

VI. DEVELOPMENT OF STANDARD

Basis for Previous Standards

(a) Petroleum Ether

No previous health environmental limits for petroleum ether have been recommended.

(b) Rubber Solvent and Varnish Makers' and Painters' Naptha

In 1946, the Subcommittee on Threshold Limits of the American Conference of Governmental Industrial Hygienists (ACGIH) [140] adopted a maximum allowable concentration (MAC) of 500 ppm (2,000 mg/cu m) for all petroleum-derived naphthas. Most of the data compiled in the 1946 ACGIH publication were taken from three sources: the 1942 National Conference of Governmental Industrial Hygienists Subcommittee on Maximum Allowable Concentrations (now known as the ACGIH), Cook's compilation [141] of MAC's in 1945, which listed MAC values for the industrial atmospheric contaminants proposed or accepted by six states and two governmental agencies; and the recommendations of the American Standards Association Committee Z-37, now known as the American National Standards Institute (ANSI). In 1948, the ACGIH still regarded 500 ppm (2,000 mg/cu m) as the recommended environmental limit for petroleum-derived naphthas but changed the designation from MAC to a threshold limit value (TLV). Both the 1962 and 1966 ACGIH Documentation of Threshold Limit Values [142,143] recommended an 8-hour TWA concentration of 500 ppm (2,000 mg/cu m). These recommendations were based on the ACGIH recommendations for gasoline. From a review by Elkins [144], the ACGIH concluded that the aromatic hydrocarbon content of the petroleum naphthas in question should be used in determining

an appropriate TLV. The current federal occupational health standard (29 CFR 1910.1000) for petroleum distillates (naphtha) is 500 ppm (2,000 mg/cu m) as an 8-hour TWA concentration. In 1976, the ACGIH [117] recommended that the TLV for rubber solvent and varnish makers' and painters' naphtha be set at 400 ppm (1,600 and 1,800 mg/cu m, respectively). This was the first TLV assigned specifically for these two solvents.

(c) Mineral Spirits

No previous health or environmental limits for mineral spirits have been recommended.

(d) Stoddard Solvent

In his 1945 compilation of MAC's for the states of California, Connecticut, Massachusetts, New York, Oregon, and Utah, the US Public Health Service, and the American Standards Association, Cook [141] reported a limit for Stoddard solvents set only by New York at 750 ppm. This limit was used as a guide by the New York State Division of Industrial Hygiene for assessing occupational exposure. Reporting no specific basis on which the above standard was set, Cook recommended an MAC for Stoddard solvents of 500 ppm (approximately 2,950 mg/cu m calculated with an assumed molecular weight of 144) basing his proposal on work done with gasoline in 1927 by Sayers et al [145] and in 1943 by Drinker et al [146], and believing the higher boiling constituents of Stoddard solvents to be more toxic than those included in gasoline. Drinker et al [146] noted that gasoline vapor at concentrations of 1,000 ppm caused slight dizziness, nausea, and headache in several volunteers exposed for 1 hour. Sayers et al [145] observed similar symptoms in humans exposed at comparable

concentrations of ethyl gasoline (700-2,800 ppm) for 14.5-50 minutes. Nelson et al [55], also cited by Cook [141], reported that, based on the subjective responses of persons exposed to Stoddard solvent at concentrations of 400 ppm for brief, 3- to 5-minute periods, such a concentration could not be tolerated for an 8-hour exposure.

In 1946, the Subcommittee on Threshold Limits of the ACGIH [140] adopted an MAC for Stoddard solvents of 500 ppm (2,950 mg/cu m) based on recommendations by Cook [141]. In 1948, the ACGIH changed the name of Maximum Allowable Concentration to Threshold Limit Value. The ACGIH TLV tables for both 1948 [147] and 1949 [148] listed Stoddard solvents at 500 ppm as a TWA concentration. This recommended airborne concentration was set to prevent subjective symptoms. The recommended TLV was based on work done with gasoline by Sayers et al [145], Drinker et al [146], and Elkins [144]. In 1970, however, the ACGIH [149] lowered its TLV recommendation for Stoddard solvents to 200 ppm (1,180 mg/cu m) as an 8-hour TWA concentration. The 1971 Documentation of the Threshold Limit Values for Substances in Workroom Air [150] proposed a TLV of "150 or 200 ppm (approximately 800 or 1,100 mg/cu m)" for Stoddard solvents. To estimate the toxicity of Stoddard solvents, the ACGIH defined this solvent as a mixture of 85% nonane, isodecane, and their isomers, and 15% aromatic hydrocarbons, predominately isomers of trimethyl benzene, including the 1,3,5-isomer or mesitylene. For nonane and isodecane, a combined air concentration of 250 ppm was recommended based on a comparison of the increasing toxicity of pentane through octane series, and 50 ppm was recommended for mesitylene. These two recommended limits were incorporated into a composite formula for the determination of TLV's of mixtures,

