Presenter:

Ralph Clayton, CFPS, PMSFPE

Nitrogen INERT and Nitrogen based Magnesium Oxide Classes A, B & D Glovebox Fire Suppression System (FSS) Research, Development and Proof of Concept Testing

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Nitrogen INERT and Nitrogen based Magnesium Oxide Classes A, B & D Glovebox Fire Suppression System (FSS) Research, Development and Proof of Concept Testing

Authors: Frank Broidy, Ralph Clayton and Brandon Troc

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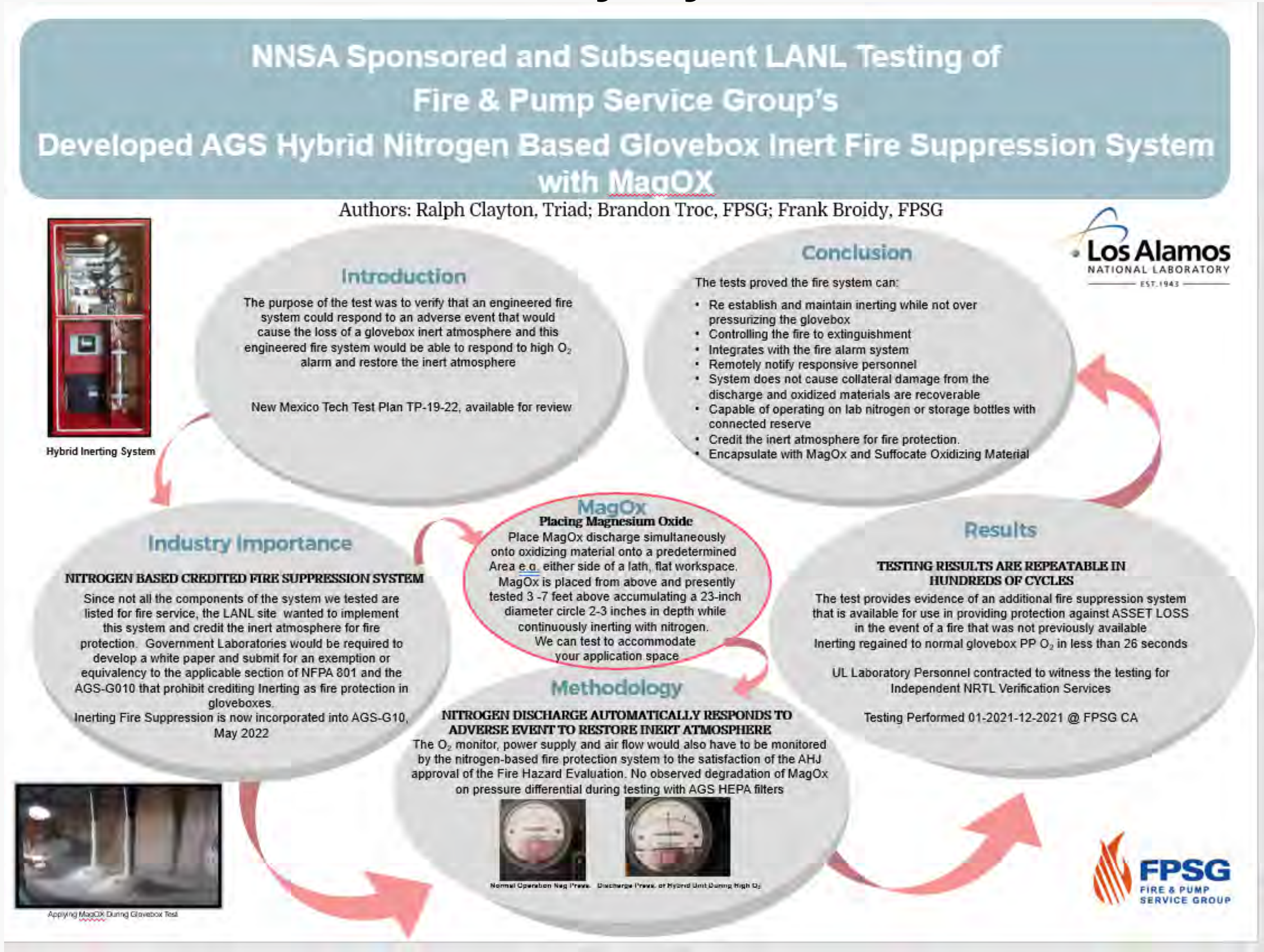
Vortex Fire Extinguishing System

- https://www.youtube.com/watch?v=JVfXnNBhL_w

Nitrogen Inerting System Combined with MagOx Delivery System



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Inert GB Fire Suppression System Testing

Underwriter's Laboratory's (UL) auditor, Michelle Sluga observed the 2020 Fire and Pump Service Group nitrogen-based fire extinguishing system (FES) testing and documented that the FPSG nitrogen based FES sufficiently controlled Class A and B fires in U.L. File NC28671, Project 3789005583, dated August 7, 2019.

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Inert System Testing

Heptane & Acetone-soaked Wipes UL Test 2127

August 30, 2019

FIRE AND PUMP SERVICE GROUP
Mr. Frank Broidy
1512 KONA DRIVE
RANCHO DOMINGUEZ, CA 90220

Reference: File NC28671 **Project :** 4789005583

Subject: Verification Services – Technical Report – Fire Suppression Systems For Use In Glovebox Applications per New Mexico Tech Test Plan, TP-19-22

Dear Mr. Broidy,

We have completed our work under the above project and this letter will serve as a letter report of our findings.

The attached report described a Verification Services Investigation conducted for Fire & Pump Service Group. The testing was to verify the proof of concept of the performance of fire suppression systems which are designed to extinguishing fires within a glovebox currently in use at Los Alamos National Lab (LANL).

The testing and report of resulting data was as specified in New Mexico Tech Test Plan TP-19-22, dated May 22, 2019. No conclusions have been made from the data obtained. The information obtained by this investigation is being submitted to the Fire & Pump Service Group for their use.

