IV. ENVIRONMENTAL DATA AND ENGINEERING CONTROLS

Sampling and Analytical Methods

During industrial operations, monomeric acrylamide may escape into the environment as both dust and vapor from the solid and as a mist from aqueous solutions [57]. Little or no information has been found in the published literature on sampling methods for either acrylamide dust or vapor. However, the major manufacturers and users of monomeric acrylamide have provided some insight into a few sampling procedures. A direct readout method for analysis of airborne monomeric acrylamide dust and vapor has not been found.

One method for the sampling of acrylamide dust involving the use of a portable pump with an 0.8-μm membrane filter (open face) at an air flowrate of 2-3 liters/minute has been recommended for breathing zone sampling [58]. The minimum sampling time at a concentration of 0.3 mg/cu m was 30 minutes. No information is available on different concentration ranges over which this method is applicable. Unless the membrane filter is properly stored after sampling either by refrigerating or in a sealed cassette, sample loss by sublimation [1] could cause an error. Also, sampling with a membrane filter does not collect the vapor portion of acrylamide in the air and tends to underestimate the total exposure.

Adsorption of acrylamide on silica gel has been used for personal and general air sampling [59]. Two silica gel tubes with small glasswool plugs on each end were connected in series to a sampling pump. The flowrate was adjusted at 0.05-0.20 liters/minute. Acrylamide collected on the silica gel was extracted with water [59] or methanol-water (80:20 V/V) solution

[58] for analysis. There is insufficient information regarding concentrations that were tested, the concentration ranges over which this method is applicable, and a minimum sampling time. Although this method can be used for collection of acrylamide vapor, it probably does not collect acrylamide particulates efficiently. In addition, glasswool plugs at both ends of the tube would probably collect some dust particles since they are inefficient filters. In any case, this system is not useful for collection of total acrylamide in air.

Another method of sampling for determination of acrylamide vapor in air was developed by using a midget fritted glass bubbler [60]. The bubbler was filled to the 20-ml mark with distilled water and air was passed at a flowrate of 1 liter/minute for 100 minutes. Data concerning concentrations of acrylamide in the air that were collected are not available. However, the sampling adsorption efficiency of one bubbler with a flowrate of 1 liter/minute and a sampling period of 100 minutes was reported to be 98%, but without supporting data.

Midget impingers, as well as silica gel tubes, have been used to sample airborne dust and vapor of acrylamide [58,61]. Two midget impingers, each containing 15 ml of distilled water, were connected in series. The recommended sampling time was a minimum of 60 minutes with an air pump adjusted to a flowrate of up to 1.75 liters/minute [58]. It was indicated that this sampling method is applicable to any acrylamide monomer which may be present in the air in an industrial environment [58]. It was also stated that, since the sample size is essentially unlimited, the limit of detection of acrylamide in air is determined by the amount of interference present. Details such as efficiency of collection by the

impingers and concentration ranges over which this sampling technique is valid were not given.

A variety of sampling methods have been discussed, such as the portable pump with a membrane filter, silica gel tube, midget fritted glass bubbler, and midget impingers. There is no one method that is uniquely applicable for collecting acrylamide aerosol and vapor. A membrane filter has been used to collect samples of acrylamide aerosol and the midget fritted glass bubbler has been used for determinations of acrylamide vapor in air. Silica gel tubes and midget impingers can be used to collect both dust and vapor with the latter method having less vapor loss. Therefore, despite the disadvantages of handling glassware and liquid solutions in field measurements, the sampling technique of using a midget impinger is recommended for personal breathing-zone sampling of airborne acrylamide dust and vapor to guard against losses attendant with filter sampling.

Samples of acrylamide in air have been analyzed by using spectrophotometry [62], gas chromatography [60,63], refractive index measurement [64], titration using bromate-bromide solution [65], thin-layer chromatography [63], direct current (DC) polarography [66], and differential pulse polarography (DPP) [67].

