

## 1.0 Introduction

### **Carrier Lightweight Structures Program**

The objective of this program is to develop weight reduction ideas using alternative materials/structure for the aircraft carrier hangar bay deck edge and divisional doors for future carriers. Previous attempts have been made in the past to utilize the built-up steel structure called NAVTRUSS and LASCOR. One such application was the design and installation a functional deck edge door on CVN66 and more recently in the helicopter bay doors on DDG 79 . Other materials have also been considered to replace steel.

The future carrier program at Newport News has decided that neither LASCOR nor composites are either cost effective or within the design and manufacturing scope for CVNX(1). This is reiterated also by Tom Nodeen of PMS 378 in the email shown in Appendix F.

Today, aluminum superstructures exist on numerous US Naval ships for lightweight deckhouse construction and their associated masting; as well as, in the elevator platforms and the jet blast deflectors used on all Nimitz class carriers. This proposal is intended to show that aluminum used as an alternate material specifically for construction of the hangar bay divisional doors (Figure 1A) offers positive, low risk, cost effective weight savings which should be part of the ECP program for CVNX(1) to enable NNS to come closer to meeting the weight goals expressed in the KPP'S.

The schedule for this program is bold, but feasible. It is anticipated that if it receives NAVSEA approval that this program could result in significant additional weight savings for CVNX(1). Also even greater weight savings are possible through a back fit program, using both the hangar bay deck edge elevator doors and the divisional doors for existing carriers that are also desperately in need of both weight reduction and balance improvement. Insertion either I CVN 70, during its schedule RCOH, or possibly CVN 74,75 or 76 as a field replacement are possibilities.

The schedule for accomplishing this program will require several phases, which can be initial funded through NNS IRAD, but will eventually need ECP funding. However, early phases can be initiated simultaneously upon receiving acceptance approval by NAVSEA of the previous phase. The phases are:

1. Passive Fire Protection Qualification
2. Preliminary Design Approval
3. Final Design Approval, include. Large Scale Modeling and Testing
4. Ship Insertion.

Completion of Phase 1 should result I a qualified " Passive Fire Protection" system for thermal protection of ship structures, especially structures, used on both existing and future naval ships. Phase2 should result in an acceptable design to adequately replace the current steel hangar bay divisional doors. Once the design is approved, the final costs and weight numbers will be derived. Once the technical and economic(costs and maintenance issues) details are resolved, a decision can be made as to the ultimate risk and whether or not to proceed further. With a positive decision, this program can proceed to Phase 3. which includes full scale modeling and testing of a representative

structure for fire, shock, ballistic (fragmentation) and any other agreed upon testing as warranted for final approval.

The final step, Phase 4, will be agreement as to the ship selection for back fit insertion demonstration. Decisions as to funding, the number and type of doors, door fabrication at Northrop Grumman Newport News, and the actual schedule for replacement can be made. Following insertion, the aluminum divisional doors will be monitored by both the Navy and Northrop Grumman Newport News for performance analyses through 05N's CWP " Aluminum Structures" forum.

## **2.0 PHASE 1. Qualification of the Passive Fire Protection (PFP) System for Aluminum Structures.**

### **2.1 Passive Fire Protection System.**

There are numerous methods which offer passive, as opposed to active, fire protection. Passive Fire Protection systems range from panels to blankets to coatings, each with its own positive aspects. The simplest to apply are the coating types that can be rolled, brushed or sprayed. Of these there are numerous varieties, mostly categorized as intumescent. The definition of an intumescent is a coating that, when exposed to a flame, will chemically transform to a less dense structure, which causes the coating to swell to many times the original thickness. This increased thickness, along with the void space created within from chemical foaming reaction, will shield the supporting structure from the flame and thus offer protection. Typically, intumescent have been shown to possess no insulating capability; and, there, only protect for short time duration. Depending on the flame temperature, the ability of an intumescent coating to protect for a sufficient length of time diminishes as the flame temperature increases. As applied, intumescent coatings are inherently brittle and tend to crack and flake with impact, which leads to the inherently low dry thickness suggested by manufacturers. Also, once they have foamed from flame contact, the resulting intumescent char has a tendency to fall off of both vertical and overhead applications. A few manufacturers will add and embedded stiffening mechanism, such as a carbon or metallic screens. Most low smoke intumescent available today are water- based. Experience has indicated that intumescent coating chemistry may not be stable over time. When paint is applied over and intumescent, its performance can be impaired. There is some indication that intumescent do not respond the same under varying heat sources, i.e. radiant versus direct flame. Testing has indicated that direct flame contact is required to activate some intumescent.

