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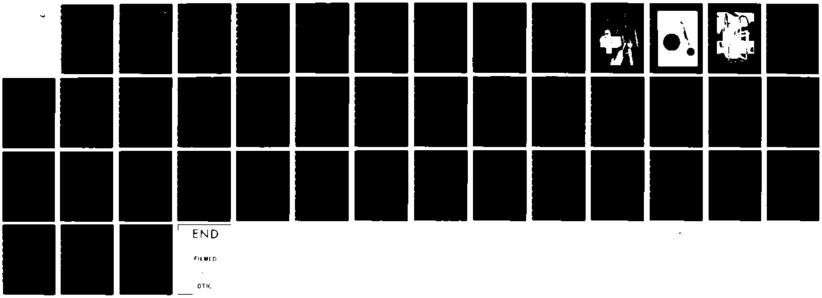

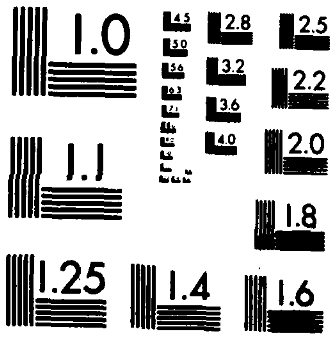

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Technical Report E06549-3
Contract No. N00039-84-C-0070

IITRI

HOUSEHOLD APPLIANCE MAGNETIC FIELD SURVEY

J. R. Gauger

March 1984

Prepared for:

U.S. Naval Electronic Systems Command
Washington, D.C. 20360

Submitted by:

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO AD A143 282	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Household Appliance Magnetic Field Survey		5. TYPE OF REPORT & PERIOD COVERED Technical Report 1983-1984
		6. PERFORMING ORG. REPORT NUMBER E06549-3
7. AUTHOR(s) J.R. Gauger		8. CONTRACT OR GRANT NUMBER(s) N00039-84-C-0070
9. PERFORMING ORGANIZATION NAME AND ADDRESS IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Electronic Systems Command, Washington, D.C. 20360		12. REPORT DATE March 1984
		13. NUMBER OF PAGES 41
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited Distribution

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Extremely Low Frequency
Magnetic Fields
Appliances
Bioelectromagnetics
Powerlines

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

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ABSTRACT

The results of a non-comprehensive survey of the 60 Hz magnetic fields produced by common household appliances and tools are reported. Maximum magnetic field levels as a function of distance for about 100 different appliances of 25 basic types are characterized by measurement and presented in graphical form. The measurements represent the highest magnetic fields generated by the appliances in any normally accessible direction from them. All sets of measurements but two were made at the fundamental powerline frequency of 60 Hz and all represent narrow band rms levels of magnetic flux density expressed in gauss. Measurements at powerline harmonic and other frequencies were not made.

FOREWORD

This document was prepared for the Special Communications Project Office of the U.S. Naval Electronic Systems Command by IIT Research Institute under Contract N00039-84-C-0070.

The technical report herein describes a survey of the 60 Hz magnetic fields produced by common household appliances and tools. Approximately 100 different appliances of 25 basic types are characterized. To provide a "worst case" measurement protocol, the maximum magnetic fields generated by each appliance were measured as a function of distance from the unit's surface. Curves showing the magnetic field versus distance data are provided.

The measurements of the appliance magnetic fields were performed by J. R. Gauger and G. L. Nicholas.

Respectfully submitted,
IIT RESEARCH INSTITUTE

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HOUSEHOLD APPLIANCE MAGNETIC FIELD SURVEY

1. INTRODUCTION

Recent public concern has focused on possible human health effects from exposure to magnetic fields produced by power lines and extremely low frequency (ELF) communication systems. The localized EM fields from these sources have been detailed analytically and empirically in many references. Only a few studies, however, have reported measurements of the ambient field levels inside homes and workplaces, or the fields generated by household appliances.[1-4] Of the limited number of appliance measurements given, all were taken either at single positions representing typical "user distances," or at unspecified distances from the devices.

The purpose of this report is to present data from nearly 100 sets of magnetic field measurements of household appliances that were made using a more definitive and "worst case" measurement protocol. Under this protocol, the maximum magnetic fields produced by an appliance were measured both near the surface of the appliance and at several locations at increasing distance from the surface. In this manner, a profile of the maximum magnetic field produced by an appliance as a function of distance could be obtained which eliminates much of the ambiguity of single point measurements. The measurement protocol is described in greater detail in the following sections.

This survey of appliance generated magnetic fields was not intended to be comprehensive, but does include at least three examples in each of 25 device categories. With this sample size trends in appliance magnetic field behavior can be estimated and order of magnitude or better values for maximum magnetic flux densities can be determined. Some idea of the spread of data within and between appliance types can also be obtained.

2. MATERIALS AND METHODS

2.1 Equipment

The sensors used for measuring the magnetic flux densities were magnetic field probes designed and fabricated by IITRI. Two types of probes were employed as illustrated in the photograph of Figure 1. Both probes produce output voltages proportional to magnetic flux density. The small air core probe was used for measurements where the distance to the field source was less than one foot. This probe is in the form of a cylindrical coil 0.75 inches long, wound on a 0.75 inch diameter acrylic rod with small gauge enameled wire. The rod extends past one end of the coil to serve as a handle and as a guide for leads to a coaxial connector. The small size of the probe makes is well suited for measurements near appliance surfaces and for resolving localized field maxima. To accurately control small surface to probe separations, foam plastic spheres are affixed over the probe coil, with their centers coincident, thereby providing a three-dimensional surface of uniform radius from the coil center (see Figure 2).

The large magnetic field probe was used for measurement distances of one foot and greater. This probe is a long, multi-layered cylindrical coil wound on an acrylic bobbin. It has a high permeability ferrite core and a resistive termination to provide high sensitivity and a flat frequency response. The off axis rejection of this probe is better than 500:1, making it highly directional. While much more sensitive and directional than the small air core probe, the large probe has less spatial resolution and tends to measure the average magnetic flux density over a larger volume. The probe employs shielding techniques to provide a high degree of immunity to radio frequency signals and interference.

Calibrations of the probes are conducted with a one meter radius Helmholtz coil-pair (coil radius equals spacing) at regular intervals. A Helmholtz coil-pair generates a very uniform and easily calcuable magnetic flux density along its axis between the coils. The large size of the coils, as pictured in Figure 3, assures a uniform magnetic field over the volume of the probes. The magnetic field probes have been shown to exhibit negligible calibration drift over very long time periods.

The meter used to measure the probes' output voltages was a Hewlett-Packard 3581A Signal Wave Analyzer. This instrument functions as a true rms, frequency selective voltmeter. It has selective bandwidths of from 1 to 300 hertz, and the capability to AFC "lock" on a particular signal. As a Figure 1.

