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Feasibility Study on Fire Suppression Properties of the Sandia Decon Foam

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Feasibility Study on Fire Suppression Properties of the Sandia Decon Foam

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ABSTRACT

A non-toxic, non-corrosive aqueous foam with enhanced physical stability for the rapid mitigation and decontamination of CBW agents has been developed at Sandia. This technology is attractive for the protection of the Nuclear Weapons facilities as well as for civilian and military applications for several reasons including 1) it requires minimal logistics support, 2) a single decon solution can be used for both CW and BW agents, 3) mitigation of agents can be accomplished in bulk, aerosol, and vapor phases, 4) it can be deployed rapidly, 5) it exhibits minimal health and collateral damage, 6) it is relatively inexpensive, and 7) it has minimal run-off of fluids and no lasting environmental impact. A range of methods including systems that yield desirable properties for fire suppression foams can deliver the foam.

Although the foam's effectiveness against CBW agents is well established, the additional capability of being used for fire suppression would provide a dual-use capability. If the foam can suppress and control fires, it could lead to a significant enhancement to the level of protection for critical nuclear weapon facilities in that existing foam-based fire suppression systems could now provide the additional protection of decontamination and CBW agent removal.

Fire suppression properties of the foam were investigated with the assistance of Southwest Research Institute Department of Fire Technology in conjunction with EnviroFoam Technologies, Inc., a technology licensee.

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The Sandia National Laboratories Laboratory Directed Research and Development for support of this work under project number 01-1430.

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EXECUTIVE SUMMARY

A non-toxic, non-corrosive aqueous foam with enhanced physical stability for the rapid mitigation and decontamination of CBW agents has been developed at Sandia. This technology is attractive for the protection of the Nuclear Weapons facilities as well as for civilian and military applications for several reasons including 1) it requires minimal logistics support, 2) a single decon solution can be used for both CW and BW agents, 3) mitigation of agents can be accomplished in bulk, aerosol, and vapor phases, 4) it can be deployed rapidly, 5) it exhibits minimal health and collateral damage, 6) it is relatively inexpensive, and 7) it has minimal run-off of fluids and no lasting environmental impact. A range of methods including systems that yield desirable properties for fire suppression foams can deliver the foam.

Although the foam's effectiveness against CBW agents is well established, the additional capability of being used for fire suppression would provide a dual-use capability. If the foam can suppress and control fires, it could lead to a significant enhancement to the level of protection for critical nuclear weapon facilities in that existing foam-based fire suppression systems could now provide the additional protection of decontamination and CBW agent removal.

Fire suppression properties of the foam were investigated with the assistance of Southwest Research Institute Department of Fire Technology in conjunction with Envirofoam Technologies, Inc., a technology licensee. The objectives of the research were:

Investigate the fire suppression capability of the Sandia Formulation against Class A fires (ordinary combustibles such as wood, paper, and trash) using controlled fires.

Investigate the fire suppression capability of the Sandia Formulation against Class B fires (flammable and combustible liquids such as gasoline, solvent, and grease) using controlled fires.

Two versions of the foam based on the Sandia formulation were tested:
Formulation prepared at Sandia National Laboratories (DF-100)
A formulation prepared by Sandia's licensee, EnviroFoam Technologies. This formulation was the commercial equivalent of the Sandia prepared formulation plus it had an added surfactant used in fire-fighting foam.

The Class A fires were conducted according to ASTM Standards D4442-92. The Class A tests are conducted on wood-cribs. The cribs are constructed of interlocking 2 by 4 kiln-dried spruce or fir lumber. The wood cribs are ignited using a 2-minute burn of commercial grade heptane. The cribs are allowed to burn for at least 8 minutes prior to attempts to extinguish the fire.

Five Class A fire tests were conducted:
2 ea Crib 20-A (162 wood members)
1 ea Crib 30-A (192 wood members)
2 ea Crib 40-A (224 wood members)
Both formulations are effective in extinguishing the Class A fires.

