aspen aerogels

NANOTECHNOLOGY AT WORK

Aspen Aerogels General Handling Guidelines

Purpose

These guidelines are designed to provide general handling information for Aerogels products (Spaceloft, Cryogel, Pyrogel, etc.) during installation. These guidelines are not a substitute for the Material Safety Data Sheets (MSDS) or product specifications. Users should review the applicable MSDS and product specifications before working with Aspen Aerogels products. Current MSDS's are available from your Aspen Aerogels representative or by accessing the Aspen Aerogels web site (www.aerogel.com). Aerogel blankets should be used in accordance with product specifications. For example, hot installation of aerogel must follow specific installation procedures.

Product Description

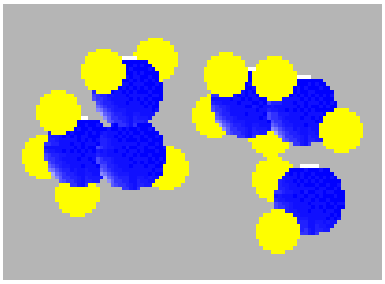
Aerogel is a synthetically produced amorphous silica gel impregnated into a non-woven flexible fabric substrate, offering the twin benefits of extreme thermal performance and a flexible blanket form. To meet customer demands, Aspen Aerogels may use a variety of aerogel additives and fabric substrate materials. Please consult the material safety data sheet or product technical data sheet for more information on aerogel additives, fabric substrate and recommended use conditions.

Frequently Asked Questions

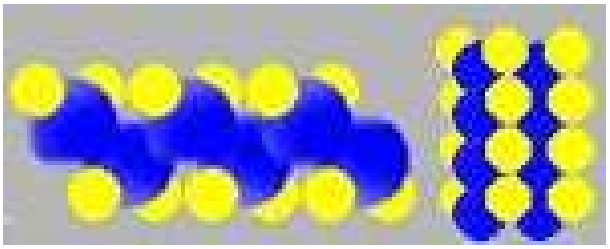
What is Aerogel?

Aerogel is a synthetic amorphous silica, which is distinctly different from crystalline silica. Silica is composed of one silica atom and two oxygen atoms.

Aspen Aerogels are nanoporous structures that utilize very small pore sizes to minimize the three mechanisms of thermal transport mechanism, typically diving values of thermal conductivity in the range of 12 – 15 mW/m-K.



Amorphous Silica



Crystalline Silica

What is Aspen Aerogels' Nanotechnology?

The "nanotechnology" aspect of Aspen's blanket products relate to the nanometer scale voids incorporated in the amorphous silica gel matrix. Thus, Aspen's materials are considered nanotechnology from a void space, rather than overall material, basis. The void space is what gives rise to the exceptional insulation performance of our materials. The structure of aerogel is much larger than a nanometer (10^{-9} meter). The pores (or air space) of the aerogel structure are on the factor of nanometers. However, it would take tremendous amounts of energy to separate the aerogel particles from their aggregated state.

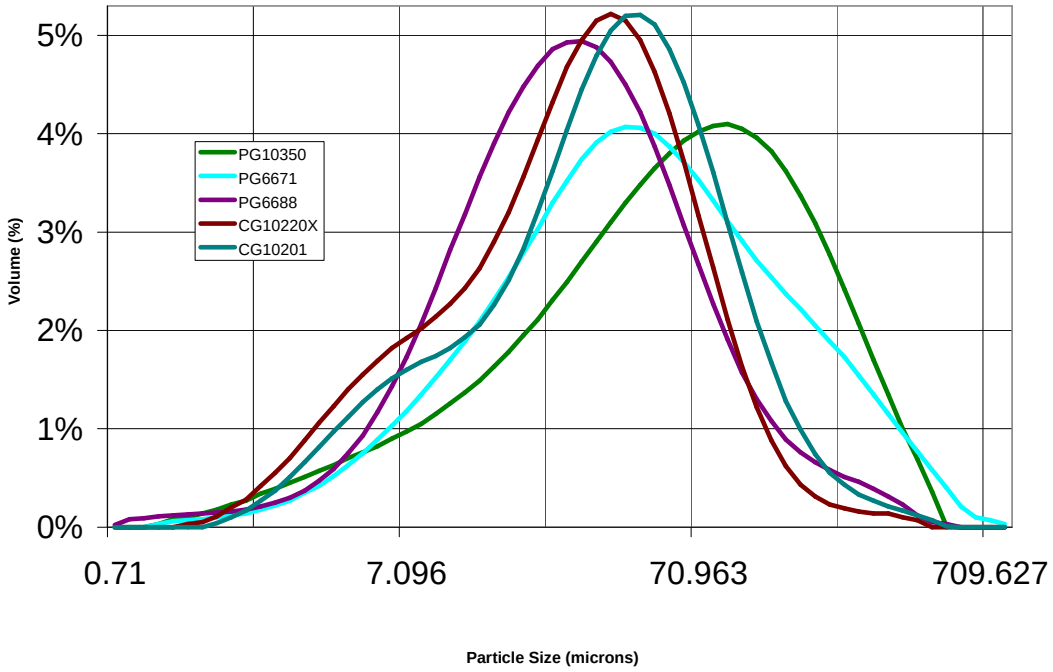
Based on independent laboratory analysis and selective electronic microscopy, the dust from Aspen Aerogel products does not contain nanoparticles. The generally accepted criteria for nanoparticles are dispersible particles having two or three dimensions greater than 1 nm and less than about 100 nm.