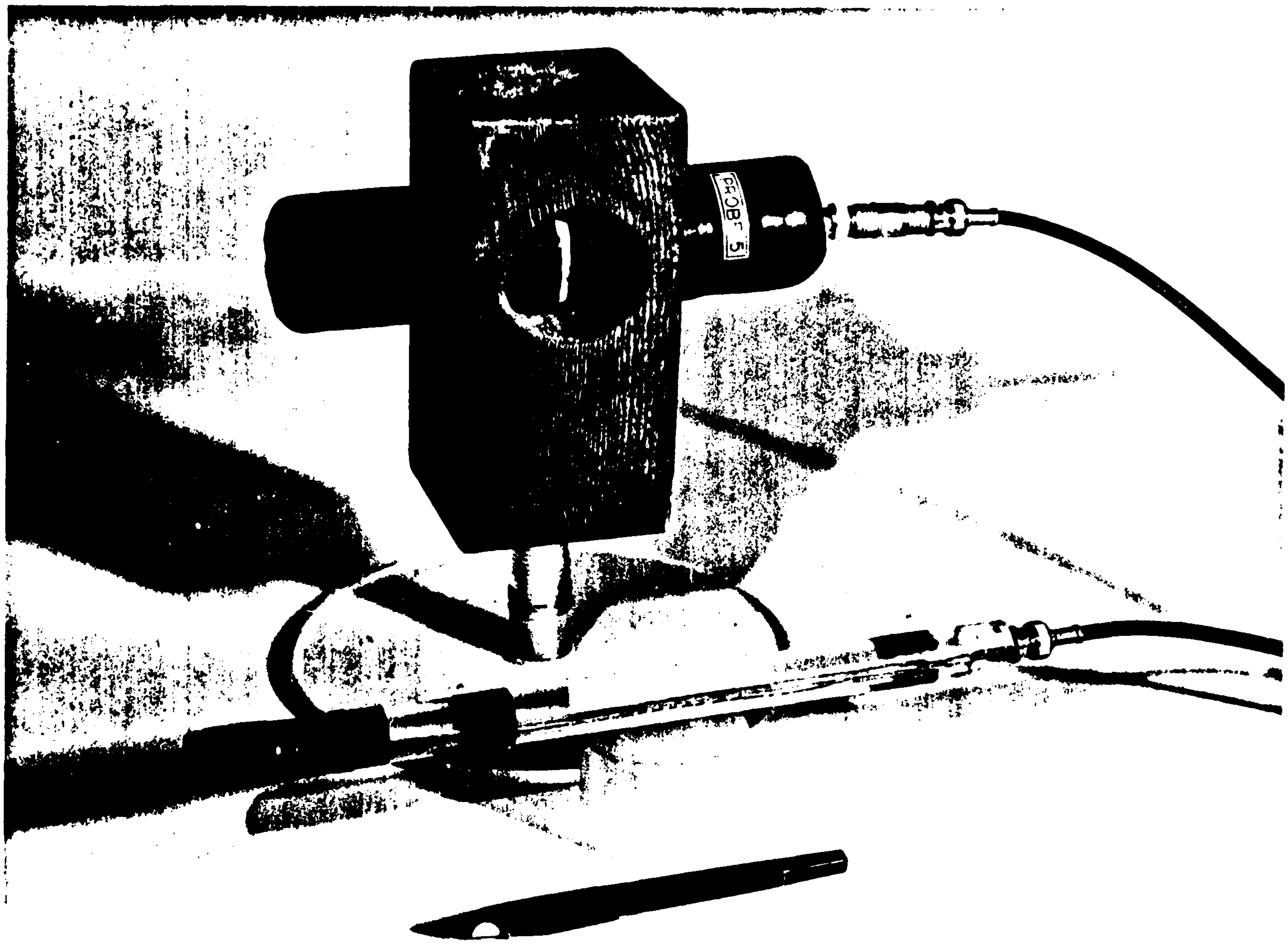

FIGURE 1 IITRI Magnetic Field Probes

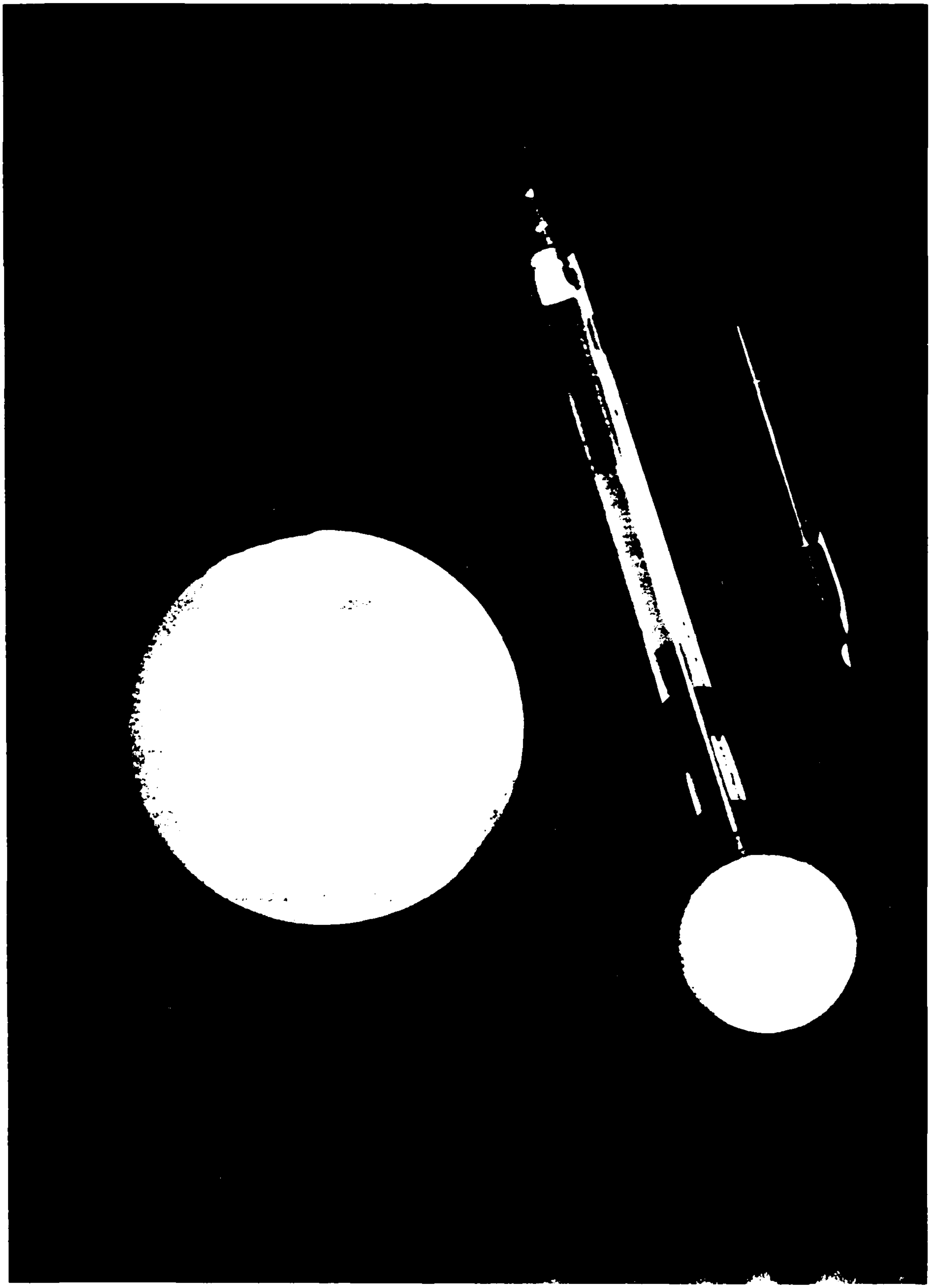

FIGURE 2 Air Core Probe With Spacing Spheres

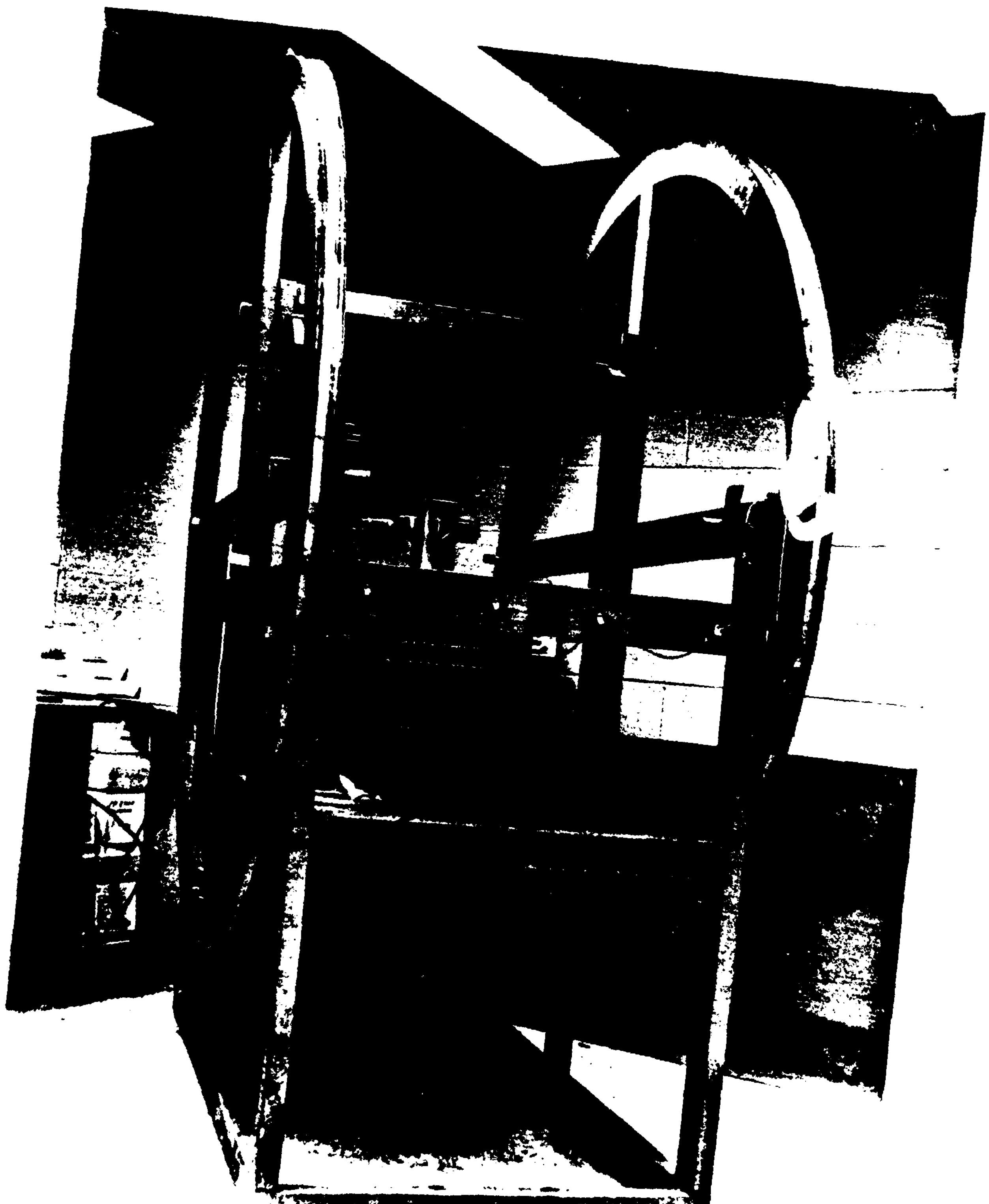

FIGURE 3 Helmholtz Coil-Pair Calibrator

battery operated instrument it affords portability and electrical isolation. For the measurements reported herein, the meter was set at a 3 Hz bandwidth and was AFC locked at a frequency of 60 Hz. The probe calibration tables were used to convert the output voltages to equivalent magnetic flux densities.

2.2 Measurement Protocol

Several protocols for measuring the magnetic fields generated by appliances can be set forth. These include making measurements at a fixed distance from the device or at a typical "user distance." Both of these techniques, however, suffer from ambiguity and subjectivity in defining "appropriate fixed distance" and "user distance." To overcome these questions of interpretation, a more definitive "worst case" measurement protocol was established. Under this protocol, the maximum magnetic field produced by an appliance as a function of the distance from its surface was determined by a sequence of measurements, as follows. In practice, the maximum magnetic flux density at any point was found by rotating the magnetic field probe slowly by hand in all directions until voltage maximum was indicated on the meter. At the beginning of a measurement sequence, the magnetic fields about the near surface of the device under test were surveyed in order to locate the region of maximum flux density. This served as a starting point. Maximum field readings were then made along a path perpendicular to the surface from this point at distances of 0.1, 0.25, 0.5, 0.75, 1, 2, and 3 ft. Readings were also taken at 5 and 7 ft, if possible. In general, the direction of the maximum flux density as well as its magnitude was a function of distance and position.

Small and large appliances were treated somewhat differently during the initial survey to determine which region of the appliance produced the maximum magnetic flux density. Hand-held and portable devices were surveyed on all sides with the exception of the bottoms of those units which normally sat on the floor. Large stationary appliances such as refrigerators and ranges, or those which were built into walls or cabinets, were surveyed only on those surfaces which were normally exposed or accessible. Measurements were always taken and referenced with respect to outer appliance surfaces.

Care was taken to assure that the measured magnetic fields were in fact produced by the device being characterized, and not by other sources. Several sources of ambient 60 Hz magnetic fields exist in typical private dwellings and in workspaces. These include electrical currents flowing on metallic pipes, conduits, and structural steel in buildings, power distribution lines, power distribution step down transformers, and other nearby electrical appliances, fluorescent lighting, and equipment. To minimize the effects of these ambient sources, several steps were taken. First, all appliances and equipment in the area of the device under test were turned off. Second, the test unit would be turned on and off while watching the effect on the meter reading. A reading which dropped from midscale to or near zero when the device was turned off confirmed the device as the field source. For smaller and portable appliances, the low level fields they produced at distances of several feet could often be resolved in the presence of similar level ambients by rotating the appliance so that its magnetic field was perpendicular to the ambient field, and then using the highly directional magnetic field probe to discriminate between them. A few large appliances that could not be moved were measured during very early morning hours when electrical demand and corresponding ambient magnetic field levels were significantly reduced.

3. DISCUSSION

Approximately 100 different appliances of 25 basic types were surveyed to determine their magnetic field characteristics. The data from these measurements is presented in the graphs of Figures 4 through 28, where the maximum magnetic flux density generated by an appliance is plotted as a function of distance from its surface. At least three examples for each device type are given.

3.1 Ranges and Ovens

Electric ranges and ovens are high current appliances and can consume upwards of 10 kW of power in resistive heating elements. A large cooktop burner may itself use 3 kW. In Figure 4, two distinct curve groupings are seen for burners. The upper curves, models A and B, are from spiral element burners employing several turns of narrow elements. The lower curves are from burners with a few turns of wider elements. Magnetic fields were maximum directly above all burners. For regular ovens (Figure 5), the magnetic fields were maximum directly in front, at a height in line with the heating

