

**Practical
Guidelines
for Measuring
Solvent Vapour
Concentrations
using Chemical
Indicator
Tubes**

European  solvents Industry

Hydrocarbon &
Oxygenated Solvents
www.esig.org

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INTRODUCTION

This guidance note is the third in the series of 'Best Practice Guidelines' published by the European Solvents Industry Group (ESIG). The guide provides practical guidance to help solvent users in the measurement of airborne solvent vapour concentrations in the workplace, which can assist in estimating exposures. It supplements Best Practice Guide 1 on basic monitoring programmes entitled 'Measuring Solvent Vapour Concentrations in the Work Environment'.

Readers are reminded that measuring exposures to chemical substances should be carried out as part of an overall programme of health risk assessment to help in the selection of appropriate exposure controls. Please refer to Best Practice Guide 2 'Guide to Managing Solvent Exposure'.

Unlike the previous guides in the series, this guide is not considered to represent industry 'best practice' in terms of monitoring methodology, but is based on a simple approach which is universally used for measuring solvent vapours in workplaces.

SCOPE AND PURPOSE

These guidelines provide advice on estimating airborne concentrations in the workplace to a range of commonly used hydrocarbon and oxygenated solvents (listed in Appendices 1 and 2) using simple, low cost equipment. This information may be used to provide a rough estimate of personal exposures for comparison with an Occupational Exposure Limit (OEL) to assist decisions on whether:

- Exposure control is adequate
- Additional exposure control measures are required, or
- A more detailed exposure assessment involving specialist input is necessary.

In addition, measurements can be used to determine which tasks, processes or equipment give rise to the greatest potential for exposure, to assess the effectiveness of ventilation systems, or to check for leaks and other vapour emission sources.

N.B.

Measurements obtained using the equipment and methodology outlined in this guideline should not be used to test statutory compliance with an OEL. This requires sampling and analytical methods which are more accurate and precise than those described in this document. Specialist advice from an occupational/industrial hygienist should be sought in such circumstances. Other practical limitations which should be taken into account are outlined in Section 4.2.

SOLVENTS AND OCCUPATIONAL EXPOSURE LIMITS (OELS)

To evaluate personal exposures to a substance it is first necessary to identify the OEL of the substance. A number of individual solvents have been assigned an OEL by national or regulatory bodies, e.g. ACGIH TLVs, UK HSE OELs, German MAK Values. For the majority of hydrocarbon solvents, a recommended list of OELs for the main commercial grades of hydrocarbon solvents have been produced by HSPA. It should be noted however, that solvents are often used as a mixture, for which there will be no overall OEL set by such authorities.

1. Where to find an OEL

It is usual for the solvent/product supplier to identify any relevant OELs under Section 8 of the Product Safety Data Sheet for the individual constituents. For hydrocarbon solvents the HSPA recommended list of OELs may also be consulted. For the purposes of this guidance, if using a product that contains a number of different solvents, it should be assumed that for a mixture, the combined health effects attributed to the individual constituents are additive (see section 2 below), unless it is known that they are not (e.g. that they may be synergistic or independent).

2. The Additive Effect Procedure

For individual constituents in a mixture that have similar toxicological effects (e.g. irritancy, depression of the central nervous system), the following formula should be applied.

$$C1/L1 + C2/L2 + C3/L3 + \dots = < 1$$

Where C1 is the concentration of constituent 1 in the atmosphere and L1 is the OEL for constituent 1 (in the same units (ppm or mg/m³)). The airborne concentration of the individual constituents need to be measured. If the sum of the individual constituent ratios is <1, the OEL for the mixture is not exceeded, although action is normally taken when this sum exceeds 0.5.

Note that if each of the constituents have different toxicological effects, the formula above should not be used as each constituent should be considered independently.

1. General

There are a number of methods available for the measurement of solvent vapours in air, however, most of these require skilled health and safety technicians and specialised monitoring equipment and/or analyses.

The measurement method recommended in this guide is based on the use of Chemical Indicator (colorimetric) Tubes in view of the following advantages:

- Easy to use
- Minimal training required
- Portable
- No laboratory analysis necessary
- No on-site calibration required
- Immediate results
- Low cost

It is considered to offer a pragmatic approach for providing a rough estimate of personal exposure. Where measurements indicate the potential for over exposure or there is any uncertainty, more detailed investigations may be needed and should be carried out by an occupational/industrial hygienist.

In summary, the method involves drawing a measured volume of air through a tube using a small hand-held pump. The amount of air sampled during each sample "stroke" is predetermined by the sampling pump design, and is tailored to the tube type, the substance being measured, and the sensitivity required. The length of the resulting "reactant" stain produced along the axis of the tube is directly related to the concentration of the solvent vapour being measured in the atmosphere over the time period during which the measurement is carried out (e.g. 1 minute). A minor calculation may be required to obtain the final concentration.

Chemical Indicator Tubes have a number of inherent limitations that must be considered both in the selection of an appropriate tube as well as in the interpretation of the measurement results obtained. See next Section.

2. Limitations of Use

It is emphasised that precautions must be exercised in the use of Chemical Indicator Tubes and in the interpretation of results obtained by this method, as the precision and accuracy is low and can also vary significantly between different tube types. For example, quoted experimental standard deviations (SD) for different tubes may vary between 10 - 50% due to inherent measurement limitations, with $\pm 25\%$ being typical value. In some circumstances variations in performance may be due to the presence of interfering chemical substances in the air being sampled. Manufacturers performance data, supplied with Chemical Indicator Tubes, must always be referenced before use.

