

DEMONSTRATING ENHANCED POWDER PANELS

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INTRODUCTION

Recent investigations have been conducted into effective, lightweight, non-halon fire protection techniques for mitigating aircraft vulnerability to ballistic threat-induced fires. This paper describes investigations to identify and demonstrate enhanced concepts for powder panels, a passive fire extinguishing device. Powder panels lining an aircraft dry bay can provide fire protection against ballistic impact by releasing powder into the fire zone to inert the space before the adjoining fuel spills into the space and is ignited by incendiaries. Much of this work was performed under the Next Generation Fire Suppression Technology Program (NGP), funded by the Department of Defense's Strategic Environmental Research and Development Program. The expected outcome of this work will be enhanced powder panel concepts that are competitive with halon 1301 in critical parameters such as weight, volume occupied, fire extinguishing capability, etc. and, thus, are candidates for use in its place.

In the first phase of an on-going two-phase NGP investigation, a series of experimental tests was performed to screen potential powder panel material and design improvements [1]. These materials and designs were notably different from those used in commercially available powder panels. The performance of these new powder panels was characterized through an examination of the panel front face fracture and material removal, the amount of fire extinguishing powder released into a dry bay, dispersion of the powder, and the time the powder remained suspended in the dry bay. The outcome of these non-fire screening tests was very promising. Testing revealed enhanced powder panel designs could afford the following benefits over current commercial powder panel designs:

- greater powder release into the dry bay,
- better dispersion of powder to prevent ignition off-shotline,
- longer powder suspension to prevent fire ignition for longer periods of time, and
- increased design flexibility of enhanced powder panels that can be utilized to target weight, durability, and application-specific design goals.

Additional confidence in enhanced powder panels was gained from live fire ballistic tests conducted during the summer of 2002. These proof-of-concept tests were conducted with enhanced powder panels in two different test series simulating aircraft dry bays and involving the potential ignition of a fuel fire. The data demonstrated the feasibility of enhanced powder panels

and their ability to significantly improve fire extinguishing effectiveness over standard powder panel designs.

The focus of the current research is to optimize the enhanced powder panels, parametrically examine design variations, and then demonstrate the optimized panels. Panel materials, thickness, and construction techniques are being optimized to reduce the panel weight, while maintaining effective powder dispersion. Live fire demonstration testing of the optimized panels will occur later this year. These and other on-going efforts are catching the interest of a number of aircraft programs and advancing the likelihood that enhanced powder panels will offer an attractive dry bay fire protection option for them.

EXPANDED SURVEY

In the first phase of this effort, a survey was conducted of powder panel applications in operational U.S. aircraft and investigations of previous powder panel testing. This survey assisted in identifying powder panel materials and designs that have been previously evaluated and those that have actually been integrated into aircraft designs. Using this information as a baseline, improvements in powder panel designs were then evaluated.

The initial survey indicated no U.S. fixed wing aircraft employ powder panels, but interest from some programs has been expressed recently. In particular, the F-35 Joint Striker Fighter program has expressed interest. U.S. rotary wing aircraft continue to consider powder panels and some incorporate them into their fire protection systems. Currently, the Navy UH-1Y Huey and AH-1W Super Cobra aircraft operate with powder panels. AH-1W and UH-1N legacy aircraft are being upgraded to the AH-1Z Super Cobra, which uses powder panels for dry bay protection. Evaluations have also been conducted recently for integrating powder panels into the AH-64 Apache and the RAH-66 Comanche helicopters. The V-22 Osprey tiltrotor aircraft uses powder panels extensively.

The second phase of the NGP project involved an expanded survey and investigation that included the identification of aircraft using active halon systems for fire protection, particularly in areas where powder panels could be used. This research is to be used for later comparisons of potential powder panel fire protection systems with current halon systems. This comparison will include weight and cost implications among other design factors. The expanded survey also included the identification of design issues for integrating enhanced powder panels into production aircraft and the identification of any necessary qualification testing required before implementation.

