Europlanet TA Scientific Report

PROJECT LEADER

Project number: 22-EPN3-060	
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TA Facility visited: Planetary Environment Facility of Aarhus University (TA2 Facility 4)	

Project Title: A new apparatus for measuring the electrical charge of volcanic ash particles

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

The electrical charge carried by volcanic ash particles is known to play a crucial role in the formation of aggregates, which modulate the atmospheric transport and deposition rate of volcanic ash. However, direct field measurements of these charges remain rare, and more investigations are required to better comprehend both charge generation and aggregation mechanisms. This study aimed at building and testing a portable device to quantify the charge of individual volcanic ash particles and aggregates using a Through-Type Faraday Cage (TTFC) connected to a charge amplifier circuit capable of detecting the very small voltages induced by charged particles entering the TTFC.

After building the apparatus, 187 tests were performed, using different quantities and types of particles, as well as varying the measurement technique. First results show that the newly built device is capable of measuring charges down to 0.1 pC and that measurements agree well with alternative estimations obtained by directly integrating the current generated in the TTFC over time. Beside the charge, results also suggest that the device can be used to obtain the particle settling velocity, based on the duration of the voltage signal. Few additionnal tests are now required to detect smaller particles (i.e., smaller charges) and the instrument will then be used for field analysis and laboratory experiments.

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The apparatus for measuring the electrical charge of volcanic ash particles was assembled at the Planetary Environment Facility in Aarhus. It consists in a TTFC connected to a charge amplifier circuit, which delivers an output voltage $V_{out} = -Q/C_{ref}$ inversely proportional to the charge Q of the object inside the TTFC and the reference capacitance of the circuit C_{ref} (Figure 1). The output voltage is recorded on a portable oscilloscope and the charge amplifier is set in a metal case, in order to make the system easily transportable and adaptable to field conditions. Casing also significantly improved the signal to noise ratio of the instrument. Several charge amplifier circuits were prepared with C_{ref} = 10 pF or 100 pF to measure small and high charges, respectively. Similarly, various TTFCs with diameters ranging from 1 to 5 cm and lengths ranging from 4 to 20 cm were designed.

Figure 1 – Apparatus used for charge measurements. Here, the diameter of the TTFC is 5 cm and its length is 20 cm. The diagram describes the charge amplifier circuit, with the properties of each electrical component.

The instrument was tested by measuring the charge of particles charged due to contact electrification (particle/particle and particle/wall interactions) when blown through an Al_2O_3 tube (4 mm internal diameter, 300 mm length). The exit velocity of the particles was controlled by adjusting the initial overpressure of the gas passing through the injector tube, which was varied between 0.2 and 3.5 bar. All the tests were performed at atmospheric pressure, at ambient temperature and relative humidity of $\sim$ 20°C and 50 %, respectively. Particles were injected either as clouds (i.e., 0.4 to 40 mg of particles injected) or individually (for diameters $\geq$ 500 µm). Different particle compositions were used, including sieved volcanic ash of basaltic and andesitic compositions, but most tests were conducted with silica glass beads. The particle size was varied between 100 and 2000 µm.

When entering the TTFC, a charged particle produces a voltage peak inversely proportional to their electrical charge, and a symmetric, opposite, peak is detected when the particle leaves the TTFC (Figure 2). Whilst the amplitude of the voltage peaks can be used to estimate the particle charge, the time separating the two peaks corresponds to the time during which the particle is inside the TTFC. It can therefore be used to estimate the average velocity of the particle crossing the TTFC.