Caution should be exercised when using Chemical Indicator Tubes for measuring solvent vapours in the following situations:

- For the identification of individual constituents within a mixture, since they may be subject to interference from the other constituents. Cross reactions may cause errors in the analysis. However, some tubes are designed and calibrated for the mixture as a whole, as are many of the tubes referenced in this guide. It should be noted that chemical interference is a severe limitation with Chemical Indicator Tubes, and alternative techniques may have to be employed.
- Solvents with final boiling points greater than 200°C (e.g. glycol ethers). In view of their low vapour pressure these solvents do not readily volatilise within the range of ambient temperatures found in many countries, and they would only give rise to significant airborne concentrations when used at elevated temperatures (i.e. when allied to a heating process). If this is the case, it is recommended that professional advice is sought or the supplier contacted.
- Where the first scalemark of the Chemical Indicator Tube is greater than the OEL for the relevant solvent. However, the tube can still be used as a practical tool to identify potentially excessive exposures.
- Where the first scalemark is within 50% of the OEL. In view of the inherent measurement error of these tubes, typically $\pm 25\%$ (see above), a measured air concentration (average of 3 readings) of 75% of the OEL may in fact represent a true reading of anything between 50% - 100% of the OEL. Therefore, in order to have some confidence that the airborne concentration is substantially below the OEL, it is advised that tubes with the first scalemark equal or below 50% of the OEL, are used. If there is any doubt speak to the tube manufacturer.

3. Using Chemical Indicator Tubes

1. Check that the hand pump is functioning correctly (i.e. it is leaktight), using the procedures detailed in the manufacturers instructions.
2. Select appropriate indicator tubes; check that the tubes are suitable for use (e.g. within their expiry date on box), compatible with the pump and that they have been correctly stored (e.g. in a laboratory refrigerator).
3. Read the instructions provided on the accompanying leaflet, which comes with the tubes (i.e. inside the box of indicator tubes). Note particularly whether a "pre-tube" is needed (e.g. 1 a 'scrubbing' tube which removes chemical interferences before the sampled air enters the main sampling tube). Check the number of pump strokes to be performed (this varies depending on concentration range of interest), and the expected delay or sample time for each stroke. Also check for likely interference(s).
4. Break the ends off the indicator tube according to the manufacturers instructions, and insert the tube firmly into the pump inlet aperture. The directional arrow imprinted on the tube indicates the orientation (i.e. air flow direction) by which it should be inserted. After breaking the ends, the tube will have sharp edges and must be handled carefully.
5. Draw the prescribed volume of workplace air through the tube by operating the pump for the set number of strokes (e.g. 5 successive strokes of 100 ml each), allowing the required sampling time between each stroke for the gas to be drawn through the tube.
6. Read off the length of stain obtained against the concentration scale markings on the outside of the tube. Sometimes the colour change is not distinct, and a degree of judgement and care must be used to decide the location of the leading edge of stain; angled or diffuse end points are read as the average value. Read the tube immediately as the stain may fade or spread. Note that most tubes are calibrated to be read-off directly in parts per million (ppm). Having made the reading, record all values in a notebook or datalogger for future reference.
7. Used tubes with broken ends must be disposed of carefully. Most tubes can be disposed of as contaminated glass waste i.e. go in ordinary domestic glass waste. You should seek the tube manufacturers guidance on disposal.

Note:

Each tube comes with a specific information sheet describing the tube and how it is to be used e.g. how many pump strokes. These instructions must be carefully followed.

4. Measurement Procedure

The following general considerations should be taken into account when measuring airborne vapour concentrations:

Application	Measurement and Other Considerations
Assessment of potential for personal exposure to solvent vapours	<p>Measurements should be taken as near as possible to the workers breathing zone (usually in front of and within 30 centimetres of the nose and mouth, although closer is even better).</p> <p>Exposure is a function of time spent carrying out tasks involving exposure and the airborne concentration of vapour. Separate measurements must be taken for each of the tasks involving exposure to allow the overall potential for exposure to be calculated.</p> <p>Generally, the greater the fluctuations (i.e. the variability) in airborne concentrations for any task, the more samples must be taken to determine the concentration range(s) and typical levels.</p> <p>Non exposure times (e.g. rest and meal breaks and office work) are included in the exposure assessment.</p>
Assessment of the effectiveness of exposure control measures e.g. ventilation	<p>Measurements should be taken before and after implementing control improvements to evaluate reduction in potential exposures.</p> <p>Measurements should be collected under actual operating conditions to take account of the varying solvent properties in usage, e.g. volatility at different temperatures, which will influence the effectiveness of controls.</p>
Checking for leaks and other emission sources	<p>Chemical Indicator Tubes can be an effective means for determining the source of fugitive vapour emissions from operating plant and equipment.</p>

The measurement procedure is illustrated in Figure 1 and includes the following steps for obtaining a rough estimate of personal exposure:

Step 1: Identify Solvent(s) OEL(s)

Step 2: Select Appropriate Chemical Indicator Tube(s)

Step 3: Identify the Tasks Involving Potential Exposure

Step 4: Perform Measurements

Step 5: Calculate Approximate Personal Exposure and Decide on Need for Action

Step 6: Record Measurement Results

Steps 3 and 5 do not apply when carrying out measurements to check for leaks and other emission sources.

A description of each step is given below and worked examples are included in Appendices 3 and 4. Focus has been placed on the determination of shift average exposures for comparison with the Long Term OEL (8 hour TWA). However, similar principles may be applied to compare exposures from individual tasks with the Short Term Exposure Limit (15 minute STEL).

This procedure should be conducted regularly to ensure that exposures are acceptable. The frequency will depend on the nature of the process and the reliability of the controls in place. Where it is unclear as to whether exposures are acceptable or not, consideration should be given to carrying out a more detailed exposure measurement survey using a more accurate method. Refer to ESIG Best Practice Guide 1 'Measuring Solvent Vapour Concentrations in the Work Environment'.