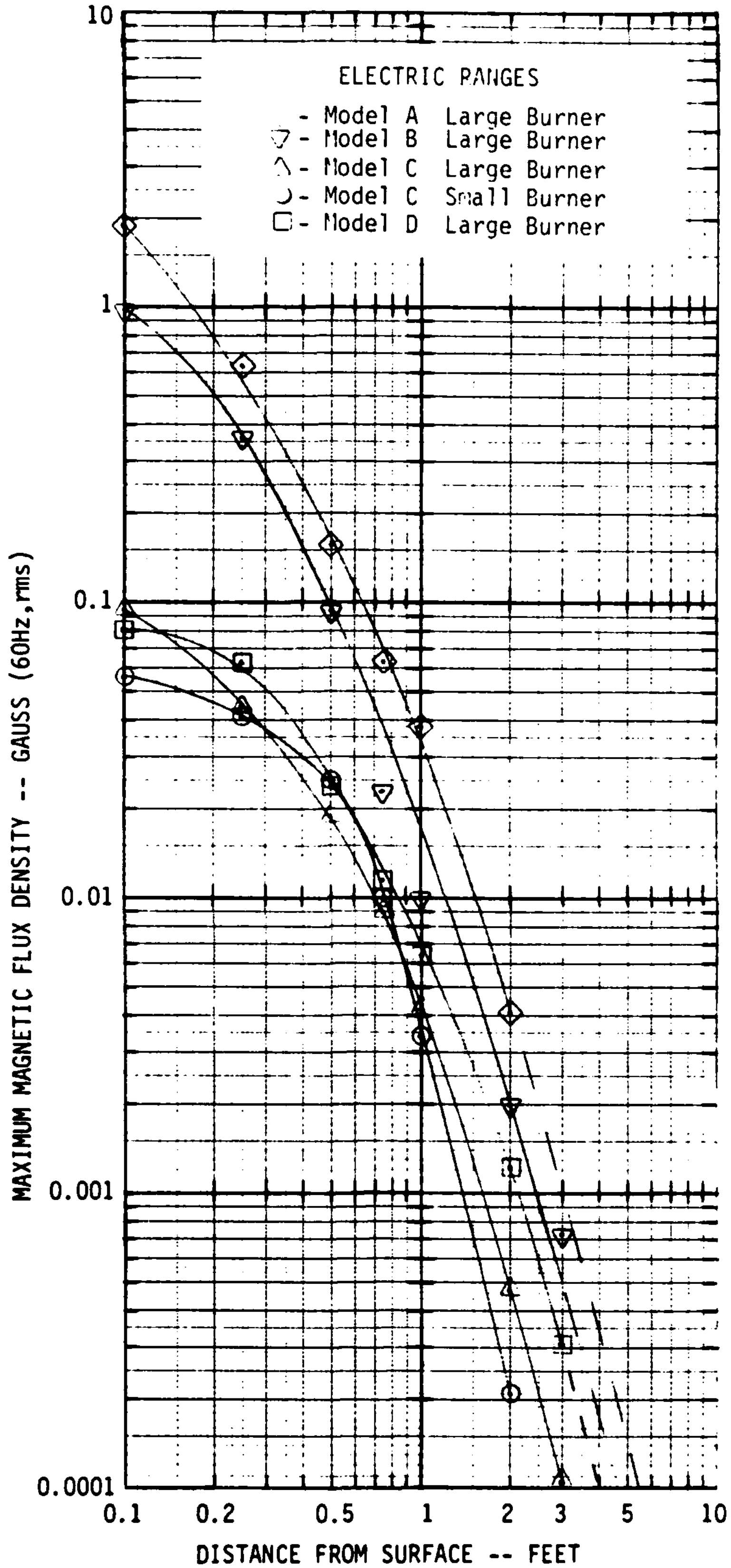

FIGURE 4 Magnetic Flux Density Produced by Ranges

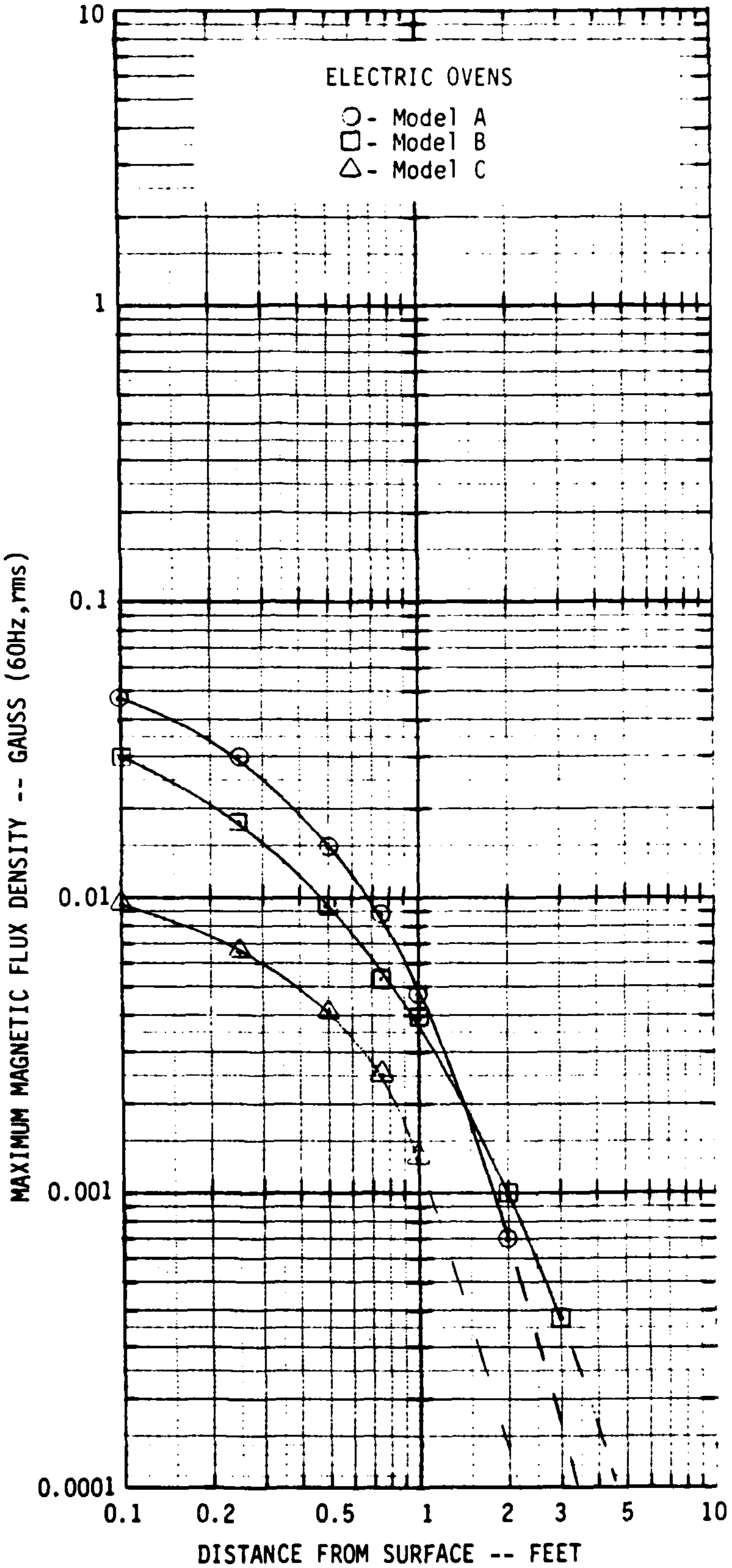

FIGURE 5 Magnetic Flux Density Produced by Ovens

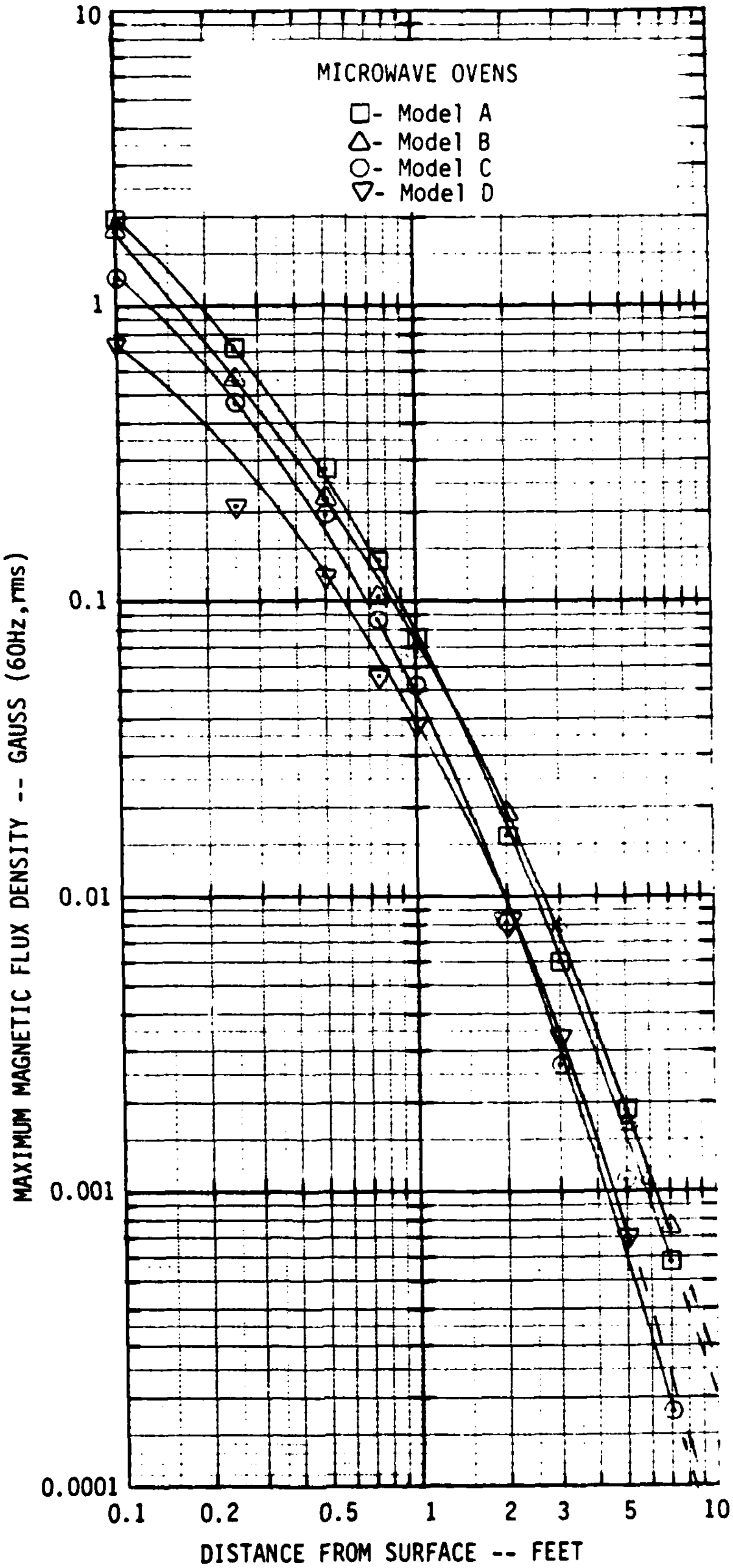

FIGURE 6 Magnetic Flux Density Produced by Microwave Ovens

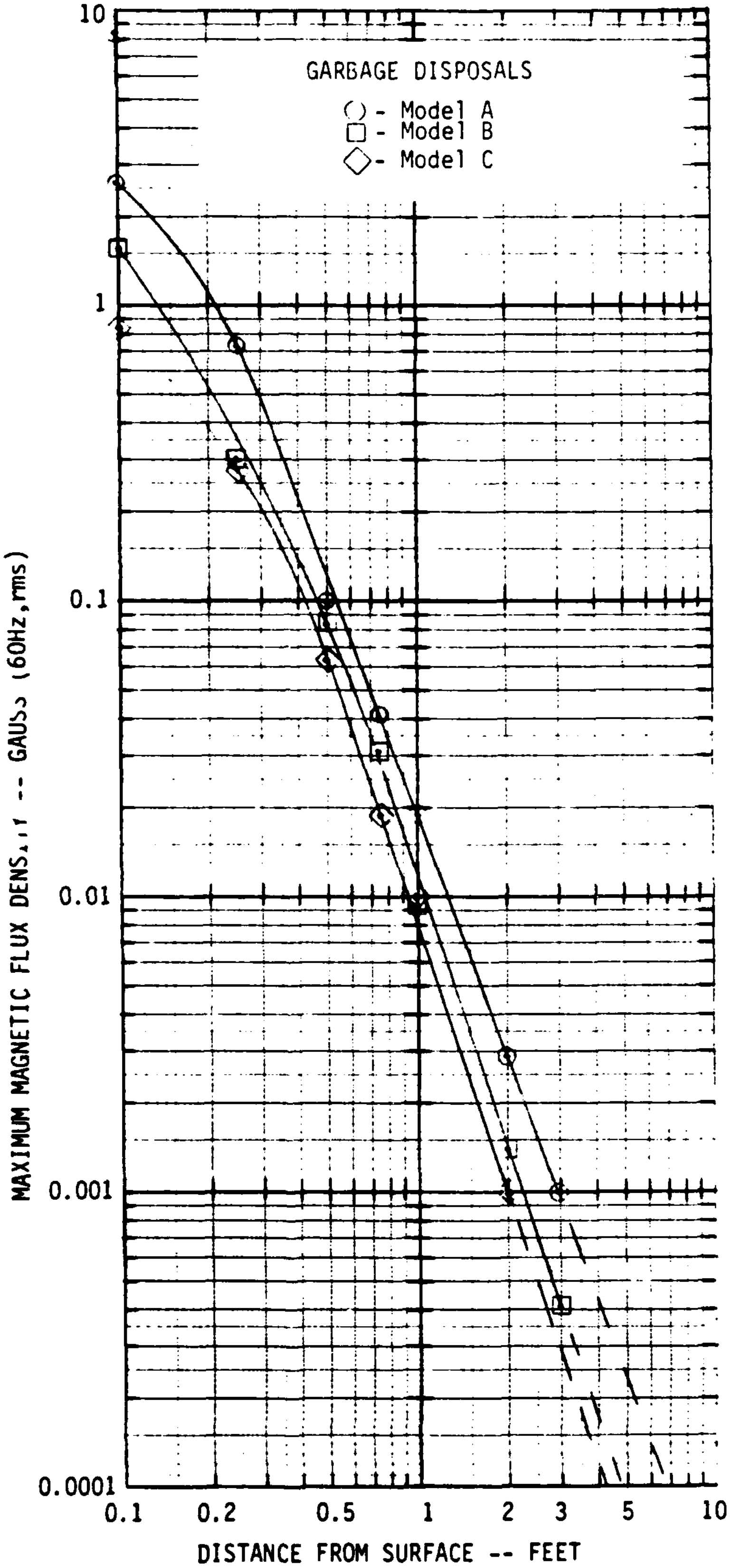

FIGURE 7 Magnetic Flux Density Produced by Disposals

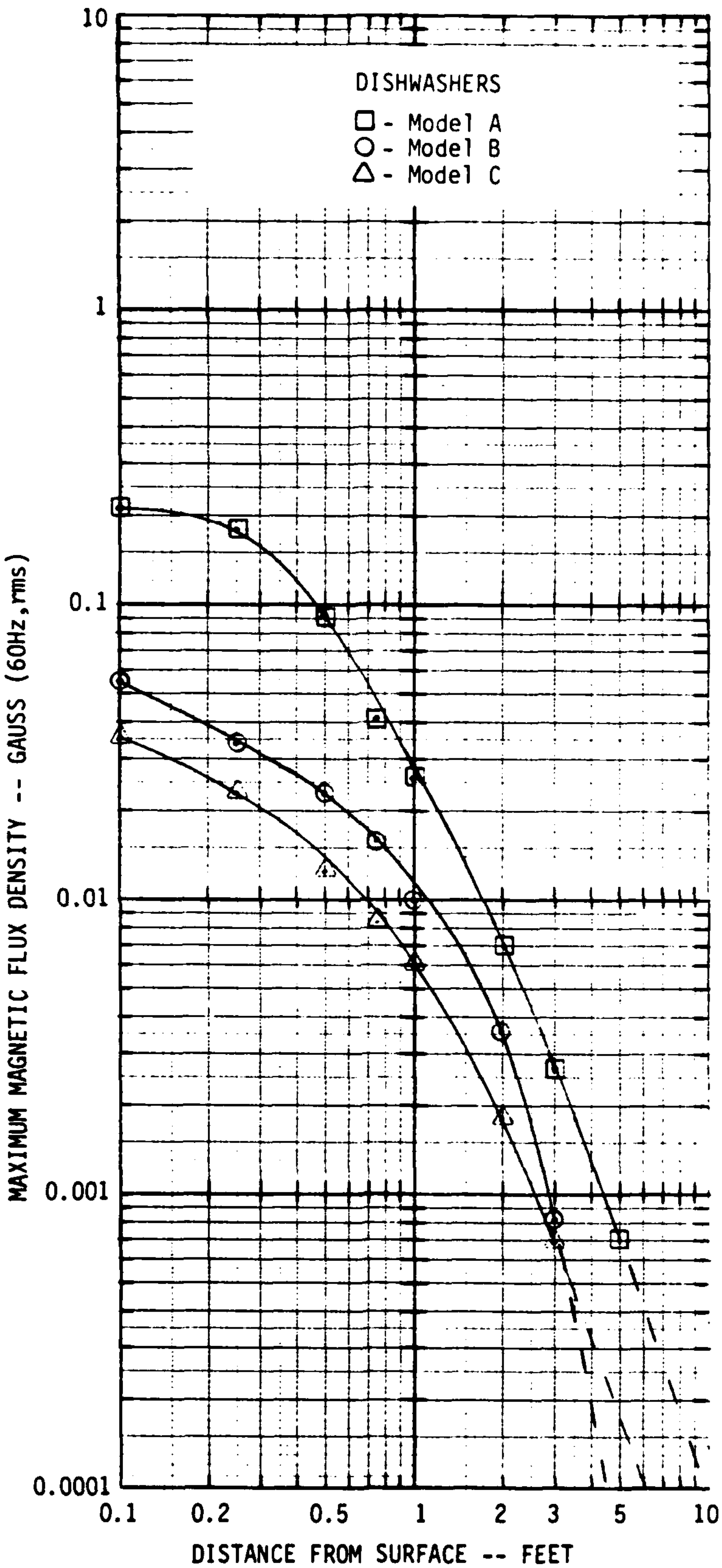

FIGURE 8 Magnetic Flux Density Produced by Dishwashers

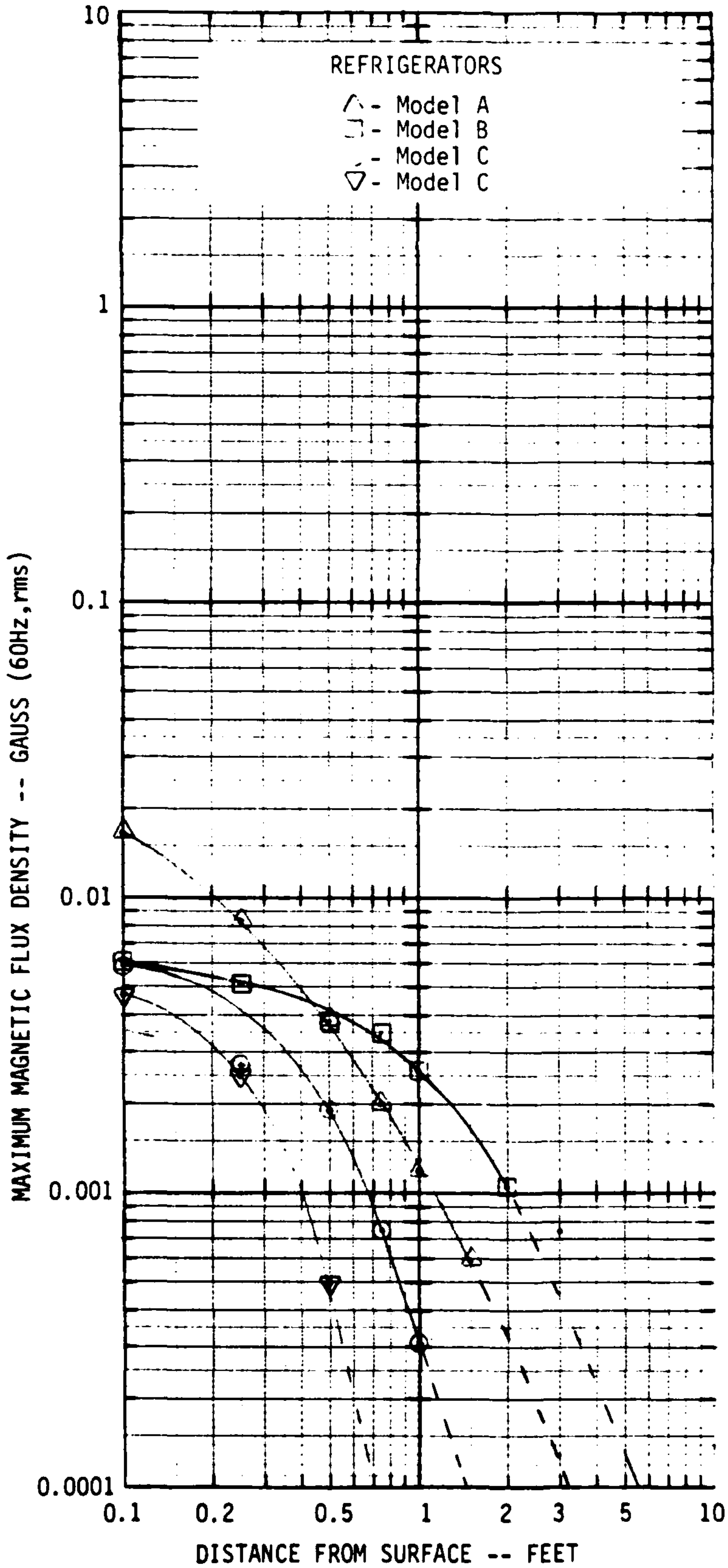

FIGURE 9 Magnetic Flux Density Produced by Regrigerators

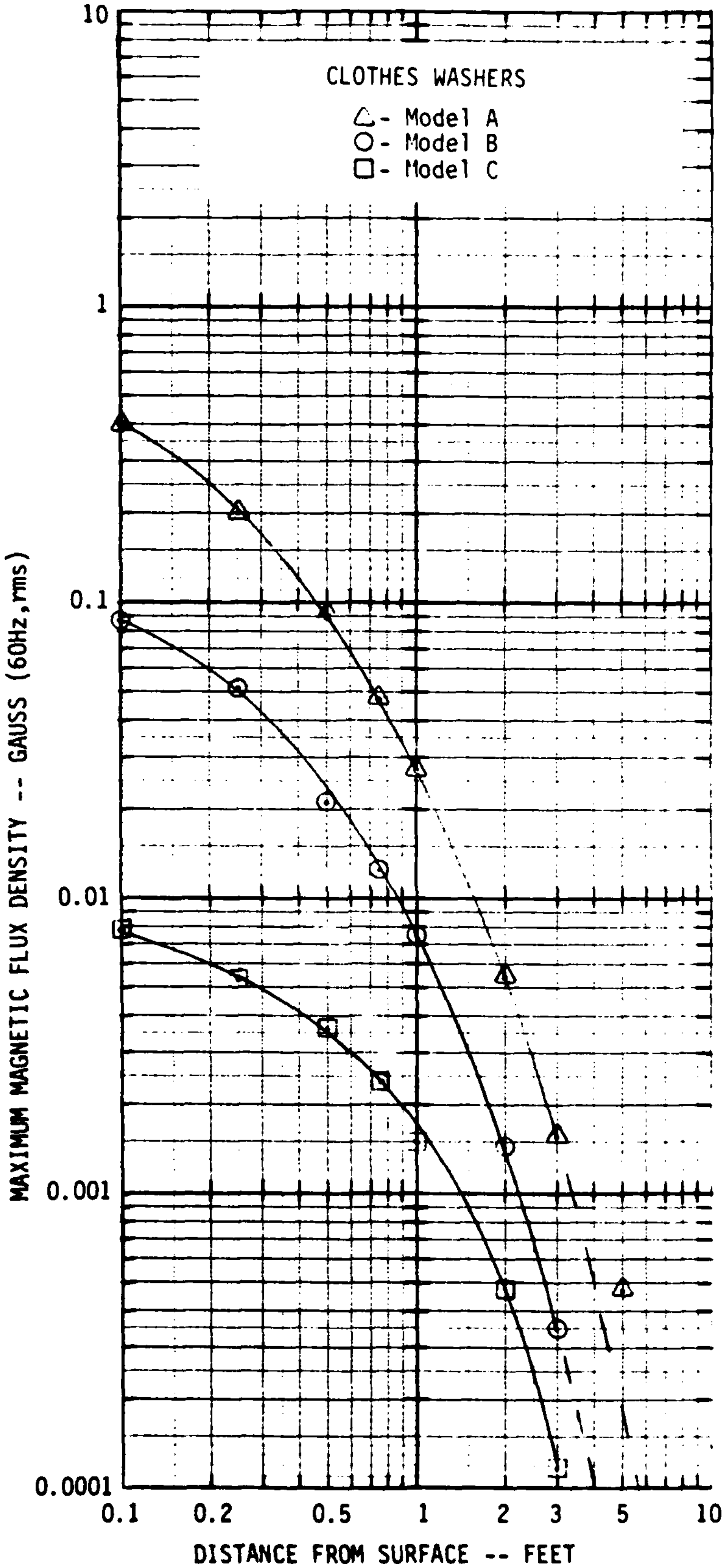

FIGURE 10 Magnetic Flux Density Produced by Washers

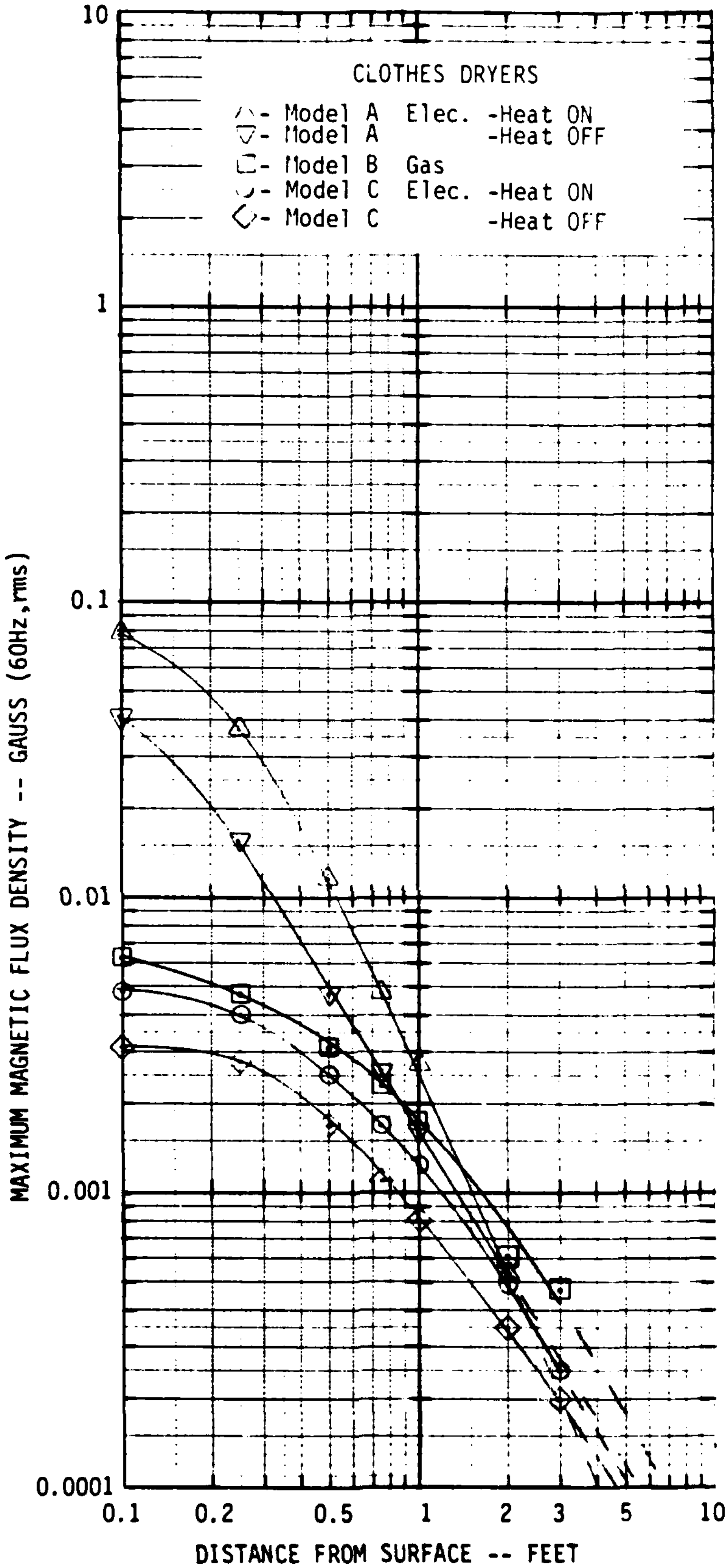

FIGURE 11 Magnetic Flux Density Produced by Dryers

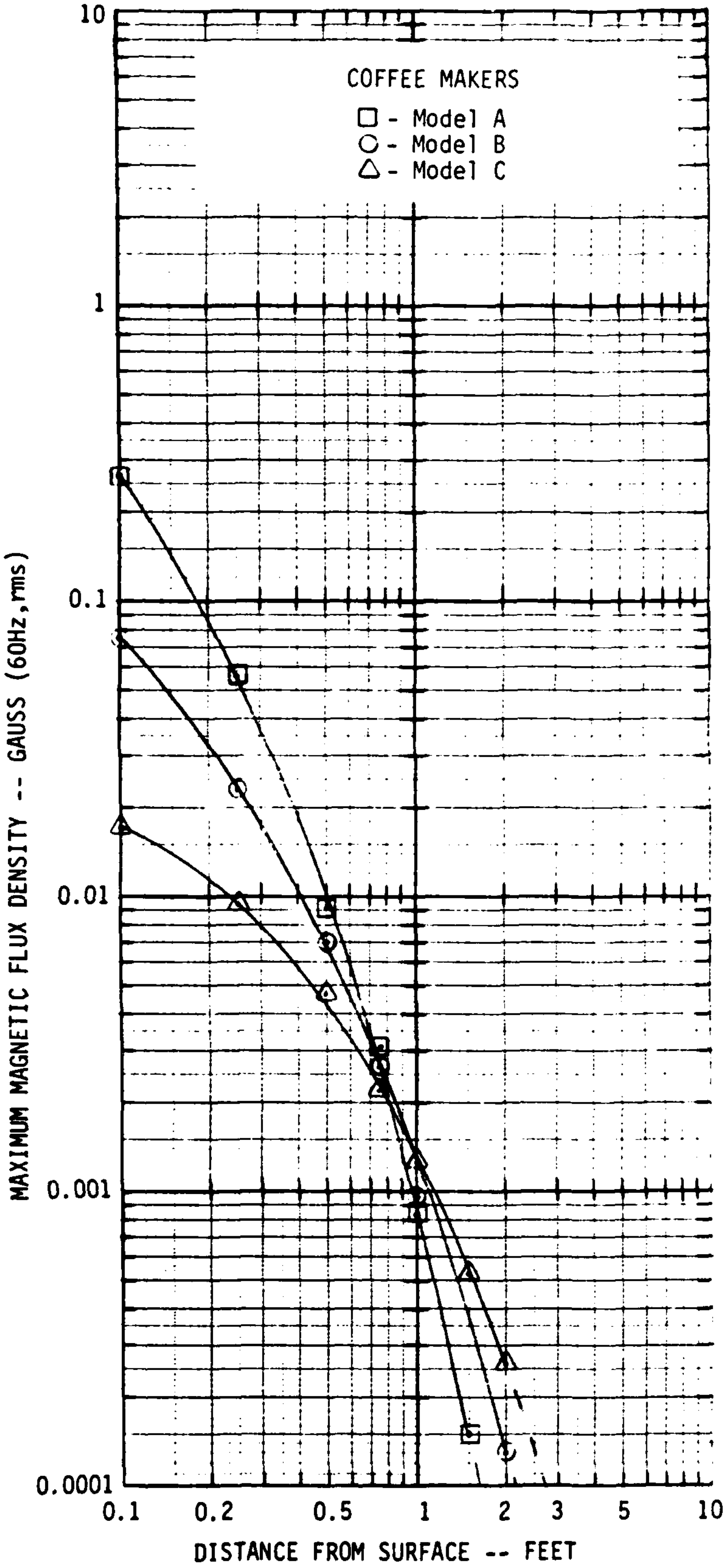

FIGURE 12 Magnetic Flux Density Produced by Coffee Makers

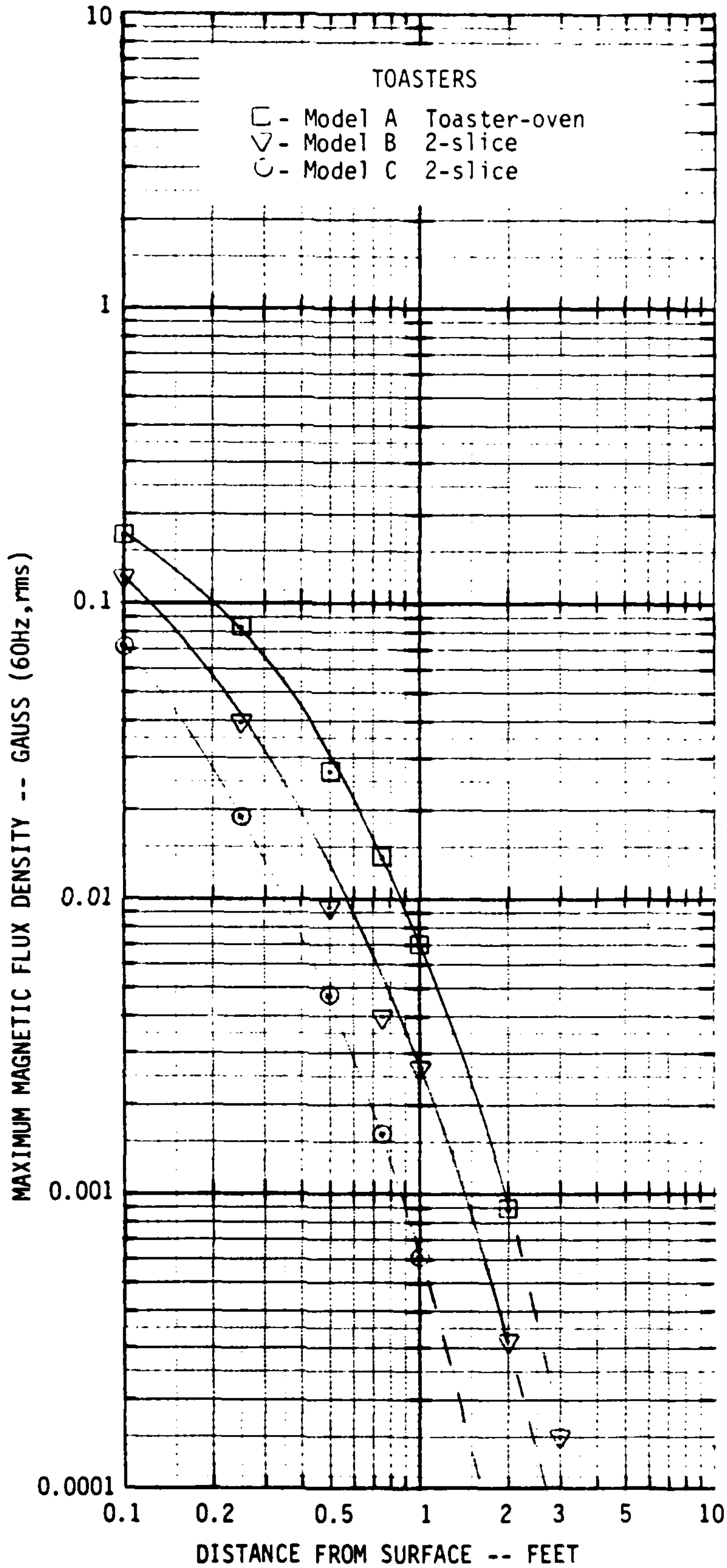

FIGURE 13 Magnetic Flux Density Produced by Toasters

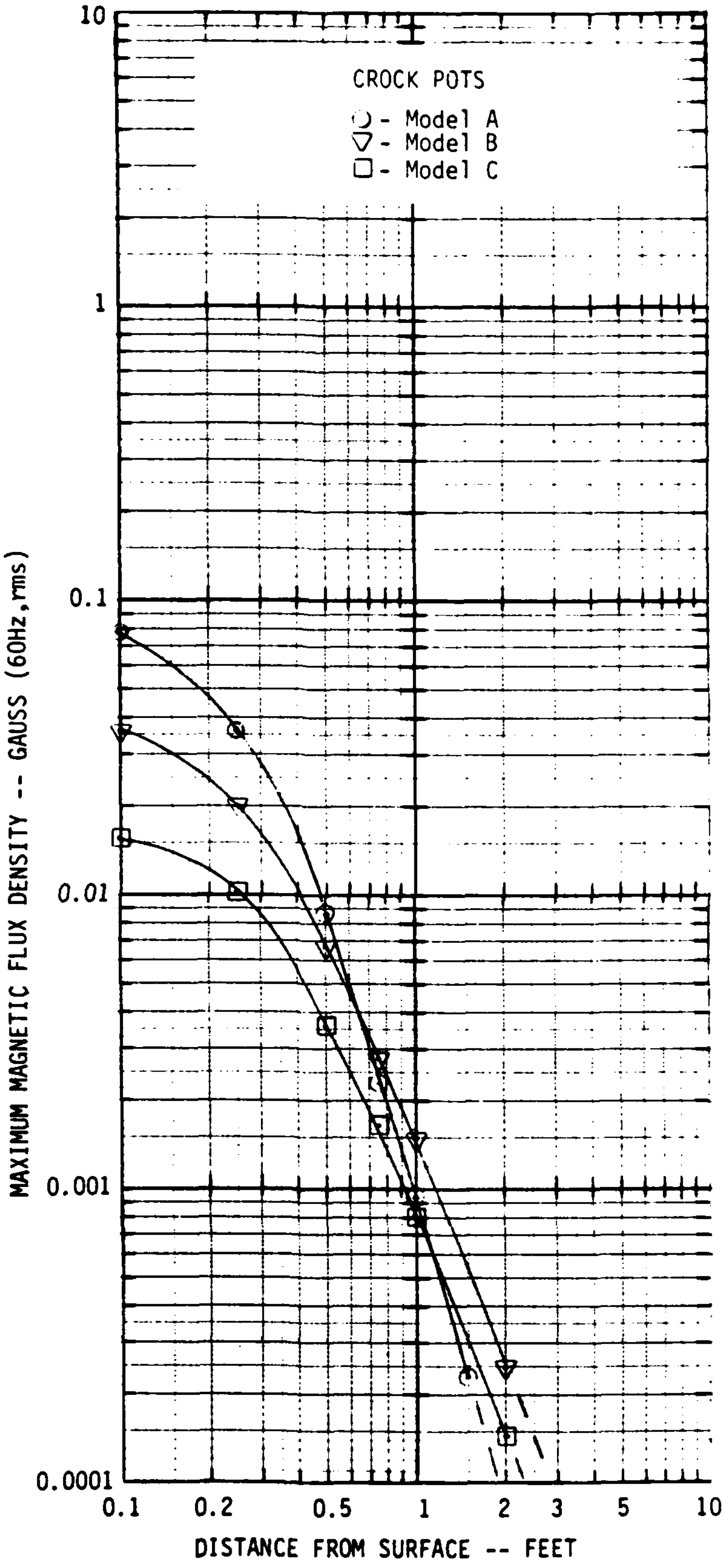

FIGURE 14 Magnetic Flux Density Produced by Crock Pots

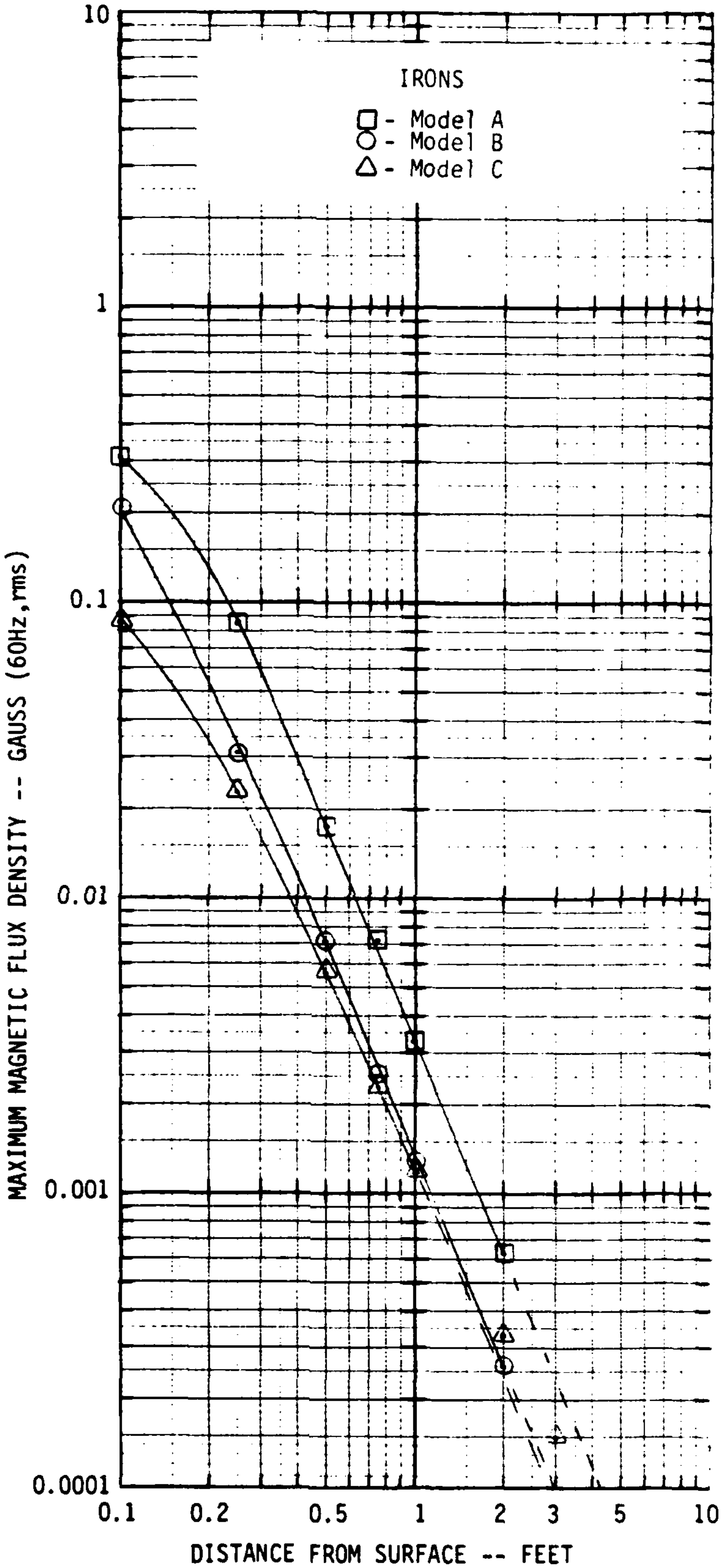

FIGURE 15 Magnetic Flux Density Produced by Irons

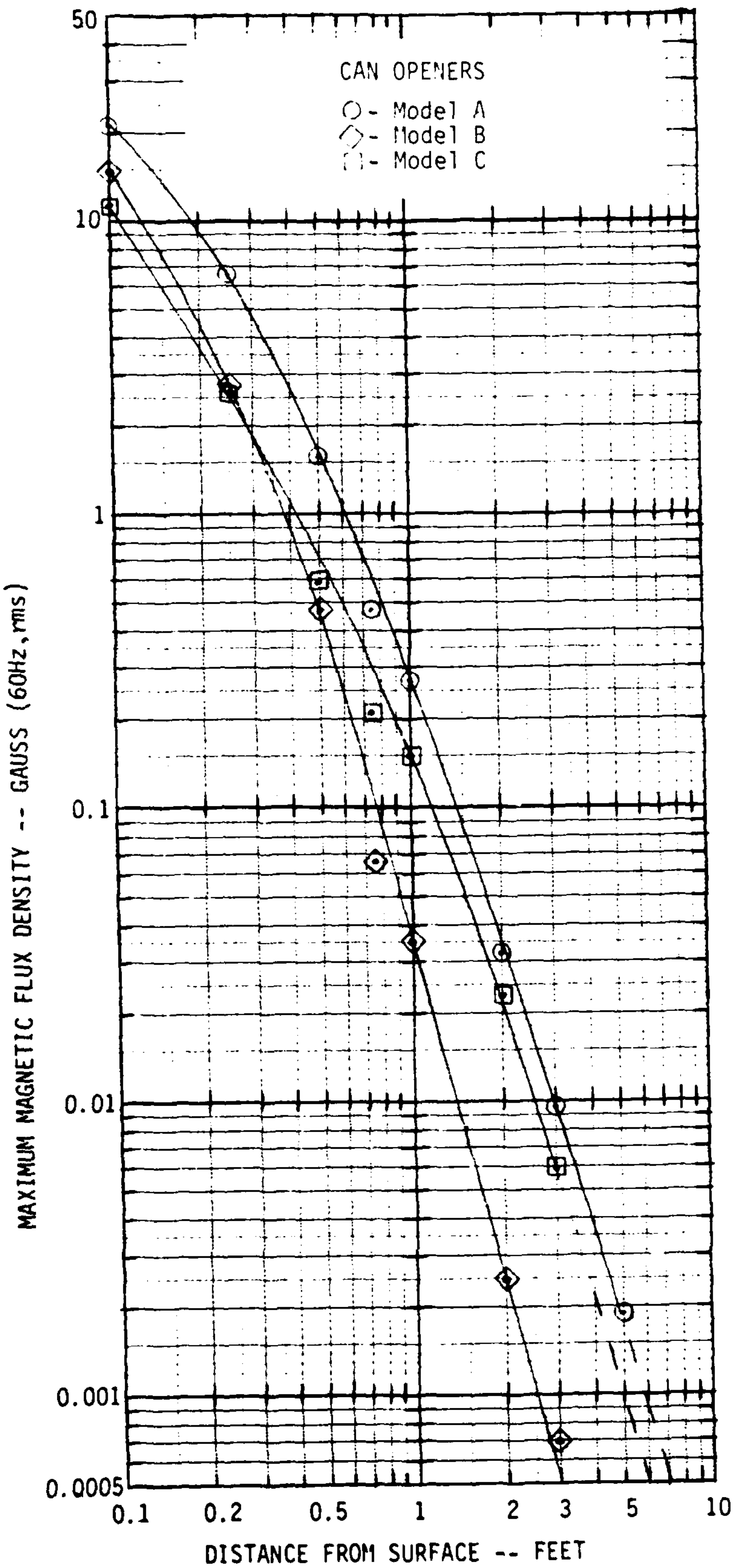

FIGURE 16 Magnetic Flux Density Produced by Can Openers

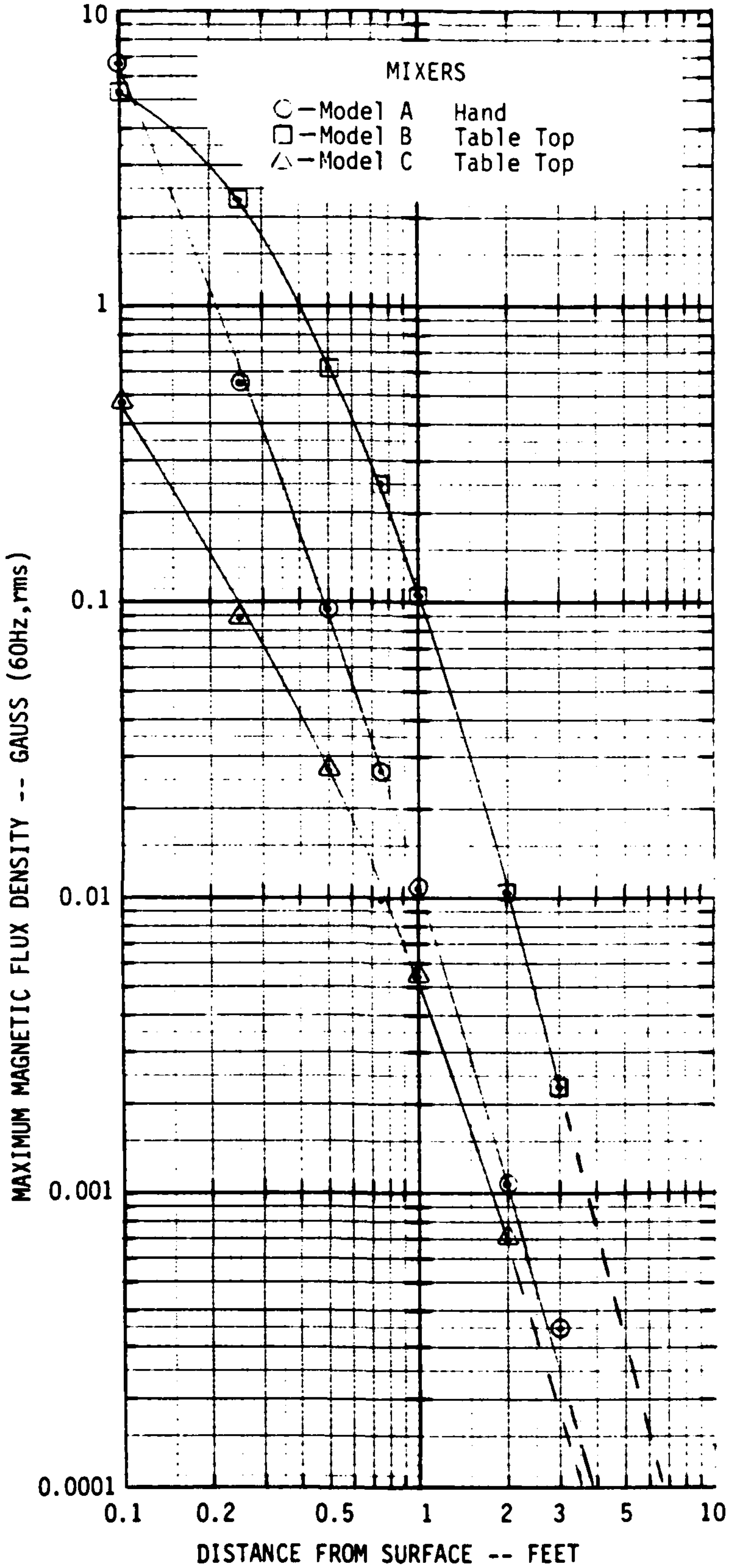

FIGURE 17 Magnetic Flux Density Produced by Mixers

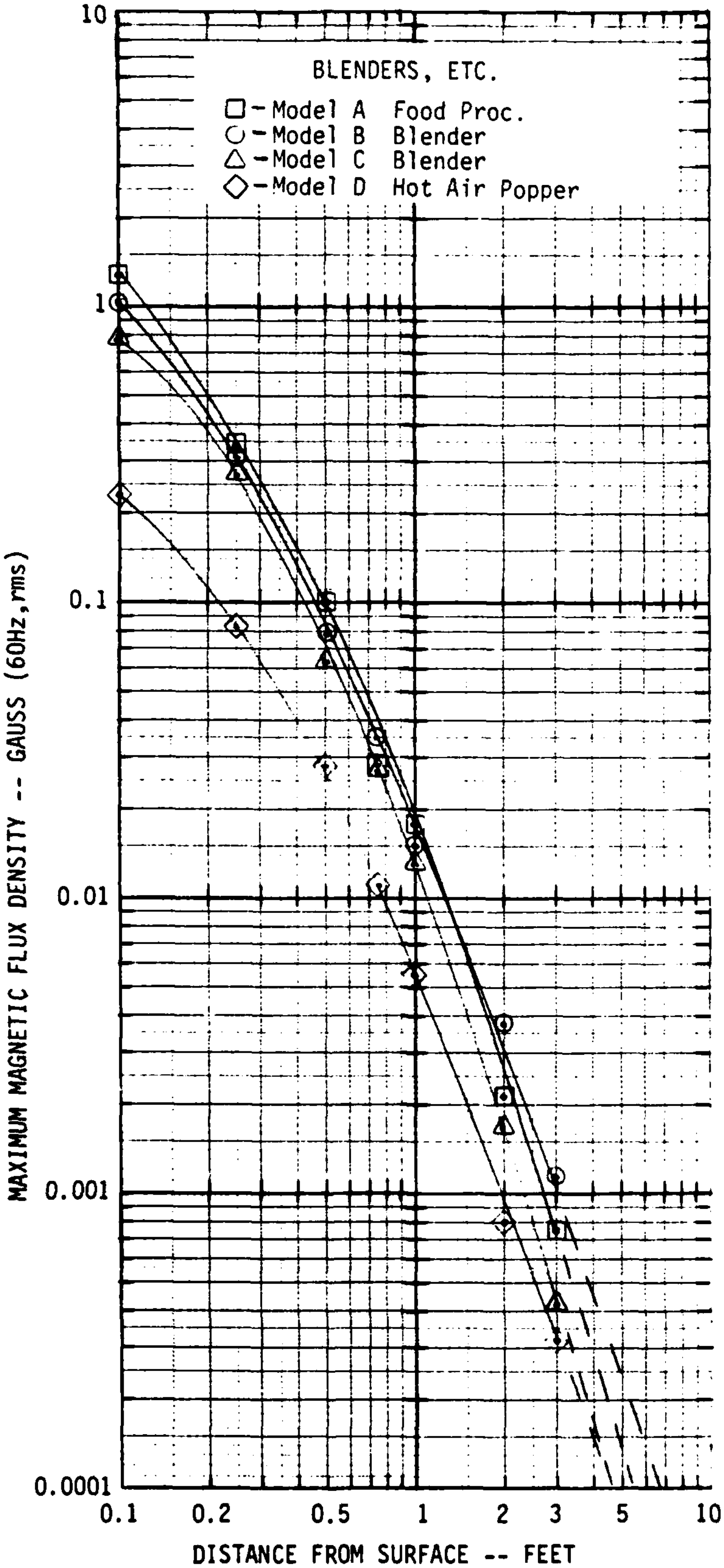

FIGURE 18 Magnetic Flux Density Produced by Blenders

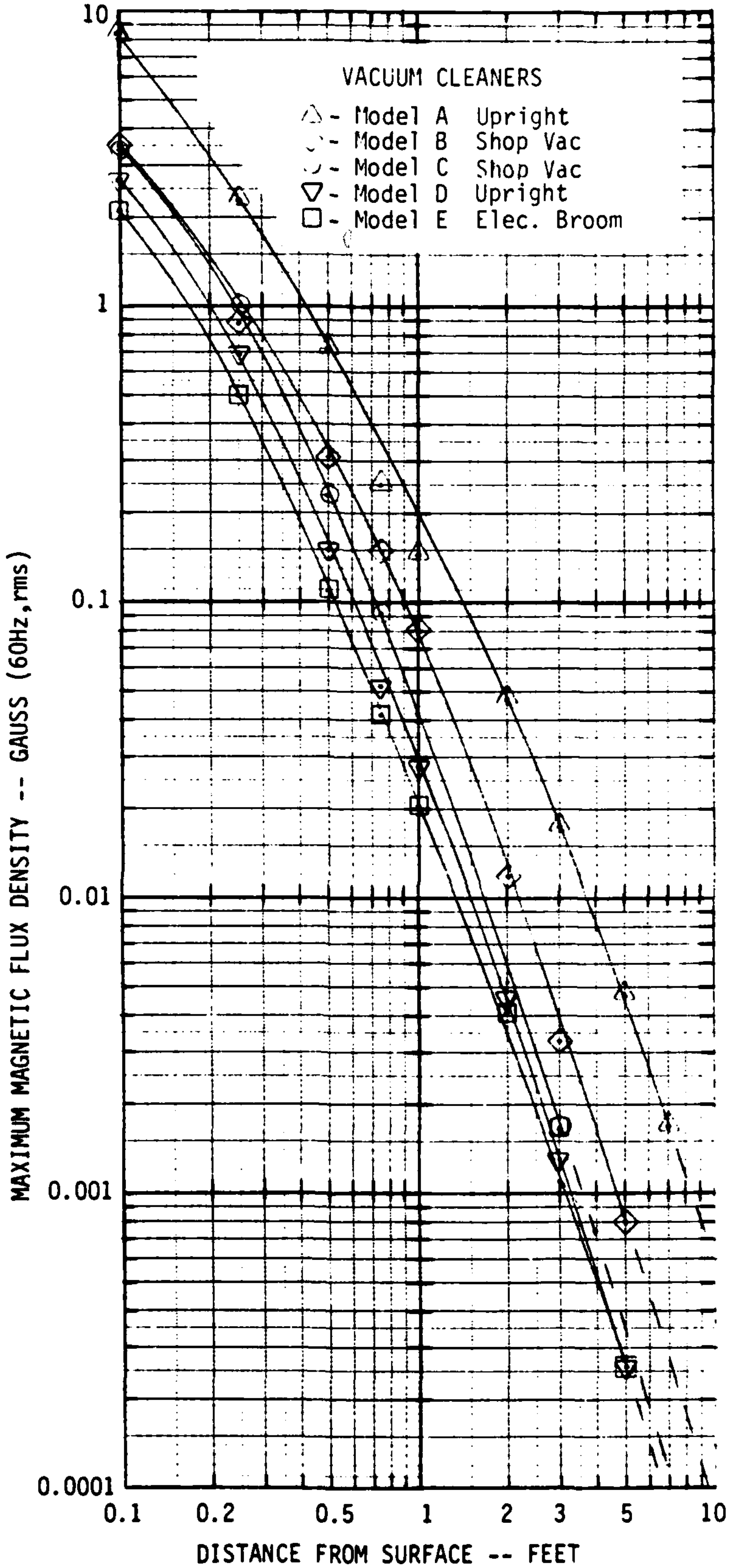

FIGURE 19 Magnetic Flux Density Produced by Vacuum Cleaners

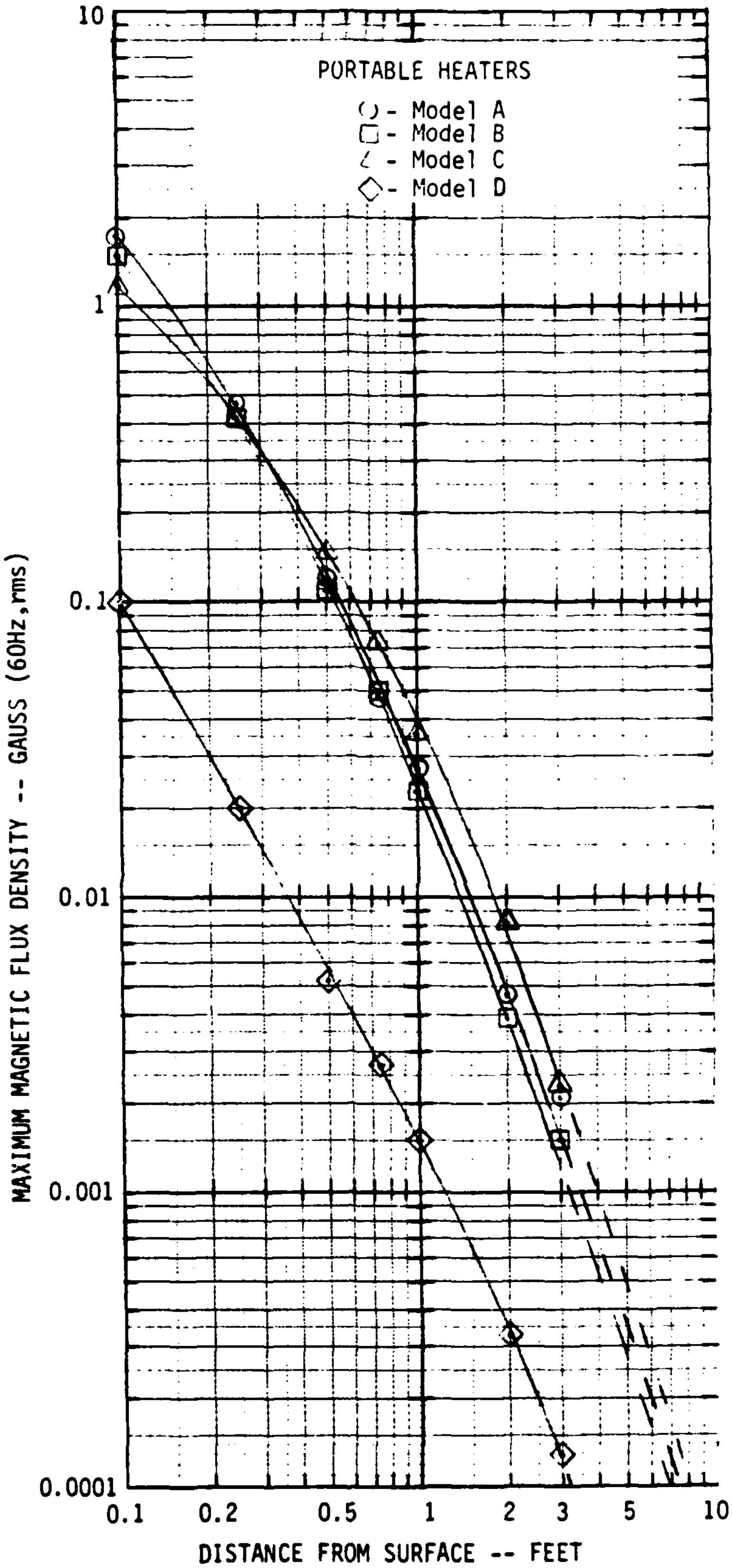

FIGURE 20 Magnetic Flux Density Produced by Portable Heaters

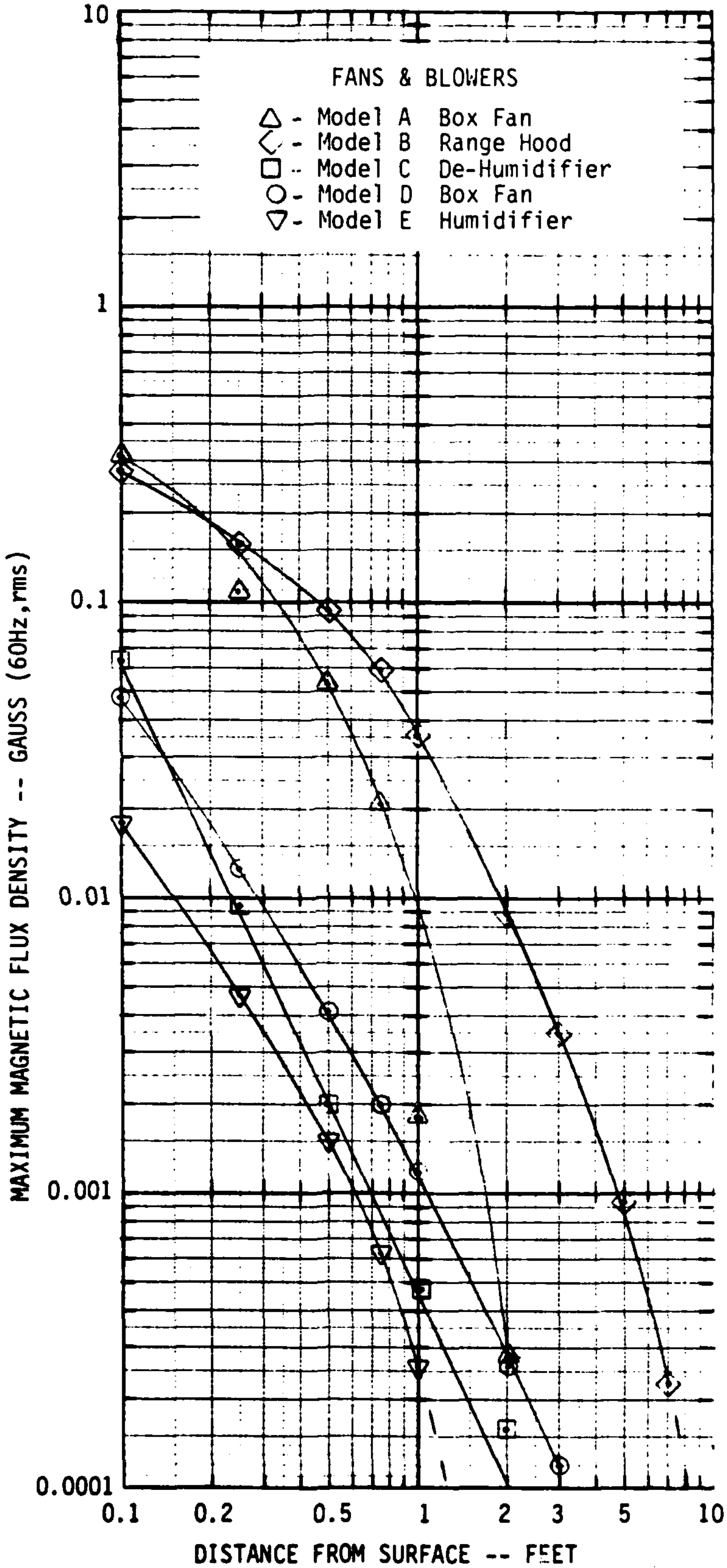

FIGURE 21 Magnetic Flux Density Produced by Fans

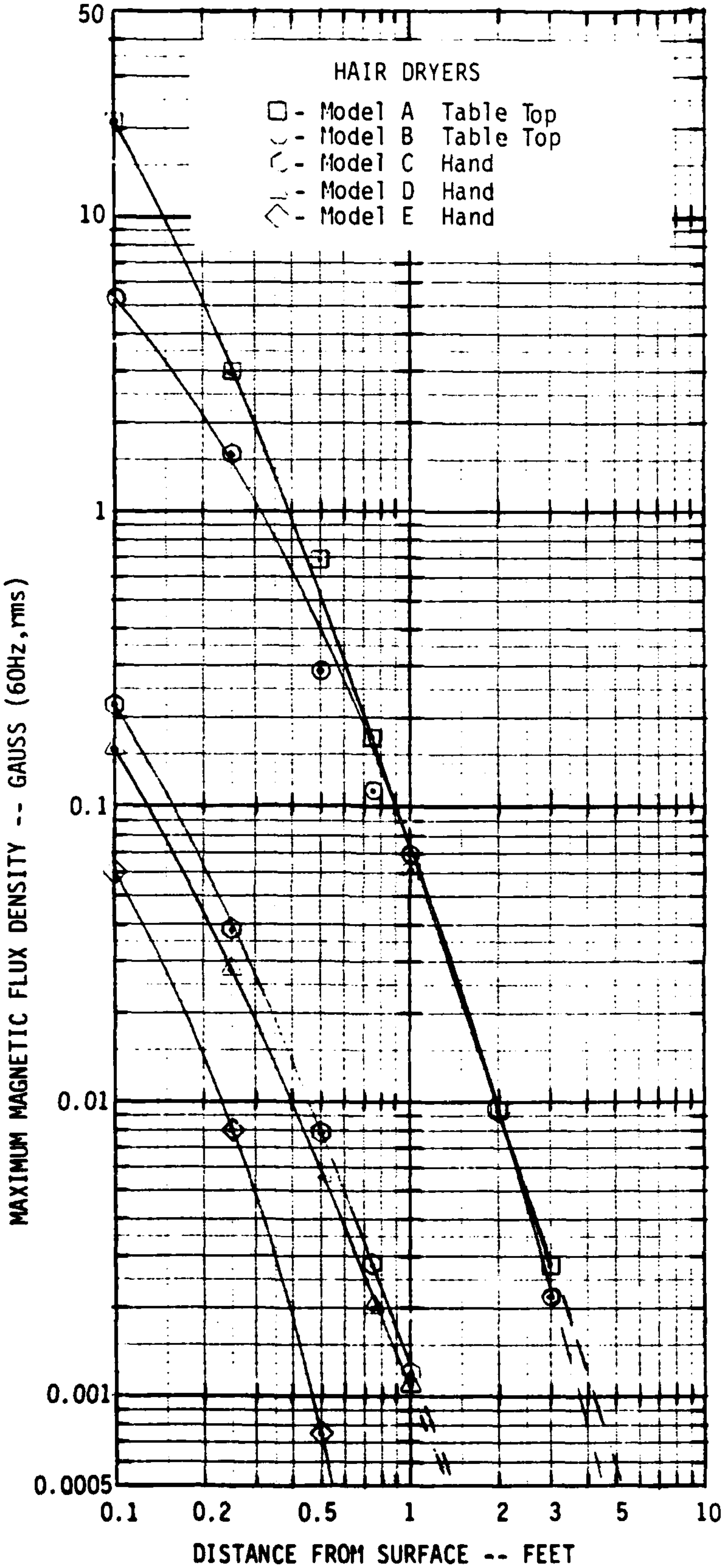

