



# Nanomaterial Safety Plan

Field Services  
SLAC-I-730-0A09M-008-R003  
4 August 2008 (updated 17 December 2010)

# Publication Data

This document was designed and published by ESH Publishing

Document Title: Nanomaterial Safety Plan

Original Publication Date: 4 August 2008

Revision Date: 4 August 2008 (updated 17 December 2010)

Effective Date: 17 December 2010

Department: Field Services

Document Number: SLAC-I-730-0A09M-008-R003

ProductID: [58](#) | RevisionID: [1268](#)

URL: <http://www-group.slac.stanford.edu/esh/eshmanual/references/hazmatPlanNano.pdf>

Prepared for the United States Department of Energy under contract DE-AC02-76-SFO0515

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# Acronyms

ANSI	American National Standards Institute
AIHA	American Industrial Hygiene Association
ASTM ASTM	International
CFR	<i>Code of Federal Regulations</i>
DOE	United States Department of Energy
ESH	Environment, Safety, and Health Division
FAR	Federal Acquisition Regulations
GSA	General Services Administration
HEPA	high-efficiency particulate air
ICAO	International Civil Aviation Organization
IHIM	Industrial Hygiene and Information Management Department
LTL less-th	an-truckload
MCEP	Motor Carrier Safety Program
MSDS	material safety data sheet
NIOSH	National Institute for Occupational Safety and Health
NSC	Nanoscience Safety Committee
NSRC	Nanoscale Science Research Center
OEL	occupational exposure limit
PPE	personal protective equipment
SSRL	Stanford Synchrotron Radiation Lightsource
UNP	unbound engineered nanoparticle



# 1 Introduction

Nanoscale materials are of considerable scientific interest because some material properties can change at this scale.<sup>1</sup> These changes challenge our understanding of hazards, and our ability to anticipate, recognize, evaluate, and control potential health, safety, and environmental risks.

Exposures to these materials may occur through inhalation, dermal contact, and ingestion.<sup>2</sup> Animal studies indicate that low-solubility ultra fine particles might be more toxic than larger ones on a mass-for-mass basis. Because of their tiny size, they can penetrate deep into the lungs and may translocate to other organs following pathways not demonstrated in studies with larger particles.

The nanoparticulate forms of some materials show unusually high reactivity, especially for fire, explosion, and in catalytic reactions. Engineered nanoparticles and nanostructured porous materials have been used effectively for many years as catalysts for increasing the rate of reactions or decreasing the temperature needed for reactions in liquids and gases. Depending on their composition and structure, some nanomaterials may initiate catalytic reactions that would not otherwise be anticipated from their chemical composition.

The Department of Energy (DOE) has made clear that it expects those engaged in the emerging field of nanotechnology to act responsibly in evaluating and controlling the associated environmental, health, and safety risks.

Although there is limited specific guidance on evaluation and control of risks posed by nanomaterials, preliminary research suggests that some controls used in conventional laboratory settings will work effectively for them.

## 1.1 Purpose

This plan, a component of the SLAC hazardous material program described in the *SLAC Environment, Safety, and Health Manual*, Chapter 40, “Hazardous Materials”,<sup>3</sup> is intended to

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1 ASTM International (ASTM) E2456-06, “Terminology Relating to Nanotechnology” (ASTM E2456-06) uses the term *transitive nanoparticles* to refer to nanoparticles that exhibit a size-related intensive property that differs significantly from that seen in fine particles or bulk materials. See also Section 1.2, “Scope and Applicability”, of this document.

See the “SLAC Research Library Community Pages”, <http://www-group.slac.stanford.edu/library/CommunityPages.asp>, for available standards. ASTM standards are available online from a SLAC login (<http://enterprise.astm.org/>); some hard copies are also available.

2 National Institute for Occupational Safety and Health, *Approaches to Safe Nanotechnology: An Information Exchange with NIOSH* (DHHS [NIOSH], version 1.1, July 2006), p. vi, <http://www.cdc.gov/niosh/topics/nanotech/safenano/>

3 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 40, “Hazardous Materials”, [http://www-group.slac.stanford.edu/esh/hazardous\\_substances/haz\\_materials/policies.htm](http://www-group.slac.stanford.edu/esh/hazardous_substances/haz_materials/policies.htm)

- Provide procedures and controls that will protect workers and the environment while recognizing the uncertainty associated with nanomaterials – the hazards of which have not been determined – and reduce to an acceptable level the risk of worker injury, worker ill-health, and negative environmental impacts
- Promote consistency in policy and procedures among DOE contractor laboratories

## 1.2 Scope and Applicability

This document sets forth required practices at the SLAC National Accelerator Laboratory (SLAC) for managing environmental, safety, and health (ESH) concerns associated with the following:

- *Engineered* nanomaterials, that is, intentionally created – in contrast with natural or incidentally formed – engineered nanomaterials with dimensions of less than 100 nanometers. This definition excludes biomolecules (proteins, nucleic acids, and carbohydrates), materials for which an occupational exposure limit (OEL), national consensus, or regulatory standard exists. Nanoscale forms of radiological materials are also excluded from this definition.
- *Nanoparticles*, that is, dispersible particles having two or three dimensions greater than 0.001 micrometer (1 nanometer) and smaller than about 0.1 micrometer (100 nanometers) and which may or may not exhibit a size-related intensive property.<sup>4</sup>
- *Unbound engineered nanoparticles (UNP)* are defined by the DOE to mean those engineered nanoparticles that, under reasonably foreseeable conditions encountered in the work, are not contained within a matrix that would be expected to prevent the nanoparticles from being separately mobile and a potential source of exposure.<sup>5</sup> An engineered nanoparticle dispersed and fixed within a polymer matrix, incapable, as a practical matter, of becoming airborne, would be “bound”, while such a particle suspended as an aerosol or in a liquid would be “unbound”.
- Precursors, intermediates, and wastes used during, or resulting from synthesizing such nanomaterials
- *Laboratory-scale* activities involving chemical containers, reaction vessels, material transfers, and other handling of substances that are designed to be easily and safely manipulated by one person. *Laboratory-scale* excludes those workplaces the function of which is to produce commercial quantities of materials.<sup>6</sup>

The requirements of this document apply wherever the above materials are used.

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4 ASTM International (ASTM) E2456-06, “Terminology Relating to Nanotechnology” (ASTM E2456-06)

See the “SLAC Research Library Community Pages”, <http://www-group.slac.stanford.edu/library/CommunityPages.asp>, for available standards. ASTM standards are available online from a SLAC login (<http://enterprise.astm.org/>); some hard copies are also available.

5 Department of Energy Notice 456.1, “The Safe Handling of Unbound Engineered Nanoparticles” (DOE N 456.1), <http://www.directives.doe.gov/pdfs/doe/doetext/neword/456/n4561.html>

6 Title 29, *Code of Federal Regulations*, “Labor”, Part 1910, “Occupational Safety and Health Standards”, Subpart Z, “Toxic and Hazardous Substances”, Section 1450, “Occupational Exposure to Hazardous Chemicals in Laboratories”, Subsection b, “Definitions” (29 CFR 1910.1450(b)), [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10106](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106)

### 1.3 Limitations

- Information about the safety and health effects caused by nanomaterials, particle measurement, and control effectiveness is evolving. This document will be updated and modified as necessary.

### 1.4 Standards

This document, which is based on the DOE Nanoscale Science Research Centers (NSRC) guidance document, *Approach to Nanomaterial ES&H*,<sup>7</sup> conforms to

- Department of Energy Policy 456.1, “Secretarial Policy Statement on Nanoscale Safety” (DOE P 456.1)<sup>8</sup>
- Department of Energy Notice 456.1, “The Safe Handling of Unbound Engineered Nanoparticles” (DOE N 456.1)<sup>9</sup>
- ASTM International (ASTM) E2535-07, “Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings” (ASTM E2535-07)<sup>10</sup>

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7 Department of Energy, Nanoscale Science Research Centers, *Approach to Nanomaterial ES&H* (NSRC, Revision 3a, May 2008), <http://orise.orau.gov/ihos/Nanotechnology/files/NSRCMay12.pdf>

8 <http://www.directives.doe.gov/pdfs/doe/doetext/neword/456/p4561.html>

9 <http://www.directives.doe.gov/pdfs/doe/doetext/neword/456/n4561.html>

10 See the “SLAC Research Library Community Pages”, <http://www-group.slac.stanford.edu/library/CommunityPages.asp>, for available standards.



## 2 General Policy

SLAC has adopted the following policies regarding nanomaterials:

1. SLAC will comply with Department of Energy Policy 456.1, “Secretarial Policy Statement on Nanoscale Safety” (DOE P 456.1),<sup>11</sup> which stipulates the use of best practices and national consensus standards to protect workers, the public, and the environment, by applying the safety requirements contained in this document.
2. The SLAC Nanoscience Safety Committee (NSC) will approve standard operating procedures for low- and medium-risk level materials and approve work plans for use when alternative approaches employing equivalent level of safety are proposed. The NSC will review and approve work plans for use with high-risk level materials (see Section 3, “Controls for Research Laboratory Operations” and Table 1, “Requirements by Risk / Material Form”).
3. In conformance with the general principle in the National Research Council’s *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, personnel should treat “all new compounds, or those of unknown toxicity, as though they could be acutely toxic in the short run and chronically toxic in the long run.”<sup>12</sup> Moreover, although exposures to airborne nanoparticles are believed likely to be extremely low in comparison to other workplace exposures, the National Institute for Occupational Safety and Health (NIOSH) observation that all poorly soluble, low-toxicity, ultra-fine particulates might be carcinogenic, even those normally considered to be nuisance particulates, makes it important to manage carefully worker exposure and avoid environmental releases.<sup>13</sup>
4. Nanomaterials the hazards of which have been studied will be managed in a manner consistent with the known risks and SLAC will follow a graded approach in specifying controls.

Implementing requirements and guidelines are described in the following sections.

