NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #99-0343-2882
Thomas Steel Strip Corporation
Warren, Ohio

November 2002

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (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 (OSHA) 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 or 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.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Christina C. Lawson, Ph.D. of Industrywide Studies Branch (IWSB), Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Donald Booher and Kevin L. Dunn. Analytical support was provided by Ardith Grote, DART. Desktop publishing was performed by Pat Lovell. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Exposures among Electroplated Steel Strip Workers

This NIOSH Health Hazard Evaluation (HHE) was requested by a representative of United Steelworkers of America Local 3523 to evaluate an apparent cluster of hypoplastic left heart syndrome among offspring of male workers employed in the Finishing Department at Thomas Steel Strip Corporation (TSS), Warren, Ohio.

What NIOSH Did

- We interviewed employees, evaluated medical records of cases, and obtained birth data from insurance records.
- We collected air samples for metals, organic solvents, plating solutions, a rust inhibitor, and ionizing radiation. We analyzed drinking water samples for selected analytes.
- We analyzed wipe samples from employees' hands, shoes, automobiles, and clothing for metals analysis.

What NIOSH Found

- We confirmed four severe heart defects; three in children born in 1998 and one born in 1993. Four additional, less severe, heart defects were identified in children born in 1996, 1998, and 1999.
- The rate of severe heart defects among children born to employees in 1998 was 21.4%, which compares to regional surveillance rates of 0.01%-0.04%.
- Airborne concentrations of all metals were well below established exposure criteria, except one breathing zone sample for nickel dust.
- Particulate cyanide levels were elevated, possibly resulting from overheating of the cyanide-containing plating bath.
- Analyses of the rust inhibitor, four organic solvents, drinking water, and whole body radiation were all unremarkable.
- Patch samples affixed to work clothes detected very low but measurable concentrations of metals. Automobile wipe samples indicated higher levels of copper, iron, nickel, and zinc from production employees than from administrative employees.

What TSS Managers Can Do

- Cyanide bath temperatures should be kept at process design levels.
- Employees should be trained in the need to practice good personal hygiene to minimize the potential for take-home exposures.
- Continue to monitor occurrence of birth defects among TSS employees.

What TSS Employees Can Do

- Shower and change work clothes and work shoes prior to leaving the plant at the conclusion of the work shift. Wash work clothes separately from family clothes.
- Wash hands before eating or smoking and at the conclusion of the work shift. Avoid eating meals near work operations.
- Notify employer of any future birth defects.

CDC Workplace Safety and Health

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National Institute for Occupational Safety and Health NIOSH

Health Hazard Evaluation Report 99-0343-2882
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SUMMARY

In September 1999, an authorized representative of Local 3523, United Steelworkers of America, asked NIOSH to evaluate an apparent cluster of hypoplastic left heart syndrome among offspring of three male workers employed at Thomas Steel Strip (TSS) Corporation, Warren, Ohio. Two of the three male employees worked in the Finishing Department. Workers in this department were exposed to nickel, copper, iron, and zinc dusts, as well as to a dust of another metal designated by TSS as a trade secret (heretofore referred to as "TS metal.") TSS advised NIOSH as to the identity of this metal. Workers in this department were also exposed to a rust inhibitor that was applied to the electroplated strip steel.

Medical records of heart defect cases born in 1998 were obtained and reviewed by NIOSH. To calculate a rate of birth defects among all TSS employees, insurance claims information was collected and analyzed. Rates were calculated separately for employees who worked in the Finishing Department during the prenatal period and those who did not.

Airborne concentrations of the following substances were measured in the Finishing Department: (1) nickel, zinc, copper, iron, and a trade secret metal (TS Metal); (2) the active ingredient in the rust inhibitor, 2,6-di-t-butyl-4-methylphenol (2 BHT); and (3) organic solvents. Workers in the Finishing Department had reported that they periodically pass through the Old Plating Department en route to their jobs. Therefore, airborne concentrations were obtained in the Old Plating Department for hydrochloric acid, sulfuric acid, nitric acid, sodium hydroxide, hexavalent chromium, ammonia, and cyanide. In addition, hand wipe samples, shoe wipe samples, and cotton pad samples (affixed to the workers' shirt and trousers) were obtained and analyzed for the five metals. The intent of this sampling effort was to assess the potential for metals to be transported from the workplace to the worker's car and home. Wipe samples for metals analyses were also obtained in defined locations within the automobiles of several workers employed in the Finishing Department. Control samples from the automobiles of workers employed outside of the Finishing Department were also obtained. Ionizing radiation measurements were obtained in and around Finishing Department work stations to evaluate potential doses from radioactive sources used in connection with the steel strip gauging systems. Water samples were obtained at drinking fountains near the Finishing and Old Plating Departments. Levels of selected substances found in samples from these locations were compared with levels found in samples taken from two off-site locations, one approximately 10 miles from TSS, another from Cincinnati.

Three major heart defects in children born in 1998 to TSS employees were confirmed, and one major heart defect in a child born in 1993 was confirmed. Four additional, less severe, heart defects were identified in children born in 1996, 1998, and 1999. The rate of severe heart defects among validated TSS births was 21.4%, and the rate of all identified heart defects among validated TSS births for 1998 was 27.8%. These rates are higher than other regional data, which show approximately 1% of live births to have major heart defects.

Airborne levels for four of the five metals of interest, as well as airborne levels of four organic solvents, were below the NIOSH recommended exposure limit (REL). One personal exposure measurement to nickel dust was above the NIOSH REL. Patch and wipe samples for several metals showed higher levels in TSS

employees compared to NIOSH control samples. Automobile wipe samples obtained from the floor and seat locations on the driver's side indicated measurable levels of copper, iron, nickel, and zinc. These levels were higher in automobiles of production employees than in automobiles of administrative employees. Thus, there is a potential for metals to be taken into the homes of workers, which may pose a risk to family members. However, the health significance of these metal levels is not known. Results of ionizing radiation measurements indicated that radiation doses are at or near background levels at the operator position of the Finishing Department work stations. Comparison of levels of selected analytes found in production area drinking water samples with those obtained at off site locations indicated no major differences in level or content. Levels that were found were well below maximum contaminant levels set by the Environmental Protection Agency.

Levels of environmental contaminants were unremarkable. In consideration of the current state of knowledge regarding known reproductive toxicants, it is concluded that the cluster cannot be clearly linked with these exposures. Recommendations regarding personal hygiene practices among TSS employees are in the Recommendations section of this report. In addition, temperature control of the cyanide-containing plating baths should be kept at process design levels.

Keywords: SIC Codes 3316 (Cold-rolled steel sheet, strip, and bars), Electroplating, Birth Defects, Cluster

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INTRODUCTION

On September 15, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the United Steelworkers of America (USWA) local 3523 union at Thomas Steel Strip Corporation (TSS). The request concerned an apparent cluster in 1998 of congenital heart defects among children of three male employees.

BACKGROUND

Thomas Steel Strip Corporation (TSS) produces electroplated strip steel for electrical applications, ordnance manufacture, and home appliances. Low carbon steel is received from an outside vendor in coil form. The steel strip is passed through pickling and rinse processes to remove metal scale, then passed through a cold rolling mill to obtain the desired thickness. The rewound roll is then brought to the Old Plating Department where metals are electroplated. Following rewinding, the electro-plated steel proceeds to a Finishing Department where it is cut into strips of customer specified width, re-rolled, packaged, and shipped to external customers. For packaging, most rolled strip may be wrapped in polyethylene film. For some orders, a rust inhibitor is applied.

Of the three employees associated with the birth defect cluster, two reportedly worked in the Finishing Department during their wives' pregnancies, and the third worked as a janitor throughout the plant, and spent much of his time in the Old Plating Department. At the time of the walk-through, there were 524 employees working at TSS: 366 hourly personnel, and 158 salaried personnel. Ninety-two percent of the TSS employees are male. In the Finishing Department, there were 48 workers employed over three shifts. There were 16 employees on each shift: for both the first and second shifts, there were 15 men and 1 woman.