Mattocks [62] reported on spectrophotometric methods which involve the formation of pyrazoline by reacting monomeric acrylamide with diazomethane in a methanol-ether solution. The formed pyrazoline yields a bright yellow derivative with acidic Ehrlich reagent (4-dimethylaminobenzaldehyde) and a more stable, purple-colored complex with 4-dimethylaminocinnamaldehyde; the yellow and purple colors are measured at 440 and 538 nm, respectively. The working range for

both assays was 0.2-2.0 μg/ml of acrylamide. One disadvantage of these methods is working with diazomethane, a suspected carcinogen [62] which has to be redistilled shortly before use to eliminate impurities. In addition, the color formation in the reaction of pyrazoline and either 4-dimethylaminocinnamaldehyde or 4-dimethylaminobenzaldehyde is subject to interference from pyrroles, indoles and related compounds, aromatic amines, hydrazine, and carbonyl compounds.

Analysis of monomeric acrylamide solutions was also determined by measuring the refractive index of a sample solution at 35 C with an Abbe refractometer and converting the reading to percent acrylamide using a standard curve [64]. Duplicate determinations were within 0.4% and the method could be applied for an aqueous acrylamide solution range of 5-60%. The usual concentration range of acrylamide monomer solutions in previously discussed analytical procedures is much lower than 5% and lacks specificity and sensitivity for a determination of acrylamide at the environmental limit.

A more sensitive, but nonspecific, analysis of monomeric acrylamide solutions can be performed by a titrimetric method [65]. This method was based on the reaction of acrylamide with bromine which is obtained from an acidified bromate-bromide solution. The excess bromine was treated with potassium iodide which generates free iodine. The iodine was then titrated with thiosulfate to yield an indirect measure of acrylamide. Any reducible substance may interfere with this method. The titrimetric method gave a relative standard deviation of 0.1 and 0.01% for concentrations above and below 2% of acrylamide in solution, respectively.

Acrylamide vapor in air was collected with a bubbler and subsequently analyzed by gas chromatography after formation of a 1,2-dibromopropionamide derivative [60]. This method was used over a concentration range of 0.005-0.160 mg/cu m over a 100-liter air sample. Contents of a bubbler diluted with sulfuric acid solution from a fritted glass midget bubbler containing monomeric acrylamide were brominated with excess bromine water, irradiated with UV light, and an ether extract was injected into a gas chromatograph and detected by electron capture. No information was reported on interferences. The conversion efficiencies from the monomer to the derivative are unknown. However, the concentration range was well within limits to test adequately for the Threshold Limit Value of acrylamide (0.3 mg/cu m). Use of bromine water and UV irradiation to form the derivative along with the steps involved in sample preparation, such as the adjustment of pH and the extraction process, are disadvantages of this method, but they are within the technical capabilities of most laboratories.

Croll [63] determined the acrylamide content in polymers and copolymers by analyzing a methanol-water (80:20 V/V) extract with a gas chromatograph. A 20% W/W Carbowax 20 M on 60/80 mesh Chromosorb W-acid-washed, dimethyldichlorosilane column was used. The sensitivity of this method for acrylamide is 4 μg in 10 ml of methanol-water extract. Extracts from some of the polymers studied contained compounds (unspecified) which had similar retention times as acrylamide. Buildup of nonvolatile compounds in the injection zone affected the column performance. These compounds made discrete acrylamide determinations impossible without further purification of the extracts. Infrared spectroscopy and thin-layer chromatography were used to confirm that peaks from the gas chromatographic

analysis tentatively identified as acrylamide were in fact from acrylamide. To prepare for infrared spectroscopy, a portion of the polymer extract equivalent to about 2 mg of acrylamide was evaporated to dryness onto potassium bromide and pressed into a disc. The infrared spectrum of this sample was so intense that other contaminants were obviously interfering. After the sample was separated by thin-layer chromatography and the acrylamide portion of the chromatogram removed with methanol, the potassium bromide disc prepared from the extract gave an infrared spectrum identical to that of the pure acrylamide standard. Direct infrared analysis is subject to interferences from unspecified contaminants from the polymers. Another disadvantage of the method is the large amount of acrylamide required for measurement.

