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Superseding AIR4170B

Reticulated Polyurethane Foam
Explosion Suppression Material for
Fuel Systems and Dry Bays

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

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Documents

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1. SCOPE

This document describes the initial development, evolution, and use of reticulated polyurethane foam as an explosion suppression material in fuel tanks and dry bays. It provides historical data, design practice guidelines, references, laboratory test data, and service data gained from past experience.

The products discussed in this document may be referred to as "Safety Foam," "Reticulated Polyurethane Foam," "Baffle and Inerting Material," or "Electrostatic Suppression Material." These generic terms for the products discussed in this document are not meant to imply any safety warranty. Each individual design application should be thoroughly proof tested prior to production installation.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

NOTE: In this Applicable Documents Section, not all publications listed are referenced in this document. The intent of this expanded list of documents is to maintain a composite listing of all known documents that are pertinent to the subject discussed in this document. Therefore, all documents in this section preceded by an asterisk (*) indicates that the specific document in the reference section is not referenced within this document, but is technical information to assist those using the document for the design, fabrication, testing, installation and maintenance of foam for inerting fuel tanks.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- *AIR1662 Minimization of Electrostatic Hazards in Aircraft Fuel Systems
- *AIR1664 Aircraft Flexible Tanks - General Design and Installation Recommendations
- *AIR 5691 Guidance for the Design and Installation of Fuel Quantity Indicating Systems

2.1.2 Air Force Publications

Available from Defense Technical Information Center, 8725 John J Kingman Road, Fort Belvoir, VA 22060. NOTE: Some of these documents may be available for download from www.dtic.mil/dtic/

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|--------------------------------|---|
| Report No. 1819 (20 May 1966) | Development and Testing of Cellular Packing Material, written by Firestone Coated Fabrics Co. under Air Force Contract No. AF33(615)-3423 |
| *ASJ-TM-66-1 (November 1966) | Investigation of Polyurethane Foam for Aircraft Fuel System Applications |
| *RPL-TDR-64-25 (November 1968) | Aerospace Fluid Component Designers Handbook |
| *ASNJI-70-2 (May 1970) | USAF Experience with Polyurethane Foam Inerting Material |
| *ENJI-70-10 (November 1970) | Effects of Polyurethane Foam on Fuel System Contamination |

*ENJPF-TM-72-1 (March 1972)	The Use of Polyurethane Foam for Fuel System Inerting (Unpublished Report)
*AFAPL-TR-72-12 (March 1972)	Advanced Flame Arrestor Materials and Techniques for Fuel Tank Protection
*AFAPL-TR-73-50 (July 1973)	Incendiary Gunfire Simulation Techniques for Fuel Tank Explosion Protection Testing
*AFML-TR-73-283 (December 1973)	Environmental Aging of Candidate for Suppressant Dry Bay Area Materials for Aircraft
*AFAPL-TR-73-76 (December 1973)	Vulnerability Assessment of JP-4 and JP-8 Under Verticle Gunfire Impact Conditions
*AFML-TR-73-278 (January 1974)	A Method to Predict the Service Life of Internal Fuel Cell Baffle Materials
AFAPL-TR-73-124 (February 1974)	Gross Voided Flame Arrestors for Fuel Tank Explosion Protection
*ASD-TR-74-34 (September 1974)	Gunfire Effectiveness and Environmental Suitability of Void Filler Materials
AFAPL-TR-74-126 (July 1975)	Void Filler Ballistic Fire Protection for Aircraft Fuel System Dry Bays
AFAPL-TR-75-93 (July 1975)	Integrated Aircraft Fuel Tank Fire and Explosion Protection Systems Phase I and II
*AFFDL-TR-76-98 (January 1978)	Ballistic Evaluation of Aircraft Explosion Suppression Materials
*AFAPL-TR-78-89 (December 1978)	Factors Affecting Electrostatic Hazards
ENFEF-TM-78-08 (June 1979)	Guidelines for Use in Design, Fabrication, Installation and Testing of Reticulated Foam Kits
*Bulletin 4-9 Part 1 (September 1979)	The Shock and Vibration Bulletin. A publication of The Shock and Vibration Information Center, Naval Research Laboratory, Washington, D.C.
*ENFEF-TM-79-08 (December 1979)	Qualification Test Results for Scott Paper Co., Blue Hybrid Polyether Foam
AFWAL-TR-80-4135 (September 1980)	Compatibility of Reticulated Foams in Typical Turbine Fuels with Currently Approved Additives
*Memorandum Report (February 1983)	Hydrodynamic Ram Attenuation ARBRL-MR-03246
*Letter report (14 June 1983)	C-130 Fuel Tank Shroud Electrostatic Evaluation, Summary of Results (POSH) Dept. of the Air Force Wright-Patterson AFB
*Final Report (September 30, 1981)	A-10A Fuel Tank Vent System, Vapor Ignition Investigation
AFWAL-TR-83-3114 (September 1983)	Survivable Aircraft Fuel System Engineering Design Guide (SAFE/DG)
AFWAL-TM-84-237-FIESL (December 1984)	A Comparison of White Reticulated Foam to Rigid Foam as Fire Protection for Aircraft Dry Bays
*AFWAL-TR-84-2048 (December 1984)	Damage Caused to Polyurethane Foams by Aging, Simulated Sunlight Exposure, Heat and Fire