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11 Department of Energy Policy 456.1, “Secretarial Policy Statement on Nanoscale Safety” (DOE P 456.1), <http://www.directives.doe.gov/pdfs/doe/doetext/neword/456/p4561.html>

12 National Research Council, *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals* (National Academy Press, Washington, DC 1995), page 3, [http://books.nap.edu/catalog.php?record\\_id=4911](http://books.nap.edu/catalog.php?record_id=4911)

13 National Institute for Occupational Safety and Health, *Current Intelligence Bulletin: Evaluation of Health Hazard and Recommendations for Occupational Exposure to Titanium Dioxide* (DHHS [NIOSH], draft, November 2005), lines 86 through 89, <http://www.cdc.gov/niosh/review/public/TiO2/pdfs/TIO2Draft.pdf>

“While the potential cancer potency of fine TiO<sub>2</sub> appears to be relatively low at current occupational exposures, NIOSH is concerned about the potential carcinogenicity of ultrafine TiO<sub>2</sub> if workers are exposed at the current mass-based exposure limits for respirable or total mass fractions of TiO<sub>2</sub>.”



# 3 Controls for Research Laboratory Operations

## 3.1 Work Planning and Approval

All experiments involving nanomaterials must be categorized according to the risk they pose. The risk level assignment is a function of the potential hazards of the material and how it will be used and determines the extent of required controls, review, and approval (see Table 1, “Requirements by Risk / Material Form”):

- Low-risk level (green) – bound or fixed nanostructures
  - Solid materials with imbedded nanostructures
  - Solid nanomaterials with nanostructures fixed to the material’s surface
- Medium-risk level (yellow) – nanoparticles suspended in liquids
- High-risk level (red) – dry, dispersible nanoparticles, nanoparticle agglomerates/aggregates or nanomaterials determined to be high risk based on safety assessment (see Section 3.1.3, “Exposure and Safety Assessment”)

### 3.1.1 Approval

#### 3.1.1.1 Stanford Synchrotron Radiation Lightsource (SSRL)

All work with low-risk and medium-risk level nanomaterials must be reviewed and approved by the SSRL safety coordinator. SSRL requires that researchers working with nanomaterials

- Submit a completed SSRL Proposal Form<sup>14</sup>
- Submit a SSRL Hazards Form four weeks prior to the experiment date<sup>15</sup>
- Comply with any requests for information and submit in written format those response procedures to be followed in the event of accidental spills of nanomaterial. The procedures should include sufficient detail and clarity so they can be carried out by laboratory-competent personnel.

No nanomaterials may be brought on-site or manufactured until approved by the SSRL safety coordinator.

All work or research with nanomaterials may only be performed by personnel who are authorized by their division and who have been properly trained (see Section 3.7, “Worker Competency”).

SSRL will maintain inventories of approved activities involving nanomaterials in an accessible electronic format and provide to the DOE SLAC Site Office an annual review of these activities.

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14 SSRL Proposal Form, [http://www-ssrl.slac.stanford.edu/userresources/documents/form\\_proposal.rtf](http://www-ssrl.slac.stanford.edu/userresources/documents/form_proposal.rtf)

15 Hazards Form, [http://www-ssrl.slac.stanford.edu/users/user\\_admin/form\\_hazards.html](http://www-ssrl.slac.stanford.edu/users/user_admin/form_hazards.html)

### 3.1.1.2 Other SLAC Entities

SSRL safety requirements for nanomaterials will be used for all of SLAC.

### 3.1.2 NSC Review

All work with high-risk level nanomaterials must be reviewed and approved by the NSC. In such cases, researchers must submit a draft work plan to the SSRL safety coordinator, who will present the information to the NSC and communicate any special controls or requirements to the researcher.

### 3.1.3 Exposure and Safety Assessment

All work with nanomaterials will be reviewed for ESH concerns by either the SSRL safety coordinator or the NSC, depending on the risk level (see Table 1, "Requirements by Risk / Material Form"). Before starting work, this safety assessment will be completed consistent with the following:

- Begin with a well defined description of the work.
- Involve subject matter experts (for example, industrial hygiene, industrial safety, fire protection) as appropriate.
- Evaluate the potential for worker exposure for all activities involving nanomaterials.
- Specify hazard controls, including
  - Engineered controls
  - Design reviews
  - Formal procedures
  - Use of personal protective equipment (PPE)
  - Training
  - Other administrative controls
  - Defined criteria for work-change control
- Consider, but do not unquestioningly rely on, chemical hazard information for bulk/raw materials when developing controls for nanomaterials and any new information specific to the material at the scale being used.
- Evaluate the potential for worker exposure to nanomaterials and their escape into the environment before removing, remodeling, servicing, maintaining, or repairing laboratory equipment and exhaust systems.
- Consider the recognized and foreseeable hazards of the precursor materials and intermediates as well as those of the resulting nanomaterials.
- Consider the higher reactivity of many nanoscale materials as suggesting that they be treated as potential sources of ignition, accelerants, and fuel that could result in fire or explosion.
- Consider the potential for reactions involving nanomaterials already captured in exhaust air filters.

## 3.2 Control Preferences

SLAC will follow a graded approach in specifying controls. Operations involving easily dispersed dry nanomaterials deserve more attention and more stringent controls than those where the nanomaterials are imbedded in solid or suspended in liquid matrixes.

From the perspective of managing laboratory worker health, the following represents the order of preference (most preferred to least preferred) for handling nanomaterials:

1. Solid materials with imbedded nanostructures
2. Solid nanomaterials with nanostructures fixed to the material's surface
3. Nanoparticles suspended in liquids
4. Dry, dispersible (engineered) nanoparticles, nanoparticle agglomerates, or nanoparticle aggregates

Do not handle nanomaterials in the open air in a *free particle* state. Handle and store dispersible nanomaterials, whether suspended in liquids or in a dry particle form in closed (tightly sealed) containers.

Consider the hazardous properties of the precursor materials as well as those of the resulting nanomolecular product. Remember, nanomaterial hazards might not be known or reliably anticipated. An environment, health and safety professional can assist with this evaluation.

Consider all routes of possible exposure to nanomaterials including inhalation, ingestion, injection, and dermal contact, including eye and mucus membranes.

## 3.3 Engineered Controls

### 3.3.1 Work Area Design

- Consider the potential need to implement additional engineered or procedural controls to ensure workers are protected in areas where engineered nanoparticles will be handled.
- Consider additional controls that will better ensure that engineered nanoparticles are not brought out of the work area on clothing or other surfaces. For example, install step-off pads, create a buffer area, and ensure the availability of decontamination facilities for workers.

### 3.3.2 Ventilation Preferences

- Conduct any work that could generate engineered nanoparticles in an enclosure that operates at a negative pressure differential compared to the worker's breathing zone. Examples of such enclosures include glove boxes, glove bags, and laboratory bench-top or floor-mounted chemical hoods. In some cases, the air reactivity of precursor materials may make it unsafe to operate in a negative pressure glove box and a positive pressure box may be used if it has passed a helium leak test. (In addition, the DOE currently requires that "enclosed systems under positive pressure must be used in a negative pressure enclosure and exhausted prior to opening."<sup>16</sup>) If a process (or subset of a process) cannot be enclosed, then use other engineered systems to control fugitive emissions of nanomaterials or

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16 Department of Energy Notice 456.1, "The Safe Handling of Unbound Engineered Nanoparticles" (DOE N 456.1), <http://www.directives.doe.gov/pdfs/doe/doetext/neword/456/n4561.html>

hazardous precursors that might be released. For example, use a local exhaust system like a snorkel hood.

- Do not exhaust effluent (air) demonstrated or strongly suspected to contain engineered nanoparticles the hazards of which are not well understood. Whenever practical, filter it or otherwise clean (scrub) it before release.

*Note* High-efficiency particulate air (HEPA) filtration effectively removes nanoparticles from air, at least to particles as small as 2 nanometers in diameter. Below that size, data suggests that filter performance degrades as particles experience thermal rebound and reaerosolization from the filter matrix.<sup>17, 18</sup>

- Minimize the dispersal and environmental release of nanomaterials. Carry out all manipulations of engineered nanoparticles in a glove box, glove bag, chemical fume hood, or other airborne contaminant control system. Whenever practical, remove (scrub or capture) the contaminant from the effluent from such a control system before the effluent is released into the general environment. If it is not practicable to handle dispersible nanoparticles in such a containment system, conduct and document the results of a hazards analysis before using alternative hazard controls.
- Exhaust the effluent from ventilated enclosures outside the building whenever feasible. Filters, scrubbers, or bubblers may be appropriate to treat unreacted precursors and may also be effective in reducing nanomaterial emissions. If using portable bench top HEPA-filtered units, exhaust them through ventilation systems that will carry the effluent outside the building whenever possible.
- If it is not feasible to duct HEPA-filtered treated exhaust air outside of the building,
  - Follow the guidance in ANSI/AIHA Z9.7-2007, “Recirculation of Air from Industrial Process Exhaust Systems”<sup>19</sup>
  - Conduct a hazards assessment and implement appropriate engineering controls. Examples of such controls include periodic air monitoring, and an accurate warning/signal capable of initiating

17 Current knowledge indicates that a well designed exhaust ventilation system with a high-efficiency particulate air (HEPA) filter should effectively remove nanoparticles [Hinds 1999]. Filters are tested using particles that have the lowest probability of being captured (typically around 300 nm in diameter). It is expected that the collection efficiencies for smaller particles should exceed the measured collection efficiency at this particle diameter [Lee and Liu 1982]. NIOSH is conducting research to validate the efficiency of HEPA filter media used in environmental control systems and in respirators in removing nanoparticles. As results of this research become available, they will be posted on the NIOSH Web site. If HEPA filters are used in the dust collection system, they should be coupled to a well designed filter housing. If the filter is improperly seated, nanoparticles have the potential to bypass the filter, leading to filter efficiencies much less than predicted [NIOSH 2003]. [ This text appears on page 22 of Version 1.1 of NIOSH’s *Approaches to Safe Nanotechnology*. Please consult the original document for more information on cited source material. See note 2.]

