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STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF HEALTH SERVICES
OCCUPATIONAL HEALTH SURVEILLANCE
AND EVALUATION PROGRAM (OHSEP)
2151 BERKELEY WAY, ROOM 504
BERKELEY, CA 94704
(415) 540 3141

August 22, 1988

VIA FACSIMILE

Roger Bernstein
Director of State Government
Affairs
Society of the Plastics Industry, Inc.
1275 K Street, NW Suite 400
Washington, DC 20005

Dear Mr. Bernstein:

Enclosed is the revised protocol for the Plastic Pipe Worker Exposure Study. This draft (#3) of the protocol includes changes agreed upon by all parties at our August 10th meeting. All changes made since draft #2, distributed August 10th, are marked.

At the August 10th meeting, all parties agreed that the proposed revisions had been addressed satisfactorily. In addition, all agreed that monitoring would begin as soon as the accepted revisions had been incorporated into the study protocol and reviewed by the California Department of Housing and Community Development, the California Pipe Trades Council, and the Society of the Plastics Industry, Inc. Consequently, we intend to begin monitoring at plastic pipe installation sites on Thursday, August 25th, unless we are notified of substantial discrepancies between the current protocol and the agreements reached on August 10th. We must receive any such notification by 3:00 p.m., Wednesday, August 24th.

Following is a brief summary of revisions to the protocol made between draft #2 (8/10/88) and draft #3(8/22/88). Page references are to draft #3.

p ~~5~~ 3, para 2 Work practices for installation of CPVC and PVC are similar only when similar-sized pipes are compared.

p 5, para 2 Evaluation of CPVC exposures may be done at out-of-state sites.

p 6, para 2 Installation of PVC waste lines will not be used to assess installation of CPVC water-supply piping.

p 6, para 4 Most monitoring will be done in the ten California counties with the most new residential construction in 1986. Both hot days and cooler days are very likely to be included in the monitoring. No additional steps will be taken to target hot days for monitoring.

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p 7, para 2 Installation of PVC waste lines may be monitored to assess the exposures that could arise when CPVC water lines are installed concurrently.

p 8, para 3 Bulk samples of each primer and cement used at each site will be collected. Products not listed by NSF for potable water use will be noted.

p 8, para 4 Samples will be kept cooled to minimize any possible changes to the substances of interest.

p 8, para 5 Photographs of working conditions will be taken.

p 9, para 2 When necessary for logistical reasons, monitoring for DMF and for the oxygenated solvents MEK, THF, and cyclohexanone will be split between workers or between sampling days.

p 9, para 4 Urinary DMF will be measured as an index of contamination.

p 11, para 3 Further explanation and justification of the sampling scheme for MEK, THF, and cyclohexanone.

p 13, para 2 For category IIIb exposures, there will be no limit on the number of samples to be collected per worker-day. When six or more periods of category IIIb exposure are anticipated, every-other period will be monitored.

p 15, para 4 For GC/MS analysis of PB decomposition products, EPA Priority Pollutants and ten additional substances will be identified.

p 16, para 1 For GC/MS analysis of flux decomposition products, a medium capable of collecting particulates will be used. EPA Priority Pollutants and ten additional substances will be identified.

p 16, para 2 Lead (Pb) will be included in monitoring of solder fumes.

p 16, para 5 Laboratory quality assurance will be done for solvent samples only. For MEK, THF, and cyclohexanone, samples will be spiked with all three substances.

p 17, para 1-3 Exposure limits are now included in the protocol, as Table 2. All exposure limits are taken from accepted values established by other agencies. The exposure limit for antimony may not protect against its possible carcinogenicity.

p 17, para 4 IARC category 2B carcinogens included in list of exposures that could trigger recommendations for follow-up study.

p 20, para 7 For MEK, THF, and cyclohexanone, the distribution of 15-minute exposures will be characterized and the percentage of days in which any short-term exposure limit is exceeded will be estimated.

page 23 References added.

The issue of monitoring exhaled breath for presence of solvents was again raised by the California Pipe Trades Council in a letter we received on August 15, 1988. After careful reconsideration, we have again decided that monitoring of exhaled breath would not be appropriate for this study. This decision was made in consultation with Jon Rosenberg, M.D. (member of ACGIH BEI committee), Stephen Rappaport, Ph.D. (actively engaged in exhaled-breath monitoring research), and Mitch Singal, M.D., Chief, Medical Section, Division of Surveillance, Hazard Evaluation and Field Studies, NIOSH. The principal reasons for this decision are as follows:

1. Lack of Pharmacokinetic Information

There is limited information on exhaled air monitoring for MEK; there is none for cyclohexanone and THF. Minimal information necessary for biological monitoring includes human pharmacokinetics (relationship between external and biological levels) and/or toxicodynamics (relationship between systemic toxicity and biological levels). There is limited information on the human pharmacokinetics of MEK; there is none for cyclohexanone and THF. There is no information on the toxicodynamics for any of the three.

The limited information on pharmacokinetics for MEK is based on inhalation exposure only. Dermal kinetics, particularly the time course of dermal absorption, are unknown for MEK (as well as THF and cyclohexanone). For many chemicals a significant delay occurs between exposure to the skin and absorption and appearance in blood and exhaled air. The appropriate time to sample exhaled air following a "short-term dermal exposure" has not been established by any field or laboratory studies. Short-term exposure limits for ambient air have been established for some substances, and short-term exposure monitoring is appropriate to assess such exposures.

2. Lack of Toxicological Significance

The TLV and STEL for MEK are based on its strong and objectionable odor and irritant properties. These are contact effects and are not directly related to absorption and systemic effects. Although data are extremely limited, MEK seems to be much less potent as a general anesthetic (nervous system depressant) than as an odorant/irritant. This is particularly true for short-term exposures. It seems extraordinarily unlikely for CNS depression to occur as a result of short-term dermal exposure. Comparing short-term dermal exposure levels gained from exhaled air monitoring to the STEL would be inappropriate since the STEL is based on odor and on eye, nose and throat irritation, which do not occur as a result of dermal absorption. In fact, the BEI Committee has been questioned for recommending BEIs for any substance whose TLV is based on irritation.

Even less is known about the toxicological significance of dermal absorption of cyclohexanone and THF. Exhaled air concentrations of cyclohexanone and THF could neither be used to measure absorbed dose or to estimate risk of any health effects from short-term exposures.

In his letter of August 12, 1988 Dr. Cox stated that "air and urine sampling will underestimate the seriousness and extent of dermal exposure to MEK, THF and cyclohexanone." While it is possible that air and urine sampling may underestimate the extent of dermal exposure in some situations, we believe that exhaled breath monitoring would add little to our knowledge of the risk from those exposures.