FIGURE 22 Magnetic Flux Density Produced by Hair Dryers

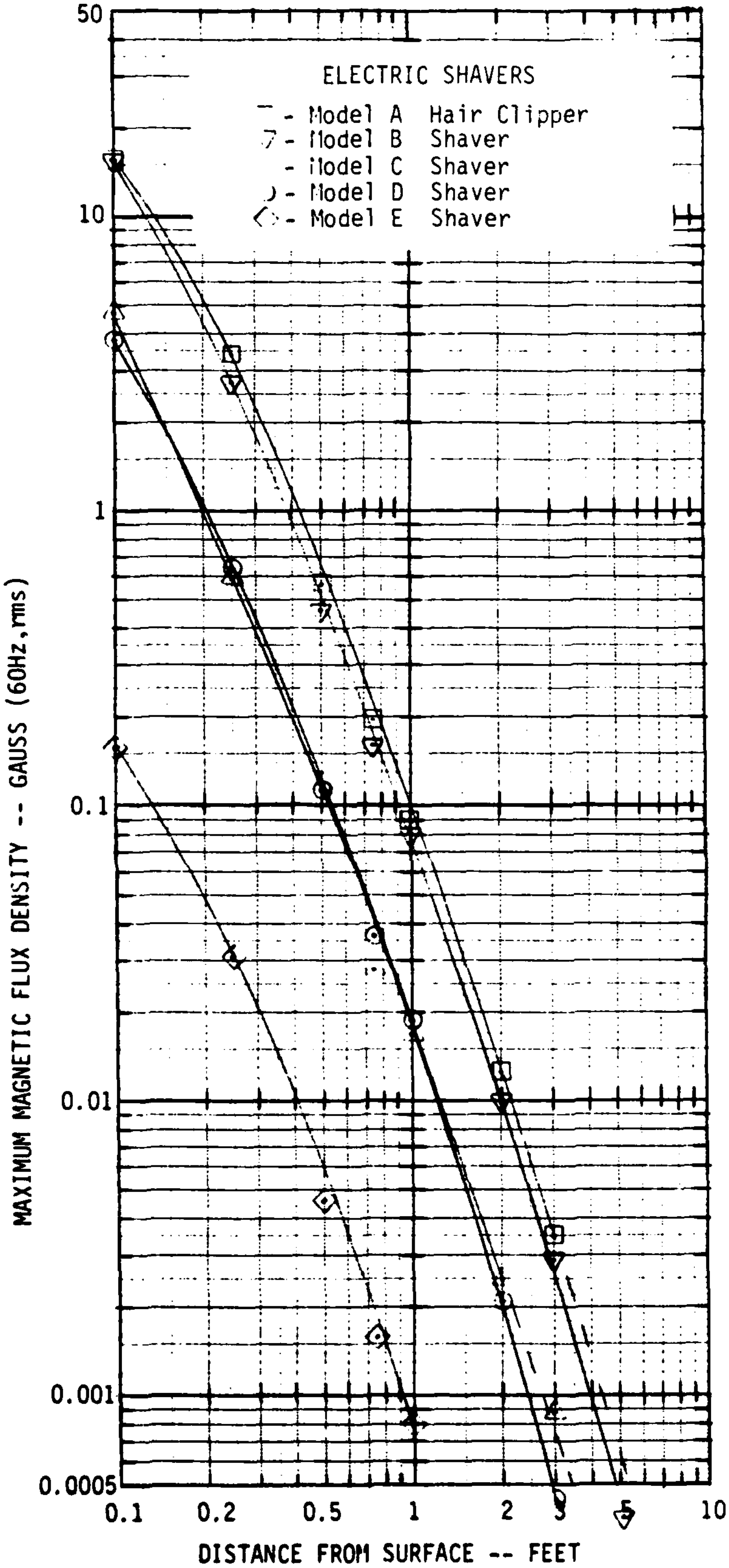

FIGURE 23 Magnetic Flux Density Produced by Shavers

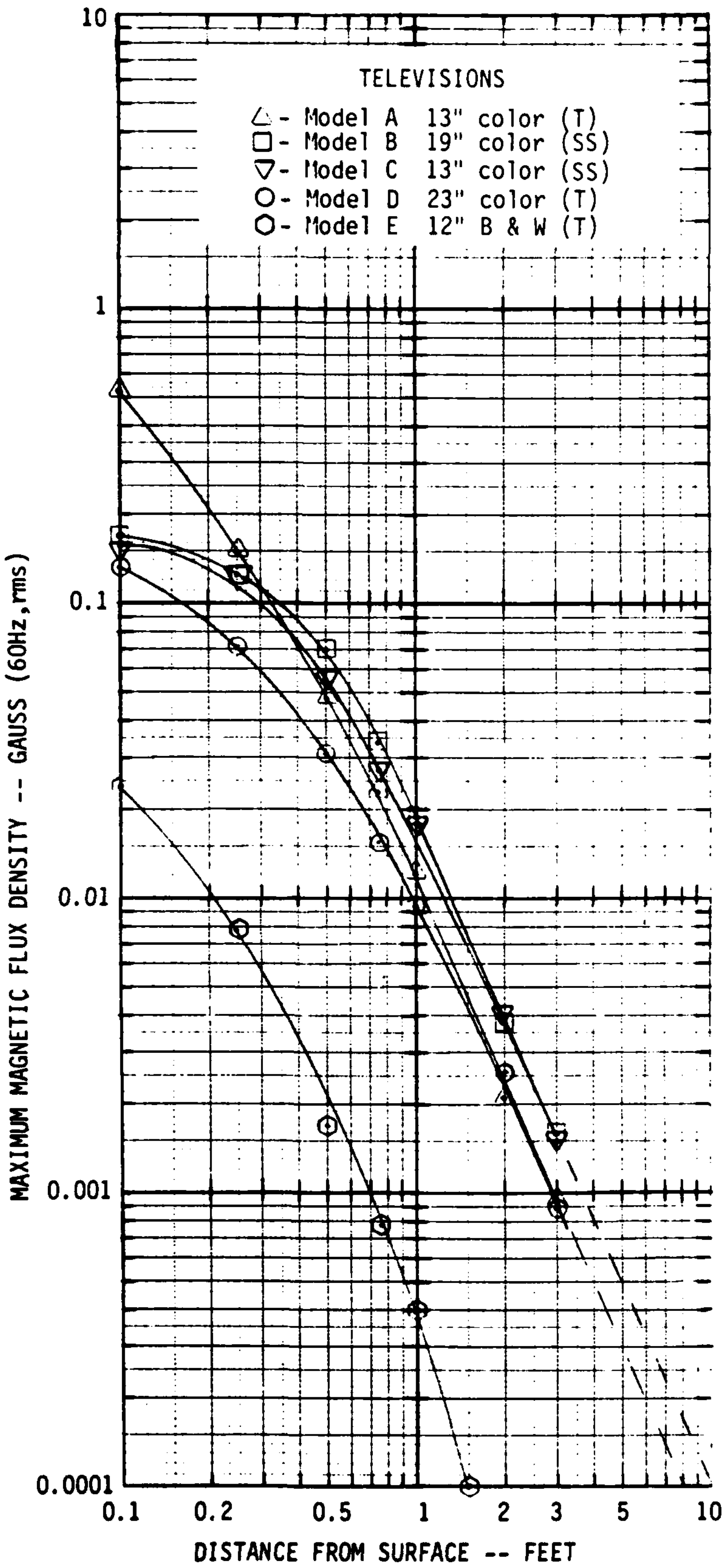

FIGURE 24 Magnetic Flux Density Produced by Televisions

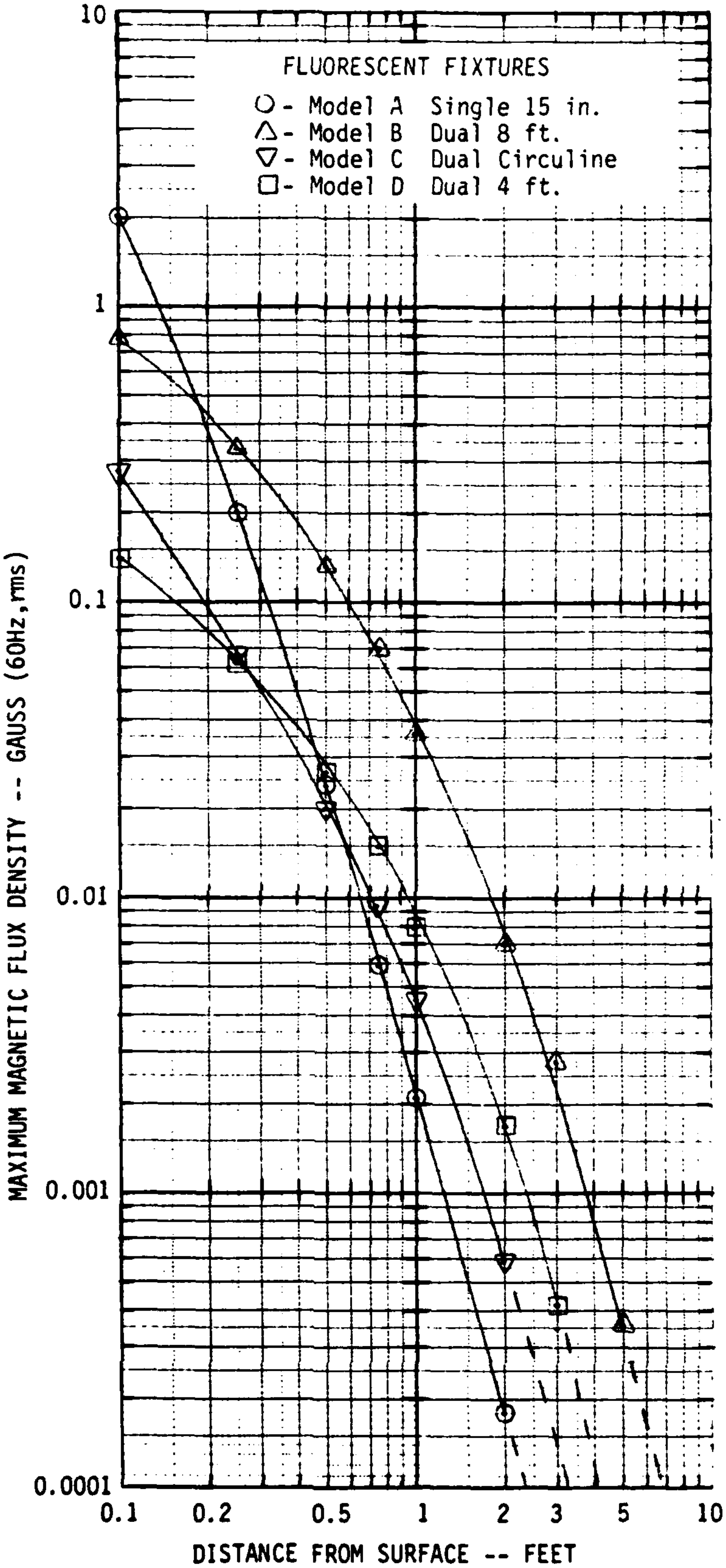

FIGURE 25 Magnetic Flux Density Produced by Flucrescent Fixtures

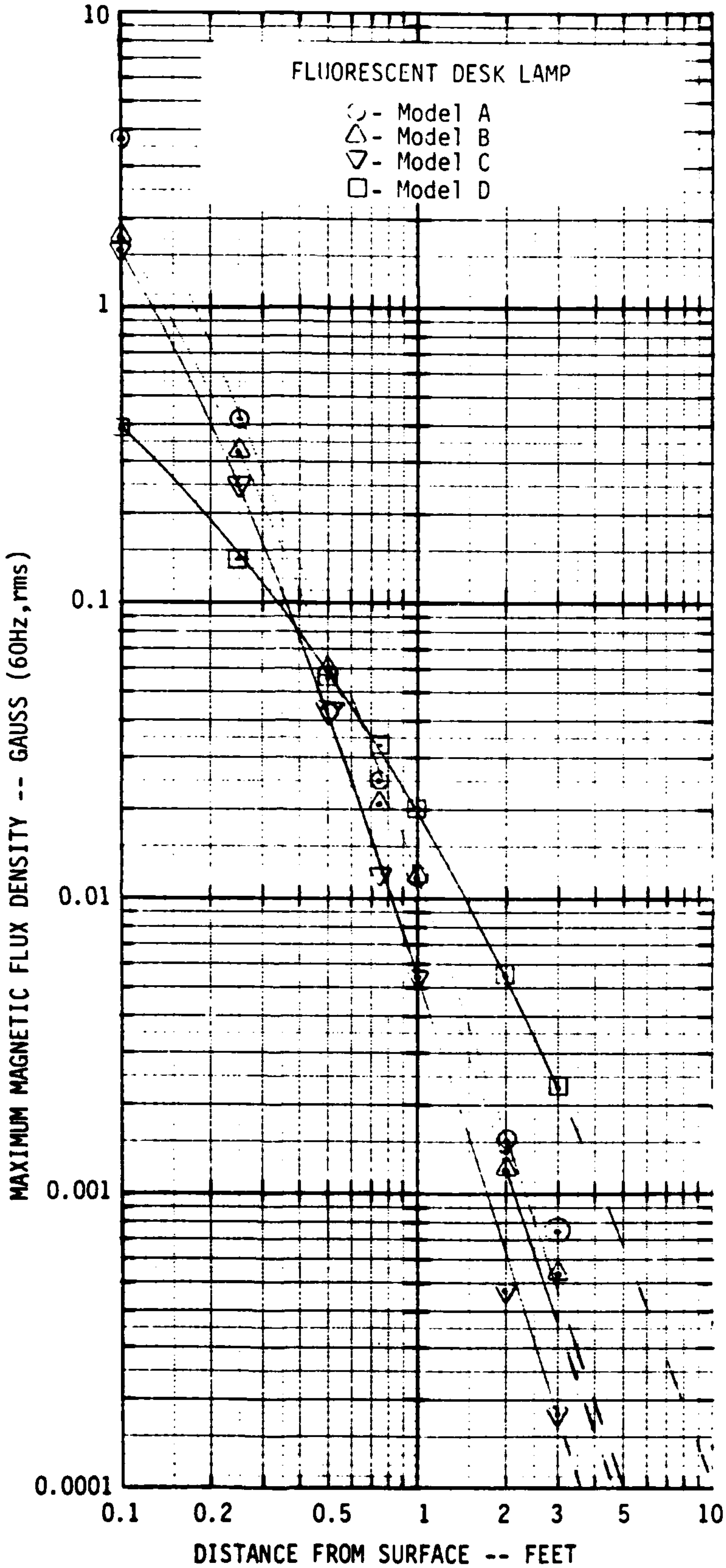

FIGURE 26 Magnetic Flux Density Produced by Fluorescent Desk Lamps

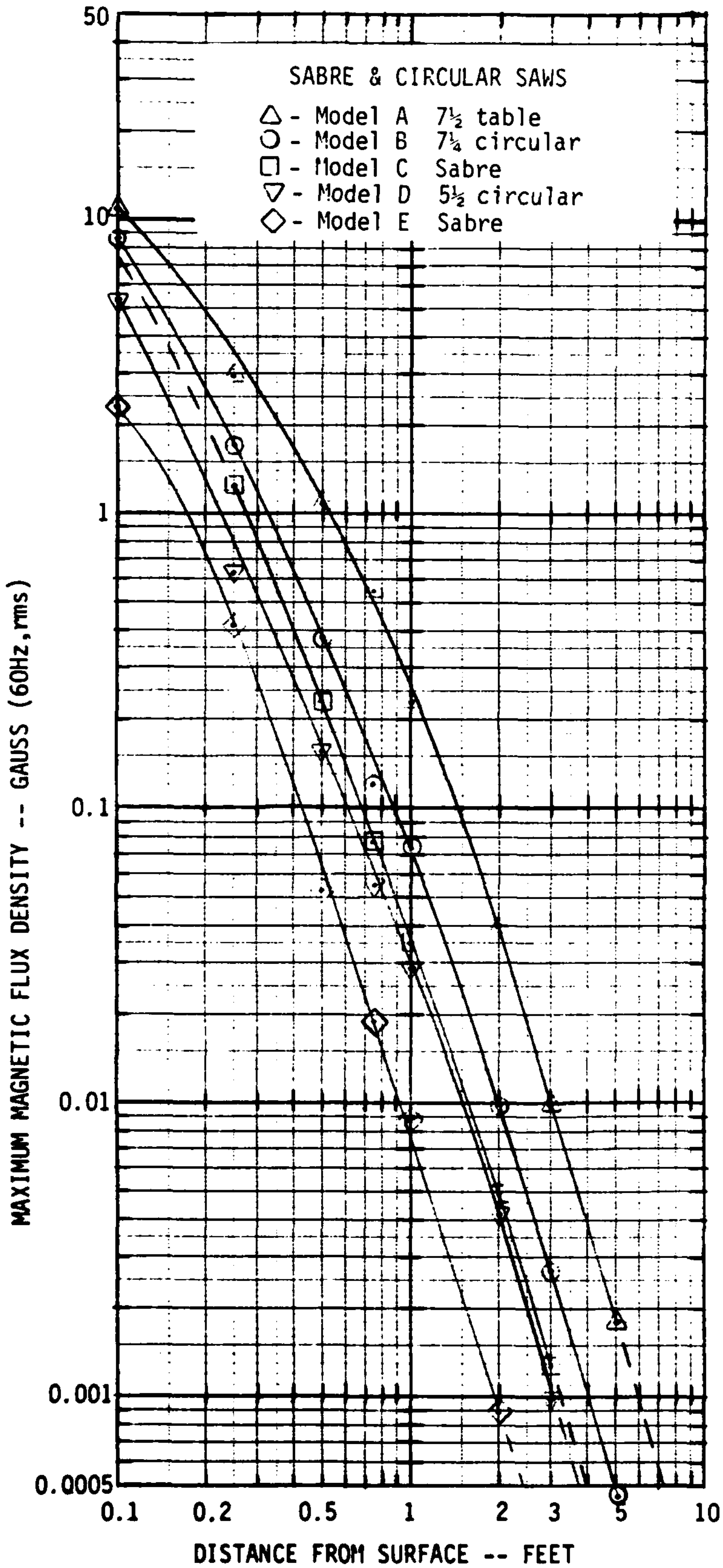

FIGURE 27 Magnetic Flux Density Produced by Saws

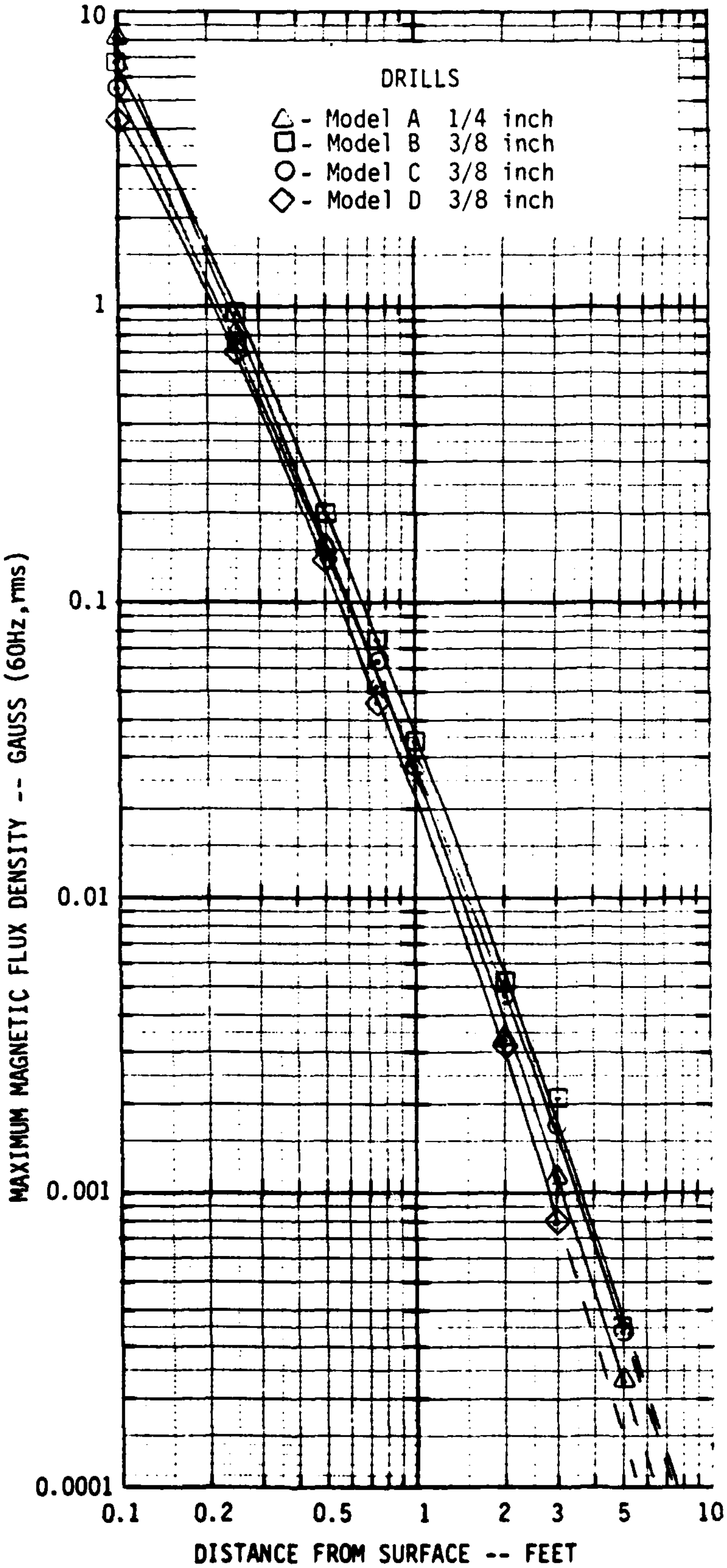

FIGURE 28 Magnetic Flux Density Produced by Drills

elements. Microwave ovens (Figure 6) cook by absorbtion of radio frequency energy rather than by resistive heating. However, these ovens have large power transformers to provide high voltage for their RF sources, and thus generate relatively high 60 Hz magnetic fields to the front, right side, and/or top of the controls area of the ovens.

3.2 Disposals

Garbage disposals employ motors in the 1 horsepower range which are integral parts of the cases (Figure 7). Close in, the maximum flux densities are to the sides of the units. For distances of a few feet, the field magnitudes are relatively constant and independent of direction for a uniform radial separation.

3.3 Dishwashers, Refrigerators, Washers, and Dryers

These large stationary appliances have large fractional horsepower motors that are almost always located at the bottom of the appliance and frequently to the rear. As such, the magnetic fields produced at the surfaces of these devices were lower than might be expected on the basis of motor size alone (Figures 8-11). Magnetic flux densities were generally greatest directly in front of the appliance and near the floor. Both electric and