The purpose of NIOSH's involvement was to investigate exposures to the fathers and changes to the processes in order to explain possible reasons for the apparent cluster. To assess the problem, NIOSH conducted a walk-through site visit on October 21, 1999, and environmental surveys on March 2-3, 2000, and February 1, 2001. In addition, NIOSH interviewed affected workers, reviewed medical and insurance claims data related to pregnancies at TSS, and reviewed work records of employees in the Finishing Department. A letter summarizing the results of the first sampling survey was issued on September 22, 2000.

METHODS

In October 1999, NIOSH investigators conducted a walk-through of the TSS plant and met with families of affected children. NIOSH asked TSS to identify any recent changes in processes. Personnel records of four affected employees were acquired that contained a listing of job titles and duties for the prior five years. Questionnaires of affected employees were conducted to inquire about job history, exposures at work, hobbies, family histories, and home environment. As part of this investigation, we also reviewed Materials Safety Data Sheets (MSDS) for several chemical materials used in the process. We obtained information on relevant work practices from both employer and employees. We reviewed medical and insurance claims records related to pregnancies at TSS, and reviewed work records of employees in the Finishing Department.

Medical / Epidemiological

Interviews with Affected Employees

A questionnaire was developed and asked to affected employees and their spouses in telephone interviews. The questionnaire assessed the workers' job titles and duties, including exposures, from January 1995 till the time of the interview. Questions also assessed personal hygiene practices and use of personal protective equipment. Non-work activities of either parent, such as hobbies or outside employment, were recorded, including exposures to various chemicals, extreme temperatures, radiation, or pesticides. Additional information of the parents included age; pregnancy history; other birth defects, heart conditions or blood disorders; source of residential water; and address at time of conception.

Review of Medical and Insurance Records

To verify the reported birth defects, medical and surgical records of the three cluster patients were obtained and reviewed by NIOSH. Experts at the Centers for Disease Control and Prevention (CDC) National Center on Birth Defects and Developmental Disabilities (NCBDDD) were consulted for interpretation of the records.

To determine the rate of birth defects among all TSS employees, Anthem Blue Cross and Blue Shield, TSS's major insurance carrier, was asked to supply all pregnancy-related claims for January 1994 through December 2000 (data previous to 1994 was not available). According to TSS, 97% of employees were insured through the company plan. NIOSH received 14,000 records from Anthem, which were sorted, analyzed, and summarized by year. Pregnancies were classified into two categories: (1) validated TSS employed births in which delivery information was available from the records, and (2) non-validated births which showed claim information after birth, such as a pediatrician check-up, and showed a date of birth, but did not show pregnancy and delivery information. Non-validated births may have occurred outside of the parent's employment, therefore only validated outcomes are presented. Birth defects were classified as major or minor by investigators from NIOSH, in consultation with staff from the NCBDDD. Rates of birth defects by year were then calculated as the number of major birth defects divided by the total number of births.

Review of Work History Records of Employees in the Finishing Department

Work histories of workers employed in the Finishing Department from January 1996 through October 1999 were obtained from TSS. Parents who worked in the Finishing Department during the prenatal period were identified. A critical exposure period for most heart defects is the first two to three months of pregnancy, while the heart is being developed.[1]

Comparison to Birth Defects Rates from Other Sources

The birth defect rates at TSS were compared to state birth defect information obtained from the Ohio Department of Health. Other birth defect statistics from two surveillance systems were also obtained for comparison: the Birth Defects Monitoring Program (BDMP)[2] and the Metropolitan Atlanta Congenital Defects Program (MACDP).[3] BDMP is based on newborn hospital discharge data across the nation. MACDP monitors all births in the greater Metropolitan Atlanta region diagnosed with at least one major birth defect within the first year of life, with diagnoses ascertained within the first 5 years of life.

Environmental Sampling Methods

Air Sampling

On March 2-3, 2000, NIOSH investigators conducted an evaluation of worker exposure to airborne substances in the Finishing and Old Plating Departments. Airborne concentrations of (1) metals, (2) the active ingredient in the rust inhibitor, 2,6-di-t-butyl-4-methylphenol (2 BHT), and (3) organic solvents were measured in the Finishing Department. Workers in the Finishing Department had reported that periodically they pass through the Old Plating Department en route to their jobs. Therefore, airborne concentrations of the following chemicals were obtained in the Old Plating Department: hydrochloric acid, sulfuric acid, nitric acid, sodium hydroxide, hexavalent chromium, ammonia, and cyanide.

Samples to Estimate the Possibility of "Take-Home" Exposures

Hand wipe samples, shoe wipe samples, and cotton pad samples (affixed to the workers' shirt and trousers) were obtained and analyzed for metals. The intent of this sampling effort was to assess the potential for metals to be transported from the workplace to the worker's car and home.

For collection of these data, employees reported to the survey staging room prior to the beginning of the shift and were given a Wash'n Dri® towelette to wipe both the front and back of each hand up to the wrist for the pre-shift sample. At the conclusion of the work shift, employees returned to the room and again wiped hands for the post-shift sample. Employees reported that they did not wash their hands with soap and water immediately prior to washing with the towelette. Shoe wipe samples were obtained at the end of the shift by wiping the sole area of one of the work shoes with a Wash'n Dri® towelette. Cotton pad samples were affixed to portions of the left and right lapels and left and right thighs of the employees' work clothes. Because there are no established exposure criteria for metal levels measured on patch and wipe samples, we obtained 'control' samples from 10 NIOSH employees on August 9, 2000, as a basis for comparison with levels among TSS employees. All NIOSH employees worked at the Alice Hamilton Laboratory in Cincinnati, Ohio.

On February 1, 2001, wipe samples for metals analyses were obtained in defined locations within the automobiles of several workers employed in the Finishing Department and also administrative offices. Samples from the latter source functioned as control samples; these samples were thought to represent data from an unexposed population.

We collected a total of 180 samples–airborne, hand wipe, shoe wipe, and cotton pad samples from five departments. All samples were obtained for the full (first) shift. Wipe samples were collected in 8 different locations in each of 10 vehicles.

Ionizing Radiation Sampling

Ionizing radiation was measured in and around Finishing Department work stations to evaluate potential doses from radioactive sources used in connection with the steel strip gauging systems.

Water Samples

Water samples were collected from the two drinking fountains in closest proximity to the Finishing and Packaging Departments. Substances selected for analysis were based in part on those thought to be present at TSS. For comparison purposes, water samples were also obtained at two off-site locations: a hotel in Warren, Ohio, and a drinking fountain at NIOSH in Cincinnati.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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 even though their exposures are maintained below these levels. It is also important to note that none of the evaluation criteria are based on teratogenicity. 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 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, which potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[4] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[5] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[6] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever is the more protective criteria. Ionizing radiation exposure criteria recommended by the International Commission on Radiological Protection (ICRP 1991) were also referenced, as were Maximum Contaminant Level regulations set by the Environmental Protection Agency (EPA) under the Safe Drinking Water Act of 1974 (EPA 1976,[7] 1979).[8]

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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 STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

RESULTS

Medical/Epidemiological

Interviews with Affected Employees

Results from questionnaires of the cluster employees revealed that at least two of the three employees reported exposure to each of the following: nickel dust, copper, brass, zinc, TS metal, oil mist, oil-containing paper, diesel fumes, fumes from the Old Plating Department (cyanide, ammonia), ionizing radiation, and public drinking water. All three employees reported that they ate in the work area and washed their hands about 50% of the time before eating. Other factors, such as family medical history, hobbies, and age were not remarkable.

Review of Medical and Insurance Records

The birth defect cluster occurred in 1998, when three children with severe heart defects were born in February, April, and September of that year. All three of the fathers were employed at TSS during the prenatal periods. Two of the cases had hypoplastic right heart with interrupted aortic arches, and both of their fathers worked in the Finishing Department. The third case had hypoplastic left heart syndrome, and the father worked as a janitor at TSS and spent break time in the Old Plating Department. The three cases are similar in that they all involve hypoplasia of a ventricle, and all three required a modified Norwood surgical procedure. The three cases each were affected by one or more of the following conditions: hypoplastic left or right heart, double outlet right or double inlet left ventricle, ventricular and atrial septal defects (VSD and ASD, respectively), hypoplastic ascending aorta, and interrupted aortic arch.

