# MEASUREMENTS OF MAGNETIC FIELDS PRODUCED BY INDUCTION COOKING HEATERS

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**Abstract:** The results of a survey of magnetic fields produced by induction cooking heaters (IH) are reported. Magnetic field levels depending on as distance from the IH characterized by measurement and presented. All sets of measurements were made at the fundamental frequency of 20 kHz and all represent narrow-band rms levels of magnetic flux density expressed in μT. Measurements at 20 kHz harmonics and other frequencies were not made. The data presented should be useful in understanding the levels of magnetic field produced by IHs, and also in estimating magnetic field exposures in homes and work places.

**Key words**: Leakage magnetic fields, Induction cooking heater (IH), ICNIRP

## 1. Introduction

New types of household appliances, such as induction cooking heaters (IH) and electric floor heating systems (EFH) have been used in all-electric homes. Recent public concern has focused on possible human health effects from exposure to magnetic fields produced by household appliances, such as IHs and EFHs. Several investigations of extremely low-frequency magnetic fields (50 Hz, 60 Hz) have been described in the literature [1],[2].

On the other hand, there is very little quantitative data on high frequency magnetic fields produced by appliances such as, high frequency induction furnaces, resistance welding units, and IHs. Recently, IHs have begun to be used in homes and restaurants. It is estimated that for year 2003, over 500,000 induction cooking units will be use in Japan. More knowledge is needed to better understand the of very low frequency (20 kHz) magnetic fields produced by IHs.

A few of the features of IH can be mentioned as follows:

1. Safe cooking appliances: the magnetic field only causes molecules in other magnetic things to heat, and since the ceramic cook top is not magnetic, it stays cool. Though the cook top does not get hot, the pan gets as hot as if it were over an open flame.
2. Direct transfer energy appliances: Traditional electrical cooking appliances use the radiation of heat that is produced when electric current is passed through an electric resistor. It radiates heat on all sides. On the other hand, a high percentage of the energy use is transferred directly to the cooking pan with an IH.
3. Clean cooking appliances: Clean-up after cooking is easy because the flat ceramic cook top can be wiped clean.

It is the purpose of the present paper to describe the results of a survey of the 20 kHz magnetic fields produced by IHs. This paper presents data from magnetic field measurements of 4 sets of IHs. Profiles of the magnetic field produced by an IH as a function of distance were obtained.

## 2. Measurement methods

### 2.1 Magnetic field measuring probe

The sensors used for measuring the magnetic flux densities were magnetic field probes. The probe (HP 11941A) was used as illustrated in Figure 1.

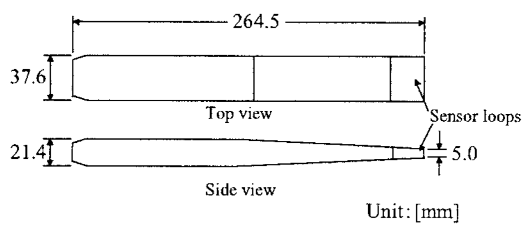



Figure 1 Magnetic field probes and dimensions in millimeters.

The probe is a hand-held electromagnetic field sensor designed to make calibrated magnetic field measurements from 9 kHz to 30 MHz. It is optimized for the location and measurement of sources of electromagnetic interference (EMI) in electronic equipment.

It is a balanced magnetic-field sensor that provides an output voltage proportional to the strength of the magnetic field at its tip. Radiated magnetic fields couple directly to the probe and produce an output signal. Radiated electric fields also couple to the probe, but do not produce an output voltage due to the construction of the probe. It uses a dual-loop sensor and a balun to reject electrically coupled signals. In our study, interaction of probes, cable and equipment were minimized to obtain accurate measurements of the field strength from the IHs.

An Anritsu MS2601B Spectrum analyzer was used to measure the probes' output voltages. The probe and spectrum analyzer were connected with shielded RF cables, which reduces measurement errors in the high field impedance. The spectrum analyzer was set at a 300 Hz bandwidth and with a 3 second sweep time. The magnetic flux density from the IHs contained numbers of harmonic frequencies, but all measurements were carried out at the fundamental frequency of 20 kHz.

### 2.2 Magnetic flux density measurement procedure

The distribution of the magnetic fields of 4 sets of IHs, were measured by magnetic field probes. Figure 2 shows the IH made by manufacturer A with dimensions in millimeters. The IH was positioned on the horizontal wooden plane of height 0.7 m in the electromagnetic shielding room. Background magnetic field level in the test area, including disturbance and internally generated noise transmitted by power line in the measuring system did not exceed 10 nT.

