

Experimental Determinations of the Electrostatic Properties of Martian Regolith Simulant Particles.

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To develop a better understanding of the techniques involved in studying the electrostatic characteristics of the Martian regolith simulant obtained from NASA Johnson Space Center, several experimental determinations were made with a number of simple setups. A brief description of these determinations will be made in this report. These determinations will serve as the basis for the development of future experimental methods.

I. Breakdown Potentials in CO₂ at Low Pressures

At the low surface pressures on the Martian atmosphere (6-9 torr), it is expected that any electrical discharges take place only through corona discharge over millimeter to centimeter distances at a few hundred volts and over centimeter to meter distances at a few thousand volts [Kolecki 1991].

Prior observations of Martian regolith simulant polarization in the presence of high mono-ionized electric fields in ambient atmosphere had shown that these particles attracted ions to their surfaces in a corona charging process [Calle and Kim 1998]. When these particles were subjected to electric field intensities of about 2.9×10^5 N/C, the magnitude of the electrostatic force on the particles became of the same order of magnitude as the magnitude of the gravitational, buoyant, and frictional forces experienced by these particles. Suspended particles were observed, allowing for the determination of the ionic charge. Ionic charges of about 30 nC/g were determined at ambient atmospheric conditions with a 40% relative humidity.

Measurements of breakdown potentials in a 100% CO₂ rarefied atmosphere, in which a pressure of 7 torr was maintained throughout the experiment, yielded corona discharges with electric field intensities of 3×10^4 N/C (figure 1). These field intensities correspond to potentials of about 250 V over a distance of 7.5 mm, in agreement with expected results [Kolecki 1991]. These electric field strengths produced electrostatic forces on the simulant particles that were much smaller than their weights. As a result, no particle levitation was observed.



Figure 1. Corona discharge observed with an electric field intensity of $\approx 10^4$ N/C in a CO₂ atmosphere at 7 torr.

Paschen discharge measurements for different gases have shown that even a 0.1% impurity added to a gas changes the breakdown curves dramatically [Leach 1991]. Further experiments in a gaseous composition closely matching the known composition of the Martian atmosphere should yield results of more interest.

II. Electrostatic Charge Measurements

Rough measurements of the electrostatic charge on the Martian regolith simulant were made using a Faraday cup. In a Faraday cup, an inner metal container is surrounded by a grounded metal screen which prevents stray external potentials from introducing extraneous electrostatic fields. This inner cup is connected to an electrometer which determines the electrostatic charge residing on any object placed within the cup by measuring the voltage across a known capacitance. When the charged object is placed in the inner cup, an equal and opposite charge is induced on the outer wall. An equal and opposite charge to this new induced charge is left behind on the capacitor of the electrometer, where it is measured.

Correct measurements of the charge on the simulant required a great deal of care to avoid the production of additional charge when delivering the simulant to the cup. The ETS Faraday Cup used for these experiments had been designed for the determination of the charge developed on films by contact with a solid cylinder of known electrical permittivity. This particular model is not suitable for measurements involving dust or sand particles. A more suitable experimental arrangement will be discussed in the Recommendations section. Nevertheless, to develop some understanding of the techniques involved, experimental attempts at determining the charge generated on the simulant particles were made with this simple cup by allowing the particles to roll along a grounded steel plane at a 45° angle (figure 2). Measurements were made in ambient atmosphere at 30% relative humidity. For each trial, one gram of the simulant was placed on disposable aluminum dishes which were kept overnight in an oven at 150 °C. The simulant had been passed through a series of sieves until dust-sized grains smaller than 40 μ m were obtained.

These simulant samples were placed on the inclined plane directly from their metal containers, which were grounded to prevent the introduction of any external fields. For comparison, the simulant samples were placed directly into the Faraday cup and a determination of its electrostatic charge was made.



Figure 2. Inclined plane and Faraday cup assembly.

Figure 3 shows the results of these trials. Essentially, no charge was measured on the simulant when it was delivered directly to the Faraday cup form the grounded aluminum dish. Repeated trials with the same simulant after it was retrieved from the cup show a slight charge build up, increasing to about 0.8 nC for the last two trials. This small build-up is probably triboelectric in nature, as the grains collide with the metal container after it is poured back into it for subsequent trials.

A small charge of about -3 nC/g was measured when the simulant was allowed to slide along a 2" x 3" stainless steel grounded plate. This charge is about 10% of the magnitude of the ionic charge acquired by the simulant under electric fields of about 0.3 MC/m.

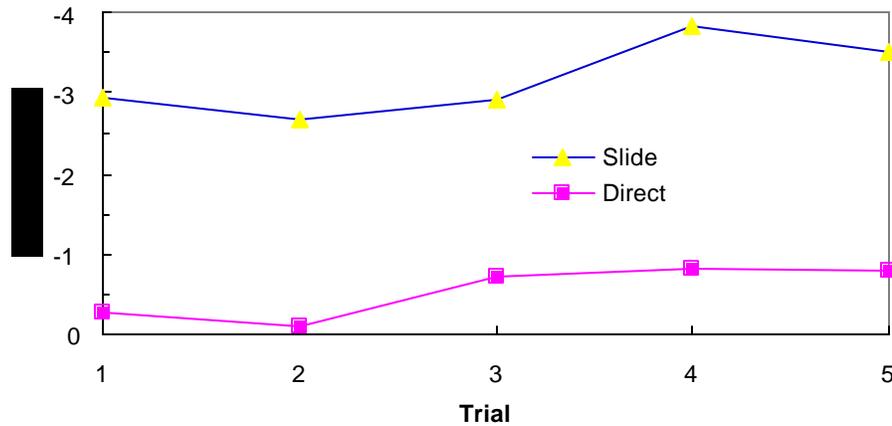


Figure 3. Charge generated on the simulant. The bottom curve corresponds to the charge measured when the simulant was placed directly on the Faraday cup. The top curve shows the charge as the simulant grains rolled down the metal incline.