3. Feasibility of Measurement

Exhaled breath monitoring has significant potential as an exposure assessment tool, but accurate, reliable testing methods have not yet been established. For most chemicals, including MEK, THF, and cyclohexanone, further research is necessary before exhaled breath monitoring could be used for field studies of workplace exposures. For example, Dr. Cox has recommended the method developed by Dr. Michael Morgan. Unfortunately, the published report by Dr. Morgan describes laboratory studies only, with no reference to field monitoring. Further, only exposures to toluene, not MEK, THF, or cyclohexanone were monitored in Dr. Morgan's study. Collection of MEK, THF, and cyclohexanone from humid exhaled breath samples poses additional problems.

From laboratory to field is a large leap, and the validity of a test system must be established with detailed workplace studies before the test can be applied to routine field monitoring. Such validation has not been done for exhaled breath monitoring of MEK, THF, or cyclohexanone.

4. Reference to BEIs

Dr. Cox's letter stated that the study team has misinterpreted the ACGIH BEI Committee. Dr. Rosenberg, a member of the study team, is a founding member of that committee, along with Dr. Thomas and Dr. Lowry, with whom Dr. Cox discussed these issues. Dr. Cox cites Dr. Thomas as explaining that "testing both is preferable to testing only one. While it is often true that two tests are better than one, assuming both are valid, the issues remain: Is there sufficient information to make exhaled air a valid measure of exposure? And does performing these tests add sufficient information to justify the effort? To the first, the answer is maybe for MEK, no for cyclohexanone and THF, and to the second no for all three solvents.

Dr. Cox stated that "the Committee did not wish to discourage other types of monitoring." The BEI Committee neither encourages nor discourages any type of biological monitoring. The activities of the Committee are confined to reviewing available information to support a reference value to be used for monitoring, and to recommend such values. The lack of a BEI for a substance is based on a determination that the information available is insufficient to support a recommended value. When there is insufficient information to recommend a value, this means that the results of monitoring cannot be compared to a reference value. In other words, the monitoring could produce results, but those results could not be adequately interpreted.

In summary, in reviewing the available information on MEK, cyclohexanone, and THF, the study team determined that there was limited information on the kinetics of exhaled air for MEK and none for cyclohexanone and THF. There is no toxicological basis to support biological monitoring for any of these substances, although a decision was made to perform end-of-shift urine monitoring on the basis of the BEI for MEK. In reviewing the available information, we determined that the amount of additional information gained from exhaled air monitoring for MEK would be extremely limited and did not justify its inclusion in the protocol.

Thank you for considering these revisions to the study protocol; we believe that it addresses all substantive concerns that have been raised. Please contact Mr. Bellows immediately if you have any questions about the protocol or the current revisions.

Sincerely,

Linda Rudolph, M.D., M.P.H., Chief

Jim Bellows, M.P.H.
Industrial Hygienist

LR/JB:mk

cc: Bill Holliman
Robert Hinderer, Ph.D.

DRAFT
for discussion
purposes only



## SUMMARY

To evaluate tho exposures to potentially hazardous substances experienced by plumbers during installation of chlorinated polyvinylchloride (CPVC), polybutylene (PB), and copper pipes for potable water supply, workplace air monitoring and biological monitoring will be conducted at representative construction sites. Installation of CPVC for water supply is rare in California, so monitoring will also be conducted during installation of similar CPVC or polyvinylchloride (PVC) piping systems.

Exposures associated with installation of CPVC/PVC pipe will be monitored during at least 16 work days at a minimum of twelve construction sites. Exposures to dimethyl formamide (DMF), methyl ethyl ketone (MEK), tetrahydrofuran (THF), and cyclohexanone will be assessed for each worker installing CPVC/PVC pipe at each site, if possible; approximately 32 worker-days of monitoring are anticipated. Exposures to vapors of MEK, THF, and cyclohexanone will be characterized by analyzing approximately five representative 15-minute air samples per shift for each worker monitored, with high-exposure periods monitored more frequently than low-exposure periods. Detailed records of work activities throughout the day will be maintained, and during each 15-minute air sampling period, factors that may affect exposure--such as temperature and air flow--will be assessed. Standard statistical techniques will be used to estimate the percentage of 15-minute exposure periods in which the short-term exposure limit is likely to be exceeded for each substance and for the additive effects of the three substances. Factors that contribute significantly to high exposure levels will be identified. The average 8-hour time-weighted average (TWA) exposure level associated with installation of CPVC/PVC pipe will be calculated for each substance, based on the 15-minute monitoring data and work activity records; the percentage of exposures likely to exceed the 8-hour TWA exposure limits will also be calculated. This method is believed to provide the best estimates of exposure levels under a wide range of working conditions.

At CPVC/PVC installation sites where the primers and cements used contain DMF, additional air monitoring and biological monitoring will be included. Full-shift air samples will be used to evaluate exposure to airborne DMF. End-of-shift urine samples will be collected to evaluate total exposure (from both inhalation and dermal absorption) and to assess the importance of skin contact with DMF-containing products. The end-of-shift urine samples--together with 4-hour MEK samples for these workers--will also be used to evaluate total exposure and the contribution of dermal absorption for MEK.

In order to evaluate any cumulative effects of installing both CPVC/PVC and acrylonitrile-butadiene-styrene (ABS) pipe during a single

work day or week, exposures to MEK, THF, cyclohexanone, and DMF will also be monitored at five ABS installation sites, using similar methods.

For CPVC/PVC worksites at which pre-fabricated assemblies are used, exposures to CPVC/PVC dust at the prefabrication areas will be evaluated.

For PB pipes held together with crimped mechanical joints, no potential for exposure to toxic substances during installation was identified during walk-through inspections of two worksites; therefore, no monitoring is planned. For PB pipes joined by thermal fusion, the potential for significant exposure seemed low during one walk-through inspection. No systematic sampling is planned, but air samples will be collected at a minimum of two sites, and the ten substances present in highest concentration will be identified for each.

To evaluate the exposures that occur during installation of copper pipe, monitoring will be conducted during at least 10 days at a minimum of 8 sites. Full-shift air samples will be collected for several workers at each site (a total of approximately 30 samples), and analyzed for presence of antimony, tin, copper, silver, and other metals which may be released during brazing. Using standard statistical techniques, the average exposure level and the percentage of work days during which overexposure is likely to occur will be calculated for each substance. To evaluate exposures that may be produced by thermal decomposition of common animal-fat fluxes, air samples will be collected at a minimum of two sites and the ten substances present in highest concentration will be identified.

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## INTRODUCTION

Newly-built housing units currently have as many as six separate piping systems installed. The two systems common to every unit are potable water supply and drain, waste, and vent (DWV). Other plumbing systems may be also be required by the developer or buyer, or by local ordinance; these systems are for: natural gas, draining air conditioners and clothes-washer overflow, fire sprinklers, and garden sprinklers. The State of California is currently considering regulatory changes that would allow use of plastic pipe made from CPVC or PB for distribution of water within homes; currently, copper pipe is the only approved, commonly-used material. Galvanized steel pipe, while approved for water supply, is rarely used in new construction.

