A Scroll Filter System for In-Situ Resource Utilization CO_2 acquisition of the Martian Atmosphere. J. H. Agui[1] and D. G. Fischer[2], [1]NASA Glenn Research Center, 21000 Brookpark Rd, Mail Stop 77-5, Cleveland OH 44135, [2]NASA Glenn Research Center, 21000 Brookpark Rd, Mail Stop 5-10, Cleveland OH 44135

Introduction: The Martian atmosphere, consisting mainly of gaseous CO_2, is regarded as one of the main planetary resources capable of providing a significant portion of the oxygen that will be needed for human missions to the planet's surface. NASA's In-Situ Resource Utilization (ISRU) project supports the development of oxygen generation technologies that can convert the Martian atmosphere into usable oxygen. The thin CO_2 based Martian atmosphere, however, carries certain levels of dust stirred up by the Martian winds that must be filtered out at the front end of any CO_2 acquisition system. Thus, the ISRU project is developing particulate filters as part of a Mars CO_2 acquisition system. A prototype filter system, known as the Scroll Filter System (SFS), is being tested under simulated Martian atmospheric conditions in the Mar Atmospheric Flow Loop at the NASA GRC. The measurement techniques as well as the preliminary results from a series of performance tests will be discussed.

The Scroll Filter System: The proposed filter system, referred to as the Scroll Filter System , has been in development for cabin environmental control and life support systems (ECLSS) cabin filtration[1-3]. A scaled version of this filter system is being considered for ISRU CO_2 acquisition systems. A picture of the SFS is shown in Fig. 1. The SFS can provide multiple automated changes of the filter media, performed through a motorized scrolling or indexing mechanism of the filter media (the drive gears can be seen on top of the filter). The filter media can be also arranged in a pleated pattern, using support spindles, to increase the filtration surface area. The current prototype only incorporates one pleat. The SFS will provide long duration service life, compactness, and use of commercial off-the-shelf (COTS) filter materials. A built-in design provision of the filter concept is a record of particle loading conditions stored on the scroll filter media that can be accessed via a return mission.

Experimental Setup: The Scroll Filter was tested in the Mars Atmospheric Flow Loop at the NASA GRC. The flow loop testing platform consists of a sealed recirculating flow loop fabricated from 6 inch pipe segments, and contains axial fans and a vacuum pump for flow induction and low pressure operation respectively. Backfilling capability with CO_2 gas is provided. The apparatus also has an integrated particle dispenser that internally introduces challenge particles from within the flow stream. The dispenser can hold most any type of solid granular particles, including Martian simulant fines. Multiple ports and viewports permit the integration of pressure and velocity sensors, light sources and imagers. To introduce the CO_2 gas the system is pumped down using the main scroll pump to its maximum vacuum level typically 50 mTorr or less and then back filled with CO_2 gas, from the supply tank, to a pressure of 5 to 7 Torr. Second, in order to ensure that clean air is returned to the test section of the flow loop, a system HEPA filter has been incorporated into the facility. DC powered axial fans (main and booster) using variable current and voltage supplies produce the axial flow. Flow straighteners for flow conditioning are placed ahead of an orifice meter.

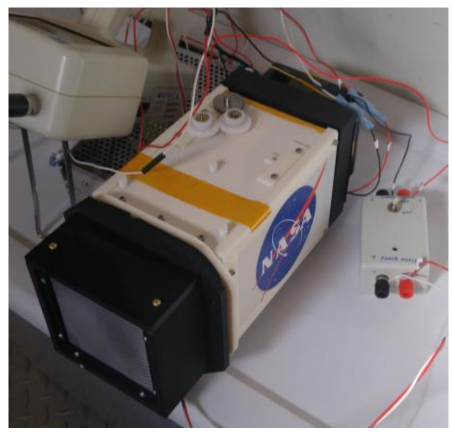

Figure 1: Scroll Fileter System prototype

Two methods are used for particle detection. First, a light sheet imaging technique was adapted to provide a method of recording real-time particle concentrations. A schematic of the technique is shown in Figure 2. A 527 nm pulsed Nd:YAG crystal laser generates a beam which is split, through a 50/50 beam splitter, and coupled into two optical fibers. The light emitted from the fiber is collimated and then spread into two diverging light sheets via cylindrical lenses into the flow volume. Two high-speed cameras are synchronized with the laser pulses through a pulse generator distributing a TTL signal at 2 kHz to the laser and the cameras to capture images of particles crossing through the light sheets. The second method consists of employing a commercial Laser Doppler Anemometer system which provides counts and velocities of particle over a small probe volume in the particle flow.

