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Development of Microwave Hygrometer Model III

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Progress Report

Prepared for

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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Abstract

This is a progress report on the design and construction of NBS microwave hygrometer, Model III. The hygrometer is intended for field or laboratory operation with a dew point range of -40° to 40°C.

Key words: Dew-point, hygrometer, microwave hygrometer

Introduction

The hygrometer contains two microwave cavities. The resonant frequency of each cavity is determined by its dimensions and the temperature, pressure and water vapor content of the gas in the cavity. Sample air is drawn through the instrument in such a manner that the air within each cavity is at the same total pressure and temperature; however, one cavity (reference cavity) contains dry air and the other cavity (sample cavity) contains moist air. Under these conditions the resonant frequency of the sample cavity differs from that of the reference cavity by an amount proportional to the water vapor content of the sample air.

In Model II, Ref. (1), the water vapor content is measured by the method illustrated in Figure 1 (A paper describing this hygrometer is now in the final stages of preparation for submission for publication). Both cavities are excited by a microwave oscillator. The microwave outputs of the two cavities are fed to two control circuits. A frequency lock circuit acts to hold the frequency of the oscillator midway between the resonant frequencies of the two cavities. At the same time, a servo control circuit tunes the resonant frequency of the sample cavity so that it is the same as that of the reference cavity. The servo controls a motor which is mechanically linked to a tuning probe in the sample cavity. The tuning probe is coaxially mounted on a precision micrometer screw which is driven by the motor.

The shaft of the micrometer screw is also directly attached to an electronic shaft position indicator. The least significant digit of this readout indicates 1/1000 of a turn, which is equivalent to a change in probe position of 6.35×10^{-4} mm (2.5×10^{-5} in.).

After the installation and operation of microwave hygrometer Model II in Townsend, Georgia, to measure humidity for warm fog research and for calibrating other field instruments, it became apparent that several mechanical features caused problems under field conditions. An improved hygrometer designated Model III, was designed to eliminate these features and also to further ruggedize the instrument without degrading the overall accuracy.

New Design Features

The major change in the new instrument, Model III, is the modification of the basic measurement method to eliminate components which are subject to mechanical wear or sensitive to mechanical shock or vibration. We have devised a measurement method which requires no moving parts. This method consists of electronic circuitry which directly measures the frequency difference between the two cavities. A block diagram of the electronic circuit is shown in Figure 2. Each microwave cavity is fed by a separate microwave oscillator. The frequency of each oscillator is controlled by a lock circuit which forces the oscillator to stay at the resonant frequency of the cavity. The outputs of the two oscillators are fed to a microwave mixer. The frequency of the mixer output is equal to the difference in frequency between its two inputs. This signal is fed to a commercial counter which displays the frequency difference between the two cavities.

The physical appearance of the hygrometer is shown in Figures 3 through 5. Figure 3 is an exterior view. The instrument is contained in a box measuring 0.46 m (18 in.) by 0.46 m (18 in.) by 0.71 m (28 in.) with a mass of 47.6 kg . All the components are inside the box for protection against the weather. The compartment at one end of the box shown in Figure 4, contains the power supplies, the vacuum pump, the dryer and much of the plumbing which forms the air path through the device. This compartment is vented to the outside air so that heat from the vacuum pump will not unduly raise the temperature. Opening the opposite end of the box (Figure 5) provides access to the outer oven of the hygrometer. Most of the electronic circuitry of the instrument is mounted in this constant temperature compartment to minimize errors caused by ambient temperature variations. This compartment is controlled to 50°C. The microwave cavities are mounted in the inner oven (Figure 5) which is contained within the outer oven. The temperature in the inner oven is controlled to 60.0°C. Precise control of the inner oven is possible because of the stable environment provided by the outer oven. The ovens have been designed to maintain control over a large range of ambient temperatures.

Further Work

The microwave hygrometer will be compared with the NBS two-pressure humidity generator over a minimum dew point range of 25° to -40°C (possibly 40° to -55°C) to determine its performance characteristics. Preliminary tests indicate that Model III performs as well as or better than Model II.

