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IMPACT OF MARS SAND ON DUST ON THE DESIGN OF SPACE SUITS AND LIFE SUPPORT EQUIPMENT - A TECHNOLOGY ASSESSMENT

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Space suits and life support equipment will come in intimate contact with Martian soil as aerosols, wind blown particles and material thrown up by men and equipment on the Martian surface. For purposes of this discussion the soil is assumed to consist of a mixture of comminuted feldspar, pyroxene, olivine, quartz, titanomagnetite and other anhydrous and hydrous iron bearing oxides, clay minerals, scapolite and water soluble chlorides and sulfates. The soil may have photoactivated surfaces that acts as a strong oxidizer with behavior similar to hydrogen peroxide.

Bearings and seals - The rotary joints used on state of the art Space Suit Assemblies such as the Ames AX-5 or the JSC Mark III are ball bearing joints integrated with one or more pressure-assisted lip seals. Both lubricated and dry bearing have been developed and either approach must be considered in any potential Mars walking suit. These bearings and seals will have to be protected with a dust restraining seal on both the inside and outside of the suit. The inside seal is to prevent grit introduced during servicing from getting into the bearings. Designing these dust inhibiting seals will be a design challenge because the total mass of the space suit must be strictly controlled to remain within a human's carrying capacity.

Linear actuators, ball screws - Various kinds of linear actuators and ball screws are likely on Mars equipment. Like the space suit bearings they must be designed so that any adhering dust is kept away from any close tolerance meshing surfaces. The magnetic attraction of the soil will also be considered in designing any device to wipe the soil off the meshing surfaces. Standard terrestrial aircraft practice could provide a point of departure for such designs or the machine-tool practice of covering linear actuators with elastomeric bellows could be followed.

Gas inlets to compressors or other devices - A wide variety of indigenous resource utilization schemes using the Mars atmosphere have been proposed. A common feature of this equipment is a mechanical or chemical compressor drawing in large volumes of the Mars atmosphere. Certainly gas inlets will have to have dust filters just as they would on Earth. Designing such filters will not be a major challenge.

Heat exchangers rejecting heat to the Martian atmosphere - The fine passages of compact heat exchangers must be protected from a build up of dust and grit. The design of the filters for this purpose will be more of a challenge than for the compressor inlets because the heat exchanger flow rates will be orders or magnitude greater. The filters will have to be very efficient to minimize pressure drop and unacceptably large power demands. Nonetheless the problem is a relatively straight forward one.

Pressure seals - Space suits and other equipment will contain numerous pressure seals which are repeatedly made up and disassembled on the Martian surface during the course of a mission. These seals inevitably will become contaminated with some soil. Conventional elastomeric seals such as O-rings are quite tolerant of such contamination unlike knife edge or other metal to metal seals. The major impact of the dust will be operational rather than on design. Even the most dust tolerant sealing system will demand that the seals and connections be wiped off each time they are made up.

Thermal protection garments - Thermal protection on the Martian surface will be quite different from the Moon during Apollo, because the Mars environment is cold and the atmosphere has a significant gas thermal conductivity. However, during daylight EVA the convective and radiation losses from a space suit will be significantly less than the the metabolic and electric heat generated in the EMU. The design challenge will thus be to keep the astronaut's arms, legs, hands, and feet warm while still having a net heat loss. Because the crew's extremities must be kept warm they will be heavily insulated. Unlike during Apollo lunar surface EVA, the increase in absorbance of visible and thermal i-r radiation due to an adhering soil coating will not adversely affect performance. Insulation will have to be similar to that used on earth with numerous small trapped gas spaces. Despite the low pressure, the thermal conductivity of the Mars atmosphere is large enough that Multi-Layer Insulation which prevents radiative heat transfer will not be effective. However, insulation approaches used in the Arctic should be effective.

Optical surfaces, radiators, and helmets - Optical surfaces will become contaminated with dust, which will have to be carefully removed to prevent scratching. Should radiators be selected as part of the heat rejection scheme, some provisions will have to be made to remove adhering dust. The dust will have to removed carefully, because current state-of-the-art low-solar-absorbance high-thermal i-r emissivity coatings are a multi-layer laminate of coated films which are not scratch resistant.

Materials constraints on pressurized volume coming in contact with the soil - The Mars astronauts will inevitably track soil into the pressurized volume exposing the soil to warm moist air. Some constituents of the soil are probably hygroscopic and any soil which comes in contact with moist air at room temperature will yield a salt solution, probably with an acidic pH. Thus any equipment which comes in contact with soil-contaminated moisture must be corrosion resistant. However fairly straight forward material control can emphasize use of corrosion resistant alloys possibly at the sacrifice of some strength, e.g. selection of 6061 aluminum alloy in preferences to the stronger but less corrosion resistant 7075. If the soil has a high level of chemical activity, as suggested by the biological experiments on Viking, it may attack some organic materials once it gets inside the pressurized volume. The impact of that chemical activity is the one aspect of the soil which could have the most significant impact on space suit and life support equipment design. However, if the the activity can be modeled as that of a peroxide or superoxide. Thus a series of tests to determine materials degradation and offgassing upon exposure to solid or liquid peroxides should define the magnitude of any physical degradation or generation of toxic vapors. Even if traces amounts of noxious gases should be generated, their significance may be quite small. the concentrations should be those levels can be evaluated in terms of the Spacecraft Maximum Allowable Concentration (SMAC) levels, and the performance of traces contaminant removal systems used on the Shuttle Orbiter or proposed for Space Station Freedom.

Summary - The existing data about the Mars soil suggests that the dust and sand will require designs analogous to those uses on equipment exposed to salt air and blowing sand and dust. The major design challenges are in developing high performance radiators which can be cleaned after each EVA without degradation, designing seals that are readily cleaned and possibly in selecting materials which will not be degraded by any strong oxidants in the soil.

The magnitude of the dust filtration challenge needs careful evaluation in terms of the trade off between fine-particle dust filters with low pressure drop that are either physically large and heavy, like filter "baghouses,", require frequent replacement of filter elements, of low volume high pressure drop thus power consumption approaches, or washable filters. In the latter, filter elements are be cleaned with water, as could the outsides of the space suits (properly designed, of course) in the airlock.