During the course of our investigation, we learned of a fourth case which was not part of the 1998 cluster. A baby with Tetralogy of Fallot was born in 1993 and his father worked as an electrician at TSS performing duties throughout the plant. Tetralogy of Fallot is a syndrome that includes Fallot's pentalogy, VSD, dextraposition of aorta, and hypertrophy of right ventricle. This case is similar to the other three, though born several years earlier. A baby of a Finishing Department employee was diagnosed prenatally in 2000 with a "hole" in the heart, which closed before the baby was born. The baby presented no abnormalities at birth. We do not consider this fifth baby to be a case.

The heart defects in the 1998 cluster were validated by insurance claims. Although the case of Tetralogy of Fallot was born in 1993, claims information obtained for 1994-2000 validated the condition.

Table 1 summarizes the birth and birth defect data. For 1998, 14 live births were validated with records that showed delivery information. An additional 4 children were identified as being born in 1998, though no claim from the delivery was available. An example of a birth that was not validated would be a claim for an immunization for a child whose birth year is recorded as 1998. Thus, these four children may have been covered by a different insurance carrier for their birth, or their parent may have started employment at TSS after their birth. Because we could not verify whether their births and prenatal periods occurred during a time of parental employment at TSS, we calculated birth defect rates for validated births only. All birth defects detected by these records occurred among validated births. In addition, even though Anthem records prior to 1994 were not available, we consider the 1993 case of Tetralogy of Fallot to be validated because we verified the father's employment at TSS during the time of the pregnancy.

In 1998, there were birth defect claims for five heart defects and one cleft palate. Of the five heart defects, three of them were severe (representing the cluster). The other two were ostium secundum atrial septal defects (ASD), which is an abnormal opening between the two atrial chambers of the heart. Two additional ASDs were identified, one in 1996 and one in 1999. The claims for the four ASDs were for diagnostic testing, and not for operations or procedures. Thus, we were not able to confirm that these ASDs were positively diagnosed, but just that they were suspected and that testing was conducted. If they had been severe, we would expect there to have been follow-up claims of operative procedures, though operations are often postponed until later in childhood. For at least the first year of life, none of the ASD cases had procedural claims for operative procedures. One of the four ASDs had been prematurely born, a risk factor for ASD; there were no indications that any of the other three were premature.

Birth Defects Rates among TSS Employees

Table 1 shows calculated birth defect rates at TSS. For the years 1994-2000, 89 live births were validated, and an additional 31 live births were identified but not verified, bringing the total count of children born in those years to 120 (there was one set of verified twins). The rate of all heart defects from 1994-2000 is 7.9% (7/89) of validated births. The rate of severe heart defects for 1998 is 21.4% of validated TSS births, and the rate of all identified heart defects for 1998 is 35.7% for validated births. The rate of orofacial clefts for 1998 is 7.1% for validated births.

Parental Work Status of 1996-1999 Births

TSS provided NIOSH with work history records of all employees who worked in the Finishing Department for at least a week between January 1996 through October 1999. Table 1 shows a breakdown of births and birth defects in those years by Finishing Department employment during the critical period of the first three months of pregnancy. In 1998, 6 of 14 births at TSS had birth defects; 3 of 5 births in the Finishing Department and 3 of 9 births in other departments. For the years 1996-1999 (for which we have work histories), all birth defects occurred in children of male employees except one, which was an ASD in 1998 born to a non-Finishing Department female employee.

Comparison of TSS Rates to Other Rates

Two of the children born with birth defects in the original cluster were born in Trumbull County and one was born in Mahoning County. In 1998, according to the Ohio Department of Health (ODH), there were four cases of heart anomalies out of 2,703 live births in Trumbull County (rate of 1.5 per 1,000, or 0.15%), and there were three cases of heart anomalies out of 3,104 live births in Mahoning County (rate of 1.1 per 1,000, or 0.11%).[9] The reported rate of heart anomalies in Ohio is 0.7 per 1,000 live births (0.07%). Unfortunately, the data from ODH only captures information recorded on Ohio birth certificates, and heart anomaly information of one of the cluster cases born in Trumbull County was not recorded on his birth certificate. Therefore, there is likely under-ascertainment of cases, and the rate is suspected to be higher than what the ODH reports.

A cluster of 14 cases of hypoplastic right heart defects occurred near Akron, Ohio, in 1979-1981.[10] A viral etiology was suspected, though not verified. Paternal occupational information was not reported.

There are no national statistics on the occurrence of heart defects, but the rate reported by various surveillance systems is about 1 heart defect in 100 live births (1%).[11] Although there are no statistics with which to compare the exact defects in the TSS cluster, the prevalence of hypoplastic left heart syndrome according to the CDC's BDMP was 1.25 cases per 10,000 live births (0.01%) in 1986-1987[2] and the rate of Tetralogy of Fallot was 4.34 per 10,000 live births (0.04%), according to data from 1989-1991 from the CDC's MACDP.[3] The MACDP reported rates for ASD of 41.53 per 10,000 (0.42%). Rates in the BDMP for the years 1990-1991 are similar. Thus, regional statistics report rates of certain heart defects that range from 0.01% to 0.42%. These compare to rates at TSS of 7.9% for total heart defects for years 1994-2000, and a rate of 21.4% for severe heart defects in 1998.

Summary

In summary, the three severe cases in 1998 are statistically unusual, but conclusions about the other heart defects (the ASDs) would warrant more diagnostic information, as well as family history, exposure to known teratogens, and genetic conditions. The occurrence of severe defects does not appear to be an ongoing problem at TSS, since there have been no reported severe heart defects since 1998.

Industrial Hygiene

TSS provides shower facilities for employees but does not provide work clothes or work shoes. TSS was asked to identify new processes in the past five years. Use of the TS metal was implemented in 1996 in the plating process. Tonnage usage of TS metal per year as reported by the company was: 3,091 in 1996; 9,472 in 1997; 18,767 in 1998; and 12,544 in 1999. According to the EPA's Toxics Release Inventory (TRI), TSS's total environmental release of TS metal was 15 lbs in 1997, 25 lbs in 1998, and 28 lbs in 1999.[12] Environmental release was primarily to the Mahoning River. TRI statistics on TSS also include reports for cyanide compounds (110 lbs in 1995, 350 lbs in 1996, 150 lbs in 1997, 42 lbs in 1998, and 170 lbs 1999) and for nickel compound (80 lbs in 1996, 355 lbs in 1997, 273 lbs in 1998, and 497 lbs in 1999).

Air Sampling

Breathing zone and general area air samples were collected for five metals (Table 2). These metals were selected for sampling because they were present in the steel strip (iron) or were plated onto the steel strip (copper, nickel, zinc, and TS metal). Nearly all of the samples were near or below the analytical limits of detection for these metals. All but one sample for airborne metals were well below OSHA PELs and NIOSH RELs. A breathing zone sample collected in the Old Plating Department contained 0.1 milligrams per cubic meter (mg/m^3) of nickel, which is above the NIOSH REL for nickel (0.015 mg/m^3). The employee who was sampled was performing tank fix work and appeared to be working between the tank lines for most of the work shift. Due to the physical requirements of the job, fresh air movement was probably limited, which caused an elevated concentration. (The nickel level measured during tank fix work is greater than a level of 0.004 mg/m^3 measured in 1999 by a TSS consultant and a level of 0.024 mg/m^3 measured in 1983 by the Industrial Commission of Ohio.) By contrast, the same employee was exposed to 0.002 mg/m^3 of nickel during work as a spot welder in a relatively open area of the old plating building.

Breathing zone and area concentrations of 2 BHT, which is the active ingredient in the rust preventive oil (based on a review of the MSDS), were well below the established exposure criterion (10 mg/m^3) (see Table 3). The rust inhibitor was not used in the Finishing Department during the March 2000 survey; however, it was used during the February 2001 survey.

For both surveys, concentrations observed were near the analytical limit of detection (0.0036 mg/m^3 for the March 2000 survey; 0.001 mg/m^3 for the February 2001 survey). The low levels may reflect an underlying ambient level from the rust inhibitor on materials or building surfaces in the finishing area. While the data would appear to suggest that concentrations were higher during the first survey (when rust inhibitor was not used), the elevated levels are likely due to the higher limit of detection and not to any real difference in concentration between the two sampling periods. It is likely that the 2 BHT concentrations did not vary between the two sampling campaigns. This occurred even though the 2 BHT-containing rust inhibitor was being applied during the February 2001 survey. However, the amount sprayed was quite small, with minimal aerosolization and dispersion, and there was good air movement in the area of the application. Therefore, the minimal concentration levels measured during the February 2001 survey are plausible. These measurements are based on use of NIOSH Manual of Analytical Methods Number 2549, which is a semi-quantitative (screening) method for detection of volatile organic compounds, allowing for detection of the 2 BHT as well as other analytes that may have been present in the rust inhibitor.