Five different aerogel dusts were tested by an independent, outside laboratory using a Malvern® Mastersizer 2000 LASER diffractor. This instrument calculates a volume distribution from the LASER diffraction pattern of a cloud of particles. The Malvern Particle Size Data Summary and particle size distribution summary are shown in Table 1 and Figure 1 below. Particles less than 0.710 microns (710 nm) were not detected in any sample analyzed. Therefore, the smallest aerogel particle size detected is more than 7 times larger than the largest nanoparticle.

Table 1: Malvern Particle Size Data Summary

Sample ID	Cumulative Volume % Less Than Indicated Size (microns)			
	D[v,0.10]	D[v,0.50]	D[v,0.90]	Smallest Size
Pyrogel 6688	8.26	27.91	93.80	0.71
Pyrogel 6671	8.07	48.44	162.66	1.00
Pyrogel 10350	9.76	64.02	220.53	1.00
Cryogel 10220	6.26	29.63	82.49	1.26
Cryogel 10201	7.52	37.47	106.95	1.59

Figure 1: Particle Size Distribution



What Health Studies have been done on Synthetic Amorphous Silica?

The United Nation's Organization for Economic Co-operation and Development (OECD) has been characterizing the hazardous properties of High Production Volume (HPV) chemicals. The "Screening Information Data Set" (SIDS) for synthetic amorphous silica was released in 2004. The SIDS report concluded that synthetic amorphous silica (SAS) is a low priority for further study. Excerpts from the OECD SIDS Human Health conclusions are included below[1]:

> ***Absorption, disposition, elimination:*** SAS forms [CAS No 7631-86-9] are rapidly eliminated from the lung tissue during and after prolonged inhalation exposure of experimental animals with no disproportionate disposition occurring in the mediastinal lymph nodes, whereas crystalline forms exhibit a marked tendency to accumulate and persist in the lung and lymph nodes. Intestinal absorption of SAS appears to be insignificant in animals and humans. There is evidence of ready renal elimination of bioavailable fractions.
>
> ***Acute toxicity:*** Following inhalation exposure of rats to the highest technically feasible concentrations of 140 to ~2000 mg/m3 SAS, no lethal effects were observed. Oral and dermal administration of SAS and amorphous silicates failed to cause mortality at the highest doses tested: LD0 values ranged from 3300 to 20000 mg/kg in rats.
>
> *Irritation and Sensitization*: Synthetic amorphous silica and silicates are not irritating to skin and eyes under experimental conditions, but may produce dryness following prolonged and repeated exposure.
>
> No sensitization experimental data are available on the synthetic amorphous silicas and silicates. There is long experience in humans. Data collected from industrial hygiene

[1] United Nations Environmental Programme (UNEP), Organization for Economic Co-operation and Development (OECD) Screening Information Data Set (SIDS) Initial Assessment Report, Synthetic Amorphous Silica, July 23, 2004.

surveillance over the last 50 years do not indicate any potential for skin sensitization. As mentioned above, there are reports describing dryness or cutaneous irritation that may be misinterpreted as a sign of sensitization or allergy.

Medical surveillance records on workers gave no evidence of skin sensitization over decades of practical experience. Given the inherent physico-chemical properties and ubiquitous nature of this class of compounds, there is no structural alert to indicate a sensitizing potential.

