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NATIONAL COVER OF ATLANTA, INC.
LAWRENCEVILLE, GEORGIA

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I. SUMMARY

On November 13, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation at National Cover of Atlanta, Inc. in Lawrenceville, Georgia. The request concerned a perceived excess of spontaneous abortions (miscarriages) during the preceding 15 months. The exposures of concern were solvents and inks used in a silk screening process and radiation from radiofrequency heat sealing equipment.

An initial site visit and walk-through was conducted in January 1986. A follow-up environmental survey was conducted on February 25-26, 1986 and a follow-up medical evaluation was conducted on April 1-2, 1986. A questionnaire regarding reproductive history and other pertinent medical and demographic information was administered to 95% of current female employees and 44% of former employees. Of the 148 women who participated in the study, there was a total of 225 pregnancies included in the analysis: 158 occurred while women were not working outside the home; 52 occurred while working, but not at National Cover; and 15 occurred while employed at National Cover. The rate of adverse outcomes were 13% and 10% for the first two groups. However, 53% of pregnancies occurring to women employed at National Cover resulted in an adverse outcome. The relative risk of these pregnancies compared to the other two groups combined is 4.5 (95% Confidence Interval: 2.3, 8.8).

Measurements of non-ionizing radiation taken at levels of the operator's head, waist, and knee for 17 of 20 heat-sealing machines were low. All measurements of both the electric and magnetic fields were below the OSHA standard. Most were also below ACGIH recommended limits. A variety of solvents, including cellosolve acetate, xylene, and methyl chloroform, were found in low levels throughout the plant. (These three solvents have been associated with a variety of reproductive disorders.) Workers in the production area were exposed to up to 80% of the Threshold Limit Value (TLV) for solvent mixtures.

It was not possible to rule out work-related exposures to solvents as a contributing factor to the excess of adverse pregnancy outcomes.

Based on results of this study, NIOSH investigators documented an excess of spontaneous abortions and stillbirths occurring among women whose pregnancies occurred while employed at National Cover. An environmental survey found low levels of radiofrequency radiation emitted from heat-sealing machines, as well as relatively low levels of a wide variety of solvents, including 2-ethoxyethylacetate, a glycol ether. Though the excess of adverse pregnancy outcomes was not associated with working in specific departments, exposure to solvents could not be ruled out as a contributing factor. Recommendations to minimize exposure to solvents and RF radiation are found in Section VIII of this report.

KEYWORDS: SIC 2782, book-cover manufacturing, spontaneous abortions, solvents, radiofrequency radiation, glycol ether, heat-sealing, silk screening

II. INTRODUCTION

On November 13, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation at National Cover of Atlanta, Inc. in Lawrenceville, Georgia. The request concerned a perceived excess of spontaneous abortions (miscarriages) during the preceding 15 months. The exposures of concern were solvents and inks used in a silk screening process and radiation from radiofrequency heat sealing equipment.

An initial site visit and walk-through was conducted in January 1986. A follow-up environmental survey was conducted on February 25-26, 1986 and a follow-up medical evaluation was conducted on April 1-2, 1986. At that time, a questionnaire regarding reproductive history and other pertinent medical and demographic information was administered to 104 of 110 current female employees. A list was obtained from the company of former female employees who had worked at least one month at National Cover at any time during the preceding three years. The questionnaire mailed to each of the 101 women on this list was completed by 27. Follow-up telephone calls resulted in completion of another 17. In total, 44% of former female employees participated in the study.

An interim report of the results of the environmental survey of National Cover of Atlanta, Inc., as well as the preliminary epidemiologic results was provided to the company and to the employee requestor in November 1986. This report includes the final epidemiologic analysis.

III. BACKGROUND

National Cover of Atlanta produces high quality three ring binders and other packaging materials. The binder covers are generally imprinted in a silk screening process and allowed to dry, or are ultraviolet cured. Fabric binder covers are glued and plastic (PVC) binder covers are sealed by radiofrequency heat sealers around a cardboard insert.

At the time of this evaluation the company employed approximately 150 persons, in seven production areas, over two shifts, five days per week. There are 110 female employees, 85% of whom are of child-bearing age (16-44). The building is a 77,000 square foot facility, originally built and operated by Georgia Pacific, in 1968. It was purchased by National Cover (Jones-Colad) in April of 1974. The screen printing process has been essentially without change since then, except for the introduction of ultraviolet cured inks in 1981.

IV. EVALUATION DESIGN AND METHODS

A. Environmental

Worker exposures to the organic vapor constituents of the inks and solvents used in the screen printing operations were determined using standard air sampling techniques. Full-shift personal breathing zone and area air samples were collected by drawing a known volume of air through glass tubes containing activated coconut shell charcoal (l50 mg), using battery-powered sampling pumps at a nominal flow-rate of 50 milliliters per minute (ml/min). For personal samples the pump was attached to the worker's belt and the charcoal tube was clipped to the collar or lapel in the worker's breathing zone. For area air samples the pump was placed at the location of interest with the charcoal tube fixed at

breathing zone height. The same sampling apparatus was used to collect short-term personal samples (<30 minutes duration), but at a flow-rate of 200 ml/min.

Higher flow-rate (200 ml/min) area air samples (nine) were collected in office, production, and assembly areas to be used for qualitative air contaminant characterization. These samples were analyzed by gas chromatography and using a mass spectrometer for analyte detection and identification (GC/MS). Major compounds found in this fashion were sought in the subsequent quantitative analysis of personal breathing zone and general area air samples.

Sixty samples were quantitatively analyzed for the compounds listed in Table l, as identified by the GC/MS analyses. The samples were first desorbed with 1 ml of carbon disulfide, then analyzed by gas chromatography using a Hewlett-Packard 5880 GC equipped with a 30 meter DB-1 fused silica capillary column and a flame-ionization detector. The limit of detection (LOD) for ethanol, acetone, and 1,1,1-trichloroethane was 10 micrograms per sample (ug/sample), and the limit of quantitation (LOQ) for these compounds was 20 ug/sample. For all other compounds the LOD and LOQ were 5 and 10 ug/sample respectively.

Breathing zone samples were obtained from l6 workers in the decoration area and the screen maker in the Art Department over two consecutive daytime work shifts. The general area samples were obtained from the administrative offices, Pre-pressed Department, and the remaining production areas.

Radiofrequency measurements were made using a calibrated Holaday Model HI-3002 broadband field strength meter equipped with an electric (E) field or a magnetic (H) field probe. The E field probe was used to measure mean squared electric field strength in volts squared per meter squared (V^2/M^2) and responded to frequencies ranging between 0.5 and 6000 megahertz (MHz). The H field probe, with a frequency response range of 5 to 300 MHz, was used to measure magnetic field strength in amperes squared per meter squared (A^2/M^2). The minimum detectable readings for the E and the H probes were 500 V^2/M^2 and 0.005 A^2/M^2, respectively. The overall accuracy of both probes was $\pm$ 2 dB.

Workers at l7 of the 20 RF heat-sealing machines were evaluated for exposure to RF radiation. Many heat-sealing machines had more than one operator. Both E field and H field measurements were taken at the head, waist, and knee on both sides of the body.

B. Medical/Epidemiologic

The medical investigation of National Cover consists of an epidemiologic evaluation of female employees who were either currently employed as of April 1986 or had been employed at any time from April 1983 to April 1986. On April 1-2, 1986, a questionnaire was administered which sought demographic information, past medical history, and specific information on personal habits, work history, outcome, and complications during each pregnancy. This questionnaire was administered to current female employees. In addition, the questionnaire was mailed to 101 former employees from a list supplied by the company. Follow-up telephone calls were made to those not responding to the mailed questionnaire. An analysis was performed to assess the potential effect of a selection bias due to lack of complete follow-up of former workers.

V. 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 up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their 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 (allergy).

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 criterion. These combined effects are often not considered in 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 on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

A. Environmental

Airborne Contaminants

Table 1 presents the evaluation criteria and a brief summary of the primary health effects of ten airborne contaminants measured during the evaluation.

Radiofrequency (RF) Radiation

The term "microwave" refers to electromagnetic radiation extending from frequencies of approximately 10 to 300,000 megaHertz ("mega" equals 1,000,000; Hertz equals 1 cycle per second). The terms "microwave" and "radiofrequency radiation" (RF) are sometimes

used interchangeably. RF sealers generally operate within the band of frequencies from 10 to 70 megaHertz (MHz). The sealers at the National Cover facility operated at 22, 25, or 27 MHz, which is typical for these types of heat sealers. RF electromagnetic energy emitted from an RF sealer is considered non-ionizing radiation by virtue of its frequency and energy. Ionizing radiation (e.g. x-rays, gamma rays, beta rays, etc.) is associated with the ability to remove electrons from neutral atoms (thus "ionization") and is generated at frequencies and powers greatly in excess of the capabilities of heat sealing operations.