Thin-layer chromatography was used to evaluate the acrylamide content in polymers extracted with acetone or a chloroform-methanol (80:20 V/V) solution [63]. Acrylamide was determined chromatographically on silica gel plates. The spots on the plates representing acrylamide were made visible by spraying with either a fluorescein-bromine reagent or 0.01% potassium permanganate reagent which produced yellow spots on a pink background plates for samples containing as little as 0.25 μg of acrylamide. The eluates of the sample scraped from the plates were analyzed by gas chromatography giving a 90% recovery of the acrylamide standard.

MacWilliams et al [66] used direct current (DC) polarographic techniques for analysis of monomeric acrylamide in polyacrylamides. The procedure involved the use of a mixed methanol-water (80:20 V/V) solution for the extraction of the monomer from the polymer. The extract was then polarographically analyzed using the supporting electrolyte tetra-n-

butylammonium hydroxide. The concentration range over which this method is sensitive was 0.01-0.5% acrylamide in polyacrylamides. The authors were able to detect acrylamide concentrations as low as 100 ppm. As long as potentials were carefully corrected for cell resistance and the acrylamide concentration was kept below 0.5 mg/ml in the extract, the DC polarographic technique was reliably accurate. Low monomer concentrations made the acrylamide wave difficult to resolve from the background.

Betso and McLean [67] adopted the polarographic technique to detect and determine monomeric acrylamide in polyacrylamides by using differential pulse polarography. The extraction procedure was similar to that of MacWilliams et al [66] except that the electroanalytical chemical instrumentation has improved since 1965. A methanol-water solvent extract of the polyacrylamides was treated with an ion-exchange resin to remove interfering cationic and anionic species. After appropriate pH adjustments, the resin-treated extract was polarographically analyzed with the supporting electrolyte, tetra-n-butylammonium hydroxide. The polarographic cell consisted of a dropping mercury electrode as the cathode and a platinum wire auxiliary electrode as the anode. Recovery of acrylamide in the polyacrylamides was reported to be greater than 90%. The detection limit for acrylamide was less than 1 μg/ml. However, the presence of some nonionic species, substituted acrylamide, or acrylates would be electroactive in the same potential region as that of acrylamide and would thus interfere with polarographic acrylamide analysis. Acrylonitrile also interfered but, because of its high volatility, it was purged readily by nitrogen from the solution with no adverse effects on acrylamide concentration. Acrolein, acrylic acid, acetone, vinyl-benzyl

chloride, vinyl-benzyl alcohol, styrene, and beta-hydroxypropionitrile did not interfere in polarographic analysis of acrylamide. Resin treatment of the methanolic extract of polyacrylamide for 20 minutes removed the ionic species, such as sodium and potassium ions, without causing any detectable loss of acrylamide concentration.

The analysis of monomeric acrylamide by differential pulse polarography has been adapted for determining airborne acrylamide [58]. The sampling solution for dust and vapor from impingers was analyzed for acrylamide polarographically after ion-exchange resin treatment and the addition of the supporting electrolyte tetra-n-butylammonium hydroxide. No information on the accuracy or the precision for this analytical method was provided. The method was claimed to be reasonably specific for acrylamide and to have relatively few interferences. It was also reported that an acrylamide concentration as low as 0.5 μg/ml could be determined by analysis.

A major factor for identifying the most appropriate analytical technique for acrylamide is the sensitivity of the instrumentation. It appears that gas-chromatographic analysis [60,63] of acrylamide in a methanol-water extract and of 1,2-dibromoproprionamide (derivative of acrylamide) yields sensitivities of 0.400 μg/ml [63] and a working concentration range of 0.005-0.160 mg/cu m [60]. The sensitivity for differential pulse polarography was less than 1 μg/ml for the detection and determination of acrylamide in polyacrylamides [67]. The differential pulse polarography adopted for determining airborne acrylamide dust and vapor concentrations has a reported sensitivity of 0.5 μg/ml of impinger solution [58]. Since both the polarographic and chromatographic analyses

have sensitivities in the microgram range, these analytical methods are applicable to measure acrylamide air concentrations down to 0.15 mg/cu m of acrylamide. However, the gas-chromatographic method involves a complex number of steps for derivative formation and sample preparation, therefore reducing reliability and reproducibility. The efficiencies of bromination and subsequent irradiation are also unknown. Therefore, differential pulse polarography is recommended as the method of choice for the determination of acrylamide.

