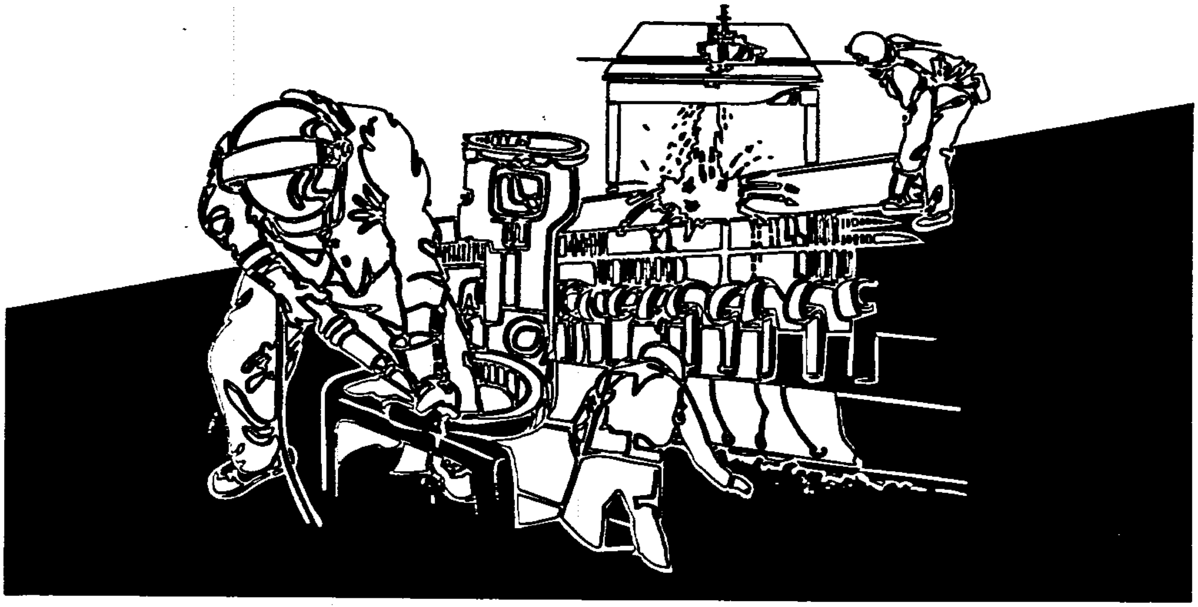
CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 92-0306-2465
U.S. TSUBAKI
SANDUSKY, OHIO



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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U.S. TSUBAKI
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NIOSH INVESTIGATORS
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I. SUMMARY

On March 3 and September 1, 1993, the National Institute for Occupational Safety and Health (NIOSH) conducted investigations at the U.S. Tsubaki (UST) Company, located in Sandusky, Ohio. This investigation was performed in response to a management request, which NIOSH received on June 18, 1992, for evaluation of occupational exposure of sub-radiofrequency electric and magnetic fields (SRE/MF) to workers at the UST Company.

Occupational SRE/MF measurements were made on electric resistance heaters (ERH) and induction heaters (INH) used by UST in their manufacturing process. Sub-radiofrequency electric fields (SREF) measurements of ERH, in the 30 to 1000 hertz (Hz) region, ranged from 0.1 to 30 volts per meter (V/m). Sub-radiofrequency magnetic fields (SRMF) levels associated with the ERH ranged from 0.1 to 13.9 Gauss (G), in the 40 to 2000 Hz region. These SRMF levels from ERH exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) of 10 G. The maximum SRMF levels associated with INH, operating near 10 kilohertz (kHz), was 40 G which exceeded both the ACGIH TLV value of 60 milligauss (mG) and the Institute of Electrical and Electronics Engineers (IEEE) maximum permissible exposure level of 2 G.

Based on the data collected in this evaluation, NIOSH investigators concluded that exposure to SRMF levels at UST, in the frequency regions from 0.1 to 2000 Hz and at 10 kHz, exceeded the appropriate occupational guideline limits on the days of measurement. Recommendations are offered to reduce exposure levels.

KEYWORDS: SIC 3568 (Mechanized Power Transmission equipment, not elsewhere classified), EMF, Sub-radiofrequency electric and magnetic fields, electric resistance and induction heaters.

