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SEEDING MATERIALS - HEALTH AND SAFETY CONSIDERATIONS

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The choice of a proper seeding material for laser velocimeters must include health and safety considerations. Failure to do so can lead to catastrophic results.

All materials are toxic, and laser velocimeter seeding materials are no exception. Toxicity may be considered an inherent property of a given material. The manifestation of that property or the physiological response to the material is dependent on dose and exposure conditions. An approximate, physiological classification of toxicity is given in Table 1. It is only approximate because the same material can produce more than one response.

Table 1. Physiological Classification of Toxic Materials

Class	Examples
Irritant	Ammonia, Sulphur Dioxide
Asphyxiant	Nitrogen Dioxide, Carbon Monoxide
Anesthetic	Aliphatic Hydrocarbons, Ethyl Alcohol
Systemic Poison	Heavy Metals, Carbon Tetrachloride
Sensitizer	Isocyanates, Formaldehyde
Fibrotic Agent	Silica, Coal Dust
Mutagens & Carcinogens	Arsenic, Asbestos
Nuisance	Alumina, Kaolin

Toxicity in some situations is not necessarily the most restrictive factor in selection of materials. It is also very important to consider how the material is used so that actual exposure to the material in a damaging form can result. For example, nickel and cadmium are both extremely toxic as systemic poisons and in the case of nickel as a carcinogen. However, a nickel-cadmium battery is relatively harmless primarily because the materials are safely packaged. Seeding materials, however, seem to be used in a manner that maximizes the hazard potential.

Seeding materials are dispersed in air under conditions that favor personnel exposure. Dispersal equipment is frequently if not normally manned, and personnel are often required to make frequent adjustments to assure proper operations.

To be useful, seeding materials must be of a particulate nature, typically on e order of one to two microns or less in diameter. A respirable dust is defined by the American Conference of Governmental Industrial Hygienists (ACGIH) (1) as having the size distribution shown in Table 2. Particulates used as seeding materials therefore can be seen to be almost completely respirable, again maximizing the hazard potential.

Table 2. Respirable Particulate Size Distribution

Aerodynamic Diameter of Unit Density Sphere	% Respirable
<2	90
2.5	75
3.5	50
5.0	25
10	0

At this point it is probably obvious to conclude the most desirable laser velocimeter seeding material should lie within the nuisance classification. More toxic materials could be used but additional exposure controls would be required in order to reduce exposure. ACGIH has published the list of nuisance particulates shown in Table 3. It should be emphasized that "nuisance" does not necessarily mean inert. As used by ACGIH, exposure to a nuisance particulate under reasonable controls does not produce significant organic disease or toxic effect and has little adverse effect on the lungs. "Little adverse effect" is specifically defined as follows: 1. The architecture of the air space remains intact; 2. Scar tissue is not formed to a significant degree; and 3. Any tissue reaction is potentially reversible.

Table 3. Nuisance Particulates

Alumnia	Plaster of Paris
Calcium carbonate	Portland Cement
Calcium silicate	Rouge
Cellulose (paper fiber)	Silicon
Emery	Silicon Carbide
Glycerin Mist	Starch
Graphite (synthetic)	Sucrose
Gypsum	Titanium Dioxide
Kaolin	Vegetable oil mists (except castor, cashew nuts or similar irritant oils)
Limestone	Zinc Stearate
Magnesite	Zinc oxide dust
Marble	
Mineral Wool Fiber	
Pentaerythritol	

Regardless of the seeding material used, personnel exposures must be controlled so as not to exceed certain limits. Recommendations for exposure limits have been published by ACGIH and the National Institute for Occupational Safety and Health (NIOSH), a governmental agency located with the Department of Health and Human Services. Legally enforceable standards for exposure limits are promulgated by the Occupational Safety and Health Administration (OSHA) within the Department of Labor. In some situations ACGIH or NIOSH recommendations may be legally enforced by OSHA. Generally, the ACGIH and NIOSH recommendations should be used as they are more conservative and are updated on a more frequent basis. The exposure limits are most commonly defined as the time weighted average concentration for a normal eight hour workday in a forty hour work week to which nearly all workers may be repeatedly exposed without adverse effect.

Personnel exposures for comparison with the exposure limits are determined by air sampling in breathing zones with methods demonstrated to meet accuracy and precision standards established by NIOSH. As the exposure limit is usually expressed as a time weighted average, extended sampling times or a series of measurements is often necessary. In any case, exposure for the entire workday must be determined. An assumption of no exposure for major portions of the day may be acceptable, however, if supportable. The eight hour, time weighted average exposure may be expressed as

$$C_{TWA} = \frac{\Sigma CnTn}{8}$$

where C_{TWA} = The 8 hour, time weighted average in ppm or mg/m3

Cn = The concentration during a given time period, n, in ppm, or mg/m3

Tn = The duration of the time period in hours

The units of concentration usually are given as volume per unit volume in parts per million parts of air (ppm) when dealing with a gas or vapor and or as mass per unit volume in milligrams per cubic meter of air (mg/m3) when dealing with a particulate.