yielding the estimated TLV of 150-200 ppm as a TWA concentration for Stoddard solvents [84]. In 1974, the ACGIH [84] published a notice of an intended reduction of the recommended limit for Stoddard solvents from 150-200 ppm to 100 ppm (575 mg/cu m). In 1976, this change was adopted by the ACGIH [117]. The following approach was used for the documentation of the current TLV: the estimated TLV for nonane and isodecane was reduced from 250 to 200 ppm, and the TLV for trimethyl benzene was reduced from 50 to 25 ppm. An additional statement was made that Stoddard solvents having flashpoints above 45 C should have a limit below 100 ppm. The short-term exposure limit (the maximal concentration, it was believed, to which workers can be safely exposed for a period up to 15 minutes) for Stoddard solvents was suggested to be 150 ppm (approximately 720 mg/cu m). In 1976, the ACGIH suggested for 140 flash aliphatic solvent, a type of Stoddard solvent, a limit of 25 ppm (150 mg/cu m) [117].

The current federal occupational standard (29 CFR 1910.1000) for Stoddard solvents is 500 ppm (2,950 mg/cu m) as an 8-hour TWA concentration.

The International Labour Office [151] published a report in 1970 on the "Permissible Levels of Toxic Substances in the Working Environment" for numerous countries. Finland was reported to have a standard for Stoddard solvents of 500 ppm (2,950 mg/cu m). In a 1975 survey [152] of "An International Comparison of Hygienic Standards for Chemicals in the Work Environment," the 1975 permissible level of Stoddard solvents for Sweden was listed as 600 mg/cu m, and the 1972 level of these solvents for the USSR as 300 mg/cu m. Aside from the references to the original publications, the report [152] did not cite specific data.

(e) Kerosene

At present, the ACGIH has no recommended TLV for kerosene, and no federal occupational exposure standard has been set for this substance. In 1967, the American Petroleum Institute [27] suggested that the 500-ppm TLV (2,000 mg/cu m) recommended by the ACGIH for petroleum naphthas as a TWA concentration might be used in assessing an occupational exposure limit for kerosene. In 1968, the USSR had a maximum air concentration of 300 mg/cu m for kerosene with a "C" or ceiling designation [151].

Basis for the Recommended Standard

(a) Permissible Exposure Limits

(1) Petroleum Ether

Toxicologic data suitable for recommending an environmental standard for petroleum ether are limited. Thus, to approximate the toxicity of petroleum ether, its components were evaluated.

Petroleum ether is a petroleum hydrocarbon mixture of alkanes, usually composed primarily of n-pentane (80%) and hexane (20%, mostly isohexane). Data that have been reported indicate that petroleum ether inhalation can cause CNS damage [37] and dermal toxicity [38]. Polyneuropathy has been associated with hexane exposure [40-43]. Yamamura [42] reported that sandal workers exposed to hexane at a concentration of 500-2,500 ppm (1,759-8,793 mg/cu m) for over 8 hours/day, 6-7 days/week, developed polyneuropathy. Inoue et al [44], reporting on the same study, indicated that some workers exposed at concentrations of n-hexane below 500 ppm (1,759 mg/cu m) developed polyneuropathy. Yamada [41] described the conditions under which 17 workers who were exposed to hexane vapor

developed polyneuropathy. Six workers were employed in a small laminating plant for about 10 hours/day, 6 days/week. During the laminating process, air levels of hexane ranged from 1,000 to 2,500 ppm (3,517 to 8,793 mg/cu m). The solvent used by these workers was composed of 16% methyl pentane, 20% methyl cyclopentane, and 64% n-hexane. The other 11 cases of polyneuropathy reported by Yamada occurred in a pharmaceutical plant where a 95% n-hexane solution was used. These workers lived as well as worked in the factory, where the concentration of airborne hexane was 500-1,000 ppm (1,759-3,517 mg/cu m).

