DOT/FAA/TC-14/24

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Thermal Acoustic Insulation Contamination Research

September 2014

Final Report

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NOTICE

This research was commissioned by Transport Canada by means of the Memorandum of Cooperation regarding Civil Aviation Research and Development between the Civil Aviation Research and Development between the Civil Aviation Authority of the United Kingdom and the Department of Transport of Canada. This activity has been carried out in cooperation with the Federal Aviation Administration and the UK Civil Aviation Authority under the auspices of the International Cabin Safety Research Technical Group whose goal is to enhance the effectiveness and timeliness of cabin safety research.

Technical Report Documentation Page

1. Report No. DOT/FAA/TC-14/24	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

THERMAL ACOUSTIC INSULATION CONTAMINATION RESEARCH

5. Report Date

September 2014

6. Performing Organization Code

7. Author(s)

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8. Performing Organization Report No.

9. Performing Organization Name and Address

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10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

U.S. Department of Transportation
Federal Aviation Administration
Transport Airplane Directorate, ANM-115
1601 Lind Avenue
Renton, WA 98057

13. Type of Report and Period Covered

14. Sponsoring Agency Code

ANM-115

15. Supplementary Notes

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16. Abstract

This report summarizes the research work carried out on behalf of Transport Canada and the UK Civil Aviation Authority into the potential threat that might exist from contaminated thermal acoustic insulation materials). The research has been conducted in the light of related activities carried out by the industry which are also described or referenced in this report. The study is based on data analysis, literature searches, aircraft surveys, consultation with the industry, and flammability testing carried out on a test rig developed especially for this study.

This report addresses the nature of contaminants found on thermal acoustic insulation on in-service airplanes, the potential fire threat that they might present, and the actions taken by the industry to mitigate these threats. The report also makes ten recommendations aimed at improving the resistance of the airplane to hidden fires that might be fueled by contaminants.

17. Key Words Thermal acoustic insulation, dust, lint, corrosion inhibiting compound, hydraulic fluid, propagation, contaminants	18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 114	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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LIST OF ACRONYMS

AC	Advisory Circular
AD	Airworthiness Directive
AFCB	Arc Fault Circuit Breaker (Arc Fault Circuit Interupter)
AFCI	Arc Fault Circuit Interupter
ATA	Air Transport Association of America
CIC	Corrosion Inhibiting Compound
CPC	Corrosion Prevention Compound
CUT	Coordinated Universal Time
DAL	Delta Air Lines
DET	Detailed Inspection
EASA	The European Aviation Safety Agency
EICAS	Engine Indicating and Crew Alerting System
EWIS	Electrical Wiring Interconnection System
EZAP	Enhanced Zonal Analysis Procedure
FAA	Federal Aviation Administration
FH	Flight Hour
FLIR	Forward Looking Infrared
GVI	General Visual Inspection
HIRF	High Intensity Radiated Fields
IAMFTWG	International Aircraft Materials Fire Test Working Group
ICA	Instructions for Continued Airworthiness
IFR	Instrument Flight Rules
MEK	Methyl ethyl ketone
MPET	Metalized polyethylene terephthalate
MRB	Maintenance Review Board
PDU	Power Drive Unit
PEEK	Polyether ether ketone
PEKK	Polyether ketone ketone
PET	Polyethylene terephthalate
TAI	Thermal Acoustic Insulation
TC	Transport Canada
TSB	Transportation Safety Board of Canada
UK CAA	United Kingdom Civil Aviation Authority

EXECUTIVE SUMMARY

This report summarizes the research work carried out on behalf of Transport Canada and the UK Civil Aviation Authority into the potential threat that might exist from contaminated thermal acoustic insulation materials). The research has been conducted in the light of related activities carried out by the industry which are also described or referenced in this report. The study is based on data analysis, literature searches, aircraft surveys, consultation with the industry, and flammability testing carried out on a test rig developed especially for this study.

This report addresses the nature of contaminants found on thermal acoustic insulation on in-service airplanes, the potential fire threat that they might present, and the actions taken by the industry to mitigate these threats. The report also makes ten recommendations aimed at improving the resistance of the airplane to hidden fires that might be fueled by contaminants.

Several conclusions have been reached as a result of this study regarding the nature and potential magnitude of the fire threat from thermal acoustic insulation contaminants in hidden areas. There have been a significant number of in-flight fires that were likely to have propagated on thermal acoustic insulation contaminants. The vast majority of which did not pose a significant threat to aircraft safety.

However, the results of this study also indicate that contaminated thermal acoustic insulation can, in certain circumstances, result in a significant in-flight fire. Based on this study, it is assessed that the most significant fire threats associated with contamination of thermal acoustic insulation are dust and lint and hydraulic fluid that has penetrated into damaged insulation bags. The current industry mitigation for hidden area contamination is based on directed cleaning tasks and a “Protect and Clean as you go” philosophy. This rational approach is likely to result in a reduction of the threat. However, the results of this study suggest that there may be opportunities to make further improvements to its implementation on in-service airplanes and design improvements for future installations of thermal acoustic insulation.

1. INTRODUCTION

Following the Swissair flight 111 accident in September 1998, the industry has focused on the potential risk to aircraft safety from fires originating in areas inaccessible to flight and cabin crews (hidden areas). As a consequence, thermal acoustic insulation (TAI) bagging film materials have been replaced on some in-service airplanes as a result of Airworthiness Directive action and an improved flammability test for TAI materials has been developed by the FAA. The industry has also addressed the threat from contaminants of TAI by improved cleaning regimes.

This report summarizes the research work carried out on behalf of Transport Canada and the UK CAA into the potential threat that might remain from contaminated thermal acoustic insulation materials. The research has been conducted taking into account related activities carried out by the industry which are also described or referenced in this report.

The study addresses the nature of contaminants found on TAI on in-service airplanes, the potential fire threat that they might present and the actions taken by the industry to mitigate these threats. The report also makes recommendations aimed at improving the resistance of the airplane to hidden fires that might be fuelled by contaminants.

The report is structured to facilitate reading by being divided into Part A and Part B with detailed information contained in appendices at the end of the report. Part A of the report contains the Summary of Conclusions from the research and a Summary of Recommendations. The Summary of Recommendations is based on the rationales contained in section 11. Part B contains the activities carried out in the research, grouped into the primary tasks (Aircraft Surveys, Flammability Testing etc.). The appendices contain detailed information on some of the issues addressed in this report.

This Report has been produced on behalf of Transport Canada and the United Kingdom Civil Aviation Authority in fulfilment of Activity 2 Phase 6 of the UK CAA Contract No. 1745.

2. BACKGROUND

As a result of the Transportation Safety Board of Canada (TSB) investigation of the Swissair flight 111 accident (see reference 1), the following recommendation suggested that further work was required to mitigate the fire threat from contaminated thermal acoustic insulation:

> *"The Department of Transport take action to reduce the short term risk and eliminate the long term risk of contaminated insulation materials and debris propagating fires, and coordinate and encourage a similar response from other appropriate regulatory authorities." A02-05 (14 November 2002)*

TSB has classified this Recommendation as "Inactive":

> Board Reassessment of the Responses to A02-05 (23 June 2006)
>
> TC's letter of 14 December 2005 indicates action to address the deficiency raised in Recommendation A02-05. MSI-42 entitled "Maintenance Schedule Amendment Instructions for the Inspection of Thermal/Acoustic Insulation," issued 30 June 2004, was intended to ensure that attention is directed to the inspection of thermal/acoustic insulation materials where increased levels of susceptibility to contamination are inadequately addressed within the air operator's maintenance schedule. On 30 September 2005, TC issued Transport Publication TP 14331 entitled Enhanced Zonal Analysis Procedures, which includes recommendations for more robust aircraft maintenance practices that promote a housekeeping philosophy to "protect, clean as you go." TC's implementation of the guidance material contained in MSI-42 and TP 14331 will substantially reduce the safety deficiency as described in Recommendation A02-05.
>
> Therefore, the assessment is now assigned Fully Satisfactory.

The FAA subsequently developed Advisory Circular AC No: 25-27A (see reference 2) to address the threat from contamination in hidden areas containing electrical wiring interconnection systems (EWIS). However, its philosophy is also applicable to contamination of thermal acoustic insulation materials. Additionally, the industry developed improved procedures for airplane cleaning in hidden areas by means of the enhanced zonal analysis procedures (EZAP) defined in reference 3 and summarized in appendix 5.

Studies related to contamination of TAI were initiated by the International Aircraft Materials Fire Test Working Group – Thermal Acoustic Insulation Contamination. The initiatives carried out by this Group are best summarized as follows:

> "As part of the FAA International Aircraft Materials Fire Test Working Group, a Contamination and Aging Task Group was created in 2003. This task group was created to evaluate the effects of contamination and aging on flammability properties of interior materials. The task group has performed an airline contamination survey, evaluated the

> effects of certain contaminants on flammability performance of insulation blankets, evaluated in-service insulation blankets, and assisted in developing an approach to mitigate the risk of contamination buildup and the associated flammability risks."[1]

As part of the Task Group activities the following tasks were initiated:

- Performance of an airline contamination survey
- Evaluation of the effects of certain contaminants on the flammability of thermal acoustic insulation.

These tasks are described in Part B of this report.

However, the precise nature and magnitude of the threat from contaminated thermal acoustic insulation and the adequacy of current mitigations was not fully understood. Hence, Transport Canada and the UK Civil Aviation Authority commissioned a series of research activities (referred to as the TC/CAA studies from this point forward) to gain a better understanding of any potential threat and the opportunity that might exist for reducing the risk of hidden fires that might be fueled by contaminated thermal acoustic insulation.

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[1] Statement from the Task Group Chairman – Dan Slaton of Boeing

PART A

3. SUMMARY OF CONCLUSIONS

The following represents the primary conclusions made from this study:

Conclusion 1: Magnitude of the Threat: There are a significant number of in-flight fires that are likely to have propagated on contaminated thermal acoustic insulation, the vast majority of which did not pose a significant threat to airplane safety. However, the results of this study also indicate that contaminated thermal acoustic insulation can, in certain circumstances result in a significant in-flight fire. 65

Conclusion 2: Current Mitigation: The current industry mitigation for hidden area contamination is based on directed cleaning tasks and a "Protect and Clean as you go" philosophy. This rational approach is likely to result in a reduction of the threat. However, the results of this study suggest that there may be opportunities to make further improvements to maintenance practices and design features associated with thermal acoustic insulation. 65

Conclusion 3: Primary Threats: Based on this study it is assessed that the most significant fire threats associated with contamination of thermal acoustic insulation are dust and lint and hydraulic fluid that has penetrated into damaged insulation bags. 65

Conclusion 4: Dust and Lint: Based on in-service incidents, airplane surveys, data analysis and flammability testing it is concluded that although for the most part this contaminant represents a relatively low flammability threat, in some circumstances it can result in significant fires. 67

Conclusion 5: Dust and Lint: In many instances, hidden areas containing thermal acoustic insulation and EWIS may be contaminated with dust and lint that could represent a flammability threat prior to the scheduled cleaning period. 67

Conclusion 6: Dust and Lint: Testing suggests that radiant heat, such as may be encountered in an established fire, is likely to result in dust and lint burning more vigorously. 67

Conclusion 7: Dust and Lint: Propagation of a fire on dust and lint is likely to progress more rapidly as the contaminant is inclined away from the horizontal. 67

Conclusion 8: Hydraulic Fluids: Whilst the flammability testing carried out in this study suggested that surface contamination of thermal acoustic insulation with commonly used hydraulic fluids is unlikely to pose a fire threat, penetration of the fluid through the bagging film material into the insulation does. 68

Conclusion 9: Hydraulic Fluids: It would appear that commonly used hydraulic fluids can damage some thermal acoustic insulation bagging films resulting in the possibility of the insulation material becoming saturated with a consequential fire threat. 69

Conclusion 10: Hydrocarbons: While hydrocarbons may be considered as a potentially flammable thermal acoustic nsulation contaminant, this study suggests that they are unlikely to be found in sufficient quantities to pose a significant fire threat in isolation. 68

Conclusion 11: Debris: The fire threat from debris in hidden areas can only be mitigated on existing airplanes by scheduled cleaning tasks. However, future airplane designs may incorporate design features that reduce the risk of debris accumulating in hidden areas. 69

Conclusion 12: Debris: Debris found during the airplane surveys and in-service occurrences is potentially flammable. 69

Conclusion 13: Corrosion Inhibiting Compounds: Based on this study it would appear that corrosion inhibiting compounds, although a common contaminant, are unlikely to be present in

4. SUMMARY OF RECOMMENDATIONS

The industry initiatives introduced under the Enhanced Zonal Analysis Procedures (see appendix 5) would seem to provide a practical solution to mitigating the threat from the majority of in-service contaminants of thermal acoustic insulation materials. However, a reduction in the threat of in-service hidden fires from these contaminants might be achieved by a review of these procedures in the light of the findings of this study. Recommendations are also made regarding potential enhancements to design features associated with thermal acoustic insulation.

The following recommendations are made based on the rationales contained in section 11:

Recommendation 1: Current Mitigation: It is recommended that the guidance given in AC 25-27A is reviewed to emphasize the fire threats related to contaminated thermal acoustic insulation found to be high risk as a result of this study and to review the threat that these contaminants might present to EWIS. 65

Recommendation 2: Dust and Lint: It is recommended that the scheduled cleaning intervals prescribed for in-service airplanes are reviewed in the light of the findings of this study particularly with regard to the likely rate of accumulation of dust and lint and its likely flammability characteristics. 67

Recommendation 3: Hydraulic Fluids: Maintenance personnel should be provided with guidance advising of the significance of damaged thermal acoustic insulation bagging film materials, in zones which may contain hydraulic fluids, and the necessity for repair or replacement at the earliest opportunity. 68

Recommendation 4: Hydraulic Fluids: The “protect and clean as you go” philosophy, defined in the FAA Advisory Circular 25-27A, should be emphasized in relation to spillage or leakage of hydraulic fluid onto thermal acoustic insulation bagging film materials. 68

Recommendation 5: Corrosion Inhibiting Compounds: It is recommended that guidance material is provided regarding the selection of corrosion inhibiting compounds that exhibit less flammable and lower dust and lint adhesion characteristics. 71

Recommendation 6: Thermal Acoustic Insulation Design Features: It is recommended that consideration be given to designing and manufacturing thermal acoustic insulation bagging film materials, tapes and patches that are resistant to hydraulic fluids, water, cleaning fluids, insecticides and other fluids commonly encountered on airplanes, particularly for yhermal acoustic insulation installed in zones that may be subject to hydraulic fluid contamination. 74

Recommendation 7: Routine Maintenance: Consideration should be given to reviewing the guidance given in current advisory material, taking into account the rate of accumulation of flammable contaminants assessed as a result of the airplane surveys carried out in this study. 74

Recommendation 8: Routine Maintenance: Maintenance instructions should ensure that damaged thermal acoustic insulation bagging film materials in zones containing potential ignition sources and having the potential for hydraulic fluids to penetrate into the insulation material are repaired or replaced at the earliest opportunity. 74

Recommendation 9: Routine Maintenance: Consideration should be given to developing training means to mitigate ambiguity in the standard of cleanliness to be achieved in contaminated hidden areas. Such training should also emphasise that a fire threat may exist from dust and lint contaminated thermal acoustic insulation at very low levels of accumulation. The training means should also identify the relative threat from various contaminants and address good cleaning practice including the need to carry out post cleaning inspections. 74

Recommendation 10: Airplane Design Features: Consideration should be given on future airplane designs to providing a means for reducing the probability of debris entering hidden areas containing potential ignition sources and routing electrical wiring in conduits in zones where flammable contaminants are likely to accumulate. 75

PART B

5. IN-SERVICE HIDDEN FIRE OCCURRENCES

5.1 SIGNIFICANT IN-SERVICE HIDDEN FIRES

A benefit analysis was carried out for the FAA and CAA, in March 2002, to assess the lifesaving potential from the eradication of hidden area fires (reference 4). A further study (reference 5) was carried out for Transport Canada in January 2008, to ascertain whether developments in techniques and additional data that had become available might influence the conclusions reached in the earlier FAA/CAA study. Both of these studies were carried out for hidden fire occurrences to passenger carrying western-built turbojet or turboprop aircraft type certificated for more than 30 seats.

From these studies five hidden fire occurrences were identified over the period 1991 to 2004, which were either fatal or had the potential to be fatal since they were of sufficient intensity that they could not be controlled by the crew and had the potential to destroy the aircraft. These occurrences are described in appendix 1. It is considered likely that the majority of these occurrences, perhaps all, had a thermal acoustic insulation involvement. However, the extent to which contaminants contributed to the fire propagation cannot be determined with any confidence.

Appendix 2 contains a further six occurrences involving hidden fires over the period 1991 to 2004. These occurrences although serious in nature did not have the potential to become fatal.

Table 1 summarizes all of the eleven hidden fire occurrences contained in appendices 1 and 2. These eleven occurrences are likely to be the most significant occurrences of hidden fires, with a thermal acoustic insulation involvement, over the period 1991 to 2004. Table 1 and figure 1 also indicate the likelihood of contamination involvement and whether the thermal acoustic insulation that may have been involved in the fire was subsequently the subject of Airworthiness Directive[2] action to remove the insulation bagging film due to its relatively high flammability characteristics.

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[2] The applicable Airworthiness Directives require the replacement of ORCON Orcofilm® AN-26 or metalized polyethylene terephthalate (MPET) film from the thermal acoustic insulation blankets.

Table 1. Contamination Identified in Significant Hidden Fire Related Occurrences

Date	Aircraft Type	Contamination Identified	Occurrence involved TAI material which was subsequently the subject of AD action
10-Aug-02	B747-436	Environmental dust, fibers and Corrosion Inhibiting Compound	NO
13-May-02	B767-300	Paper, candy wrappers, Styrofoam packing peanuts, small polyethylene beads, rubber powder from a PDU and isoparaffin solvent.	NO
29-Nov-00	MD-80	UNLIKELY [1]	YES
29-Nov-00	DC-9-32	UNKNOWN	NO
15-Nov-00	B757-236	UNLIKELY [2]	NO
08-Aug-00	DC-9-32	UNKNOWN	NO
17-Sep-99	MD-88	UNLIKELY [1]	YES
02-Sep-98	MD-11	UNKNOWN	YES
24-Nov-93	MD-87	UNKNOWN	YES
05-Sep-93	B727-200	UNKNOWN	NO
17-Mar-91	L-1011	Dust/lint, grease, tar metal nut clips, fingernail clippers, a disposable paper mask, disposable towelettes, a burned number 10 screw, a clean number 10 screw, two candy wrappers, peanut bags and a five-inch metal clamp.	NO

[1] Contamination involvement is considered unlikely as the insulation was inspected by the accident investigators and no mention of contamination was stated in the official report.

[2] Contamination was not mentioned by the accident investigating authority and it appears that the smoke was generated from charring of the insulation material.

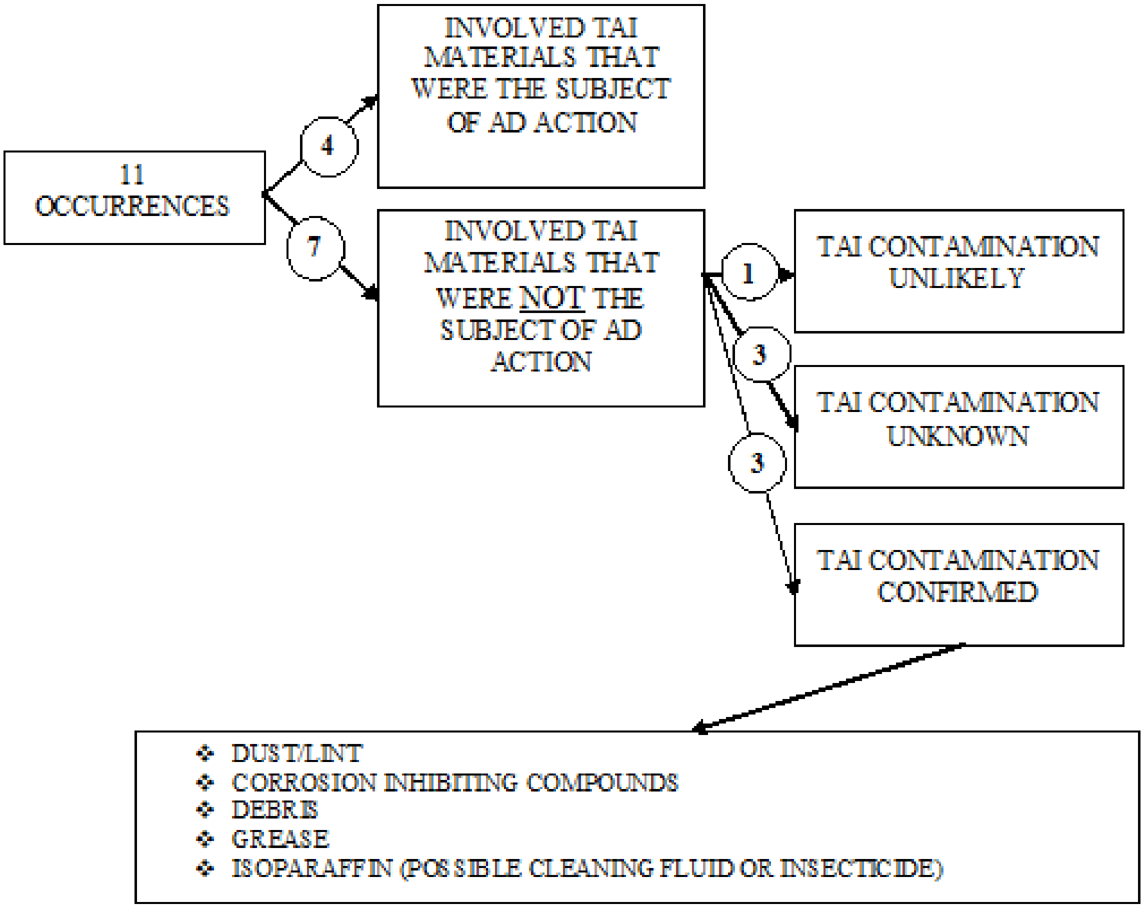

Figure 1. Contamination Involvement in Significant Hidden Fire Related Occurrences

As can be seen from figure 1, three of the most significant hidden fire related occurrences have been positively identified by the investigating authority as involving or potentially involving contaminants on thermal acoustic insulation blankets. The contaminants involved with these occurrences were primarily dust and lint, corrosion inhibiting compounds, and debris. These three occurrences were to a Boeing 767 aircraft in May 2002, a Boeing 747 aircraft in August 2002, and an L-1011 in March 1991. The Boeing 767 and the Boeing 747 occurrences involved a fire local to the aircraft cargo bay. In the L-1011 occurrence, the fire originated in the cheek area below the cabin floor to the aft of the aircraft. The Boeing 767 and the L-1011 occurrences involved contamination that presented an obvious fire propagation risk.

