POLYESTER URETHANE POWDER COATINGS
HEALTH AND SAFETY INFORMATION
SUMMARY

Polyester urethane powder coatings health and safety information has been amassed by The Powder Coating Institute in an attempt to help inform more people about this type of powder coating. The resulting “white paper” is structured to provide information about the chemistry of polyester, and polymeric blocked diisocyanate curing agents.

Toxicological information about caprolactam, which is used as a blocking agent for most polymeric blocked diisocyanates is discussed. Isocyanate monomers are used as “building blocks” to manufacture the polymeric blocked diisocyanate curing agents. Emphasis of the inherent safety associated with polymeric blocked diisocyanates verses their monomer building blocks is made.

Exposure to toxic materials such as monomeric diisocyanates during the use of polyester urethane powder coatings is not likely to occur. Poor oven exhaust and high temperatures can cause traces of monomeric diisocyanates to be generated. Decomposition of polyurethane powder coatings via high temperatures should be avoided, since toxic combustion or decomposition products such as carbon monoxide, can be present. Risks of exposure to potentially toxic materials can be minimized by providing proper cure oven exhaust and by not allowing powder to come in contact with oven heating elements. Recommendations are made to provide proper work place airflow to keep the air free of hazardous materials. Hygiene practices are also outlined.

The conclusion is reached that polyester urethane powder coatings can be used without exposure to blocking agents and decomposition products including isocyanates in a properly operating facility.
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A. INTRODUCTION

Polymeric blocked isocyanate curing agents are well known in the powder coating industry. These compounds have been used for many years to produce polyurethane powder coating compositions. The most widely used polymeric blocked isocyanate curing agent is based on isophorone diisocyanate and its higher functionality adducts. Some other polymeric blocked diisocyanate curing agents are based on ε-caprolactam blocked methylene-bis-4-cyclohexyl diisocyanate, and toluene diisocyanate. Polyester/urethane powder coatings, used in the thin-film decorative market, represent approximately 35 percent of the volume in the North American market.

Polyester/urethane powder coatings are made from the following ingredients:

- **Polyester** resins are most typically made by condensation reactions between multifunctional organic acids, anhydrides, polyols and esters.

\[
\begin{align*}
\text{O} & \quad \text{O} \\
\text{HO - C - R - C - OH} & \quad \text{+} \quad \text{HO - R - OH} \\
\text{Acid} & \quad \text{Polyol}
\end{align*}
\]

\[
\begin{align*}
\text{heat (350-500°F)} & \quad \text{catalyst} \\
\text{O} & \quad \text{O} & \quad \text{O} & \quad \text{O} \\
\text{HO [-R-O-C-R-C-O:] R-O-C-R-C-OH} & \quad \text{+} \quad \text{H}_2\text{O} \\
\text{n} & \quad \text{polyester resin} & \quad \text{reaction water}
\end{align*}
\]
Polymeric blocked diisocyanate curing agents: are made by reacting diisocyanate monomers with polyols and further reacting with blocking agents such as \(\epsilon\)-caprolactam (see example below). Other blocked isocyanates are based upon dimeric or oligomeric IPDI (isophorone diisocyanate).

\[
\begin{align*}
\text{IPDI (isophoronediisocyanate)} \\
\text{polyol}
\end{align*}
\]

Polyurethane Prepolymer

\[
\begin{align*}
\text{blocked polymeric diisocyanate curing agent}
\end{align*}
\]
Polyester resins designed to react (cure) with polymeric blocked diisocyanates are hydroxyl functional (OH). These polyester resins are thermosetting. They are part of a powder coatings system, which when cured by baking, forms a film that does not reflow if heated again and possesses good physical and chemical properties.

\[
\text{polyester/urethane powder coating}
\]

\[
\begin{align*}
\text{OH} & \\
\text{polyester resin} & + \varepsilon\text{-caps} & \\
\text{NCO} & \\
\text{diisocyanate} & \\
\text{curing agent} & \\
\text{heat/cure} & \\
\varepsilon\text{-cap} & \text{(some is exhausted from the cure oven)} & \\
\varepsilon\text{-cap} & \text{(some stays in the film)} & \\
\text{cured polyurethane film} & \\
\text{polyester} & \text{curing agent} & \text{polyester}
\end{align*}
\]