18 Kim, SC; Harrington, M; Pui, D, “Experimental Study of Nanoparticle Penetration through Commercial Filter Media”, *Journal of Nanoparticle Research* 9 (2007): page 9

19 American National Standards Institute/American Industrial Hygiene Association (ANSI/AIHA) Z9.7-2007, “Recirculation of Air from Industrial Process Exhaust Systems” (ANSI/AIHA Z9.7-2007)

See the “SLAC Research Library Community Pages”, <http://www-group.slac.stanford.edu/library/CommunityPages.asp>, for available standards. For a list of ANSI standards, see the American National Standards Institute “ANSI Standards Store”, <http://webstore.ansi.org/>.

corrective action or process shutdown before nanoparticles could be exhausted or re-entrained into the work area.

- Do not use horizontal laminar-flow hoods (*clean benches*) that direct a flow of HEPA-filtered air into the user's face for operations involving nanomaterials that might easily become entrained in the air.
- Consider exhausting Type II biological safety cabinets, in which free nanomaterials are handled, directly to the exterior (hard ducted) or through a thimble connection over the cabinet's exhaust. Air from inside the cabinet, even if HEPA-filtered, should not be recirculated within the laboratory except as provided for in ANSI/AIHA Z9.7-2007.
- Maintain and test the effectiveness of exhaust systems and components as specified by the manufacturer. Evaluate equipment previously used to synthesize, handle or capture nanoparticles for contamination and incompatibility before reusing or disposing of it.
- Evaluate equipment previously used to synthesize, handle or capture nanoparticles for contamination and incompatibility before removing, remodeling, repairing, reusing or disposing of it. Due to the potential for residual contamination, use appropriate cleaning methodologies (that is, wet wiping).

## 3.4 Administrative Controls

### 3.4.1 Chemical Hygiene Plan

Implement the SLAC *Chemical Hygiene Plan*<sup>20</sup> (as required under 10 CFR 851.23<sup>21</sup> and 29 CFR 1910.1450<sup>22</sup>).

### 3.4.2 Housekeeping

Practice good housekeeping in laboratories where nanomaterials are handled. Follow a graded approach paying attention where dispersible nanomaterials are handled.

- Insofar as practicable, maintain all working surfaces (that is, benches, glassware, apparatus, exhaust hoods, support equipment) free of engineered nanoparticle contamination and otherwise limit worker exposure engineered nanoparticles and associated hazards.
- In areas where engineered nanoparticles might settle, perform precautionary cleaning, for example, by wiping horizontal surfaces with a moistened disposable wipe, no less frequently than at the end of each shift.
- Before selecting a cleaning method, consider the potential for complications due to the physical and chemical properties of the engineered nanoparticles, particularly in the case of larger spills.

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20 *Chemical Hygiene Plan* (SLAC-I-730-0A09M-002), <http://www-group.slac.stanford.edu/esh/documents/techbas/chp.pdf>

21 Additional information on 10 CFR 851 and its implementation is available from the following site: "Worker Safety and Health Program Final Rule - 10 CFR 851", <http://www.hss.energy.gov/healthsafety/WSHP/rule851/851final.html>

22 Title 29, *Code of Federal Regulations*, Part 1910, "Occupational Safety and Health Standards", Section 1450, "Occupational Exposure to Hazardous Chemicals in Laboratories" (29 CFR 1910.1450), [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10106](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106)

<sup>23</sup> Such locations include vacuum cleaner filters and canisters.

- Clean up dry, engineered nanomaterials using
  - Wet wiping
  - A dedicated, approved HEPA vacuum the filtration effectiveness of which has been verified (consider possible pyrophoric hazards associated with vacuuming up nanoparticles)
  - Other SLAC-approved methods that do not involve dry sweeping or the use of compressed air
- Dispose of used cleaning materials and wastes in accordance with Chapter 17, “Hazardous Waste”.<sup>24</sup> (See Section 6, “Management of Nanomaterial-bearing Waste Streams”.)

### 3.4.3 Work Practices

- Transfer engineered nanomaterial samples between workstations (such as exhaust hoods, glove boxes, furnaces) in closed, labeled containers.
- Take reasonable precautions (see Section 3.5, “Clothing and Personal Protective Equipment”) to minimize the likelihood of skin contact with engineered nanoparticles or nanoparticle-containing materials likely to release nanoparticles (nanostructures).
- If engineered nanoparticle powders must be handled without the use of exhaust ventilation (that is, laboratory exhaust hood, local exhaust) or enclosures (that is, glove box), evaluate hazards and implement alternative work practice controls to control potential contamination and exposure hazards.
- Handle nanomaterial-bearing waste according to Chapter 17, “Hazardous Waste”,<sup>25</sup> and Section 6, “Management of Nanomaterial-bearing Waste Streams”.
- Vacuum dry-engineered nanoparticulates only with a HEPA vacuum cleaner that has been performance tested and certified.

### 3.4.4 Inventory Requirements

[ Reserved ]

### 3.4.5 Marking, Labeling, and Signage

- Post signs indicating hazards, personal protective equipment requirements, and administrative control requirements at entry points into designated areas where dispersible, engineered nanoparticles are handled. A *designated area* may be an entire laboratory, an area of a laboratory, or a containment device such as a laboratory hood or glove box (see Figure 1).

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23 An exothermic reaction involving nanomaterials and wipes at a DOE facility reportedly resulted in discovery of an incipient fire in a domestic trash container.

24 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 17, “Hazardous Waste”, [http://www-group.slac.stanford.edu/esh/environment/hazardous\\_waste/policies.htm](http://www-group.slac.stanford.edu/esh/environment/hazardous_waste/policies.htm)

25 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 17, “Hazardous Waste”, [http://www-group.slac.stanford.edu/esh/environment/hazardous\\_waste/policies.htm](http://www-group.slac.stanford.edu/esh/environment/hazardous_waste/policies.htm)

- Where appropriate, label storage containers to indicate plainly that the contents are in engineered nanoparticulate form, for example, “nanoscale zinc oxide particles” or other identifier instead of just “zinc oxide”.
- When engineered nanoparticles are being moved within SLAC or off-site, follow Section 5, “Transportation of Nanomaterials”, labeling requirements.

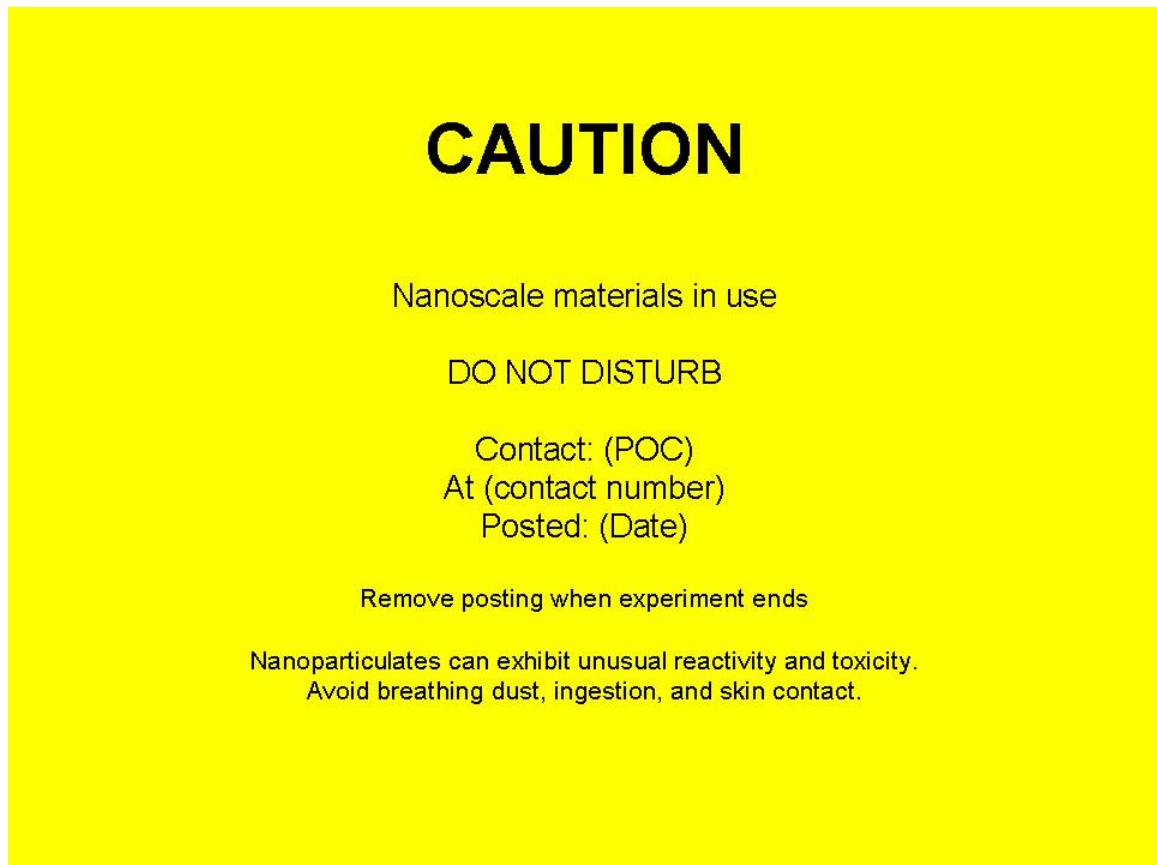


Figure 1 Sample Laboratory Sign

### 3.5 Clothing and Personal Protective Equipment

- Wear appropriate PPE, including respiratory protection, on a precautionary basis whenever the failure of a single control, including an engineered control, could entail a significant risk of exposure to researchers or support personnel. Ensuring that engineered controls (for example, laboratory chemical hoods) are equipped with performance monitors that will notify users of equipment malfunction may be considered as an alternative.
- Conduct a hazard evaluation to determine the selection and use personal protective equipment (PPE) appropriate for the level of hazard as per the requirements set forth in Chapter 19, “Personal Protective