Herskowitz et al [40] noted that three employees exposed to n-hexane for 6-10 months at concentrations which averaged 650 ppm (2,286 mg/cu m) developed sensorimotor polyneuropathy. Takeuchi et al [43] found that four persons exposed to petroleum benzine for 5 months to several years developed signs and symptoms of polyneuropathy. The petroleum benzine was composed of 13% n-pentane, 12.5% n-hexane, 10% n-heptane, 7.5% n-octane, 3% benzene, 3% toluene, and 57% unspecified components. Analysis of the workroom air indicated that the n-hexane and n-pentane concentrations probably did not exceed 240 and 210 ppm (844 and 618 mg/cu m), respectively.

Animal data also indicate the neurotoxic potential of n-hexane. In mice, the neurotoxic threshold concentration for n-hexane was reported by Miyagaki [79] to be 250 ppm (879 mg/cu m), and, at a concentration of 100 ppm (352 mg/cu m), no toxic signs were found. In these experiments, the animals were exposed to n-hexane for 24 hours/day, 6 days/week, for 1 year.

Because exposure to n-hexane at concentrations as low as 844-1,759 mg/cu m has been associated with polyneuropathy [41,43], and because

Miyagaki [79] reported that 879 mg/cu m was a neurotoxic threshold concentration in mice, whereas a concentration of 352 mg/cu m produced no neurotoxic signs in mice, NIOSH has recommended that the current federal environmental limit (29 CFR 1910.100) for hexane of 1,760 mg/cu m (500 ppm) be reduced to 350 mg/cu m (100 ppm) in a criteria document entitled Criteria for a Recommended Standard...Occupational Exposure to Alkanes [78].

Very little toxicologic data have been found on pentane, the major constituent of petroleum ether, in either animals or humans.

Although polyneuropathy in humans has not been attributed to exposure to hexane-free pentane alone, evidence indicates that it may be similar in toxicity to hexane. Five workers in a belt-manufacturing plant developed polyneuropathy as a result of exposure to a solvent that contained 80% pentane, 14% heptane, and only 5% hexane [45], although neither the concentration of the solvent nor the duration of exposure was mentioned. The authors concluded that pentane and heptane might also cause polyneuropathy. Pentane concentrations as low as 210 ppm may have caused, in part, the polyneuropathy in the brocade sash workers reported on by Takeuchi [43]. Truhaut et al [80] observed that components other than straight chain alkanes may cause neurologic disorders.

Since there is a possibility that n-pentane may cause polyneuropathy [43,45], NIOSH recommended a limit, as a TWA concentration, of 350 mg/cu m (120 ppm) for a 10-hour work shift for n-pentane [78]. This concentration offers a sufficient margin of safety to protect the worker from possible chronic neurologic disorders.

Because the TWA concentration limits for all C5-C8 alkanes recommended by NIOSH are 350 mg/cu m [80], NIOSH also recommends that a TWA concentration for petroleum ether, a mixture of 80% n-pentane and 20% isohexane, be set at 350 mg/cu m. This recommended standard assumes additive toxic effects between hexane and pentane which is a premise consistent with data and analysis presented in the criteria document on alkanes [78].

(2) Rubber Solvent

Carpenter et al [9] found that a concentration of 1,700 mg/cu m (430 ppm) of rubber solvent produced transient eye or nose irritation in one of seven volunteers; all seven subjects noted olfactory fatigue. At higher concentrations, progressively more subjects showed signs of sensory irritation. Carpenter et al [9] reported that concentrations of 1,900-7,900 mg/cu m (480-2,000 ppm) produced no mortality or other signs of adverse effects except for an increase in serum alkaline phosphatase in rats repeatedly exposed to rubber solvent. The increase in serum alkaline phosphatase occurred in rats exposed at 1,900 mg/cu m (480 ppm) of rubber solvent. This was the lowest concentration tested. Although no solvent-induced microscopic lesions were found in any tissue during necropsy, and this enzyme activity change was not observed in dogs similarly exposed, the possibility exists that the increase in alkaline phosphatase was indicative of a functional change that presaged a morphologic change. Considering the possibility of potential tissue damage as a result of exposure to rubber solvent at 1,900 mg/cu m, and since no toxicologic data are available to indicate a specific concentration between 0 and 1,900 mg/cu m that would prevent long-term toxic effects, NIOSH

recommends that 350 mg/cu m be established as a TWA concentration limit for rubber solvent. In arriving at this recommended limit, NIOSH recognizes that rubber solvent is composed primarily of C5-C8 hydrocarbons (41.5% paraffins and 53.6% naphthenes) [9], and, since all C5-C8 alkanes have a TWA concentration limit of 350 mg/cu m [78], it is appropriate that a limit similar to those for alkanes be adopted for rubber solvent. This recommended standard assumes additive toxic effects between the C5-C8 alkanes, and this premise is consistent with data and analysis presented in Criteria and Recommendations for a Standard...Occupational Exposure to Alkanes [78].