The US EPA reviewed several toxicity studies for synthetic amorphous silica including four acute toxicity studies (acute oral LD_{50} in the rat, acute inhalation LC_{50} in the rat, primary eye irritation in the rabbit, and primary dermal irritation in the rabbit); four mutagenicity studies, and an oral toxicity study. The US EPA summary of these study results was as follows[2]:

1. *Acute toxicity studies.* No mortalities were observed for the oral and inhalation studies. For the primary eye irritation study, there was no corneal opacity or iridial irritation in any of the eyes. For the dermal study, there was no dermal irritation at 72 hours. For the acute toxicity study, the oral LD50 is >5,000 milligrams/kilograms (mg/kg). For the acute inhalation study, the LC50 is >2.08 mg/L. All studies are toxicity category IV.
2. *Mutagenic studies.* In all four studies there was no indication of any mutagenic activity associated with exposure to silica, amorphous, fumed (crystalline free).
3. *Oral toxicity of fumed silica.* There were no mortalities or clinical signs. There was no significant difference between the test group and the control group with respect to silica concentration in the carcass.

Based on their analysis of the reviewed studies, the US EPA concluded the following[3]:

"Silica, amorphous, fumed (crystalline free) has a demonstrated lack of toxicity. The acute toxicity studies are toxicity category IV. The mutagenicity studies are negative. Silica, amorphous, fumed (crystalline free) is not classifiable, as to its carcinogenicity however, given its amorphous nature, it is not expected to pose a carcinogenic risk. Silicas are considered to be inert when ingested, and due to the high molecular weight it is unlikely to be absorbed through the skin. There should be no concerns for human health, whether the exposure is acute, subchronic, or chronic by any route."

The health effects of synthetic amorphous silica are significantly different from the health effects of crystalline silica. No evidence of silicosis has been found from epidemiological studies of workers with long-term exposure to intentionally manufactured synthetic silica[4]. From a health standpoint, a significant different between crystalline and amorphous silica could be lung clearance. Studies of various animal species have shown that amorphous silica products can be completely cleared from the lungs[5].

The International Agency for Research on Cancer (IARC) considers synthetic amorphous silica to be not classifiable as to its carcinogenicity to humans (Group 3).

[2] Federal Register, Vol. 67, No. 94, May 15, 2002, 34616-34620.
[3] Federal Register, Vol. 67, No. 94, May 15, 2002, 34616-34620.
[4] Merget, R et al, "Health hazards due to the inhalation of amorphous silica", *Arch Toxicol* (2002) 75: 625-634, November 29, 2001.
[5] Warheit, David, "Inhaled Amorphous Silica Particulates: What Do We Know About Their Toxicological Profiles?", *Journal of Environmental Toxicology and Oncology*, 20(Suppl. 1) 133-141 (2001).

What are the health effects of Aerogel dust?

Handling of aerogel blankets will produce dust. Aerogel dust exposure can produce the following effects:

- A sensation of dryness to skin
- Irritation to eyes, skin, respiratory track

These effects are not unique to aerogels, but are consistent with the handling of a host of dusty materials. When inhaled in sufficient amounts, any dust or particulate will cause respiratory effects. Excessive exposure to any type of dust can cause skin or mucous membrane irritation by chemical or mechanical action or rigorous skin cleaning.

What are the exposure limits for Aerogel dust?

The US OSHA standard for amorphous silica is: (80 mg/m^3)/(%SiO2). The NIOSH Sampling Method 7501 for Amorphous Silica calculates the %SiO2 based on the percentage of crystalline silica in the sample. Because the percentage of crystalline silica in aerogel is 0%, OSHA's particulate limits of 15 mg/m^3 (total dust) and 5 mg/m^3 (respirable dust) apply to Aerogel exposure. The US National Institute for Occupational Safety & Health (NIOSH) standard for amorphous silica is 6 mg/m^3. The German MAK for amorphous silica is 4 mg/m^3 (inhalable fraction).

The American Conference of Governmental Industrial Hygienists (ACGIH) withdrew their threshold limit values (TLV) for amorphous silica in 2005 due to insufficient data on single-substance exposure. The withdrawn ACGIH TLVs which included co-exposure with crystalline silica were: 10 mg/m^3 (total dust) and 3 mg/m^3 (respirable dust). The ACGIH recommendations for Particles (insoluble or poorly soluble) Not Otherwise Specified [PNOS] are maintaining airborne concentrations below 3 mg/m^3, respirable particles, and 10 mg/m^3, inhalable particles.