Two Class B fire tests were conducted. Neither the Sandia nor the EnviroFoam specially prepared formulation was effective against the Class B fire. Extinguishing of Class B fires is important because terrorists use petroleum product as accelerants EnviroFoam has identified a nontoxic surfactant that claims to be effective against both Class A and Class B fires. Future work includes addition of this surfactant to the Sandia formulation and testing for CBW and fire suppression capability.

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1.0 TEST UNIT

An EasyCAFS foam generating unit was provided by EnviroFoam Technologies. The unit consists of a 250-gal water reservoir with a 10-gal (approximate) foam concentrate reservoir. A diesel-driven CAF pump is mounted atop the reservoirs. The variable-speed pump was throttled to deliver the desired foam flow rate, while a concentrate proportioning valve and solution/air metering valve controlled the concentration and aeration of the solution, respectively. The unit was filled with water and foam concentrate, and flow settings were verified prior to testing.

The foam agent was discharged through a 1.5-in. fire hose with a smooth-taper, 1-in. nozzle, manufactured by Task Force Tips, Inc. (Part No. KKF-320543).

Two types of foam concentrate were used in the testing. The concentrates evaluated were:

- "EFT Easy Decon 25 Penetrator D25F3" (pre-mix)
- "Sandia" decontamination foam (consisting of a 50% solution [Part I] and a 7.99% hydrogen peroxide mixture [Part II].

The foam concentrate and flow rate were verified prior to each test. Foam Concentration was maintained by setting the proportioning valve on the flow unit prior to testing and checking the foam concentration using a refractometer. The target flow rate of 2 gpm was maintained by careful control of the pump speed.

2.0 CLASS A TEST PROCEDURE (UL 711)

A series of extinguishment tests was conducted in accordance with Section 5.2 of the UL 711 Standard. These tests covered Class A wood cribs ranging from a 20A size to a 40A size. The descriptions of the cribs used are provided in Table 1.

The Easy CAFS unit was set to produce a fire fighting foam using U.S. Foam First Strike AFFF. These settings were used in the Class A fire suppression tests using the two types of foam concentrate.

Table 1. UL 711 Crib Descriptions.

CLASS	DIMENSIONS (IN.) L X W X H	NUMBER OF 2X4 BOARDS	HEPTANE CHARGE (GAL)	STARTER PAN DIMENSIONS (IN.)
20A	62 x 62 x 22.5	160	7.5	54 x 54
30A	75 x 75 x 27	192	10	66 x 66
40A	87 x 87 x 31.5	224	13	76 x 76

Each crib is supported 32 in. above the notional floor level. A properly sized pan is placed beneath the crib, and the appropriate heptane starter charge is poured into the pan. The heptane charge is ignited and allowed to ignite the wood crib above. The heptane charge lasts approximately 2 min, by which time the wood crib has been ignited and is self-sustaining. The wood crib is allowed to pre-burn for a period of 6-7 min, allowing sufficient time for the fire to become well seated within the crib. During the pre-burn, the heptane charge duration, crib flame height, and degree of involvement are documented. Extinguishment can commence once it has been determined that the crib is fully involved.

The attack is made from the front and sides of the crib at a distance of not less than 6 ft. In general, a systematic side-to-side and top-to-bottom spray pattern is employed. The time to control and extinguishment is documented. The crib is observed for an additional 5 min following extinguishment to assess re-flash potential.

3.0 TEST RESULTS

Class A testing was conducted at the Southwest Research Institute Department of Fire Technology's High-Bay Test Facility. Testing was witnessed by Ms. Cecelia Williams, representing, Sandia National Laboratories, Mr. James Morand, representing EnviroFoam Technologies, and Mr. William Hall, representing SwRI's Listing, Labeling, and Follow-Up Inspection Section.

Complete photographic and video documentation accompany this report. Representative photographs of each test are presented as Attachment A to this report.

3.1 Class 20A Testing

Class 20A testing was conducted on September 24, 2001. The unit was charged with approximately 5 gal of the Sandia prepared formulation foam concentrate. The unit was functionally tested and the refractive index of the mixed foam was measured. The refractive index was indicative of a 1-2% foam concentration.

