

Pine Tar Removal Project
Air Monitoring Plan
Springstead and Hogtown Creeks
Gainesville, Florida

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1 Introduction

Weston and Gradient have developed this air monitoring plan for the pine tar removal project to be conducted in Springstead and Hogtown Creeks ("Creeks") in Gainesville, Florida. This plan is being incorporated into the project specific health and safety plan (HASP). The plan was developed based on the sediment analytical data collected by Alachua County Environmental Protection Department (ACEPD, 2009) and compositional information of pine tar. The ACEPD study focused primarily on identifying and sampling areas with evidence of tar-like material. The most visually impacted deposits were selected for comprehensive chemical analysis, including semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) analysis. To provide more complete characterization, results for tentatively identified compounds (TICs) were also reported. Review of these data show that it is highly unlikely that health-based action levels, protective of remediation workers and the surrounding community, would be exceeded during a short term exposure scenario represented by removal of the sediment. However, some of the pine tar constituents can exhibit a strong odor and have low odor thresholds (*i.e.*, the smell can be perceptible even at low concentrations in air). Therefore, a comprehensive air monitoring program is proposed to obtain data required to fully understand air concentrations during the remediation and to ensure that workers and community members are not exposed to concentrations that could pose adverse health effects.

Health-based action levels were developed to assess both occupational exposure (*i.e.*, for remediation workers) and ambient exposure (*i.e.*, for the nearby community) to pine tar constituents that may become airborne during the sediment remediation work. In particular, action levels were developed for two classes of compounds: 1) volatile organics; and 2) particulates. Of the VOCs present in pine tar, terpenes were identified as the most appropriate class of compounds to monitor due to their high relative abundance in tar, high volatility, and low odor threshold values. Based on available toxicity data, action levels (ambient and occupational) were developed for turpentine, which was selected since it contains high levels of terpenes. Of the semi-volatile constituents of pine tar, PAHs were selected for monitoring due to their relatively high toxicity. However, exposure to PAHs in sediments will occur *via* inhalation of airborne particulate matter (PM₁₀); thus, occupational and ambient action levels were developed for PM₁₀. A summary of the action levels that were developed for occupational and ambient exposure to VOCs and particulates (PM₁₀) for the tar removal project is presented in the table below:

Constituents of Concern	Health-Based Action Levels		Instrument Monitoring Limit	
	Occupational	Ambient Air	Occupational	Ambient Air
VOCs	7 ppm Turpentine	2.8 ppm Turpentine	20 ppm as Isobutylene*	8 ppm as Isobutylene*
PM ₁₀	NA	0.15 mg/m ³	NA	0.15 mg/m ³ / 1 mg/m ³ **

*The instrument monitoring limit was determined for a PID calibrated with isobutylene using the calibration response factor of 0.3 for turpentine (Attachment B).

** 0.15 mg/m³ is a daily average value and 1 mg/m³ is a ceiling limit.

2 Monitoring Objectives

As previously discussed, based on the chemical analysis of the impacted sediments in the creeks, health-based risk action levels are not expected to be triggered during the tar removal work. Nevertheless, a comprehensive and conservative air monitoring plan has been developed to address the following objectives:

- Ensure that the tar removal work is performed in a safe manner, *i.e.*, workers are protected from unacceptable exposures; and
- Monitor ambient exposure to compounds of concern and ensure that the nearby community is protected.

The sections below discuss the approach proposed for exposure evaluation and air monitoring in further detail.

3 Constituents of Concern for Air Monitoring

A review of the literature indicates that the main components of retort-generated pine tar are as follows (Norway, undated) :

- Terpenes (*e.g.*, alfa-pinene, 3-carene, limonene, camphene) (18% w/w);
- Resin acids and aldehydes (*e.g.*, dehydroabietic acid, abietic acid, palustric acid, pimaric acid) (16% w/w);
- Decarboxylated resin acids and alkylphenantrenes (*e.g.*, retene) (13% w/w);
- Fatty acids (mainly C14-18) (7% w/w); and
- Phenols (*e.g.*, methyl- and ethylguaiacol, guaiacol, cresols, phenol) (6% w/w).

Other components present at low concentrations in pine tar include: PAHs and volatile substances (Norway, undated). Pine oils and most terpenes are defined by the United States Food and Drug Administration (US FDA) as Generally Recognized As Safe (GRAS) due to their low toxicity. Pine oils are commonly used in household cleaners (*e.g.*, Pinesol) because they are effective disinfectants. Phenols are also used in pharmaceuticals, mouthwashes, and a variety of soaps. Overall, compounds associated with pine tar have low inherent toxicities.

Of the above listed pine tar constituents, terpenes have the highest propensity to volatilize from the tar being removed from the Creeks and could result in perceptible odors near the remediation areas, leading to health concerns by residents and other members of the community (Tables 1 and 2). Therefore, terpenes are the most appropriate group of compounds for monitoring volatile emissions during the planned pine tar removal project. However, no health criteria were available for terpenes, so a health criterion for turpentine, which contains mostly terpenes (58%-65%) (ACGIH, 2010), was used.

VOCs (*e.g.*, xylenes) were also detected in the tar samples collected during the ACEPD study, but at low concentrations, *i.e.*, on the order of magnitude of 1 mg/kg or less. As a result, monitoring of standard VOCs is not needed. In addition, given the multiple urban sources of such compounds, it would be difficult to differentiate between contributions from pine tar in the creek *vs.* contributions from urban sources.

The semi-volatile organic compounds present in pine tar have high partitioning coefficients and are bound tightly to sediment particles. From an air exposure standpoint, these particulates could possibly become airborne during the removal activities. However, since the sediment targeted for excavation will be wet, the likelihood of significant dust generation is extremely low. Nonetheless to be conservative, dust monitoring will be conducted to ensure protection of workers and the nearby community.

Of the SVOCs present in pine tar, PAHs are expected to exhibit the highest toxicity to human health. As previously mentioned, the toxicity of the major pine tar constituents is relatively low. Accordingly, relatively few toxicity factors, used for developing health-based concentrations, are available. Consequently, despite being present in pine tar at low concentrations, PAHs were selected to be representative of SVOCs present in pine tar in order to establish dust target concentrations or action levels for the pine tar removal project.

The approach used for development of action levels for the tar removal project is presented below.

4 Action Levels

Action levels were developed for: 1) occupational exposure, *i.e.*, for remediation workers that may be exposed to airborne contaminants during the excavation of sediments, and 2) ambient air, *i.e.*, protective of community members and residents in the vicinity of the excavation areas.

4.1 Occupational

4.1.1 Volatile Organics

As previously discussed, terpenes is the most appropriate group of compounds for monitoring volatile emissions from pine tar. However, since there are no occupational exposure limits for individual terpenes, the available exposure limits for turpentine, which contains high concentrations of terpenes, were evaluated. The current permissible exposure limit (PEL) established by OSHA for turpentine is 100 ppm (560 mg/m³ of air) as an 8-hour time-weighted average (TWA) concentration (US DOL, 2010). Similarly, the National Institute of Occupational Health and Safety (NIOSH) has a recommended exposure limit (REL) of 100 ppm (CDC, 2010a). The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned turpentine a threshold limit value (TLV) of 20 ppm as a TWA for an 8-hour workday and a 40-hour workweek (ACGIH, 2010). These limits are set to protect workers from irritation and long-term respiratory effects (ACGIH, 2010). To develop an action level for turpentine, a safety factor of 3 was applied to the TLV of 20 ppm. Thus, the action level for occupational exposure to VOCs for the tar removal work is 7 ppm turpentine.

4.1.2 Particulates

Occupational exposure to PAHs present in the sediment during the remediation work would be expected to occur *via* inhalation of airborne particulate matter (PM₁₀) on which PAHs may be adsorbed. Thus, a health-based action level for PM₁₀ to protect the remediation workers from exposure to PAHs in the sediment was developed.

The OSHA PEL and ACGIH TLV for PAHs as coal tar pitch is 0.2 mg/m³ (US DOL, 2010; ACGIH, 2010). Note, the material being removed from the Creeks is not coal tar pitch, but pine tar. However, since no occupational threshold value for pine tar SVOCs is readily available, the coal tar pitch

TLV was used to be health protective. Coal tar has extremely high levels of PAHs compared to pine tar; consequently, the choice of the coal tar pitch value is conservative.

The ACEPD sediment study (ACEPD, 2009) indicated that the maximum concentration of total PAHs detected in the sediment was 146 mg/kg. Based on the maximum concentration for total PAHs (*i.e.*, 146 mg of total PAHs contained in 1000 grams of sediment) and using a ratio, it was determined that 0.2 mg of total PAHs would be contained in 1.37 grams of sediment. Thus, assuming that 100% of the PAHs in the sediment becomes airborne, the calculations indicate that for the PAH PEL of 0.2 mg/m³ to be exceeded, the particulate concentration in air would have to be 1,370 mg/m³. This level of airborne dust is a practical impossibility. Concentration of particulates in an urban setting with construction sites and smog ranges from approximately 0.025 to 0.075 mg/m³ (MADEP, 2006; US EPA, 2000). Even using the NIOSH REL for coal tar pitch volatiles of 0.1 mg/m³ (CDC, 2010b) and a conservative safety factor of 10, one would still have to be exposed to more than 68 mg/m³ of airborne particulates to exceed the conservative NIOSH REL. This level of particulates in the air is not expected to be encountered during the sediment remediation work. Therefore, no particulate action level is required for worker protection. As discussed in Section 5, dust monitoring will be conducted downwind (and upwind) of the work area; if high dust levels are recorded at the downwind location (*i.e.*, greater than the NAAQS of 0.150 mg/m³ as a daily average or a ceiling of 1 mg/m³), then work practices will be reviewed and modified, if needed.

4.2 Ambient Air Monitoring

Action levels for ambient exposure were developed for two classes of compounds: VOCs and particulates. For volatile organic compounds, a toxicity criterion for turpentine was used, since turpentine primarily contains terpenes and pinenes (ACGIH, 2010). A monitoring concentration was developed for turpentine using occupational limits and appropriate adjustment factors, as identified in the literature (*e.g.*, Kasanen *et al.*, 1999; Damgard Nielsen *et al.*, 1995). The action level for particulates was based on the NAAQS standard of 0.15 mg/m³ for PM₁₀ (US EPA, 2010a).

For both turpentine and PM₁₀, toxicity criteria for a sub-chronic exposure scenario assuming an averaging time of 5 days per week, 8 hours/day over a remediation period of about a month, were identified. The toxicity criteria were then used as the basis for calculating action levels during site remediation. Compliance with a particular action level is based on meeting that concentration on average over 8 hours/day, 5 days/week, the anticipated worst-case remediation period.

