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I. SUMMARY

On November 16, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Utility Workers Union of America (UWUA), Local 377. The request referenced smoke, gases and other unknown toxic substances thought to be responsible for various health effects among employees working in underground utility vaults (UUVs) of the Boston Edison Company (BECO), Boston, Massachusetts. The UWUA Local 377 was also concerned with the working conditions and integrity of electrical transmission equipment. On October 15-16, 1991, an environmental survey of UUVs was conducted to assess exposure to lead from cable splicing activities and to observe work practices and procedures.

Selected BECO workers' lead exposure was evaluated by collecting personal breathing zone (PBZ) air samples during work in the UUVs, and collecting wipe samples from various UUVs work surfaces, service vehicles, and employees' clothing and hands. Hand wipe samples were taken before and after completing a cable splicing activity, as well as before and after hand washing. Similar wipe samples were taken at the BECO training center during a training session for cable splicers.

Airborne lead concentrations, measured in each worker's PBZ, ranged from 0.22 to 17 micrograms per cubic meter ($\mu g/m^3$), expressed as 8-hour time-weighted averages (TWAs). The Occupational Safety and Health Administration (OSHA) Permissible Exposure Level (PEL) for airborne lead is 50 $\mu g/m^3$ as an 8-hour TWA. Analysis of wipe samples taken from work surfaces, clothing, and hands of employees working in UUVs showed concentrations of lead ranging from non-detectable to 9.3 milligrams per wipe sample.

Blood specimens for blood lead levels (BLLs) and zinc protoporphyrin (ZPP) were collected from 43 employees who worked in the Underground Transmission and Distribution (UTD) system of BECO. Workers' BLLs ranged from less than 5 micrograms per deciliter (µg/dL) of blood to 43 µg/dL. BBLs from two employees exceeded 40 µg/dL, a level at which OSHA requires more frequent testing. The current U. S. Public Health Service (PHS) policy for workers exposed to lead is to eliminate, by the year 2000, all exposures that result in BLLs

greater than 25 µg/dL. ZPP levels in blood samples ranged from 12 to 72 µg/dL. Questionnaires concerning lead exposure were completed by 75 of the 160 UTD system employees.

Observation of work practices and procedures were made of workers entering and working in the UUVs. Potentially hazardous work practices observed in and around the UUVs included the handling of molten lead in uncovered containers, use of infrequently calibrated gas detection meters, the generation of smoke, gases, and vapors during cable splicing operations, poor housekeeping practices, cramped working conditions, and working on uneven surfaces.

Based on environmental sample results and a review of current pertinent industrial hygiene and safety program elements at BECO, the NIOSH investigators concluded the following during the time of this evaluation: (1) several workers' BLLs exceeded the PHS goal of 25 µg/dL, and (2) many potential safety hazards existed in daily operations within the UUVs. Although substantial safety and health improvements have been made by BECO, additional work needs to be done to revise, improve, and strengthen basic safety and health practices associated with UUVs. Recommendations addressing these practices are presented in Section IX of this report.

KEYWORDS: SIC 4911 (Electric Services), lead exposure, enclosed spaces, power cable, electrical shock, carbon monoxide, explosive gases.

II. INTRODUCTION

On November 16, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Utility Workers Union of America (UWUA), Local 377. NIOSH was asked to evaluate smoke, gases and other unknown potentially toxic substances experienced during work in underground utility vaults (UUVs) of the Boston Edison Company (BECO).

NIOSH investigators held an initial meeting in April 1990 with management and union representatives. In addition to the exposures mentioned in the HHE request, union representatives expressed concern about the death of two BECO underground transmission and distribution (UTD) workers. At the close of the meeting, NIOSH personnel were escorted on a walk-through of several UUVs in the BECO system.

In August 1990, two meetings were held; one with management of BECO, and subsequently with representatives of UWUA Local 377, to determine specific hazards of concern and how the HHE would be conducted. In a second walk-through survey in September 1991, a potential health hazard from exposure to lead was identified. An industrial hygiene survey was conducted on October 15-16, 1991, to collect air and wipe samples to evaluate occupational exposure to lead and to observe work practices of employees entering and working in UUVs. A medical evaluation for lead exposure was conducted at that time.

III. BACKGROUND

BECO provides electrical service to approximately 700,000 customers in 40 cities and towns (approximate 600 square mile area) in and around the metropolitan area of Boston, Massachusetts. BECO employs approximately 4,600 workers. BECO's UTD system is composed of more than 1,100 miles of concrete duct work serving as transmission and distribution cable raceways, and has over 26,000 UUVs which are used to install, operate, and maintain the electrical transmission and distribution conductors and equipment.

A. Underground Utility Vaults

The older UUVs are constructed of brick, while newer ones are constructed of pre-cast or cast-in-place concrete. A UUV is a subterranean chamber generally about 10' x 15' x 10' and designed to permit access to electrical cables. System descriptions are continuously updated on engineering drawings to reflect changes made in the electrical distribution system or physical changes made to the UUVs. BECO is the sole user of this UTD system.

B. Electrical Distribution System

The transmission voltage levels in the UTD system are either 4,160 or 13,800 volts alternating current (VAC), transformed down to 240 and 480 VAC, 3-phase distribution levels. A mixture of voltage levels exists in virtually all vaults. When the HHE began, BECO personnel informed NIOSH that direct current (DC) voltage was still in use in some parts of the BECO system, but that it was being rapidly phased out.

No work is performed on a transmission conductor while it is energized or "live;" however, it was reported by BECO employees that "live" work is routinely performed on the lower voltage distribution system. All transmission and distribution conductors are lead-sheathed insulated copper, with a grounded neutral. All electrical equipment, conductors, and splices are rated as submersible since partial or complete flooding of the UUVs, in some locations, is a common occurrence.

C. BECO Safety and Health Organization

A corporate safety director and several department-level safety managers are employed to administer the company's written safety program. The safety managers serve as staff advisors to organizational divisions such as the UTD Division.

BECO has developed a comprehensive standard operating procedure (SOP) manual that details various actions to be taken in performing job tasks encountered during daily operations. This SOP manual was first issued in 1957 and, as of this evaluation, had undergone 19 major revisions.[1]

The UTD Division's safety program contains provisions for training employees, conducting regular safety meetings, using tag-out procedures for energy control, worker entry into the UUVs, etc. The program does not provide for monitoring of lead exposures in the UUVs during splicing operations.

During the late 1980's, BECO initiated a program to remove the polychlorinated biphenyl (PCB) fluids from transformers and switches. A majority of the PCB fluids were removed during this program; however, some transformers still contain PCBs according to both union and management officials. In recent years, BECO has also initiated an aggressive program to remove asbestos-containing material from UUVs.

D. Injury and Illness Data

Injury data recorded on the Occupational Safety and Health Administration (OSHA) Form 200 Illness and Injury logs for the years 1985 to 1990 indicate that a number of injuries occur as a result of cramped conditions in UUVs. For example, lifting cables in UUVs has resulted in several back injuries. The OSHA 200 logs for the BECO Massachusetts Avenue Operation Centers showed that the number of reported incidents have almost doubled in the last six years (see Table I).

Two deaths were reported on the OSHA 200 logs between 1985 and 1990. A cable splicer was electrocuted in 1987, and a construction inspector died of electrical burns in 1989.

Discussions with BECO personnel suggest that injuries recorded on the OSHA 200 logs can result from working on uneven surfaces around UUVs, including entry and exit from service vehicles. In fact, some of these types of injuries can occur at night and/or during inclement weather and also involve walking or stepping on or over street curbing or other uneven street or sidewalk surfaces.

IV. METHODS AND MEASUREMENTS

The sampling program used by NIOSH to evaluate potential UUV hazards contained the following elements:

A. Lead

1. Sampling for airborne lead was performed by NIOSH personnel using NIOSH Method 7082.[2] Before entering the UUVs, BECO employees were asked to wear a battery-powered sampling pump attached via flexible tubing to a filter cassette with a 37-millimeter mixed cellulose ester (MCE) filter, 0.8 micron pore size, and calibrated at a flowrate of 2 liters per minute. The sampling equipment was removed from BECO employees after completion of the work activity and exiting the UUVs.

For analysis, the filters were removed from the cassette, digested in nitric acid and 30% hydrogen peroxide, and analyzed for lead using atomic absorption, graphite furnace. The analytical limits of detection and quantitation were 0.03 and 0.11 micrograms (µg) of lead per filter, respectively.

2. Surface lead contamination levels were measured using NIOSH Method 0700.[2] Commercially available, pre-moistened baby wipes (Chubs™ brand) were used to wipe pre-measured areas upon surfaces of interest. Most samples were collected from 0.25 square-foot (ft^2) areas; however, due to varying surface characteristics, other sized areas were also used. Disposable gloves were donned for each surface sample, and the pre-measured area was wiped with a series of vertical strokes in an "S"-pattern. The exposed side of the pad was folded inward and the area was wiped with a series of "S"-strokes at a 90° angle to the previous pattern.

Wipe samples were collected from various work surfaces including those in the UUVs, in service vehicles, and in the BECO training center (used to train cable splicers). Surface wipe samples were also obtained from equipment and employee clothing and boots. In addition to the surface wipe samples, employees were asked to wipe their hands for 30 seconds using the baby wipes (both before and after cable splicing operations or hand washing). These wipes were used to determine the amounts of lead accumulated during cable splicing and removed by hand washing.

All the wipes were digested in nitric acid and 30% hydrogen peroxide, heated, and quantitatively transferred to 25-milliliter (ml) volumetric flasks. The solutions were analyzed for lead by atomic absorption, graphite furnace, according to NIOSH Method 7105.[2] The analytical limit of detection and limit of quantitation were 5 µg and 17 µg of lead per sample, respectively.

3. Blood specimens were collected by venipuncture from employees working in the UTD system. NIOSH investigators recruited volunteers from all shifts and underground job categories to form the study sample for blood specimens. The blood specimens were sent to an independent laboratory and analyzed for the presence of lead (blood lead level [BLL]) by anodic stripping voltometry and for zinc protoporphyrin (ZPP) by a fluorometric method. The blood specimens were stored in a cooler immediately after collection and remained refrigerated in the cooler until delivery to the laboratory. Duplicate blood specimens were obtained from seven employees to test laboratory reliability. The pooled relative standard deviation of the seven sample pairs was five percent. This level of precision meets the criteria suggested by the accuracy requirements of the OSHA standard for blood lead. The workers selected were notified by letter of their individual results (see Appendix A).

4. All employees working in the UTD system were asked to complete a self-administered questionnaire addressing occupational exposure to lead. All workers who had blood specimens drawn also completed a questionnaire (see Appendix B).

B. Work Practices

Observation of work practices performed both in and out of UUVs was conducted by NIOSH personnel. Observation of work practices conducted in a given UUV was limited to those procedures that could be observed from aboveground while looking down into the UUVs. Observation of work practices in cable splicing procedures identified potential chemical exposure from heating of cable sealant materials. Bulk samples of the no void and anti-oxidant cable sealant compounds were collected to qualitatively identify potential emissions by gas chromatography (GC) mass spectrometry.

V. EVALUATION CRITERIA

As a guide to the evaluation of hazards posed by work place 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 ten hours per day, 40 hours per week, for a working lifetime without experiencing adverse effects if their exposures are maintained below these levels. A small percentage of workers 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 work place 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 levels set by the evaluation criterion. These combined effects are not often considered by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the work place are the following: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Levels (PELs). It must be noted that the OSHA PELs are required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease.

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

1. **Lead.** Inhalation (breathing) of dust and fume, and ingestion (swallowing) resulting from hand-to-mouth contact with lead-contaminated food, cigarettes, clothing, or other objects are the major routes of worker exposure to lead. Once absorbed, lead accumulates in the soft tissues and bones, with the highest accumulation initially in the liver and kidneys.[3] Lead is stored in the bones for decades and may cause toxic effects as it is slowly released over time. Overexposure to lead results in damage to the kidneys, gastrointestinal tract, peripheral and central nervous systems, and the blood-forming organs (bone marrow).

   A BLL measures the amount of lead present in the blood at the time of the test. While the BLL is a reliable indicator of current exposure to lead, it does not indicate the total body burden of lead.[4] The ZPP is a measure of the effects of lead on blood cells; it is an indicator of exposure to lead over the preceding four months. The ZPP will also rise if there is an inadequate amount of iron in the body. Both BLL and ZPP are measured in micrograms per 100 milliliters (or one deciliter) of blood (µg/dL).

   The OSHA PEL for airborne lead is 50 micrograms per cubic meter (µg/m^3) as an 8-hour TWA.[5] The standard requires semi-annual monitoring of BLL for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8-hour TWA), specifies medical removal of employees whose average BLL is 50 µg/dL or greater, and provides economic protection for medically removed workers.

