CONF-910204--2

LA-UR -90-3705

LA-UR--90-3705

DE91 001803

TITLE: DUST--A MAJOR ENVIRONMENTAL HAZARD ON THE EARTH'S MOON

AUTHOR(S): Grant Heiken, David Vaniman, and Bruce Lehnert

SUBMITTED TO: 1991 SME Annual Meeting
Society for Mining, Metallurgy, and Exploration, Inc.
Denver, CO
February 25-28-1991

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DUST—A MAJOR ENVIRONMENTAL HAZARD ON THE EARTH'S MOON

by

Grant Heiken
Earth and Environmental Sciences Division
Los Alamos National Laboratory
Los Alamos New Mexico, 87545

David Vaniman
Earth and Environmental Sciences Division
Los Alamos National Laboratory
Los Alamos New Mexico, 87545

Bruce Lehnert
Life Sciences Division
Los Alamos National Laboratory
Los Alamos New Mexico, 87545

Environmental Hazards on the Earth's Moon

On the Earth's Moon, obvious hazards to humans and machines are created by extreme temperature fluctuations, low gravity, and the virtual absence of any atmosphere. The most important other environmental factor is ionizing radiation. Less obvious environmental hazards that must be considered before establishing a manned presence on the lunar surface are the hazards from micrometeoroid bombardment, the nuisance of electro-statically-charged lunar dust, and an alien visual environment without familiar clues. Before man can establish lunar bases and lunar mining operations, and continue the exploration of that planet, we must develop a means of mitigating these hazards.

Dust

> "After lunar liftoff....a great quantity of dust floated free within the cabin. This dust made breathing without the helmet difficult, and enough particles were present in the cabin atmosphere to affect our vision. The use of a whisk broom prior to ingress would probably not be satisfactory in solving the dust problem, because the dust tends to rub deeper into the garment rather than to brush off" (Allen Bean, Apollo 12 lunar module pilot, 1970).

During the Apollo missions, it was impossible for the astronauts to avoid bringing at least some dust into the landing module at the end of each period of surface activity.

Lunar soils, which make up most of the regolith that covers the Moon's surface, are similar to silty sands on Earth, with mean grain sizes ranging from 45 to 100 μm. Many of the grains are sharp and glassy and analogies have been made between lunar soil and fine-grained slag or volcanic ash (Heiken, Vaniman, and French, 1991). Lunar dust has very low electrical conductivity and dielectric losses, permitting accumulation of electric charge under ultraviolet irradiation. Consequently, with every step and with every turn of a Rover wheel, the astronauts kicked up dust, which settled on their suits and equipment. Dust coatings reduced the albedo of thermally-sensitive surfaces, obscured visibility through helmet visors and camera lenses, caked and clogged moving parts, and created continual abrasion hazards (Carrol and Blair, 1971).

Although the mean grain sizes of most analyzed lunar soil samples fall between ~45 and 100 μm, many particles are much smaller, falling within a size range that will allow their penetration into the respiratory tract and deposition within the lungs when inhaled. Unlike on Earth, where aerosols in the range of micrometers tend to be unstable and settle as an air-clearance mechanism, the condition of reduced gravity on the Moon favors the stability of aerosolized lunar soil and thereby will prolong its availability for inhalation if it is not removed from resident atmospheres by appropriate filtration systems. Even under conditions of atmospheric filtration, individuals working on the Moon would be expected to experience intermittent exposure to lunar dust during suiting for and unsuiting after lunar surface activities.

In terms of chemical composition, the major constituents in lunar soil are generally considered to be relatively innocuous in terms of their pulmonary pathogenicity when deposited as pure materials at low lung burdens. At higher mass burdens, various substances common to lunar dust, such as silica and otherwise benign titanium dioxide, cause pulmonary fibrosis and even lung cancer in animal models. Aside from their chemical constituents, the actual physical structures of lunar particles may be the primary determinants of any injurious response(s) to their pulmonary deposition. For example, certain particulate crystalline structures are known to cause cell death, whereas other crystalline structures of similar chemical composition do not. As yet, state-of-the-art inhalation toxicology does not provide predictive insight as to how the numerous chemical constituents that make up lunar soil particles might lead to pathologic states following deposition in the respiratory tract.

In addition to incidental dust kicked up during surface activities, evidence accumulated during the Apollo missions suggests that exposed surfaces become dust coated as a result of phenomena associated with passage of the solar terminator—the boundary between day and night. What may happen is that the sharp gradient in ultraviolet flux across the terminator may generate clouds of electrostatically-supported dust and set them into motion as the terminator moves across the Moon (Alvarez, 1977). Evidence for dust lofting at the terminator comes both from astronaut observations of "streamers" and corona/zodiacal light extending several kilometers above the lunar surface near the sunrise terminator and from increased counts of particles with high electrostatic charge found by the lunar ejecta and meteorite experiment during passage of the terminator (Apollo 17 mission; McCoy and Criswell, 1977).

