#2410: TESTING THE MARS 2020 OXYGEN IN-SITU RESOURCE UTILIZATION EXPERIMENT (MOXIE) HEPA FILTER AND SCROLL PUMP IN SIMULATED MARS CONDITIONS

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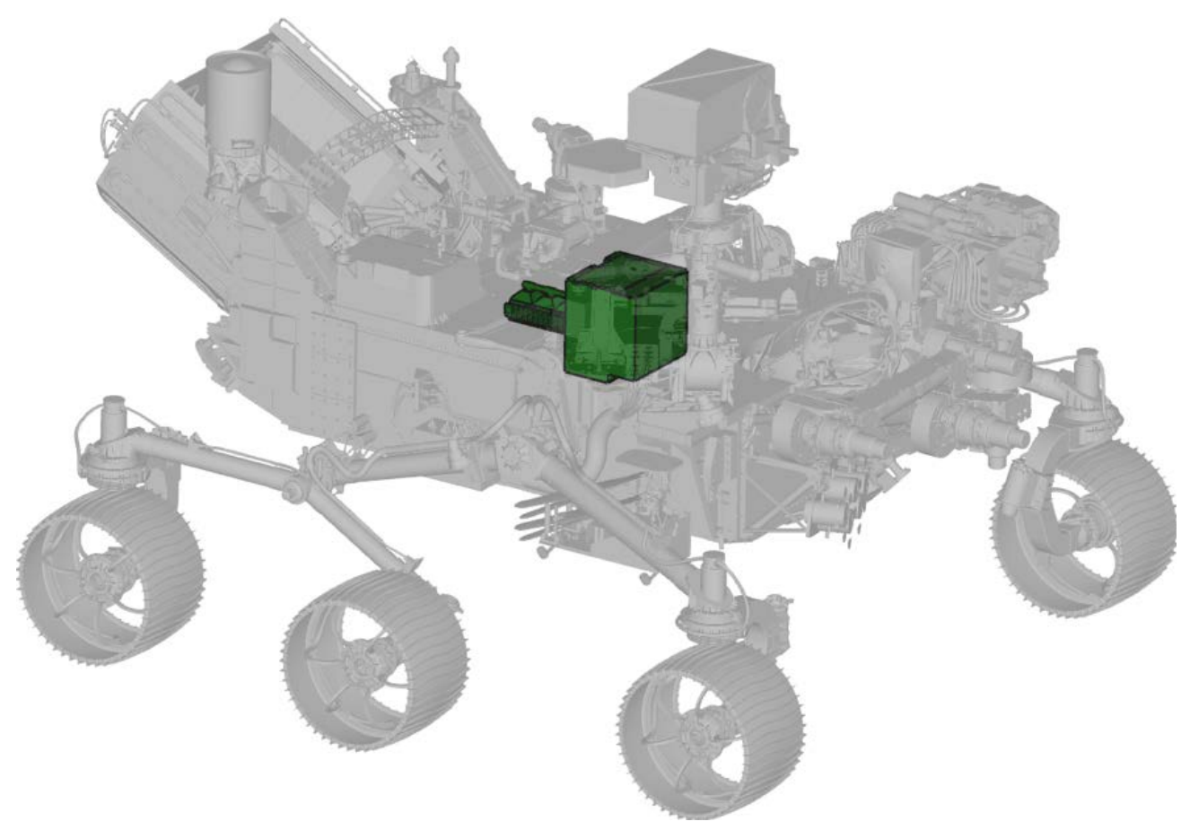
INTRODUCTION

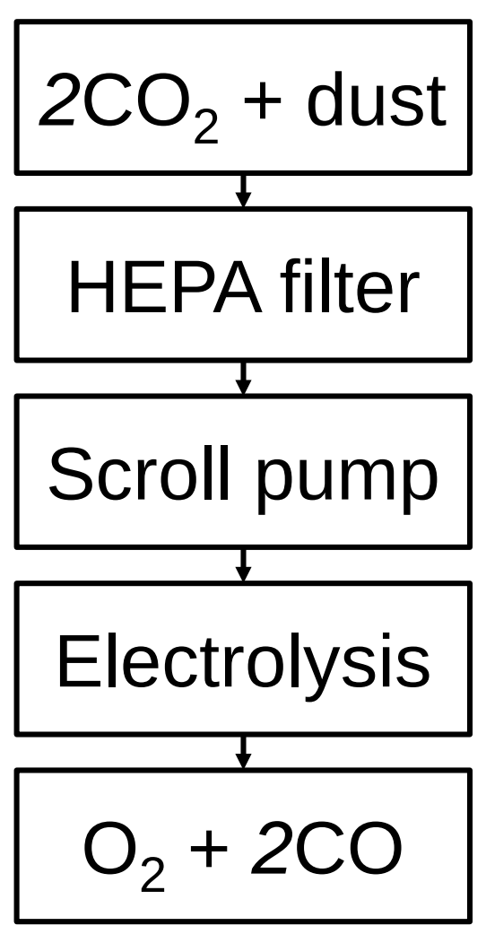
MOXIE is Mars 2020's in-situ resource utilization technology demonstrator (Fig. 1). Its goal is to electrolyze atmospheric CO_2, producing O_2 [1].