The attached report was prepared as an account of work sponsored by Fire & Pump Service Group. In no event shall UL LLC be responsible to anyone for whatever use or non-use is made of the information contained in this Report and in no event shall UL LLC, its agents, incur any obligation or liability for damages, including, but not limited to consequential damages arising out of or in connection with the use of, or inability to use, the information contained in this Report.

The Classification Marking of UL LLC on the product is the only method provided by UL LLC to identify products which have been produced under its Classification and Follow-Up Service. No use of a Classification Marking has been authorized as a result of this investigation.

This completes the work anticipated under Project 4789005583. We are closing the project with this letter.

Your business is very important to us and if there is any additional information that we may provide to you about the investigation or UL's other services, please do not hesitate to contact us.

Sincerely,

Michelle Sluga
Staff Engineer
Department: 3019BFPD
E-mail: Michelle.Sluga@ul.com

Reviewed by:

Kevin Holly Jr.
Staff Engineer
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Extinguishment of Classes A,B & D Fires within Gloveboxes

Fire and Pump Service Group (FPSG) engineering personnel preformed research and development activities, then manufactured, constructed and tested a “Proof of Concept” Nitrogen/Magnesium Oxide (N/MgO) sand, suffocation fire suppression system (FSS) prototype. This effort occurred at the FPSG Rancho Dominguez, California facility.

The principal N/MgO FSS Engineering Team consisted of Frank Broidy, President FPSG, Brandon Troc, VP FPSG, Ralph Clayton, CFPS, PMSFPE and Joseph Mirabal, FPSG, engineer in training.

The FPSG engineering team researched different means of using inert gases (nitrogen), pneumatic pressures and gravity to deliver MgO sand into and throughout a glovebox, while also considering GB operations related criteria, discussed later.

A conceptual delivery system was agreed upon, a prototype was manufactured and tested.

A final delivery system was developed and tested using a mock GB that could maintain the inert atmosphere provided during the discharge of the nitrogen gas throughout the GB and the MgO sand over a pre-engineered coverage area.

MgO sand is documented as an effective fire suppressant in plutonium and uranium metal fires (R.E Felt. 1967). There is currently no FSS that will automatically deliver MgO sand as a fire suppressant. FSSET members researched different methods of delivery, designed, and constructed prototype models, and tested the prototype Nitrogen/MgO based FSS. Testing focused on defining and evaluating the MgO sand effective coverage area to a minimum depth of one inch (R.E Felt. 1967) and reestablishing and maintaining the inert atmosphere within the mock GB during and after the MgO sand discharge.

A primary concern was the anti-clumping additive in the MgO sand dusting up and plugging the GB ventilation exhaust HEPA filter, resulting in a loss of GB airflow and thus inability to maintain a negative atmosphere. To evaluate potential changes in airflow magnehelic pressure gauges were installed up and down stream of the HEPA filter. Minimal difference in airflow was observed after numerous MgO discharges were conducted utilizing the same HEPA filter indicated that the anti-clogging agent releases is not sufficient to noticeably obstruct air flow through the 8” Flanders HEPA filter in use during the all the discharge tests.

Another primary consideration was ensuring continued GB containment during MgO sand discharge. A double check valved nitrogen line provides positive pressure and inerting during discharge, but also prevents contamination backflow into the hopper body. The stainless-steel hopper body also acts as a contamination barrier during a discharge event. Certain solutions that will need to be considered in concert with the client’s needs i.e further containment barrier solutions.

Codes and standards considered:

- NFPA 484 – Standard for Combustible Metals, 2019 Edition
- NFPA 770 – Standard on Hybrid (Water and Inert Gas) Fire Extinguishing Systems, 2021 Edition
- NFPA 2001 – Standard on Clean Agent Fire Extinguishing Systems, 2018 Edition

Other prototype FSS design considerations also included the following:

- Seismic moment,
- space above/around glovebox,
- glovebox design/operation,
- preventing clumping of MgO sand while in the hopper,
- helium leak testing of the system,
- maintaining the glovebox barrier throughout the discharge,
- maintaining inert atmosphere during MgO sand discharge,
- ensuring an even and predictable dispersal of MgO sand over the target area, and
- reliability, availability, maintainability, and inspect ability (RAMI).

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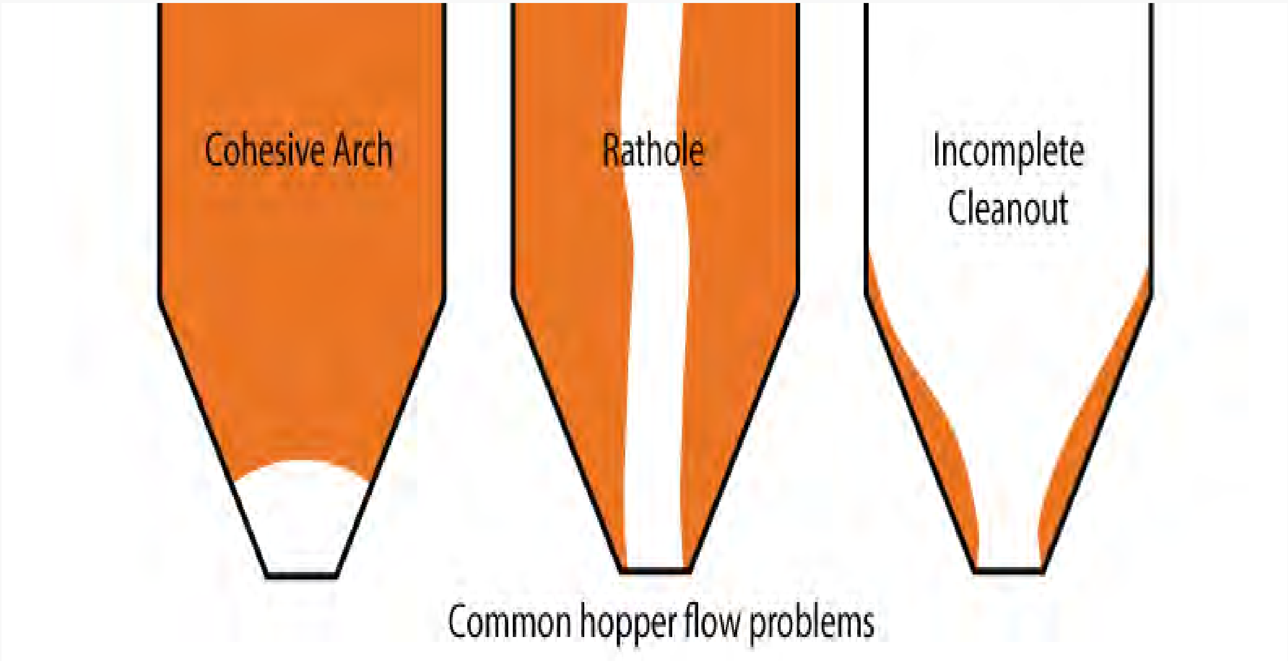