*AFWAL-TM-85-237-FIESL (September 1985)	A Comparison of Electric Field Measurements on Conductive and Nonconductive Explosion Suppressant Foams in C-130 External Fuel Tanks
*AFWAL-TR-85-2060 (January 1986)	Vulnerability Methodology and Protective Measures for Aircraft Fire and Explosion Hazards
*AFWAL-TR-82-2022 (March 1986)	Electrostatic Hazards of Urethane Packed Fuel Tanks
*86-MMSRE-011 (12 May 1986)	Baffle and Inerting, Conductive, Aircraft Fuel Tank
*AFWAL-TR-86-2077 (November 1986)	Study of Aeropropulsion Lab Pressure Drop Rig and Recommended Test Procedure
ESL-TR-84-63 (January 1987)	Effective Disposal of Fuel Cell Polyurethane Foam
TE-ENFE-86-1 (1 Nov. 1987)	Electrically Conductive Explosion Suppression Material, General Exhibit for
*MS-MMSR-87-100 (12 Sept. 1988)	A-10 Aircraft Electrically Conductive Explosion Suppression Material, Material Specification for
*USAAVSCOM TR 89-D-16 (February 1990)	Aircraft Fuel System Fire and Explosion Suppression Design Guide
WRDC-TR-90-4074 (28 Sept. 1990)	Foam, Explosion Suppressant, Thermal Resistance Electrical Conductivity, High Temperature
AFRL-PR-WP-TR-2000-2015 (October 2001)	Fuel and Fuel System Materials Compatibility Test Program for a JP-8 +100 Fuel Additive

2.1.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

ARAC FTHWG Final Report (July 1998)	Aviation Rulemaking Advisory Committee – Fuel Tank Harmonization Working Group Final Report
FAA-1999-6411, SFAR 88 (09 Dec. 2002)	Fuel Tank System Fault Tolerance Evaluation Requirements
AC 25.981-1C (19 Sept. 2008)	Fuel Tank Ignition Source Prevention Guidelines
AC 25.981-2A (19 Sept. 2008)	Fuel Tank Flammability Reduction Means
AC 120-98A (22 June 2012)	Operator Information for Incorporating Fuel Tank Flammability Reduction Requirements into a Maintenance or Inspection Program

2.1.4 Military Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

A-A-3174	Plastic Sheet, Polyolefin
A-A-208	Ink, Marking, Stencil, Opaque
MIL-PRF-81705	Barrier Materials, Flexible, Electrostatic - Free, Heat Sealable
*MIL-DTL-27422F (6 Feb. 2014)	Tank, Fuel, Crash Resistant, Aircraft (Non-Self-Sealing and Self-Sealing)