Airborne cyanide samples were collected at the aisle way location to determine potential exposures experienced by individuals who were passing through the old plating building en route to their jobs in the finishing area. As Table 4 indicates, concentrations of 3.06 mg/m^3 (on 3/2/2000) and 1.91 mg/m^3 (on 3/3/2000) were measured near the aisle way at Fire Station 3-41. These levels are contrasted with concentrations measured by a TSS consultant in August 1999 much closer to the tanks on the plating lines. Concentrations of 0.17 mg/m^3—4 feet from the Brass plating tank at the Copper/Brass plating line; and 0.009 mg/m^3—6 feet from a storage tank at the Nickel/Zinc plating line were measured. Exposure levels would have been expected to be higher in closer proximity to the plating tanks. Subsequent additional laboratory analysis confirmed that the measured cyanide concentrations were not due to analytical interference from other airborne metals that may have been present. While below established exposure criteria, these airborne cyanide particulate levels seem high given the distance (approximately 12 feet) from the plating tanks. Since it only takes approximately 1-3 minutes to pass through the Old Plating Department, however, workers in the Finishing Department would likely experience a TWA exposure that would be well below established exposure limits (5 mg/m^3). These measurements, however, indicate a significant source of potential exposure to cyanide in the Old Plating Department. These data may indicate an operating deficiency in the environmental control system for the cyanide-containing bath.

The appendix shows results of several other area samples that were below the established exposure criteria.The appendix includes tables for: (1) elemental carbon, a surrogate measure of exposure to diesel exhaust; (2) total particulate airborne concentrations, reflecting potential exposure to paper dust; (3) four solvents–benzene, toluene, perchloroethylene, and butyl cellosolve; (4) hydrochloric acid, sulfuric acid, nitric acid; (5) sodium hydroxide; (6) ammonia, and (7) hexavalent chromium.

Samples to Estimate Possible "Take-Home" Exposures

Tables 5 and 6 show results of the metals analyses of the hand wipe samples, shoe wipe samples, cotton patch and automobile samples. The results show that these metals were detected on workers' clothing, skin, shoes, and automobiles, and had potential to have been transported to the workers' homes. The mean hand levels increased over the work shift (Table 5), with marked increases for the two workers in the 215 Finishing Department (data not shown). The data suggest that slitter operators had comparatively higher levels on the hands than did other work groups, notably iron, copper, and zinc were higher for the slitter operators in 214, 215, and 216 Finishing Departments. Because the metals were on the hands prior to beginning work, there is a possibility of a (low level) metals contamination source external to TSS. Such sources could have included the automobiles driven by the employees or the homes of the employees. Another possibility is the accumulation of a residual concentration on the skin due to inability to completely remove the metals during washing.

As was expected, the shoe soles for all employees contained higher levels of the five metals of interest, compared to the NIOSH levels (Table 5). Several other metals were analyzed from the shoe wipes, selected due to their potential presence as an alloying element in the strip steel or due to their presence as 'detectable' quantities in the hand wipe, patch, or shoe wipe samples. Compared to the NIOSH levels, magnesium, and to a lesser extent, manganese and phosphorus were present in departments 214, 215, 216, and Old Plating. We did not identify specific sources of magnesium or phosphorus. Based on a review of a 1985 MSDS pertaining to the strip steel, manganese may have been present as an alloying element. Manganese, magnesium, and phosphorus were found in low level amounts (near the analytical limit of detection) on the hand wipe and patch samples. Phosphorus was found in air samples collected in the Old Plating, 214, and 216 departments.

The data from the cotton patches indicated that higher metal levels were found for TSS employees, compared to NIOSH levels. The levels for the slitter operators and for the worker in the Old Plating Department were higher than for employees working in packaging area jobs.

Table 6 shows wipe sample data collected from two locations in the automobiles: the driver's side floor and the driver's side seat. Of all the data collection sites, data from these locations were considered to be the best indicator of the potential for contaminants to be removed from the plant and taken home. The data indicated that iron was the predominant metal found at both locations. The data also indicated that contaminant levels in the cars driven by production workers were clearly elevated above those levels in cars driven by administrative workers who were employed in office areas. Compared to iron, levels of copper, zinc, nickel, and TS metal were minimal at both automobile sampling locations.

Ionizing Radiation

Table 7 shows the results of whole body radiation doses measured near the slitting operations. All three slitting machines utilized a shielded ionizing radiation source (Americium 241) to gauge the thickness of the plated material on the steel strip. Compared to background levels obtained in the training room, located in a building separate from the building housing the Finishing Department, measurements made at the operator position during activation of the gauging system indicated that levels were at background level (6-10 microRem/hour [uR/hr], with an average of 8 uR/hr). Assuming a 2000 hour/year exposure (i.e., 40 hours/week for 50 weeks/year), total dose equivalent for background level exposure over a one-year period would have been approximately 16 millirem. This level would be well below the 2000 millirem/year level recommended by the International Commission on Radiological Protection[13] and the 5000 millirem/year PEL.

Water Samples

Table 8 shows water analyte concentrations of selected substances found in tap water samples collected at TSS and at two control sites: a hotel approximately 10 miles from TSS, and a NIOSH research facility in Cincinnati, Ohio. Data are also included for additional analytes. The primary objective was to determine if concentrations of analytes contained in TSS tap water were different than those contained in tap water sources external to the plant. In general, concentrations for analytes present at *detectable* levels compared closely among the three tap water sources. In several instances, analytes were present in external sources that were not present in TSS tap water. These included ammonia, tribromomethane, and methyl chloride.

Data do show that for some analytes, concentrations were somewhat higher in TSS water than in external sources. These included bromodichloromethane (a by-product of water disinfection), trichloromethane (chloroform), and calcium. Levels in TSS tap water appear significantly higher for zinc. Where comparisons with current EPA drinking water standards are available, levels of analytes in TSS tap water were below applicable standards.[7,8]

Several analytes—aluminum, cadmium, lithium, manganese, lead, and thallium—were detected in samples collected from both TSS and external sources. However, the reliability of these measurements is subject to a significant degree of uncertainty due to close proximity to the limit of detection. It is not known if these data represent true levels of the contaminant or analytical instrument "noise."

Discussion

As initially reported to NIOSH, there appears to have been a cluster of severe heart defects in 1998 among children of TSS male employees who worked in the Finishing Department. The etiology of this cluster could not be determined.

Possible explanations for the cluster include the following:

1. The cluster may have been due to chance.

2. The cluster may have been due to occupational and/or non-occupational factors that were not identified by the investigators.

3. Levels of exposures may have been higher during the critical windows of development of the pregnancies in the cluster (1997-1998) than during the NIOSH evaluation. However, sampling conducted in 1999 by a TSS company consultant were similar to NIOSH measurements made in 2000 and 2001.

4. The cluster may have been related to exposures at TSS in one of two ways:

    a. The cluster may have been due to exposures at TSS that were transported home on workers' clothes, shoes, skin, and automobiles. Levels of metals were detected in various take-home measurements. Contaminant levels were measured in the microgram per square inch range, and it is unknown what, if any, significance can be attached to these low levels. This scenario seems unlikely, though it would be prudent to avoid such take-home exposures in the future.

    b. In general, these data suggest a working environment characterized by low level exposures and no major airborne health hazard potential. However, it is possible that exposures at TSS were absorbed by the men and transmitted to the fetus via seminal fluid. Environmental or occupational toxicants present in seminal fluid could enter the female reproductive tract during intercourse or may interfere with spermatozoa prior to fertilization. In rabbit studies the presence of thalidomide in semen has been linked with malformations in the offspring.[14] Since couples can continue to engage in intercourse during pregnancy, there is the possibility that the fetus may be exposed to chemicals in semen at various critical times during development. Although many chemicals can appear in semen, most will be present at very low levels; the potency of the toxicant, level of exposure, and timing during development all need to be considered.[15,16]

1. Male-mediated developmental toxicity may also occur via genetic (gene mutation or chromosomal abnormality), and epigenetic (effect on gene expression, genomic imprinting, or DNA methylation) mechanisms which could cause the fetus to develop abnormally.[15,16] Though possible, it is unlikely that such a specific genetic aberration would occur affecting the development of the heart, while allowing other systems to develop correctly and the fetus to survive. However, there is limited suggested evidence of this mechanism in animal studies of male-mediated congenital anomalies and exposure to therapeutic drugs and x-rays.[17-24] The evidence of such male-mediated developmental toxicity in humans is sparse, though research is continuing in this area.

