

## VI. DEVELOPMENT OF STANDARD

### Basis for Previous Standards

#### (a) Acetone

In 1945, Cook [156] compiled a list of maximum allowable concentrations (MAC's) for industrial atmospheric contaminants. He noted that the California Industrial Accident Commission, the Oregon State Board of Health, and the Massachusetts Department of Labor and Industries recommended a 500-ppm (1,180 mg/cu m) MAC for exposure to acetone, while the Utah Department of Health used a 200-ppm (474 mg/cu m) MAC and the New York State Department of Labor used a 1,000-ppm (2,370 mg/cu m) MAC as the guidelines for exposure to acetone. Cook recommended 1,000 mg/cu m as a tentative limit for occupational exposure to acetone. This recommendation was based on the findings of Nelson and coworkers [15], who reported that, at a concentration of 500 ppm (1,180 mg/cu m), acetone caused eye, nose, and throat irritation in humans exposed for 3-5 minutes.

In 1946, the Subcommittee on Threshold Limits of the American Conference of Governmental Industrial Hygienists (ACGIH) [157] adopted a list entitled "Maximum Allowable Concentrations of Air Contaminants for 1946," which included a 500-ppm (1,180-mg/cu m) MAC for acetone as noted by Cook [156].

In 1948, the designation of the environmental limit was changed from an MAC to a TLV (Threshold Limit Value), but the value remained at 500 ppm (1,180 mg/cu m) for acetone [158]. In 1953, the ACGIH [159] defined a TLV as the "maximum average atmospheric concentration of contaminants to which workers may be exposed for an eight-hour working day without injury to

health," and it adopted a TLV of 1,000 ppm (2,370 mg/cu m) for acetone. No justification for the change in the limit was reported at that time, but the basis for the change was presented in the 1962 ACGIH Documentation of Threshold Limit Values [160], which cited reports by Nelson et al [15], Lehmann and Flury [57], and Vigliani and Zurlo [28]. Nelson et al [15] stated that, although acetone caused slight irritation at 300 ppm (711 mg/cu m), most humans tolerated exposure at 500 ppm (1,180 mg/cu m). Lehmann and Flury [57] noted a fatal acetone poisoning in a 12-year-old child who wore a damp acetone dressing. Vigliani and Zurlo [28] found chronic inflammation of the respiratory tract in workers exposed to acetone at 1,000 ppm (2,370 mg/cu m) for 3 hours daily for 7-15 years, and complaints of dizziness were reported. Since 1958, the 2,400 mg/cu m TLV was referred to as a time-weighted average (TWA) concentration for a normal workday [161].

In 1966, the ACGIH Committee on Threshold Limit Values [162] questioned whether the exposure of workers to acetone reported by Vigliani and Zurlo [28] was "pure." The level has remained at 2,400 mg/cu m since 1953 [163]. Review of the more detailed study [27] of the workers, however, does not confirm the suspicion that exposures were mixed.

In 1976, the ACGIH [164] proposed a Threshold Limit Value-Short Term Exposure Level (TLV-STEL) for acetone of 3,000 mg/cu m. The ACGIH defined the TLV-STEL as the "maximal concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from 1) intolerable irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than

four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded."

Occupational exposure limits to ketones in other countries are listed in Table VI-1 [165].

The current US Federal standard for occupational exposure to acetone is 2,400 mg/cu m (1,000 ppm) as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard was based on the TLV adopted by ACGIH in 1968 [166].

(b) Methyl Ethyl Ketone

In 1945, Cook [156] noted that a limit for methyl ethyl ketone exposure in workplaces of 500 ppm (1,470 mg/cu m) was recommended by the California Industrial Accident Commission and a 300-ppm (882 mg/cu m) limit was used as a guideline by the Massachusetts Department of Labor and Industries. Cook recommended 500 mg/cu m as a tentative limit, because of the nose and throat irritation experienced by humans exposed at 350 ppm (1,032 mg/cu m) [15]. He also cited the work of Patty et al [19] that showed no "serious disturbance" in guinea pigs exposed to methyl ethyl ketone at 0.3% by volume for a few hours.

In 1946, the ACGIH [157] adopted a 200-ppm (588 mg/cu m) MAC for methyl ethyl ketone. In 1948, the ACGIH [158] adopted a 250-ppm (735 mg/cu m) limit for methyl ethyl ketone when the designation was changed from an MAC to a TLV. No justification for this change was reported at that time. This TLV was retained until 1961, when the ACGIH [167] lowered the TLV as a TWA concentration to 590 mg/cu m. The basis for this recommendation was provided in the 1962 ACGIH documentation [160], which included the reports

TABLE VI-1

## OCCUPATIONAL EXPOSURE LIMITS (MG/CU M) OF KETONES

Countries	Acetone	Methyl Ethyl Ketone	Methyl n-Propyl Ketone	Methyl n-Butyl Ketone	Methyl n-Amyl Ketone	Methyl Isobutyl Ketone	Methyl Isoamyl Ketone	Diisobutyl Ketone	Cyclo-hexanone	Mesityl Oxide	Diacetone Alcohol	Isophorone
Australia	2,400	590	700	410	465	410	475	150	200	100	240	140
Belgium	2,400	590	700	410	-	410	475	150	200	100	240	25
Bulgaria	-	200	200	-	-	-	-	-	10	-	-	-
Czechoslovakia	800	-	-	-	-	-	-	-	200	-	-	-
Finland	2,400	590	700	410	465	410	475	150	200	100	240	55
German Democratic Republic	1,000	300	-	-	-	-	-	-	-	-	-	-
Federal Republic of Germany	2,400	590	700	410	-	400	-	290	200	100	240	28
Hungary	200	200	-	-	-	-	-	-	-	-	-	-
Italy	1,000	400	-	-	-	300	-	150	200	-	-	-
Japan	480	590	-	-	-	410	-	-	100	-	-	-
Netherlands	2,400	590	700	100	-	410	475	150	200	100	240	25
Poland	200	200	100	200	-	200	-	-	20	20	-	5
Romania	1,000	200	250	200	-	200	-	150	100	100	150	50
Sweden	1,200	440	-	-	-	210	-	-	-	-	-	-
Switzerland	2,400	590	700	410	-	410	475	150	200	100	240	25*
USSR	200	200	200	-	-	-	-	-	10	1**	-	-
Yugoslavia	800	200	700	410	465	410	-	290	200	100	240	140
United States												
<u>1978 Federal Standards (29 CFR 1910.1000)</u>												
	2,400	590	700	410	465	410	-	290	200	100	240	140
<u>NIOSH Recommended Exposure Limits</u>												
	590	590	530	4	465	200	230	140	100	40	240	23

\*Ceiling value

\*\*Skin irritant

Adapted from reference 165

of Patty et al [19] and Nelson et al [15], cited earlier. In addition, Smith and Mayers [33] found that dermatitis and numbness in the arms occurred in humans exposed to methyl ethyl ketone vapor at 300-600 ppm (882-1,760 mg/cu m).