4.2.1 Volatile Organics

For turpentine, the action level was based on indoor guidelines developed based on the occupational exposure limit (OEL) for turpentine (Kasanen *et al.*, 1999). Kasanen *et al.* recommended a range of 1/4 to 1/40 of the OEL, based on previous work published by the authors (Damgard Nielsen *et al.*, 1995). Damgard Nielsen *et al.* (1995) combined OELs, Harber's Law¹, and a safety factor in deriving this range of concentrations. According to this methodology, OELs can be divided by a total safety factor of 40, comprised of a safety factor of approximately 4 to account for differences between occupational exposure (8 hours/day, 5 days/week) and residential exposure (24 hours/day, 7 days/week), and a factor of 10 to account for differences in sensitivity between workers, and potentially more susceptible individuals, such as young children, the elderly, or individuals with pre-existing health conditions. Because exposure during remediation could only occur during the standard occupational exposure period (*i.e.*, 8 hours/day, 5 days/week), the safety factor of 4 is not needed, *i.e.*, a safety factor of 10 is appropriate. The toxicity criterion for turpentine was derived based on the ACGIH-recommended occupational TLV of 20 ppm, which is more conservative than the 35 ppm used by Kasanen *et al.* (1999)². The turpentine TLV of 20 ppm was adjusted by a safety factor of 10, yielding a toxicity criterion of 2 ppm (11 mg/m³).

After identifying an appropriate toxicity criterion, it was related to monitoring levels in air to derive an action level, as described in Attachment A. The acceptable daily average concentration was 16 mg/m³ (2.8 ppm). To be conservative (*i.e.*, health-protective), this concentration will be used as the action level in the field during the pine tar removal project.

Ambient Air Action Levels (as Turpentine)

	Concentration (mg/m ³)	Concentration (ppm)
Toxicity Criterion	11	2
Action Level (Concentration_{daily})	16	2.8

4.2.2 Particulates

The 24-hour NAAQS for PM₁₀ (0.15 mg/m³) will be used as an action level for particulates. However, to ensure that this value will be protective of potential exposure to PAHs present in Creek

¹ Harber's Law states that the effect is determined by the cumulative dose ($C \times t = K$), determined by the product of the concentration (C) and the exposure time (t) (Damgard Nielsen *et al.*, 1995).

² For the OEL, Kasanen *et al.* (1999) used a turpentine concentration of about 35 ppm, which was based on their own analysis of the toxicity information. At the time their article was published, the TLV was 100 ppm. Since then the TLV has been decreased to 20 ppm (ACGIH, 2010). To be conservative, we based our calculation on 20 ppm.

sediments that may become air borne during the tar removal project, the evaluation described below was undertaken.

The NAAQS for PM₁₀ (0.15 mg/m³) is based on a 24 hour exposure duration. To account for differences in exposure duration (pine tar removal work will take place for 8 hours per day rather than 24 hours per day), an adjustment factor of 24/8 was applied to the PM₁₀ NAAQS to yield an acceptable concentration of 0.45 mg/m³. US EPA's Residential Air Regional Screening Level (RSL) for B(a)P (8.7 x 10⁻⁴ µg/m³) (US EPA, 2010b; US EPA 2010c) was then utilized to ensure that inhalation exposure to PAHs *via* particulates will not be associated with unacceptable risk during the removal project. Since the B(a)P RSL is based on a 30-year exposure duration, the average air concentration for total PAHs (TPAH) that could result from resuspension of sediment during the removal action was first estimated, assuming a maximum PM concentration of 0.45 mg/m³ (or 450 µg/m³), using the following equation:

$$TPAH_{air} \left(\frac{\mu g}{m^3} \right) = \frac{TPAH_{sed} \times PM_{10} \times ET \times EF \times ED \times CF}{AT}$$

Where:

TPAH _{sed}	=	TPAH Concentration in Sediment (146 mg/kg);
PM ₁₀	=	PM ₁₀ concentration (450 µg/m ³);
ET	=	Exposure Time (8 hours/day)
EF	=	Exposure Frequency (45 days/year)
ED	=	Exposure Duration (1 year)
CF	=	Conversion Factor (1 x 10 ⁻⁶ kg/mg)
AT	=	Averaging Time (262,800 hours)

Thus, the average TPAH concentration in air expected for the duration of the remediation project was calculated to be 8.9 x 10⁻⁵ µg/m³. This concentration was then compared to US EPA's Residential Air Regional Screening Level (RSL) for B(a)P, of 8.7 x 10⁻⁴ µg/m³, which is based on an exposure duration of 30 years. This comparison assumes that the TPAH concentration in sediment would be the same as the TPAH concentration in airborne, resuspended sediment. This comparison also assumes that all of the PAHs in the sediment have the same potency as B(a)P.³ Because the average TPAH air concentration that could result from resuspension of sediment during remediation is 10-fold lower than

³ Note, the maximum B(a)P equivalent concentration detected in Creek sediments in the ACEPD (2009) study was 2.2 mg/kg, *i.e.*, approximately 75 fold lower than the concentration value used in the calculation.

the Residential RSL for B(a)P, and because the TPAHs in the sediment includes PAHs which are less potent than B(a)P, exposure to PAHs during remediation should not be associated with unacceptable risks.

Based on these risk-based calculations, an action level of 0.45 mg/m³ of PM₁₀ would be protective. However, to be conservative, the NAAQS of 0.15 mg/m³ will be adopted as the action level for the tar removal project.

5 Air Monitoring Approach

The planned air monitoring approach will have three key components designed to be protective of workers and surrounding residents: (1) real time aerosol dust (PM₁₀) monitoring to measure airborne dust levels to evaluate PAH exposure potential, (2) real time air monitoring to evaluate VOC concentrations, and (3) air sampling for laboratory analysis to document terpenes concentrations. A description of the air monitoring approach is provided below.

5.1 Pre-Pine Tar Removal Monitoring

Pre-pine tar removal air monitoring will be conducted at locations along the creeks to evaluate ambient air conditions for the project area prior to the start of tar removal activities. This monitoring will include dust monitoring using a MIE DataRAM's with PM₁₀ heads as well as ambient air monitoring for VOCs using the RAE Photo Ionization based instruments. Additionally, a total of up to 5 air samples will be collected in the pre-removal monitoring using SUMMA canisters. The samples will be analyzed for terpenes, including alpha and beta pinene, 3-carene and terpineol using Method TO 15. The deployment of the pre-removal monitoring array will be field determined by the industrial hygienist based on site specific field conditions. Action levels may be adjusted based on results of this pre-removal air monitoring, if background levels exceed or are of the order of magnitude of the current, extremely conservative, risk-based values.

5.2 Monitoring During Removal Action

5.2.1 Dust Monitoring

The dust monitoring will be accomplished using MIE DataRAM's with PM₁₀ heads. The DataRAM Real-Time Aerosol Monitor measures mass concentrations of airborne dust, smoke, mists, haze, and fumes from 0.0001 mg/m³ (0.1µg/m³) to 400 mg/m³ and provides continuous real-time readouts with high-level built-in audible signal alarm. It is designed for ambient and area air monitoring. One of these battery operated monitors, will be operated upwind of the excavation site and a second will be operated downwind. Monitors will be stationary (i.e., on a table top or stand) and located as close to the excavation as is practical, without interfering with worker activities and putting the monitoring equipment at undue risk. Workers may use the monitors down in the excavation, if site

conditions warrant closer monitoring. The monitors will be moved as necessary to maintain an upwind and downwind orientation. Instrument readings will be checked throughout the day and alarms will be set on the instruments so that workers will know immediately if concentrations are approaching action levels. The data will be downloaded on a daily basis. Action levels will be 0.150 mg/m^3 as a daily average and 1.0 mg/m^3 as the occupational action level. The downwind DataRAM alarm will be set at 1 mg/m^3 . If the ceiling limit is exceeded, work will cease till dust suppression is implemented. If any daily PM_{10} average exceeds 0.150 mg/m^3 (i.e., the NAAQ Standard), the upwind monitoring data will be evaluated and determinations made to modify work practices or dust suppression to limit particulate release from the excavation site.

5.2.2 VOC Monitoring

Real time monitoring for VOCs will be performed using RAE instruments ppbRAE Photo Ionization based instruments that can detect VOC emissions and quantify the normal ambient levels surrounding the excavation sites. These instruments can detect the VOCs associated with pine tar for which there are established risk based threshold limit values (i.e., turpentine and selected monoterpenes (alpha and beta pinene and 3-Carene). The ACGIH has established a threshold limit value of 20 ppm for turpentine, which contains high levels of terpenes. Because the response factor for the RAE Instruments PIDs relative to alpha and beta pinene is positive (i.e., actual concentration of 3 ppm of alpha pinene yields a reading of approximately 10 ppm on the PID calibrated with isobutylene), an instrument action level of 20 ppm can be safely used. This instrument action level represents a terpenes concentration less than half the TLV, the most conservative occupational exposure limit. In other words, when a ppbRAE calibrated with isobutylene reads 20 ppm, that would correspond to approximately 7 ppm of turpentine, considerably less than half of the TLV.

Two monitors will be employed, one upwind and one downwind of the excavation site. Monitors will be stationary (i.e., on a table top or stand) and located as close to the excavation as is practical, without interfering with worker activities and putting the monitoring equipment at undue risk. Workers may use the monitors down in the excavation, if site conditions warrant closer monitoring. Data will be downloaded and averaged each day. The occupational action levels will be set at 20 ppm as isobutylene or 7 ppm turpentine above the upwind ambient concentration. The community based action level will be 2.8 ppm turpentine. This corresponds to a PID instrument reading of 8 ppm as isobutylene. If daily average instrument readings are more than 8 ppm above the upwind ambient VOC level (corresponding to a

downwind contribution of 2.8 ppm turpentine), work practices and additional monitoring options will be evaluated.

5.2.3 Terpenes Air Sampling

To provide laboratory documentation of measured concentrations of VOCs associated with pine tar, air samples will be collected for terpenes analysis using USEPA Reference Method TO 15. Samples will be analyzed for alpha and beta pinene, 3-carene and alpha-terpeneol. Samples will be collected both upwind and downwind of the tar impacted areas in locations deemed representative of the current ambient background conditions. Up to 5 samples will also be collected during excavation at the SS5 location. This location has been chosen because it will be the first tar deposit to be excavated. A one-week turnaround will be requested from the laboratory. Laboratory sample results will be compared to the appropriate risk based action levels. If these action levels are exceeded, then work practices will be modified to reduce VOC emissions associated with the pine tar removal.