gas clothes dryers were surveyed, as both have motors (Figure 11). Electric dryers were measured with and without heat to ascertain the contribution to the magnetic field of their cyclic operation resistive heating elements. As shown, the heating elements increased the total magnetic field for the two electric dryers by at least 50 percent.

3.4 Coffee Makers, Toasters, Crock Pots, and Irons

These small appliances contain only resistive heating elements, which approximate line or single loop sources of magnetic field. As shown in Figures 12-15 the fields produced by these devices were usually lower and did not project as far as the fields produced by motors or transformers. The magnetic flux densities from these units tended to be greatest to their sides.

3.5 Can Openers, Mixers, and Blenders

Hand-held and tabletop kitchen appliances in these categories have small, fractional horsepower motors that are optimized for high torque (flux, current) and low cost. Such motors have lightweight cases that do little to contain the motors' magnetic flux. Because of this situation, the magnetic fields produced by these appliances are higher than might be expected based on physical size, and can be greater than those produced by much larger appliances and motors. Figures 16-18 illustrate these points. The locations of field maxima varied considerably.

3.6 Vacuum Cleaners

Several upright and shop (canister) vacuum cleaners were measured. As shown in Figure 19, all the examples surveyed had relatively high magnetic field levels that projected a considerable distances. Again, weight and economic restrictions dictate that vacuums employ lightweight motors which do an inherently poor job of containing the motors' magnetic flux. The maximum fields occurred above the uprights and to the sides of the shop vacs.