MIL-DTL-83054 C (20 October 2003)	Baffle and Inerting Material, Aircraft Fuel Tank
*JSSG-2009	Air Vehicle Subsystems
MIL-PRF-87260 B (2 November 2006)	Foam Material, Explosion Suppression, Inherently Electrically Conductive, for Aircraft Fuel Tank and Dry Bay Areas
MIL-DTL-5578	Tank, Fuel, Aircraft, Self-sealing
MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-DTL-6396	Tank Aircraft Propulsion Fluid Systems, Internal, Removable, Nonsealing
MIL-DTL-83133	Turbine Fuel, Aviation, Grade JP-8
MIL-STD-129	Markings for Shipment and Storage

2.1.5 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D2276-73	Test Methods for Particulate Contamination in Aviation Turbine Fuels
ASTM D910	Gasolines, Aviation
*ASTM D1655	Specification for Aviation Turbine Fuels
*ASTM D3574	Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams

2.1.6 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

*71-GT-54	Effects of Polyurethane Foam on Fuel System Contamination
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2.2 Applicable Films

Ounces of Protection, Firestone, circa 1960	Firestone accepted the challenge from the auto racing industry to develop safer fuel systems for racing cars. Adaption of flexible bladder used in aircraft to racing cars using foam as the baffling system to attenuate slosh.
Polyurethane Foam for Explosion Suppression Air Force - Color/Sound 7 min	Explains use of reticulated polyurethane foam and how it is installed: making, cutting, and stuffing. Shows C-123, RB-57 "Canberra," F-105 "Thunderchief," C-130 and AC-130 "Gunship 2." Shows stuffing wet wing in C-130, toughest type of installation due to intricacy of plumbing in C-130.
Crashworthy Integral Fuel Cells, Photographic Instrumentation Data Film, Color/No Sound 12 min	Compares fuel spread of dropped (ruptured) tip tank with fuel only and then with fuel and foam inside.

The Unseen Storm, Firestone Tire & Rubber Co., circa 1970 16MM/10 min/Color/ Sound	Deals with suppressing surge and slosh in fuel tanks, specifically in competitive racing speed boats.
Survivability, Enhancement Through Aircraft Design T.O. Reed ASD/ENFEF May 1979 Copy #6 Unclassified, 16MM/20 min/Color/ Sound	Approximately middle of film deals with fuel tank protection with foam and dry bay protection with foam.
Fairchild A-10 Gunfire Film, Air Force Flight Dynamics Laboratory, 1973/16MM/Color/Sound/ 10 min	Deals with survivability testing of A-9 and A-10 by the Air Force after the GOA determined that the craft had a low level of survivability. Foam was not designed into the fuel cells because the Air Force had no test results supporting it. So the Air Force conducted a 20-month evaluation of evaluation of the fuel system survivability using external dry bay rigid foam and internal Safety Foam.
Firestone, US News Release, circa 1965 16MM/Color/No Sound/ 2 min	Firestone brochure and intro to reticulated polyurethane foam with surge demo and explosion suppression demo.
Wing Foam Test, circa 1989	VHS Tape, 10 min John F. Barnes, Engineering Branch Naval Weapons Center China Lake, CA 93555

2.3 Definitions

RETICULATED POLYURETHANE FOAM: Low density flexible urethane foams characterized by a three-dimensional skeletal structure of interconnected strands with few or no membranes between the strands, containing up to 97% or more of void space.

IN SITU: In natural order - a foam that has a conductive additive included in the chemical foam formulation prior to blowing and curing.

HYDROLYTIC STABILITY: The foam's ability to resist a chemical process of decomposition involving splitting of a bond and the addition of the elements of water. In the case of polyurethane foam, the decomposition is usually caused by a cycling of temperature, heat, and humidity.

COALESCE: To unite into a whole, to grow together. In the case of reticulated foam, the geometric structure catches the minuscule droplets of fuel, not permitting them to vaporize and combine with oxygen into an explosive mixture.

