CDC
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NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 95-0105-2540
LTV Steel Company
Cleveland, Ohio

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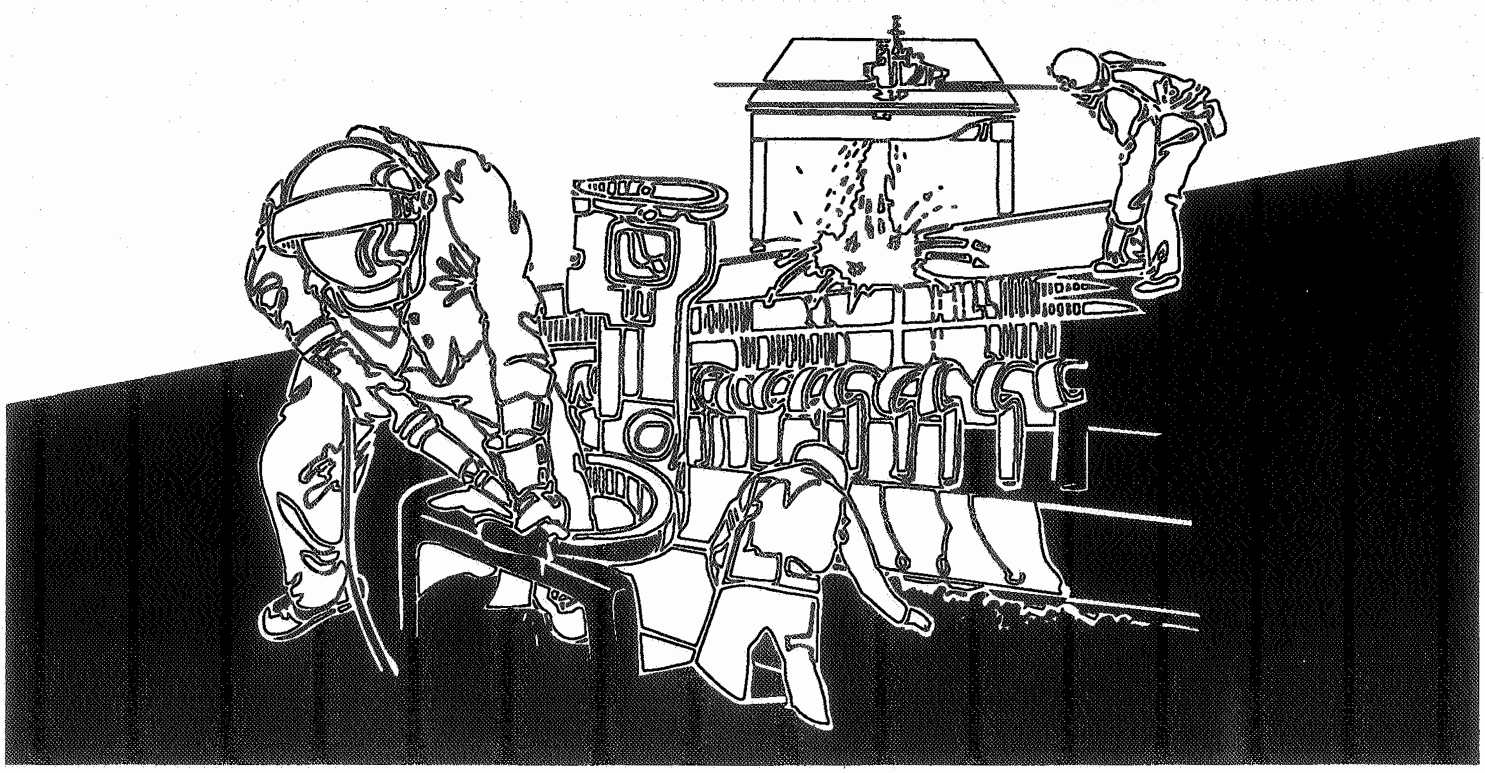

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

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

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

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 95-0105-2540
NOVEMBER 1995
LTV STEEL COMPANY
CLEVELAND, OHIO

NIOSH INVESTIGATORS:
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SUMMARY

In December 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers of America, Local 1157 for a health hazard evaluation (HHE) at LTV Steel Company in Cleveland, Ohio (LTV). The request concerned reports of skin rashes among employees in the basic oxygen furnace (BOF) area of the plant. The requestors were specifically concerned with a potential relationship between the skin rashes and exposure to a slag conditioning agent (Syn Slag).

