A COLLECTOR TO RETRIEVE MICROMETEORITES FROM THE SOUTH POLE WATER WELL

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A Rodriguez well melted into the polar ice cap supplies drinking water at the Amundsen-Scott South Pole station. Micrometeorites incorporated into this ice are liberated as the well progressively melts its way downward. During December 1995, we deployed a collector that suctioned particulates from the bottom of the South Pole water well (SPWW); the material retrieved contained extraterrestrial particles [1]. The collector, designed to meet stringent environmental, water-quality and access constraints, worked quite well despite encountering much more severe well-bottom topography than anticipated.

COLLECTOR DESIGN. The collector had to meet the constraints imposed by the SPWW: it must not jeopardize water quality; it must descend through a 30-cm-diameter access hole and operate remotely up to 200 m below the snow surface in water depths of at least 20 m; it must tolerate -50 C temperatures during deployment and recovery. In addition, scientific objectives imposed performance requirements: it should collect all particles in the size range 50-1,000 µm without bias to composition; it should cause no physical or chemical changes to the particles; it should minimize handling losses subsequent to collection.

We chose a collector configuration that suctions and internally filters the particles while traversing the well bottom. We control the collector from the surface via a waterproof electro-mechanical cable, using an underwater video system for visual feedback. The main body of the collector consists of a machined and folded sheet of low-density polyethylene (LDPE) and holds a nylon filter fabric (53 µm openings). When folded, the main body measures 1.2 m long x 20 cm wide x 2.8 cm high and forms a 2-mm-wide slot through which the pump draws water and entrained particles. A thin strip of LDPE forms a check valve to seal the slot when the pump is off. A central waterproof housing contains the pump, drive motors and electrical connections. Traction is via heavy spiked wheels driven through articulated shafts at opposite ends of the collector by the two independent drive motors. All materials (aluminum and stainless steel metal components, polyethylene collector body and cable jacket, nylon filter fabric and pump impeller, and silicon pump hose) were accepted for use in the SPWW. Figure 1 shows the assembled collector while Figure 2 shows a section through the main body.

The collector lies slot-down on the ice surface and is quite flexible to help it conform to vertical curves of the well bottom. Flow develops between the collector and the ice surface and reaches about 60 cm/s at the slot. The filter fabric bag attaches immediately inside of the slot to minimize loss of particles on the collector intake. The long, narrow collector body allows it to hold 3,600 cm^2 of filter fabric yet pass through the narrow well access hole.

We tested the collector extensively in the laboratory on submerged iced surfaces to refine its design and establish its collection efficiency. The test particles consisted of angular quartz sand and silicon oxide, and nickel and glass spheres, in the size range 50-500 µm. On ice that was globally flat and either locally smooth or with low surface roughness (1-3 mm deep over 1-10 cm scales) the collection efficiency exceeded 99% after 1-3 passes. Use of an external polyethylene sheet to restrict flow to one side of the collector allowed it to achieve this collection efficiency on rougher ice with fewer passes. We also tested the collector on an iced ramp with a parabolic profile that approximated the bottom shape reported for earlier Rodriguez wells [2, 3, 4], rising about 2 m over 4 m horizontal distance. The collector climbed this ramp to a 30° slope, and rotated through a 45° slope, while collecting particles.

FIELD DEPLOYMENT. In December 1995, the water pool in the SPWW began 90 m below the snow surface and measured about 16 m deep x 23 m diameter. However, the well bottom topography was much more complicated than anticipated. It consisted of a gently curved central plateau (about 20 m^2) sculptured at its periphery into fairly steep arcuate dips that were 0.3-0.6 m below the plateau and 1-3 m wide; these dips led to smaller plateaus (1-3 m^2). Farther away from the center, the bottom rose steeply and the sculptured features appeared to be more severe (either deeper or at shorter length scales). Associated with most sculptured features were visibly dark pockets of particulates; on plateau areas particles were visible but not concentrated into pockets. Local surface roughness was quite smooth (perhaps 1 mm depressions over 1-5 mm scales).