- Equipment”,<sup>26</sup> and 29 CFR 1910.<sup>27</sup> Protective clothing that would typically be required for a wet-chemistry laboratory would be appropriate, including
- Closed-toed shoes made of a low-permeability material. (Disposable over-the-shoe booties may be necessary to prevent tracking nanomaterials from the laboratory.)
  - Gauntlet-type gloves or nitrile gloves with extended sleeves
  - Laboratory coats
- Wear polymer (for example, nitrile rubber) gloves when handling engineered nanomaterials and particulates in liquids.<sup>28</sup> Choose gloves only after considering the resistance of the glove to the chemical attack by both the nanomaterial and, if suspended in liquids, the liquid.
    - Recognizing that exposure to nanomaterials is not known to have good warning properties, change gloves routinely to minimize potential exposure hazards. Alternatively, double glove.<sup>29</sup>
    - Keep contaminated gloves in a plastic bag or other sealed container in a hood until disposed.
    - Dispose of contaminated gloves in accordance with Section 6, “Management of Nanomaterial-bearing Waste Streams”.
    - Wash hands and forearms after wearing gloves.
  - Wear eye protection, for example, spectacle-type safety glasses with side shields (meeting basic impact resistance of ANSI Z87.1), face shields, chemical splash goggle, or other safety eyewear appropriate to the type and level of hazard. Do not consider face shields or safety glasses to provide sufficient protection against unbound, dry materials that could become airborne.
  - Use industrial hygiene professionals or paraprofessionals working under the direction of an industrial hygiene professional to evaluate airborne exposures to engineered nanomaterials. If respirators are to be used for protection against engineered nanoparticles, select and use half-mask, P-100 cartridge-type respirators or respirators that provide a higher level of protection.
  - Keep potentially contaminated clothing and PPE in the laboratory or change out area to prevent engineered nanoparticles from being transported into common areas.
  - Appropriately clean and/or dispose of all potentially contaminated clothing and PPE.

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26 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 19, “Personal Protective Equipment”, <http://www-group.slac.stanford.edu/esh/general/ppe/policies.htm>

27 Title 29, *Code of Federal Regulations*, Part 1910, “Occupational Safety and Health Standards”, (29 CFR 1910), [http://www.osha.gov/pls/oshaweb/owastand.display\\_standard\\_group?p\\_toc\\_level=1&p\\_part\\_number=1910](http://www.osha.gov/pls/oshaweb/owastand.display_standard_group?p_toc_level=1&p_part_number=1910)

28 When handling articles having nanomaterials in a securely bound form, that is, when protection from nanoparticles and other hazards is not needed, cotton gloves and other gloves not typically appropriate in chemical laboratories can be considered. However, steps must be taken to avoid their misuse as protective equipment.

29 Wearing an inner glove can lessen the likelihood of contaminating hands while removing a contaminated outer glove.

### 3.6 Monitoring and Characterization

- When appropriate or when requested, the SLAC industrial hygiene group will use a direct-reading particle-measuring device to screen for suspect emissions.
- When appropriate, the SLAC industrial hygiene group will collect samples to characterize emissions and determine if a control is needed or must be upgraded or serviced.
- The SLAC Industrial Hygiene Document Database<sup>30</sup> and SLAC Medical Department<sup>31</sup> records will be used to link environmental data indicative of exposure to nanoparticulate with potentially exposed workers.

### 3.7 Worker Competency

- SLAC staff who work with nanomaterial in laboratories within the scope of this plan (nanoparticle workers and their supervisors) must complete the following:
  - ESH Course 161, Nanomaterials Laboratory Safety<sup>32</sup>
  - The course must be completed upon initial assignment to the laboratory. The course will define nanomaterials and provide information on how to carry out activities with nanomaterials in a safe and environmentally responsible way.
- Visiting scientists, guest researchers, and other lab users who are not SLAC employees or subcontractors must take ESH Course 161 or demonstrate that they understand applicable chemical hygiene principles. This can be accomplished by providing acceptable proof of nanomaterial laboratory safety training from another institution or passing an exam.
- Specific procedural requirements will be incorporated into the laboratory safe operating procedures written and maintained by the laboratory supervisor

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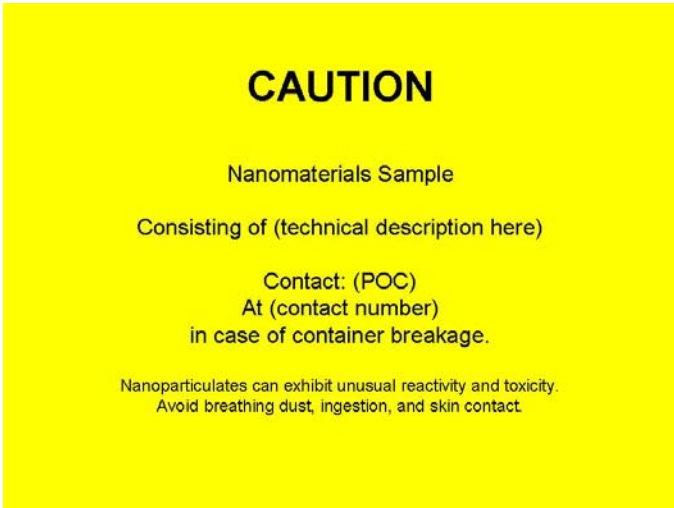
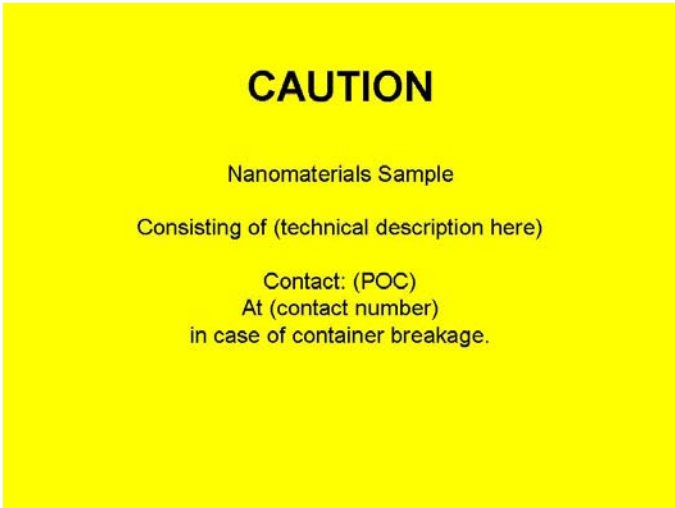
30 “IH Measurements”, <https://www-internal.slac.stanford.edu/esh-db/IH/Measurements/Default.aspx>

31 “SLAC Medical Department”, <http://www-group.slac.stanford.edu/esh/medical/>

32 ESH Course 161, Nanomaterial Laboratory Safety, [https://www-internal.slac.stanford.edu/esh-db/training/slaonly/bin/catalog\\_item.asp?course=161](https://www-internal.slac.stanford.edu/esh-db/training/slaonly/bin/catalog_item.asp?course=161)

Table 1 Requirements by Risk / Material Form

	Risk / Material Form		
	Low	Medium	High
Requirements	Bound or Fixed Nanostructures	Nanoparticles Suspended in Liquids	Dry Dispersible Nanoparticles and Agglomerates (or otherwise hazardous – see Section 3.1.3)
Review / Approval	SSRL Safety Coordinator	SSRL Safety Coordinator	NSC
PPE Requirements for Handling	Standard PPE required for the work area. No additional PPE is needed for this nanomaterial work.	Standard PPE required for the work area plus: <ul style="list-style-type: none"> <li>▪ Gauntlet-type nitrile gloves or wrist length disposable nitrile gloves with extended sleeves</li> <li>▪ Eye protection: safety glasses with side shields for handling powders only. Chemical splash goggle for handling either powders or liquids.</li> </ul>	
Handling Requirements	<p>For work outside of a HEPA-filtered exhaust hood:</p> <ul style="list-style-type: none"> <li>▪ No mechanical abrasion</li> <li>▪ No thermal stresses that might crack binder material</li> <li>▪ Cover samples when practical to protect the sample, for example use a slide cover</li> <li>▪ Store in sealed container when not in use</li> </ul>	<p>If there is a potential for particle aerosol formation, manipulate within a HEPA-filtered laboratory exhaust hood over adsorbent paper to capture any spills.</p> <p>Solutions brought to the beam line must be:</p> <ul style="list-style-type: none"> <li>▪ Transported in sealed containers</li> <li>▪ Manipulated over an adsorbent paper to capture any spills</li> </ul> <p>Work surfaces must be wiped with dampened adsorbent paper towels at the completion of the experiment (aqueous soap solution).</p>	<p>At a minimum:</p> <ul style="list-style-type: none"> <li>▪ Material must be manipulated within a HEPA-filtered laboratory exhaust hood over water-soaked adsorbent paper to capture any spilled materials.</li> <li>▪ Exhaust hood work surfaces must be wiped with dampened adsorbent paper towels at the completion of the experiment (aqueous soap solution).</li> <li>▪ When ejecting samples from a capillary, that sample must be directed to water for capture. Compressed nitrogen (&lt;5 psi) or other inert gas must be used to eject the sample from the capillary tube. A covered beaker is best to contain any splash. This must be completed within a laboratory HEPA exhaust hood.</li> <li>▪ Nanoscale materials brought to the beam line must be sealed within a sample holder, a capillary tube, or with at least two layers of Kapton, Mylar or cellophane tape.</li> <li>▪ Only sealed containers are allowed at the beam lines for storage during an experiment.</li> <li>▪ Experiments that involve gas flow over particles must include a water scrub of the gas exhaust to provide a final barrier to particle loss.</li> </ul>
Spill Response	NA	Powder spills within an exhaust hood can be cleaned by using paper towels and an aqueous soap solution. Liquid spills within a hood can be cleaned with paper towels and then wiped with an aqueous soap solution. For spills outside of an exhaust hood, control access to the area and immediately notify the laboratory supervisor.	