RF radiation attains its desired thermal effect in industrial applications by acting upon the polar disposition of molecules. When a polar molecule is placed in a changing electric field, it attempts to align itself with the field. In the example of microwave cooking, the water molecules (which usually make up greater than 50% of the aggregate molecules) will change directions by 180° 2.5 billion times every second. With every change in direction, the molecules give off heat. This principle is also used for RF heat sealing operations. Although lower frequencies are used (27 MHz vs. 2450 MHz for microwave cooking), heat is generated by rapidly changing the polar disposition of molecules within the plastic.

RF electromagnetic radiation can be described in terms of interrelated electric and magnetic fields propagating through space in the form of waves. The wave has an electric field strength (E-field), expressed in volts per meter (V/m) and a magnetic field strength (H-field), expressed in amperes per meter (A/m). The E-field is measured by the force that it exerts on an electric charge, while the H-field is measured by the force that it exerts on a magnetic north pole. Power density is also an important quantity used to describe an electromagnetic wave. Power density is defined as the rate at which energy is transported across an area, averaged over one cycle of the wave. Power density has traditionally been expressed in units of milliwatts per square centimeter (mW/cm^2). While the E- and H-fields can be measured at any distance from the RF source, a power density can only be measured in the far field (far field is defined as at least one to five wave lengths away from the source; usually 10-11 yards), because the E and H-fields must have sufficient distance to align themselves perpendicularly. Reflections near the source interfere with this alignment.

Traditional problems encountered with measurement of RF energy involve expression of the evaluation criteria in the form of a power density. However, a power density value, which can be measured or calculated for far-field conditions, is not appropriate (or possible) for quantifying near-field exposure of a worker operating a RF heat sealing device. Therefore, measurements of both the E-field and H-field are necessary for exposure evaluations. While these cannot be directly converted to a power density as prescribed in the OSHA protection standard, they can be compared to the far-field equivalencies (40,000 V^2/m^2 and/or 0.25 A^2/m^2).

The ACGIH TLV for RF radiation specifies various field strengths dependant upon the frequency. At 27 MHz (the frequency used for 80% of the heat sealers at the National Cover facility) the TLV would be 4654 V^2/m^2 (E-field) and 0.033 A^2/m^2 (H-field). In terms of power density equivalents, these are approximately one-tenth of the OSHA standard.

In a recent study by NIOSH of 82 heat seal operators in 13 facilities[9], 55% of the operators were exposed to levels for the E-field above the OSHA standard, and 21% were exposed to levels for the H-field above the standard. This type of environmental

information, along with experimental animal studies which suggest that the potential consequences of absorbing excessive amounts of RF energy may include changes in the eye, central nervous system, conditioned reflex behavior, heart rate, chemical composition of the blood, and the immunologic system, prompted NIOSH to publish a Current Intelligence Bulletin[10] recommending precautionary measures to be instituted to protect workers from unwarranted exposure to RF energy. These precautionary measures are listed in Appendix A.

B. Medical/Epidemiologic

Prevalence rates of spontaneous abortions and stillbirths were ascertained in women employed at National Cover between 1983 and 1986. Estimates of spontaneous abortion rates in the general population vary from 10-25%, depending upon which ascertainment method is used and how early the pregnancies are documented[11,12].

VI. RESULTS

A. Environmental

The inhalation exposures at National Cover were to a rather complex mixture of organic compounds. It is difficult to quantitate exact amounts of all components in such a mixture in a simple fashion. Therefore, the analytical results should be interpreted with some qualifications. Hexane, which elutes at the same time as ethyl acetate under the conditions of these analyses, was detected on a few of the samples. Because of this hexane interference, the values reported for ethyl acetate should be considered maximum values. Breakthrough and possible sample loss was detected for ethanol and acetone on most of the samples. Breakthrough was considered to be present when more than 10% of the analyte found on the front section of the sample was found on the back section. The values reported for ethanol and acetone should be considered as minimum values.

Airborne Contaminants

Individual personal sample results are presented in Tables 2 and 3 for the samples collected on February 25-26, 1986. The averages for all personal exposure results are shown in Table 4. The average exposure concentrations for six of the ten analytes were less than any applicable exposure criteria. These six were ethanol (OSHA permissible exposure limit (PEL), 1000 parts per million (ppm), ACGIH TLV, 1000 ppm), acetone (NIOSH recommended exposure limit (REL), 250 ppm, OSHA PEL, 1000 ppm, ACGIH TLV, 750 ppm), MEK (NIOSH REL, 200 ppm, OSHA PEL, 200 ppm, ACGIH TLV, 200 ppm), ethyl acetate (OSHA PEL, 400 ppm, ACGIH TLV, 400 ppm), MIBK (NIOSH REL, 50 ppm, OSHA PEL, 100 ppm, ACGIH TLV, 50 ppm), and xylene (NIOSH REL, 100 ppm, OSHA PEL, 100 ppm, ACGIH TLV, 100 ppm). Of more interest, are exposures to the remaining four compounds (p-dioxane, cellosolve acetate, isophorone, and methyl chloroform), as well as the combined exposure to the mixture of the ten components. This interest is due to their known or suspected carcinogenic potential, the potential to cause adverse reproductive effects, and potential irritant and narcotic effects.

From Table 4, the average personal exposures in the Decoration area for consecutive days to p-dioxane were 0.39 and 0.31 ppm. NIOSH recommends that exposures to p-dioxane be maintained at the lowest feasible level (LFL) due to the belief that it is a potential human

carcinogen. The ACGIH has recommended a 25 ppm time weighted average (TWA) threshold limit value (TLV) for p-dioxane based on hepatotoxic (liver) and nephrotoxic (kidney) effects in workers. The compound is given a "skin" notation due to the potential contribution to the overall exposure by the cutaneous route, either by airborne, or by direct contact with the skin. The rate of absorption is a function of the concentration to which the skin is exposed. The OSHA PEL for p-dioxane is 100 ppm as an 8-hour TWA.

Plant-average personal exposures to cellosolve acetate (2-ethoxyethyl acetate) for the two sample days were 0.08 and 0.l0 ppm. NIOSH recommends that cellosolve acetate be regarded in the workplace as having the potential to cause adverse reproductive effects in male and female workers and embryotoxic effects, including teratogenesis (developmental malformations), in the offspring of the exposed, pregnant female. NIOSH urges employers to reduce exposure to the lowest extent possible or LFL. The ACGIH recommends a 5 ppm TWA-TLV based upon reported testicular effects in mice. A "skin" notation is also given. The OSHA PEL is l00 ppm for 8-hour TWA exposure.

Isophorone plant-average personal exposures for the two days were 0.5 and 0.3 ppm. NIOSH and the ACGIH both recommend that exposures not exceed 5 ppm based on irritative and narcotic effects. The NIOSH recommended exposure limit (REL) is a TWA concentration for up to a l0-hour workday, 40-hour workweek, while the ACGIH TLV is a recommended "ceiling" value which should never be exceeded. The OSHA PEL is 25 ppm for an 8-hour TWA exposure.

The plant-average personal exposures for methyl chloroform (l,l,l-trichloroethane) are l0.7 and 8.0 ppm for the survey days. NIOSH has no REL for methyl chloroform, however it is recommended that it be treated in the workplace with caution because of its relation to other chloroethanes shown to be carcinogenic in laboratory animals. Methyl chloroform exposure may also be associated with adverse reproductive effects[13]. The ACGIH recommends a TWA-TLV of 350 ppm due to anesthetic effects above this concentration. The OSHA PEL is also 350 ppm for an 8-hour TWA exposure.

Table 5 presents range and mean personal exposure results by job category. Those workers in the Decoration area (all but the screen maker) had average exposures to p-dioxane ranging from 0.l0 to 2.02 ppm on February 25, with the highest single exposure occurring to one of the lead operators (3.89 ppm, Table 2). p-Dioxane is a stablizer in solution with methyl chloroform which is the degreaser used to clean vinyl stock. The high exposure to p-dioxane resulted from the task of cleaning stacks of soiled vinyl stock. With the exception of this exposure, the range is narrow, between 0.l and 0.3 ppm. On the second day, average p-dioxane exposures for the six Decoration jobs ranged from a trace value (t) of 0.08 ppm to 2.6 ppm. A trace value is one which falls between the analytical limit of detection (LOD = 5 ug/sample) and limit of quantitation (LOQ = 10 ug/sample). Trace values are prefixed with a "t" in all tables and were used in the calculation of all mean exposures. The 2.6 ppm exposure to the stamper, on February 26, also resulted from cleaning a stack of soiled vinyl sheets with the methyl chloroform. Otherwise, the exposure averages ranged from t0.08 to 0.20 ppm.