The test chamber was closed with the exception of a small opening at the base of a 16-ft door, provided for ventilation. The wood crib was ignited using a 7.5-gal charge of heptane. Once lit, the heptane charge burned for 1 min 35 sec. The fully involved crib produced flame heights in excess of 20 ft during the pre-burn period. Flames were allowed to engulf all sides of the test crib prior to extinguishment. Test observations are provided in Table 2.

Table 2. Class 20A Wood Crib Test Observations.

TIME	OBSERVATION
0:00	Heptane charge is ignited
1:35	Heptane charge burns out. Crib is successfully ignited.
6:10	Initial attack made from front of crib and alternated to sides of crib as necessary.
6:40	Surface burning on crib is extinguished; however, continued burning within crib members is observed.
7:25	Initial attack stopped. Crib monitored.
8:30	Extinguishment resumes, directed to a deep-seated fire on the left side of the crib.
9:00	Extinguishment of left side stopped.
9:10	Light extinguishment (~15 sec) directed towards the right side of the crib.
9:50	Light extinguishment (~15 sec) directed towards the right side of the crib.
10:05	Attack stopped. Crib appears extinguished.
15:05	Crib investigated and confirmed extinguished without re-ignition.

An estimated 60 gal of suppression water and foam were used, yielding an equivalent discharge rate of 25-30 gal/min. The foam concentration, measured at the conclusion of the test, was consistent with readings for 1-2% concentration.

3.2 Class 30A Testing

Class 30A testing was conducted on September 24, 2001. The unit was charged with approximately 5 gal of the *U.S. First Strike*, Class A liquid foam concentrate. The unit was functionally

tested and the refractive index of the mixed foam was measured. The refractive index was indicative of a 1-2% foam concentration.

The wood crib was ignited using a 10-gal charge of heptane. Once lit, the heptane charge burned for 2 min 10 sec. The fully involved crib produced flame heights in excess of 30 ft during the pre-burn period. Flames were allowed to engulf all sides of the test crib prior to extinguishment. Test observations are provided in Table 3.

Table 3. Class 30A Wood Crib Test Observations.

TIME	OBSERVATION
0:00	Heptane charge is ignited
2:10	Heptane charge burns out. Crib is successfully ignited.
6:15	Initial attack made from front of crib and alternated to sides of crib as necessary.
7:05	Surface burning on crib is extinguished; however, continued burning within crib members is observed.
9:50	Initial attack stopped. Crib monitored.
12:40	Extinguishment resumes, directed towards a deep-seated fire on the right side of the crib.
13:30	Attack stopped. Crib appears extinguished.
19:00	Crib investigated and confirmed extinguished without re-ignition.

An estimated 160 gal of suppression water and foam were used, yielding an equivalent discharge rate of approximately 30-35 gal/min. The foam concentration, measured at the conclusion of the test, was consistent with readings for 1-2% concentration. The foam concentrate reservoir was measured, and approximately 2 gal of concentrate were consumed, verifying the measured concentration.

3.3 Class 40A Testing

Class 40A testing was conducted on September 24, 2001. The unit was charged with approximately 5 gal of the "*U.S. First Strike*," Class A liquid foam concentrate. The unit was functionally tested and the refractive index of the mixed foam was measured. The refractive index was indicative of a 1-2% foam concentration.

The test chamber was closed with the exception of a small opening at the base of a 16-ft door provided for ventilation. The wood crib was ignited using a 5-gal charge of heptane. Once lit, the heptane charge burned for 2 min 4 sec. The fully involved crib produced flame heights in excess of 38 ft (maximum ceiling height) during the pre-burn period. Flames were allowed to engulf all sides of the test crib prior to extinguishment. Test observations are provided in Table 4.

Table 4. Class 40A Wood Crib Test Observations.