Environmental Levels

No published information has been found on atmospheric concentrations of acrylamide in industry. Two companies have supplied NIOSH with the results of air sampling data taken at their plants.

Clyne (written communication, July 1976) reported on sampling performed in the breathing zone of workers who wore respirators and were exposed in the acrylamide operation. The results of the 4-hour samples for two packers, the reactor operator, and the dryer operator were 0.22 ppm (0.76 mg/cu m), 0.15 ppm (0.52 mg/cu m), 0.14 ppm (0.48 mg/cu m), and 0.15 ppm (0.52 mg/cu m), respectively.

The Vistron Corporation (DR Brinkley, written communication, June 1976) supplied information on stationary sampling sites of an acrylamide manufacturing plant. Eight-hour samples were collected in water containing impingers and analyzed by a colorimetric method using a ferric chloride reagent. The sampling was begun in January 1971 for the control room and bagging room and in June 1974 for the second-floor processing area. The sampling continued until May 1975. The data were presented as weekly

averages and ranged from 0.1 to 0.4 mg/cu m for the control room, 0.1 to 0.9 mg/cu m for the bagging room, and 0.1 to 0.4 mg/cu m for the second-floor processing area. The stationary air monitoring was reported not to be representative of worker exposure and, therefore, exposure concentrations were estimated from the time each employee worked in the three areas where stationary air monitoring was done. These calculated concentrations usually did not exceed 0.3 mg/cu m during normal operation.

Limited personal monitoring was performed in one plant from late 1974 until June 1975. Two methods were used for collecting acrylamide samples, ie, an 0.8-μm cellulose acetate membrane filter and sodium carbonate. No other specific information was given. The limited personal monitoring data indicated that the actual exposure concentrations were two to three times higher than those of the stationary sites. Table XII-3 shows these data.

Engineering Controls

In the industrial manufacturing of monomeric acrylamide and in the production of its polymers and copolymers, both the solid and aqueous forms of acrylamide are encountered [1,68], the solid having a vapor pressure of 0.007 mmHg at 25 C [1]. The saturated vapor concentration in air for solid acrylamide monomer under standard conditions is estimated to be 27 mg/cu m. During industrial operations in which acrylamide is used for polymerization, both vapor and particulate forms of acrylamide are, and should be, monitored [57 (pp 47-48)]. Concentrations and relative percentage data are not available. The control of exposure to acrylamide should therefore emphasize engineering designs which prevent the escape of

both vapor and dust into the environment.

Any line system or storage vessel necessary for the transfer, maintenance, or manufacture of solid or aqueous acrylamide should be enclosed, ventilated, and have other engineering controls, preferably automated systems, to provide a healthful work environment to minimize worker exposure to acrylamide [57 (pp 133-36)]. In the handling of aqueous acrylamide, skin and eye contact must be prevented. A closed system may be the best way to accomplished this. The liquid should be transferred in a closed-line system from the storage vessel to the polymerization reactor [57 (p 133)]. Closed systems that are properly designed, operated, and maintained should be used, where practical, for the containment of vapor and dust from acrylamide. The conventional method of filling storage tanks or reactor vessels manually with the solid or aqueous acrylamide monomer should be replaced with an automated, enclosed, or ventilated system [57 (pp 133-36)]. Strict engineering controls should minimize skin contact and inhalation hazards associated with acrylamide exposure.

If closed systems are not feasible, local exhaust ventilation should be provided. Guidance for proper design can be obtained in Industrial Ventilation--A Manual of Recommended Practice [69], or more recent revisions, and in ANSI Z9.2-1971 [70]. All ventilation air that contains acrylamide vapor or dust or has contacted solid acrylamide shall be controlled to meet with EPA and local air standards; exhaust air shall not be recirculated into the workplace [57 (p 59)].

