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Advanced Measurements of Microwave Oven Leakage

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Abstract

Reports of excessive leakage from apparently undamaged domestic microwave ovens have prompted an investigation by ARPANSA. For many years up to now, domestic microwave ovens were not considered to leak levels of microwave radiation that caused concern, consequently, they have not been regularly monitored. This paper reports the investigation of oven leakage, the issue of emission levels versus exposure levels and the application of specific absorption rate (SAR) measurements. Preliminary measurements indicate that under certain circumstances, microwave oven emission limits may not prevent the ARPANSA SAR limits from being exceeded.

Introduction

The lodging of the microwave oven patent in 1945 by Percy Spencer heralded a dramatic change in the way that food was going to be cooked in homes across the world. However, it was not until 1967 that an affordable and compact microwave oven was readily available for domestic use. The obvious cooking advantages provided by the microwave oven ensured that its uptake would be rapid and extensive with up to 90 percent of the western world's households currently owning one. Public concern over leakage from the microwave ovens was present from the very beginning with many people believing that radiation leakage was similar to atomic radiation that could lead to serious health problems, including cancer.

Earlier microwave ovens relied on accurate engineering of the oven door and metal-to-metal contact where the door closed. This type of design allowed higher levels of leakage that increased when the door/oven interface became dirty or distorted. During the 1970s door design changed to incorporate a quarter wavelength choke that effectively created a short circuit at the door/oven interface that prevented any leakage. The use of a quarter wavelength choke did away with the requirement for clean metal-to-metal contact and allowed small gaps at the door interface.

The general consensus from authorities around the world concerned with microwave oven leakage is that leakage levels from ovens in good working order are low and that they do not pose a health hazard. Both anecdotal reports and scientific surveys support this view. A more recent survey of 106 domestic and restaurant microwave ovens in Saudi Arabia by Zeyad Alhekail (2001)[1] showed that only one oven exceeded the 5 mW/cm^2 emission limit.

Public concern over radiofrequency radiation from mobile phones and towers has heightened general concern over any device that may be perceived as a "radiation" source. This, along with vigorous marketing by companies offering measurement services for microwave ovens has renewed concern over microwave oven leakage. A number of businesses are now offering leakage measurement services both for commercial and domestic ovens. A consequence of the renewed interest in leakage levels has been a supply of leakage level data from what has been an extensive informal survey. One company (Microwave Safe Australia) that inspects ovens in workplaces has provided data from its measurements of up to 12,000 ovens per year. Their results indicate that 0.8% of ovens leak microwave radiation in excess of the 5 mW/cm^2 limit. A sample of these ovens was supplied to the author for testing, our tests confirmed that the ovens were leaking in excess of the 5 mW/cm^2 limit.

The apparent rise in leakage levels from ovens could be due to the declining manufacturing standards that stem from the low cost ovens now produced at a fraction of the cost of ovens manufactured years ago. Ovens produced 20 years ago were far more expensive, robust and used higher-grade materials. Excessive wear and tear on door hinges and relaxed manufacturing tolerances may account for much of the excessive leakage seen from more modern ovens.

Occupational health and safety requirements place the responsibility on employers of providing a safe workplace. Because microwave ovens used in food preparation and staff canteen areas need to be in safe working condition, the question has been raised over the possibility that leaky ovens may pose a health risk to workers. This concern has resulted in a number of people claiming that regular leakage tests need to be conducted on microwave ovens that are used in a workplace. To date there is no evidence to support the claim that leakage from a microwave oven has caused harm to any person. The only reports of harm stem from food burns that could also be caused by conventional ovens.

Oven emission limits

Microwave ovens commonly available for the domestic market have a full power capacity between 600 to 1000 watts. There is no doubt that considerable injury could occur to a person fully exposed to these power levels. Medical diathermy utilises the same radio frequency but only to power levels of up to 200 watt to treat localised injuries under medical supervision. At this power level, tissue heating is quite rapid and exposure to limbs may only need to last for a period of five minutes to result in a 50^{o}C temperature rise in the exposed tissue. Damage to the eye would occur if this level of exposure occurred. Because of the potential to cause an injury, emissions from the oven must be limited to safe levels.

