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Journal of Electrostatics 64 (2006) 424–430
Journal of ELECTROSTATICS
www.elsevier.com/locate/elstat

Advanced Faraday cage measurements of charge and open-circuit voltage using water dielectrics

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Available online 8 November 2005

Abstract

Distilled water, tap water, Sargasso Sea water and 0.9% NaCl solution contained in a Nalgene 30 ml polyallomer centrifuge tube are found to maintain distinct negative non-zero equilibrium charges as measured within a grounded patented Faraday cage. Here, the Faraday cage is composed of two identical in-line hollow, gold-plated Faraday cup electrodes which enclose the sample that moves between them during each measurement under computer control. Charge measurements using various electrometers were conducted to rule out the possibility of false instrument readings due to input offset voltage and other experimental effects. Charge, voltage and capacitance are presented as a function of the water dielectric temperature.

Keywords: Faraday cage; Water dielectrics; Negative non-zero equilibrium charge; Capacitance; Open-circuit voltage

1. Background

It is known that leaving charged objects within a grounded metallic enclosure for a long enough time allows the charge to decay to zero due to the slight ohmic conductivity of air, object and supporting structures. We have found a new phenomenon using distilled water, tap water, Sargasso Sea water and 0.9% sodium chloride (NaCl) solution, where each maintains a different negative non-zero equilibrium charge when measured within a grounded Faraday cage.

Fig. 1 shows a drawing of the experiment. Measurements of charge and voltage are performed in a patented [1], gold-plated Faraday cup device housed in a grounded Faraday shield. The water dielectric samples are contained in 30 ml polyallomer centrifuge tubes. The samples move between two identical in-line hollow gold-plated brass Faraday cup electrodes during each measurement. A metal screw in the tube's cap holds the dielectric to a gold-plated motor-controlled rod, and the screw makes contact between the water sample and Earth ground throughout the experiment. The upper Faraday cup electrode is permanently grounded, and the lower active cup electrode is grounded between measurements by the zero check input of the Keithley model 617 electrometer. The electrometer is then set to the Coulomb mode to integrate the current flow from the lower electrode as the water sample moves between electrodes. If the polarity displayed by the electrometer is positive after the sample comes to rest within the upper electrode, it means that the given sample is negatively charged, because it had induced a positive charge upon the inner surface of the lower electrode which flowed to ground through the electrometer as the sample left the lower Faraday electrode. The sample can be moved in three ways. One way is by activating a switch in the motor relay to allow the sample to ascend and descend. The second way to control the motion is to program a Keithley model 2001 digital multimeter's digital I/O port. The third way is through automatic computer control using Testpoint data acquisition software. We did this to run experiments

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0304-3886/$ - see front matter
doi:10.1016/j.elstat.2005.10.020

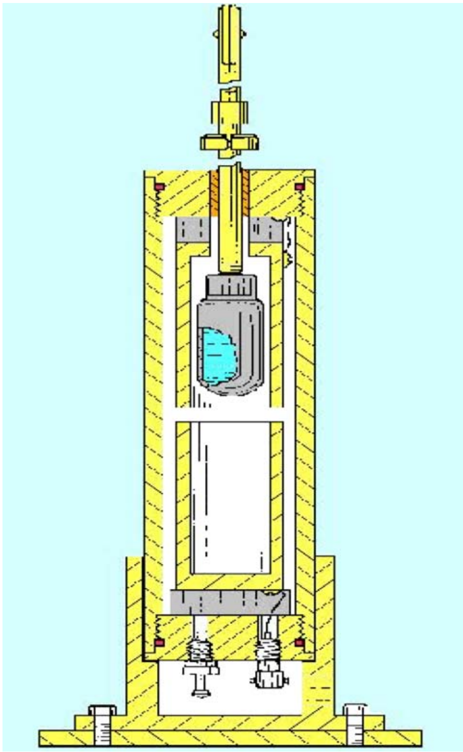

Fig. 1. Faraday cage internal structure consists of two Faraday cup electrodes. The upper electrode is permanently grounded. The lower electrode connects with the electrometer and is grounded between measurements. Liquid samples are raised and lowered using a lifting rod, flexible cord, pulley and computer controlled motor (not shown).

continuously and often unattended for longer periods. To determine the effect of temperature upon the magnitude of charge and voltage, we used an exterior water jacket and temperature controller to heat and cool the internal temperature of the Faraday cage chamber. Ambient laboratory temperature and internal temperature of the Faraday cage are measured using Omega RTD (resistance temperature detector) sensors. Values are displayed by the 2001 multimeter that can be programmed to display both ambient and internal temperatures [2].

A Testpoint program acquires data from the electrometer and the multimeter every 60 s. After the sample comes to rest within the upper electrode, the values are transferred to the computer and are recorded on a floppy disk. At the completion of each experiment, the values are copied to Statmost to plot the variation of charge or voltage measurements as a function of temperature and time.

Peterson had conducted similar experiments using distilled water, glycerol and methanol in the same Faraday cage. He noted that electrometer charge measurements were a function of sample temperature [3]. The value of measured charge was also found to correlate to the relative dielectric permittivity, which is a function of temperature [4]. This paper investigates those measurements.

2. Measurements of charge

2.1. Verification of data using different electrometers

Additional electrometer charge measurements were conducted to rule out the possibility of false readings due to input offset voltage or other experimental effects. Two more Keithley 617 electrometers and one Keithley 614 electrometer were used. Distilled water had been taken from Cleveland. Tap water had been taken from our MIT lab. The Sargasso Sea surrounds Bermuda. The results are tabulated in Table 1. The values recorded here, although similar in time, are not long-term equilibrium values. We note that the electrometer values are similar for each type of water.

2.2. Measurements of equilibrium charge

Table 2 shows the range of equilibrium charge values reached after keeping the water dielectrics in the Faraday cage for a few days with no change in internal temperature. The equilibrium value depends upon the age and temperature of each sample.

2.3. Measurements of charge using different metal grounding screws

To determine whether the source of the charge we measure could be related to galvanic action, we also conducted an experiment to measure charge of the water dielectrics using different metal grounding screws. We used a brass screw and a stainless steel screw to hold the dielectric. Results are tabulated in Table 3. The values are essentially similar, and the difference is not thought to be significant.

3. Capacitance measurements

Capacitance of the Faraday cage was precisely measured with and without any sample inside using a Model AH

Table 1
Charge (nC) using different electrometers

Electrometer	Distilled water	Tap water	Sargasso Sea water
#1 617	−0.39	−3.23	−1.23
#2 617	−0.40	−3.20	−1.25
#3 617	−0.41	−3.15	−1.24
614	−0.39	−3.21	−1.27

Table 2
Equilibrium charge (nC) of water dielectrics

Distilled water	Tap water	Sargasso Sea water
−2.04 to −1.2	−5 to −4.7	−2.02 to −1.1