Engineering controls should be complimented with good work practices for more effective control of exposure to acrylamide. Respiratory

protective equipment should not be used as a substitute for proper engineering controls but must be worn when the worker is exposed to dust or vapor concentrations exceeding the environmental exposure limit.

V. DEVELOPMENT OF A STANDARD

Basis for Previous Standards

The acrylamide environmental limit was first introduced in 1966 in the United States by the American Conference of Governmental Industrial Hygienists (ACGIH) as a tentative Threshold Limit Value (TLV) of 0.3 mg of acrylamide/cu m of air with the notation "Skin" [71]. This designation is intended to suggest the need for appropriate measures for the prevention of dermal or other local contact or absorption. The tentative TLV of 0.3 mg/cu m was adopted as the recommended value by the ACGIH the following year [72], and has remained unchanged since 1967 [73].

According to the 1971 (third) edition of Documentation of the Threshold Limit Values for Substances in Workroom Air [74], the basis for the ACGIH TLV was extrapolation from long-term feeding experiments on cats reported by McCollister et al [34] in 1964. The oral LD50 for laboratory animals (rats, guinea pigs, and rabbits) was in the range of 150-180 mg/kg and the document [74] further stated that "toxic effects may be produced by any route of administration--ingestion, inhalation, injection, skin contact, or contact with the eye." The cat was described in this document as the most sensitive species. Cats given acrylamide at a dose of 1 mg/kg/day by iv or ip injection developed the neurologic effects in about 6 months; however, long-term feeding experiments (0.3 and 1 mg/kg/day, 5 days/week, for 1 year) in this same species apparently did not produce any ill effect. From the results of long-term feeding experiments in the most sensitive species, the cat, the ACGIH recommended "that no more than 0.05

mg/kg/day be absorbed by workmen" [74].

According to this 1971 ACGIH Documentation of TLV's [74], an absorption of 0.05 mg/kg/day, assuming a ventilation rate of 10 cu m of air for each 8-hour workday, corresponds to an environmental limit of 0.3 mg/cu m, or about 0.1 ppm. The present federal standard for acrylamide, 0.3 mg/cu m as a TWA concentration with the notation "Skin" (29 CFR 1910.1000), is based on the 1968 ACGIH Threshold Limit Value.

According to a 1968 joint report of the International Labour Office and the World Health Organization [75], no standards for acrylamide had been promulgated by countries other than the United States.

Basis for the Recommended Standard

The studies of human intoxication with acrylamide have indicated that dermal absorption [16-18,20,21,23] and ingestion [22] have been the main routes of exposure without, however, ruling out the possible contribution of inhalation of aerosol or vapor. In addition, the airborne form of acrylamide (vapor or aerosol) has not been positively identified. Little information has been found on the acrylamide concentrations to which people are occupationally exposed [16-21,23], much less the airborne concentrations of acrylamide that have caused adverse effects (DR Brinkley, written communication, June 1976). However, data obtained from Vistron Corporation (DR Brinkley, written communication, June 1976) showed that airborne concentrations of acrylamide ranged from 0.1 to 3.6 mg/cu m for personal monitoring and from 0.1 to 0.3 mg/cu m for stationary sites at an acrylamide manufacturing plant. No information was presented in this report to correlate personal monitoring data with the incidence of skin

peeling. The author indicated that a correlation existed between skin reactions and airborne acrylamide concentrations obtained from stationary site data in the plant. In addition to these airborne concentrations of acrylamide, Brinkley stated that two employees experienced neurologic symptoms and initial symptoms of erythema and skin peeling were noted in almost every employee who was working in the acrylamide plant.