   In recognition of the health risks associated with exposure to lead, a goal for reducing occupational exposure was specified in *Healthy People 2000*, a recent statement of national consensus and U.S. Public Health Service (PHS) policy for health promotion and disease prevention. The goal for workers exposed to lead is to eliminate, by the year 2000, all exposures that result in BLLs greater than 25 µg/dL.[6]

   Lead can accumulate in the body over time and produce health effects long after exposure has stopped. Long-term overexposure to lead may cause infertility in both sexes, fetal damage, chronic kidney disease (nephropathy), and anemia. The frequency and severity of symptoms associated with lead exposure increase with increasing BLLs. Signs or symptoms of acute lead toxicity include weakness, excessive tiredness, constipation, anorexia, abdominal discomfort, colic, anemia, high blood pressure, irritability or anxiety, fine tremors, pigmentation of the gums ("lead line"), and "wrist drop."[7-9]

Recent studies suggest that there are adverse health effects at BLLs below current standards for occupational exposure. A number of studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dL. Male BLLs are associated with increases in blood pressure, with no apparent threshold through less than 10 µg/dL. Other studies have suggested decreased fertility in men at BLLs as low as 40 µg/dL. Prenatal exposure to lead from maternal BLLs as low as 10 to 15 µg/dL have been associated with reduced gestational age, low birthweight, and delayed early mental development.[10]

In homes with a family member occupationally exposed to lead, lead dust may be carried home on clothing, skin and hair, and in vehicles. High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure.[11] The adverse affects of lead on children and fetuses include decrease in intelligence and brain development, developmental delays, behavioral disturbances, decreased stature, anemia, decreased gestational weight and age, and miscarriage or stillbirth. Lead exposure is especially devastating to fetuses and young children due to potentially irreversible toxic effects on the developing brain and nervous system.[10]

2. **Confined Space.** The NIOSH definition of a confined space is an area which, by design, has <u>limited</u> openings for entry and exit, <u>unfavorable natural ventilation</u> which could contain (or produce) dangerous air contaminants, and which is <u>not intended for continuous employee occupancy</u>. The NIOSH criteria for working in confined spaces further classifies confined space based upon characteristics such as oxygen level, flammability, and toxicity.[12] As shown in Table II, if any of the hazards present a situation which is immediately dangerous to life or health (IDLH), the confined space is designated **Class A**. A **Class B** confined space has the potential for causing injury and/or illness but is not IDLH. A **Class C** space would be one in which the hazard potential would not require any special modification of the work procedure. The NIOSH investigators consider the UUVs to be a Class B confined space.

   The Check List of Consideration (Table III), as taken from reference 12, delineates the minimum entry preparation required for each class of confined space. In the recommended standard where specific procedures, activities or requirements are correlated with a classification, the procedure, activity or requirement is mandatory. As an example, Item 1 - Permit (Class A, B and C) means that a permit is mandatory for Class A, B, and C confined space entries.

3. **OSHA Proposed Standard entitled, "Electric Power Generation, Transmission, and Distribution."** In 1989, OSHA proposed a new standard 1910.269, "Electric power generation, transmission, and distribution."[13] This

proposed standard covers work practices, installations, and equipment associated with the operation and maintenance of electric power generation, control, transformation, transmission, and distribution lines and equipment. The proposed standard applies to power generation, transmission, and distribution installations which are under the exclusive control of the utility and are accessible only to qualified employees as part of the utility operation. Table IV lists the key topical elements covered by this proposed standard.

Paragraph (e) of the proposed OSHA standard has particular importance to this HHE as it identifies requirements for entry and work in enclosed spaces. An "enclosed space" is defined to be a space such as a manhole, vault, tunnel, or shaft, that has a limited means of egress or entry, and that is designed for periodic employee entry under normal operating conditions. The enclosed space under normal conditions does not contain a hazardous atmosphere, but may contain a hazardous atmosphere under abnormal conditions. Additionally, OSHA defines a qualified employee as "one knowledgeable in the construction and operation of electrical generation, transmission, and distribution equipment and the hazards involved."

In 1989, NIOSH presented testimony in support of the proposed rule on electric power generation, transmission, and distribution.[14] The testimony given specifically addressed issues of cardiopulmonary resuscitation (CPR), control of hazardous energy, line mechanics, and enclosed spaces. The NIOSH position on these issues was the following: 1) to recommend that workers who may contact energized electrical circuits work in pairs and that both members of each team be trained in CPR; 2) preference for lockout over tagout provisions; and 3) continued support for enclosed spaces as long as the enclosed space had a well-maintained atmosphere and did not contain a hazardous atmosphere. If a hazardous atmosphere may exist, more detailed precautions are required than what are presently contained in the proposed ruling. For example, if enclosed spaces become hazardous (i.e., molten lead, flooding, gases, electrical hazards, extremely low frequency (ELF) fields, etc.) then it may be necessary to treat that previously defined enclosed space as a confined space.

VI. RESULTS

A. Assessment of Occupational Exposure to Lead

1. **Airborne Lead.** Eighteen personal breathing zone (PBZ) samples for airborne lead in various UUVs where work was being performed were collected and submitted for analysis. The samples measured exposure during splicer operations performed at a single UUV. Airborne lead concentrations

(Table V) ranged from 1.2 to 55 µg/m^3 over the actual sampling times, which ranged from 86 to 399 minutes. The 8-hour TWAs for these data, assuming no further lead exposure over the remainder of the shift, equate to 0.22 to 17.0 µg/m^3, respectively. Although all of these values are below the current OSHA PEL for airborne lead (50 µg/m^3 as an 8-hour TWA) UUV workers sometimes work in more than one location per day; therefore their 8-hour TWA exposures could be significantly higher than what is reported.

2. **Surface Lead.** A total of 45 wipe samples were collected from employees' work clothes and various surfaces inside service vehicles and in the training center. UTD employees were also asked to perform 30-second wipes of their hands. These samples were used to determine the amount of lead accumulated during work and/or the amount of lead removed by hand washing.

   The surface lead concentrations are presented in Table VI. A total of 14 samples were collected by wiping specific, measured areas on the various surfaces. This sampling protocol allowed surface concentrations to be calculated in micrograms of lead per square foot (µg/ft^2). The calculated surface lead concentrations ranged from 48 to 15,200 µg/ft^2. There are no occupational guidelines for lead on surfaces. Surface sampling is used to assess contamination of the work environment rather than to quantify exposures.

   A total of 20 hand wipe samples were collected to demonstrate levels of lead contamination possible from various splicing tasks as well as to determine levels of lead reduction achievable by washing employee's hands. Table VII shows the results of the wipes collected from a given splicer before and after cable splicing operations. In performing this particular sampling protocol, no allowances were made for whether the chosen splicer had previously (on that same day) performed splicing operations where residual lead could have accumulated on the hand. Table VII demonstrates that workers can be contaminated with lead as a result of job activities. Table VIII shows the results of the wipes collected before and after employees washed their hands. The percent reduction of lead from washing was calculated by dividing the difference between the before and after wipes by the amount on the before wipes, and then multiplying by 100. The percent of lead reduction appeared to be similar for each of the employees, with values ranging from 80 to 89% and an average lead reduction of 85%. The amount of residual lead left after washing ranged from 250 to 680 µg/wipe. The results from Table VII and VIII suggest that hand washing be performed after all job activities involving lead.

The results of single wipe samples collected from various BECO employees are presented in Table IX. A total of 11 samples were collected, with the residual amounts of lead on their hands ranging from 120 to 3,300 µg/wipe. Splicers and helpers had the highest overall residual lead, with a splicer trainee having the highest amount.

3. **Blood Lead.** Forty-three current employees participated in the blood lead survey. These 43 represent approximately 25% of the 160 UTD workers employed at BECO as of the date of evaluation. Though a formal sampling process was not feasible, participants were selected from each of the six job categories to assure representation from each group. These job categories included supervisors, troubleshooters, cable splicer grade A, cable splicer grade B, and cable splicer grade C (includes splicer helpers). In addition, two of the instructors at the BECO training facility were included in the group.

   Table X shows the results of the blood lead analyse. The average BLL for the 43 workers tested was 20 µg/dL. The BLLs ranged from <5 to 43 µg/dL of blood. BLLs of two persons exceeded 40 µg/dL, the level at which the current OSHA standard requires more frequent testing. Fifteen (35%) of the workers sampled, however, had BLLs which exceeded the PHS goal of less than 25 µg/dL of blood. Table X also shows the ZPP results. The mean ZPP for the 43 persons tested was 25 µg/dL, with a range of 12-72 µg/dL of blood. All of these values are below 100 µg/dL, the reference level cited in the OSHA standard. The ZPP's of two workers were over 50 µg/dL. A ZPP concentration in excess of 50 µg/dL may indicate chronic overexposure to lead or iron deficiency. In adult men who work with lead, lead exposure is a more likely cause than iron deficiency of an elevated ZPP.

4. **Questionnaire Results.**

   All of the 43 workers who had blood specimens drawn completed the questionnaire. From the remaining 117 UTD workers not selected for the blood lead monitoring survey, 32 individuals volunteered to complete the lead questionnaire. The questionnaires included information on demographics, work history, work practices, personal habits, health and safety training, and non-occupational exposures to lead.

   a. **Demographics:** The ages of the 75 employees who completed questionnaires ranged from 20-61 years. The mean (average) age was 36 years. All 75 employees were male. Most (53%) participants worked the day shift, with the fewest number of employees rotating between shifts (4%). The majority (75%) of the workers were cable splicers (either grades A, B, or C). Twenty-nine (38%) of the respondents indicated they were in the Splicer A job category. The non-splicer employees represented 19 (26%) of the respondents and included inspector, troubleshooter, and trainer job categories. Two training supervisors participated. Of the 70 workers who share their home with others, 35 (50%) reported having children under six years old at home.

b. **Work History:** None of the 75 workers had been removed from a job or had their job changed because of a high BLL. One worker indicated that he was treated for lead poisoning in the past (this worker's BLL was <25 µg/dL at the time of this study).

c. **Work Practices:** Questions on employee work practices included information on personal protection, smoking, eating, and hygiene. Thirteen (18%) of 73 workers reported ever wearing a respirator on the job. Two of these employees indicated that they removed the respirator in the middle of performing a task.

Potential risk factors for ingestion of lead included smoking, eating, and hand washing. Thirty-three (44%) of the 75 workers were current cigarette smokers. The mean number of cigarettes smoked per day was 19. Of the 33 workers who smoked, 30 (91%) indicated that they smoked either in the vehicle or at the worksite when on the job. Furthermore, 64 (85%) workers indicated that they ate their lunch either in the vehicle or at the worksite. Of the 70 respondents who answered an open-ended question about hand washing while at work, only 24 respondents (30%) indicated they wash their hands "before eating" or "at lunch."

Additional questions on hygiene consisted of information on showering, changing work clothes and shoes, and the laundering of work clothes. Results indicate that most of the workers who completed a questionnaire showered, changed clothes, and changed their shoes before leaving work. Sixty-eight (92%) of 74 workers showered before leaving work; 67 (92%) of 73 changed their clothes before leaving work; and 70 (93%) of 75 workers changed their shoes before leaving work.

Sixty-eight (91%) of the 75 workers took their work clothes home. Of those 68, 19 (25%) kept their work clothes with other clothes before laundering, and 15 (22%) of the 68 laundered their work clothes with other clothes. There was no association between hygiene practices and having children under six years old at home. Twelve (16%) of 75 workers indicated that they had received training in how to protect themselves from overexposure to lead, the health effects of lead, and the signs and symptoms of lead poisoning.

d. **Miscellaneous:** Other miscellaneous questions consisted of information on non-occupational exposures to lead. One of 75 workers indicated he had removed lead-based paint within the past six months. His BLL was <25 µg/dL at the time of the study. None of the 75 workers indicated that they worked with stained glass. Two workers used indoor firing ranges. The BLLs of both of these workers were <25 µg/dL.

B. Observation of UUV Work Practices/Procedures

The following general pattern of work in UUVs was observed during several visits to various BECO UUVs:

Employees enter the UUVs to perform a variety of job tasks such as the removal of deteriorated cable conductors, replacement of new conductors, splicing of cables, transformer replacement and repair, maintenance of switchgear, and removal of PCBs from transformers. Prior to entering an UUV, pre-testing of the air is performed using gas meters to test for explosive gases and/or oxygen deficient atmospheres. Once these tests have determined that it is safe to enter the vault, the employee removes the access cover, lowers a ladder, a light source, and ventilation tube into the UUV and enters the vault. Employees are trained not to enter the UUVs unless the tests indicate it is safe to enter. Continuous UUV ventilation is maintained with the use of an air blower.