Industrial hygiene and medical evaluations were conducted on March 22 and May 25, 1995. The industrial hygiene evaluation included observation of work practices (including the use of personal protective equipment) and environmental sampling in the BOF area. Seven personal breathing zone (PBZ) air samples and 12 bulk samples of settled dust were obtained from locations throughout the BOF area. The PBZ samples were analyzed for elemental metals, and the bulk samples were analyzed for elemental metals, pH, and hexavalent chromium [Cr(VI)]. The medical evaluation included a review of medical records and the Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses, employee interviews, and skin examinations. A determination of a 'work-related' skin condition was made based on: 1) a history of a temporal relationship of the skin condition to work in the BOF **and** compatible physical examination findings by the NIOSH dermatologist; **or** 2) medical records including a diagnosis by a dermatologist of a probable work-related skin condition.

On May 25, 1995, PBZ air sampling indicated that employee exposures to elemental metals in airborne dust were well below all occupational evaluation criteria. Bulk dust samples were found to be alkaline and to contain a variety of metals which have the potential to act as dermal irritants. Seven workers were identified as having a current or recent history consistent with a work-related irritant contact dermatitis (airborne) or an exacerbation of an underlying skin condition by workplace exposure to dusts. Although we are not able to identify a specific causative agent(s), several components of the dust present in the BOF, including calcium aluminate, could be causing or contributing to skin irritation among some of the BOF workers.

The dust in the BOF area is a potential skin irritant. Recommendations to minimize the potential for irritant dusts to cause irritant contact dermatitis or exacerbate preexisting skin conditions among BOF workers include: reducing the handling of slag in the BOF area, removing dust from surfaces where workers may contact or disturb it, using disposable one-piece coveralls to act as a dust barrier, and periodic washing with a mild soap and water to remove dust from the skin.

KEYWORDS: SIC 3312 (Steel works), steel mill, slag, basic oxygen furnace, irritant contact dermatitis (airborne), dust.

INTRODUCTION

In December 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers of America, Local 1157 for a health hazard evaluation (HHE) at LTV Steel Company in Cleveland, Ohio (LTV). The request concerned reports of skin rashes among employees in the basic oxygen furnace (BOF) area of the plant. The requestors were specifically concerned with a potential relationship between the skin rashes and exposure to a slag conditioning agent (Syn Slag).

NIOSH representatives made an initial site visit to LTV on March 22, 1995. After an opening conference with management and union representatives, NIOSH representatives conducted a walk-through survey of the BOF area and interviewed employees. A follow-up site visit on May 25, 1995, included an industrial hygiene evaluation, medical interviews, and skin examinations.

BACKGROUND

The LTV plant in Cleveland, which produces flat-rolled steel, employs approximately 5800 people. Steel is produced in the BOF area from molten iron and scrap steel, which are combined in an oxygen furnace at approximately 3000 degrees Fahrenheit. Additives to the steel at this point in the process include Syn Slag, which is added in powder form to enhance the removal of impurities. The impurities are removed by removing a floating layer of slag from the top of the molten steel. The Syn Slag is composed of 60-80% calcium aluminate ($3CaO{\cdot}Al_2O_3$), with the remainder being calcium and magnesium oxides (CaO, MgO). Prior to the NIOSH site visit in May, Syn Slag mixtures used at LTV reportedly contained between 32% and 100% calcium aluminate. During the steel-making process, a small percentage of oxides of a number of other metals may also be added to the molten steel to alter various characteristics of the final product. A material safety data sheet (MSDS) for the BOF slag included the following components: calcium oxide (42-48%), iron oxide (as FeO) dust (18-21%), silica (fused) (12-14%), magnesium oxide (6-10%), iron oxide (as Fe_2O_3) dust (7-9%), manganese oxide (3-7%), aluminum oxide (0.5-2%), and sulfur (<1%).

Approximately 300 employees work in the BOF area over four shifts, including approximately 170 production personnel. Skin rashes had been reported among employees in a number of different job titles, including vessel men, material handlers, ladle liners, and laborers. In addition to working in the area of the oxygen furnace, BOF employees may also work in nearby areas of the plant where the slag from the steel-making process is handled, including the pit where the slag is dumped and temporarily stored (#6 pit).

