VI. DEVELOPMENT OF STANDARD

Basis for Previous Standards

In the United States, the present Federal standards for occupational exposure are 8-hour TWA limits of 1.3 mg/cu m for hydrazine, 1.0 mg/cu m for 1,1-dimethylhydrazine, 22 mg/cu m for phenylhydrazine, and a ceiling concentration of 0.35 mg/cu m for methylhydrazine (29 CFR 1910.1000). These present standards are based on the Threshold Limit Values (TLVs) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1968. Several foreign countries also have standards for occupational exposure to various hydrazines. These exposure limits are listed in Table VI-1.

(a) Documentation for Hydrazine

A TLV of 1 ppm (1.3 mg/cu m) for workplace exposure to hydrazine was adopted in 1956 by the ACGIH [203]. In addition, the ACGIH suggested that the dermal route, as well as mucous membranes and eyes, might contribute to the overall exposure to hydrazine by either airborne or direct contact with the substance.

The 1962 edition of the Documentation of the Threshold Limit Values for Substances in the Workroom Air [204] indicated a basis derived from the work of Comstock et al [55]. The 1966 edition of the documentation [205] also listed 1.3 mg/cu m as the TLV but added a study by Thomas and Back [206] as a further basis. In the 1971 documentation [207], the review of Smyth [208], and the studies of Reinhardt and Dinman [209], Patrick and Back [60], and Weatherby and Yard [210] were included to support the TLV

TABLE VI-1

OCCUPATIONAL EXPOSURE LIMITS (MG/CU M)
FOR HYDRAZINES IN FOREIGN COUNTRIES

Country	Hydrazine	Methylhydrazine	1,1-Dimethylhydrazine	Phenylhydrazine
Australia	1.3	0.2	1	22
Belgium	1.3	0.2	1	22
Federal Republic of Germany	0.13	-	-	-
Finland	0.13	0.2	1	22
German Democratic Republic	0.11	-	-	-
Netherlands	0.13	0.2	1	22
Rumania*	0.7	0.1	0.7	15
Sweden	0.13	-	-	-
Switzerland	0.13	0.2	1	22
USSR	0.1**	-	-	-
Yugoslavia	1.3	0.2	1	22

*Average concentration limit
**Hydrazine derivatives

Adapted from reference 202

for hydrazine. The 1976 documentation [211] referred to a study by Haun and Kinkead [56] in which animals were exposed to hydrazine at 1 or 5 ppm intermittently and 1 or 0.2 ppm continuously for 6 months. Depressed erythrocyte counts, hemoglobin concentrations, and hematocrit values were observed in dogs exposed at 1 ppm continuously. At the two highest

concentrations, dogs also developed fatty livers. Liver damage occurred in mice at all exposure levels. In the exposed mice that survived for a year, MacEwen [69] found a dose-related increase of lung tumors. The ACGIH concluded from these two additional studies that the TLV for hydrazine should be lowered to 0.1 ppm as a TWA concentration for a 40-hour workweek.

In Czechoslovakia, the committee for documentation of MAC's has recommended a maximum allowable concentration (MAC) of 0.1 mg/cu m for hydrazine with a peak of 0.2 mg/cu m [212]. In 1974, a commission of the German Research Association concluded that 1.0 ppm, the previous standard in the Federal Republic of Germany, could not assure protection in chronic exposure [213]. In addition, consideration was given to the carcinogenicity demonstrated in animal experiments, and the maximum workplace concentration (MAK) for hydrazine was reduced to 0.1 ppm. The conclusions of the commission were based on a review of the literature that included reports on humans [20,37,39,42,214], acute [20,57,58,215] and subchronic [55,216,210] animal experiments, and studies on the carcinogenic potential of hydrazine sulfate in animals [76,78,79,217,218].