FIGURE 1



MOXIE's location in the Mars 2020 rover (image NASA/JPL-Caltech)

FIGURE 2



Block diagram of MOXIE [1]. The HEPA filter creates a pressure drop.

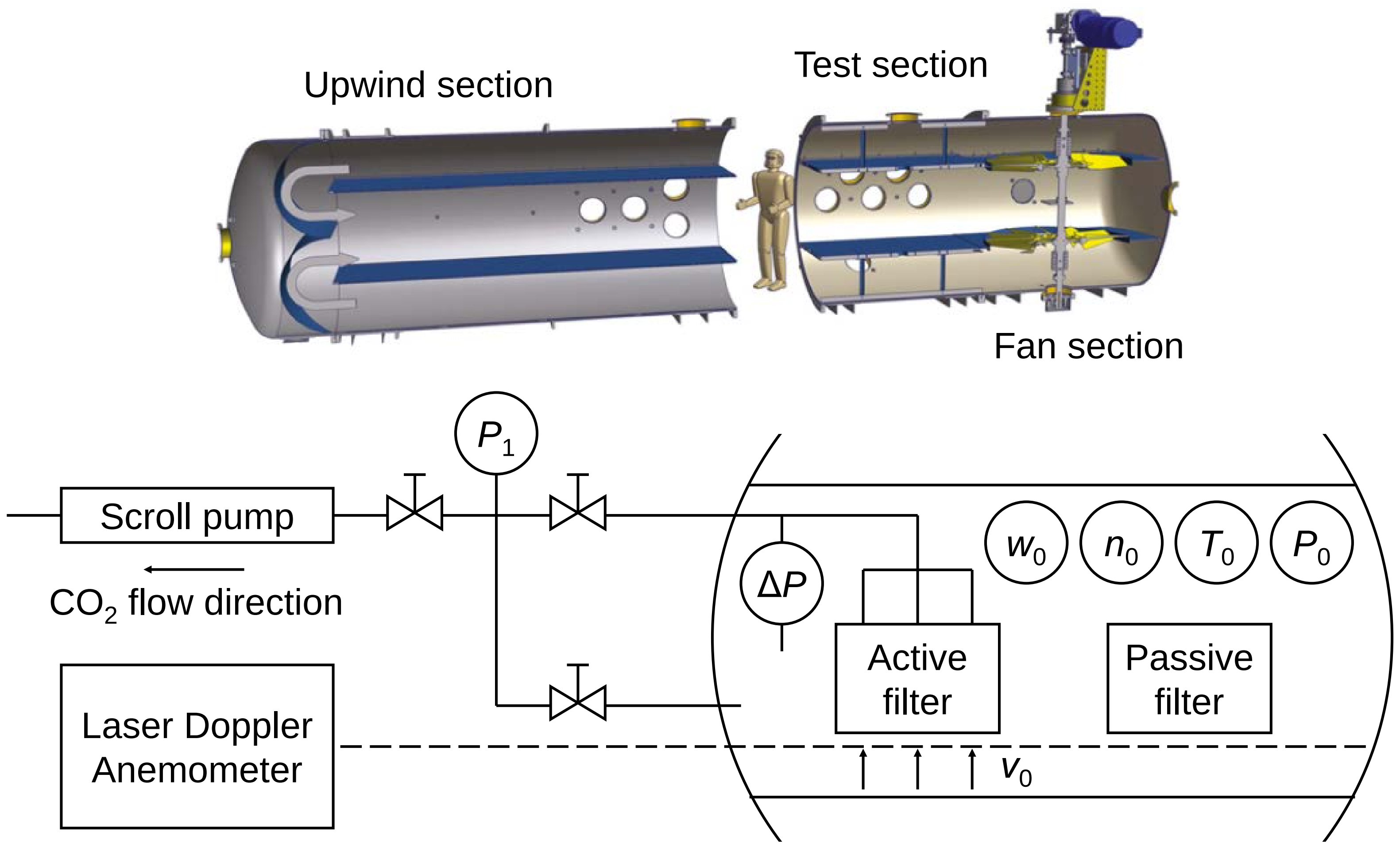
One of the risks to MOXIE is the dust in the Martian atmosphere. To protect MOXIE from dust, a High Efficiency Particulate Arrestance (HEPA) filter is fitted at the inlet (Fig. 2). However, as the filter accumulates dust, the pressure drop across the filter will increase. If the pressure drop becomes large enough, there is a risk that the CO_2 compressor (a scroll pump) will not be able to deliver the required 1 atm outlet pressure for electrolysis [2].

