Journal of Medical Engineering & Technology, Volume 10, Number 1 (January/February 1986), pages 7–10

Reduction of radiofrequency exposure to the operator during short-wave diathermy treatments

J. Skotte

Danish National Institute of Occupational Health, Baunegaardsvej 73, DK-2900 Hellerup, Denmark

Radiofrequecy electromagnetic fields near short-wave diathermy equipment operating at a frequency of 27·12 MHz can expose the physical therapist to levels above those recommended in standards for radiofrequency exposure in Western countries. Electric and magnetic fields around air-gap, diplode, monode and circuplode applicators were mapped by the author.

Large differences in stray field intensities were found for the various applicators. The air-gap electrodes caused the highest levels of unwanted radiation, and the circuplode caused the lowest levels. The use of the circuplode would normally ensure an operator exposure far below the levels in recommended standards. In order to reduce the exposure during the first few minutes of a treatment, when air-gap electrodes or diplode are used, the operator should stand at the end of the diathermy console opposite to the applicator and cables and not, as is often the case, at one side. It is recommended that manufacturers change the design of the diathermy console (a minor modification) in order to ensure this operating position.

KEYWORDS: SHORT WAVE DIATHERMY, RADIOFREQUENCY RADIATION, REDUCTION OF EXPOSURE.

Introduction

Short wave diathermy is used in medical therapy to produce local heating in tissue through the conversion of electromagnetic energy into thermal energy. The frequency used is almost exclusively 27·12 MHz, which is one of the frequencies allocated for industrial, scientific and medical purposes. The electromagnetic energy is coupled to the body by a capacitive-type applicator or an inductive-type applicator. Most applicators are connected to a generator by unshielded leads, which are approximately 1 m in length.

An example of a capacitive applicator is the air-gap electrode (figure 1). The diplode, monode and circuplode are inductive-type applicators, where the electromagnetic field is generated by a coil. The diplode is flexible and connected to the generator by two unshielded (remote) leads like the air-gap electrodes. The monode is an inductive applicator, having a smaller coil than the diplode, but connected to the generator by an unshielded parallel wire cable. The circuplode can be considered as a shielded version of the monode. It is equipped with a screen to reduce E-field radiation and , unlike other types of applicators, is fed by a coaxial cable. The high frequency ouput power of the generator is 100–500 W. Not all of the electromagnetic energy is confined to the treatment area—to some extent it is radiated to the surroundings. This stray radiation can expose the physical therapist and others standing near to the diathermy device. Several surveys [1, 2 and 3] have shown that the intensities of the fields to which operators are exposed frequently exceed recommended standards for radiofrequency exposure of personnel. The circuplode applicator appears to operate with reduced radiated fields [4].

Radiofrequency protection guides used in most Western countries recommend a maximum electric (E) field strength in the range 60–300 V/m, and a maximum magnetic (H) field strength in the range 0·16–0·8 A/m. These field strengths correspond to plane-wave equivalent power densities of 1–25 mW/cm^2 (10–250 W/m^2).

Unnecessary exposure to radiation should always be avoided. It is therefore desirable to reduce radiation as