2. At the times of the two industrial hygiene surveys (March 2000; February 2001) environmental data collected at TSS indicated, in general, that airborne exposure levels to metals, solvents, rust inhibitor and plating chemicals were well below established exposure criteria. Exposure to one metal, nickel, was above the NIOSH REL, but well below the current OSHA PEL, and ACGIH TLV. Elevated concentrations of particulate cyanide were recorded in the aisleway in the old plating area. Concentrations were, however, below established exposure criteria.

3. Ionizing radiation measurements were low. Levels of analytes contained in TSS drinking water samples compared to off-site locations indicated no significant difference in water quality—as would be defined by the levels/presence of the selected contaminants. We could find no epidemiologic studies of paternal drinking water and cardiac defects, though there is conflicting evidence of maternal consumption.[25]

Because the levels measured by NIOSH were low, scenario 4b does not seem likely.

Several limitations to the design of the current investigation are recognized. Environmental data were collected during 2000 and 2001. Concenra-ion levels measured may not necessarily be reflective of those that existed during the 1997-998 time period, which is considered to be the critical exposure window for development of the reproductive effects in question. However, NIOSH results were compared to sampling conducted by a TSS consultant in 1999 and were similar.

The records obtained from Anthem Blue Cross Blue Shield allowed for the calculation of total births and birth defect rates. Because the Anthem records were derived from information to reimburse insurance claims, however, their usefulness in diagnosing birth defects is limited. The codes themselves could merely indicate a reason for a test to be conducted and not reflect a diagnosis, or could be erroneous altogether. However, for the four severe defects which we already knew about (three in 1998 and one in 1993), the records showed several pages of claims, including operations and procedures, confirming the severity of these defects. Aside from these four cases, no other defects were identified through these records that had similar indications of severity.

A review of paternal occupations and exposures related to congenital malformations revealed that this is an understudied area[16,26,27] though some suggestive associations have been reported and provide direction for future studies.[15] Men employed as janitors, woodworkers, firemen, electrical workers, printers, and painters have been reported to be at increased risk of having a child with a birth defect.[28-30] These occupations include exposures to substances such as solvents, wood, wood products, metals, and pesticides. Investigators of the Baltimore-Washington Infant Study analyzed paternal exposures and found lead soldering and welding, jewelry making, and ionizing radiation to be significantly associated with various heart defects.[31] In that same study, hypoplastic left heart syndrome was significantly related to paternal paint stripping when there was a family history of cardiac defects. Results from studies of male workers in a nuclear power plant and medical practitioners suggested that exposures to low levels of ionizing radiation before conception were not associated with birth defects,[32-34] though these studies may have lacked statistical power.[27] Female workers at a nickel refinery in Russia had higher incidence of cardiac defects than controls, but the levels of exposure in the Russian cohort are much higher than the levels found at TSS, with nickel dust levels ranging from 3.1 to 42 mg/m^3, and there is little information on paternal exposures.[35,36]

Although some of the studies reviewed have shown positive associations, there are several methodological limitations to consider. One of the limitations of epidemiologic studies of paternal exposures is that there is usually no data on the specific chemical, dose, duration, and chemical interactions.[16] In some studies, fathers' occupation was determined from registry data, which can lead to misclassification. Most paternal exposures involve multiple agents, and it is difficult to identify a causative agent in an epidemiologic study. Animal studies have shown that cardiac defects, including Tetralogy of Fallot and interrupted aortic arch, can be induced by bis-diamine and retinoic acid,[37-40] though information on medication use by the workers and their spouses was not obtained as part of this investigation.

Summary

Three major heart defects in children born in 1998 were confirmed, and one major heart defect in a child born in 1993 was confirmed. Four additional, less severe, heart defects were identified in children born in 1996, 1998, and 1999. The rate of severe heart defects among total TSS births was 21.4%, and the rate of all suspected heart defects among verified TSS births for 1998 was 27.8%. These rates are higher than other U.S. data, which show approximately 1% of live births to have major heart defects. In general, the results of the sampling surveys suggest a working environment characterized by low level exposures and no major airborne health hazard potential. The possibility does exist for low levels of exposures at TSS to be transported home on workers' clothes, shoes, skin, and automobiles.

This cluster investigation has led, in part, to the following research: (1) proposed laboratory animal studies at the National Toxicology Program (NTP) on TS metal; (2) epidemiologic analysis and assessment of exposure to nickel, TS metal, and solvents of cases and controls in the Baltimore-Washington Infant Study of congenital heart defects; and (3) analysis and exposure assessment of heart defect cases and controls exposed to heavy metals and solvents in the National Birth Defects Prevention Study.

CONCLUSIONS

NIOSH investigators concluded that compared to other regional birth defect surveillance data, there was an increased rate of heart defects among children of TSS employees, especially men who worked in the Finishing Department in 1998. The cause of the cluster could not be identified. Most likely it was due to chance or some other factor that the investigators could not measure. The possibility exists that exposures could have been transported to employees' homes on workers' skin, clothing, shoes, or automobiles. A follow-up of pregnancies from 1999 and 2000 revealed that there were no additional severe heart defects among employees' insured children. Thus, although a heart defect cluster appeared to have occurred, it does not appear to be an ongoing problem. In consideration of the current state of knowledge regarding known reproductive toxicants, it is concluded that the cluster cannot be clearly linked with exposures at TSS.

RECOMMENDATIONS

1. To minimize the potential for workplace chemicals and metals to be taken home, workers should change out of work clothes and work shoes prior to leaving the plant at the conclusion of the work shift. Workers should also shower prior to leaving the plant at the conclusion of the work shift.

2. To minimize the potential for ingestion of work- place chemicals and metals, workers should wash their hands before eating or smoking and at the conclusion of the work shift. Workers should avoid eating meals near work operations.

3. To minimize the likelihood of elevated cyanide exposures, the cyanide bath temperatures should be kept at process design levels.

4. Employees should be trained to practice good personal hygiene to minimize the potential for take home exposures.

5. Employees should be encouraged to report any future reproductive health concerns, especially cardiac defects. TSS can consult with NIOSH in the future if birth defects re-occur.

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Table 1: Birth and birth defect data from insurance claims records of TSS employees for 1994-2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Year of Birth	Description of Birth Defects	Worked in Finishing Department During Early Gestation (1/1996-10/1999)	Total Live Births	Validated Live Births*	Worked in Finishing Department	Birth Defect Rate per Validated Births	Birth Defect Rate from Regional Statistics†
1994	1 Cleft Palate with Cleft Lip	data not available	21	14	data not available	7.1%	0.1%
1995		data not available	17	14	data not available	0.0%	
1996	1 Atrial Septal Defect	Y	25	16	5-Y, 11-N	6.3%	0.1%-0.4%
1997		not applicable	16	11	2-Y, 9-N	0.0%	
1998	3 Severe Heart Defects 2 Atrial Septal Defect 1 Cleft Palate with Cleft Lip 6 Total Major Birth Defects	2-Y, 1-N 2-N Y 3-Y, 3-N	18	14	5-Y, 9-N	21.4% 14.3% 7.1% 42.9%	0.01%-0.04% 0.1%-0.4% 0.1% 3.0%
1999	1 Atrial Septal Defect (twin) 1 Congenital Hydrocephaly (twin)	Y Y	9	7	3-Y, 4-N	14.3% 14.3%	0.1-0.4% 0.05%
2000		data not available	14	13	data not available	0.0%	
Total	3 Severe Heart Defects 7 Total Heart Defects 10 Total Major Birth Defects	data not available	120	89	data not available	3.4% 7.9% 11.2%	0.01%-0.04% 1.0% 3.0%

* Births classified into two categories: (1) validated TSS employed births refer to births in which delivery information was available from the records, and (2) non-validated births are births which showed claim information after birth, such as a pediatrician check-up, and showed a date of birth, but did not show pregnancy and delivery information. Non-validated births may have occurred outside of the parent's employment, therefore employment in the Finishing Department and rate calculations are based only on validated births.