The examination of aircraft fire protection systems in the expanded survey revealed halon systems are infrequently used in areas where powder panels have been demonstrated to be effective [2]. Active halon fire extinguishing systems are prevalent in engine nacelles or auxiliary power unit compartments for fire protection (e.g., C-130 aircraft) or for inerting in fuel tank ullage areas to protect against ullage explosion (e.g., F-16). Powder panels have typically been evaluated in aircraft dry bay areas and have only been integrated into production aircraft in these areas. Therefore, as a part of a cost-benefit analysis to be conducted in the second phase of the NGP effort, a direct comparison of an existing halon fire extinguishing system with an

enhanced powder panel system has proven to be difficult. There are only a few potential examples that could provide direct comparisons for a dry bay area. Most of these examples, however, do not offer likely replacement possibilities and are not applicable across a wide range of aircraft. For example, the C-5 aircraft has a center wing leading edge dry bay, which is protected by a halon fire extinguishing system. However, this system was incorporated to protect against overheating or a safety fire from hydraulic components, not ballistic impact. It is located above the fuselage and would be difficult to hit for most reasonable combat scenarios. Replacement with a passive powder panel fire protection system may not prove practical in this case.

Aircraft dry bay fires are a known vulnerability for many aircraft. However, the infrequent use of halon fire extinguishing systems in aircraft dry bays implies that cost, weight, maintenance, and/or performance parameters have not been sufficient to justify such a system for these areas. It is possible, a more effective powder panel could offer a justifiable option for previously unprotected dry bay areas. Therefore, some estimates may be made for integrating powder panels into forward-fit or currently unprotected areas. Some generic estimates may be possible for integrating an active system for the same area. Typically, information for systems already considered in trade studies has been proprietary and could not be used in a published comparison.

Other potential comparisons were discovered for enhanced powder panels, including comparisons with current production powder panel applications and comparisons with other active fire extinguishing systems, such as solid propellant gas generators (SPGGs). The V-22 aircraft offers several areas where comparisons can be made. Both commercially available powder panels and SPGG systems are present.

Comparisons with halon fire extinguishing systems in engine nacelles or APU compartments will be considered, but are most likely not practical. Significant work would be necessary to demonstrate powder panels in areas where airflow or hot surface ignition would be a concern. Additionally, in areas where safety fires are of an equal or greater concern than ballistic threat-induced fires, powder panel protection is not currently a consideration.

Discussions were held in the survey with particular aircraft manufacturers to examine production design requirements or issues and provide data, which would allow for the consideration of enhanced powder panels in design trade studies. Discussions were held with Bell Helicopter - Textron, Inc., The Boeing Company, Sikorsky Aircraft Corporation, and Lockheed Martin Corporation. Specific aircraft discussed were the V-22, RAH-66, and F-35. Proprietary agreements were established with Bell/Boeing and Sikorsky/Boeing to assist in the exchange of design details and production or qualification requirements that may be levied on newly developed panels.

The aircraft prime contractors were asked if enhanced powder panels would have to undergo any qualification tests such as thermal cycling, impact resistance, vibration or other durability testing, chemical resistance examinations, and moisture absorption evaluations, for example. Based upon their responses, data suggest that commercially available powder panels may have individual material data to support such qualification testing, but the assembled powder panels

did not appear to be subjected to this testing for production qualification. Some limited production design criteria were considered such as panel thickness, areal density (weight per unit area), and perhaps temperature.

FEASIBILITY DEMONSTRATION

Experimental testing with enhanced powder panels began in the fall of 2001. An experimental test device (dry bay/fuel tank simulator) was designed and fabricated to enable a direct comparison of powder panel materials and designs, both existing and improved concepts. Through an impact dynamics study, various characteristics critical to the fire extinguishing effectiveness of powder panels were examined. The test device shown in Figure 1 allows for the experimental screening of candidate powder panels by comparing these characteristics in a highly repeatable fashion. Among the characteristics that can be examined are panel fracture, including cracking and material removal, the amount of fire extinguishing powder released into the test article, the dispersion of this powder, and the time the powder remains suspended in the dry bay.