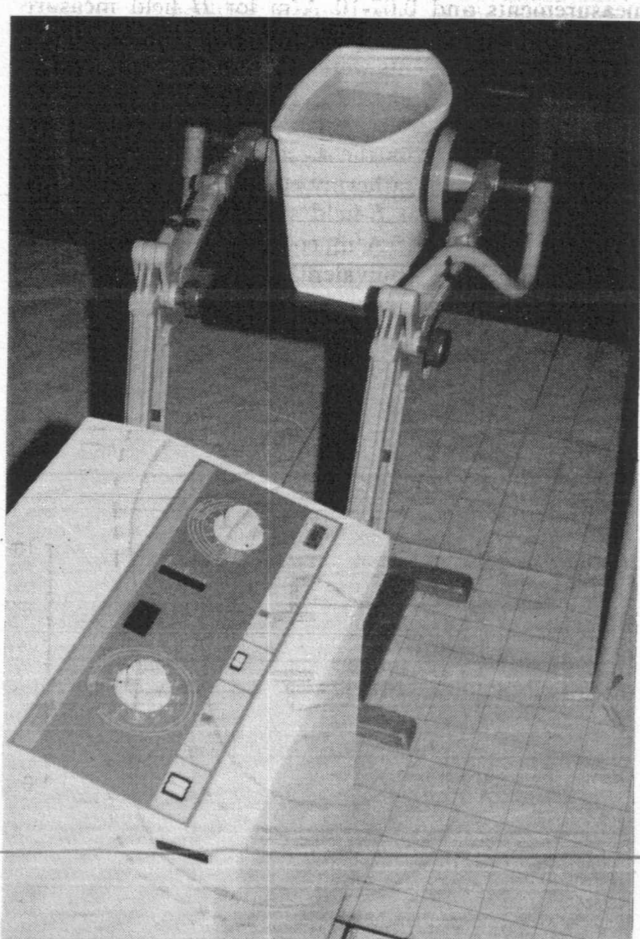

Figure 1. Air-gap electrodes (13 cm in diameter) 25 cm apart. The plastic container holds 15 l of saline solution (0·9%).

much as possible, whether it involves a risk of biological effects or not. In addition, short-wave diathermy is often a source of electromagnetic interference.

This paper reports on comparative measurements of field intensities around short-wave diathermy devices for various applicators, with special reference to the reduction of unnecessary operator exposure. The results show that it is possible to substantially reduce the operator's exposure to radiation.

Measurements

E-field and *H*-field intensities around four types of applicators were measured: these were the air-gap electrode, diplode, monode and circuplode.

During all measurements the intensity control of the generator (Enraf Nonius/Curapuls 419) was adjusted to position 5; the generator was operating in continuous mode. Measurements were done with both unloaded and loaded applicators. The load was 15 l saline solution (0·9%) in a plastic container (figure 1), simulating the load of the applicator during the treatment of a patient.

The measurements were made with broad-band *E*-field and *H*-field probes and a metering instrument supplied by Holaday Industries (Model HI–3002). The dynamic range of this instrument is 20–3000 V/m for *E*-field measurements and 0.07-10 A/m for *H* field measurements. The measurement accuracy is estimated to ± 20%. All measurements were made at a distance of 5 cm or more from any object.

For all the applicators the *E*- and *H*-field probes were moved around the diathermy equipment in such a way that contour lines for *E*-field strength at 60 V/m, and *H*-field strength at 0·16 A/m, could be determined. These field strengths are equivalent to a plane-wave power

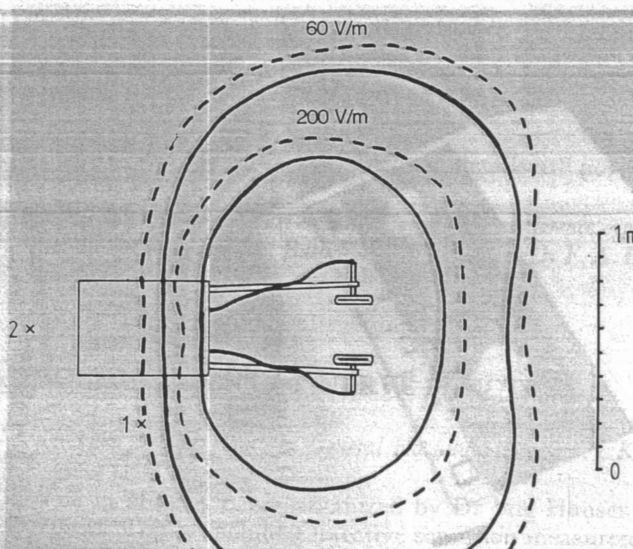

Figure 2. Contours of electric field strength around air-gap electrodes. Loaded (—) and unloaded (- - -) measurements.

