Scaled Down Substrate Module Test

Background

The PTIM flight hardware design includes 3 removable substrate modules (See Figure 2). These modules are filled with a substrate material (turface/arcillite) of 1-2 mm granular size. The modules are flooded with approximately 300 ml of solution through the use of a piston pump operating at a rate of 100 µl/sec. The water flows into the module through a porous tube which is in contact with a capillary mat. Seeds are glued to the top of the capillary mat and through capillary action, transfers water to the seeds. The module is constructed of aluminum sides and floor, perforated with venting holes. These surfaces are covered by a gas permeable PTFE/Polypropylene membrane (Mupor) to allow gas transfer but remain leak resistant. A perforated cover over the top of another sheet of Mupor is used to hold the substrate, capillary mat and plants in place.

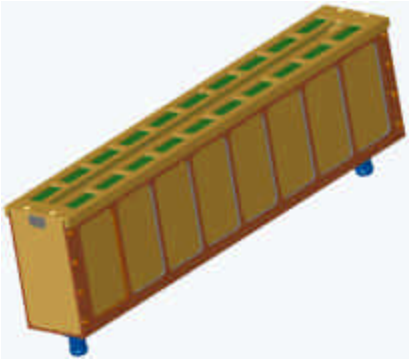

Figure 2 – Model of Full Scale PTIM Substrate Compartment. Notice Vents on Sides and Top.

Test Objectives

A concern regarding water escaping from the substrate module during fill was raised at the PTIM Critical Design Review. Because liquid flow characteristics differ in 0-g (versus 1-g) environment, the liquid injected into the module could possibly cling to and flow along the sides of the modules and escape out the top of the unit. The objective was to completely fill a substrate module at a rate more closely resembling the rate of the PTIM designed units (100 µL/sec). The fill was required to be accomplished in the 20 seconds of reduced gravity available at each parabola.

Hardware Design and Setup

A total of 10 miniature substrate modules were fabricated for this test. These modules were scaled down from the full size module design by a ratio of 3.2:1. The reason for the reduction in size was because of the requirement to fill the module within 20 seconds at a rate near 100 µl/sec (filling a full size module at 100 µl/sec takes approximately 50 minutes). The PTIM substrate module flight design includes a pump that injects at a maximum of 100 µl/sec per module. In order to fill the small scale versions within 20 seconds, the injection rate was required to be 470 µl/sec or above. This flow rate is still 4.7 times the rate incorporated in the PTIM design. The miniature modules were not made any smaller due to manufacture, cost, component availability and procedural issues.

At the bottom of each PTIM growth module is a porous tube used to evenly inject the liquid at the bottom of the module. The size of a scaled down porous tube was calculated at 0.125" outer diameter (OD). Porous tubes of this size are not available so a perforated tube design was used. Polyetheretherketone (PEEK) tubing (plastic) was perforated with 15 holes (axially) at each 90^{o} turn. Holes of 0.010" diameter were drilled in a staggered pattern to provide increased resistance to flow (and more uniform fluid excretion). The PTIM capillary mats were simulated with 1/3 thickness absorbent paper. The mats were wrapped around the tube and held in place by the top cover as in the full scale units. Capillary mats were not used in modules filled with glass beads or with unfilled modules.

The base, walls and cover of the modules were fabricated from optically clear acrylic. This provided visual feedback of fluid dynamics. The top cover was perforated to allow air to flow through the cover and into the substrate (as in the full size units). A Mupor (Teflon/Polypropylene) membrane was installed beneath the cover to prevent liquid from escaping the module (as in the full size units).

Since the full size PTIM modules include perforations on the sidewalls and floor covered with a Mupor lining, four of the units were modified to further simulate this design. On these four units all but the end walls were covered by Mupor, visually concealing the fluid flow. The mesh polypropylene side of the membrane was installed outward on 3 of these 4 units. The single indicator of fluid dynamics issues was the monitoring of the top cover for leakage during fill. Of the six units that did not have perforated walls or floor, one unit was lined with Mupor (polypropylene side out) to test any affects of the perforations on fluid flow.

A variety of fills were used for the testing. To simulate scaled down substrate material, turface was sieved down to three separate particle sizes. The full size PTIM modules incorporate 1 to 2 mm Turface. For this test, the following particle ranges were used: 0.25 to 0.50 mm, 0.5 to 1.0 mm, 1 to 2 mm

The modules were tested with a leak resistant glovebox designed and built by JSC (See Figure 3, Glovebox POC: David Treat). The glovebox was mounted to a fixture built by Texas A&M specifically for KC-135 use (POC: Cable Kurwitz). Each module was equipped with a syringe and tubing leading to the perforated tube. The syringes were filled with a predetermined volume of red dyed water to inject into the units. An 8 mm video camera was situated inside the glovebox for video capture. In front of the camera, a small stand was mounted to the glovebox floor. This stand properly positioned the units in the camera's view. Three vials of desiccant particles were fixed to the backing of the stand. These vials provided visual indications of basic vertical acceleration levels and were recorded by the video camera.

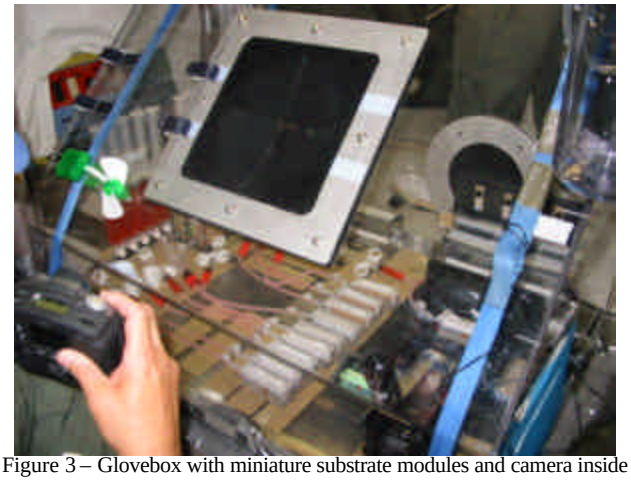

Figure 3 – Glovebox with miniature substrate modules and camera inside

Figure 4 – Miniature Substrate Module with Optically Clear Walls (5 units fabricated)

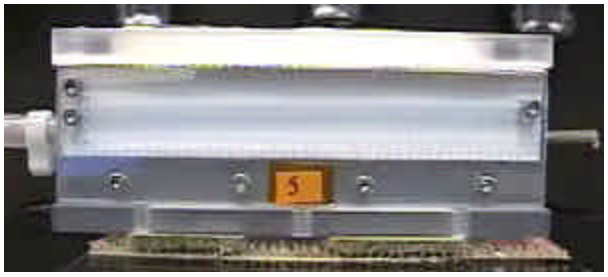

Figure 5 – Miniature Substrate Module with Optically Clear Walls and Mupor Lining (1 unit fabricated)

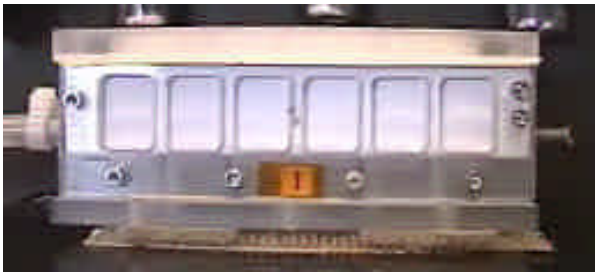

Figure 6 – Miniature Substrate Module with Perforated, Mupor Lined Walls (4 units fabricated)