Cellosolve acetate average personal exposures in the Decoration area ranged from t0.06 (LOD = 5ug/sample, LOQ = 10ug/sample) to 0.ll ppm. The higher exposures were experienced by the mixer, and the operators and inspectors on printing machines l and 5, who used conventional inks (versus inks dried by ultraviolet light). Cellosolve acetate is a

solvent in the inks used in screen printing. The operators, inspectors, and the mixer are the workers using inks the entire shift. A similar exposure pattern occurred on the second survey day, however the averages were higher. The conventional ink was used only at printing machine 5 on this day. The range of personal exposure means for February 26 was from none detected (ND) to 0.l7 ppm.

Average personal exposures to isophorone, another ink solvent, ranged from 0.3 to 0.6 ppm in the Decoration workers during the first day of the survey. The higher exposures were experienced by the operators and inspectors using the conventional inks. The same exposure pattern was seen on February 26, with the mean personal exposures ranging from 0.2 to 0.5 ppm.

Methyl chloroform was the principal solvent used by the workers in Decoration. Average personal exposures to the solvent ranged from 3.4 to 60.7 ppm on the first day, and from 2.3 to 7l.3 ppm on the second day. On February 25, one of the lead operators was exposed to ll8 ppm, and on February 26 the stamper was exposed to the 7l.3 ppm. These exposures resulted from cleaning vinyl stock, as mentioned before.

When workers are exposed simultaneously to two or more hazardous substances which act upon the same organ system, even at concentrations below recommended criteria, their combined effect should be given consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. The ACGIH recommends that if the sum of the following fractions,

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} \cdots \frac{C_n}{T_n}$$

exceeds unity, then the criteria for the mixture should be considered as being exceeded. C_1 indicates the observed atmospheric concentration and T_1 the corresponding exposure criteria[14].

From Tables 2 and 3 it can be seen that a number of the TLV's for the mixture are between 0.5 and 1.0. One of the lead operators (combined TLV = 0.8), the operators and inspectors for machines #1 and #5 (combined TLV's = 0.6-0.7), and the mixer (combined TLV =0.6) had the higher values on 2/25/86. Machines #1 and #5 were operated with the conventional inks on this day. Those using the conventional inks (machine #5), the stamper, and the mixer also had the higher TLV's for the mixture on 2/26/86 (combined TLV $\geq$0.5).

In Table 6 the results from short-term (5-15-minutes duration) samples collected on 2/26/86 are presented. These samples were collected during typical cleanup tasks which may be performed a number of times per day. For one reason or another, a stack of vinyl stock, which may contain greater than 100 pieces, may need to be cleaned with either the degreasing solvent (methyl chloroform) or the alcohol solvent (ethyl alcohol, ethyl acetate, and methyl alcohol). Also, at the end of a run, the screens are cleaned of ink, using the wash up solvent, VF-184 (acetone and xylene). The stamper experienced high exposures to ethanol (550 ppm) and methyl chloroform (125 ppm) during a 6-minute period of cleaning vinyl stock. An 11-minute sample collected while using the screen wash up solvent resulted in exposures to ethanol (140 ppm), acetone (960 ppm), and xylene (140 ppm). The acetone and xylene exposures were at the level of the ACGIH TLV's for short-term

exposures of 1000 ppm and 150 ppm respectively. Another sample, collected later in the day, also showed high exposures to acetone and xylene.

Tables 7 and 8 present the general area sample results for February 25-26, 1986. These are summarized in Table 9. Area samples were collected in the Pre-pressed, Office, Turned-edge, Die-cutting, Assembly, and Heat Sealing areas. The samples collected in the latter four areas were combined into a Production area category for the purposes of Table 9 and discussion. There were six compounds found to be present throughout the plant, resulting from ink and solvent use in the Decoration area. The average concentrations (Table 9) of ethanol ranged from 14 to 17 ppm, and acetone from 19 to 22 ppm among the three other areas during the first day of sampling. Lower concentrations of xylene (7 ppm), methyl chloroform (2-3 ppm), ethyl acetate (0.5 ppm), and isophorone (0.2 ppm) were also detected. On February 26 the concentrations of ethanol and acetone ranged from 10 to 13 ppm and 11 to 15 ppm respectively. The other three compounds were present at about the same levels as on the first day.

Radiofrequency Radiation

Table 10 presents results of the RF measurements obtained at the left and right position of heat seal operators' head, waist, and knees. None of the operators was exposed to RF radiation in excess of the OSHA standard for occupational exposure to RF and microwave radiation (29 CFR 1910.97) of 10 mW/cm^2, as averaged over any possible 6-minute period during the work shift. In the far field (10-11 yards from the source) a power density of 10 mW/cm^2 is equivalent to a mean squared E-field strength of 40,000 $volts^2/meter^2$ (V^2/m^2) or a mean squared H-field strength of 0.25 $amperes^2/meter^2$ (A^2/m^2).

When compared to the ACGIH TLV for RF radiation (a level of approximately 10% of the OSHA standard), 6 (24%) of the 25 heat seal operators whose exposures were measured were exposed to RF radiation levels above these criteria (4654 V^2/m^2 E-field, and 0.033 A^2/m^2 H-field). This included operators at H.S. #s 1, 2, 4, 7, 16, and 21. Overexposures were measured for only the E-field. Duty-cycle corrections were made.

B. Medical/Epidemiologic

Of the 104 current female employees, 101 (94.5%) completed questionnaires. In addition, of the 101 former employees to whom questionnaires were mailed, 27 (26.0%) were completed and returned. Telephone numbers of the remaining 74 were sought from the company and directory assistance. Of these, 17 completed questionnaires, 2 refused to participate, 6 did not answer after several attempts, and 49 had either moved without a forwarding number or did not have listed numbers. In all, completed questionnaires were obtained from 44% of the former workers.

Among the 148 women who completed questionnaires, there was a total of 243 pregnancies (Table 11). Only single live births (N=192) and spontaneous abortions (miscarriages occurring before 20 weeks) and stillbirths (occurring after 20 weeks) (N=33), a total of 225 pregnancies, are considered here. Other pregnancy outcomes (therapeutic abortions, ectopic and molar pregnancies) did not, by definition, have the potential to result in a normal birth and, therefore, are not included in the analyses. Similarly, women who were pregnant at the time of the study are also not included.

For many of the following analyses, the pregnancies are considered separately for those which occurred to women while they were working at National Cover,and those which occurred when the mother was not working outside the home, or when the mother was working, but not at National Cover. The last group is to investigate the effect of working per se on pregnancy outcome. Among the 158 pregnancies which occurred to women who were not working outside the home, 20 (12.6%) resulted in an adverse outcome (spontaneous abortion or stillbirth). Women who were working, but not at National Cover, had a slightly lower rate of adverse outcomes of 9.6% (5/52). These prevalence rates (12.6% and 9.6%) are approximately those which would be expected in the general population[11,12]. Only 15 pregnancies occurred to women while working at National Cover; however, of these, eight (53%) resulted in adverse outcomes. The relative risk of adverse outcomes among pregnancies occurring to women while working at National Cover and all others (the other two groups were pooled since there was no difference between them) is 4.48 (95% Confidence Interval: 2.29, 8.78; p=.0003 (Fisher's exact test)).

To investigate the relationship of pregnancy outcome with calendar time, pregnancies were stratified by year. Very few pregnancies occurred prior to 1980 among women employed at National Cover; therefore, rates cannot be calculated. In a 14-month period in 1984 and 1985, 10 pregnancies occurred among women at National Cover, 8 (80%) of which resulted in an adverse outcome. The relative risk during that period is 6.7. There was no clustering in time within that 14-month period, arguing against a point source infectious agent.

In order to investigate potential reasons for this marked excess, a number of possible confounding factors were considered. These included order of pregnancy, maternal age at time of pregnancy, and tendency toward spontaneous abortions ("repeaters"). There is no remarkable trend in pregnancy outcome by order of pregnancy. In addition, there is no association between maternal age at time of pregnancy and outcome of the pregnancy. Table 12 demonstrates that there is no significant difference in the mean age of women with normal births and those with adverse outcomes. This is true overall, as well as by working status.

Because a number of genetic and hormonal mechanisms are suspected to cause recurrent spontaneous abortions (SAs) in the same woman, women with more than one SA were considered separately. There were four women with two SAs. However, none of the pregnancies of any of the three occurred while they were employed at National Cover. Elimination of the pregnancies of these 4 women from the analysis increases the relative risk of from 4.5 to 6.4 (95% CI: 3.2, 12.9).

In an attempt to elucidate possible associations between pregnancy outcome and specific work-related or other lifestyle factors, analyses were done among the 15 pregnancies which occurred to women while employed at National Cover. Eight departments were identified within National Cover. Of these, the departments with potential exposures of most concern are Heat-sealing (radiofrequency radiation) and Decoration (solvents). It can be seen in Table 13 that no pattern of occurrence was found which demonstrates a clustering of adverse outcomes in these, or any, departments. Similarly, though the numbers are small, no associations were found between pregnancy outcome and a variety of lifestyle and job-related factors, including cigarettes, alcohol, and medication,; and lifting, standing, and exposure to vibration at work.