The TLV has remained the same since 1961 [163]. In 1976, the ACGIH [164] proposed, in addition to the existing TLV-TWA, a TLV-STEL of 885 mg/cu m.

The current US Federal standard for occupational exposure to methyl ethyl ketone is 590 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the TLV of 1968 adopted by ACGIH [166].

(c) Methyl n-Propyl Ketone

In 1945, in his list of MAC's for atmospheric contaminants, Cook [156] noted that the California Industrial Accident Commission recommended a 500-ppm (1,760 mg/cu m) MAC for exposure to methyl n-propyl ketone in the workplace and the Utah Department of Health recommended a 1,500-ppm (5,280 mg/cu m) MAC. Cook [156] considered 1,000 mg/cu m to be a tentative concentration limit for occupational exposure to methyl n-propyl ketone. This conclusion was based on the results of an inhalation study with guinea pigs by Yant and associates [52], who reported that guinea pigs exposed at 0.15 vol% for 810 minutes exhibited little or no effects and that short exposures to methyl n-propyl ketone at 0.15% by volume were irritating to humans.

In 1946, the Subcommittee on Threshold Limits of the ACGIH [157] adopted a 200-ppm (704 mg/cu m) MAC for methyl n-propyl ketone. No justification for this level was reported. In 1948, the designation of the

limit was changed from an MAC to a TLV, but the value remained at 200 ppm (704 mg/cu m) [158].

In the 1962 documentation [160], the ACGIH presented the basis for their TLV as a TWA concentration of 700 mg/cu m. It referred to the inhalation study by Yant et al [52] on guinea pigs exposed to methyl n-propyl ketone at 0.15% by volume for several hours. The guinea pigs showed little or no effect from the exposure. In 1966, the ACGIH [162] still considered the 700 mg/cu m TLV "low enough to prevent onset of narcosis and irritation."

The ACGIH, in the 1974 documentation [168], cited the findings of Specht et al [34] and of Yant and associates [52]. Specht et al reported that, when exposed to methyl n-propyl ketone at 0.25% by volume, guinea pigs exhibited irritation and weakness, and coma resulted in animals exposed at 0.50% by volume.

The current US Federal standard for occupational exposure to methyl n-propyl ketone is 700 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the TLV adopted by the ACGIH in 1968 [166].

(d) Methyl n-Butyl Ketone

In 1945, Cook [156] recommended 500 mg/cu m as a tentative MAC for exposure to methyl n-butyl ketone in the workplace. This recommendation was based on findings by Schrenk et al [169] about the responses of guinea pigs and humans to methyl n-butyl ketone vapor. The guinea pigs had no abnormal signs during or after an exposure to methyl n-butyl ketone at 0.1% by volume for 810 minutes. However, humans exposed at that concentration for a few minutes noted a strong odor and developed eye and nose

irritation. Cook [156] derived the 500 mg/cu m limit for prolonged exposure by arbitrarily making it one-fourth of the concentration at which there was irritation.

In 1946, the Subcommittee on Threshold Limits [157] adopted the 200-ppm (820 mg/cu m) MAC for methyl n-butyl ketone recommended by Cook [156]. In 1947, the MAC was reduced to 100 ppm (410 mg/cu m), but no reason was given [170]. In 1948, when the designation of an MAC was changed to a TLV, the limit remained at 100 ppm (410 mg/cu m) [158]. In the 1962 documentation [160], ACGIH cited the study of guinea pig and human responses conducted by Schrenk et al [169] to justify setting the TLV as a TWA concentration at 410 mg/cu m.

In 1966, the ACGIH [162] once again recommended the TLV as a TWA concentration of 410 mg/cu m for exposure to methyl n-butyl ketone and cited the study of Specht et al [34] in the 1966 ACGIH documentation. Specht and his coworkers found that guinea pigs developed progressive narcosis leading to coma and death when they were exposed to methyl n-butyl ketone at concentrations of 0.13, 0.6, and 1.2% by volume for 12, 7, and 4 hours, respectively. The ACGIH considered the TLV of 410 mg/cu m sufficient to "provide protection against irritation and, by a large margin, against initiation of narcosis." The same information was reported in the 1974 ACGIH documentation [168]. In 1976, the ACGIH [164] adopted a TLV-TWA of 100 mg/cu m with a proposed TLV-STEL of 150 mg/cu m.

The current US Federal standard for occupational exposure to methyl n-butyl ketone is 410 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the ACGIH's TLV set in 1968 [166].

(e) Methyl n-Amyl Ketone

In 1971, the ACGIH [171] adopted a TLV of 465 mg/cu m as a TWA concentration for methyl n-amyl ketone, stating that the limit "should be low enough to prevent onset of narcosis and to serve as a guide for practical control." The level was based on a recommendation by Rowe and Wolf [9], who had reviewed the data from an inhalation exposure study on guinea pigs by Specht et al [34]. Mucous membrane irritation occurred at a concentration of 0.15% by volume, narcotic effects were apparent at 0.20% by volume, and, at 0.48% by volume, narcosis and death resulted in guinea pigs exposed for 4-8 hours. In 1976, the ACGIH [164] proposed a 710 mg/cu m TLV-STEL in addition to the TLV-TWA.

The current US Federal standard for occupational exposure to methyl n-amyl ketone is 465 mg/cu m (100 ppm) as an 8-hour TWA concentration limit (29 CFR 1910.1000).