II. BACKGROUND

The National Institute for Occupational Safety and Health (NIOSH) received a management request on June 18, 1992, for a health hazard evaluation concerning possible employee exposures to electromagnetic fields (EMF) produced at the U. S. Tsubaki (UST) Company located in Sandusky, Ohio. On March 2-3 and September 1-2, 1993, NIOSH investigators visited and performed measurements at the UST facility in Sandusky.

UST is a major manufacturer of power transmission products in the United States. At the Sandusky facility, UST produces steel engineering drive and conveying chains for use in such applications as mining, construction, paper and sugar mills, amusements parks, and the automobile industry. During the manufacturing process, electrical equipment is used that produces high levels of EMF. Only the areas in the facility using electric resistance heaters (ERH) and induction heaters (INH) were evaluated for occupational exposure to EMF. UST is a Japanese owned company and has union affiliation through the International Association of Machinist and Aerospace Workers (IAMAW), Local 1329.

A. Electric Resistance Heaters

There were four Cheston ERH in operation at the UST facility on the days of evaluation. The units are rated at 480 volts, single phase, and 400 amperes. The ERH can be visualized as an automated, heavy-duty step-down transformer. Figures 1 through 3 show additional details about the nature of the work and the position workers stand in performing their work tasks. The insertion of a workpiece directly into the secondary circuit of the transformer that carries a high current causes the workpiece to heat up rapidly. The manufacturer of the ERH informed NIOSH that the frequency of the magnetic field is dominant 60 hertz (Hz). The ERH have a silicon controlled rectifier phase controller, whose frequency is 9 kilohertz (kHz), that aids in the regulation of the voltage applied to the primary.

The carbon workpieces are delivered to the ERH electrodes for approximately 30 seconds of heating. At the end of a two-stage heat cycle, shown in Figure 4, the electrodes retract and the heated workpiece is conveyed to a forge where it is shaped into a single chain link. The largest link takes 30 seconds to heat while the smallest link takes about 16 seconds.

The four units have been at the facility for eight years and have the potential to produce about 2000 chain links per shift. There are two workers per shift and two shifts per day. All service work on the ERH is performed by plant workers. Potential occupational EMF exposure to workers will occur when the worker stands next to the heaters (either for adjustment purposes or for unjamming heated workpieces going to the forge). Occupational exposure can be considered continuous since the four ERH operate simultaneously.

B. Induction Heaters

Induction heaters (INH) are used to heat electrically conducting material used to join the chain links together. The material is placed in an alternating current magnetic field produced by unshielded coils of various sizes and designs. High power levels are then delivered to the workpiece in order to heat it. As a result of the high power levels that must be used, as well as the lack of coil shielding, INH operators can be exposed to high levels of EMF which may increase the potential for health effects.

All of the INH measured at UST were manufactured by Tocco, Inc. These units produced power levels ranging from 35,000 to 70,000 watts at frequencies value ranging from 7 to 10 kHz. Two of these units are shown in Figures 5 and 6. Since INH operators tend to handle the workpiece with tongs or by hand, then arm/hand/wrist locations are the more prominent sites of worker exposure.

III. EVALUATION DESIGN AND METHODS

Emphasis was placed in this evaluation on documenting occupational levels of sub-radiofrequency electric and magnetic fields (SRE/MF) found at the UST facility in Sandusky. The evaluation was designed to survey actual worker exposures to SRE/MF during work tasks. The limited number of measurements taken in and around the facility were not intended to represent an in-depth evaluation of the SRE/MF radiation fields at the site, but were rather intended to approximate occupational exposure levels on the days of measurement.

The following equipment was used to document levels of EMF at UST:

- A Holaday Industries, Inc. model HI-3602 ELF Sensor, connected to a HI-3600 survey meter, was used to document both the magnitude of SRE/MF and the electrical frequency (as well as the waveforms) produced by such fields. The SREF can be measured either in volts per meter (V/m) or kilovolts per meter (kV/m). The sub-radiofrequency magnetic fields (SRMF) can be expressed in units of gauss (G) or milligauss (mG). One G equals 1000 mG.