The potential for a significant selection bias exists in this investigation. This bias would result from a possible difference in the rates of adverse outcomes among current and former employees. For example, one might expect a higher percentage of normal pregnancies among the former workers, resulting in their leaving the workforce to care for their children. The potential for this bias is of particular concern because virtually all the non-respondents in the study are former employees.

To assess the potential effect of a selection bias caused by the relatively low participation rate of former employees, we stratified the analysis by working status. The relative risk of adverse outcomes among former workers is slightly lower than that of the current workers, though the difference is not statistically significant (current: RR= 5.1; former: RR=3.4). To provide a conservative estimate of the effect of lack of information regarding 56% of the former workers, we made the following assumptions about the non-respondents: 1) that they experienced the same pregnancy rate as the former employees who did respond to either the mail or telephone survey; 2) pregnancies occurring to non-respondents who were not working at National Cover at the time of their pregnancies had the same rate of adverse outcomes as the former workers who participated in the study; and 3) that pregnancies which occurred to the non-respondents who were working at National Cover at the time of their pregnancies all resulted in normal births. In Table 14, the 61 pregnancies that would have been expected among women not working at National Cover have been distributed at the same rate as experienced by the study participants. Ten pregnancies would have been expected to occur to non-respondents who were working at National Cover. Assuming them all to have been normal yields a Relative Risk of 2.71, with a confidence limit which excludes 1.0. If our assumptions are valid, this is an estimate of the minimum true relative risk of adverse outcomes among women working in this plant.

VII. DISCUSSION

A. Environmental

The workers at National Cover Of Atlanta, Inc., Lawrenceville, Georgia, plant are exposed to a number of organic solvents during normal operations. Those workers in the Decoration area have somewhat higher exposures, since their use of the inks and solvents needed for screen printing are the sources of the contaminants. Inhalation exposures to individual compounds are generally below applicable criteria. However, combined exposures at some times approach the ACGIH TLV for mixtures. Also, skin contact can increase biological uptake, since most of these solvents are absorbed. The contribution to the body burden by this route is difficult to estimate.

Four of the compounds found in this environment are considered more toxic than the rest. These are p-dioxane, methyl chloroform, cellosolve acetate, and isophorone. NIOSH recommends that exposure to the three former compounds be reduced to the lowest feasible level, because of their carcinogenic potential (p-dioxane and methyl chloroform) or their potential to cause adverse reproductive effects (cellosolve acetate). Methyl chloroform and isophorone were the only two from this group consistently found outside of the Decoration area.

Some of the workers operating the RF heat sealers were over-exposed to the E-field component of the RF radiation. Many of the heat sealing machines had no shielding in place. Of those with shielding, some were only partially shielded or the shielding was in need of repair.

Efforts should be taken to control worker exposures to the mixture of organic solvents and both components of the RF radiation. The basic elements of control technology

which are implemented to minimize or eliminate hazards in the workplace are: (1) engineering controls; (2) environmental and medical monitoring; (3) training and education that results in effective work practices; and (4) personal protective equipment.

Engineering controls are preferred and include ventilation, enclosure or confinement of operations, substitution of hazardous agents, process modifications, and automation.

Engineering controls in-place at the time of the investigation for the purposes of organic vapor control consisted of a laboratory-type hood in the screenmaking room. This hood was exhausted through a canopy. The heating and cooling system at this plant used 100% recirculated air.

The primary engineering controls most applicable in the Decoration and Screenmaking areas are dilution and local exhaust ventilation, and product substitution. Product substitution means replacing currently used inks or solvents with those which are less toxic, or which are made up from less toxic components. Dilution ventilation, as the name implies, refers to dilution of contaminated air with uncontaminated air in a general area, room, or building for the purpose of health hazard or nuisance control. Local exhaust ventilation is used to control atmospheric contamination at its source.

In general, dilution ventilation is not as satisfactory for health hazard control as local exhaust ventilation. However, there are circumstances in which dilution ventilation must be used because the operation or process prohibits the application of local exhaust. Printing processes in general can be unfavorably affected by local exhaust systems because increased airflow close to the printing surface has an adverse effect on the application and drying of screenprinting inks.

In order to use dilution ventilation in an economic fashion, it should be applied to a volume as small as possible. In this plant it would be logical to segregate the decoration area from the adjacent areas by a barrier or wall. Then, a properly designed single-pass dilution system used in this area, with make-up air being drawn from the other plant areas, should be effective in minimizing exposures due to ink and solvent emissions from the printing machines.

Properly designed local exhaust hoods should be installed for the screen and soiled stock cleanup tasks, and the ink mixer work station in the decoration area. This would minimize fugitive solvent emissions from these sources. Also, workers who perform the cleanup jobs should be advised that wearing impermeable gloves can decrease exposure potential.

The ventilation system in the screen making room should be redesigned to include dilution air with enough excess to provide make-up air for proper operation of the laboratory hood there. The measured face velocity of 45 feet per minute (fpm) should be increased to a value between 100 and 150 fpm.

All RF heat sealing equipment should be properly shielded.

B. Medical/Epidemiologic

Epidemiologic analysis of the available questionnaire data confirm the occurrence of a significant cluster of adverse outcomes (spontaneous abortions and stillbirths) among women who became pregnant while employed at National Cover. Cross-sectional occupational studies of reproductive outcomes are subject to over-estimation of rates of adverse outcomes, since women whose pregnancies result in normal births often leave the workplace. Of the former workers eligible for the study, 44% participated. An analysis performed to estimate the potential bias caused by this relatively low participation rate revealed that the minimum true relative risk is still elevated.

VIII. CONCLUSIONS

The marked excess of adverse outcomes experienced by women employed at National Cover cannot be explained by a number of potential confounding factors. Nor can it be associated with working in specific departments within National Cover or job characteristics, such as posture and vibration. Levels of radiofrequency (RF) radiation were measured to be under the OSHA Permissible Exposure Limits (PEL's); however, 6 of 25 heat seal operators were determined to be exposed to E-field radiation above the ACGIH recommended levels. Although the levels of solvents are, on the whole, quite low and well within OSHA's PEL's, these legal standards do not take into consideration dermal exposure, which may be significant with organic solvents. In addition, they are based on evidence of the effects of the exposure considered individually and they do not consider more recent information regarding reproductive hazards, particularly of the glycol ethers. Little is known about the possible effects on reproduction of simultaneous exposure to a number of potential teratogens. Although the cluster of adverse outcomes reported here could have occurred by chance, in the absence of data regarding possible interactions of mixed exposures, it is not possible to rule out work-related exposures as a contributing factor.

For this reason, we believe that it would be prudent to decrease workers' exposure to solvents and radiofrequency radiation to the extent feasible. Toward this end, we make the following specific recommendations.

IX. RECOMMENDATIONS

A. Environmental

1. Product substitutions should be made, where possible, to eliminate potential exposures to organic vapor components of solvents and inks.

2. A contractor knowledgeable of industrial ventilation systems should be contracted to design a comprehensive ventilation system for the National Cover plant at Lawrenceville, Georgia. To be prudent, this system should provide properly distributed percentages of tempered outside air to all areas of the plant in accordance with the guidelines recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The decoration area should be enclosed and serviced by a single-pass dilution system, local exhaust hoods for the screen and soiled stock cleanup tasks, and the ink mixer work station, with make-up air provided from the adjacent plant areas. Similarly, the screen making room should have a dilution system and the local exhaust hood should be upgraded to provide proper airflow across the face of the hood. The decoration area and screen making room systems can be incorporated into one system. These areas should be kept negatively pressurized with respect to adjacent areas.

3. The manufacturer of your RF heat sealing equipment should be consulted concerning the proper design of shielding for your equipment. One such design is a segmented shielding arrangement similar to that illustrated in Figure 1. These shields, consisting of aluminum sheet connected to a phosphor bronze spring, should be fastened so that the spring makes electrical contact with the table top (ground plate) when the press is in the down position. The advantage of segmented shielding is twofold: (1) they can be repositioned on the existing die shield in a manner to accommodate the various mandrel configurations and (2) they will provide more effective containment of the RF energy, since these shields make electrical contact with the table top.

4. The recommendations for hazard control for RF energy sources in Appendix A should be followed.

B. Medical/Epidemiologic

1. Pending implementation of the environmental recommendations to reduce exposure to radiofrequency radiation, pregnant women and women who might become pregnant should be removed from work in the Heat-Sealing Department.

2. In order to assess more fully the possible reproductive hazards presented by exposure to the agents in this workplace, on-going surveillance is advisable. The pregnancy outcomes in this plant should continue to be monitored and further action be taken as warranted.