(f) Methyl Isobutyl Ketone

In 1945, Cook [156] recommended an MAC of 200 ppm as a tentative concentration limit for exposure to methyl isobutyl ketone in workplaces. This recommendation was based on Specht's [59] inhalation study of guinea pigs which showed that, at a concentration of 0.1% by volume, methyl isobutyl ketone caused nose and eye irritation in a man but was well tolerated by the guinea pigs.

In 1946, the Subcommittee on Threshold Limits of the ACGIH [157] adopted the 200-ppm (820 mg/cu m) MAC for methyl isobutyl ketone recommended by Cook [156]. In 1948, the designation of the limit was changed from an MAC to a TLV, and the ACGIH [158] lowered the limit to 100 ppm (410 mg/cu m). The justification for this reduction was not reported



at the time. In addition to citing Specht's findings [59], the ACGIH in their 1962 documentation mentioned the report of Silverman and coworkers [16] as justification for the TLV of 410 mg/cu m. Silverman et al [16] found that most people exposed to methyl isobutyl ketone at 200 ppm (820 mg/cu m) experienced eye irritation. They concluded that 100 ppm (410 mg/cu m) was a sensory response limit and that most people experimentally exposed to 100 ppm found this limit acceptable for an 8-hour exposure. In 1966, the ACGIH [162] stated that the TLV as a TWA concentration of 410 mg/cu m "should be sufficiently low to permit exposures without eye irritation during the working day." This statement was based on the previously mentioned studies. [59,16].

The ACGIH has retained the TLV-TWA of 410 mg/cu m [164]. In 1976, the ACGIH [164] proposed a 510 mg/cu m TLV-STEL in addition to the TLV-TWA.

The current US Federal standard for occupational exposure to methyl isobutyl ketone is 410 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the ACGIH's 1968 TLV for methyl isobutyl ketone [166].

(g) Methyl Isoamyl ketone

In 1971, the Committee on Threshold Limit Values of the ACGIH [171] adopted a TLV of 460 mg/cu m for methyl isoamyl ketone. The Committee assumed that the toxicities of methyl isoamyl ketone and methyl isobutyl ketone would be similar because their structures are similar. In the 1971 documentation [171], the ACGIH recommended a TLV of 460 mg/cu m as a TWA concentration to protect against eye irritation to methyl isoamyl ketone in the workplace. The limit was based on information from Rowe and Wolf [9],

who stated that 100 ppm (466 mg/cu m) was well below the concentration at which methyl isobutyl ketone produced narcotic effects.

At present, there is no Federal standard for occupational exposure to methyl isoamyl ketone in the United States.

(h) Diisobutyl Ketone

In 1956, the ACGIH [172] recommended a TLV of 50 ppm (290 mg/cu m) for occupational exposure to diisobutyl ketone. The basis for this recommendation was not published at that time. A study by Carpenter et al [20] on animals' responses to exposure of diisobutyl ketone was cited in 1962 documentation [160] by ACGIH. Carpenter and colleagues [20] found that at 125 ppm (726 mg/cu m) the vapor had no adverse physiologic effects on rats and guinea pigs exposed for 7 hours/day for 30 days. However, the guinea pigs exposed at 250 ppm (1,450 mg/cu m) for the same duration had a decrease in liver weight. According to Carpenter et al, humans considered exposure at 50 ppm (290 mg/cu m) for 8 hours to be "satisfactory." The TLV of 290 mg/cu m was designated as a TWA concentration.

In the 1971 documentation [171], the ACGIH included a study by Silverman and associates [16], describing the sensory response to industrial solvent vapors, to substantiate the recommendation that 290 mg/cu m was a concentration at which "no toxic effects will occur and irritation should be minimal." Silverman et al reported that humans exposed to diisobutyl ketone above 50 ppm (290 mg/cu m) experienced eye irritation and an unpleasant odor.

In 1973, the ACGIH [173] recommended a lower TLV as a TWA concentration, 150 mg/cu m, for exposure to diisobutyl ketone. In the 1974 documentation [168], the ACGIH again cited the studies of Carpenter et al

[20] and Silverman et al [16] to justify the recommended TLV as one that should prevent eye irritation from exposure to diisobutyl ketone.

The current US Federal standard for occupational exposure to diisobutyl ketone is 290 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the TLV adopted by ACGIH in 1968 [166].

(i) Cyclohexanone

In 1945, Cook [156] recommended a tentative MAC of 400 mg/cu m for exposure to cyclohexanone in workplaces. This tentative value was based on the experimental human exposure study by Nelson and his associates [15] and the exposure study of rabbits by Treon et al [54]. At a concentration of 75 ppm (301 mg/cu m), Nelson et al [15] noted that cyclohexanone caused eye, nose, and throat irritation in humans exposed for 3-5 minutes. Treon et al [54] found that, at a concentration of 0.75 mg/liter (750 mg/cu m) in air, cyclohexanone induced degenerative changes in the liver and kidneys of rabbits exposed for fifty 6-hour periods.

In 1946, the Subcommittee on Threshold Limits of the ACGIH [157] adopted the 100-ppm (401 mg/cu m) MAC for cyclohexanone recommended by Cook [156].

In 1948, the designation of the limit was changed from an MAC to a TLV [158], but the level remained at 100 ppm (401 mg/cu m) for cyclohexanone through 1960 [174]. In 1961, the ACGIH [167] recommended a lower TLV of 200 mg/cu m as a TWA concentration. The justification was included in the 1962 documentation [160], in which the ACGIH referred to a report by Treon et al [54] stating that 0.75 mg/liters (750 mg/cu m) was just above the maximal safe level for rabbits. Nelson and associates [15]

reported that throat irritation was the most marked effect on humans exposed to cyclohexanone at 50 ppm (200 mg/cu m) for 3-5 minutes. Most subjects in their study were able to tolerate exposure to cyclohexanone at 25 ppm (100 mg/cu m).

The TLV of 200 mg/cu m as a TWA concentration remained unchanged [163,166,175]. However, the ACGIH, in 1974 documentation [168], stated that, although 200 mg/cu m "is recommended as the TLV, some complaints of irritation may be raised by some unaccustomed individuals at this level. It should provide a good margin of safety against systemic effects because concentrations that might be harmful are not likely to be tolerated."

In 1976, the ACGIH [164] proposed a TLV-STEL of 200 mg/cu m in addition to the TLV-TWA.