- SRMF measurements were made with the EMDEX II exposure system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Inc. The EMDEX II is a programmable data-acquisition meter which measures the orthogonal vector components of the magnetic field through its internal sensors. Measurements can be made in the instantaneous read or storage mode. The system was designed to measure, record, and analyze power frequency magnetic fields in units of mG in the frequency range from 30 to 3000 Hz. Measurements were made in both the walk-around mode and personal dosimetry mode.

- Holaday Industries, Inc. models HI-3600-01 and HI-3600-02 survey meters were used to document the electric and magnetic fields in the very low frequency (1 to 30 kHz) and extremely low frequency (0.1 to 1000 Hz) bands. The sub-radiofrequency electric fields (SREF) can be measured either in V/m or kV/m while the SRMF can be expressed in units of mG. These instruments also provided the ability to record the frequencies, as well as the waveforms, produced by such fields. Frequency measurements were made at locations where personnel worked during the day.

- Holaday Industries, Inc. model 3637 3-axis very low frequency (VLF) was used to make isotropic measurements of the magnetic field in and around the INH. The magnetic field is measured over the frequency region from 2 to 400 kHz and the dynamic range of the instrument is from 6 to 400,000 mG with special probe adapters.

- Holaday Industries, Inc. model HI-3627 3-axis ELF magnetic field meter. This meter was used to make isotropic measurements of the magnetic field in and around different heaters. The magnetic field is measured over the frequency region from 30 to 2000 Hz, and the dynamic range of the instrument is from 0.2 mG to 20 G.

All measurements were taken during daylight hours and at positions considered to be typical of occupational exposure (one meter away and one meter from the floor). Where possible, at least two readings were taken at each measurement site with the equipment and the average reading recorded. All equipment used to document exposure to SRE/MF had been calibrated within six months use either by NIOSH or their respective manufacturer.

IV. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed without experiencing adverse health effects. It is, however, important to note that not all exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity situation.

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information about chemical and physical agents become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH criteria documents and Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV), and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL). The OSHA PELs are required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational diseases. In evaluating the exposure levels and the recommendations for reducing these levels found in these reports, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

At present, there is limited information from OSHA on exposure criteria for workers exposed to physical agents. Criteria for physical agents not covered by OSHA come from either ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI).

Sub-Radiofrequency Electric and Magnetic Fields

At the present time, there are no OSHA or NIOSH exposure criteria for sub-radiofrequency (RF) fields covering the frequency region from 0.1 to 30,000 Hz. However, the ACGIH has published TLVs for SRE/MF in this frequency region.[1] The TLV for SRMF states "routine occupational exposure should not exceed:

$$\text{SRMF (in mT)} = 60/f$$

where f is the frequency in hertz." One millitesla (mT) equals 10 G. Conversely, the SREF TLV states "occupational exposures should not exceed a field strength of 25 kV/m from 0 to 100 Hz. For frequencies in the range of 100 Hz to 4,000 Hz (or 4 kHz), the SREF TLV is given by:

$$\text{SREF (in V/m)} = 2.5 \times 10^6/f$$

where f is the frequency in hertz. A value of 625 V/m is the exposure limit for frequencies from 4 kHz to 30 kHz."

This means, for example, at 60 Hz, which is classified as extremely low frequency (ELF), the SREF TLV is 25,000 V/m and the SRMF TLV is 1 mT or 10,000 mG. At 10 kHz, the SREF TLV is 625 V/m and the SRMF TLV is 60 mG. The basis of the ELF SREF TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The SRMF TLV addresses induction of magnetophosphenes in the visual system and production of induced currents in the body. Prevention of cancer is not a basis for this TLV because exposure has not been conclusively linked to cancer.

The ACGIH has recently proposed new TLVs for the SRE/MF region that will alter the above levels. The proposed TLV for SRMF recommends the use of the same magnetic field equation TLV but has adopted a ceiling value of 10 G from 1 to 300 Hz and a ceiling value of 2 G from 300 to 30,000 Hz.