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A second category of PFP is classified a thermal and acoustic panels, such as ' Structogard". These panels have demonstrated that they perform adequately when subjected to the UL 1709 fire test protocol. These panels currently are the only PFP system that has successfully met the Navy's requirements. The "Structogard" also has the ability to insulate acoustic noise, which is another of its positive attributes. As with most solutions, it has its

negative attributes. These panels must be hung technology has been estimated to cost in the range of \$30 per square foot (once the panels are purchased, hung, finished off and the backside steel painted).

Another PFP system can be classified as insulative. The basis for this technology is in the chemistry of the coating formulation, which is primarily made up of simple benign oxides which offer insulating characteristics. Typically this category is water-based and can be applied by a brush, roller or potentially spray. Also, these coatings have demonstrated that once dried, they are compliant, tough and adherent. The chemistry of these coatings allows them to resist heat transfer, reflect radiant heat and thus insulate the substructure. This insulation differs from rock wool in that it reflects thermal energy rather than acting as a barrier.

One such product, marketed by Superior Products International is called " Hot Surface Coating" which is an insulative type coating. To enhance the PFP capability of their hot surface coating, Superior added an intumescent component and the identification became " SP 2001F" PFP fire protection system. In general the Superior SP 2001F has demonstrated that it has the ability to protect a substructure (either steel or aluminum) for an adequate time against the most severe flame temperature (UL 1709) exposure, as compared to either a bare substructure or one coated with one of the best intumescent.

When the vertically oriented fire evaluation panels were removed from the test fixture, the resulting char was intact and adherent, as can be seen in Figure 5. One advantage of the SP 2001F is that unreacted coating can be designed to remain at the end of the flame exposure time requirement, depending on the initial application thickness. The initially applied coating thickness will be directly related to the time-temperature requirement for the particular application involved. This residual coating layer will enhance the adherence of the char to the substrate being protected. This is a significant advantage over intumescent type coatings that completely intumesce during a fire incident and loose adhesion.

Due to the insulating nature of these coatings, they also provide improved thermal environment efficiency in work and living spaces. Typical industrial insulation is installed on the interior side of outside walls and roofs, which allows the heat load to build on the interior of the structure. These insulative coatings can be applied to the exterior of a structure, where it prevents heat from entering the interior as well as, protecting the structure from exterior fire exposure.

## **2.2 NNS Passive Fire Protection Evaluation.**

Phase 1 of our program began in 2000, when initial contact was made with Dr. Robert Asaro, professor at the University of California- San Diego. At that time, he was involved with a Mantech/. NSRP funded program to develop both aluminum and composite structures for both naval and

commercial marine applications. His work successfully utilized several coatings to protect aluminum structures on fast ferries from various types of fire incidents, ranging from fuel pool fires to the ASTM F119 protocol. His program produced success and was recognized by the Coast Guard for commercial ship and fast ferry application.

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Late in 2000, Newport News contracted with Dr. Asaro, through an independent company, Modeling & Engineering Services (MES), to evaluate these fire protection coatings using the more severe UL 1709 protocol. An integral part of his evaluation was to perform a finite element simulation of the effects of a fire incident on the carrier hangar bay deck edge elevator and divisional doors, for both the conventional steel design for CVN 76 and the proposed aluminum replacement design. He was asked to determine what thermal problems may have to be addressed in the final design. This evaluation was funded by NNS Internal R&D(IRAD). In August 2001 the initial evaluation program, was completed by Modeling & Engineering Services (MES) and reported to Northrop Grumman Newport News.

Dr. Asaro proposed and conducted an evaluation program on FEA models of both types of doors and UL 1709 testing of both coatings (examples of FEA analysis for thermal expansion are shown in Figure 1B). Samples designed to simulate carrier hangar bay divisional door construction (shown in Figure 2) were designed and fabricated by Newport News for the UL 1709 testing at VTEC Laboratories. Analysis of the existing steel and proposed aluminum alloy door systems included detailed thermal structural analysis of the performance of the doors when they are subjected to asymmetric thermal loads caused by exposure to fire. Fire testing was performed by subjecting full-scale sections of the proposed aluminum alloy divisional doors, 2'x 3'x24" thick with 0.625" face plates and two 0.625" stiffeners (Figure 2), to UL 1709 flame histories.

The two novel insulative coatings, previously described, were applied to the face of the aluminum divisional door fire test samples to be exposed to the flame (Figure 2). Both coatings provided adequate levels of thermal protection, according to MIL PERF XX381. Also, from this study, several recommendations were made, based on the modeling effort, concerning potential design changes that could ensure improved performance of the door systems vis-à-vis, for example, thermal expansion and maximum service temperature based on sustaining structural integrity.