Step 1: Identify Solvent(s) OEL (refer also to Section 3)

Identify the OEL of the solvent(s) from the Safety Data Sheet (SDS), (reference Section 8 of the SDS). In the case of a hydrocarbon solvent, the OEL may need to be taken from the list of recommended OELs issued by HSPA.

Step 2: Select Appropriate Chemical Indicator Tube(s)

A broad listing of suggested detector tubes for selected solvents is shown in Appendix 1 for hydrocarbon solvents and Appendix 2 for oxygenated solvents. Appendix 2 also lists existing suppliers of CITs.

Determine if an appropriate tube is available, taking into account the limitations identified in Section 2 on page 5. and the identified OEL for the solvent of interest. If a mixture of solvents is being used, users should contact the tube manufacturers for advice on the most suitable tubes to use for the solvents in question. In the event of no tube being available the advice of an occupational hygienist should be sought.

Step 3: Identify the Tasks Involving Potential Exposure

In order to estimate personal exposure to the solvent, it is necessary to first organise the workforce into groups of workers with similar exposures (Job Types). For each Job Type identify those tasks involving potential exposure carried out over a typical shift, e.g. collecting a sample, drum filling, decanting, application of the solvent, exposure to background concentrations within the work area(s).

Step 4: Perform Measurements

For each identified task, take three airborne concentration readings in close succession using the selected tube. When assessing personal exposure these readings should be taken within the breathing zone of the worker (see table above).

Calculate the mean for each set of 3 readings (i.e. the arithmetic average). In view of the potential variability of vapour levels, ensure that none of the readings is greater or less than double the arithmetic mean concentration (or $\pm 100\%$). If one or more readings do not match this criteria, then take a further 2 readings. If this does not apply, progress to Step 5.

Note:

Three readings are likely to be sufficient where steady plant or operating conditions prevail. Where the nature of the activity or process gives rise to markedly fluctuating concentrations, more readings may be necessary to characterise the spread of concentrations and the typical average reading.

Note down the duration of each task (e.g. 60 minutes, 2 hours). This is required in order to estimate the Time Weighted Average exposure for the duration of the Operator's whole shift.

Carry out a similar exercise when checking for plant and equipment leaks.

Step 5: Calculate Approximate Personal Exposure and Decide on Need for Action

For each task, take the average reading and multiply this by the duration of the task. Add up the results obtained for each task, taking account of periods of non-exposure over the shift (e.g. during meal breaks where these have been taken outside the work area), and divide the total by 8 hours (or 480 mins) to obtain a rough estimate of the Time Weighted Average exposure for the appropriate Job Type. Refer to Appendices 3 and 4 for examples.

Note:

This indication of exposure is based on the assumption that these measurements are representative of exposures throughout the work shift.

If using a single solvent, then for situations where exposure levels are not acceptable (greater than 50% OEL), then remedial action should be taken to improve controls with immediate effect. In the short term it may be necessary to use respiratory protective equipment whilst an engineering solution, such as installing local exhaust ventilation, is planned. It should be noted that control measures used for one solvent, may not necessarily provide the same degree of control for another. Information on controls is provided in ESIG Best Practice Guide 2: 'Guide to Managing Solvent Exposure'.

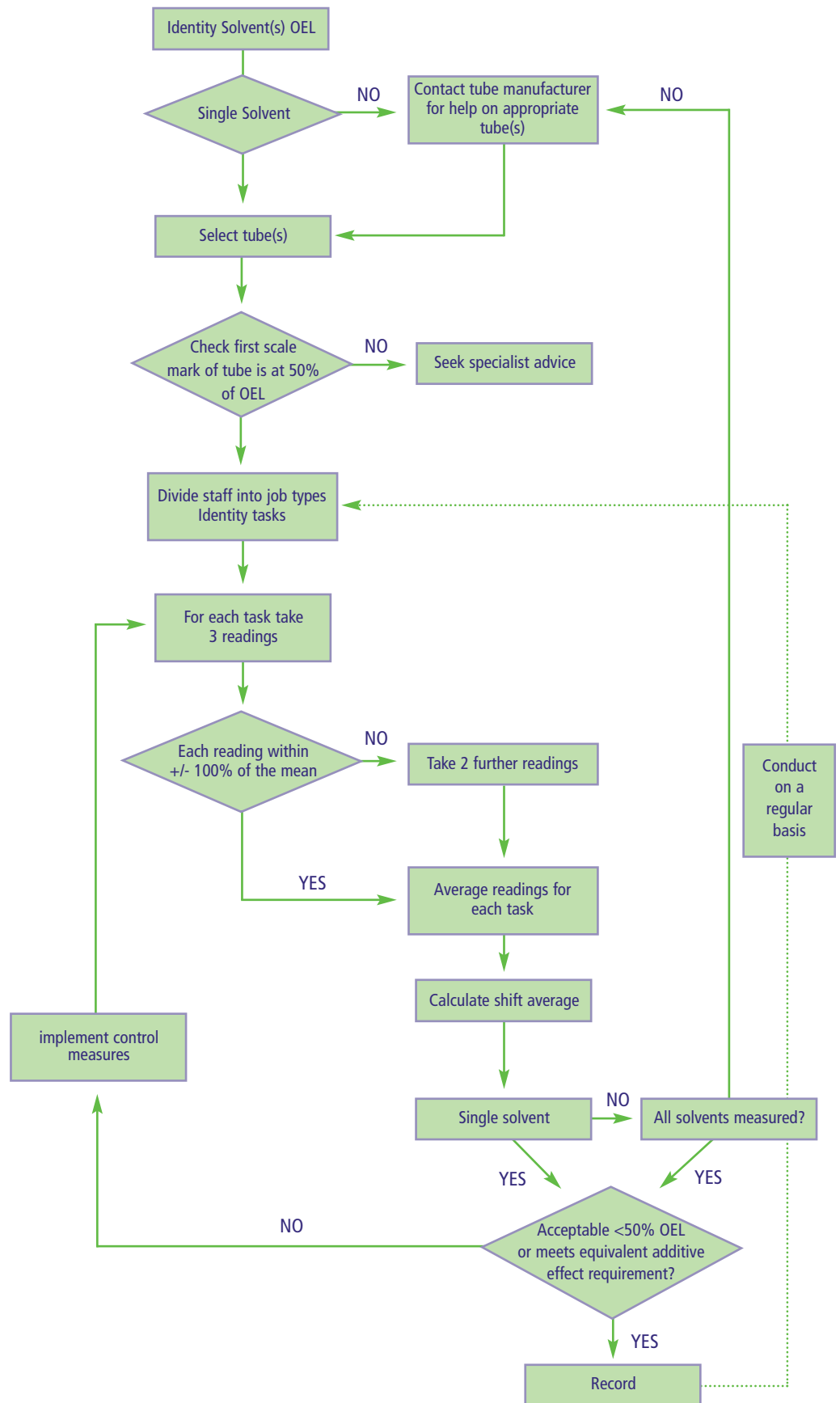
If using a mixture of solvents, then repeat the procedure from step 1 for each of the solvents and use the additive procedure shown in section 2 on page 3 to determine approximate personal exposure to the solvents in question. Where results of the additive calculation are >0.5 , this should be interpreted as being equivalent to $>50\%$ OEL, and hence remedial action to improve controls should be implemented. See previous paragraph.