When exposures do not extend over the entire work day, levels to which personnel may be exposed may be increased proportionately with corresponding reduction in exposure time. However, there is a limit to the truncating process, and it should not be carried to extremes. Clearly, exposure to an average ethyl alcohol concentration of 1,000 ppm for 8 hours would not produce the same response as exposure to 32,000 ppm for 15 minutes even though the 8 hour time weighted average exposure,

],000 ppm, would be the same.

Another major area of concern is that of flammability. The most commonly referenced property of a material for assessment of flammability hazard is lower explosive limit (LEL). The LEL may be considered the same as the expression lower flammable limit. The LEL is defined as the minimum air concentration at which a homogeneous mixture can be burned when subjected to an ignition source of adequate temperature and energy. Health hazardous concentrations of any material other than a simply asphyxiant which simply displaces oxygen are always considerably less than lower explosive limits, generally by several orders of magnitude. The LEL for a gas or vapor is usually expressed as volume per unit volume in parts per hundred or percentage.

The volume per unit volume estimate for vaporization of a solvent dispersed into a test chamber of known volume can be calculated as follows:

$$C = \frac{(M)(24.45)}{(MW)(V)} \times k$$

where C = Concentration in ppm for k = million
and % for k = hundred
M = Mass of solvent in grams
MW = Molecular weight
V = Test Volume in liters

Ignition hazards from carbonaceous, chemical, plastic and miscellaneous dusts are reported in numerous Bureau of Mines publications. A single number describing the lower explosive limit for combustible dusts is sometimes available, but it may not be applicable to a given situation because of uncertainties. For examples, it is well recognized flammability increases with decreasing particle size. However, it is difficult to fully quantitate this because of inherent difficulty in maintaining dust laden atmospheres, both spatially and temporally. Other uncertainties include relative humidity of the air and temperature and energy of the ignition source. Generally speaking, however, dust concentrations need to be on the order of grams per cubic meter to be at the LEL.

A summary of health and safety considerations for some commonly used or proposed seeding materials is presented in Table 4. The exposure limits are those recommended by ACGIH (1) except for kerosene where the NIOSH recommendation (2) is given. The data for LEL are found in numerous references. Several entries

Table 4. Properties of Seeding Materials

Name	Exposure Limit	Health Effects*	LEL
Aluminum Oxide	10 mg/m^3	Nuisance, Carcinogen (!?)	
Kaolin	10 mg/m^3	Nuisance	
Silicon Carbide	10 mg/m^3	Nuisance	
Polystyrene Latex	10 mg/m^3	Nuisance, Carcinogen (!?)	15 g/m^3
	50 ppm	Anesthetic, Irritant	1.1%
Vinyl Toluene	10 mg/m^3	Nuisance	
	50 ppm	Irritant, anesthetic	0.1%
Propylene Glycol		Nuisance, slight irritant	2.6%
Kerosene	14 ppm	Irritant	0.9%
Ethyl Alcohol	1,000 ppm	Anesthetic, Irritant, Systemic	3.3%
Methyl Alcohol	200 ppm	Systemic, anesthetic Irritant	6.7%

* Varies with concentration, exposure conditions

deserve comment. A carcinogenic effect is given for both aluminum oxide and polystyrene latex even though these materials are generally considered to be only of nuisance hazard. In both instances, the materials were reported by NIOSH (3) to have equivocal tumorogenic properties. It is highly improbable these materials could be carcinogenic under any conceivable exposure conditions that would result from use as seeding materials. Curently no regulatory agency considers them as posing anything other than a potential nuisance hazard.

Use of polymeric materials such as the polystrene or vinyl toluene can also pose a hazard from the unreacted monomer. The monomer will always be more hazardous. Polymeric materials, therefore, should be used only after careful consideration of possible presence of unreacted monomers.

A final consideration in the choice of material is that of availability of or willingness to implement necessary controls. Hazard control generally falls into three categories: engineering, administrative, or use of personal protective equipment. There is a great latitude in the choice of controls, and discussion must be limited to a few examples.

Probably the simplest control is the administrative control of substitution with a less hazardous material. Use of a nuisance particulate such as kaolin instead of a heavy metal dust such as lead is an obvious example. Limitation of personnel exposure time has been alluded to previously.

An example of an engineering control could be to incorporate an exhaust system into the test chamber so the area can be periodically purged with fresh air to dilute the contaminated air volume. The effect of dilution ventilation is given by the equation:

$$C_F = C_0 e^{-RT/V}$$

where C_F = Final contaminant concentrations
C_O= Originial concentrtion
R = Ventilation rate
T = Ventilation Time
V = Test Chamber Volume

Personal protective equipment includes respirators, rubber gloves, goggles, faceshields and the like. These devices are not failsafe and depend upon individual acceptance and attention for proper utilization. Peronal protective equipment, particularly respirators, should be used only when other controls are not effective or while they are being implemented.

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3. National Institute for Occupational Safety and Health: Registry of Toxic Effects of Chemical Substances. HEW (NIOSH) Publication Number 83-107-4, Washington, DC (1985),