The goal of this study is to assess the work-related health hazards associated with installation of three types of water-supply pipe: CPVC, PB, and copper. Although the hazards associated other piping materials and with other piping systems are not themselves the focus of this study, installation of some other systems will also be evaluated for two reasons: First, a plumber who installs water supply on one day is likely to be assigned to work on DWV or other piping on subsequent days, so consideration must be given to cumulative exposures. Second, because CPVC is not approved or installed for water supply in most of California, an adequate number of construction sites is not available for monitoring; therefore, information about patterns of exposure in similar installations will be used to help characterize the exposures expected due to CPVC work. For example, selected installations of small-diameter PVC pipes may be monitored because similar materials and work practices are used.

The results of the monitoring conducted in this study will be used to characterize the exposure associated with installation of CPVC/PVC, PB, and copper pipe, and could be used to assess the likelihood that workers will experience any associated adverse health effects from these exposures. However, no assessment of health status or health effects will be performed.

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## SITE SELECTION

The fundamental goal of any selection scheme is to direct monitoring to sites that are both representative of normal working conditions and--at the same time--diverse enough to include a broad range of conditions. In addition, a balance must be struck between using the available monitoring period to monitor a large number of sites, or to return repeatedly to a smaller number of sites, gathering information about the variability of exposures that occurs day-to-day at a single site. For this study, several characteristics of the construction industry impose limitations on the methods that can feasibly be used to select monitoring sites. The best available selection methods are described below, for each type of site to be evaluated.

In this protocol, the term "site" refers to a construction site at which a given type of installation is monitored. At a single construction site, more than one type of installation may be monitored (for example, both copper water supply and ABS waste lines), and would be considered as a separate site for each type of installation.

For each day at each site, the exposures of all workers engaged in the type of installation selected will be monitored, if feasible. The average number of workers monitored at each CPVC/PVC installation site is expected to be approximately two; the average number of plumbers to be monitored at each copper installation site is expected to be approximately three.

The minimum number of sites to be monitored, and the approximate number of samples of each type that are to be collected, are summarized in Table 1 below.

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Table 1. Minimum number of sites and site-days to be monitored, and the approximate number of samples to be collected, for each type of pipe installation.

| Installation | | Sites/Site-days | Samples |
|---|---|---|---|
| **CPVC PIPE** | | | |
| *CPVC/PVC sites* | | | |
| water supply | | 2/ 4 | |
| other | | 10/12 | |
| total | | 12/16 | |
| Samples by type: | DMF, full-shift | | 20 |
| | other solvents, short-term | | 150 |
| | urine samples for DMF, MEK | | 23 |
| | MEK, 4-hour | | 23 |
| | CPVC/PVC dust | | 8 |
| *ABS sites* | | 5/ 5 | |
| Samples by type: | DMF, full-shift | | 5 |
| | other solvents, short-term | | 30 |
| | urine samples for DMF, MEK | | 5 |
| | MEK, 4-hour | | 5 |
| **PB PIPE** | | | |
| PB thermal fusion | | 2/ 2 | 2 |
| **COPPER PIPE** | | 8/10 | |
| Samples by type: | solder fumes | | 30 |
| | flux fumes | | 2 |

*CPVC/PVC Sites*

The fact that CPVC is not currently approved for potable-water distribution by the State of California makes difficult the identification of CPVC water-supply installations to be monitored. In the planning of this study, plumbing inspectors (or other building department officials) from over 50 California cities were contacted. All reported that CPVC water-supply pipe is either not approved or not installed in their areas, although several recalled that it had been installed several years in the past. Thus, much of the evaluation of CPVC-related exposures will done at sites in other states or at sites where CPVC or PVC pipe is being installed for uses other than potable water. Specifically, the sites selected for monitoring may include:

- installation of PVC garden sprinkler systems, which is substantially similar to installation of under-floor CPVC water-supply plumbing;

- installation of CPVC fire sprinkler systems or installation of PVC condensate-drain lines, which are substantially similar to top-off of CPVC water-supply plumbing;

- plumbing (especially finish work) in CPVC-plumbed mobile homes, which is substantially similar to plumbing in non-mobile CPVC-plumbed homes;

- prefabrication of any CPVC or PVC components; and

- any other site where CPVC or PVC is being installed under conditions that are analogous to any phase of CPVC home plumbing.

Sites other than CPVC water-supply installation will be considered substantially similar to water-supply installation only if pipes of 1.25 inch diameter or less are being installed, using work practices similar to those used in residential construction. This restriction intentionally excludes monitoring of larger-diameter PVC waste pipe for evaluation of the exposures expected during installation of CPVC water-supply systems.

Monitoring will be conducted at a minimum of 12 sites, including a minimum of two sites of actual CPVC water-supply installation; the remainder may be other sites as described above. For at least two of the sites, including one CPVC water-supply installation, monitoring will also be conducted on two subsequent days (for the same workers if possible), for a total of at least 16 monitoring days (approximately 32 worker-days). Of the worker-days monitored, approximately 50% will be representative of top-off plumbing (at installations as described above), 30% will be representative of under-floor work, 10% will be finish work, and 10% will be prefabrication. These percentages reflect the approximate proportion of CPVC/PVC installation time spent in each phase during residential construction.

Because of the difficulty of identifying appropriate sites, any CPVC or PVC site identified by any means will be considered a candidate for monitoring. Suitability for monitoring will be determined by similarity of work practices to those used in residential water-supply plumbing, without regard to perceived exposure levels. The search for CPVC/PVC sites will be focussed on the ten California counties that had the most new construction activity in 1986 (Los Angeles, Orange, San Diego, San Bernardino, Riverside, Contra Costa, Sacramento, Santa Clara, Alameda, and Ventura); these counties are expected to have, during the sampling period, a large number of hot days that are typical of California during the construction season. ~~not be limited to any particular geographic area of the state or~~ The search will not be limited to either union or non-

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union contractors. Both single-family homes and multiple residences will be included, and at least one custom home.

Exposures associated with installation of plastic (generally ABS but sometimes PVC) DWV systems will be assessed at a minimum of five sites, in order to account for possible cumulative exposures when installation of DWV and of CPVC water supply occurs on successive days. If DWV installation is done concurrently with CPVC/PVC water-supply installation at any of the CPVC/PVC sites monitored, then DWV installation will be monitored at that site, to account for additive exposures when installation of both occurs on the same day.

Because many plumbers work in both residential and industrial construction during their careers, one or more industrial sites may also be evaluated to give limited information about possible cumulative lifetime exposures to the substances used in plastic pipe installation.

*Polybutylene Sites*

PB pipe joints are made with two different methods: crimped mechanical fittings and thermally fused joints. In neither case are cements or other substances used to form the joints. Based on observations during initial walk-through inspections, no exposures to toxic substances are believed to result from mechanical crimping. To determine whether thermal fusion joining creates potentially harmful exposures, air monitoring will be conducted at a minimum of one site. Thermal fusion of PB is uncommon for water-supply systems in California, so installation of fire sprinklers is likely to be selected for monitoring. The substances released during fire sprinkler installation are believed to be the same as those released during water-supply installation, even if the concentrations are different.