When it is necessary to cut and splice electrical cable, the circuit containing the cable involved is "tagged" at the substation by a substation attendant as "out of service." Prior to cutting into a cable, the splicer tests the circuit involved to assure it is de-energized. The portions of cable to be worked on are isolated by installing grounding jumpers on both ends of the conductor to be removed or spliced. The cable splicer then proceeds with the splicing operation.

The complexity and length of time required to accomplish a cable splicing operation varies considerably. Typically, one or more cables are removed from cable hanger brackets attached to the wall of the UUV, the lead sheathing is opened using a hooked knife and pliers, various layers of insulating materials are removed to expose the bare conductor, and then the conductor is cut.

Prior to soldering, the cut ends of the conductor(s) are cleaned with a rag wetted with 1,1,1-trichloroethane. An anti-oxidant compound is applied to the surface areas to be soldered. Soldering of the conductors is then accomplished using a lead-based solder. Electrical tape is applied to the solder joint followed by the application of a "no void" sealant. The sealant is a mixture of pine resin and castor oil. Molten lead, prepared outside of the UUVs, is then handed down to the employee in the vault using an open ladle and line. The molten lead is applied to the spliced area of the cable to re-establish an intact lead sheathing, making it once again suitable for submersion.

After continuity checks of the spliced conductors are made, power is then returned to the spliced cables in the circuit. The cable(s) is placed back on the cable hanger bracket, and the employee removes equipment and any remaining materials and exits the UUV.

1. **Handling of Molten Lead.** Figure 1 shows the lead being heated to approximately 700°F in a ladle close to the UUV opening. The molten lead is then picked up and carried to the UUV (Figure 2). Finally, the molten lead is handed down to the worker (already in the UUV) using an open ladle and line (Figure 3). In many UUVs, the space where the worker was located was so restricted that he could not move from under the descending open ladle, posing a risk of severe burn.

2. **Removal of UUV Covers.** The UUV covers are made of cast steel and are perforated to allow the escape of gas. Entry to the UUVs is accomplished by inserting a special tool (see Figure 4) into one of the ventilation holes and lifting/dragging the cover one to two feet. There are at least two cover types, one for normal UUVs, and a larger one for transformer vaults.

3. **Water in UUVs.** Water can enter UUVs by seeping around the cover-head or through its ventilation slots/holes and by filling the surrounding subterranean space from sources such as the Boston Harbor or Massachusetts Bay. Regardless of the source, water must be pumped from the UUV before a worker can enter.

   At times, it necessary to place wooden planks in the bottom of the UUV to provide adequate footing and a working surface (Figure 5). Although BECO procedures require all scrap scaffold planking and splicing debris to be removed at the end of the job, a number of UUV contained planks that had been left in them. These damp/wet planks are slick, creating slipping hazards.

4. **Smoke And Fume Production.** Smoke and gases were observed during certain cable splicing operations (Figure 6), particularly, when antioxidant and sealant compounds were heated.

5. **Cables and Electrical Components.** Space in the UUVs is often limited by the presence of a large number of electrical cables. In fact, some downtown BECO vaults have so many cables that it is difficult to both enter and egress the UUVs. Figures 7-10 exemplify the number and general condition of cables that can be found in a typical UUVs in that area. Most of the electrical cables seen by NIOSH investigators appeared to be in good condition, but in UUVs that contained transformers, many of the transformers appeared old and showed evidence of rust (Figures 11-12).

   When problems develop in the transmission system, a troubleshooter must locate and determine the extent of the problem. This requires the troubleshooter to perform electrical measurement tests on energized conductors in the system's transmission and distribution circuitry. Prior to the troubleshooter's initiating circuit testing, the substation attendant replaces the circuit's normal overload protective device with a low current device. This action reduces the possibility that a sustained, high-current flow will occur should a ground fault develop while the troubleshooter tests the circuit. Once the troubleshooter has identified the "problem" section of cable, the substation attendant tags the circuit disconnect device disconnecting the circuit "out of service," and that section of cable is scheduled for replacement by the splicers.

   The cable splicers must remove the section of "problem" conductor from the underground network and replace it with a new conductor. Prior to severing the "problem" section from the network, the splicers test the circuit to assure it is de-energized, and then isolate it by installing grounding jumpers on the conductor at both ends of the section to be removed. When the splicers have completed installation of the replacement conductor, they exit the UUVs and place a radio request for the substation attendant to re-energize the circuit.

   Although not observed, UTD workers reported that electrical arcing and explosions occur. This creates a potential for electrical shocks in UUVs, which have in fact, occurred in the recent past.

   NIOSH investigators noted the general poor condition of cable identification tags used to identify cable voltage. These cable tags were often illegible, missing, or hidden due to the presence of other cables.

6. **Preventative Maintenance.** UTD workers indicated that they regularly report preventative maintenance problems, such as deteriorating transformers and cables. Although a recent preventative maintenance program has been initiated by BECO, the large number of UUVs with maintenance problems, may prevent a short response time to these reports. Workers are concerned that the inability to correct these maintenance problems will expose them to hazardous conditions in UUVs.

C. Enclosed Space Entry

BECO has developed written procedure for UUV entry and safe work procedures implementing OSHA's proposed standard 1910.269.[13] In these procedures, BECO considers all supervisors, troubleshooters, and splicers to be qualified employees based on training and experience.

The following observations were noted regarding BECO entry procedures for enclosed space:

1. BECO uses two separate types of air monitoring meters to determine the quality of the enclosed space atmosphere. One is a multiple-function instrument for explosive gases, O_2 level, and carbon monoxide (CO). This meter can continuously monitor the atmosphere while work is being done in the enclosed space. The other meter set includes an explosive gas meter and an O_2 analyzer. Although BECO's procedures require combustible gas and O^2 measurement devices to be calibrated prior to use, NIOSH investigators observed that some of these measurement devices were only calibrated periodically and <u>not</u> immediately prior to use. BECO reported that, on infrequent occasions, explosive gas concentrations have been detected.

2. If the CO level is above 35 ppm, the UUV is ventilated with an air blower until acceptable levels are present and maintained. The air blower is used to continually ventilate the UUV, as long as it does not interfere with the work. If it interferes, the blower is removed from the enclosed space. Work continues without additional protective measures being implemented to protect the worker. NIOSH was informed by BECO workers that, in some cases, the ventilation is turned off prior to pouring the molten lead to achieve a more reliable cable lead seal.

3. BECO does not require employees in enclosed spaces to wear a safety belt or harness, lifeline, or respirator. BECO is of the opinion that this safety equipment creates additional hazards for employees. For example, BECO contends that safety lines and fresh air hoses could get caught on cable

support brackets and/or the use of safety belts or harnesses could cause damage to the cable insulation thereby exposing live conductors. The use of such safety equipment would also limit the ability of the employee to work in the usually cramped space in the UUVs.

4. In work on certain UUVs the presence of a ladder, ventilation tubing, and barriers can radically restrict access to the UUVs. Perhaps the use of an oval or oblong-shaped ventilation tube, in contrast to the presently used circular shaped tube, can aid in alleviating difficulty when entering or exiting the UUVs.

D. Bulk Sample Analysis

Two bulk samples of solid cable sealant material collected at BECO were submitted for qualitative heated headspace analysis to identify organic compounds by GC-MS. The samples were analyzed after heating to 400°F (maximum BECO operating condition). The results of the analyses showed that both bulk materials contained identical components. A copy of the reconstructed total ion chromatogram is found in the Appendix C. The major compounds identified were terpenes, terpene derivatives, and phenolic compounds. Lower levels of organic acids, acetates, and ketones were also detected. The MSDS stated that the materials contained pine wood resin and castor oil.

VII. DISCUSSION

A. Lead

In this survey, workers who actually performed splicing had higher BLLs than those who did not. Only the Splicer C and Inspector groups were without members in excess of the PHS goal of 25 µg/dL. The Splicer A group contained two members with a BLL in excess of 40 µg/dL. These results indicate that some UTD workers are being exposed to lead at unacceptable levels.

Airborne lead concentrations in most cases were relatively low in the enclosed space of UUVs. However, lead may also be absorbed via ingestion, as well as inhalation, and significant lead concentrations were found on various surfaces in the work area and on the hands of employees. Eating and smoking in lead contaminated areas could increase the potential for ingestion. By self report, such behavior among the UTD workers surveyed was common.

The practice of transporting work clothes home for laundering may increase the potential for exposing employees' children to lead.

The relatively high BLLs of two school instructors deserve attention. Since the training activities are continuous, these employees may have ongoing exposures.

B. Smoking Policy

Cigarette smoking is the leading cause of preventable morbidity and death in this country. The PHS has developed a position over the last few years that strongly encourages those who smoke to stop. The PHS also recommends that all employees be provided with a workplace free of cigarette smoke. NIOSH has recommended that environmental tobacco smoke (ETS) be regarded as a potential occupational carcinogen in conformity with the OSHA carcinogen policy, and that exposures to ETS be reduced to the lowest feasible concentration. Employers should eliminate occupational exposure to ETS by prohibiting smoking in the workplace or restricting it to separate enclosed areas with separate ventilation.[15]

C. Generation of Smoke and Fume in UUVs

Smoke and gases were produced in the UUVs by at least two major means:

1. heating of a no-void sealant in splicing operations.

2. heating of the anti-oxidant compounds during soldering activities.

Analysis of the two samples of no-void sealant did not identify any highly toxic chemicals as a result of heating this compound to the desired temperature (400°F). Air samples were not taken to determine if there were toxic chemicals generated as a result of heating the anti-oxidant during soldering operations. While it was not determined whether chemical exposures (other than lead) in UUVs present any major health hazards, exposure to smoke and fumes, from any source, can cause irritation and reduce visibility in the UUVs.

A degreasing solvent containing 1,1,1-trichloroethane is also used during cable splicing operations. The solvent is poured on a rag, which is then used in wiping down cable surfaces to be spliced. Air levels of 1,1,1-trichloroethane were not determined in this evaluation. BECO has recently initiated the use of "towelettes" moistened with 1,1,1-trichloroethane in UUVs, replacing the use of open containers and rags.

BECO has recently initiated the use of a heat shrink joint to reseal spliceable joints. This technique may reduce smoke and fume production in UUVs, however, the Material Safety Data Sheet (MSDS) for the heat shrink material recommends use of approved respirators in enclosed (confined) unventilated areas.

The NIOSH investigators observed on several occasions that the ventilation tube intake was often located next to truck exhausts, on-board gas generators, etc. (see Figure 13). This increases the possibility that contaminants (such as CO) may enter the enclosed space. In order to minimize exposure to the possible accumulation of gases as well as to reduce exposure to smoke, fumes, and vapors, the enclosed space of the UUVs should be continuously ventilated when occupied.

The use of air blowers to ventilate the UUVs is a practice already employed by BECO. However, NIOSH investigators noted that if the ventilation tube of the air blower is in the way of the work activity, it may be removed from the UUV. Also, the air blower may be turned off during certain phases of cable splicing activities, such as the pouring of molten lead in re-sealing electrical power cables.

D. Molten Lead

Because of the limited space in UUVs, cable splicers are often placed at risk of being splashed with molten lead while it is being lowered into the UUVs. In some instances, splicers cannot position themselves away from the descending ladle. No personal protective equipment was required or provided for this operation. One method to minimize this major concern would be use of spill-resistant containers to lower molten lead down into the UUVs.

E. Monitoring of air in UUVs

Using the older air monitoring and analysis instruments requires two separate tests to be taken. Also, testing for CO concentrations is not done when these older meters are used. The levels of explosive gases, O_2, and CO can be determined with one test using a multiple-function instrument. This meter can also be used to continually monitor the atmosphere inside an enclosed space and sounds a warning alarm at a preset level. This provides the workers with additional protection if an unusual situation should occur that could alter atmospheric conditions.

While a program has been initiated by BECO to replace all combustible gas and oxygen deficiency measuring devices with multiple-function, continuous detection monitors, the NIOSH investigators believe this replacement program should be accelerated.

BECO has an instrument shop responsible for calibrating the air analysis meters. A meter used for worker training programs was found to be approximately six months past due for recalibration. A spot check in the field also found a meter that was past its recalibration date. BECO should develop and enforce a more aggressive calibration program consistent with the manufacturer's recommendations.

Although there have been no reported oxygen deficient conditions detected in UUVs by BECO to-date, BECO should modify current procedures for entry into enclosed spaces to require additional air quality checks at different levels within the UUVs to insure that heavier than air gases and vapors did not collect in a low area of the UUVs and create an explosive environment.