(b) Documentation for Methylhydrazine

In 1966, the ACGIH [219] adopted as a TLV a ceiling concentration of 0.2 ppm (0.35 mg/cu m). In addition, the ACGIH pointed out that the dermal route, as well as the mucous membranes and eyes, might contribute to the overall exposure to methylhydrazine. The selection of the ceiling concentration was based on a comparison of the acute toxicity of methylhydrazine with that of 1,1-dimethylhydrazine [20,208]. This was largely based on the observation of Jacobson et al [20] that methylhydrazine resembled 1,1-dimethylhydrazine and hydrazine in its toxic

effects and that the acute toxicity of methylhydrazine was about three times that of 1,1-dimethylhydrazine. Since neither intermittent nor continuous exposure data were available for methylhydrazine, the ACGIH recommended that methylhydrazine exposure be limited to 0.2 ppm as a ceiling, which is about one-third the TLV for 1,1-dimethylhydrazine. The ACGIH ceiling concentration limit for methylhydrazine has not been changed since it was established. The documentation published in 1971 [207] referred to the studies of Haun et al [92] and Back and Pinkerton [100], but the conclusion reached in the 1971 edition did not differ from that in the 1966 edition.

In a 1974 report [213] prepared by a commission of the German Research Association, subacute and subchronic experiments on animals given methylhydrazine were cited [101,220]. On the basis of other animal studies [58,96,99,102,215,221,222], the commission concluded that methylhydrazine was more acutely toxic than hydrazine and 1,1-dimethylhydrazine so that an MAK should be below 0.1 ppm. However, the commission found no practical need for an exposure limit in the Federal Republic of Germany.

(c) Documentation for 1,1-Dimethylhydrazine

A TLV of 0.5 ppm (1.0 mg/cu m) for workplace exposure to 1,1-dimethylhydrazine was adopted in 1960 by the ACGIH [223]. In addition to recommending this environmental limit, the ACGIH stated that the dermal route, as well as mucous membranes and eyes, was a potential contributor to the overall exposure to 1,1-dimethylhydrazine. Although no basis for this TLV was provided in 1960, the 1962 edition of the Documentation of the Threshold Limit Values for Substances in the Workroom Air [204] indicated that the TLV was based primarily on studies of acute toxicity by Jacobson

et al [20] and Hodge [114]; anemia, weight loss, and lethargy observed by Reinhart et al [110] in dogs exposed at 5 ppm; and questionable evidence of liver dysfunction that Shook and Cowart [49] observed in workers exposed to 1,1-dimethylhydrazine. After considering data from these studies, the ACGIH recommended that a concentration of 0.5 ppm, or one-tenth the concentration causing anemia, weight loss, and lethargy in dogs, be adopted as the TLV for 1,1-dimethylhydrazine. The ACGIH TLV has not been modified since it was originally recommended, and the documentation [207] published in 1971 referred to the same information as the 1962 edition.

In 1974, a commission of the German Research Association of the Federal Republic of Germany recommended an MAK of 0.1 ppm (0.25 mg/cu m) for 1,1-dimethylhydrazine [213]. Although supporting results from several other studies [20,49,111,117,215,] were mentioned, the study of Rinehart et al [110] was the main basis for the conclusion of the commission that a maximum tolerated dose had not yet been determined in animal experiments. Because the possibility of the previous MAK of 0.5 ppm causing damage could not be discounted and because 1,1-dimethylhydrazine was considered more toxic than hydrazine in short-term exposure, the commission lowered the MAK for 1,1-dimethylhydrazine to 0.1 ppm. Dermal absorption was also noted as a possible route of entry. Several studies [78,81,224-226] on the carcinogenicity of 1,1-dimethylhydrazine were reviewed, but the carcinogenic potency of this compound was considered to be very weak.

(d) Documentation for 1,2-Dimethylhydrazine

There currently is no Federal standard for occupational exposure to 1,2-dimethylhydrazine. In 1974, a commission of the German Research Assocation of the Federal Republic of Germany cited several estimates

[20,215,227] of LC50's or LD50's in a report on 1,2-dimethylhydrazine [213]. It also mentioned that 1,2-dimethylhydrazine caused carcinomas in the intestines of rats after sc and oral administration [227-229], and in the colon of mice after sc injection [135]. The commission concluded that 1,2-dimethylhydrazine was highly carcinogenic, but it saw no practical need for establishing an MAK.