The FSSET assessed the condition of the MgO sand relative to being staged in the hopper over time. Sand materials are known to settle or increase in density while in storage. This can lead to ratholing, arching, bridging, and clinging. This condition was evaluated in Phase Two.

The FSSET also researched multiple methods of applying the MgO sand to the affected area of the glove box:

- Specially designed discharge nozzles,
- Heat seeking robotic arm, to respond to flare up
- Jet Venturi Ejectors,
- Flexible discharge hose, A slinky like hose allowing personnel to control the MgO sand discharge and direct by hand.

The above potential applications were explored but were determined to cost prohibitive and presented other design and performance drawbacks such as GB over-pressurization. The final design utilizes a commercially available stainless-steel hopper for “Proof of Concept” that contains the MgO sand installed outside the glovebox and a source of nitrogen. The FSS operates control valves that disperse MgO sand and nitrogen through stainless steel piping onto the coverage area and into the glovebox atmosphere.

Test Plans

Testing included several phases that occurred concurrent with the FSSET's design process.

- **Testing Phase 1** revolved around observing how MgO sand accumulates when dropped from various heights and in varying amounts, (exterior to an GB enclosure). This was an exploratory test using cups to pour the MgO sand and was the FSSETs first look at how the material would behave. In all phases the area of effective coverage was calculated by measuring the radius of the MgO sand pile that had a depth greater than one inch.

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- Released MgO Sand at Various Drop Heights
- In this first preliminary test MgO sand was dropped from a 600 ml cup at various heights to give the FSSET a general idea of the piling properties of the material. Testing data revealed that area of effective coverage (AoEC) formed a logarithmic line. At around 2400ml of MgO Sand the AoEC stopped growing in linear fashion with the addition of more MgO sand. This was a result of the MgO sand present on the ground dampening the impact of additional MgO sand. Testing also revealed that AoEC began to reduce from a from above four feet off the ground. Observed dusting was very minimal.

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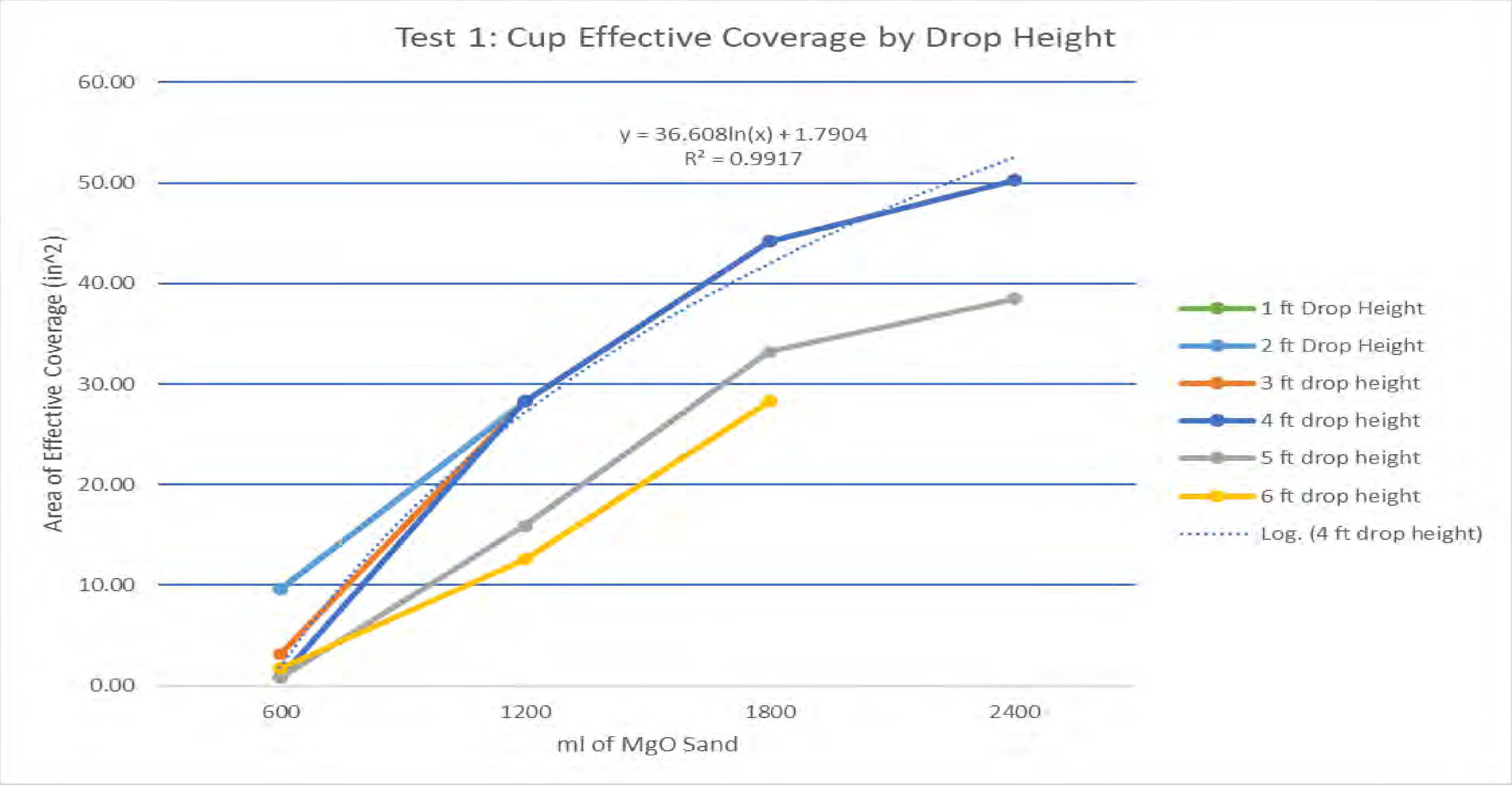
Phase 1 Results