Another issue of importance for air monitoring equipment is the accuracy of the readings. Humidity, temperature, and chemical interferences will effect the accuracy of monitoring devices used in confined spaces. NIOSH has published articles in these areas and the reader is encouraged to read the cited material for more information.[16-18]

BECO should assure that monitoring and testing devices are properly used, maintained, and calibrated at all times. They should provide operators with training, adequate time, tools, facilities to maintain, and calibrate (including a stock of spare parts), and a system to record use time and maintenance performed.

F. Enclosed Space Rescue Procedures

BECO has established a procedure for rescuing a worker from enclosed spaces. In the event of a downed or seriously injured worker in an enclosed space, the standby person working at the top of the UUV is to immediately make a MAYDAY call on the vehicle's radio. After confirming that help is on the way, the standby person will then test the atmosphere in the enclosed space. If the results of the atmosphere tests are acceptable for entry, the standby worker may then enter the enclosed space to initiate a rescue. The victim is to be checked to insure there is no contact with electrical conductors and that the victim can be moved safely. If the victim can be moved, a lifting strap and lifeline attached to a winch located on the quadripod stanchion (barrier) above the opening of the enclosed space is secured around the victim's upper torso. The standby person is then to exit the enclosed space, winch the victim to the surface, and remove him from the enclosed space. If rescue by this means cannot be accomplished, the standby person must wait for assistance to arrive at the site.

The quadripod stanchion used by BECO contained manufacturer warning labels that suggest they are not to be used for lifting humans. The presence of these labels suggest that these lifting devices may not be appropriate for enclosed space rescue procedures.

BECO should modify the worker training materials concerning rescue of workers from UUVs. This training should emphasize that the rescuer check the atmosphere before entering the UUV and stress that the rescuer delay entry until assistance arrives at the site. The current training material (a video tape) recommends the standby worker place a MAYDAY call via company vehicle radio and obtain a response to that call before entering the UUV. The video tape recommends, only once, that the rescuer check the atmosphere in the UUV before entering. The rescuer must know if hazardous atmospheric conditions exist in the UUVs in order to adequately protect himself from those hazards.

In past emergencies, BECO employees and fire department personnel have responded to rescue sites in less than ten minutes. The presence of other trained personnel at the scene, prior to initiating rescue efforts, would help assure that proper procedures are followed and would provide assistance to the rescuer in the event of complications.

G. Extremely Low Frequency Fields

Many BECO UUV workers, in the course of performing their job tasks, are required to come close to current-carrying cables and transformers which produce sub-radiofrequency (less than 1000 hertz [Hz]) electric and magnetic fields. In recent years, controversy has arisen as to whether there are any health consequences from exposure to these fields.[19] Several studies have found an excess risk of cancer among workers employed in electrical occupations, but the lack of consistent findings for health effects has not allowed firm conclusions to be drawn. While BECO safety personnel are aware of the presence of such fields in UUVs, they have not undertaken any program to assess these levels. BECO should initiate ELF exposure assessment programs in and around selected UUVs and transformer vaults. In performing these exposure assessments, the following issues should be considered:

1. Area and personnel measurements need to be made for both electric and magnetic field levels. Maximum, minimum, average, and time-varying levels should be determined. Frequency levels and waveforms also need to be evaluated.

2. Measurements need to be taken both inside and outside UUVs. It would be anticipated that transformer vaults and UUVs containing many cables would produce higher electric and magnetic fields.

3. Evaluate the relationship, if any, between field levels in UUV as a function of the number of cables it contains.

4. Evaluate the drop-off in magnetic field exposure in and around the UUVs as a function of distance. This evaluation could be important for transformer vaults.

5. If BECO exposure assessments demonstrate elevated peaks, then a review of work practices needs to be performed in order to eliminate or modify those procedures that could result in short-term elevated field levels.

6. Results of these assessments by BECO may be compared with ACGIH TLVs or other appropriate ELF occupational exposure standards.

H. Electrical Concerns

Many of the UUVs were built at least 60 years ago, contain equipment that is both old and rusting, can be filled with large quantities of water daily, are not opened regularly "on-demand," and can contain many electrically energized cables. The presence of electrical cables in such an environment gives rise to questions about cable integrity.

NIOSH investigators were not able to determine if hazardous conditions could exist in UUVs from loss of electrical cable integrity resulting from deterioration of the cable conductor and insulating materials due to electrical stress and/or submersion in water over many years. While the issue of cable integrity was not resolved in this evaluation, it needs to be identified, for future study, as a possible factor in occupational safety and health concerns.

The NIOSH investigators observed some UUVs which contained a hundred or more electrical cables. In a few UUVs the number of cables occupy more space than what appeared to be the design capacity of the vault. In situations where the UUVs contain a large number of different types of cables, egress from the enclosed space can be affected, especially under an emergency condition.

When isolating a transmission cable, the circuit containing the conductor should be locked-out and tagged-out by those individuals working on the conductor. The lock-out is recommended to avoid inadvertent energization of the conductor circuit while it is undergoing repair. The tag-out-only procedure can allow the cable to become energized while an employee has the conductor exposed. The use of a lock-out procedure provides additional protection from inadvertent energization of the cable for an employee working at a remote location. Additionally, the employee should isolate/dissipate any stored energy and verify that de-energization has been accomplished prior to the initiation of work. Lock-out procedures should be used in the UUVs whenever applicable, rather than depend upon other systems (i.e., tagout) outside of the UUVs, which are not under the direct control of the worker and/or foreman at the UUV.

VIII. CONCLUSIONS

BECO has made progress in replacing older gas monitoring equipment with multiple-function, continuous detection monitors. BECO has updated their SOP manual on a regular basis, initiated preventive maintenance programs, and has recently developed a multi-rescue program with the City of Boston's Fire and Gas companies.

The number of reportable incidents on the OSHA 200 Injury and Illness log have been increasing. Some UTD workers have exposures to lead that result in BLLS that exceed the PHS goal of 25 µg/dL. During the evaluation we observed enclosed work environments which contain water, slippery surfaces, electrical fields, smoke/gas, deteriorating electrical components and cables, plus ergonomic problems. Additionally, limited preventive maintenance programs, inadequate gas monitor calibration efforts, and questionable enclosed space rescue procedures underscore the need for BECO to revise, improve, and strengthen basic safety and health practices.

IX. RECOMMENDATIONS

The recommendations given below are offered to reduce potentially hazardous occupational exposures and safety risks at BECO.

A. BECO should initiate a complete lead exposure reduction program which includes at least the following elements:

1. Sanitation facilities. Hand washing facilities should be readily available for use by workers prior to eating and smoking. Showering facilities should be readily available, and employees should shower and change into non-contaminated clothing at the end of their work-shift.

2. Appropriate clean and dirty locker areas.

3. A medical monitoring program. Particular effort must be made to ensure that workers, especially splicers, who work in areas having potential lead exposure are routinely tested for BLLs by a qualified health-care provider. Periodic blood lead testing will identify inadequacies in the worker protection program. Cases of significant BLL increase or BLLs exceeding 25 µg/dL should trigger timely investigation of potential sources and routes of exposure, work practices, and use of personal protective equipment.

4. Hazard communication. BECO should take an active role in training and encouraging workers who work in areas having high lead exposure potential to have their children tested for BLLs by a qualified health-care provider.

B. Modify enclosed space entry procedures to require additional air quality checks at multiple levels, as well as at the bottom of the UUVs and at all conductor duct banks.

C. Accelerate the replacement program for all combustible gas and oxygen deficiency measurement devices with multiple-function, continuous detection monitors.

D. Implement and enforce a calibration program for the air monitoring equipment consistent with the manufacturer's recommendations.

E. BECO has recently initiated a preventive maintenance program designed to reduce hazards in the UUVs. BECO should address these reported deficiencies in the program in a timely manner and communicate any changes or other actions to the workers.

F. A spill-resistant container should be used to lower the ladles of molten lead into the enclosed spaces. The device should be able to contain spillage of molten lead and prevent splashing in the event the container is either inadvertently dropped or contacts workers while being lowered into the space.

G. The use of an oval or oblong-shaped ventilation tube, in contrast to the presently used circular shaped tube, can aid in alleviating difficulty when entering or exiting the UUVs.

H. Air blowers should be used during <u>ALL</u> phases of cable splicing activities to reduce the amount of smoke, fumes, and vapors generated in the enclosed space.

I. Develop procedures and special lifting tools by which the truck (or other mechanical equipment) could be used to lift lid covers from the UUVs.

J. Modify the training materials concerning worker rescue from a UUV to emphasize the need to check the atmosphere BEFORE entering the UUV, and to stress that the rescuer delay entry until assistance arrives at the site.

K. In designing future UUVs, consideration should be given to making them larger in order to improve mobility and alleviate cramped conditions.

L. Improve those elements within the hazardous energy control policy which address de-energization, lock-out/tag-out of energy control source, isolation/dissipation of stored energy, and verification testing prior to initiation of work.

M. Improve the present cable tagging system to assure proper cable handling procedures.

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Copies of this report have been sent to:

1. The Boston Edison Company

2. Utility Workers Union of America, Local 369

3. OSHA Region I Office

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

TABLE I

BECO Injury Data
As Reported on OSHA 200 Logs
From 1985--1990
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 15-16, 1991

YEAR	TOTAL NUMBER REPORTS/YEAR
1985	58
1986	53
1987	82
1988	84
1989	106
1990	109
6 YEAR TOTALS	**492**

TABLE II

NIOSH Confined Space Classification Table
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

Parameters	**Class A**	**Class B**	**Class C**
Characteristics	immediately dangerous to life - rescue procedures require the entry of more than one individual fully equipped with life support equipment - maintenance of communication requires an additional standby person stationed within the confined space	dangerous, but not immediately life threatening - rescue procedures require the entry of no more than one individual fully equipped with life support equipment - indirect visual or auditory communication with workers	potential hazard - requires no modification of work procedures - standard rescue procedures - direct communication with workers, from outside the confined space
Oxygen	16% or less *(122 mm Hg) or greater than 25% *(190 mm HG)	16.1% to 19.4% *(122 - 147 mm Hg) or 21.5% to 25% (163 - 190 mm Hg)	19.5 % - 21.4% *(148 - 163 mm Hg)
Flammability Characteristics	20% or greater of LFL	10% - 19% LFL	10% LFL or less
Toxicity	**IDLH	greater than contamination level, referenced in 29 CFR Part 1910 Sub Part Z - less than **IDLH	less than contamination level referenced in 29 CFR Part 1910 Sub Part Z

* Based upon a total atmospheric pressure of 760 mm Hg (sea level)

** Immediately Dangerous to Life or Health - as referenced in NIOSH Registry of Toxic Effects of Chemical Substances, Manufacturing Chemists Association data sheets, industrial hygiene guides or other recognized authorities.