† Rates of selected birth defects from regional surveillance systems: Birth Defects Monitoring Program, 1990-1991,[2] and Metropolitan Congenital Defects Program, 1989-1991.[3]

Table 2. Copper, iron, nickel, trade secret metal, and zinc airborne concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Date	Sample Type*	Area	Operation	Job Title/ Location	Time (min)	Vol (m^3)	Product	Copper (mg/m^3)	Iron (mg/m^3)	Nickel (mg/m^3)	Trade Secret Metal (mg/m^3)	Zinc (mg/m^3)
			PEL					1	10	1	0.05	10
			REL					1	5	0.015	0.05	5
			TLV					1	5	1.5	0.02	10
			Limit of detection†					0.0001	0.0004	0.0003	0.0002	0.0003
Date	**Sample Type***	**Area**	**Operation**	**Job Title/ Location**	**Time (min)**	**Vol (m^3)**	**Product**	**Copper (mg/m^3)**	**Iron (mg/m^3)**	**Nickel (mg/m^3)**	**Trade Secret Metal (mg/m^3)**	**Zinc (mg/m^3)**
3/3	PBZ	214	Package	PLO‡	457	0.91	Ni	0.0005	0.002	0.0006		
3/2	PBZ	214	Slitting	Slitter Opr	488	0.98	Ni, NiZn	0.0002	0.0009	0.001		
3/3	PBZ	214	Slitting	Slitter Opr	483	0.98	Ni	0.0005	0.004	0.001		
3/2	PBZ	215	Slitting	Slitter Opr	239	0.48	None	0.0002		0.0008		
3/3	PBZ	215	Slitting	Slitter Opr	471	0.94	Ni, NiZn, Cu	0.001	0.003	0.002		0.01
3/2	PBZ	216	Slitting	Slitter Opr	476	0.97	TS metal	0.0004	0.005	0.006	0.0008	0.0004
3/3	PBZ	216	Slitting	Slitter Opr	463	0.72	NiDiff	0.005		0.004	0.0003	
3/2	PBZ	OP	Plating	Spot Weld	207	0.41		0.009		0.002		0.007
3/3	PBZ	OP	Plating	Tank Fix	451	0.91		0.04	0.04	0.1§	0.0004	0.02
3/3	GA	214	Package	Instr	453	0.90	Ni	0.0003				

Table 2. Copper, iron, nickel, trade secret metal, and zinc airborne concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Date	Sample Type*	Area	Operation	Job Title/ Location	Time (min)	Vol (m^3)	Product	Copper (mg/m^3)	Iron (mg/m^3)	Nickel (mg/m^3)	Trade Secret Metal (mg/m^3)	Zinc (mg/m^3)
3/2	GA	214	Package	Instr	367	0.73	Ni, NiZn	0.0003				
3/3	GA	214	Slitting	Instr	508	1.01	Ni	0.0004				
3/2	GA	214	Slitting	Instr	450	0.92	Ni, NiZn	0.0001				
3/3	GA	215	Slitting	Instr Console	456	0.92	Ni, NiZn, Cu	0.001				0.05
3/3	GA	216	Package	Instr	438	0.88	NiDiff	0.0002				
3/2	GA	216	Package	Instr	439	0.86	TS metal	0.0002				
3/2	GA	216	Slitting	Instr	462	0.90	TS metal	0.0003			0.0003	
3/3	GA	216	Slitting	Instr	440	0.90	Ni	0.0004			0.0003	
3/3	GA	OP	Plating	Isleway	439	0.87		0.09			0.0002	0.009
3/3	GA	OP	Plating	Isleway	477	0.95		0.03				0.0005
3/2	GA	OP	Plating	Picnic	471	0.96		0.02				0.0007
3/3	GA	OP	Plating	Picnic	431	0.85		0.004				

* PBZ: Breathing zone sample; GA: Area sample.
† Limits of detection are based on a air sample volume of 0.9 m^3.
‡ Packaging line operator.
§ Exceeds NIOSH REL.
NOTE: Blank cells indicate concentration was below limit of detection.

Table 3. 2,6-di-tert-butyl-p-cresol (butylated hydroxytoluene [2BHT]) concentrations.
March 2-3, 2000; February 1, 2001
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

							2BHT (mg/m³)
			PEL				10
			REL				10
			TLV				10
			Limit of detection*				0.0011 - 0.0036†
Date	**Sample Type‡**	**Area**	**Operation**	**Job Title/ Location**	**Time (min)**	**Vol (m³)**	**2BHT (mg/m³)**
3/2/00	PBZ	214	Package	PLAO§	479	0.01	0.004
3/3/00	PBZ	214	Package	PLAO	458	0.009	0.0039
2/1/01	PBZ	214	Package	PLO	463	0.009	0.001**
3/2/00	GA	214	Package	Instr Console	442	0.009	<0.004
3/3/00	GA	214	Package	Instr Console	453	0.009	0.0036
3/3/00	GA	214	Slitting	Instr Console	448	0.009	0.0038
3/2/00	GA	214	Slitting	Instr Console	450	0.009	0.0037
2/1/01	GA	214	Slitting	Instr Console	455	0.009	<0.001
3/3/00	GA	215	Slitting	Instr Console	456	0.009	0.0046
2/1/01	GA	215	Slitting	Instr Console	449	0.009	0.001
3/3/00	PBZ	215	Package	PLAO	469	0.009	0.0039
3/2/00	PBZ	215	Package	PLAO	233	0.005	<0.004
2/1/01	PBZ	215	Package	PLO	478	0.010	0.002**
3/2/00	GA	216	Slitting	Instr Console	462	0.009	<0.004
3/3/00	GA	216	Slitting	Instr Console	440	0.009	0.0040
2/1/01	GA	216	Slitting	Instr Console	444	0.009	0.001
3/2/00	GA	216	Package	Instr Console	439	0.009	0.0037
3/3/00	GA	216	Package	Instr Console	426	0.009	0.0038

* Limit of Detection (LOD) is based on an air sample volume of 0.009 m^3.
‡ PBZ: Breathing zone sample; GA: Area sample.
† LOD was 0.0036 mg/m^3 for March 2000 sample campaign; 0.0011 mg/m^3 for February 2001 sample campaign.
§ Packaging line assistant operator.
** Packaging line operator: applying rust preventive.

**Table 4. Cyanide area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882**

					Hydrogen Cyanide (mg/m³)	Particulate Cyanide (mg/m³)
		PEL			5C*	5
		REL			5C	5
		TLV			5C	5
		Limit of detection‡			0.00018	0.006
Date	**Area**	**Location**	**Time (min)**	**Vol (m^3)**	**Hydrogen Cyanide (mg/m^3)**	**Particulate Cyanide (mg/m^3)**
3/2	OP†	Isleway near Fire St # 3-41	439	0.46	0.003	3.06
3/3	OP	Isleway near Fire St # 3-41	477	0.50	0.001	1.91

*Ceiling value; concentration should not be exceeded at any time during sample period.
†Old Plating.
‡Limit of detection based on an air sample volume of 0.5 m^3.

