Flame Propagation Test for Space Bound Materials

Sponsor: Dr. Fletcher Miller
Advisor: Dr. Alexander Lehman

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Problem Statement:

Dr. Fletcher Miller lacks a test chamber that can run NASA's Standard 6001B Test 1 to compare with his current line of tests. NASA's Standard 6001B Test 1 burns material samples to determine if they are fit to be used in space. The current NASA test lacks the ability to gather additional data that Dr. Miller wishes to have from the burning of the sample. Instead the original experiment simply passed or failed each specimen based on if it stopped burning before reaching 6 inches.

Overview:

NASA's Standard 6001B Test 1 determines if different types of materials are safe for space travel based on their ability to self extinguish when ignited. If the flame burns past 6 inches up on a 2.5x12 inch specimen the material fails the test. The material also fails the test if it ignites a piece of paper 7 inches below the burning sample through falling debris. The standard test is run in simulated environments consisting of an oxygen nitrogen gas mixture containing around 34% oxygen, while our setup will allow for for variation in this percentage. We have created a testing rig made from two vacuum chambers that were donated to our team by NASA. The two chambers stack on top of one another and house many other sub assemblies required to meet the test requirements. In all the bottom chamber contains two air inlet assemblies, a wire feed through panel, and a window. In order to get the additional data that Dr. Miller desires, the test rig is outfitted with the following data acquisition sensors: a load cell, a pressure sensor, thermocouple, thermistors, a thermopile radiometer, and a camera. We also created a MATLAB GUI to aid in running tests.

Meet the Team

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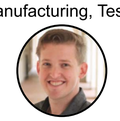
Control Systems, Design, Manufacturing, Testing

David Fredriksson
Design, Manufacturing, Testing

Brandon Huffman
Fluid Flow Analysis, Design, Manufacturing, Testing



Alexander Poirier
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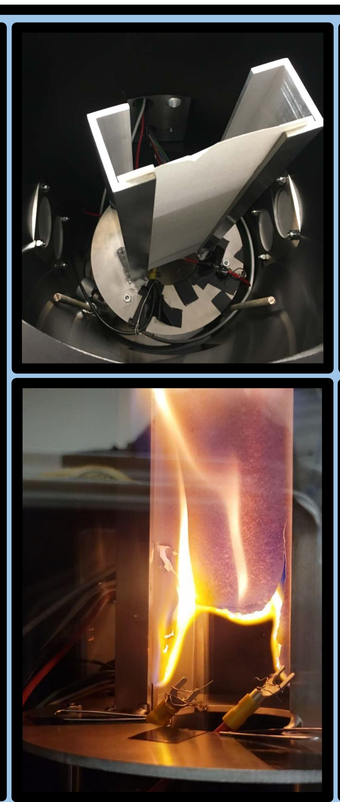
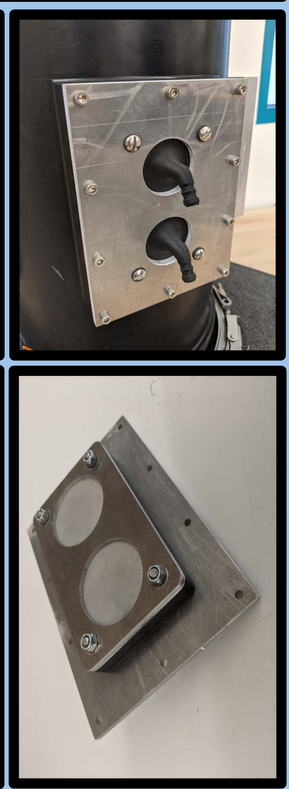
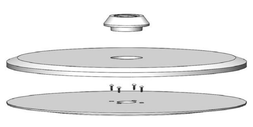




Lid Assembly:

The lid assembly is fastened to the vacuum chamber via v-clamp. To maintain a vacuum of 0.1 torr, o-rings and a welded adapter are implemented. In order to guide the smoke to the outlet hose, a stainless steel sheet metal dome acts as a 10 to 1 inch flow reducer. The assembly also includes a silicone gasket around the edge of the bowl reducer to make sure that air flow cannot move past the reducers and get stuck in between it and the lid.

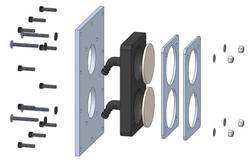


Sample Holder:

The sample holder is required to hold a 2.5 x 12 inch sample of testing material seven inches above a piece of paper. If when burning, the sample material transfers burning debris to the paper and ignites the paper the sample is deemed unsafe for use in space.This sample holder features a circular base with an opening for debris to drop if necessary, spring loaded clamps to hold samples in place, and threaded legs to allow for variability in height.