Although no specific data on the dermal effects of rubber solvent have been found, alkanes and solvents that boil below 232 C (450 F) are known to be primary irritants [59,78], and thus, rubber solvent should be considered to be a dermal irritant. Dermal exposure to this solvent should, therefore, be minimized. The benzene content of rubber solvent should be evaluated to assure that the federal exposure limit for benzene is not exceeded.

(3) Varnish Makers' and Painters' Naphtha

Carpenter et al [17] observed that olfactory fatigue occurred in volunteers exposed to VM and P naphtha at concentrations of 660-4,100 mg/cu m (140-880 ppm). Solvent concentrations from 660 to 2,100 mg/cu m (140 to 450 ppm) caused slight or transitory eye and throat irritation in two of seven subjects. Carpenter et al also found that rats and dogs subjected to repeated daily inhalation of VM and P naphtha at 0-5,800 mg/cu m (0-1,200 ppm) for 6 hours/day, 5-days/week, for 65 days developed no outward signs of distress. Slight changes in the percentage of

reticulocytes and immature neutrophils were noted in dogs at concentrations of 1,300 mg/cu m, the lowest concentration tested, or greater. Exposure of dogs at 5,800 mg/cu m of VM and P naphtha caused an increase in serum alkaline phosphatase activities after 13 weeks of exposure. Rats exposed to VM and P naphtha showed no major changes in hematologic or clinical chemistry values as a result of solvent exposure.

Since sensory irritation was observed in humans exposed for only 15 minutes at a concentration of VM and P naphtha at 660 mg/cu m, and because there were alterations in the reticulocyte and immature neutrophil counts in dogs exposed at 1,300 mg/cu m for 6 hours/day for 13 weeks, NIOSH recommends that a TWA concentration limit of 350 mg/cu m be adopted for VM and P naphtha. It is felt that this limit is sufficiently low to prevent sensory irritation and long-term toxicity. In recommending this limit, NIOSH recognizes that VM and P naphtha is composed of about 26.0% C5-C8 paraffins and 21.2% C5-C8 naphthenes [17], for which all C5-C8 alkanes have a limit of 350 mg/cu m and that there is a similarity in the toxicity between VM and P naphtha and rubber solvent [9,17].

No studies have been found on the effect of dermal exposure to VM and P naphtha, but it is evident that, since C5-C8 alkanes, Stoddard solvents, and mineral spirits are primary irritants [51,75,78], VM and P naphtha, whose boiling range overlaps the ranges of these solvents, has solvent properties similar to these other solvents. VM and P naphtha is, accordingly, also considered to be a dermal irritant. Thus, contact of the skin as well as the eyes should be avoided.

The benzene content of VM and P naphtha should be evaluated to ensure that federal exposure limits are not exceeded.

(4) Mineral Spirits

While mineral spirits and Stoddard solvents are not always considered the same petroleum products and are used differently for different purposes in industry, their boiling ranges (Stoddard solvents, 160-210 C; mineral spirits, 150-200 C) [1] are almost identical, and, therefore, their chemical compositions are similar. In fact, many investigators use the terms mineral spirits and Stoddard solvents interchangeably [3,4,18,19,21].

White spirits (mineral spirits) at concentrations of 2,500 mg/cu m or greater have been shown to cause nausea and vertigo in humans [48]. Concentrations of 625-2,500 mg/cu m (about 98-392 ppm) of white spirits for periods up to 2 hours had no effect on performance tests, such as perceptual speed, reaction time, short-term memory, numerical ability, and manual dexterity [50]. Exposure to white spirits at 4,000 mg/cu m (627 ppm) for 50 minutes caused a prolongation of the reaction time and a possible impairment of short-term memory [50]. The concentration of white spirits in the alveolar air during exposure to 4,000 mg/cu m, at rest, was similar to the alveolar air concentration of this solvent when the white spirits concentration was 2,500 mg/cu m and the subject was doing light manual work [48,50]. Thus, as should be expected, physical activity can increase the solvent concentration in the lungs and magnify its toxic potential.