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Tables

Table 1
Vapor Pressure of Pine Tar Constituents

Compound	Vapor Pressure (mm Hg)	Source
alfa-pinene	4.75	1
beta-pinene	2.93	1
alpha-terpineol	0.0423	1
Abietic acid	3.19E-07	2
Dehydroabietic acid	2.88E-07	2
Retene	2.64E-06	2
C14 Fatty acid	1.40E-06	2
Phenol	0.35	2
4-ethylguaiacol	0.0248	2
Guaiacol	0.103	2

Sources:

1) *US EPA, 2006a.*

2) *SRC Physical Properties Database (<http://www.syrres.com/what-we-do/databaseforms.aspx?id=386>).*

Table 2
Odor Threshold Values for Terpenes

Chemical	Odor Threshold (mg/m³)	Source
alpha-pinene	3.9, 23	1
	0.033	2
beta-pinene	0.78	2
alpha-terpineol	0.24, 0.86	1

Sources:

1) *Molhave et al., 2000.*

2) *Buttery et al., 1974.*

Attachment A

Derivation of Ambient Air Action Level for Turpentine

After identifying appropriate toxicity criteria for turpentine, the toxicity criteria were related to monitoring levels in air to derive an action level for turpentine. Average air concentrations downwind of a source have been found empirically to decrease with averaging time, according to an inverse power law relationship,

$$C1/C2 = (t2/t1)^{-0.2}$$

or C is proportional to the averaging time raised to the (0.2) power (Turner, 1970).

A two-step process was used to calculate the action level based on the subchronic criteria. In the first step, a daily (*i.e.*, 8 hour) average concentration was scaled from the weekly subchronic criteria, taking into account the diurnal nature of the remediation period, namely 8 hours per day for 5 days per week. Mathematically, this relationship is:

$$C_{\text{daily}} = C_{\text{weekly}} \times [\text{exposure period}/\text{remediation period}] \times [T_{\text{weekly}}/T_{\text{daily}}]^{0.2}$$

where:

C_{weekly} = Subchronic "criteria to maintain" (2 ppm) (*i.e.*, toxicity criterion)

Exposure period = 8 hours per day for 5 days, or 40 hours

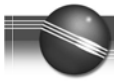
Remediation period = 8 hours per day for 5 days per week, or 40 hours

T_{weekly} = 8 hours per day for 5 days, or 40 hours

T_{daily} = 8 hours

The result was an action level of 2.8 ppm (15.5 mg/m³).

Attachment B
RAE PID Response Factor



Correction Factors, Ionization Energies*, And Calibration Characteristics

Correction Factors and Ionization Energies

RAE Systems PIDs can be used for the detection of a wide variety of gases that exhibit different responses. In general, any compound with ionization energy (IE) lower than that of the lamp photons can be measured.* The best way to calibrate a PID to different compounds is to use a standard of the gas of interest. However, correction factors have been determined that enable the user to quantify a large number of chemicals using only a single calibration gas, typically isobutylene. In our PIDs, correction factors can be used in one of three ways:

- 1) Calibrate the monitor with isobutylene in the usual fashion to read in isobutylene equivalents. Manually multiply the reading by the correction factor (CF) to obtain the concentration of the gas being measured.
- 2) Calibrate the unit with isobutylene in the usual fashion to read in isobutylene equivalents. Call up the correction factor from the instrument memory or download it from a personal computer and then call it up. The monitor will then read directly in units of the gas of interest.
- 3) Calibrate the unit with isobutylene, but input an equivalent, "corrected" span gas concentration when prompted for this value. The unit will then read directly in units of the gas of interest.

* The term "ionization energy" is more scientifically correct and replaces the old term "ionization potential." High-boiling ("heavy") compounds may not vaporize enough to give a response even when their ionization energies are below the lamp photon energy. Some inorganic compounds like H_2O_2 and NO_2 give weak response even when their ionization energies are well below the lamp photon energy.

Example 1:

With the unit calibrated to read isobutylene equivalents, the reading is 10 ppm with a 10.6 eV lamp. The gas being measured is butyl acetate, which has a correction factor of 2.6. Multiplying 10 by 2.6 gives an adjusted butyl acetate value of 26 ppm. Similarly, if the gas being measured were trichloroethylene (CF = 0.54), the adjusted value with a 10 ppm reading would be 5.4 ppm.

Example 2:

With the unit calibrated to read isobutylene equivalents, the reading is 100 ppm with a 10.6 eV lamp. The gas measured is m-xylene (CF = 0.43). After downloading this factor, the unit should read about 43 ppm when exposed to the same gas, and thus read directly in m-xylene values.

Example 3:

The desired gas to measure is ethylene dichloride (EDC). The CF is 0.6 with an 11.7 eV lamp. During calibration with 100 ppm isobutylene, insert 0.6 times 100, or 60 at the prompt for the calibration gas concentration. The unit then reads directly in EDC values.

Conversion to mg/m^3

To convert from ppm to mg/m^3 , use the following formula:

$$\text{Conc. (mg/m}^3\text{)} = \frac{[\text{Conc. (ppmv)} \times \text{mol. wt. (g/mole)}]}{\text{molar gas volume (L)}}$$

For air at 25 °C (77 °F), the molar gas volume is 24.4 L/mole and the formula reduces to:

$$\text{Conc. (mg/m}^3\text{)} = \text{Conc. (ppmv)} \times \text{mol. wt. (g/mole)} \times 0.041$$

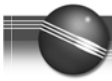
For example, if the instrument is calibrated with a gas standard in ppmv, such as 100 ppm isobutylene, and the user wants the display to read in mg/m^3 of hexane, whose m.w. is 86 and CF is 4.3, the overall correction factor would be $4.3 \times 86 \times 0.041$ equals 15.2.

Correction Factors for Mixtures

The correction factor for a mixture is calculated from the sum of the mole fractions X_i of each component divided by their respective correction factors CF_i :

$$CF_{\text{mix}} = 1 / (X_1/CF_1 + X_2/CF_2 + X_3/CF_3 + \dots X_i/CF_i)$$

Thus, for example, a vapor phase mixture of 5% benzene and 95% n-hexane would have a CF_{mix} of $CF_{\text{mix}} = 1 / (0.05/0.53 + 0.95/4.3) = 3.2$. A reading of 100 would then correspond to 320 ppm of the total mixture, comprised of 16 ppm benzene and 304 ppm hexane.



For a spreadsheet to compute the correction factor and TLV of a mixture see the appendix at the end of the CF table.

TLVs and Alarm Limits for Mixtures

The correction factor for mixtures can be used to set alarm limits for mixtures. To do this one first needs to calculate the exposure limit for the mixture. The Threshold Limit Value (TLV) often defines exposure limits. The TLV for the mixture is calculated in a manner similar to the CF calculation:

$$TLV_{mix} = 1 / (X_1/TLV_1 + X_2/TLV_2 + X_3/TLV_3 + \dots X_i/TLV_i)$$

In the above example, the 8-h TLV for benzene is 0.5 ppm and for n-hexane 50 ppm. Therefore the TLV of the mixture is $TLV_{mix} = 1 / (0.05/0.5 + 0.95/50) = 8.4$ ppm, corresponding to 8.0 ppm hexane and 0.4 ppm benzene. For an instrument calibrated on isobutylene, the reading corresponding to the TLV is:

$$Alarm\ Reading = TLV_{mix} / CF_{mix} = 8.4 / 3.2 = 2.6\ ppm$$

A common practice is to set the lower alarm limit to half the TLV, and the higher limit to the TLV. Thus, one would set the alarms to 1.3 and 2.6 ppm, respectively.

Calibration Characteristics

a) Flow Configuration. PID response is essentially independent of gas flow rate as long as it is sufficient to satisfy the pump demand. Four main flow configurations are used for calibrating a PID:

- 1) Pressurized gas cylinder (Fixed-flow regulator):** The flow rate of the regulator should match the flow demand of the instrument pump or be slightly higher.
- 2) Pressurized gas cylinder (Demand-flow regulator):** A demand-flow regulator better matches pump speed differences, but results in a slight vacuum during calibration and thus slightly high readings.
- 3) Collapsible gas bag:** The instrument will draw the calibration gas from the bag at its normal flow rate, as long as the bag valve is large enough. The bag should be filled with enough gas to allow at least one minute of flow (~ 0.6 L for a MiniRAE, ~0.3 L for MultiRAE).

4) T (or open tube) method: The T method uses a T-junction with gas flow higher than the pump draw. The gas supply is connected to one end of the T, the instrument inlet is connected to a second end of the T, and excess gas flow escapes through the third, open end of the T. To prevent ambient air mixing, a long tube should be connected to the open end, or a high excess rate should be used. Alternatively, the instrument probe can be inserted into an open tube slightly wider than the probe. Excess gas flows out around the probe.

The first two cylinder methods are the most efficient in terms of gas usage, while the bag and T methods give slightly more accurate results because they match the pump flow better.

- b) Pressure.** Pressures deviating from atmospheric pressure affect the readings by altering gas concentration and pump characteristics. It is best to calibrate with the instrument and calibration gas at the same pressure as each other and the sample gas. (Note that the cylinder pressure is not relevant because the regulator reduces the pressure to ambient.) If the instrument is calibrated at atmospheric pressure in one of the flow configurations described above, then 1) pressures slightly above ambient are acceptable but high pressures can damage the pump and 2) samples under vacuum may give low readings if air leaks into the sample train.
- c) Temperature.** Because temperature effects gas density and concentration, the temperature of the calibration gas and instrument should be as close as possible to the ambient temperature where the unit will be used. We recommend that the temperature of the calibration gas be within the instrument's temperature specification (typically 14° to 113° F or -10° to 45° C). Also, during actual measurements, the instrument should be kept at the same or higher temperature than the sample temperature to avoid condensation in the unit.
- d) Matrix.** The matrix gas of the calibration compound and VOC sample is significant. Some common matrix components, such as methane and water vapor can affect the VOC signal. PIDs are

most commonly used for monitoring VOCs in air, in which case the preferred calibration gas matrix is air. For a MiniRAE, methane, methanol, and water vapor reduce the response by about 20% when their concentration is 15,000 ppm and by about 40% at 30,000 ppm. Despite earlier reports of oxygen effects, RAE PID responses with 10.6 eV lamps are independent of oxygen concentration, and calibration gases in a pure nitrogen matrix can be used. H₂ and CO₂ up to 5 volume % also have no effect.

- e) Concentration.** Although RAE Systems PIDs have electronically linearized output, it is best to calibrate in a concentration range close to the actual measurement range. For example, 100 ppm standard gas for anticipated vapors of 0 to 250 ppm, and 500 ppm standard for expected concentrations of 250 to 1000 ppm. The correction factors in this table were typically measured at 50 to 100 ppm and apply from the ppb range up to about 1000 ppm. Above 1000 ppm the CF may vary and it is best to calibrate with the gas of interest near the concentration of interest.
- f) Filters.** Filters affect flow and pressure conditions and therefore all filters to be used during sampling should also be in place during calibration. Using a water trap (hydrophobic filter) greatly reduces the chances of drawing water aerosols or dirt particles into the instrument. Regular filter replacements are recommended because dirty filters can adsorb VOCs and cause slower response time and shifts in calibration.
- g) Instrument Design.** High-boiling (“heavy”) or very reactive compounds can be lost by reaction or adsorption onto materials in the gas sample train, such as filters, pumps and other sensors. Multi-gas meters, including EntryRAE, MultiRAE and AreaRAE have the pump and other sensors upstream of the PID and are prone to these losses. Compounds possibly affected by such losses are shown in green in the table, and may give slow response, or in extreme cases, no response at all. In many cases the multi-gas meters can still give a rough indication of the relative concentration, without giving an accurate,

quantitative reading. The ppbRAE and MiniRAE series instruments have inert sample trains and therefore do not exhibit significant loss; nevertheless, response may be slow for the very heavy compounds and additional sampling time up to a minute or more should be allowed to get a stable reading.