STOICHIOMETRIC MIXTURE: The optimum ratio of air and fuel required to provide a maximum possible combustion pressure.

SWITCH LOADING - SWITCH REFUELING: Refueling with a grade of fuel different than the residual fuel occupying the tank.

ULLAGE: Vapor space above the fuel surface at any fuel level.

HEI: High Explosive Incendiary

COMBUSTION PRESSURE: Increase in pressure within the fuel tank due to combustion of a flammable mixture (ΔP in PSID). Sometimes defined or referred as combustion overpressure.

COMBUSTION VOLUME: Percent of ullage space which is ignited by a projectile or some other ignition source.

COMPONENT VOID: Cutout in the foam which provides clearance between the foam and an internal element of the fuel tank (e.g., pump, quantity probe, or fuel inlet). Void Volume = cutout volume - component volume.

DRY BAY: Space (cavity) within the mold line of an aircraft that is normally dry but may contain an explosive gas mixture in the event of combustible fluid leakage due to combat damage or natural causes.

FOAM POROSITY: Numerous, small openings in the foam structure; coarse and fine classifications are indicative of the size of the openings and are based upon air pressure drop tests.

FUEL TANK: Volume in an aircraft designated for carrying fuel. Can be integral, bladder or self-sealing, external droppable, or portable tanks.

OPERATING PRESSURE: The pressure within the fuel system during normal system operation.

OPTIMUM VOID LEVEL/FOAM KIT CONFIGURATION: Foam kit which contains sufficient foam to protect the tank, but no more than is necessary.

PLAN VOID: Cutout intentionally designed into the foam for weight reduction and to aid fuel flow through the foam. Void volume = cutout volume.

PSID: Pounds per square inch differential; unit of pressure measurement.

PSIG: Pounds per square inch gage; unit of pressure measurement.

PSIA: Pounds per square inch absolute; unit of pressure measurement.

SINGLE VOID COMBUSTION: Combustion occurs only in the void which is initially ignited, i.e., no propagation.

TOTAL VOID: Sum of designed voids and component voids.

VOID: Absence of foam in a given volume or space (cutout).

EXPLOSION SUPPRESSION MATERIAL (ESM): A general term used to define materials used in fuel tanks to prevent fuel tank overpressures, i.e., reticulated polyurethane foam, one such material.

3. DISCUSSION OF FUEL SYSTEM EXPLOSION SUPPRESSION

3.1 History of Reticulated Polyurethane Foam

In the early 1960s, the USAC (United States Automobile Club) was concerned with the rising number of accidents involving fuel explosions and fires. The primary contributing factors were increasing speeds, and the use of lighter weight materials and structures, which contributed to fuel tanks being ruptured on impact. At this time, USAC approached industry to investigate the cause and to provide a feasible solution that would help suppress explosions and fires. As a result of this development program, a successful crashworthy fuel cell tank system was designed by private industry and implemented by automotive racing associations.

In 1965, as the initial development of reticulated polyurethane foam was completed, and the Vietnam conflict was escalating, the U.S. Air Force sustained an increasing number of aircraft losses and pilot fatalities due to fuel tank explosions caused by small arms gunfire.

During this period the U.S. Air Force began searching for a solution to reduce vulnerability of the fuel tanks and improve survivability. They approached industry, (airframe manufacturers, bladder manufacturers and a foam manufacturer who had developed the reticulated polyurethane foam system) to determine if this same concept could be applied as an Explosion Suppressant Material (ESM) in aircraft fuel tanks. Additional research ascertained that reticulated polyurethane foam was an excellent explosion suppressant for aircraft wet wing and bladder fuel tanks. Type I orange reticulated foam gained widespread acceptance by the military for use in F-105s, AC-47s, A-37s, O2s, B-57s, C-123s, C-130s, helicopters, and other aircraft.

Although weight and fuel penalties accompanied use of foam they were considered small in relation to the benefits. The military was made aware from the onset that the usable life was estimated to be 5 years for reticulated polyester polyurethane foam (Type I orange).