	Risk / Material Form		
	Low	Medium	High
Requirements	Bound or Fixed Nanostructures	Nanoparticles Suspended in Liquids	Dry Dispersible Nanoparticles and Agglomerates (or otherwise hazardous – see Section 3.1.3)
Posting	No posting requirements	Post required sign at each designated nanomaterial workstation (beam line hutch and laboratory exhaust hood) for the duration of experiment. See Section 3.4.5, "Marking, Labeling, and Signage".	
Labeling of Containers	Follow the labeling requirements list below in Section 5, "Transportation of Nanomaterials".		
Transportation and Labeling	<p>Any nanomaterial that meets the definition of hazardous materials according to 49 CFR 171.8 (<a href="http://www.gpoaccess.gov/cfr/">http://www.gpoaccess.gov/cfr/</a>) or has known hazardous properties (toxic, flammable, reactive) must be shipped according to the SLAC Shipping Requirements for Hazardous Materials (SLAC Shipper Form, <a href="https://www-bis1.slac.stanford.edu/Public/shipper/shipintro.asp">https://www-bis1.slac.stanford.edu/Public/shipper/shipintro.asp</a>)</p> <p>Other nanomaterials may be carried in private vehicles when labeled and packaged as follows:</p> <p>Labeling:</p> <ol style="list-style-type: none"> <li>The inner package must be labeled as follows:</li> </ol> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>For dry particulates</p> </div> <div style="text-align: center;">  <p>For non-particulates</p> </div> </div> <p>Packaging:</p> <ol style="list-style-type: none"> <li>Inner containers must be a tightly sealed, rigid, and leak proof. Use tape on the cap to prevent the container from being unintentionally opened.</li> <li>Place the inner container in a &gt;=6 mil plastic bag.</li> <li>The outer package (sealed cardboard box "or" sealed plastic container) must be filled with absorbent material to protect the inner container and absorb liquids during an inner container failure.</li> </ol>		
Waste Management	All waste in contact with nanomaterials must be disposed as hazardous waste (eg, swabs, Kim wipes, blotter paper, beakers, flasks, tape, sample holders). Chemicals containing nanomaterials must NOT be released to the sink or disposed in the regular trash.		

	Risk / Material Form		
Requirements	Low	Medium	High
	Bound or Fixed Nanostructures	Nanoparticles Suspended in Liquids	Dry Dispersible Nanoparticles and Agglomerates (or otherwise hazardous – see Section 3.1.3)
	<ol style="list-style-type: none"> <li>1. Waste containers:               <ol style="list-style-type: none"> <li>a. Liquids: must be stored in a rigid leak proof container.</li> <li>b. Particulates: must be stored in a rigid leak proof containers OR &gt;=6 mil plastic bags.</li> </ol> </li> <li>2. Satellite accumulation areas:               <ol style="list-style-type: none"> <li>a. Liquids: must be stored in a secondary tray on the bench top or in a HEPA exhaust hood.</li> <li>b. Particulates: must be stored in a secondary container inside the designated nanomaterials HEPA-filtered exhaust hood. Waste must be placed into a clean secondary bag, within the HEPA exhaust hood, before transferring to the 90-day area.</li> </ol> </li> <li>3. Waste container labeling:               <ol style="list-style-type: none"> <li>a. No formulas, spell out the chemical name.</li> <li>b. The contents line on the label must contain the chemical composition and the word NANOMATERIALS.</li> <li>c. A second label is required on the outside of the bag stating CONTAINS NANOMATERIALS.</li> </ol> </li> </ol>		

## 4 Verifying Program Effectiveness

Section 3, “Controls for Research Laboratory Operations”, of this document defines policies and procedures intended to ensure that worker exposure to engineered nanomaterials, the hazards of which are not well understood, is kept as low as practicable in the research environment.<sup>33</sup> While effective management of engineered nanomaterials should ensure that ill-health effects and adverse environmental consequences will not result, the general uncertainty associated with engineered nanoparticle toxicology and environmental fate and reports of ill-health effects in test animals make it appropriate to attempt to verify the absence of unusual health effects in exposed workers. Respecting the limits imposed by current knowledge and the absence of consensus standards, this document recommends basic worker health and environmental monitoring consisting of the following:

1. Identifying staff (*nanoparticle workers*) exposed to engineered nanoparticles of unknown health effects
2. Conducting workplace characterization and worker exposure assessments
3. Providing, when appropriate, nanoparticle workers with baseline medical evaluations and including them in a non-specific routine health monitoring program
4. Checking wastes for evidence of uncontrolled release of engineered nanomaterials
5. Periodic effluent monitoring

Each of these program elements should be periodically reviewed by the NSC and the approaches refined in a manner reflective of newly available knowledge about human and environmental health effects. They should also be kept as rigorous as current recommendations in professionally recognized national and international consensus standards. The NSC will conduct an annual self-assessment of compliance with nanotechnology policies and procedures at SLAC and a written report of this assessment will be filed with the SLAC Office of Assessment.

### 4.1 Nanoparticle Worker Identification

Unlike substances the effects of which have been more thoroughly studied, there are no definitions of an action (exposure) level for nanoparticles that should trigger worker inclusion in a more formal medical surveillance program. Consequently, SLAC will adopt a broad definition of nanoparticle-exposed workers that will be refined as more reliable information on human health effects becomes available. This definition should be understood as initially causing identification of a larger group than is at significant risk.

Any staff member<sup>34</sup> meeting one or more of the following criteria be considered a *nanoparticle worker*:

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- 33 National Research Council, *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals* (National Academy Press, Washington, DC 1995), page 3, [http://books.nap.edu/catalog.php?record\\_id=4911](http://books.nap.edu/catalog.php?record_id=4911)
  - 34 *Staff member* includes SLAC employees and long-term (more than three months) collaborators, guests, and visitors.

- Handles nanoscale particulates that have the potential to become dispersed with the potential for inhalation or dermal contact
- Routinely spends significant amounts of time in an area in which nanoparticles have the potential to become dispersed in the air
- Works on equipment that is believed to be contaminated and could foreseeably release engineered nanoparticles during servicing or maintenance

*Note* Given the lack of current understanding about dose-response, workers whose exposures might be relatively high and those whose exposures might be relatively low will be included. This policy also reflects the lack of consensus on how to measure worker exposure.

SSRL will

- Record the identity of personnel who satisfy the preceding definition of engineered nanoparticle workers using the SSRL Proposal Form tracking system
- Consistent with the recommendation in Section 3.7, “Worker Competency”, ensure that personnel who satisfy the preceding definition of engineered nanoparticle workers take ESH Course 161, Nanomaterial Laboratory Safety<sup>35</sup>
- Coordinate with the SLAC industrial hygiene group to assure that available methods are used to characterize workplace conditions and exposures for nanoparticle workers (see Section 3.6, “Monitoring and Characterization”)
- Coordinate with the SLAC Medical Department to ensure that, when appropriate, SLAC staff classified as nanoparticle workers are offered baseline medical evaluations (see Section 4.3, “Worker Health Surveillance”)
- Coordinate with the NSC, the SLAC industrial hygiene group, and the SLAC Medical Department to revisit and refine the definition of engineered nanoparticle workers and make recommendations for changes to any applicable medical examination program

## 4.2 Workplace Characterization and Exposure Assessments

Workplace characterization and nanomaterial exposure assessment challenges include

- Substantially different parameters may prove hygienically significant for different nanomaterials
- Materials of the same chemical composition can have markedly different forms at the nanoscale and the different forms can have markedly different properties
- No professional consensus on monitoring instrumentation and protocols exists and it may be a decade (or more) before one emerges

*Note* It has been suggested that there is value in attempting to measure workplace conditions and characterize worker exposures to nanoparticles in the interim.<sup>36</sup> (There may also be value in characterizing airborne and waterborne emissions.)

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35 ESH Course 161, Nanomaterial Laboratory Safety, [https://www-internal.slac.stanford.edu/esh-db/training/slaonly/bin/catalog\\_item.asp?course=161](https://www-internal.slac.stanford.edu/esh-db/training/slaonly/bin/catalog_item.asp?course=161)

36 Maynard, A. et al., “Commentary: Safe Handling of Nanotechnology”, *Nature* 444 (16 November 2006): page 268; and *Approaches to Safe Nanotechnology*, see note 2.

Although there is no validated or consensus approach for characterizing worker exposure, SLAC will make a good-faith effort to characterize the exposures of personnel exposed to nanoparticles and to link the resulting data to those nanoparticle-exposed personnel.

As appropriate, SLAC will use available instruments and methods to characterize workplace conditions and estimate exposures of engineered nanoparticle workers by performing the following:

- Conduct baseline monitoring by measuring conditions before start up. Measure again at the conclusion of system commissioning and periodically thereafter. These efforts should be considered a vital part of an overall strategy of ensuring that controls are well conceived, well constructed, and remain effective. Investigate significantly atypical and unexpected measurements.
- Use direct-reading particle-measuring devices to screen for suspect emissions and atypical conditions that deserve further investigation
- Collect and analyze samples that will be used to characterize emissions and potential exposures.

### 4.3 Worker Health Surveillance

Until a consensus emerges regarding health monitoring, the SLAC Medical Department will provide the following:

- SLAC staff identified as *nanoparticle workers* will be offered a baseline medical evaluation by enrollment in ESH Course 161ME.<sup>37</sup> This baseline medical evaluation will consist of a general physical exam, including general blood work, pulmonary function test, and other tests and exams as determined by the SLAC Medical Department.
- SLAC staff involved in any incident that results in an unexpected and/or unusually high exposure to nanomaterials, through any route of entry, will be examined by the SLAC Medical Department for a post-incident evaluation as per 29 CFR 1910.1450(g)(1)(i).<sup>38</sup>
- Non-resident personnel (for example, facility users) will be exempted from medical surveillance.