Although HEPA filters have been widely studied on Earth (e.g. [3]), their performance under Martian conditions is less well known. We investigated the effect of dust loading, filtration velocity, and ambient pressure on the filter's pressure drop.

EQUIPMENT

Hardware consisted of a rig to emulate the MOXIE HEPA filter and scroll pump, with ambient Mars conditions provided by the Aarhus Wind Tunnel Simulator II in the Mars Simulation Laboratory at the University of Aarhus, Denmark (Fig. 3) [4].

FIGURE 3



(Top) 3D rendering of the wind tunnel [4]. (Bottom) Schematic of the experimental set-up. For definitions of symbols, see the table below.

PROCEDURE

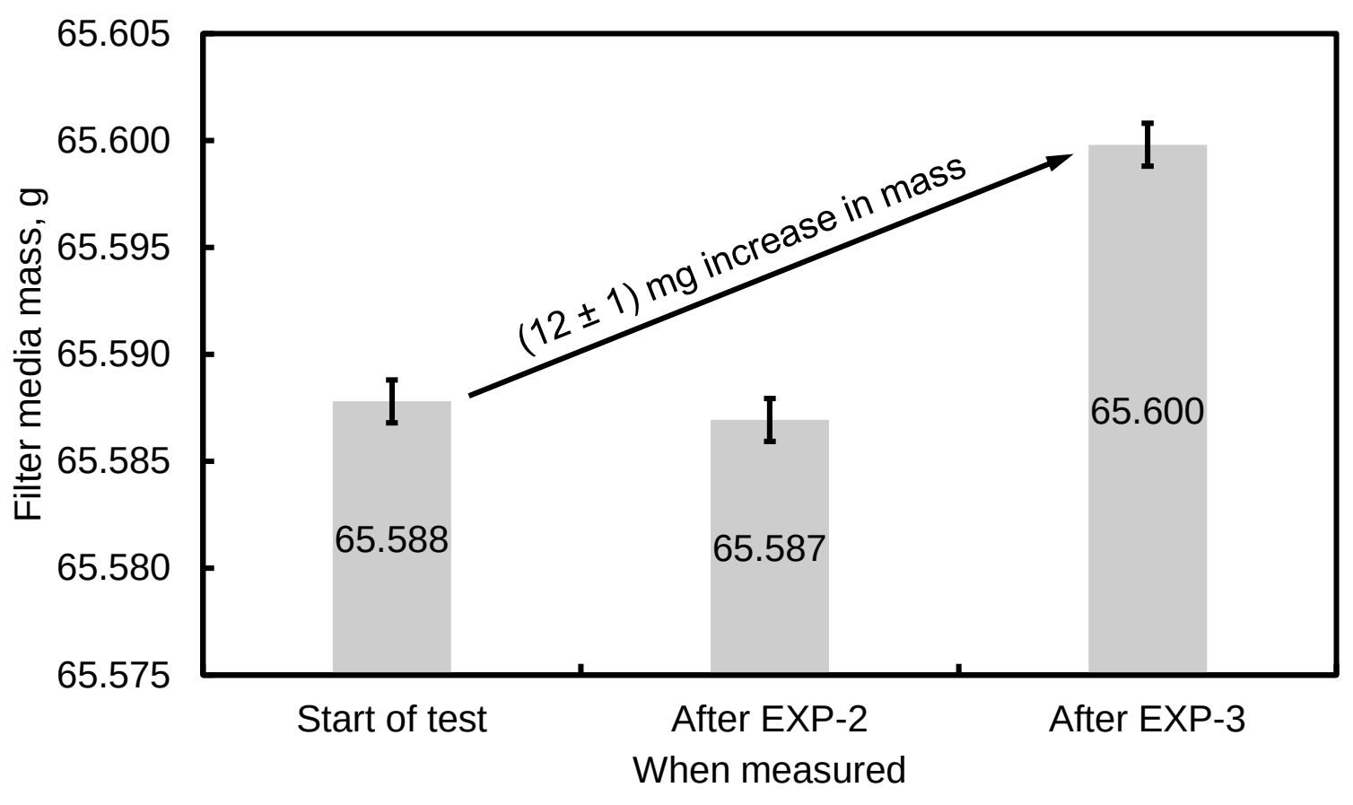
The wind tunnel was evacuated and backfilled with CO_2 to a target pressure, P_0. The fan was set to provide a wind speed w_0 and dust simulant, Salten Skov I [5], injected. The scroll pump speed N_P was set to its maximum, and the filter pressure drop ΔP and inlet face velocity v_0 recorded for one hour. Three one-hour runs were carried out at target average dust particle number densities n_0 of 40, 400, and 800 cm^{-3}.

