OASIS
TEST EQUIPMENT DATA PACKAGE

April 2000

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Approved by: S. Alan Stern
Principal Investigator

Date: 04-06-2001
KC-135 Quick Reference Data Sheet

Principal Investigator: **S. Alan Stern**

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**Experiment Title:** OASIS (Orbital Accretion Science in Space)

**Flight Date(s):** 17, 18 April 2001

**Overall Assembly Weight (lbs):** 146.4

**Assembly Dimensions (L x W x H):** 25.5 inches x 22.1 inches x 50 inches

**Equipment Orientation Requests:** Preferred orientation is with sample load window facing aircraft forward or aft (experiment x-axis parallel to aircraft forward/aft direction).

**Proposed Floor Mounting Strategy (Bolts/Studs or Straps):** Bolts

**Gas Cylinder Requests (Type and Quantity):** None

**Overboard Vent Requests (Yes or No):** Yes

**Power Requirements (Voltage and Current Required):** 115 VAC, 0.2 A, 60 Hz

**Free Float Experiment (Yes of No):** No

**Flyer Names for Each Proposed Flight Day:**
- Flight #1: S. Alan Stern, Daniel D. Durda, and Faith Vilas
- Flight #2: S. Alan Stern, Daniel D. Durda, and Michael Epperly
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### DOCUMENT REVISION HISTORY

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<td>CCD</td>
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1. Flight Manifest

The following individuals are the primary and backup flight operators that will fly aboard the KC-135 Zero-g aircraft that will perform the OASIS experiment:

<table>
<thead>
<tr>
<th>Name</th>
<th>Preferred Flt Dates</th>
<th>Mission Status</th>
<th>Prior Experience/Dates</th>
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<tr>
<td>S. Alan Stern, PI</td>
<td>17, 18 Apr ‘01</td>
<td>Primary</td>
<td>Yes/~15 flts, 1980-1981</td>
</tr>
<tr>
<td>Daniel D. Durda, Co-I</td>
<td>17, 18 Apr ‘01</td>
<td>Primary</td>
<td>None</td>
</tr>
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<td>Faith Vilas, Co-I</td>
<td>17, 18 Apr ‘01</td>
<td>Primary</td>
<td>None</td>
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<tr>
<td>Michael Epperly</td>
<td>17, 18, Apr ‘01</td>
<td>Backup</td>
<td>None</td>
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We also request an experiment load date of 16 April 2001.

2. Experiment Background

Numerous lines of evidence, derived from physical characteristics of our own planetary system and from astrophysical observations of the formative conditions of other stars, have demonstrated that the planets were formed through the accretion of material in the solar nebula, the disk-shaped cloud of gas and particulates ("dust") left over from the formation of the Sun itself (e.g., Levy and Lunine 1993).

From the beginning, after the collapse of the solar nebula from an interstellar cloud of gas and dust, the terrestrial (i.e., the inner, Earth-like) planets formed via a process involving accretion of progressively larger particles striking each other one at a time in random collisions and often sticking together (Ward 1996). During the first "early stage" of this growth, dust grains in the nebula accumulate into pebble-size particles through low-speed (of order centimeters per second) collisions, which in turn grow to boulders and ultimately, "planetesimals" some 1 to 10 km across. The "mid stage" of planetary growth is characterized by the "runaway growth" of some planetesimals whereby several dozen 500-1000 kilometer diameter protoplanetary "embryos" grow to dominate the protoplanetary disk. Finally, during the "late stage" of planetary growth, the protoplanetary embryos sweep up most of the remaining debris and (owing to mutual gravitational perturbations) cross paths and merge via inelastic collisions into a small number of final planets.

The mid and late stages of planet growth are better understood because there is a large body of physical observations (e.g., surface cratering, asteroid-asteroid collisions) available to guide modelers toward successful results. However, there remain fundamental gaps in our knowledge regarding the details of the early stages of planetary accretion. Primary among these is understanding just how dust grains accreted into larger aggregates in the first place, since ordinary experience and experimental evidence (e.g., Kerridge and Vedder 1972; Bridges et al. 1996) suggests that if solar-orbiting rock grains hit each other at low speeds, they simply bounce apart without sticking. So, how did dust grains initially aggregate?

To get around this problem, it is generally thought that some form of 'stickiness' (due to electrostatic charges, gooey organic coatings, interlocking filamentary structures, or a
A combination of such effects may assist dust particles in accreting initially, but actual experimental work in this area has not been particularly forthcoming. This is primarily due to the fact that the conditions under which dust-size particles accreted in the solar nebula (i.e., microgravity, low gas pressures, the possible dominance of electrostatic forces between particles, etc.) are not easily reproducible under terrestrial laboratory conditions, so that there are very few experimental results directly applicable to the accretion of the fluffy dust aggregates that are expected to have formed in the early solar nebula.

For example, an important parameter determining whether two particles will ultimately stick together or bounce apart after a low-speed collision is the coefficient of restitution, measured by the ratio of the rebound speed to the impact speed. Laboratory measurements of the coefficient of restitution for some planet building materials (silicate minerals, ices, etc.) have been conducted using pendulum apparatuses to achieve the requisite low impact speeds and reproducible results (e.g., Hatzes et al. 1990), but in the Earth surface gravity under which these experiments have been conducted, the samples measured have necessarily been composed of competent, comparatively strong materials that can hold up under their own weight on Earth.

In contrast to these competent materials on which accretionary experiments have been performed, evidence of the proposed fluffy structure of the first aggregated planetary matter comes from microscopic meteoritic particles collected in space and in the uppermost atmosphere. Among the numerous particles that have been collected, many clearly show very fragile, low-density structures more equivalent to "dust bunnies" than the solid rocky or icy targets that have been used in experiments so far. In the microgravity conditions that existed in the solar nebula, fluffy dust particle aggregates too weak to survive intact in Earth-bound laboratories could accrete into larger planetary building blocks. These ideas are now part of the accepted "standard model" for planetary accretion; however, what is lacking is experimental verification of these processes in a microgravity environment. We intend to develop a flight experiment to conduct such a verification.

This KC-135 Reduced Gravity Aircraft project is intended to further develop the design, discussed in the following section, for an experiment in the physics of the early stages of planetary accretion suitable for flight in the microgravity conditions on the Space Shuttle and the International Space Station. This project, called OASIS, builds upon a series of Space Shuttle experiments conducted by our Co-I John Marshall and collaborators in the early 1990s that were intended to examine the dynamics of granular particles in microgravity (Marshall 1994, 2000). Instead of the freely flowing collection of sand grains he expected to see, Marshall's experiments produced instead "dust bunny"-like masses of sand grains (Fig. 2-1) clustered together by electrostatic forces that are completely masked in the 1-g environment on the ground (Marshall and Freund 1996). These dust bunnies closely resemble the fluffy aggregates that are expected to have accreted in the early solar nebula (Blüm et al. 2000). OASIS will take the next step beyond Marshall's experimental results and collide these dust bunnies together to study the accretion of cm-scale fluffy aggregates in microgravity.

Development of OASIS is funded through seed funding provided by Dr. Mike Devirian of NASA's Jet Propulsion Laboratory Microgravity Fundamental Physics Program, and through internal research funding provided by Southwest Research Institute.
Figure 2-1. Image of a cm-scale "dust bunny" aggregation of 400-micron diameter quartz grains in a microgravity particle dynamics experiment aboard the Space Shuttle. The grains are held together by weak electrostatic forces; such an aggregate would collapse into a pile of sand in an Earthbound laboratory. The image is approximately 3 cm across. Image courtesy of John Marshall.

