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DOMETIC CORPORATION  
LA GRANGE, INDIANA**

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## **SUMMARY**

In July 1991, the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation at the Dometic Corporation in LaGrange, Indiana. The evaluation was made in response to a request from the United Automobile, Aerospace, Agricultural Implement Workers of America (UAW) Local 871 to evaluate occupational radiofrequency (RF) radiation exposure during the use of seven heat sealers at this facility. The requestors were concerned because three women working in the area of concern had experienced miscarriages.

Electric and magnetic field strengths and induced body current levels were measured during routine use of the heat sealers. Interviews were conducted with the three women who had experienced a pregnancy loss, and with 21 (81%) of current heat sealer operators from the first and second shifts.

None of the electric and magnetic field strength measurements made with the workers standing at typical work locations exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs). However, two of the six units measured resulted in electric field exposures of 6000 and 9000 volts squared per meter squared ( $V/m^2$ ), exceeding the American Conference of Governmental Industrial Hygienists (ACGIH) and American National Standards Institute (ANSI) recommended levels of 4613 and 4610 ( $V/m^2$ ), respectively. Much higher RF exposures were documented behind the heat sealers. While this is not considered a typical work area, these measurements indicate that maintenance personnel working behind the units can receive exposure to RF radiation exceeding the applicable evaluation criteria when the heat sealers are in operation.

Induced body current levels measured near one of the RF sealer units ranged from 1100 to 1600 milliamperes (mA) with the worker standing on the floor, and from 120 to 133 mA with the worker standing on a wooden pallet. These results document the importance of interrupting the worker-to-surface ground in reducing body current levels. ANSI recommends that body current levels do not exceed 200 mA through both feet.

Physician-diagnosed medical conditions other than RF radiation exposure were present in two of the three reported cases of pregnancy loss. No cause was identified in the remaining case, and no additional adverse pregnancy outcomes were reported by other female employees who were interviewed. Two workers reported more frequent headaches while at work, and two others reported an increase in abdominal cramping associated with menses since beginning work. No other changes in health status since beginning work at Dometic Corporation were reported by the interviewed employees.

The RF measurements made during this evaluation indicate that a potential hazard existed from exposure to electric fields produced during the routine use of two heat sealer units. In addition, body current levels exceeding the ANSI recommendations were measured when a worker stood directly on the floor surface but not when the worker stood on a wooden pallet (which interrupted the worker-to-surface ground). Recommendations for reducing RF exposures and induced body current levels are made in the report.

**KEYWORDS:** SIC 3089 (plastic products, not elsewhere classified), RF radiation, heat sealer, body current, miscarriage.

## **INTRODUCTION**

In September 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the United Automobile, Aerospace, Agricultural Implement Workers of America (UAW) Local 871. NIOSH was asked to evaluate potential occupational exposures to radiofrequency (RF) radiation during the use of RF heat sealers at Dometic Corporation in LaGrange, Indiana. The request stated that three women who work in the area of concern had "miscarriages" during a two-week period in August-September 1990.

A site visit was initially scheduled in January 1991, but due to a plant layoff, was postponed until operations were back to full capacity. On July 15-16, 1991, NIOSH investigators conducted an environmental and medical evaluation at this facility. Preliminary recommendations were presented at the closing meeting and in subsequent phone conversations.

## **BACKGROUND**

Dometic Corporation assembles vinyl awnings for mobile home and recreational vehicles. During the assembly process RF heat sealers are used to seal vinyl sections together to form the awnings. The seven RF heat sealers are of conventional design, having an approximately four-foot welding head. The heat sealers, manufactured by either Solidyne or Thermax, operate at a reported frequency of 27 megahertz (MHz) and 10 to 20 kilowatts (kW) of power. These heat sealers are used on two shifts by about 30 workers. All but one heat sealer requires two workers to operate; the other unit requires only one operator.