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XI. AUTHORSHIP AND ACKNOWLEDGEMENTS

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XII. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. National Cover of Atlanta, Inc.
   Lawrenceville, Georgia
2. Requestor
3. NIOSH Region IV
4. OSHA Regional Administrator, Region IV

TABLE 1

EVALUATION CRITERIA

National Cover of Atlanta, Inc.
Lawrenceville, Georgia

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Substance	Evaluation Criteria (ppm) NIOSH	OSHA	ACGIH	Primary Health Effects
Methyl ethyl ketone (2-Butanone)	200	200	200	This class of solvents may produce a dry, scaly, and fissured dermatitis after repeated exposure. High vapor concentrations may irritate the conjunctiva and mucous membranes of the nose and throat, producing eye and throat symptoms. Narcosis is also possible at high concentrations, with headache, nausea, light headedness, incoordination, and unconsciousness.[1,2]
1,1,1-Trichloroethane (Methyl Chloroform)	LFL	350	350	In 1976, NIOSH published a Criteria Document for a Recommended Standard for Occupational Exposure to 1,1,1-trichloroethane, recommending that exposures be controlled below a ceiling concentration of 350 ppm. This level was designed to prevent acute respiratory, eye, nose and throat irritation, and chronic effects on the central nervous system . In 1978, NIOSH published a Current Intelligence Bulletin (#27) which reviewed the toxicity of nine chloroethane compounds, four of which should be handled in the workplace as if they were human carcinogens. The CIB recommended caution in the use of 1,1,1-TCE because of its chemical similarity to the four chloroethane compounds designated as potential carcinogens. NIOSH recommends prudence in the use of this substance, including control of workplace exposures to the fullest possible extent.[3,4]
Methyl Isobutyl Ketone (Hexone)	50	100	50	May produce a dry, scaly, and fissured dermatitis following repeated exposure. High vapor concentrations may irritate the eyes, nose, and throat, and repeated exposure to high concentrations may produce symptoms of headache, nausea, light headedness, vomiting, and dizziness.[1,2]
Ethyl alcohol (Ethanol)	-----	1000	1000	The acute toxicity of ethanol is low for both animals and man. The commonly recognized signs of overexposure are ataxia, incoordination, and drowsiness. The inhalation of alcohol vapor causes local irritating effects on the eyes, headaches, sensation of heat, intraocular tension, stupor, fatigue, and a great need for sleep.[5]
Xylene	100	100	100	May cause irritation of the eyes, respiratory tract, and skin. High exposure may result in central nervous system depression and minor reversible effects upon the liver and kidneys.[5]
Ethyl acetate	-----	400	400	Overexposure to ethyl acetate may cause irritation of the eyes, nose, and throat. Severe overexposure may cause weakness, drowsiness, and unconsciousness. Prolonged overexposure may produce irritation of the skin.[6]
Acetone	250	1000	750	Inhalation of acetone vapor in high concentrations produces dryness of the mouth and throat, dizziness, nausea, incoordinated speech, drowsiness, and in extreme cases coma. Inhalation of small quantities of acetone vapor over long periods causes irritation of the respiratory tract, coughing, and headache.[2,5]
Isophorone	4	25	(C)5	Exposure to high concentrations (> 40 ppm) of isophorone may cause eye, nose, and throat irritation, nausea, headache, dizziness, faintness, inebriation, and a feeling of suffocation. Prolonged exposure to low concentrations of isophorone may cause fatigue and malaise.[5]

(cont.)

TABLE 1 (cont.)

Substance	Evaluation Criteria (ppm) NIOSH	OSHA	ACGIH	Primary Health Effects
2-Ethoxyethylacetate (Cellosolve Acetate)	LFL	100	5	In 1983 NIOSH published Current Intelligence Bulletin 39 which reviewed the toxicity of the glycol ethers 2-methoxyethanol and 2-ethoxyethanol. NIOSH recommended that these substances be regarded in the workplace as having the potential to cause adverse reproductive effects in male and female workers. These recommendations were based the results of several studies that demonstrated dose-related embryotoxicity and other reproductive effects in several species of animals exposed by several different routes of administration. Exposures of pregnant animals to concentrations of 2ME or 2EE at or below their respective OSHA PEL's led to increased incidences of of embryonic death, teratogenesis, or growth retardation. Exposure of male animals resulted in testicular atrophy and sterility. NIOSH urges employers to reduce exposures to 2ME and 2EE to the lowest extent possible. The CIB recommended caution in the use of other structurally related glycol ethers, including 2-ethoxyethylacetate. Preliminary test results indicate that they also have the potential for causing adverse reproductive effects similar to 2ME and 2EE. NIOSH recommends that worker exposure to these structurally related glycol ethers be controlled to the fullest possible extent.[7]
p-Dioxane	LFL	100	(C)25	In 1977 NIOSH published Criteria for a Recommended Standard .... Occupational Exposure to Dioxane (DHEW (NIOSH) publication no. 77-226). In this document, NIOSH concluded that dioxane may penetrate intact skin to cause systemic effects including renal and hepatic changes. Dioxane was also found to be a potential occupational carcinogen. NIOSH recommends that exposure to dioxane be controlled to the lowest feasible level.[8]

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TABLE 2
PERSONAL SAMPLE RESULTS
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 25, 1986

Job	Volume (liters)	Concentration (ppm) Ethanol	Acetone	2-Butanone (MEK)	Ethyl Acetate	Methyl Chloroform	p-Dioxane	Hexone (MIBK)	Xylene	Cellosolve Acetate	Isophorone	TLV of Mixture
Supervisor	26.6	43.0	44.2	0.2	1.6	5.6	0.20	0.21	12.2	t 0.06	0.4	0.4
Lead	24.5	87.0	34.7	0.6	2.6	118.1	3.89	0.33	10.4	t 0.06	0.4	0.8
Stamper	24.7	18.5	41.5	0.2	0.8	3.4	0.12	0.12	10.5	t 0.06	0.3	0.3
Mixer	24.4	39.8	106.1	0.2	2.1	9.2	0.33	0.27	24.3	0.08	0.4	0.6
Operator, #5	25.2	43.2	58.9	0.4	1.6	7.5	0.28	0.21	15.0	0.11	1.2	0.6
Inspector, #1	23.6	77.9	62.3	0.4	5.1	5.4	0.20	0.53	15.2	0.09	1.1	0.6
Lead	22.6	18.9	58.8	0.2	0.8	3.4	0.15	0.11	13.8	t 0.07	0.4	0.4
Operator, #4	23.5	25.1	52.9	0.2	0.8	5.4	0.16	0.12	14.3	t 0.07	0.4	0.4
Inspector, #4	24.1	15.4	23.0	0.2	0.5	2.4	t 0.10	t 0.08	7.3	ND	0.2	0.2
Inspector, #5	24.0	4.6	102.6	0.2	2.3	3.0	0.12	0.27	23.7	0.18	1.2	0.7
Operator, #1	24.3	19.7	57.0	0.4	1.0	3.1	t 0.11	0.15	14.2	0.14	0.6	0.4
Operator, #2	23.7	49.2	47.8	0.2	3.0	2.7	t 0.10	0.31	13.1	t 0.06	0.3	0.4
Operator, #6	23.7	19.0	47.0	0.2	0.8	3.3	0.13	0.12	10.4	t 0.05	0.3	0.3
Inspector, #2	23.0	43.8	53.8	0.2	2.4	2.4	t 0.09	0.25	12.9	t 0.05	0.4	0.4
Operator, #3	22.8	18.5	21.1	0.2	0.5	3.5	0.14	t 0.09	6.4	ND	0.2	0.2
Inspector, #3	22.5	13.9	21.6	0.2	0.5	2.4	t 0.10	t 0.08	6.6	ND	0.2	0.2
Green Maker	16.2	24.9	31.1	0.0	0.7	1.5	ND	t 0.11	9.5	ND	0.2	0.2
Criteria:	NIOSH	----	250	200	---	LFL	LFL	50	100	LFL	5	
	OSHA	1000	1000	200	400	350	100	100	100	100	25	
	ACGIH	1000	750	200	400	350	25(C)	50	100	5	5(C)	<1.0

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TABLE 3
PERSONAL SAMPLE RESULTS
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 26, 1986