A photograph of the existing bare steel design divisional door sample (2'x3'x24" thick with 0.375" face plates with two 0.375" stiffeners) showing its performance in the UL 1709 fire test, is included in Figure 3. This steel sample experienced severe warpage after only 8 minutes of exposure to the 2000°F flame temperature. The backside temperature of the exposed steel face reached approximately 1500°F. The temperature and the warpage caused the test to be terminated after 8 minutes of exposure.

The tested bare aluminum sample is shown in Figure 3B. It suffered melt through, after 12 minutes of exposure to the 2000°F flame followed by heat soak after flame shut down. Neither the back side face plate nor the stiffeners of the uncoated aluminum sample were thermally or mechanically compromised, as can be seen in the time-temperature plots in Figure 4. Warpage of the much thicker bare aluminum sample was minimal compared to that of the steel sample.

These same aluminum test panels, painted with the insulative coatings, significantly out performed the bare samples (as can be seen in Figure 5 compared to Figure 3). The backside temperature of the exposed face of the coated sample remained below 300°F (150° C) as shown in the T-T plots in Figure 6.

Due to the success of our PFP development program, a plan has been put together to move forward with additional testing and potential qualification of these novel insulative PFP coatings. Following-on successful completion of the initial flame spread testing and thermal modeling; the second step was implemented in late '01, again funded by Newport News IRAD.

Step 2 was scheduled for completion around 05/15/02, depending upon completion of testing by MES, VTEC and NSWC Carderock. The test matrix devised for step 2 was established jointly with NNS. MES and Carderock following-on testing recently reported in the Navy study entitled "Evaluation of Intumescent Coatings as Passive Fire Protection System for Shipboard Interior Applications " performed under the direction of Usman Sorathia, et al, at NSWC Carderock (NSWCCD-64-TR-2001/10). The Carderock study involved assessment of the performance of numerous passive fire protection systems, including intumescent coatings, but did not include the insulative PFP coatings being studied in the Northrop Grumman Newport News-MES program.

The evaluation matrix used in the Navy study (Table 1) included testing for flame spread, toxicity, smoke generation, and cone calorimeter testing to document basic combustibility characteristics of the various systems evaluated in that study. Flame spread was assessed via performance in the UL 1709 test according to MIL PERF XX381. Coating adhesion was evaluated, using the ASTM D4541 pull off strength test. In addition, cone calorimeter tests were conducted, including a two-stage heat flux, to simulate a kind of "aging" by exposure to a low heat flux followed by exposure to a higher flux to initiate the intumescent reaction.

The initial Newport News/MES study included extensive and detailed UL 1709 flame spread testing. These test results are summarized in Section 6. No additional UL 1709 flame spread tests are proposed herein for Phase 1 of the PFP qualification program.

Step 2 of Phase 1 is currently being conducted according to the program listed in TABLE 2 and, again, mirrors the Carderock work. Mr. Usman Sorathia agreed to perform the ASTM D4541 pull-off adhesion test at the NSWC Carderock facility. VTECII, located in the Bronx, N.Y., performed the flame exposure tests. MES arranged for and oversaw these tests. The impact and knife tests were performed by MES. A preliminary report summarizing some of the test results is attached in Appendix B. The results of these tests are also shown in the right two columns of Table 3. The ignitability data for both coatings exceeded the desired values, but are not considered a serious contributor to enhancing the fire.

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TABLE 1.

**: Acceptance Criteria for Small Scale Screening Tests**

TEST	ACCEPTANCE CRITERIA			SOURCE
Areal Density	Maximum areal density of 1.02lbs/ft <sup>2</sup>			MIL-PRF-XX381(8)
Adhesion Tests ASTM D4541 Pull-off Test	270 psi			Equal to or better than Ocean 9788 (G)AT 50mils
Knife Test MIL-PFR 24596	Difficult to furrow; No Flaking or Chipping			MIL-PRF 24596(10)
Impact Tests ASTM D2794	50 IN-lb			Performance Equivalent or better than Coatings Ocean 9788, and Ocean 477(11)
Flame Spread ASTM E 162(14)	Not greater than 25			MIL-PRF-XX381
Smoke Generation ASTM E 662(15)	Not greater than 200			MIL-STD 2031(9)
Heat Release, kW/m <sup>2</sup>  ASTM E 1354	Heat Flux	Peak	Avg.300s	MIL-STD 2031
	25	50	50	
	50	65	50	
75	100	100		
Ignitability ASTM E 1354	Heat Flux	Time to Ign, secs		MIL-STD 2031
	25	300		
	50	150		
75	90			
Simulated UL-1709 Fire Resistance Test	Duration : 30 minutes; unexposed avg. temp. rise: 250°F			MIL-PRF-XX 381
TGA-FTIR	No super toxins, no toxic gases			NAVSEA consultation