Step 6: Record Measurement Results

Record the measurement results obtained in Steps 4 and 5.

Where remedial control measures are implemented, repeat Steps 3 - 6 to determine the effectiveness of these controls in reducing exposure.

FIGURE 1: FLOW DIAGRAM OF CHEMICAL INDICATOR TUBE MEASUREMENT PROCEDURE



5. Solvents containing n-Hexane

The hydrocarbon solvent n-hexane (i.e. n-C6) represents a particular hazard to health as it may cause peripheral nerve damage following chronic (long term) exposure. In view of this it has a lower OEL than many other hydrocarbon solvents. Where n-hexane is a constituent within a solvent mixture, it is important to ensure that exposures are controlled not only to within the OEL of the mixture itself, but also to the specific OEL for n-hexane.

With this in mind, the following is offered as a guide:

- Where the solvent mixture contains less than 40% n-hexane, exposure may be considered acceptable where the personal exposure measurement is less than 50% of the OEL (of the mixture)
- Where the solvent mixture contains more than 40% n-hexane, exposure may be considered acceptable where the personal exposure measurement is less than 20% of the OEL (of the mixture).

Examples are given in Appendix 4.

This document outlines a simple but pragmatic approach to estimating exposures in the workplace as an initial assessment, and for determining whether exposures are likely to be potentially excessive (i.e. significantly exceeding exposure limits). In some circumstances, however, a more detailed and formal investigation involving an occupational health specialist will be necessary in order to obtain a more accurate estimate of exposures.

Such situations may include:

- Situations where measurements clearly indicate potential for overexposure
- Where the solvent mixture cannot be measured using indicator tubes due to chemical interferences and related difficulties between the individual constituent solvents in the mixture
- Where the first scale mark of the tube is greater than 50% of the OEL
- Where workplace conditions give rise to markedly fluctuating solvent vapour concentrations, preventing any degree of confidence in the measurements and the efficiency of corresponding exposure controls
- To confirm regulatory compliance with OELs

APPENDIX 1 | SUGGESTED CHEMICAL INDICATOR TUBES FOR SELECTED HYDROCARBON SOLVENTS

Solvent	n-hexane %	Aromatics %	Boiling range °C	Tube Manufacturer and Overall Concentration Range ¹ (units are ppm volume unless otherwise specified)				
				Dräger	Gastec	Kitigawa	MSA	RAE
Pentanes	<1	<0.1	24-50	100 - 2,500	30 - 1680 375 - 18000	50 - 1000	50 - 3900	50 - 1000 25 - 2000
Technical hexane	40-55	<0.1	65-70	5 - 150 10 - 300 100 - 2,500	50 - 1200 10 - 50	5 - 200 5 - 1400	50 - 3900	50 - 1000 25 - 2000
Iso hexanes	<5	<0.1	55-65	20 - 600	50 - 1200 10 - 50	Indication only	-	50 - 1000 25 - 2000
Aliphatic solvents 60-85, low n-hexane	<5	<0.1	60-100	10 - 300 100-2500	500 - 1000 1000 - 12000 12000 - 2400	5 - 200	-	50 - 1000 25 - 2000
Dearomatised Heptane Fraction	<3	<0.1	94-100	100 - 2,500	500 - 1000 1000 - 12000 12000 - 24000	5 - 200	20 - 2600	50 - 1000 25 - 2000
Aliphatic Dearomatised Solvents 80-110	<5	<0.1	75-115	10 - 300 100 - 2500	500 - 1000 1000 - 12000 12000 - 24000	Wide range available	-	50 - 1000 25 - 2000
Aliphatic Dearomatised Solvents 100-140	<1	<1	95-140	10 - 300 100 - 2,500	500 - 1000 1000 - 12000 12000 - 24000	Wide range available	-	50 - 1000 25 - 2000
Toluene	NA	100	110	5 - 80 50-300 100-600 100-1800 300-600	2 - 50 5-10 10-300 50-100 300-600	2-100 10-500 100-3000	5-1000	10-300 5-600
Aliphatic Dearomatised Solvents 135-165	NA	<0.1	130-170	10 - 300 100-2500	500-1000 1000-12000 12000-2400	-	-	50-1000 25-2000
Solvent Xylene	NA	100	137-142	5 - 80 10-400 50-300 100-1800 250-1000	10-250 250-625 1000-12000	5-200 5-1000	-	10-200 5-400
Mineral Spirits 150-200	NA	20	140-200	10 - 300 100 - 2,500	50 - 800mg/m3	0 - 35mg/l	-	50 - 1000 25 - 2000
Dearomatised Mineral Spirits 150-200	NA	<1	145-200	10 - 300 100 - 2,500	50 - 800mg/m3	0 - 35mg/l	-	50 - 1000 25 - 2000
Mineral Spirits 175-220	NA	20	175-220	10 - 300 100 - 2,500	50 - 800mg/m3	50 - 1400	-	-
Dearomatised Mineral Spirits 176-220	NA	<1	175-220	10 - 300 100 - 2,500	50 - 800mg/m3	-	-	-
Aliphatic Solvents 200-250	NA	20	180-250	10 - 300 100 - 2,500	100 - 200 200 - 3000	-	-	-
Aliphatic Dearomatised Solvent 200-250	NA	<1	190-250	10 - 300 100 - 2,500	100 - 200 200 - 3000	-	-	-
Aromatic Solvents 160-185	NA	100	155-185	5 - 80 50 - 300 100 - 1800	-	-	-	-
Aromatic Solvents 180-215	NA	100	180-215	5 - 80 50 - 300 100 - 1800	-	-	-	-
Isoparaffinic Solvents 150-180	NA	<1	150-185	10 - 300 100 - 2,500	50 - 800mg/m3	-	-	50 - 1000 25 - 2000
Isoparaffinic Solvents 180-220	NA	<1	175-220	10 - 300 100 - 2,500	50 - 800mg/m3	-	-	-