3. Experiment Description

OASIS is a rack mounted experiment that allows study of the preparation and launch of centimeter-sized dust aggregates (“dust-bunnies”) into a simulated target in a microgravity environment. A minimum of two (preferably three) individuals operate the experiment during the flight test. The experiment (see Figure 3-1) consists of an enclosure that houses the sample dust material (500-micron diameter silica sand inside the material hopper section), a small linear actuator (the “projectile launcher”), a target disk of aluminum, lexan (polycarbonate) window ports and a 20-inch lexan flight tube to allow the video recording (via a small CCD camera attached to a window port) of the sample prep and launch phases of the experiment. The above elements are all contained within the experiment housing. The housing itself is hard-mounted to a shelf that is attached to an AMCO Engineering instrument rack that also contains a small video recorder (data recorder), an LCD monitor, the launcher control electronics and power supply, a flashlight, and small AA battery packs for the CCD camera and LCD monitor. A hand-held camcorder is also used to record the impact of the dust-bunny into the simulated target. The CCD camera, LCD monitor, battery pack, and flashlight are all stowed items during takeoff and landing; they are attached to the instrument rack during the experiment prep stages of the flight (see section 19).

During the KC-135 microgravity flight, a series of test runs will be conducted with the experiment. During each test run (one run per parabolic), a dust bunny sample is prepared inside
the launcher sample cup and then launched into an aluminum plate (the simulated target) at velocities of less than 20 cm/s. Video images of the load and launch sequences are recorded via two CCD cameras: one CCD is attached to the experiment housing and peers through a lexan view port to image the loading of the launch cup; the second camera is a hand-held camcorder which is operated by one of the two flight operators. Images of the projectile hitting the target are recorded through the rear portion of the experiment housing made of clear lexan. Each sample is loaded into the launcher cup during the first few seconds of microgravity using a custom sample load mechanism inside the housing. The KC-135 overboard vent system is used to provide suction of air through the load mechanism to draw the sample dust material into the launcher cup. After the sample is loaded in the cup (which may take up to 10-15 seconds to complete), the sample is launched using a preprogrammed launch sequence profile towards the simulated target. Both CCD cameras are operating and recording video images of the load and launch sequences. A light source (small flashlight) attached to the housing is used to illuminate the interior of the housing during these events. At the conclusion of each load and launch cycle, the dust material will settle to the bottom of the housing during the 1.8 G pullout at the end of the parabolic maneuver.

Figure 3-1. OASIS microgravity experiment.
The scientific and engineering objectives of the above described experiment are a) to determine if our sample preparation technique is adequate in microgravity to prepare dust aggregates that are held together via self-imposed tribo-electrostatic forces (resulting from frictional charging of the particles during the load sequence); b) determine the dust bunny structure and its fragility in microgravity; c) test the effects of the launch forces on the dust bunny in microgravity (do they stay together or come apart?); and d) study the effects of target collision on the dust bunny. All these objectives must be thoroughly understood before a more comprehensive experiment can be designed for use aboard the ISS or space shuttle.

These objectives will be satisfied with two test flights aboard the KC-135 Zero-g aircraft with the OASIS experiment hardware. Results of these tests will allow our team to validate the experimental design for a more comprehensive microgravity experiment that we plan to propose and fly aboard the ISS.

4. Equipment Description

A dimensional drawing of the OASIS experiment is shown in Figure 4-1. Table 4-1 lists the experiment components, their sizes, weights, and material makeup. Photographs of the experiment showing the instrument rack and experiment housing are shown in Figure 4.2. A proposed layout of the experiment in the aircraft during all phases of the flight (takeoff, landing, and flight parabolas) is shown in Figure 4-3. Three flight operators are required to run the experiment during the flight. Figure 4-3 also shows the position of the three operators during an experiment run. One operator will perform the sample load sequence and launch sequence; the second operator will assist the load sequence by controlling the airflow vent sequence through the overboard vent. The third operator will operate the hand-held camcorder to record the activities of the other two operators during the experiment runs and will record the sample collisions with the sample target at the end of the lexan flight tube. Each operator will also act as a backup to their flight companions in case they become ineffective during the flight due to motion sickness. All three operators will be seated in their assigned locations during takeoff and landing.

There are no laser, fluid, chemical, or pressure vessel requirements. There are no free float requirements (the OASIS experiment remains attached to the aircraft floor during the entire flight). There are no special handling requirements or special hazards.

Items that are stowed during takeoff and landing, and which are attached to the OASIS experiment console during the prep stages of the experiment prior to the start of the flight parabolas are as follows:

a) 3.5” LCD monitor (attaches to rack during experiment prep);

b) 3.5” CCD camera and battery pack (attaches to rack during experiment prep);

c) 8-mm video recorder;

d) penlight (attaches to rack during experiment prep).

Additional personal items that are planned to be taken aboard the aircraft by one or more OASIS team members are as follows (all appropriately stowed during takeoff/landing):
e) 8 mm video camcorder (for experiment documentation);

f) 35 mm camera (for experiment documentation and personal records);
g) personal flashlight;
h) note book or note pad and pen/pencil (equipped with velcro for in-flight use);
i) personal emergency/rescue gear stowed in flightsuit pockets (signal mirror, whistle, rescue streamer, etc.);
j) a couple bandaids;
k) rubber bands;

Figure 4-1. Dimensional drawings of the OASIS experiment. All units are inches.
1) short lengths of RGO-supplied duct tape (affixed to blank sticky-label paper for easy removal);

m) sick bag;

n) eye-glasses retainer straps.

There is one set of experiment runs which involves opening the housing at the external load flange to load a 1-cm diameter styrofoam ball into the sample load cup. The loading of this sample is conducted using a hand-held forceps by an operator prior to the beginning of a parabolic run. Immediately following the load of this sample, the external load flange is closed and sealed. During the following parabolic run, the launcher is activated to launch this sample into the simulated target. Video image data is taken of this load and launch sequence by a second operator using the hand-held camcorder, and by the CCD camera attached to the window port. This special experiment run is done before any of the dust bunny runs are attempted so that the housing is free of free floating sample dust material that could potentially leak out of the housing during the load sequence of the styrofoam balls.

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<thead>
<tr>
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<tr>
<td>Component</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>Housing</strong></td>
</tr>
<tr>
<td>6-way cross</td>
</tr>
<tr>
<td>Nipple (material hopper mount)</td>
</tr>
<tr>
<td>Material Hopper</td>
</tr>
<tr>
<td>Material Hopper Endcap</td>
</tr>
<tr>
<td>Actuator Assembly</td>
</tr>
<tr>
<td>CCD Lexan Window Port</td>
</tr>
<tr>
<td>Lamp Window Port</td>
</tr>
<tr>
<td>Lexan Flight Tube</td>
</tr>
<tr>
<td>Target (Flight Tube Cap)</td>
</tr>
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<td>Vent Valve</td>
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<td>Launcher Control Electronics</td>
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<tr>
<td>Launcher Power Supply</td>
</tr>
<tr>
<td>AC Power Strip/Cables</td>
</tr>
<tr>
<td>LCD Monitor</td>
</tr>
<tr>
<td>CCD Camera/Lens</td>
</tr>
<tr>
<td>CCD Camera Battery Pack</td>
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<tr>
<td>Video Recorder/Battery Pack</td>
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</tr>
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</tr>
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<td><strong>TOTAL</strong></td>
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Figure 4-2. Photographs of the OASIS experiment. (Note: when these photos were taken, some of the OASIS parts were not yet permanently attached to the payload shelf: i.e. OASIS not yet in full flight configuration).
Figure 4-3. Operator positions (marked by “X”s) during the flight experiment runs (viewed looking from the top of the experiment). Figure also indicates the preferred experiment orientation in the aircraft (x-axis pointing either towards the front or rear of the aircraft). The X-Y axes indicate the experiment axes.

5. **Structural Analysis**

The complete structural analysis is in Appendix B of this TEDP package.