Dust accumulations experienced by the Apollo crews tended to be more of a nuisance than a hazard, but there are clear indicators that, in a lunar base era, the potential problems might be serious. Dust accumulates in every joint, every moving part, and every latch. As indicated by examination of parts of the Surveyor III spacecraft recovered by the Apollo 12 crew, lunar dust adheres to both painted and metallic surfaces; and lunar dust will easily impregnate porous surfaces like the cloth coverings of the Apollo space suits. Wiping or brushing dust off of visors and camera lenses caused scratches; after extended use, moving parts and repeatedly rubbed surfaces such as glove fingers showed evidence of wear; and a Surveyor mirror showed clear evidence of sand blasting as a result of the Apollo 12 landing, 183 m away.

Mitigation of the Lunar Dust Hazard

We have rudimentary knowledge of lunar-dust-charging phenomena but do not understand their magnitude and their overall effects on lunar colonization and exploration. Before mining can begin, new research must be initiated concerning basic physical and chemical properties of lunar soils:

(1) Analyze data collected during the Surveyor, Apollo, and Luna missions that pertain to electrostatically-supported lunar dust. What evidence supports the preliminary conclusions, developed during the Apollo program, that there is a dust cloud composed of charged dust particles that follows the terminator? Determine, if possible, the magnitude of the problem, including the dust cloud density, particle size distribution, and the electrostatic charge. What is the variation in dust behavior between lunar day and night?

(2) After analysis of existing data, numerical models of electrostatically-supported lunar dust clouds should be created.

(3) If existing data are not sufficient to address the problem, experiments should be designed to evaluate the physical properties and temporal variation of the terminator dust cloud and any electrostatic charge buildup. Such instruments can be designed and tested before being emplaced by unmanned landers.

(4) Appropriate analyses and experiments could be performed to address the possibility that during lunar night, the low conductivity of the soil will also create significant electrical charging hazards between mobile objects on the lunar surface—producing the well-known wintertime "spark" electrical discharge when charged objects meet.

In the area of dust mitigation during base development and mining, the following activities should be pursued:

(1) Continued research on the properties and genesis of the lunar regolith, terrestrial dust, and clastic (fragmental) terrestrial rocks. Quantitative image analytical techniques using scanning electron microscopes have been developed for the purpose of particle characterization. None of these techniques was available for lunar sample analysis during the Apollo Program. Comprehensive analysis of the complete spectrum of soils collected at a variety of sites during the Apollo and Luna programs is necessary for the data base required to establish the methods and materials necessary to mitigate the effect of lunar dust on operating a lunar mining operation.

(2) Reducing the levels of operationally-generated dust at a lunar base will require "paving" areas of heavy traffic and "sealing" the regolith used to bury structures for the purpose of reducing the dust hazard. A research and development program to develop large-scale, energy-efficient means of stabilizing lunar regolith can be developed

(3) Investigations are needed to directly examine the acute and chronic functional, cellular, and biochemical responses of the lung to lunar soil particles collected at the variety of sites visited during the Apollo Program; a particular emphasis will be made on the toxicity of particles that are predicted to deposit in the human lung under the condition of reduced lunar gravity. Lunar soil samples for such work can be characterized jointly by planetologists and medical researchers. The results of such studies would also serve to provide direction with regard to the efficiency with which air filtration systems must operate within spacecraft and lunar habitats.

(4) Materials or coatings to minimize dust accumulation on equipment and spacesuits must be developed. Perhaps the same materials could also have the ability to absorb the impact of micrometeorites. Various cleaning technologies must be

evaluated or developed to remove dust from space suits, equipment, and lenses and visors. Dust mitigation techniques can be tested in large vacuum chambers such as the proposed Los Alamos/University of New Mexico CETEC facility; Although lunar gravity itself cannot be simulated on Earth, many of the other environmental conditions can be created at CETEC. Consultations with the Apollo astronauts would provide checks on the validity of at least some aspects of the simulations.

References

1. Alvarez, R., 1977, "On Charge Transport in the Terminator's Vicinity" (abstract) Lunar Science VIII, pp. 28-30.

2. Carrol, W. F., and Blair, P. M., 1971, "Discoloration and Lunar Dust Contamination of Surveyor III Surfaces" Proceedings of the Lunar Science Conference 2nd, pp. 2735-2742.

3. Heiken, G., Vaniman, D., and French, B. (editors), 1991, Lunar Sourcebook, Cambridge University Press, New York, 736 pp.

4. McCoy, J. E., and Criswell, D. R., 1974, "Additional Astronaut Observations of Possible Light Scattering by Lunar Dust Atmosphere, Lunar Interactions (D. R. Criswell and J. R. Freeman, editors), Lunar Science Institute, Houston, pp. 105-106.

END

DATE FILMED

01 / 08 / 91