As the frequency region increases in magnitude many of the observed biological effects of exposure to what is known as microwave (MW) and radiofrequency (RF) radiation can be attributed to a rise in body temperature. The heating effect of MW/RF radiation depends on the amount of energy absorbed by the body. The rate of absorption, denoted the specific absorption rate (SAR), is measured in watts per kilogram (W/kg) for the whole body or parts of the body. The SAR depends on many factors such as the frequency and intensity of the radiation, size and shape of the exposed worker, and the worker's orientation in the radiation field.

Another standard for occupational exposure to MW/RF radiation is the Institute of Electrical and Electronics Engineers (IEEE) standard published under the auspices of the ANSI and known as IEEE C95.1-1991.[2] The IEEE scientific committee concluded that a SAR of 4 W/kg represents the threshold absorption level above which adverse health effects may arise as body temperature increases. A safety factor of 10 was then added to give a SAR of 0.4 W/kg as the maximum permissible exposure limit, averaged over the entire body. This standard uses dosimetry measurements of MW/RF radiation to calculate the power density limit necessary to achieve a SAR of 0.4 W/kg. Under the IEEE standard for a frequency of 10 kHz, the magnetic field power density limit is 1,000,000 milliwatt per square centimeter. This is equivalent to a magnetic field strength of 2.01 G. The basis of the IEEE standard is to minimize adverse biological effects due to excessive heating of internal body tissues. The human body absorbs maximally in the frequency region from 30 to 300 Megahertz (MHz). Outside this region, such as 10 kHz, much less energy is absorbed by the body from the radiation field.

V. RESULTS AND DISCUSSION

A. Electric Resistance Heaters

Table 1 indicates that workers can be exposed to SRMF levels as high as 13.9 G at waist locations for long periods of time. If the workers were to perform any type of maintenance or service work while the units were activated, the levels of SRMF, in the 30 to 3000 Hz frequency region, would be much higher since the workers would need to lean over the heaters and be located closer to the radiated fields. An example of a higher exposure scenario is shown in Figure 2.

SRMF levels associated with ERH ranged from 0.1 to 13.9 G in the 30 to 2000 Hz region while SREF levels ranged from 0.1 to 30 V/m over the 30 to 1000 Hz region. While time-weighted ELF levels of SRMF were not documented in this evaluation, it is noted that these levels would probably be well below the levels shown in Table 1 since the workers do move about the area during the conduct of their jobs. However, the NIOSH investigators did observe ERH workers staying in the close vicinity of these heaters for relatively long periods of time, (i.e., 1 to 2 hours) and would therefore be exposed SRMF ceiling levels above the new proposed ACGIH TLVs. Finally, the maximum measured VLF level shown in Table 1 was 50 mG, which is below both the ACGIH TLV and IEEE exposure limit for a 9 kHz source.

B. Induction Heaters

All magnetic field measurements of INH were corrected for the work cycle duration before comparison with occupational exposure criteria. This was accomplished by multiplying the estimated duty cycle factor (df) by the measured exposure level. The df is defined as the ratio of the magnetic field on-time in seconds to the sum of the time on and time off during any six minutes of operation, and it is expressed as a fraction.

Table 2 shows duty-factor-corrected data on occupational SRMF maximum levels for INH at UST as a function of process, power, and measurement location at the worker site. The shaded zones in Table 2 indicate levels that exceed the TLV. The levels shown in Table 2 were averaged over two trials. Notice that hand exposures to the 10 kHz INH gave the highest occupational exposure. Table 2 shows that 75% of the body measurements were below the IEEE limits while 67% of the hand measurements were above the IEEE limits. Moreover, the hand measurements were much higher in intensity than the body levels.

Very few measurements on INH have been reported in the literature but those results that do exist suggest that INH operators are exposed to SRMF levels which are high relative to recommended exposure limits.[3-4] The review of the limited literature suggests that the hands were the most exposed parts of the body and, in most cases, the total body exposure was low. During this evaluation, several INH workers were asked if they ever perceived any effects of exposure to such fields. No effects were reported by any of the workers. It is noted that while metal objects can be heated to high temperatures in short periods of time, exposure to the hands did not produce the same effects. Power absorption is directly proportional to the conductivity of the object. At 10 kHz, there is a factor of 10^8 difference between conductivity of the hands and metals.