The current US Federal standard for occupational exposure to cyclohexanone is 200 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the TLV adopted by the ACGIH in 1968 [166].

(j) Mesityl Oxide

In 1942, Smyth and coworkers [21] reported that no adverse effects occurred in animals exposed to mesityl oxide vapor at 50 ppm (201 mg/cu m) for thirty 8-hour exposures. They found that mesityl oxide at 250-500 ppm (1,000-2,010 mg/cu m) had primarily narcotic effects on guinea pigs and rats, and they concluded that it might cause damage to the lungs, liver, and kidneys [21]. In 1945, Cook [156] recommended an MAC value of 200 mg/cu m as a tentative limit for exposure to mesityl oxide in the workplace. He used the report of Smyth et al [21] to substantiate his recommendation. The ACGIH Committee on Threshold Limits [157] adopted 50

ppm (201 mg/cu m) as the recommended environmental limit in 1946, as proposed by Cook.

In 1948, the ACGIH [158] recommended a limit of 50 ppm (201 mg/cu m), although the designation was changed from an MAC to a TLV. The TLV value remained at 50 ppm (201 mg/cu m) until 1958, when the ACGIH [16] lowered it to 100 mg/cu m. No reason for this change was given at that time. The ACGIH, in the 1962 documentation [160], cited a study of human sensory response conducted by Silverman et al [16] showing eye irritation at 25 ppm (100 mg/cu m) and nose irritation at 50 ppm (200 mg/cu m), to justify the TLV as a TWA concentration of 100 mg/cu m for mesityl oxide. Some subjects found that the odor was objectionable at 50 ppm (201 mg/cu m) and that they had a persistent, unpleasant taste that remained for 3-6 hours after the exposure [16]. The level has remained at 100 mg/cu m for mesityl oxide since 1972 [164]. In 1976, the ACGIH [164] proposed a TLV-STEL of 100 mg/cu m.

The current US Federal standard for occupational exposure to mesityl oxide is 100 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard was based on the 1968 TLV adopted by the ACGIH [166].

(k) Diacetone Alcohol

In 1955, the ACGIH [176] established a tentative TLV of 50 ppm (237 mg/cu m) for occupational exposure to diacetone alcohol. No basis for recommending this level was reported at that time. The ACGIH later provided the justification for this level in the 1962 documentation [160], where the studies of Silverman et al [16] and Von Oettingen [177] were discussed. Silverman and associates [16] reported that, at a concentration

of 100 ppm (474 mg/cu m), the vapor of diacetone alcohol caused eye, nose, and throat irritation in humans. They concluded that 50 ppm (237 mg/cu m) was a "more reliable limit." Von Oettingen [177] reported that restlessness, irritation of the mucous membranes, and excitement followed by drowsiness were observed in mice, rats, rabbits, and cats exposed to diacetone alcohol vapor at 2,100 ppm (10,000 mg/cu m). The ACGIH [160] concluded: "In view of eye, nose and throat irritation occurring in persons exposed to 100 parts per million, a value of 50 parts per million is suggested." The TLV of 239 mg/cu m as a TWA concentration has not been changed by the ACGIH [162,163,168].

The current US Federal standard for occupational exposure to diacetone alcohol is 240 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the TLV adopted by the ACGIH in 1968 [166].

(1) Isophorone

In 1945, Cook [156] recommended a tentative value of 100 mg/cu m as an MAC for exposure to isophorone in the workplace. This tentative value was based on an inhalation study with guinea pigs and rats by Smyth and coworkers [21]. The animals were exposed to isophorone vapor for thirty 8-hour exposures at concentrations of 25-500 ppm (140-2,800 mg/cu m) [21]. The exposures at 25 ppm (140 mg/cu m) had no adverse effects on rats and guinea pigs.

In 1946, the ACGIH [157] recommended an MAC of 25 ppm (140 mg/cu m) which was based on the recommendation by Cook [156]. In 1948, the designation of the limit changed from an MAC to a TLV, and the 25-ppm (140 mg/cu m) limit was again recommended by the ACGIH [158]. The ACGIH, in the

1962 documentation [160], cited a report by Smyth et al [58] of the warning properties of isophorone vapor in humans exposed for a few minutes at concentrations of 40-400 ppm (230-2,300 mg/cu m). Eye, nose, and throat irritation was reported at all concentrations, and nausea, headache, dizziness, faintness, intoxication, and a feeling of suffocation occurred in a few subjects at concentrations of 200 ppm (1,130 mg/cu m) and 400 ppm (2,300 mg/cu m). The ACGIH [162] established a TLV of 140 mg/cu m to prevent irritative and narcotic effects, stating that the level was well below the concentration at which systemic effects might occur.

The ACGIH cited a study by Silverman and coworkers [16] on human sensory response to isophorone in the 1966 documentation [162]. Eye, nose, and throat irritation was experienced by subjects exposed to isophorone vapor at 25 ppm (140 mg/cu m). However, the TLV as a TWA concentration was not changed from 140 mg/cu m [162].

In the 1971 documentation [171], the ACGIH included the comments by Rowe and Wolf [9] that impure commercial products containing appreciable amounts of material more volatile than isophorone were used in the studies by Smyth and coworkers [21] and Smyth and Seaton [58] and, therefore, that the results should not be considered in evaluating the hazards of exposure to isophorone. Rowe and Wolf [9] recommended a lower TLV of 10 ppm (56 mg/cu m).

In 1972, the ACGIH [178] recommended that the TLV for isophorone be lowered. A ceiling TLV of 28 mg/cu m was recommended and documented in 1974 documentation [168]. GD Ware (written communication, June 1973) reported to the ACGIH that fatigue and malaise were experienced by employees exposed to isophorone at 5-8 ppm (28-45 mg/cu m) for 1 month.

This study found that, when the concentrations were lowered to 1-4 ppm (6-23 mg/cu m) with exhaust ventilation, complaints about such effects were no longer made.

The current US Federal standard for occupational exposure to isophorone is 140 mg/cu m as an 8-hour TWA concentration limit (29 CFR 1910.1000). This standard is based on the TLV adopted by the ACGIH in 1968 [166].