(e) Documentation for Phenylhydrazine

In 1956, the ACGIH established a TLV for phenylhydrazine of 5 ppm (22 mg/cu m) [203]. The ACGIH noted that the dermal route was a potential contributor to the overall exposure to phenylhydrazine. The 1962 edition of the Documentation of the Threshold Limit Values for Substances in the Workroom Air [204] suggested that the TLV should be the same as that for aniline or phenol, ie, 5 ppm. The current TLV for phenylhydrazine still is 5 ppm. Later editions of the documentation [207] contained the same substance and conclusion as the 1962 edition.

Basis for the Recommended Standard

(a) Permissible Exposure Limits

The potential for worker exposure to the hydrazines is primarily through two routes of exposure, inhalation and contact with skin or eyes. Hydrazine [59], methylhydrazine [98], and 1,1-dimethylhydrazine [115] were all readily absorbed through the shaved skin of dogs. Each compound was detectable in the blood in 30 seconds, and signs of acute toxicity ensued. Two drops of anhydrous hydrazine applied to the shaved skin of rats, as well as 3 ml applied to rabbits, were lethal [57], suggesting that even a small spill on the skin of workers could be toxic. In general, the

compound with the highest vapor pressure, 1,1-dimethylhydrazine, should be the least toxic by skin absorption because of rapid evaporation. Since 1,1-dimethylhydrazine is toxic by this route [115], other hydrazines are likely to have a similar effect. In regard to eye damage, as little as two drops of a 25% solution of hydrazine applied to the eyes of animals caused permanent damage [57]. Methylhydrazine, 1,1-dimethylhydrazine, and 1,2-dimethylhydrazine, however, produced only temporary, mild effects [58]. These effects are probably pH dependent, since alkaline compounds would be expected to cause more damage to eye surfaces; thus, the eye damage expected for phenylhydrazine and the salts of hydrazines may be similarly related to pH. The salts would be at least as water soluble, if not more so than the free bases, and many are acidic, suggesting they would be more readily removed by tear formation or induced flushing.

Results of animal studies [20,92,111] suggest that methylhydrazine may be the most acutely toxic of the hydrazines. In humans, 90 ppm (169 mg/cu m) of methylhydrazine when inhaled for 10 minutes was tolerated [44]. The median concentrations for detectable odor have been reported to be 3-4 ppm (3.92-5.22 mg/cu m) for hydrazine, 1-3 ppm (1.88-5.64 mg/cu m) for methylhydrazine, and 6-14 ppm (14.7-34.3 mg/cu m) for 1,1-dimethylhydrazine [20], but, as was discussed in Effects on Humans, actually may be lower for many people. An additional report [48] indicated a lower value for 1,1-dimethylhydrazine, 0.3 ppm (0.74 mg/cu m). The odor of phenylhydrazine, described as faint [10], may not be strong enough to warn workers of its presence. Since methylhydrazine at 90 ppm did not impair a worker's ability to escape, other less acutely toxic hydrazines at the same concentration would not be expected to interfere with this ability. To

this end, the odor of the three hydrazines studied could provide warning of acutely dangerous concentrations; however, odor should not be relied on routinely because of such problems as individual variations in threshold and odor fatigue.

Hydrazine and its salts are believed to pose a carcinogenic risk to humans since a wide variety of studies have shown that exposed rodents have developed an elevated incidence of lung tumors. Adenomas and some carcinomas have been observed in mice receiving hydrazine or its sulfate salt in drinking water [80,79] and by intubation [70-75,77,78,81], ip injection [78,81,82,84], and inhalation [69]. Lung tumors were also found in rats [76]; however, hydrazine was not carcinogenic in hamsters [75,85]. In a few cases [70,71,75], liver tumors were also reported. Some studies may be deficient in certain areas, such as inadequate controls, insufficient numbers of experimental animals, insufficient time of observation, or failure to examine all animals or all target organs; nevertheless, these deficiencies are not enough to negate the obvious conclusion, namely, that hydrazine is a carcinogen in mice and rats and that the lungs are the primary target organ.

Liver damage is the most serious effect, other than cancer, of hydrazine toxicity. In one study [56], 4 of 80 mice exposed to hydrazine at 30-33.6 ppm-hours/week died of liver damage in the form of lipid accumulation, and some survivors developed lung tumors [69]. This exposure is equivalent to 1 mg/cu m over a 40-hour week. In dogs, both anemia and fatty livers were seen in those exposed at 150 or 168 ppm-hours/week [56].