Time	Observation
0:00	Heptane charge is ignited
2:04	Heptane charge burns out. Crib is successfully ignited.
7:00	Initial attack made from front of crib and alternated to sides of crib as necessary.
10:10	Surface burning on crib is extinguished; however, continued burning within crib members is observed.
13:40	Initial attack stopped. Crib appears extinguished.
20:10	Crib investigated and confirmed extinguished without re-ignition.

The effective flow rate was not measured at the conclusion of the test. Assuming a 30-35 gpm flow rate, the amount of solution consumed would have been on the order of 200-230 gal. The foam concentration, measured at the conclusion of the test, was consistent with readings for a 1-2% concentration.

3.4 Class 40A Repeatability Testing

The Class 40A wood crib extinguishment test was replicated on September 25, 2001, to demonstrate the repeatability of the system. The "U.S. First Strike" agent was used at the same concentration (1-2%) as previous testing.

Once lit, the heptane charge burned for 2 min 20 sec. The fully involved crib again produced flame heights in excess of 38 ft (maximum ceiling height) during the pre-burn period. Flames were allowed to engulf all sides of the test crib prior to extinguishment. Test observations are provided in Table 5.

Table 5. Class 40A Repeatability Test Observations.

TIME	OBSERVATION
0:00	Heptane charge is ignited
2:20	Heptane charge burns out. Crib is successfully ignited.
7:05	Initial attack made from front of crib and alternated to sides of crib as necessary.
9:20	Surface burning on crib is extinguished; however, continued burning within crib members is observed.
12:40	Initial attack stopped. Crib appears to be extinguished.
14:10	Attack resumed, directed at the right side, front, and left side of the crib.
17:10	Attack stopped. Crib appears extinguished.
21:10	Crib investigated and confirmed extinguished without re-ignition.

The effective flow rate was not measured at the conclusion of the test. The foam concentration, measured at the conclusion of the test, was consistent with readings for a 1-2% concentration.

4.0 CLASS A FIRE TEST CONCLUSIONS

The EnviroFoam Technologies' EasyCAFS System was evaluated in conjunction with two distinct foam concentrates. The Sandia formulation foam, at a 1-2% concentration, was successful at extinguishing a Class 20A wood crib. The *U.S. First Strike* foam, at a 1-2% concentration, was successful at extinguishing a Class 30A wood crib. The *U.S. First Strike* foam also demonstrated repeated ability to extinguish Class 40A fires when used at 1-2% concentration.

5.0 CLASS B TEST PROCEDURE (UL 162)

A series of extinguishment tests was conducted in accordance with Section 10 of the UL Standard. These tests covered a series of Class B flammable liquid pool fire tests. The East CAFS unit was set to produce a fire fighting foam using U.S. Foam First Strike AFFF. These settings were used in the Class B fire suppression tests.

5.1 Class B Pool Fire Test

Class B pool fire tests were conducted indoors using a standard, 50-ft^2 (7 x 7 ft) pan. The pan was designed per Section 10.3 of the Standard. A 2-in. depth of heptane was poured over a layer of water, leaving a freeboard distance of 6 in. in the pan. The pan was ignited and allowed to burn for a period of one min before extinguishment was attempted.

5.1.1 Extinguishment Test

Agent was dispensed at a rate of 2 gpm (0.04 gpm/ft^2) for a total of 3 min (from Table 10.1 of the Standard, referring to AFFF agents). Agent was dispensed against the back wall of the fire pan and allowed to flow freely over the surface. Only slight lateral motion was used to disperse the foam blanket. The time to extinguishment of the fuel surface was noted.

5.1.2 Re-ignition Test

Re-ignition testing was conducted at intervals following the initial fire suppression test. A lighted torch was passed over the surface of the foam blanket in an attempt to ignite fugitive vapors permeating through the foam. Incidences of flashing, candling, and sustained re-ignition were noted. The re-ignition test was conducted 9 min after the initial suppression.

