Background: This new guideline has been developed to explain a change by ACGIH in the method for determining occupational exposure limits for certain refined hydrocarbon mixtures (Rubber Solvent, VM & P Naphtha).

G5.48-11 Establishing exposure limits for certain refined hydrocarbon mixtures
Preliminary Issue July 1, 2009

Regulatory excerpt
Section 5.48 of the OHS Regulation (“Regulation”) states:

Except as otherwise determined by the Board, the employer must ensure that no worker is exposed to a substance that exceeds the ceiling limit, short-term exposure limit, or 8-hour TWA limit prescribed by ACGIH.

(TWA refers to time-weighted average, and ACGIH refers to American Conference of Governmental Industrial Hygienists.)

Purpose of guideline
This guideline provides an explanation of the means to determine occupational exposure limits for certain refined hydrocarbon solvent mixtures such as rubber solvent and VM & P Naphtha. Hydrocarbon solvents affect the central nervous system and can cause a variety of symptoms including dizziness, drowsiness, and eye and respiratory tract irritation.

Note: Due to the complexities inherent in the use and interpretation of the Reciprocal Calculation Procedure (RCP), it will usually be necessary for an occupational hygiene professional to be involved in the application of this method.

Background
The majority of WorkSafeBC exposure limits are for single substances (e.g. toluene) or for substances containing a common element (e.g. tungsten metal and insoluble compounds). These exposure limits are those prescribed by ACGIH or as otherwise determined by WorkSafeBC. They are shown in the WorkSafeBC Table of Exposure Limits for Chemical and Biological Substances.

Refined hydrocarbon solvents, such as Rubber Solvent and VM & P Naphtha, are complex mixtures produced by the distillation of petroleum over a particular boiling range. They consist of aliphatic (alkane), cycloaliphatic (cycloalkane), and aromatic hydrocarbons ranging from 5 to 15 carbon atoms in each molecule. The use of the mixture formula expressed in Regulation section 5.51, which takes additive effects into consideration, is difficult in these cases because these petroleum mixtures contain a large number of unique compounds and isomers, many of which do not have specific exposure limits. Because there are very many possible combinations of the various alkane, cycloalkane, and aromatic mixtures, it is necessary to calculate an exposure limit for each combination rather than list all possible calculated exposure limits in the Table of Exposure Limits for Chemical and Biological Substances.
The ACGIH has developed a means to calculate an exposure limit for specific refined hydrocarbon solvents, and has published the method (RCP) in Appendix H of the ACGIH publication *Threshold Limit Values and Biological Exposure Indices*, since 2009. The remainder of this guideline explains WorkSafeBC’s adoption of this method and provides example calculations.

**Reciprocal Calculation Procedure**
The RCP is a method for deriving exposure limits (EL) for refined hydrocarbon solvents. This method is applicable if the toxic effects of the individual chemical components are additive (e.g., similar effects on the same organ or system).

The RCP calculation can only be applied to petroleum-based hydrocarbon solvents containing saturated aliphatics (alkanes and cycloalkanes) and aromatics with 5 to 15 carbon atoms and boiling points between 35°C and 329°C. The substances for which the RCP calculation applies are identified with an "(H)" in the Table of Exposure Limits (e.g. see Rubber Solvent, VM & P Naphtha). It would not apply to petroleum fuels, lubricating oils or solvents or solvent mixtures that already have an EL (e.g. benzene has its own EL and would have to be considered separately).

The RCP formula calculates an EL based on
- The mass composition of the mixture
- Hydrocarbon group “guidance values”
- Substance-specific ELs, where applicable (see Note)

Note: The RCP does not apply to solvents containing benzene, n-hexane, or methyl naphthalene, which have individual ELs significantly less than the guidance values to which they would belong and have unique toxicological properties. Whenever present in the mixture, these components should be measured individually.

Guidance values have been developed by a number of researchers, groups, and regulatory authorities, based on the chemical and toxicological properties of various hydrocarbon groups (e.g., C5 - C6 alkanes and C7 - C8 aromatics). The guidance values adopted by WorkSafeBC (Table 1) were developed by the UK Health and Safety Executive, a recognized health and safety authority.