Table 5: Measurements of metals on hands, shoes, and clothing to estimate take-home exposures.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Samples		**Summary Statistics for Metals** Geometric Mean* (Standard Deviation)† Minimum value - Maximum value Number of Non-detected‡ Samples/Total Number Sampled				
Sample Type	**Group**	**Copper**	**Iron**	**Nickel**	**TS metal**	**Zinc**
Hand Wipe	TSS Pre-shift	0.24 (1.6) 0.13 - 0.52 0 / 8	0.97 (1.7) 0.45 - 1.8 0 / 8	0.18 (2.8) 0.05 - 0.76 0 / 8	0.002 (3.7) 0.000 - 0.021 0 / 8	0.48 (1.4) 0.29 - 0.96 0 / 8
	TSS Post-shift	0.60 (4.4) 0.14 - 9.5 0 / 8	4.4 (3.5) 0.77 - 30 0 / 8	1.24 (6.2) 0.10 - 10 0 / 8	0.01 (7.3) 0.001 - 0.16 0 / 8	2.1 (4.2) 0.31 - 34 0 / 8
	NIOSH controls	0.12 (2.4) 0.03 - 0.47 0 / 10	0.43 (2.1) 0.21 - 2.4 0 / 10	0.04 (2.7) 0.01 - 0.37 0 / 10	0.001 (2.7) <LOD - 0.005 3 / 10	0.51 (1.5) 0.30 - 0.89 0 / 10
Shoe Wipe	TSS Post-shift	4.1 (2.8) 1.2 - 21 0 / 8	48 (3.6) 2.3 - 150 0 / 8	13 (4.0) 0.72 - 68 0 / 8	0.15 (3.8) 0.01 - 0.71 0 / 8	19 (3.6) 1.6 - 160 0 / 8
	NIOSH controls	0.12 (1.4) 0.08 - 0.19 0 / 10	4.5 (1.4) 2.7 - 7.0 0 / 10	0.05 (1.8) 0.03 - 0.18 0 / 10	0.003 (1.4) 0.002 - 0.006 0 / 10	2.1 (1.2) 1.6 - 3.2 0 / 10
Cotton Patch (Left Thigh)	TSS Post-shift	0.70 (10.2) 0.09 - 48 0 / 8	7.9 (3.5) 1.8 - 51 0 / 8	3.0 (11) 0.20 - 140 0 / 8	0.02 (6.9) <LOD - 0.26 1 / 8	4.3 (3.6) 1.4 - 39 0 / 8
	NIOSH controls	0.32 (2.0) <LOD - 0.06 3 / 10	0.78 (1.4) 0.50 - 1.2 0 / 10	0.09 (1.4) 0.06 - 0.15 0 / 10	10 / 10	0.53 (1.2) 0.44 - 0.81 0 / 10

* Geometric mean and range are in units of mg/in^2.

† The geometric mean and geometric standard deviation are not reported if the number of detectable samples is less than 5 or the percent of non-detectable samples is 50% or higher. Samples below the limit of detection (LOD) were assigned ½ the LOD for statistical analyses. If all samples were below the limit of detection, no statistics are reported.

‡ The LOD varied depending on sample type and metal. The LODs for hand and shoe wipe samples are 0.04, 0.1, 0.4, 0.3, and 0.3 mg/sample for TS metal, copper, iron, nickel, and zinc, respectively. A worker with a total hand wipe surface area of 100 in^2 would have concentration LODs of 0.0004, 0.001, 0.0004, 0.003, and 0.003 mg/in^2, respectively. A worker with a total shoe wipe area of 40 in^2 would have concentration LODs of 0.001, 0.0025, 0.01, 0.0075, and 0.0075 mg/in^2, respectively. The LODs for thigh patch samples (16 in^2) are 0.04, 0.4, 3, 0.2, and 4 mg/sample for TS metal, copper, iron, nickel, and zinc, respectively. Thigh patch samples have concentration LODs of 0.0025, 0.025, 0.19, 0.013, and 0.25 mg/in^2, respectively.

Table 6: Measurements of metals in workers' automobiles to estimate take-home exposures.
February 1, 2001
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Samples		**Summary Statistics for Metals** **Geometric Mean* (Standard Deviation)†** **Minimum value - Maximum value** **Number of Non-detected‡ Samples/Total Number Sampled**				
Sample Type	**Group**	**Copper**	**Iron**	**Nickel**	**TS metal**	**Zinc**
Driver's Seat	TSS Plant Workers	0.07 (2.9) 0.01 - 0.31 0 / 8	0.21 (6.7) <LOD - 1.7 3 / 8	0.06 (5.7) <LOD - 0.29 1 / 8	<LOD - 0.006 6 / 8	<LOD-0.49 6 / 8
	TSS Office Controls	0.02 - 0.02 0 / 2	2 / 2	0.01 - 0.01 0 / 2	2 / 2	2 / 2
Driver's Floor	TSS Plant Workers	0.31 (2.2) 0.12 - 0.84 0 / 8	23 (2.1) 5.1 - 53 0 / 8	0.11 (6.1) <LOD - 0.61 1 / 8	0.01 (2.2) 0.002 - 0.02 0 / 8	0.81 (2.4) 0.14 - 2.4 /0 / 8
	TSS Office Controls	0.09 - 0.10 0 / 2	9.6 - 27 0 / 2	0.04 - 0.06 0 / 2	0.004 - 0.004 0 / 2	2 / 2

* Geometric mean and range are in units of mg/in^2.

† The geometric mean and geometric standard deviation are not reported if the number of detectable samples is less than 5 or the percent of non-detectable samples is 50% or higher. Samples below the limit of detection (LOD) were assigned ½ the LOD for statistical analyses. If all samples were below the limit of detection, no statistics are reported.

‡ The LOD varied depending on sample type, metal, and analysis batch. All driver's seat and driver's floor samples are 49 in^2. The LODs for TS metal are 0.2 or 0.06 mg/sample, depending on the analysis batch, which standardizes to 0.0041 or 0.0012 mg/in^2; the LOD for copper and nickel samples is 0.2 mg/sample or 0.0041 mg/in^2; the LOD for iron samples is 3 mg/sample or 0.061 mg/in^2; and the LOD for zinc samples is 6 mg/sample or 0.12 mg/in^2.

Table 7. Ionizing radiation survey data.
February 1, 2001
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882
Instrument: Victoreen P450 Ion Chamber
Background Radiation Level: 6 microrem/hour (μR/hr), measured in TSS auditorium

Area	Operation	Source	Measurement Location	Radiation Level (μR/hr)	Comment
			Training Room	6-10	Background
214	Slitting	^{241}Am*	Operator Position	6-10	Background Level
214	Slitter	^{241}Am*	6 in from source window	13	Operator not at this location during normal operation
215	Slitting	^{241}Am*	Operator Position	6-10	Background Level
215	Slitter	^{241}Am*	6 in from source window	13	Operator not at this location during normal operation
216	Slitter	X-ray†	6 inches from gauging head with shudder closed‡	6	Background level - Operator would not be at this position during normal operation
216	Slitter	X-ray†	6 inches from gauging head with shudder open‡	3.6 milli-rem/hour;	Operator would not be at this position during normal operation
216	Slitter	X-ray†	At table circular handle with shudder open‡	112	Operator would not be at this position during normal operation
216	Slitter	X-ray†	At operator position with shudder open‡	7-9	Background level - Normal operation

* Americium-241(^{241}Am) is primarily an alpha particle (a 5.5 MeV particle for 85% of disintegrations; a 5.44 MeV particle for 13% of disintegrations) emitter. When the source is properly situated in the system, the alpha particles cannot penetrate the glass shield or gauging system housing and would not constitute a radiation hazard. However, ^{241}Am also emits a 60 keV (X-ray) photon–a penetrating electromagnetic radiation form---in connection with the Neptunium nuclide formed (from alpha decay of ^{241}Am). It is this radiation form that is being detected by the radiation measurement instrument.

† An X-ray fluorescence gauging system was installed in early 1999 when the new slitting machine was added. During normal operation, a gating system is in place preventing access to the area near the x-ray port on the gauging system. When the slitting machine is stopped, there is a shudder that closes the x-ray port. During normal operation, the operator is situated at a control console, approximately 20 feet from the location of the x-ray port.

‡ To obtain levels at various locations, the operator was instructed to activate the gauging system. Measurements were then taken at several locations.