Rector et al [82] observed that five species of animals exposed continuously for 60-90 days or exposed intermittently for 8 hours/day, 5 days/week, for 6 weeks to mineral spirits at 1,271 mg/cu m (200 ppm) showed no consistent pattern of dose-related hematologic relationships or any

remarkable gross changes except for lung irritation. Deaths were not seen at any concentration in rats, rabbits, dogs, or monkeys; however, some guinea pigs exposed at concentrations of 363 mg/cu m (57 ppm) or greater died. No guinea pigs died as a result of exposure at 288 mg/cu m (37 ppm). Animals intermittently exposed at 593-1,353 mg/cu m (93-212 ppm) displayed no adverse toxic signs except for slight lung irritation. The lung irritation was seen mainly in the animals exposed at 1,353 mg/cu m for 8 hours/day, 5 days/week, for 6 weeks.

Unless workers are several times more sensitive to intoxication by these hydrocarbons than the animals tested by Rector and coworkers [82], these animal data do not argue for a limit as low as those for the previously discussed solvents, 350 mg/cu m, inasmuch as the exposures were continuous rather than the intermittent type of exposure encountered in occupational exposure. Other tests with humans [48,50], limited mainly to acute sensory or performance responses, also suggest that a higher limit might be acceptable. However, none of these data give assurance that chronic intoxication, such as the polyneuropathy associated with one or more of the lower molecular weight hydrocarbons, might not occur. Exposures to jet fuels, ie, to mixtures of kerosene and gasoline, have caused polyneuropathy [77]. While the C5-C8 alkanes present in the jet fuel might have caused the neurologic effects, a contribution by higher boiling fractions seems possible. Since the workers described did not have eye irritation, it seemed to the authors that kerosene, which, unlike gasoline, is not a significant eye irritant, was the major component in the exposure mixture. In view of the uncertainties, it is proposed that a more conservative approach be followed until more definitive data are available,

specifically, that the same limit proposed for lower boiling fractions be recommended, viz, 350 mg/cu m as a TWA concentration.

Mineral spirits have been shown to cause dermatitis [72], and Stoddard solvents have been recognized as being capable of causing skin irritation [51,75] and possibly aplastic anemia [52,53] after dermal exposure. Of these several cases of aplastic anemia, one may have been from myelodepressant drugs. While benzene may not be expected to be an important contaminant of mineral spirits or Stoddard solvents, because of the boiling range, there is no other evident cause of anemia. From present knowledge, there seems to be no reason in addition to a small number of case histories to suggest that aliphatic hydrocarbons can cause aplastic anemia, but further research on the point seems warranted. Since there is a similar composition between mineral spirits and Stoddard solvents, it is recommended that dermal exposure to mineral spirits be avoided. The benzene content of mineral spirits should be evaluated to ensure that the federal exposure limit for benzene is not exceeded.

(5) Stoddard Solvents

There are four classes of Stoddard solvents that are used in the drycleaning industry: regular Stoddard solvent, 140 flash solvent, odorless solvent, and low end point solvent [24]. Inhalation toxicologic data exist for only two of the four classes: regular Stoddard solvent [21] and 140 flash solvent [56]. The studies [51-53,55] that did not specify the specific class of this solvent were considered to be regular Stoddard, since it is the solvent primarily used by the drycleaning industry and is commercially known as "Stoddard solvent" [25]. Henceforth in this

discussion, regular Stoddard solvent will be referred to as simply as Stoddard solvent.

The effects of Stoddard solvent exposure on humans have been reported by several investigators [21,51-53,55,75], but few were quantitative inhalation studies. Carpenter et al [21] noted that Stoddard solvent at a concentration of 144 mg/cu m (24 ppm) was not irritating to humans. At a concentration of 850 mg/cu m (150 ppm), slight and transitory eye irritation occurred during a 5-minute exposure in one of six subjects, but at 2,700 mg/cu m (470 ppm), definite eye, nose, and throat irritation was observed. Nelson et al [55] found that Stoddard solvent in excess of 400 ppm (2,290 mg/cu m) was irritating to the eyes, nose, and throat of most volunteers, and suggested that a concentration of less than 400 ppm would be an acceptable concentration for an 8-hour day, in terms of comfort.

