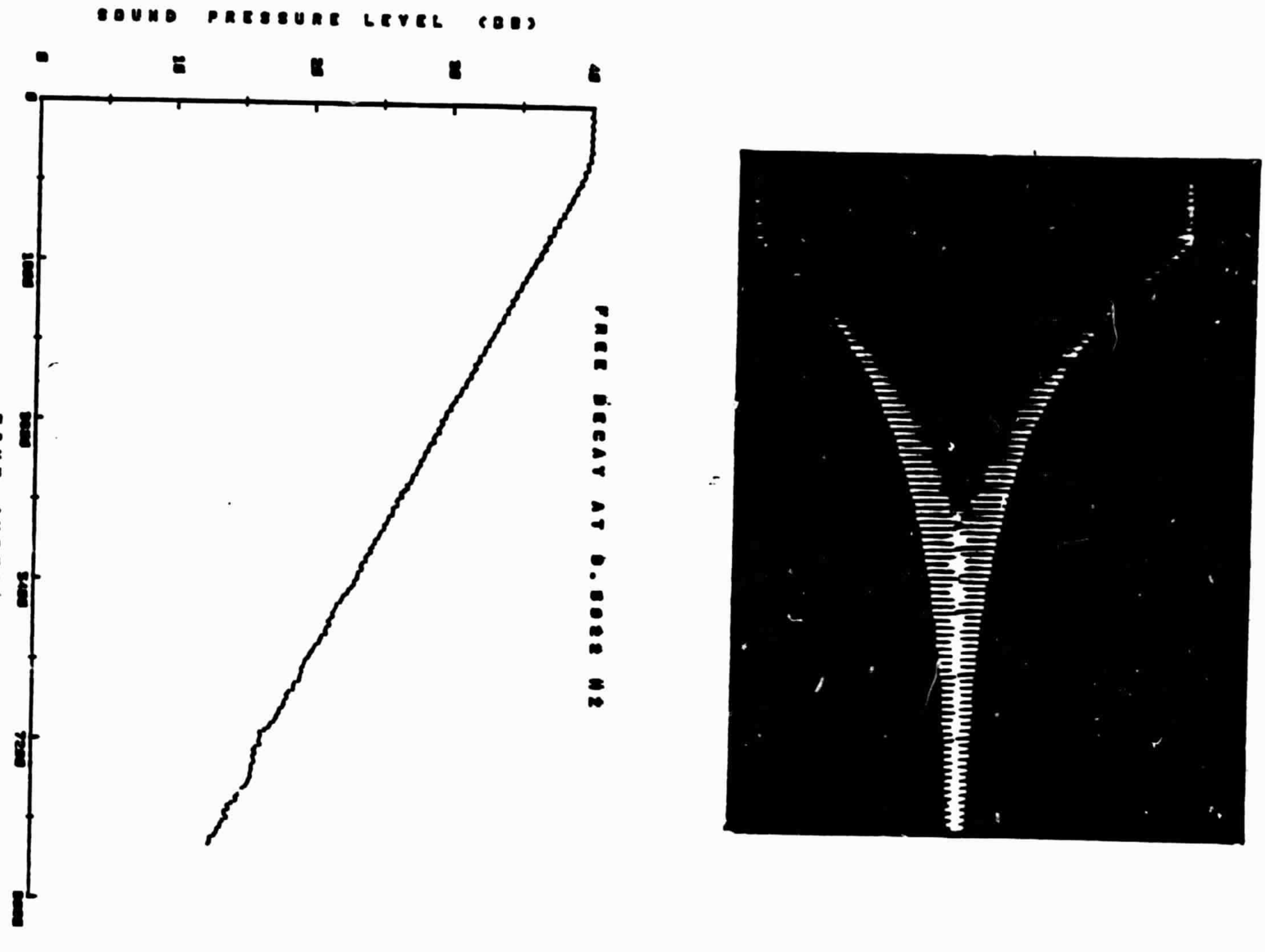

Figure 3. Free decay of acoustical standing wave at low frequencies; osc·llographic trace (upper) and digital reproduction of th· ·ogari·hmic envelope (lower).