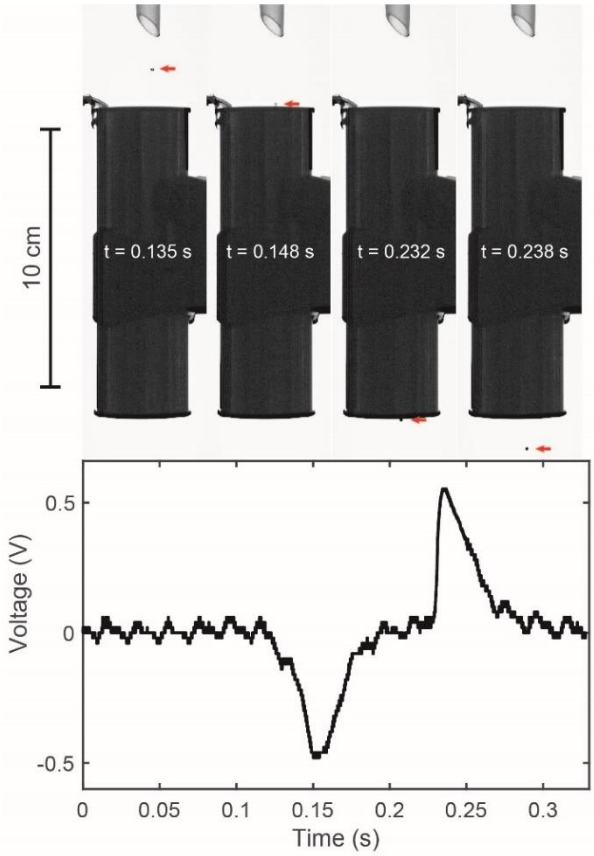

Figure 2 – Typical signal recorded by the instrument for a charged 2 mm glass sphere exiting the tube at a low velocity ~ 1.5 m s^{-1}. Here, the reference capacitance of the charge amplifier is 100 pF. Snapshots from a synchronised high-speed video are shown on top, with the position of the particle highlighted by the red arrow.

Measurements obtained with the new instruments were compared with estimations of the charge estimated from direct measurements of the current induced in the TTFC. In this configuration, the oscilloscope was connected to the TTFC, and the charge of the particle crossing the TTFC was obtained by integrating the current generated over time. In total, 187 tests were performed using both measurement techniques. The charges estimated with and without the charge amplifier circuit agree well and are of the same polarity, with similar values, within the standard deviation between repeated measurements for individual particles (Figure 3). For particle clouds, charge amplifiers with a C_{ref} = 10 pF are seen to slightly underestimate the bulk charge, potentially because the signal reaches saturation under these conditions for which higher C_{ref} are required (i.e., C_{ref} = 100 pF).

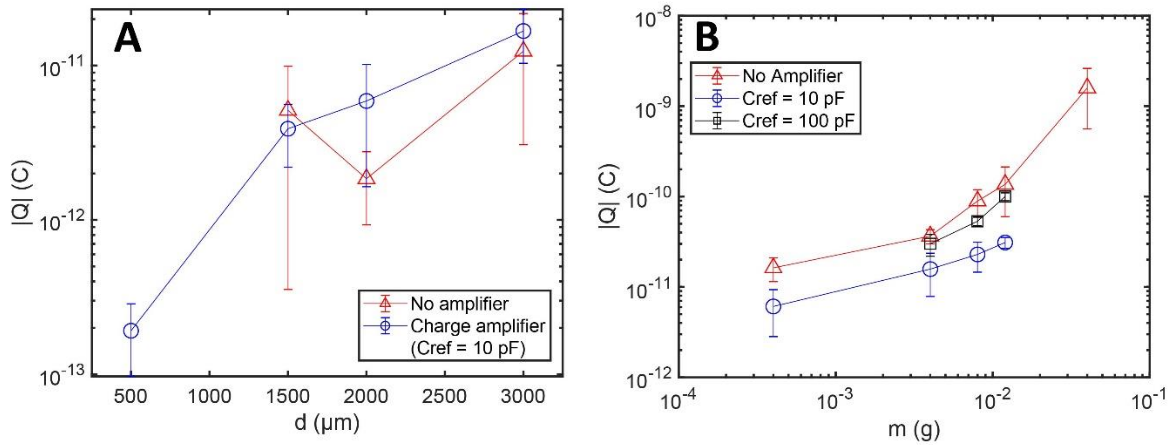

Figure 3 – Comparison between the bulk particle charge $\boldsymbol{Q}$ obtained with and without charge amplifier for **(A)** individual particles of different diameters $\boldsymbol{d}$ and **(B)** particle clouds containing different initial masses of particles $\boldsymbol{m}$ ($\boldsymbol{d}$ = 100 µm). Vertical error bars show the standard deviation of repeated tests.

Additional laboratory tests are required to detect individual particles smaller than 500 µm using the charge amplifier, notably by reducing the value of C_{ref} and adding a stage of voltage amplification. First field measurements are planned in November 2023 at Sakurajima volcano (Japan).

- Give details of any publications arising/planned (include conference abstracts etc)

- Host confirmation

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Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: 01-08-2023 Arrived: 01-08-2023	02-08-2023	[0]	8	[0]	11-08-2023	Departed: 13-08-2023 Arrived: 13-08-2023

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	**Jonathan Merrison**
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Project Leader Name	**Allan Fries**
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Date	**14/09/2023**