The Boeing 747 occurrence was less obvious as to the contribution that contaminants made to the propagation of fire. The Australian Transport Safety Bureau Air Safety Occurrence Report (reference 6) states:

> *"Although the insulation blanket had been subjected to in-use contamination, the material composition of the insulation blanket (and sidewall lining) was able to prevent a rapid spread of fire. However, due to the temperatures involved, localized burning had occurred."*

However, the Transportation Safety Board of Canada (TSB) concluded in their Aviation Occurrence Report relating to the L-1011 incident (reference 7):

> *"A large accumulation of dust and lint in the area provided a source of fuel for the fire."*

It should be noted that all three of these occurrences occurred prior to the implementation of the Enhanced Zonal Analysis Procedure. However, the degree to which this process mitigates the fire threat from contaminants is not entirely understood.

5.2 OTHER IN-SERVICE OCCURRENCES

In support of the TC/CAA studies, the Boeing Aircraft Company supplied data on 73 hidden fire occurrences to aircraft manufactured at their Washington plant that had a thermal acoustic insulation involvement. The data related to hidden fires that occurred over the period 1985 to 2004. From this study, it was evident that the vast majority of hidden fires propagating on thermal acoustic insulation materials are benign – in many instances not being discovered until the airplane was subjected to routine maintenance.

However, the testing of contaminated thermal acoustic insulation materials described in this report suggests that certain contaminants, if present in sufficient quantity, combined with both an ignition source and given ambient conditions (temperature, airflow, etc.) could pose a significant in-flight fire threat.

The analysis of the reported contaminants associated with the Boeing hidden fire occurrences are is contained in section 6.1 .

6. STUDIES RELATED TO THE NATURE OF THERMAL ACOUSTIC INSULATION CONTAMINANTS

6.1 CONTAMINANTS FOUND IN THE VICINITY OF IN-SERVICE HIDDEN FIRES

Analysis of the Boeing data, discussed in section 5.2, suggested that thermal acoustic insulation materials were confirmed as being contaminated within the vicinity of the hidden fire location in 24 of the 73 occurrences. For two of the occurrences it appeared that there was no contamination of the blankets. For the remaining 47 occurrences, it could not be determined whether the blankets were contaminated or not. For the most part, it could not be confirmed whether the contaminants played a part in either the initiation or propagation of the fire. Some caution is required in drawing conclusions regarding the part that contaminants might have played in the propagation of the fire since contaminants might not have been discovered simply because they had been consumed by the fire.

It should be noted that the data relates to the frequency of reporting of contaminants and is not necessarily indicative of the quantities of the contaminants found.

The relative frequency of the reported contaminants, based on the hidden fire occurrences, is shown in figure 2.

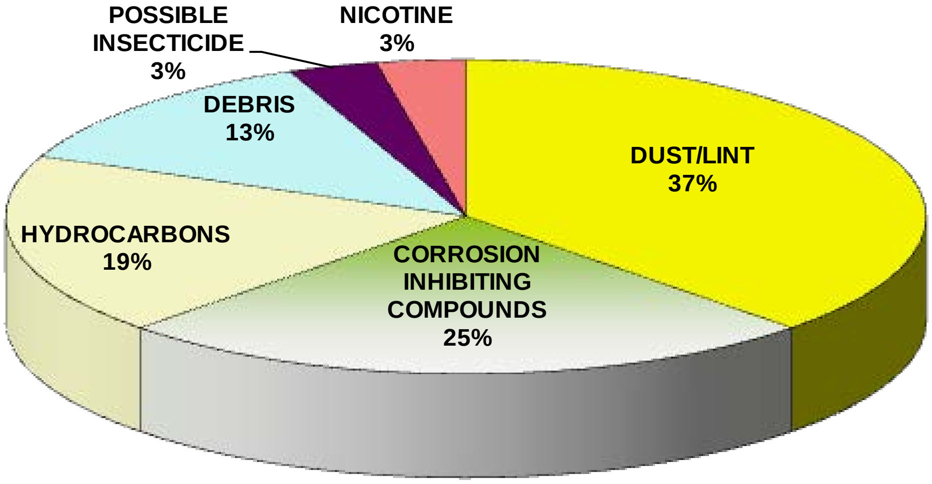

Figure 2. Contaminants Found in the Vicinity of In-Service Hidden Fires

6.2 CONTAMINANTS IDENTIFIED FROM RESULTS OF AIRLINE SURVEYS

The Boeing Aircraft Company carried out a survey of operators in support of the activities of the IAMFTWG[3] Thermal Acoustic Insulation Contamination and Aging Task Group (reference 8). The survey was aimed at determining the contaminants that were found on the insulation blankets of in-service aircraft.

Thirty five airlines responded to the survey and the relative frequency of reported occurrences of contaminants identified is as shown in figure 3. As with the analysis of hidden fire occurrences, described in section 6.1 , it should be noted that the data relates to the frequency of reporting of contaminants and is not necessarily indicative of the quantities of the contaminants found.

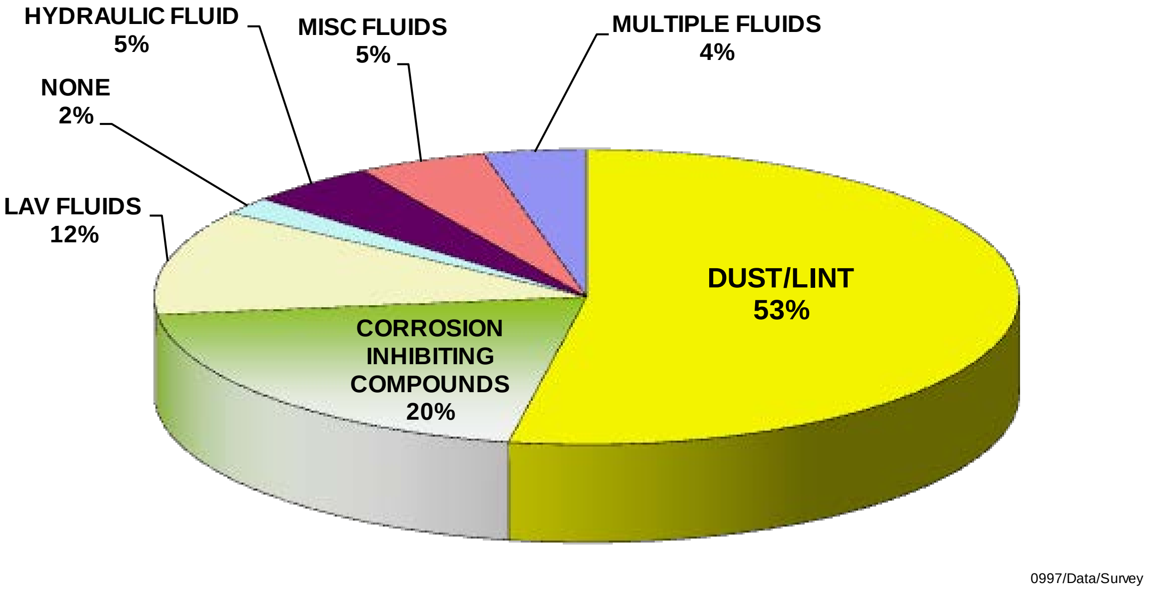

Figure 3. Results of Survey on Contaminants Found on In-Service Aircraft

It is noteworthy that the survey did not identify debris as a contaminant. This could however be due to the reporters not considering debris to be a TAI contaminant.

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[3] International Aircraft Materials Fire Test Working Group

7. THE TRANSPORT CANADA ARC FAULT TEST RIG

7.1 GENERAL

This section summarizes the test equipment and methodology used for flammability testing of contaminated thermal acoustic insulation (TAI) throughout the study using the Transport Canada Arc Fault Test Rig.

7.2 TEST EQUIPMENT

7.2.1 Test Rig

Transport Canada commissioned the development of an arc fault test rig for testing thermal acoustic insulation materials either in an uncontaminated or contaminated state. The test rig is intended to simulate possible ignition sources that might be generated by an electrical fault. The key features are outlined below:

The test rig (see figure 4) consisted of an aluminum alloy receptacle mounted on a rigid steel frame to hold the insulation test specimens and a pair of arc electrodes (R.G.W Cherry and Associates drawing number 0961/D/000361/KK Rev 1). Mains powered quartz radiant heater panels, controlled with a variable transformer, are located approximately 75 mm (3 inches) above the test samples.

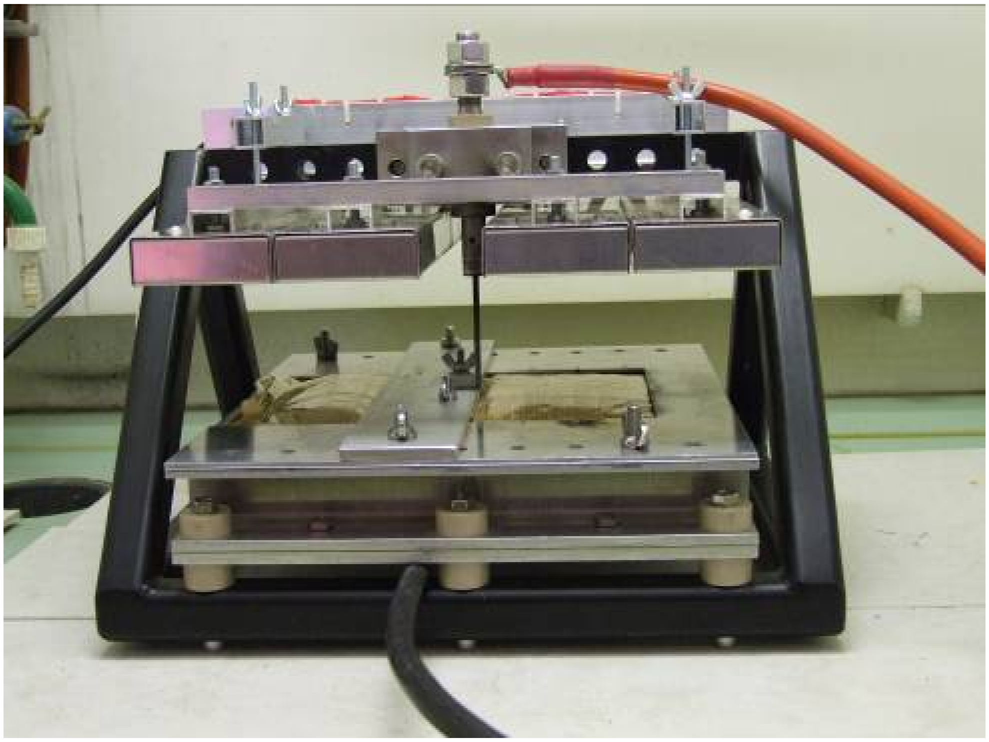

Figure 4. Test Rig Including Sample Holder, Electrodes, and Quartz Heaters

7.2.2 Arc Generator

A mains/battery powered arc generator specially designed and manufactured by Culham Lightning Ltd is used to create and control the arc at the electrodes.

The arc generator is set up so that a continuous electrical arc of 20 – 30 volts dc with a power of 400 watts may be generated immediately against the surface of the TAI and contamination materials being tested. The arc is applied continuously until ignition of the test materials occurred. The maximum duration of the arc is around 10 seconds, limited by burning of the electrodes on the test rig.

7.2.3 Laboratory Setup

The test rig is located within a laboratory fume cupboard to allow the extraction of smoke and fumes at the end of each test run. The arc generator, batteries and instrumentation are set up in the laboratory adjacent to the test rig (see figure 5).

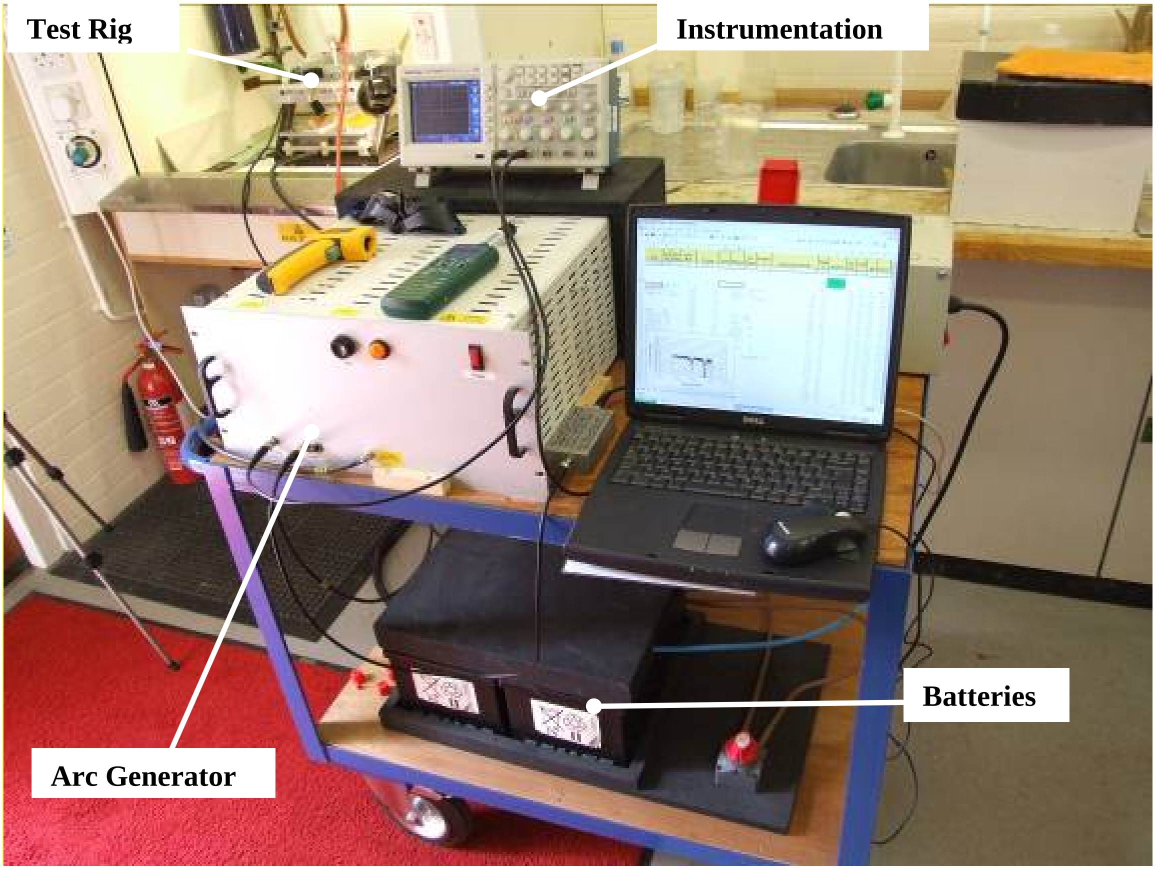

Figure 5. Arc Generator and Test Rig Set Up in Laboratory

7.3 TEST SAMPLES

7.3.1 Test Sample Construction

Testing was carried out on thermal acoustic insulation samples measuring 240 mm x 190 mm (9.5 x 7.5 inches) - see figure 6. The construction incorporates a layer of bagging film material and a layer of 25 mm (1 inch) thick fiberglass insulation stapled to 6 mm (¼ inch) thick rigid cardboard. The edges of the bagging film and insulation were thus constrained in a manner representative of an airplane installation.

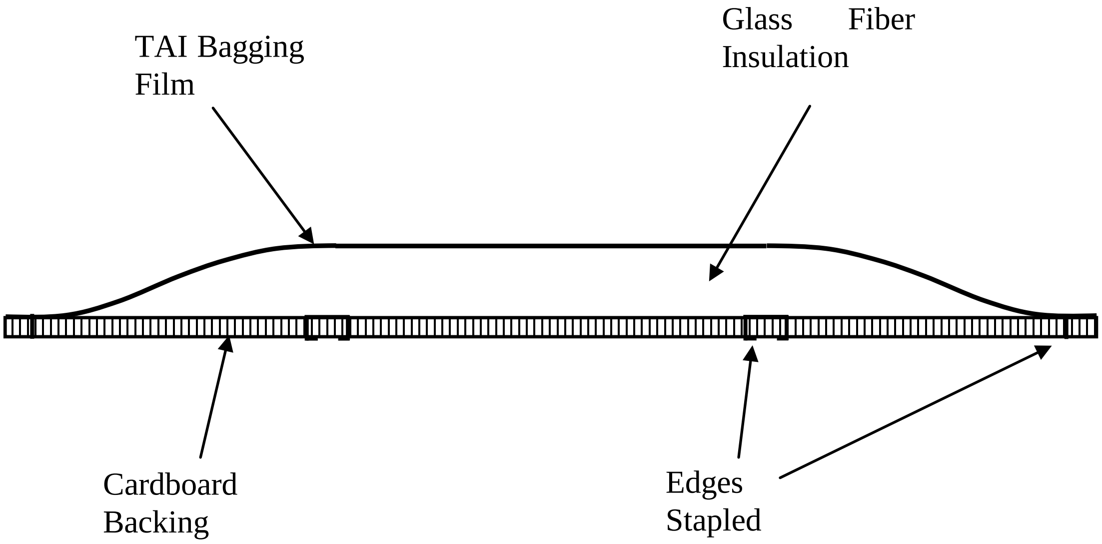

Figure 6. Test Sample Detail

7.3.2 Test Sample Temperature

Tests are conducted with the sample at ambient temperature or with radiant heat applied that raises the surface temperature of the test sample to a nominal 100° C or 200° C. Test results for uncontaminated TAI when radiant heat is applied such that the sample is at 200° C correlate well with the FAA Radiant Panel Test [4].

The objective of the ambient temperature tests (nominally 20° C) is to represent the test materials being in an airplane undergoing normal operations in order to explore the potential for their ignition and propagation when subjected to an electrical arc.

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[4] "FAA Radiant Panel Test" refers to the equipment and test method defined in part VI of Appendix F to Part 25, which is the required method for demonstration of compliance with airworthiness regulations CAR/CS/FAR 25.856(a).

The objective of the 100° C surface temperature tests is similar to the ambient temperature tests with the exception that the test materials are in a heated environment, such as might occur where heat is released from airplane electrical equipment or in parts of an airplane which have undergone a hot soak in the sun.

The objective of the 200° C surface temperature tests is to broadly represent the materials being in an environment already subjected to the effects of fire, in which the heat flux from the fire would substantially elevate the surface temperature of the material. This is similar to the FAA Radiant Panel Test; information from the FAA suggests that the surface temperature of Polyimide TAI bagging film material at the ‘zero point’ builds up to approximately 218° C during the 15 second duration of the test. However, in the 200° C tests, the ignition source is an electrical arc whereas in an in-service fire occurrence the ignition source would be flames from an existing fire.

The effects of variations in sample temperature on the flame characteristics of dust and lint are contained in appendix 3.

7.3.3 Test Sample Attitude

The attitude of the test rig and sample can be set to any angle between horizontal and vertical. The majority of tests were conducted with the samples horizontal, however, various other angles were used throughout the study for comparison purposes.

The effects of variations in sample attitude on the flame characteristics of dust and lint are contained in appendix 4.

7.4 PASS/FAIL CRITERIA

The pass/fail criteria used throughout the study are similar to those for the FAA Radiant Panel Test.

The result is a FAIL if ignition occurs and the flame propagates further than 2 inches from the arc electrode position. (This is referred to as the propagation distance.) Or -

The result is a FAIL if ignition occurs and the flame propagates for a time of more than 3 seconds after the arc is switched off. (This is referred to as the after-flame time.)

8. FLAMMABILITY TESTING OF CONTAMINANTS

8.1 GENERAL

This section provides details of the more significant results and findings from the flammability testing carried out on contaminated thermal acoustic insulation using the Transport Canada Arc Fault Test Rig. Where available, comparison is also made with similar tests conducted by Boeing and Airbus on the FAA Radiant Panel Test.

Details of the equipment and test methodology adopted for testing, carried out on the Transport Canada Arc Fault Test Rig, are contained in section 7. .

Throughout this section, test results are declared as ‘Pass’ or ‘Fail’. The following key is applicable to all tabulated test results:

P	**= Pass**
F	**= Fail**
▨	**= Not Tested**

The pass/fail criteria, for the Transport Canada Arc Fault Test Rig, used throughout the study are similar to those for the FAA Radiant Panel Test and are explained in section 7.4.

8.2 DUST AND LINT ON THE SURFACE OF THERMAL ACOUSTIC INSULATION

8.2.1 General

The primary objective of the testing was to determine the threshold contamination level (grams/m^2) required for dust and lint to be ignitable by an electrical arc and to propagate, when contaminating the surface of thermal acoustic insulation (TAI). Section 9.6.2 addresses the levels of dust and lint contamination actually experienced on in-service airplanes.

8.2.2 Testing

Flammability testing using the Transport Canada Arc Fault Test Rig was conducted on TAI test samples having the external surface of the bagging film material contaminated with dust and lint collected from in-service airplanes. Testing was carried out using only Polyimide bagging film material. This was chosen because of its excellent flammability resistance, thus enabling the flammability properties of only the dust and lint to be assessed.