#### Basis for the Recommended Standard

Many workers are exposed to small amounts of airborne ketones or have negligible contact with these compounds. Under these conditions, many provisions of the recommended standard need not be complied with since they are intended to protect workers' health under hazardous circumstances. Concern for workers' health requires that protective measures be instituted below the enforceable limit to ensure that exposures stay below that limit, so NIOSH has defined the action level as one-half of the recommended environmental limit. Occupational exposure is defined as exposure above the action level. This definition delineates those work situations that do not require the expenditure of health resources for environmental and medical monitoring and associated recordkeeping. The action level has been chosen on the basis of professional judgment rather than on quantitative data that delineate nonhazardous areas from potentially hazardous areas.

##### (a) Permissible Exposure Limits

Because all of these ketones are CNS depressants, exposure to several of them, even at or below the recommended workplace environmental concentration, might produce additive effects. Employers should consider



these additive effects when simultaneous exposures to several ketones, or to ketones and other CNS depressants, occur. The following formula can be used to determine compliance with the recommended TWA environmental limits when such additive effects may occur:

$$\frac{C1}{PEL1} + \frac{C2}{PEL2} + \frac{C3}{PEL3} + \dots + \frac{Cn}{PELn} \leq 1$$

where:

C = the concentration of a substance

PEL = the permissible exposure limit of that substance

Peripheral neuropathy caused by methyl n-butyl ketone is the most serious known form of occupational illness from these ketones. Although narcosis may result from exposure to all of these ketones at high concentrations, irritation of the eyes, nose, and throat occurs first and should act as a warning property.

Studies have indicated that the high molecular weight ketones in a homologous series are more irritating and have a stronger narcotic action. Therefore, the higher molecular weight ketones of a homologous series should have exposure limits that are less than those of the low molecular weight ketones when toxicity is based solely on irritation.

(1) Acetone (1 ppm = 2.37 mg/cu m)

Eight workers exposed to acetone at concentrations above 12,000 ppm had throat and eye irritation, weakness in the legs, and headache [25]. One worker fainted; several felt dizzy and lightheaded. The symptoms and urinary acetone levels indicate that even a short exposure to acetone at concentrations above 12,000 ppm is hazardous.

Six studies have reported possible adverse effects on humans from acetone at concentrations at and below 1,000 ppm. In one study [17], exposure at an average concentration of 1,000 ppm for 8 hours resulted in headaches and lightheadedness in some workers. A second study [28] indicated that exposure to acetone at 1,000 ppm for 3 hours/day for 7-15 years and at 700 ppm for an unreported length of time resulted in inflammation of the respiratory tract, stomach, and duodenum, occasional dizziness, and loss of strength. In a third study [27], which may have been the basis for part of the data in the second study, employees exposed to acetone at 307-918 ppm (730-2,180 mg/cu m) had irritation of the eyes, nose, throat, and lungs and CNS disturbances. In addition, these investigators presented evidence that daily 6-hour exposures to acetone at 833 ppm (2,000 mg/cu m) did lead to an accumulation in the body, which persisted into the next workday. A fourth report [18] revealed that several subjects experienced irritation of the eyes, nose, and throat, tension, general weakness, heavy eyes, or lack of energy the morning after 6 hours of exposure to acetone at 1,000 ppm. This study also found the same complaints in those exposed at 500 ppm for 6 hours and the same but fewer complaints in those exposed at 250 ppm for 6 hours. These results are consistent with those in a fifth report [15] in which acetone at 350 ppm for 3-5 minutes caused irritation of the eyes, nose, and throat in a majority of 10 subjects exposed to it. In this report it was also noted that at 300 ppm there was slight irritation and that most of the 10 volunteers estimated 200 ppm was the highest concentration that would be satisfactory for an 8-hour exposure. A sixth study [42] indicated that employee volunteers who were exposed to acetone for 2 or 4 hours, with

exercise in some cases, suffered no untoward effects and had no symptoms after exposure at 100 ppm, a finding consonant with that in another paper [18] in which none of five young men exposed for 6 hours at 100 ppm in an unstressed situation complained of any adverse reaction.

From the above six studies, it is apparent that untoward effects have occurred at 1,000 ppm and have become decreasingly severe as the concentration decreases. As the concentrations of acetone have decreased below 200 ppm, few or no complaints of adverse reactions have occurred.

One report [42], in which an unreported number of men (probably four or less) were unaffected by acetone at 500 ppm for between 2 and 4 hours, seems to be inconsistent with the trend indicated by the results of other exposures. It is unclear whether a longer exposure, such as that during a normal 8-hour workday, would have resulted in adverse reactions similar to those seen in the other five studies; however, it is clear from this report that acetone did accumulate in the body and that some of it would probably remain to the next workday.

The preponderance of exposure data at concentrations of 1,000 ppm and less leads to the conclusion that some untoward effects will occur in those exposed to acetone at concentrations below 500 ppm. Furthermore, the available evidence indicates that occupational exposure to acetone may lead to its accumulation in the body. It seems reasonable to conclude that a workplace environmental limit of about 250 ppm (590 mg/cu m) should be established. Therefore, it is recommended that acetone concentrations in the workplace air not exceed 250 ppm (590 mg/cu m) as a TWA concentration limit for up to a 10-hour workshift in a 40-hour workweek.

(2) Methyl Ethyl Ketone (1 ppm = 2.95 mg/cu m)

Nelson et al [15] reported that most volunteers exposed to methyl ethyl ketone estimated that 200 ppm (590 mg/cu m) would be satisfactory for an 8-hour exposure. However, at 100 ppm, slight nasal irritation and throat irritation were produced, while at 200 ppm it caused mild eye irritation in some subjects. At 350 ppm (1,030 mg/cu m), methyl ethyl ketone irritated the eyes, nose, and throat of most subjects.

Patty et al [19] detected no serious disturbances in guinea pigs exposed to methyl ethyl ketone at 3,000 ppm (8,850 mg/cu m) for a few hours. In animals, methyl ethyl ketone did not produce any signs of peripheral neuropathy [73,74,77]. However, animals exposed to a combination of methyl n-butyl ketone and methyl ethyl ketone developed paralysis in a much shorter period of time than did animals exposed to only methyl n-butyl ketone [73]. Couri et al [87] presented evidence that methyl ethyl ketone may potentiate the toxicity of methyl n-butyl ketone by stimulating the metabolic activation of the latter ketone.