Dropping MgO sand in 600 milliliter Increments							
Height of Drop in Feet	Milliliters of MgO	Radius of Effective Coverage in Inches	Area of Effective Coverage in Squared Inches	Height of Drop in Feet	Milliliters of MgO	Radius of Effective Coverage in Inches	Area of Effective Coverage in Squared Inches
1 ft	600	1-3/4”	9-10/16”	4 ft	600	½”	12/16”
	1200	3”	28-4/16”		1200	3”	28-4/16”
	N/A	N/A	N/A		1800	3-3/4”	44-3/16”
	N/A	N/A	N/A		2400	4”	50-4/16”
2 ft	600	1-3/4”	9-10/16”	5 ft	600	½”	12/16”
	1200	3”	28-4/16”		1200	2-1/4”	15-14/16”
	N/A	N/A	N/A		1800	3-1/4”	33-3/16
	N/A	N/A	N/A		2400	3-1/2”	38-7/16
3 ft	600	1”	3-2/16”	6 ft	600	¾”	1-12/16”
	1200	3”	28-4/16”		1200	2”	12-13/16”
	1800	3-3/4”	44-3/16”		1800	3”	28-4/16”
	2400	4”	50-4/16”		2400	4-1/2”	N/A

Phase 1 Results



Test Plan Phase 2

- Phase 2 testing focused on the flow and area of coverage characteristics of MgO sand while being discharged by our hopper. MgO Sand was dropped at predetermined amounts and heights to create sufficient data points to allow the engineering team to interpolate an Area of Effective Coverage (AoEC) at a specified glovebox height. Important to phase two was looking out for any of the potential common hopper flow problems during testing and simulating the material settling that takes place over time. To simulate settling the hopper was struck by the mallet 100 times prior to discharge. At 100 mallet taps the MgO sand in the hopper had leveled out and reduced in height by a quarter of an inch. Additional tapping did not settle the MgO sand Further therefore 100 hammer taps was deemed sufficient to relive the gas pressure between the compacted sand granules simulating the settlement that will occur over time (T. Anthony Royal and Dr. John W. Carson. 1991).