### 4.4 Domestic Waste Surveys

Currently, methods for surveying wastes for nanoparticles have not yet been established. However, rather than reserving this section, this document suggests that SLAC staff be instructed to conduct periodic visual inspections of domestic wastes and to report to corresponding laboratory supervisors instances involving the appearance of suspect nanomaterial, including contaminated wipes, in domestic trash containers.

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37 ESH Course 161ME, Medical Surveillance for Nanoparticle Workers, [https://www-internal.slac.stanford.edu/esh-db/training/slaonly/bin/catalog\\_item.asp?course=161ME](https://www-internal.slac.stanford.edu/esh-db/training/slaonly/bin/catalog_item.asp?course=161ME)

38 Title 29, *Code of Federal Regulations*, Part 1910, “Occupational Safety and Health Standards”, Section 1450, “Occupational Exposure to Hazardous Chemicals in Laboratories” (29 CFR 1910.1450(g)(1)(i)), [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10106](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106)

## 4.5 Effluent Monitoring

[ Reserved – techniques for monitoring have not yet been established. However, this should not be interpreted as discouraging interested groups from collaborating on the development of methods. ]

# 5 Transportation of Nanomaterials

The requirements under this heading apply to the movement of material from SLAC to and from off-site locations. It assumes that SLAC personnel who package and prepare nanomaterials for shipment off-site have and are current on HazMat employee training required by 49 CFR Subpart H.

## 5.1 Categories of Materials

### 5.1.1 Recognized HazMat

Any nanomaterial that meets the definition of a hazardous material according to 49 CFR 171.8<sup>39</sup> and can be classified as a hazardous material in accordance with 49 CFR 173.115–141 and 173.403–173.436,<sup>40</sup> must be packaged, marked, labeled, shipping papers prepared, and shipped in accordance with 49 CFR 100–185<sup>41</sup>.

Any nanomaterial being shipped by air that meets the definition of dangerous goods according to the International Civil Aviation Organization (ICAO) must be packaged, marked, labeled, and shipped, with an accompanying properly prepared dangerous goods declaration, in accordance with the ICAO technical instructions.

### 5.1.2 Suspected DOT HazMat

Nanomaterials that are suspected to be hazardous (for example, toxic, reactive, flammable) should be classified, labeled, marked, and manifested as though that hazard exists in accordance with Section 5.1.1, “Recognized HazMat”. These materials should be classified and shipped as samples per 49 CFR 172.101(c)(11)<sup>42</sup> unless the material is specifically prohibited by 173.21, 173.54, 173.56(d), 173.56(e), 173.224c or 173.225(b). These suspect materials should be packaged in accordance with section below.

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39 Title 49, *Code of Federal Regulations*, “Transportation”, Chapter 1, “Pipeline and Hazardous Materials Safety Administration, Department of Transportation”, Part 171, “General Information, Regulations, and Definitions”, Section 8, “Definitions and Abbreviations” (49 CFR 171.8), “Code of Federal Regulations: Main Page”, <http://www.gpoaccess.gov/cfr/>

40 Title 49, *Code of Federal Regulations*, “Transportation”, Chapter 1, “Pipeline and Hazardous Materials Safety Administration, Department of Transportation”, Part 173, “Shippers–General Requirements for Shipments and Packagings” (49 CFR 173), “Code of Federal Regulations: Main Page”, <http://www.gpoaccess.gov/cfr/>

41 Title 49, *Code of Federal Regulations*, “Transportation”, Chapter 1, “Pipeline and Hazardous Materials Safety Administration, Department of Transportation” (49 CFR 100–185), “Code of Federal Regulations: Main Page”, <http://www.gpoaccess.gov/cfr/>

42 Title 49, *Code of Federal Regulations*, “Transportation”, Chapter 1, “Pipeline and Hazardous Materials Safety Administration, Department of Transportation”, Part 172, “Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements”, Subpart B, “Table of Hazardous Materials and Special Provisions”, Section 101,

### 5.1.3 Other Nanomaterials

Nanomaterials that do not meet the DOT criteria listed above still may pose health and safety issues to personnel handling the material if they are released during its transport. Therefore, all shipments of nanomaterials, regardless of whether they meet the definition for hazardous materials or not, should be consistently packaged using the equivalent of a DOT-certified Packing Group I (PG I) container and labeled as described in Section 5.2, “Off-site Shipments”.

## 5.2 Off-site Shipments

The information under this heading applies to materials sent to SLAC, and materials sent from SLAC to off-site locations, that do not otherwise meet the DOT definition of hazardous material.

### 5.2.1 Packaging

The outer and inner package should meet the definition of a Package Group I (PG I) type package. The innermost container should be tightly sealed to prevent leakage of nanomaterials. It should have a secondary seal, such as tape seal, or a wire tie to prevent a removable closure from inadvertently opening during transport.

The outer package should be filled with shock absorbing material that can

- Protect the inner sample container(s) from damage
- Absorb liquids that might leak from the inner container(s) during normal events in transport

### 5.2.2 Labeling

As depicted in Figure 2 and Figure 3, the inner package should be labeled (not to be confused with DOT hazard labeling) “Caution: Nanomaterials sample consisting of (technical description here). Contact (name of point of contact) at (contact number) in case of container breakage”.

If the nanomaterial is in the form of dry dispersible particles, add the following line of text:

- “Nanoparticulates can exhibit unusual reactivity and toxicity. Avoid breathing dust, ingestion, and skin contact.”

Documentation and notifications for off-site transfer of nanomaterials should include the following:

- A signed and complete dangerous goods declaration or shipping papers prepared in accordance with the ICAO and DOT regulations by certified/qualified HazMat employees who are authorized to release materials from the site.
- Available descriptions of the material, for example, material safety data sheets (MSDSs). (With respect to samples researchers should prepare a document that describes known properties and other properties that deem reasonably likely to be exhibited by samples.)<sup>43</sup>

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“Purpose and Use of Hazardous Materials Table” (49 CFR 172.101c(11)), “Code of Federal Regulations: Main Page”, <http://www.gpoaccess.gov/cfr/>

43 “Hazard Communication and MSDS References”, <http://www-group.slac.stanford.edu/esh/groups/cgs/hmaq/hazmat/hazcom.htm>

- A notification to receiving facility of the incoming shipment.