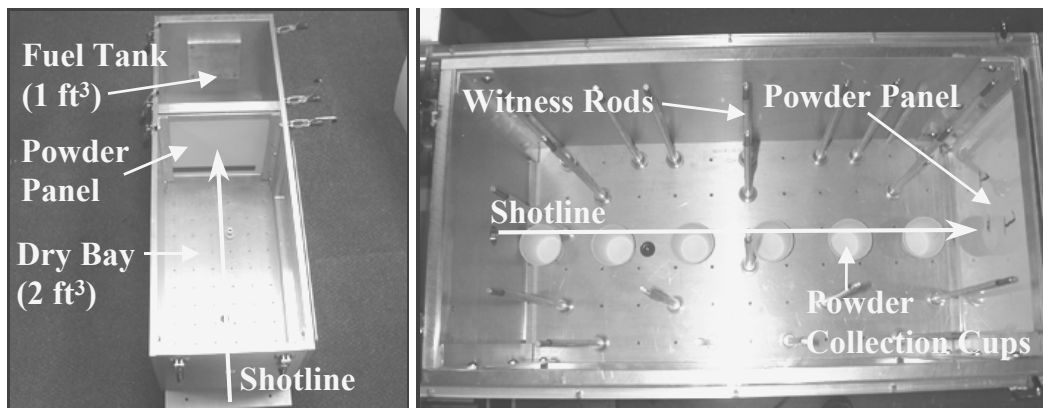


Figure 1. Experimental Test Device and Powder Collection Methods

The test device simulates a 0.057 m^3 (2 ft^3) aircraft dry bay and a 0.028 m^3 (1 ft^3) fuel tank. The fuel tank is capable of holding fluid, and the dry bay is designed with Lexan windows to allow for visual observation of each test. Testing in the first phase did not involve fluid in the tank or airflow so the screening process would be simplified. Replaceable 7075-T6 aluminum panels of 2.032 mm (0.08 inch) thickness are inserted to represent the fuel tank wall adjacent to the dry bay. In most of the tests, powder panels were secured directly in front of the fuel tank wall. This likely offers the worst-case scenario for evaluating the amount of powder released into the dry bay. The test device also allows for the installation of powder panels directly behind the dry bay wall where the projectile enters the test article.

The test device is designed to capture powder dispersion information so a direct comparison between candidate powder panels can be made. Figure 1 (right side) shows the powder collection methods used in the dry bay. Witness rods are located throughout the dry bay. Plastic tubes are slid over the rods to capture released powder during each test. The rods are placed in a pattern to ensure that the powder dispersion characteristics throughout the dry bay are understood. The plastic tubes are observed for qualitative signs of powder after each test.

Powder collection cups are also located in the dry bay. These cups are located along the shotline, where the powder concentration is most important during a ballistic projectile impact. The path of the projectile incendiary or impact flash is the location where the mixture of flammable fluid and ignition source is most likely to result in fire initiation. The collection cups are examined and weighed after each test to determine the amount of powder collected. In addition to these collection methods, each panel is weighed before and after each test to determine the amount of powder released. Panel components are also individually weighed before each test. The removed area of the front face (dry bay side) of the powder panels is also determined. This area is typically a direct correlation with the amount of powder released into the dry bay and provides another measure to compare the panels. For comparison, the back face (fuel tank side) removed area of the powder panel is determined as well. Digital video is captured for each test to assist in determining characteristics related to powder suspension and dispersion.

Experimental testing is conducted at the Air Force 46th Test Wing Aerospace Survivability and Safety Flight's Aerospace Vehicle Survivability Facility (AVSF) at Wright-Patterson Air Force Base (WPAFB), Ohio (Figure 2). In Range A of this facility, a light-gas gun (compressed helium-filled bottle rated at 20.68 MPa (3,000 psi)) is used to launch 0.50 caliber hard steel ball projectiles at velocities of approximately 670 meters/second (2,200 feet per second). The kinetic energy of these projectiles is roughly equivalent to a threat greater than a 7.62mm armor piercing incendiary (API), but somewhat less than a 12.7mm API projectile.