C. *Fire and Fume Issues*

During the evaluation for EMF at UST, it was noted that lubricating oil on the top surface of the ERH heater would occasionally flame causing fire and fume problems (see Figure 7). One explanation was that lubricating oil was used to inhibit corrosion and to assist in delivering the workpieces to the ERH electrodes. This practice needs to be fully investigated by UST safety personnel due to potential fire concerns and occupational exposure to toxic vapors.

VI. CONCLUSIONS AND RECOMMENDATIONS

Based on the data collected in this evaluation, and comparison with current occupational criteria, the NIOSH investigators concluded that SRMF measured on the days of evaluation exceeded applicable exposure limits suggesting the potential for a health hazard to exist.

The following recommendations are offered to reduce potentially significant occupational exposures and safety risks at the UST facility:

1. UST should consider purchasing appropriate static magnetic and SRE/MF monitoring instruments to monitor levels of electric and magnetic field produced on the plant property.

2. UST needs to investigate the possibility of either requiring IH operators to work at distances further away from the units or consider developing control measure techniques, such as automated systems or shielding that will eliminate excessive hand/body exposures.

3. Operators should be positioned further from the ERH when work does not demand being close to units. In addition, automation of some elements of the INH processes could reduce occupational exposure levels which are above the exposure limit.

4. UST safety personnel need to investigate the practice of using flammable oils on the hot surfaces of ERH.

VII. REFERENCES

1. ACGIH [1993-94]. Threshold limit values and biological exposure indices for 1993-94. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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3. Lovsund P, Oberg PA, Nilsson SEG [1982]. ELF magnetic fields in electrosteel and welding industries. Radio Science 17(5S):35S-38S.

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VIII. AUTHORSHIP AND ACKNOWLEDGEMENTS

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Table 1
Maximum and Steady State ELF and VLF Magnetic Field Levels at Waist Level near ERH

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Heater Number	Maximum Levels (G)	Steady State Levels (G)	Maximum VLF (mG)
1	12.3	7	50
2	13.6	6	50
3	13	7	50
4	13.9	8	30

G = Gauss
mG = Milligauss

Table 2

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Process	Applied Power (kW)	Operating Frequency (kHz)	Estimated Duty Factor (DF)	Maximum DF-Corrected Exposures (G)		Current TLV (mG)	IEEE MPE (G)	ELF Exposure Level (mG)
				Hand	Body			
Hot Bender 50 kW	35	10	0.6	24	0.96	60	2.0	460
Hot Bender 100 kW	70	10	0.6	NM	0.24	60	2.0	NM
Hot Header	70	7	0.75	7.5	3	86	2.0	200
Induction Hardener	60	10	0.6	0.24	0.03	60	2.0	10