Table Abbreviations:

- CF** = Correction Factor (multiply by reading to get corrected value for the compound when calibrated to isobutylene)
- NR** = No Response
- IE** = Ionization Energy (values in parentheses are not well established)
- C** = Confirmed Value indicated by “+” in this column; all others are preliminary or estimated values and are subject to change
- ne** = Not Established ACGIH 8-hr. TWA
- C##** = Ceiling value, given where 8-hr.TWA is not available

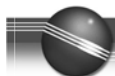
Disclaimer:

Actual readings may vary with age and cleanliness of lamp, relative humidity, and other factors. For accurate work, the instrument should be calibrated regularly under the operating conditions used. The factors in this table were measured in dry air at room temperature, typically at 50-100 ppm. CF values may vary above about 1000 ppm.

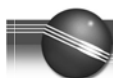
Updates:

The values in this table are subject to change as more or better data become available. Watch for updates of this table on the Internet at <http://www.raesystems.com>

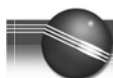
IE data are taken from the CRC Handbook of Chemistry and Physics, 73rd Edition, D.R. Lide (Ed.), CRC Press (1993) and NIST Standard Ref. Database 19A, NIST Positive Ion Energetics, Vers. 2.0, Lias, et.al., U.S. Dept. Commerce (1993). Exposure limits (8-h TWA and Ceiling Values) are from the 2005 ACGIH Guide to Occupational Exposure Values, ACGIH, Cincinnati, OH 2005. Equations for exposure limits for mixtures of chemicals were taken from the 1997 TLVs and BEIs handbook published by the ACGIH (1997).



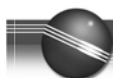
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Acetaldehyde		75-07-0	C ₂ H ₄ O	NR	+	6	+	3.3	+	10.23	C25
Acetic acid	Ethanoic Acid	64-19-7	C ₂ H ₄ O ₂	NR	+	22	+	2.6	+	10.66	10
Acetic anhydride	Ethanoic Acid Anhydride	108-24-7	C ₄ H ₆ O ₃	NR	+	6.1	+	2.0	+	10.14	5
Acetone	2-Propanone	67-64-1	C ₃ H ₆ O	1.2	+	1.1	+	1.4	+	9.71	500
Acetone cyanohydrin	2-Hydroxyisobutyronitrile	75-86-5	C ₄ H ₇ NO					4	+	11.1	C5
Acetonitrile	Methyl cyanide, Cyanomethane	75-05-8	C ₂ H ₃ N					100		12.19	40
Acetylene	Ethyne	74-86-2	C ₂ H ₂					2.1	+	11.40	ne
Acrolein	Propenal	107-02-8	C ₃ H ₄ O	42	+	3.9	+	1.4	+	10.10	0.1
Acrylic acid	Propenoic Acid	79-10-7	C ₃ H ₄ O ₂			12	+	2.0	+	10.60	2
Acrylonitrile	Propenenitrile	107-13-1	C ₃ H ₃ N			NR	+	1.2	+	10.91	2
Allyl alcohol		107-18-6	C ₃ H ₆ O	4.5	+	2.4	+	1.6	+	9.67	2
Allyl chloride	3-Chloropropene	107-05-1	C ₃ H ₅ Cl			4.3		0.7		9.9	1
Ammonia		7664-41-7	H ₃ N	NR	+	9.7	+	5.7	+	10.16	25
Amyl acetate	mix of n-Pentyl acetate & 2-Methylbutyl acetate	628-63-7	C ₇ H ₁₄ O ₂	11	+	2.3	+	0.95	+	<9.9	100
Amyl alcohol	1-Pentanol	75-85-4	C ₅ H ₁₂ O			5		1.6		10.00	ne
Aniline	Aminobenzene	62-53-3	C ₇ H ₇ N	0.50	+	0.48	+	0.47	+	7.72	2
Anisole	Methoxybenzene	100-66-3	C ₇ H ₈ O	0.89	+	0.58	+	0.56	+	8.21	ne
Arsine	Arsenic trihydride	7784-42-1	AsH ₃			1.9	+			9.89	0.05
Benzaldehyde		100-52-7	C ₇ H ₆ O					1		9.49	ne
Benzenamine, N-methyl-	N-Methylphenylamine	100-61-8	C ₇ H ₉ N			0.7				7.53	
Benzene		71-43-2	C ₆ H ₆	0.55	+	0.53	+	0.6	+	9.25	0.5
Benzonitrile	Cyanobenzene	100-47-0	C ₇ H ₅ N			1.6				9.62	ne
Benzyl alcohol	α-Hydroxytoluene, Hydroxymethylbenzene, Benzenemethanol	100-51-6	C ₇ H ₈ O	1.4	+	1.1	+	0.9	+	8.26	ne
Benzyl chloride	α-Chlorotoluene, Chloromethylbenzene	100-44-7	C ₇ H ₇ Cl	0.7	+	0.6	+	0.5	+	9.14	1
Benzyl formate	Formic acid benzyl ester	104-57-4	C ₈ H ₈ O ₂	0.9	+	0.73	+	0.66	+		ne
Boron trifluoride		7637-07-2	BF ₃	NR		NR		NR		15.5	C1
Bromine		7726-95-6	Br ₂	NR	+	1.30	+	0.74	+	10.51	0.1
Bromobenzene		108-86-1	C ₆ H ₅ Br			0.6		0.5		8.98	ne
2-Bromoethyl methyl ether		6482-24-2	C ₃ H ₇ OBr			0.84	+			~10	ne
Bromoform	Tribromomethane	75-25-2	CHBr ₃	NR	+	2.5	+	0.5	+	10.48	0.5
Bromopropane, 1-	n-Propyl bromide	106-94-5	C ₃ H ₇ Br	150	+	1.5	+	0.6	+	10.18	ne
Butadiene	1,3-Butadiene, Vinyl ethylene	106-99-0	C ₄ H ₆	0.8		0.85	+	1.1		9.07	2
Butadiene diepoxide, 1,3-	1,2,3,4-Diepoxybutane	298-18-0	C ₄ H ₆ O ₂	25	+	3.5	+	1.2		~10	ne
Butanal	1-Butanal	123-72-8	C ₄ H ₈ O			1.8				9.84	
Butane		106-97-8	C ₄ H ₁₀			67	+	1.2		10.53	800
Butanol, 1-	Butyl alcohol, n-Butanol	71-36-3	C ₄ H ₁₀ O	70	+	4.7	+	1.4	+	9.99	20
Butanol, t-	tert-Butanol, t-Butyl alcohol	75-65-0	C ₄ H ₁₀ O	6.9	+	2.9	+			9.90	100
Butene, 1-	1-Butylene	106-98-9	C ₄ H ₈			0.9				9.58	ne
Butoxyethanol, 2-	Butyl Cellosolve, Ethylene glycol monobutyl ether	111-76-2	C ₆ H ₁₄ O ₂	1.8	+	1.2	+	0.6	+	<10	25
Butoxyethanol acetate	Ethanol, 2-(2-butoxyethoxy)-, acetate	124-17-4	C ₁₀ H ₂₀ O ₄			5.6				≤10.6	
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol	112-34-5	C ₈ H ₁₈ O ₃			4.6				≤10.6	
Butyl acetate, n-		123-86-4	C ₆ H ₁₂ O ₂			2.6	+			10	150
Butyl acrylate, n-	Butyl 2-propenoate, Acrylic acid butyl ester	141-32-2	C ₇ H ₁₂ O ₂			1.6	+	0.6	+		10
Butylamine, n-		109-73-9	C ₄ H ₁₁ N	1.1	+	1.1	+	0.7	+	8.71	C5
Butyl cellosolve	see 2-Butoxyethanol	111-76-2									
Butyl hydroperoxide, t-		75-91-2	C ₄ H ₁₀ O ₂	2.0	+	1.6	+			<10	1
Butyl mercaptan	1-Butanethiol	109-79-5	C ₄ H ₁₀ S	0.55	+	0.52	+			9.14	0.5
Carbon disulfide		75-15-0	CS ₂	4	+	1.2	+	0.44		10.07	10
Carbon tetrachloride	Tetrachloromethane	56-23-5	CCl ₄	NR	+	NR	+	1.7	+	11.47	5
Carbonyl sulfide	Carbon oxysulfide	463-58-1	COS							11.18	
Cellosolve	see 2-Ethoxyethanol										
CFC-14	see Tetrafluoromethane										
CFC-113	see 1,1,2-Trichloro-1,2,2-trifluoroethane										