We successfully deployed and retrieved the collector 6 times yielding 5 separate collections (one filter bag deployed twice). The collector could maneuver easily over the central plateau, and we devoted one collection exclusively to it. Movement onto the adjoining dips and plateaus was possible with some practice, and we collected from five of these (about 10 m^2 total) including three particle pockets. We collected as much as 50 g of material at once without appreciably reducing pumping efficiency. Plateau areas suctioned were visibly cleaner, and gently curved dark areas changed from black to white with a single pass (although several passes were needed to maneuver the collector across entire pockets due to severe topography). Time limits and progressive drive motor failures prevented us from dedicating an entire deployment to repeat suctioning of the central plateau. However, the fourth deployment repeated coverage of about half of the central plateau and one pocket. Upon retrieval of the collector, we found very little material in the filter bag and decide to reuse it for the next deployment to save time. This and the visual evidence suggests a high in-situ collection efficiency.

Preliminary results [1] suggest that the well circulation can concentrate micrometeorites into the pockets observed. This is despite the relatively small flow rate (about 1 litre/s) discharged about 13 m above the bottom. Also, we saw no trace of particle transport by the circulating flow even with the collector nearby to act as a local disturbance. However, the compressed air pockets entrapped in the snow-ice release bubbles into the water as the well melts downward, and perhaps this agitation helps to entrain the micrometeorites. Nevertheless, the dark pockets preferentially contain iron-oxide grains derived from the water-supply system; the circulating flow can easily concentrate this injected material. Detailed analysis of the separate collections from the central plateau and the isolated pockets will reveal the degree of micrometeorite concentration possible by the circulating flow.

COLLECTOR IMPROVEMENTS. Available motor torque (rather than traction) limited the collector's mobility over the well bottom. In addition, visual feedback is essential to negotiate the well's complex topography, and our camera lacked the ability to track the collector more than 5 m away from the center. For next year, we hope to install more powerful motors and a pan/tilt camera to overcome these problems to increase the collection area and operational efficiency. However, the more severe topography away from the center of the well dictates the need for a second, more agile collector. Its design and testing would require considerably more time and money, but it is essential if we hope to retrieve the micrometeorites contained in all or most the isolated pockets.

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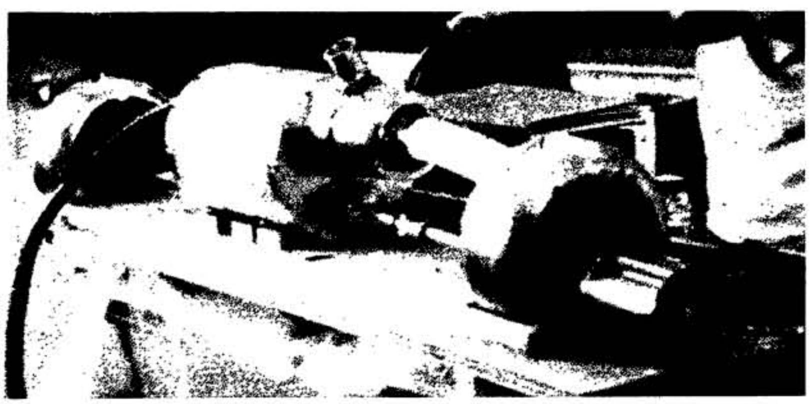

Figure 1. Assembled micrometeorite collector, showing main body, pump, central housing and spiked wheels.

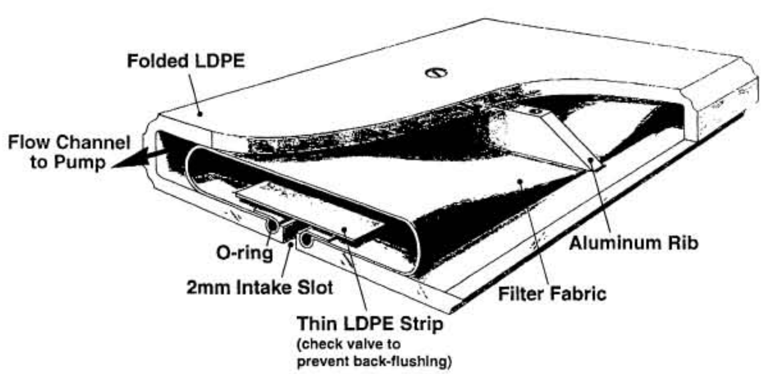

Figure 2. Cross-section through collector main body.