6. **Electrical Analysis**

6.1. **Schematic**

The electronics for the OASIS experiment are very simple. Figure 6-1 shows a functional electrical schematic showing the top-level details of the experiment. The launcher mechanism, a linear motor and its associated control electronics, is the only component of the experiment requiring external power from the KC-135. The CCD camera, lamp (penlight), LCD monitor, and video recorder all operate from batteries (each component has its own separate AA battery pack).
6.2.  **Load Tables**

We have measured the total current drawn by the launch mechanism in the lab and its maximum value was 160 mA at 115VAC 60Hz. Based on this power draw, the OASIS experiment will only require a single 115VAC 20A service from a standard 20A outlet. The actual plug inserted into the outlet will be a standard 15A plug on a 20 foot, 14 gauge extension cord. A load analysis of the launch mechanism is provided in Table 6-1 below. A power distribution strip with an integral surge suppressor, 15A breaker is plugged into the extension cord. The power strip switch serves as the kill switch for the experiment.

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<td>Linear Motor and Drive Electronics - 200 mA</td>
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<td>Voltage : 115 VAC, 60 Hz</td>
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<td>Wire Gauge : 12</td>
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<tr>
<td>Max Outlet Current : 20 Amps</td>
<td>Total Current Draw : 200 mA</td>
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All other electrical components of the OASIS experiment are manufacturer supplied battery packages operating commercial equipment. A summary of these batteries along with their type and voltage is provided in Table 6-2 below.
<table>
<thead>
<tr>
<th>Component</th>
<th>Battery Type</th>
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<tr>
<td>CCD Camera</td>
<td>8 AA batteries</td>
</tr>
<tr>
<td>Lamp (penlight)</td>
<td>2 AA batteries</td>
</tr>
<tr>
<td>LCD Monitor</td>
<td>4 AA batteries</td>
</tr>
<tr>
<td>Video Recorder</td>
<td>Sony NiCd rechargeable battery pack (4 1.5 V batteries)</td>
</tr>
</tbody>
</table>

6.3. **Emergency Shutdown Procedure**

The switch located on the power strip provided the OASIS experiment kill switch function. This switch will remove all power from the experiment.

6.4. **Loss of Electrical Power**

The OASIS experiment will be in a safe condition after any loss of 115VAC power to the OASIS experiment whether via the kill switch or removal of power by the aircrew. When power is removed the linear motor simply stops moving which may affect the results of the experiment, but will in no way place the experiment in an unsafe configuration.

7. **Pressure Vessel Certification**

The OASIS housing is not hermetically-sealed and therefore is not considered a vacuum or pressure vessel. Air from the aircraft cabin can flow through many of the housing joints and through small holes drilled in the Lexan flight tube (these holes are covered with a filter mesh to prevent dust from escaping the housing). The experiment does require a flow of air from the exterior of the housing through a fine mesh in the launcher cup, through the center shaft of the launcher, then out of the housing to the Overboard Vent. This flow of air is necessary during the sample preparation stage of an experimental run to force the silica dust material into the sample cup from the sample hopper interior to the housing. If the sample cup becomes clogged with dust, air is still able to flow through small vents that surround the cup. In addition, a valve attached to the airflow line at the rear of the instrument housing can be opened to allow air to flow from the cabin through the airflow line if all airflow vents in the cup region become clogged.

8. **Laser Certification**

OASIS contains no laser device.

9. **Parabola Details and Crew Assistance**

In order to achieve our OASIS test objectives, we require 24 zero-g parabolas of the standard 23 sec duration (which can be achieved in 3 normal parabola sets) per flight, with two separate flights aboard the KC-135 Reduced Gravity Aircraft. Our preference is for the second flight to take place two days after the first flight (thus providing a one day break between flights to allow time to examine test results of the first flight and to make possible equipment/procedure adjustments in preparation for the second flight), but we recognize that the constraints of other
experimenters may require us to fly both flights on back-to-back days; the OASIS team can work to this schedule if necessary.

It would be beneficial to the OASIS team if the Flight Director could repeat the "RELEASE" call to the cabin after the "RELEASE" call is returned to the Pilot in Command during each parabola. OASIS has no specific requirements for breaks between parabola sets (the standard 2-3 minute break is acceptable). OASIS requires no special documentary photographic services during experiment runs; all photography/videography can be provided by OASIS researchers.

10. **Free Float Requirements**

OASIS is not a free float experiment.

11. **Institutional Review Board (IRB)**

OASIS does not involve any human or animal subjects, and will not conduct any biological experiments.

12. **Hazard Analysis**

The hazards applicable to OASIS are described below following the format given in the *JSC Reduced Gravity Program User’s Guide*, section 6.14. The corresponding Hazard Source Checklist is on page 15 of this document.

**Hazard 1**

**Title:** Frangible material

**Description:** The CCD cameras utilize attached lenses made of glass for imaging.

**Cause:** Glass lens can break or shatter if hit with hard object.

**Control:** The front exposed surface of each lens will be covered with a window of Lexan which is a shatterproof material. In addition, all experiment viewports are made of Lexan as well.

**Hazard 2**

**Title:** Articulating experiment element (collision)

**Description:** A linear motion launch mechanism is utilized to launch the lightweight dust bunny projectile particles towards the target for the collision experiments.

**Cause:** Linear motion of launch mechanism can cause injury to personnel if directly struck during actuation.

**Control:** The linear actuator mechanism is built into the interior of the experiment housing which is closed and therefore inaccessible to personnel during each experiment run.

**Cause:** Damage to experiment caused by projectile material collision with the target.

**Control:** The projectile material is composed of a lightweight dust aggregate with a mass of less than 0.2 g. At launch velocities of <20 cm/s, the collision energy is less than 1 µJ, which is too small to cause any damage to the interior of the experiment housing due to collision.
Hazard 3
Title: Vacuum vent failure (i.e., loss of pressure/atmosphere)
Description: The center linear motion shaft in the launcher assembly is a hollow shaft with the sample launch/load cup mounted at one end, and a sealed vacuum vent at the other. The launch cup has small perforations in its surface to allow air to flow through the cup from the interior of the OASIS housing and from the aircraft cabin (the housing is not a hermetically sealed device; air from the aircraft cabin can flow into the housing through some of the housing component joints). In addition, a fine mesh (100 µm sized openings) is mounted over the sample cup’s surface to trap the silica dust material and prevent it from flowing into the launcher shaft. The airflow exits the launcher shaft via a tygon tubing vent line that interfaces to the flange at the rear of the actuator section (see Figures 3-1 and 4-2). A vent line is mated to the exterior of this housing flange through a vent valve that interfaces to a vent line that is attached to the aircraft’s Overboard Vent system. During the sample load operations, the vent valves are opened to allow cabin air to flow through the sample launch/load cup, the launch center shaft, through the housing vent valve, then out through the aircraft’s Overboard Vent system.

Cause: Possible vacuum vent failure of the above described air vent flow if the launch load cup becomes clogged with the sample silica dust material, or some other location within the vent system becomes obstructed preventing airflow through the vent system.

Control: The OASIS housing is not hermetically-sealed and therefore is not considered a vacuum or pressure vessel. Air from the aircraft cabin can flow through many of the housing joints. In addition, the airflow path through the launcher shaft passes through a valve at the exterior of the instrument which can be opened to the aircraft cabin to bypass any clog that develops in the airflow stream inside the housing (i.e. if a clog were to form at the launcher sample cup due to an excess of dust accumulating in the cup).

Hazard 4
Title: Over-temperature explosive rupture (including electrical battery)
Description: The CCD camera, LCD display, the light source, and the portable video recorder require the use of AA batteries. The CCD camera requires 6 AA batteries; the LCD display requires 4 AA batteries; the light source requires 2 AA batteries; and the portable video recorder requires 4 AA batteries.

Cause: Possible over-temperature explosive rupture if any of above battery packs are electrically shorted to ground.