Weighed amounts of dust and lint were dispersed as evenly as practical over the test area of the TAI samples to provide the required contamination level.

Testing was conducted with the samples at 20 degrees from horizontal at ambient temperature with no radiant heat applied.

8.2.3 Test Results

The test results are summarized in table 2.

Tests with the dust and lint contamination level greater than 20 g/m^2 failed. Typical flame propagation is illustrated in figure 7.

Table 2. Test Results for TAI Contaminated With Dust and Lint

DUST/ LINT CONTAMINATION LEVEL (grams/m^2) 9925/R/000548/KK Section 5	Test Result
120	F
80	F
40	F
20	P

Figure 7. Flame Propagation (dust and lint contamination level 80 grams/m^2)

8.2.4 Findings

Based on the testing conducted in this study, the threshold contamination level required for dust and lint to be ignitable by an electrical arc and propagate when contaminating the surface of TAI at ambient temperature has been established to be in the region of 20 grams/m^2. This contamination level represents a relatively light covering. This threshold is likely to be lower at higher temperatures, however, the degree to which lower levels of contamination will pose a realistic fire threat is unknown.

Testing in this study showed that test sample attitude and radiant heat have a marked effect on the flame characteristics of burning dust and lint. Details are shown in appendices 3 and 4 respectively. The application of radiant heat will cause dust and lint to burn more vigorously.

For all contamination levels of dust and lint where ignition occurred during testing, the resulting flames appeared relatively weak and gave the appearance of minimal heat release. No appreciable difference in the flame size or propagation characteristics were observed for differing amounts of contamination. This would suggest that fires involving dust and lint alone are likely to be relatively benign and possibly have limited threat. This is supported by an analysis of in-service hidden fire occurrences on Boeing airplanes – see section 5.2 . However, evidence from the L-1011 in-flight fire occurrence in 1991 (reference 7) would suggest that this might not always be the case. Since, for this hidden fire occurrence which involved dust and lint as the primary combustible material, flames two feet high above the cabin floor occurred requiring a concerted in-flight fire-fighting effort and causing extensive fire damage to the airplane floor, carpet, and passenger belongings.

Given the available evidence, it is likely that once ignited, a dust and lint fire might initially progress gently, if at all, but then accelerate considerably if sufficient radiant heat has been generated and concentrations of dust and lint or other flammable contaminants are sufficient.

8.3 HYDRAULIC FLUID ON THE SURFACE OF THERMAL ACOUSTIC INSULATION

8.3.1 Testing

Flammability testing using the Transport Canada Arc Fault Test Rig was conducted on thermal acoustic insulation (TAI) test samples having the external surface of the bagging film material contaminated with phosphate ester based hydraulic fluid. The hydraulic fluid was a type approved for use by major airplane manufacturers.

Prior to testing, the outer surface of the samples was thoroughly wetted with hydraulic fluid, left to stand for 100 hours at ambient temperature (15° - 30° C) then superficially wiped with a dry cotton cloth prior to testing. A slight oily residue remained on the surface of the sample at the time of testing.

Testing was conducted with the samples horizontal and with radiant heat applied.

8.3.2 Test Results

The test results, for five TAI bagging film Materials are summarized in table 3.

Table 3. Test Results for TAI with Hydraulic Fluid Surface Contamination

TAI BAGGING FILM MATERIAL 0998/R/000466/KK Section 7.2.4	**ARC FAULT TEST RIG**		
	Sample Temperature		
	Ambient	**100° C**	**200° C**
Polyimide	▨	P	P
PET	▨	P	P
MPVF	▨	P	P
PEEK	▨	P	P
PEKK	▨	P	P

8.3.3 Findings

The test results indicate that short term exposure to hydraulic fluid is unlikely to have a detrimental effect on the flammability properties of TAI bagging film materials and that the hydraulic fluid residue that could remain after superficial cleaning is not flammable. However, the long term effects of hydraulic fluids on the integrity of bagging film materials requires further consideration as discussed in section 11.3.

8.4 HYDRAULIC FLUID SOAKED INTO FIBERGLASS

8.4.1 Testing of Purpose Made Samples

Flammability testing using the Transport Canada Arc Fault Test Rig was conducted on thermal acoustic insulation (TAI) test samples having the internal fiberglass insulation contaminated with phosphate ester based hydraulic fluid. The samples simulated fluid leakage from the airplane hydraulic systems entering the TAI bag through a damaged bagging film and wicking into the fiberglass. The hydraulic fluid used in the testing was a type approved for use by major airplane manufacturers.

TAI samples were prepared using PEKK bagging film material. This material was chosen, since unlike Polyimide, it melts in the presence of a flame. This could potentially provide a worst case scenario in which the contaminated fiberglass is progressively exposed as the flame propagates and melts the TAI bag.

A 25 mm (1 inch) square hole was made in the bag at the electrical arc location. Immediately prior to the test, 5 ml of hydraulic fluid was poured into the hole and allowed to soak into the fiberglass insulation batting material. It was noted that the hydraulic fluid dispersed around 2 inches.

Testing was conducted with the samples horizontal with and without radiant heat applied.

The test results are summarized in table 4. The test samples failed at all temperatures tested - Ambient, 100° C, and 200° C.

Table 4. Test Results for TAI Contaminated with Hydraulic Fluid in the Fiberglass

TAI BAGGING FILM MATERIAL 9917/R/000498/KK Section 3	**ARC FAULT TEST RIG**			**RADIANT PANEL**	
	Sample Temperature				
	Ambient	**100° C**	**200° C**	**Boeing**	**Airbus**
Polyimide					
PET					
MPVF					
PEEK					
PEKK	F	F	F		

It was noteworthy that despite the amount of contamination applied to the fiberglass insulation being relatively small, the extent of fire during each test was significantly longer lasting than had been experienced with other potentially flammable contaminants such as corrosion inhibiting compounds and dust and lint. The hydraulic fluid that had wicked into the fiberglass appeared to provide a reservoir of fuel for the fire.

Figure 8 shows the fire during a 200° C test.

Figure 8. Hydraulic Fluid Fire During 200° C Test

8.4.2 Testing TAI Blankets Contaminated with Hydraulic Fluid

A TAI blanket heavily contaminated with hydraulic fluid was extracted from an in-service airplane - see figure 9.

Figure 9. TAI Contaminated with Hydraulic Fluid

Following removal from the airplane and during a six month period of storage, the TAI cover material appeared to have been degraded by the hydraulic fluid and had become relatively fragile.

The hydraulic fluid had dispersed by leaking out of the bag leaving the fiberglass damp rather than wet. The fiberglass was also rather fragile. The salvageable area of the blanket was sufficient to make only four test samples.

The test sample, cut from the hydraulic fluid contaminated TAI blanket that had been extracted from an airplane, marginally passed at ambient temperature when in the horizontal attitude. However, samples tested at ambient temperature failed when inclined at 20-degrees and 90-degrees to the horizontal. The overall test result for ambient temperature is therefore considered to be a fail.

The sample tested at 100° C, mounted horizontally, failed. (Tests were not considered necessary at 200° C because the samples failed at the lower temperatures.)

As with the purpose made test samples, in order to ignite the samples at ambient temperature, it was necessary to continue the arc for much longer than for the higher temperature tests.

8.4.3 Findings

Using the Transport Canada Arc Fault Test Rig, thermal acoustic insulation test samples having the fiberglass insulation contaminated with phosphate ester based hydraulic fluid were shown to be ignitable with an electrical arc at ambient temperature. The resulting fires propagated across the contaminated insulation. With the samples at elevated temperatures, ignition with the arc was more rapid and the resulting fires were more extensive. Samples cut from an airplane thermal acoustic insulation blanket contaminated with hydraulic fluid were similarly flammable.

These test results demonstrate that even a small amount of phosphate ester based hydraulic fluid contamination entering a thermal acoustic insulation blanket could present a significant flammability threat in the hidden areas of an airplane.

8.5 CORROSION INHIBITING COMPOUNDS ON THE SURFACE OF THERMAL ACOUSTIC INSULATION

8.5.1 Testing

Flammability testing using the Transport Canada Arc Fault Test Rig was conducted on thermal acoustic insulation (TAI) test samples having the external surface of the bagging film material contaminated with corrosion inhibiting compound (CIC). Five TAI bagging film materials were tested when contaminated with five different CICs. The CICs were approved for use by major airplane manufacturers. Three of the CICs were of the non-waxy type and two were of the waxy type which remains soft when fully cured. One of the CICs had also been tested by Boeing using the radiant panel test (reference 9).

The outer surface of the samples were aerosol spray coated with CIC, allowed to dry and left to stand for a total of 100 hours at ambient temperature (15° - 30° C) prior to testing. Validation of the 100 hour drying time is detailed in section 8.7. The CIC contamination level was approximately 20 – 30 grams/m^2 (when dry).

Testing was conducted with the samples horizontal with and without radiant heat applied.

8.5.2 Test Results

The test results are summarized in table 5. For some CICs in order to establish their flammability characteristics it was not considered necessary to test them with all TAI bagging film materials or at all temperatures.

8.5.3 Findings

When contaminating the surface of TAI bagging film materials, all of the CICs tested were shown to be flammable under certain temperature conditions. Some are ignitable by an electrical arc and will propagate a fire when at room ambient temperature (20° C). In contrast, others were only ignitable by an electrical arc when exposed to a relatively high level of radiant heat such as might be experienced in a fire already in progress.

The variability of the flammability properties of the five CICs tested in this study would suggest that there is potential for reducing the fire threat that might be posed by TAI contaminated with CIC if CICs having the best flammability properties were to be chosen.

Table 5. Test Results for TAI Contaminated with CIC

	Transport Canada Arc Test Rig			**FAA Radiant Panel Test**	
	Sample Temperature			**Boeing**	**Airbus**
Bagging film Material	**Ambient**	**100° C**	**200° C**		
CIC – A (Non-Waxy Type)					
Polyimide	P	P	F		
PET	P	P	F		
MPVF	P	P	P		
PEEK		P	F		
PEKK		P	F		
CIC – B (Non-Waxy Type)					
Polyimide	P	F			
PET					
MPVF					
PEEK					
PEKK	P	F	F		
CIC – C (Non-Waxy type)					
Polyimide	P	F	F	F	
PET				F	
MPVF				P	
PEEK					
PEKK	F	F	F		
CIC – D (Waxy Type)					
Polyimide	P	P	F		
PET	P	P	F		
MPVF	P	P	P		
PEEK		P	F		
PEKK		P	F		
CIC – E (Waxy Type)					
Polyimide	F	F	F		
PET					
MPVF					
PEEK					
PEKK	**F**	**F**			

8.6 CORROSION INHIBITING COMPOUNDS ON METAL AIRPLANE STRUCTURE

8.6.1 General

Given the high degree of flammability exhibited by some CICs when contaminating the surface of TAI, it was considered important to establish whether CICs are flammable when in their intended use - coating metal airplane components and structure.

8.6.2 Testing

Flammability testing using the Transport Canada Arc Fault Test Rig was conducted on both aluminum foil and aluminum sheet when coated with the CIC – E. This CIC was assessed as being the most flammable CIC of the five tested in this study (see table 5). The aluminum foil was 0.08 mm (0.003 inches) thick and the aluminum sheet was 0.68 mm (0.066 inches) thick. Both were unpainted.

The outer surface of the samples were aerosol spray coated with CIC, allowed to cure and left to stand for a total of 100 hours at ambient temperature (15° - 30° C) prior to testing. Validation of the 100 hour drying time is detailed in section 8.7. The CIC contamination level was approximately 20 – 30 grams/m^2 (when dry).

Testing was conducted with the samples horizontal with radiant heat applied.

8.6.3 Test Results

The aim of the tests was to raise the surface temperature of the metal samples to 200° C and then apply the arc ignition source. This was in order to represent CIC coated metal airplane structure being exposed to conditions that might be present in an established on board fire.

With the radiant heaters operating at maximum output it was just possible to raise the aluminum foil samples to 200° C. However at maximum heater output the highest surface temperature achievable for the sheet aluminum samples was only 180° C; possibly due to the greater heat dissipation of the thicker aluminum material. The test results are shown in table 6.

Table 6. Test Results for Aluminum Coated with CIC

	Transport Canada Arc Test Rig		
	Sample Temperature		
	150° C	**180° C**	**200° C**
Aluminum Foil	P		F
Sheet Aluminum		P	

8.6.4 Findings

The failure of the CIC contaminated aluminum foil sample at 200° C would suggest that if a thin metal substrate reaches a sufficiently high temperature, such as in an established fire, then the CIC coating is likely to aid the fire propagation. However, the ‘Pass’ test result for the CIC contaminated aluminum sheet at 180° C and the aluminum foil at 150° C indicates that an arc fault is unlikely to ignite the CIC coating on an airplane structure. It would appear that heat is readily dissipated by the aluminum – this would be even more pronounced with the potential that exists for heat dissipation from the airplane structure in flight. These results are in contrast to TAI contaminated with CIC where the insulation would appear to reduce heat dissipation significantly.

8.7 CORROSION INHIBITING COMPOUND FLAMMABILITY WITH TIME

8.7.1 General

All the CICs tested using the Transport Canada Arc Test Rig during this study contain flammable solvents. It would be expected that after application of the CIC its flammability would be affected by the amount of solvent present. It would also be expected that the flammability will have reached a minimum once the CIC is dry.

Drying/handling times quoted by the CIC manufacturers vary from 1 to 3 hours. While not precisely measured, drying times similar to these were experienced during the manufacture of the test samples used in this study.

The interval that is likely to occur between the application of a CIC during maintenance and when an airplane re-enters service has been assumed in this study to be at least four days. Consequently, prior to arc testing CIC contaminated samples have been allowed to dry in ambient conditions for four days (approximately 100 hours), which is well beyond the expected drying times. In order to validate that 100 hours drying time is sufficient to allow for evaporation of all the solvent within the CICs, an investigation into the relationship between residual solvent level and drying time was carried out as follows:

8.7.2 Testing (Solvent Evaporation Times)

Samples of Polyimide TAI bagging film material measuring 100 mm x 100 mm (4 x 4 inches), were coated with three different CICs and weighed on digital laboratory weighing scales at intervals over a period of four days to determine the time taken for the solvents to evaporate fully while drying at room temperature (18° – 25° C), as indicated by the time taken for the sample weights to stabilize.

8.7.3 Results

For all three CICs investigated, the sample weights reached a minimum within around five hours after application. (Beyond five hours there was no appreciable weight reduction.)

By 100 hours (four days) the weights of the CIC samples had been stable for more than 3 days, indicating that the 100 hour (four day) drying time used for test samples was sufficient to ensure that any residual solvent was negligible.

8.7.4 Findings

Based on the limited number of CICs tested, the results would suggest that providing an airplane is not returned to service within 5 hours of CIC application then any residual solvent within the CIC, and hence the flammability, will be minimized.

8.8 CLEANING FLUIDS ON THE SURFACE OF THERMAL ACOUSTIC INSULATION

8.8.1 Testing

Flammability testing using the Transport Canada Arc Fault Test Rig was conducted on thermal acoustic insulation (TAI) test samples having the external surface of the bagging film material contaminated with solvent cleaning fluids. Five TAI bagging film materials were tested when contaminated with Acetone, Isopropyl Alcohol (IPA), or a proprietary cleaning fluid designed as a substitute for Methyl Ethyl Ketone (MEK). Some of the cleaning fluids had also been tested by Boeing (reference 10) or Airbus (reference 11) using the radiant panel test.

Two simulated cleaning operations were carried out one hour apart on the outer surface of the samples. The samples were then left to stand at ambient temperature (15° - 30° C) for 100 hours prior to testing. The simulated cleaning operations involved thoroughly wetting the TAI surface with cleaning agent then scrubbing the surface with a wetted cotton cloth for one minute. Care was taken to ensure the surface of the TAI was thoroughly wet with cleaning agent while scrubbing. In all cases, residual cleaning agent evaporated rapidly.

Testing was conducted with the samples horizontal with and without radiant heat applied.

8.8.2 Test Results

The test results are summarized in table 7.

Tests on all five of the TAI bagging film materials passed when tested using the Transport Canada Arc Fault Test Rig. However, two of the cleaning fluids failed on PEKK bagging film material when tested by Boeing using the radiant panel test.

Table 7. Test Results for TAI Contaminated with Cleaning Fluids

TAI BAGGING FILM MATERIAL 0998/R/000466/KK Section 7.2.3	**ARC FAULT TEST RIG**			**RADIANT PANEL**	
	Sample Temperature				
	Ambient	**100° C**	**200° C**	**Boeing**	**Airbus**
Acetone					
Polyimide	P	▨	P	▨	P
PET	P	▨	P	▨	▨
MPVF	P	▨	P	P	▨
PEEK	P	▨	P	▨	▨
PEKK	P	▨	P	F	▨
Isopropyl Alcohol (IPA)					
Polyimide	P	▨	▨	▨	▨
PET	P	▨	▨	▨	▨
MPVF	P	▨	▨	P	▨
PEEK	P	▨	▨	▨	▨
PEKK	P	▨	▨	P	▨
Proprietary Substitute for MEK					
Polyimide	▨	P	P	▨	▨
PET	▨	P	P	▨	▨
MPVF	▨	P	P	P	▨
PEEK	▨	P	P	▨	▨
PEKK	▨	P	P	F	▨

8.8.3 Findings

Solvent cleaning fluids (Acetone, IPA, and a proprietary substitute for MEK) are unlikely to increase the flammability of TAI bagging film materials. The solvents evaporate readily and leave no deposit that could potentially act as a fuel. However, the solvents may potentially remove flame retardant coatings or even degrade the bagging film material but this was not established during the tests conducted in this study.

9. AIRPLANE SURVEYS

9.1 GENERAL

This section provides details of surveys carried out primarily intended to quantify the levels of contamination that may be present on in-service airplanes. The surveys also identified other issues that might affect the potential for hidden fires e.g. degradation of TAI bagging film material.

The survey data were analyzed in order to characterize the factors influencing the degree of fire threat that might be present in any airplane zone. For example, the rate of contamination build-up and how individual airplane designs and operating environments may affect the type and extent of contamination present.

9.2 CATEGORIZATION OF THERMAL ACOUSTIC INSULATION CONTAMINANTS

The contaminants that may be found on thermal acoustic insulation may be divided into the following categories:

1. Approved materials used or recommended by the airplane manufacturer or operators for use on the airplane (including corrosion inhibiting compounds, cleaning fluids, hydraulic fluids, etc.)

2. Materials that contaminate thermal acoustic insulation simply as a result of airplane usage (including debris, dust, lint, etc.)

These contaminants may be further divided according to the mechanism by which they might degrade the flammability of TAI materials:

Mechanism A -	Materials that coat or remain on the surface of the TAI blanket which might act as a fuel (including corrosion inhibiting compounds, dust, lint, hydraulic fluids, etc.)
Mechanism B -	Materials that might chemically degrade the TAI blanket or remove flame retardant coatings (including solvent cleaning fluids, hydraulic fluids, etc.)

Some contaminants might act as a fuel and chemically degrade the TAI blanket.

It is not feasible for the surveys to encompass all of the possible TAI material/contaminant combinations and hence primary attention has been directed toward flammability degradation (mechanism A). However, consideration of degradation (mechanism B) is given in section 11.11 of this report.

9.3 AIRPLANE SURVEY DETAILS

Fourteen airplanes were surveyed including narrow body and wide body jets and a turboprop.

The surveys primarily addressed zones of the airplanes that were likely to contain contaminants which in certain circumstances could pose a fire threat when contaminating thermal acoustic insulation blankets. These contaminants included dust and lint, corrosion inhibiting compounds, and hydraulic fluids.

As well as collecting contamination samples, primarily dust and lint, each survey involved photographs being taken of zones subjected to the survey and any particular irregularities that might exist that might contribute to the fire threat – such as damaged thermal acoustic insulation in zones that could be subjected to hydraulic system fluid leaks.

9.4 AIRPLANE SURVEY TECHNIQUE

Surveys were planned to commence as soon as practicable after removal of cabin and cargo compartment lining panels during airplane maintenance or refurbishment. Ideally, all panels were needed to be removed to allow full access, but this was not always achievable since the extent of panel removal was dependent on the scope of maintenance being carried out.

Where possible during each survey, the entire passenger cabin was inspected behind panels to assess whether there was a variation in dust and lint contamination over its length. The areas with the highest contamination level, as determined by visual examination, were then inspected in more detail. A sample (or samples) of dust and lint measuring 50 mm x 50 mm was removed from the surface of the TAI at a location assessed to have the highest contamination level. The samples were carefully bagged to allow accurate weighing to determine the contamination level in grams/m^2. For each sample location, the maintenance organization identified the airplane hours and cycles when the location was last cleaned. The cleaning interval was thus calculated based on the airplane hours and cycles at the time of the survey. To enable flammability testing of the dust and lint, larger amounts were also gathered from suitable locations.

It was initially intended to measure the thickness of the dust and lint at each of the sample locations, however, this was discovered to be impractical and considered to be of limited benefit due to the high degree of thickness variation observed even over the small 50 mm x 50 mm sample areas.

Where significant differences in dust and lint contamination level were observed throughout the hidden areas of the cabin, attempts were made to identify potential reasons. (It was envisaged that differences in contamination levels might be attributable to variables such as cleaning interval, air distribution system design, air flow rates, cabin materials, or cabin class.)

The amount of dust and lint on potential ignition sources such as electrical wiring and equipment was noted and a visual assessment was made as to whether the contamination level was different to areas devoid of EWIS.

Throughout the dust and lint surveys, other contaminants including corrosion inhibiting compounds, hydraulic fluid, and debris such as food wrappers were also identified. In addition, damage or degradation of the TAI was noted.

The above process was also carried out in areas below the passenger cabin floor including behind cargo bay liners and in equipment bays. Generally, no samples of dust and lint were taken from these areas for weighing because it was found that the contamination level was visibly less than in the vicinity of the passenger cabin.