Carpenter et al [56] examined the human sensory toxic effects of 140 flash aliphatic solvent, a type of Stoddard solvent. Minor eye irritation was the only discomfort expressed by one of six subjects exposed to 140 flash aliphatic solvent at either 110 or 310 mg/cu m (17 or 49 ppm) for 15 minutes. All subjects experienced olfactory fatigue at both concentrations. No other signs of irritation were reported.

Animal experiments also have examined toxic effects of Stoddard solvent. In 1975, Carpenter et al [21] saw that rats and dogs subjected to repeated daily inhalation of Stoddard solvent at 1,900 mg/cu m (330 ppm) for 6 hours/day, 5 days/week, for 13 weeks survived the exposures. The authors reported that the only toxic effects at the 1,900 mg/cu m exposure were a change in the blood urea nitrogen levels in rats, marked tubular regeneration in the kidneys, and an insignificant but distinct dilation of

the loops of Henle at either 8 or 13 weeks. Similar renal changes were seen after 8 and 13 weeks' exposure at 1,100 mg/cu m (190 ppm) of Stoddard solvent. Solvent exposure did not cause blood or tissue changes in dogs.

Carpenter et al [56] demonstrated that rats and dogs repeatedly exposed at concentrations of 230 mg/cu m (37 ppm) of 140 flash aliphatic solvent had no treatment-related effects at any of the levels tested.

Following the same argument (qv) previously presented on mineral spirits, an environmental limit of 350 mg/cu m as a TWA concentration is recommended for Stoddard solvents until more definitive data are available. Compliance with this limit should prevent sensory irritation and long-term toxicity.

Braunstein [51] and Larsen and Shmunis [75] showed that contact with liquid Stoddard solvent caused dermatitis in industrial workers. Scott et al [52] found four cases and Prager and Peters [53] reported one case of aplastic anemia after dermal exposure to Stoddard solvent. Stoddard solvents are capable of causing skin irritation from dermal exposure [51-53,75], so dermal exposure to Stoddard solvents must be avoided. As mentioned in the discussion of mineral spirits, dermal exposure to Stoddard solvent has been associated with several cases of aplastic anemia [52,53], but this seems unlikely to occur from present knowledge with benzene-free solvents. But the benzene content of Stoddard solvents should be evaluated to ensure that the federal exposure limit for benzene is not exceeded.

(6) Kerosene

Carpenter et al [67] reported that acute human exposure at 140 mg/cu m (20 ppm) of deodorized kerosene was innocuous. None of the subjects expressed discomfort or irritation during or after a 15-minute

inhalation period. Fifty percent of the subjects, however, developed olfactory fatigue. Rats and dogs exposed at 100 mg/cu m (14 ppm) of deodorized kerosene for 6 hours/day, 5 days/week, for 67 days showed no toxic effects. In the Carpenter study, deodorized kerosene was used and, as such, may not truly reflect the toxicity of regular kerosene since deodorized kerosene contains less aromatics (3.9% versus 5-20%) than regular kerosene [27,67]. Volkova et al [90] showed that aerosol exposure to unpurified kerosene was more toxic than purified kerosene, but there is no indication that any grade of kerosene causes toxicity at concentrations of 100 mg/cu m or below. Although short-term exposures to aerosols for 8 hours/day for 1 day or 6 hours/day for 4 days did not produce signs of systemic toxicity (dermal irritation did occur), aerosol exposure to unpurified kerosene at 500-12,000 mg/cu m for 2 hours/day for 2-4 weeks caused leukocytosis, tracheitis, bronchitis, and pneumonia [90]. Similar aerosol exposure to purified kerosene, however, did not produce any significant signs of toxicity [90]. Thus, exposure to kerosene in the aerosol form should be minimized, unless proper respiratory equipment is used, to prevent the possible accumulation of kerosene in the lungs which could result in pneumonitis. Because kerosene is less volatile than the other solvents discussed in this criteria document, hydrocarbon mists are more likely at a specific concentration with kerosene than with the other solvents. Thus, an environmental limit lower than those recommended for the other solvents is proposed in the absence of definitive data delineating safe from unsafe concentrations of kerosene. Therefore, 100 mg/cu m, as a TWA concentration, is recommended for kerosene. While particulates may exist at even lower concentrations, it is believed that

kerosene vapor, rather than particulate, will more often be formed at this concentration [67], while at higher concentrations more particulate formation is likely.