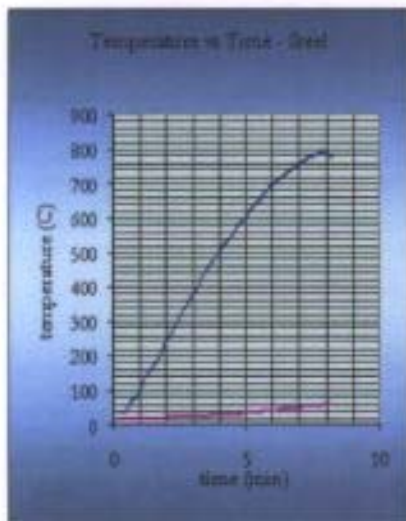


A. Typical Steel (CVN 76)

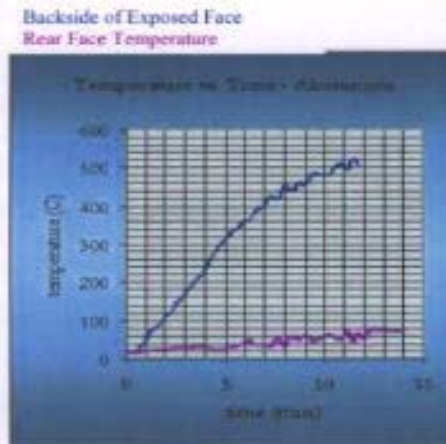


B. Proposed Bare Aluminum

FIGURE 3. Results of Bare Panel Tests



A. Bare Steel



B. Bare Aluminum

FIGURE 4. Bare Metal Temperature Profiles, UL 1709 Flame Exposure of 2000°F.

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## 2.3 Proposed Qualification Program for the Insulative Passive Fire Protection Systems.

It is expected that the PFP coatings being investigated in the NNS study for protection of aluminum structures, potentially, could also be used for general fire zone bulkhead protection on all naval ship platforms. The following proposed qualification program will attempt to address the various imposed requirements and fire protection concerns of those involved in the decision process for both the aircraft carrier aluminum hangar bay division doors and for general fire barrier usage.

The requirements of our qualification plan are outlined in Table 3. This is an attempt toward Naval usage qualification of a new type of PFP coating system, such as the Superior Products, Inc. SP2001F insulative type coatings. It is intended that qualification of the fire protection capability of these coatings should be performed according to both MIL Performance Specifications XX381 and 24596A. XX381 is entitled "Insulation Panel, High Temperature, Thermal and Acoustic", which incorporates the UL 1709 time-temperature flame specifications as described in Appendix A, ENTITLED 'Method of Fire Tests for Fire Resistance of Bulkheads and Decks'. The heat transmission requirement for the backside temperature will be according to XX381 with an average backside temperature rise of 250°F(139°C) above the initial sample temperature and a maximum single point temperature rise of 325°F(180°C) for a minimum fire exposure time of 30 minutes.

Because the aircraft carrier divisional doors are two faced structures, the backside temperature is proposed to be measured on the outside surface of the unexposed face. However, for structural safety reasons, the temperature of the backside of the exposed face is proposed to be restricted to an average of 425°F according to reference 2 and ASTM E 119. Typically, structural members are designed to withstand thermal excursions that lead to a 50% reduction in ultimate strength. For steel, this temperature is 1000°F and for aluminum it is approximately 450°F.

To qualify these coatings for general use on fire zone bulkheads, the backside temperature requirement, will be as stated in MIL PERF XX381. A maximum temperature rise of 250°F average and 325°F maximum rise as measured on the backside of the exposed face of the bulkhead (or in this case the exposed face of the door sample) is the requirement. The PFP coating thickness will have to be slightly greater for the fire zone bulkhead application than the thickness required for divisional door application. Flame spread tests have been performed on variable coating thickness in the NNS study and are summarized in Appendix A. The two coatings proposed in this program have successfully met the MIL PEFR 24596A entitled "Performance Specification for Coating Compounds, Nonflaming, Fire Protective". The XX381 specification is primarily proposed as a performance specification to compare insulation and acoustic panels for use on fire zone bulkheads.