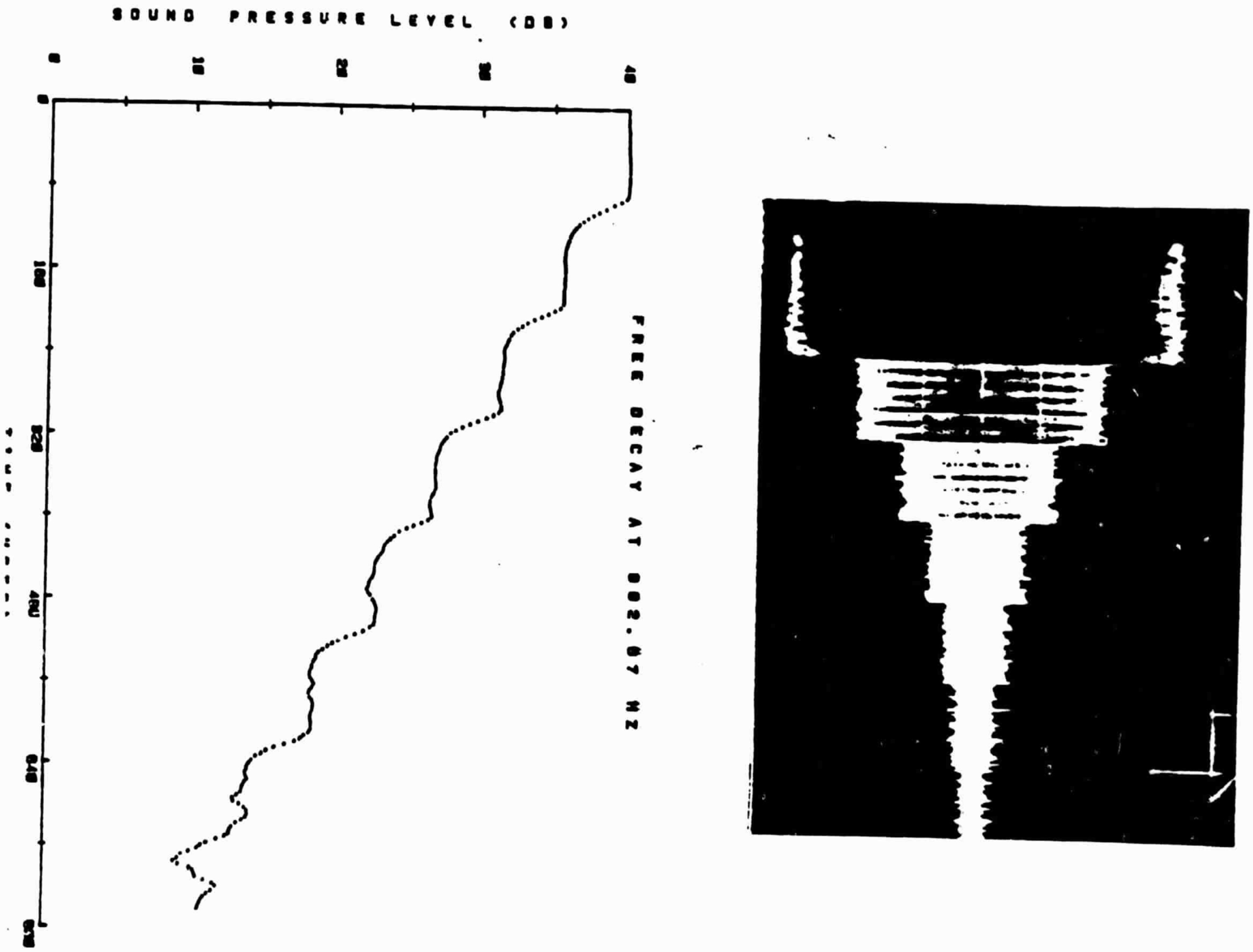

Figure 4. Free decay of acoustical standing wave at high frequencies; oscillographic trace (upper) and digital reproduction of the logarithmic envelope (lower).