At present the output of the hygrometer is in terms of the frequency difference between the reference and sample cavities which is displayed on the frequency counter readout. With appropriate interfacing, the output can be fed to an analog recorder, ADP equipment, a minicomputer, etc.

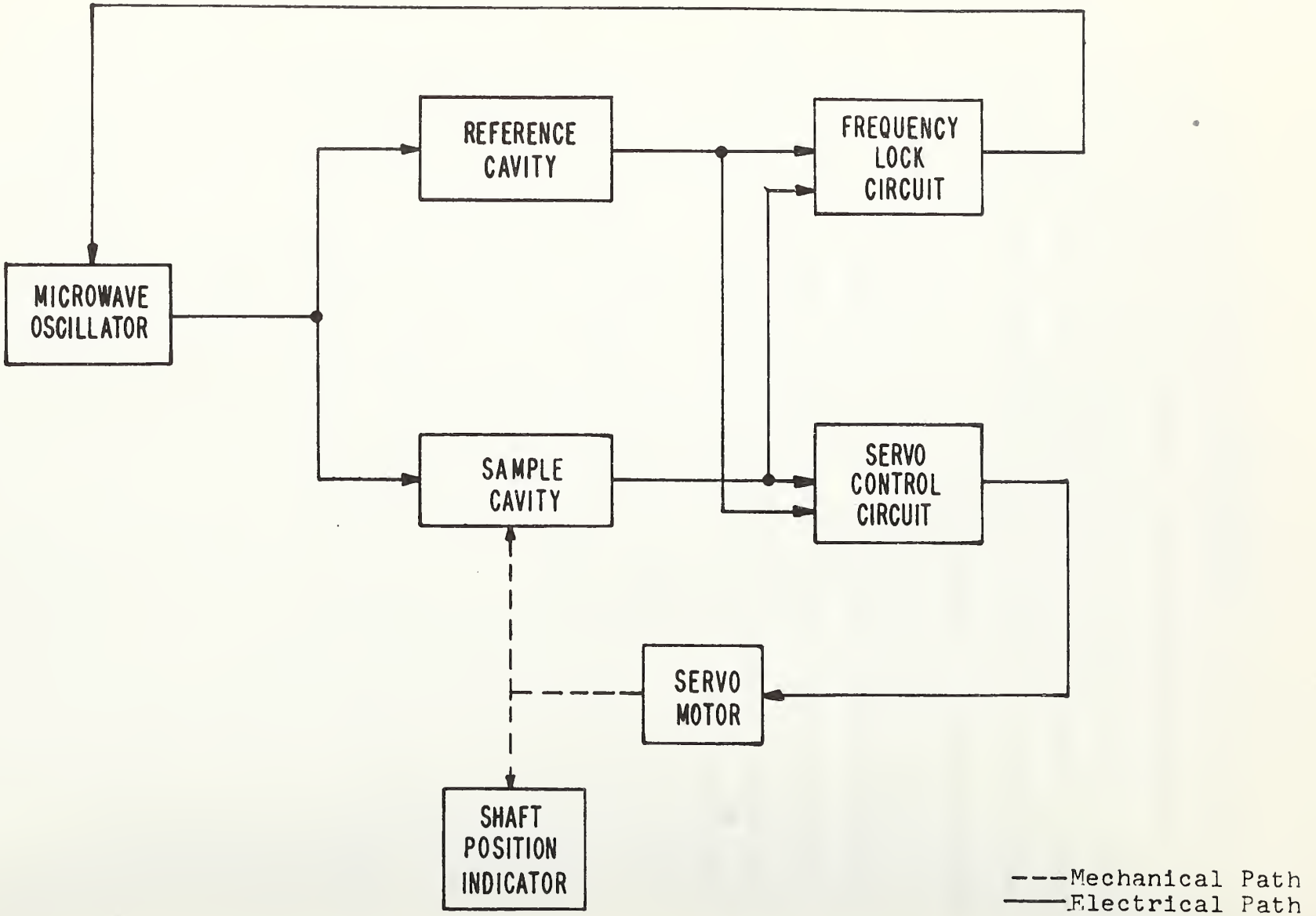

Figure 1. Block diagram of the measurement method used in Microwave Hygrometer Model II.