Table 3 lists the various requirements that are proposed for both a successful PFP and a fire retardant coating. In the far right two columns of Table 3, the data generated to-date is shown for each of the two insulative coatings being evaluated in this program. It is intended to continue to pursue the qualification process according to Table 3. It is expected that the final qualification data could be completed by the end of '02.

To prove their ability to meet the requirements, final testing will most likely involve a large simulation structure tested aboard the USS Shadwell. The details of a large scale test program will be discussed in the next section regarding proof of design regarding the hangar bay divisional doors.

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### 3.0 Phase II. Preliminary Design Approval

The next phase of this proposal is intended to deal with the overall performance concerns of NAVSEA regarding the use of aluminum for construction of carrier hangar bay divisional doors. Attached in appendices C & C are a list of questions/ statements previously put forth by NAVSEA 05P9/05P/05L regarding the application of aluminum to the DIV doors.

#### 3.1 Passive Fire Protection Durability Evaluation in a Marine Environment:

Beyond the Phase 1 qualification steps, it is anticipated that aging tests will be required to assess the durability/performance of the insulative PFP coatings when exposed to long-term ship-board environments. The following are answers to 05L's durability questions(Appendix C).

Questions A & D : ASTM B117 accelerated salt fog corrosion testing is proposed according to Table 4. An initial test has been performed for Superior by VTECH. The results (summarized in Appendix A) after 2000 hours of exposure are positive. The final mode of exposure(i.e. open or covered, etc.) will have to be determined by consensus among those involved. The samples used in the evaluation will be the final proposed system, to included primer, over-coat or whatever else is decided is the PFP system makeup.

In conjunction with the B117 testing, additional adhesion and fire performance testing is proposed to evaluate question D. These insulative PFP coating will be tested under conditions which reflect more realistic naval ship usage.

	<b>Accelerated Life Cycle Corrosion Test</b>	<b>Adhesion</b>	<b>Fire Performance</b>
<b>1. Salt fog Exposure</b>	<b>ASTM B 117 35°C for 30days</b>	<b>ASTM D 4541 270 psi</b>	<b>ASTM E 1354 25kW/m<sup>2</sup> 50kW/m<sup>2</sup> 75kW/m<sup>2</sup></b>
<b>2. Seashore Exposure</b>	<b>ASTM D 4141</b>	<b>ASTM D 4541 270 psi</b>	<b>ASTM E 1354 25kW/m<sup>2</sup> 50kW/m<sup>2</sup> 75kW/m<sup>2</sup></b>

Question B; Heat source effects have been tested in our program and the resulting data indicates that heat source type does not affect the insulative fire protection performance, according to the data shown in Table 3 and Appendix B for the cone calorimeter results versus UL 1709 fire spread testing.

Question C: Chemistry stability deals with time related changes to the chemical makeup that can lead to performance deterioration. In the case of these insulative coatings, the chemical makeup utilizes stable inert oxides. There also is an intumescent component and a binder that are secondary to the oxides insulation component. It is anticipated that post ASTM B117 fire testing will address this issue. It has not yet been established what length of time an acceptable life cycle might be expected.

Over-coating will most likely be required for the divisional door application. It is anticipated that when the final insulative PFP coat is applied and the coating fully dried that it will be followed by an over-coat of the current paint. Initially, either a small E 162 fire test of E1354 cone calorimeter test will provide the comparative information to answer Appendix C, question E.

Question F: The performance of these coatings when subjected to shipboard cleaners and hydrocarbons is not a requirement for water based coatings, according to MIL PERF 24596. Also, according to 24596, washability shall be evaluated in accordance with method 6141.1(cancelled) of FED-STD-141. It is intended that these PFP coatings will be top coated with the typical Hanger Bay alkyd finish coat. Maintenance of the coating will then become that of the of the specific top coat.

Question G: Tell-tales can be accomplished by assigning a particular color pigment to these coatings so as to allow the coating to be identified either before the final overcoat or in the case of damage to the overcoat and the insulative coating.

Question H: Once the coating has successfully performed according to MIL PERF XX381 in a fire incident, it is suggested that the resulting char capability be assessed according to the following test protocol:

1. Perform UL 1709 test on a coated panel of both aluminum and steel.
2. Provide thermocouple data regarding the test cycle.
3. Immediately upon removal of the sample, generate a photo of the char.
4. Follow the initial photo with a fire hose spray simulation as described in E119
5. Once the sample has been cooled, document the char again with a photograph.
6. The resulting char condition can be visually assessed as to its continued performance capability, if for example the fire is reestablished.