III. Charge Characteristics of Materials Exposed to the Simulant

Samples of mass 1.00 g of 40 μ m simulant grains were prepared and placed in an oven at 150°C overnight. These samples were delivered in a grounded aluminum dish to a mechanical delivery apparatus and sample holder carousel previously designed (figure 4) [Calle *et al*, 1998]. The simulant was delivered to 10 different materials at a speed of 12 m/s. Electrostatic potentials generated on the samples were measured with a Keithley Model 2501 detector, Keithley 610C Electrometer and a Nicolet model 310 digital storage oscilloscope. For comparison, the results of electrostatic charge and discharge (ESD) tests performed at NASA KSC on plastic films are shown for the materials for which data was available [Gompf 1988]. These tests evaluate the material's capability to develop a charge and its ability to discharge it to a grounded frame. If the electrostatic potential decays below 350 V in 5 seconds, the ESD test is said to pass. Results of these tests are shown in Table 1.

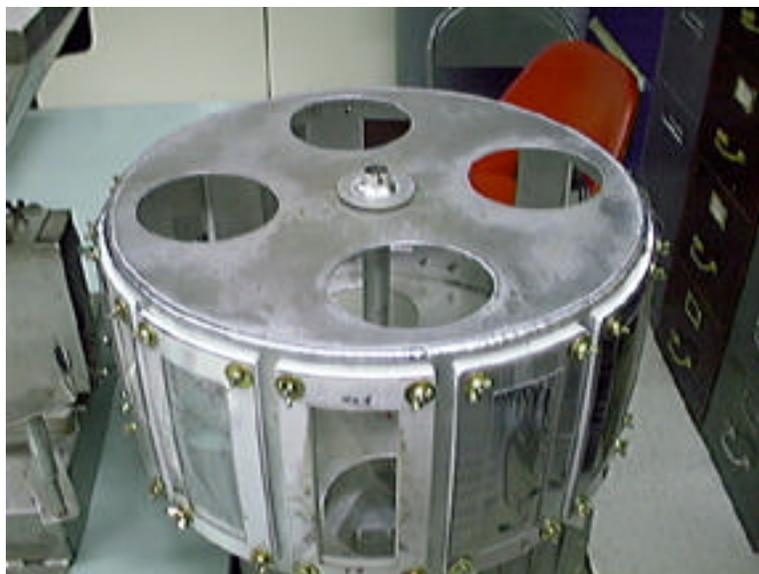


Figure 4. Mechanical delivery apparatus and sample holder carousel. The steel apparatus was grounded to prevent any transfer of charge to the simulant.

Table 1. Electrostatic Potentials Generated on Samples

Material	? (V)?	ESD	Material	? (V)	ESD
Teflon	-350	Fail	RCAS 2400	0	Fail
Velostat	0	Pass	Carbon Steel with Zn Primer	0	NA
Llualoy HST	0	Pass	Aluminum	550	NA
Aclar 22A	-1000	Fail	Stainless Steel	450	NA
FDX-2707	0	n.a.	Carbon Steel	550	NA

In all cases in which a potential was measured, clods of the simulant dust particles remained attached to the sample surface, affecting the real values of the potentials generated on the samples themselves. At the fairly high speeds at which the dust was delivered to the samples, the collision produced pits on the surfaces, creating regions of high friction which prevented all the dust particles from sliding off the samples.

IV. Conclusions and Recommendations

Measurements of breakdown potentials in a CO₂ atmosphere at 7 torr were in agreement with predictions [Kolecki 1991]. Since the addition of a small impurity even as low as 0.1% changes the discharge characteristics of a gas, experiments with a gaseous mixture closely matching the Martian atmosphere should be made.

Methods to obtain more reliable data on the triboelectric properties of the Martian simulant should be developed. Perhaps the main difficulty when measuring the triboelectric charge of small particles is that most powders are known to develop bipolar charge. It is not known whether the JSC1 simulant exhibits this particular characteristic. An experimental method to determine the bipolar response of the simulant to triboelectric charging must be attempted. If the

simulant is found to be bipolar, a Differential Faraday cup needs to be designed so that a charge to mass ratio distribution function can be determined.

This particular experimental method will present some additional challenges. A technique to retrieve the sample from the cup to allow for multiple measurements of a single sample should be developed. A stream of pressurized dry air can be used to slide the particles along the incline plane and to deliver them to the Faraday cup. Thus, a design with small openings at the sides of the inner cup lined with fine filters to allow the air to escape, while keeping the dust particles inside the cup, should be implemented. Different incline materials, preferably at the extreme ends of the triboelectric series, should be used so that a more complete characterization of the electrostatic properties of the simulant is made.

Sample testing...

References

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