Control: Each of these units has its own self-contained battery pack that is completely enclosed inside a plastic cover. The possibility of a short within any pack is near zero. If a short did exist, the batteries would drain quickly; no explosive rupture would take place because of the low total energy stored in the batteries.
Hazard 5
Title: Sharp corner/edge/protrusion/protuberance
Description: Some of the outside surfaces of the experiment including the support structure have sharp corner and edges.
Cause: Can cause injury to personnel if any of these surfaces are contacted with any appreciable force.
Control: All such corner and edges shall be either filed down to provide a minimum radius of 0.02”, or will be covered with a thick foam material.

Hazard 6
Title: Containment of fine-grain dust particles
Description: The projectile material is composed of fine 500-micron diameter SiO₂ dust particles.
Cause: Dust particles that escape the experiment housing could be inhaled or get into an operator’s eyes; free dust particles could also cause damage to exposed hardware.
Control: During all dust projectile runs, the housing is never opened to expose the interior contents to the aircraft cabin. During the projectile load sequence, air is vented through the interior of the launch rod mechanism, which allows the dust to flow and collect inside the projectile cup (which contains a 100 μm sized square mesh openings to trap the silica dust inside the cup). Again, all components involved in the load cycle are contained within housing. In addition, a fine meshed filter exists in the flow line inside the housing that will prevent the escape of dust particles through the flow line to the aircraft overboard vent system. No frangible material exists in the housing as well that could break and cause leakage of dust outside the housing.
## HAZARD SOURCE CHECKLIST

Enumerate or mark N/A

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Flammable/combustible material, fluid (liquid, vapor, or gas)</td>
</tr>
<tr>
<td>N/A</td>
<td>Toxic/noxious/corrosive/hot/cold material, fluid (liquid, vapor, or gas)</td>
</tr>
<tr>
<td>N/A</td>
<td>High pressure system (static or dynamic)</td>
</tr>
<tr>
<td>N/A</td>
<td>Evacuated container (implosion)</td>
</tr>
<tr>
<td>1</td>
<td>Frangible material</td>
</tr>
<tr>
<td>N/A</td>
<td>Stress corrosion susceptible material</td>
</tr>
<tr>
<td>N/A</td>
<td>Inadequate structural design (i.e., low safety factor)</td>
</tr>
<tr>
<td>N/A</td>
<td>High intensity light source (including laser)</td>
</tr>
<tr>
<td>N/A</td>
<td>Ionizing/electromagnetic radiation</td>
</tr>
<tr>
<td>N/A</td>
<td>Rotating device</td>
</tr>
<tr>
<td>2</td>
<td>Extendible/deployable/articulating experiment element (collision)</td>
</tr>
<tr>
<td>N/A</td>
<td>Stowage restraint failure</td>
</tr>
<tr>
<td>N/A</td>
<td>Stored energy device (i.e., mechanical spring under compression)</td>
</tr>
<tr>
<td>3</td>
<td>Vacuum vent failure (i.e., loss of pressure/atmosphere)</td>
</tr>
<tr>
<td>N/A</td>
<td>Heat transfer (habitable area over-temperature)</td>
</tr>
<tr>
<td>4</td>
<td>Over-temperature explosive rupture (including electrical battery)</td>
</tr>
<tr>
<td>N/A</td>
<td>High/Low touch temperature</td>
</tr>
<tr>
<td>N/A</td>
<td>Hardware cooling/heating loss (i.e., loss of thermal control)</td>
</tr>
<tr>
<td>N/A</td>
<td>Pyrotechnic/explosive device</td>
</tr>
<tr>
<td>N/A</td>
<td>Propulsion system (pressurized gas or liquid/solid propellant)</td>
</tr>
<tr>
<td>N/A</td>
<td>High acoustic noise level</td>
</tr>
<tr>
<td>N/A</td>
<td>Toxic off-gassing material</td>
</tr>
<tr>
<td>N/A</td>
<td>Mercury/mercury compound</td>
</tr>
<tr>
<td>N/A</td>
<td>Other JSC 11123, Section 3.8 hazardous material</td>
</tr>
<tr>
<td>N/A</td>
<td>Organic/microbiological (pathogenic) contamination source</td>
</tr>
<tr>
<td>5</td>
<td>Sharp corner/edge/protrusion/protuberance</td>
</tr>
<tr>
<td>N/A</td>
<td>Flammable/combustible material, fluid ignition source (i.e., short circuit; undersized wiring/fuse/circuit breaker)</td>
</tr>
<tr>
<td>N/A</td>
<td>High voltage (electrical shock)</td>
</tr>
<tr>
<td>N/A</td>
<td>High static electrical discharge producer</td>
</tr>
<tr>
<td>N/A</td>
<td>Software error or compute fault</td>
</tr>
<tr>
<td>N/A</td>
<td>Carcinogenic material</td>
</tr>
<tr>
<td>6</td>
<td>Other: Silica dust material</td>
</tr>
<tr>
<td>N/A</td>
<td>Other:</td>
</tr>
<tr>
<td>N/A</td>
<td>Other:</td>
</tr>
</tbody>
</table>
13. Tool Requirements

The following Table 13-1 lists the tools required to operate OASIS. All the tools are stored inside a small satchel that will be carried aboard the aircraft by one of the OASIS operators (and stowed with his/her personal belongings during takeoff and landing phases of the flight).

<table>
<thead>
<tr>
<th>Tool Description</th>
<th>Tool Identification</th>
<th>Storage Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>½-inch open/box wrench</td>
<td>OASIS Tool #1</td>
<td>Tool box*</td>
</tr>
<tr>
<td>7/16-inch open/box wrench</td>
<td>OASIS Tool #2</td>
<td>Tool box*</td>
</tr>
<tr>
<td>8-inch crescent wrench</td>
<td>OASIS Tool #3</td>
<td>Tool box*</td>
</tr>
<tr>
<td>Philips screwdriver</td>
<td>OASIS Tool #4</td>
<td>Tool box*</td>
</tr>
<tr>
<td>Slotted screwdriver</td>
<td>OASIS Tool #5</td>
<td>Tool box*</td>
</tr>
<tr>
<td>Allen wrench kit</td>
<td>OASIS Tool #6</td>
<td>Tool box*</td>
</tr>
<tr>
<td>3/8-inch socket wrench</td>
<td>OASIS Tool #7</td>
<td>Tool box*</td>
</tr>
<tr>
<td>½-inch socket</td>
<td>OASIS Tool #8</td>
<td>Tool box*</td>
</tr>
<tr>
<td>7/16-inch socket</td>
<td>OASIS Tool #9</td>
<td>Tool box*</td>
</tr>
<tr>
<td>Wire cutters</td>
<td>OASIS Tool #10</td>
<td>Tool box*</td>
</tr>
<tr>
<td>Forceps</td>
<td>OASIS Tool #11</td>
<td>Tool box*</td>
</tr>
<tr>
<td>Tiewraps</td>
<td>N/A</td>
<td>Tool box*</td>
</tr>
</tbody>
</table>

* Stowed during takeoff and landing.

14. Photo Requirements

We do not require any formal photography requirements that must be performed by personnel from the RGO. All video and still photography will be performed by an OASIS flight operator during the flights.

15. Aircraft Loading

The OASIS experiment can be easily loaded into the aircraft either by rolling the instrument rack up the access ramp (casters are attached to the bottom of the rack), or by a lifting pallet. Use of the attached casters is also allows manipulation of OASIS inside the KC-135 test cabin.

The total weight of the OASIS instrument rack and experiment assembly is 146.4 lbs. The baseplate area is 2.125 ft x 1.842 ft = 3.914 ft². During aircraft loading operation, the load to the aircraft floor will be 37.4 lbs/ft². The maximum expected weight per caster wheel is 73 lbs.