Schwetz et al [97] found some evidence of teratogenicity when pregnant rats were exposed to methyl ethyl ketone at 1,126 and 2,618 ppm (3,320 and 7,720 mg/cu m). However, as discussed in Chapter III, it is not clear that this evidence can be reliably extrapolated to humans. In addition, the possible potentiation of neurotoxicity induced by methyl n-butyl ketone should be handled by stringent control of methyl n-butyl ketone rather than by regulating methyl ethyl ketone for possible effects. A review of the available data provides no basis for a change in the present Federal workplace environmental limit of 200 ppm (590 mg/cu m). Therefore, it is recommended that methyl ethyl ketone concentrations in the

workplace air not exceed 200 ppm (590 mg/cu m) as a TWA concentration for up to a 10-hour workshift in a 40-hour workweek.

(3) Methyl n-Propyl Ketone (1 ppm = 3.52 mg/cu m)

Specht et al [34] found that methyl n-propyl ketone was considerably less toxic than methyl n-butyl ketone but more toxic than methyl ethyl ketone in guinea pigs. Narcosis was produced in guinea pigs exposed at 5,000 ppm (17,600 mg/cu m). Interpretation of the data of Specht et al suggests that methyl n-propyl ketone might be more irritating to the eyes, nose, and throat than was either acetone or methyl ethyl ketone.

It is believed that an extrapolation from the data of Specht et al [34] to the findings of Nelson et al [15] is appropriate. Nelson et al reported that 100 ppm (350 mg/cu m) of methyl ethyl ketone produced slight irritation in volunteers. Interpretation of the data of Specht et al [34], as mentioned before, suggests that methyl n-propyl ketone is at least as irritating as methyl ethyl ketone. Thus, it is believed that a slight reduction in the current Federal standard of 700 mg/cu m (200 ppm) is warranted to protect employees from irritation to the eyes, nose, and throat. Therefore, an exposure limit for methyl n-propyl ketone of 150 ppm (530 mg/cu m) for up to a 10-hour TWA concentration in a 40-hour workweek is recommended.

(4) Methyl n-Butyl Ketone (1 ppm = 4.10 mg/cu m)

Allen et al [37] found 81 cases of peripheral neuropathy, 11 of which were diagnosed as moderate to severe, in a coated-fabric plant where methyl n-butyl ketone and methyl ethyl ketone were used. Employees who worked at or near the print machines, where both ketones were used as

solvents, had a significantly higher incidence of neuropathy than did employees who worked in other departments. Analysis of the areas around the print machine showed methyl n-butyl ketone at 9.2-36 ppm (38-148 mg/cu m) and methyl ethyl ketone at 331-516 ppm (1,360-2,115 mg/cu m) when 9 of 17 machines were in operation. No neuropathy was found in a similar plant that used methyl ethyl ketone without methyl n-butyl ketone.

In 1976, Mallov [39] investigated peripheral neuropathy in three spray painters. The onset of neuropathy correlated with the substitution of methyl n-butyl ketone in a paint formulation for methyl isobutyl ketone and methyl isoamyl ketone. Although no environmental sampling or analysis was reported, Mallov stated that the three workers had ample opportunity for exposure to methyl n-butyl ketone by inhalation and skin absorption.

Studies on a variety of animals have conclusively demonstrated that repeated exposure to methyl n-butyl ketone produced peripheral neuropathy [70,71,73,179]. A comparison of data indicated that the no effect concentration for methyl n-butyl ketone in animals was probably less than 100 ppm [76,77,80].

Exposure concentrations at the coated-fabric plant varied over a considerable range, so it is difficult to interpret which concentrations were safe and which were not. While methyl n-butyl ketone at higher concentrations probably caused the neuropathy, a review of the data of Billmaier et al [38] indicates that apparently 2.3 ppm (9.4 mg/cu m) cannot be ruled out. Because of the severity of the toxic effects and the incomplete reversibility of the lesions in these fabric workers, a cautious approach which views the lowest concentration as a possible toxic concentration is needed and a recommendation for a very low environmental

limit seems appropriate. Thus, a limit at least as low as 1 ppm (4 mg/cu m) is recommended, pending the development of suitable data that will allow a more rigorous development of a permissible limit.

Inasmuch as methyl n-butyl ketone penetrates skin, it might be interpreted that percutaneous absorption played a significant, conceivably even the predominant, part in the development of neuropathy in the fabric workers. This interpretation is supported by evidence that the workers washed their hands in the ketone solution. However, a study of the relevant data does not support this interpretation. Calculations based on quantitative data on percutaneous absorption [45] and some assumptions about likely immersion times (see Chapter III, Correlation of Exposure and Effect for an example of these calculations) suggest that percutaneous absorption was less important than inhalation in what was undoubtedly a dose-related neuropathogenesis. However, the ability of this ketone to penetrate skin as well as to cause local skin effects is sufficiently evident to warrant work practices to prevent skin contact. It is recommended, therefore, that methyl n-butyl ketone concentrations in workplace air not exceed 1 ppm (4 mg/cu m) as a 10-hour TWA concentration.

(5) Methyl n-Amyl Ketone (1 ppm = 4.67 mg/cu m)

Specht et al [34] found that methyl n-amyl ketone at 1,500 ppm (7,000 mg/cu m) produced irritation of the mucous membranes of guinea pigs. At 2,000 ppm, it was strongly narcotic, and 4-8 hours of exposure at 4,800 ppm (22,400 mg/cu m) produced narcosis and death. Because repeated exposure of rats and monkeys to methyl n-amyl ketone did not produce any evidence of peripheral neuropathy, it is believed that the standard for this ketone should be based on its irritating properties.

As was the case for methyl n-propyl ketone, methyl n-amyl ketone was also more irritating than acetone and methyl ethyl ketone [34]. Because methyl n-amyl ketone was at least as irritating to animals as methyl n-propyl ketone [34], the recommended exposure limit should be at least as low as that for methyl n-propyl ketone. However, the concentration at which methyl n-amyl ketone does not produce irritation in humans was not found. Therefore, there is no basis for a change in the present Federal workplace environmental limit of 100 ppm (465 mg/cu m). It is therefore recommended that the concentration of methyl n-amyl ketone in workplace air not exceed 100 ppm (465 mg/cu m) as a TWA concentration for up to a 10-hour workshift in a 40-hour workweek. It seems probable that this exposure limit should prevent most irritation in workers exposed to methyl n-amyl ketone.