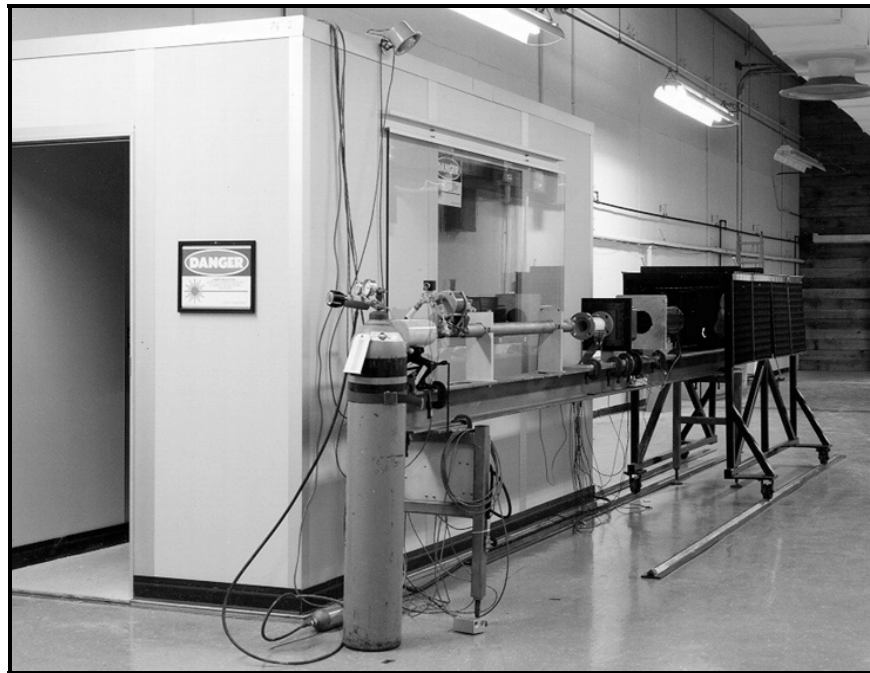


Figure 2. AVSF Range A Light-Gas Gun

Testing during the first phase involved only one dry chemical fire extinguishing agent. The powder selected was KHCO_3 (Purple K) due to its non-toxic nature, visibility for post-test inspection, and fire extinguishing effectiveness. Corrosion from long-term exposure was not a concern in these tests.

A total of 32 powder panel tests were conducted during the first phase of this program. These tests included components similar to those examined in previously tested powder panel programs to provide some baseline data. The majority of tests, however, featured unique materials and designs not evaluated in previous powder panel ballistic testing. Thermoplastic and thermoset materials were the focus of most testing. For the front panel face (dry bay side), materials that exhibited brittle properties upon impact, but durability in handling, were of utmost interest. The goal has been to find a front face material and powder panel design that results in significant front face material loss and powder release into the dry bay during the ballistic impact event. The impetus for experimenting with the back panel is to determine if the fracture characteristics of the back panel influence the front panel in any way. For the dry bay/fuel tank configuration examined, there was a desire to inhibit the back panel hole size to reduce flammable fluid leakage, which could assist in reducing fire ignition probability in an actual production configuration. The rib structure was also evaluated in experimental testing. The ribs add rigidity and strength to the panel, prevent settling of the powder, and must allow for easy release of as much powder as possible.

First phase testing identified novel powder panel designs with enhanced performance over more standard design concepts. Table 1 describes some of the more effective panels tested. Some measures of effectiveness are noted, including powder loss as a result of the ballistic test, percentage of the powder lost, and the front face area removed. Table 1 also indicates the weight of each near one-foot square powder panel. Total powder-filled weights for panels tested in the first year of testing ranged from 428.2 grams (0.944 pounds) to 1,403.0 grams (3.093 pounds). This is obviously one design feature that required optimization in phase two testing.