TABLE III

Check List Of Considerations For Entry, Working In And Exiting Confined Spaces

Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

	ITEM	CLASS A	CLASS B	CLASS C
1.	Permit	X	X	X
2.	Atmospheric Testing	X	X	X
3.	Monitoring	X	0	0
4.	Medical Surveillance	X	X	0
5.	Training of Personnel	X	X	X
6.	Labeling and Posting	X	X	X
7.	Preparation			
	Isolate/lockout/tag	X	X	O
	Purge and ventilate	X	X	0
	Cleaning processes	0	0	O
	Requirements for special equipment/tools	X	X	O
8.	Procedures			
	Initial plan	X	X	X
	Standby	X	X	0
	Communications/observation	X	X	X
	Rescue	X	X	X
	Work	X	X	X
9.	Safety Equipment and Clothing			
	Head protection	O	O	0
	Hearing protection	O	O	0
	Hand protection	O	O	0
	Foot protection	O	O	0
	Body protection	O	O	0
	Respiratory protection	X	O	-
	Safety belts	X	X	X
	Life lines, harness		0	-
10.	Rescue Equipment	X	X	X
11.	Recordkeeping/Exposure	X	X	-

X = indicates requirement
0 = indicates determination by the qualified person
- = indicates no requirement

TABLE IV

Key Topical Elements in the OSHA Proposed Standards "Electric Power Generation, Transmission, and Distribution"

Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

a. Training of Personnel
b. Medical Services and First Aid
c. Job Briefing
d. Hazardous Energy Control (Lockout/Tagout) Procedures
e. Enclosed Space
f. Trenches & Excavations
g. Personal Protective Equipment
h. Ladders, Platforms, Stepbolts, and Manhole Steps
i. Hand and Portable Power Tools
j. Live Line Tools
k. Materials Handling and Storage
l. Working on or Near Exposed Energized Parts
m. De-energizing Lines and Equipment for Employee Protection
n. Grounding for Protection of Employee
o. Testing and Test Facilities
p. Mechanical Equipment
q. Overhead Lines
r. Line Clearance Tree-Trimming Operations
s. Communication Facilities
t. Underground Electrical Installation
u. Substations
v. Power Generation
w. Special Conditions

TABLE V
Airborne Lead Concentrations
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

Sample Description	Date	Sample Volume (liters)*	Lead Concentration (µg/m³)	
			Avg. Conc.	8-hour TWA
UUVs #2440 Splicer B	10/14	426	12	5.3
UUVs #2440 Splicer A	"	416	7.0	3.0
UUVs #22373 Splicer C**	"	172	6.4	1.1
UUVs #10331 Splicer B	10/15	228	4.8	1.1
UUVs #10331 Splicer A	"	220	14	3.2
UUVs #6261 Splicer A	"	290	55	17
UUVs #6261 Splicer B	"	282	5.0	1.5
UUVs #22371 Splicer A	"	312	6.1	2.0
UUVs #22371 Splicer B	"	300	2.7	0.84
UUVs #22373 Splicer B	"	174	1.2	0.22
UUVs #22373 Splicer A	"	170	25	4.4
Splicer-Training Station #3	10/16	798	5.0	4.2
Splicer-Training Station #2	"	396	5.8	2.4
Training Supervisor	"	798	1.8	1.5
Splicer-Training Station #1	"	790	5.1	4.2
Trainer	"	786	1.8	1.5
UUVs #22780 Splicer A	"	382	7.3	2.9
UUVs #22780 Splicer B	"	386	3.4	1.4

µg/m³ - micrograms per cubic meter of air.
Avg. Conc. - average concentration over the sample duration.
8-hour TWA - time-weighted average concentration, calculated assuming no further exposures after sampling period, based on 8-hr shift.

* The flowrate used during the collection of all samples was 2 liters per minute; therefore, sample duration (in minutes) is 1/2 the sample volume.

** A sample was also collected from the other splicer working at this UUV; however, a sample volume could not be calculated (or estimated) because the sampling pump failed. (0.21 µg of lead was detected on this filter)

TABLE VI

Surface Lead Concentrations
Equipment, Work Surfaces, and Clothing
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16,1991

Sample Description	Date	UUVs No.	Concentration ($\mu g/ft^2$)
Dash table in service truck	10/14	22373	480
Dash table in service truck	"	2440	352
Engine cover inside cab of service truck	"	"	2,880
Right half of service truck steering wheel	"	"	291*
Dash table in service truck	10/15	10331	48
Engine cover inside cab of service truck	"	"	12,400
Splicer A, Clothing - left chest	"	"	3,880
Splicer A, Clothing - right thigh	"	"	2,720
Splicer A, Clothing - left thigh	"	"	4,880
Dash table in service truck	10/16	22780	128
Training Center, break room table	"	--	200
Training Center, break room table	"	--	600
Splicer Trainee, Clothing - right thigh	"	--	15,200
Training Center, refrigerator door handle	"	--	68

* Area measured for steering wheel was approximately 1.1 square feet. Sample was spilled during analysis; therefore, only a minimum concentration could be presented.

TABLE VII

Accumulation of Lead on Hands From Job Sampling Technique (Hand Wipes*)
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

Sample Description	Date	UUVs No.	Concentrations (µg/wipe)** Before	After
Splicer A, accumulation from job	10/14	22373	1,400	3,900
Splicer C, accumulation from job	"	"	120	720
Splicer A, accumulation from job	"	2440	970	9,300
Splicer B, accumulation from job	"	"	290	670
Splicer A, accumulation from job	10/15	10331	NA	1,100
Splicer B, accumulation from job	"	"	1,700	5,200

* Employees were provided with a moist hand wipe and directed to wipe their hands for a period of 30 seconds.

** It cannot be assumed that all of the lead on the hands was transferred to the hand wipe as a result of the 30 second hand washing activity. Therefore, the amount of lead may actually be higher than reported.

NA Laboratory error with sample. Therefore, values not applicable.

TABLE VIII

Reduction in Lead from Hand Washing
Sampling Technique (Hand Wipes*)
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

Sample Description	Date	UUVs No.	Concentrations (µg/wipe)** Before	After	Difference	% Reduction
Splicer A	"	22371	2,800	460	-2,340	84
Splicer B	"	"	1,800	360	-1,440	80
Splicer A	10/16	22780	4,900	680	-4,220	86
Splicer B	"	"	2,300	250	-2,050	89

* Employees were provided with a moist hand wipe and directed to wipe their hands for a period of 30 seconds.

** It cannot be assumed that all of the lead on the hands was transferred to the hand wipe as a result of the 30 second hand washing activity. Therefore, the amount of lead may actually be higher than reported.

NA Laboratory error with sample. Therefore, values not available.

TABLE IX

Surface Lead Concentrations
Hand Wipes*
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

Sample Description	Date	UUV No.	Concentration (µg/wipe)**
Splicer A, after "sweating" job	10/15	6261	700
Splicer B, after "sweating" job	"	"	1,500
Splicer Helper, end of shift	"	22371	2,100
Splicer Helper, end of shift	"	"	2,400
Splicer A, end of shift	"	22373	1,100
Splicer B, end of shift	"	"	1,400
Splicer Trainee, after 1/2 day	10/16	--	3,300
Splicer Trainee, before commencing work after lunch	"	--	760
Splicer Trainee, before commencing work after lunch	"	--	820
Splicer Trainee, before commencing work after lunch	"	--	230
Splicer Trainee, before commencing work after lunch	"	--	120

* Employees were provided with a moist hand wipe and directed to wipe their hands for a period of 30 seconds.

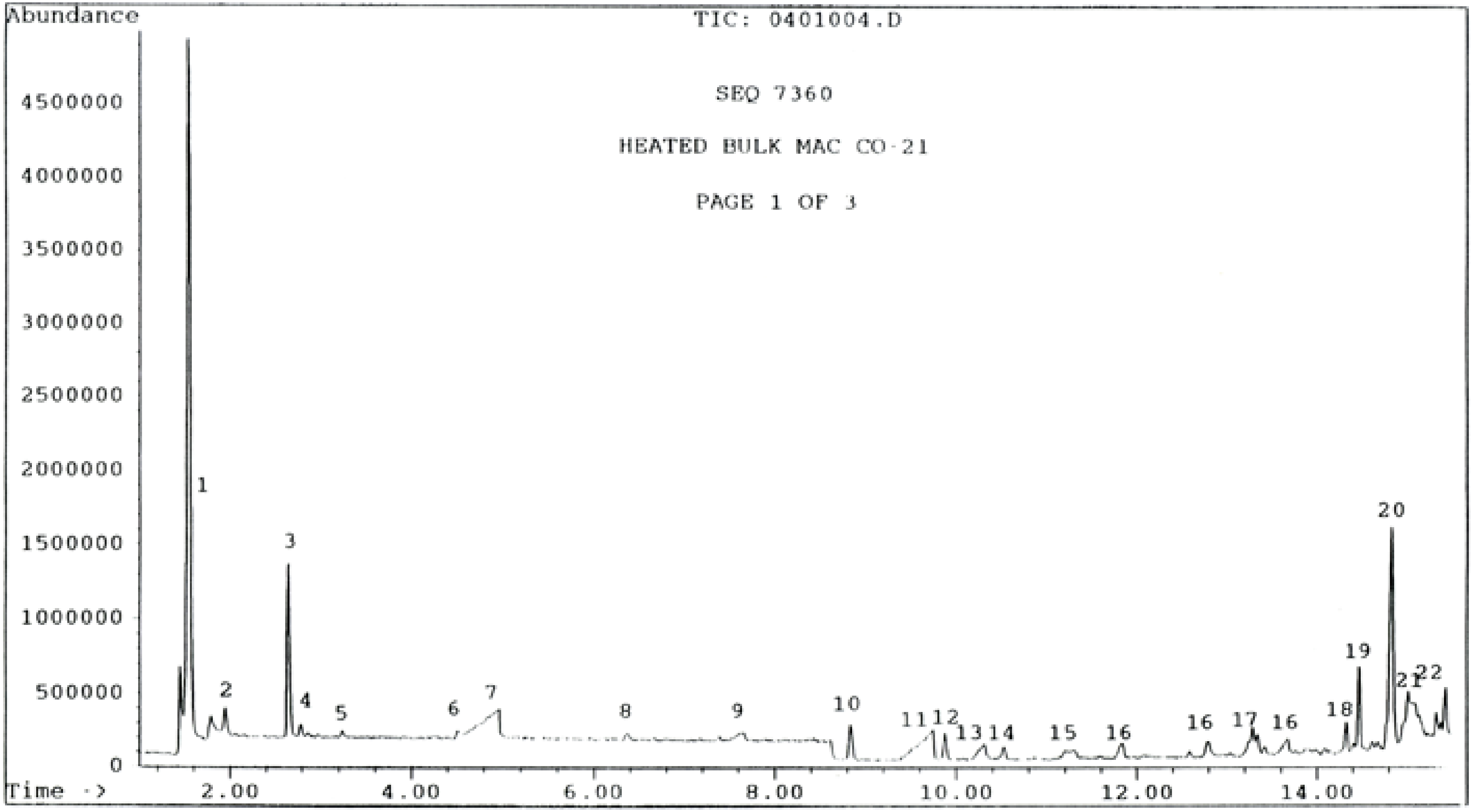
** It cannot be assumed that all of the lead on the hands was transferred to the hand wipe as a result of the 30-second hand washing activity. Therefore, the amount of lead may actually be higher than reported.

TABLE X

Blood-Lead and Zinc Protoporphyrin Levels
Boston Edison Company
Boston, Massachusetts
HETA 90-075
October 14-16, 1991

Blood Sample Results in µg/dL* of Blood	Number of Workers	%	Concentration in µg/dL* of Blood	
			Average	Range
Blood Lead Levels (N = 43)				
<25 µg/dL*	28	65%		
25-40 µg/dL	13	30%		
(>40 µg/dL)	2	5%		
Total	**43**	**100%**	**20**	**<5-43**
Zinc Protoporphyrin Levels (N = 43)				
<50 µg/dL	41	95%		
50-100 µg/dL	2	5%		
>100 µg/dL	0	0%		
Total	**43**	**100%**	**25**	**12-72**