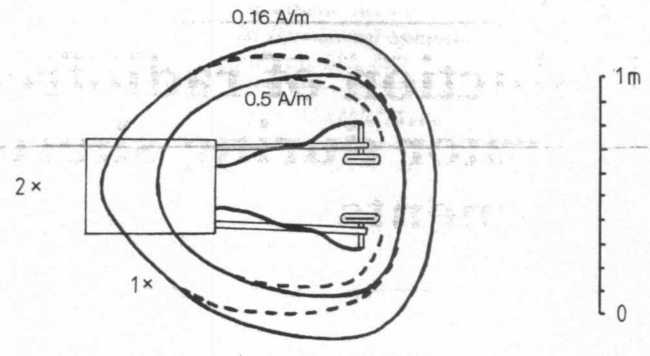

Figure 3. Contours of magnetic field strength around air-gap electrodes. Loaded (—) and unloaded (- - -) measurements.

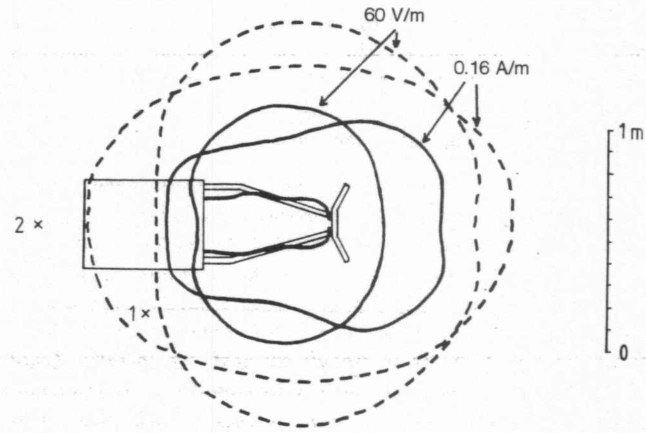

Figure 4. Contours of electric and magnetic field strength around diplode. Loaded (—) and unloaded (- - -) measurements.

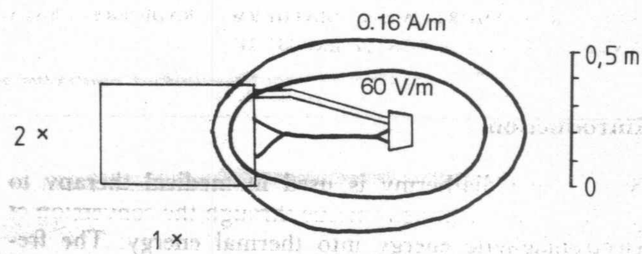

Figure 5. Contours of electric and magnetic field strength around loaded monode. The load caused no significant change in contours compared to unloaded measurements.

density of 10 W/m². Additionally, the contours for 200 V/m and 0·5 A/m, which are equivalent to a plane-wave power density of 100 W/m², were determined for air-gap electrodes. The measurement height ranged from 0·6 to 1·2 m, corresponding to the height where the maximum field strengths were found. Furthermore, measurements were done at two fixed positions at a distance of 0·2 m in front of the diathermy console and at the end of the diathermy console (position 1 and 2 in figures 2 to 6). The operator's position during the first few minutes of a typical diathermy treatment is normally position 1. Finally, the *E*-field strength was measured as a function of distance near unloaded air-gap electrodes. A Siemens Ultratherm 608 generator was used instead of the Enraf Nonius generator to include another generator in general use in the measurement programme. The field strengths near air-gap electrodes are similar for both generators.

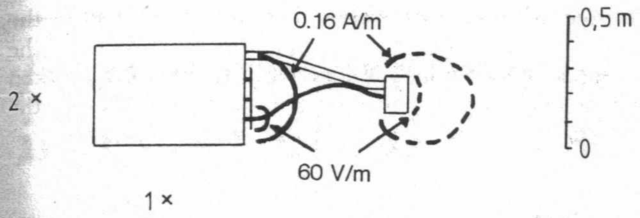

Figure 6. Contours of electric and magnetic field strength around circuplode. Loaded (—) and unloaded (- - -) measurements. Around the connector of the cable the load caused no significant change in contours compared to unloaded measurements.