TABLE 1. MORE EFFECTIVE POWDER PANEL DESIGNS IN EXPERIMENTAL TESTING

Test No.	Material Description	Thickness (mm)	Panel Weight (g)	Powder Loss (g)	% Powder Loss	Front Face Area Removed (cm ²)
8	2.03 mm clear acrylic faces, 9.53 mm acrylic tube ribs	13.5	1402	48	5.6	31.6
9	1.78 mm cracked ice acrylic front, 1.52 mm white styrene back, two white styrene ribs (3.05 mm thick)	6.9	769	23	5.0	17.7
12	2.03 mm (50.8 mm x 50.8 mm scored) clear acrylic, 2.03 mm clear acrylic back, 3.18 mm polycarbonate honeycomb rib	7.6	579	9	4.6	22.6
21	1.78 mm acrylic prismatic front, 1.52 mm white styrene back, two white styrene ribs (3.05 mm thick)	7.8	552	30	12.8	20.3
23	1.78 mm styrene prismatic front, 1.52 mm white styrene back, two white styrene ribs (3.05 mm thick)	6.5	517	28.4	12.8	25.6
27	2.49 mm polyester resin front, 1.52 mm white styrene back, two white styrene ribs (3.05 mm thick)	7.1	620	8.2	4.0	25.4
28	2.49 mm polyester resin front, 1.52 mm white styrene back, two white styrene ribs (3.05 mm thick)	7.4	876	83.3	18.7	80.6

Comparing the first phase experimental results of baseline tests using more standard powder panel designs to these more effective designs, revealed some significant findings. Results

indicated the powder panel front face area removed could be increased by 15 to 20 times over more standard designs. Testing also revealed the amount of powder released into a dry bay could be increased 5 to 10 times with an enhanced powder panel design. Testing also indicated that powder dispersion could be enhanced, even with dry bay clutter, ensuring the prevention of fire ignition over a wider area. Effective designs resulted in powder being suspended in the dry bay for much longer periods of time than standard powder panels. Finally, the design and fabrication effort revealed enhanced powder panels afforded greater design flexibility, which can be utilized to target weight, durability, and other application-specific design goals. These findings revealed that realistic powder panel concepts could significantly enhance the fire extinguishing effectiveness of this vulnerability reduction method, thereby demonstrating the feasibility of enhanced powder panels.

Enhanced powder panel research created interest by some other research programs, which resulted in opportunities for enhanced powder panel live fire proof-of-concept testing in 2002. Discussions were held with the NAVAIR Weapons Survivability Laboratory, China Lake, California and arrangements were made to incorporate some enhanced powder panel tests with some of their research. Lessons learned from the experimental testing were used to design and fabricate some new, slightly more optimized powder panels. These panels again incorporated thermoplastic materials. However, thinner panel thicknesses and reduced powder loading resulted in reduced weights, and new rib structural designs were utilized. Weights were decreased on average 100 to 200 grams (0.22 to 0.44 pound) from those designs evaluated in experimental testing for 30.16 cm (11.875 inches) by 30.16 cm panels. Panels evaluated at China Lake varied from 320 grams (0.71 pound) to 422 grams (0.93 pound) in weight. Thicknesses ranged from 0.24 cm (0.095 inch) to 0.33 cm (0.13 inch).

The ability of these enhanced powder panels to prevent fire ignition was first demonstrated in a Joint Technical Coordinating Group on Aircraft Survivability (now Joint Aircraft Survivability Program Office) test program at China Lake [3]. This program was examining a reactive powder panel concept, which is a method of using a reactive energetic backing with any powder panel design to enhance powder delivery effectiveness. Four tests of enhanced powder panels without reactive backing were conducted, demonstrating their capability to prevent dry bay fires in tests involving JP-8 fuel and 12.7mm API Projectiles. Figure 3 compares the amount of fire extinguishing powder released from an enhanced powder panel with a commercially available powder panel. Figure 4 shows some images captured from high-speed video demonstrating the fire mitigation capability of enhanced powder panel designs over a commercially available powder panel.