*dL = Deciliter of Blood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SEQ 7360
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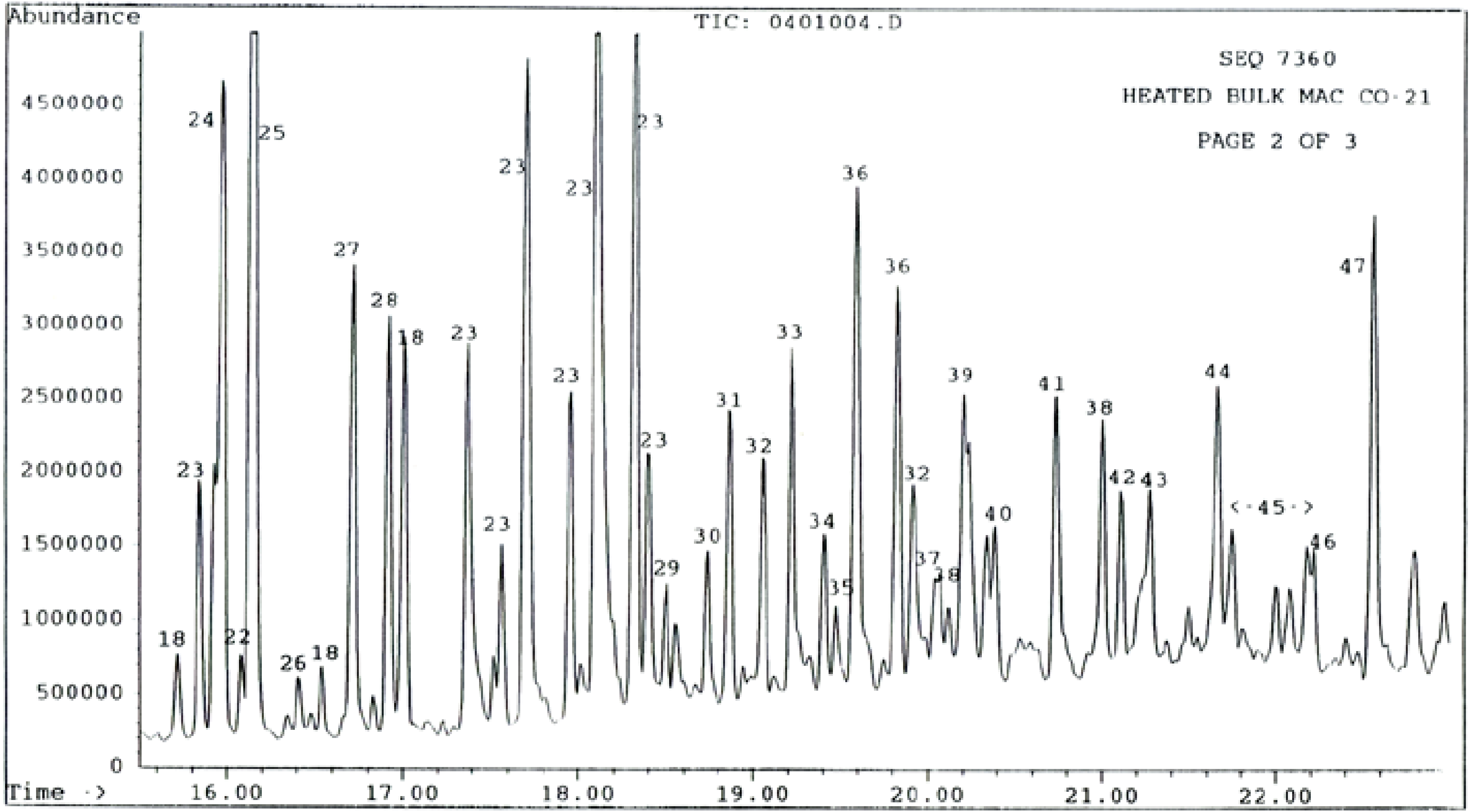
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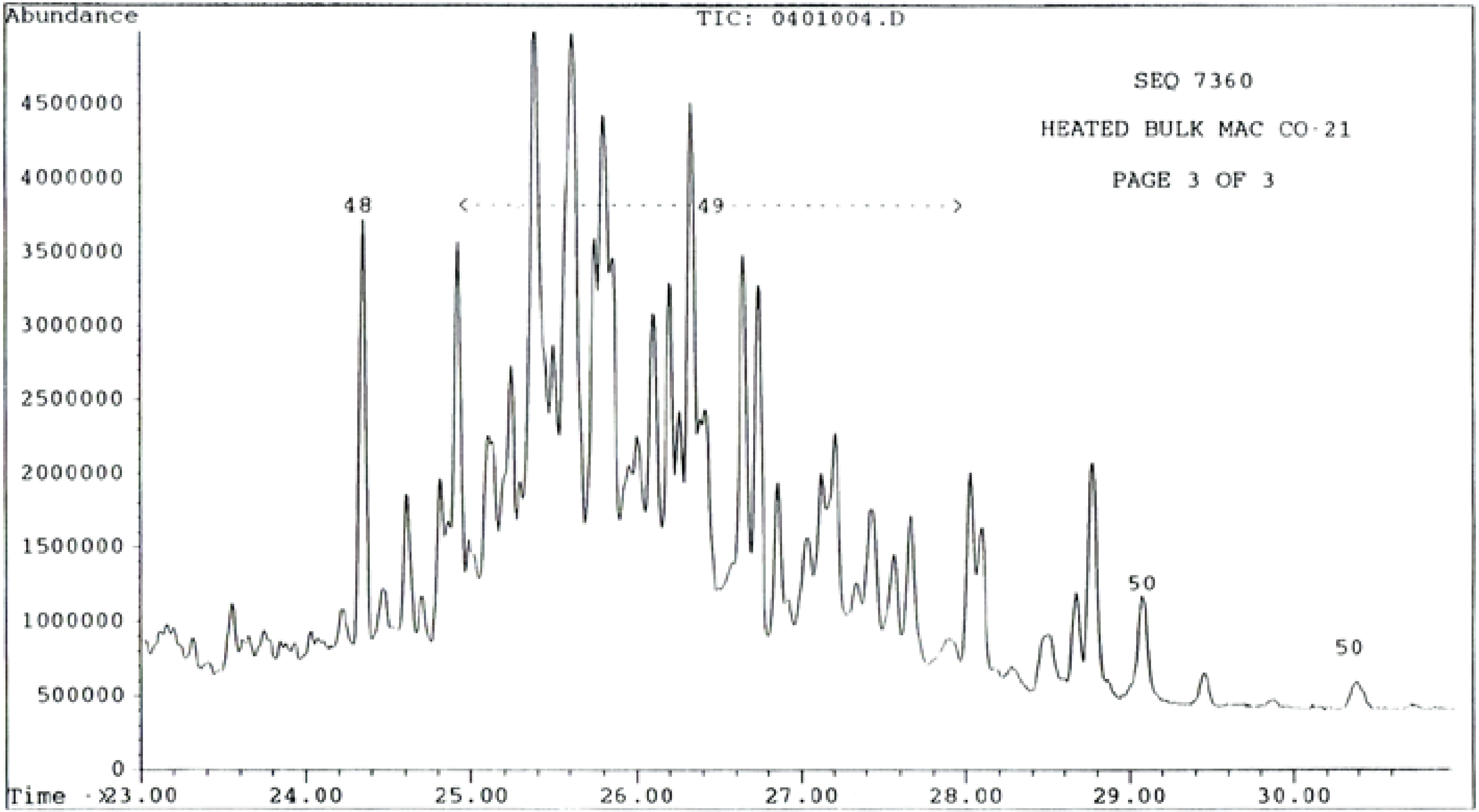

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50
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Figure 1. Lead being heated in open ladle in general vicinity of UUV.

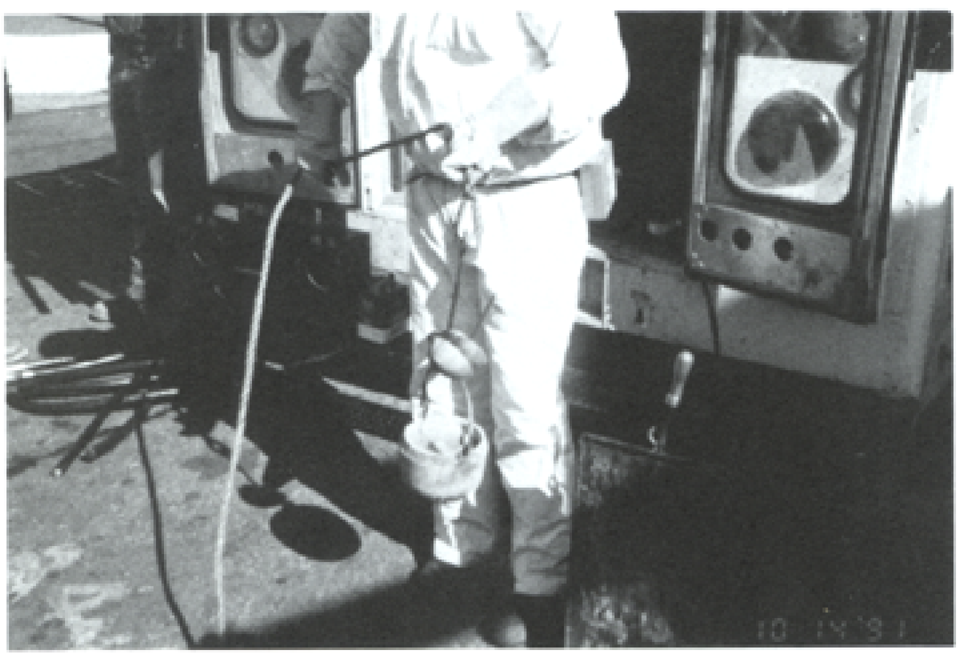

Figure 2. Transporting hot lead to UUV.

Figure 3. Lowering hot lead ladle into UUV above space where worker is located.

Figure 4. Use of special tool to lift UUV cover.

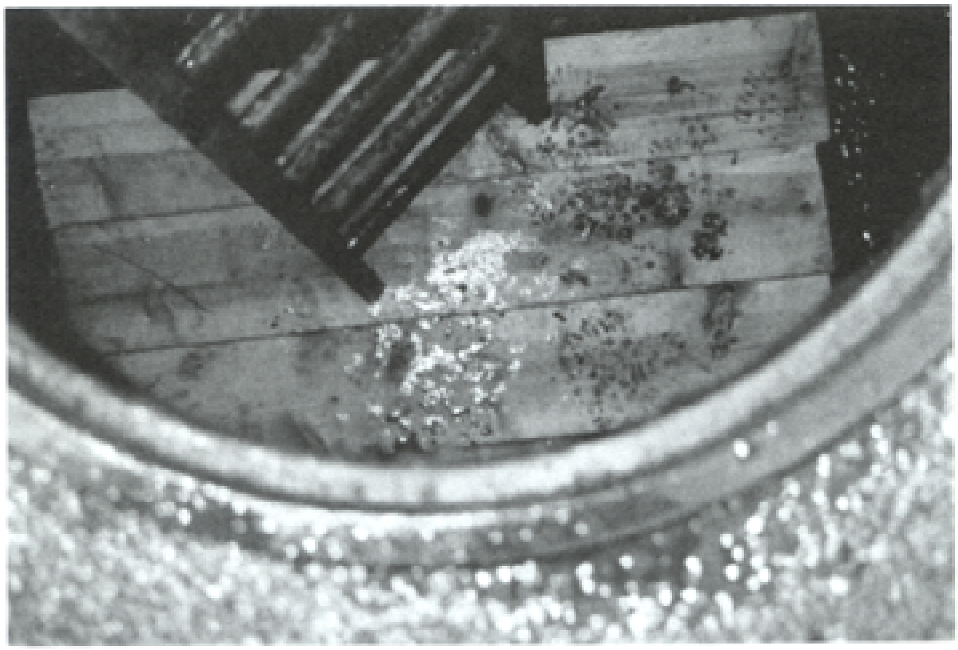

Figure 5. Placement of boards in UUV after water was removed.

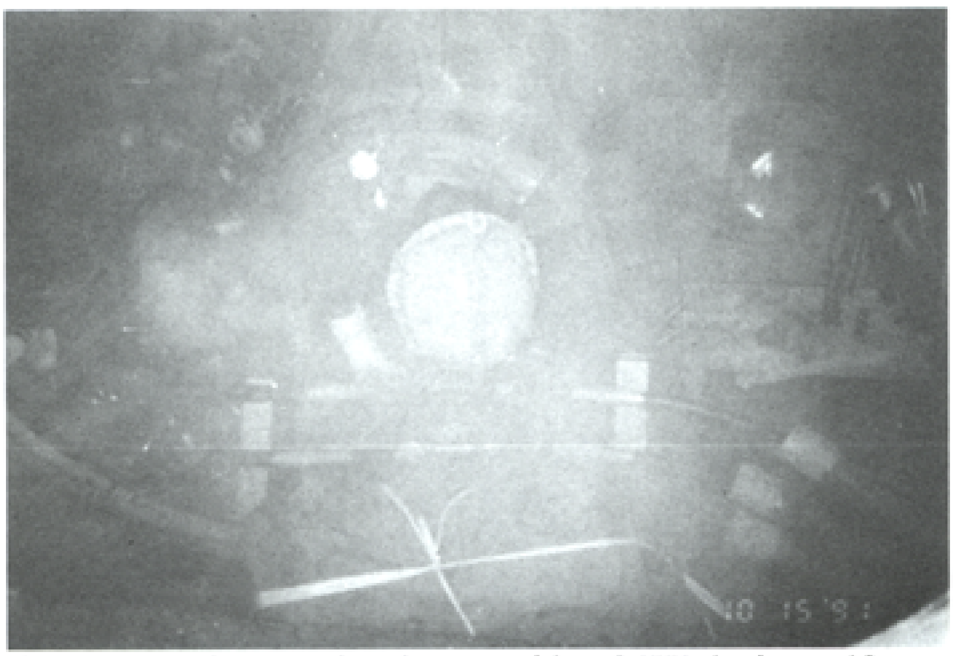

Figure 6. Photograph taken outside of UUV during cable splicer activity.