With Type I orange reticulated polyurethane foam acceptance regarded as a significant advancement in survivability, the U.S. Air Force came back to the foam industry with a request to reduce the weight penalty. As a result of this request, and with additional development effort during the 1970 through 1972 time frame, Type II yellow reticulated polyurethane foam was developed. It exhibited a lower density, with the equivalent explosion suppression protection of Type I orange. Lower density reduced the foam kit weight by 25%. This resulted in additional allowable fuel and munitions to be carried, thus extending the aircraft mission capabilities. The kit designs using Type I and II are considered fully packed systems, but inherently contain up to a 15% void volume.

Paralleling the development program for Type II, yellow reticulated polyurethane foam, a major airframe designer/manufacturer was developing an aircraft fuel system utilizing reticulated foam for a new fighter aircraft design. Their ultimate goal was to provide explosion suppression using a grossly voided reticulated polyurethane foam kit, with up to 70% void volume. The revolutionary design would greatly reduce the weight, and fuel retention penalties compared to traditional fully packed systems. Laboratory testing determined that a finer foam cell structure was required to equal the flame arrestor and explosion suppression capabilities of a fully packed design. A joint research effort between the aircraft manufacturer and the foam producer successfully resulted in Type III, red reticulated polyester polyurethane foam for use in grossly voided explosion suppression systems. This new system greatly enhanced the life cycle costs of aircraft employing this new concept.

In the early 1970s as the Vietnam conflict was coming to an end, the U.S. Air Force was experiencing degradation of the reticulated polyester polyurethane foam (Type I, orange). As originally anticipated, due to environmental conditions encountered in Southeast Asia, the combination of extreme temperatures, high humidity, and cool evenings accelerated the problem of foam hydrolysis. (See Lesson Learned Section for a detailed discussion on the effects of foam degradation, and resulting contamination of the fuel system.) Again, the U.S. Air Force approached the foam industry to solve the degradation problem. All reticulated polyurethane foams up to this time were of a polyester type, which has inherent limitations with hydrolytic stability. In 1974, a major development breakthrough by the resin chemical producer/suppliers, namely a polymer-polyol resin, became available enabling production of a hybrid polyether type polyurethane foam. Development of Types IV and V reticulated polyether polyurethane foams was accomplished by the original manufacturer of reticulated polyurethane foam and the USAF; installations of Type IV and Type V kits were being used in military systems by 1978.

Types IV and V provided the equivalent explosion suppression capabilities of the original polyester reticulated polyurethane foam products. At the same time, they offered an expectant life 5 to 10 times greater than the earlier polyester reticulated polyurethane foams. All foams were produced in accordance with MIL-DTL-83054C.

In the late 1970s the U.S. Air Force undertook major retrofit programs, with the installation of blue polyether reticulated polyurethane foam ESM kits in A-10 and, in the early 1980s in the C-130 aircraft. Widespread implementation of both Types IV and V also took place in newly designed aircraft such as the F-15 and F-18.

Beginning in the mid-1970s, the U.S. Air Force began experiencing numerous electrostatic ignitions. The problem was confined only to two types of aircraft, the A-10 and C-130. Electrostatic ignitions were reported mostly during cold weather operations. The ignitions occurred during ground refueling operations, in-flight fuel/air purging and during special operating missions being performed. The problem occurred as a result of charge separation due to fuel passing through the foam. Electrostatic charge generation related to aircraft, fuel handling, and electrical storms has always been a major concern. Limited information existed pertaining to electrostatic generation and the associated behavioral relationship between reticulated polyurethane foam installed in fuel cells in combination with the usage of hydrocarbon fuels.

During the 1980s comprehensive research programs were undertaken by the U.S. Air Force, airframe manufacturers, foam manufacturers, and academic research people to investigate the electrostatic phenomenon. Extensive laboratory test programs were conducted to better understand the complex mechanism of electrostatic generation/ignition. The programs included inspection of aircraft, and stationary simulation on actual fuel tankage sections. Once a basic understanding of the mechanics of the electrostatic generation/ignition problem was ascertained, the reticulated foam manufacturers entered into various research and development programs. This work ultimately produced a conductive reticulated polyether type polyurethane foam that would reduce the hazard of electrostatic generation and minimize foam related ignitions in aircraft fuel systems.