EVALUATION CRITERIA

Occupational Skin Diseases

Occupational skin diseases account for approximately 40 - 50% of all occupational illnesses, and approximately 80 - 90% of these skin diseases may be classified as contact dermatitis.[1] Contact dermatitis refers to the induction of changes in the skin, usually accompanied by inflammation, from direct skin exposure to a wide variety of chemical or physical substances. Physical factors, such as heat and sweating, can exacerbate the irritant response of agents capable of causing contact dermatitis. The inflammation of contact dermatitis is caused by irritation (80 - 90% of cases), allergy, or both. The usual symptoms of irritant contact dermatitis include itching, stinging, and burning sensations, which may occur on both exposed and unexposed areas of the skin.[2]

Both irritant and allergic reactions can be caused by a variety of dusts.[3] Exposed areas of skin where airborne dusts may accumulate include the neck, the wrists (if long-sleeved shirts are worn), the beltline, and the ankle (above the shoes or socks). Airborne irritant contact dermatitis affecting areas of unexposed skin is usually caused by solid (airborne) particles which pass under or through protective clothing.[2]

Contact dermatitis among employees working in a steel production facility has been attributed to exposure to dust containing additives used in the steel-making process.[4] The additives described in that report were in powder form and, when airborne, contacted bare skin and/or penetrated clothing to cause irritant reactions or irritant dermatitis. Some of the additives reported to cause this airborne irritant dermatitis include silicon, calcium, magnesium, aluminum, ferric, and sodium oxides and calcium fluoride. Another report of airborne irritant contact dermatitis, thought to be due to chromate present in refractory brick dust, has been described in a boiler worker.[5]

Despite measures such as changing jobs to decrease exposure to the offending agent(s), only approximately 25% of those who develop occupational contact dermatitis experience complete clearing of their skin condition.[1] This is why primary prevention of exposure to potentially causative agents is so important.

Environmental

As a guide to the evaluation of hazards posed by workplace exposures, NIOSH 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

Twelve bulk samples of settled dust were obtained from locations throughout the BOF area. The bulk samples were analyzed for elemental metals according to NIOSH Method 7300 (NMAM Fourth Edition, 8/15/94) modified for microwave digestion of bulk samples. These samples were also evaluated for pH and hexavalent chromium (Cr(VI)). For the pH determination, approximately 0.10 g of each sample was moistened with 0.1 ml of deionized water (in an attempt to simulate the presence of dust in perspiration on a worker's skin). The pH was determined using E.M. Laboratories colorpHast indicator strips of the appropriate range. Hexavalent chromium content was evaluated using a K-2810 CHEMets Chromate kit (CHEMetrics Inc.) which employs diphenylcarbazide indicator solution. The limits of detection (LOD) and quantitation (LOQ) for ICP and hexavalent chromium analyses are listed in Appendix B. Cr(VI) concentration was evaluated because chromium has a greater potential to induce dermatitis as Cr(VI) than as Cr(III).

Medical

The medical survey included a review of medical records and the OSHA Log and Summary of Occupational Injuries and Illnesses (Form 200), employee interviews, and skin examinations. During the March 22, 1995, site visit the NIOSH medical officer was available in the BOF area and at the local union office to interview all BOF employees who wished to be interviewed. During the follow-up visit May 25, 1995, NIOSH medical staff, including a dermatologist, again were available at the BOF area and at the union office. Union and management representatives informed all BOF employees of the NIOSH site visit and asked if they wanted to be interviewed by NIOSH representatives. All those employees who were interviewed and who reported a current skin problem underwent a focused skin examination.

We defined a "work-related" skin condition as one in which the condition was likely caused by a workplace exposure, or one in which an underlying condition was likely aggravated by a workplace exposure. This determination was made by: 1) a history of a temporal relationship of the skin condition to work in the BOF **and** compatible physical examination findings by the NIOSH dermatologist; **or** 2) medical records including a diagnosis by a dermatologist of a probable work-related skin condition.

FINDINGS AND DISCUSSION

Industrial Hygiene

Operations which generate dust in the BOF area include the addition of Syn Slag into the BOF, the handling of slag at #6 pit using a front-end loader, and the removal of ladle refractory using pneumatic tools. Although the conveyor on the bin floor was not operating during our visits, settled dust was observed on horizontal surfaces on the bin floor which indicated that the conveyor is a source of dust. This observation is supported by air sampling data which was compiled at the request of the American Iron and Steel Institute in 1993. In addition to hard hats, safety glasses, and steel-toe shoes, and other required personal protective equipment, employees in the BOF area generally wore one piece heavy-cotton coveralls. Some employees, however, wore clothing consisting of a separate shirt and pants.