Kerosene has been shown to cause skin irritation [60-62,67,85] and possibly bone marrow depression [57-59], probably from benzene absorption [57,58], after dermal exposure. Therefore, when this substance is used, care must be taken to prevent dermal exposure. Thirty minutes of dermal kerosene exposure has caused changes in skin structure [62]. The skin has developed a burning sensation during the 1st hour of kerosene exposure, erythema by the 2nd hour, and blister formation by the 12th hour [139]. A solution of 40% kerosene has been shown to be innocuous to the human skin, but 55, 70, and 85% kerosene solutions caused dermatitis in 24, 85, and 100% of volunteers, respectively [61]. Naphthenic-type kerosene has a greater skin-irritating potential than paraffinic-type kerosene [60]. Kerosene has also been shown to augment the toxicity of a skin-sensitizing agent [86]. Thus, it is possible that other sensitizing agents which may come in contact with the worker's skin may heighten the response to dermal kerosene exposure. Kerosene should never be ingested since, in addition to its oral toxicity [88], aspiration can occur and result in pneumonitis and possibly in death [70,89,92,93,153,154]. The benzene content of the kerosene should also be evaluated to ensure that federal exposure limits are not exceeded.

In summary, it is recommended that 350 mg/cu m be adopted as a TWA concentration limit for up to a 10-hour work shift in a 40-hour workweek for petroleum ether, rubber solvent, varnish makers' and painters' naphtha, mineral spirits, and Stoddard solvents. On a volume/volume basis, these

concentrations are equal to about 114 ppm for petroleum ether, 88 ppm for rubber solvent, 75 ppm for varnish makers' and painters' naphtha, 55 ppm for mineral spirits, and 59 ppm for Stoddard solvents. The recommended TWA concentration limit for kerosenes is 100 mg/cu m (about 14 ppm). In addition, a ceiling concentration limit of 1,800 mg/cu m (about 590 ppm of petroleum ether, 454 ppm of rubber solvent, 386 ppm of varnish makers' and painters' naphtha, 282 ppm of mineral spirits, and 306 ppm of Stoddard solvents), based on a sample collection period of 15 minutes, is recommended to protect workers from short-term exposures that might cause effects, such as vertigo or other adverse reactions, which could result in accidents. No ceiling limit is believed needed for kerosene.

It is recognized that many workers handle small amounts of petroleum ether, rubber solvent, varnish makers' and painters' naphtha, Stoddard solvents, mineral spirits, and kerosene or work in situations where, regardless of the amount used, there is only negligible contact with these substances. Under these conditions, it should not be necessary to comply with many of the provisions of these recommended standards, which have been prepared primarily to protect workers' health under more hazardous circumstances. Concern for the workers' health requires that protective measures be instituted below the enforceable limit to ensure that exposures stay below that limit. For these reasons, action levels for petroleum ether, rubber solvent, and varnish makers' and painters' naphtha have been defined as 200 mg/cu m (about 66 ppm for petroleum ether, 50 ppm for rubber solvent, and 43 ppm for varnish makers' and painters naphtha, thereby delineating those work situations which do not require the expenditure of health resources for environmental and medical monitoring and associated

recordkeeping. The action levels for Stoddard solvents, mineral spirits and kerosene are identical to the TWA concentration for these solvents because of the lower volatility of these solvents and the lower likelihood of developing toxicity. The action levels have 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. Because of nonrespiratory hazards such as those resulting from skin or eye contact or from ingestion of petroleum ether, rubber solvent, VM and P naphtha, mineral spirits, Stoddard solvents, and kerosene, it is recommended that appropriate work practices and protective measures be required regardless of the air concentration.

(b) Sampling and Analysis

Sampling and analytical methods are reviewed in Chapter IV and Appendices II, III, and IV. According to the recommended sampling method, solvent vapors (except petroleum ether) are collected in charcoal-filled tubes and then desorbed from the charcoal with carbon disulfide or toluene. An aliquot of the solution of desorbed solvents and carbon disulfide is analyzed with a gas chromatograph. The areas of the resulting peaks are determined and compared with those of injected standards. The sampling method was chosen because it is the best available at the present time and is expected to provide adequate collection efficiency for airborne solvents. The gas-chromatographic method of analysis was selected because it is reliable, sensitive, and relatively simple to perform. Moreover, the method is capable of analyzing for the constituent compounds in these solvents (eg, benzene and toluene), many of which have federal standards. The method is not entirely specific for solvents. Other compounds having

retention times similar to the solvents being analyzed will interfere with the analysis; however, mass spectrometry can be used to identify most of the eluted interfering compound. Petroleum ether can also be sampled and analyzed by a combustible gas meter.

