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# THE PERFORMANCE OF INDUCTIVE SHORTWAVE DIATHERMY APPLICATORS

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## Abstract

Test methods were developed for evaluating the heating effectiveness and radiation safety of two different inductive shortwave diathermy applicators. Heating pattern characteristics, absorbed dose rates and leakage were determined.

## Introduction

A recently published survey of radiofrequency (27.12 MHz) applicators indicates that the test methods that have been developed for evaluating the effectiveness and safety of microwave diathermy applicators can be used to evaluate shortwave diathermy applicators (1). The purpose of this paper is to utilize these test methods to evaluate two different inductive shortwave (27.12 MHz) diathermy applicators that are commercially available. A comparison of their heating patterns, absorbed dose rate and leakage radiation is obtained.

## Description of Applicators

In figure 1, the ENRAF Circuplode applicator, 19 cm in diameter, is shown on the left and the Mettler Autotherm applicator, 22 cm in diameter, is shown on the right. The aperture

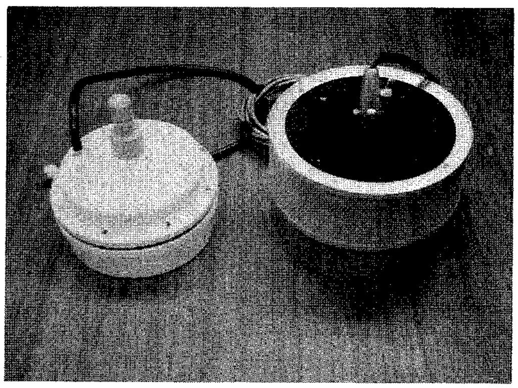

Figure 1. Circuplode and Mettler Applicators

of the Circuplode is covered with a screen of radial conductive strips to prevent the electric field of the applicator from heating fat tissue and to suppress RF leakage. The Mettler applicator includes a 27 MHz generator totally contained in its applicator housing. It is mounted on a support carriage, but for convenience of our testing procedure, an electrical cable extension between the carriage and the applicator housing was connected.

## Experimental Setup

The measurement system for evaluating internal heating patterns was described in detail in a previous publication on microwave diathermy (2). The upper sketch of figure 2 shows the heating of a planar phantom with a shortwave diathermy applicator. The phantom consists of simulated muscle material (3) sandwiched between simulated fat material (4) with a top layer of 2 cm and a bottom layer of 1 cm thickness. The fat material was designed for use at microwave frequencies, but it has a conductivity that falls within the range of tissue dielectric properties at 27.12 MHz (5). The muscle material is similar to the one used in two studies on the heating capability of induction coils (6,7). The temperature depth data obtained in these phantom studies are in agreement with corresponding data obtained in patients (8). The net power at the input of an applicator can only be obtained for the Circuplode since the Mettler applicator-generator interconnection is inaccessible for power monitor connections. After the phantom was heated for 5 minutes with the Circuplode and 6 minutes with the Mettler applicators, the heating patterns were measured as shown in the lower sketch of figure 2. The

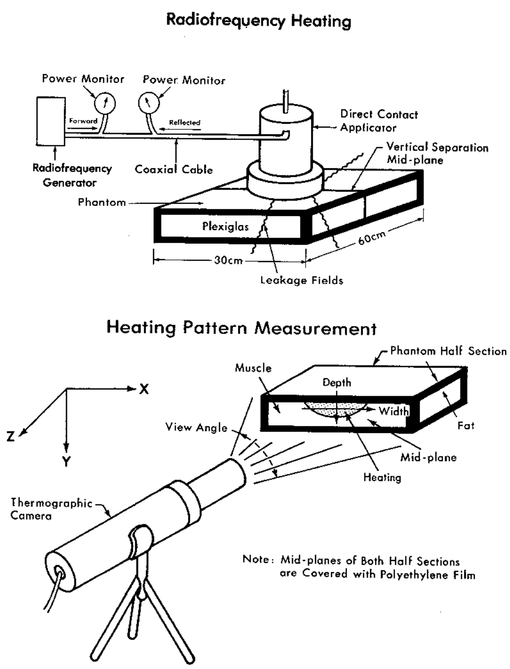


Figure 2. Experimental Setup

thermographic camera data thus obtained is fed into a minicomputer for mapping the temperature distribution (Since the heating patterns, observed after five minutes, contained steep temperature gradients, it is assumed that the thermal diffusion over this time does not significantly change the spatial distribution of the instantaneous heating pattern in the phantom.) To obtain specific absorption rates (SAR) with minimal thermal diffusion errors (9), a nonperturbing Vitek probe is positioned in the midplane and at the maximum temperature region. While the phantom is being heated by an applicator, the change from the original local temperature is determined during the first minute of heating.