9.5 AIRPLANE SURVEY LIMITATIONS

Several difficulties were experienced during some of the surveys which limited the usability of data for determining the accumulation rate of dust and lint.

i. For a small number of surveys, there was low confidence in the cleaning interval provided by the maintenance organization. For example, this was immediately apparent when very highly contaminated areas were observed at areas declared to have been cleaned as little as 700 flying hours previously. Data such as these were not utilized in the analysis.

ii. On two surveys where the airplanes were undergoing third party maintenance, the maintenance organizations were unable to provide the airplane usage to establish when they had last been cleaned since this information was held by the airplane operators. On these particular surveys, it was not possible to obtain the information from the operators. Consequently, surveys involving airplanes undergoing third party maintenance were avoided.

The experience gained in early surveys was used to influence the planning of subsequent surveys.

9.6 AIRPLANE SURVEY FINDINGS

9.6.1 Airplanes Surveyed

Surveys were carried out on 14 airplanes as illustrated in table 8. These comprised of 6 wide-bodied turbojets, 7 narrow-bodied turbojets, and 1 narrow-bodied turboprop. The names of maintenance organizations and airplane types are not identified in this report in order to respect the confidentiality of the study.

Table 8. Summary of Airplane Surveys

SURVEY NO.	AIRPLANE SIZE	ENGINE TYPE	OPERATION	MAXIMUM DUST & LINT CONTAMINATION LEVEL (grams/m^2)	CABIN CLASS[5]
1	Narrow Body	Turbojet	Short haul	-	Economy
2	Narrow Body	Turbojet	Short Haul	41	Economy
3	Narrow Body	Turbojet	Short Haul	-	Economy
4	Wide Body	Turbojet	Medium Haul	-	-
5	Narrow Body	Turbojet	Short haul	-	Economy
6	Narrow Body	Turbojet	Short haul	-	Economy
7	Wide Body	Turbojet	Long Haul	60	Business
8	Narrow Body	Turbojet	Short haul	-	Economy/QC[6]
9a	Wide Body	Turbojet	Long Haul	124	Economy
9b	Wide Body	Turbojet	Long Haul	73	Business
9c	Wide Body	Turbojet	Long Haul	155	Economy
10a	Narrow Body	Turbojet	Short Haul	6	Economy
10b	Narrow Body	Turbojet	Short Haul	12	Economy
11	Wide Body	Turbojet	Medium Haul	-	-
12a	Wide Body	Turbojet	Long Haul	36	Economy
12b	Wide Body	Turbojet	Long Haul	51	Business
12c	Wide Body	Turbojet	Long Haul	6	First
13	Wide Body	Turbojet	Long Haul	11	Business
14	Narrow Body	Turboprop	Short Haul	-	Economy

Where surveys are shown as 9a, 9b and 9c etc., this signifies that the airplane had more than one cabin class or that sections of the airplane had different cleaning intervals. Each cabin class/section was surveyed separately

An additional survey was carried out on a wide body airplane at an earlier stage in the study. Although this survey was not carried out to the same level of detail as the main program of surveys, some data were however obtained.

9.6.2 Dust and Lint Contamination

The distribution of dust and lint contamination throughout the airplane was surveyed using the technique described in section 9.4.

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[5] 'Cabin Class' refers to the class of cabin at or adjacent to where the dust and lint samples were taken.

[6] 'QC' refers to a cabin that can undergo 'Quick Change' from passenger to cargo configuration.

9.6.2.1 Passenger Cabin – Interior Sidewall Hidden Areas

In all surveys, the heaviest deposits of dust and lint were located on thermal acoustic insulation and EWIS behind the dado panels[7] just above the cabin floor close to the cabin return air grills. There were variations in the level of contamination along the length of the cabin. Figure 10 shows a typical dado panel installation with dust and lint concentrated on the thermal acoustic insulation surface behind the panel in a location that corresponds to the path of the cabin return air flow. Thermal acoustic insulation and EWIS located further above the air return grills were free from dust and lint contamination.

Figure 10. Dust and Lint Deposits Behind Dado Panel

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[7] Dado panels are the interior lining panels generally located between the cabin floor and windows.

Passenger Cabin – Hidden Area above Ceiling

Hidden areas above cabin ceilings were generally free from any significant deposits of dust and lint as illustrated in figure 11.

Figure 11. Clean TAI and EWIS Above Cabin Ceiling

However, on one airplane type the cabin air supply system included air recirculation outlets in the attic area above the cabin ceiling. Dust and lint had been ejected from the outlets on to the surface of the thermal acoustic insulation, EWIS, and system control cables as illustrated in figure 12.

Figure 12. Dust and Lint Above Cabin Ceiling Ejected From Air Recirculation Outlet

9.6.2.2 Cargo Bay Hidden Areas

Significant accumulations of dust and lint were also visible on thermal acoustic insulation and EWIS immediately below the cabin floor in the fuselage cheek hidden areas located behind the cargo bay lining panels. The contamination level in these areas was visibly no greater than above the cabin floor. Again, the contamination level varied along the length of the fuselage. Typical accumulations are illustrated in figure 13 and figure 14.

Figure 13. Dust and Lint Accumulation Below Cabin Floor

Figure 14. Dust and Lint Accumulation Below Cabin Floor

Accumulations of dust and lint in the proximity of the cabin air outflow valve (figure 15) and recirculation system inlets (figure 16) covered TAI and EWIS over a wider area than other areas beneath the cabin floor. In the other areas, any significant dust and lint accumulations were typically localized just beneath the cabin floor. However, the thicknesses of the accumulations near the cabin air outflow valve and recirculation system inlet were no greater than in any other areas.

Figure 15. Significant Accumulations of Dust and Lint on TAI, EWIS, and Structure Near to Cabin Air Outflow Valve (Outflow valve is located behind mesh guard)

Figure 16. Significant accumulations of Dust and Lint on TAI and EWIS Near to Cabin Air Recirculation Inlet in the Under-Floor Cheek Area

9.6.2.3 Avionics Bay

As illustrated in figure 17, dust and lint deposits were virtually non-existent in avionics bays and on the surrounding thermal acoustic insulation and structure. Only a very fine layer was evident in a few places.

Figure 17. Clean TAI and EWIS in Avionics Bay

9.6.2.4 Flight Deck Hidden Areas

During the surveys, minimal access was available to the hidden areas of flight decks. Where access was available, dust and lint contamination was seen to be at a low level.

9.6.3 Hydraulic Fluid Contamination

In an earlier survey of a single airplane, hydraulic fluid was found to have leaked from a hydraulic pipe connection, damaged the covering of the thermal acoustic insulation and permeated into the fiberglass insulation. The saturated fiberglass was flammability tested using the Transport Canada Arc Fault Test Rig and found to be highly flammable - see section 8.4.2.

During the survey of fourteen airplanes, hydraulic fluid contamination of thermal acoustic insulation was found on one airplane. Figure 18 shows the hydraulic fluid contamination on the TAI lining. The thermal acoustic insulation bagging film was locally damaged, but hydraulic fluid had not permeated into the fiberglass on this occasion. It was not possible to confirm that the TAI damage was a consequence of the hydraulic fluid leak.

Figure 18. Hydraulic Fluid Leakage and Damaged TAI

9.6.4 Corrosion Inhibiting Compound (CIC) Contamination

No evidence of any significant CIC contamination was found on any of the fourteen airplanes surveyed. Any small amounts are likely to have been obscured by general dirt on the surface of the thermal acoustic insulation. However, a localized area of CIC contamination was noted on a single airplane survey carried out in the early part of this study. This is shown in figure 19.

Figure 19. Localized Area of CIC Contamination on TAI

9.6.5 Debris

On one survey, food wrappers were found lying on thermal acoustic insulation located behind cargo bay liners below the rear galley as shown in figure 20. It is likely that the wrappers had dropped down from a waste container in the galley above.

Figure 20. Food Wrappers Lying on TAI

9.6.6 Other Contamination

On one survey, a large amount of leaking hydraulic fluid had dissolved the corrosion inhibiting compound (CIC) coating on the fuselage keel structure as shown in figure 21. This resulted in pools of potentially flammable liquid (hydraulic fluid combined with CIC) lying on the painted metal structure. The flammability characteristics of this liquid are not known although flammability testing of hydraulic fluid on the surface of thermal acoustic insulation was generally found not to present a significant fire threat (see section 8.3) and testing of CICs on aluminum sheet was also shown to be relatively benign (see section 8.6).

However, if the liquid were to be flammable, it might contribute to an already established fire. It is understood from the airplane maintainer that further occurrences of identical contamination have been observed on other examples of the airplane type.

Figure 21. Pools of CIC Dissolved by Hydraulic Fluid in Keel Structure

9.6.7 Thermal Acoustic Insulation Degradation

9.6.7.1 Moisture Contamination/Degradation

Two examples of severe moisture degradation of thermal acoustic insulation were observed. Both were in ‘wet’ areas prone to condensation. One example was observed on thermal acoustic insulation installed adjacent to a passenger door surround (figure 22) and the other was observed on TAI within the fuselage keel (figure 23).

Figure 22. Degraded TAI in ‘Wet’ Area Near Passenger Door Surround

Figure 23. Degraded TAI in ‘Wet’ Area in Fuselage Keel

It is likely that where degradation exists to the extent observed, the flammability properties of the thermal acoustic insulation might also be significantly degraded. The thermal acoustic insulation reinforcing scrim, when exposed as shown in figure 24, could potentially be ignitable and propagate a fire.

Figure 24. Exposed Reinforcing Scrim on Degraded TAI

9.6.7.2 Miscellaneous Degradation

Several occurrences of thermal scoustic insulation degradation with unidentifiable causes were observed. These are shown in figure 25 and figure 26. The flammability properties of the degraded thermal acoustic insulation are unknown.

Figure 25. Degraded TAI

Figure 26. Degraded TAI

9.7 AIRPLANE SURVEY ANALYSIS

9.7.1 Dust and Lint Accumulation Rate

On all surveys, the highest contamination level of dust and lint was always witnessed at the hidden area behind the dado panels just above cabin floor level in the proximity of the cabin return air grills.

The process employed for taking dust and lint samples was to remove a sample 50 mm x 50 mm from the surface of the thermal acoustic insulation behind the lining panels at a location assessed to have the highest contamination level. This assessment was made based on a thorough visual examination of all of the hidden areas. On airplanes with more than one class of cabin, wherever possible, samples were taken from areas adjacent to each class of cabin. At each sample location, the maintenance organization identified the flight hours and cycles when the location was last cleaned. The cleaning interval was thus calculated based on the flight hours and cycles at the time of the survey.

The 50 mm x 50 mm dust and lint samples were weighed in a laboratory using highly accurate electronic weighing scales. The contamination level of each sample was calculated based on the sample area and weight. These contamination levels are shown in table 8 on page 38.

At the study outset, it was considered likely that the accumulation of dust and lint might be related to flight hours or cycles and that it might be possible to determine generic accumulation rates based on these criteria. The measured dust and lint contamination levels were therefore plotted against the time that the zone was last cleaned, measured in flight hours and cycles as shown in figure 27 and figure 28 respectively. The data illustrated are shown for all areas irrespective of their location. Linear lines of best fit (shown dashed) have been added to the graphs with corresponding R^2 (Coefficient of Determination) values[8].

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[8] R^2 values lie in the range from 0 to 1, where a high R^2 value indicates that the points are close to the line of best fit as opposed to a low R^2 value which indicates that the points are not close to the line of best fit.

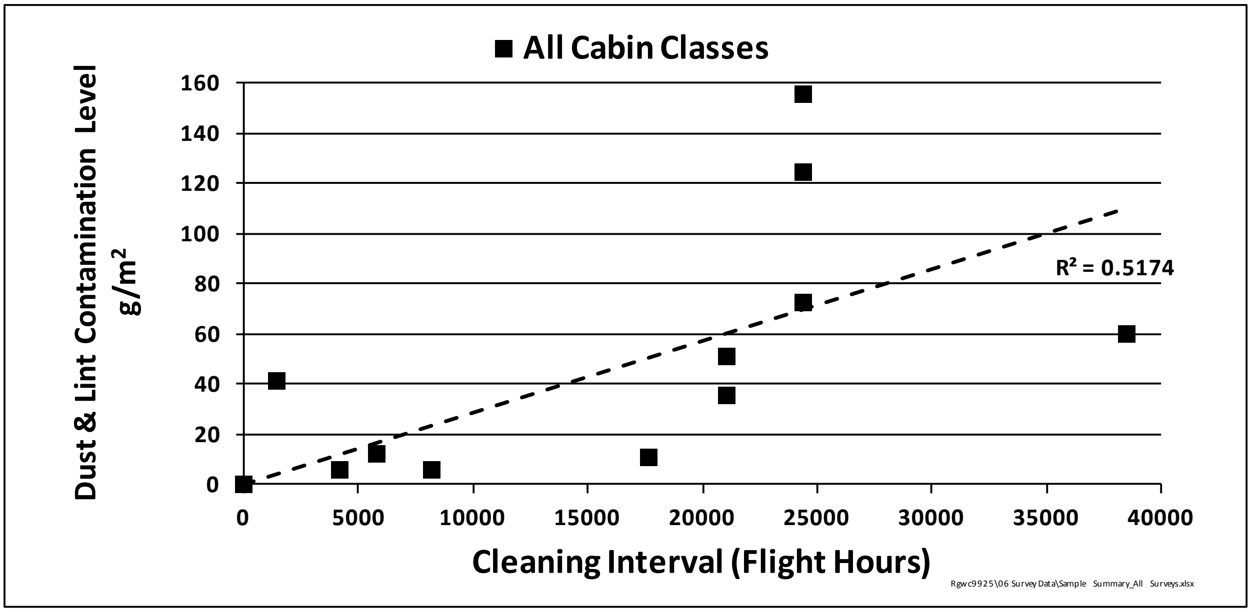

Figure 27. Dust and Lint Contamination Level vs. Cleaning Interval (hours)

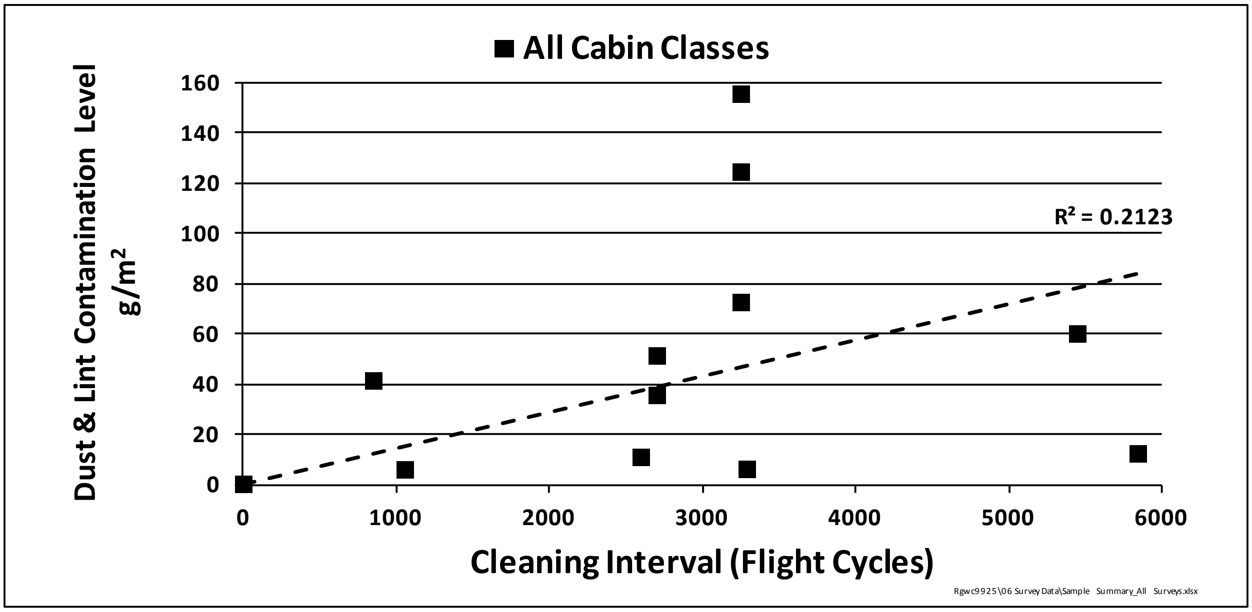

Figure 28. Dust and Lint Contamination Level vs. Cleaning Interval (cycles)

It can be seen that the points are closer to the line of best fit in figure 27 than in figure 28, as indicated by the respective R^2 values. This would suggest that there is a closer correlation between dust and lint contamination level and flight hours than there is with flight cycles.

It is considered that other variables such as class of cabin might influence the accumulation rate of dust and lint. Therefore, the measured dust and lint contamination levels are also plotted against flight hours for areas adjacent to economy class, and business/first class cabins separately. These graphs are shown in figure 29 and figure 30 respectively.

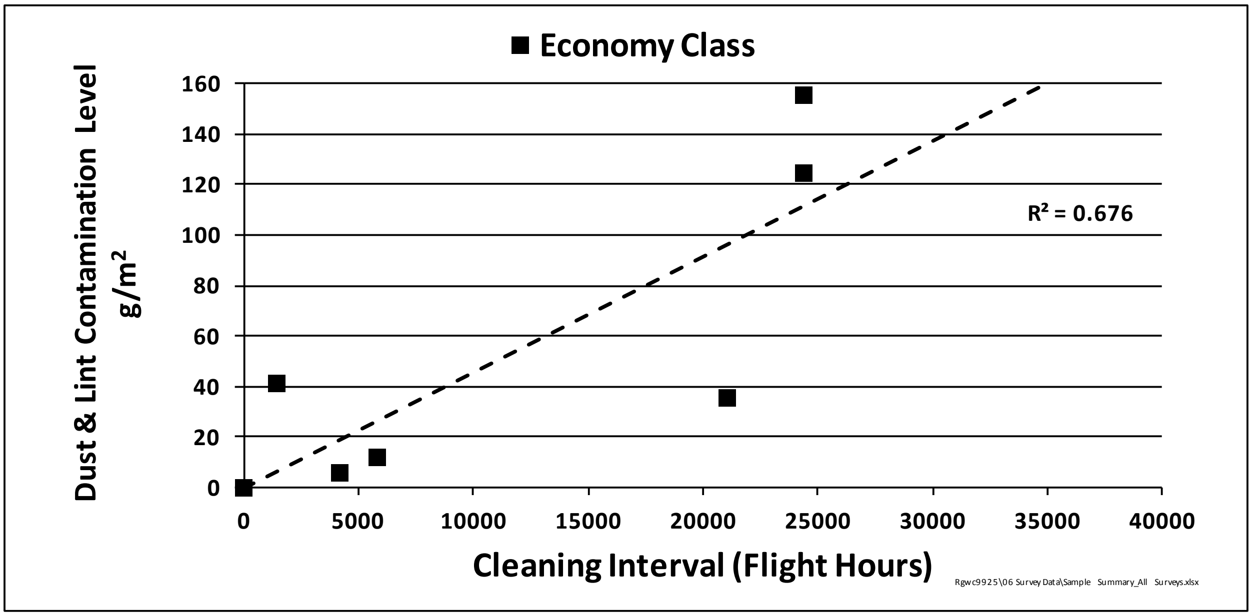

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Figure 29. Economy Class - Dust and Lint Contamination Level vs. Cleaning Interval (hours)

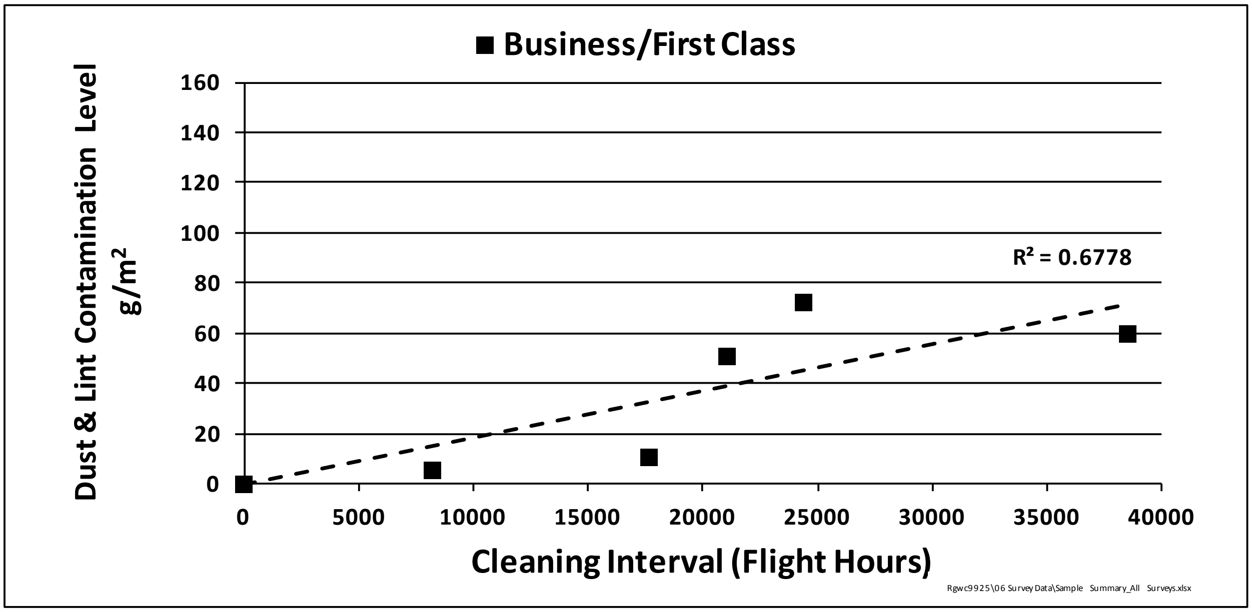

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Figure 30. Business & First Class - Dust and Lint Contamination Level vs. Cleaning Interval (hours)

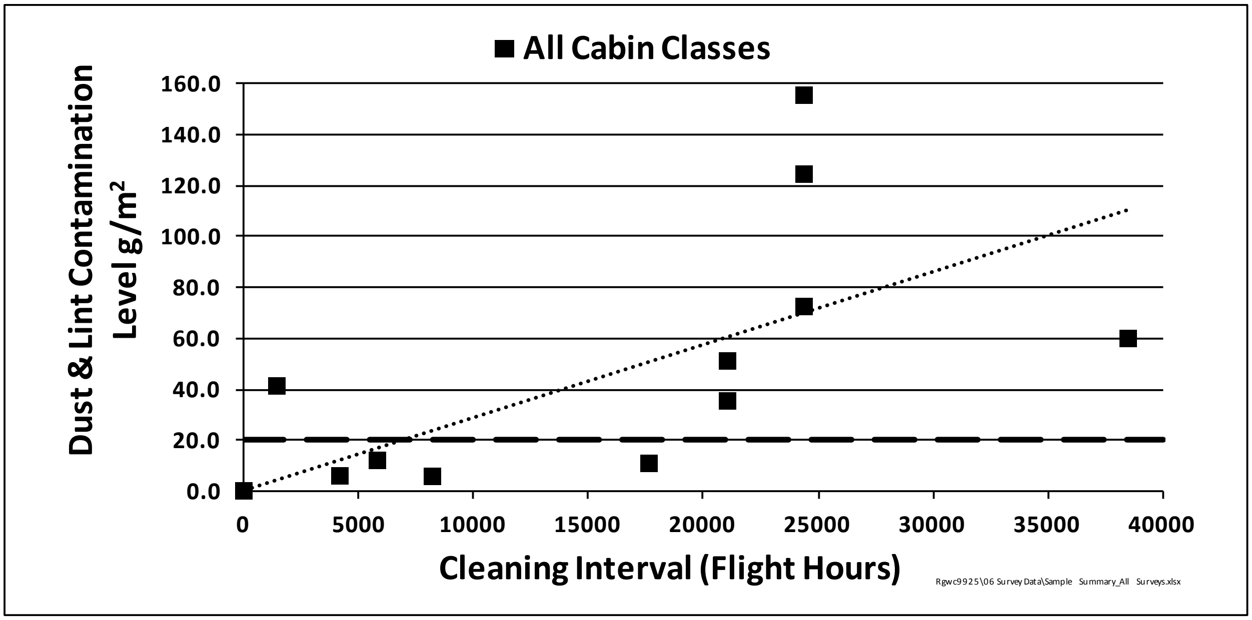
Given the small amount of data available, it would be inappropriate to derive a precise dust and lint accumulation rate. However, it may be seen when comparing figure 29 and figure 30 that the accumulation rate of dust and lint appears to be greater in areas adjacent to economy class than business/first class. This might be explained by differences in passenger seating density, since it is logical that cabins with higher density seating are likely to result in more fibers being shed from the airplane's carpets and seats and more skin dust being generated by the greater number of passenger movements.