Microwave leakage standards

The current emission limit is based on an approach taken in 1968 following the US Senate Hearings where it was agreed that the upper limit of microwave leakage should be related to the American National Standards Institute (ANSI) C95.1 – 1966 exposure limit[2]1. This was done in a conservative way by applying the whole body exposure limit of 10 mW/cm2 for an exposure occurring at a distance of 5 cm from the external surface of the microwave oven – because as one industry spokesman said, “that is as close as the human eyeball can come to the oven”.[3] Unfortunately, the use of an exposure2 limit when determining an emission3 limit confused the issue. This has lead to the ongoing misunderstanding that the emission limit is a safety limit, implying that safety will be compromised if the emission limit is exceeded.

From the beginning it was well understood that compliance with the emission specification gave a large margin of safety when considering the exposure of a person operating a leaky microwave oven, factors as high as 10,000 were accepted[3]. However, the concern over perceived safety issues at that time pressured the US Bureau of Radiological Health (BRH) to further tighten the emission limit and adopt a standard[4] that specified an emission limit of 1 mW/cm2 at 5 cm at manufacture and 5 mW/cm2 at 5 cm after sale. This standard is still in place in the US and Canada. In 1971 the 5 mW/cm2 at 5 cm emission standard was adopted in Australia by the National Health and Medical Research Council [5]. In 1976 the International Electrotechnical Commission (IEC) issued an emission standard of 5 mW/cm2 at 5 cm.

The 5 mW/cm2 at 5 cm exposure limit was written into an Australian Standards Association standard in 1978[6] as an approval and test specification and was derived from the IEC standard. The Electrical Regulatory Authority in each State of Australia (Office of Chief Electrical Inspector in Victoria) requires evidence of compliance with this standard as a condition for the issuing of a Certificate of Approval which is needed for the approval for sale of prescribed electrical equipment. Other than a piece of WA legislation that requires testing of microwave ovens in commercial premises, there is no regulation in Australia that requires periodical after market testing of leakage from domestic microwave ovens. ARPANSA believes that annual leakage testing of microwave ovens is not required. Ovens only need to be tested for leakage following repair or if damage is suspected. While it is possible for microwave ovens that appear in acceptable working condition to leak microwave levels that exceed the

[1] The ANSI C95.1 - 1966 exposure limit was a frequency independent whole body exposure limit of 10 mW/cm^2

[2] A situation that occurs when a person is subject to the influence of a radiofrequency (RF) field. Exposure is the measurement of the field level where a person is located.

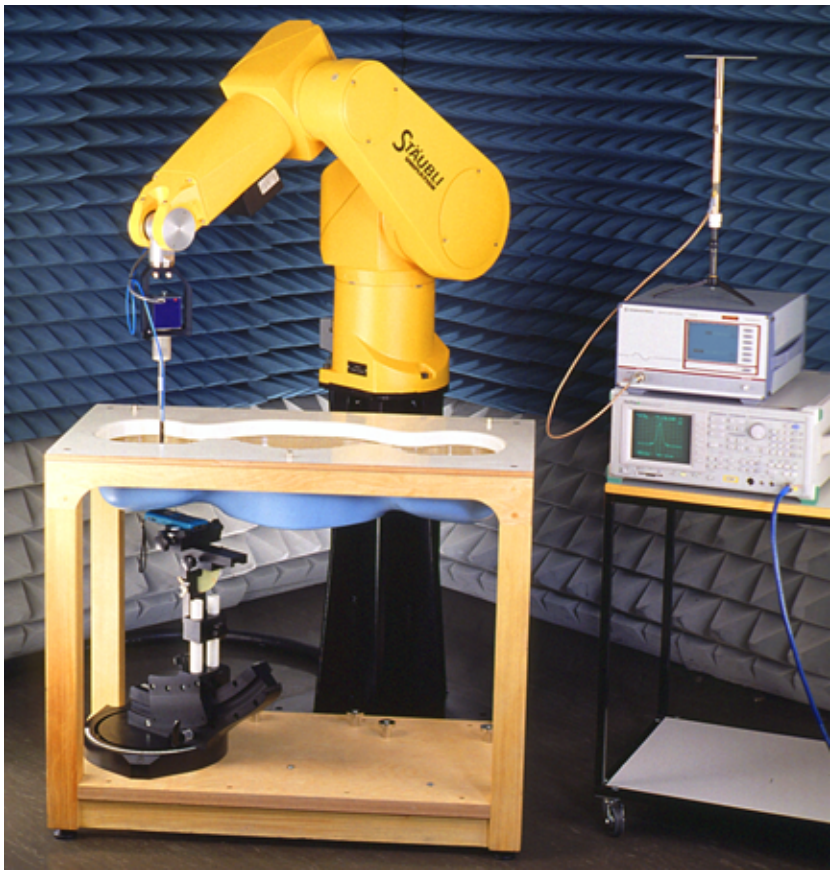
[3] The localised RF field near a typically small source of diverging RF radiation. Emission is the measurement of the RF field at a specified distance from the radiator.

emission limit, they are not necessarily hazardous. The emission limit is primarily a manufacturing specification, exceeding the emission limit does not imply that safety will be compromised. Compliance with safety limits is determined by referring to relevant radiofrequency exposure standards and not emission limits.