Two types of conductive reticulated polyurethane foams were developed by the mid to late 1980s. The initial approach utilized the basic Type IV and Type V foam products, subjecting the base foam to a post-reticulation treatment to make it conductive per the requirements of TE-ENFE-86-1. These materials became known as Type VI Dark Beige and Type VII Light Beige, reflecting the differences between coarse and fine pore sizes, respectively. The USAF utilized post-reticulation treated Type VI and VII starting in 1986 and ending in the early 1990s.

A second alternative development, also started in 1986, provided inherently conductive reticulated polyether type polyurethane foam, also known as in situ conductive reticulated polyether polyurethane foam. The USAF has been utilizing the in situ conductive reticulated foam approach supplied by the foam industry in sufficient quantities for in-flight service testing and evaluation in C-130 and A-10 aircraft.

Four types of in situ conductive reticulated foam have been developed, in accordance with MIL-PRF-87260B. Class 1 performance per the military specification identifies foam with in situ conductive properties over a temperature range from 0 to 160 °F (-17.7 to 71.1 °C). Class 2 performance per the military specification identifies foam with in situ conductive properties over a temperature range from -25 to 160 °F (-31.7 to 71.1 °C). Within the two class designations, the pore size difference between coarse and fine is determined by Grade IC and Grade IIC, respectively. Regardless of Class designation, Grade IC is now also known as Type VI Black and Grade IIC is now also known as Type VII Grey. The use of in situ conductive reticulated polyether polyurethane foam materials have proven to be completely successful in the elimination of the foam electrostatic generation/ignition problem in aircraft fuel tanks.

In 1987 a new program was initiated by the U.S. Air Force to develop and evaluate a high temperature reticulated foam for use in advanced aircraft. The new material developed as a result of this program can sustain temperatures of 300 °F for an extended period. The new foam material will also meet the USAF's requirements for improved hydrolytic stability and electrical conductivity. The program was successfully completed in 1990 and samples of the material were submitted to the Project Director at the Materials Laboratory, Wright Patterson AFB. The program demonstrated that this product can be produced commercially if there is an existing need. This program was completed September 28, 1990 Report No. GJ-0928-90, WRDC-TR-90-4074.

In 1996 TWA Flight 800 exploded over Long Island, NY shortly after take-off from John F. Kennedy International Airport. The most likely cause of this explosion was a spark in the center fuel tank which ignited heated fuel vapor. This event prompted an industry-wide review of aircraft fuel tank safety, culminating in a series of recommendations from the Fuel Tank Harmonization Working Group (FTHWG) in 1999. Various industry-expert led teams under FTHWG produced reports outlining improvements that should be made to prevent fuel tank explosions. Reticulated polyurethane foam as an ESM was reviewed under Chapter 8 of FTHWG and found to support all of the conclusions shown in Section 3.3 of this document. In addition, the use of reticulated polyurethane foam as an ESM was estimated to improve the mean-time between a fuel tank explosive event from one every five years to one approximately every fifty years – a ten-fold increase in safety performance.

Since the FTHWG report, the Federal Aviation Authority (FAA) enacted Special Federal Aviation Regulation (SFAR) 88, which requires operators of type certificated aircraft of a certain size and passenger load to mitigate fuel tank explosions in their aircraft fleet. The FAA also enacted rulemaking changes for 14 CFR 25.981 addressing fuel tank explosion prevention. Subsequent aviation Advisory Circulars have noted reticulated polyurethane foam as a mitigation technology for prevention of fuel tank explosions (AC25.981-1C, AC25.981-2A and AC120-98A). This guidance has led to industry use of reticulated polyurethane foam for commercial aircraft applications through engineering designs.