*Copper Sites*

For evaluation of exposures during installation of copper pipe, monitoring will be conducted at a minimum of 8 sites. For at least one of the sites, monitoring will also be conducted on two subsequent days, for a total of at least 10 monitoring days (approximately 30 worker-days). In addition, an attempt will be made to monitor at least one site at which extensive rework in enclosed spaces is required, if such work is not included in the sites specified above. Of the plumber-days monitored, approximately 60% will be top-off plumbing, 30% will be under-floor work, and 10% will be prefabrication. These percentages reflect the approximate proportion of copper pipe installation time spent in each phase.

The sites selected for monitoring will include various geographic areas, both single-family and multiple units, and at least one custom home. At least 35% of the sites will be union sites and at least 35% non-union.

## EXPOSURE MONITORING

*General*

For each site at which monitoring is conducted, the following information about the site will be collected: the number of homes to be built, the size of the homes, the number of plumbers on the site and their jobs, and the approximate amount of time required to complete each phase of the plumbing. A form for recording this information will be developed.

Workers whose exposures are monitored will be interviewed to determine: their training, usual work practices, usual job assignments, use of personal protective equipment, any health effects experienced during the day of monitoring, and any observations about unusual conditions on the day of monitoring. Workers' age, sex, and English proficiency will also be determined. Workers not monitored may also be interviewed. A form for recording the information will be developed. Job task data, such as the number of joints glued in a day and the number glued in enclosed spaces, will also be collected for the individuals monitored.

A record will be made of all materials used in the installation monitored, and of the various piping materials used on the site. For sites at which CPVC/PVC or ABS installations are monitored, each primer and cement used will be noted, and information about product formulation will be obtained from the manufacturer or from the National Sanitation Foundation (NSF). Use of primers or cements that are not listed with NSF for potable water will noted. Bulk samples of each primer and cement used at each site will be collected. The most commonly used ~~products may be collected,~~ and will be analyzed to determine the concentrations of major constituents. Manufacturers work practice recommendations will be noted from product containiers.

Flow rates of pumps used to collect air samples will be calibrated periodically to ensure accurate knowledge of sample volume. For lowflow pumps with stroke counters, calibration will be checked at least once per week against a primary standard. Other air sampling equipment--including high-flow pumps and flow regulators--will be calibrated at least at the beginning and end of each sample collection period with a calibrated rotameter. Each full-shift air sample will be collected over a period of at least seven hours or will include all exposure periods for the day; work periods will be accepted as no-exposure periods only if worker activities are directly observed by a member of the study team. Air samples to be analyzed for organic solvents will be frozen as soon *as possible after collection, shipped* on ice to the laboratory, and kept frozen until they are analyzed. Urine samples will also be kept refrigerated or frozen.

Whenever possible, photographs will be taken to document the working conditions at the sites monitored. In particular, circumstances such as spills, enclosed spaces, and unusual work practices will be photographed. Each monitoring days' maximum temperature will be measured (in the shade) between 2:00 and 4:00 pm.

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*Chlorinated Polyvinylchloride Pipe*

Several potential exposures have been identified by previous studies of plumbers installing PVC pipe, using materials and work practices similar to those required for CPVC. The most significant exposures are: DMF, the oxygenated solvents MEK, THF, and cyclohexanone, and dusts of the sawed polymer. Residual vinyl chloride monomer and phthalate plasticizers have not been detected during exposure monitoring of plumbers installing PVC pipe, and are not included in this study. Sample collection and analytical methods to be used for each substance are described below.

At sites where worker exposures to both DMF and the oxygenated solvents MEK, THF, and cyclohexanone are to be monitored, and where four or more workers are performing the installation of interest, approximately half the workers will be monitored for DMF exposure while the others are monitored for exposure to the oxygenated solvents. At sites where three or fewer workers are performing the installation of interest, then monitoring for DMF and the oxygenated solvents may be conducted on separate days if simultaneous monitoring for both proves to be impractical.

**Dimethyl formamide**

At each site selected for monitoring CPVC, PVC, or ABS installation, presence of DMF in any of the cements or primers to be used will be established by measuring the DMF vapor concentration in the headspace of a can immediately after opening. The measurement will be made with a DMF detector tube (Draeger 10/b) with a detection limit of 10 ppm; DMF concentrations in the cement as low as 1% by weight would produce vapor concentrations detectable by this method.[1]

At each site where DMF is detected in any of the materials to be used, DMF exposure will be assessed for each worker included in the study. In addition, DMF exposure will be assessed for at least three workers using materials with no detected DMF. Exposure to airborne DMF will be measured with full-shift air samples according to NIOSH Method 2004, with collection on silica gel and analysis by gas chromatography.[2] Because DMF is readily absorbed through the skin, air concentrations alone may not adequately reflect total exposures. Therefore, total exposure (inhalation plus skin absorption) will be assessed by measuring monomethyl formamide (MMF) in urine. Urine will be collected and MMF analyzed according to methods specified in the ACGIH Biological Exposure Index (BEI) for DMF; urine creatinine will also be measured.[3] Unmetabolized DMF in urine will also be determined as a measure of gross contamination of the urine samples, since this substance is present only at very low levels even in highly exposed workers.[3] The time of previous void before urine collection will be noted.

The minimum number of samples to be collected cannot be determined in advance, since the proportion of worksites with DMF present is not known. Monitoring for DMF may be discontinued after air and urine samples have been collected for 20 worker-days.

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For each worker included in biological monitoring, the extent of contact between workers' skin and the primers and cements used will be qualitatively assessed, and ranked on a three-level scale:

| Level | Definition |
|---|---|
| Light | skin contact less than 25 $cm^2$ (approximately one finger) at any time,<br>OR<br>skin contact less than 10 times per day |
| Heavy | skin contact 25-100 $cm^2$, more than 10 times per day,<br>OR<br>skin contact greater than 100 $cm^2$ (whole hand, one side) at any time |
| Gloves | cotton or leather gloves worn during at least 50% of joints glued. |

Because DMF is primarily a systemic toxicant, short-term levels of DMF exposure will not be measured.

### Oxygenated Solvents

#### General Approach

For the oxygenated solvents MEK, THF, and cyclohexanone, current NIOSH and ACGIH exposure limits are set to prevent acute irritation. In animal studies, chronic toxicity has been observed only at levels substantially above those which most people find objectionable. In previous studies of exposure to MEK, THF, and cyclohexanone during plastic pipe installation, short-term exposures have been much closer to their respective short-term exposure limits than full-shift exposures have been to their 8-hour TWA exposure limits. Therefore, monitoring will focus on short-term (15 minute) exposure measurements.

For each worker whose exposures to CPVC/PVC are monitored, several 15-minute air samples will be collected during the work day and analyzed for MEK, THF, and cyclohexanone. Detailed records of work activities throughout the day will be kept. The resulting data will be used in two ways: first, to characterize the distribution of short-term exposures, and second, to estimate the mean and variance of 8-hour TWA exposures associated with CPVC/PVC installation. In order to maximize the precision of exposure estimates derived from the short-term monitoring data, monitoring will be concentrated during the highest exposure periods.