ARPANSA Safety limits

The ARPANSA Standard; Maximum Exposure Levels to Radiofrequency Fields 3 kHz to 300 GHz[7], sets recommended limits of exposure. At the microwave frequency of 2450 MHz, the whole body exposure limit when averaged over a six-minute period is 10 W/m2. Spatial averaging of the radiated signal is allowed, at this frequency it means taking the average of five measurements over a square of 25 cm at the location where the person is exposed. It is reasonable to assume that the exposure of a person will occur at about 30 cm – 40 cm from the above door on the basis that this is an arms distance (for operating controls) and the door opening distance. It is suggested that 30 cm be considered to be the closest distance that an exposure measurement should be performed at. The emission characteristics of an oven do not create whole body exposure; spatial averaging allows the maximum measured level to be reduced by a factor of about five.

The ARPANSA general public limit at 2450 MHz for whole body exposure is designed to limit the core body temperature increase to no more than 0.020C. Based on modelling, an average whole body specific absorption rate (SAR) of 0.08 W/kg will cause this level of temperature rise. A SAR of 0.08 W/kg will be created by a whole body exposure in a 10 W/m2 power density field. As absorption is non-uniform over the body there will be areas of greater or lesser absorption. Modelling shows the variation to be as much as 25 times greater than the average showing that spatial peaks of 2 W/kg can occur without adverse effect. The ARPANSA RF Standard has general public basic restrictions of 0.08 W/kg for average whole body SAR, 2 W/kg for spatial peak SAR in the head/torso and 4 W/kg for spatial peak SAR in the limbs. The measurement of field strength (and calculated equivalent power density) is a conservative surrogate of SAR.



SAR measurements

ARPANSA collaborated with EMC Technologies to measure the SAR produced by leaky microwave ovens. In the first place, a new oven was manipulated by forcing the door/safety switch adjustment to create an emission level of 5 mW/cm2 at 5 cm. SAR testing deals with the thermal effects of human exposure to RF electromagnetic fields. The SAR is a value that corresponds to the relative amount of RF energy absorbed by the user of a device in close proximity to the body. The measurement methodology was similar to that used for assessing a mobile phone's SAR. Essentially, the method uses a probe that measures the RF electric field in tissue equivalent gel that is in a phantom placed alongside the RF source (phone/microwave oven). Figure 1. shows the SAR measurement equipment used for the leakage tests.

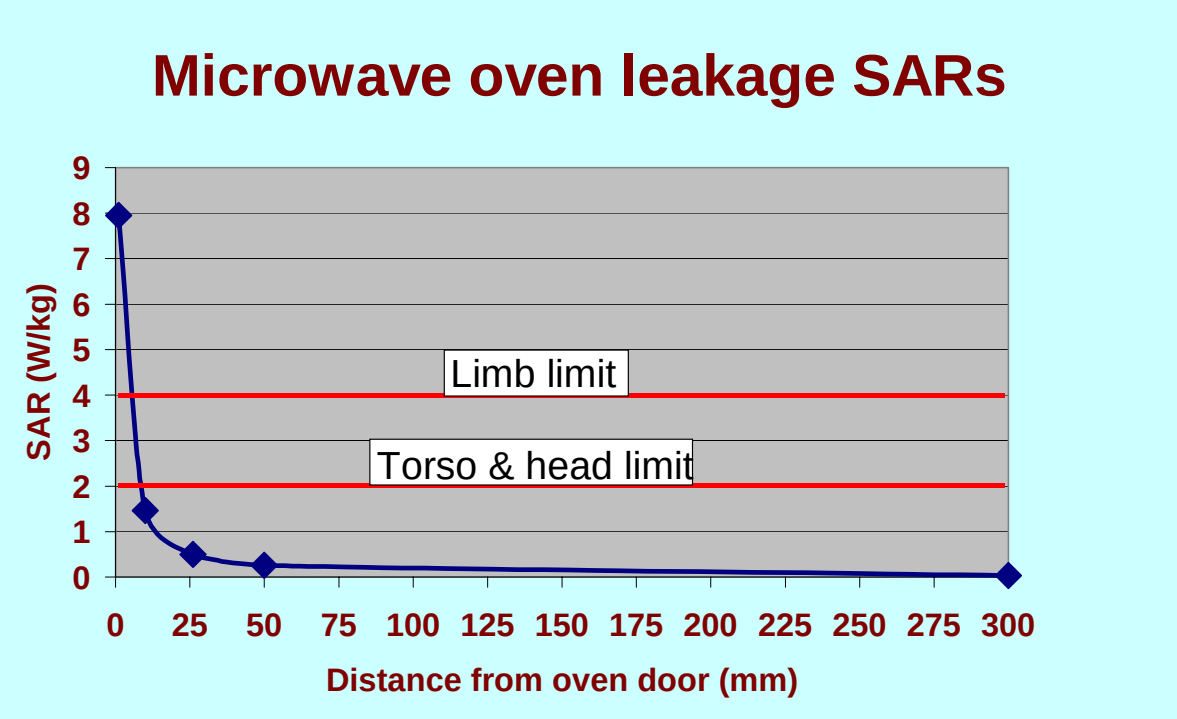
Figure 1.