5.1.3 Stovepipe Test

A stovepipe is lowered into a corner of the foam blanket and the foam is removed from the area inside the stovepipe. The exposed surface is ignited and allowed to burn for a period of 1 min. The stovepipe is removed and the flames initiated at the center of the stovepipe are monitored for further growth or subsequent extinguishment from the foam blanket. The flames should be limited to the area of the stovepipe for the next 5 min.

The successful completion of all three phases of the test would demonstrate an agent's compliance with UL 162 for Class B fire tests, topside discharge.

6.0 CLASS B TEST RESULTS

Testing was conducted on September 24 and 25, 2001, at the Southwest Research Institute's Department of Fire Technology's High-Bay Test Facility, in San Antonio, Texas. Testing was witnessed by Ms. Cecelia Williams, Mr. James Morand, representing EnviroFoam Technologies, and Mr. William Hall, representing SwRI's Listing, Labeling, and Follow-Up Inspection Section.

Complete photographic and video documentation accompany this report. Representative photographs of each test are presented in Attachment b to this report.

6.1 Test 1

Test 1 was conducted on September 24, 2001, and evaluated the delivery of *EFT Easy Decon 25 Penetrator D25F3* onto the Class B fire source. The unit was cleaned and charged with the appropriate test agent. Flow rates and concentrations were verified. The pan was fueled, ignited, and allowed to pre-burn for a period of 1 min.

The pump was brought up to delivery speed, and foam was applied to the fuel surface. A summary of the suppression test results is provided in Table 6.

Table 6. Test 1 Observations.

TIME	OBSERVATION
0:00	Heptane pool fire is ignited.
1:00	Extinguishment commences. A 2-gpm flow is delivered to the burning fuel surface. Attack is made from front of pan in a side-to-side motion.
2:30	Flames not retreating.
4:00	Extinguishment terminated after 3 min of foam application. Flames not extinguished. Flames subsequently attacked using supplemental fire extinguishment.
8:30	Flames extinguished.
8:30+	Pan is monitored for some time following extinguishment. Foam blanket deteriorates within 10 min following suppression efforts. Fuel surface is exposed and represents an ignition hazard.

6.2 Test 2

Test 2 was conducted on September 25, 2001, and evaluated the delivery of Sandia formulation onto the Class B fire source. The unit was cleaned and charged with the appropriate test agent. Flow rates and concentrations were verified. The pan was fueled, ignited, and allowed to pre-burn for a period of 1 min.

The pump was brought up to delivery speed, and foam was applied to the fuel surface. A summary of the suppression test results is provided in Table 7.

Table 7. Test 2 Observations.

TIME	OBSERVATION
0:00	Heptane pool fire is ignited.
1:00	Extinguishment commences. A 2-gpm flow is delivered to the burning fuel surface. Attack is made from front of pan in a side-to-side motion.
2:30	Flames not retreating.
4:00	Extinguishment terminated after 3 min of foam application. Flames not extinguished.
4:30	EasyCAFS unit brought to higher rpm (flow rate) and extinguishment is resumed.
5:50	Flames extinguished.
5:50+	Pan is monitored for some time following extinguishment. Foam blanket deteriorates at a similar rate to Test 1, indicating potential problems with re-flash hazards.

7.0 CLASS B FIRE TEST CONCLUSIONS

The agents evaluated were not capable of extinguishing the prescribed, Class B fires in accordance with UL 162. In general, some degree of incompatibility and chemical attack was observed between the heptane fuel and the delivered foam. This attack led to deterioration of the foam during suppression efforts and shortly after suppression efforts were terminated.

APPENDIX A - CLASS A FIRE TESTING

PHOTOGRAPHIC DOCUMENTATION

Figure A-1. "U.S. First Strike" Foam Concentrate.
A firefighting foam (AFFF) used to set the Easy CAFS unit prior to use with the DF-100

Figure A-2. "DF-100" Foam Concentrate Components (2 Parts).