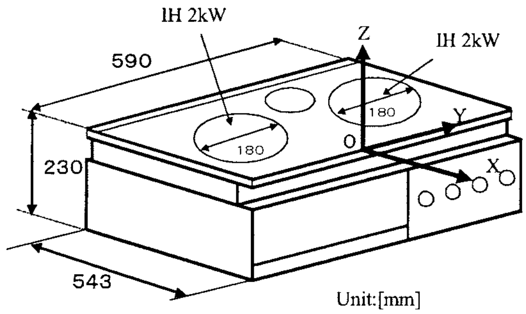



Figure 2 Induction cooking appliance made by manufacturer A. (dimensions in millimeters)

Care was taken to ensure that the measured magnetic fields were in fact produced by the IH, and not by other sources. The probe was set in a movable support that allowed scanning along the *X*, *Y*, and *Z*-axes with steps of 5 cm (as shown in figure 3). Figure 4 shows a photograph of measurement apparatus. For each step *Bx*, *By* and *Bz* were measured. The resulting magnetic field is given by the expression (1)

$$B_r = \sqrt{B_x^2 + B_y^2 + B_z^2} \qquad (1)$$

where *Bx*, *By*, and *Bz* are the rms values of the three orthogonal field components.

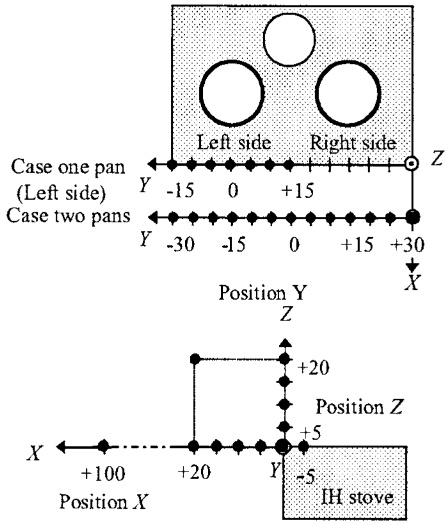



Figure 3 Measurement point of magnetic field produced by induction cooking appliance.

Figure 4 Photograph of measurement apparatus.

Table 1 Principle measured induction cooking appliance.

L:left, R:Right

| Model | IH | Induction Frequency [kHz](rpm) | Rating [W] |
|---|---|---|---|
| A | 2 kW (L)<br>2 kW (R) | 18.93-19.82 | 4000 (IH)<br>1500 (heater) |
| B | 3 kW (L)<br>2 kW (R) | 20.31 | 4800 (IH)<br>1250 (range) |
| C | -------(L)<br>2 kW (R) | 19.91-20.11 | 2000 (IH)<br>3230 (range) |
| D | 2 kW (L)<br>2.5 kW (R) | 21.48 | 4500 (IH)<br>1200 (range) |

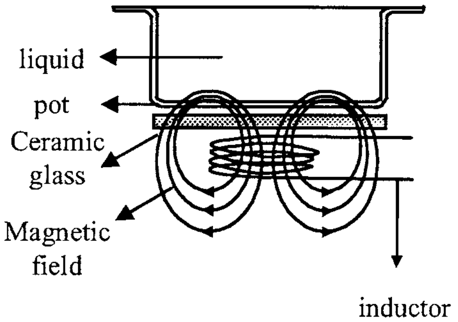
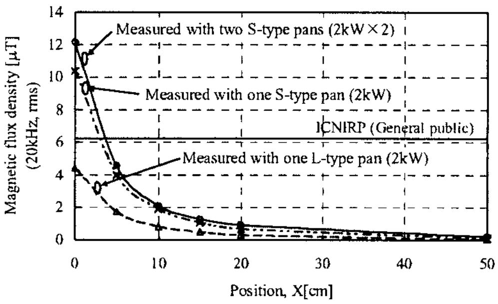
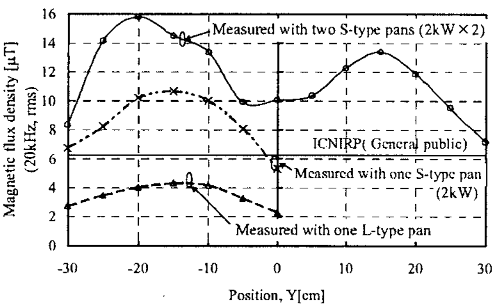


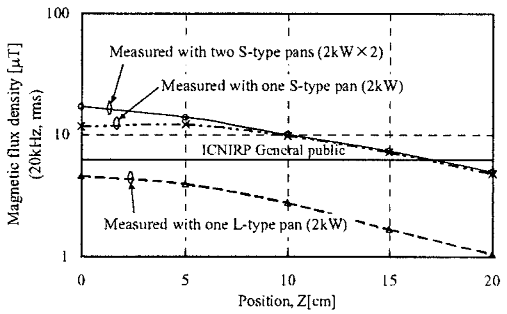

Figure 5 The components of induction cooking appliances.