Personal air sampling results are presented in Table 1. The air contaminant concentrations which were assessed during this evaluation were well below all workplace environmental evaluation criteria on the day of the sampling visit.* It should be noted that workplace evaluation criteria are primarily intended to protect workers from health effects other than dermal irritation or sensitization. Due to production factors on the day sampling was performed, air sampling was conducted during periods of minimal dust generation in at least two operations. It was reported that, on average, two slide gates are cleaned each day; no slide gates were available for cleaning during our follow-up site visit. Thus, air concentrations measured at slide gate repair represent "background" dust exposure. Similarly, air samples at ladle lining were obtained during the installation of refractory, and do not represent exposures resulting from the use of pneumatic equipment, such as air hammers, to remove old refractory. Ladle lining workers reported that refractory removal and installation occur on alternate workdays.

Analysis of the bulk dust samples indicates that the major elemental components of settled dust throughout the BOF area are aluminum, calcium, magnesium, and iron (Table 2). Table 2 presents analytical data for specific elements, selected for inclusion in the table based on the element's presence in the dust samples and/or it's irritatant or sensitizing properties. Because elemental analysis does not distinguish between the various compounds containing these elements, information indicating the specific contribution made by each compound is not available, e.g., calcium aluminate, aluminum oxide, and calcium oxide. Each bulk sample was evaluated for the presence of hexavalent chromium using a diphenylcarbazide indicator solution. No hexavalent chromium was detected. The limit of estimation for this sample set was 10 μg Cr(VI) per gram of sample.

The bulk sample analysis for pH revealed that all samples produced alkaline solutions (Table 3). Alkaline dust can be a potential skin irritant (based on its alkalinity) if allowed to remain in contact with skin for a sufficient period, conditions which could exist if dust becomes trapped beneath clothing at a belt line or other similar site.

Medical

Record Review

Review of the OSHA 200 logs for 1993 and 1994 revealed four and two entries, respectively, for an occupational skin disorder among employees from steel producing areas of the plant, which includes the BOF. The diagnoses reported included chemical irritation (3), dermatitis (2), and rash (1).

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*Only elements which were detected are listed in Table 1. The following elements were not detected in any of the samples: Be, Cd, Co, Cr, Li, Mo, Ni, P, Pt, Se, Ag, Te, Tl, and Zr.

Medical department records for 1992, 1993, and 1994 revealed that one, four, and seven persons, respectively, from the BOF area were seen in the LTV dispensary for a skin rash. Those who were seen in the dispensary with an active skin eruption were referred to a consulting dermatologist. Records from the consulting dermatologist concerning eight employees were reviewed (not all referred employees were evaluated by the consulting dermatologist). Six of these persons had diagnoses in which workplace dust exposure was related to the employees' skin condition; two had skin conditions thought not to be work-related. The employees with work-related skin conditions had diagnoses of: 1) "eczematous dermatitis (airborne contact dermatitis or low grade primary irritancy dermatitis)"; 2) eczema of face and chest "classic for airborne contact dermatitis (could also be low grade primary irritancy airborne dermatitis)"; 3) "post-adolescent acne aggravated by dust particles"; 4) "eczematous dermatitis of unknown origin - dust likely involved as primary irritant or contactant for contact dermatitis"; 5) "atopic dermatitis aggravated by airborne contactants at work"; and 6) "eczematous (probably contact) dermatitis, possibly from airborne contactants at work."

Medical records from another dermatologist concerning a seventh employee (who had been identified in the LTV medical department logs as having a skin rash) revealed a diagnosis of generalized allergic dermatitis which initially began on the posterior neck and at the beltline; the dermatitis was not identified as work-related by the dermatologist.