3.2 Special Note Regarding Export Classifications for ESM

Export requirements for reticulated polyurethane foam as an ESM have changed following the classification of certain Grades and Classes of the technology as Defense Articles by the Department of State following September 11, 2001. The technology is capable of being exported under license from either the Department of State or the Department of Commerce depending on the application of the foam in a military or commercial fuel tank, respectively. This paragraph is offered as guidance to non-US users of reticulated polyurethane foam as an ESM for purposes of planning when designing the product into a new application. The manufacturer of the reticulated polyurethane foam has the responsibility to control the export of the technology when applicable by obtaining an export license or release from the appropriate authority.

3.3 History of Dry Bay Reticulated Polyurethane Foam

Since the early to mid-1970s, the U.S. Air Force and private industry have been actively engaged in the engineering, development and installation of reticulated polyurethane foam as a dry bay suppressant material. The earliest known technical report on this subject is Air Force Document Number AFAPL-TR-74-126. The basic concept was to use 25 and 29 pores per inch reticulated polyurethane foams that had been developed for fuel tank explosion suppression.

The use of flexible reticulated polyurethane foam in a dry bay will inhibit the mixing of air and the spray of fuel from leaking tanks or lines, thus minimizing explosion and possible sustained fires. The open pores permit any fuel escaping from the tank to drain to the low points of the aircraft where it can be exhausted overboard. The foam acts as an explosion and fire suppressor in much the same manner as it does inside the tank. Current testing indicates that the support provided to a fuel tank by the external installation of foam reduces the severity of hydrodynamic ram effects.

The application of dry bay foam requires minimum logistic support and provides multi-hit capability. Foam pieces should be designed for installation under 3 to 5% compression. The dry bay foam can be cut to the shape of the bay using the same techniques used for reticulated polyurethane foam.

After the initial acceptance and implementation of reticulated polyurethane dry bay foams as an explosion suppression material for aircraft dry bay protection, further development and testing resulted in use of finer pore foams. Gunfire testing and evaluation in the mid-1980s for the F-15 aircraft proved that a 45 pores per inch white reticulated polyether polyurethane dry bay foam provides maximum protection. The results for this series of gunfire testing may be found in Air Force Document Number AFWAL-TM-84-237-FIESL.

Just as the finer pore (45 ppi) dry bay foam development was completed, the U.S. Navy became interested in the use of this product for the A-6D/E aircraft. They stipulated that it must be a flame retardant-type foam. The fire retardant requirement had a dual purpose. First, the A-6 is a carrier-based aircraft and may be exposed to enemy gunfire while on the carrier deck. The U.S. Navy did not want the risk of dry bay explosion suppressant material contributing to a deck fire as a result of combat damage. Secondly, spare dry bay foam components/kit(s), or bulk replacement reticulated polyurethane dry bay foam is stored on shipboard, and the flame retardant precaution was taken in the unlikely event of a shipboard fire. Ultimately, implementation of the Magenta, 45 ppi, fire retardant, reticulated polyurethane dry bay foam began in 1987.

The most recent development of dry bay foam was provided as the result of a helicopter aircraft manufacturer requiring a stiff dry bay explosion suppressant material offering maximum drainability. The desired stiffness provided sufficient support for a bladder type fuel cell. To satisfy this request, a gold, 30 ppi, fire retardant, reticulated polyurethane dry bay foam was qualified for their application.

Currently, there are two dry bay foam products in production that are not specified under either MIL-DTL-83054C or MIL-F-7260B. All the products for dry bay applications are noted in Tables 4 and 5.

Other applications utilizing reticulated polyurethane foam explosion suppression technology:

3.3.1 Military

- a. Round ball spheres of reticulated polyurethane foam kits for single port entry of limited access composite tanks.
CAUTION: Protection effectiveness using round ball spheres must be verified by testing of the specific application.
- b. Aircraft and tracked vehicle refuelers
- c. Armored tracked vehicles
- d. Marine target boats
- e. Hovercraft/landing craft
- f. High speed turbine-powered boats
- g. Unmanned flight platforms
- h. Military wheeled vehicles