**Commercial Powder Panel
~5-10% Powder Release**



**Enhanced Powder Panel
~90% Powder Release**



Figure 3. Comparison Of Commercial And Enhanced Powder Panel Agent Release In JTCG/AS Dry Bay Fire Extinguishing Testing

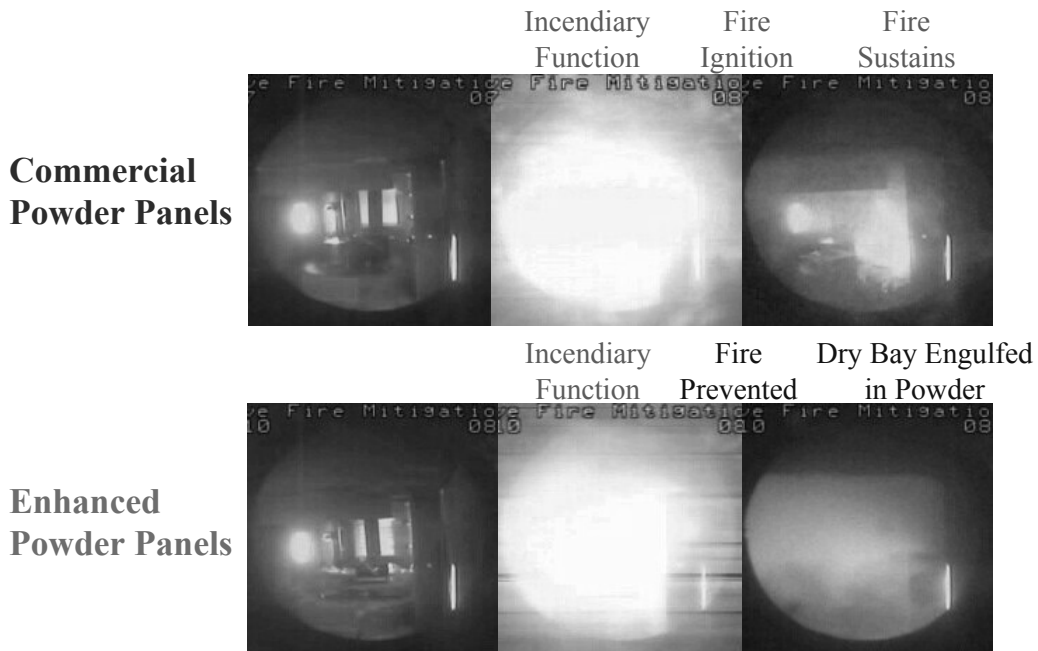


Figure 4. Enhanced Powder Panel Fire Mitigation Capability Demonstrated

Another demonstration test of an enhanced powder panel was conducted in a Federal Aviation Administration (FAA)-sponsored program at China Lake [4]. This test examined the feasibility of powder panels in preventing fuselage fires in commercial aircraft, caused by the release and impact of an uncontained engine rotor blade with flammable fluid lines. Figure 5 shows that impact of the enhanced powder panel by a rotor blade resulted in release of all the fire extinguishing agent, and it prevented a fire ignition. Baseline testing showed that unprotected fuselage areas did indeed result in sustained fires.



Figure 5. Entire Contents of Enhanced Powder Panel Released and Fire Prevented

In both the JTCG/AS and FAA test programs, the enhanced powder panels showed a vast improvement over current powder panel designs. Powder discharge was estimated to be at least 90% of the pretest powder loading for the enhanced powder panels, compared to 5% to 10% for commercial powder panels. Greater powder dispersion throughout the dry bays was also evident for the enhanced powder panels. Fire ignition was prevented in all five valid tests involving enhanced powder panels, further demonstrating the feasibility of these new powder panel designs.