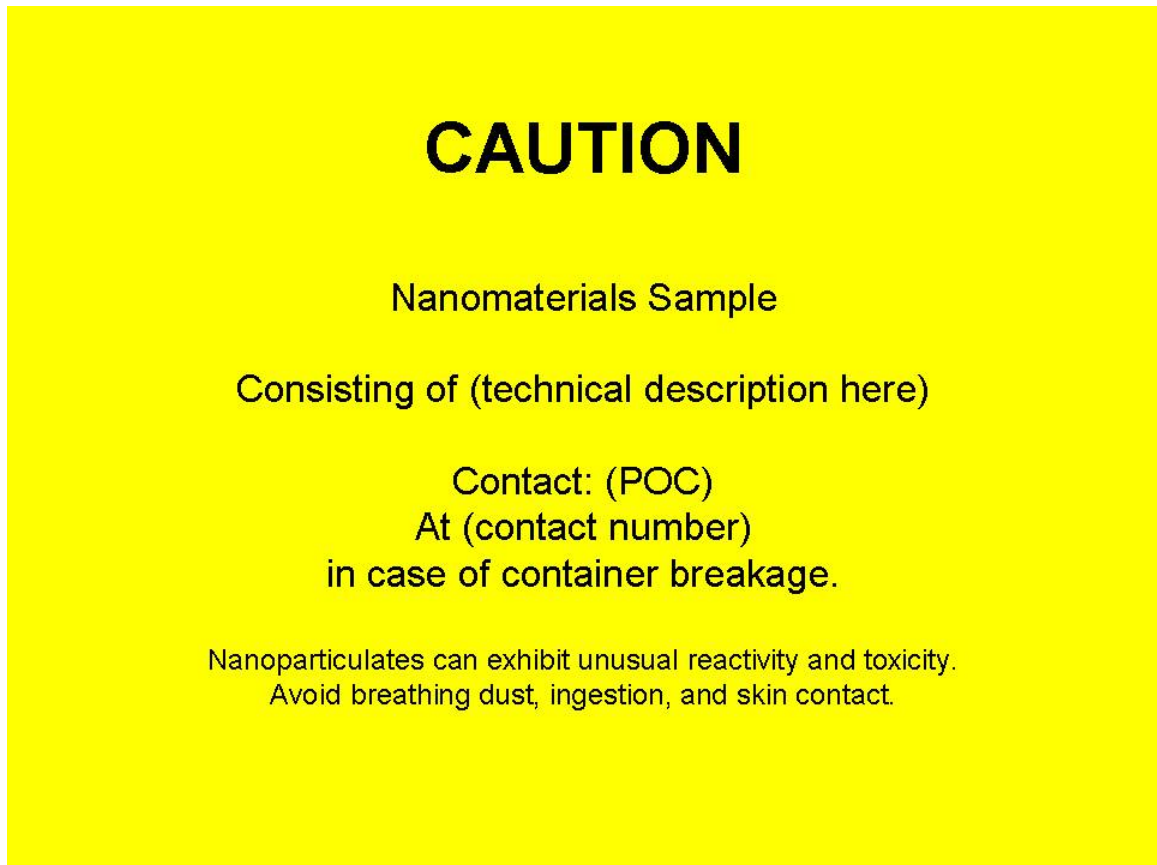


Figure 2 Inner Packaging Label for Dry Particulates

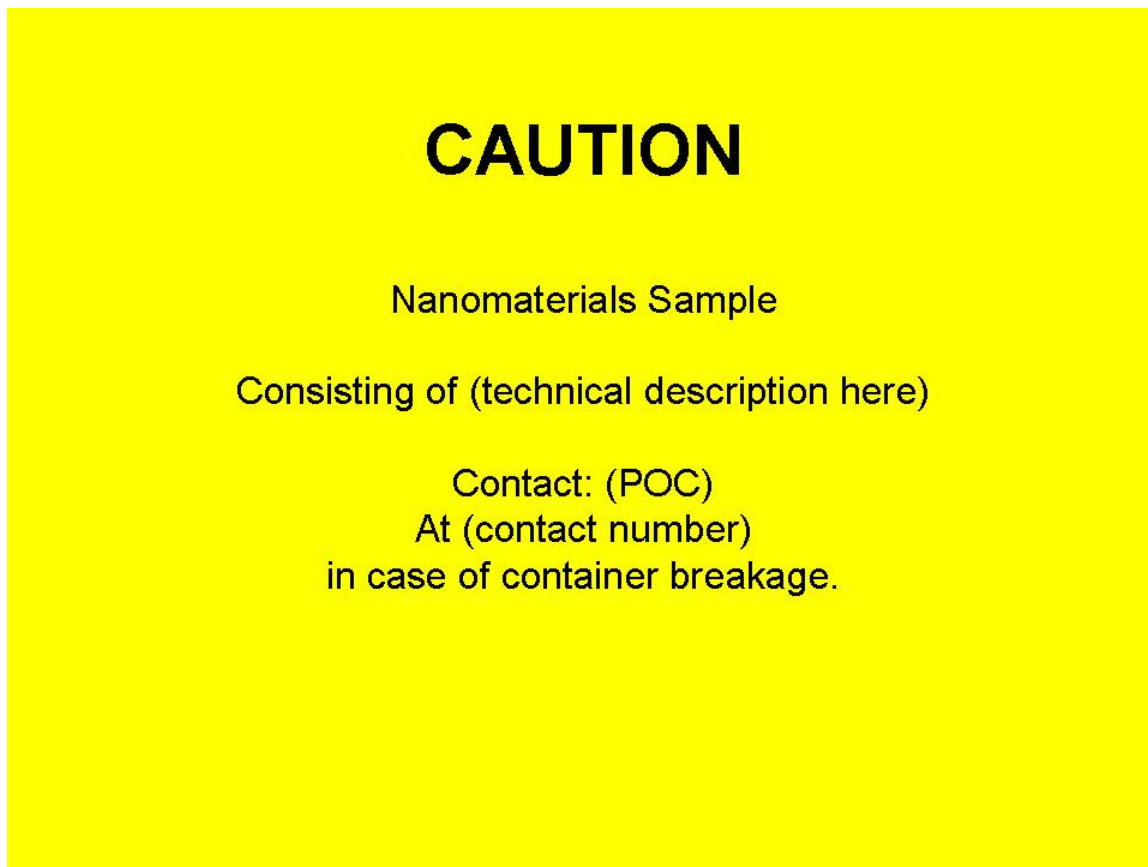


Figure 3 Inner Packaging Label for Non-particulates

### 5.2.3 Modes of Transport

All materials should be transported by a qualified carrier, for which the DOE or the General Services Administration (GSA) has a tender on file. All transportation services must comply with the Federal Acquisition Regulations (FAR).<sup>44</sup> Recommended modes for off-site shipment of nanomaterials include

- FedEx, or other certified hazardous-materials carrier
- Roadway, UPS Ground, or other commercial less-than-truckload (LTL)-certified hazardous-materials carrier
- Dedicated highway hazardous-materials carriers for exclusive-use shipments using a carrier approved by the DOE Motor Carrier Safety Program (MCEP)<sup>45</sup>

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44 Title 48, *Code of Federal Regulations*, “Federal Acquisition Regulations System” (48 CFR), “Code of Federal Regulations: Main Page”, <http://www.gpoaccess.gov/cfr/>

45 Department of Energy, National Transportation Program, *DOE’s Motor Carrier Evaluation Program*, [http://www.em.doe.gov/PDFs/transPDFs/MCEP\\_factsheet.pdf](http://www.em.doe.gov/PDFs/transPDFs/MCEP_factsheet.pdf)

- Shipments of nanomaterials classified as *other materials* (neither recognized HazMat or suspected DOT HazMat) may be transported using the most expeditious method provided they are packaged as per the requirements in Section 5.2.1, “Packaging”, and
  - The driver must have a valid state driver’s license appropriate for the vehicle being operated.
  - The vehicle must be in good mechanical condition and have a valid state safety inspection.
  - The vehicle must be insured with at least the required minimum liability insurance required by the state where the vehicle is registered.
  - The driver must obey all state and local traffic rules and regulations.
  - The driver must possess basic hazard information on the commodity being transported, that is, material name, quantity, form and material safety data sheet if available.

### 5.3 On-site Transfers of Nanomaterials

The on-site transfer of nanomaterials must follow the requirements outlined in Hazardous Waste: On-site Transportation Requirements<sup>46</sup> and Hazardous Materials: On-site Transportation Requirements.<sup>47</sup> For nanomaterials, add the following:

- Assess and record the hazards posed by the material(s) following a graded approach that takes into account the form of the material(s) (for example, free particle versus fixed on substrate).
- Use packaging consistent with the recommendations for off-site shipment or packaging that affords an equivalent level of safety.
- Mark the transfer containers in accordance with the (above) recommendations for off-site shipments.
- Include the following documents in the package:
  - The results of the safety assessment
  - An MSDS, if available, or a similar form detailing possible hazards associated with the material; otherwise, if an MSDS is unavailable, the principal investigator should supply material-specific knowledge
  - Notify the receiving facility of the incoming shipment

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46 Hazardous Waste: On-site Transportation Requirements (SLAC-I-750-0A08S-005), <http://www-group.slac.stanford.edu/esh/eshmanual/references/hazwasteReqTransport.pdf>

47 Hazardous Materials: On-site Transportation Requirements (SLAC-I-730-0A09S-019), <http://www-group.slac.stanford.edu/esh/eshmanual/references/hazmatReqTransport.pdf>



# 6 Management of Nanomaterial-bearing Waste Streams

## 6.1 Applicability

The following waste management guidance applies to nanomaterial-bearing waste streams consisting of

- Nanomaterials (for example, carbon nanotubes)
- Items contaminated with nanomaterials (for example, wipes and PPE)
- Liquid suspensions containing nanomaterials (for example, hydrochloric acid containing carbon nanotubes)
- Hazardous solids containing or coated with nanomaterials that can be released into the air or leach into liquids. This includes nanomaterials that can be dislodged via mechanical forces, such as scraping.

The requirements do not apply to nanomaterials embedded in a solid matrix that cannot reasonably be expected to break free or leach out when they contact air or water.

## 6.2 Nanomaterials in Waste Streams

- Consider any material that has come into contact with dispersible engineered nanoparticles (that has not been decontaminated) as belonging to a nanomaterial-bearing waste stream. This includes PPE, wipes, blotters and other disposable laboratory materials used during research activities.
- In order to reduce waste generated, consider reducing the risk of loss of nanomaterials into the air and surrounding environment by suspending powders in a small volume of a non-hazardous liquid. Balance the added safety, if any, against the risks and costs of the increased volume of waste.
- Evaluate surface contamination or decontaminate equipment used to manufacture or handle nanoparticles before disposing of or reusing it. Treat wastes (cleaning solutions, rinse waters, rags, PPE) resulting from decontamination as nanomaterial-bearing waste.

## 6.3 Classification and Disposal of Nanomaterial-bearing Waste Streams

- Do not put material from nanomaterial-bearing waste streams into the regular trash or down the drain.
- Do not permit nanomaterial-bearing wastes to be shipped off-site to researchers' home institutions for disposal.

- Characterize and manage nonmaterial-bearing waste streams as either hazardous or non-hazardous waste based on the requirements in 40 CFR 261.10–38,<sup>48</sup> or equivalent state regulations, considering their known characteristics and/or listing of the waste.
- Package nanomaterial-bearing wastes in containers that are compatible with the contents, in good condition, and that afford adequate containment to prevent the escape of the nanomaterials.
- To the extent possible, segregate nanomaterial waste from other waste during management and disposition.
- Label the waste container with a description of the waste and the words “contains nanomaterials”. Include available information characterizing known and suspected properties.
- Collect paper, wipes, PPE and other items with loose contamination in a plastic bag or other sealing container stored in the laboratory hood. When the bag is full, close it, take it out of the hood and place it into a second plastic bag or other sealing container. Label the outer bag with the laboratory’s proper waste label.
- Keep an inventory record of all nanomaterial waste that is shipped off site; the inventory will maintain a description of the waste, the quantity, and means and location of final disposition.

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48 Title 40, *Code of Federal Regulations*, “Protection of the Environment”, Chapter 1, “Environmental Protection Agency”, Part 261, “Identification and Listing of Hazardous Waste”, sections 10 through 38 (40 CFR 261.10–38), “Code of Federal Regulations: Main Page”, <http://www.gpoaccess.gov/cfr/>

# 7 Management of Nanomaterial Spills

## 7.1 Access Control

- Determine the extent of the area reasonably expected to have been affected, and demarcate it with barricade tape or use another reliable means to restrict entry into the area.
- Refer personnel exposed to nanomaterials in the course of a spill to the SLAC Medical Department.<sup>49</sup>

## 7.2 Dry Materials

- Position a walk-off mat (for example, Tacki-Mat®) where cleanup personnel will exit the access-controlled area to reduce the likelihood of spreading nanoparticles.
- Clean using wet-wiping methods. Characterize, collect, and dispose of spill cleanup materials as nanomaterial-bearing waste. (See Section 6, “Management of Nanomaterial-bearing Waste Streams”.)
- Use a tested and certified HEPA vacuum; do not use dry sweeping or compressed air.
  - Ensure that the effectiveness of HEPA filters is verified at a frequency consistent with manufacturer recommendations.
  - When feasible, use only dedicated HEPA vacuums used for nanomaterial cleanup. Label the units accordingly, for example, “Use only for nanomaterial spill cleanup.” Use a log to record the type of material collected and avoid mixing potentially incompatible materials in the vacuum or filters.
  - Characterize, collect, and dispose of used HEPA filters as nanomaterial-bearing waste.
  - Consider the possible air reactivity of nanoparticles prior to using a vacuum cleaner. Some normally stable powders may become pyrophoric if deposited on a filter and subject to high airflow.