In considering the environmental limit, it is not possible to derive a level that can be demonstrated to protect workers against the predicted

carcinogenic effect of hydrazine. The control of hydrazine in breathing zone air should be attained better by a ceiling rather than a TWA limit, in large part because of the resultant limitation on excursions. However, certain restrictions are imposed by the limited sensitivity of the recommended analytical method. At a sampling rate of 1 liter/minute, if a 2-hour sample is collected and a relative standard deviation of 15% in the reproducibility of the analysis is accepted, then the lowest concentration of hydrazine in the air that is detectable should be sufficiently low to protect against hepatotoxicity and significantly lower the risk of cancer. A permissible limit for hydrazine of 0.04 mg/cu m (0.03 ppm) measured over 2 hours is, therefore, recommended.

Animal studies also provide evidence of the carcinogenicity of methylhydrazine. Lung tumors were found in mice given either methylhydrazine or its sulfate salt in drinking water [80]. In hamsters, malignant histiocytomas of the liver (54% incidence) and tumors of the cecum (14% incidence) were found in a similar drinking water study [106]. In another study [107], with a different experimental design, no tumors were found in hamsters given methylhydrazine adjusted to pH 3.5; a 12% incidence of liver tumors was found only in hamsters given unbuffered solutions of methylhydrazine. Since the site of tumor formation was species specific, it is not possible to conclude what the primary site affected might be in humans; however, the results in animals suggest that methylhydrazine poses a carcinogenic risk to workers.

As mentioned above, in considering the environmental limit for hydrazine, a short-term ceiling limit provides better control than a TWA limit. As in the case of hydrazine, there are severe limitations placed on

the environmental limit because of the lack of sensitivity of the analytical method. Even without consideration of possible carcinogenicity, there are severe toxic effects that can occur as the result of exposure to methylhydrazine. In dogs, hepatic choleostasis [93,94] and anemia [93] have been observed at exposures of 30-33.6 ppm-hours/week. Anemia was also observed in dogs and rats exposed at 16.8 ppm-hours/week [95] and in dogs exposed at 6 ppm-hours/week [93]. This lowest dose would correspond to a 40-hours/week exposure concentration of about 0.3 mg/cu m (0.15 ppm). In a 2-hour sample, the lowest concentration at which a 15% relative standard deviation in the reproducibility of the analysis is obtained is about 0.08 mg/cu m (0.04 ppm). This concentration is therefore recommended as a 2-hour limit for methylhydrazine. Even though carcinogenicity is the primary concern, the results of animal studies suggest that this environmental limit may not have a great margin of safety for other effects of exposure.

Mice given 1,1-dimethylhydrazine in drinking water for life developed a 79% incidence of blood vessel tumors and a 71% incidence of lung tumors, primarily adenomas but also some adenocarcinomas [127]. A second study suggests that lung tumors in mice were induced after intubation of 1,1-dimethylhydrazine [78]. The other effects of 1,1-dimethylhydrazine in animals appear to be mild compared with those of the other hydrazines. At 5 ppm (12.2 mg/cu m), slight anemia [110] and elevation of SGPT activity [112] have been observed in dogs. However, toxic effects on the liver have been ascribed to nitrosodimethylamine contamination [113] and, indeed, nitrosodimethylamine has been reported to be present in the air over containers of 1,1-dimethylhydrazine [187]. Though 1,1-dimethylhydrazine is toxic by itself, it is perhaps not heptotoxic unless contaminated. While

it can be speculated that contaminants also play a role in the induction of tumors in animals given 1,1-dimethylhydrazine, the evidence for this is not strong enough to suggest that pure material would not cause cancer; thus, 1,1-dimethylhydrazine should be regulated as a carcinogen. From the recommended analytical method, it can be shown that the lowest concentration of 1,1-dimethylhydrazine that can be detected with a 15% relative standard deviation is about 0.15 mg/cu m (0.06 ppm) in a 2-hour sample at 1 liter/minute, so this concentration is recommended as the environmental limit for 1,1-dimethylhydrazine. It does offer a high degree of protection against all except anticipated carcinogenic effects, and, if adhered to, it should substantially reduce, if not prevent, the expected development of 1,1-dimethylhydrazine induced cancer.