## **EVALUATION DESIGN AND METHODS**

### *Environmental Evaluation*

The RF measurements were made with a Holaday Model 3002 survey meter using two probes, a Model STE-02 probe for the electric (E) field, and a Model STH-02 probe for the magnetic (H) field. The E-field probe is designed for the frequency range of 0.5 to 6000 MHz and measures the electric field strength in units of volts squared per meter squared ( $V/m^2$ ). The H-field probe is designed for the frequency range of 5 to 300 MHz and measures the magnetic field strength in units of amperes squared per meter squared ( $A/m^2$ ).

Body currents resulting from occupational exposure to electric fields were evaluated using a body current detector system.<sup>1</sup> This system is based on the principle that when RF energy is absorbed, electrical currents are induced within the body. These body currents can be measured by using a foot current sensor designed to respond only to currents induced by external electric fields. The body currents were measured by having the worker stand on a 6-millimeter (mm)-thick, 32 X 32-centimeter (cm) polyethylene sheet clad on both sides with copper. The current from the upper plate, where the worker stands, passes to the lower copper plate, which is in contact with the floor surface through a non-inductive carbon resistor located in the center of the bi-layer sensor. The RF current across the resistor is measured with a calibrated RF milliammeter. All current measurements were made with the worker standing on the sensor, in front of the heat sealer with his/her shoes on. A

"background" measurement was made without the worker on the sensor in order to eliminate spurious readings that could occur from sources of electromagnetic radiation interference.

The frequency of the heat sealer was measured using a Continental Specialties Corporation Mini-max Model MM50 battery-powered frequency counter.

Radiofrequency measurements were taken at selected anatomical locations, at distances where the workers stood in performing their tasks. Body current levels were measured at the site where the operator worked.

Since the RF output of the heat sealer was not continuous (operations were performed for short periods of time over the course of the work day), all E and H field measurements were corrected for the work cycle duration before comparison with applicable occupational exposure criteria. This was accomplished by multiplying the measured duty cycle factor by the recorded RF exposure level. The duty cycle is defined as the total length of RF on-time (in seconds) measured during any six minute sampling period. The duty cycle is expressed as a fraction, and for this evaluation was found to be about 0.1. Body current values do not need to be corrected for the duty cycle.

#### *Medical Evaluation*

The medical evaluation included interviews with the three women who had experienced a pregnancy loss, interviews with all first-and second-shift heat sealer operators who agreed to participate, and a review of the Occupational Safety and Health Administration (OSHA) 200 Logs. The interviewer briefly reviewed the health effects that have been associated with RF radiation exposure and then asked the employee if he/she had experienced any changes in his/her health status since beginning work at Dometic Corporation. Women were asked about pregnancy outcomes since beginning work at Dometic Corporation.

## **EVALUATION CRITERIA**

#### *Health Effects of Exposure to Radiofrequency Radiation*

Human and animal studies indicate that overexposure to RF radiation may cause harmful biological effects due to excessive heating of internal tissues. The effects include changes in the eye, central nervous system, conditioned reflex behavior, chemical composition of the blood, immune system, reproductive system, and endocrine (hormone) system.<sup>2</sup> Because the body's surface heat sensors, located in the skin, are not activated when RF energy is absorbed deep within body tissues, workers may be unaware that they are absorbing RF energy.

Absorption of RF energy may also result in "non-thermal" effects on cells or tissues, which occur without a measurable increase in tissue or body temperature. Such effects are reported to occur from exposure to RF energy at levels lower than those sufficient to cause thermal effects.<sup>2</sup>

There is general agreement that the incidence and severity of RF biological effects are related to the magnitude of radiation power absorbed by the body. This absorption depends strongly upon the frequency and intensity of the radiation, the size and shape of the exposed worker, and the worker's orientation in the radiation field. The human body absorbs

maximally in the frequency range of 30 to 300 Megahertz (MHz).<sup>3</sup> Outside this range, much less energy is absorbed by the body from the field.