However, there is no performance requirement beyond the 30 minutes of initial fire exposure.

Question I : Quality Assurance Instruction (QAI 642.1) for coatings does not currently contain procedures for the application of spray applied passive fire protection (PFP). Specialized equipment and procedures are required for the application of liquid PFP.A comprehensive QAI will therefore be written by subject matter experts within the

production engineering departments. Manufacturer's recommendations from the coating and the equipment suppliers will be adhered to, as well as, the requirements of NAVSEA and the relevant industry standards. Final approval and issuance of the QAI is accomplished by the Quality Assurance Department (QA). QA will also make the final determination of the inspection procedure, required documentation and the approval authority necessary for the various inspection points. A similar process has recently been completed for both the application of 100% solids tank lining coatings and non-skid deck coatings. Repair procedures for damaged coatings will also be incorporated in the governing QAI . The PFP will be top coated with the typical Hanger Bay alkyd finish coat. Maintenance of the coating will be the typical maintenance required for the specific top coat.

## APPENDIX A

### **7.0 Fire Test History**

Previous testing of the Super SP 2001F insulative PFP coating has been performed at VTEC Laboratories with funding from either Superior Products, Inc. or Northrop Grumman Newport News. This is testing consisted of flame spread and heat conduction as follows:

- √ E84 flame spread
- √ E119 Heat conduction.
- √ UL 1709 Heat conduction.
- √ Marine environment corrosion.

The results are presented and discussed below.

### **7.1 E 84 Flame Spread - Superior 2001F PFP Coating**

These results were generated for Superior Products by MES regarding performance of their product prior to initiation of the Newport News study. The test specimen and all procedures conformed to the ASTM E84 " Standard Test Method for Surface Burning Characteristics of Building Materials". The coating had a thickness of 0.100". The results are summarized below in Table 7. These results are considered to be very good to excellent.

TABLE 7.		
Material Description	Flame Spread	Smoke Index
High Density Inorganic	0	0
Red Oak Flooring	100	100
SP 2001F Coating	15	70

### **7.2 ASEM E 119 Heat Conduction - Superior 2001F PFP Coating**

These results were generated prior to initiation of the Newport News study by

MES for Superior Products. The test procedures and specimen size for these tests conformed to ASTM E119 "Standard Test Methods for Fire Tests of Building Construction and Materials". The coating thickness was 0.300 and was applied to a steel plate specimen that was 0.125" thick and 14 square inches. The backside of the steel plate specimen was instrumented with three thermocouples. The results were as follows:

At 70 minutes 50 seconds (> 1 hr.), the temperature, measured at the thermocouple reading the highest temperature, on the backside of the steel plate exceeded 400°F. After 86 minutes 49 seconds, a second thermocouple exceeded 400°F.

Recently a second series of both E 119 and UL1709 tests were completed by VTECH directly for Superior Products. The objective of this more recent testing was to determine the effectiveness of the SP2001F coating to insulate and protect structural members. The metallic backing plate was 14"×14"×0.25" steel. Three coating thicknesses were tested (400, 500 and 600 mils). To simulate the commercial structural fire encapsulation environment, the backside surface (including the three backside thermocouples) was covered with three 1" thick layers of Kaowool insulation to simulate encapsulation (the 400 mil sample was tested without the backside insulation). The 500 and 600 mil thick tests indicate that, for steel structural protection to a maximum temperature of 100°F, SP2001F coating will allow 2 hours of exposure to UL1709 and 3 hours of exposure to E119 as a structural survivability rating. These results are graphically represented in Figures 7& 8 for the E 119 and the UL 1709 tests, respectively.

### **7.3 NNS-MES-VTECH Test Results for UL 1709 Flame Spread - Superior 2001F and ZERO Coatings**

The test hardware, procedures and specimen design conformed to the ASTM E119 standards and the UL1709 temperature profile. The evaluation protocol was according to MIL PERF XX381. The coating thicknesses tested ranged from 200, 250 and 300 mils for the Superior 2001F and 150 & 300mils for the ZERO. The coatings were applied to one face of an aluminum door simulation specimen (Figure 2) with exposed face dimensions of 2'× 3'× 0.625" thick. The backside of the exposed face of each specimen was instrumented with three thermocouples (shown in Figure 2A), which were insulated from the ambient air. Also, thermocouples were placed on the inside face of the opposite side panel. The results of the exposed panel backside temperatures are summarized in the graphs, shown in Figures 9& 10.