Even though there are no data on humans or on inhalation studies of 1,2-dimethylhydrazine, it appears obvious that this compound should be considered as a carcinogen for humans. The exact form of cancer that would be expected in humans, however, is less clear since metabolic activation is likely to play a role in the selection of target organs at which tumors appear. Rats [131] and mice [127] given 1,2-dimethylhydrazine in drinking water developed hemangiosarcomas and lung tumors; hamsters developed primarily hemangiosarcomas [85]. 1,2-Dimethylhydrazine, given by intubation, induced colonic tumors in rats [130,131]. Guinea pigs developed bile duct carcinomas [126]. Colon tumors have been the predominant finding after sc injections in mice [128,132-136,143] and in rats [131,137,138,140,142]. In one injection study [85], blood vessel tumors, lung tumors, and kidney tumors were also reported, but these tumors were not found in other studies [131,132], which indicates that these

tumors are probably not of major significance in animals when compared to colon tumors. No tumors were found in miniature swine and dogs, but these animals had severe liver damage and most died of intoxication [126]. Even though an acceptable analytical method has not been developed for the measurement of 1,2-dimethylhydrazine, the overwhelming evidence of its carcinogenicity in animals argues for the strict regulation of 1,2-dimethylhydrazine in the workplace. Stringent work practices, proper engineering controls, and closed systems must be considered where this compound is encountered in the workplace.

Angiomas and angiosarcomas of the blood vessels were found in mice given phenylhydrazine hydrochloride in the drinking water [152]. In mice given the same compound by intubation, an increased incidence of adenomas and adenocarcinomas of the lungs was observed [151]. The difference in the sites of tumor formation according to the route of administration is not unlike the results seen for 1,2-dimethylhydrazine. The information presented indicates that phenylhydrazine should be regulated as a carcinogen. Phenylhydrazine is also a hemolytic agent [145,147,148], but sufficient information on which to establish a safe environmental limit for protecting against blood effects is not available. The lowest concentration tested in which the reproducibility of the analysis was within 15% relative standard deviation is the equivalent of 0.6 mg/cu m (0.14 ppm) when the sample is collected over 2 hours at a flowrate of 1 liter/minute. Thus, this concentration is proposed as the environmental limit for phenylhydrazine. The protective value of this limit cannot now be determined.

The worker must be protected to minimize the risks of systemic toxicity, eye damage, and sensitization that can result from contact with the hydrazines and their salts and of cancer that is predicted to be a possible result from contact with or inhalation of these hydrazines. For these reasons, occupational exposure to hydrazines is defined as work in any area where one or more of the hydrazines is stored, produced, processed, transported, handled, or otherwise used and present in such a manner that vapors or aerosols may be released in workroom air or that the hydrazines may spill or splash onto the skin or into the eyes. Because even small spills of hydrazines on the skin can result in severe systemic toxicity, all employees assigned to such a work area, even temporarily, for any purpose, including maintenance or repair, should be regarded as occupationally exposed. Workers in areas where hydrazines are used, either in open or closed systems should be considered to be occupationally exposed, since there is no effective way to demonstrate that a closed system remains completely free of leaks. Conversely, workers assigned only to control rooms in which no air from other hydrazine containing areas is present, should not be considered occupationally exposed.

Although information is not available on the effects of exposure to mixtures of hydrazines or to combinations of the free bases and the acid salts, it seems reasonable that their toxicity would be additive. While the analytical method outlined in Appendix I is not capable of the reliable measurement of concentrations below the recommended limits, it will provide at least a semiquantitative indication of potentially hazardous combinations. Should such a situation exist, employee exposure must be

lowered below the recommended limits for individual compounds to ensure adequate protection of employees.