Studies of the effects of RF radiation on reproductive function in rats and mice have reported decreased testicular weight,<sup>4,5</sup> reductions in sperm count, and changes in shape.<sup>6,7</sup> These effects are generally attributed to excessive heating of the testicles. One human study suggested that long-term RF radiation exposure may decrease sperm production and motility.<sup>8</sup>

Limited information is available about the potential effects of RF radiation on human female reproductive function. A study of Czechoslovakian female RF workers found changes in menstrual patterns, retarded fetal development, birth defects, decreased lactation in nursing mothers, and an increase in the number of miscarriages.<sup>9,10</sup>

Results of human observational studies of RF-exposed workers must be interpreted with caution because of design limitations such as small sample sizes and inadequate documentation of RF exposure among workers.<sup>11,12</sup> In general, human studies have not conclusively associated low-level RF radiation with adverse health outcomes, nor have they ruled out that potential adverse health effects may exist.<sup>11,13,14</sup> Current scientific literature indicates that heating of the uterus to greater than 39°C is likely to effect the human embryo.<sup>15,16,17</sup> RF exposures would have to be substantially in excess of the ANSI standard to create core body temperatures greater than 39°C (102.2°F).<sup>13</sup>

ORGANIZATI ON	$E^2$ (V/m) <sup>2</sup>	$H^2$ (A/m)
OSHA	40,000	0.25
ACGIH	4613	0.032
ANSI	4610	0.36

*Occupational Exposure Limits*

Table 1 shows the occupational exposure limits for radiofrequency radiation at 27.12 MHz electric and magnetic fields permitted by the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and the American National Standards Institute (ANSI).<sup>3,18,19</sup> Exposures for these standards are averaged over a 0.1 hour period. There are presently no NIOSH recommended exposure limits for RF radiation.

In addition to electric and magnetic field exposure limits, the ANSI C95.1 - 1991 Committee has recently adopted a body current limit of 200 milliamperes (mA) through both feet to prevent shocks and burns.<sup>3</sup> This value of 200 mA limits the partial body specific absorbed rate (SAR) to levels less than 20 watts per kilogram (W/kg) in the extremities. The SAR reflects the amount of energy absorbed in one kg of tissue.

Table 2  
Electric and Magnetic Field Strengths  
at Various Body Positions (a,b,c)  
July 15-16, 1991

RF Sealer No.	Eye		Waist		Knee		Frequency (MHz)(f)
	E <sup>2</sup> (d)	H <sup>2</sup> (e)	E <sup>2</sup>	H <sup>2</sup>	E <sup>2</sup>	H <sup>2</sup>	
Unit 1	3500	0.01	2500	0.015	1800	0.017	27.36
Unit 2	1000	0.001	1000	0.002	1000	0.005	26.90
Unit 3	No Available operator at time of measurement						
Unit 4	3500	0.005	2500	0.005	1500	0.006	27.02
Unit 5	120	0.0005	60	0.0007	180	0.0007	27.12
Unit 6	6000	0.011	1500	0.025	1200	0.028	27.09
Unit 7	9000	0.020	2500	0.030	2000	0.030	27.17

**Evaluation Criteria:**  
 (OSHA) E<sup>2</sup> = 40,000 (V/m)<sup>2</sup>  
 H<sup>2</sup> = 0.25 (A/m)<sup>2</sup>  
 (ACGIH) E<sup>2</sup> = 4613 (V/m)<sup>2</sup>  
 H<sup>2</sup> = 0.032 (A/m)<sup>2</sup>  
 (ANSI) E<sup>2</sup> = 4610 (V/m)<sup>2</sup>  
 H<sup>2</sup> = 0.36 (A/m)<sup>2</sup>

a. Maximum reading from two trials at each location.  
 b. Measurements were corrected based on duty cycle factor of 0.1.  
 c. Measurements were made in front of heat sealer with worker positioned on the right side.  
 d. In units of volts squared per meter squared (V/m)<sup>2</sup>.  
 e. In units of amps squared per meter squared (A/m)<sup>2</sup>.  
 f. Frequency of units measured in megahertz (MHz).