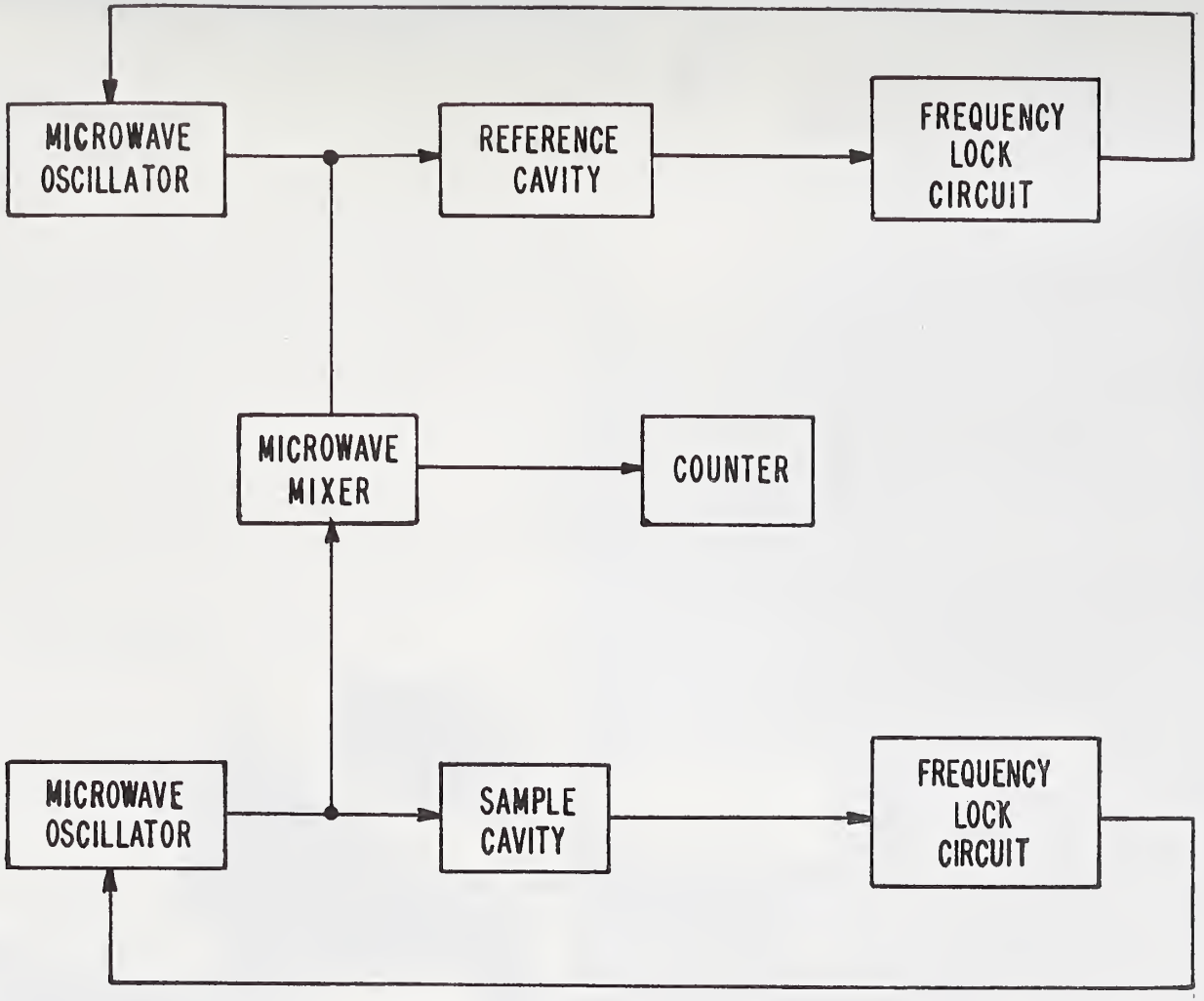

Figure 2. Block diagram of the measurement method used in Microwave Hygrometer Model III.