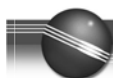
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA	
Chlorine		7782-50-5	Cl ₂					1.0	+	11.48	0.5	
Chlorine dioxide		10049-04-4	ClO ₂	NR	+	NR	+	NR	+	10.57	0.1	
Chlorobenzene	Monochlorobenzene	108-90-7	C ₆ H ₅ Cl	0.44	+	0.40	+	0.39	+	9.06	10	
Chlorobenzotrifluoride, 4-	PCBTf, OXSOL 100 p-Chlorobenzotrifluoride	98-56-6	C ₇ H ₄ ClF ₃	0.74	+	0.63	+	0.55	+	<9.6	25	
Chloro-1,3-butadiene, 2-	Chloroprene	126-99-8	C ₄ H ₅ Cl					3			10	
Chloro-1,1-difluoroethane, 1-	HCFC-142B, R-142B	75-68-3	C ₂ H ₃ ClF ₂	NR		NR		NR		12.0	ne	
Chlorodifluoromethane	HCFC-22, R-22	75-45-6	CHClF ₂	NR		NR		NR		12.2	1000	
Chloroethane	Ethyl chloride	75-00-3	C ₂ H ₅ Cl	NR	+	NR	+	1.1	+	10.97	100	
Chloroethanol	Ethylene chlorhydrin	107-07-3	C ₂ H ₅ ClO					2.9		10.52	C1	
Chloroethyl ether, 2-	bis(2-chloroethyl) ether	111-44-4	C ₄ H ₈ Cl ₂ O	8.6	+	3.0	+				5	
Chloroethyl methyl ether, 2-	Methyl 2-chloroethyl ether	627-42-9	C ₃ H ₇ ClO					3			ne	
Chloroform	Trichloromethane	67-66-3	CHCl ₃	NR	+	NR	+	3.5	+	11.37	10	
Chloro-2-methylpropene, 3-	Methallyl chloride, Isobutenyl chloride	563-47-3	C ₄ H ₇ Cl	1.4	+	1.2	+	0.63	+	9.76	ne	
Chloropicrin		76-06-2	CCl ₃ NO ₂	NR	+	~400	+	7	+	?	0.1	
Chlorotoluene, o-	o-Chloromethylbenzene	95-49-8	C ₇ H ₇ Cl					0.5		0.6	8.83	50
Chlorotoluene, p-	p-Chloromethylbenzene	106-43-4	C ₇ H ₇ Cl							0.6	8.69	ne
Chlorotrifluoroethene	CTFE, Chlorotrifluoroethylene Genetron 1113	79-38-9	C ₂ ClF ₃	6.7	+	3.9	+	1.2	+	9.76	5	
Chlorotrimethylsilane		75-77-4	C ₃ H ₉ ClSi	NR		NR		0.82	+	10.83	ne	
Cresol, m-	m-Hydroxytoluene	108-39-4	C ₇ H ₈ O	0.57	+	0.50	+	0.57	+	8.29	5	
Cresol, o-	o-Hydroxytoluene	95-48-7	C ₇ H ₈ O					1.0		8.50		
Cresol, p-	p-Hydroxytoluene	106-44-5	C ₇ H ₈ O					1.4		8.35		
Crotonaldehyde	<i>trans</i> -2-Butenal	123-73-9	C ₄ H ₆ O	1.5	+	1.1	+	1.0	+	9.73	2	
		4170-30-3										
Cumene	Isopropylbenzene	98-82-8	C ₉ H ₁₂	0.58	+	0.54	+	0.4	+	8.73	50	
Cyanogen bromide		506-68-3	CNBr	NR		NR		NR		11.84	ne	
Cyanogen chloride		506-77-4	CNCl	NR		NR		NR		12.34	C0.3	
Cyclohexane		110-82-7	C ₆ H ₁₂	3.3	+	1.4	+	0.64	+	9.86	300	
Cyclohexanol	Cyclohexyl alcohol	108-93-0	C ₆ H ₁₂ O	1.5	+	0.9	+	1.1	+	9.75	50	
Cyclohexanone		108-94-1	C ₆ H ₁₀ O	1.0	+	0.9	+	0.7	+	9.14	25	
Cyclohexene		110-83-8	C ₆ H ₁₀					0.8	+	8.95	300	
Cyclohexylamine		108-91-8	C ₆ H ₁₃ N					1.2		8.62	10	
Cyclopentane 85%		287-92-3	C ₅ H ₁₀	NR	+	15	+	1.1		10.33	600	
2,2-dimethylbutane 15%												
Cyclopropylamine	Aminocyclopropane	765-30-0	C ₃ H ₇ N	1.1	+	0.9	+	0.9	+		ne	
Decamethylcyclopentasiloxane		541-02-6	C ₁₀ H ₃₀ O ₅ Si ₅	0.16	+	0.13	+	0.12	+		ne	
Decamethyltetrasiloxane		141-62-8	C ₁₀ H ₃₀ O ₃ Si ₄	0.17	+	0.13	+	0.12	+	<10.2	ne	
Decane		124-18-5	C ₁₀ H ₂₂	4.0	+	1.4	+	0.35	+	9.65	ne	
Diacetone alcohol	4-Methyl-4-hydroxy-2-pentanone	123-42-2	C ₆ H ₁₂ O ₂					0.7			50	
Dibromochloromethane	Chlorodibromomethane	124-48-1	CHBr ₂ Cl	NR	+	5.3	+	0.7	+	10.59	ne	
Dibromo-3-chloropropane, 1,2-	DBCP	96-12-8	C ₃ H ₅ Br ₂ Cl	NR	+	1.7	+	0.43	+		0.001	
Dibromoethane, 1,2-	EDB, Ethylene dibromide, Ethylene bromide	106-93-4	C ₂ H ₄ Br ₂	NR	+	1.7	+	0.6	+	10.37	ne	
Dichlorobenzene, o-	1,2-Dichlorobenzene	95-50-1	C ₆ H ₄ Cl ₂	0.54	+	0.47	+	0.38	+	9.08	25	
Dichlorodifluoromethane	CFC-12	75-71-8	CCl ₂ F ₂					NR	+	11.75	1000	
Dichlorodimethylsilane		75-78-5	C ₂ H ₆ Cl ₂ Si	NR		NR		1.1	+	>10.7	ne	
Dichloroethane, 1,2-	EDC, 1,2-DCA, Ethylene dichloride	107-06-2	C ₂ H ₄ Cl ₂					NR	+	0.6	11.04	10
Dichloroethene, 1,1-	1,1-DCE, Vinylidene chloride	75-35-4	C ₂ H ₂ Cl ₂					0.82	+	0.8	9.79	5
Dichloroethene, c-1,2-	c-1,2-DCE, <i>cis</i> -Dichloroethylene	156-59-2	C ₂ H ₂ Cl ₂					0.8			9.66	200
Dichloroethene, t-1,2-	t-1,2-DCE, <i>trans</i> -Dichloroethylene	156-60-5	C ₂ H ₂ Cl ₂					0.45	+	0.34	9.65	200
Dichloro-1-fluoroethane, 1,1-	R-141B	1717-00-6	C ₂ H ₃ Cl ₂ F	NR	+	NR	+	2.0	+		ne	
Dichloromethane	see Methylene chloride											



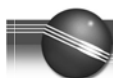
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C IE (eV)	TWA	
Dichloropentafluoropropane	AK-225, mix of ~45% 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca) & ~55% 1,3-Dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)	442-56-0 507-55-1	C ₃ HCl ₂ F ₅	NR	+	NR	+	25	+	ne	
Dichloropropane, 1,2-		78-87-5	C ₃ H ₆ Cl ₂					0.7		10.87	75
Dichloro-1-propene, 1,3-		542-75-6	C ₃ H ₄ Cl ₂	1.3	+	0.96	+			<10	1
Dichloro-1-propene, 2,3-		78-88-6	C ₃ H ₄ Cl ₂	1.9	+	1.3	+	0.7	+	<10	ne
Dichloro-1,1,1-trifluoroethane, 2,2-	R-123	306-83-2	C ₂ HCl ₂ F ₃	NR	+	NR	+	10.1	+	11.5	ne
Dichloro-2,4,6-trifluoropyridine, 3,5-	DCTFP	1737-93-5	C ₅ Cl ₂ F ₃ N	1.1	+	0.9	+	0.8	+		ne
Dichlorvos *	Vapona; O,O-dimethyl O-dichlorovinyl phosphate	62-73-7	C ₄ H ₇ Cl ₂ O ₄ P			0.9	+			<9.4	0.1
Dicyclopentadiene	DCPD, Cyclopentadiene dimer	77-73-6	C ₁₀ H ₁₂	0.57	+	0.48	+	0.43	+	8.8	5
Diesel Fuel		68334-30-5	m.w. 226			0.9	+				11
Diesel Fuel #2 (Automotive)		68334-30-5	m.w. 216	1.3		0.7	+	0.4	+		11
Diethylamine		109-89-7	C ₄ H ₁₁ N			1	+			8.01	5
Diethylaminopropylamine, 3-		104-78-9	C ₇ H ₁₈ N ₂			1.3					ne
Diethylbenzene	See Dowtherm J										
Diethylmaleate		141-05-9	C ₈ H ₁₂ O ₄			4					ne
Diethyl sulfide	see Ethyl sulfide										
Diglyme	See Methoxyethyl ether	111-96-6	C ₆ H ₁₄ O ₃								
Diisobutyl ketone	DIBK, 2,2-dimethyl-4-heptanone	108-83-8	C ₉ H ₁₈ O	0.71	+	0.61	+	0.35	+	9.04	25
Diisopropylamine		108-18-9	C ₆ H ₁₅ N	0.84	+	0.74	+	0.5	+	7.73	5
Diketene	Ketene dimer	674-82-8	C ₄ H ₄ O ₂	2.6	+	2.0	+	1.4	+	9.6	0.5
Dimethylacetamide, N,N-	DMA	127-19-5	C ₄ H ₉ NO	0.87	+	0.8	+	0.8	+	8.81	10
Dimethylamine		124-40-3	C ₂ H ₇ N			1.5				8.23	5
Dimethyl carbonate	Carbonic acid dimethyl ester	616-38-6	C ₃ H ₆ O ₃	NR	+	~70	+	1.7	+	~10.5	ne
Dimethyl disulfide	DMDS	624-92-0	C ₂ H ₆ S ₂	0.2	+	0.20	+	0.21	+	7.4	ne
Dimethyl ether	see Methyl ether										
Dimethylethylamine	DMEA	598-56-1	C ₄ H ₁₁ N	1.1	+	1.0	+	0.9	+	7.74	~3
Dimethylformamide, N,N-	DMF	68-12-2	C ₃ H ₇ NO	0.7	+	0.7	+	0.8	+	9.13	10
Dimethylhydrazine, 1,1-	UDMH	57-14-7	C ₂ H ₈ N ₂			0.8	+	0.8	+	7.28	0.01
Dimethyl methylphosphonate	DMMP, methyl phosphonic acid dimethyl ester	756-79-6	C ₃ H ₉ O ₃ P	NR	+	4.3	+	0.74	+	10.0	ne
Dimethyl sulfate		77-78-1	C ₂ H ₆ O ₄ S	~23		~20	+	2.3	+		0.1
Dimethyl sulfide	see Methyl sulfide										
Dimethyl sulfoxide	DMSO, Methyl sulfoxide	67-68-5	C ₂ H ₆ OS			1.4	+			9.10	ne
Dioxane, 1,4-		123-91-1	C ₄ H ₈ O ₂			1.3				9.19	25
Dioxolane, 1,3-	Ethylene glycol formal	646-06-0	C ₃ H ₆ O ₂	4.0	+	2.3	+	1.6	+	9.9	20
Dowtherm A	see Therminol® *										
Dowtherm J (97% Diethylbenzene) *		25340-17-4	C ₁₀ H ₁₄			0.5					
DS-108F Wipe Solvent	Ethyl lactate/Isopar H/Propoxypropanol ~7:2:1	97-64-3 64742-48-9 1569-01-3	m.w. 118	3.3	+	1.6	+	0.7	+		ne
Epichlorohydrin	ECH Chloromethyloxirane, 1-chloro2,3-epoxypropane	106-89-8	C ₂ H ₅ ClO	~200	+	8.5	+	1.4	+	10.2	0.5
Ethane		74-84-0	C ₂ H ₆			NR	+	15	+	11.52	ne
Ethanol	Ethyl alcohol	64-17-5	C ₂ H ₆ O			10	+	3.1	+	10.47	1000
Ethanolamine *	MEA, Monoethanolamine	141-43-5	C ₂ H ₇ NO	5.6	+	1.6	+			8.96	3
Ethene	Ethylene	74-85-1	C ₂ H ₄			9	+	4.5	+	10.51	ne
Ethoxyethanol, 2-	Ethyl cellosolve	110-80-5	C ₄ H ₁₀ O ₂			1.3				9.6	5
Ethyl acetate		141-78-6	C ₄ H ₈ O ₂			4.6	+	3.5		10.01	400
Ethyl acetoacetate		141-97-9	C ₆ H ₁₀ O ₃	1.4	+	1.2	+	1.0	+	<10	ne
Ethyl acrylate		140-88-5	C ₅ H ₈ O ₂			2.4	+	1.0	+	<10.3	5
Ethylamine		75-04-7	C ₂ H ₇ N			0.8				8.86	5