(6) Methyl Isobutyl Ketone (1 ppm = 4.10 mg/cu m)

Silverman et al [16] reported that 100 ppm was the highest concentration that most volunteers estimated to be satisfactory for an 8-hour exposure. At 200 ppm, the eyes of most persons were irritated. Specht [59] reported that methyl isobutyl ketone at 1,000 ppm (4,100 mg/cu m) was exceedingly irritating to the eyes and nose of the investigator during an experiment in which guinea pigs showed little disturbance. Linari et al [30] reported that methyl isobutyl ketone at 80-500 ppm produced weakness, loss of appetite, headache, eye irritation, sore throat, stomach ache, nausea, and vomiting in exposed workers. In a followup study, Armeli et al [31] reported that these signs were reduced to the point of disappearing in workers exposed to methyl isobutyl ketone at 50-105 ppm (205-430 mg/cu m); however, a few workers still had CNS and



gastrointestinal disorders. It seems probable that the effects noted in these few workers resulted from exposures at the higher concentrations.

Spencer et al [71] reported that rats exposed to methyl isobutyl ketone at 1,500 ppm for 5 months developed minimal neuropathologic changes in the most distal portions of the tibial and ulnar nerves. The authors related these findings to the presence of 3% methyl n-butyl ketone as a contaminant of the methyl isobutyl ketone. In a later study, Spencer et al [74] reported that purified methyl isobutyl ketone (9 % purity) did not cause peripheral neuropathy in animals.

Because of the studies of Silverman et al [16], Linari et al [30], and Armeli et al [31], it is believed that the current Federal standard for methyl isobutyl ketone of 410 mg/cu m (100 ppm) is not adequate to protect employees from adverse effects, but the concentration at which methyl isobutyl ketone will produce no adverse effects is not known. The study of Armeli et al [31] indicated that the adverse effects were virtually eliminated when the concentration of airborne methyl isobutyl ketone was reduced to 50-105 ppm. Thus, it is recommended that the concentration of methyl isobutyl ketone in the workplace air not exceed 50 ppm (200 mg/cu m) as a TWA concentration for up to a 10-hour workshift in a 40-hour workweek.

(7) Methyl Isoamyl Ketone (1 ppm = 4.67 mg/cu m)

Currently, there is no information to firmly support a limit for methyl isoamyl ketone. Because methyl isoamyl ketone contains one more carbon atom than does methyl isobutyl ketone, methyl isobutyl ketone might produce irritation and narcosis at concentrations at least as low as those at which methyl isobutyl ketone produces these effects. Therefore, a limit of 50 ppm (230 mg/cu m), corresponding to that of methyl isobutyl ketone,

is proposed for up to a 10-hour TWA concentration in a 40-hour workweek.

(8) Diisobutyl ketone (1 ppm = 5.82 mg/cu m)

Two volunteers had slight irritation of the eyes and nose when exposed to diisobutyl ketone at 100 ppm (582 mg/cu m) [20]. Another person had slight tearing and two others had headaches at the same concentration. Two of the subjects exposed at 50 ppm (290 mg/cu m) experienced transitory, slight irritation of the eyes and nose at the beginning of the exposure. However, Carpenter et al [20] stated that the vapor could be smelled and tasted throughout the exposure period. All three subjects exposed at 100 ppm estimated that a workplace atmosphere of 100 ppm would be unsatisfactory for continuous exposure. Silverman et al [16] reported that 25 ppm (145 mg/cu m) was the highest concentration that most subjects considered satisfactory for an 8-hour exposure to diisobutyl ketone. Because of these findings, it is recommended that to reduce eye irritation, the concentration of diisobutyl ketone in workplace air not exceed 25 ppm (140 mg/cu m) for up to a 10-hour TWA concentration in a 40-hour workweek.

(9) Cyclohexanone (1 ppm = 4.01 mg/cu m)

Nelson et al [15] reported that 25 ppm (100 mg/cu m) was the highest concentration that most subjects considered satisfactory for an 8-hour exposure to cyclohexanone. At 50 ppm, throat irritation was reported, while, at 75 ppm (300 mg/cu m), most subjects had irritation of the eyes, nose, and throat.

Cyclohexanone at 190 ppm (762 mg/cu m) for fifty 6-hour exposures produced liver and kidney damage in rabbits [54]. Cutaneous or subcutaneous application of cyclohexanone produced cataracts in guinea pigs [66]. In some cases, lens damage was reversed within 3 months after

exposure. No such findings in humans have been reported (see discussion in paragraph (c) of this section). Because of the findings of Nelson et al [15], and because of the ability of cyclohexanone to produce liver and kidney damage at relatively low concentrations in rabbits, it is recommended that the exposure limit for cyclohexanone be set at 25 ppm (100 mg/cu m) as a TWA concentration for up to a 10-hour workshift in a 40-hour workweek.

(10) Mesityl Oxide (1 ppm = 4.01 mg/cu m)

Silverman et al [16] reported that the majority of volunteers exposed to mesityl oxide for 15 minutes had eye irritation at 25 ppm and nose irritation at 50 ppm (200 mg/cu m). Smyth et al [21] reported that mesityl oxide at 50 ppm had no adverse effects on rats and guinea pigs exposed for thirty 8-hour periods. An extrapolation of the data of Smyth et al to humans might indicate that repeated exposures to mesityl oxide at 50 ppm would be safe. However, eye irritation was reported at 25 ppm (100 mg/cu m), and there is reason to believe that eye irritation by mesityl oxide is more serious than that produced by the lower ketones. (See Correlation of Exposure and Effect.) In addition, systemic effects (liver and kidney changes) occurred in animals exposed (at higher concentrations) to mesityl oxide. Thus, it is recommended that the concentration of mesityl oxide in workplace air not exceed 10 ppm (40 mg/cu m) as a TWA concentration for up to a 10-hour workshift in a 40-hour workweek.