16. Ground Support Requirements

No special ground support requirements are necessary except for use of electrical power on the ground for testing the experiment. We will need access to 110 VAC, with the capability of delivering 100 W (max 1 A of current). This will allow us to load the actuator launch controller electronics with the desired launch profiles using a laptop computer. In addition, we will need to store the experiment between flights and possibly just prior to the first flight in a safe location.
We may require access to the experiment storage location after-hours if we need to make any minor experiment changes (e.g., changes to the launch profiles) the night before the second flight.

17. **Hazardous Material**

OASIS does not use nor contains any toxic, corrosive, explosive, and/or flammable materials.

18. **Material Safety Data Sheets (MSDS)**

All MSDSs that were acquired for the OASIS experiment are attached in Appendix A of this TEDP.

19. **Experiment Procedures**

The following procedures are preliminary. Modifications may be required based on the review of these procedures by the RGO.

19.1. **Equipment Shipment to Ellington Field**

The OASIS experiment will be shipped from SwRI, San Antonio, Texas to Ellington Field via personal vehicle by OASIS personnel on 16 April 2001.

19.2. **Ground Operations**

The following steps will prepare and test OASIS during ground operations and test. No special ground equipment is required to operate OASIS other than the identified OASIS flight hardware and tools (see section 13 for a list of tools). The OASIS actuator controller will have two stored launch profiles already preloaded into the controller memory. If a new launch profile is desired, the controller must be interfaced with a GSE laptop computer that has the controller interface software installed.

**Setup**

1. Roll OASIS to a suitable location for setup and test (require 110 VAC power at 1 A max).
2. Remove the material hopper end cap using the ½-inch socket/wrench.
3. Load the sample material into the material hopper.
4. Close the material hopper end cap and torque the bolts to the required torque value.
5. Plug in the OASIS power strip to the 110 VAC receptacle. Make sure the power strip power on/off switch is in the OFF position.
6. Plug in the actuator power supply to the OASIS power strip.
7. Check the wiring harness between the actuator controller electronics and the power supply.
8. Move the hopper load cup to the “launch” position.
9. Set the actuator toggle switch to “Launch Profile B”

10. Attach the penlight to the lamp bracket.

11. Attach the 8-mm video recorder to the payload shelf.

12. Attach the CCD camera to the CCD bracket.

13. Attach the CCD camera battery pack to the payload shelf.

14. Attach the LCD monitor to the payload shelf.

15. Connect the power and signal cables between the CCD camera, LCD monitor, 8-mm video recorder and CCD camera battery pack.

**Power On and Launch Sequence**

16. Visually inspect the interior of the experiment housing making sure the launcher cup/shaft is clear of the hopper load cup.

17. Power on the actuator power supply using the OASIS power strip on/off switch. The actuator will move to reset its position to the start position.

18. Power on the penlight, the LCD monitor, the CCD camera, and the 8-mm video recorder.

19. Check to see that a suitable image of the launcher cup is displayed on the LCD monitor.

20. Load a fresh 8-mm video tape in the video recorder.

21. Start recording the video image by pressing “rec/play” on the video recorder.

22. Adjust the CCD pointing and lighting via minor adjustments to the penlight and CCD camera for best results.

23. Open the “Load Window”; load a test styrofoam test ball into the actuator load cup using the forceps from the OASIS toolkit.

24. Fire the launcher by moving the actuator toggle switch to “Launch Profile A”.

25. Fire the launcher by moving the actuator toggle switch to “Launch Profile B”.

26. Rewind and play back the video tape. Review results for adequate picture.

**Shutdown and Stow**

27. Power off the actuator power supply using the OASIS power strip on/off switch.

28. Power off the penlight, the LCD monitor, the CCD camera, and the 8-mm video recorder.

29. Open the “Load Window” and extract the styrofoam test ball.

30. Disconnect all video signal and power cables between the CCD camera, LCD monitor, 8-mm video recorder and CCD camera battery pack.

31. Remove and stow the following OASIS items: penlight, CCD camera, 8-mm video recorder, LCD monitor, and CCD camera battery pack.

32. Disconnect the OASIS power strip from the 110 VAC receptacle.
19.3. **Loading**

1. Make sure all experiment stowage items are detached from the instrument console and stowed properly (penlight, CCD camera, 8-mm video recorder, LCD monitor, and CCD camera battery pack).

2. Load OASIS aboard the KC-135 aircraft in one of the following ways: a) roll the experiment up an access ramp using the casters attached to the bottom of the instrument rack; b) roll the experiment up an access ramp using a lifting pallet; attach the experiment console to a lifting pallet and use a forklift to lift the experiment to the aircraft load door.

3. Once inside the aircraft cabin, roll the experiment rack to the OASIS assigned location. Attach the experiment to the floor of the aircraft via the attachment bolts (these bolts attach to a mounting plate being supplied by NASA Glenn Research Facility that is bolted to the OASIS experiment rack).

19.4. **Pre-Flight**

There are no special requirements for pre-flight operations except to check the OASIS actuator operation with aircraft power. A check that all OASIS experiment items are properly stowed is also conducted (i.e. LCD monitor, CCD camera and battery pack, penlight, 8-mm video recorder, camcorder, spare AA batteries, OASIS toolkit, and personal carry-on items).

**Setup**

1. Plug in the OASIS power strip to the aircraft 110 VAC receptacle. Make sure the power strip power on/off switch is in the OFF position.

2. Connect the OASIS vent line to the aircraft overboard vent system. Close the OASIS vent valve.

3. Plug in the actuator power supply to the OASIS power strip.

4. Check the wiring harness between the actuator controller electronics and the power supply.

5. Extract the hopper load cup to the “launch” position.

6. Set the actuator toggle switch to “Launch Profile B”

**Power On and Launch Sequence Check**

7. Visually inspect the interior of the experiment housing making sure the launcher cup/shaft is clear of the hopper load cup.

8. Power on the actuator power supply using the OASIS power strip on/off switch. The actuator will move to reset its position to the start position.

9. Fire the launcher by moving the actuator toggle switch to “Launch Profile A”. Visually check the motion of the actuator for proper operation.

10. Fire the launcher by moving the actuator toggle switch to “Launch Profile B”. Visually check the motion of the actuator for proper operation.
Shutdown

11. Power off the actuator power supply using the OASIS power strip on/off switch.

19.5. Take-Off/Landing

There are no special procedures for take-off and landing. All OASIS experiment stowage items must be removed from the OASIS instrument console and stowed during these phases of the flight. All stowed hardware will be located in a carry-on bag(s) taken aboard the aircraft by one or more of the OASIS flight operators. These items include the LCD monitor, CCD camera and battery pack, penlight, 8-mm video recorder, camcorder, spare AA batteries, OASIS toolkit, and personal carry-on items. There are no power requirements during take-off and landing.

19.6. In-Flight

Setup (prior to start of parabolic maneuvers)

1. Set the actuator toggle switch to “Launch Profile B”
2. Attach the penlight to the lamp bracket.
3. Attach the 8-mm video recorder to the payload shelf.
4. Attach the CCD camera to the CCD bracket.
5. Attach the CCD camera battery pack to the payload shelf.
6. Attach the LCD monitor to the payload shelf.
7. Connect the power and signal cables between the CCD camera, LCD monitor, 8-mm video recorder and CCD camera battery pack.
8. Remove the hand-held camcorder and have ready for recording images by a designated OASIS operator (fresh tape loaded, fresh battery attached to unit).