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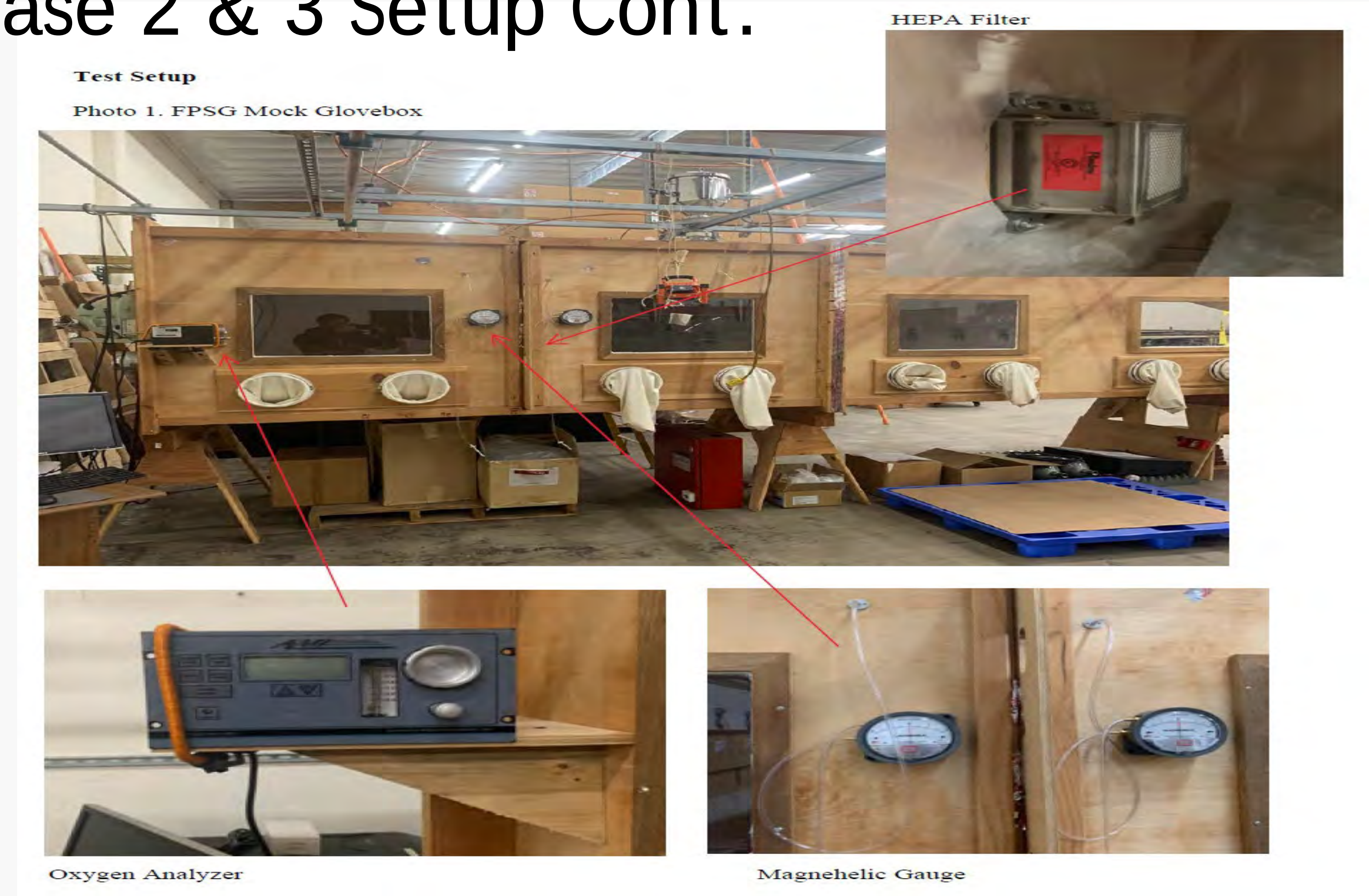
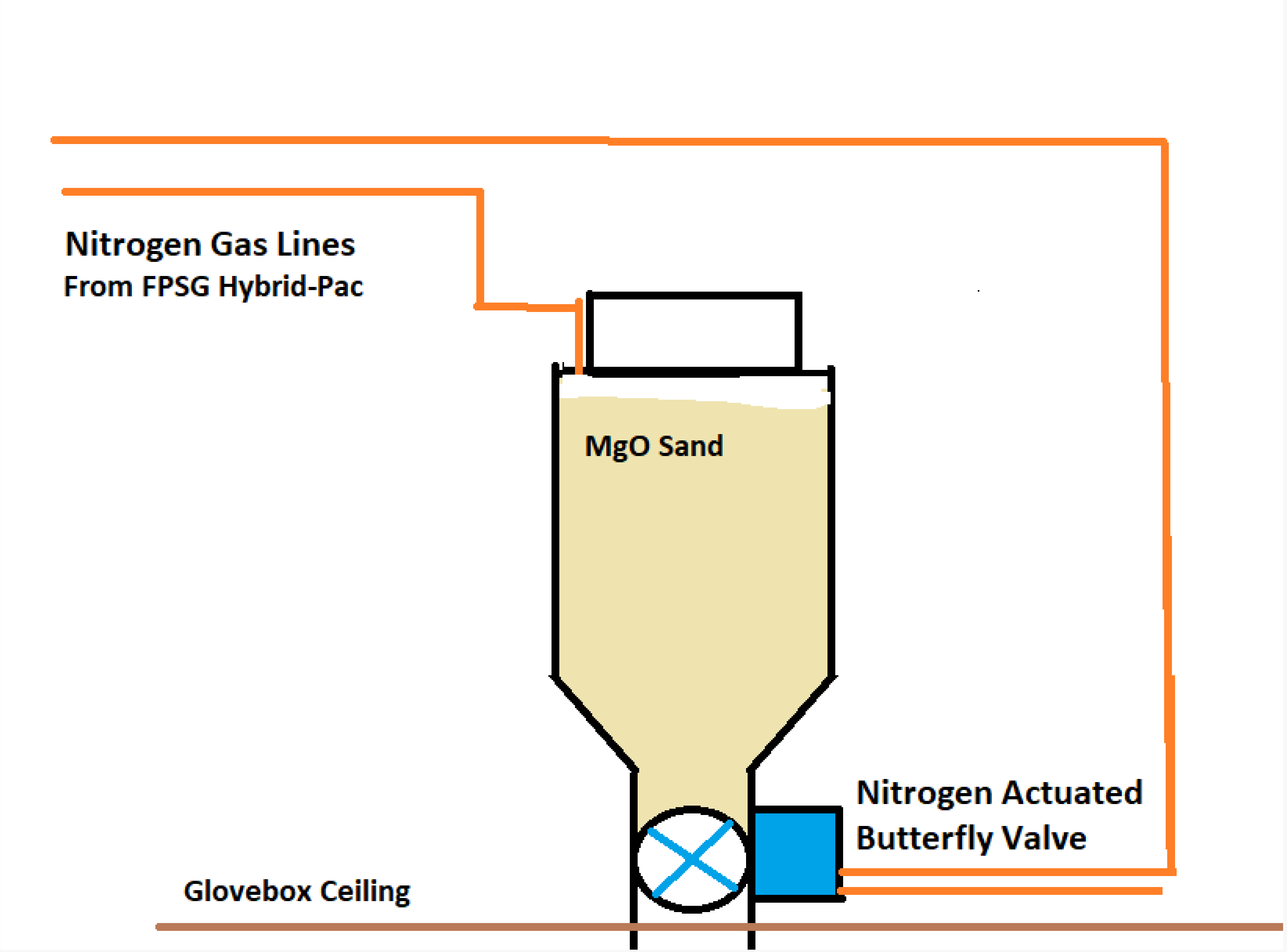
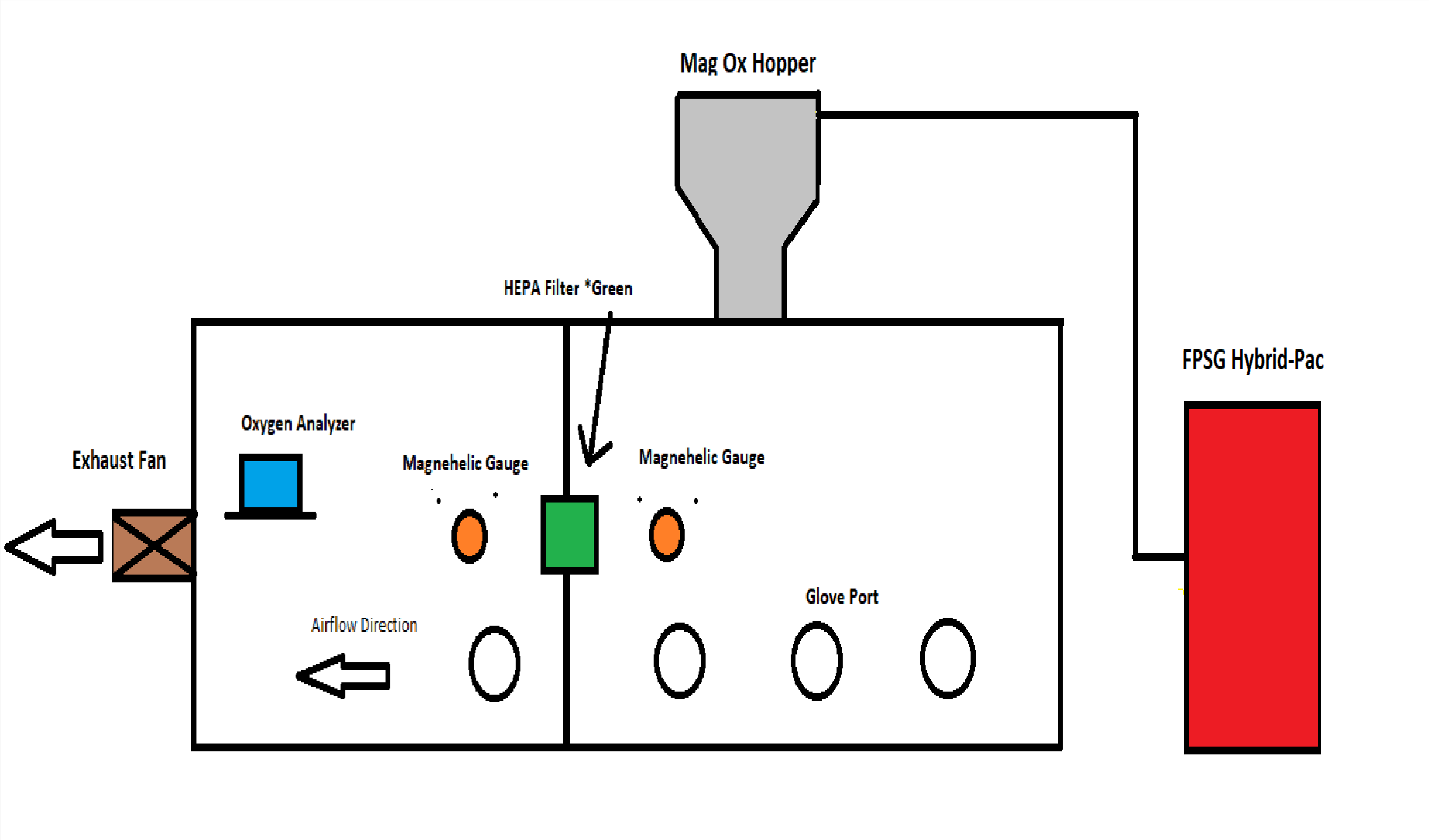
Phase 2 & 3 Setup Cont.