B. HEALTH CONCERNS AND SAFETY CONSIDERATIONS

1. TOXICOLOGY OF CAPROLACTAM

The toxicology of Caprolactam has been extensively investigated. The most likely route of exposure to powder coating applicators is through inhalation of vapors produced during baking of coated parts. The following exposure limits have been established by ACGIH and OSHA: Vapor: 5 ppm TWA, 10 ppm STEL. Dust: 1 mg/m³ TWA, 3 mg/m³ STEL. The workplace should be monitored to assure that these limits are not exceeded. Inhalation of caprolactam vapors may cause irritation of the mucous membranes of the nose, throat and respiratory tract. Prolonged exposure to high concentrations may cause nausea, vomiting, dizziness, headache and tremors. Ingestion may irritate the gastrointestinal tract resulting in nausea or vomiting. Caprolactam is moderately toxic by this route. A LD₅₀ value for ingestion by rats has been reported to be 1155-2140 mg/kg. The ACGIH has indicated in its 1986 Documentation of the TLVs and BEIs that caprolactam is a dermal sensitizer. A producer of caprolactam, however, states that the studies cited do not support this contention but rather provide evidence that caprolactam causes dermatitis. Numerous studies indicate that caprolactam is clearly non-carcinogenic, non-teratogenic, non-mutagenic and has a relatively low toxicity to humans. Numerous additional studies of the toxicology of caprolactam can be found in the November 1989 issue of Mutation Research (NETHERLANDS) volume 224.
2. TOXICOLOGY OF ISOCYANATES

Isocyanate vapors or mists at concentrations above the established TLV irritate the mucous membranes in the respiratory tract. Persons with a preexisting, nonspecific bronchial hyper-reactivity can respond to concentrations below the TLV with similar symptoms as well as an asthma attack. Exposure well above the TLV may lead to bronchitis, bronchial spasm and pulmonary edema. After repeated overexposures certain individuals will develop isocyanate sensitization which will cause them to react to a later exposure to isocyanates at levels well below the TLV. Chronic overexposure to isocyanates has also been reported to cause lung damage, including a decrease in lung function, which may be permanent. Isocyanates react with skin protein and moisture and can cause irritation; some persons may develop skin sensitization.

Isophorone diisocyanate and methylene-bis-4-cyclohexyl isocyanate are not listed as a carcinogen by either NTP, IARC or OSHA. Toluene diisocyanate is a potential human carcinogen. It has caused cancer in experimental laboratory animals (see National Toxicology Program [NTP] “4th Annual Report on Carcinogens,” U.S. Dept. of Health and Human Services, Public Health Service, 1985).18

The following are the current exposure limits established for the most common isocyanates used in powder coating curatives:

<table>
<thead>
<tr>
<th>IPDI, Isophorone Diisocyanate:</th>
<th>OSHA-PEL 0.005 ppm TWA (skin)</th>
<th>ACNIH-TLV 0.005 ppm TWA (skin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCI, Methylene-bis-4-cyclohexyl Isocyanate:</td>
<td>OSHA-PEL 0.010 ppm Ceiling</td>
<td>ACNIH-TLV 0.005 ppm TWA</td>
</tr>
<tr>
<td>TDI, Toluene Diisocyanate:</td>
<td>OSHA-PEL 0.005 ppm TWA</td>
<td>0.04 mg/m³ TWA</td>
</tr>
<tr>
<td></td>
<td>0.02 ppm STEL</td>
<td>0.15 mg/m³ STEL</td>
</tr>
<tr>
<td></td>
<td>ACNIH-TLV 0.005 ppm TWA</td>
<td>0.045 mg/m³ TWA</td>
</tr>
<tr>
<td></td>
<td>0.02 ppm STEL</td>
<td>0.15 mg/m³ STEL</td>
</tr>
</tbody>
</table>
3. TOXICOLOGY OF POLYMERIC BLOCKED DIISOCYANATES

Toxicity testing of Caprolactam blocked Isophorone diisocyanate (IPDI) curatives show them to be practically nontoxic. LD$_{50}$ values for oral feeding of rats have been reported to be >5000 mg/kg$^2$, LC$_{50}$ for rat inhalation has been reported to be >1255 mg as aerosol l/m$^3$, 4 hours of exposure. For Toluene Diisocyanate based curatives LD$_{50}$ values for oral feeding to rats have been reported* to be >5000 mg/kg and LC$_{50}$ values for inhalation are reported to be >267 mg/m$^3$. Similar toxicology data for Methylene-bis-4-cyclohexyl isocyanate (MCI) based curatives is not available. The mutagenicity of both caprolactam blocked IPDI and an "internally" blocked IPDI-butanediol adduct have been investigated**. Both the Caprolactam blocked IPDI adduct and the internally blocked adduct were found to be nonmutagenic by means of the Ames Salmonella typhimurium/microsomes mutagenicity test. The internally blocked adduct was also tested via a mammalian (rats) micronucleus test and was found nonmutagenic with and without the addition of S9 liver fraction.