¹N.B. The concentration range specified in the table represents the overall range of the tube for hydrocarbon solvents, however, the actual range for a particular solvent type may be slightly different. In addition, clarification of the actual tube required may be necessary, in particular for solvent mixtures.. Users are advised to contact the supplier for specific guidance.

Product Group Solvent CAS Number	Tube Manufacturer and Overall Concentration Range (i.e. units are ppm volume unless otherwise specified)				
	Dräger	Gastec	Kitigawa	MSA	RAE u/c
ALCOHOLS					
For mixtures contact the manufacturers listed for the most suitable tubes					
Methanol 67-56-1	25 - 5000 100 - 3000	20 - 40 40 - 1000 20 - 45000	20 - 1000	100 - 2350	-
Ethanol 64-17-5	12 - 50 25 - 2000 100 - 3000	50 - 100 100 - 2000 100 - 75000	500 - 50000	100 - 6000	-
n-Propanol 71-23-8	100-3000	65-1040	20 - 300	100 - 3000	-
iso-Propanol 67-63-0	15 - 40 50-4000 100 - 3000	25-50 50-800	20 - 480 50 - 1200	100 - 5000	-
n-Butanol 71-36-3	30 - 50 100-5000	10-150	5 - 100	100 - 3900	-
sec- Butanol 78-92-2	qualitative	5-150	4 - 120 10 - 300	100 - 5100	-
tert-Butanol 75-65-0	50 - 500	500-12000	indication	-	-
Hexanol 111-27-3	100-500	75-2400	-	-	-
Cyclohexanol 108-93-0	50	5 - 100	5-500	-	-
Amyl Alcohol 71-41-0	100-2000	-	5 - 100	-	-
iso-Amyl Alcohol 123-51-3	5	5 - 300	5 - 100	-	-
ESTERS					
For mixtures contact the manufacturers listed for the most suitable tubes					
Methyl acetate 79-20-9	200-3000	-	100 - 30000	-	-
Ethyl acetate 141-78-6	200-3000	25-800	20 - 1000	200 - 300	-
n-Propyl acetate 109-60-4	200-3000	20-500	20 - 1000	-	-
iso-Propyl acetate 108-21-4	200-3000	20-500	20 - 1000	-	-
n-Butyl acetate 123-86-4	200-3000	10-300	10 - 400	-	-
iso-Butyl acetate 110-19-0	100-1000	10-300	10 - 400	-	-
Amyl/isoamyl acetate 628-63-7 / 123-92-2	200-1000	10-200	10 - 400	-	-
GLYCOL ETHERS					
Only a small range of detector tubes are currently available for measuring glycol ethers and esters (see section 4.2). You should contact one of the suppliers listed. Kitagawa supplies a tube for measuring butyl glycol ether (10-1000)					
KETONES					
For mixtures contact the manufacturers listed for the most suitable tubes.					
Acetone 67-64-1	100-12000	50-4000	40 - 800 100 - 2000	10 - 10000	1000-20000 500 - 40000
Diacetone alcohol 123-42-2	qualitative	2.5-100	10 - 250	-	-
Methyl Ethyl Ketone 78-93-3	100-12000	21-1680	20 - 1500	50 - 4000	200 - 6000 100 - 18000
Methyl iso Butyl Ketone 108-10-1	1300-156000	500-6000	5 - 300	-	-
Cyclohexanone 108-94-1	<50	2-30 30-75	2-100	-	-
Ethyl Amyl Ketone 541-85-5	100	-	-	-	-
Isophorone 78-59-1	No	2-30	5 - 80	-	-
Hexan-2-one (Methyl n-Butyl Ketone) 591-78-6	qualitative	-	5 - 80	-	-
Methyl iso Amyl ketone 110-12-3	100-5000	-	-	-	-
OTHERS					
Tetrahydrofuran 109-99-9	50-400	20-50 50-800	20-500	half qualitative; 30 - 980	-

Suppliers of chemical indicator tubes

The tables above attempt to provide an overview of the commercially available detector tubes as at June 2002. It is recommended that you contact these suppliers for further information about their latest range of products and the services they can offer. For example, Dräger have recently introduced an 'electronic tube', the Chip Measurement System (CMS). Also, MSA provide a service where they will perform a specific tube calibration for those solvents that do not have a standard tube available.