(11) Diacetone Alcohol (1 ppm = 4.75 mg/cu m)

Silverman et al [16] reported that most subjects had eye irritation and all subjects had nose and throat irritation when exposed to diacetone alcohol at 100 ppm (475 mg/cu m) [16]. The highest concentration

of diacetone alcohol judged to be satisfactory for an 8-hour exposure was 50 ppm. Lehmann and Flury [57] found irritation of mucous membranes and somnolence in a variety of experimental animals exposed to diacetone alcohol at 2,100 ppm (9,975 mg/cu m). Kidney injury was also reported in rabbits at that concentration. To prevent eye irritation, an exposure limit for diacetone alcohol of 50 ppm (240 mg/cu m) for up to a 10-hour TWA concentration in a 40-hour workweek is recommended. This is identical to the present Federal standard.

(12) Isophorone (1 ppm = 5.65 mg/cu m)

Silverman et al [16] reported that 10 ppm was the highest concentration that most volunteers considered satisfactory for an 8-hour exposure. They noted that irritation of the eyes, nose, and throat was produced in the majority of persons exposed at 25 ppm.

Smyth et al [21] exposed animals to isophorone for 8 hours/day, 5 days/week, for 6 weeks. They reported that isophorone at 25 ppm produced no adverse effects. In six animals exposed at 50 ppm, the liver of one and the kidneys of four were affected; the nature of these changes was not described. All of 20 animals survived exposures at 50 ppm, but 2 of 16 died after exposure at 100 ppm.

GD Ware (written communication, June 1973) of Western Electric Company reported to the TLV Committee of the ACGIH that workers suffered fatigue and malaise after exposure to isophorone at 5-8 ppm. When air levels were reduced to 1-4 ppm, no further complaints were received. (A copy of this letter to the TLV Committee has been furnished to NIOSH.) Based on this information, a permissible exposure limit of 4 ppm (23

mg/cu m) as a TWA concentration for up to a 10-hour workshift, 40-hour workweek is recommended.

(b) Sampling and Analysis

The recommended sampling method, reviewed in more detail in Chapter IV, involves collecting airborne ketones in charcoal-filled tubes, followed by desorption with carbon disulfide. Gas-liquid chromatography is the recommended analytic procedure. The sampling method was chosen because it has been validated for 11 of the ketones and because it is expected to provide adequate collection efficiency for airborne ketones. The gas-chromatographic method of analysis was selected because it is sensitive and relatively simple to use, although it is not entirely specific for ketones. Other compounds having the same retention time as the ketone being analyzed will interfere with the analysis; however, mass spectrometry can be used to identify some of the eluted compounds.

(c) Medical Surveillance

Because repeated exposure to methyl n-butyl ketone can produce peripheral neuropathy [37,39,70-72,74], electrodiagnostic examinations including electromyography and nerve conduction and velocity measurements must be made available to workers exposed to this ketone. These types of electrodiagnostic studies are objective tests which are the most sensitive indicators of early peripheral neuropathy. Employees' weight should also be monitored, since unexpected weight loss may be an advanced indicator of peripheral neuropathy. Exposure to the 12 ketones can also irritate the eyes, nose, and throat. These effects should be considered in medical examinations of exposed employees. Furthermore, because acetone and cyclohexane have produced cataracts in experimental animals, particular

attention should be given to the eyes where exposure to these substances may occur [66]. Although the evidence of kidney and liver damage [30,54,55,57] was developed from exposures at high concentrations or, in the case of animal studies, at high doses, and thus not weighed heavily in developing environmental limits, workers' kidney and probably liver functions should be monitored. Therefore, periodic urinalysis is proposed as a requirement, and periodic monitoring of liver enzymes is proposed as an additional recommendation.

(d) Personal Protective Equipment and Clothing

Because these ketones are defatting agents that can cause skin irritation and dermatitis, workers who are likely to have skin contact with the liquid ketones must wear protective gloves. The use of safety goggles or face shields (20-cm minimum) is recommended to prevent eye irritation when contact of ketones with the eyes is likely. Other personal protective equipment should include respirators when necessary, and appropriate protective clothing. The types of respiratory protective devices described in Tables I-2 should be those approved under the provisions of 30 CFR 11.

(e) Informing Employees of Hazards

Personnel in areas where a ketone is present must be advised of the adverse effects of exposure and informed of the signs and symptoms of the disorders. Employees exposed to methyl n-butyl ketone should be warned that the neurotoxic symptoms of this ketone may have an insidious onset. A continuing education program is an important part of a preventive hygiene program for employees occupationally exposed to ketones. Properly trained persons should periodically inform employees about the dangers of improper work practices, such as washing their hands with ketones, and of exposure

by other routes, such as inhalation and ingestion. Additionally, employees should be informed of engineering controls and work practices used to limit exposure and of the environmental and medical monitoring practices for checking control procedures and determining the health status of employees.

(f) Work Practices

Procedures that minimize the volatilization of ketones and workers' contact with ketones should be used for the cleanup of spills, waste disposal, general housekeeping, and storage of ketones. Personal hygienic measures should be adopted to prevent ingestion of ketones and to further reduce the probability of skin contact. Work practices that will prevent ingestion and limit inhalation or skin contact with ketones must be implemented. Smoking, eating, and food preparation should be prohibited in areas where ketones are present. Spilled ketones must be cleaned up promptly by trained personnel wearing adequate protective equipment and clothing. Employees must be prohibited from washing their hands with ketones, and handwashing facilities must be provided. If contamination of clothing with ketones is likely, employees should wear protective outer garments. Because of the adverse effects associated with exposure to ketones, entry into areas where there is occupational exposure to ketones should be restricted to authorized persons.

(g) Monitoring and Recordkeeping

Industrial hygiene surveys should be made to determine in which areas there may be occupational exposure to ketones. Thereafter, where there is occupational exposure to ketones, the exposure of each employee should be determined, and the workplace air in the breathing zones of employees in every operation should be sampled and analyzed at least every 3 months.

Changes in production or process necessitate additional monitoring to detect any changes in the concentrations of airborne ketones.

The Toxic Substances Control Act of 1976 requires that "Records of...adverse reactions to the health of employees shall be retained for thirty years from the date such reactions were first reported to or known by the person maintaining such records...." Because medical examinations will often provide the first recognized evidence of an adverse reaction, whether at the time of the examination or retrospectively, it appears consonant with the Toxic Substances Control Act to require medical records on ketone workers to be maintained for 30 years. Furthermore, records of environmental exposures should be kept for the same period, to allow correlation of a ketone worker's exposure with his or her health.