Parameter	Actual (Mars, typical)	Simulated (wind tunnel)		
Pressure, P_0	6.0 mbar	10.3 mbar		
Temperature, T_0	220 K	293 K		
Wind speed, w_0	0 – 10 m s^{-1}	3 m s^{-1}		
Filter inlet face velocity, v_0	0 – 5 cm s^{-1} (MOXIE)	0 – 3 cm s^{-1}		
Dust number density, n_0	4 cm^{-3}	40 cm^{-3}	400 cm^{-3}	800 cm^{-3}
Duration	30 hr (MOXIE)	1 hr	1 hr	1 hr

RESULTS

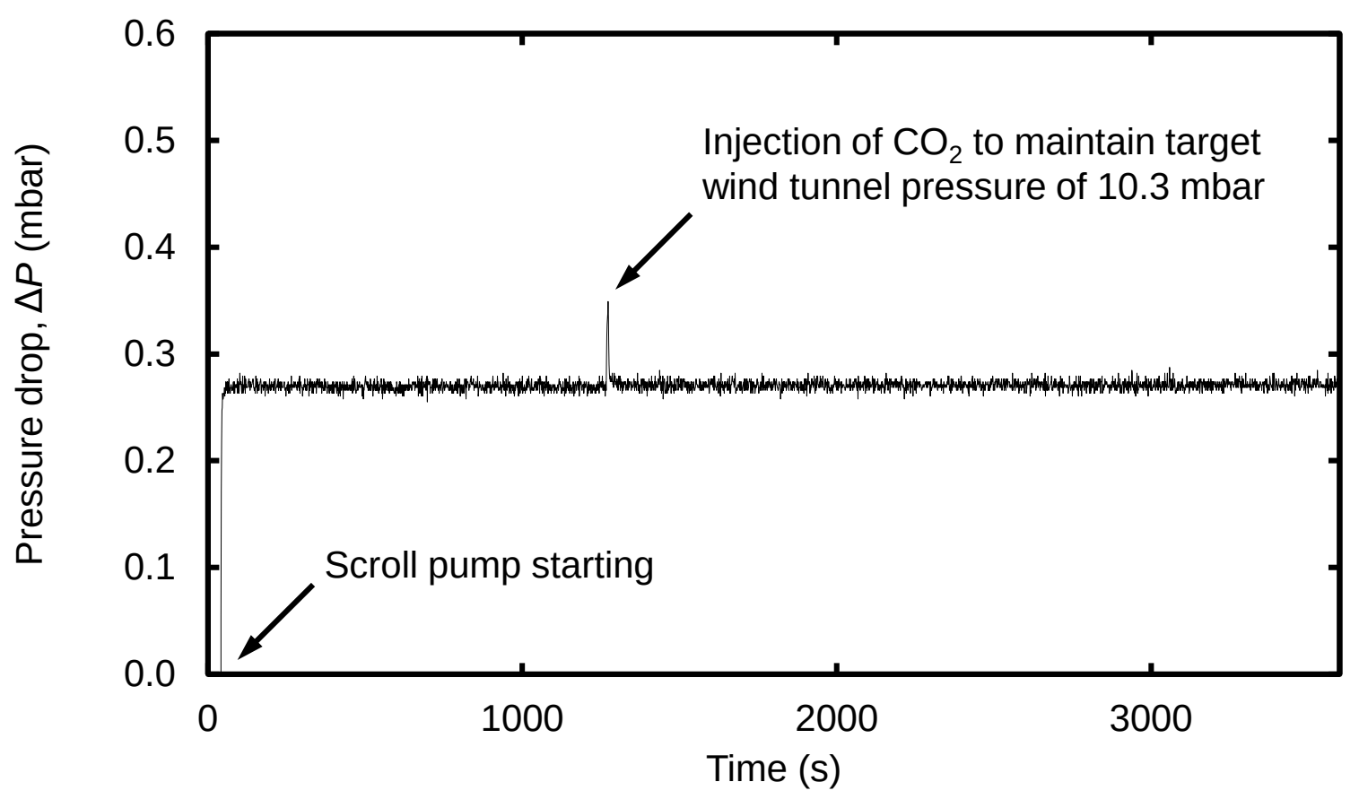
After all three dust exposure runs, the filter had increased in mass by (12 ± 1) mg (Fig. 4). At this level of dust loading – (0.03 ± 0.002) g per m^2 of filter media area – minimal pressure drop was expected, and none was observed (Fig. 5).