Dräger	
Austria; +43 1/6 09 36 02	Belgium; +32 2/4 62 62 11
Denmark; +45 44/50 00 00	Finland; +358 (0)9-503771
France; +33 388/40 76 76	Germany; +49 451 882-0
Italy; +39 02 48 6971	Netherlands; +31 79/3 44 4666
Norway; +47 23069500	Spain; +34 91/3 58 02 44
Sweden; +46 325/129 60	UK; +44 (0)1670 35 28 91
Gastec	
Belgium (Scantec); + 32 3 6469896	Denmark (Claus Orno Agency); + 45 42852266
France (Prolabo); + 33 (1) 45148517	Greece (C.D.Kakavoulis); +30 7777911
Germany (al-envirotech); +49 211 75848 301	Netherlands (Buveco Instrument b.v); + 31 10 5217344
Italy (Velp Scientifica srl); +39 674632	UK (Anachem); +44 (0)1582 456666
Spain (Técnicas Ecologicas Indalo); + 34 912548029	
Kitagawa; Sabre and Protector International (Distributor)	
Germany; + 49 2103 2090	Ireland; + 353 43 46209/41984
Netherlands; + 31 10 2730397	Sweden (& all Nordic Countries); + 46 40302992
UK; +44 1252 342 352	
MSA	
Austria (MSA-AUER Sicherheitstechnik); +43 2278 3111	Belgium (MSA Benelux); +32 2 29250303
Europe (MSA Europe); +49 (30) 681 3028	France (MSA de France); +33 (1) 34 32 34 32
Germany (AuerGesellschaft GmbH); +49 (30)6886-0	Greece (Vanos S.A.); +30 1 4208840
Italy (MSA Italiana S.p.A.); +39 (2) 89-20-19-18	Netherlands (MSA Nederland B.V.); +31 (2290) 503-03
Norway (Lexow A.S.) +47 22 087575	Spain (MSA Español S.A.); +34 (3) 372-51-62
Sweden (AB Tegma); +46 (40) 80200	UK (MSA (Britain) Ltd); +44 236 424 966
RAE u/c Systems	
Austria (Inovex GmbH); +43 1786 1640	Belgium: Supplied via Netherlands
Denmark (Instrumatic a/s); +45 868 90911	Finland (Senveco OY); +358 (0)9-5611270
France (Panametrics); +33 1 47 824281	Germany (Ansyco); +49 721 626560
Greece (Purcon Ltd); +30 1 779 3231	Ireland (Medical Supply Co.Ltd); +35 01 822 4222
Italy (Recom Industriale S.r.l); +39 10 4695325	Netherlands (Euro Index); +31 10 2888 000
Norway (Industriell Maleteknikk); +47 6 7972262	Portugal (Eximo); +351 69 827061
Spain (Sensotran S.L.); +34 9-3 431 4885	Sweden (Maetforum AB); +46 8 822550
UK (Shawcity Ltd); +44 1367 241675	

Refer to Appendix 4 for work examples of Solvents containing n-hexane.

**EXAMPLE 1:
Exposure to hydrocarbon solvent 'Aliphatic
dearomatised solvent 80-110'**

Step 1: Identify solvent OEL

OEL identified from the suppliers safety data sheet or the HSPA list of OELs for commercial grade hydrocarbon solvents, as follows:-

**OEL = 1200 mg/m³ (8 hour Time Weighted Average)
[equivalent to 289 ppm*]**

* As Chemical Indicator Tubes are almost exclusively calibrated in units of ppm it is necessary to convert the OEL from units of mg/m³ to ppm - see Appendix 5 for conversion formula.

Step 2: Select appropriate Chemical Indicator Tube

See Appendix 1 for list of known CITs for hydrocarbon solvents. Identify the tubes listed for Aliphatic dearomatised solvent 80-110 with a Lower Detection Limit (LDL) of * 50% of the OEL, i.e. an LDL of * 144 ppm. Tube with range 10 - 300 ppm selected.

Step 3: Identify the tasks involving potential exposure

Job Type: Operator

Tasks involving potential exposure identified:

- Task 1: Decanting solvent from bulk container
- Task 2: Using solvent
- Task 3: Background concentration in work area (i.e. away from workstations where solvent is used)

Step 4: Perform Measurements

Airborne concentrations measured in workers breathing zone:

Task 1: Decanting solvent from bulk container - duration 1 hour (T1)

3 measurements taken: 75 ppm; 125 ppm; 55 ppm

Arithmetic Mean: $(75 + 125 + 55)/3 = 85$ ppm

Record average exposure: 85 ppm (C1)

Task 2: Using solvent - duration 4 hours (T2)

3 measurements taken: 100 ppm; 90 ppm; 105 ppm

Average measurements: $(100 + 90 + 105) / 3 = 98$ ppm

Record average exposure: 98 ppm (C2)

Task 3: Background concentration in work area (i.e. away from workstations where solvent is used) - duration 1 hour (T3)

3 measurements taken: 20 ppm; 100 ppm; 25 ppm

Arithmetic Mean: $(20 + 100 + 25) / 3 = 48$ ppm (C3)

Two further measurements are taken as the 100 ppm reading is greater than double the Arithmetic Mean of 48 ppm

2 further measurements: 45 ppm; 30 ppm

Record average exposure: $(20 + 100 + 25 + 45 + 30) / 5 = 44$ ppm

The Operator spends the remainder of the 8 hour work shift, 2 hours (T4) in the rest room or office which are both located in 'clean' areas away from solvent exposure (C4)

Step 5: Calculate approximate personal exposure and decide on need for action

Combine the average exposures, taking account of periods when no exposure would have occurred, such as during breaks and offices where these are located in 'clean' areas away from solvent exposure.