What is the SAR?

RF dosimetry is the quantification of the magnitude and distribution of absorbed electromagnetic energy within human and biological objects that are exposed to electromagnetic radiation (EMR). SAR is the dosimetric quantity at RF, and is defined as the rate at which energy is absorbed per unit mass.

What is a phantom?
The phantoms are human body cavity models containing a fluid that closely approximates the density and conductivity of human blood and tissue. The phantom used for the microwave oven test was flat box unit. The phantom was filled with a liquid having the characteristics of muscle tissue at 2450 MHz, the characteristics were:
conductivity (σ) = 1.96 mho/m,
relative permittivity (εr)= 51.8,
mass (ρ) = 1000 kg/m3.
For the more usual mobile phone testing, body symmetry is exploited in the whole body phantoms and a computer controlled robot-mounted probe is used to plot the electromagnetic field density, yielding whole-body field maps when reflected in the centre sagittal plane.

SAR levels around the tested microwave oven
The SAR at 5 cm from the oven where the emission was 5 mW/cm2 was found to be 0.256 W/kg. When measured as close as practical to the door (<1mm) the SAR was 7.95 W/kg. This would result in an estimated SAR of 0.0056 W/kg at a distance of 30 cm from the oven. From this estimate, we can be confident that no hazard exists for a person standing alongside a leaky oven as this is the minimum distance that the operator's body would normally be located. While it is highly unlikely that a person operating an oven would remain closer than 30 cm, it is conceivable that their arm may rest on the oven if the oven was located on the edge of a table or counter top. Under these circumstances their exposure would result in a SAR that exceeds the ARPANSA spatial limb SAR of 4 W/kg. The plot of SAR at different distances is shown below. The SAR at 300 mm is an estimate and is based on the trend line for the curve, the SAR should decline at the inverse square of the distance.



Graph 1.

Anecdotal reports indicate that on rare occasions, emission leakage levels as high as 30 mW/cm2 may be encountered with SAR levels rising in proportion to leakage levels. This level of leakage could possibly result in a SAR of 35 W/kg at the oven's surface. A SAR of this level could raise the temperature of exposed tissue up to 1.5 °C. A temperature rise of this magnitude in a localised area of a person's arm resting on the oven does not necessarily have any health consequence. Based on the curve above and a proportional relationship between leakage level and SAR, the leakage level at 5 cm would need to be 550 mW/cm2 to produce a SAR of 4 W/kg in a person located 30 cm away from the oven. Similarly, the head and torso SAR limit of 2 W/kg would be exceeded if the leakage at 5 cm were 225 mW/cm2. Given the absence of data that shows ovens of undamaged appearance having emission levels in excess of 30 mW/cm2, there is a high probability that there are no microwave ovens that cause exposures in excess of SAR exposure limits.

Summary

The emission limit for microwave ovens should not be interpreted as exposure or safety limit. The limit is in place to provide a manufacturing specification and the basis for issuing an Approvals Certificate for regulatory authorities. Although the emission limit is very conservative it is recommended that it be continued.

SAR measurements show that emission limit provides for a large margin of safety, consequently, there is no need for regular testing of emission levels for ovens that appear to be in good working order.

There is no evidence that emission levels from undamaged ovens could ever create exposure levels that may exceed the ARPANSA SAR limits for a person at 30 cm distance.

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