As shown in Table 2, none of the measurements exceeded the OSHA Permissible Exposure Limits (PELs) for E and H fields; however, measurements made on Units 6 and 7 exceeded the ACGIH Threshold Limit Value (TLV) of 4613 (V/m)<sup>2</sup> and ANSI recommended limit of 4610 (V/m)<sup>2</sup> for the E field at eye height, and were near the TLV of 0.032 (A/m)<sup>2</sup> for the H field at waist and knee height. The operating frequencies of the heat sealers as measured by a frequency counter are also shown in Table 2. The measured values are all very close to the design frequency of 27 MHz.

Although the areas behind the heat sealers are not typical work locations, these areas represent a potential hazard for maintenance workers. As shown in Table 3, the E<sup>2</sup> values for radiofrequency measurements made in back of the heat sealers ranged from 300 to 27,000 (V/m)<sup>2</sup>. Measurements taken behind all but two of the units (5 and 7) exceeded the ACGIH TLV and ANSI standard; none of the E<sup>2</sup> measurements exceeded the OSHA PEL. Magnetic field strengths ranged from 0.02 to 5.0

## RESULTS

### RF Measurements

The electric and magnetic field strength measurements made at different body locations during the operation of six of seven heat sealers are shown in Table 2. The values listed in the table have been corrected by the appropriate duty cycle factor to enable direct comparison with the occupational exposure criteria. Measurements were not obtained on Unit 3 as there was no operator available at the time of measurement.

Table 3  
Electric and Magnetic Field Strengths  
Behind RF Heat Sealers(a)  
July 15-16, 1992

RF Sealer No.	Right Side(b)		Left
	E <sup>2</sup> (c)	H <sup>2</sup> (d)	E <sup>2</sup>
Unit 1	22,000	0.035	10,000
Unit 2	10,000	0.02	7,000
Unit 3	4,000	0.30	10,000
Unit 4	5,000	0.60	4,000
Unit 5	1,500	0.06	300
Unit 6	27,000	0.025	25,000
Unit 7	3,000	0.035	3,500

**Evaluation Criteria:**  
 (OSHA) E<sup>2</sup> = 40,000 (V/m)<sup>2</sup>  
 H<sup>2</sup> = 0.25 (A/m)<sup>2</sup>  
 (ACGIH) E<sup>2</sup> = 4,613 (V/m)<sup>2</sup>  
 H<sup>2</sup> = 0.032 (A/m)<sup>2</sup>  
 (ANSI) E<sup>2</sup> = 4,610 (V/m)<sup>2</sup>  
 H<sup>2</sup> = 0.36 (A/m)<sup>2</sup>

a. Measurements were corrected based on duty cycle factor of 0.1.  
 b. Measurements were made behind RF Heat Sealers facing unit back.  
 c. In units of volts squared per meter squared

Table 4  
Induced Body Current Levels  
With and Without Operator  
Using a Platform(a)  
July 15-16, 1992

Trial No.	Induced body current (mA)(b)	
	Operator Standing on Floor	Operator Standing on Wooden Platform
1	1600	120
2	1200	133
3	1300	130
4	1100	128
Avg:	1300	128

Average Reduction Factor = 10 (for use with wooden platform)

**Evaluation Criteria:**  
(ANSI) = 200 mA

a. Body current levels measured at Unit 4.  
b. In units of milliamperes (mA).

(A/m)<sup>2</sup>. Measurements made behind all units had H<sup>2</sup> values exceeding the ACGIH TLV, and H<sup>2</sup> values behind units 1,3,4, and 6 exceeded the OSHA PEL.

Table 4 lists the results of the body current measurements made near heat sealer Unit 4. The body current levels ranged from 1100 to 1600 mA, all of which exceeded the ANSI criteria of 200 mA. When workers stood on a wooden platform (pallet), the induced body current levels were markedly reduced, ranging from 120 to 133 mA. This documents the importance of interrupting the ground between the worker and the floor surface. The use of the platform reduced the body current levels by a factor of approximately 10. It should be noted that the pallet was readily available at the plant and contained nails. No attempt was made to optimize the interruption of the ground between the worker and the floor surface, but further reductions in body current levels could be achieved with the use of other

devices specifically designed for this purpose (i.e., ones which do not contain nails).

### Medical Interviews

Personal interviews with the three women who had experienced a pregnancy loss revealed that potential causes other than RF radiation exposure had been identified by their physician in two cases.