Interviews and Examinations
At the March 22, 1995, site visit, four BOF employees were interviewed, all of whom reported a history of skin rash. All reported improvement of their skin eruptions when away from the BOF area. During the May 25, 1995, site visit, among 68 BOF production workers on-site who had been notified of our visit by union and management officials, 22 (32%) persons were interviewed, including the 4 persons who had been interviewed during the previous site visit. Of the 22 interviewed, 17 reported a history of a skin condition, and 8 had a current problem affecting their skin. Five of these employees were determined (during the NIOSH examination) to have an active dermatitis or evidence of past dermatitis potentially related to workplace dust exposure. Physical examination of these five employees revealed three with localized areas of eczematous dermatitis in a distribution (at the beltline, face, back of the neck, or shoe/ankle line) which was consistent with an airborne contact dermatitis, one with a nummular (coin-like) dermatitis, and one with evidence of past dermatitis at the beltline. Four of these five employees had previously been seen by the consulting dermatologist and diagnosed with a probable work-related dermatitis.

Based on a combination of record review, interview, and examination, seven employees were identified who appeared to have a work-related irritant dermatitis or an exacerbation of an underlying skin condition associated with contact with airborne dust in the BOF area (Table 4). Of these seven, three reported a history that their skin condition began prior to working in the BOF area, and three reported that their skin condition began after working in the BOF area (one was not interviewed). Several employees reported that their dermatologic symptoms began after

Syn Slag was introduced into the BOF area; this observation was not confirmed by other interviewed employees.

CONCLUSION

Seven BOF employees were found to have a history and/or physical examination consistent with a work-related irritant contact dermatitis (airborne) or an exacerbation of an underlying skin condition by workplace exposure to dusts. Although we are not able to identify a specific causative agent(s), several components of the dust present in the BOF, including calcium aluminate (the principal component of Syn Slag), could be acting as irritants and causing or contributing to the employees' conditions. The alkalinity of the dust may contribute to its potential to cause irritation. To minimize the potential for irritant dusts to cause irritant contact dermatitis or exacerbate preexisting skin conditions, contact of these dusts with the skin should be minimized.

RECOMMENDATIONS

1. Employee exposure to dust in the BOF area should be minimized.

   a. Dumping and handling of slag at #6 pit generates significant amounts of airborne dust several times during the workday. Dust levels may be reduced by eliminating the practice of dumping slag in the BOF area. LTV should evaluate other means of handling slag, including the use of the "lobster" to transport slag away from occupied area, as was reported to have been done previously.

   b. The settled dust from rafters and other surfaces should be removed from areas where workers contact or disturb the dust. A vacuum truck could be used to vacuum dust from workplace surfaces.

   c. The practice of dumping Syn Slag into the oxygen furnace should be evaluated to determine ways to reduce dust emissions. Methods to reduce dust emissions may involve improving the local exhaust ventilation at the chute.

   d. Employees should be encouraged to wear disposable coveralls (e.g., uncoated Tyvek suits) when working in very dusty areas. The coveralls would act as a barrier which would reduce the amount of dust on workers' clothing and skin.

2. Employees should be encouraged to wash dust from skin during their break periods and after any particularly dusty job. Employees should be able to wash with a mild soap and water at readily available wash stations.

3. Air sampling for total dust and metals should be conducted at operations when maximum dust generation is anticipated (e.g., removal of ladle refractory using pneumatic tools).

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1. LTV Steel Co.
2. United Auto Workers
3. Department of Labor/OSHA Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1. Personal Breathing Zone Air Sampling. LTV Steel (HETA 95-0105), May 25, 1995

Job Title	Time (min) / Volume (L)	Al	As	Ba	Ca	Cu	Fe	Mg	Mn	Pb	Na	Ti	V	Y	Zn
		Concentration* ($\mu g/m^3$)													
slide gate repair	411 / 863	13	(1)	0.15	56	1.3	300	16	2.2	nd	(10)	0.59	nd	nd	2
ladle liner	391 / 782	20	nd	0.42	58	(0.3)	12	42	1.1	nd	(10)	1.1	nd	nd	1.4
ladle liner	383 / 789	27	nd	0.75	57	0.23	15	47	1.3	nd	(10)	2.2	nd	(0.04)	1.3
2nd vessel man helper	398 / 804	29	nd	0.21	170	0.24	40	50	6.5	nd	(10)	0.7	(0.3)	nd	6
1st vessel man	399 / 806	20	(1)	0.14	200	0.35	45	67	7.8	nd	(10)	0.5	nd	nd	7.1
2nd vessel man	395 / 806	17	nd	0.16	160	(0.2)	43	62	7.9	(0.7)	(10)	0.63	nd	nd	6.6
material handler	304 / 611	12	nd	0.16	570	(0.08)	25	110	5.4	nd	(20)	0.52	(0.3)	nd	1.8
blank1*		nd	nd	(0.03)	(4)	(0.05)	(0.7)	(0.9)	(0.07)	nd	(20)	nd	nd	nd	0.56
blank2		nd	nd	nd	nd	nd	nd	nd	nd	nd	(7)	nd	nd	nd	0.51

$\mu g/m^3$= Micrograms of contaminant per cubic meter of air.
nd = None detected (see Appendix A for analytical limits)
( ) = Value is between the LOD and LOQ (See Appendix A).
* Blank results are reported as μg/filter.