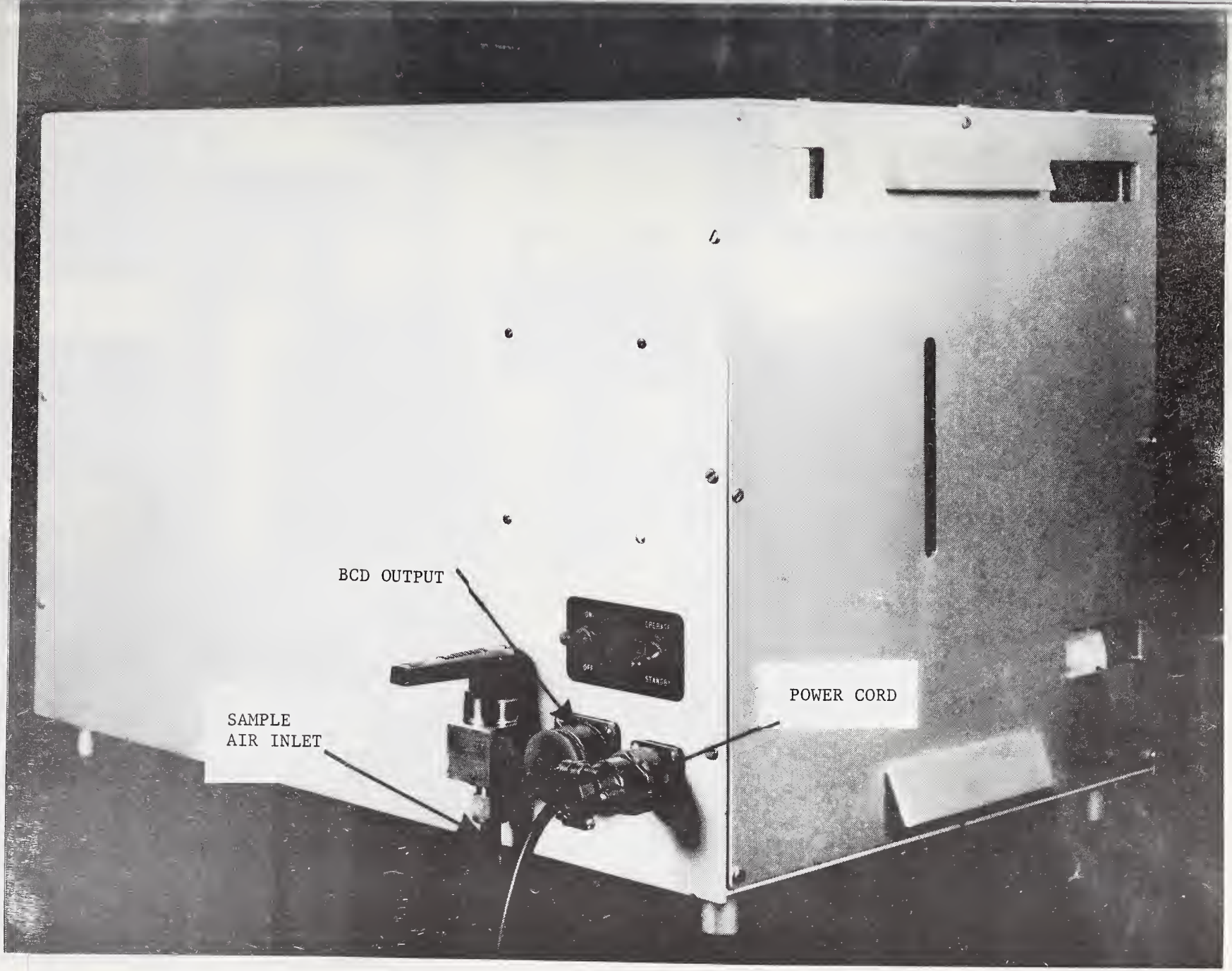

Figure 3. Exterior view of NBS microwave hygrometer, Model III.