## 7.3 Liquids

Employ normal HazMat response based on the spilled material’s known hazards. The following are additional requirements to mitigate nanomaterials left behind once the liquids have been removed:

- Position an absorbent walk-off mat where the cleanup personnel will exit the access-controlled area to prevent the spread of liquids containing suspended nanoparticles.
- Place barriers (for example, plastic sheeting) that will minimize air currents across the surface affected by the spill.
- Use a wet-wiping method to clean the spill. A HEPA-filtered vacuum dedicated to the cleanup of nanomaterials may also be used to clean up residual nanomaterials left behind after the spill area has dried.

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49 “SLAC Medical Department”, <http://www-group.slac.stanford.edu/esh/medical/>

- Manage all materials used to clean up the spill (such as absorbent mats, absorbent material, wipes) as hazardous or potentially hazardous waste based on the material involved.

## 7.4 Wastes

- Manage all debris resulting from the cleanup of a spill as though it contains sufficient nanomaterials to be managed in accordance with Section 6, “Management of Nanomaterial-bearing Waste Streams”.

## 8 Related Documents

The following are related documents and forms. Always locate and use the latest version, either online from the addresses below or from the originating group.

Table 2 Related Documents

Title	Document Number	Originating Unit	URL
<b>Implementing Documents</b>			
Hazards Form		SSRL	<a href="http://www-ssrl.slac.stanford.edu/users/user_admin/form_hazards.html">http://www-ssrl.slac.stanford.edu/users/user_admin/form_hazards.html</a>
SSRL Proposal Form		SSRL	<a href="http://www-ssrl.slac.stanford.edu/userresources/documents/form_proposal.rtf">http://www-ssrl.slac.stanford.edu/userresources/documents/form_proposal.rtf</a>
<b>ESH Chapters / Programs</b>			
<i>Chemical Hygiene Plan</i>	SLAC-I-730-0A09M-002	IHIM	<a href="http://www-group.slac.stanford.edu/esh/document/techbas/chp.pdf">http://www-group.slac.stanford.edu/esh/document/techbas/chp.pdf</a>
<i>Consolidated Chemical Contingency Plan</i>	SLAC-I-730-3A86H-008	IHIM	<a href="http://www-group.slac.stanford.edu/esh/documents/CCCP.pdf">http://www-group.slac.stanford.edu/esh/documents/CCCP.pdf</a>
<i>SLAC Environment, Safety, and Health Manual, Chapter 40, "Hazardous Materials"</i>	SLAC-I-720-0A29Z-001	IHIM	<a href="http://www-group.slac.stanford.edu/esh/hazardous_substances/haz_materials/policies.htm">http://www-group.slac.stanford.edu/esh/hazardous_substances/haz_materials/policies.htm</a>
<i>SLAC Environment, Safety, and Health Manual, Chapter 17, "Hazardous Waste"</i>	SLAC-I-720-0A29Z-001	EP	<a href="http://www-group.slac.stanford.edu/esh/environment/hazardous_waste/policies.htm">http://www-group.slac.stanford.edu/esh/environment/hazardous_waste/policies.htm</a>
<i>SLAC Environment, Safety, and Health Manual, Chapter 19, "Personal Protective Equipment"</i>	SLAC-I-720-0A29Z-001	IHIM	<a href="http://www-group.slac.stanford.edu/esh/general/pe/policies.htm">http://www-group.slac.stanford.edu/esh/general/pe/policies.htm</a>
<b>ESH Other</b>			
"Hazard Communication and MSDS References"		IHIM	<a href="http://www-group.slac.stanford.edu/esh/groups/cgs/hmaq/hazmat/hazcom.htm">http://www-group.slac.stanford.edu/esh/groups/cgs/hmaq/hazmat/hazcom.htm</a>
"SLAC Medical Department"		Medical	<a href="http://www-group.slac.stanford.edu/esh/medical/">http://www-group.slac.stanford.edu/esh/medical/</a>
Nanomaterial Laboratory Safety	ESH Course 161	IHIM	<a href="https://www-internal.slac.stanford.edu/esh-">https://www-internal.slac.stanford.edu/esh-</a>

Title	Document Number	Originating Unit	URL
			<a href="http://www.slac.stanford.edu/esh/db/training/slaonly/bin/catalog_item.asp?course=161">db/training/slaonly/bin/catalog_item.asp?course=161</a>
Medical Surveillance for Nanoparticle Workers	ESH Course 161ME	IHIM	<a href="https://www-internal.slac.stanford.edu/esh/db/training/slaonly/bin/catalog_item.asp?course=161ME">https://www-internal.slac.stanford.edu/esh/db/training/slaonly/bin/catalog_item.asp?course=161ME</a>
Hazardous Materials: On-site Transportation Requirements	SLAC-I-730-0A09S-019	IHIM	<a href="http://www-group.slac.stanford.edu/esh/eshmanual/references/hazmatReqTransport.pdf">http://www-group.slac.stanford.edu/esh/eshmanual/references/hazmatReqTransport.pdf</a>
Hazardous Waste: On-site Transportation Requirements	SLAC-I-750-0A08S-005	EP	<a href="http://www-group.slac.stanford.edu/esh/eshmanual/references/hazwasteReqTransport.pdf">http://www-group.slac.stanford.edu/esh/eshmanual/references/hazwasteReqTransport.pdf</a>
Industrial Hygiene Document Database		IHIM	"IH Measurements", <a href="https://www-internal.slac.stanford.edu/esh/db/IH/Measurements/Default.aspx">https://www-internal.slac.stanford.edu/esh/db/IH/Measurements/Default.aspx</a>
<b>SLAC Other</b>			
SLAC Shipper Form		Purchasing	<a href="https://www-bis1.slac.stanford.edu/Public/shipper/sHIPintro.asp">https://www-bis1.slac.stanford.edu/Public/shipper/sHIPintro.asp</a>
<b>Other</b>			
American National Standards Institute/American Industrial Hygiene Association (ANSI/AIHA) Z9.7-2007, "Recirculation of Air from Industrial Process Exhaust Systems"	ANSI/AIHA Z9.7-2007	American National Standards Institute/American Industrial Hygiene Association	See the "SLAC Research Library Community Pages", <a href="http://www-group.slac.stanford.edu/library/CommunityPages.asp">http://www-group.slac.stanford.edu/library/CommunityPages.asp</a> , for available standards. For a list of ANSI standards, see the American National Standards Institute "ANSI Standards Store", <a href="http://webstore.ansi.org/">http://webstore.ansi.org/</a> .
ASTM International (ASTM) E2456-06, "Terminology Relating to Nanotechnology"	ASTM E2456-06	ASTM International	See the "SLAC Research Library Community Pages", <a href="http://www-group.slac.stanford.edu/library/CommunityPages.asp">http://www-group.slac.stanford.edu/library/CommunityPages.asp</a> , for available standards. ASTM standards are available online from a SLAC login ( <a href="http://enterprise.astm.org/">http://enterprise.astm.org/</a> ); some hard copies are also available.
Department of Energy Policy 456.1, "Secretarial Policy Statement on Nanoscale Safety"	DOE P 456.1	United States Department of Energy	<a href="http://www.directives.doe.gov/pdfs/DOE/doetext/neword/456/p4561.html">http://www.directives.doe.gov/pdfs/DOE/doetext/neword/456/p4561.html</a>
Department of Energy Notice 456.1, "The Safe Handling of Unbound Engineered Nanoparticles"	DOE N 456.1	United States Department of Energy	<a href="http://www.directives.doe.gov/pdfs/DOE/doetext/neword/456/n4561.html">http://www.directives.doe.gov/pdfs/DOE/doetext/neword/456/n4561.html</a>

Title	Document Number	Originating Unit	URL
<i>Approach to Nanomaterial ES&amp;H</i>	NSRC, Revision 3a, May 2008	United States Department of Energy, Nanoscale Science Research Centers	<a href="http://orise.orau.gov/ihos/Nanotechnology/files/NSRCMay12.pdf">http://orise.orau.gov/ihos/Nanotechnology/files/NSRCMay12.pdf</a>
<i>DOE's Motor Carrier Evaluation Program</i>		United States Department of Energy, National Transportation Program	<a href="http://www.em.doe.gov/PDFs/transPDFs/MCEP_factsheet.pdf">http://www.em.doe.gov/PDFs/transPDFs/MCEP_factsheet.pdf</a>
"Experimental Study of Nanoparticle Penetration through Commercial Filter Media"	<i>Journal of Nanoparticle Research</i> 9 2007	Kim, SC; Harrington, M; Pui, D	
"Commentary: Safe Handling of Nanotechnology"	<i>Nature</i> 444 16 November 2006	Maynard, A. et al	
<i>Approaches to Safe Nanotechnology: An Information Exchange with NIOSH</i>	DHHS [NIOSH], version 1.1, July 2006	National Institute for Occupational Safety and Health	<a href="http://www.cdc.gov/niosh/topics/nanotech/safenano/">http://www.cdc.gov/niosh/topics/nanotech/safenano/</a>
<i>Current Intelligence Bulletin: Evaluation of Health Hazard and Recommendations for Occupational Exposure to Titanium Dioxide</i>	DHHS [NIOSH], draft, November 2005	National Institute for Occupational Safety and Health	<a href="http://www.cdc.gov/niosh/review/public/TiO2/pdfs/TiO2Draft.pdf">http://www.cdc.gov/niosh/review/public/TiO2/pdfs/TiO2Draft.pdf</a>
<i>Prudent Practices in the Laboratory: Handling and Disposal of Chemicals</i>	National Academy Press, Washington, DC 1995	National Research Council	<a href="http://books.nap.edu/catalog.php?record_id=4911">http://books.nap.edu/catalog.php?record_id=4911</a>