(b) Sampling and Analysis

The recommended method of sampling and analysis should be simple, sensitive, and selective for the individual compounds. In addition, sampling should be representative of the workers' breathing zone air without impeding their normal job performance. As was discussed in more detail in Chapter IV, sampling on silica gel tubes followed by gas chromatographic analysis is recommended. Detailed information on these methods is given in Appendix I. The sampling tubes are easily handled and do not interfere with the worker and the method is specific for each hydrazine compound. Where mixtures are present, all compounds can be determined at the same time on a single sample. However, the method has been developed only recently, so that its limitations are not as well known as are those of the colorimetric methods [155]. A suitable method for collection of the salts of hydrazines has not been attempted, either in the laboratory or in field studies. There is some question as to whether or not the other compounds are as stable as 1,1-dimethylhydrazine when they are stored in the collection tube for several days, a factor of great importance if the samples must be shipped from their collection site to a laboratory in a different location. Even more important, information on the precision, accuracy, and sensitivity of the method is limited and appears to indicate that the method may be less sensitive than would be desired. While slight alterations in the method might improve sensitivity, necessary information is not available at the present time. In addition, since the complex with furaldehyde would not form, the same gas-

chromatographic method is not suitable for measurement of 1,2-dimethylhydrazine.

(c) Medical Surveillance

Mandatory medical surveillance for workers exposed to the hydrazines should include comprehensive preplacement and periodic examinations giving particular attention to signs of liver, kidney, or blood cell damage, such as jaundice or anemia, and to evidence of possible dermal exposure. The frequency of periodic examinations should depend on the probable exposure of the workers, but in all cases examinations should be conducted at least annually. For those who work with hydrazines intermittently, examinations should be conducted during or shortly after such work. Because the hemolytic effects ranged from moderate to severe in animals exposed to all the hydrazines, specific clinical tests should include complete blood counts including differential. Similarily, varying degrees of liver damage have been observed, so tests of liver function, including SGOT and SGPT are recommended. Complete urinalysis should be performed and should include microscopic examination, determination of specific gravity, and glucose content. Tests for urobilinogen and serum bilirubin should also be considered. Chest roentgenograms should be performed to aid in the detection of any adverse effects of hydrazines on the lungs. In workers over 40, proctosigmoidoscopy must be performed on those exposed to 1,2-dimethylhydrazine, and it should be considered for workers exposed to the other hydrazines.

Preplacement and interim medical and work histories should supplement the information obtained from medical tests. Because animal studies show that numerous body systems have been adversely affected by exposure to the

hydrazines, regardless of the type of exposure, medical and work histories and physical examinations should be thorough, with particular attention being paid to combinations of signs or symptoms that may point to a toxic action of the hydrazines. The results of animal experiments make it evident that these hydrazines are eye irritants. If hydrazines are accidentally splashed into the eyes, they should be treated by immediate flushing with copious quantities of water. All of the free bases, and probably the salts as well, are readily absorbed through the skin. Responsible medical personnel should ensure that plant personnel are properly instructed on these points, as appropriate to the forms of hydrazines being handled.

Since there is evidence from animal experiments to suggest that these hydrazines are carcinogenic, all pertinent medical records should be kept for 30 years after the last occupational exposure to the hydrazines.

(d) Personal Protective Equipment and Clothing

The hydrazines, especially hydrazine, may damage the eyes, and they are likely to be dermal irritants that penetrate the skin to cause systemic toxicity. Therefore, full-face plastic shields (8-inch minimum) and goggles, gloves, boots, and other impervious protective clothing should be used to prevent direct contact. During emergencies, nonroutine maintenance, or entry into confined spaces, respirators may be used to minimize inhalation exposure. Since these hydrazines are judged to pose a risk of cancer to employees, only self-contained, air-supplied respirators with positive pressure in the facepiece are recommended for working in areas where vapors or aerosols of the hydrazines are present.

All foreseeable events that could result in a need to escape from a hazardous area should be evaluated to establish evacuation procedures and to determine the equipment needed. Escape equipment should be kept in readily accessible locations. A self-contained breathing apparatus with positive pressure in the face piece should be provided for escape except for those situations where the time otherwise needed for escape from the area is less than that required to put on the respirator or those cases in which an immediate life-threatening situation, such as explosion, exists.