Seventeen of the 21 (81%) first- and second-shift heat sealer operators who were present agreed to be interviewed. Ten females and 7 males participated. Ages ranged from 18 to 49 years, with an average age of 31 years for the 15 workers for whom age was recorded. Duration of employment as an operator ranged from one to 13 months. Operators reported being trained by group leaders or by experienced machine operators. They reported that no formal health and safety education regarding RF heat sealers was offered to new employees.

No additional adverse pregnancy outcomes (beyond the three already discussed) were reported by the female employees. Two heat sealer operators reported more frequent headaches while at work than while at home, and two operators reported an increase in abdominal cramping associated with menses since beginning work. No other changes in health status since beginning work at Dometic Corporation were reported.

## DISCUSSION

The RF measurements made in typical work locations (in front of the RF heat sealers) indicated that electric field exposures exceeded those recommended by the ACGIH for operators of Units 6 and 7. These values did not, however, exceed the OSHA PELs for electric or magnetic fields, which are considerably higher, approximately eight times above

the TLVs. RF field strengths behind the sealer units were much higher exposures than those measured in front of the units. These values emphasize the need to limit access to these areas when the heat sealers are in operation. The body current measurements made near Unit 4 indicate the need to interrupt the ground between the worker and the floor surface to reduce body current levels and the resulting SAR to below the ANSI criteria.

Physician-diagnosed medical conditions other than RF radiation exposure were present in two of the three reported cases of pregnancy loss. No cause was identified in the remaining case. Estimates of miscarriage rates in the general population vary from 10-25%, depending upon the ascertainment method used and how early the pregnancies are documented.<sup>20,21</sup> It is not known what causes most miscarriages. Many factors have been implicated (chromosomal abnormalities, chemical exposures, lifestyle habits, etc.), but in most instances, a specific cause or combination of causes of a miscarriage cannot be identified.

While scientists are not in complete agreement on the interpretation of available data on biological effects of RF radiation, NIOSH believes that there is sufficient evidence of such effects to cause concern about human exposures.<sup>2</sup> Precautionary measures such as those listed below are recommended to further reduce worker exposures to E and H fields and body currents induced by the heat sealers. The joint NIOSH/OSHA Current Intelligence Bulletin entitled Radiofrequency (RF) Sealers and Heaters: Potential Health Hazards and their Prevention contains more detailed information on health issues associated with heat sealers and methods to reduce worker RF exposures.<sup>2</sup> Additional information on the use of shielding to reduce operator exposure to RF radiation was recently published<sup>22</sup> and can be consulted for further information.

## RECOMMENDATIONS

Since the initial NIOSH investigation, a number of changes have been made in response to our preliminary recommendations, as well as those of an outside consultant. The changes that were reported include the periodic evaluation of RF levels; the logging of operators and positions used; the institution of a formalized training program for operators, including the need to keep hands and arms away from the units during the "on" cycle and to stand in prescribed locations during operation of the sealers; the posting of operator instructions; and the use of platforms to interrupt the worker-to-surface electrical ground.

1. The following methods should be considered to further reduce operator exposure to RF radiation produced by the heaters:
  - a. move the activating buttons further away from the table, thereby increasing the worker-unit distance;
  - b. improve the shielding of the units (See reference 22);
  - c. where there are two heat sealers close together, separate them;
  - d. provide training programs for all new heat sealer operators on the health and safety aspects of working in close proximity of heat sealers.
2. No worker should be permitted to stand behind any operating heat sealer. The RF fields can be very high, and the risk of electrical shock is increased.

3. The heat-sealing area should be appropriately posted to identify the presence of RF energy.
4. There are some locations in the facility where non-heat sealing personnel are close to heat sealers (sewing and fabric personnel, for example). Exposures at these locations should be further studied by management, and workers should be informed as to the possible hazards to which they are exposed. Overexposures, of course, should be eliminated.
5. RF and body current measurements should be made during the use of the new RF heat sealing unit and all other units whenever changes in work practices or operations are made which may affect worker exposures.

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