(c) Medical Surveillance and Recordkeeping

Physical examinations should include medical and work histories, complete blood counts, urinalysis, and appropriate liver function tests. The selection of tests to be included in the physical examination are based on studies which indicated that refined petroleum solvents may cause liver or kidney effects. While aplastic anemia occasionally encountered in solvent exposures may be the result of exposure to benzene, a complete blood count is a desirable additional test and should be performed even if the solvent is known to be benzene-free.

Medical records should be kept by the employer for all employees exposed to refined petroleum solvents in the workplace. These records should be kept for at least 30 years after employment has ended, in keeping with the requirements of the Toxic Substances Control Act.

(d) Personal Protective Equipment and Clothing

The use of safety goggles and face shields (8-inch minimum) is recommended to prevent eye irritation when contact of solvents with the eyes is likely. Other personal protective equipment should include respirators, appropriate gloves, and protective clothing. It must be remembered that the solvents discussed in this document are all dermal irritants. The types of respiratory protective devices described in Tables I-1, I-2, and I-3 are those approved under the provisions of 30 CFR 11 for the concentrations specified.

(e) Informing Employees of Hazards

The employer should develop a continuing education program to ensure that all employees occupationally exposed to refined petroleum solvents have current knowledge of job hazards, signs and symptoms of overexposure, proper maintenance and emergency procedures, proper use of protective clothing and equipment, and precautions to ensure safe use of, and minimal exposure to, these solvents. Where a potential for emergencies exists, periodic drills should be held to provide employees with an opportunity to develop skill in dealing with emergency situations.

(f) Work Practices

Work practices and environmental controls are discussed in Chapters V and IV, respectively. They are directed to the prevention of undue skin contact and to the prevention of fire and explosion. Precautions against fire and explosion hazards are emphasized to ensure that flammable or combustible substances are handled properly and that their vapors do not build up to explosive levels in the work environment. In the event of eye or skin contact, contaminated clothing should be removed immediately and the eyes and skin should be flushed with water since all the refined petroleum solvents examined in this document are primary irritants.

(g) Monitoring and Recordkeeping Requirements

To ensure that sampling and analysis information is available for later reference and possible correlation to disease states, the employer should keep records of environmental monitoring for at least 30 years.

VII. RESEARCH NEEDS

Although there have been numerous studies on "solvent" toxicity, many investigators failed to adequately specify the type of solvent used in their studies. In future experiments, it is imperative that the physical and chemical characteristics of a solvent, such as boiling range, flashpoint, evaporation rate, and aromatic as well as benzene content, be given so that the solvent can be adequately defined. This information is necessary since manufacturers may give identical names to chemically dissimilar products. Universally accepted definitions are needed for all solvents.

All the solvents examined in this document need further toxicologic evaluation. There are few animal or human inhalation studies concerning petroleum ether, rubber solvent, VM and P naphtha, Stoddard solvent, mineral spirits, and kerosene; there have been no quantitative inhalation studies on petroleum ether or nondeodorized kerosene. Additional studies on these solvents should be undertaken, using various species of animals. More human studies should also be undertaken.

The exact mechanism of the CNS depressant action of these solvents has not been fully elucidated, and future studies should explore this area. The role of benzene in solvent toxicity should be evaluated. The possibility of a synergistic or additive toxic effects of multiple solvent usage should be examined. Research is needed on the effects of solvents on behavior and reflexes. The possibility that workers become lethargic or lose mental acuity during exposure to small amounts of solvents should be

studied. These questions should be answered by using both epidemiologic studies and animal experimentation.

More studies on the dermal effects of solvents on both animals and humans are needed to determine the onset of skin irritation. The teratogenic, mutagenic, and carcinogenic potentials of these solvents should also be assessed. Additionally, long-term epidemiologic studies should be undertaken to evaluate solvent toxicity and to correlate observed effects with exposure concentrations of the solvents to which workers are exposed during normal working conditions.

More specific and efficient sampling devices should be designed and improved analytical procedures developed for personal, automatic, and continuous monitoring systems.