This method of characterizing the distribution of 8-hour TWA exposures has two important advantages--for this study--over the more traditional method of collecting full-shift samples only:

1) Data collected at CPVC/PVC sites other than actual CPVC water-supply installations can validly be used by this method to

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calculate the exposures expected during CPVC water-supply installation and the factors affecting those exposures, even though the full-shift exposures may not be comparable. This is because the exposures that occur during various tasks are believed to be comparable among installations, but the time devoted to various tasks differs among installations. In calculating the exposure expected during CPVC water-supply installation, the periods spent in each task or exposure category will be based on the periods spent in those categories during water-supply installation only.

2) The data collected will be sufficient not only to estimate 8-hour TWA exposures but also to analyze the factors that affect those exposures. Knowledge of these factors could then be used to calculate estimates of 8-hour TWA exposures under conditions that did not happen to occur at any of the sites monitored. For example, knowing the separate effects of ambient temperature and of prolonged work in enclosed spaces, the 8-hour TWA exposure of a worker spending 3 hours working under a floor and 5 hours above the floor--in 100° F heat--could be calculated. The methods used to assess these factors are described in the data analysis section.

A stratified random sampling scheme, such as that described here, is the best available method for characterizing the distribution of 15-minute exposures, including the percentage that exceed the short-term exposure limit.[4] Information about the mean and variance of 15-minute exposures can then be used to calculate the distribution of exposure levels for any other averaging period of interest, including 8-hour TWA exposures.[5] The calculation methods, including upper and lower-bounds on the variance of 8-hour TWA exposures, have been described elsewhere.[6] Most importantly, the mean exposure level is identical for all averaging times. For work activities in which the amount of time spent in various exposure categories can be determined, an estimate of the average 8-hour TWA derived by this method may have even less uncertainty with it than does a similar estimate based on 8-hour TWA samples taken for the same number of worker-days.[7]

MEK, THF, and cyclohexanone are all volatile solvents. The main variable factors expected to affect their air concentrations are, in order of descending importance: concentration in products used, ventilation, number of joints to be glued in a given period, and temperature. Skin contact has been suggested as an additional factor that contributes to total exposure, but its effect is not known. Information on each of these factors will be collected during each 15-minute monitoring period.

The basic steps of water-supply installation (prefabrication, underfloor, topping-off, and finish work) involve many similar tasks. The tasks can be grouped into five exposure categories, based on two major factors that can be determined at the time of monitoring: the number of joints per unit time, and the presence or absence of structures enclosing the work space. These categories of exposure are shown below:

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I. No joints glued in 15 minute period

IIa. Space NOT enclosed; 1-7 joints per 15 minutes

IIb. Space NOT enclosed; >7 joints per 15 minutes

IIIa. Enclosed space; 1-7 joints per 15 minutes

IIIb. Enclosed space; >7 joints per 15 minutes

Based on existing exposure data, the categories above are listed in ascending order of likely exposure level. Each type of plumbing work can be characterized by various periods of exposure in the above categories. For example, under-floor water-supply work often involves many 15-minute periods in category IIa while joints are rapidly cemented in place, but scarcely any work in categories IIIa or IIIb, because no enclosed spaces are involved. Top-off typically features many periods in either IIa or IIIa, depending on the house plan and on the whether exterior sheathing has been applied. Top-off may also include periods of category IIIb exposure whenever the under-floor plumbing needs to be repaired or redone. Finish plumbing is characterized by a few periods of category IIIa or IIIb exposure when plumbers work in cabinets connecting fixtures.

For this categorization, enclosed and unenclosed spaces will include the following:

<u>Enclosed:</u>
- inside a house where air flow is blocked by exterior walls (or sheathing), windows, and doors
- attic, with roof covering on,
- between joists or closely spaced beams which are covered above,
- inside cabinet or in enclosed soffet,
- under floor level, with floor in place, or
- worker's breathing zone in trench;

<u>Unenclosed:</u>
- inside a house, before exterior walls, windows, and doors have been installed,
- outdoors, except in trench, or
- pipe in trench, but breathing zone out of trench during gluing.

For this categorization, a workers' breathing zone will be considered to be in a trench or between joists or under the floor only if the nose itself is in the space described. Exposure category will be determined by the working conditions during the majority of each 15-minute period.

Air Monitoring

A systematic sampling scheme will be used to ensure that the highest exposure categories are monitored most frequently, but that within each exposure category, the periods selected will be representative. For each exposure category, the pattern for determining which 15-minute

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periods are to be monitored during each plumber-day, and the approximate total number of air samples to be collected, is as follows:

| Category | Frequency | Total |
|---|---|---|
| I | one-half of all site-days | 8 |
| IIa | once per plumber-day | 32 |
| IIb | every-other period in category | 64 |
| IIIa | every-other period in category | 64 |
| IIIb | every period in category | 32 |

A coin flip at the beginning of the day will be used to determine whether category I monitoring will be done and whether the category IIb and IIIa periods monitored will be the odd or even periods, according to their order during the day. The maximum number of samples to be collected ~~for any~~ in category I through IIIa for any worker-day is three. If six or more periods in category IIIb are anticipated for any worker-day, then every-other such period, rather than every period, will be monitored. Monitoring periods will be selected according to the working conditions anticipated during the upcoming 15-minute period. If the working conditions are not as anticipated, then the exposure category of the period monitored will be reclassified according to the conditions that actually occurred. If a scheduled monitoring period is missed, the next period in the same exposure category will be monitored instead.

For each 15-minute monitoring period, information about the number of joints glued and the air temperature and average air flow in the worker's breathing zone will be recorded. The pattern of exposures will be recorded as accurately as possible throughout the work day (not only during monitoring periods) according to the five-category scheme above.

Monitoring of all three oxygenated solvents simultaneously is important so that additive exposures can be evaluated; unfortunately, this will require use of two different media side-by-side. Monitoring for MEK and cyclohexanone will be conducted according to NIOSH Method 2500, with collection on Ambersorb XE-347 and analysis by gas chromatography.[8] This is the standard method for MEK but not for cyclohexanone; however, previous laboratory studies have indicated that Ambersorb may be a better sorbent for cyclohexanone than is charcoal.[9] Monitoring for THF will be conducted according to NIOSH Method 1609, with collection on activated charcoal and analysis by gas chromatography.[10] For at least 10 samples, all three components will be analyzed in both the Ambersorb and charcoal samples collected side-by-side. If the weighted average discrepancy between the two methods for each substance is 20% or less, further monitoring will be done with only one monitoring medium. If the weighted average discrepancy is more than 20% for any substance, both sampling media will be used for the remainder of sampling, but analyses will be done for each substance only for air samples collected on the better medium.

