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Inexpensive Microwave Survey Instruments: An Evaluation

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Director
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WHO Collaborating Center for
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INEXPENSIVE MICROWAVE SURVEY INSTRUMENTS: AN EVALUATION

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INTRODUCTION

In accordance with the Radiation Control for Health and Safety Act of 1968, the Bureau of Radiological Health is responsible for the development and assessment of methods for measuring radiation from electronic products. Evaluations of the sophisticated regulatory instrumentation used for precise measurement of microwave oven emissions have been performed previously (1). The recent commercial availability of several simpler, less expensive, and less precise instruments has generated considerable interest from repair shops and consumers. While the possibility of reliable readings from such devices is clearly a potential benefit, the possibility of unreliable readings presents several potential problems. If the readings are erroneously low, the instruments might fail to identify a hazard; if the readings are erroneously high, the consumer may incur the expense of an unnecessary house call by repair personnel. In this paper we describe the results of our laboratory evaluations of these instruments. Comments were solicited from manufacturers of the instruments, and those received have been incorporated into the report.

INSTRUMENTS

We have chosen for our testing three instruments of recent design, all of which have been widely advertised. Each sells for about $50 or less. We have not attempted a comprehensive evaluation of all such instruments, but these may serve as a reasonable sampling. The instruments tested were (1) the Micromate (by Princeton Microwave & Testing, Inc., 633 Prospect Avenue, Princeton, New Jersey 08540); (2) the Guard-Rod (by Tanray Associates, Inc., P.O. Box 99, Elberon, New Jersey 07740); and (3) two Australian instruments which share a very similar design, the Interceptor (by Electrobits, Pty., Ltd., P.O. Box 232, Clayton, Victoria, Australia 3168) and the Microscan (by Birene Medical Supplies, Pty, Ltd., 29 Whiting Street, Artarmon, N.S.W. 2064). Each of these instruments employs diode detectors.

The Micromate

The Micromate (Fig. 1) employs a single diode-dipole combination, and an electronic processing circuit. This is the only one of the units tested which requires a battery for operation. The battery used is a conventional 9-V type, and the instrument includes a "battery-test" circuit operated by pressing a second "oven-test" button. The instrument is read out via an analog meter which is divided into a green (safe) region and a red (unsafe) region. The meter's calibration point is a line dividing the two regions.

The Guard-Rod

The Guard-Rod (Fig. 2) employs two crossed diodes with loop-like antennas. The diode outputs are read by a resistor-shunted analog meter. This meter also is divided into two regions: black (safe) and red (unsafe). This unit employs no batteries, but drives the readout meter with the power coupled from the radiation field being measured. According to the manufacturer's literature it can perform a measurement through the end surface or through the back surface of the instrument.

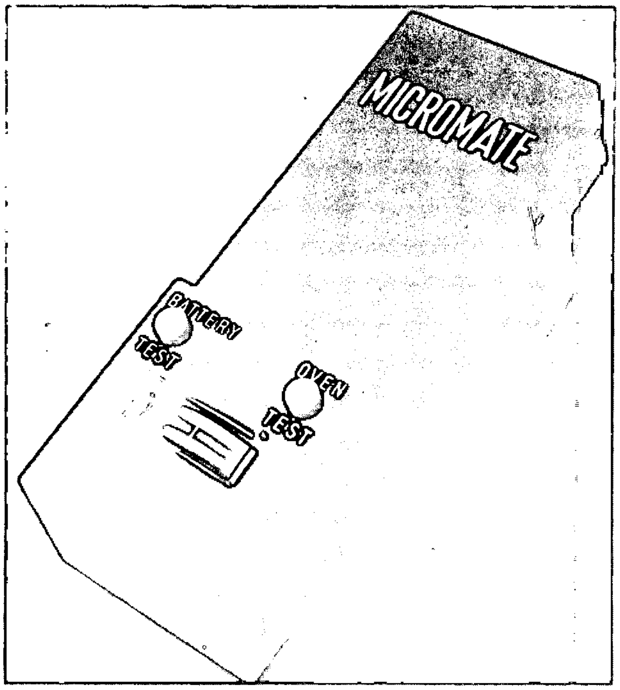

Figure 1. The Micromate.

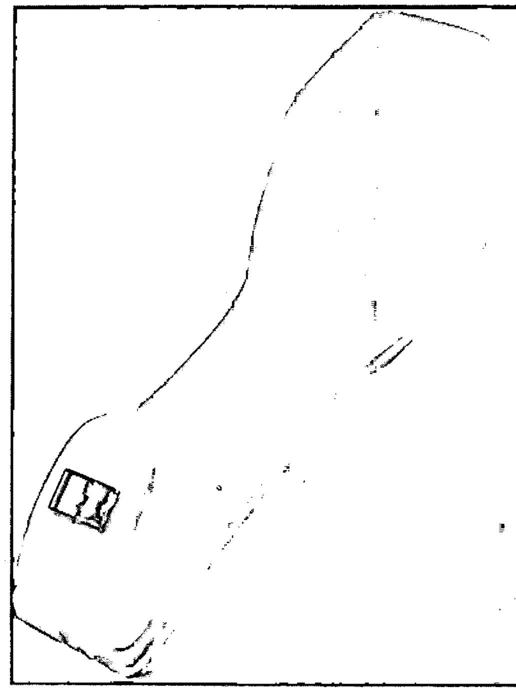

Figure 2. The Guard-Rod.