Estimate of 8 hour exposure:

- $(C1 \times T1) + (C2 \times T2) + (C3 \times T3) + (C4 \times T4) / 8$ hr
- $(85 \times 1) + (98 \times 4) + (44 \times 1) + (0 \times 2) / 8$ hr
- $85 + 392 + 44 + 0 / 8$ hr
- 65 ppm (8 hour Time Weighted Average)

i.e. 22% of the OEL

If the measurements are representative of normal working, then exposures to airborne concentrations of this solvent are satisfactory as they are less than 50% OEL.

Step 6: Record measurement results

Make a written record of the measurement results also identifying: task details including control measures used, source of vapour, duration, frequency, occurrence that may have lead to an increased exposure, e.g. spillage.

EXAMPLE 2:

Exposure to isopropanol from washing down of lithographic printing presses in a UK industrial setting.

Step 1: Identify solvent OEL

OEL identified from the suppliers safety data sheet.

UK OEL = 999 mg/m³ (8 hour Time Weighted Average)

[equivalent to 400 ppm - see Appendix 5]

Step 2: Select appropriate Chemical Indicator Tube

See Appendix 2 for list of known CITs for oxygenated solvents. Identify the tubes listed for isopropanol with a Lower Detection Limit (LDL) of * 50% of the OEL, i.e. an LDL of * 200 ppm. Tube with range 20 - 480 ppm selected.

Step 3: Identify the tasks involving potential exposure

Job Type: Operator

Tasks involving potential exposure identified

- Task 1: Using solvent
- Task 2: Background concentration in work area (i.e. away from workstations where solvent is used)

Step 4: Perform Measurements

Airborne concentrations measured in workers breathing zone:

Task 1: Using solvent - duration 30 mins (T1), undertaken on 2 occasions during the workshift (i.e. 2 x 30 min = 1 hour)

3 measurements taken: 105 ppm; 150 ppm; 85 ppm

Arithmetic Mean: $(105 + 150 + 85)/3 = 113$ ppm

Record average exposure: 113 ppm (C1)

Task 2: Background concentration in work area (i.e. away from workstations where solvent is used) - duration 4 hours (T2)

3 measurements taken: 20 ppm; 60 ppm; 25 ppm

Arithmetic Mean: $(20 + 60 + 25)/3 = 35$ ppm (C3)

Record average exposure: 35 ppm

The Operator spends the remainder of the 8 hour work shift, 3 hours (T3) in areas away from solvent exposure (C3)

Step 5: Calculate approximate personal exposure and decide on need for action

Combine the average exposures, taking account of periods when no exposure would have occurred, such as during breaks and offices where these are located in 'clean' areas away from solvent exposure.

Estimate of 8 hour exposure:

- $(C1 \times T1) + (C2 \times T2) + (C3 \times T3) / 8 \text{ hr}$
- $(113 \times 1) + (35 \times 4) + (0 \times 3) / 8 \text{ hr}$
- $113 + 140 + 0 / 8 \text{ hr}$
- 32 ppm (8 hour Time Weighted Average)

i.e. 22% of the OEL

If the measurements are representative of normal working, then exposures to airborne concentrations of this solvent are satisfactory as they are less than 50% OEL.

Step 6: Record measurement results

Make a written record of the measurement results also identifying: task details including control measures used, source of vapour, duration, frequency and occurrence that may have lead to an increased exposure, e.g. spillage.

The following examples have been based on the scenarios and concentrations given in Appendix 3. Refer to Section 5 on page 11 "Solvents containing n-hexane".

**EXAMPLE 3:
USING SINGLE SOLVENT CONTAINING N-HEXANE >40%
TECHNICAL HEXANE (40 - 55% N-HEXANE)**

HSPA OEL for Technical hexane = 300 mg/m³ (8 hour TWA) [equivalent to 100 ppm]

TWA Personal exposure measurement from Example 1= 65 ppm (8 hour TWA)

i.e. 65% of the OEL

This exceeds the 20% safe cut-off for solvents containing >40% n-hexane, therefore immediate measures to improve exposure controls must be taken. Repeat exposure measurements to check effectiveness of new controls.

TWA Personal exposure measurement from Example 2= 32 ppm (8 hour TWA)

i.e. 32% of the OEL

As above.

**EXAMPLE 4:
USING SOLVENT CONTAINING N-HEXANE <5% - ISOHEXANES**

HSPA OEL for Isohexanes = 1200 mg/m³ (8 hour TWA) [equivalent to 400 ppm]

TWA Personal exposure measurement from Example 1 = 65 ppm (8 hour TWA)

i.e. 16.25% of the OEL

This is within the 40% safe cut off for solvents containing <40% n-hexane, therefore exposures are acceptable.

TWA Personal exposure measurement from Example 2 = 32 ppm (8 hour TWA)

i.e. 8% of the OEL

As above.

1. Converting between ppm and mg/m³

From mg/m³ to ppm

$$C \text{ (ppm)} = \frac{C \text{ (mg/m}^3\text{)}}{\text{Mol.Wt}} \times 24.055$$

Where 24.055 is the mole volume of an ideal gas at 20°C and 1 atmosphere (760 mm Hg, 101325 Pa, 1.01325 bar).

Molecular weight (i.e. the molar mass, in g/mole) is substance specific and should be referenced from chemical suppliers or scientific texts.

Example for ethanol:

$$C \text{ (ppm)} = \frac{500 \text{ (mg/m}^3\text{)}}{46.1} \times 24.055$$

Molecular weight = 46.1 (i.e. the molar mass, in g/mole)

Assumed concentration = 500 mg/m³

Concentration = 261 ppm

From ppm to mg/m³

$$C \text{ (mg/m}^3\text{)} = \frac{C \text{ (ppm)}}{24.055} \text{ Mol.Wt (g)}$$

Using the assumed concentration calculated above;

$$C \text{ (mg/m}^3\text{)} = \frac{261 \text{ (ppm)}}{24.055} \times 46.1 \text{ (g)}$$

Concentration = 500 mg/m³

2. Converting between % volume and ppm

Some indicator tubes have a measurement range listed in %volume. To convert to ppm multiply by 10000.