3.7 Heaters, Fans, and Related Equipment

The heaters, fans, and related appliances that were surveyed all contained bladed or squirrel cage blowers to move air. The heaters were portable units rated from 1300 to 1550 watts of resistive heating. The humidifier and de-humidifier were floor standing units, the latter of which contained a small refrigeration type compressor. Data is given in Figures 20 and 21. The magnetic fields produced by the heaters were dominated by their fan motors. The line of maximum magnetic field for each device was approximately coaxial with its fan motor shaft.

3.8 Shavers and Hair Dryers

Figures 22 and 23 present curves for hair dryers and electric shavers. Hair dryer models A and B were table top units. They had their heating element and blower mounted in their base and used a flexible hose to duct the warm air to a bonnet. These dryers had much higher magnetic fields than the hand-held dryer models C, D, and E. A hair clipper, model A, and three shavers, models B, C, and D also produced relatively high field levels. Shaver model E with "solid state control" had much lower fields, but generated its field at a frequency of 120 Hz instead of 60 Hz.

3.9 Televisions

The data from surveys of several televisions are plotted in Figure 24. The 60 Hz magnetic fields generated by televisions were somewhat difficult to measure, even with a flat response probe and a frequency selective voltmeter, because of high levels of RF noise and other low frequency magnetic fields generated by the vertical and horizontal output transformers and the deflection yoke coils. Both tube type and solid state TVs of various sizes were measured. A predominant factor in the level of 60 Hz magnetic field produced by a set appeared to be whether or not