NM = not measured

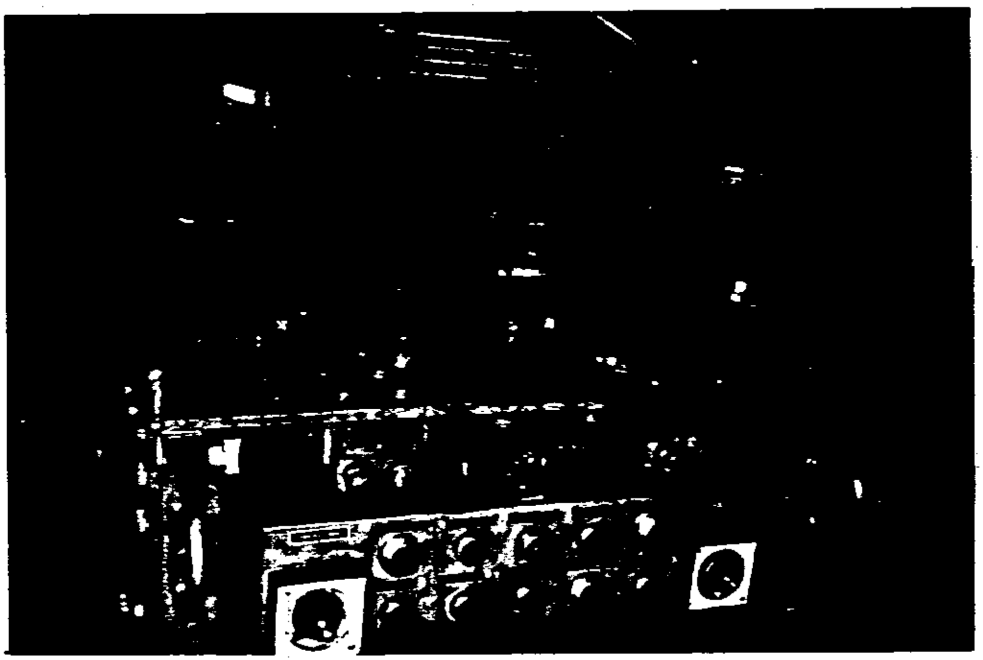

FIGURE 1. FRONTAL PICTURE OF ERH DEVICE. NOTE THE STORAGE OF CARBON ELECTRODES.

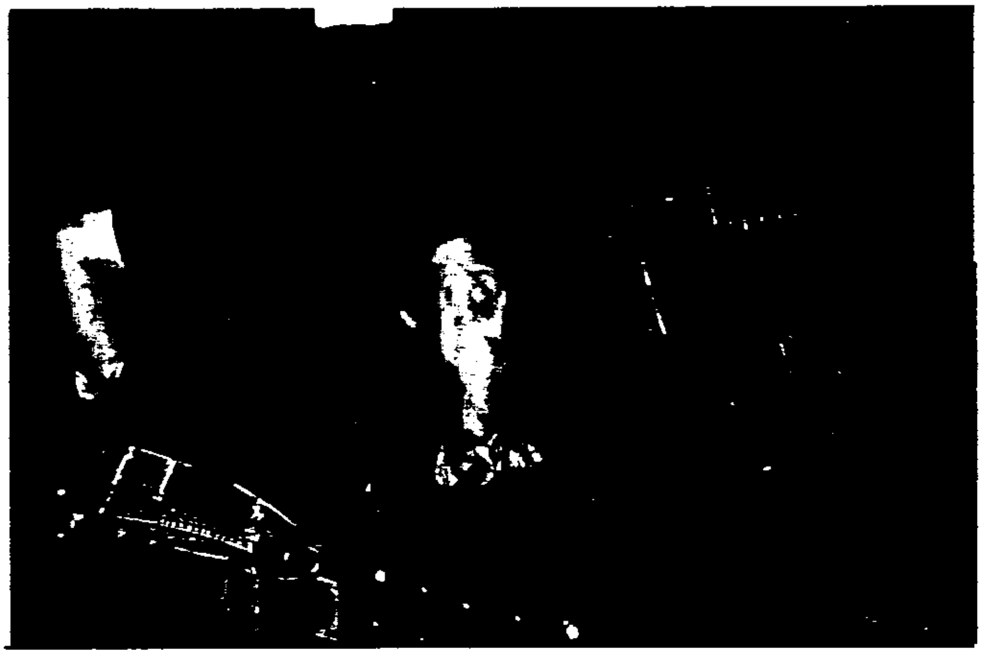

FIGURE 2. EXTREME CLOSE-UP ERH WORKER LOCATION DURING HEATING CYCLE.