O_2 Sensor, Gauges and Filters Same as Used at LANL; all were Calibrated


Nitrogen Gas Lines
From FPSG Hybrid-Pac
MgO Sand
Nitrogen Actuated
Butterfly Valve
Glovebox Ceiling

Phase 2 & 3 Setup, Cont.



Phase 2 Discharge Through Hopper

MgO Sand was placed inside the hopper and mechanically settled by tapping the hopper wall 100 times with a rubber mallet.

- MgO sand settling resulting from hammer taps dropped the height of the MgO sand inside the hopper by approximately ¼ inch each time.
- “Settled” MgO sand completely flowed through the hopper
- Use the hopper did not cause any observable detrimental effects to the MgO sand dispersal pattern.
- MgO sand Flowed out of a 4” diameter 4-inch-long coupling attached to the hopper.
- The area of effective coverage (AoEC) continued to increase as the hopper was raised in height; at a height above 4ft, height the AoEC began to decrease regardless the amounts of MgO sand dispersers.
- Between two and eight liters of MgO sand the AoEC trended linearly to the equation:

Example; y” = 36.05x” + 12.684”

y = Sand Depth, x = Sand pile width

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Phase 2 Cont.


Test 2: Discharge from Hopper Settled With 100 Mallet Taps
250.00
200.00
150.00
100.00
50.00
0.00
Area of Effective Coverage (in^2)
2
3
4
6
8
Liters of MgO Sand
y = 36.05x + 12.684
5 Foot Discharge Height
4 Foot Discharge Height
3 Foot Discharge Height
2 Foot Discharge Height
Linear (4 Foot Discharge Height)

Phase 2 Cont.

Hopper with Dual Coverage Areas

These tests demonstrated the tapered Y nozzle configuration attached to the hopper opening. The same configuration to be used in the simulated glove box testing. The nozzles are 16.5” apart (center to center). With the hopper diameter reducing from four inches to two inches at each nozzle.

Area of Effective Coverage Test Wye configured with Tapered Nozzles, 16.5" Center to Center Outside Glovebox				
Height to Drop	Liters of Mag Ox	Average Radius of Effective Coverage 1 (in)	Average Radius of Effective Coverage 2 (in)	Total Area of Effective Coverage (in^2)
2 ft	6.5	6-1/8”	6-1/8”	235-11/16”
	6.5	8”	8”	402-2/16”
	6.5	7-3/8”	7-1/8”	341-3/4”

Phase 2 Cont.