Job	Volume (liters)	Concentration (ppm)										TLV of Mixture
		Ethanol	Acetone	2-Butanone (MEK)	Ethyl Acetate	Methyl Chloroform	p-Dioxane	Hexone (MIBK)	Xylene	Cellosolve Acetate	Isophorone	
Supervisor	25.2	22.9	20.6	ND	0.6	2.3	t 0.10	0.10	7.7	t 0.05	0.2	0.2
Stamper	23.8	30.5	31.9	0.2	0.7	71.3	2.58	0.11	8.5	ND	0.2	0.5
Mixer	24.7	28.2	154.1	0.2	0.8	4.2	0.16	0.11	27.0	0.17	0.5	0.7
Lead	23.9	34.5	31.8	ND	1.2	2.6	t 0.11	0.14	10.0	t 0.06	0.3	0.3
Inspector, #5	23.9	31.6	38.4	ND	1.1	4.7	0.19	0.14	12.7	0.26	0.9	0.5
Operator, #5	24.7	34.2	45.4	ND	0.9	4.3	0.18	0.13	14.2	0.23	0.8	0.5
Inspector, #4	25.2	57.8	24.2	ND	2.8	2.8	0.12	0.27	8.5	t 0.06	0.3	0.3
Operator, #4	24.7	26.7	37.2	ND	0.7	2.8	0.12	t 0.10	8.2	t 0.05	0.2	0.2
Operator, #2	12.2	48.5	48.4	ND	1.3	3.8	t 0.15	t 0.18	17.0	ND	0.3	0.4
Inspector, #2	23.7	49.0	73.5	ND	1.7	10.3	0.38	0.18	15.3	t 0.07	0.3	0.4
Inspector, #1	23.7	53.1	29.0	ND	2.2	5.9	0.23	0.24	9.1	t 0.07	0.3	0.3
Operator, #1	24.3	53.1	38.7	ND	2.4	4.3	0.18	0.25	11.5	0.08	0.3	0.3
Operator, #6	23.6	20.5	21.7	ND	0.6	2.3	0.12	t 0.09	8.3	t 0.05	0.2	0.2
Inspector, #3	22.2	13.0	14.7	ND	0.3	2.0	t 0.12	t 0.07	5.7	ND	0.2	0.1
Operator, #3	25.6	14.2	33.3	ND	0.5	2.1	t 0.09	t 0.08	9.9	t 0.05	0.2	0.2
Screen Maker	24.4	16.4	16.6	ND	0.8	1.6	t 0.08	t 0.06	7.5	ND	0.2	0.2
Criteria:	NIOSH	----	250	200	---	LFL	LFL	50	100	LFL	5	
	OSHA	1000	1000	200	400	350	100	100	100	100	25	
	ACGIH	1000	750	200	400	350	25(C)	50	100	5	5(C)	<1.0

TABLE 4
PLANT AVERAGE PERSONAL EXPOSURES
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 25-26, 1986

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Substance	n	—Concentration, ppm— February 25	February 26	—Criteria, ppm— NIOSH	OSHA	ACGIH
p-Dioxane	16	0.39	0.31	LFL	100	25(C)
Cellosolve Acetate	13	0.08	0.10	LFL	100	5
Isophorone	17	0.5	0.3	5	25	5(C)
Methyl Chloroform	17	10.7	8.0	—	350	350
Ethanol	17	33.1	33.4	—	1000	1000
Acetone	17	50.9	41.2	250	1000	750
2-Butanone	17	0.2	0.2*	200	200	200
Ethyl Acetate	17	1.6	1.2	—	400	400
Hexane	17	0.20	0.14	50	100	50
Xylene	17	12.9	11.3	100	100	100

ppm - parts per million

* - n=2

TABLE 5
PERSONAL EXPOSURE SUMMARY BY JOB
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 25-26, 1986

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Job Category	n	Concentration (ppm) p-Dioxane Range	p-Dioxane Mean	Cellosolve Acetate Range	Cellosolve Acetate Mean	Isophorone Range	Isophorone Mean	Methyl Chloroform Range	Methyl Chloroform Mean	TLV of Mixture Range	TLV of Mixture Mean
February 25											
Supervisor	1	-----	0.20	-----	t0.06	-----	0.4	-----	5.6	-----	0.4
Lead	2	0.15-3.89	2.02	t0.06-0.07	t0.07	-----	0.4	3.4-118	60.7	0.4-0.8	0.6
Operator	6	t0.10-0.28	0.15	ND-0.14	0.09	0.2-1.2	0.5	2.7-7.5	4.3	0.2-0.6	0.4
Inspector	5	t0.10-0.20	0.12	ND-0.18	0.11	0.2-1.2	0.6	2.4-5.4	3.1	0.2-0.7	0.4
Mixer	1	-----	0.30	-----	0.08	-----	0.4	-----	9.2	-----	0.6
Screen Maker	1	-----	ND	-----	ND	-----	0.2	-----	1.5	-----	0.2
Stamper	1	-----	0.10	-----	t0.06	-----	0.3	-----	3.4	-----	0.3
Criteria	NIOSH		LFL		LFL		5		---		---
	OSHA		100		100		25		350		---
	ACGIH		25(C)		5		5(C)		350		<1

(continued)

Table 5 (continued)

Job Category	n	Concentration (ppm) p-Dioxane Range	p-Dioxane Mean	Cellosolve Acetate Range	Cellosolve Acetate Mean	Isophorone Range	Isophorone Mean	Methyl Chloroform Range	Methyl Chloroform Mean	TLV of Mixture Range	TLV of Mixture Mean
February 26											
Supervisor	1	----	t0.10	----	t0.05	----	0.2	----	2.3	----	0.2
Lead	1	----	t0.11	----	t0.06	----	0.3	----	2.6	----	0.3
Operator	6	t0.09-0.18	0.10	ND-0.23	0.09	0.2-0.8	0.3	2.1-4.3	3.3	0.2-0.5	0.3
Inspector	5	t0.12-0.38	0.20	ND-0.26	0.11	0.2-0.9	0.4	2.0-10.3	5.1	0.1-0.5	0.3
Mixer	1	----	0.20	----	0.17	----	0.5	----	4.2	----	0.7
Screen Maker	1	----	t0.08	----	ND	----	0.2	----	1.6	----	0.2
Stamper	1	----	2.6	----	ND	----	0.2	----	71.3	----	0.5
Criteria	NIOSH		LFL		LFL		5		---		---
	OSHA		100		100		25		350		---
	ACGIH		25(C)		5		5(C)		350		<1

ppm - parts per million
t - values prefixed with a "t" are values between the analytical limit of detection (LOD) and limit of quantitation (LOQ)
ND - none detected, values below the analytical LOD

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TABLE 6
SHORT-TERM PERSONAL SAMPLE RESULTS
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 26, 1986

Job	Sample Duration	Volume (liters)	Concentration (ppm) Ethanol	Acetone	Ethyl Acetate	Methyl Chloroform	p-Dioxane	HEXONE (MIBK)	Xylene
Vinyl Clean	T 0935-0941	1.5	547.3	12.9	11.3	123.9	3.5	1.7	6.7
Screen Cleanup	T 1117-1128	2.1	138.2	961.1	3.8	1.2	ND	ND	138.2
Screen Cleanup	T 1430-1440	1.5	23.9	680.4	0.0	6.9	ND	ND	84.2
	Criteria: NIOSH		----	----	----	LFL	LFL	---	200
	OSHA		----	----	----	---	----	---	---
	ACGIH		----	1000	----	450	25(C)	75	150

The following definitions apply to Tables 2, 3, and 6:

ppm - parts per million

t (trace) - a value between the analytical Limit of Detection (LOD) and the Limit of Quantitation (LOQ)

ND - none detected, a value below the analytical LOD

LOD - 10 micrograms per sample (ug/sample) for ethanol, and methyl chloroform
5 ug/sample for all other compounds

LOQ - 20 ug/sample for ethanol, and methyl chloroform
10 ug/sample for all other compounds

C - ceiling exposure value

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TABLE 7
AREA SAMPLE RESULTS
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 25, 1986

Area	Volume (liters)	Concentration (ppm)						
		Ethanol	Acetone	Ethyl Acetate	Methyl Chloroform	p-Dioxane	Xylene	Isophorone
Pre-pressed, central	22.1	15.8	19.6	0.7	1.7	ND	6.3	0.2
Pre-pressed, east wall	23.4	15.3	21.2	0.6	1.8	t 0.07	6.5	0.2
Production, break area	22.5	15.5	20.1	0.5	1.7	ND	6.1	0.2
Turned-edge	22.1	16.7	21.1	0.5	2.5	t 0.09	6.4	0.2
Die cutter	21.9	18.2	20.7	0.6	9.9	0.42	6.7	0.2
Board cutter	21.4	16.1	21.5	0.5	2.5	t 0.10	6.9	0.2
Assembly, finishing	21.5	17.0	22.1	0.6	2.6	t 0.09	7.1	0.2
Heat sealer, 87	23.9	19.1	25.6	0.6	3.0	t 0.11	7.7	0.3
Office, 81 (NW)	22.3	14.3	20.1	0.5	1.6	t 0.07	7.0	0.2
Office, 82 (SE)	21.3	13.7	19.0	0.5	1.5	ND	6.1	0.2
Office, 83 (SW)	21.8	10.8	15.8	0.4	1.4	ND	5.7	0.1
Office, break area	23.9	16.0	22.0	0.6	1.7	t 0.07	7.4	0.2

ppm - parts per million

t (trace) - a value between the analytical Limit of Detection (LOD) and the Limit of Quantitation (LOQ)