Garland and Patterson [20] reported six human cases of occupational acrylamide intoxication. The duration of exposure before the onset of symptoms varied from 4 weeks to 13 months. Though no solid or aqueous acrylamide concentrations to which people were dermally exposed was reported, most of the patients showed excessive sweating, weakness, and skin peeling as initial signs of toxicity. In another occupational dermal exposure study, Auld and Bedwell [16] described a 21-year-old worker who came into contact with a 10% aqueous solution of acrylamide. The patient showed hand and leg muscle weakness as the first symptom of acrylamide intoxication. The authors [16] reported that another worker stopped work because of tiredness and skin rashes. After 2 weeks, he was able to return to work with no complaints. The other occupational incidents of monomeric acrylamide intoxication were reported by Cavigneaux and Cabasson [18], Graveleau et al [17], and Morviller [19] in France and by Fujita et al [23] and Takahashi et al [21] in Japan. However, all of these reports on human effects are qualitative and deal only with clinical signs and symptoms of acrylamide intoxication.

Igisu et al [22] described a nonoccupational exposure to monomeric acrylamide in a family of five persons who used acrylamide contaminated well water for cooking, drinking, washing, and bathing. Three adults in

the family showed signs of CNS toxicity manifested by ataxia. This was followed in 2-4 weeks by symptoms of peripheral neuropathy. The well water was analyzed by gas chromatography and shown to contain 400 ppm of acrylamide and a trace of dimethylaminoproprionitrile. Although slightly more quantitative information was presented in this report than in the reports on occupational exposures [16-21,23], no information is available which would allow estimation of dermal or airborne exposure limits from this report.

There is abundant documentation that experimental administration of acrylamide has produced peripheral neuropathy in many animal species: hens [56], rats [27,38,39], mice [33], cats [34-36,41], dogs [14,30], baboons [31,32], and monkeys [34]. There is some evidence that acrylamide, at a higher dose than that necessary to produce peripheral neuropathy, has caused damage to the CNS of a baboon [32]. Hamblin [14] reported that neurotoxic effects of acrylamide were dose dependent and cumulative, similarly Kuperman [41] found that the CNS effects of acrylamide depended on the dose magnitude, rate of administration, and the length of time during which it was administered in cats. The author [41] did not find any differences in the chronic effects of acrylamide when given by different routes. Kuperman [41] stated that whether the route was iv, ip, im, oral, or subcutaneous, the characteristic effects of chronic poisoning appeared at identical dose levels and after equivalent latencies.

Hashimoto and Ando [37] and McCollister et al [34] have described studies in which acrylamide was applied dermally. Hashimoto and Ando [37] demonstrated the dermal penetration of a 10-30% solution of acrylamide which subsequently appeared in the blood. In rabbits, application of

aqueous solutions of acrylamide (10 and 12.5%) killed one of two rabbits at a dose of 1 g/kg and resulted in slight toxicity at 0.5 g/kg [34]. McCollister et al [34] also studied the effects of 10 and 40% aqueous solutions of acrylamide instilled into the eyes of rabbits. The 10% aqueous solution caused signs of slight pain and slight conjuctival irritation, while the 40% aqueous solution caused moderate pain, slight conjunctival irritation, and marked corneal injury.

McCollister et al [34] found that acrylamide in the feed at 0.3 mg/kg/day, 5 days/week, for 1 year produced no adverse effect on cats. A dose of 1 mg/kg/day caused questionable effects, whereas the higher doses of 3 and 10 mg/kg/day resulted in definite signs of neurotoxicity. The authors [34] found that one monkey fed with 0.1 mg/kg/day, two with 0.3 mg/kg/day, and one with 1 mg/kg/day, 5 days/week, for one year also showed no adverse effects. However, 3 and 10 mg/kg/day levels did cause signs of neurotoxicity in monkeys. The authors [34] concluded that the "no adverse effect" level for monkeys on a diet containing acrylamide lay between 1 and 3 mg/kg/day. It was the authors' [34] suggestion that the summation of industrial exposures should be so controlled that it will be almost impossible for a worker to absorb more than 0.05 mg/kg/day of acrylamide on a day-to-day basis. As previously stated, studies of human intoxication with acrylamide have indicated that dermal contact and ingestion may have been the main routes of exposure without neglecting the possible contribution of inhalation of aerosol or vapor. Consequently, without knowing the airborne acrylamide concentrations at which skin and neurologic symptoms manifest themselves, and also in the absence of information as to the primary routes of exposure, ie, dermal, inhalation, or ingestion, by

which these symptoms may be produced, it is difficult to correlate dermal or neurologic symptoms with worker exposure to airborne acrylamide. The available human and animal studies do not provide enough information to alter the existing federal standard for acrylamide of 0.3 mg/cu m of air as a TWA value. NIOSH, therefore, recommends that the present federal standard be kept.