- e.g. 0.001% = 10ppm
- e.g. 0.05% = 500ppm

APPENDIX 6 GLOSSARY OF ABBREVIATIONS AND SELECTED DEFINITIONS

ACGIH	American Conference of Governmental Industrial Hygienists; a group of American scientists who set exposure limits for industrial chemicals by examining information on their effects. ACGIH set Threshold Limit Values (TLVs).
Additive effect	These are exposures where the effects of the constituents reinforce each other and the substances are additive in effect.
CAS No.	The Chemical Abstract Service Number. A unique number assigned to individual compounds.
CIT	Chemical Indicator Tube.
ESIG	European Solvents Industry Group.
HRA	Health Risk Assessment. The identification of health hazards in the work place and subsequent assessment of risk to health, taking account of existing control measures. Where appropriate, the need for further measures to control exposure is identified.
HSPA	Hydrocarbon Solvents Producers Association.
Independent effect (mixtures)	Where no synergistic or additive effects are known or considered likely, the constituents can be regarded as acting independently.
LDL	Lower Detection Limit. The lowest airborne concentration that the measurement method can detect.
MAK	Maximum Concentration Values in the Workplace. The German system for setting exposure limits to airborne chemicals.
OEL	Occupational Exposure Limit. This is the general term for the airborne concentration of a chemical judged to be adequate to protect against adverse health effects when compared to a standard reference period. Two time periods are normally used, long term (8 hours) and short term (15 minutes). It should be noted that in some countries different types of OEL may be set which may require achievement of exposure levels as far below the OEL as reasonably practicable, e.g. the UK Maximum Exposure Limit. It is recommended that fuller definitions of national, regulatory OELs should be sought within the country of use.
OSPA	Oxygenated Solvents Producers Association.
PID	Photo-Ionisation Detector
ppm	Parts per million.
Synergistic effect (mixtures)	The overall effect is considerably greater than the sum of the individual effects. This may arise from the mutual enhancement of the effects of the constituents of the mixture or because one substance potentiates another, causing it to act in a way which it would not do alone.
SDS	Safety Data Sheet. A legal requirement for all chemical substances for supply that provides comprehensive safety, health and environmental information. In particular they provide: information on the main HSE hazards; how to protect against them in normal usage and in emergency situations; OELs; handling, storage and transport; spills and disposal advice; regulatory information such as classification and labelling; toxicity and environmental information.
STEL	Short Term Exposure Limit, reference period normally 15 minutes.
TLV	Threshold Limit Values. The ACGIH system for setting exposure limits to airborne chemicals.
TWA	Time Weighted Average. The normal method for calculating how much airborne chemical a worker has been exposed to. Often measured over an 8-hour working day.

APPENDIX 7 | THE USE OF PORTABLE PHOTO-IONISATION DETECTORS (PIDS) FOR REAL-TIME HYDROCARBON VAPOUR MONITORING

Chemical Indicator Tubes (CITs) offer a high level of simplicity of use coupled with low unit cost. However, new technology for monitoring solvent vapours is gradually being introduced to supplement, and in some cases, replace, the use of tubes. This new technology comes in the form of portable detectors utilising the principle of photo-ionisation. These devices are increasingly being used for real-time and TWA monitoring of Volatile Organic Hydrocarbons in workplace environments.

The principle is electrodeless 10.6 eV UV lamps which ionise chemical compounds. Note that these can only be used for compounds with ionisation potentials below 10.6 eV. Higher energy lamps (11.7 eV) can also be obtained and used for some applications.

The practical advantages include :

- low limits of detection e.g. < 1 ppm, ranging to 2000 ppm;
- real-time LED display for user;
- ease of portability;
- datalogging facility, linked to TWA/STEL calculations;
- alarms can be set at various concentration levels.

PIDs can be used to measure the airborne concentrations of single solvents or mixtures of solvents. Detailed calibration protocols are provided with PID devices, including calibrant materials. It is however recommended that potential users of PID devices contact the manufacturer for specific instructions when performing calibration. Note that whereas calibration for single substances is relatively straightforward, calibration for complex hydrocarbon solvent mixtures may be progressively more complicated and may not yield a quantitatively accurate result. Advice and guidance from the manufacturer should be sought whenever the PID user wishes to monitor airborne mixtures of solvent vapours.

Currently, most commercial PID devices cost between (Euro) 1900 - 8000, hence the unit purchase cost exceeds the cost of CIT monitoring apparatus by several orders of magnitude.

However, potential users should consider two factors :

- As with most new and emerging technology, unit costs fall as useage increases.
- PIDs are "re-useable devices", whereas CIT tubes are "use once, throw away" devices. An SME carrying out more than 300 - 500 indicator tube determinations in a year would incur the same level of cost as that incurred in purchasing a basic PID device (e.g. a RAE u/c Systems "Toxirae" PID).

ESIG are monitoring developments in the application of PID technology for the monitoring of solvent vapours (i.e. hydrocarbon and oxygenated) which may represent the basis of a future Best Practice Guidance Document. In the meanwhile, potential users are welcome to seek advice and guidance on their use via ESIG.

Other Guides available in the series are:

- BPG1: Measuring Solvent Vapour Concentrations in the Work Environment
- BPG2: Guide to Managing Solvent Exposure

All the guides can be obtained either electronically from the ESIG web site at www.esig.org or by contacting the ESIG Secretariat by telephone at +32 2 676 72 64 or by fax at +32 2 676 72 16.

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