Power On Check (prior to start of parabolic maneuvers)

9. Start documenting all OASIS operations using the hand-held camcorder by the designated OASIS operator.
10. Visually inspect the interior of the experiment housing making sure the launcher cup/shaft is clear of the hopper load cup.
11. Power on the actuator power supply using the OASIS power strip on/off switch. The actuator will move to reset its position to the start position.
12. Power on the penlight, the LCD monitor, the CCD camera, and the 8-mm video recorder.
13. Check to see that a suitable image of the launcher cup is displayed on the LCD monitor.
14. Load a fresh 8-mm video tape in the video recorder.
15. Start recording the video image by pressing “rec/play” on the video recorder.
16. Adjust the CCD pointing and lighting via minor adjustments to the penlight and CCD camera for best results.
17. Start record of test fire sequence using the hand-held camcorder viewing through the load window.

18. Fire the launcher by moving the actuator toggle switch to “Launch Profile A”.

19. Fire the launcher by moving the actuator toggle switch to “Launch Profile B”.

20. Rewind and play back the video tape. Review results for adequate picture.

**Experiment Load and Fire Sequence 1 (prior to start of parabolic maneuver #1)**

21. Open the “Load Window”; load a styrofoam test ball into the actuator load cup using the forceps from the OASIS toolkit.

22. Close the “Load Window” and start recording video images using the CCD camera and the hand-held camcorder.

23. Standby for the “RELEASE” call by the pilot (parabola start).

24. Two seconds after the pilot calls “RELEASE”, fire the launcher by moving the actuator toggle switch to “Launch Profile A”.

25. Record the motion of the styrofoam ball through the OASIS flight tube using the hand-held camcorder.

26. Fire the launcher by moving the actuator toggle switch to “Launch Profile B” to reset the launcher to “Launch Profile A” on the next fire.

27. Repeat steps 21-26 for as many of the following parabolas as is deemed necessary by the OASIS PI.

**Experiment Load and Fire Sequence 2**

28. During the period between parabolas move the material load cup over the launcher cup.

29. Start recording video images using the CCD camera and the hand-held camcorder.

30. At the command “PULL WHEN READY”, open the vent valve to start the flow of air through the actuator assembly. This will start the flow of sample material into the load cup.

31. Standby for the “RELEASE” call by the pilot (parabola start).

32. Close the vent valve at some point after the “RELEASE” call.

33. Move the hopper load cup to the “launch” position.

34. Record the build-up of the “dust bunny” in the load cup with the hand-held camcorder during the first 10-15 seconds of the parabola.

35. When a dust bunny has formed fire the launcher by moving the actuator toggle switch to “Launch Profile A”.

36. Record the motion of the dust bunny through the OASIS flight tube using the hand-held camcorder.
37. Repeat steps 28-36 for as many of the following parabolas as is deemed necessary by the OASIS PI.

**Shutdown and Stow (Emergency Shutdown Procedure)**

38. Power off the actuator power supply using the OASIS power strip on/off switch.
39. Power off the penlight, the LCD monitor, the CCD camera, and the 8-mm video recorder.
40. Disconnect all video signal and power cables between the CCD camera, LCD monitor, 8-mm video recorder and CCD camera battery pack.
41. Remove and stow the following OASIS items: penlight, CCD camera, 8-mm video recorder, LCD monitor, CCD camera battery pack, and the hand-held camcorder.

19.7. **Post-Flight**

42. Remove the material hopper end cap (using the ½-inch socket/wrench) and load sample material into the material hopper.
43. Replace the material hopper end cap.
44. Remove and clean experiment housing windows as deemed necessary.
45. Remove load window and vacuum out interior of housing using an OASIS-supplied GSE vacuum cleaner.
46. Reattach experiment housing window flanges and load window.
47. Review the video data from both the camcorder and the CCD camera.
48. Determine need to load new launch profiles into actuator controller electronics. If so, prepare new profiles and load to controller via connection to the GSE lap top computer.
49. Test new launch profiles following steps 8, 16-17, 24-25 in section 19.2 of this TEDP.
50. Power off the actuator power supply.

19.8. **Off-Loading**

1. Disconnect OASIS power strip cord from the aircraft 110VAC receptacle.
2. Disconnect the OASIS vent line from the aircraft overboard vent system.
3. Unbolt the OASIS instrument rack from the aircraft floor mounting plate.
4. Remove OASIS from the aircraft either by rolling it out the load door and down the load ramp, or via the load pallet and a forklift (or rolling pallet lifter).
5. OASIS will be shipped to SwRI via personal vehicle by the OASIS team.
20. Bibliography


21. APPENDIX A – EXPERIMENT MATERIAL SAFETY DATA SHEETS
U. S. SILICA COMPANY

MATERIAL SAFETY DATA SHEET

SILICA SAND SOLD UNDER VARIOUS NAMES:

ASTM TESTING SANDS • GLASS SAND • FLINT SILICA •
F-SERIES FOUNDRY SANDS • H-SERIES •
L-SERIES • N-SERIES • OK-SERIES • P-SERIES •
T-SERIES • HYDRAULIC FRACING SANDS •
MIN-U-SIL® • MYSTIC WHITE® • #1 DRY •
# 1 SPECIAL • PENN SAND® • Q-ROK® •
SIL-CO-SIL® • SILURIAN FILTER SAND • SUPERSIL® •

Dated July 15, 1997
MATERIAL SAFETY DATA SHEET

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Names/Trade Names: Silica Sand sold under various names: ASTM TESTING SANDS, GLASS SAND, FLINT SILICA, F-SERIES FOUNDRY SANDS, H-SERIES, L-SERIES, N-SERIES, OK-SERIES, P-SERIES, T-SERIES, HYDRAULIC FRACING SANDS, MIN-U-SIL®, MYSTIC WHITER®, #1 DRY, #1 SPECIAL, PENN SAND®, Q-ROKE®, SIL-CO-SIL®, SILURIAN FILTER SAND, SUPERSIL®.

Synonyms/Common Names: Sand, Silica Sand, Quartz, Crystalline Silica, Flint, Ground Silica.

Manufacturer's Name: U. S. Silica Company
P. O. Box 187
Berkeley Springs, WV 25411

Emergency Telephone Number: 304-258-2500
304-258-8295 (fax)

Date Prepared: July 15, 1997

SECTION 2 - COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous Ingredient: Crystalline silica (quartz), typically 99.2% to 99.9%

Chemical Formula: SiO₂

CAS#: 14808-60-7

OSHA PEL: Exposure to airborne crystalline silica shall not exceed an 8-hour time-weighted average limit as stated in 29 CFR §1910.1000 Table Z-1-A, Air Contaminants, specifically:

\[
\frac{10 \text{ mg/m}^3}{\text{SiO}_2}\]

ACGIH TLV: Crystalline Silica (quartz) TLV-TWA = 0.1 mg/m³ Respirable Crystalline Silica (quartz)

See Threshold Limit Value and Biologic Standardized Exposure Indices for American Conference of Governmental Industrial Hygienists (latest edition).

Other Recommended Limits: National Institute for Occupational Safety and Health (NIOSH). Recommended standard maximum permissible concentration=0.05 mg/m³ (respirable free silica) as determined by a full-shift sample up to 10-hour working day, 40-hour work week. See NIOSH Criteria for a Recommended Standard Occupational Exposure to Crystalline Silica.

CAUTION: Crystalline silica exists in several forms, the most common of which is quartz. If crystalline silica (quartz) is heated to more than 870°C it can change to a form of crystalline silica known as tridymite, and if crystalline silica (quartz) is heated to more than 1470°C, it can change to a form of crystalline silica known as cristobalite. Crystalline silica as tridymite and cristobalite are more fibrogenic than crystalline silica as quartz. The OSHA PEL for crystalline silica as tridymite and cristobalite is one-half the PEL for crystalline silica (quartz); the ACGIH TLV for crystalline silica as tridymite and cristobalite is one-half the TLV for crystalline silica as quartz.

SECTION 3 - HAZARD IDENTIFICATION

EMERGENCY OVERVIEW:

The U. S. Silica Company material is a white or tan sand, or ground sand. It is not flammable, combustible or explosive. It does not cause burns or severe skin or eye irritation. A single exposure will not result in serious adverse health effects. Crystalline silica (quartz) is not known to be an environmental hazard.