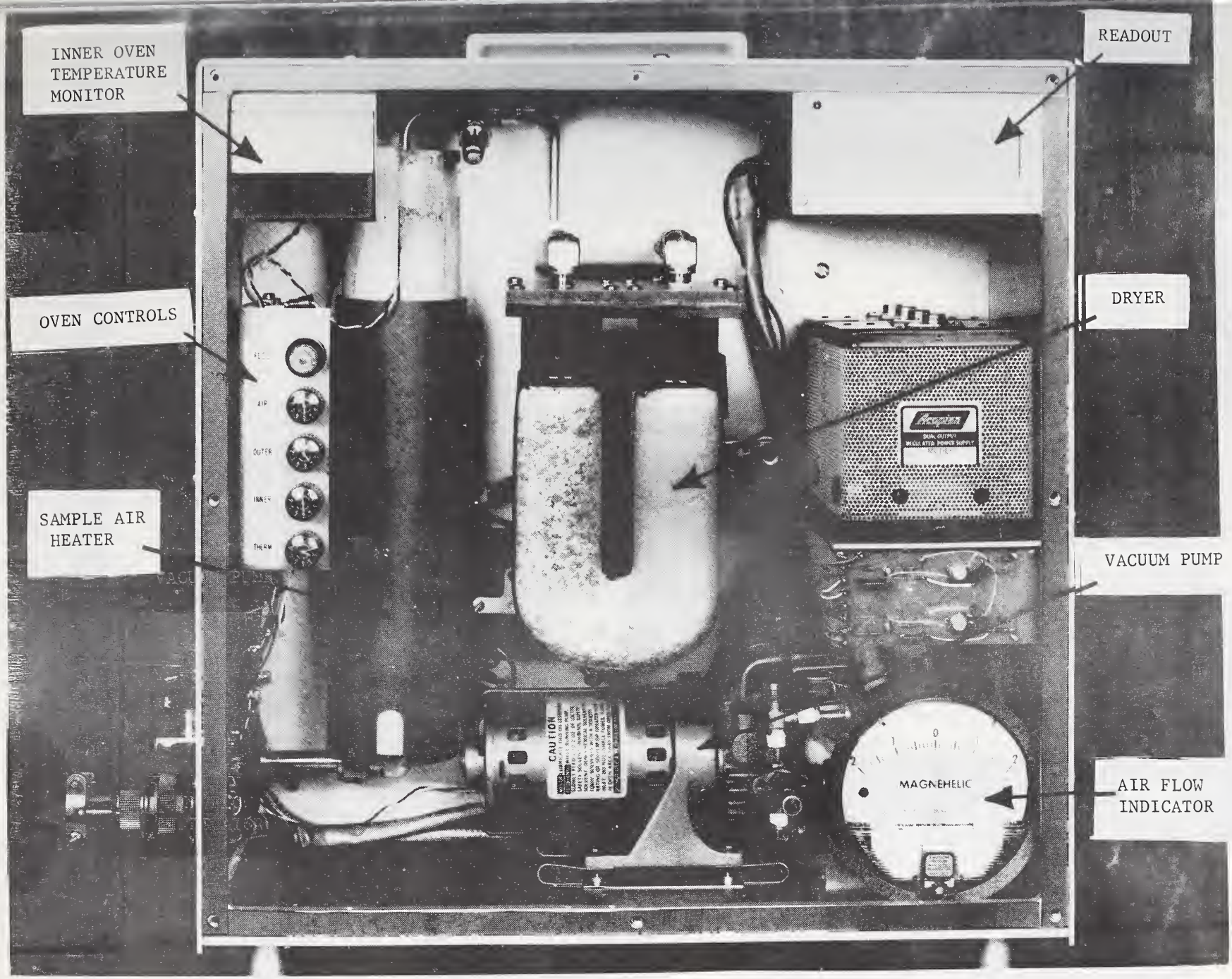

Figure 4. Interior view of one compartment of NBS microwave hygrometer Model III.