4. EXPOSURE CONSIDERATIONS

The polymeric blocked diisocyanate curing agents have been tested for monomeric isocyanate content by several producers. For IPDI based curatives, no monomeric isocyanate was found above the detection limit of 500 ppm$^3$. For TDI based curatives, one supplier has detected less than 65 ppm monomeric TDI$^4$. Unreacted caprolactam levels in similar curatives have been estimated to be in the range of 0.5% or less. Typical blocked isocyanates contain approximately 40% reacted caprolactam. These curatives are used at a level of up to 60% of the total resin plus curative. In the most common systems, the curative is about 20% of the sum of resin plus curative. Air monitoring for monomeric IPDI during extrusion of powder coating paints has not shown the presence of this monomer at or above the detection limit of 0.005 mg/m$^3$ (0.6 ppb)$^7$. A recent Gas chromatograph/Mass Spec study of volatiles released during the curing of typical powder coatings at elevated temperature detected IPDI at a level of 2% of total volatiles, MCI at a level of 4% but found no TDI$^8$. An isothermal Thermogravimetric study has indicated that the amount of caprolactam evolved from a typical powder coating is about 4.7%$^8$. Total weight loss during cure of a typical white polyester/urethane usually is 1.5-5.0%.

Studies of worker exposure to IPDI at a well ventilated powder applicator showed no significant exposure to IPDI at or above the detection limit of 0.001 ppm$^9$. In application plants with poorly ventilated ovens, worker exposure to monomeric IPDI and also caprolactam was well above the OSHA PEL thus indicating the need for properly ventilated ovens$^{10}$. Where engineering controls are not practical, air supplied respirators should be used. During the application
tion of powder coating, persons potentially exposed to the powder should wear air purifying/toxic dust respirators unless air sampling shows that airborne dust concentrations are consistently controlled and below 10 mg/m³ for total dust (ACGIH-TLV) and below 5 mg/m³ for respirable dust (OSHA-PEL).

Exposure to monomeric diisocyanates during the baking process is unlikely. Proper oven exhaust prevents the likelihood of any trace amounts of diisocyanate monomer entering the workplace.

ε-caprolactam or other blocking agents are chemically bound to the curing agent polymer until heated in the baking oven. Exposure to ε-caprolactam or other blocking agents is possible if the curing/baking oven is not properly vented.

Since ε-caprolactam is considered an irritant, avoid skin contact with ε-caprolactam which may condense in oven air ducts or on roofs near oven exhausts. Avoid breathing oven exhaust or “smoke” from ovens that finds its way back into the workplace. Make sure that oven exhaust rates are sufficient to prevent “smoke” in the workplace.

Trace ppm levels of diisocyanate monomer can be present in oven exhaust gas. If a caprolactam blocked polyester urethane powder coating is decomposed from exposure to heat greater than 600°F, or burned, toxic combustion products will be formed. These toxic decomposition products are: carbon dioxide, carbon monoxide, nitrous oxides, hydrogen cyanide, isocyanate and various hydrocarbons.

5. RISK CONSIDERATIONS

Exposure to hazardous decomposition products can be avoided by providing proper cure oven exhaust and by not allowing powder to come in contact with flame in a direct fired gas oven or having powder come in contact with electric heating elements.

A good analogy of the toxic nature of oven combustion gases is burning firewood in a home fireplace. If the fireplace flue is not open, toxic combustion products, smoke, enters the home. People do not remain inside a smoke filled house, they either open the flue to properly ventilate the fireplace or leave the area.

The risks associated with burning a powder coating which is an organic material, or burning wood which is an organic material, are similar. Both produce toxic combustion products which can be harmful.

Proper oven exhaust prevents the possibility of trace levels of monomeric diisocyanate from entering the workplace.

Avoid breathing oven exhaust or “smoke”.

Toxic combustion products will be formed if powder coatings are subjected to temperatures greater than 600°F.

Exposure to hazardous decomposition products can be avoided by providing proper oven exhaust.

Risks associated with burning (decomposing) a powder coating and burning wood are quite similar.
6. INDUSTRIAL SAFETY

• Air Flow

Ventilation should be sufficient to keep the workplace air free of hazardous materials. Dust levels must be kept below the industry maximum (10 mg/m³).