FIGURE 4



Filter mass vs. when measured

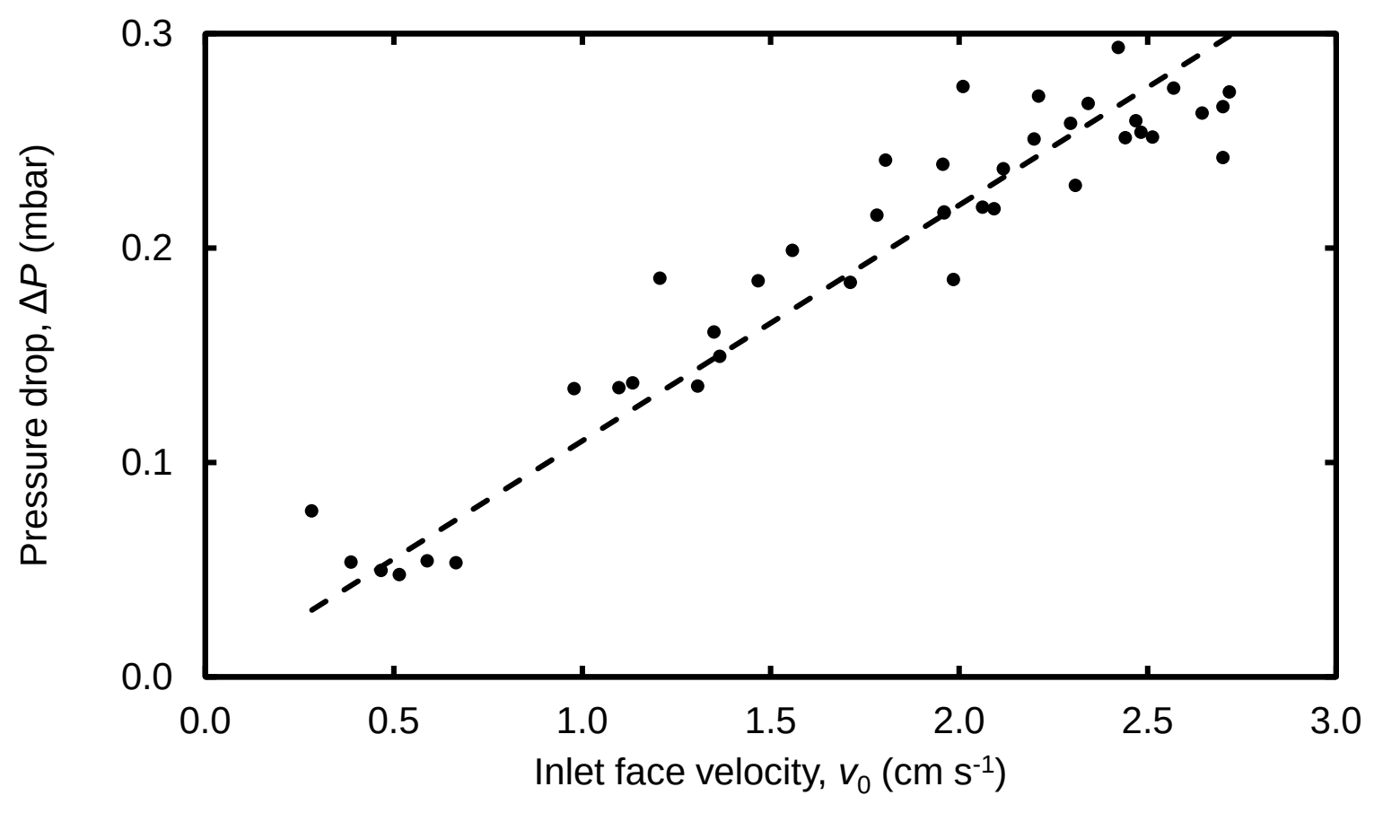
FIGURE 5



Pressure drop across filter, ΔP vs. time

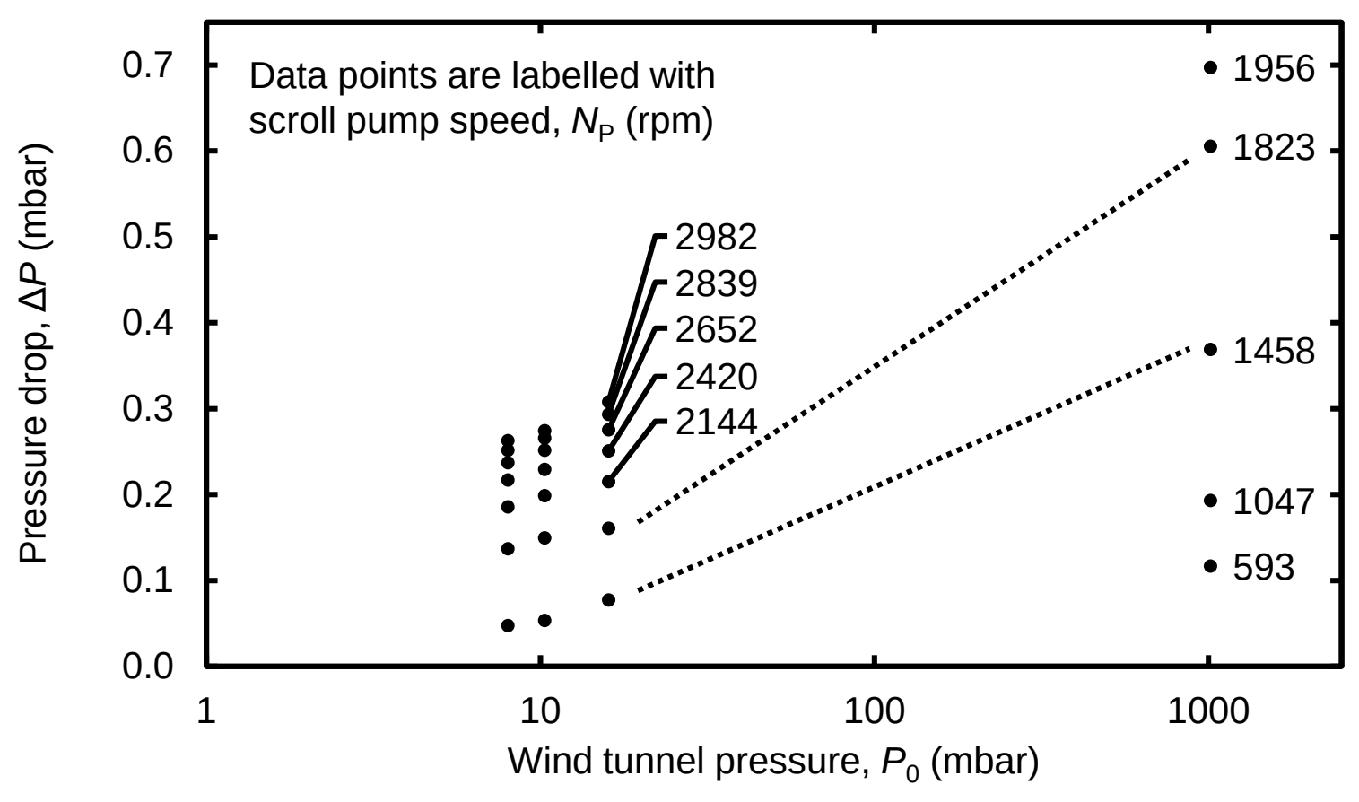
The pressure drop across the filter was found to be linear with inlet face velocity (Fig. 6), confirming the relationship found at 1 atm in air [3]. The pressure drop across the filter increased with ambient pressure (Fig. 7).