ND - none detected, a value below the analytical LOD

LOD - 10 micrograms per sample (ug/sample) for ethanol, and 1,1,1-trichloroethane
5 ug/sample for all other compounds

LOQ - 20 ug/sample for ethanol, and 1,1,1-trichloroethane
10 ug/sample for all other compounds

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TABLE 8
AREA SAMPLE RESULTS
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
FEBRUARY 26, 1986

Area	Volume (liters)	Concentration (ppm) Ethanol	Acetone	Ethyl Acetate	Methyl Chloroform	p-Dioxane	Xylene	Isophorone
Pre-pressed, east wall	23.8	12.3	13.1	1.6	1.6	ND	5.4	0.1
Pre-pressed, central	22.4	11.7	12.0	0.6	1.5	ND	5.1	0.1
Production, break area	23.3	11.3	12.8	0.4	1.7	t 0.07	5.3	0.1
Assembly, ring attach	23.0	10.6	14.0	0.4	2.2	t 0.10	6.3	0.2
Board cutter	23.2	14.0	15.0	0.5	2.2	t 0.11	6.2	0.2
Turned-edge	24.4	12.4	13.9	0.4	2.6	t 0.11	5.8	0.2
Die cutter/flow mold	23.6	14.3	15.0	0.4	2.0	t 0.8	6.2	0.2
Heat sealer, 018	24.9	18.8	18.3	0.6	2.6	0.11	7.4	0.2
Office, 01 (NW)	24.7	10.0	12.1	0.3	1.4	t 0.07	5.5	0.2
Office, 02 (SE)	24.2	9.7	11.2	0.3	1.3	t 0.06	4.8	0.1
Office, 03 (NE)	24.0	8.1	9.1	0.3	1.0	ND	4.2	0.1
Office, break area	27.1	10.4	11.9	0.3	1.4	t .0.06	5.4	0.2

ppm - parts per million

t (trace) - a value between the analytical Limit of Detection (LOD) and the Limit of Quantitation (LOQ)

ND - none detected, a value below the analytical LOD

LOD - 10 micrograms per sample (ug/sample) for ethanol, and 1,1,1-trichloroethane
5 ug/sample for all other compounds

LOQ - 20 ug/sample for ethanol, and 1,1,1-trichloroethane
10 ug/sample for all other compounds

TABLE 9
COMBINED AREA SAMPLE RESULTS
NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
HETA 86-051 FEBRUARY 25-26, 1986

Area	n	Concentration (ppm) Ethanol	Acetone	Ethyl Acetate	Methyl Chloroform	Xylene	Isophorone
February 25							
Pre-pressed	2	15.5	20.4	0.6	1.7	6.4	0.2
Production	6	17.1	21.9	0.5	3.7	6.8	0.2
Office	4	13.7	19.2	0.5	1.6	6.5	0.2
February 26							
Pre-pressed	2	12.0	12.5	1.1	1.5	5.3	0.1
Production	6	13.5	14.8	0.4	2.2	6.2	0.2
Office	4	9.6	11.1	0.3	1.3	5.0	0.1

ppm - parts per million

TABLE 10
RF RADIATION MEASUREMENTS: HEAT SEAL DEPARTMENT
NATIONAL COVER OF ATLANTA, INC
LAWRENCEVILLE, GEORGIA
FEBRUARY 25-26, 1986
HETA 86-051

Electric (E) and Magnetic (H) Field Strength Measurements

		Head		Waist		Knee	
Location		V^2/m^2	A^2/m^2	V^2/m^2	A^2/m^2	V^2/m^2	A^2/m^2
H.S. #1	left:	15000	0.004	1500	0.004	1000	0.010
	right:	5000	0.010	500	0.020	2000	0.012
H.S. #2	left:	3500	0.007	700	0.010	50	0.010
	right:	700	0.002	350	0.002	100	0.005
H.S. #2	left:	700	0.003	350	0.004	140	0.007
	right:	7000	0.010	700	0.007	70	0.009
H.S. #3	left:	1750	0.005	250	0.005	100	0.005
	right:	150	0.005	100	0.005	150	0.005
H.S. #3	left:	500	0.001	200	0.002	150	0.001
	right:	1000	0.005	500	0.001	500	0.004
H.S. #4	left:	5600	0.002	625	0.001	1875	0.001
	right:	250	0.001	156	0.001	312	0.001
H.S. #4	left:	500	0.009	940	0.004	625	0.009
	right:	1560	0.004	1250	0.004	312	0.019
H.S. #5	left:	50	0.0004	80	0.0004	60	0.0004
	right:	560	0.0004	240	0.001	50	0.001
H.S. #6	left:	2800		350		140	
	right:	315		175		210	
H.S. #6	left:	700		35		105	
	right:	2800		350		35	
H.S. #7	left:	26800	0.012	670	0.010	3015	0.020
	right:	1005	0.013	1005	0.010	1005	0.017
H.S. #8	left:	60	0.004	90	0.005	60	0.001
	right:	60	0.006	60	0.0003	60	0.0006
H.S. #9	left:	60	0.0002	25	0.0002	25	0.0002
	right:	175	0.0002	100	0.0006	25	0.0002

Criteria: OSHA $E^2 = 40{,}000\ V^2/M^2$
$H^2 = 0.25\ A^2/M^2$

ACGIH* $E^2 = 4654\ V^2/M^2$
$H^2 = 0.033\ A^2/M^2$
*f = 27 MHZ

(cont.)

TABLE 10 (cont.)
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Electric (E) and Magnetic (H) Field Strength Measurements

Location		Head		Waist		Knee	
		V^2/m^2	A^2/m^2	V^2/m^2	A^2/m^2	V^2/m^2	A^2/m^2
H.S. #10	left:	60	0.0003	30	0.0006	30	0.0003
	right:	180	0.0004	60	0.0006	30	0.0004
H.S. #12	left:	2700	0.004	225	0.007	225	0.011
	right:	2700	0.004	450	0.004	450	0.007
H.S. #14	left:	1350	0.004	225	0.004	450	0.009
	right:	1800	0.018	180	0.009	450	0.014
H.S. #15	left:	500	0.008	375	0.001	500	0.004
	right:	1000	0.0008	75	0.002	375	0.002
H.S. #16	left:	13400	0.013	300	0.013	16700	0.013
	right:	11700	0.007	335	0.010	10000	0.020
H.S. #18	left:	205	0.001	205	0.001	260	0.001
	right:	1540	0.001	410	0.003	100	0.003
H.S. #18	left:	2050	0.001	500	0.003	500	0.009
	right:	260	0.002	205	0.002	100	0.006
H.S. #18	left:	205	0.001	250	0.001	1025	0.004
	right:	205	0.001	205	0.002	600	0.004
H.S. #19	left:	120	0.0008	40	0.0008	240	0.001
	right:	320	0.0008	80	0.0008	158	0.002
H.S. #19	left:	80	0.0008	80	0.001	120	0.002
	right:	80	0.0008	80	0.0008	240	0.0008
H.S. #21	left:	1200	0.002	120	0.001	120	0.004
	right:	3600	0.006	1800	0.012	1200	0.010
H.S. #21	left:	8400	0.001	1800	0.002	2400	0.002
	right:	1200	0.002	480	0.004	3000	0.002

Criteria: OSHA $E^2 = 40{,}000\ V^2/M^2$
$H^2 = 0.25\ A^2/M^2$

ACGIH* $E^2 = 4654\ V^2/M^2$
$H^2 = 0.033\ A^2/M^2$
*f = 27 MHZ

TABLE 11

PREGNANCY OUTCOMES AMONG WOMEN WORKING AT NATIONAL COVER (1983-1986)

NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
APRIL 1-2, 1986

HETA 86-051

	Single Live Birth	Twins	Spont. Abort.	Still-Birth	Therap. Abort.	Ectopic Preg.	Molar Preg.	Current Preg.	TOTAL
At Home	138	0	18	2	5	1	0	0	164
Working - Not at NC	47	1	4	1	1	4	0	1	59
Working - At NC	7	0	7	1	0	1	1	3	20
TOTAL	192	1	29	4	6	6	1	4	243

PREVALENCE OF ADVERSE OUTCOMES (Adverse outcomes/Normal births + adverse outcomes):

where: "Normal" birth = single live births
Adverse outcome = spontaneous abortions and stillbirths

At home: 20/158 = .126

Working - not at NC: 5/52 = .096

Working - at NC: 8/15 = .533

Prevalence Rate Ratio: $\frac{\text{Working at NC}}{\text{Others}} = \frac{8/15}{25/210}$ 4.48 (95% C.I.: 2.29, 8.78)