Proper airflow must be maintained in powder coating spray booths to contain the powder. This prevents powder from contaminating the workplace air and creating additional exposure. It also prevents powders from being drawn into oven combustion areas where powder can be transformed to toxic combustion products.

Air from the workplace should always be flowing into the oven openings. Ovens should not be fuming into the workplace. Oven gas burners should be properly exhausted. This air should not be returned to the workplace. Oven cure zones should be exhausted. This air should not be returned to the workplace. One possible indication that an oven is not properly vented, is the presence of a haze in the workplace.

If there is any question about workplace air quality, an industrial hygienist should be consulted and specific measurements should be made.

The National Fire Protection Association in publication NFPA 86 specifies oven ventilation requirements for fire protection. NFPA 86 should be reviewed in its entirety. Some of the NFPA 86 recommendations (air intake basis at 70°F) and other considerations are as follows:

- One ft³/min for every 5700 btu/hr oven capacity rating for removal of by-products of combustion of natural gas, plus
- 2.2 ft³/min for every lb/hr of powder through the oven for removal of potential volatile compounds which may be generated in the powder curing operation.
- The workplace environment should be monitored to ensure that the combination of bake oven venting and room air turnover is sufficient to meet Permissible Exposure Limits (PEL) and other exposure limits for regulated substances as outlined on the powder MSDS (Material Safety Data Sheet) and in this publication.

• Hygiene

Always wash skin and clothing which has been exposed to powder coatings. Work clothes should be cleaned with soap and water, not dry-cleaned. Dry-cleaning solvents tend to partially dissolve the resins used in powder coatings and ruin the garment.

Since powder coatings are quite abrasive, promptly clean exposed skin, gently flushing with water and washing with mild soaps. Do not rub powder or leave powder on skin for long periods of time.

Problems associated with skin irritation and powder coatings can be prevented by using proper hygiene techniques.

Good workplace ventilation is necessary.

Powder should always be contained within the spray booth.

Ovens should not be fuming into the workplace.

Always wash skin and clothing which has been exposed to powder coatings.

Polyester/urethanes pose no greater risks than other powder coating products.
C. CONCLUSIONS

Polyester urethane powder coatings can be used without exposure to blocking agents and decomposition products of combustion including isocyanates.

The key to eliminating the risk of exposure associated with diisocyanate monomer and caprolactam is to make sure that bake ovens are properly exhausted and building air turn over is sufficient to keep the above materials below TLV's. This is important since there are no detectable levels of monomeric diisocyanate present in powder coatings stored at room temperature.

Any possible monomeric isocyanate that is generated occurs during the cure process inside the oven. Therefore, with a properly vented oven, there is no employee exposure to monomeric isocyanate or caprolactam blocking agent.
D. REFERENCES

1. Bayer DIN Safety Data Sheet for Crelan UI, August 26, 1988
2. Hüls product information on blocked IPDI adduct B 1065 and B989
4. Hüls Aktiengesellschaft Investigation Report, Dr. P. Scobert, March 12, 1987
4a. Hüls Mutagenicity test on IPDI Adduct B 1530 R&D Project Title 0780/HA, Sept. 1, 1989
5. RUco report to Morton Thiokol on monomeric disocyanate detection via HPLC for IPDI and TDI, October 26, 1988
6. Cargill MSDS for Powder coating Curing Agents 24-2400 and 24-2450, October 20, 1988
8. Allied report to RUco and Cargill; study of blocked isocyanate curative deblocking, volatilization and volatiles, March 23, 1990
16. Adler, ID, et al., Evaluation of Chromosomal Sberrations In Bone Marrow of 1C3F1 Mice, Mutation Research (NETHERLANDS), Vol. 224, pages 343-345, November 1989
E. GLOSSARY

ACGIH American Conference of Governmental Industrial Hygienists. ACGIH publishes threshold limit values, (TLV's), for chemical substances in the workplace and updates them annually.

Acute means a short term period of action measured in seconds, minutes, hours or days.

Carcinogen means a chemical which has been demonstrated to cause cancer in humans, or to cause cancer in animals and, therefore, is considered capable of causing cancer in humans. A chemical is considered to be a carcinogen if:

(a) it has been evaluated by the International Agency for Research on Cancer (IARC), and found to be a carcinogen or potential carcinogen; or

(b) it is listed as a carcinogen or potential carcinogen in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or

(c) it is regulated by OSHA as a carcinogen.