## Performance

Initially, only the 2 cm fat layer phantom was used to evaluate the performance of the two applicators. But since the maximum temperature and the temperature half the maximum value occur inside the 2 cm fat layer, the depths of penetration were evaluated in detail with the 1 cm instead of the 2 cm fat layer.

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Figure 3 shows a three-dimensional plot of the heating pattern induced in the midplane of the planar phantom by the Circuplode applicator. Figure 4 is an isocontour representation of a heating pattern of the Mettler applicator describing quantitatively its induced temperature distribution. A temperature profile as a function of depth through the maximum temperature point in the midplane of the planar phantom was also obtained for each applicator. These data were analyzed for the 50% depth values of heating (2).

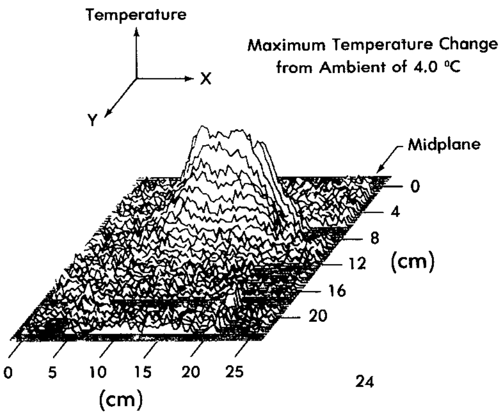


Figure 3. Circuplode Induced Heating Pattern

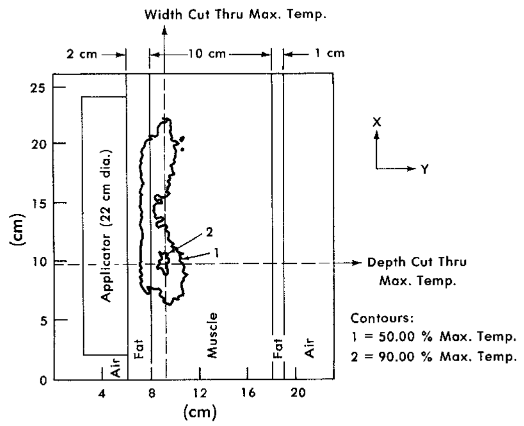


Figure 4. Mettler Induced Isocontours

Table 1 summarizes the performance of the two applicators. Depths of pentration of 2.4 cm from the fat-muscle boundary in the muscle layer were obtained for both applicators. The SAR values for the two applicators cannot be meaningfully compared since the net power at the Mettler applicator input could not be measured as previously discussed. With each applicator on top of the 2 cm fat layer of the phantom, the net power for the Circuplode was set to 100 watts and the power for the Mettler was set for maximum. The associated leakage values of the electric (E) fields and magnetic (H) fields were measured at 15 cm from the phantom-applicator boundary with a Holaday 3002 probe. The E and H fields expressed in an equivalent plane wave power density in $mW/cm^2$ show considerably less leakage for the Circuplode than the Mettler applicator, due to the presence of the metal screen.

Table 1

Performance of Inductive Applicators

| | | Fat Layer (cm) | Mettler | Circuplode |
|---|---|---|---|---|
| Depth of penetration (cm) | | 1 | 2.4* | 2.4* |
| SAR (W/kg) | | 2 | 23.4** | 41.0** |
| with Vitek Probe at: x-axis position (cm) (below fat-muscle boundary) | | | 1.2 | 0 |
| y-axis position (cm) (left from midplane center axis) | | | 3.0 | 1.5 |
| Leakage ($mW/cm^2$) | E | | 2 | 0.3 |
| with Holaday Probe 15 cm from phantom-applicator boundary | H | 2 | 189 | 22 |

* After 5 minute heating

** After 1 minute heating

## Summary

The test methods previously developed for evaluating the heating effectiveness and safety of microwave diathermy were extended to evaluate shortwave diathermy. In this paper two inductive applicators of different design were selected to illustrate the use of the test methods. It is shown that a comparison of heating pattern characteristics, absorbed dose rate, and leakage radiation can quantitatively assess their difference in performance. A measurement program to use these test methods for evaluating hyperthermia applicators operating at radiofrequencies is being developed in our laboratory.

The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

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