The Interceptor and Microscan

The Interceptor instrument (Fig. 3) uses a single dipole-diode combination. Like the Guard-Rod it requires no external batteries, deriving its readout with power absorbed from the radiation field. This readout is a red light-emitting-diode (LED). According to the manufacturer, the LED lights up at a predetermined radiation level. The Microscan is similar to the Interceptor, except for the addition of a simple, passive processing circuit.

All of the instruments are portable and light-weight, all are encased in plastic.

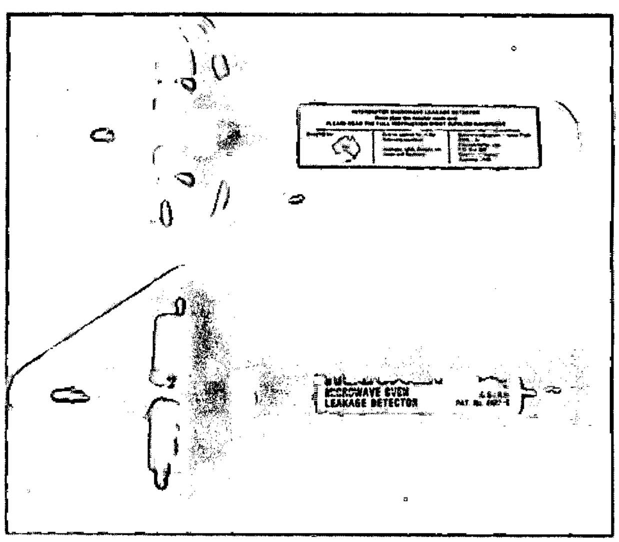

Figure 3. The Interceptor (top). The Microscan (bottom).

MEASUREMENTS

To assess the usefulness and reliability of each of the instruments, we evaluated several test parameters.

Spacer Accuracy

Spacer accuracy determines the ability of the instrument to provide an accurate 5-cm spacing between a leaking oven and the detector, as specified in the Federal Performance Standard for Microwave Ovens (CFR 1030.10). Each instrument incorporates a plastic structure of some configuration to achieve a reliable spacing. The length of these spacers was compared against a standard rule. The length measured is from the external surface of the instrument to the apparent effective center of the detector.

Calibration

The calibration of each instrument is associated with a single point: the "safe/danger" transition for the Micromate and Guard-Rod, and the diode-lighting level for the Interceptor and Microscan. The calibration of these points was checked 5 cm from a slot radiator by comparison to calibrated reference survey meters **(2)** which, in turn, had previously been checked against a nonperturbing miniature probe **(3)**. The calibration tests were all performed using continuous-wave radiation, with the instruments oriented according to the manufacturers' instructions. It should be noted that this calibration may also be affected by scattering between the probe and oven surface. Because of potential complexities in the latter, we have not attempted to quantify this error.

Polarization Ellipticity

The sensitivity of each instrument's reading to polarization orientation was evaluated. This was done by rotating the instrument 90° with respect to the electric field vector and noting changes in its calibration level. All instruments are supplied with orientation instructions which illustrate the intended orientation with respect to an oven door, and our results are expressed as variations from its sensitivity in that orientation. It should be noted that cross-polarization effects can be encountered near the corner of an oven door, or in the event of leakage through a door screen. If the field is equally divided between orthogonal components, even a thorough survey could result in half the field being multiplied by the cross-polarization error. Consequently, in computing total error, we have used a range of 0 percent (best case: no cross-polarized components of the field) to one-half the total cross-polarization error (worst case for a thorough survey: half the field cross-polarized).

AM Response

Because oven emissions often carry considerable amplitude-modulation (AM), each instrument was checked for modulation response. The test evaluated any changes in instrument response when a continuous-wave (CW) field was replaced with an amplitude modulated field having a 5:1 peak-to-average ratio (both fields having the same average power density). Our results are expressed as the difference in response to the modulated field, as compared with the continuous-wave field.

Overload Sensitivity

Our last test was designed to determine the effect of exposing the instruments to a high field ($\sim$70 mW/cm^2) which simulates a potentially hazardous oven leak. After exposing the instrument to such a field, we rechecked its calibration for any change in its initial calibration. The test was intended to assess the reliability of the instrument in case it should be used to measure significant leaks in actual use. This is important since none of the instruments tested provides any clear means of determining the operating condition of its detector. Thus, if damage occurred, the operator would probably be unaware of it, and might continue to use an inoperative instrument.