(a)X- positions

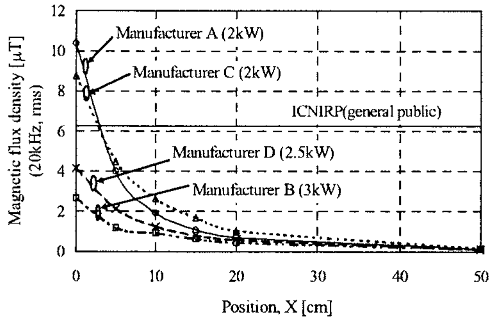



(b)Y- positions

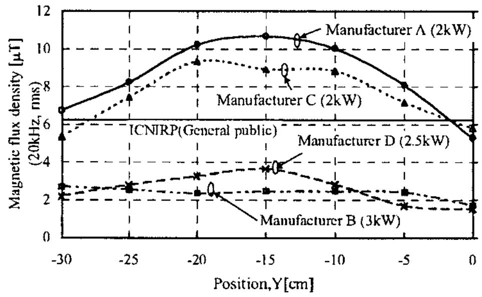



(c)Z- positions

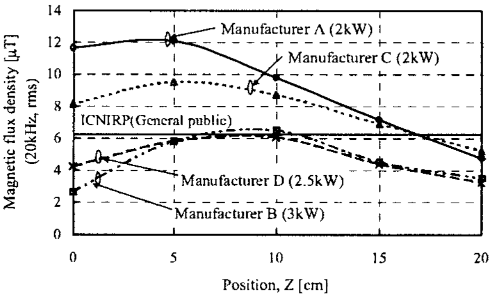
Figure 6 The magnetic field densities produced by IH of manufacture A.




(a)X- positions




(b)Y- positions




(c)Z- positions

Figure 7 The magnetic field densities produced by IH of manufacture A, B, C, and D.

### 3. Results and discussion

An induction cooking heater works like this: The core of the unit is an electric generator and an electromagnetic coil (as shown in figure 5). The coil is energized by the generator and creates a magnetic field.

When an iron or ferrous metal pan is placed on the glass cook top, the magnetic field links with the pan and causes the molecules in the pan to move rapidly, so the metal heats up. That is, the numbers of the flux linkage depend on size of pan. We used two types of pans, S (18 cm in diameter) and L (24 cm in diameter) type, recommended by the manufacturers.

The thickness of each was 9 mm. 4 different IHs made by 4 manufacturers were surveyed for their magnetic field characteristics. Table 1 shows the principle measured indcution cooking appliances.

The IHs of manufacturer A have two rings (two electromagnetic coils energized by 2 kW of electric power), those of manufacturer B have two rings (two electromagnetic coils energized by 2 kW and 3 kW of electric power), those of manufacturer C have one ring (one electromagnetic coil energized by 2 kW of electric power) and those of manufacturer D have two rings (two electromagnetic coils energized by 2 kW and 2.5 kW of electric power). The data from these measurements are presented in the graphs of Figure 6 and 7, where the magnetic flux density generated by the IHs is plotted as a function of distance from the origin of an orthogonal coordinate system. The IHs were operated at full power by putting a pan filled with water on the cook top while measuring the magnetic flux density from the IHs. The power line currents were monitored by a cramped current meter.

Figure 6 (a), (b) and (c) show the magnetic field densities generated by one IH (from manufacturer A) with two S-type pans, one S-type pan, and one L-type pan along the *X*, *Y*, and *Z*-axes plotted as a function of distance from origin, respectively. The maximum magnetic field densities were observed in case of two S-type pans, because magnetic field densities produced from both electromagnetic coils energized by 2 kW electric power were added. When the L-type pan was put on the cook top, where the magnetic field was shielded by the pan, leakage magnetic field densities were small. The measured magnetic field densities of two S-type pans and one S-type pan, at distances along the *X*-axes is closer than $X$ = 29 mm and 36 mm, exceed the limit of general public exposure to 20 kHz magnetic field (ICNIRP:6.25 μT) [3], respectively. In a similar way, measurement values along the *Y* and *Z*-axes exceeded the limit. The magnetic field densities near the surface of IHs tend to be quite localized.

Figure 7 (a), (b) and (c) show the magnetic field densities generated by IHs (manufacture A, B, C, and D) along the *X*, *Y* and *Z*-axes. Positions *X*, *Y*, and *Z* are plotted as a function of distance from origin, respectively. It becomes evident that the magnetic field densities generated by IHs depend on manufacturers.

## 4. Conclusions

4 different IHs made by 4 manufacturers were surveyed for their magnetic field characteristics.

The magnetic field levels of IH appliances as a function of distance were presented in graphical form. All sets of measurements were carried out at the fundamental frequency of 20kHz and narrow-band rms levels of magnetic flux densities expressed in μT.

The magnetic field densities generated by IHs of manufacture A, B, C and D are different. The maximum magnetic field measurement was 16 μT in the case of manufacture A with two S-type pans at $X = Z = 0$, $Y = -20$ cm.

The data presented should be useful in understanding the levels of magnetic field produced by IHs, and also in estimating magnetic field exposures in homes and work places.

## References

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