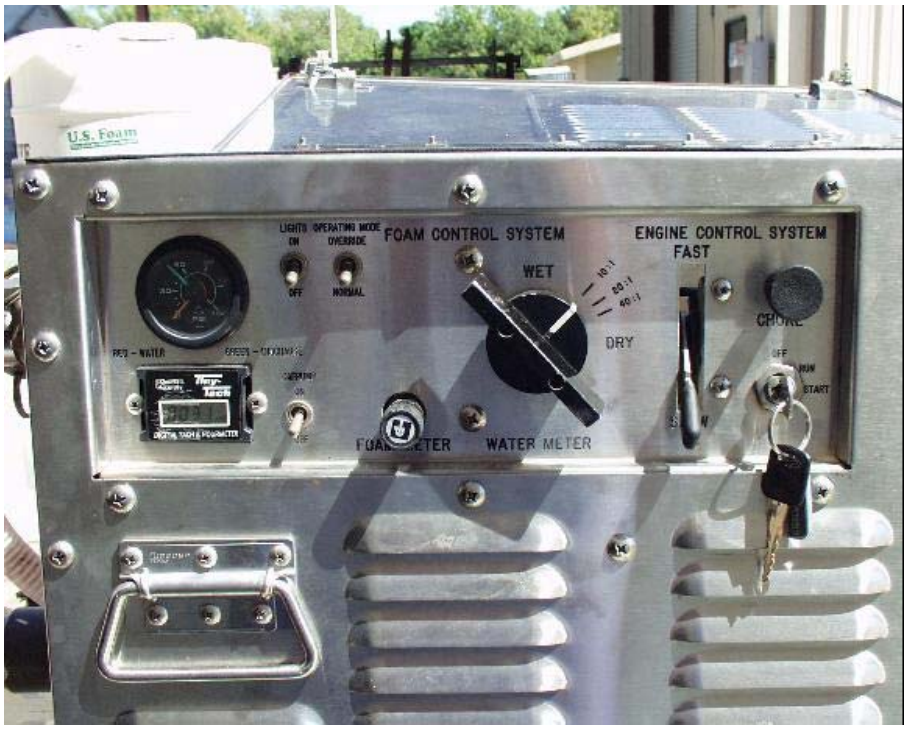

Figure A-3. EasyCAFS Console Settings for Class A and B Testing.

Figure A-4. "Task Force" Selectable Nozzle.

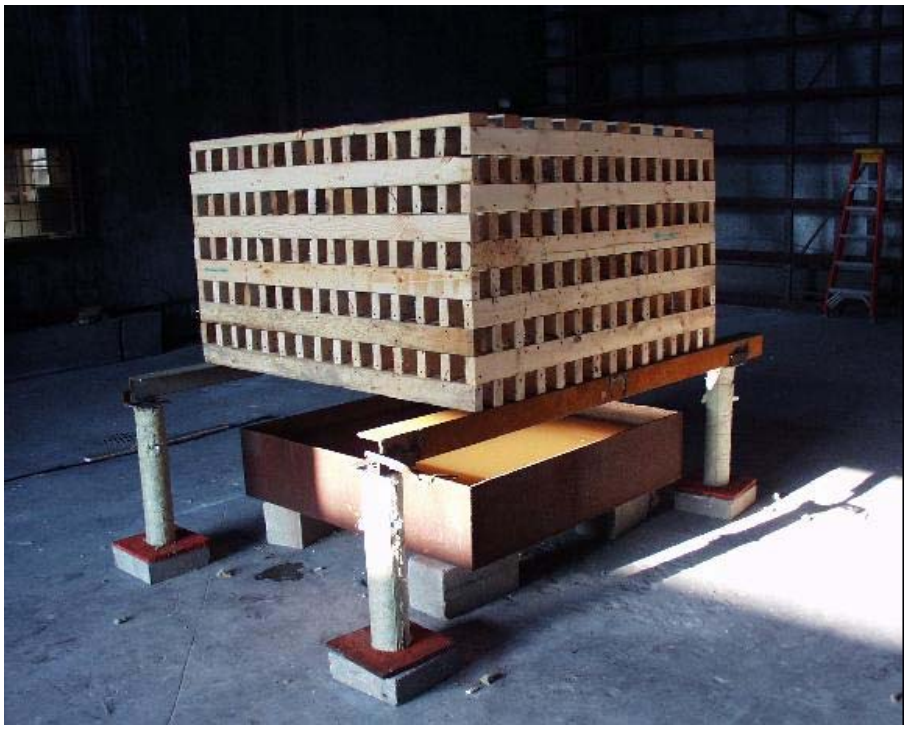

Figure A-5. Class 20A - Wood Crib Fire Test Setup.