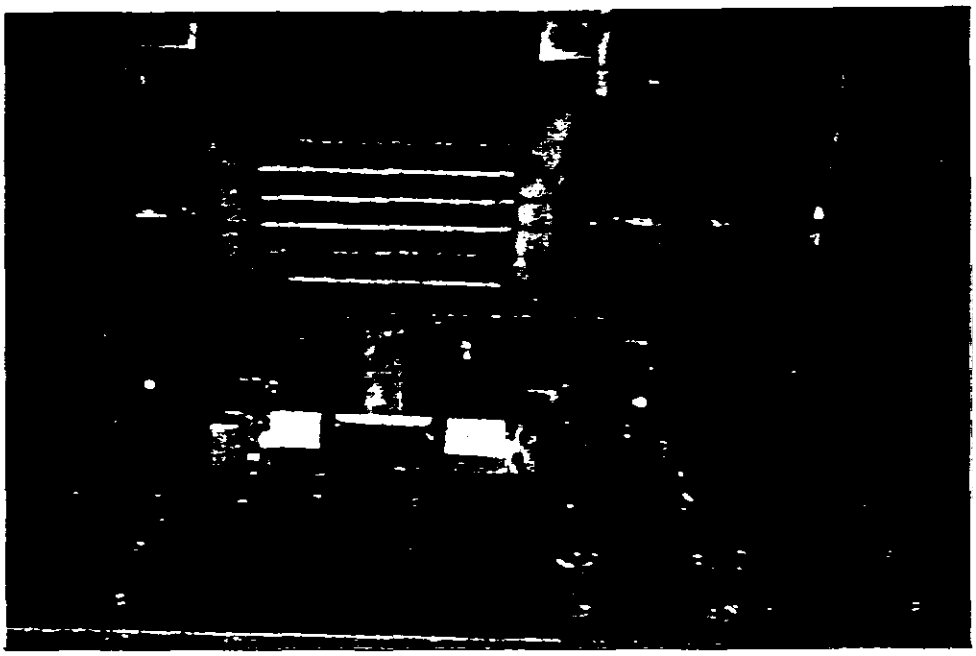

FIGURE 3. CARBON ELECTRODE BEING HEATED IN EHR.

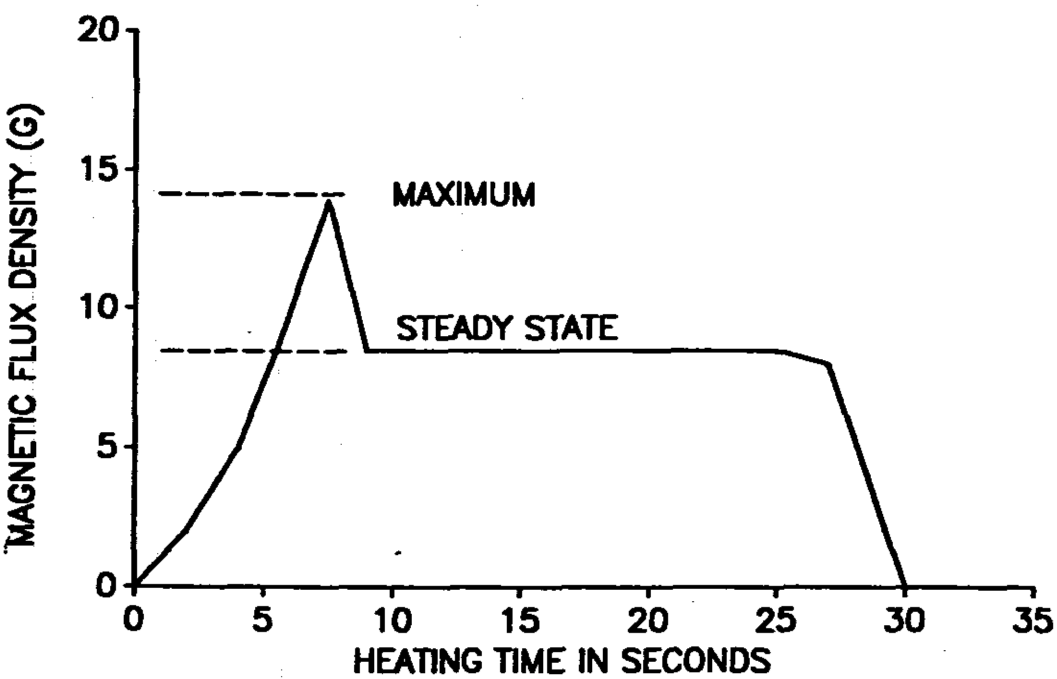

FIGURE 4. TYPICAL HEAT CURVE FOR RESISTANCE HEATERS SHOWING MAGNETIC FIELD PRODUCED AT EDGE OF HEATER (WORKER WAIST POSITION) AS FUNCTION OF TIME.