FIGURE 6



Pressure drop across filter, ΔP
vs. inlet face velocity, v_0

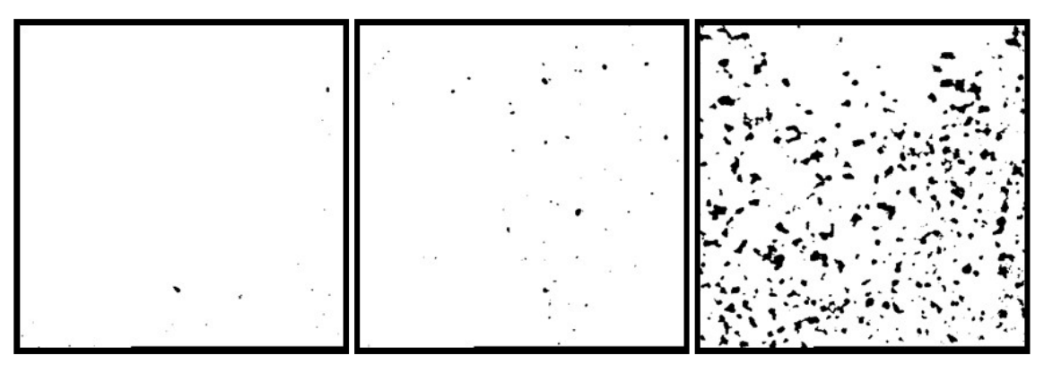
FIGURE 7



Pressure drop across filter, ΔP
vs. wind tunnel pressure, P_0

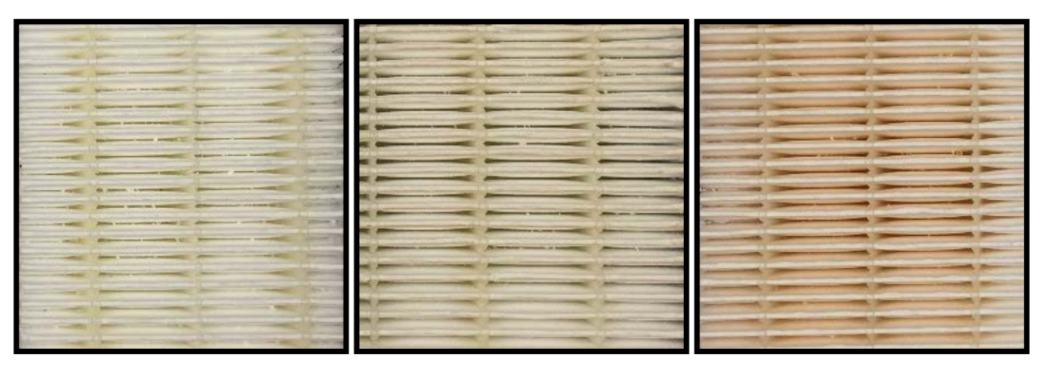
Although dust didn't cause a measurable increase in the filter pressure drop, it did lead to a difference in color between the clean, passive and active filters (Fig. 9).

FIGURE 8



Processed microscope images of filter material with dust loadings of approx. 0, 0.015, and 5.7 g m^{-2} (L-R).

FIGURE 9



Photographs of filters with dust loadings of approx. 0, 0.015, and 0.03 g m^{-2} (L-R).

DISCUSSION

A dust dose equivalent to 310 hours of exposure to a dust particle number density of 4 cm^{-3} produced a filter dust loading of (0.03 ± 0.002) g m^{-2}. This is a low loading: no increase in filter pressure drop, nor decrease in filter inlet face velocity, was seen. However, filter color is a sensitive indicator of dust loading. The main limitations of this work are poor knowledge of the particle size distribution ingested by the filter, some lack of flight hardware representativeness, and its relatively short duration.

CONCLUSIONS

Suspended dust at typical background levels is unlikely to produce a problematic filter pressure drop during the operational lifetime of MOXIE (30 hours), with margin to 300 hours. However, 30 hours is a small fraction of the total mission, during which the filter will be continuously exposed to the environment. Therefore, long-duration testing is needed to study dust ingestion from landing, winds, dust devils and storms.

ACKNOWLEDGEMENTS AND REFERENCES

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