On all but one of the surveys which yielded dust and lint accumulation data, the carpets fitted were made of synthetic materials as opposed to wool. Insufficient data is therefore available in this study to determine whether carpet composition affects dust and lint levels.

9.7.2 Comparison Between In-Service Dust and Lint Levels and Flammability Threshold

The threshold contamination level required for dust and lint to be ignitable by an electrical arc and propagate when contaminating the surface of TAI at ambient temperature was assessed to be in the region of 20 grams/m^2. The threshold is likely to be lower for surfaces inclined at greater than 20 degrees to the horizontal and at elevated temperatures - see section 8.2.

This flammability threshold represents a relatively light covering. When compared to the contamination levels of dust and lint measured on in-service airplanes this is quite low. The highest contamination level measured on the surveys was eight times greater than the flammability threshold as illustrated in figure 31. The flammability threshold is shown by the bold dashed line.



Rgwc9925\06 Survey Data\Sample Summary_All Surveys.xlsx

Figure 31. Dust and Lint Flammability Threshold in Relation to Survey Measurements

It is recommended that no firm conclusions should be made with regards to a precise cleaning interval necessary to restrict the amount of dust and lint accumulation to non-combustible levels based on the limited data available in this study. However, the analysis does provide guidance on what might constitute an acceptable level of dust and lint contamination.

9.7.3 EWIS Cleaning

Many examples of EWIS heavily contaminated with dust and lint were observed during the surveys. Moreover, as illustrated in figure 32, many examples were observed where contaminated EWIS was adjacent to or resting on contaminated TAI. This situation could be regarded as a worst case flammability threat, because not only is there a potential risk of ignition from the contaminated EWIS, there is also a risk of fire propagation across the contaminated thermal acoustic insulation[9].

Figure 32. Dust and Lint Contaminated EWIS and TAI

Guidance given in EASA AMC 20-21 (reference 12) and FAA Advisory Circular AC No: 25-27A (reference 2) includes the planning and execution of maintenance activity to ensure combustible material is minimized on EWIS via appropriate cleaning intervals. It would appear from the surveys that the intent of the guidance is not always fully achieved in practice.

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[9] Due to the thermal insulating properties of TAI, a fire involving a combustible material on its surface is likely to propagate more readily than if the combustible material was on a thermally conductive surface such as metal.

9.7.4 Airplane Design Considerations

The surveys have shown that the hidden areas most seriously affected by dust and lint accumulation are just above and below the dado panel return air grills along the length of the cabin, and in the general proximity of the outflow valve and recirculation inlets.

Notwithstanding the periodic cleaning activity undertaken, it is evident that simple design measures could be taken to address the flammability risk associated with EWIS and TAI contaminated with dust and lint.

It is considered that the worst flammability threat occurs where electrical wiring or equipment and thermal acoustic insulation coexist if both are contaminated with dust and lint. This would provide potential for both ignition and fire propagation. Many examples of this situation were observed in the surveys.

It is clear that contaminated thermal acoustic insulation remote from electrical wiring or equipment would have no electrical ignition source and therefore pose a lesser flammability threat. Similarly, contaminated electrical wiring or equipment remote from contaminated thermal acoustic insulation may introduce a potential ignition threat, but there would be limited potential for a significant fire. A design aim that achieved the following would therefore be beneficial:

- Avoidance of dust and lint where electrical wiring or equipment and thermal acoustic insulation coexist, or
- Avoidance of electrical wiring or equipment where dust and lint accumulates on thermal acoustic insulation

There may be potential for achieving these aims by:

- Running wire bundles in conduits and shrouding electrical equipment in areas vulnerable to dust and lint accumulation
- Routing wire bundles and locating electrical equipment to avoid areas affected by high volumes of cabin return air laden with dust and lint
- Controlling the route of cabin return air laden with dust and lint to avoid electrical wiring or equipment
- Utilizing cabin interior materials that minimize the shedding of fibers

While it is recognized that there are many factors that will affect the optimal choice of electrical wiring or equipment installation and the choice of cabin materials, the above issues are worthy of consideration in future aircraft designs.

9.7.5 Summary of Airplane Survey Findings

The following is a summary of findings from the airplane surveys conducted in this study including pertinent findings from the flammability testing:

1. The threshold contamination level required for dust and lint to be ignitable by an electrical arc and propagate, when contaminating the surface of TAI at ambient temperature, is assessed to be in the region of 20 grams/m^2. This represents a fine covering significantly less than the amounts observed in many instances on in-service airplanes and one eighth of the maximum contamination level measured.

2. Levels of dust and lint above this flammability threshold were observed on some EWIS and thermal acoustic insulation on the majority of airplanes surveyed.

3. No significant levels of dust and lint or other contaminants were observed on EWIS or thermal acoustic insulation in airplane zones that accommodate large amounts of EWIS.

4. Cleaning intervals might be longer than are necessary to ensure dust and lint is kept below the flammability threshold. In some instances, levels of EWIS and thermal acoustic insulation contamination appear to be much higher than those intended in the applicable guidance material.

5. Once ignited, dust and lint at ambient temperature burns with a relatively weak flame. The heat flux output from such a flame and the propensity of the flame to propagate to other airplane materials including EWIS has not been explored in this study.

   (Note: Evidence from the L-1011 in-flight fire occurrence in 1991 (reference 7) shows a fire involving dust and lint as the primary combustible material had the potential to cause flames two feet high above the cabin floor, requiring a concerted in-flight fire-fighting effort and causing extensive fire damage to the airplane’s floor, carpet, and passenger belongings).

6. In some locations, dust and lint contamination on EWIS coexisted with large amounts of dust and lint on thermal acoustic insulation giving rise to a propagation risk in the event of electrical arcing.

7. A precise dust and lint accumulation rate was not established in this study due to limited data although the surveys indicate an increasing level of contamination with time.

8. Dust and lint accumulation appears to be related more closely to flight hours than cycles (based on the limited data available).

9. The rate of dust and lint accumulation appears to be greater adjacent to economy class than business/first class cabins (based on the limited data available).

10. On all but one of the surveys which yielded dust and lint accumulation data, the carpets fitted were made of synthetic materials as opposed to wool. Insufficient data are available in this study to determine whether carpet composition affects dust and lint levels.

11. EWIS location and cabin return air routings do not appear to be optimized to minimize dust and lint accumulation on EWIS.

12. Relatively simple design features might be considered for future airplanes to reduce dust and lint accumulation on EWIS or to protect EWIS from dust and lint accumulations.

13. Significant degradation of thermal acoustic insulation was observed on several surveys. The effect of the degradation (primarily resulting from fluid contamination) on the flammability characteristics are unknown.

14. Evidence of hydraulic fluid contamination on thermal acoustic insulation was observed on one of the fourteen airplanes surveyed in the latter part of the study. Although the thermal acoustic insulation cover was locally damaged, the hydraulic fluid had not entered the thermal acoustic insulation or permeated into the fiberglass insulation, unlike on an earlier survey of a single airplane carried out in the early stages of the study. Hydraulic fluid that has permeated into fiberglass insulation has been shown to be flammable (see section 8.4).

15. A hydraulic fluid leak was observed to have dissolved the corrosion inhibiting compound coating over a large area of the fuselage keel during one survey. While this is unlikely to result in a significant fire threat in its own right, it could contribute to an already established fire.

16. No corrosion inhibiting compound contamination of thermal acoustic insulation was observed during the fourteen airplane surveys, although one small area of contamination had been seen during a survey, carried out in an earlier part of the study on a single airplane. While corrosion inhibiting compound contamination on thermal acoustic insulation is likely to be combustible, the survey results would suggest the fire risk is minimal compared to dust and lint.

10. ISSUES RESULTING FROM CONSULTATION WITH INDUSTRY

In the final stages of the research study carried out in 2013, consultation was undertaken with industry organizations involved with the design, installation, and maintenance of thermal acoustic insulation. This included representation from those within both the aircraft manufacturing and operator sectors of the industry and those involved in post-manufacture customization of cabin interiors and their specified thermal acoustic insulation materials. The following represents the results of that consultation.

10.1 CONTAMINANTS

10.1.1 Hydraulic Fluid

One maintenance organization has a policy that thermal acoustic insulation contaminated with hydraulic fluid must be removed. Since the threat of hydraulic fluid permeating into thermal acoustic insulation may pose a significant fire threat, in association with an ignition source, consideration should be given to ensuring that removal of thermal acoustic insulation contaminated with hydraulic fluid is recommended or seen as best practice especially in areas that contain electrical wiring or equipment.

10.1.2 Carpets

Carpet types are likely to exhibit varying rates of release of fibers and hence rate of accumulation onto thermal acoustic insulation.

The consultations suggested that carpet types typically featured on high grade VIP completions are more susceptible to shedding of fibers than synthetic types used more commonly on more standard airline completions.

One maintenance organization identified that additional maintenance tasks are generally specified for the first three years following completion of the VIP style interior and such tasks may then be subsequently escalated to widen the intervals at which these additional maintenance (predominantly cleaning) tasks are performed once the carpet’s initial fiber shedding has ended.

A participating airline design organization was able to demonstrate the work that had been done on their selection of carpet for the various cabin areas and also identified restrictions that had been placed on their completion standards in order to reduce the presence of high fiber release carpet types.

10.1.3 Corrosion Inhibiting Compounds

Aircraft manufacturers publish information regarding specific corrosion inhibiting compounds to be used in the Instructions for Continued Airworthiness. This is intended to assist operators with their selection. However, the criteria used in the selection process are unknown, i.e. whether considerations associated with potential thermal acoustic insulation contamination and flammability issues influence selection. This subject is addressed further in section 11.6.

10.1.4 Water

The study found deterioration of thermal acoustic insulation bagging films as a consequence of water contamination (see section 9.6.7). Damage to the bagging film material can result in penetration of contaminants into the fiberglass insulation material with a consequential fire threat; particularly from hydraulic fluid.

One participant identified that water contamination (salt water) of thermal acoustic insulation was often seen in the vicinity of cargo compartments when live fish were transported.

10.1.5 Fat Deposits

One airline design organization reported experience of thermal acoustic insulation contamination by fat from the galley area which resulted in a localized fire on an aircraft in August 2002. Although thermal acoustic insulation contamination by hydrocarbons was identified in the study of hidden fire occurrences (see section 6.1), catering fats have not been previously identified in this study as a specific contaminant.

10.2 THERMAL ACOUSTIC INSULATION DESIGN FEATURES

10.2.1 Stitching

From the consultations, it was noted that stitching of thermal acoustic insulation is required by the design specifications of certain aircraft manufacturers. There is a clear degradation in the integrity of the thermal acoustic insulation in relation to contamination from fluids if the thermal acoustic insulation is perforated by stitching. Consideration could be given as to whether alternatives such as heat welding of thermal acoustic insulation might be used in place of stitching, particularly in areas where the risk of contamination by hydraulic fluid exists.

10.2.2 Drainage and Ventilation Holes

From the consultations, it was noted that some thermal acoustic insulation blankets feature holes positioned to accommodate both ventilation and drainage. The thermal acoustic insulation specification will identify where these holes are required to be placed.

Drain holes are normally about 5 mm diameter with the ventilation (breathing) holes being pin holes. Both drainage and pin holes are capable of allowing liquids to enter as well as exit the thermal acoustic insulation blankets. See figure 33 as an example of ‘pin’ ventilation holes and figure 34 as an example of drainage holes.

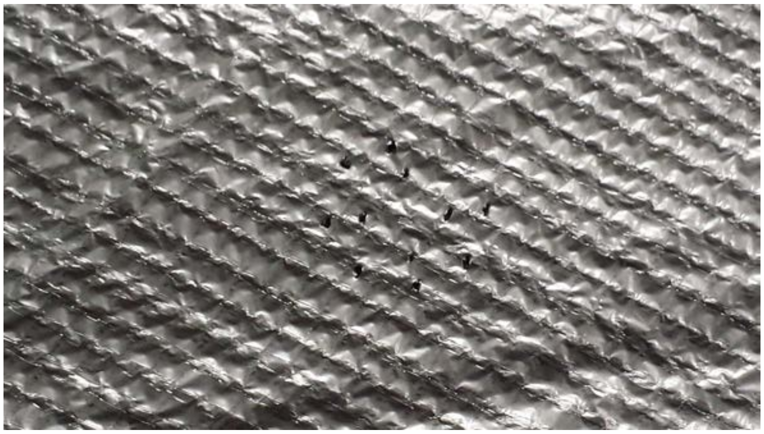

Figure 33. TAI ‘Pin’ Ventilation Holes

Figure 34. TAI Drainage Holes (bottom edge view)

Certain thermal acoustic insulation blankets, particularly where they are located in the upper fuselage area, tend to have ventilation holes only and not drainage holes.

Consideration should be given to whether ventilation holes, in particular, could be positioned so as to reduce the risk of fluid ingress. For example, consideration might be given as to whether they are only located on surfaces which are less likely to be exposed to contamination with hydraulic fluids.

10.2.3 Apertures and Repairs

From the consultations, it was noted that thermal acoustic insulation blankets are sometimes stitched, taped, or welded during manufacture – often around apertures. Where tape is used, the integrity of such sealing is substantially harder to achieve than when thermal sealing (welding) is employed prior to generation of an aperture. An example of tape sealing and thermal sealing of apertures may be seen in figure 35 and figure 36 respectively.

Figure 35. Taped Apertures

Figure 36. Thermal Weld Showing Provision for Apertures to Be Cut

Thermal sealing would seem to offer significant advantages over tape sealing with respect to mitigation of the threat from fluid ingress into the thermal acoustic insulation.

It was identified that while wet tests may be conducted by aircraft manufacturers on the integrity of repair tape and their sealing against water contamination, no such tests are known to be conducted with respect to corrosion inhibiting compounds or hydraulic fluids.

One thermal acoustic insulation manufacturer considered that hydraulic fluids are “corrosive” to adhesive tape and cause de-bonding. It was also reported that while there was no accurate ranking of tape joint versus thermal sealing (welding) joints when tested following exposure to hydraulic fluid, it is considered that the relative performance is in the region of 1:5. That is, the tape sealing will de-bond five times faster than a welded aperture joint.

Therefore, consideration should be given as to whether the resistance of sealing means and repair schemes to contaminants especially hydraulic fluids should be determined during the approval process.

10.2.4 Metalized Film

One thermal acoustic insulation manufacturer suggested that thermal acoustic insulation with metalized film can attract dust due to the build-up of static.

This study has not addressed the effects of thermal acoustic insulation with metalized film on dust and lint accumulation. However, consideration should be given to ensuring that any such effect is considered by design organizations.

10.2.5 Surface Adhesion

Some thermal acoustic insulation bagging films have low adhesion properties and hence are less likely to accumulate large quantities of dust and lint. However, it was considered that such materials are usually heavier than the materials necessary to comply simply with the flame propagation requirements of 25.856(a). Some thermal acoustic insulation bagging film materials, compliant with the flame penetration (burnthrough) requirements of 25.856(b), offer low adhesion characteristics. However, these are generally on the airframe side of the blanket rather than the cabin side.

If bagging film materials having low adhesion characteristics could be shown to provide a cost effective mitigation for dust and lint accumulation, then there could be a reduction in the time to reach contamination levels that are potentially flammable. This could result in a reduction in the maintenance burden that might be needed to achieve the level of cleanliness required. It is suggested that consideration be given to commissioning tests to establish the effect of surface adhesion of dust and lint accumulation to bagging film materials to establish relative performance data in a representative environment.

10.3 ROUTINE MAINTENANCE

From the consultations, it is understood that engineers considered that the introduction of scheduled maintenance specifically for general cleaning activities would be a substantial burden. However, the engineers stated that specific tasks have been generated as a consequence of in-service experience where the level of accumulation of dust and lint has been found to be significantly higher than initially expected and a potential ignition source exists.

Based on the consultation with maintenance planning engineers it is understood that they would expect that an inspection be carried out after cleaning operations are complete, since the cleaning activity itself may introduce damage. If post cleaning inspections are not performed, any consequential damage may not be discovered.

A survey contributor reported that some operators are required to update their maintenance tasks when the Maintenance Review Board (MRB) Report is published, but that this may not be the case for all operators.

10.3.1 Required Level of Cleaning

There was general agreement from engineers from both aircraft manufacturing and maintenance and repair organizations that the guidance material associated with the EWIS ’Clean as You Go’ philosophy (reference 2) was open to interpretation. This ambiguity primarily relates to what constitutes an acceptable standard of cleanliness and the specific contaminant threats that might exist. A further issue experienced by a participating airline is that thermal acoustic insulation may seem clean in appearance, but when touched, is sticky from fluid contamination.

It was reported that previous discussions between European airworthiness authorities and industry has resulted in an accumulation level of 5 mm thickness of dust and lint contamination being defined as the contamination level that requires cleaning. Tests conducted in this study suggest that thermal acoustic insulation contamination with dust and lint will readily ignite at accumulation levels lower than 5 mm thickness.

10.3.2 Maintenance Personnel Training

From the consultations, it was identified that the qualification or training requirements for some maintenance personnel may not include a specific provision for understanding the issues relating to thermal acoustic insulation contamination and the associated fire threats. It is also understood that web-based training on EWIS installation considerations is undertaken by some maintenance organizations. Such training content is often regulated by the organization rather than the airworthiness authorities.

Consideration should be given to ensuring that maintenance organization training programs are reviewed to ensure that on-going training in relation to thermal acoustic insulation contamination and the associated fire threats is provided as a minimum to certifying staff.

10.4 AIRPLANE DESIGN FEATURES

The study did not find any special design features, beyond cabin grills, which had been introduced to preclude debris from falling onto thermal acoustic insulation.

It was noted that interiors with leather seats are likely to assist with reducing the level of thermal acoustic insulation contamination by virtue of the inherent features of leather over woollen covered seats although the extent to which this is a factor in the accumulation of dust and lint on thermal acoustic insulation is unknown.

10.4.1 EWIS

Certain later aircraft designs are reported to limit the level of wiring in the most vulnerable areas for dust and lint contamination (i.e. floor to dado level). Where wiring is routed in conduit in areas of thermal acoustic insulation contamination, there is an inherent reduction in the risk of an ignition source to initiate a fire. One aircraft manufacturer identified that some EWIS is run in conduit as a positive design feature to reduce fire risk. This resulted from the zonal analysis carried out during the design phase. However, conduit is not considered necessary for all wiring. Guidance material identifying design objectives or features that might mitigate the risks associated with contaminants of thermal acoustic insulation in zones containing electrical wiring or equipment would be useful in the mitigation of the fire threat.

10.4.2 Air Distribution System

From the consultations, it was reported that maintenance planning engineers have noted significantly less dust and lint accumulation where the cabin air distribution is said to be designed for less air movement behind the sidewall panels. Some later wide body aircraft are reported to have been designed with this concept in mind. However, specific data on the effect of such a design concept will not be available for up to 5 years when the relevant areas are scheduled to be inspected.

From the consultations, it was identified that the air directed into avionics bays is generally fresh air as opposed to recirculated air. This is considered to be a primary factor to the very low levels of thermal acoustic insulation contamination seen in avionics bays.

It would be useful to conduct a future assessment of in-service experience when it becomes available of the effect of design features put in place to reduce the air movement behind sidewall panels in certain later wide body aircraft to see if such design considerations offer a significant mitigation to the dust and lint accumulation risk.

11. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

11.1 GENERAL

It would seem that based on the analysis of the Boeing in-service hidden fire occurrences, for the most part, contaminants found on in-service thermal acoustic insulation materials do not normally present a major fire threat.

It is likely that ambient temperatures and airflows are significant factors in the likelihood that a fire will develop to the point that it becomes uncontrollable. If this is the case, it might explain why so many of the in-flight fire occurrences involving contaminants are relatively benign.

However, it is also evident from this study that some contaminants can represent a significant fire threat in certain circumstances. This is supported by the in-service occurrences when contaminants have posed an in-flight fire threat (notably the accident to the Boeing 767 in May 2002, and the incident involving the Lockheed L-1011 in March 1991).

Since the time of these occurrences, the flammability threat presented by contaminants would have been reduced by the initiatives already introduced by the industry. These initiatives are primarily based on routine directed cleaning tasks implemented by the EZAP process and the “protect and clean as you go” philosophy defined in the FAA Advisory Circular 25-27A. However, this study has resulted in recommendations for potential enhancements that might be made to maintenance practices and design features associated with thermal acoustic insulation.

Based on the surveys and testing carried out during this study, it is considered that the primary threats related to contamination of thermal acoustic insulation are dust and lint and hydraulic fluid that has penetrated through the bagging film into the insulation material. Other factors pertinent to the mitigation of fires propagating on thermal acoustic insulation material have been identified by this study and are addressed in this section of the report.

11.1.1 Conclusions

Conclusion 1: Magnitude of Threat: There are a significant number of in-flight fires that are likely to have propagated on contaminated thermal acoustic insulation. The vast majority of which did not pose a significant threat to airplane safety. However, the results of this study also indicate that contaminated thermal acoustic insulation can, in certain circumstances, result in a significant in-flight fire.

Conclusion 2: Current Mitigation: The current industry mitigation for hidden area contamination is based on directed cleaning tasks and a "Protect and Clean as you go" philosophy. This rational approach is likely to result in a reduction of the threat. However, the results of this study suggest that there may be opportunities to make further improvements to maintenance practices and design features associated with thermal acoustic insulation.

Conclusion 3: Primary Threats: Based on this study, it is assessed that the most significant fire threats associated with contamination of thermal acoustic insulation are dust and lint and hydraulic fluid that has penetrated into damaged insulation bags.

11.1.2 Recommendations

Recommendation 1: Current Mitigation: It is recommended that the guidance given in AC 25-27A is reviewed to emphasize the fire threats related to contaminated thermal acoustic insulation found to be high risk as a result of this study and to review the threat that these contaminants might present to EWIS.

11.2 DUST AND LINT

Dust and lint appear to be the most common contaminant. Samples collected during airplane surveys and tested on the Transport Canada Arc Fault Test Rig were flammable at ambient temperatures. Dust and lint was found to be prevalent in almost all of the hidden areas on the airplanes surveyed. Based on the testing and an analysis of in-service hidden fire occurrences, it would appear likely that, for the most part, fires propagating on dust and lint are likely to be relatively benign and likely to result in minimal heat release. However, in-service occurrences also suggest that in some, perhaps rare circumstances, concentrations of dust and lint can present a significant fire threat. Propagation of fires on dust and lint can also present an ignition source for further escalation of a fire on other contaminants (e.g. debris or hydraulic oil that has penetrated into thermal acoustic insulation).

The issue regarding the potential threat from dust and lint contamination was highlighted by the TSB following the incident on the L-1011 in 1991 (reference 7):

> *"The most probable cause of the fire was electrical arcing or short circuiting in an electrical wire bundle under the cabin floor on the left side of the aircraft at a position just aft of FS 1645. A factor contributing to the severity of the fire was the large accumulation of dust and lint in the area."*

Testing conducted in this study, suggests that the threshold contamination level required for dust and lint to be ignitable by an electrical arc and propagate when contaminating the surface of thermal acoustic insulation at ambient temperature is in the region of 20 grams/m^2. Based on airplane surveys and sample testing, it was found that the levels of contamination can be such as to represent a flammability threat in less than 10,000 flight hours. In many instances, hidden areas will contain quantities of dust and lint that represent a flammability threat well in advance of the scheduled cleaning period. It is possible that cleaning intervals needed to prevent levels of dust and lint accumulating to levels that could result in fire propagation may not be practical, however, the periodicities specified for scheduled cleaning tasks are worthy of review based on the findings of this study.

Testing in this study showed that test sample attitude and radiant heat have a marked effect on the flame characteristics of burning dust and lint. Details are shown in appendices 3 and 4 respectively. The application of radiant heat will cause dust and lint to burn more vigorously as will increasing attitude of the thermal acoustic insulation. It might therefore be expected that dust and lint accumulating vertically would present a greater fire threat than horizontal accumulations.

Figure 37 illustrates the levels of dust and lint contamination of thermal acoustic insulation and EWIS that may be experienced on in-service airplanes.

Figure 37. Significant Accumulations of Dust and Lint on TAI and EWIS Near to Cabin Air Recirculation Inlet in the Under-Floor Cheek Area

11.2.1 Conclusions

Conclusion 4: Dust and Lint: Based on in-service incidents, airplane surveys, data analysis, and flammability testing it is concluded that although, for the most part, this contaminant represents a relatively low flammability threat, in some circumstances it can result in significant fires.

Conclusion 5: Dust and Lint: In many instances, hidden areas containing thermal acoustic insulation and EWIS may be contaminated with dust and lint that could represent a flammability threat prior to the scheduled cleaning period.

Conclusion 6: Dust and Lint: Testing suggests that radiant heat, such as may be encountered in an established fire, is likely to result in dust and lint burning more vigorously.

Conclusion 7: Dust and Lint: Propagation of a fire on dust and lint is likely to progress more rapidly as the contaminant is inclined away from the horizontal.

11.2.2 Recommendations

Recommendation 2: Dust and Lint: It is recommended that the scheduled cleaning intervals prescribed for in-service airplanes are reviewed in the light of the findings of this study particularly with regard to the likely rate of accumulation of dust and lint and its likely flammability characteristics.

11.3 HYDRAULIC FLUIDS

As discussed in section 6. , hydraulic fluid does not appear to occur as frequently as some of the other potentially flammable thermal acoustic insulation contaminants. Furthermore, testing on the Arc Fault Test Rig at 200° C suggested that hydraulic fluid on the surface of thermal acoustic insulation passed with all bagging film materials tested and thus is not likely to present a significant fire threat (see section 8.3).

However, on the first airplane survey carried out in this study, hydraulic fluid was found to have leaked from a hydraulic pipe connection and appeared to have damaged the bagging film of the thermal acoustic insulation permeating into the fiberglass insulation. The saturated fiberglass was tested using the Transport Canada Arc Test Rig and found to be highly flammable. Similar results were obtained when flammability testing was carried out on customized thermal acoustic insulation samples with hydraulic fluid intentionally introduced into the insulation material (see section 8.4).

On a subsequent survey, hydraulic fluid contamination of thermal acoustic insulation was found on one airplane. The thermal acoustic insulation covering was locally damaged, but hydraulic fluid had not permeated into the fiberglass on this occasion. It was not possible to determine whether the thermal acoustic insulation damage was a consequence of the hydraulic fluid leak. Damage to thermal acoustic insulation bagging films from hydraulic fluid is considered further in section 11.11.

Consultation with industry suggests that some maintenance organizations remove thermal acoustic insulation that is contaminated with hydraulic fluid. However, the extent to which this practice is adopted across the industry is unknown.

The accident to the BAC 1-11 in 1967, near Blossburg, Pennsylvania, (reference 13) is interesting to note in the context of absorption of thermal acoustic insulation with hydraulic fluid. The NTSB accident report states:

> *"Based on tests and operational experience, it is probable that the acoustic linings on N1116J were contaminated with Skydrol fluid which had leaked into the plenum chamber due to inadequate drainage and imperfect sealing. Moreover, such Skydrol would have been in a partially decomposed state due to having been subjected to heat over an extended period of time, and thus would have been more rapidly ignited than fresh Skydrol. Accordingly, once the blanket material itself ignited, the Skydrol with which it was wetted or soaked would in turn have ignited, and thus acted as an additional fuel for the fire within the plenum chamber."*

11.3.1 Conclusions

Conclusion 8: Hydraulic Fluids: While the flammability testing carried out in this study suggested that surface contamination of thermal acoustic insulation with commonly used hydraulic fluids is unlikely to pose a fire threat, penetration of the fluid through the bagging film material into the insulation does.

Conclusion 9: Hydraulic Fluids: It would appear that commonly used hydraulic fluids can damage some thermal acoustic insulation bagging films resulting in the possibility of the insulation material becoming saturated with a consequential fire threat.

11.3.2 Recommendations

Recommendation 3: Hydraulic Fluids: Maintenance personnel should be provided with guidance advising of the significance of damaged thermal acoustic insulation bagging film materials in zones which may contain hydraulic fluids and the necessity for repair or replacement at the earliest opportunity.

Recommendation 4: Hydraulic Fluids: The "protect and clean as you go" philosophy, defined in the FAA Advisory Circular 25-27A, should be emphasized in relation to spillage or leakage of hydraulic fluid onto thermal acoustic insulation bagging film materials.

Further recommendations relating to hydraulic fluid contamination of thermal acoustic insulation materials are made in section 11.11.2.

11.4 HYDROCARBONS

Although no testing has been carried out to date on this contaminant, it is considered that most hydrocarbons are likely to be flammable. The study of in-service hidden fire occurrences (see section 6.1) suggested that hydrocarbons (oil, grease, etc.) were relatively common contaminants. As part of the consultation with industry, one airline reported experience of thermal acoustic insulation contamination by fat from the galley area which resulted in a localized fire. However, hydrocarbons were not identified in any of the aircraft surveys carried out as part of this study.

11.4.1 Conclusions

Conclusion 10: Hydrocarbons: While hydrocarbons may be considered as a potentially flammable thermal acoustic insulation contaminant, this study suggests that they are unlikely to be found in sufficient quantities to pose a significant fire threat in isolation.

11.4.2 Recommendations

No recommendations are made regarding the contamination of thermal acoustic insulation materials with hydrocarbons.

11.5 DEBRIS

Based on the contaminants present during in-flight fire occurrences, debris is a relatively common contaminant that is likely to pose a moderate to high flammability threat. Testing is probably inappropriate since the potential exists for all manner of debris to be found in certain areas of the aircraft (in the Toronto B767 occurrence in 2002, debris included paper, candy wrappers, styrofoam packing peanuts, small polyethylene beads, and rubber powder).

On the surveys carried out in this study, only one instance was found of debris on thermal acoustic insulation. This was in a hidden area that did not contain EWIS. However, on some aircraft types it is feasible that potentially flammable debris originating from the cabin might fall into areas that do contain EWIS. While not subjected to flammability testing during this study, it is likely that much of the debris originating from the cabin is flammable and might compound a fire threat if other contaminants are present (e.g. dust and lint). For existing in-service aircraft, this threat can only be mitigated by scheduled cleaning tasks. However, future aircraft designs may incorporate design features that reduce the risk of debris accumulating in hidden areas (see section 11.13).

11.5.1 Conclusions

Conclusion 11: Debris: The fire threat from debris in hidden areas can only be mitigated on existing airplanes by scheduled cleaning tasks. However, future airplane designs may incorporate design features that reduce the risk of debris accumulating in hidden areas.

Conclusion 12: Debris: Debris found during the airplane surveys and in-service occurrences is potentially flammable.

11.5.2 Recommendations

No recommendations are made regarding the contamination of thermal acoustic insulation materials from debris other than those related to future airplane designs contained in section 11.13.2.

11.6 CORROSION INHIBITING COMPOUNDS

Other than on thermal acoustic insulation bagging films made from MPVF (which ‘shrinks away’ when heated by a potential ignition source), all corrosion inhibiting compounds tested failed on the Arc Fault Test Rig at 200° C. Corrosion inhibiting compounds were identified as being present in 25 percent of the in-service hidden fire occurrences analyzed and in 20 percent of occasions from the airline surveys (see section 6.). However, only one small area of corrosion inhibiting compound contamination of thermal acoustic insulation was observed on the airplane surveys carried out in this study. It is therefore considered likely that although corrosion inhibiting compounds are frequent contaminants, they are not often found in large quantities on thermal acoustic insulation. Testing carried out in this study indicates that an arc fault is unlikely to ignite the corrosion inhibiting compound (CIC) coating on an airplane structure. However, the CIC may contribute to an already existing established fire.

Limited testing was also carried out to determine the variation in flammability of corrosion inhibiting compounds on thermal acoustic insulation during the drying process. Although the testing was limited, it suggests that providing an airplane is not returned to service within 5 hours of application, then the flammability of any corrosion inhibiting compound spilt onto thermal acoustic insulation will be minimized.

On this basis, corrosion inhibiting compounds are currently assessed as posing a low to moderate flammability threat.

However, there are significant differences in the flammability of the corrosion inhibiting compounds currently in use. It is also feasible that dust and lint will adhere to certain corrosion inhibiting compounds, thus increasing the potential fire threat. Therefore, selection of corrosion inhibiting compounds having lower flammability properties and providing less adhesion for dust and lint would seem to be desirable.

11.6.1 Conclusions

Conclusion 13: Corrosion Inhibiting Compounds: Based on this study, it would appear that corrosion inhibiting compounds, although a common contaminant, are unlikely to be present in large quantities on thermal acoustic insulation, and, thus, although they are flammable, are unlikely in isolation to constitute a significant threat to aircraft safety.

Conclusion 14: Corrosion Inhibiting Compounds: Although not considered to be a significant threat to aircraft safety, some corrosion inhibiting compounds are more likely to propagate a fire than others either because of their inherent flammability properties or their tendency to attract dust and lint.

Conclusion 15: Corrosion Inhibiting Compounds: Testing carried out in this study suggests that an arc fault is unlikely to ignite the corrosion inhibiting compounds (CICs) on structural elements of the airplane although some CICs may contribute to the fire.

11.6.2 Recommendations

Recommendation 5: Corrosion Inhibiting Compounds: It is recommended that guidance material is provided regarding the selection of corrosion inhibiting compounds that exhibit less flammable and lower dust and lint adhesion characteristics.

11.7 CLEANING FLUIDS

There were no reports in the airline survey and only one report in the study of hidden fire occurrences indicating cleaning fluids as a contaminant on insulation materials. Furthermore, the testing carried out during this study indicates that cleaning fluids do not present a significant fire threat as a contaminant on thermal acoustic insulation materials, although radiant panel testing carried out by Boeing suggests that Acetone and a proprietary substitute for MEK (see section 8.8) may present a degree of fire hazard on some materials[10].

The introduction of the EZAP process and the "protect and clean as you go" philosophy defined in the FAA Advisory Circular 25-27A, could result in cleaning fluids becoming more frequently found on thermal acoustic insulation materials.

The extent to which cleaning fluids may degrade the flammability characteristics of thermal acoustic insulation bagging films over time is unknown. Guidance is required from thermal acoustic insulation bagging film manufacturers regarding the cleaning fluids that should be used to prevent degradation of their bagging film materials.

11.7.1 Conclusions

Conclusion 16: Cleaning Fluids: Based on the in-service experience and the testing carried out, it would appear that cleaning fluids are not a common contaminant and do not pose a major flammability threat. However, no conclusions can be reached in this study regarding the degradation of thermal acoustic insulation bagging film materials by the cleaning fluids used on in-service aircraft.

11.7.2 Recommendations

The extent of any degradation effects that cleaning fluids may have on thermal acoustic insulation materials may need to be determined by the TAI bagging film manufacturers. This is

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[10] It is likely that most cleaning fluids are flammable when wet – but they evaporate readily.

considered important in the light of the flammability threat posed by contaminants, particularly hydraulic fluid, penetrating into insulation bags.

Recommendations, relating to cleaning fluid contamination of thermal acoustic insulation materials, are made in section 11.11.2.

11.8 OTHER FLUIDS

From the Boeing airline Survey (see section 6.2) approximately 21 percent of thermal acoustic insulation contaminants were identified as “Lav Fluids”, “Miscellaneous Fluids”, and “Multiple fluids”. Since the fluids were not identified precisely, no testing of these contaminants could be carried out. Perhaps the primary threat is associated with fluid contaminants that might physically or chemically damage the thermal acoustic insulation bagging film resulting in perforation of the material or compromising its flammability characteristics.

11.8.1 Conclusions

No conclusions can be reached in this study regarding the degradation of thermal acoustic insulation bagging film materials by fluids commonly in use on aircraft or those that might be anticipated to be contaminants (e.g. “Lav Fluids”).

11.8.2 Recommendations

No recommendations are made regarding contamination from “Other Fluids” other than those related to the design of thermal acoustic insulation materials contained in section 11.11.2.

11.9 INSECTICIDES

There was only one report of insecticides in the data relating to contaminants found during in-flight fire occurrences, and no test evidence is currently available to determine their relative flammability or their effects on the flammability of thermal acoustic insulation materials. The quantities of insecticides likely to be found on insulation materials will be small an, therefore, the threat is likely to be comparatively low. However, the potential for insecticides degrading TAI bagging film materials is unknown and this should be established by thermal acoustic insulation material manufacturers.

11.9.1 Conclusions

No conclusions can be reached in this study regarding the degradation of thermal acoustic insulation bagging film materials by insecticides.

11.9.2 Recommendations

It is likely that no mitigation is needed regarding this potential threat subject to manufacturers of thermal acoustic insulation materials confirming that the flammability standards of their products are not degraded by the insecticides currently in use - see the recommendation contained in section 11.11.2.

11.10 NICOTINE

There was only one report of nicotine in the data relating to contaminants found during in-flight fire occurrences. This contaminant is not likely to be flammable nor is it likely to be found on the vast majority of current in-service aircraft.

11.10.1 Conclusions

Nicotine is not considered a significant flammability threat.

11.10.2 Recommendations

No recommendations are made regarding the contamination of thermal acoustic insulation material by nicotine.

11.11 THERMAL ACOUSTIC INSULATION DESIGN FEATURES

Flammability testing has demonstrated that even a small amount of phosphate ester based hydraulic fluid penetrating into a thermal acoustic insulation blanket could present a significant flammability threat.

The surveys carried out in this study have illustrated that bagging film materials are occasionally designed with holes that could allow penetration of flammable fluids into the insulation material. Thermal acoustic insulation bagging films may be manufactured with holes for ventilation or drainage purposes. Insulation bags may also be stitched during manufacture resulting in holes in the bagging films. In other instances, holes which may be covered with patches are introduced as part of the manufacturing process. Patches are also used to repair holes in bagging film materials that may have been caused during airplane maintenance. Tapes are also used in the manufacture of insulation bags. However, deterioration of the patches and tapes in-service may result in the protective bagging film being breached with a consequential fire threat if hydraulic fluid penetrates into the insulation.

Instances of bagging film materials becoming damaged by contaminant fluids particularly hydraulic fluid and perhaps water were also found during the airplane surveys.

11.11.1 Conclusions

Conclusion 17: Thermal Acoustic Insulation Design Features: Thermal acoustic insulation bagging films, tapes, and patches which are used during manufacture or in-service repair may be degraded by contaminant fluids. Some bagging films are stitched or have ventilation holes, thus allowing potentially flammable fluids to enter into the insulation material. Penetration of thermal acoustic insulation by flammable fluids can present a significant fire threat. It is, therefore, important that the bagging films and patches are resistant to damage and chemical degradation from contaminants.

11.11.2 Recommendations

Recommendation 6: Thermal Acoustic Insulation Design Features: It is recommended that consideration be given to designing and manufacturing thermal acoustic insulation bagging film materials, tapes, and patches that are resistant to hydraulic fluids, water, cleaning fluids, insecticides, and other fluids commonly encountered on airplanes, particularly for thermal acoustic insulation installed in zones that may be subject to hydraulic fluid contamination.

11.12 ROUTINE MAINTENANCE

Based on the consultation with industry, one of the more important issues regarding routine maintenance is that there is a clear understanding of the potential threats from thermal acoustic insulation contaminants. It is also considered important that the results of this study are promulgated as a first step toward a consensus of what might be required to mitigate further the threat that these contaminants might pose. The following conclusions and recommendations represent the more significant issues that were identified in the study in relation to routine maintenance discussed in sections 10.1 - Contaminants, and 10.3 - Routine Maintenance.

11.12.1 Conclusions

There are many observations made based on the airplane surveys and consultations with industry carried out in this study. However, perhaps the most significant conclusion in relation to routine maintenance is as follows:

Conclusion 18: Routine Maintenance: It is evident that there is ambiguity as to the level of cleanliness required from routine cleaning tasks.

11.12.2 Recommendations

Recommendation 7: Routine Maintenance: Consideration should be given to reviewing the guidance given in current advisory material taking into account the rate of accumulation of flammable contaminants assessed as a result of the airplane surveys carried out in this study.

Recommendation 8: Routine Maintenance: Maintenance instructions should ensure that damaged thermal acoustic insulation bagging film materials in zones containing potential ignition sources and having the potential for hydraulic fluids to penetrate into the insulation material are repaired or replaced at the earliest opportunity.

Recommendation 9: Routine Maintenance: Consideration should be given to developing training means to mitigate ambiguity in the standard of cleanliness to be achieved in contaminated hidden areas. Such training should also emphasise that a fire threat may exist from dust and lint contaminated thermal acoustic insulation at very low levels of accumulation. The training means should also identify the relative threat from various contaminants and address good cleaning practice including the need to carry out post cleaning inspections.

11.13 AIRPLANE DESIGN FEATURES

Based on the consultation with industry, airplane design features were identified that were aimed at mitigating the potential fire threat from thermal acoustic insulation contaminants. It would seem that there is an opportunity to consider these features on other future airplane designs. The following conclusions and recommendations represent the more significant issues that were identified in the study in relation to airplane design features discussed in section 10.4 - Airplane Design Features.