Figure A-6. Class 20A - Wood Crib During Pre-Burn Period (Heptane Charge Out).

Figure A-7. Class 20A - Wood Crib Following Extinguishment.

Figure A-8. Class 30A - Wood Crib Fire Test Setup.

Figure A-9. Class 30A - Wood Crib During Pre-burn Period (Heptane Charge Burning).

Figure A-10. Class 30A - Wood Crib Following Extinguishment.

Figure A-11. Class 40A - Wood Crib Fire Test Setup.

Figure A-12. Class 40A - Wood Crib Fire Test During Preburn (Heptane Charge Burning).

Figure A-13. Class 40A - Wood Crib Following Extinguishment.

Figure A-14. Class 40A Repeat Test

APPENDIX B - UL 162-CLASS B FIRE TEST

PHOTOGRAPHIC DOCUMENTATION

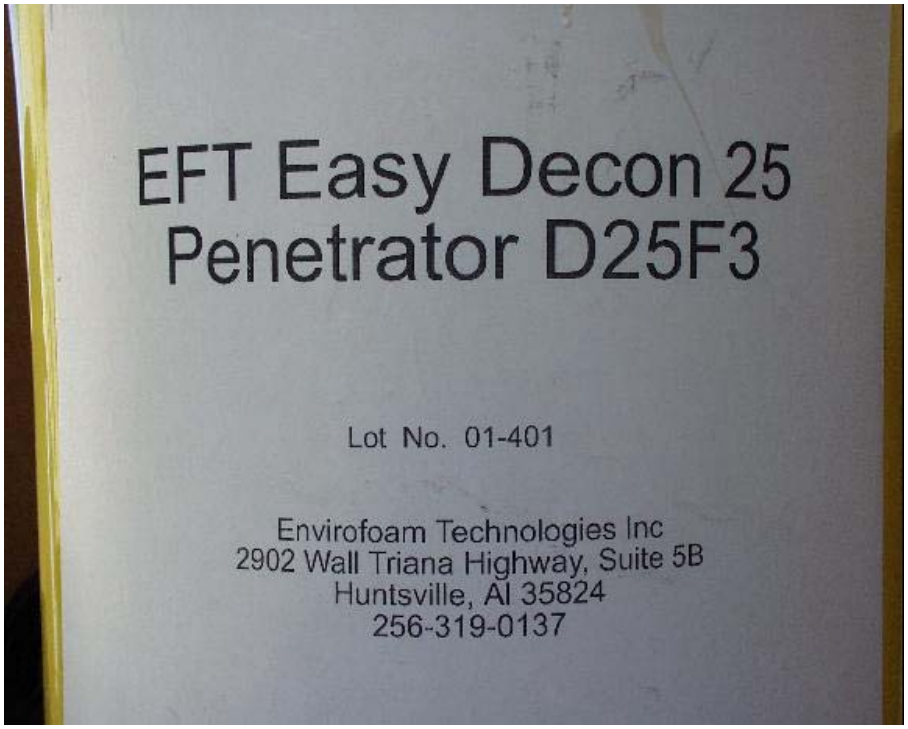

Figure B-1. "EFT Easy Decon 25" Agent Label.

Figure B-2. "DF-100" Foam Concentrate Components (2 Parts).

Figure B-3. UL 162 Containment Pan (7 x 7 ft with Backboard).

Figure B-4. UL 162 Fire (Preburn).

Figure B-5. UL 162 Test in Progress

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