<table>
<thead>
<tr>
<th>Hydrocarbon Group</th>
<th>Number of Carbon Atoms</th>
<th>Guidance Value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal and branched chain alkanes (excluding n-hexane and n-heptane)</td>
<td>C5 - C6</td>
<td>1800</td>
</tr>
<tr>
<td></td>
<td>C7 - C8</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>C9 - C15</td>
<td>1200</td>
</tr>
<tr>
<td>Cycloalkanes (excluding cyclohexane)</td>
<td>C5 - C6</td>
<td>1800</td>
</tr>
<tr>
<td></td>
<td>C7 - C8</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>C9 - C15</td>
<td>800</td>
</tr>
</tbody>
</table>
The reciprocal calculation mixture formula is

\[
EL_{\text{solvmix}} = \frac{1}{\text{Liquid mass fraction of group “a” (value between 0 and 1) } \times \text{Guidance value for group “a” (from Table 1)} + \ldots + \text{Guidance value for group “n” (from Table 1)}}
\]

The resulting calculated \( EL_{\text{solvmix}} \) value should follow established recommendations regarding rounding. For calculated values <100 mg/m\(^3\), round to the nearest 25. For calculated values between 100 and 600 mg/m\(^3\), round to the nearest 50, and for calculated values >600 mg/m\(^3\), round to the nearest 200 mg/m\(^3\).

**Example 1**
The following is an example of how the RCP is applied to determine the EL for a solvent mixture (\( EL_{\text{solvmix}} \)). Rubber solvent typically contains the following percentage of hydrocarbons:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent Hydrocarbon Composition</th>
<th>Guidance Value (mg/m(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>C7 - C8 alkanes &amp; cycloalkanes</td>
<td>52%</td>
<td>800</td>
</tr>
<tr>
<td>C9 - C10 alkanes &amp; cycloalkanes</td>
<td>40%</td>
<td>800</td>
</tr>
<tr>
<td>C7 - C8 aromatics</td>
<td>10%</td>
<td>500</td>
</tr>
<tr>
<td>Toluene</td>
<td>6%</td>
<td>75 (see Note)</td>
</tr>
</tbody>
</table>

Note: The exposure limit is expressed in mg/m\(^3\). The EL in the EL Table has been converted from ppm.

The RCP calculation for this mixture is

\[
EL_{\text{solvmix}} = \frac{1}{0.52 \left( \frac{800}{800} \right) + 0.40 \left( \frac{800}{800} \right) + 0.10 \left( \frac{500}{500} \right) + 0.06 \left( \frac{75}{75} \right) } = \frac{1}{0.00215}
\]
= 465 mg/m³, rounded to 450 mg/m³

Hence the EL for this particular type of refined hydrocarbon solvent mixture is 450 mg/m³.
Example 2
The material safety data sheet for a solvent showed the following percentages and chemical composition:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent Hydrocarbon Composition</th>
<th>Guidance Value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C7 - C8 alkanes &amp; cycloalkanes</td>
<td>45%</td>
<td>800</td>
</tr>
<tr>
<td>C9 - C10 alkanes &amp; cycloalkanes</td>
<td>40%</td>
<td>800</td>
</tr>
<tr>
<td>C7 - C8 aromatics</td>
<td>9%</td>
<td>500</td>
</tr>
<tr>
<td>Toluene</td>
<td>6%</td>
<td>75 (OEL)</td>
</tr>
<tr>
<td>Benzene</td>
<td>&lt;1%</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

The RCP calculation for this mixture is:

\[
\text{EL}_{\text{solvmix}} = \frac{1}{\frac{0.45}{800} + \frac{0.40}{800} + \frac{0.09}{500} + \frac{0.06}{75}}
\]

\[
= \frac{1}{0.00204} = 490 \text{ mg/m}^3, \text{ rounded to 500 mg/m}^3
\]

The EL for this particular solvent mixture is 500 mg/m³. However, benzene must be evaluated separately at the current EL for benzene.

**Limitations of the reciprocal calculation method**
Care in the use of the \( \text{EL}_{\text{solvmix}} \) should be observed where the mixture in question is known to have significant toxicokinetic interactions of components that are manifested at or below the guidance values.

The use of the RCP should be restricted to applications where the boiling points of the solvents in the mixture are relatively narrow, within a range of less than 45°C (i.e., vapour pressure within approximately one order of magnitude). The procedure should not be used in situations where the liquid composition is significantly different from the vapour composition.

The guidance values apply only to vapours and do not apply to mists or aerosols. The calculation does not apply to mixtures containing olefins or other unsaturated compounds or polycyclic aromatic hydrocarbons (PAHs).
Further reading
ACGIH *Threshold Limit Values and Biological Exposure Indices*, Appendix H (2009)
European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC).
  Brussels, Belgium (1997).
Farmer TH: *Occupational hygiene limits for hydrocarbon solvents*. Annals of
McKee RH; Medeiros AM; Daughtrey, WC: *A proposed methodology for setting
  occupational exposure limits for hydrocarbon solvents*. J of Occ and Env Hygiene
UK Health and Safety Executive (UKHSE) EH40/2000. *Occupational Exposure Limits*
  (2000).