11.13.1 Conclusions

Conclusion 19: Airplane Design Features: Airplane design features were identified in this study that might be appropriate to the mitigation of potential fire threats from contaminated thermal acoustic insulation on future airplane designs.

11.13.2 Recommendations

Recommendation 10: Airplane Design Features: Consideration should be given on future airplane designs to providing a means for reducing the probability of debris entering hidden areas containing potential ignition sources and routing electrical wiring in conduits in zones where flammable contaminants are likely to accumulate.

12. REFERENCES

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APPENDIX A—FATAL AND POTENTIALLY FATAL HIDDEN FIRE OCCURRENCES

OCCURRENCE 1.1

Date	**Source of Information**		**Aircraft Type**
08-Aug-00	NTSB Accident Database Identification DCA00MA079		DC-9-32
Operator	**Location**		**Registration**
Air Tran	Greensboro NC, USA		N838AT
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
63	0	0	Not known

Description of Occurrence

The captain and first officer noticed a smell of smoke shortly after takeoff. The crew immediately donned oxygen masks and smoke goggles. The smoke became very dense and restricted the crew's ability to see both the cockpit instruments and the visual references outside the airplane. The cabin crew noticed a smell of smoke followed by a visual sighting of smoke and sparks in the area of the forward flight attendant jump-seat. The flight-crew was able to identify the Greensboro airport and make a successful emergency landing. The airplane was immediately stopped, and an emergency evacuation was conducted on a taxiway.

The Board's initial investigation found extensive heat damage to wires and insulation in the electrical panel behind the captain's seat. The heat was sufficient to blister the primer on the fuselage crown skin.

Four crewmembers received minor injuries from smoke inhalation in-flight and one passenger received a minor injury during the evacuation; one crewmember and 57 passengers were uninjured. The airplane was substantially damaged from the effects of fire, heat, and smoke.

Figure A-1. Greensboro, 08-Aug-00

OCCURRENCE 1.2

Date	**Source of Information**		**Aircraft Type**
29-Nov-00	NTSB Accident Database Identification DCA01MA005		DC-9-32
Operator	**Location**		**Registration**
Air Tran	Atlanta GA, USA		N826AT
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
97	0	0	Not known

Description of Occurrence

During initial climb, the flight crew noted numerous circuit breaker trips and illumination of several indicator lights. The crew declared an emergency with air traffic control and requested a return to the airport. The airplane landed safely and cleared the runway onto a taxiway. At some point during the landing rollout and taxi, the flight attendants notified the flight crew of smoke in the forward section of the cabin. An emergency evacuation ensued. The FAA advises that the fire was extinguished by the Fire Brigade.

Examination of the airplane revealed fire damage to an area of the left fuselage below and aft of the forward passenger entry door, and to the adjacent forward cargo and main cabin floor areas. Wiring, ducts, and hydraulic lines located in this area were also burned.

Figure A-2. Atlanta, 29-Nov-00

OCCURRENCE 1.3

Date	Source of Information		Aircraft Type
05-Sept-93	AGARD 1997 Conference Proceedings 587 "A Review of Recent Civil Air Transport Accidents/Incidents and their Fire Safety Implications" - Richard G. Hill, David R. Blake		Boeing 727-200
Operator	**Location**		**Registration**
Dominicana	Santo Domingo, Dominican Republic		HI-617CA
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
105	0	0	Approx. 20 mins.

Description of Occurrence

Approximately fifteen minutes into a thirty minutes flight from San Juan to Santo Domingo, a flight attendant noticed a flight attendant call button lit for the aft lavatory. She checked the lavatory and saw smoke inside. The airplane landed at Santo Domingo and the passengers exited normally through the L1 door as the cabin began to fill with smoke. The flight crew requested a mechanic with a fire extinguisher to check the lavatory. The mechanic opened the ventral stairs and saw fire that he judged to be too big to attempt to fight with a hand held extinguisher. The airplane was destroyed by fire. The fire was determined to have originated in the area of the aft lavatory but the cause was never found.

OCCURRENCE 1.4

Date	**Source of Information**		**Aircraft Type**
02-Sep-98	TSB Aviation Safety Recommendations Report "The Circumstances of Swissair Flight 111 accident"		MD-11
Operator	**Location**		**Registration**
Swiss Air	Peggy's Cove, Nova Scotia, Canada		HB-IWF
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
231	231	0	16 minutes

Description of Occurrence

On 2-Sep-1998, about 2230 local time, a Swiss Air flight 111, McDonnell Douglas MD-11, registered as HB-IWF, crashed into a bay near Blandford, Nova Scotia (the nearest area is called Peggy's Cove). The airplane was a regularly scheduled passenger flight from JFK International Airport, Jamaica, New York to Geneva, Switzerland, operating under 14 CFR Part 129. The flight also operated as Delta flight 111 under a code sharing agreement.

56 minutes into the flight in normal cruise at FL330, the flightcrew issued a 'Pan'-call reporting smoke in the cockpit and requesting emergency vectoring to the nearest airport, which they thought was Boston. The Moncton controller cleared the flight to descend to FL310 and offered Halifax as the closest airport available, which was accepted by the crew. The flight was handed over to Moncton Centre and was vectored for a back course approach to Halifax runway 06. While the airplane was just 30 miles from the threshold, so Moncton Centre vectored the plane for a 360-degree turn to lose some altitude and to dump fuel off the coast. The situation in the cockpit apparently became worse. At this point and about 10 minutes after the first alert message, the crew declared an emergency and reported that they were starting the fuel dump and that they had to land immediately.

There were no more radio communications and the aircraft disappeared from radar approximately 5nm off Peggy's Cove and 35nm from the airport off the Nova Scotia coast. The airplane hit the water 16 minutes after the alert message.

There were 14 crewmembers and 217 passengers (including 2 children) aboard, all were fatally injured. The plane was destroyed as a result of the accident.

Since the aircraft crashed into water, all fire damage occurred in flight. The ongoing investigation (A98H0003) has identified substantial fire damage above the drop-down ceiling in the forward section of the aircraft extending about 1.5 meters forward and 5 meters aft of the cockpit wall.

OCCURRENCE 1.5

Date	**Source of Information**		**Aircraft Type**
24-Nov-93	Cabin Safety Research Technical Group Accident Database - Accident Reference 19931124A		MD-87
Operator	**Location**		**Registration**
SAS	Copenhagen, Denmark		SE-DIB
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
85	0	0	Not Applicable

Description of Occurrence

During landing the CA2 cabin attendant, who was positioned in the aftmost part of the cabin, noticed that her work lights suddenly lit up brightly and then went out. While taxiing towards the assigned gate, she noticed a faint smell of electrical smoke/fire and immediately informed the CA1 about her observations. The CA1 immediately informed the first officer about the situation.

When the CA2 checked the lavatory on the right hand side, she noticed whitish smoke in front of and above the lavatory door. The CA2 immediately informed the flight deck about her observations via the interphone. The first officer, who answered the call, told the CA2 that they were just about to turn into the parking gate and that he suggested they kept the interphone connection open until the aircraft was parked and the engines were shut down. The first officer repeated all the conversation out loud so that the captain was able to follow developments.

The CA3, who was seated at the over wing exit position, got up and walked to the forward galley where she heard that there was a smell of something burning at the back of the cabin. Consequently she decided to go to the aft cabin and offer her assistance. When she reached the aft rows of seats she sensed a fairly strong smell of burning. When she opened the right-hand lavatory door, heavy smoke build-up was evident and smoke also entered the cabin through the ventilation ducts in the ceiling.

After the aircraft was parked, the crew turned off the generators, shut down the engines and selected emergency power ON. The captain requested the assistance of a fire vehicle over the radio.

The ground engineer who met the flight routinely connected the external power supply. While he was doing so the captain, who had opened the sliding window, attracted the engineer's attention and asked him to go to the aft stairway and check for smoke. The ground engineer entered the cabin via the aft stairway to check the aft lavatory and cabin area for the origin of the fire. However, as the engineer only identified lots of smoke and smell of electrical fire in the cabin, he left the cabin and inspected the lower aft cargo compartment, but without actually seeing the flames.
After personally having checked that the cabin was empty, the captain checked the outside of the aircraft and noticed a bright glowing spot on the fuselage in front of and above the right hand

engine. He quickly returned to the cockpit and used the radio to emphasize the urgent need for assistance from fire and rescue services.

At about 3 minutes after the captain's second radio request for assistance, the first fire vehicle arrived and initiated the firefighting. The full airport fire detachment arrived 3 minutes later. The first of the vehicles from the county fire brigade arrived 3 minutes after that.

The captain remained at the scene until the fire and rescue services arrived so that he could inform the rescue crew that all the crew and passengers had indeed vacated the aircraft.

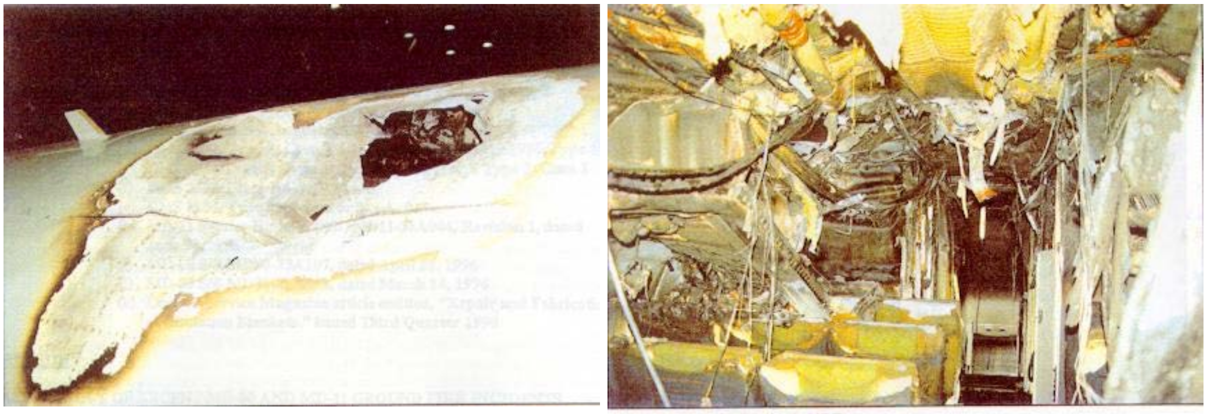
About 15 minutes after the sounding of full scale alarm the fire was under control and the firefighting ended a total of about 1 hour and 5 minutes after the captain's second radio call.

Later investigation revealed that factory installed wiring had been pinched and chafed, which led to arcing and ignition of the cabin sidewall insulation material.

The fierce fire that erupted in the aft right-hand side of the cabin destroyed major parts of all of the equipment installed in that particular area. The extreme heat development destroyed the fuselage skin and structure over a large area on the aft right-hand side of the aircraft. Additionally, the entire cabin furnishings, i.e. seats, partition, galleys, lavatories and paneling were severely damaged by smoke and heat. This form of damage extended as far forward as to include the cockpit and cockpit equipment.

The overhead stowage bins on the right-hand side of the cabin has suffered various degrees of damage. From seat row 20 and aft, the bin doors were totally burned away.

The seats in row 21 to 23 were severely heat damaged as they had been exposed not only to heat but also to hot/burning debris falling on them. The right-hand stowage closet and the right-hand galley, which had been exposed to direct fire and very high temperatures, exhibited severe heat deformation mainly around the upper and outboard parts of the units.



AFT CABIN RIGHT-HAND SIDE

Figure A-3. Copenhagen 24-Nov-93

APPENDIX B—OTHER SIGNIFICANT HIDDEN FIRE OCCURRENCES

OCCURRENCE 2.1

Date	**Source of Information**		**Aircraft Type**
17-Mar-91	Transportation Safety Board of Canada Report A91A0053		L-1011-385-3
Operator	**Location**		**Registration**
Delta Air Lines	Goose Bay, Labrador, Canada		N753DA
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
226	0	0	Not Applicable

Description of Occurrence

Delta Air Lines Flight 15, a Lockheed L-1011-385-3, was en route from Frankfurt, Germany, to Atlanta, Georgia. Approximately 170 nautical miles east of Goose Bay, Newfoundland, a cabin fire was reported on the left hand side of the aircraft towards the rear of the aircraft. The cabin crew extinguished the fire, and the aircraft diverted to Goose Bay where it landed safely without further incident.

The Transportation Safety Board of Canada determined that the most probable cause of the fire was electrical arcing or short circuiting in an electrical wire bundle under the cabin floor on the left side of the aircraft at a position just aft of fuselage station 1645. A factor contributing to the severity of the fire was the large accumulation of dust and lint in the area.

The fire originated under the rear passenger cabin floor on the left side of the aircraft between the side wall of the mid-cargo compartment and the exterior wall of the aircraft. This area is known as the “cheek” area and extends from the main wheel well to the aft pressure bulkhead. The fire was limited longitudinally to the area between fuselage stations (FS) 1645 and 1665. Flames entered the cabin through a return air vent at the bottom of the interior side wall panel outboard of seat 41A, which is in the next to last row of seats from the end of the cabin. The outbreak of the fire was sudden, and the flames were reported to have extended approximately two feet above the cabin floor. It was reported that there was little or no smoke associated with the fire. Acrid fumes were present, but these were not particularly strong or bothersome.

A passenger’s coat that was lying on the floor caught fire, as did a few smaller, personal items. Beneath the cabin floor, the main generator cables from the number two engine and the cables from the auxiliary power unit were also severely burn-damaged. The primary structure of the aircraft was not damaged, but was extensively sooted in the vicinity of the fire as were various other components in the area. A wire bundle containing 15 wires and routed under the floor in front of seat 41A and just aft of FS 1645 was also severely damaged with the damage concentrated near the center of the fire area. The insulation on the wires was extensively burned away and some of the wires had separated. Damage to the wires was consistent with electrical arcing or short circuiting which could occur if the conductor became exposed.

The area where the fire developed is not accessed on a regular basis, and it had probably been several years since work had been done in the area. It was noted that there was a large accumulation of lint and dust in the area that had evidently entered through the return air system. Grease and tar residues appeared to have provided a bond, and the material had accumulated to an average depth of approximately three-eighths of an inch with the depth in some areas exceeding two inches. The material was on all wiring bundles, cables, lines, ducts, insulation blankets and other aircraft components and parts throughout the area.

There was also an assortment of foreign material found in the area including metal nut clips, fingernail clippers, a disposable paper mask, disposable towelettes, a burned number 10 screw, a clean number 10 screw, two candy wrappers, peanut bags and a five-inch metal clamp. Much of the debris was resting on electrical wiring, including the 90 KVA power cables leading from the number two engine and from the auxiliary power unit generators.

Samples from the lint and dust accumulation in the area were tested for flammability. These samples were found to support combustion and would serve as a source of fuel for a fire.

<u>OCCURRENCE 2.2</u>

Date	**Source of Information**		**Aircraft Type**
17-Sep-99	National Transportation Safety Board Report NYC99IA231		MD-88
Operator	**Location**		**Registration**
Delta Air Lines	Covington, Kentucky, USA		N947DL
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
118	0	0	Not Applicable

Description of Occurrence

On September 17, 1999, about 2230 eastern daylight time, a McDonnell-Douglas MD-88, N947DL, operated by Delta Air Lines (DAL) as flight 2030, performed a precautionary landing at the Cincinnati/Northern Kentucky International Airport (CVG), Covington, Kentucky. There were no injuries to the 2 certificated airline transport pilots, 3 flight attendants, and 113 passengers. The airplane received minor damage.

At 2214, as the airplane was climbing through FL230 (23,000 feet), the flight crew reported that there was smoke in the cabin and declared an emergency. According to the captain's written statement:

> *"...Shortly after takeoff the flight attendants reported a 'funny smell' in the cabin and described it as 'sulfurous'. This was quickly followed by a report of the fumes growing stronger and smoke. An emergency was declared and the aircraft was turned back to CVG. The first officer continued to fly the aircraft and I initiated the Smoke Identification/Removal checklist in the Pilot's Operating Manual.*

> *During the descent, the flight attendants reported a 'glow' coming from the floor grille near the sidewall in the vicinity of seat 11E. At least one halon extinguisher was discharged in the direction of the glow. Shortly after, the flight attendants reported that smoke seemed to be dissipating.*
>
> *The landing was performed on runway 18L in CVG. Fire crews immediately met the aircraft, and reported smoke and signs of a fire in the forward cargo bin. A passenger evacuation was performed."*

Interviews with the flight attendants disclosed that the smoke was in the forward portion of the coach class cabin. Passengers were moved away from the area, and as one passenger moved his bag, one side was observed to be "scorched." A flickering red glow was observed coming from the floor vent. While one flight attendant went to the cockpit to notify the captain what had been seen, another flight attendant sprayed the contents of a halon fire extinguisher into the vent, after which the red glow disappeared.

Examination of the airplane revealed that the interior framework of the fuselage was covered with insulation referred to as thermal blankets. The blankets were separated by the ribs of the fuselage. The insulation consisted of fiberglass, overlaid by a layer of metallized Mylar coating on each side. Examination of the insulation in the vicinity of the right side alternate static port heater revealed that the metallized Mylar covering over the fiberglass had burned away in a 5-foot by 5-foot area, with the edges of the Mylar charred. The damage consisted of sooting, and heat distress to the underside floor structure and a fiberglass potable water bottle. A nearby fiberglass cargo bin wall panel was also burned. In addition, in the cabin, soot damage was visible on the right cabin sidewall in the vicinity of passenger row 11.

As a result of this occurrence, and their fleet wide inspection, DAL removed all Mylar covered insulation blankets from around the primary and alternate static port heaters on their MD-88/MD-90 fleet.

OCCURRENCE 2.3

Date	**Source of Information**		**Aircraft Type**
15-Nov-00	Danish Aircraft Accident Investigation Board (DK AAIB) report HCL 67/00		B 757-236
Operator	**Location**		**Registration**
Air Greenland	Copenhagen, Denmark		OY-GRL
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
97	0	0	Not Applicable

Description of Occurrence

On 15 November 2000, a Boeing 757-236 registration OY-GRL was on a scheduled flight from Sondre Stromfjord (BGSF), Greenland to Copenhagen International Airport, Kastrup (EKCH), Denmark. The cockpit crew consisted of a Commander and a First officer. Besides the cockpit crew there was a flight mechanic seated in the cockpit.

When the aircraft approached Copenhagen, there was scattered CB activity in the area surrounding Copenhagen. The first officer was flying pilot and turned the aircraft onto the base leg for a long finale, 9-12 miles out, and the aircraft's altitude was at that time approximately 3000 feet. Shortly after having completed the base turn, the aircraft was hit by lightning. The cockpit crew checked their instruments and systems for indications of abnormalities or damage as a result of the lightning strike. None was observed.

Approximately one minute after having informed the passengers, the cabin chief called the cockpit crew and said that a smoke formation arose in the cabin from the ceiling above row nine. The Commander then declared an emergency through a mayday call to the ATC. The ATC was informed that there was smoke and a possible fire in the cabin. The Commander then asked for a priority landing and an evacuation on the runway was requested. The mechanic was then told by the Commander to leave the cockpit and help the cabin crew. As the mechanic came into the cabin, a standby cockpit crew was trying to knock down the panels in the ceiling with a fire axe in the attempt to gain access to the possible fire. The mechanic observed that there was something glowing above the panels and took a halon fire extinguisher and utilized it into the area between the fuselage and the panels. Then the mechanic removed the panels and could observe that no fire was present, and the only thing that seemed damaged was the insulation blanket.

This incident shows that the energy in this lightning was adequate to penetrate the fuselage skin. The heat from the penetration was sufficient to cause a singeing of the insulation blanket and smoke was developed in the cabin. The damage caused by this lightning strike indicates that the energy in the lightning was higher than normally encountered.

Figure B-1. Copenhagen 15-Nov-00

<u>OCCURRENCE 2.4</u>

Date	**Source of Information**		**Aircraft Type**
29-Nov-00	National Transportation Safety Board Report IAD01IA017		MD-80
Operator	**Location**		**Registration**
American Airlines	Dulles, Virginia, USA		N3507A
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
66	0	0	Not Applicable

Description of Occurrence

On November 29, 2000, about 1753 Eastern Standard Time, a McDonnell Douglas DC-9-82 (MD-80), N3507A, operated by American Airlines as flight 1683, sustained minor damage from an in-flight fire that began shortly after takeoff from Ronald Reagan-Washington National Airport (DCA), Washington, DC. The 2 certificated airline transport pilots, 3 flight attendants, and 61 passengers were not injured.

In a written statement, the captain stated:

> *"Normal take-off from runway 19 at DCA. Weather conditions were light rain with winds 210/8. Climbing through 9-10,000 feet radar displayed light rain with scattered areas of moderate rain. As we continued our climb, there was a bright flash/static discharge on the left side of the aircraft. There were no indications of any malfunctions in the cockpit. We began to notice a smell that we believed was electrical in nature. Shortly thereafter, the number one flight attendant notified me of smoke coming out of an overhead florescent light fixture. I directed her to turn off all of the overhead lighting and keep me advised of the situation in the cabin. After she turned off all of the lights, she informed me the smoke*

> *appeared to be dissipating. In a few moments, she notified me the smoke was beginning to increase in the forward section of the coach cabin. We declared an emergency, requested radar vectors to Dulles and notified ATC to have ARFF [airport rescue and fire fighting] available. On approximately a 20-mile final, a flight attendant notified me they were using the fire extinguisher on an overhead panel in the coach cabin. I immediately notified the flight attendants to prepare the aircraft for evacuation. We notified Dulles we would be evacuating. Flight landed 19R. Evacuation of passengers and crew was successfully completed."*

In a written statement, the lead flight attendant (FA) said:

> *"Shortly after take-off, I heard a loud boom and saw a flash of light. The FA 2 and 4 called me. I said I thought the plane had been struck by lightning. I called the cockpit and they said we had static electricity. Soon thereafter, smoke started coming out of the fluorescent lighting in the [forward] entry areas. I turned the light off and called the cockpit. They said they believed the smoke was caused by ballast and that it was unrelated to the static electricity. A minute later smoke started coming out of the ceiling compartments in the front of the coach cabin. I opened the cockpit door to tell the captain and he said we were headed to Dulles for an emergency landing, we would be there in 10 minutes, and the evacuation signal would be 'easy victor.' He told me to prepare the cabin, and as we were doing so, the smoke got thicker. I called [name] and [name] and told them to come to the front of the coach cabin with their fire extinguishers. A passenger cut a hole in the ceiling and we used our fire extinguishers to extinguish the smoke. We never saw flames. The smoke became thicker at one point. When our captain told us to take our seats, I made an announcement briefing our passengers on our emergency landing procedures, I also asked four passengers to help at the bottom of the slides. When we landed and came to a complete stop the captain said 'easy victor.' The evacuation went really well."*

Initial examination of the airplane's interior revealed that airport rescue and firefighting (ARFF) personnel had removed the overhead panels between rows 7AB and 11AB. The interior framework of the fuselage was exposed and covered with yellow insulation blankets. The ribs of the fuselage and ducting separated the blankets. The insulation consisted of fiberglass overlaid by a layer of metallized Mylar. Examination of the insulation in the area between rows 7AB and 11AB revealed that the coating of metallized Mylar had burned away over a majority of the area with the edges of the Mylar charred. The surface of the insulation was soot and fire damaged. The insulation above row 8AB exhibited the most fire damage, and extended from the air conditioning duct down to the top of the window frames.