Table 2. Elemental Analysis of Bulk Samples. LTV Steel (HETA 95-0105), May 25, 1995

#	Location	Concentration (μg/g)														
		Al	As	Ba	Ca	Cr†	Co	Cu	Fe	Mg	Mn	Ni	Ti	V	Zi	Zr
K-1	slide gate repair	75000	31	420	210000	760	9.3	260	71000	58000	14000	45	1600	330	820	540
K-2	ladle lining	31000	(20)	48	44000	1900	16	7.4	22000	180000	2400	46	630	83	6.2	42
K-3	ladle dig out	24000	(10)	130	85000	790	5.5	11	50000	320000	5400	16	1100	300	(4)	230
K-4	ladle dig out	110000	(30)	82	200000	150	(4)	8.9	24000	180000	5200	nd	1300	120	nd	520
K-5	Stein slag separator	15000	nd	110	190000	990	nd	14	170000	49000	12000	nd	2000	910	89	140
K-6	#6 pit	140000	nd	190	310000	480	(9)	4.7	31000	58000	21000	(8)	4400	660	6.5	1100
K-7	#1 vessel	77000	64	95	150000	190	9.4	43	64000	150000	8800	17	720	190	2000	110
K-8	#2 vessel	63000	nd	290	250000	290	9.4	78	49000	88000	11000	30	1900	220	3400	470
K-9	LMF VCP	9100	nd	59	55000	130	(3)	28	26000	350000	2700	nd	480	96	700	99
K-10	#1 vessel	88000	61	150	340000	120	14	29	15000	63000	9900	17	1500	53	610	220
K-11	bin floor	18000	nd	120	150000	140	5.3	68	37000	190000	6200	23	610	150	3900	190
K-12	Syn Slag 60 (virgin)	2500	nd	13	370000	(7)	nd	(0.4)	1800	200000	110	nd	120	4.2	nd	19

μg/g = Micrograms of contaminant per gram of bulk sample.
nd = None detected (see Appendix B for analytical limits).
( ) = Value is between the LOD and LOQ (See Appendix B).
† Visual color comparison using a K-2810 CHEMets Chromate kit did not detect hexavalent chromium. The limit of estimation for hexavalent chromium in this sample set was 10μg Cr(VI) per gram of sample.

Table 3
pH of Bulk Samples*
LTV Steel (HETA 95-0105), May 25, 1995

Sample Number	Location	pH
K-1	slide gate repair	9.0
K-2	ladle lining	9.0
K-3	ladle dig out	9.5
K-4	ladle dig out	10.5
K-5	Stein slag separator	11.0
K-6	#6 pit	9.5
K-7	#1 vessel	10.5
K-8	#2 vessel	10.5
K-9	LMF VCP	10.5
K-10	#1 vessel	10.0
K-11	bin floor	9.7
K-12	Syn Slag 60 (virgin)	10.0

*For pH determination, approximately 0.1 g of each sample was weighed and then moistened with 0.1 ml deionized water. The pH was estimated using calorimetric indicator strips.

Table 4
Summary of Findings for Ten Employees with Current Skin Problem
Basis for Determining Work-relatedness of Employee Dermatitis
LTV Steel (HETA 95-0105)

Employee	Dermatologist Diagnosis[1]	Current History[2]	PE: Work-Related[3]	PE: Non Work-Related[4]
1	X[5]	X	X	
2	X	X		
3	X	X	X	
4	X	X	X	
5	X	X	X	
6		X	X	
7	X	NE[6]	NE	
8				X
9				X
10				X

1 Medical records with dermatologist diagnosis of dermatitis potentially related to workplace dust exposure.
2 History of recent dermatitis and evidence supporting relationship between dermatitis and workplace dust exposure (temporal relationship, anatomical distribution of dermatitis).
3 Physical examination on May 25, 1995, revealing evidence of dermatitis consistent with airborne contact dermatitis, or exacerbation of underlying skin condition by airborne dust.
4 Physical examination on May 25, 1995, revealing no evidence work-related dermatitis
5 X = factor present.
6 NE = Employee not examined or interviewed by NIOSH representatives.