During industrial hygiene studies conducted during Aerogel fabrication operations, total dust concentrations ranged from 0.44 to 4.6 mg/m^3 and respirable dust concentrations ranged from <0.15 to 1.2 mg/m^3.

Do Aspen Aerogel products comply with RoHS?

Yes. Aspen Aerogel products comply with the EC Directive 2002/95/EC on the Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS Directive). Based on X-Ray Fluorescence (XRF), Aspen Aerogel products do not contain more than the indicated maximum concentration values by weight in homogeneous materials of the following substances:

Restricted Chemical Substances (Chemical Abbreviation)	Maximum Concentration Value (Homogeneous Material)
Cadmium (Cd)	0.01%
Hexavalent Chromium (Cr^{+6})	0.1%
Lead (Pb)	0.1%
Mercury (Hg)	0.1%
Polybrominated Biphenyls (PBBs)	0.1%
Polybrominated Diphenyl Ethers (PBDEs)	0.1%

How do you dispose of waste Aerogel blanket?

Aspen Aerogels insulation blanket is composed primarily of synthetic amorphous silica impregnated onto a fabric material. The final product does not contain any liquid material. Scrap aerogel blanket can be disposed in landfills that are approved to accept industrial waste. Scrap aerogel blankets will generate dust during landfill operations. Industrial waste landfills should be informed of the potential for dust generation during the waste approval process. Scrap materials from Aspen's Manufacturing operations are disposed in a licensed, industrial landfill in Massachusetts.

To meet customer demands, Aspen Aerogels may use a variety of aerogel additives and fabric substrate materials. These additives may include materials such as carbon black, titanium dioxide and aluminum oxide. Aerogel blankets do not meet any of the characteristics of a US EPA hazardous waste [40 CFR Part 40, Subpart C].

What is the combustibility of Aerogel Dust?

An independent laboratory measured the **Minimum Explosible Concentration (MEC)** for Aerogel dust to be 575 g/m^3 per ASTM E1515-03, *"Standard Test Method for Minimum Explosible Concentration of Combustible Dusts"*. The laboratory also performed a **Minimum Ignition Energy (MIE)** test on the dust per ASTM E2019-03, *"Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air"*. No ignition was observed at 28.8 Joules Capacitor Stored Energy, the maximum capacitor stored energy delivered by Electrostatic Discharge Tester used for the test.

General Handling Guidelines

Proper Handling
Aerogel blankets will generate dust when handled. Workplace exposure to all dusts should be controlled with standard industrial hygiene practices. Work places should be kept clean. Aerogel blankets should be kept in their original shrink wrapping until they are ready to be used. Unpack the material in the work area. This will help to minimize the area where dust exposure may occur. Trimmed material and scrap should be promptly packed in disposal bags.

Dust released during the handling of aerogel blankets should be cleaned up promptly. Dry vacuuming is the preferred method for cleaning up dust. Because aerogel dust is hydrophobic, water is not effective as a dust control agent.

Fabrication Methods
Clean cutting methods such as die cutting or hot knife should be used to avoid tearing and dust evolution. Machine cutting should be equipped with adequate dust collection. The handling and transfer of aerogel materials should be minimized. The use of downdraft tables has been noted to reduce dust generation.

Local Exhaust Ventilation
Aerogel blankets should be handled and installed in a well ventilated area. Local exhaust ventilation should be the primary dust control method.

Skin Protection
Silica aerogels are hydrophobic (repel water) and may cause drying and irritation of the skin, eyes, and mucous membranes. For this reason, nitrile, latex, or other impermeable gloves should be worn when handling aerogel blankets. Long-sleeved, long-legged work clothes are also advised. Disposable coveralls should be considered to minimize skin exposure and track out of aerogel dusts into adjacent areas. Aerogel dust can be washed from the skin using soap and water.

Eye Protection
In most conditions, side shield safety glasses are acceptable for eye protection. Where dusty conditions prevail, goggles should be worn.

Respiratory Protection
In situations where ventilation cannot be used or is not sufficient to reduce exposure levels below applicable exposure limits, respiratory protection should be utilized, in accordance with local regulations.

Fire & Explosion
Aerogel blanket materials that become involved in fire situations will retain heat due to their insulating properties and may contribute to re-igniting fires. Material that has been involved in a fire should be watched closely to insure that no smoldering material is present.