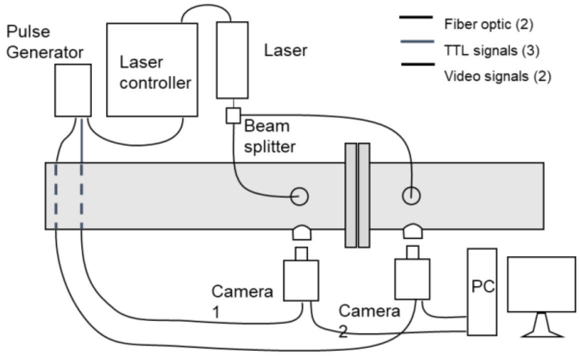

Figure 2: Schematic of light sheet imaging technique

Results: The first set of tests were focused on the hydrodynamic performance of the filter. Figure 3 shows the pressure drop as a function of flow rate. The pressure drops were substantially lower than the rated pressure drop (44 Pa at .053 m/s) for this media at atmospheric pressure. This is due in large part the departure from Stoke's law for small diameter particles, such as the fibers of the filter media, at low pressures where slip effects become significant[4-6]. Here the overall drag across the filter media was reduced by at least a factor of 8 to 9 (extrapolated from data in figure) over its nominal rating at standard conditions. Figure 4 shows an image of the particle flow taken with the laser light sheet imaging system. The image shows a large concentration of particles headed towards the face of the filter (to the right of this image). Finally, Fig. 5 is a velocity histogram of the particle flow obtained with a Laser Doppler Anemometry system. It shows a distribution of particle velocities centered around 0.25 m/s, which is close to the expected center velocity of the flow loop (assuming a parabolic velocity profile). Note that velocities are negative due to the orientation of the probe head as it was mounted on the flow loop.

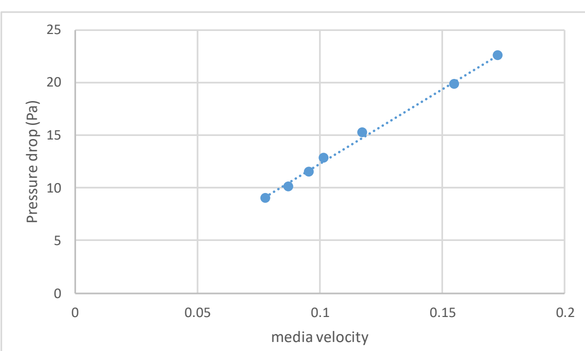

Figure 3: Flow rate vs pressure drop for high efficiency filter media

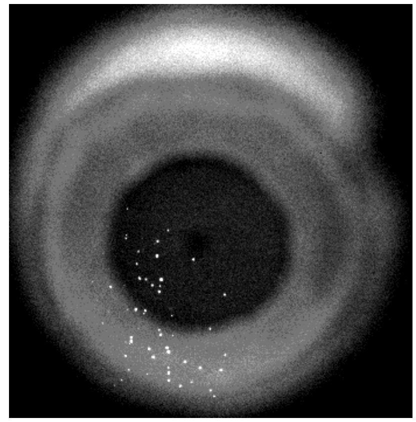

Figure 4: Image snapshot of the particle flow taken with the light sheet imaging system.

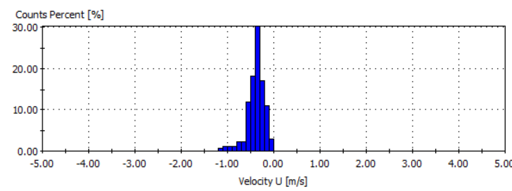

Figure 5:Velocity histogram taken with the Laser Doppler Anemometer system (sampled at 50 Torr to capture larger particle concentrations).

References:

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