Results

Contours of electric and magnetic field strength around the diathermy devices are shown in figures 2–6. Field strengths at positions 1 and 2 measured 0·5 m, 1·0 m and 1·5 m above the floor are shown in tables 1 and 2. The *E*-field strength as a function of distance near air-gap electrodes is plotted in figure 8.

Discussion

To facilitate the comparison of the stray radiation for the various applicators, the *E*-field and/or *H*-field contours from figures 2–6 are plotted in figure 7. The contours in figure 7 represent positions where the *E*-field or the *H*-field strengths are equivalent to a plane-wave power density of 10 W/m^2.

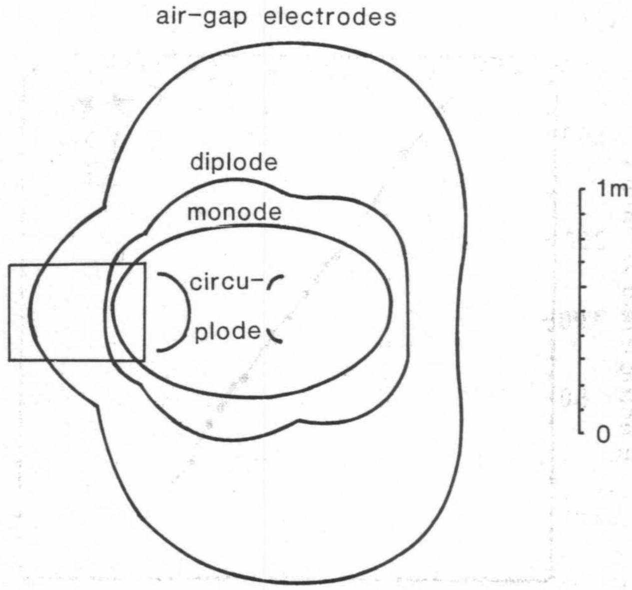

Figure 7. A comparison of contours in figures 2–6 representing positions, where the electric field or the magnetic field strength are equivalent to a plane-wave power density of 10 W/m^2. Loaded meaurements. Only a part of the 10 W/m^2 contour line is shown close to the circuplode since no measurements were made closer than 5 cm from any object (applicator, load etc).

Large differences in stray fields were found. Field strengths are neglible around most of the circuplode's cable—the cable's connector, however, is a source of a

Table 1. Measured electric and magnetic field strengths at positions 1 and 2 by unloaded electrodes.

Position	Height (m)	Air-gap		Diplode		Monode		Circuplode	
		E (V/m)	*H* (A/m)	*E* (V/m)	*H* (A/m)	*E* (V/m)	*H* (A/m)	*E* (V/m)	*H* (A/m)
1a	0·5	30	0·14	30	0·16	—	—	—	—
1b	1·0	80	0·10	40	0·22	—	—	—	—
1c	1·5	55	0·07	20	0·14	—	—	—	—
2a	0·5	—	—	20	—	—	—	—	—
2b	1·0	—	0·07	—	0·10	—	—	—	—
2c	1·5	—	—	—	0·07	—	—	—	—

— = values less than 20 V/m or 0·07 A/m.

Table 2. Measured electric and magnetic field strengths at positions 1 and 2 by loaded electrodes.

Position	Height (m)	Air-gap		Diplode		Monode		Circuplode	
		E (V/m)	*H* (A/m)	*E* (V/m)	*H* (A/m)	*E* (V/m)	*H* (A/m)	*E* (V/m)	*H* (A/m)
1a	0·5	25	0·16	—	—	—	—	—	—
1b	1·0	55	0·19	—	0·07	—	0·07	—	—
1c	1·5	40	0·10	—	—	—	—	—	—
2a	0·5	—	—	—	—	—	—	—	—
2b	1·0	—	0·07	—	—	—	—	—	—
2c	1·5	—	—	—	—	—	—	—	—

— = values less than 20 V/m or 0·07 A/m.