Area of Effective Coverage Test Settled MgO Sand 100x Mallet taps Hopper No Reducer							
Height to Drop	Liters of Mag Ox	Radius of Effective Coverage (in)	Area of Effective Coverage (in^2)	Heigh t to Drop	Liters of Mag Ox	Radius of Effective Coverage (in)	Area of Effective Coverage (in^2)
2 ft	2	3-1/2”	38”-7/16”	4ft	2	4”	50-4/16”
	3	4-1/2”	63-10/16”		3	5-1/2”	95-1/16”
	4	5”	78-7/16”		4	5-3/4”	103-14/16”
	6	7”	153-15/16”		6	7”	153-15/16”
	8	7-1/2”	176-11/16”		8	8”	201-1/16”
3 ft	2	2-1/2”	19-10/16”	5ft	2	3-1/2”	38-7/16”
	3	4-1/2”	63-10/16”		3	4-1/2”	56-3/4”
	4	5-1/2”	95-1/16”		4	5-1/2”	95-1/16”
	6	6-7/16”	130-3/16”		6	6-3/4”	146-1/8”
	8	7-1/2”	176-11/16”		8	7-3/4”	188-11/16”
4ft	2	4”	50-4/16”	N/A	N/A	N/A	N/A
	3	5-1/2”	95-1/16”		N/A	N/A	N/A
	4	5-3/4”	103-14/16”		N/A	N/A	N/A
	6	7”	153-15/16”		N/A	N/A	N/A
	8	8”	201-1/16”		N/A	N/A	N/A

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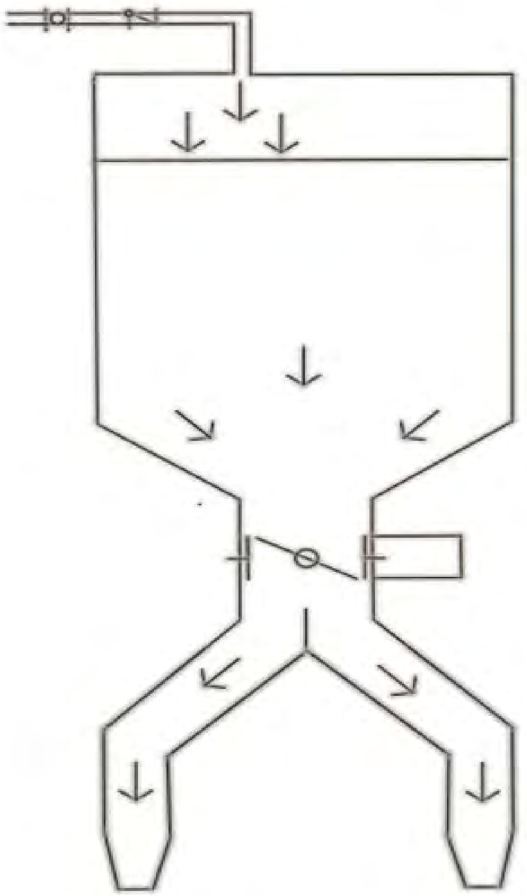
Test Plan Phase 3

Phase 3 testing focused on the “Y” shaped hopper configuration to see how different nozzle configurations effected AoEC. Phase three also included testing of the final Nitrogen/MgO sand FSS configuration within a mock GB. This phase of testing looked to determine if dusting from the FSS would impact the glovebox HEPA filter, compromising the GB negative atmosphere. Pressure differential gauges across the HEPA filter and oxygen sampling were used to determine that the FSS drove down the partial pressure of oxygen in the glovebox while maintaining a negative pressure difference across the HEPA filter.

Phase 3 Setup

Figure 3. Hopper Detail



Note: Prototype hopper was created from commercially available and sourced parts.

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Dual Coverage Hopper Test with Nitrogen flow through hopper (tested within Glovebox).

Phase 3 included a discharge with the hopper with the Y nozzle configuration was mounted on top of the mock glovebox to create a sealed environment with a negative pressure differential over the HEPA filter.

A ¼" Line was attached to the hopper lid to introduce nitrogen to the hopper to prevent backflow of contaminated gasses into the hopper as well as prevent any ratholing or arching through additional positive pressure.

This test was primarily concerned with the dusting effects on the installed HEPA filter and if a negative pressure differential could be maintained despite dusting. While some anti-clumping additive was observed, the negative pressure differential was never compromised as can be observed in the data below. It should be noted that in these tests the N2 line was placed closer to the nozzle associated with pile two, as a result that pile was constantly slightly larger than pile one. Future designs will split the introduced N2 over each nozzle. See photo two for anti-clumping additive cloud and photo four for the DeltaP observed while discharging the MgO sand.

Area of Effective Coverage Test Y configured with Tapered Nozzles, 16.5" Center to Center Inside Glovebox with 40 CFM Nitrogen Flow Through Hopper								
Height to Drop	Liters of MgO Sand	Average Radius of Effective Coverage Pile 1	Average Radius of Effective Coverage Pile 2	Area of Effective Coverage (in^2)		Pressure Before HEPA Filter (inches of H20)	Pressure Before HEPA Filter (inches of H20)	Partial Pressure of Oxygen
17-3/4"	6.5	6-3/4”	7”1/16	297-1/16”	Before Discharge	1.4”	.3”	N/A
					MgO Discharge	1.4”	.2”	N/A
					30 Seconds After Discharge	1.4”	.3”	N/A
	6.5	6-5/8”	7-1/8”	297-6/16”	Before Discharge	1.7”	.3”	N/A
					MgO Discharge	1.7”	.3”	N/A
					30 Seconds After Discharge	1.7”	.3”	N/A
	6.5	6-1/8”	6-3/8”	260-6/16”	Before Discharge	1.7”	.35”	N/A
					MgO Discharge	1.7”	.3”	N/A
					30 Seconds After Discharge	1.65”	.3”	N/A
Area of Effective Coverage Test Y configured with Tapered Nozzles, 16.5" Center to Center Inside Glovebox with 40 CFM Nitrogen Flow Through Hopper and Victaulic Emitter @30psi								
17-3/4"	6.5	7”	7”	307-7/8”	Before Discharge	1.65”	.3”	20.5%
					MgO Discharge	1.6”	.05”	19.75%
					30 Seconds After Discharge	1.65”	.3”	17.30%