Crystalline silica (quartz) is incompatible with hydrofluoric acid, fluorine, chlorine trifluoride or oxygen difluoride.

POTENTIAL HEALTH EFFECTS:

Inhalation:

a. Silicosis: Respirable crystalline silica (quartz) can cause silicosis, a fibrosis (scarring) of the lungs. Silicosis may be progressive; it may lead to disability and death.
b. **Cancer**  
Crystalline silica (quartz) inhaled from occupational sources is classified as carcinogenic to humans.

c. **Scleroderma**  
There is evidence that exposure to respirable crystalline silica or that the disease silicosis is associated with the increased incidence of scleroderma, an autoimmune disorder manifested by a fibrosis (scarring) of the skin and internal organs.

d. **Tuberculosis**  
Silicosis increases the risk of tuberculosis.

e. **Nephrotoxicity**  
There are several studies suggesting that exposure to respirable crystalline silica or that the disease silicosis is associated with the increased incidence of kidney disorders.

**Eye Contact:** Crystalline silica (quartz) may cause abrasion of the cornea.

**Skin Contact:** Not applicable.

**Ingestion:** Not applicable.

**Chronic Effects:** The adverse health effects -- silicosis, cancer, scleroderma, tuberculosis, and nephrotoxicity -- are chronic effects.

**Signs and Symptoms of Exposure:** There are generally no signs or symptoms of exposure to crystalline silica (quartz). Often, chronic silicosis has no symptoms. The symptoms of chronic silicosis, if present, are shortness of breath, wheezing, cough and sputum production. The symptoms of acute silicosis are the same; additionally, weight loss and fever are associated with acute silicosis. The symptoms of scleroderma include thickening and stiffness of the skin, particularly in the fingers, shortness of breath, difficulty swallowing and joint problems.

**Medical Conditions Generally Aggravated by Exposure:** The condition of individuals with lung disease (e.g., bronchitis, emphysema, chronic obstructive pulmonary disease) can be aggravated by exposure.

See Section 11, Toxicological Information, for additional detail on potential adverse health effects.

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### SECTION 4 - FIRST-AID MEASURES

**Inhalation:** No specific first-aid is necessary since the adverse health effects associated with exposure to crystalline silica (quartz) result from chronic exposures. If there is a gross inhalation of crystalline silica (quartz), remove the person immediately to fresh air, give artificial respiration as needed, seek medical attention as needed.

**Eye Contact:** Wash immediately with water. If irritation persists, seek medical attention.

**Skin Contact:** Not applicable.

**Ingestion:** Not applicable.

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### SECTION 5 - FIRE FIGHTING MEASURES

<table>
<thead>
<tr>
<th>Flammability:</th>
<th>Crystalline silica (quartz) is non-flammable and non-explosive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extinguishing Media:</td>
<td>None required</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flash Point:</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special Fire Fighting Procedures:</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flammable Limits:</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unusual Fire and Explosion Hazards:</td>
<td>None</td>
</tr>
</tbody>
</table>

---

### SECTION 6 - ACCIDENTAL RELEASE MEASURES

**Spills:** Use dustless methods (vacuum) and place into closable container for disposal, or flush with water. Do not dry sweep. Wear protective equipment specified below.

**Waste Disposal Method:** See Section 13.
SECTION 7 - HANDLING AND STORAGE

Precautions During Handling and Use: Do not breath dust. Use adequate ventilation and dust collection. Keep airborne dust concentrations below PEL. Practice good housekeeping. Do not permit dust to collect on walls, floors, sills, ledges, machinery, or equipment. Maintain, clean, and fit test respirators in accordance with OSHA regulations. Maintain and test ventilation and dust collection equipment. Wash or vacuum clothing which has become dusty. See also control measures in Section 8.

Precautions During Storage: Avoid breakage of bagged material or spills of bulk material. See control measures in Section 8.

Do not use U. S. Silica Company materials for sandblasting.

The OSHA Hazard Communication Standard, 29 CFR Sections 1910.1200, 1915.99, 1917.28, 1918.90, 1926.59, and 1928.21, and state and local worker or community "right to know" laws and regulations should be strictly followed. WARN YOUR EMPLOYEES (AND YOUR CUSTOMERS IN CASE OF RESALE) BY POSTING AND OTHER MEANS OF THE HAZARDS AND THE REQUIRED OSHA PRECAUTIONS. PROVIDE TRAINING FOR YOUR EMPLOYEES ABOUT THE OSHA PRECAUTIONS.

See also American Society for Testing and Materials (ASTM) standard practice E 1132-86, "Standard Practice for Health Requirements Relating to Occupational Exposure to Quartz Dust."

SECTION 8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

Local Exhaust: Use sufficient local exhaust to reduce the level of respirable crystalline silica to below the PEL. See ACGIH "Industrial Ventilation, A Manual of Recommended Practice" (latest edition).

Respiratory Protection: The following chart specifies the types of respirators which may provide respiratory protection for crystalline silica.

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>MINIMUM RESPIRATORY PROTECTION*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Concentration</td>
<td></td>
</tr>
<tr>
<td>5 x PEL or less</td>
<td>Any particulate respirator.</td>
</tr>
<tr>
<td>10 x PEL or less</td>
<td>Any particulate respirator, except single-use or quarter-mask respirator.</td>
</tr>
<tr>
<td></td>
<td>Any fume respirator or high efficiency particulate filter respirator.</td>
</tr>
<tr>
<td></td>
<td>Any supplied-air respirator.</td>
</tr>
<tr>
<td></td>
<td>Any self-contained breathing apparatus.</td>
</tr>
<tr>
<td>50 x PEL or less</td>
<td>A high efficiency particulate filter respirator with a full facepiece.</td>
</tr>
<tr>
<td></td>
<td>Any supplied-air respirator with a full facepiece, helmet, or hood.</td>
</tr>
<tr>
<td></td>
<td>Any self-contained breathing apparatus with a full facepiece.</td>
</tr>
<tr>
<td>500 x PEL or less</td>
<td>A powered air-purifying respirator with a high efficiency particulate filter.</td>
</tr>
<tr>
<td></td>
<td>A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.</td>
</tr>
<tr>
<td>Greater than 500 x PEL or entry and escape from unknown concentrations</td>
<td>Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.</td>
</tr>
<tr>
<td></td>
<td>A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.</td>
</tr>
</tbody>
</table>

*Use only NIOSH-approved or MSHA-approved equipment. See 29 CFR §1910.134 and 42 CFR §84.

See also ANSI standard Z88.2 (latest revision) "American National Standard for Respiratory Protection"
Permissible Exposure Levels:

<table>
<thead>
<tr>
<th>Component</th>
<th>CAS No.</th>
<th>Percentage (by wt.)</th>
<th>Exposure Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>OSHA TWA</td>
</tr>
<tr>
<td>Crystalline silica</td>
<td>14808-60-7</td>
<td>99.2-99.9</td>
<td>10</td>
</tr>
</tbody>
</table>

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

**Appearance:** White or tan sand; granular, crushed, or ground

**Boiling Point:** 4046°F

**Vapor Pressure (mm Hg):** None

**Vapor Density (Air = 1):** None

**Solubility in Water:** Insoluble in water

**Odor:** None

**Specific Gravity (Water = 1):** 2.65

**Melting Point:** 3110°F

**Evaporation Rate (Butyl Acetate = 1):** None

SECTION 10 - STABILITY AND REACTIVITY

**Stability:** Crystalline silica (quartz) is stable.

**Incompatibility (Materials to Avoid):** Contact with powerful oxidizing agents such as fluorine, chlorine trifluoride, oxygen difluoride, may cause fires.