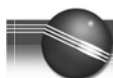
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (Ev)	TWA
Ethylbenzene		100-41-4	C ₈ H ₁₀	0.52	+	0.52	+	0.51	+	8.77	100
Ethyl caprylate	Ethyl octanoate	106-32-1	C ₁₀ H ₂₀ O ₂			+	0.52	+	0.51	+	
Ethylenediamine	1,2-Ethanediamine; 1,2-Diaminoethane	107-15-3	C ₂ H ₈ N ₂	0.9	+	0.8	+	1.0	+	8.6	10
Ethylene glycol *	1,2-Ethanediol	107-21-1	C ₂ H ₆ O ₂				16	+	6	+	10.16 C100
Ethylene glycol, Acrylate	2-hydroxyethyl Acrylate	818-61-1	C ₅ H ₈ O ₃				8.2				≤10.6
Ethylene glycol dimethyl ether	1,2-Dimethoxyethane, Monoglyme	110-71-4	C ₄ H ₁₀ O ₂	1.1		0.86		0.7		9.2	ne
Ethylene glycol monobutyl ether acetate	2-Butoxyethyl acetate	112-07-2	C ₈ H ₁₆ O ₃			1.3				≤10.6	
Ethylene glycol, monothio	mercapto-2-ethanol	60-24-2	C ₂ H ₆ OS			1.5				9.65	
Ethylene oxide	Oxirane, Epoxyethane	75-21-8	C ₂ H ₄ O			13	+	3.5	+	10.57	1
Ethyl ether	Diethyl ether	60-29-7	C ₄ H ₁₀ O			1.1	+	1.7		9.51	400
Ethyl 3-ethoxypropionate	EEP	763-69-9	C ₇ H ₁₄ O ₃	1.2	+	0.75	+				ne
Ethyl formate		109-94-4	C ₃ H ₆ O ₂					1.9		10.61	100
Ethylhexyl acrylate, 2-	Acrylic acid 2-ethylhexyl ester	103-11-7	C ₁₁ H ₂₀ O ₂			1.1	+	0.5	+		ne
Ethylhexanol	2-Ethyl-1-hexanol	104-76-7	C ₈ H ₁₈ O			1.9				≤10.6	
Ethylidenenorbornene	5-Ethylidene bicyclo(2,2,1)hept-2-ene	16219-75-3	C ₉ H ₁₂	0.4	+	0.39	+	0.34	+	≤8.8	ne
Ethyl (S)-(-)-lactate see also DS-108F	Ethyl lactate, Ethyl (S)-(-)-hydroxypropionate	687-47-8 97-64-3	C ₅ H ₁₀ O ₃	13	+	3.2	+	1.6	+	~10	ne
Ethyl mercaptan	Ethanethiol	75-08-1	C ₂ H ₆ S	0.60	+	0.56	+			9.29	0.5
Ethyl sulfide	Diethyl sulfide	352-93-2	C ₄ H ₁₀ S			0.5	+			8.43	ne
Formaldehyde	Formalin	50-00-0	CH ₂ O	NR	+	NR	+	1.6	+	10.87	C0.3
Formamide		75-12-7	CH ₃ NO			6.9	+	4		10.16	10
Formic acid		64-18-6	CH ₂ O ₂	NR	+	NR	+	9	+	11.33	5
Furfural	2-Furaldehyde	98-01-1	C ₅ H ₄ O ₂			0.92	+	0.8	+	9.21	2
Furfuryl alcohol		98-00-0	C ₅ H ₆ O ₂			0.80	+			<9.5	10
Gasoline #1		8006-61-9	m.w. 72			0.9	+				300
Gasoline #2, 92 octane		8006-61-9	m.w. 93	1.3	+	1.0	+	0.5	+		300
Glutaraldehyde	1,5-Pentanedial, Glutaric dialdehyde	111-30-8	C ₅ H ₈ O ₂	1.1	+	0.8	+	0.6	+		C0.05
Glycidyl methacrylate	2,3-Epoxypropyl methacrylate	106-91-2	C ₇ H ₁₀ O ₃	2.6	+	1.2	+	0.9	+		0.5
Halothane	2-Bromo-2-chloro-1,1,1-trifluoroethane	151-67-7	C ₂ HBrClF ₃					0.6		11.0	50
HCFC-22	see Chlorodifluoromethane										
HCFC-123	see 2,2-Dichloro-1,1,1-trifluoroethane										
HCFC-141B	see 1,1-Dichloro-1-fluoroethane										
HCFC-142B	see 1-Chloro-1,1-difluoroethane										
HCFC-134A	see 1,1,1,2-Tetrafluoroethane										
HCFC-225	see Dichloropentafluoropropane										
Heptane, n-		142-82-5	C ₇ H ₁₆	45	+	2.8	+	0.60	+	9.92	400
Heptanol, 4-	Dipropylcarbinol	589-55-9	C ₇ H ₁₆ O	1.8	+	1.3	+	0.5	+	9.61	ne
Hexamethyldisilazane, 1,1,1,3,3,3- *	HMDS	999-97-3	C ₆ H ₁₉ NSi ₂			0.2	+	0.2	+	~8.6	ne
Hexamethyldisiloxane	HMDSx	107-46-0	C ₆ H ₁₈ OSi ₂	0.33	+	0.27	+	0.25	+	9.64	ne
Hexane, n-		110-54-3	C ₆ H ₁₄	350	+	4.3	+	0.54	+	10.13	50
Hexanol, 1-	Hexyl alcohol	111-27-3	C ₆ H ₁₄ O	9	+	2.5	+	0.55	+	9.89	ne
Hexene, 1-		592-41-6	C ₆ H ₁₂			0.8				9.44	30
HFE-7100	see Methyl nonafluorobutyl ether										
Histoclear (Histo-Clear)	Limonene/corn oil reagent		m.w. ~136	0.5	+	0.4	+	0.3	+		ne
Hydrazine *		302-01-2	H ₄ N ₂	>8	+	2.6	+	2.1	+	8.1	0.01
Hydrazoic acid	Hydrogen azide		HN ₃							10.7	
Hydrogen	Synthesis gas	1333-74-0	H ₂	NR	+	NR	+	NR	+	15.43	ne
Hydrogen cyanide	Hydrocyanic acid	74-90-8	HCN	NR	+	NR	+	NR	+	13.6	C4.7
Hydrogen iodide *	Hydriodic acid	10034-85-2	HI			~0.6*				10.39	
Hydrogen peroxide		7722-84-1	H ₂ O ₂	NR	+	NR	+	NR	+	10.54	1
Hydrogen sulfide		7783-06-4	H ₂ S	NR	+	3.3	+	1.5	+	10.45	10
Hydroxypropyl methacrylate		27813-02-1 923-26-2	C ₇ H ₁₂ O ₃	9.9	+	2.3	+	1.1	+		ne
Iodine *		7553-56-2	I ₂	0.1	+	0.1	+	0.1	+	9.40	C0.1



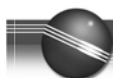
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Iodomethane	Methyl iodide	74-88-4	CH ₃ I	0.21	+	0.22	+	0.26	+	9.54	2
Isoamyl acetate	Isopentyl acetate	123-92-2	C ₇ H ₁₄ O ₂	10.1		2.1		1.0		<10	100
Isobutane	2-Methylpropane	75-28-5	C ₄ H ₁₀			100	+	1.2	+	10.57	ne
Isobutanol	2-Methyl-1-propanol	78-83-1	C ₄ H ₁₀ O	19	+	3.8	+	1.5		10.02	50
Isobutene	Isobutylene, Methyl butene	115-11-7	C ₄ H ₈	1.00	+	1.00	+	1.00	+	9.24	Ne
Isobutyl acrylate	Isobutyl 2-propenoate	106-63-8	C ₇ H ₁₂ O ₂			1.5	+	0.60	+		Ne
Isoflurane	1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether, forane	26675-46-7	C ₃ H ₂ ClF ₅ O	NR	+	NR	+	48	+	~11.7	Ne
Isooctane	2,2,4-Trimethylpentane	540-84-1	C ₈ H ₁₈			1.2				9.86	ne
Isopar E Solvent	Isoparaffinic hydrocarbons	64741-66-8	m.w. 121	1.7	+	0.8	+				Ne
Isopar G Solvent	Photocopier diluent	64742-48-9	m.w. 148			0.8	+				Ne
Isopar K Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 156	0.9	+	0.5	+	0.27	+		Ne
Isopar L Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 163	0.9	+	0.5	+	0.28	+		Ne
Isopar M Solvent	Isoparaffinic hydrocarbons	64742-47-8	m.w. 191			0.7	+	0.4	+		Ne
Isopentane	2-Methylbutane	78-78-4	C ₅ H ₁₂			8.2					Ne
Isophorone		78-59-1	C ₉ H ₁₄ O					3		9.07	C5
Isoprene	2-Methyl-1,3-butadiene	78-79-5	C ₅ H ₈	0.69	+	0.63	+	0.60	+	8.85	Ne
Isopropanol	Isopropyl alcohol, 2-propanol, IPA	67-63-0	C ₃ H ₈ O	500	+	6.0	+	2.7		10.12	200
Isopropyl acetate		108-21-4	C ₅ H ₁₀ O ₂			2.6				9.99	100
Isopropyl ether	Diisopropyl ether	108-20-3	C ₆ H ₁₄ O			0.8				9.20	250
Jet fuel JP-4	Jet B, Turbo B, F-40 Wide cut type aviation fuel	8008-20-6 + 64741-42-0	m.w. 115			1.0	+	0.4	+		Ne
Jet fuel JP-5	Jet 5, F-44, Kerosene type aviation fuel	8008-20-6 + 64747-77-1	m.w. 167			0.6	+	0.5	+		29
Jet fuel JP-8	Jet A-1, F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 165			0.6	+	0.3	+		30
Jet fuel A-1 (JP-8)	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 145			0.67					34
Jet Fuel TS	Thermally Stable Jet Fuel, Hydrotreated kerosene fuel	8008-20-6 + 64742-47-8	m.w. 165	0.9	+	0.6	+	0.3	+		30
Limonene, D-	(R)-(+)-Limonene	5989-27-5	C ₁₀ H ₁₆			0.33	+			~8.2	Ne
Kerosene C10-C16 petro.distillate	– see Jet Fuels	8008-20-6									
MDI – see 4,4'-Methylenebis(phenylisocyanate)											
Maleic anhydride	2,5-Furandione	108-31-6	C ₄ H ₂ O ₃							~10.8	0.1
Mesitylene	1,3,5-Trimethylbenzene	108-67-8	C ₉ H ₁₂	0.36	+	0.35	+	0.3	+	8.41	25
Methallyl chloride	– see 3-Chloro-2-methylpropene										
Methane	Natural gas	74-82-8	CH ₄	NR	+	NR	+	NR	+	12.61	Ne
Methanol	Methyl alcohol, carbinol	67-56-1	CH ₄ O	NR	+	NR	+	2.5	+	10.85	200
Methoxyethanol, 2-	Methyl cellosolve, Ethylene glycol monomethyl ether	109-86-4	C ₃ H ₈ O ₂	4.8	+	2.4	+	1.4	+	10.1	5
Methoxyethoxyethanol, 2-	2-(2-Methoxyethoxy)ethanol Diethylene glycol monomethyl ether	111-77-3	C ₇ H ₁₆ O	2.3	+	1.2	+	0.9	+	<10	Ne
Methoxyethyl ether, 2-	bis(2-Methoxyethyl) ether, Diethylene glycol dimethyl ether, Diglyme	111-96-6	C ₆ H ₁₄ O ₃	0.64	+	0.54	+	0.44	+	<9.8	Ne
Methyl acetate		79-20-9	C ₃ H ₆ O ₂	NR	+	6.6	+	1.4	+	10.27	200
Methyl acrylate	Methyl 2-propenoate, Acrylic acid methyl ester	96-33-3	C ₄ H ₆ O ₂			3.7	+	1.2	+	(9.9)	2
Methylamine	Aminomethane	74-89-5	CH ₅ N			1.2				8.97	5
Methyl amyl ketone	MAK, 2-Heptanone, Methyl pentyl ketone	110-43-0	C ₇ H ₁₄ O	0.9	+	0.85	+	0.5	+	9.30	50
Methyl bromide	Bromomethane	74-83-9	CH ₃ Br	110	+	1.7	+	1.3	+	10.54	1
Methyl t-butyl ether	MTBE, <i>tert</i> -Butyl methyl ether	1634-04-4	C ₅ H ₁₂ O			0.9	+			9.24	40
Methyl cellosolve	see 2-Methoxyethanol										
Methyl chloride	Chloromethane	74-87-3	CH ₃ Cl	NR	+	NR	+	0.74	+	11.22	50
Methylcyclohexane		107-87-2	C ₇ H ₁₄	1.6	+	0.97	+	0.53	+	9.64	400
Methylene bis(phenylisocyanate), 4,4'- *	MDI, Mondur M		C ₁₅ H ₁₀ N ₂ O ₂							Very slow ppb level response	0.005