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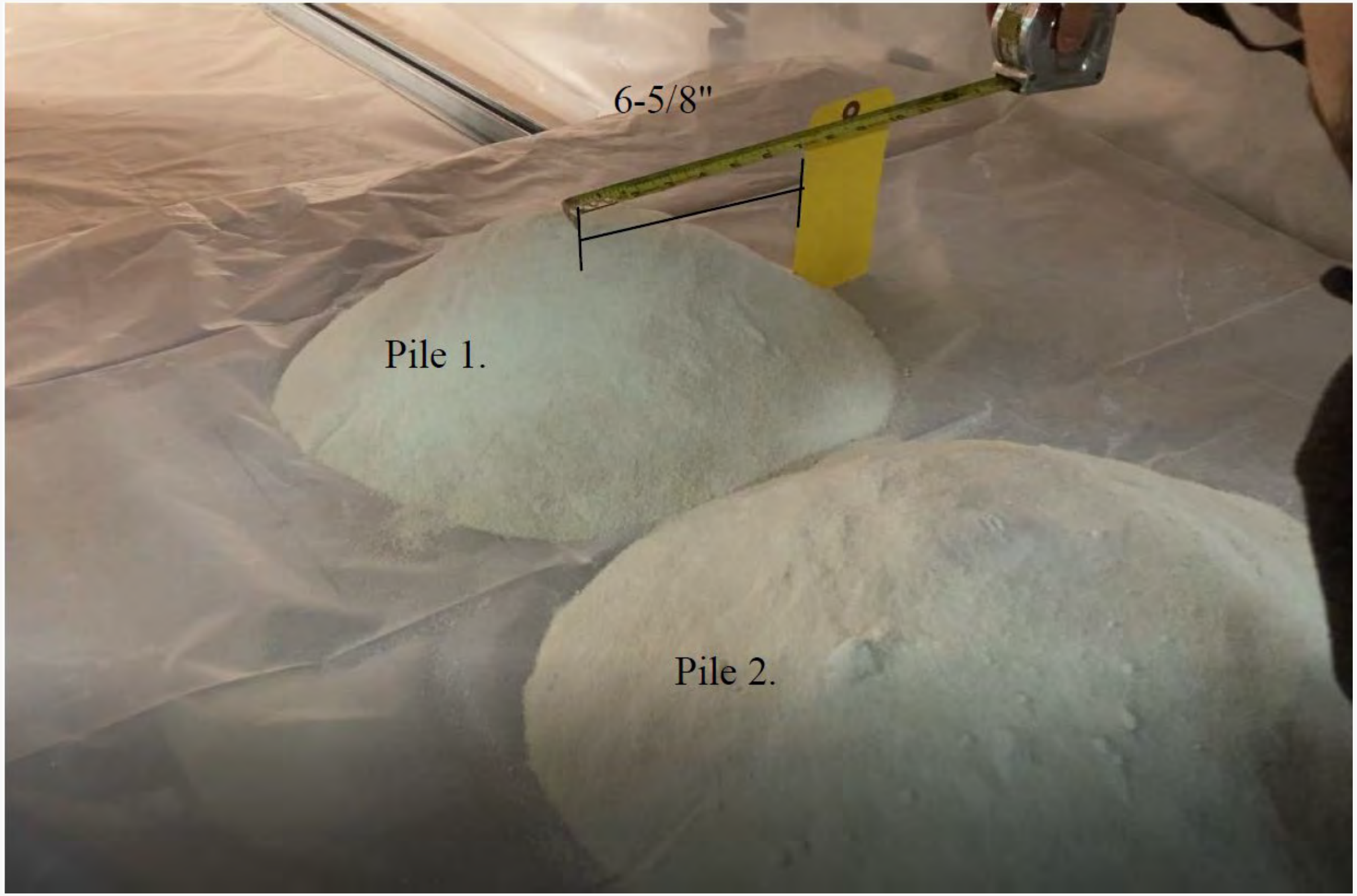
Video MgO Sand Discharge

Result

Results


AoEC, Diameter of pile with depth greater than one inch: 13.75"
Pile 1
AoEC, Diameter of pile with depth greater than one inch: 13"
Pile 2

Results



Measurement taken from center line to 1" of depth

Negative Pressure Differential Test, with no MgO sand:

GB inerting by discharging nitrogen through Victaulic Emitter tests were designed to determine the maximum nitrogen flow rate while maintaining the negative pressure differential over the HEPA filter.

Two different flowrates of nitrogen were tested: 40 and 30 Psi of nitrogen.

Testing demonstrated that even though filter had been through several discharge events and the associated dusting, a negative pressure differential over the HEPA filter was maintained up to 40 psi.

Maintain pressure differential across HEPA filter while inerting Glovebox with N_2					
Pounds of N_2		Pressure upstream HEPA Filter (inches of H_20)	Pressure downstream HEPA Filter (inches of H_20)	Partial Pressure of Oxygen	Notes:
40	Before Discharge	1.65”	.3”	20.20%	
	60 Seconds into Discharge	1.6”	.0"	18.65%	Partial pressure of oxygen continued to rapidly drop until flow of N2 was stopped
30	Before Discharge	1.6”	.3”	20.50%	
	60 Seconds into Discharge	1.6”	.1"	18.50%	Partial pressure of oxygen continued to rapidly drop until flow of N2 was stopped

Data and Results

The developed Nitrogen/MgO sand prototype FSS consistently discharged a metered volume of MgO sand that when combined with the nitrogen gas discharge would effectively control Class A and B fires within a GB and Class D fires within the defined coverage area(s).

Minimal pressure changes across the HEPA filter were observed during each test and no cumulative measurable degradation of HEPA filter performance was noted after conducting all tests using the same HEPA filter.

Accelerated clumping and compression evaluations utilizing mechanical vibration resulted in no detectable adverse conditions to MgO sand flow.

- ✓ To prevent MgO Sand clumping and to establish and maintain a dry atmosphere in the hopper, the use of desiccants is recommended. *Note* Testing of desiccant application was not within the scope of this project, but could be researched later.

Inert atmospheres were maintained before, during and after testing.

Implementation of the nitrogen MgO sand FSS into commercial use requires the FSS to be engineered for the specific GB application(s).

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