Carcinogen Listed In chemical is:

1. Listed in the National Toxicology Program (NTP) Annual Report on Carcinogens (latest edition)

2. Has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs or

3. Has been found to be a potential carcinogen by OSHA.

If the chemical is not listed, this is also indicated.

Chronic means a long time period of action in weeks, months or years.

Hazardous Decomposition Products

Hazardous materials produced in dangerous amount by burning, oxidation or heating are listed. Thermal decomposition products might include CO, CO₂, SO₂, NH₃, NO, oxides of nitrogen, phosgene, aniline, etc.

Example: Carbon tetrachloride undergoes thermal oxidation to produce phosgene and hydrogen chloride.
Hazardous Materials Identification System (HMIS)

It shows people how to safely handle the materials they work with.

This label is the key to the whole system.

<table>
<thead>
<tr>
<th>HEALTH (blue) Rating</th>
<th>FLAMMABILITY (red) Rating</th>
<th>REACTIVITY (yellow) Rating</th>
<th>PERSONAL PROTECTION (white) Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEALTH</td>
<td>FLAMMABILITY</td>
<td>REACTIVITY</td>
<td>PERSONAL PROTECTION</td>
</tr>
<tr>
<td>Minimal Hazard</td>
<td>No significant risk to health</td>
<td>Ignition or minor reversible injury possible</td>
<td>Minimal Hazard</td>
</tr>
<tr>
<td>Slight Hazard</td>
<td>Minimal Hazard</td>
<td>Temporary or minor injury may occur</td>
<td>Materials that are normally stable, even under fire conditions, and will not react with water</td>
</tr>
<tr>
<td>Moderate Hazard</td>
<td>Slight Hazard</td>
<td>Major injury likely unless prompt action is taken and medical treatment is given</td>
<td>Materials that are normally stable but can become unstable at high temperatures and pressures. These materials may react with water but they will not release energy violently</td>
</tr>
<tr>
<td>Serious Hazard</td>
<td>Moderate Hazard</td>
<td>Life-threatening, major or permanent damage may result from single or repeated exposures</td>
<td>Materials that, in themselves, are normally unstable and will readily undergo violent chemical change but will not detonate. These materials may also react violently with water</td>
</tr>
<tr>
<td>Severe Hazard</td>
<td>Serious Hazard</td>
<td>Uses of an asterisk (*) or other designation indicates that there may be chronic health effects present. See safety file on the product.</td>
<td></td>
</tr>
</tbody>
</table>

SUMMARY OF HMIS RATINGS

I. HEALTH HAZARD RATING

0 Minimal Hazard No significant risk to health
1 Slight Hazard Ignition or minor reversible injury possible
2 Moderate Hazard Temporary or minor injury may occur
3 Serious Hazard Major injury likely unless prompt action is taken and medical treatment is given
4 Severe Hazard Life-threatening, major or permanent damage may result from single or repeated exposures

Note: Use of an asterisk (*) or other designation indicates that there may be chronic health effects present. See safety file on the product.

II. FLAMMABILITY HAZARD RATING

0 Minimal Hazard Materials that are normally stable and will not burn unless heated
1 Slight Hazard Materials that must be preheated before ignition will occur. Flammable liquids in this category will have flash points (the lowest temperature at which ignition will occur) at or above 200°F (NFPA Class IIIB)
2 Moderate Hazard Material that must be moderately heated before ignition will occur, including flammable liquids with flash points at or above 100°F and below 200°F (NFPA Class II & Class IIIA)
3 Serious Hazard Materials capable of ignition under almost all normal temperature conditions, including flammable liquids with flash points below 73°F and boiling points above 100°F as well as liquids with flash points between 73°F and 100°F (NFPA Class 1B and 1C)
4 Severe Hazard Very flammable gases or very volatile flammable liquids with flash points below 73°F and boiling points below 100°F (NFPA class 1A)

III. REACTIVITY HAZARD RATING

0 Minimal Hazard Materials that are normally stable, even under fire conditions, and will not react with water
1 Slight Hazard Materials that are normally stable but can become unstable at high temperatures and pressures. These materials may react with water but they will not release energy violently
2 Moderate Hazard Materials that, in themselves, are normally unstable and will readily undergo violent chemical change but will not detonate. These materials may also react violently with water
3 Serious Hazard Materials that are capable of detonation or explosive reaction but require a strong initiating source or must be heated under confinement before initiation; or materials that react explosively with water
4 Severe Hazard Materials that are readily capable of detonation or explosive decomposition at normal temperatures and pressures

IV. CHRONIC EFFECTS INFORMATION

Chronic health effects are not rated because of the complex issues involved and the lack of standardized classifications and tests. However, based on information provided by the supplier, the presence of chronic effects may be indicated by (1) use of an asterisk (*) or other designation after the health hazard rating corresponding to other information that may be available; or (2) use of written warnings in the upper white section of the NFPA HMIS label.