the set employed a power transformer. Sets without a power transformer, such as model E, a line-operated 12 inch black and white tube portable, had almost no magnetic field at 60 Hz but had measurable field levels at about 58 Hz, the vertical sweep frequency. The 60 Hz magnetic fields produced by set A, B, C, and D were maximum off the lower left or right sides.

3.10 Fluorescent Lights

Fluorescent light fixtures and desk lamps are characterized in Figures 25 and 26. Fluorescent lights use a ballast transformer to step up the line voltage; the size of the transformer is directly related to the size and number of tubes in the fixture. From Figure 25 it can be seen that the larger the fixture, and hence ballast, the further the magnetic field of a given level will project in distance. Maximum field levels were obtained directly below the fixtures and in line with the ballast transformers. The field curves for the desk lamps are more tightly grouped as shown in Figure 16. All four desk lamps had dual 15 watt tubes mounted in a reflector head, a flexible gooseneck or mechanical arm, and a base which contained the ballast. Field maximums were located at various positions about the bases.

3.11 Power Tools

Figures 27 and 28 present magnetic field data for several hand drills, sabre saws, circular saws, and one small table saw. The curves for the saws in Figure 27 shows a rough relationship between the magnitude of the field generated and the size/power of the saw. The drills that were measured were all 1/4 or 3/8 inch models and their curves are nearly indistinguishable. Maximum field levels were found to the sides of the drills and sabre saws, and above the motors of the circular saws.

4. CONCLUSIONS