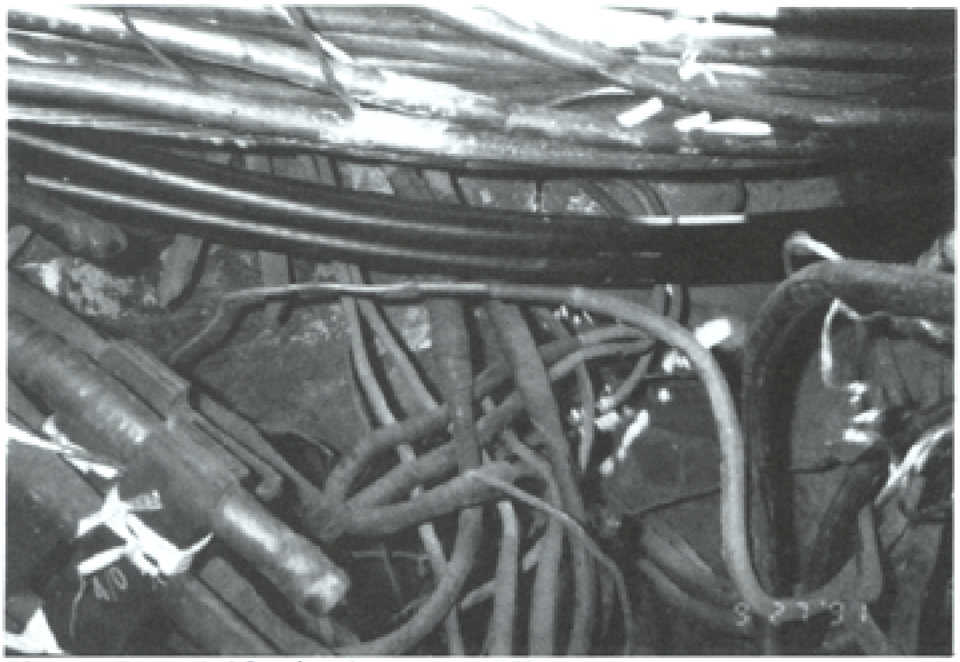

Figure 7. Cable in downtown UUV.

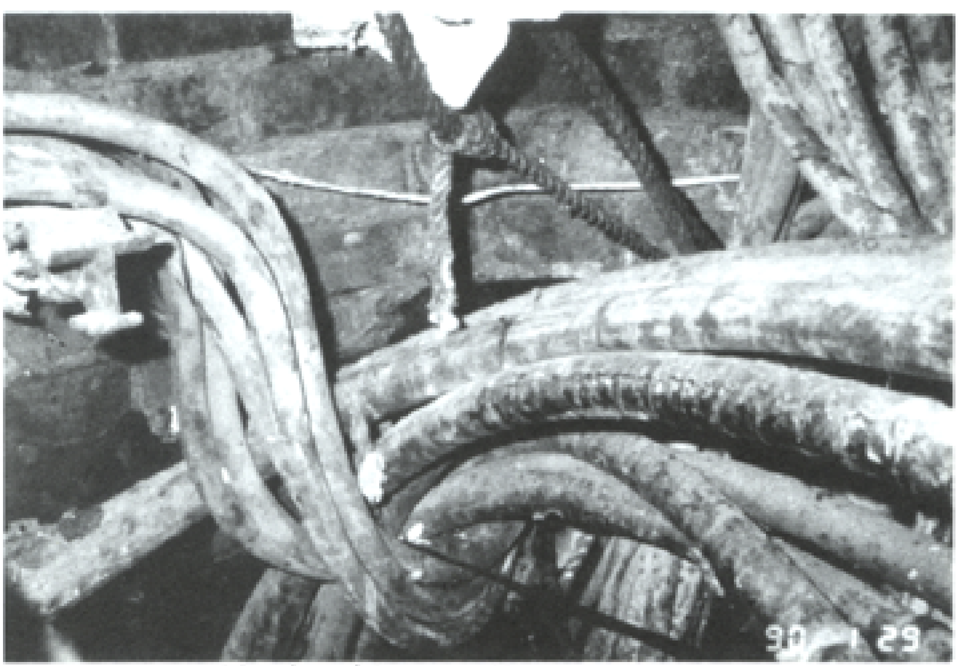

Figure 8. Cable in midtown UUV.

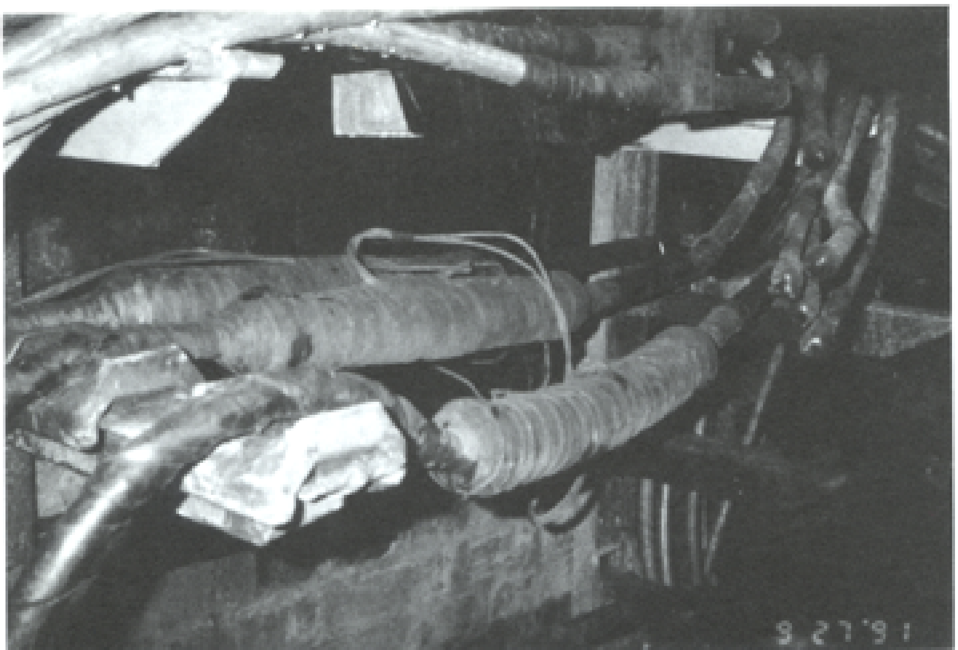

Figure 9. Cables in uptown UUV.

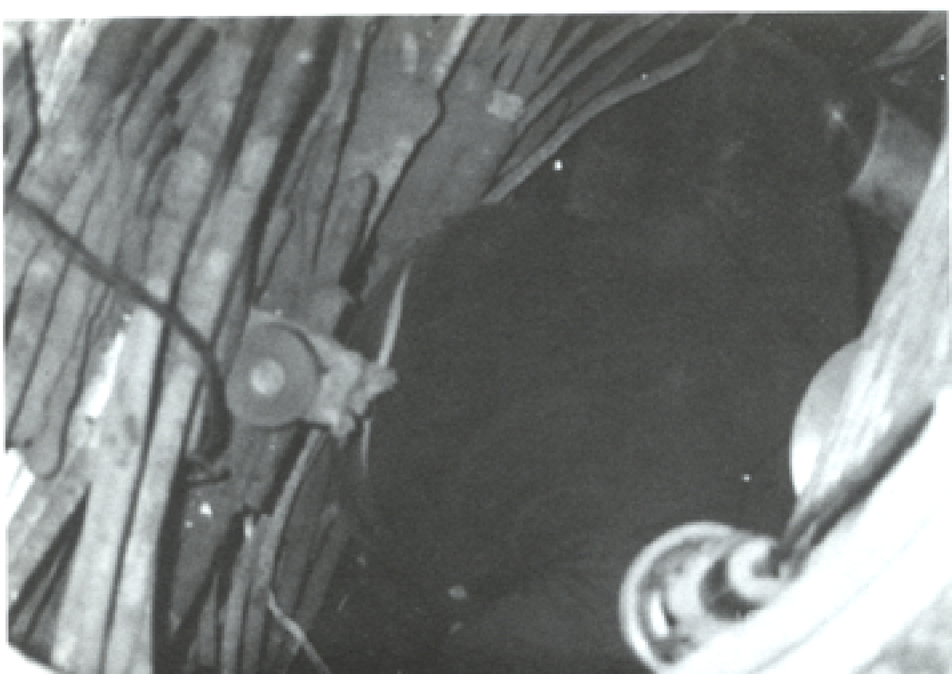

Figure 10. Cables rising almost to top of UUV making entry difficult.

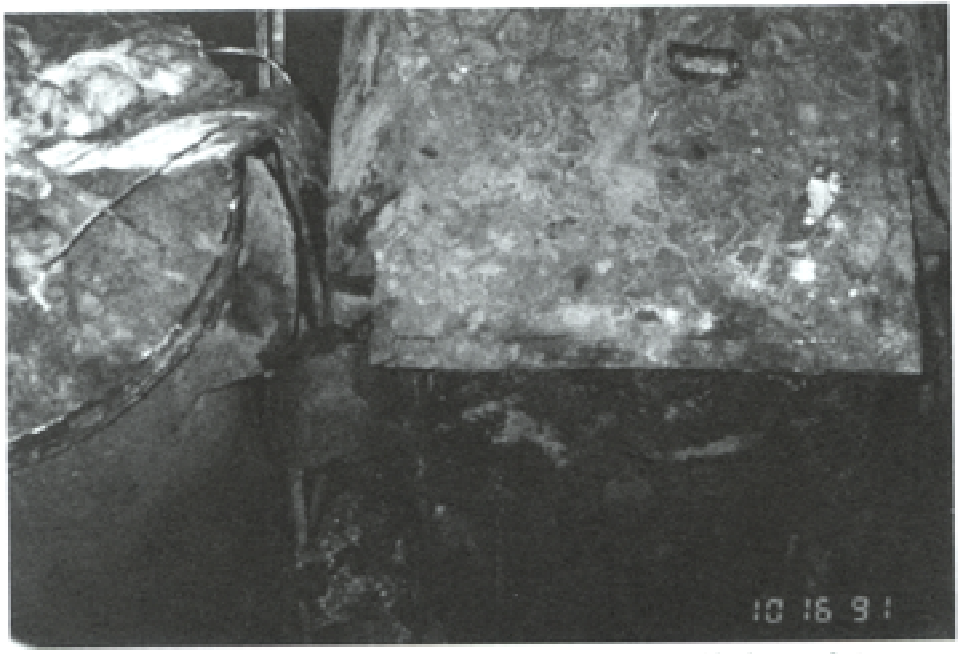

Figure 11. Photograph showing physical condition of two transformers in downtown UUV.

Figure 12. Photograph showing physical condition of a transformer in small UUV.

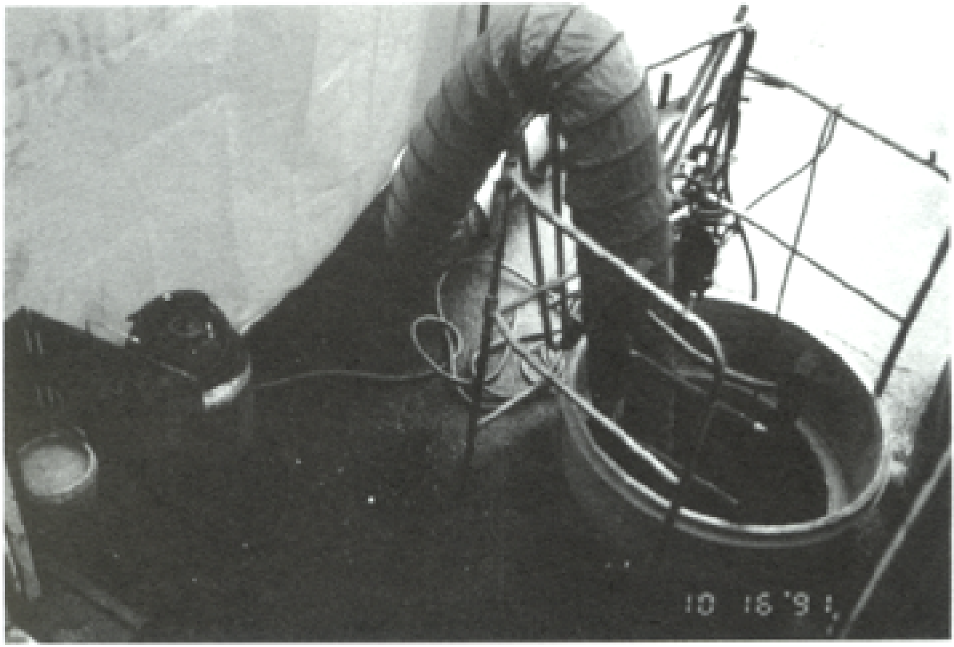

Figure 13. Presence of ventilation tubing, ladder, and barrier make for a tight entrance.

APPENDIX A

LETTER USED BY NIOSH TO REPORT BLOOD LEAD TEST RESULTS FOR BECO EMPLOYEES

Dear :

On October 15, 16, and 17, 1991, the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the Massachusetts Avenue Boston Edison facility. The HHE was requested by
Local 369, Utility Workers Union of America, AFL-CIO. One component of the HHE addressed concerns about worker exposures to lead during underground cable splicing and repair. As part of the HHE, you completed a questionnaire, and a blood specimen was taken to test for the presence of lead in your body. This letter is a report of the results of the blood tests.