After a required 30 minutes of exposure time to the 2000°F average T-T flame curve for UL1709, the maximum and average backside temperatures of the exposed surface that were treated with the insulative coatings did not exceed 400°F at most coating thicknesses. The thicker insulative coatings maintained a backside temperature of 300°F or less. A similar test conducted on the same sample configuration for FF88 intumescent paint supplied by International Fire, survived for only 19 minutes at the 80 mils thickness (14 mins. for 50 mils) before exceeding the 450°F aluminum structural limit.

The results of the Newport News flame spread testing for bare steel, bare and coated aluminum is summarized in Figure 9. Figure 10 shows the test results for the coating thickness evaluation according to MIL PERF XX381 requirements.

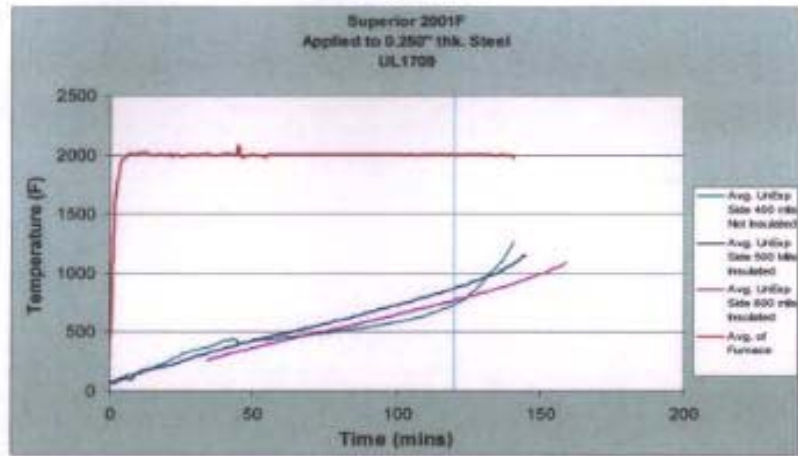


FIGURE 8. Results of Extended Time Exposure to UL 1709 Fire Test.

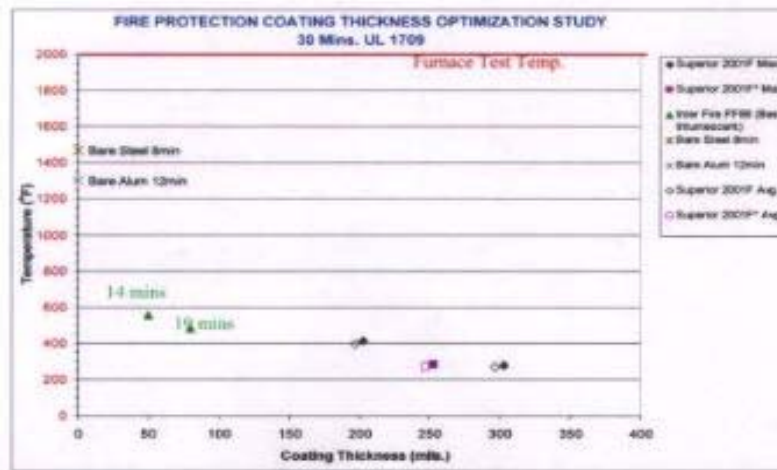


FIGURE 9. Summary of the NGNN/MES/VTECH fire spread testing on bare steel and coated aluminum 2'x3' DIV door test samples using UL 1709 flame temperature of 2000°F.

All thicknesses of both coatings protected the backside of the exposed face against an average temperature rise of 250°F, except the 200 mil SP 2001F, and all thicknesses of both coatings protected against a single maximum temperature rise of 325°F. Based on these results, it is projected that the SP 2001F be applied at 200 mils for the DIV door application and will provide adequate fire protection according to the requirements specified in MIL PERF XX381.

For the fire zone bulkhead (FZB) application on single faced structure, the SP 2001F will most likely have to be applied to both sides. The thickness needed in this application will be different than for the divisional doors. If both sides of a FZB must utilize a coating then further testing will be required to understand the effects of these coatings when applied to both the exposed and the unexposed faces. It may be found that less overall thickness is requirement. However, the testing to-date in our work indicates that the SP 2001F coating will protect a single faced bulkhead across most all ship platforms.

#### **7.4 Superior/VTECH - ASTM B117 Salt Spray (Fog)Testing**

Five steel plates were brush coated with 133 mils of SP 2001F, dried for two weeks, scribed with an "X"(according to ASTM D 1654) and exposed for 2000 hours to 95°F, 5% salt solution, 6.5 - 7.2 pH (according to ASTM B117).