TABLE 12

MATERNAL AGE AT TIME OF PREGNANCY BY WORKING STATUS

NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
APRIL 1-2, 1986

HETA 86-051

	N	AGE	S.D.	t-test p value
At Home:				
Normal births	138	21.6	5.3	.64
Adverse outcomes	20	20.8	6.7	
Working - not at NC:				
Normal births	47	21.2	3.4	.32
Adverse outcomes	5	22.8	3.3	
Working - at NC:				
Normal births	7	21.3	2.1	.11
Adverse outcomes	8	23.4	2.1	

TABLE 13

PREGNANCIES OCCURRING TO WOMEN EMPLOYED AT NATIONAL COVER
BY DEPARTMENT

NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
APRIL 1-2, 1986

HETA 86-051

	Heat Sealing	Turned Edge	Screen-making	Art	Assembly	Cutting	Decoration	Office
Normal Births	2.3*	1.3*	0	0	0.3*	0	2	1
Adverse Outcomes	1	2	0	1	2	0	0	2

* 1 person working in heat sealing, turned edge, assembly

TABLE 14

ESTIMATION OF EFFECT OF POSITIVE RESPONSE BIAS

NATIONAL COVER OF ATLANTA, INCORPORATED
LAWRENCEVILLE, GEORGIA
APRIL 1-2, 1986

HETA 86-051

ASSUMPTIONS:

1. Non-respondents experienced same pregnancy rate as responding former employees.

2. Pregnanacies occurring to non-respondents not working at National Cover had same rate of adverse outcomes as responding former employees.

3. Pregnancies occurring to non-respondents working at National Cover were all normal.

	Pregnant While Working at NC			Pregnant While Working at NC	
	Yes	No		Yes	No
Adverse Outcomes	8 + 0	25 + 7	==	8	32
Normal Births	7 + 10	185 + 54		7	239

Relative Risk: 2.7
(95% CI: 1.4, 5.4)
(p=0.0002)

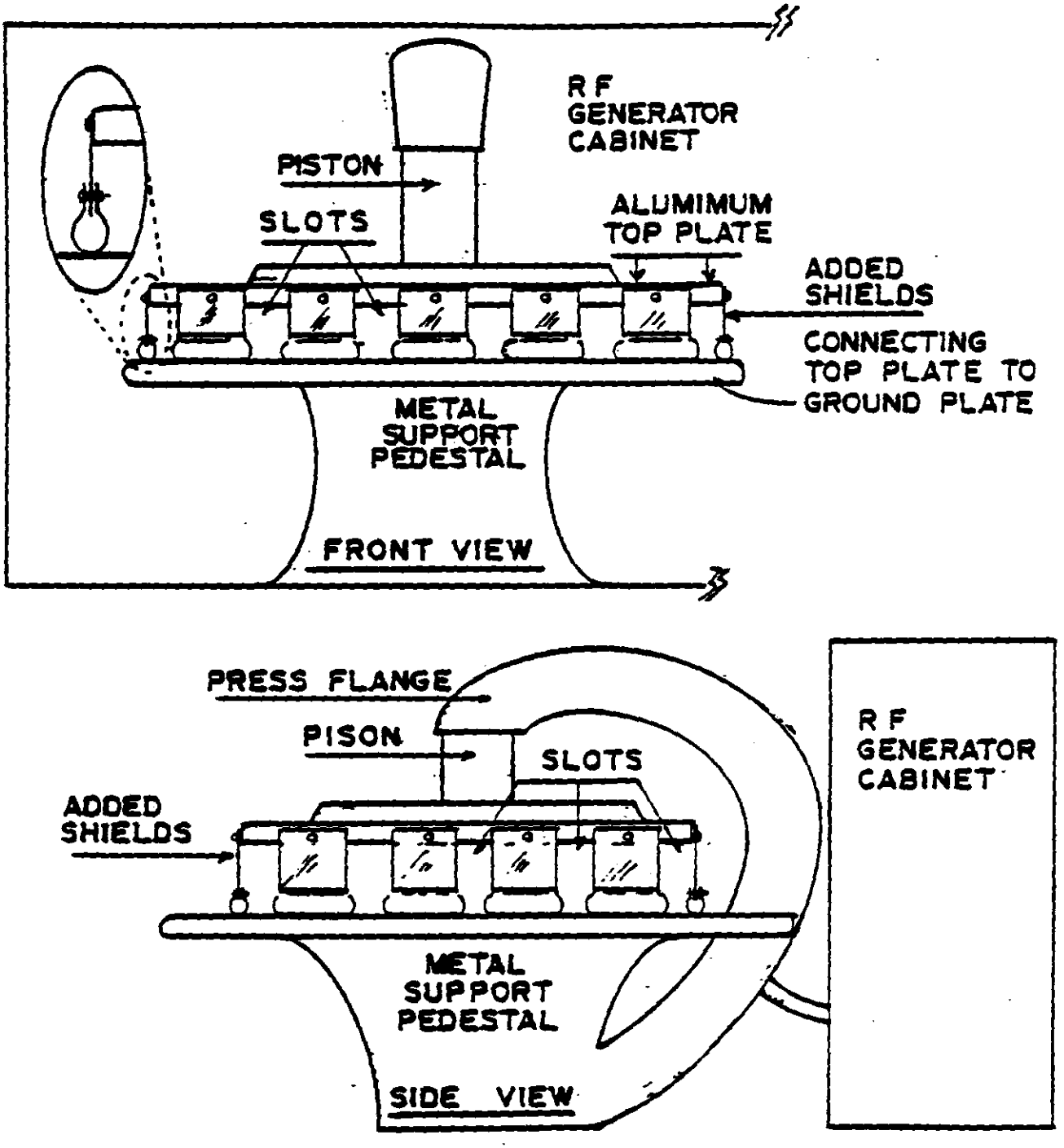

FIGURE 1. Phosphor-bronze spring shielding

APPENDIX A

Recommendations for RF Hazard Control

Immediate Actions

Control of the emission of RF energy from RF sealers and heaters should rely on the application of properly designed and installed shielding material. The shielding should be placed on or around the equipment so as to minimize occupational exposure due to emissions of stray RF energy. All shielding material should be properly grounded. Shielded conductors should be used for conveying RF current, and path impedance should be minimized by using good conductor materials.

The distance between the worker and the source of RF energy emission should be maximized. Examples of means to accomplish this include the use of automatic feeding divices, rotating tables, and remote materials handling.

The RF sealing and heating equipment should be electronically tuned to minimize the stray power emitted.

Whenever possible, equipment should be switched off when not being used. Maintenance and adjustment of the equipment should be performed only while the equipment is not in operation.

After the performance of maintenance or repair, all machine parts, including cabintry, should be reinstalled so that the equipment is intact and its configuration is unchanged.

Warnings and Information

Access to the vicinity of RF sealers and heaters where there may be stray RF energy should be limited as much as possible to the operator and necessary assistants, maintenance personnel, and industrial hygiene or safety personnel. Use of the RF equipment should be restricted to properly trained personnel.

Areas in which exposures to RF energy have been determined to be appreciable should be posted. Any signs should be of such size as to be recognizable and readable from a distance of three meters. All warning signs must be printed in English and in the predominant languages of non-English-reading workers, and should conform to the desing recommended by OSHA.

Areas in which the RF energy is present at levels higher than the permissible exposure limit also should be posted. The warning signs should contain the following additional information: HAZARD -- DO NOT ENTER. The sign must be readable from a distance of three meters. The perimeter of the restricted area should be clearly demarcated with signs visible to all personnel approaching the area.

Medical Monitoring

A medical surveillance program, tailored to the expected degree of employee use of RF equiment and potential for exposure to RF energy, should be developed. The program should include preplacement examination of all new employees and an initial examination of all present employees subject to occupational exposure to RF energy, annual examinations should be considered for workers who may be exposed to RF energy on a regular, long-term basis. Work histories should be included in all examinations.

Medical histories and physical examinations should have particular emphasis upon target organs potentially affected by RF energy including the eye (cataracts), the central nervous system, the blood (decreased leukocyte count), the immune defense system, and the reproductive system. Adverse reproductive effects may involve both maternal and paternal exposure. For persons occupationally exposed to RF energy, medical records including health and work histories should be maintained throughout the period of employment and for an extended period after termination of employment.

Exposure Measurements

Areas in the occupational environment where levels of RF energy have been determined to be appreciable should be surveyed at regular intervals. Immediately following a physical or electronic alteration of the equipment or an alteration in the process, a complete survey should also be performed. If measurments taken during a survey indicate that occupational exposure exceeds the permissible exposure limit, a second survey should be made on the next workday. If the limit is still exceeded, the use of RF equipment producing excessive values should be prohibited until appropriate controls have been instituted. The survey data sheets should contain all information pertaining to the survey, and should include the date and time of measurement, the type of monitoring equipment used, the employees' names, and the remedial actions taken, if any. These records should be maintained for an extended period of time.