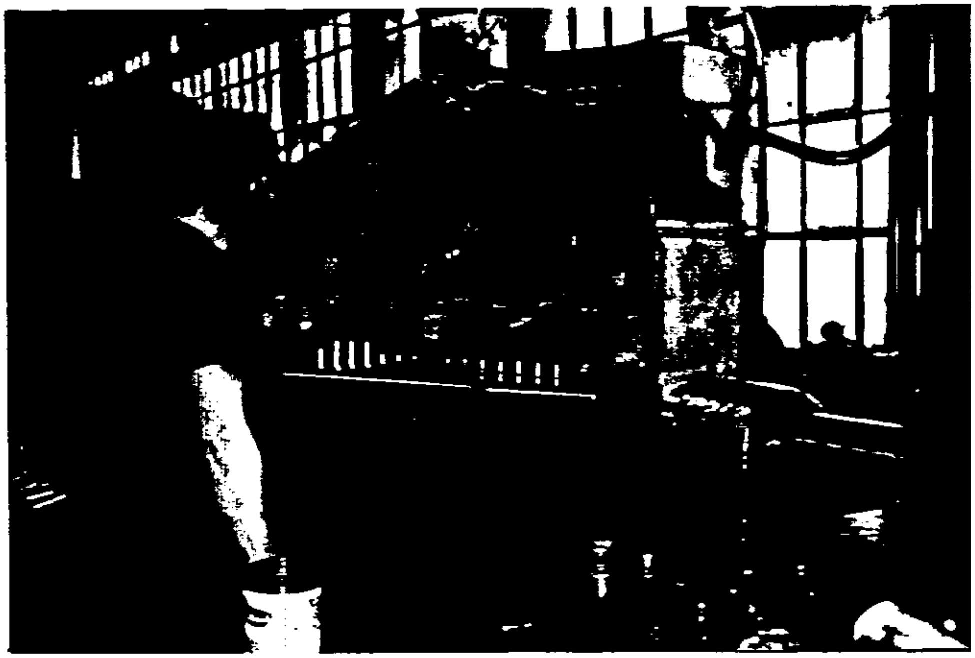

FIGURE 5. INH WORKER HANDLING WORK PIECES BY HAND DURING HEATING CYCLE.

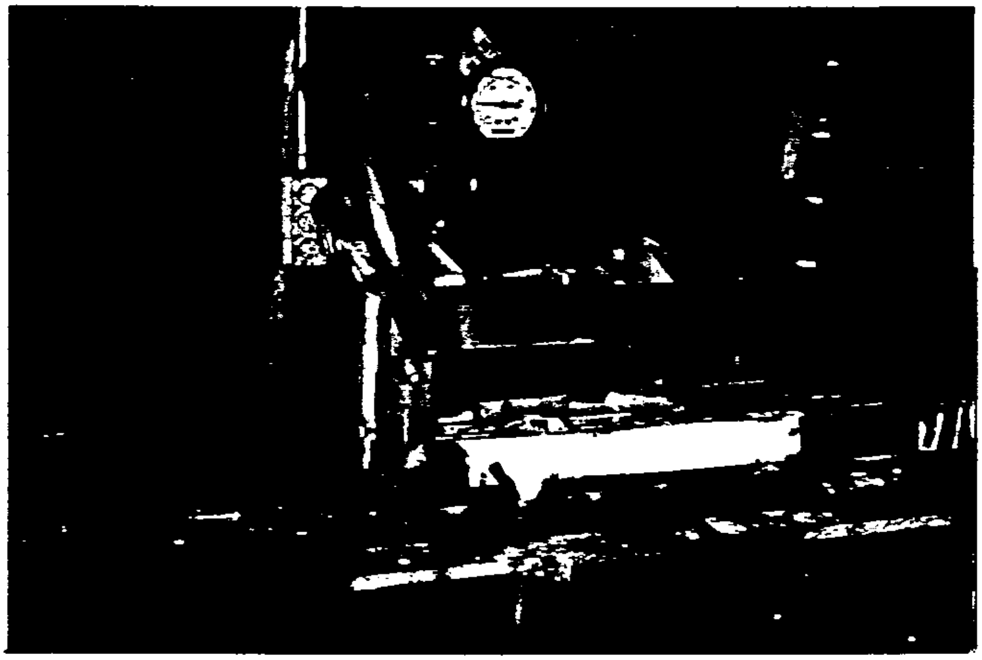

FIGURE 6. UNSHIELDED WORK PIECES MOVING IN COIL OF INH.

FIGURE 7. SPARKS AND FIRE ON TOP OF ERH PROBABLY DUE TO HEATING OF OIL RESIDUALS.