The 5 test panels were not weighed before the start of the test. They were removed from the cabinet and weighed after exposure for 500 and 1000 hours. After 1,000 hours of constant exposure in the salt fog cabinet, panels A, B and C showed a loss of adhesion on the face of the panel. No rust was visible. Panels D and E had no lifting of the coating. After 2,000hours of exposure, all panels showed lifting of the coating on the face of the panels. After 24 hours drying recovery time, the lifting was no longer visible. A few rust spots were visible.

## APPENDIX B

### Results for the Superior 2001 Coating

The results for the Superior coating system are shown in Table IIa below.

TEST	ACCEPTANCE CRITERIA			RESULTS	
Areal Density  Adhesion Tests ASTM D 4541 Pull-Off	Maximum areal density of 1.02 lbs/ft <sup>2</sup>  270psi				
Knife Test MIL-PRF 24596 Impact Tests ASTM D 2794	Difficult to furrow; No flaking or chipping 50 in-lb			No flaking or chipping; simple indentation only Tests to 50 in-lb showed only small indent; no flaking or spalling observed	
Flame Spread ASTM E 162[14] Smoke Generation E 662[15]	Index not greater than 25  Not greater than 200			Average Index 14.3 Maximum Index 15.79 Flaming                      Non-Flaming 149    60	
Heat Release, kW/m <sup>2</sup> ASTM E 1354	Heat Flux	Peak	Avg.	Peak	Avg. 300s
	25	50	300s	67.6	24.39
	50	65	50	97.55	31.9
	75	100	50	81.68	24.3
			100		
Ignitability ASTM E 1354	Heat Flux	Time to Ign,s		Heat Flux	Time to Ign,s
	25	300		25	61
	50	150		50	33
	75	90		75	17
TGA - FTIR	No super toxins			No matches to known toxic gases or toxins	
Cone Test 10kW/m <sup>2</sup> + 35kW/m <sup>2</sup>	10kW/m <sup>2</sup> for 5min + 35kW/m <sup>2</sup>			Peak Heat Flux 78.9	Avg/ 300s 17.5

(Table IIa. Results for Test matrix for Superior Coating)

In all categories the performance of this coating system was found to be excellent, except with respect to " time to sustained flaming ". However it should be noted that this may, in fact be an artifact of the E 1354 test procedure, and may not reflect a tendency for the coating to present a problem with respect to promoting fire. These coatings react to heat so as to produce "chars" which are themselves protective. The flaming observed is modest and lasts only for one minute or so followed by complete self extinction of all flame. The heat release rates are, as can be noted from Table IIa, quite modest and well below the respective acceptance criteria.

## APPENDIX C

### From NAVSEA 05L

Factors to be considered in applying coatings and intumescent (in addition to passing the fire performance test criteria) for aluminum marine applications

- A. Long term testing is required which encompasses temperature and humidity cycling to determine time durability.
- B. Past studies by NAVY laboratories indicated intumescent paints do not react under all fire conditions. We seek a test where a sample is subjected to a heat buildup to 300 degrees F (or whatever temperature is about 50 deg less than the temp required to intumesce), be held at that for one hour, be subjected to a fire exposure, and evaluated for performance as advertised.
- C. Has testing been done to identify the expected life relative to the intumescent chemistry. That is, for how many years after application, will the paint continue to perform as advertised? Shelf life also needs to be established.
- D. Adhesive stability must be demonstrated. At the proposed mil thickness plus a TBD QA allowable excess, there must be no loss of coating or adhesion due to a shock blow applied to the opposite side of the bulkhead. Also, at the design application thickness plus QA excess, will the coating peel or flake under its own weight?
- E. Overcoating. Provide technical test data to verify that TBD overcoats of standard paints will not impede the coatings ability to effectively intumesce and protect.
- F. An evaluation of coating removal, damage, or other loss of effectiveness is required relative to exposure to shipboard cleaners and hydrocarbons.
- G. Can tell-tales be identified to indicate "damage" to the intumescent coat (such as a color change)? Can tell-tales be identified to verify that coatings/intumescent are present on a bulkhead?
- H. What is the stability of the coating after it has intumesced? Consider that a fire exposure could reasonably last longer than one hour. Does the coating begin to flake/peel off at some point, is there a time decline in insulating capability, would being hit with a fire hose stream remove the char layer? Would a shock event remove the char layer?
- I. What is the shipyard quality assurance plan for the application process and resultant mil thickness verification? What are the life-of-ship monitoring and maintenance procedures as required by contract?