(e) Informing Employees of Hazards

A continuing education program is an important part of preventive hygiene. At the beginning of employment and periodically thereafter, employees who are potentially exposed to hydrazines should be instructed by properly trained persons about job hazards, signs and symptoms of overexposure, proper procedures for routine handling and disposal, and proper use and maintenance of protective clothing and equipment. The function of monitoring equipment, such as personal samplers, should be explained so that employers understand their part in workplace monitoring. Medical monitoring procedures and their importance in detecting possible adverse effects should be explained and the importance of employees participating in these procedures emphasized. Periodic drills on emergency situations, evacuation procedures, spill cleanup, and decontamination procedures should be held to ensure that employees can perform their assigned duties in these situations.

(f) Work Practices

Severe health effects, both acute and chronic, can result from exposure to hydrazines and their salts. For this reason, both the number

of persons handling hydrazines and their exposures should be limited to the greatest extent possible. Regulated areas should be established where hydrazines are present and only those employees needed to perform the job and knowledgeable of the hazards associated with the handling of hydrazines should be given access. Records of persons entering regulated areas should be maintained to provide documentation of those employees who may be occupationally exposed to hydrazines. Proper exhaust ventilation, waste disposal, and hygiene practices, including the removal of work clothing and showering when leaving the regulated area, should minimize the spread of contamination to other areas.

Within the regulated area, workrooms should be designed to prevent the buildup of vapor or aerosol concentrations of hydrazines. Engineering controls, such as process enclosure, can be an effective way to minimize airborne contamination. All process equipment should be designed to minimize the possibility of leaks. Sanitation measures, such as prohibiting smoking or eating in work areas where hydrazines are present, are necessary to limit ingestion of hydrazines.

Contact with hydrazines can result in irreversible eye damage, and the five hydrazines, as well as their salts, probably all penetrate the skin readily. When hydrazines are used in open systems, a condition often found in laboratories or following a spill or leak, it is especially important that the employee not come into contact with hydrazines or their concentrated solutions. Proper procedures must be followed to prevent such contact.

Hydrazine can be ignited either in the liquid or vapor phase. At normal temperatures, aqueous solutions of hydrazine, methylhydrazine, and

1,1-dimethylhydrazine at concentrations greater than 40, 50, and 25%, respectively, are also ignitable. Because of relatively high vapor pressures, the lower explosion limits for methylhydrazine and 1,1-dimethylhydrazine can be reached at room temperature. While it is unlikely that the lower explosion limit for hydrazine would be reached at normal temperatures, as pointed out in Chapter V, hydrazine, methylhydrazine, and 1,1-dimethylhydrazine are pyrophoric under some conditions and hypergolic with some oxidizing substances. To avoid the formation of explosive concentrations in air and also to retard air oxidation, an inert gas should blanket these hydrazines. In storing, handling, and transporting flammable or combustible hydrazines, employees should remove all sources of sparks and oxidants and keep other incompatible material away to reduce the possibility of fire or explosion. The explosion hazard, along with the toxicity of hydrazines, makes it necessary to establish stringent procedures in case of emergencies, including fires, or for entry into confined spaces.

(g) Monitoring and Recordkeeping Requirements

The need for medical and environmental monitoring is established by an evaluation of the work situation. Likewise, whether or not protective clothing and equipment are needed to prevent direct skin and eye contact must be determined by conditions present in the workplace. Those areas that must be regulated also have to be established. For these reasons an industrial hygiene survey should be conducted before any new operation is begun to determine the areas where employees may be exposed to hydrazines. A similar survey should be conducted once a year and within 14 days after

any process changes likely to increase the concentration of hydrazines to ensure that employees continue to be adequately protected.

In work areas in which occupational exposure to hydrazines is found, a program of monitoring of the breathing zone of workers should be instituted. Other monitoring, such as area monitoring, may be a useful supplement to personal monitoring, especially for evaluation of the process and of methods of controlling the process. Records of monitoring and logs of those entering regulated areas should be kept, and copies should be maintained together with individual medical records to help answer questions about possible associations, casual or otherwise, between health effects and the work environment. Environmental and medical records should be kept for 30 years after the individual's last occupational exposure to hydrazines because of the long induction time, often 20 or more years, in tumor development. This is also compatible with requirements of the Toxic Substances Control Act.