Magnetic field levels as a function of distance for about 100 household appliances have been presented in graphical form. These measurements represent the "worst case" magnetic fields generated by the appliances in any normally accessible direction from them. All sets of measurements but two were made at the fundamental power line frequency of 60 Hz and all represent narrow band rms levels of magnetic flux density expressed in gauss. Measurements at powerline harmonic and other frequencies were not made.

This magnetic field survey is not comprehensive in the sense of including all categories of appliances or all makes and models within a category. Further, rigorous statistical treatment of this data is not appropriate. However, an adequate number of examples per type are provided so that trends in the magnetic field behavior can be established, and that order of magnitude or better values for the maximum magnetic field versus distance can be determined. The data presented herein should be especially useful in understanding the fall off of the magnetic field from an appliance with distance, and the differences in the rate of this fall off between different device types. For appliances of the same type, some idea of the spread of the data between similar devices can also be ascertained.

A qualitative summary of the appliance magnetic field survey is as follows. At a distance of 1 ft, the maximum magnetic field measurements ranged from about 0.3 mG to 270 mG, with 95 percent of the measurements below 100 mG. At a distance of 5 ft, 95 percent of the maximum fields were less than 1 mG, with a high valve of 4.7 mG. The furthest distance at which a 1 mG field was measured was 8.5 ft. Background magnetic flux densities in the homes where appliances were measured were on the order of 0.5 to 1.0 mG.

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