Table 8. Concentration (micrograms/liter) of analytes detected in drinking water samples.
January 31, 2001
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Analyte	Analytical Method No	Max Contaminant Level[*]	Limit of Detection µg/l	Hotel (Warren, Ohio)[†]	NIOSH-Cincinnati[‡]	TSS[§] Old Plating	TSS[§] Shipping
Ammonia	EPA 350.1		10.4	360	69		
Cyanide	EPA 9012A	200	3.32				
Polychlorinated Biphenyls	EPA 8082	0.5					
AR1016			0.01				
AR1221			0.09				
AR1232			0.03				
AR1242			0.01				
AR1248			0.06				
AR1254			0.005				
AR1260			0.02				
Volatile Organic Hydrocarbons	EPA 524.2						
Bromodichloromethane[††]		0[‡‡]	0.104	1.8	3.8		11
Tribromomethane (Bromoform)[††]		0[‡‡]	0.24		2.1		
Trichloromethane (Chloroform)[††]			0.0528	44	2.1	0.11	75
Methyl Chloride (Chloromethane)			0.27	0.39			
Dibromochloromethane[††]		60[‡‡]	0.158		4.7		1.3
Methylene Chloride		5	0.259				0.4
Metals	NMAM[**] 7300						
Aluminum		50-200	57	[62][§§]		[81]	[120]
Arsenic		10	180				
Beryllium		4	0.42				
Chromium Metal		100	6.2				
Chromium +6	EPA 7196A		8.56				
Cadmium		5	1.6	[3.2]			
Calcium			21	24000	37000	36000	35000
Cobalt			23				
Copper		1300	8.2		46	69	73
Iron		300[***]	36				
Lithium			3.4	[3.8]	[3.4]		
Magnesium			44	7300	9800	6400	6500
Manganese		50	2	[3.1]	[4.5]	[5.7]	[3.1]
Molybdenum			35				
Sodium			31	48000	34000	25000	24000
Nickel			35				
Lead		15	21		[29]		
Phosphorus			120				
Selenium		50	120				
Silver		100	5.3				
Strontium			1.5	82	220	77	73
Titanium			3				

**Table 8. Concentration (micrograms/liter) of analytes detected in drinking water samples.
January 31, 2001
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882**

Analyte	Analytical Method No	Max Contaminant Level*	Limit of Detection µg/l	Hotel (Warren, Ohio)†	NIOSH-Cincinnati‡	TSS§	
						Old Plating	Shipping
Thallium		2	64	[70]	[130]		[67]
Vanadium			9.1				
Zinc		5000***	8.3		13	100	340

* National Primary Drinking Water Regulations: Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are enforceable standards

† Water samples collected from bathroom sink.

‡ Water samples collected on February 15, 2001.

§ Water samples collected from drinking fountains.

** NIOSH Manual of Analytical Methods.

†† By-product of drinking water disinfection

‡‡ Maximum Contaminant Level Goal. Level of contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

§§ Measurements in brackets indicate that the reliability of measurement is subject to significant degree of uncertainty due to close proximity to limit of detection.

*** National Secondary Drinking Water Standard: National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Note: Blank cells indicate concentration was below limit of detection.

Appendix

Appendix Table A: Diesel exhaust area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

						Elemental Carbon (mg/m^3)	Organic Carbon (mg/m^3)
			PEL			---	---
			REL			POC*	---
			TLV			0.15	---
			Limit of detection†			0.005	0.005
Date	**Area**	**Operation**	**Location**	**Time (min)**	**Vol (m^3)**	**Elemental Carbon (mg/m^3)**	**Organic Carbon (mg/m^3)**
3/2	214	Package	Instrument Console: PLO‡	442	0.86	0.02	0.07
3/3	214	Package	Table: PLAO§	452	0.90	0.01	0.06
3/3	214	Receiving	Near Dock	453	0.91	<0.005	0.05

*Potential occupational carcinogen.
†Limits of detection based on an air sample volume of 0.9 m^3.
‡Packaging line operator.
§Packaging line assistant operator.

Appendix Table B: Particulates (insoluble) not otherwise classified area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

	Particulates (mg/m^3)
PEL [Total]	15
REL	---
TLV [Inhalable]	10
Limit of detection*	0.022

Date	Area	Operation	Location	Time (min)	Vol (m^3)	Particulates (mg/m^3)
3/2	216	Slitter	Instr Console	455	0.90	0.10
3/3	214	Slitter	Instr Console	448	0.89	0.08

*Limit of detection based on an air sample volume of 0.9 m^3.

Appendix Table C: Solvent area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Date	Area	Operation	Location	Time (min)	Vol (m^3)	Benzene (ppm)	Toluene (ppm)	Perchloro-ethylene (ppm)	Limonene (ppm)	Aliphatic HC[1] $[C_{10}-C_{13}]$ (mg/m^3)	Butyl Cello-solve[*] (ppm)	DGME[†] (mg/m^3)
PEL						1	200	100	---	---	50	---
REL						0.1	100	POC[‡]	---	---	5	---
TLV						0.5	50	25	---	---	20	---
Limit of Detection[§]						0.0014	0.0012	0.0082	0.0008	0.22	0.0045	0.44
3/2/00	214	Slitter	Instr Console	450	0.09		0.0018		0.0125	0.55		
3/3/00	214	Slitter	Instr Console	448	0.09		0.0027		0.0046			
2/1/01	214	Slitter	Instr Console	459	0.02		0.0023			1.9		
3/3/00	214	Package	Instr Console	453	0.09		0.0032	0.04	0.0044	0.33		
3/3/00	215	Slitter	Instr Console	456	0.09	0.0017	0.0073		0.0049	0.72	0.0045	
2/1/01	215	Slitter	Instr Console	449	0.02					3.5		
3/2/00	216	Package	Instr Console	462	0.09				0.0058			
3/2/00	216	Package	Instr Console	439	0.02				0.0033			
3/3/00	216	Slitter	Instr Console	440	0.02							
2/1/01	216	Slitter	Instr Console	444	0.02					42.3		
3/3/00	216	Package	Instr Console	440	0.02							

[*] Butyl cellosolve also known as 2-butoxyethanol.
[†] Diethylene Glycol Methyl Ether.
[‡] Potential occupational carcinogen.

[§] Limits of detection based on an air sample volume of 0.09 m^3.
NOTE: Blank cells indicate concentration was below limit of detection.

Appendix Table D: Acid area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

Date	Area	Location	Time (min)	Vol (m^3)	Sulfuric Acid (mg/m^3)	Hydrochloric Acid (mg/m^3)	Nitric Acid (mg/m^3)
		PEL			1	7C*	5
		REL			1	7C	5
		TLV			1	7C	5
		Limit of Detection†			0.002	0.001	0.001
3/2	OP‡	Aisle way near Fire St # 3-41	437	0.18	0.016	0.013	0.005
3/3	OP	Aisle way near Fire St # 3-41	452	0.20	0.005	0.002	0.006

*Ceiling value; concentration should not be exceeded at any time during sample period.
†Limits of detection based on an air sample volume of 0.17 m^3.
‡Old Plating.

Appendix Table E: Sodium hydroxide area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

					Sodium Hydroxide (mg/m^3)
		PEL			7C*
		REL			7C
		TLV			7C
		Limit of detection†			0.04
Date	**Area**	**Location**	**Time (min)**	**Vol (m^3)**	**Sodium Hydroxide (mg/m^3)**
3/2	OP‡	Aisle way near Fire St # 3-41	438	0.46	0.15
3/3	OP	Aisle way near Fire St # 3-41	476	0.50	0.14

*Ceiling value; concentration should not be exceeded at any time during sample period.
†Limit of detection based on an air sample volume of 0.9 m^3.
‡Old Plating.

Appendix Table F. Ammonia area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882

					Ammonia (ppm)
		PEL			25
		REL			35
		TLV			25
		Limit of detection*			0.32
Date	**Area**	**Location**	**Time (min)**	**Vol (m^3)**	**Ammonia (ppm)**
3/2	OP†	Aisle way near Fire St # 3-41	437	0.09	5.9
3/3	OP	Aisle way near Fire St # 3-41	477	0.09	2.0

* Limit of detection based on an air sample volume of 0.09 m^3.
† Old Plating.

**Appendix Table G. Chromium [hexavalent] area concentrations.
March 2-3, 2000
Thomas Steel Strip Corporation, Warren, Ohio
HETA 99-0343-2882**

					Chromium (mg/m^3)
		PEL			0.1
		REL			0.001
		TLV			0.05
		Limit of detection*			0.00004
Date	**Area**	**Location**	**Time (min)**	**Vol (m^3)**	**Chromium (mg/m^3)**
3/2	OP†	Aisle way near Fire St # 3-41	437	0.44	0.0002
3/3	OP	Aisle way near Fire St # 3-41	452	0.46	0.0001

* Limit of detection based on an air sample volume of 0.45 m^3
† Old Plating

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