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Biological Monitoring

Of the oxygenated solvents, MEK in particular is believed to be readily absorbed through the skin, so biological monitoring is considered an important adjunct to air monitoring. The ACGIH has adopted a BEI for MEK, based on measurement of MEK in end-of-shift urine samples. Sufficient information is not presently available to assess exposures to THF or cyclohexanone using urine or exhaled-air indices.

For each participating worker for whom a urine sample is collected for DMF monitoring, MEK will be measured in the same sample. To obtain corresponding long-term TWA exposure information, airborne MEK will be monitored during the last 4 hours of the shift, using collection on activated charcoal passive monitors (3M) and analysis by gas chromatography. This collection method was selected for two reasons: 1) all three previous studies establishing the correlation between airborne MEK exposure and urine MEK concentration have based that correlation on air samples collected with charcoal passive dosimeters during the last four hours of the work shift,[11,12,13] so this collection method must be used for the data collected in this study to be compared with previous results; and 2) MEK is eliminated rapidly from the body ($t_{1/2} < 2$ hr), so exposures early in the day make little contribution to the amount of MEK in end-of-shift urine.

At least 20 plumber-days will be included in the biological monitoring for MEK. If necessary, this monitoring will include some workers who are not using DMF-containing products. Extent of skin contact during the four-hour monitoring period will be assessed according to the three-level scale described above.

Although BEIs are not established for THF and cyclohexanone, these will also be measured in the urine and 4-hour samples collected. The resulting data will be used to generate hypotheses about patterns of exposure or the contribution of skin absorption, as described below.

Continuous exposure profiles

Continuous, moment-by-moment exposure profiles will be recorded for at least ten workers, performing the basic operations--prefabrication, under-floor, top-off, and finish. A total of a least two hours, including typical tasks, will be profiled for each worker. Measurements will be made with a photoionization meter (H-Nu or equivalent); such an instrument gives an approximate measure of the total airborne concentration of photoionizable organic molecules. MEK, THF, and cyclohexanone all have very similar photoionization sensitivites, so variations in the relative proportions of the three substances will not substantially affect data collected by this method. Since previous studies of plastic pipe installation have found that the vapors present in highest concentration were THF and MEK, the moment-by-moment profile is expected to reflect predominantly the concentrations of these two solvents. The toxicology of these two substances (and of DMF and cyclohexanone) suggests that assessment of combined exposure is biologically meaningful, since the two are likely to have an additive effect in producing irritation or CNS depression. The information

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gained will be semi-quantitative, and will be used only to provide detailed characterizations of exposure patterns within various 15-minute periods.

CPVC/PVC Dust

On construction sites, CPVC/PVC pipe is most often cut with a knife-edged manual tool--either clippers or a rolling-wheel tubing cutter--that creates no dust. Portable reciprocating saws are used infrequently, and are expected to create little dust, especially in the respirable size range. The operation most likely to produce CPVC/PVC dust is cutting with a high-speed circular cut-off saw during prefabrication. If this task is performed for any of the sites monitored, full-shift monitoring for CPVC/PVC dust will be conducted in the prefabrication area. Full-shift CPVC/PVC dust monitoring will also be conducted if high-speed sawing of PVC pipe is done at any of the construction sites monitored. If no high-speed sawing of CPVC/PVC is done for any of the sites selected, no monitoring for CPVC/PVC dust will be done.

For each site monitored, measurement of exposure to total particulates (or total inspirable particulates) and total respirable particulates will be made by collection of personal or area air samples on pre-weighed 37 mm Teflon filters, with gravimetric analysis. Cyclone preselectors meeting the ACGIH criteria for respirable dust[14] will be used in collecting the respirable dust samples. Filters will be retained for one year for analysis by a more specific technique if such a technique becomes available. Such analysis is not a part of this study.

*Polybutylene Pipe*

In order to assess qualitatively the production of any decomposition products during thermal fusion, at least two air samples will be collected with suitable media and analyzed by gas chromatography-mass spectrometry. In previous studies, various aldehydes and organic acids have been the principal components produced by oxidative thermal decompositition of polyolefins;[15] the collection media used will be capable of retaining these substances. The presence of any substances on the EPA Priority Pollutant list will be identified. The ten additional subetances substances present in highest concentration will also be identified.

*Copper Pipe*

While soldering copper pipe joints, plumbers are most likely to be exposed to solder fumes and to flux fumes and decomposition products. California plumbers currently use fluxes composed primarily of animal fats. Because animal fat fluxes are believed to have less toxicity than acid fluxes or fluoride fluxes, and because the thermal decomposition products are not known, no systematic exposure measurements will be made. In order to assess qualitatively the production of flux decomposition products during brazing, at least two air samples will be collected on suitable media and analyzed by gas chromatography-mass



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spectrometry (GC-MS). As for PB decomposition products, the media will be capable of collecting aldehydes and organic acids. Because flux decomposition produces particulate as well as vaporized substances, a second medium capable of collecting aerosols will be used. The presence of any substances on the EPA Priority Pollutant list will be identified. The ten additional substances present in highest concentration will be identified.

Solder fumes will be monitored according to NIOSH Method 7300, with collection of full-shift air samples on 37 mm cellulose ester filters and analysis by inductively coupled plasma spectroscopy or by atomic absorption spectrophotometry. The principal constituents of currently allowable solders (tin, copper, silver, and antimony) can all be measured with this method. The same methods will be used to measure lead fumes, since plumbers at some worksites use 50%-lead solder for installation of copper DWV lines, and may sometimes improperly use that solder for water-supply installation as well. At least 20 plumber-days will be sampled, including both under-floor and top-off work, and prefabrication if any is done for the sites sampled.

No biological monitoring for exposure to metal fumes will be conducted, because lead is no longer allowable in solders used for potable water systems, and no biological indices of exposure are presently available for antimony (Sb), copper (Cu), silver (Ag), or tin (Sn).

*Other exposures*

At some construction sites, plumbers may have exposures in addition to those listed above, which could occur during installation of any type of pipe. The most common of these are exposure to *noise* and *to silica*. The industrial hygienists may elect to measure these exposures as appropriate, using standard techniques.

*Quality assurance*

To provide information about the integrity of the sample handling methods and laboratory analyses to be used, a limited quality assurance program will be included. For each of the major types of solvent samples to be collected (full-shift air samples for DMF-and-solder fumes, 4-hour air samples for MEK, 15-minute air samples for MEK, THF, and cyclohexanone, and urine samples for DMF, MMF, and MEK) a minimum of three spiked samples will be prepared by the laboratories performing the analyses, delivered to CPHF, and returned blind to the laboratory for analysis along with actual field samples. For MEK, THF, and cyclohexanone, all three substances will be mixed and spiked onto a single sample, and the mixture analyzed blind.

For each type of sample listed above, field blanks will also be submitted blind for analysis. The number of field blanks for each type of sample will be at least 10% of the total number of samples, up to 10 field blanks of each type.