OPTIMIZATION TESTING

Enhanced powder panel testing continues in the second phase of NGP research, with an emphasis on parametric analyses of enhanced powder panels to optimize the designs. Testing is being conducted in the same simulated dry bay/fuel tank experimental device used for concept evaluations in the first phase of research. Testing also involves the same light gas gun launching 0.5 inch diameter ball projectiles. Optimization test variables include panel materials and thicknesses, fire extinguishing powder loading (density of powder inserted into a given panel size), rib designs, and the assembly process. However, lessons learned from the first phase of testing are being incorporated into the test process, so the governing design concept is not being altered. Optimization testing focuses on three primary areas of investigation outlined below:

- effectiveness optimization (increase front face fracture, maximize powder release),
- practicality enhancement (reduce weight, decrease panel thickness, address production issues), and
- reliability improvement (increase durability, reduce risk of accidental leakage).

Maximizing powder release into the dry bay will continue to be the defining goal, but other requirements are being levied on the design effort to ensure the enhanced powder panels are as practical and reliable as possible. Weight is being reduced, panel thickness is being minimized, and other potential production requirements are being considered. An areal density (weight per unit area) target was provided by one of the vehicle manufacturers for the design effort. This specific requirement is proprietary to the manufacturer, but will be used as a design guideline.

Front face materials evaluated in the first phase of screening tests proved to be effective. Therefore, optimization testing may involve some unique materials, but will continue to focus on thermoplastics with brittle material properties and those that meet perceived operational environment requirements. Additional experimentation will be conducted for the materials and designs used for the ribs and back face material.

Second phase testing involves primarily aluminum oxide (Al_2O_3) as the fire extinguishing agent. Aircraft manufacturers have expressed skepticism regarding the potential for other, more effective, fire extinguishing powders to be considered for powder panels due to concerns over accidental leakage and the potential for corrosion. Al_2O_3 is the only known powder panel agent to be incorporated into an aircraft due to its lack of reactivity with aircraft structure. A related goal for the enhanced powder panels is to use bonding techniques and materials that maintain a low risk to accidental leakage.

Other test variables to be considered in second phase testing include a fluid-filled fuel tank, the location of the powder panel, the addition of dry bay clutter, projectile velocity, and perhaps ventilation airflow. These variables will be evaluated in more depth once an optimized powder panel design is more defined.

Testing thus far has indicated further decreases in weight are possible, while maintaining effective powder release. Enhanced powder panels weights have been further reduced, with as much as a 55% decrease in weight from some of the lightest panels tested in the first phase. Two of the lightest pretest filled panel weights were 193.48 grams (0.43 pounds) and 201.2 grams (0.44 pounds).

Enhanced powder panel thicknesses have been tested between 0.216 cm (0.085 inch) and 0.279 cm (0.110 inch) in optimization evaluations. Reductions in thickness reduce the powder loading or the amount of powder in the panel, which is the significant weight consideration. This is particularly true for the aluminum oxide. However, the thickness of the panel along the shotline also reduces the potential powder loss, which obviously affects powder panel effectiveness. Therefore, there is a balance necessary between panel thickness, which affects panel weight, and the effectiveness of the panel, as measured by powder loss. Front and back face materials and the rib structure design are other variables being considered to increase performance without increasing weight.

Powder release into the dry bay is important because the greater the amount of powder dispersed in the dry bay, particularly along the shotline, the lower the chance of an ignited fire. The amount of powder loss in second year testing ranged from as low as 0.75 grams to as much as

5.15 grams. This powder loss is lower than the most effective panels in previous testing, but the panel thickness and available powder has been significantly reduced to meet design goals. The percentage of powder loss (powder lost divided by pretest total powder available multiplied by 100%) has also been used as a measure of powder release effectiveness. The enhanced powder panel design attempts to maximize the release of the available powder in the panel. Optimized panels tested thus far have ranged from 0.53% to 3.2% of the total powder lost. A ranking of the panels using percentage of powder loss does not track directly with a ranking of the panels by total powder loss. It does, however, take into account pretest panel weight, since the powder is the significant weight factor. Table 2 lists panels tested thus far in optimization testing, showing pretest panel weights and areal densities, along with the amount of powder loss, percentage of powder loss, and the estimated front face area removed. The panels are ranked by powder loss for all valid tests conducted so far.