Several human [16-18,20,21,23] and animal [34,37] studies reported that dermal exposure of monomeric acrylamide produced skin peeling, eye irritation, and signs of neurotoxicity. Thus, a medical surveillance program should include preplacement and periodic medical examinations that give attention to nervous system, skin, and eyes. Medical attention should be provided to workers accidentally overexposed to acrylamide. Personnel occupationally exposed to acrylamide must be warned and advised of the adverse effects of accidental overexposure and must be informed of the symptoms of the disorders and that they may be delayed in onset. If eye contact occurs, the affected eye should be immediately flushed with water and examined by a physician. Each worker's fingers should be examined by medical, paramedical, or other properly trained personnel. Workers should be informed of the importance of this examination.

A continuing education program is an important fact of a preventive hygiene program for employees exposed to hazardous materials such as acrylamide. Workers should be periodically apprised by properly trained persons about the possible sources of acrylamide exposure, the adverse health effects associated with excessive exposure to acrylamide, the engineering and work practice controls in use and being planned to limit exposure to acceptable concentrations, and on environmental and medical

monitoring procedures used to check on control procedures and on the health status of employees. The types and functions of monitoring equipment, such as personal samplers, should be explained so that each employee understands his or her part in environmental monitoring.

Because dermal contact by acrylamide induced skin irritation and neuropathy in humans and animals, care must be exercised to ensure adequate protection against contact with acrylamide. Personal protective clothing and respiratory protective equipment should be available and worn where indicated. Work practices that prevent skin and eye contact must be followed. Showers and eyewash fountains must be available for immediate use if accidental contact occurs.

Engineering controls must be used whenever feasible to control airborne concentrations of acrylamide monomer within the recommended TWA limit. Where acrylamide monomer is present, a closed system of control should be used. During the time required to install adequate controls and equipments, to make process changes, to perform routine maintenance and operations, or to make repairs, overexposure to acrylamide can be prevented by the use of respirators and protective clothing and in some cases by administrative controls.

Because acrylamide produces delayed neuropathy, it is recommended that all medical and other pertinent records involving acrylamide exposure be maintained for 20 years after termination of employment. This will allow enough time for future detection of chronic neurotoxicity of acrylamide which may be related to the employee's known occupational exposure.

The technology is currently available to sample and analyze the present environmental limit to institute appropriate engineering controls. As was discussed in greater detail in Chapter IV, a midget impinger is recommended for personal breathing zone sampling of airborne acrylamide aerosol and vapor to guard against losses attendant with filter sampling. Current analytical techniques commonly used for the determination of acrylamide in the industrial environment are differential pulse polarography and gas chromatography. As was discussed in Chapter IV, differential pulse polarography is the analytical method of choice for airborne acrylamide since gas chromatography involves complex derivative formations of unknown efficiencies and sample preparation.

Concern for worker health requires that protective measures be instituted below the enforceable limit to ensure that exposures stay below that limit. An action level is set as a TWA concentration of one-half the environmental limit. It has been chosen on the basis of professional judgment rather than on quantitative data that delineate nonhazardous areas from areas in which a hazard may exist. However, in the case of acrylamide it is also recognized that many employees work with solid or liquid forms of the substance in situations where there may be skin contact with the substance resulting in dermal or systemic effects. Consequently, appropriate work practices, training, and other protective measures should be required regardless of concentrations of acrylamide in air. Therefore, occupational exposure to acrylamide has been defined as work in an area where acrylamide is stored, produced, processed, or otherwise used, except as an unidentified contaminant in other material at a concentration of less than 1% by weight. Under these conditions, all provisions of this

recommended standard except environmental monitoring and associated recordkeeping should be complied with; in work areas where the action level is exceeded, this requirement (Section 8) should also be complied with.