RESULTS

Test results are summarized in Table 1, and described below.

Table 1. Test results: Effects on instrument sensitivity

Instrument	CW calibration level	A.M. sensitivity	Polarization ellipticity
Micromate	1.9 mW/cm^2	+ 3.4 dB	+ 5 dB
Guard-Rod			
end surface	5 mW/cm^2	- 4.5 dB	+ 3 dB
back surface	37 mW/cm^2	- 1 dB	+ 9 dB
Interceptor	3.6 mW/cm^2	+ 7 dB*	- ∞ **
Microscan	4.4 mW/cm^2	+ 7 dB*	- ∞ **

*peak detectors
**linearly polarized

Spacer Accuracy

Each instrument's spacer was found to be approximately 5.0 cm in length (± 0.3 cm) when measured from the unit's external surface to the apparent effective-location of the detector.

Calibration

The Micromate moved into the "danger" area on its meter at 1.9 mW/cm^2. The Guard-Rod literature identifies two surfaces (on the end and back of the instrument) which can be used for measurement. The transition point into the "danger" region on the meter occurred at 5 mW/cm^2 for the end, but not until 37 mW/cm^2 for the back. The Interceptor version of the LED instrument lit up at 3.6 mW/cm^2; the Microscan version lit up at 4.4 mW/cm^2. Both of these instruments exhibited a hysteresis effect, staying lit until the power density had been reduced to about one-third of the threshold level required to turn it on.

Polarization Ellipticity

When the Micromate was exposed to a cross-polarized field, its sensitivity was increased by 5 dB (an increase of 216 percent). The Guard-Rod's sensitivity was increased by 3 dB (an increase of 100 percent) on the end surface and by 9 dB (an increase of 694 percent) on the back surface. The Interceptor/Microscan design is, for practical purposes, completely insensitive to a cross-polarized field.

AM Response

The Micromate sensitivity is increased by 3.4 dB (an increase of 119 percent) in the amplitude-modulated field. The Guard-Rod sensitivity decreased by 4.5 dB (a decrease of 64.5 percent) on the end and by 1 dB (a decrease of 20 percent) on the back surface in the amplitude-modulated field. The Interceptor/Microscan design responded to the peak power density, not the average. Consequently, for the test field, their sensitivity was increased by a factor of five.

Overload Sensitivity

After being exposed to 70 mW/cm^2, the Micromate sensitivity was decreased by 2.0 dB (a decrease of 37 percent), the result of apparent overload damage. The Guard-Rod and Interceptor/Microscan instruments were unaffected by this exposure. However, while the initial firing level of the Interceptor/Microscan devices were unaffected, the test revealed that their warning lights extinguished at levels from 28 to 52 mW/cm^2 depending on the instrument and the modulation. They remained extinguished at higher levels. There was no apparent damage to the devices, as they were subsequently found to light up at the same threshold levels as before.

CONCLUSIONS

Based on the findings presented above, it seems clear that there are serious questions about the ability of each of these instruments to distinguish oven leakage levels which exceed the requirements of the Federal Performance Standard for Microwave Ovens (CFR 1030.10) from lower levels which do not.

Depending upon the oven modulation and leak location, these tests show that the Micromate will yield a "warning" reading at levels from 0.6 to 1.9 mW/cm^2, when the effects of modulation sensitivity and polarization ellipticity are considered. It is to be expected, then, that this instrument will yield "warning" readings even when the oven emission being measured lies well within applicable standards. Its apparent susceptibility to overload damage, however, could decrease its sensitivity with no clue to the user as to what had happened.

Given the same considerations and parameters, the tests show that the Guard-Rod will yield a "warning" reading at levels from 3.7 to 47 mW/cm^2, depending on which measurement surface is used. Thus, this instrument will sometimes yield warnings for oven emissions lying within applicable standards, and sometimes will fail to yield such warnings for emissions 10 times greater than allowable levels.

Finally, the same considerations show that the Interceptor/Microscan units will light up at levels from as low as 0.7 to 0.8 mW/cm^2 (depending on the unit) or may require levels of 7 to 9 mW/cm^2. At levels of 28 to 52 mW/cm^2 or higher, however, the warning LED does <u>not</u> light. If part of the field is cross-polarized, this threshold of extinction may be greater. In any case, there is no apparent way for the user to discern the presence of some potentially hazardous fields, and no way to distinguish such fields from a very low-level field. In summary, instruments of the Interceptor/Microscan design may light up at very low power densities, but fail to light at very high power densities. Clearly, this characteristic is extremely undesirable and potentially dangerous to a user relying on such a device.

All of these values assume that the instruments are used in accordance with manufacturer's instructions. Otherwise, results may be worse. Moreover, the range of values given take little or no account of unit-to-unit variation, which may be considerable.

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