Tests 9 and 15 in Table 2 were conducted on the commercially available powder panels used on V-22 aircraft. These panels are composed of a Nomex honeycomb core and two thin composite face sheets. The V-22 panels are the lightest of the panels tested (empty weight and with powder), but also released the least amount of powder and the smallest percentage of powder. The least effective enhanced powder panels still resulted in almost three times greater powder loss and well over double the percentage of powder lost. As discovered in previous testing with Nomex honeycomb cores, powder is lost from those cells directly penetrated by the projectile and those torn on the perimeter of the penetration, but powder is not able to escape from the rest of the panel. Enhanced powder panels offer the potential for a much greater percentage of the panel's contents to be released. It is anticipated the effects of hydrodynamic ram on the powder panel will only increase the amount of improvement an enhanced powder panel can offer. Further testing will verify this assertion.

TABLE 2. OPTIMIZED PANEL TESTING

Test No.	Total Thickness (mm)	Empty Weight (grams)	Pretest Weight (grams)	Areal Density (g/cm ²)	Post-test Weight (grams)	Estimated Powder Loss (grams)	Estimated % Powder Loss	Estimated Front Face Area Removed (cm ²)
5	2.41	135.0	295.00	0.324	289.50	5.15	3.20	11.10
8	3.05	178 (estimated)	347.96	0.382	343.80	2.99	1.76	11.87
14	2.67	252.0	368.46	0.405	365.30	2.17	1.90	9.75
2	2.41	134.0	251.60	0.277	249.20	2.15	1.80	4.84
10	2.79	174 (estimated)	453.13	0.498	450.97	2.06	0.74	1.26
4	2.41	133.0	330.00	0.363	327.50	1.66	0.84	24.58
6	2.16	111.0	201.20	0.221	199.67	1.36	1.52	9.81
11	2.67	245.0	403.94	0.444	402.03	1.04	0.65	7.74
13	2.67	255.0	410.54	0.451	409.42	0.82	0.53	3.02
7	2.16	111.0	193.48	0.213	192.71	0.75	0.90	5.81
9	2.69	41.7 (estimated)	174.95	0.192	174.69	0.26	0.20	1.11
15	2.69	41.7 (estimated)	174.99	0.192	174.75	0.24	0.18	0.49

OPTIMIZED PANEL DEMONSTRATION

NGP research will conclude in 2003 with live fire demonstration tests of the optimized powder panels. At least three tests will be conducted to demonstrate the most promising enhanced powder panel concept can prevent fire ignition. Testing will be conducted at the Air Force 46th Test Wing Aerospace Vehicle Survivability Facility, Wright-Patterson Air Force Base, Ohio. Demonstration testing will involve a standard commercial powder panel and two tests or more of the most promising enhanced powder panels. A dry bay/fuel tank simulator, representative of a production dry bay size and configuration, will be used for this testing. Testing will involve JP-8 fuel and actual ballistic projectiles.

CONCLUSIONS

The optimization of enhanced powder panels continues, with design goals based upon potential production requirements. Environmental conditions are being considered in the design process, including temperature, moisture, vibration, and chemical exposure. The weight of earlier feasible designs has been decreased substantially, while design efforts continue to focus on maximizing powder release. A balance will need to be reached between panel weight, driven by powder content, and the release of sufficient powder to mitigate fire. The flexibility of enhanced powder panels will allow for panel designs that can be configuration-specific and perhaps even specific to a design ballistic threat. Research into improved powder panel fire protection has already resulted in a demonstration of the feasibility of enhanced powder panels and their potential effectiveness improvement over standard commercial designs. Proof-of-concept live fire testing has been completed and soon optimized powder panels will be demonstrated.

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