Your blood specimen was analyzed for the presence of lead (blood lead level or BLL) and zinc protoporphyrin (ZPP). Both BLL and ZPP are measured in micrograms per 100 milliliters (or 1 deciliter) of blood (µg/dL). The results of your BLL is _______µg/dL and you ZPP is_______µg/dL. The BLL measures the amount of lead present in your blood at the time of the test. It is a reliable measure of your current exposure to lead.

The Occupational Safety and Health Administration (OSHA) requires the immediate medical removal of a worker in general industry whose BLL is 60 µg/dL or greater on one occasion, or an average of 50 µg/dL on three occasions over a six-month period. Furthermore, under the OSHA standard, workers whose BLLs are over 40 µg/dL should have their BLLs monitored every two months. Regardless of your current BLL, your doctor may place you on medical removal protection if you have a health condition that may be made worse by exposure to lead.

The ZPP is a measure of the effects of lead on blood cells. The ZPP increases when your BLL remains high for at least several months. The ZPP will also rise if you have inadequate amounts of iron in your body. If you have a ZPP level of 50 µg/dL or greater, you should tell your doctor and give him or her a copy of this letter.

SIGNS AND SYMPTOMS OF LEAD POISONING

Lead is a metal with no known purpose in humans. Lead enters the body when you breathe lead dust or fumes, or eat lead particles. In adults, lead poisoning usually occurs due to exposure to lead at work. Lead can cause either immediate (acute) or delayed (chronic) health effects. Acute lead poisoning is a serious condition requiring prompt medical attention. Adults with BLLs of 80 µg/dL or greater may have severe symptoms such as wrist or foot drop, tremors, convulsions or seizures. Persons with BLLs below 80 µg/dL may have stomach cramps, nausea, vomiting, constipation, and/or anemia. In some individuals, symptoms may be so mild as to be overlooked.

Common symptoms that may be caused by lead exposure include loss of appetite, difficulty sleeping, tiredness, moodiness, headache, joint or muscle aches, and/or decreased sex drive. A lead-exposed worker with any of these symptoms should be examined by a physician. The worker should tell the doctor about his or her lead exposure.

At lower levels of exposure, lead may be harmful to various organs, including the brain, the nerves in the arms and legs, the blood-forming organs, the kidneys, and the reproductive systems of men and women. Overexposure to lead may also increase the risk of high blood pressure and stroke in men. Because of the effects of lower levels of lead exposure, the Centers for Disease Control Year 2000 objective is for no worker to have a blood lead level greater than 25 µg/dL.

Workers may contaminate their homes by bringing home lead dust on skin and clothing. Children and pregnant women may then be exposed to potentially harmful amounts of lead. Children are very sensitive to the effects of lead. Lead may harm the developing brain of fetuses and children. These effects occur at BLLs as low as 10 µg/dL, well below those permitted in industry. Household members of workers with lead poisoning should be medically evaluated for lead exposure.

PREVENTING LEAD EXPOSURE

Your employer has the primary responsibility for providing you with a work environment safe from the dangers of overexposure to lead. However, there are a number of simple steps you can take to reduce the amount of lead entering your body.

-Do not eat, drink, or smoke in work areas.
-Wash your hands and face before eating or smoking.
-If possible, shower, wash your hair, and change into clean clothes, including shoes, before leaving the workplace.
-Store street clothes in a separate locker from work clothes.
-Do not take your work clothes/shoes home.
-Launder your work clothes separately from your other clothes.
-Eat a well-balanced diet. Proper nutrition can reduce lead absorption.
-Use the correct respirator. Make sure it is clean, in good repair, and fits properly. (Your employer is responsible for providing you with a proper respirator and keeping it in good working order.)

We recommend that you keep this letter for future reference and that you give a copy of the letter and test results to your physician and your children's physician. If you have any questions or concerns, please contact either of us at (513) 841-4353.

For further information about lead exposures in Massachusetts, contact Richard Rabin at the Massachusetts Department of Labor and Industries, Division of Occupational Hygiene, Newton MA 02165, telephone (617) 969-7177.

Sincerely,

Catherine L. Connon, R.N., M.N.
Medical Section
Surveillance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

Eugene Freund, M.D., M.S.P.H.
Medical Section
Surveillance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

APPENDIX B

OCCUPATIONAL HEALTH QUESTIONNAIRE FOR LEAD EXPOSURE

DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL AND PREVENTION
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

OCCUPATIONAL HEALTH QUESTIONNAIRE

BOSTON EDISON
BOSTON, MASSACHUSETTS
HETA 90-075

Personnel from the National Institute for Occupational Safety and Health (NIOSH) are conducting a study of possible health and safety hazards among underground workers. The study consists of three parts:

1. Collection of health information and work history from questionnaires filled out by employees,
2. Blood lead and zinc protoporphyrin testing,
3. Industrial hygiene sampling of the work environment.

Please fill out the attached questionnaire. The questionnaire takes approximately 10 minutes to complete. It contains questions about background information, your present and past jobs, medical history, and selected work practices. Please return the completed questionnaire to NIOSH personnel.

Your participation is completely voluntary. You may refuse to participate at any time or refuse to answer any questions you wish. All personal information provided will be considered confidential in accordance with the Privacy Act of 1974 (Public Law 93-579).

Please do not hesitate to ask NIOSH personnel if you have any questions.

Thank you.

OCCUPATIONAL HEALTH QUESTIONNAIRE
HETA 90-075

DATE:______________

PART I PERSONAL INFORMATION

1. NAME: ______________________________

2. ADDRESS: ______________________________
(street)
____
(city) (state) (zip)
Telephone: ___________

3. DATE OF BIRTH: ______

AGE: ______

SEX: ______

RACE: (1) Black (4) Asian/Pacific Islander
(2) Hispanic (5) American Indian/Alaskan Native
(3) White (6) Other ________

PART II WORK HISTORY

4. How long have you worked at Boston Edison? yrs. ___ mos. ___

5. What is your current job position or job title?

(1) Splicer A (3) Splicer C
(5) Trouble-shooter
(2) Splicer B (4) Inspector
(6) Other _______

6. When have you worked in any of the following jobs?

	Begin (mo/yr)	End (mo/yr)
(1) Splicer A	_______	_______
(2) Splicer B	_______	_______
(3) Splicer C	_______	_______
(4) Inspector	_______	_______
(5) Trouble-shooter	_______	_______
(6) Other _____________		

7. What shift do you usually work? Circle one.
(1) Day (2) Evening (3) Night

8. On the average, how many hours per day do you work? ____ hours

9. On the average, how many days per week do you work? ____ Days

10. On the average, how many hours of overtime do you work per month? ____ hours

PART III   PREVIOUS WORK HISTORY

11. Please list all jobs (other than at Boston Edison) in which you were exposed to lead dust or fumes (solder, worked with or removed lead-based paint, foundry or battery factory work, use of firearms, etc.). Begin with the most recent job.

JOB TITLE	COMPANY	STARTED	ENDED
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________
____________________	______________________	____________	_____________

12. Have you ever received treatment for, or been told by a doctor that you have any of the following medical conditions?

Condition		Year Diagnosed
High Blood Pressure	Yes No	____
Diabetes	Yes No	____
Kidney Problems	Yes No	____
Heart Problems	Yes No	____
Lung Problems	Yes No	____
Seizures or Convulsions	Yes No	____
Anemia or low blood count	Yes No	____
Gout	Yes No	____
Arthritis	Yes No	____

Hearing Loss Yes No ____

13. Have you ever been removed from a job or has your job changed because of a high blood lead level? Yes No
If yes, list date(s): ________________________

14. Were you ever treated for lead poisoning? Yes No
If yes, list date(s): ________

15. List all medications that you take on a regular basis:

__________ __________ __________

__________ __________ __________

PART IV WORK PRACTICES

16. Do you wear a respirator on the job? Yes No
If yes, what percent of the time on the job do you wear your respirator? ____ %

17. When you are working, do you remove your respirator in the middle of performing a task? Yes No

18. Do you smoke cigarettes? Yes No
If yes, please answer the following questions:

a. On the average, how many cigarettes do you smoke during the day? ____

b. Where do you smoke at work? Circle all that apply.
(1) Work-site (3) Don't smoke at work
(2) Vehicle (4) Other: ______

19. When you are at work, where do you usually eat?
(1) Work-site (3) Restaurant
(2) Vehicle (4) Other: ______

20. During the workday, when do you wash your hands? ___________

21. Do you shower before leaving work? Yes No

22. Do you change clothes before leaving work? Yes No

23. Do you change your shoes before leaving work? Yes No

24. Do you take your work clothes home? Yes No
If yes, please answer the following questions:

a. Do you store your work clothes with other clothes before laundering? Yes No

b. Are your work clothes laundered with other clothes? Yes No

PART V MISCELLANEOUS

25. While not at work, have you used or removed lead-based paint during the past six months? Yes No

26. Do you work with stained glass? Yes No

27. Do you use indoor firing ranges? Yes No

28. Have you been trained in the following areas?

(1) Health effects of lead Yes No
(2) Symptoms of lead poisoning Yes No
(3) How to protect yourself from overexposure to lead Yes No

29. Do other persons share a household with you? Yes No
If yes, are they male or female, and what are their ages?

Gender (M/F)	Age (years)
___	___
___	___
___	___
___	___
___	___

Thank you for your cooperation.

APPENDIX C

CHROMATOGRAM FOR HEATED CABLE SEALANT MATERIAL WITH PEAK IDENTIFICATION CHART

SEQ 7360
PEAK IDENTIFICATION
HEATED BULK MAC CO-21

1) Air/CO_2
2) Methanol
3) Acetone
4) Isopropanol
5) Methyl acetate
6) Methyl ethyl ketone (MEK)
7) Acetic acid
8) Methyl isopropyl ketone
9) Propanoic acid
10) Methyl isobutyl ketone (MIBK)
11) Methyl propanoic acid
12) Tolune
13) Butyric acid
14) Hexanal
15) Butenoid acid?
16) Fatty acids, C_5-C_7
17) Styrene
18) $C_{10}H_{16}$, M.W.136 terpenes (includes compounds such as pinenes, terpinenes, camphene terpinolenes, etc.)
19) Benzaldehyde
20) Phenol
21) Propanetroil?
22) $C_{10}H_{18}$, M.W.138 isomers (methene, methyl(methylethyl) cyclohexene, etc.)
23) $C_{10}H_{18}O$, M.W.154 terpene terpineols, borneol, fenchyl alcohol, etc.)
24) p-Cymene
25) $C_{10}H_{16}$ terpene, limenone
26) Cresol isomer
27) C_7H_8O, M.W.124 phenol (2-methyoxyphenol)
28) Dimethyl styrene isomer
29) $C_9H_{12}O$, M.W.136 phenol (isopropyl phenol)
30) $C_{10}H_{12}O$, phenyl butanone
31) $C_9H_{12}O$, M.W.136 phenol (propyl phenol)
32) $C_{10}H_{16}O$, M.W.152 terpene derivatives (carvenone?)
33) $C_9H_{12}O_2$, M.W.152 phenol (ethylmethoxy phenol)
34) $C_{10}H_{14}O$, M.W.150 phenol (tetramethyl phenol)
35) $C_{12}H_{20}O_2$, bornyl acetate?
36) $C_{10}H_{20}O_2$, terpin hydrate?
37) 4-Phenyl-3-buten-2-one?
38) $C_{10}H_{12}O_2$, M.W.164 phenol (allyl methoxy phenol)
39) $C_{10}H_{14}O_2$, M.W.166 phenol (methoxy propyl phenol)
40) Hydroxymethoxybenzaldehyde
41) $C_{10}H_{16}O_2$, hydroxycarvotanacetone?
42) $C_{12}H_{16}O$, phenyl hexanone
43) $C_9H_{10}O_3$, (hydroxy methoxy-phenyl)ethanone
44) $C_{10}H_{12}O_3$, (hydroxymethoxy-phenyl)propanone
45) $C_{15}H_{24}$ isomers (sesquiterpenes?)
46) Diethylmethyl benzamine?
47) $C_{11}H_{12}O_2$, M.W.176 phenyl pentanedione
48) $C_{14}H_{14}O$, M.W.198 phenol (phenyl ethyl phenol)
49) Unknowns, possibly decomposition products of resin acids? ($C_{19}H_{28}$, $C_{20}H_{14}$ isomers?)
50) C_{24}-C_{25} alkanes