The eyebrow panels were removed, and the overhead bins were dropped. The insulation was removed and the fuselage wall was examined. The fire did not extend to the exterior wall of the fuselage except in a contained area above row 8AB. However, no discoloration of the metal was noted.

The top section of the overhead bins was burned, but there was no damage to the interior of the bins. One of the overhead bin support brackets was discolored from heat damage. The backside of the eyebrow panel for row 7AB was also burned. The ballast lights in the overhead bins for rows 7AB through 11AB were intact and appeared undamaged.

Further examination of the area above rows 7AB through 11AB found two mechanically cut cables installed in the ceiling. Also, a 1-inch wide wire bundle ran along the top of the overhead bins. The wire bundle exhibited localized areas of soot and heat damage.

The National Transportation Safety Board determined the probable cause(s) of this incident as follows:

The operator's inadequate maintenance procedure to disconnect the Omega navigational system, which resulted in coaxial cables being cut and not properly protected. A factor in the incident was the lightning strike.

<u>OCCURRENCE 2.5</u>

Date	**Source of Information**		**Aircraft Type**
13-May-02	Canadian TSB Accident Report A 02O0123		B 767-300
Operator	**Location**		**Registration**
Air Canada	Toronto, Ontario, Canada		C-GHML
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
185	0	0	Not Applicable

Description of Occurrence

On 13 May 2002, at 1617:00 [CUT], Flight 116 departed Vancouver International Airport, British Columbia, on a scheduled instrument flight rules (IFR) flight to Toronto/Lester B. Pearson International Airport, Ontario. The flight was uneventful until 2132:07, when the Master Warning Fire/Overheat light illuminated, the fire warning bell sounded, and the Aft Cargo Fire light illuminated. At 2132:09, the master warning was reset. The flight crew followed the procedures for a cargo fire, as outlined in Air Canada's 767 Quick Reference Handbook, and activated the cargo fire extinguishing system. An emergency was declared and emergency vehicles were requested to meet the flight on arrival. At 2132:59 the Aft Cargo Fire light returned to normal. The flight crew advised the flight attendants that there had been a fire indication, but that it was now indicating safe.

At 2138:31, the aircraft stopped on the runway. The aircraft was examined externally by airport firefighters both visually and by using forward-looking infrared (FLIR) cameras. Firefighters did not see or detect anything unusual; however, the crew members reported an acrid smell and a slight haze inside the passenger cabin. The aircraft was given taxi instructions and proceeded to the gate, with firefighters following.
Concerned that the fire might reignite, the captain stopped the aircraft approximately 40 feet back from the gate and requested that firefighters inspect the aft cargo compartment. The aircraft exits

remained armed while maintenance crews opened the aft cargo compartment. When the cargo doors were opened, smoke and fumes flowed out of the compartment. The firefighters entered the compartment with a handheld FLIR camera and located a single heat source behind the aft wall of the cargo compartment. Maintenance personnel removed the aft wall, and the heat source was identified as a recirculating fan. With no other indications of fire, the aircraft was assessed as safe and the passengers were deplaned. Several hours later, after the aircraft had been towed to a hangar, the maintenance crew discovered that there had been a fire in the bilge area of the cargo compartment under the last two baggage containers. They also determined that the recirculating fan had been operating and was serviceable.

The following morning, the Transportation Safety Board of Canada (TSB) was notified of the occurrence. A preliminary examination showed that the B110 heater ribbon, made by Electrofilm Manufacturing Co., on the aft water supply/drain line had failed and ignited the fire. Several factors led to the safe conclusion of Air Canada Flight 116 at its planned destination. The duration of the flight was approximately 5 hours and 21 minutes. The Master Warning Fire/Overheat light illuminated very near the end of the flight, 6 minutes and 24 seconds before the aircraft stopped on the runway. The aircraft fire detection and extinguishing system functioned properly, and the fire was effectively extinguished even though it was beginning to spread up behind the right sloping sidewall of the aircraft, outside the cargo compartment. The last line of defense, the compartment liner that was designed to contain the fire, had been breached. The fire spread and increased in intensity until it was successfully detected and extinguished by the on-board system.

Contaminated thermal acoustic insulation blankets in the vicinity of the heater ribbon provided fuel for the fire. The contamination consisted of soiled insulation blankets and of flammable debris in the form of paper, candy wrappers, Styrofoam packing peanuts, small polyethylene beads, and rubber powder from a PDU [power drive unit]. Samples of the burnt PET-covered insulation blankets were analyzed for the presence of fire accelerants. An isoparaffin solvent was detected. These types of solvents are often clear combustible liquids that readily form flammable mixtures; they are used for parts cleaning and degreasing applications and as solvents in inks, paints, and agrochemical formulations such as pesticides. They may have originated from sources such as aircraft cargo, luggage, recent repair or maintenance activities, or from pesticide products. The occurrence aircraft had been operated in South America and may have been exposed to pesticides in association with operations in a tropical environment. The isoparaffin contaminant would, if retained, create a significant heat release once ignited. The relatively high-temperature, localized fire damage observed on the floor beam web of the occurrence aircraft is consistent with a post-fire effect from the isoparaffin solvent alone or in combination with combustible debris."

In the main section of the cargo compartment, there are floor boards, approximately 22 inches wide, running along the left and right side of the compartments between BL 22 and BL 44; however, the middle of the floor area is open to the fuselage skin below. In the bulk cargo section, there is no open floor area.

Figure B-2. Toronto 13-May-02

Figure B-3. Toronto 13-May-02

OCCURRENCE 2.6

Date	Source of Information		Aircraft Type
10-Aug-02	Australian Transport Safety Bureau Air Safety Occurrence Number 200203671		B 747-436
Operator	**Location**		**Registration**
British Airways	Sydney, Australia		G-BNLK
Total Aboard	**Fatalities**	**Serious Injuries**	**Time to become uncontrollable**
UNKNOWN	0	0	Not Applicable

Description of Occurrence

Shortly after take-off from runway 34L at Sydney, the flight crew of the Boeing 747-400 aircraft received a forward cargo compartment fire warning on the Engine Indicating and Crew Alerting System (EICAS). On receiving the warning message the crew actioned the appropriate checklist, activated the fire suppression system and transmitted a MAYDAY. At the same time, flight attendants noticed a fine mist and the smell of smoke in the passenger cabin. The crew then returned the aircraft to Sydney, where an uneventful overweight landing was conducted.

Prior to landing, the EICAS fire warning message ceased. This indicated that the aircraft fire suppression system may have successfully extinguished any fire, however the cabin fumes were still evident. After landing, the flight crew stopped the aircraft on the runway where emergency services came to their assistance. After confirming with the flight crew that the fire warning message was no longer present, the emergency services assessed the aircraft from the ground, then allowed the passengers and cabin crew to disembark to a safe distance via mobile stairs positioned at the aircraft’s front left door. Once the passengers and cabin crew were clear of the aircraft, the emergency services opened the forward cargo door.

A hot spot was detected on the left side of the forward cargo bay at body station STA900, where the side wall lining was found to be heat affected. Removal of the lining revealed burned insulation blanket material, discoloration of the aircraft skin and burned/broken electrical wires that powered the forward galley chiller boost fan situated in the area. As the fire was no longer evident, ground engineers isolated the chiller boost fan electrical circuit and towed the aircraft clear of the runway.

The fiberglass sidewall lining between STA880 to STA900 was visibly heat damaged with discoloration observed on the side facing into the cargo compartment. Inspection of the reverse side revealed burned layers of fiberglass confined to a localized area approximately 30 cm x 45 cm. The insulation blankets that lined the aircraft skin were made of a fiberglass core with a metallized Tedlar^{TM} film on one side and a Mylar^{TM} film on the other and had been subjected to localized heat and fire.

Figure B-4. Sydney 10-Aug-02

Samples of the sidewall lining and insulation blanket were sent to the United States of America, Federal Aviation Administration (FAA) Technical Center and the aircraft manufacturer for analysis and testing.

The examinations determined that both the sidewall lining and insulation blanket samples complied with the appropriate material specifications for aircraft use.

The flammability testing conducted by the FAA on samples of the insulation blanket included a vertical Bunsen burner test, which was mandated in Federal Aviation Regulation FAR 25.853 – Appendix F. The samples tested met the requirements, but due to their limited size, the result was not conclusive as to the integrity of the entire blanket.

The aircraft manufacturer's tests revealed contamination on the insulation blanket samples. This contamination consisted of environmental dust, fibers, and corrosion inhibiting compound. These contaminants were consistent with general contamination found during evaluations of other in-service insulation blankets and were considered to be normal.

The aircraft manufacturer's 'flame propagation cotton swab tests' found areas on the blanket samples that were self-extinguishing while other areas showed "flame propagation uncharacteristic of that expected for new insulation blankets". It was unknown whether contamination, in-service aging, or heat exposure, or a combination of these, altered the blanket's flame propagation characteristics.

Although the insulation blanket had been subjected to in-use contamination, the material composition of the insulation blanket (and sidewall lining) was able to prevent a rapid spread of fire. However, due to the temperatures involved, localized burning had occurred.

APPENDIX C—EFFECT OF SAMPLE TEMPERATURE ON FLAME CHARACTERISTICS OF DUST AND LINT

The very marked effect that radiant heat has on the fire characteristics of dust and lint contaminated thermal acoustic insulation is as follows:

AMBIENT TEMPERATURE (20 ºC)

With the test sample at ambient temperature, the flame propagates slowly across the dust and lint contamination. The flame is relatively small and remains small as it propagates.

100 ºC

With the test sample at 100 ºC, the flames are taller, more extensive and propagate faster than during the ambient temperature test.

200 ºC

With the test sample at 200 ºC, the flames propagate faster, rapidly forming a fire across the entire surface of the contamination.

APPENDIX D—EFFECT OF SAMPLE ATTITUDE ON FLAME CHARACTERISTICS OF DUST AND LINT

The effect of test sample attitude on the fire characteristics of dust and lint contaminated thermal acoustic insulation is as follows:

VERTICAL
With the surface of the test sample vertical, the flames quickly spread upwards over the dust and lint contamination. The flames barely take hold and die relatively quickly.

45°
At this intermediate angle, the flames spread more rapidly than the horizontal sample, but less rapidly than the vertical sample. The flames are more robust and longer lived than for the vertical test.

HORIZONTAL
With the sample horizontal, the flame propagation is relatively slow. The flames are whiter than seen on the vertical and 45° tests and give the appearance of having a much greater heat output and potentially more damaging effect on an aircraft.

APPENDIX E—ENHANCED ZONAL ANALYSIS PROCEDURE

The procedure adopted by the industry to mitigate the potential for fire hazards resulting from electrical faults is based on the FAA Advisory Circular 25-27 (see reference 2) and the Enhanced Zonal Analysis Procedures (EZAP) defined in ATA MSG-3 “Operator/Manufacturer Scheduled Maintenance Development” (see reference 3). The part of the analysis methodology contained in these documents that is most pertinent to thermal acoustic insulation contamination is shown in figure C-1.

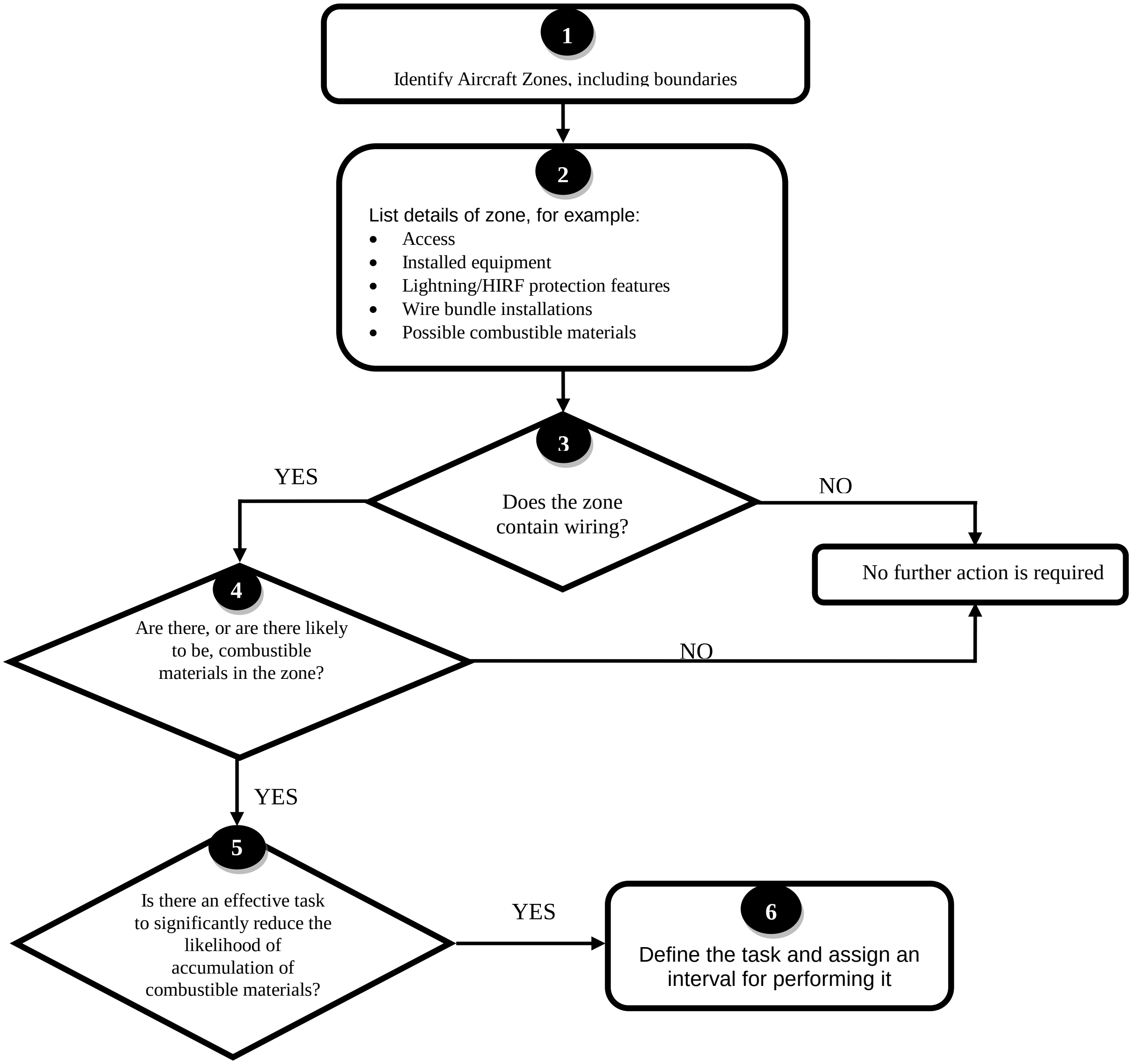


Figure E-1. Enhanced Zonal Analysis Procedures (EZAP)

The primary principle of the procedure may be summarized as follows:

1. For zones of the aircraft that contain wiring, and are likely to contain combustibles, a determination is made as to whether there are effective maintenance tasks that would significantly reduce the accumulation of combustible materials. Advisory Circular 25-27 gives guidance with respect to combustible materials including the following:

   "With respect to commonly used liquids (oils, hydraulic fluids, corrosion prevention compounds, for example) refer to the product specification to assess potential for combustibility. The product may be readily combustible only in vapor mist form. If so, an assessment is required to determine if conditions might exist in the zone for the product to be in this state."

   The effective maintenance tasks that are likely to be considered as reducing the accumulation of combustible materials on thermal acoustic insulation will most probably be a scheduled cleaning task.

2. *If it is deemed that there are effective maintenance tasks that could significantly reduce the likelihood of combustible materials the next part of the process is to define the maintenance task interval based on the likelihood of damage, and the hostility of the environment, to electrical wiring.*

   The likelihood of accidental damage to the wiring is given a scoring from 1 to 3 based on a consideration of the following issues:

   - Ground Handling Equipment
   - Foreign Object Debris
   - Weather Effects (Hail, Rain, etc.)
   - Frequency of Maintenance Activities
   - Fluid Spillage
   - Passenger Traffic
   - Other

   The hostility of the environment is also given a scoring from 1 to 3 based on a consideration of the following issues:

   - Temperature
   - Vibration
   - Chemicals (Toilet Fluids, De-icing Fluid, etc)
   - Humidity
   - Contamination
   - Other

Table 9 illustrates an example of task interval determination based on the scoring of the likelihood of accidental damage and the hostility of the environment to the electrical wiring:

Table 9. Example Task Interval Matrix

EXAMPLES OF TASK INTERVAL RANGES		**Likelihood of Accidental Damage**		
		1- Passive	**2- Moderate**	**3- Severe**
Hostility of Environment	**1- Passive**	**4C - 6C** **14,400 - 21,600 FH**	**2C - 4C** **7,200 - 14,400 FH**	**1C - 2C** **3,600 - 7,200 FH**
	2- Moderate	**2C - 6C** **7,200 - 21,600 FH**	**1C - 4C** **3,600 - 14,400 FH**	**A - 1C** **450 - 3,600 FH**
	3- Severe	**1C - 6C** **3,600 - 21,600 FH**	**1C - 4C** **3,600 - 14,400 FH**	**A - 1C** **450 - 3,600 FH**

0980\Support Information\Task Interval Matrix.xls

3. *If it is deemed that there are no effective maintenance tasks that would significantly reduce the likelihood of combustible materials in the zone the next part of the process is to define the maintenance task interval based on the density of installed electrical equipment, and the potential effects on aircraft safety of a fire.*

   The density of installed electrical equipment in the zone is given a scoring from 1 to 3 based on a consideration of the number of electrical components, their relative closeness to one another, and the complexity of these components (e.g., multiple electrical, mechanical, or hydraulic connections). The potential effects on aircraft safety of a fire in the zone are taken into account. This assessment includes the potential that might exist for loss of multiple functions of aircraft critical systems. The presence of flammable fluids is also considered.

   Inspection intervals are allocated based on the density scoring and the potential effects on aircraft safety. For those zones having high equipment density and a greater potential for an aircraft fire presenting a threat to aircraft safety, more frequent and more detailed inspections are required. This could involve an intensive examination of a specific item, installation, or assembly to detect damage, failure, or irregularity. These intensive examinations are known as DET[11]. For zones with low density electrical installations where a fire is assessed to have a potentially low effect on aircraft safety, then it is likely that only GVI[12] will be required.

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[11] Detailed Inspection (DET)

—An intensive examination of a specific item, installation, or assembly to detect damage, failure, or irregularity. Available lighting is normally supplemented with a direct source of good lighting at an intensity deemed appropriate. Inspection aids such as mirrors, magnifying lenses, or other means may be necessary. Surface cleaning and elaborate access procedures may be required. A DET can be more than just a visual inspection, since it may include tactile assessment in which a component or assembly is checked for tightness/security. It may require the removal of items such as access panels and drip shields, or the moving of components.

[12] General Visual Inspection (GVI)

The above is a very simple overview of the process which is explained in detail in the FAA Advisory Circular 25-27 (see reference 2) and the Enhanced Zonal Analysis Procedures (EZAP) defined in ATA MSG-3 “Operator/Manufacturer Scheduled Maintenance Development” (see reference 3).

Advisory Circular 25-27 also stresses the importance of inspecting EWIS (Electrical Wiring Interconnection Systems) and promoting a philosophy of “protect and clean as you go” when performing maintenance, repair, or alterations on aircraft.

The procedure is carried out for each aircraft type under the auspices of the aircraft Maintenance Review Board (MRB). The assigned tasks are identified in the MRB Report and thus become incorporated into the aircraft Maintenance Planning Document and subsequently into the Aircraft Maintenance Manual and the customized maintenance program.

The EZAP process requires that an assessment be made for each zone of the aircraft of the potential for combustible materials being present. However, the assessment is likely to be based on the declared flammability standards for the contaminants alone (corrosion inhibiting compounds, cleaning fluids, hydraulic fluids, etc.) which may not be the same for the contaminants being present on thermal acoustic insulation. Furthermore, with respect to corrosion inhibiting compounds [corrosion prevention compounds], AC 25-27 offers the following guidance to operators:

> *l. Applying Corrosion Prevention Compounds (CPC). When applying CPC in airplane zones containing EWIS, use care to prevent CPC from contacting it. Dust and lint are more likely to collect on wire that has CPC on it. Apply CPCs according to the aircraft manufacturer’s maintenance instructions…*

—A visual examination of an interior or exterior area, installation, or assembly to detect obvious damage, failure, or irregularity. This level of inspection is made from within touching distance unless otherwise specified. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight, or droplight and may require removal or opening of access panels or doors. Stands, ladders, or platforms may be required to gain proximity to the area being checked.