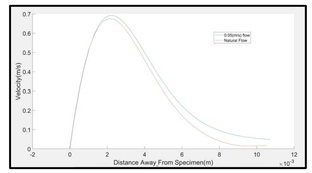
Air Inlets:

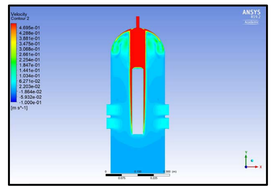
The air inlets are used to force small particulates and smoke out of the chamber in order to create an unobstructed view to the chamber for both viewing and filming. There is an inlet assembly on 2 opposites sides of the chamber and each consists of a 3D printed barbed inlet, aluminum frames that house 2 discs of porous stainless steel, an aluminum plate that allows for attachment to the vacuum chamber and fasteners. The porous stainless steel disc serve the purpose of diffusing the air to make the fluid flow uniform. The whole assembly is sealed to avoid any air leaks using RTV Silicone, rubber washers, and an o-ring housed in the vacuum chamber opening.

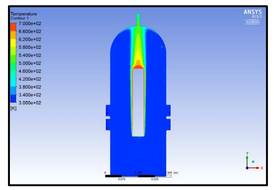


Fluid Flow Analysis:

The compact size of the chamber may cause the smoke that originates from the burning specimen to build up and suffocate the flame making it difficult to videotape. Improving and visualizing the removal efficiency of the smoke is a necessity. The inlet must help remove the smoke without blowing too quickly over the specimen. ANSYS Fluent was used to create a CFD model of the smoke removal process. The smoke produced by the specimen was simulated by setting its walls to a flow velocity of 0.05 m/s and a temperature to 700k. The maximum air inlet speed was set to 0.05 m/s because that was the maximum velocity before affecting the flow over the specimen. The final analysis validates that some type of dome or cone reducer to help build up pressure and remove the smoke was needed. It also validated that an extra chamber is required, because the smoke accumulated to a constant volume near the top of the dome. Later, different types of gas were simulated to determine the concentration of smoke. Since the simulation reached steady state without having smoke accumulate around the specimen the current configuration should perform well.

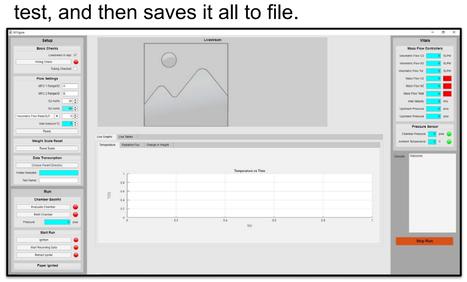






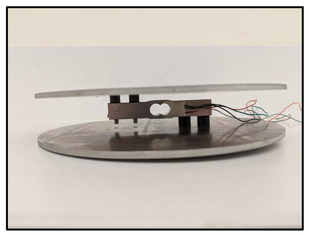
GUI

A MATLAB GUI was made to aid in running tests. It initiates and reads all the sensors, livestreams data and a video recording from the test, and then saves it all to file.



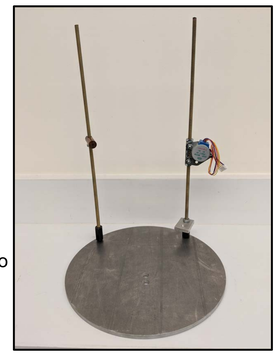
Scale Assembly:

To measure the change in weight of the burning sample a load cell was used to make a scale. The moment caused by weight being applied to the top plate causes a change in the resistance of the load cell. This signal is then converted to get accurate readings of the change in weight.



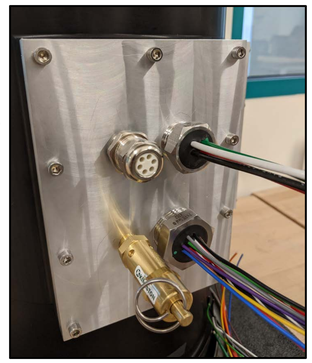
Base Plate Assembly:

A bottom plate was machined to hold two threaded rods, one holding the ignition system and the pressure sensor, and the other holding the radiometer. The ignition system ignites the sample with ignition wire, which is removed from the sample with a stepper motor once the sample is ignited. The holder for the pressure sensor is also mounted to this rod.
On the other rod is the holder for the radiometer. A sleeve for the radiometer had to be made to restrict its field of view and allow it to more accurately record more radiative samples without damaging the sensor.



Wire Feed Through Panel:

Since the chamber houses various sensors and electronics on the inside, wire feed throughs are required to pass wires into the chamber while being able to maintain a vacuum. There are two feed throughs dedicated to wires for sensors and electronics, along with one feed through for thermocouple wires. A fourth port is included on the feed through panel to house a pressure relief valve in case of an exhaust malfunction that may cause unsafe pressure build up in the chamber. All of the fittings are NPT threaded and installed into the aluminum feed through panel with teflon tape on the threads.



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