Shaded area includes those seven employees identified as having a work-related irritant dermatitis or an exacerbation of an underlying skin condition associated with contact with airborne dust in the BOF area.

Appendix A. Analytical Limits, Air Samples. LTV Steel, HETA 95-0105

Analyte	LOD (μg/filter)	LOQ (μg/filter)	MDC ($\mu g/m^3$)	MQC ($\mu g/m^3$)
Aluminum	0.5	1.6	0.6	2.1
Arsenic	1.	3.1	1.	4.0
Barium	0.02	0.040	0.03	0.051
Beryllium	0.02	0.064	0.03	0.082
Calcium	2.	4.1	3.	5.3
Cadmium	0.07	0.21	0.09	0.27
Chromium	0.4	1.2	0.5	1.5
Cobalt	0.2	0.62	0.3	0.79
Copper	0.05	0.16	0.06	0.21
Iron	0.6	1.9	0.8	2.4
Lead	0.6	1.8	0.8	2.3
Lithium	0.05	0.17	0.06	0.22
Magnesium	0.7	2.3	0.9	2.9
Manganese	0.03	0.091	0.04	0.12
Molybdenum	0.2	0.43	0.3	0.55
Nickel	0.4	1.3	0.5	1.7
Phosphorus	4.	11.	5.	14.
Platinum	2.	4.1	3.	5.3
Selenium	0.9	3.0	1.	3.8
Silver	0.04	0.13	0.05	0.17
Sodium	5.	17.	6.	22.
Tellurium	0.7	2.3	0.9	2.9
Thallium	2.	4.0	3.	5.
Titanium	0.06	0.19	0.08	0.24
Vanadium	0.2	0.39	0.3	0.50
Yttrium	0.02	0.041	0.03	0.053
Zinc	0.07	0.22	0.09	0.28
Zirconium	0.2	0.36	0.3	0.46

LOD = Analytical limit of detection.
LOQ = Analytical limit of quantitation.
MDC = Minimum detectable concentration based upon an average sample volume of 780 liters.
MQC = Minimum quantifiable concentration based upon an average sample volume of 780 liters.
$\mu g/m^3$ = Micrograms of contaminant per cubic meter of air.

Appendix B. Analytical Limits, Bulk Samples. LTV Steel, HETA 95-0105

The limits of detection (LOD) and quantitation (LOQ) were calculated from NIOSH LODs and LOQs for NIOSH method 7300, modified for microwave digestion of filters, and have been corrected for units ($\mu g/g$). Since all samples were diluted due to matrix interferences and high analyte concentrations, the LODs and LOQs should be multiplied according to the sample dilutions. The reported results for analytes not listed in the following table correspond with a two-fold (2x) dilution.

Sample	Dilution	Analyte
K-1	1x	As
	5x	Al, Ca, Cr, Ti
K-3	5x	Cr, Mg, Mn, Zn
K-4	5x	As, Ca, Cr, Mg, Mn, Ti, Zn
K-5	10x	all analytes
K-6	5x	Ca, Co, Cr, Cu, Fe, Mg, Mn, Ni, Ti, V, Zn, Zr
K-8	5x	Al, Ca, Cr, Mg, Mn, Ni, Zn
K-9	5x	Al, Ca, Mg, Mn, Ti, Zn, Zr
K-10	5x	Ca, Mg, Mn, Ti, Zn
K-11	1x	Co
	5x	Mn, Ti, Zn
K-12	5x	Ca, Mg, Ti

The limits of detection and quantitation for an undiluted sample are as follows:

Analyte	LOD ($\mu g/g$)	LOQ ($\mu g/g$)
Aluminum	2.	6.4
Arsenic	4.	13.
Barium	0.05	0.16
Calcium	5.	17.
Chromium	2.	4.6
Cobalt	0.8	2.5
Copper	0.2	0.64
Iron	3.	7.4
Magnesium	3.	9.1
Manganese	0.2	0.37
Nickel	2.	5.1
Titanium	0.3	0.76
Vanadium	0.5	1.6
Zinc	0.3	0.87
Zirconium	0.5	1.5

$\mu g/g$ = Micrograms of contaminant per gram of bulk sample.

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