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Methylene chloride	Dichloromethane	75-09-2	CH ₂ Cl ₂	NR	+	NR	+	0.89	+	11.32	25
Methyl ether	Dimethyl ether	115-10-6	C ₂ H ₆ O	4.8	+	3.1	+	2.5	+	10.03	Ne
Methyl ethyl ketone	MEK, 2-Butanone	78-93-3	C ₄ H ₈ O	0.86	+	0.9	+	1.1	+	9.51	200
Methylhydrazine	Monomethylhydrazine, Hydrazomethane	60-34-4	C ₂ H ₆ N ₂	1.4	+	1.2	+	1.3	+	7.7	0.01
Methyl isoamyl ketone	MIAK, 5-Methyl-2-hexanone	110-12-3	C ₇ H ₁₄ O	0.8	+	0.76	+	0.5	+	9.28	50
Methyl isobutyl ketone	MIBK, 4-Methyl-2-pentanone	108-10-1	C ₆ H ₁₂ O	0.9	+	0.8	+	0.6	+	9.30	50
Methyl isocyanate	CH ₃ NCO	624-83-9	C ₂ H ₃ NO	NR	+	4.6	+	1.5		10.67	0.02
Methyl isothiocyanate	CH ₃ NCS	551-61-6	C ₂ H ₃ NS	0.5	+	0.45	+	0.4	+	9.25	ne
Methyl mercaptan	Methanethiol	74-93-1	CH ₄ S	0.65		0.54		0.66		9.44	0.5
Methyl methacrylate		80-62-6	C ₅ H ₈ O ₂	2.7	+	1.5	+	1.2	+	9.7	100
Methyl nonafluorobutyl ether	HFE-7100DL	163702-08-7, 163702-07-6	C ₅ H ₃ F ₉ O			NR	+	~35	+		ne
Methyl-1,5-pentanediamine, 2-(coats lamp) *	Dytek-A amine, 2-Methyl pentamethylenediamine	15520-10-2	C ₆ H ₁₆ N ₂			~0.6	+			<9.0	ne
Methyl propyl ketone	MPK, 2-Pentanone	107-87-9	C ₅ H ₁₂ O			0.93	+	0.79	+	9.38	200
Methyl-2-pyrrolidinone, N-	NMP, N-Methylpyrrolidone, 1-Methyl-2-pyrrolidinone, 1-Methyl-2-pyrrolidone	872-50-4	C ₅ H ₉ NO	1.0	+	0.8	+	0.9	+	9.17	ne
Methyl salicylate	Methyl 2-hydroxybenzoate	119-36-8	C ₈ H ₈ O ₃	1.3	+	0.9	+	0.9	+	~9	ne
Methylstyrene, α-	2-Propenylbenzene	98-83-9	C ₉ H ₁₀			0.5				8.18	50
Methyl sulfide	DMS, Dimethyl sulfide	75-18-3	C ₂ H ₆ S	0.49	+	0.44	+	0.46	+	8.69	ne
Mineral spirits	Stoddard Solvent, Varsol 1, White Spirits	8020-83-5 8052-41-3 68551-17-7	m.w. 144	1.0		0.69	+	0.38	+		100
Mineral Spirits - Viscor 120B Calibration Fluid, b.p. 156-207°C		8052-41-3	m.w. 142	1.0	+	0.7	+	0.3	+		100
Monoethanolamine - see Ethanolamine											
Mustard *	HD, Bis(2-chloroethyl) sulfide	505-60-2 39472-40-7 68157-62-0	C ₄ H ₈ Cl ₂ S			0.6					0.0005
Naphtha - see VM & P Naptha											
Naphthalene	Mothballs	91-20-3	C ₁₀ H ₈	0.45	+	0.42	+	0.40	+	8.13	10
Nickel carbonyl (in CO)	Nickel tetracarbonyl	13463-39-3	C ₄ NiO ₄			0.18				<8.8	0.001
Nicotine		54-11-5	C ₁₀ H ₁₄ N ₂			2.0				≤10.6	
Nitric oxide		10102-43-9	NO	~6		5.2	+	2.8	+	9.26	25
Nitrobenzene		98-95-3	C ₆ H ₅ NO ₂	2.6	+	1.9	+	1.6	+	9.81	1
Nitroethane		79-24-3	C ₂ H ₅ NO ₂					3		10.88	100
Nitrogen dioxide		10102-44-0	NO ₂	23	+	16	+	6	+	9.75	3
Nitrogen trifluoride		7783-54-2	NF ₃	NR		NR		NR		13.0	10
Nitromethane		75-52-5	CH ₃ NO ₂					4		11.02	20
Nitropropane, 2-		79-46-9	C ₃ H ₇ NO ₂					2.6		10.71	10
Nonane		111-84-2	C ₉ H ₂₀			1.4				9.72	200
Norpar 12	n-Paraffins, mostly C ₁₀ -C ₁₃	64771-72-8	m.w. 161	3.2	+	1.1	+	0.28	+		ne
Norpar 13	n-Paraffins, mostly C ₁₃ -C ₁₄	64771-72-8	m.w. 189	2.7	+	1.0	+	0.3	+		ne
Octamethylcyclotetrasiloxane		556-67-2	C ₈ H ₂₄ O ₄ Si ₄	0.21	+	0.17	+	0.14	+		ne
Octamethyltrisiloxane		107-51-7	C ₈ H ₂₄ O ₂ Si ₃	0.23	+	0.18	+	0.17	+	<10.0	ne
Octane, n-		111-65-9	C ₈ H ₁₈	13	+	1.8	+			9.82	300
Octene, 1-		111-66-0	C ₈ H ₁₆	0.9	+	0.75	+	0.4	+	9.43	75
Pentane		109-66-0	C ₅ H ₁₂	80	+	8.4	+	0.7	+	10.35	600
Peracetic acid *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	C ₂ H ₄ O ₃	NR	+	NR	+	2.3	+		ne
Peracetic/Acetic acid mix *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	C ₂ H ₄ O ₃			50	+	2.5	+		ne
Perchloroethene	PCE, Perchloroethylene, Tetrachloroethylene	127-18-4	C ₂ Cl ₄	0.69	+	0.57	+	0.31	+	9.32	25
PGME	Propylene glycol methyl ether, 1-Methoxy-2-propanol	107-98-2	C ₆ H ₁₂ O ₃	2.4	+	1.5	+	1.1	+		100