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## EVALUATION CRITERIA

~~Unless other data become known to us between development of this protocol and final reporting, evaluation criteria for DMF, MEK, THF, cyclohexanone, Sb, Cu, Ag, and Sn will be based on established ACGIH and NIOSH criteria, as shown in Table 2. (A toxicity evaluation of these substances has not yet been completed, so Table 2 is not included with this draft of the sampling protocol. A complete set of evaluation criteria will be distributed by August 15, 1988) Any substances measured in the samples but not shown in Table 2 will be judged according to the relevant NIOSH Recommended Exposure Limit, if any, or ACGIH TLV. If the estimate of the 95th percentile of the exposure distribution exceeds the relevant exposure limit for any substance, recommendations may be made for follow-up investigation or for medical surveillance of health effects related to the exposure.~~

The exposure limits to be used for evaluation of exposures to DMF, MEK, THF, cyclohexanone, Sb, Cu, Ag, Pb, and Sn are shown in Table 2. These exposure limits are taken from values established by U.S. OSHA comprehensive standards, NIOSH Recommended Exposure Limits, and ACGIH TLVs, listed in order of preference. For antimony, animal evidence--supported by limited epidemiologic data--suggests that it is carcinogenic, but it has not been evaluated by IARC; the exposure limit listed in Table 2 may not protect against carcinogenicity. Any substances measured in the air samples but not shown in Table 2 will be evaluated according to the relevant exposure limits established by the same agencies. Concentrations of HMF and MEK in urine will be evaluated according to their established ACGIH BEIs of 40 $mg/g_{creatinine}$ and 2 mg/L, respectively. If new data become available indicating that any of these exposure limits are not sufficiently protective of worker health, revised evaluation criteria will be used and a full justification of the revisions provided.

If the estimate of the 95th percentile of the exposure distribution exceeds the relevant exposure limit for any substance, recommendations may be made for follow-up investigation or for medical surveillance of health effects related to the exposure.

For the samples of volatilized organic compounds collected during PB thermal fusion and during copper/flux soldering, further study may be recommended if any of the ten principal components identified by GC-MS is classified by the International Agency for Research on Cancer-IARC as a Category 1, 2A, or 2B carcinogen.[16] or meets criteria

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Table 2. Exposure limits to be used for evaluation of worker exposures measured.

| | EXPOSURE LIMIT | | SOURCE | |
|---|---|---|---|---|
| Substance | 8-Hour TWA | 15-Minute | 8-Hour | 15-Minute |
| DMF | 10 ppm | none | A,O | -- |
| MEK | 200 ppm | 300 ppm | N,A,O | A |
| THF | 200 ppm | 250 ppm | A,O | A |
| cyclohexanone | 25 ppm | 75 ppm | N,A | A(excursion limit) |
| antimony | 0.5 mg/m$^3$ * | none | N,A,O | -- |
| copper | 0.2 mg/m$^3$ | none | A | -- |
| lead | 0.05 mg/m$^3$ | none | O | -- |
| silver | 0.01 mg/m$^3$ | none | O | -- |
| tin | 2 mg/m3 | none | A,O | -- |

?

*Does not address the potential carcinogenic risk of antimony.

Sources:
N - NIOSH Recommended Exposure Limits, as listed in Morbidity and Mortality Weekly Report 1986;35(1s):1s-33s.
A - American Conference of Governmental Industrial Hygienists. Threshold Limit Values and Biological Exposure Indices for 1987-1988.
O - US OSHA Regulations; 29 CFR 1910.

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# DATA ANALYSIS

### *General*

For each substance and type of installation monitored, appropriate statistical methods will be used to estimate the mean exposure level and to evaluate the variability of exposure levels.

For any individual exposures that exceed the exposure limit cited in the Evaluation Criteria section, the conditions associated with those overexposures will be tabulated. When sufficient data are available, the proportion of total variability that occurs among sites, among workers in a single site, and day-to-day for individual workers will be evaluated. For exposures to DMF, MEK, THF, and cyclohexanone, the relative contributions of the various factors affecting exposure levels (such as air flow, temperature, or skin contact) will be assessed.

For each substance and each exposure category, exposure levels will be assumed to be lognormally distributed, unless the data indicate that such an assumption is unwarranted. The parameters of a lognormal distribution (geometric mean and geometric standard deviation) will be used to describe the data and to calculate arithmetic means and variances.

For substances present in individual air samples at levels below the analytical limit of quantitation (LOQ), a value of one-half the LOQ will be assigned. Sample values which seem to reflect extraordinarily high or low concentrations will be assessed with a standard test for homogeneity of data. Values unlikely to have originated from the same underlying data set as the rest of the sample group (with a confidence of 0.99), and with no apparent contributing factors, will be rejected.

For each air sample collected, sample volume will be calculated from the sample duration and the calibration flow rates, assuming that any changes in flow rate between calibrations have been linear during periods of pump operation.

Unless otherwise specified, a confidence level of 0.95 will be used for all statistical tests. For each average exposure level and each estimate of the fraction of exposures likely to exceed the relevant exposure limit, the 95% confidence interval will also be reported, if sufficient data are available.

### *Dimethyl formamide*

Monitoring for DMF will produce two types of data for each worker sampled: concentrations of DMF in full-shift air samples and concentrations of DMF in end-of-shift urine, as well as information about working conditions during the days monitored and the extent of skin contact with primers and cements.

Estimates will be calculated of the average 8-hour TWA exposure level, the variance of exposure levels, and the fraction of exposures likely to exceed the 8-hour exposure limit. Standard multiple

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regression techniques will be used to assess the strength of association between airborne exposure to DMF and several job factors which may affect exposure levels: the number of joints glued, the daily high temperature, the concentration of DMF in the products used, and the amount of time spent gluing in enclosed spaces.

Estimates will be calculated of the average urinary MMF concentration, the variance of MMF concentrations, and the percentage of workdays for which the end-of-shift urinary MMF concentration is likely to exceed the BEI. Analysis of covariance techniques will be used to assess the differences in adjusted mean urinary MMF levels among the three skin-contact groups, and the association between urinary MMF level and concentration of DMF in the products used, independent of airborne DMF levels. The correlation between airborne DMF and urinary MMF will be compared to that found in previous studies.

*MEK, THF, and cyclohexanone*

Monitoring for MEK, THF, and cyclohexanone will produce data of four types: 15-minute exposure levels and the amount of time spent in each exposure category (I-IIIb) for all workers monitored, and urine concentrations and 4-hour exposure levels for workers included in biological monitoring. Accompanying data on working conditions during the monitoring periods and on extent of skin contact will also be available.

The cut-off for periods of concentrated gluing was set at seven joints per 15 minutes based on field observations during walk-through inspections. During a typical day, 3-10 such periods are anticipated. If the cut-off proves to put too many or too few exposure periods in categories IIb and IIIb (and thus impedes data analysis by putting too few of the measurements in any of the categories) then a new cut-off may be selected to better balance the number of measurements in each category.