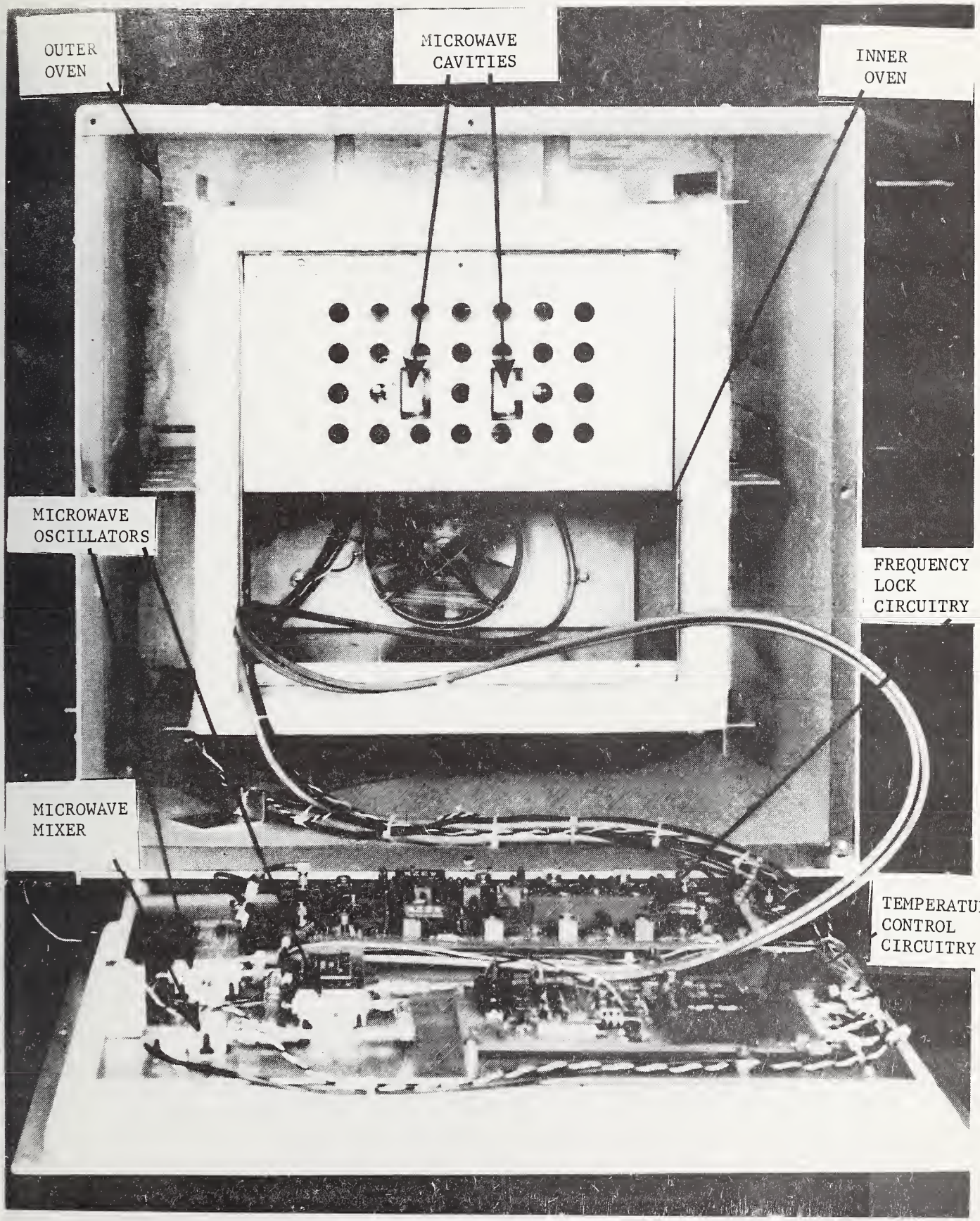

Figure 5. Interior view of the oven compartment of NBS microwave hygrometer, Model III.

Reference

(1) Hasegawa, S. and D. P. Stokesberry, Microwave Hygrometer, NBS Report 10 334, September 1970.

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This is a progress report on the design and construction of NBS microwave hygrometer, Model III. The hygrometer is intended for field or laboratory operation with a dew point range of -40° to 40°C.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*) Dew-point; hygrometer; microwave hygrometer

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