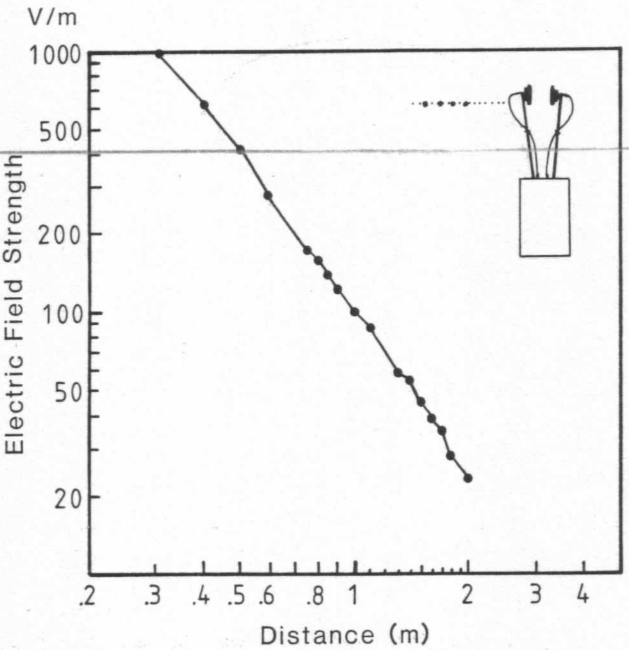

Figure 8. The electric field strength as a function of distance in a horizontal plane. The distance to the left cable of the air-gap electrode ranges from 0·3 m to 2·0 m. Unloaded measurements. Generator Siemens/Ultratherm 608, intensity control in position 4.

small amount of radiation. This leakage could probably be further reduced by changing the connector's design [5].

The measured field strengths at position 1 are higher than the field strengths at position 2. This can also be seen from the *E*- and *H*-field contours in figures 2 to 6. The equivalent power density was normally below 2 W/m^2 at (and around) position 2. The highest value measured at position 1 was 16 W/m^2 (air-gap electrode) and 0·2 m closer to the cable of the electrodes, 100–200 W/m^2 could be measured. It is thus obvious that the operator should *not* stand at position 1, which he normally does at the beginning of the treatment. Rather he should move to position 2, which is behind the end of the diathermy console. Manufacturers should change the layout of the console so that the natural operating position for the therapist is position 2. Figure 8 illustrates the marked dependence of the field strength on the distance to the source.

Conclusion

Large differences exist in the unwanted radiation from electrodes and cables for various short-wave diathermy applicators. Air-gap electrodes cause the highest level of stray fields and the circuplode causes the lowest level. The use of the circuplode would normally ensure an operator exposure far below the guidelines used in Western countries. The distance to the applicator and cables is significant in terms of exposure. It is recommended that the short-wave diathermy equipment manufacturers change the design of the console in order to ensure that the operator would normally stand at the end of the console opposite to the applicator and cables. The modification required would be simple. In this way the exposure of the operator's body could be reduced to levels below current Western standards even when using air-gap electrodes.

References

1. Mild, K. H. (1980) Occupational exposure to radiofrequency electromagnetic fields. *Proceedings of the IEEE*, **68**, 1, pp. 12–17.
2. Ruggera, P. S. (1980) *Measurement of Emission Levels During Microwave and Shortwave Diathermy Treatments* (US Department of Health and Human Services, HHS Publication [FDA]), 80–8119.
3. Stuchly, M. A., Repacholi, M. H., Lecuyer, D. W. and Mann R. D. (1982) Exposure to the operator and patient during short wave diathermy treatments. *Health Physics*, **42**, 3, pp. 341–366.
4. *Health Devices* (June 1979) Short wave diathermy units, pp. 175–192.
5. Poulsson, L. E. and Kristiansson, I. (1981) *Kortvågsdiatermiapparat med skärmad induktiv applikator* (Arbetsdokument a 81–24, Statens Strålskydds-institut, Sverige).