**Hazardous Decomposition or Byproducts:** Silica will dissolve in hydrofluoric acid and produce a corrosive gas - silicon tetrafluoride.

**Hazardous Polymerization:** Will not occur.

SECTION 11 - TOXICOLOGICAL INFORMATION

A. SILICOSIS

The major concern is silicosis, caused by the inhalation and retention of respirable crystalline silica dust. Silicosis can exist in several forms, chronic (or ordinary), accelerated, or acute.

**Chronic or Ordinary Silicosis** is the most common form of silicosis, and can occur after many years of exposure to relatively low levels of airborne respirable crystalline silica dust. It is further defined as either simple or complicated silicosis.

Simple silicosis is characterized by lung lesions (shown as radiographic opacities) less than 1 centimeter in diameter, primarily in the upper lung zones. Often, simple silicosis is not associated with symptoms, detectable changes in lung function or disability.

Simple silicosis may be progressive and may develop into complicated silicosis or progressive massive fibrosis (PMF). Complicated silicosis or PMF is characterized by lung lesions (shown as radiographic opacities) greater than 1 centimeter in diameter. Although there may be no symptoms associated with complicated silicosis or PMF, the symptoms, if present, are shortness of breath, wheezing, cough and spum production. Complicated silicosis or PMF may be associated with decreased lung function and may be disabling. Advanced complicated silicosis or PMF may lead to death. Advanced complicated silicosis or PMF can result in heart disease secondary to the lung disease (cor pulmonale).

**Accelerated Silicosis** can occur with exposure to high concentrations of respirable crystalline silica over a relatively short period; the lung lesions can appear within five (5) years of the initial exposure. The progression can be rapid. Accelerated silicosis is similar to chronic or ordinary silicosis, except that the lung lesions appear earlier and the progression is more rapid.

**Acute Silicosis** can occur with exposures to very high concentrations of respirable crystalline silica over a very short time period, sometimes as short as a few months. The symptoms of acute silicosis include progressive shortness of breath, fever, cough and weight loss. Acute silicosis is fatal.
B. CANCER

IARC - The International Agency for Research on Cancer ("IARC") concluded that there was "sufficient evidence in humans for the carcinogenicity of crystalline silica in the forms of quartz or cristobalite from occupational sources," and that there is "sufficient evidence in experimental animals for the carcinogenicity of quartz and cristobalite." The overall IARC evaluation was that "crystalline silica inhaled in the form of quartz or cristobalite from occupational sources is carcinogenic to humans (Group 1)." The IARC evaluation noted that "carcinogenicity was not detected in all industrial circumstances studies. Carcinogenicity may be dependent on inherent characteristics of the crystalline silica or on external factors affecting its biological activity or distribution of its polymorphs." For further information on the IARC evaluation, see IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 68, "Silica, Some Silicates..." (1997).

NTP - The National Toxicology Program, in its Sixth Annual Report on Carcinogens, concluded that "silica, crystalline respirable" may reasonably be anticipated to be a carcinogen, based on sufficient evidence in experimental animals and limited evidence in humans.

OSHA - Crystalline silica (quartz) is not regulated by the U. S. Occupational Safety and Health Administration as a carcinogen.

There is substantial literature on the issues of the carcinogenicity of crystalline silica, which the reader should consult for additional information. A summary of the literature is set forth in "Exposure to crystalline silica and risk of lung cancer: the epidemiological evidence," Thorax, Volume 51, pp. 97-102 (1996). The official statement of the American Thoracic Society on the issue of silica carcinogenicity was published in "Adverse Effects of Crystalline Silica Exposure," American Journal of Respiratory and Critical Care Medicine, Volume 155, pp. 761-765 (1997). The official statement concluded that "The available data support the conclusion that silica exposure increases risk for bronchogenic carcinoma. The cancer risk may also be increased by smoking and other carcinogens in the workplace. Epidemiologic studies provide convincing evidence for increased cancer risk among tobacco smokers with silicosis. Less information is available for never-smokers and for workers exposed to silica but who do not have silicosis. For workers with silicosis, the risks for lung cancer are relatively high and consistent among various countries and investigators. Silicosis should be considered a condition that predisposes workers to an increased risk of lung cancer." Id. at 763.

C. SCLERODERMA

There is evidence that exposure to respirable crystalline silica or that the disease silicosis is associated with the increased incidence of scleroderma, an immune system disorder manifested by a fibrosis (scarring) of the lungs, skin and other internal organs. Recently, the American Thoracic Society noted that "there is persuasive evidence relating scleroderma to occupational silica exposures in settings where there is appreciable silicosis risk." The following may be consulted for additional information on silica, silicosis and scleroderma (also known as progressive systemic sclerosis): Occupational Lung Disorders, Third Edition, Chapter 12, entitled "Silicosis and Related Diseases," Parkes, W. Raymond (1994). "Adverse Effects of Crystalline Silica Exposure," American Journal of Respiratory and Critical Care Medicine, Volume 155, pp. 761-765 (1997).

D. TUBERCULOSIS


E. NEPHROTOXICITY


SECTION 12 - ECOLOGICAL INFORMATION

Crystalline silica (quartz) is not known to be ecotoxic; i.e., there is no data which suggests that crystalline silica (quartz) is toxic to birds, fish, invertebrates, microorganisms or plants. For additional information on crystalline silica (quartz), see Sections 9 (physical and chemical properties) and 10 (stability and reactivity) of this MSDS.

SECTION 13 - DISPOSAL CONSIDERATIONS

General: The packaging and material may be landfilled; however, material should be covered to minimize generation of airborne dust.

RCRA: Crystalline silica (quartz) is not classified as a hazardous waste under the Resource Conservation and Recovery Act, or its regulations, 40 CFR §261 et seq.
National Fire Protection Association (NFPA):
- Health: 0
- Flammability: 0
- Reactivity: 0

Warning Label Text:

WARNING
Contains Silica Dust
Can Cause Silicosis and Cancer
Avoid Breathing Dust

HAZARDS
Silica dust can cause severe and permanent lung damage and other diseases.
- Breathing silica dust can cause silicosis, a lung disease that can lead to serious breathing difficulties and death. Silicosis also increases the risk of tuberculosis.
- Breathing silica dust can cause cancer.
- Breathing silica dust may cause scleroderma, a scarring of the skin and internal organs.

Breathing silica dust may not cause noticeable injury or illness, even though permanent lung damage may be occurring.

PRECAUTIONS
Avoid breathing dust. Use with adequate and properly maintained dust collection systems to keep silica dust below permissible limits.

Avoid creating dust when using, handling, storing, or disposing of this product or bag.
- Do not dry sweep product. Wet product with water or use a dustless method (vacuum) to clean spills.
- Do not allow dust to collect on floors, sills, ledges, machinery, or equipment.

Do not rely on your sight to determine if dust is in the air. Silica may be in the air without a visible dust cloud. If dust cannot be kept below permissible limits, wear a respirator approved for silica dust when using, handling, storing or disposing of this product or bag.

DO NOT USE FOR SANDBLASTING!
See U. S. Silica Company Material Safety Data Sheet in Your Employer’s Possession for More Information on Hazards and Precautions
CAS#14808-60-7

Web Sites With Information About Effects of Crystalline Silica Exposure:
http://www.msha.gov - The Mine Safety Health Administration Home Page, which contains general (not mining specific) information on silicosis. Click on “Silicosis Prevention”.

U. S. SILICA COMPANY DISCLAIMER
The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind, express or implied, is made with respect to the information contained herein. We accept no responsibility and disclaim all liability for any harmful effects which may be caused by purchase, resale, use or exposure to our silica. Customers-users of silica must comply with all applicable health and safety laws, regulations, and orders, including the OSHA Hazardous Communication Standard.
22. APPENDIX B – STRUCTURAL ANALYSIS