For each 15-minute air sample, the additive dose of the three solvents will be calculated as:

$$D_{15} = c_{MEK}/STEL_{MEK} + c_{THF}/STEL_{THF} + c_{CYC}/STEL_{CYC}$$

where $D_{15}$ is the additive dose for the 15-minute period; $c_{MEK}$, $c_{THF}$, and $c_{CYC}$ are the air concentrations of MEK, THF, and cyclohexanone; and $STEL_{MEK}$, $STEL_{THF}$, and $STEL_{CYC}$ are the short-term exposure limits for MEK, THF, and cyclohexanone, as shown in Table 2.

Exposure levels measured in 15-minute air samples will be grouped by the exposure category, I-IIIb. Within each exposure category, the average exposure level, variance, and percentage of 15-minute periods likely to exceed the short-term exposure limit will be calculated for each substance and for the additive dose.

Based on the distribution of exposures in the five categories and on the amount of time spent working in each category during CPVC water-supply installation, the average 15-minute exposure level will be

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estimated for all periods throughout the day, for each substance and for additive dose. The variance of the 15-minute exposure levels and the percentage of all 15-minute exposures that exceed the relevant short-term exposure limits will also be estimated. The percentage of worker-days in which any of the short-term exposure limits will be exceeded during any 15-minute period will be estimated.

For each exposure category, analysis of covariance techniques will be used to assess the strength of association between airborne exposure levels for each substance and several job factors which may affect exposure levels: the number of joints glued, the breathing-zone temperature, the breathing-zone air flow rate, and the concentration of each substance in the products used. Differences in adjusted means between the exposure categories will also be assessed.

The average 8-hour TWA exposures expected for workers installing CPVC water-supply systems will be estimated from the short-term monitoring data for each substance as:

$$c_8 = (t_I \cdot C_I + t_{IIa} \cdot C_{IIa} + t_{IIb} \cdot C_{IIb} + t_{IIIa} \cdot C_{IIIa} + t_{IIIb} \cdot C_{IIIb})/32$$

where $c_8$ is the average 8-hour TWA exposure expected during CPVC water-supply installation; $t_I$-$t_{IIIb}$ are the number of 15-minute periods spent in each exposure category by workers monitored during CPVC water-supply installation only; $C_I$-$C_{IIIb}$ are the average 15-minute concentrations for each category among all types of CPVC/PVC installations; and 32 is the number of 15-minute periods in an 8-hour day. Individual 8-hour TWA exposures will not be reported, because they cannot be reliably calculated from the data to be collected. The average 8-hour additive dose will be calculated as:

$$D_8 = d_{MEK} + d_{THF} + d_{CYC}$$

where $D_8$ is the 8-hour additive dose; and $d_{MEK}$, $d_{THF}$, and $d_{CYC}$ are the estimated average 8-hour TWA exposure levels to the three substances divided by their 8-hour TWA exposure limits (as shown in Table 2).

When suffient data are available, the variance of expected 8-hour TWA exposures and the fraction exceeding the 8-hour TWA exposure limit will be calculated for each substance and for 8-hour additive dose.

For workers involved in biological monitoring, the average urinary MEK concentration, variance, and percentage of workdays for which urinary MEK is likely to exceed the BEI will be calculated. Analysis of covariance techniques will be used to assess the differences in adjusted mean urinary MEK levels among the three skin-contact groups and the association between urinary MEK level and concentration of MEK in the products used, independent of 4-hour airborne MEK levels. The correlation between airborne and urinary MEK will be compared to that found in previous studies. The average MEK exposure as measured by the 4-hour samples will be compared with the average estimated 8-hour TWA value derived from short-term sampling data.

*CPVC dust*

Results reported will include the percentage of housing construction sites monitored for which CPVC/PVC was prefabricated (with sawing), estimates of the mean exposure levels to CPVC/PVC dust and respirable CPVC/PVC dust, and the variance of these exposure levels.

*Polybutylene thermal fusion by-products*

For each sample, the most likely chemical identities will be reported for the ten compounds present at highest concentration, along with approximate concentration data. Because of the sampling uncertainties involved, exact chemical identities and concentrations may not be available.

*Solder fumes*

For each element detected in solder fumes, estimates will be calculated of the average exposure level, the variance of exposure levels, and the percentage of exposures likely to exceed the exposure limits. The various factors that might affect exposure levels to solder fumes will not be specifically assessed; rather each will be considered to contribute to overall variability.

*Flux fumes*

For each sample, the most likely chemical identities will be reported for the ten compounds present at highest concentration, along with approximate concentration data. Because of the sampling uncertainties involved, exact chemical identities and concentrations may not be available.

REFERENCES

[1]Leichnitz K, Foster A. Drager detector tube handbook, sixth edition, Dragerwerk AG Lubeck, 1985;73.

[2]U.S. Department of Health and Human Services. NIOSH manual of analytical methods, second edition, 1984;2004.

[3]American Conference of governmental Industrial Hygienists Inc. Documentation of the threshold limit values and biological exposure indices 1986, fifth edition;209-210, BEI 63-BEI 65.

[4]Levy PS, Lemeshow S. Sampling for Health Professionals. Belmont, California: Lifetime Learning Publications, 1980.

[5]Rappaport S. Personal communication, 1988.

[6]Spear R, Selvin S, Francis M. The influence of averaging time on the distribution of exposures. Am Ind Hyg Assoc J 1986;47:365-368.

[7]Nicas, M. Unpublished paper, available from M. Nicas, Hazard Evaluation System and Information Service, California Department of Health Services, 2151 Berkeley Way, Room 504, Berkeley, CA.,94704.

[8]U.S. Department of Health and Human Services. NIOSH manual of analytical methods, second edition, 1984;2500.

[9]Levin JO, Carleborg L. Evaluation of solid sorbents for sampling ketones in work-room air. Ann Occup Hyg 1987; 31:31-38.

[10]U.S. Department of Health and Human Services. NIOSH manual of analytical methods, second edition, 1984;1609.

[11]Miyasaka M, Kumai M, Koizumi A, Watanabe T, Kurasako K, Sato K, Ikeda M. Biological Monitoring of occupational exposure to methyl ethyl ketone by means of urinalysis for methy ethyl ketone itself. Int Arch Occup Environ Health 1982;50:131-137.

[12]Ghittori S, Imbriani M, Pezzagno G, Capodaglio E. The urinary concentration of solvents as a biological indicator of exposure: proposal for the biological equivalent exposure limit for nine solvents. Am Ind Hyg Assoc J 1987;48(9):786-790.

[13]Perbellini L, Brugnone F, Mozzo P, Cocheo V, Caretta D. Methyl ethyl ketone exposure in industrial workers. Int Arch Occup Environ Health 1984;54:73-81.

[14]American Conference of governmental Industrial Hygienists Inc. Documentation of the threshold limit values and biological exposure indices 1986, Fifth edition; 524.

[15]Hoff A, Jacobsson S, Pfaffli P, Itting A, Frostling H. Degradation products of plastics. Scand J Work Environ Health 1982;8(suppl 2):17-21.

[18]International Agency for Research on Cancer. Biennial Report, 1986-1987. Lyon: World Health Organization, 1987;41-44.