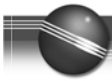
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
PGMEA	Propylene glycol methyl ether acetate, 1-Methoxy-2-acetoxypropane, 1-Methoxy-2-propanol acetate	108-65-6	C ₆ H ₁₂ O ₃	1.65	+	1.0	+	0.8	+		ne
Phenol	Hydroxybenzene	108-95-2	C ₆ H ₆ O	1.0	+	1.0	+	0.9	+	8.51	5
Phosgene	Dichlorocarbonyl	75-44-5	CCl ₂ O	NR	+	NR	+	8.5	+	11.2	0.1
Phosgene in Nitrogen	Dichlorocarbonyl	75-44-5	CCl ₂ O	NR	+	NR	+	6.8	+	11.2	0.1
Phosphine (coats lamp)		7803-51-2	PH ₃	28		3.9	+	1.1	+	9.87	0.3
Photocopier Toner	Isoparaffin mix					0.5	+	0.3	+		ne
Picoline, 3-	3-Methylpyridine	108-99-6	C ₆ H ₇ N			0.9				9.04	ne
Pinene, α-		2437-95-8	C ₁₀ H ₁₆			0.31	+	0.47		8.07	ne
Pinene, β-		18172-67-3	C ₁₀ H ₁₆	0.38	+	0.37	+	0.37	+	~8	100
Piperylene, isomer mix	1,3-Pentadiene	504-60-9	C ₅ H ₈	0.76	+	0.69	+	0.64	+	8.6	100
Propane		74-98-6	C ₃ H ₈			NR	+	1.8	+	10.95	2500
Propanol, n-	Propyl alcohol	71-23-8	C ₃ H ₈ O			5		1.7		10.22	200
Propene	Propylene	115-07-1	C ₃ H ₆	1.5	+	1.4	+	1.6	+	9.73	ne
Propionaldehyde	Propanal	123-38-6	C ₃ H ₆ O			1.9				9.95	ne
Propyl acetate, n-		109-60-4	C ₅ H ₁₀ O ₂			3.5		2.3		10.04	200
Propylamine, n-	1-Propylamine, 1-Aminopropane	107-10-8	C ₃ H ₉ N	1.1	+	1.1	+	0.9	+	8.78	ne
Propylene carbonate *		108-32-7	C ₄ H ₆ O ₃			62	+	1	+	10.5	ne
Propylene glycol	1,2-Propanediol	57-55-6	C ₃ H ₈ O ₂	18		5.5	+	1.6	+	<10.2	ne
Propylene glycol propyl ether	1-Propoxy-2-propanol	1569-01-3	C ₆ H ₁₄ O ₂	1.3	+	1.0	+	1.6	+		ne
Propylene oxide	Methyloxirane	75-56-9	C ₃ H ₆ O	~240		6.6	+	2.9	+	10.22	20
		16088-62-3									
		15448-47-2									
Propyleneimine	2-Methylaziridine	75-55-8	C ₃ H ₇ N	1.5	+	1.3	+	1.0	+	9.0	2
Propyl mercaptan, 2-	2-Propanethiol, Isopropyl mercaptan	75-33-2	C ₃ H ₈ S	0.64	+	0.66	+			9.15	ne
Pyridine		110-86-1	C ₅ H ₅ N	0.78	+	0.7	+	0.7	+	9.25	5
Pyrrolidine (coats lamp)	Azacyclohexane	123-75-1	C ₄ H ₉ N	2.1	+	1.3	+	1.6	+	~8.0	ne
RR7300 (PGME/PGMEA)	70:30 PGME:PGMEA (1-Methoxy-2-propanol:1-Methoxy-2-acetoxypropane)	107-98-2	C ₄ H ₁₀ O ₂ / C ₆ H ₁₂ O ₃			1.4	+	1.0	+		ne
Sarin	GB, Isopropyl methylphosphonofluoridate	107-44-8	C ₄ H ₁₀ FO ₂ P			~3					
		50642-23-4									
Stoddard Solvent - see Mineral Spirits		8020-83-5									
Styrene		100-42-5	C ₈ H ₈	0.45	+	0.40	+	0.4	+	8.43	20
Sulfur dioxide		7446-09-5	SO ₂	NR		NR	+	NR	+	12.32	2
Sulfur hexafluoride		2551-62-4	SF ₆	NR		NR		NR		15.3	1000
Sulfuryl fluoride	Vikane	2699-79-8	SO ₂ F ₂	NR		NR		NR		13.0	5
Tabun *	Ethyl N, N-dimethylphosphoramidocyanidate	77-81-6	C ₅ H ₁₁ N ₂ O ₂ P			0.8					15ppt
Tetrachloroethane, 1,1,1,2-		630-20-6	C ₂ H ₂ Cl ₄					1.3		~11.1	ne
Tetrachloroethane, 1,1,1,2,2-		79-34-5	C ₂ H ₂ Cl ₄	NR	+	NR	+	0.60	+	~11.1	1
Tetrachlorosilane		10023-04-7	SiCl ₄	NR		NR		15	+	11.79	ne
Tetraethyl lead	TEL	78-00-2	C ₈ H ₂₀ Pb	0.4		0.3		0.2		~11.1	0.008
Tetraethyl orthosilicate	Ethyl silicate, TEOS	78-10-4	C ₈ H ₂₀ O ₄ Si			0.7	+	0.2	+	~9.8	10
Tetrafluoroethane, 1,1,1,2-	HFC-134A	811-97-2	C ₂ H ₂ F ₄			NR		NR			ne
Tetrafluoroethene	TFE, Tetrafluoroethylene, Perfluoroethylene	116-14-3	C ₂ F ₄			~15				10.12	ne
Tetrafluoromethane	CFC-14, Carbon tetrafluoride	75-73-0	CF ₄			NR	+	NR	+	>15.3	ne
Tetrahydrofuran	THF	109-99-9	C ₄ H ₈ O	1.9	+	1.7	+	1.0	+	9.41	200
Tetramethyl orthosilicate	Methyl silicate, TMOS	681-84-5	C ₄ H ₁₂ O ₄ Si	10	+	1.9	+			~10	1
Therminol® D-12 *	Hydrotreated heavy naphtha	64742-48-9	m.w. 160	0.8	+	0.51	+	0.33	+		ne
Therminol® VP-1 *	Dowtherm A, 3:1 Diphenyl oxide:	101-84-8	C ₁₂ H ₁₀ O			0.4	+				1
	Biphenyl	92-52-4	C ₁₂ H ₁₀								
Toluene	Methylbenzene	108-88-3	C ₇ H ₈	0.54	+	0.50	+	0.51	+	8.82	50



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Tolylene-2,4-diisocyanate	TDI, 4-Methyl-1,3-phenylene-2,4-diisocyanate	584-84-9	C ₉ H ₆ N ₂ O ₂	1.4	+	1.4	+	2.0	+		0.002
Trichlorobenzene, 1,2,4-	1,2,4-TCB	120-82-1	C ₆ H ₃ Cl ₃	0.7	+	0.46	+			9.04	C5
Trichloroethane, 1,1,1-	1,1,1-TCA, Methyl chloroform	71-55-6	C ₂ H ₃ Cl ₃			NR	+	1	+	11	350
Trichloroethane, 1,1,2-	1,1,2-TCA	79-00-5	C ₂ H ₃ Cl ₃	NR	+	NR	+	0.9	+	11.0	10
Trichloroethene	TCE, Trichloroethylene	79-01-6	C ₂ HCl ₃	0.62	+	0.54	+	0.43	+	9.47	50
Trichloromethylsilane	Methyltrichlorosilane	75-79-6	CH ₃ Cl ₃ Si	NR		NR		1.8	+	11.36	ne
Trichlorotrifluoroethane, 1,1,2-	CFC-113	76-13-1	C ₂ Cl ₃ F ₃			NR		NR		11.99	1000
Triethylamine	TEA	121-44-8	C ₆ H ₁₅ N	0.95	+	0.9	+	0.65	+	7.3	1
Triethyl borate	TEB; Boric acid triethyl ester	150-46-9	C ₆ H ₁₅ O ₃ B			2.2	+	1.1	+	~10	ne
Triethyl phosphate	Ethyl phosphate	78-40-0	C ₆ H ₁₅ O ₄ P	~50	+	3.1	+	0.60	+	9.79	ne
Trifluoroethane, 1,1,2-		430-66-0	C ₂ H ₃ F ₃					34		12.9	ne
Trimethylamine		75-50-3	C ₃ H ₉ N			0.9				7.82	5
Trimethylbenzene, 1,3,5- - see Mesitylene		108-67-8									25
Trimethyl borate	TMB; Boric acid trimethyl ester, Boron methoxide	121-43-7	C ₃ H ₉ O ₃ B			5.1	+	1.2	+	10.1	ne
Trimethyl phosphate	Methyl phosphate	512-56-1	C ₃ H ₉ O ₄ P			8.0	+	1.3	+	9.99	ne
Trimethyl phosphite	Methyl phosphite	121-45-9	C ₃ H ₉ O ₃ P			1.1	+		+	8.5	2
Turpentine	Pinenes (85%) + other diisoprenes	8006-64-2	C ₁₀ H ₁₆	0.37	+	0.30	+	0.29	+	~8	20
Undecane		1120-21-4	C ₁₁ H ₂₄			2				9.56	ne
Varsol – see Mineral Spirits											
Vinyl acetate		108-05-4	C ₄ H ₆ O ₂	1.5	+	1.2	+	1.0	+	9.19	10
Vinyl bromide	Bromoethylene	593-60-2	C ₂ H ₃ Br			0.4				9.80	5
Vinyl chloride	Chloroethylene, VCM	75-01-4	C ₂ H ₃ Cl			2.0	+	0.6	+	9.99	5
Vinyl-1-cyclohexene, 4-	Butadiene dimer, 4-Ethenylcyclohexene	100-40-3	C ₈ H ₁₂	0.6	+	0.56	+			9.83	0.1
Vinylidene chloride - see 1,1-Dichloroethene											
Vinyl-2-pyrrolidinone, 1-	NVP, N-vinylpyrrolidone, 1-ethenyl-2-pyrrolidinone	88-12-0	C ₆ H ₉ NO	1.0	+	0.8	+	0.9	+		ne
Viscor 120B - see Mineral Spirits - Viscor 120B Calibration Fluid											
V. M. & P. Naphtha	Ligroin; Solvent naphtha; Varnish maker's & painter's naphtha	64742-89-8	m.w. 111 (C ₈ -C ₉)	1.7	+	0.97	+				300
Xylene, m-	1,3-Dimethylbenzene	108-38-3	C ₈ H ₁₀	0.50	+	0.44	+	0.40	+	8.56	100
Xylene, o-	1,2-Dimethylbenzene	95-47-6	C ₈ H ₁₀	0.56	+	0.46	+	0.43		8.56	100
Xylene, p-	1,4-Dimethylbenzene	106-42-3	C ₈ H ₁₀	0.48	+	0.39	+	0.38	+	8.44	100
None				1		1		1			
Undetectable				1E+6		1E+6		1E+6			

* Compounds indicated in green can be detected using a MiniRAE 2000 or ppbRAE/+ with slow response, but may be lost by adsorption on a MultiRAE or EntryRAE. Response on multi-gas meters can give an indication of relative concentrations, but may not be quantitative and for some chemicals no response is observed.

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**Appendix I:****Example of Automatic Calculation of Correction Factors, TLVs and Alarm Limits for Mixtures
(Calculations performed using Excel version of this database, available on request)**

Compound	CF 9.8 eV	CF 10.6 eV	CF 11.7eV	Mol. Frac	Conc ppm	TLV ppm	STEL Ppm
Benzene	0.55	0.53	0.6	0.01	1	0.5	2.5
Toluene	0.54	0.5	0.51	0.06	10	50	150
Hexane, n-	300	4.3	0.54	0.06	10	50	150
Heptane, n-	45	2.8	0.6	0.28	50	400	500
Styrene	0.45	0.4	0.42	0.06	10	20	40
Acetone	1.2	1.1	1.4	0.28	50	750	1000
Isopropanol	500	6	2.7	0.28	50	400	500
None	1	1	1	0.00	0	1	
Mixture Value:	2.1	1.5	0.89	1.00	181	56	172
TLV Alarm Setpoint when Calibrated to Isobutylene:	26 ppm	37 ppm	62 ppm		ppm	ppm	ppm
STEL Alarm Setpoint, same Calibration	86 ppm	115 ppm	193 ppm				