V. PERSONAL PROTECTIVE EQUIPMENT

Information provided by the supplier will be used by the paint manufacturers to determine the proper personal protective equipment.
Health Hazards indicates acute and/or chronic hazards that result from exposure to the hazardous chemical. Acute hazards are quickly apparent effects of the chemical as a result of short-term exposure and are of short duration. Tissue damage or irritation sensations and lethal dose are among those things considered.

Chronic effects generally result from long term exposure. The effects may not be immediately apparent and are likely to be of long duration. Long term changes in the body should be included. Some of these characteristics of the chemicals are:

- Carcinogen (cancer causing)
- Teratogen (tumor causing)
- Mutagen (genetic changes)
- Blood dyscrasias (anemia)
- Chronic bronchitis
- Liver atrophy (degeneration)
- Kidney damage

Hygienic Work Practices

Indicates personal hygienic steps to be taken when handling the chemical. Washing hands after use, not smoking or disposal or laundering of contaminated clothing may be indicated here.

LEL (Lower Explosive Limit)

refers to the lowest concentration of gas or vapor (% by volume in air) which will burn or explode if an ignition source is present.

Material Safety Data Sheet (MSDS)

means a document that contains information and instructions on the chemical and physical characteristics of a substance, its hazards and risks, the safe handling requirements and actions to be taken in the event of fire, spill or overexposure, etc.

Median Lethal Concentration LC₅₀

means that concentration in air of gas vapor, mist, fume or dust for a given period of time that is most likely to kill one-half of a group of test animals using a specified test procedure. Inhalation is route of exposure and the value LC₅₀ is usually expressed as parts per million or milligrams per cubic meter (ppm or mg/m³).
Median Lethal Dose LD₅₀

means that dosage of a substance or mixture that is most likely to kill one-half of a group of test animals using a specified test procedure. The dose is expressed as the amount per unit of body weight, the most common expression being milligrams of material per kilogram of body weight (mg/kg of body weight). Usually refers to oral or skin exposure.

Mutagen

means those chemical or physical effects which can alter genetic material in an organism and results in physical or functional changes in all subsequent generations.

NFPA Rating

The National Fire Protection Association (NFPA) has developed a system for indicating the health, flammability and reactivity hazards of chemicals. In addition, a special precaution symbol may be used where necessary.

Rating Summary - Health

4 - Danger: May be fatal on short exposure. Specialized protective equipment required.
3 - Warning: Corrosive or toxic. Avoid skin contact or inhalation.
2 - Warning: May be harmful if inhaled or absorbed.
1 - Caution: May be irritating.
0 - No unusual hazard.

Health hazard describes short term contact or inhalation hazard only.

PEL

Permissible exposure limits (established by OSHA) (TLV’s are more up-to-date than PEL’s)

Sensitizer

means a chemical substance or mixture that causes a substantial number of persons to develop a hypersensitive reaction in normal tissue upon reapplication of the chemical substance or mixture, through an allergic or photodynamic reaction.

Teratogen

means a chemical which has been demonstrated to cause physical defects in the developing embryo.
"Threshold Limit Values" (TLV*)

means the airborne concentration of the substance which represent conditions under which it is believed nearly all workers may be repeatedly exposed day after day without adverse effect. There are three categories of Threshold Limit Values (TLVs*):

1. Time Weighted Average (TWA) - the time weighted average concentration for a normal 8-hour work day or 40-hour work week, to which nearly all workers may be exposed, day after day, without adverse effect.

2. Short Term Exposure Limit (STEL) - the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from, (1) irritation, (2) chronic or irreversible tissue change, or (3) narcosis of sufficient degree to increase accidental injury, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TWA also is not exceeded.

3. Ceiling (C) - the concentration that should not be exceeded even instantaneously.

Toxic refers to a chemical falling within any of the following Toxic categories:

a. A chemical that has a median lethal dose (LD50) of more than 50 milligrams per kilogram but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

b. A chemical that has a median lethal dose (LD50) of more than 200 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

c. A chemical that has a median lethal concentration (LC50) in air of more than 200 parts per million but not more than 2000 parts per million by volume of gas or vapor, or more than 2000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.