Aviation Rulemaking Advisory Committee

Fuel Tank Harmonization Working Group

Final Report

July 1998

Submitted jointly by

AIA, AECMA, ATA, ALPA, IATA, FAA, JAA, GAMA, API

Aerospace Industries Association

The European Association of Aerospace Industries

AECMA

alpa

Air Transport Association of America

Joint Aviation Authorities

American Petroleum Institute

IATA

GAMA

FAA

FUEL TANK HARMONIZATION WORKING GROUP
FINAL REPORT

Executive Summary

The overall goal of the aviation industry and the regulatory agencies is to enhance aircraft safety in an effective and practical manner. The Fuel Tank Harmonization Working Group has spent the last six months aggressively pursuing means to improve airplane safety by reducing flammability in fuel tanks. The group investigated the history of the commercial fleet to understand the significance of each event involving fuel tank flammability, and to look for underlying causes that would assist our investigation. Thermal analyses of a wide range of airplanes operating in worldwide environmental conditions were used to correlate the historical record with the flammability exposure of fuel tanks, and to evaluate potential solutions.

The industry and the FAA have already taken actions to:

- Identify and correct equipment and installations that have the potential to be an ignition source in a fuel tank through service bulletins and Airworthiness Directives,

- Develop and execute inspection programs to assess the conditions of the fuel systems in the fleet and to develop maintenance programs based on those inspection results,

- Initiate work on a Special Federal Aviation Regulation (SFAR) to review system design and certification, and maintenance practices, with the goal of reducing the probability of ignition sources occurring in fuel tanks,

- Establish the Fuel Tank Harmonization Working Group (FTHWG) to investigate means to reduce or eliminate explosive mixtures in fuel tanks.

This comprehensive effort is attempting to address both ignition sources in the fuel system and exposure to flammable fuel-air mixtures.

The FTHWG studies showed that flammability exposure varies among airplane types and depends on fuel tank location. Some fuel tanks (e.g., wing tanks and some center tanks) already have a low exposure to flammable conditions. Reducing flammability in all fuel tanks to the level of the wing tanks on most airplanes, was seen as a worthwhile goal. A variety of possible means to achieve this goal were evaluated for technical and economic merits.

The following conclusions were reached:

- Techniques to reduce or eliminate heat input to the tanks from nearby heat sources were evaluated. Of these techniques, directed ventilation and relocation of the significant heat sources reduce the exposure to an acceptable level. However, relocation is only feasible for new airplane designs. Directed ventilation for in service aircraft is estimated to have an overall cost for a ten-year period of $3.5 billion.

- To reach the goal by changing fuel properties, a minimum flash point specification of 140°F would be required. A change of this magnitude falls outside of the current experience base and may require engine re-design/re-qualification. The overall fuel manufacturing cost increase for a ten-year period is estimated at $15 billion in the USA and $60 billion for the rest of the world and could result in a significant shortfall of jet fuel.

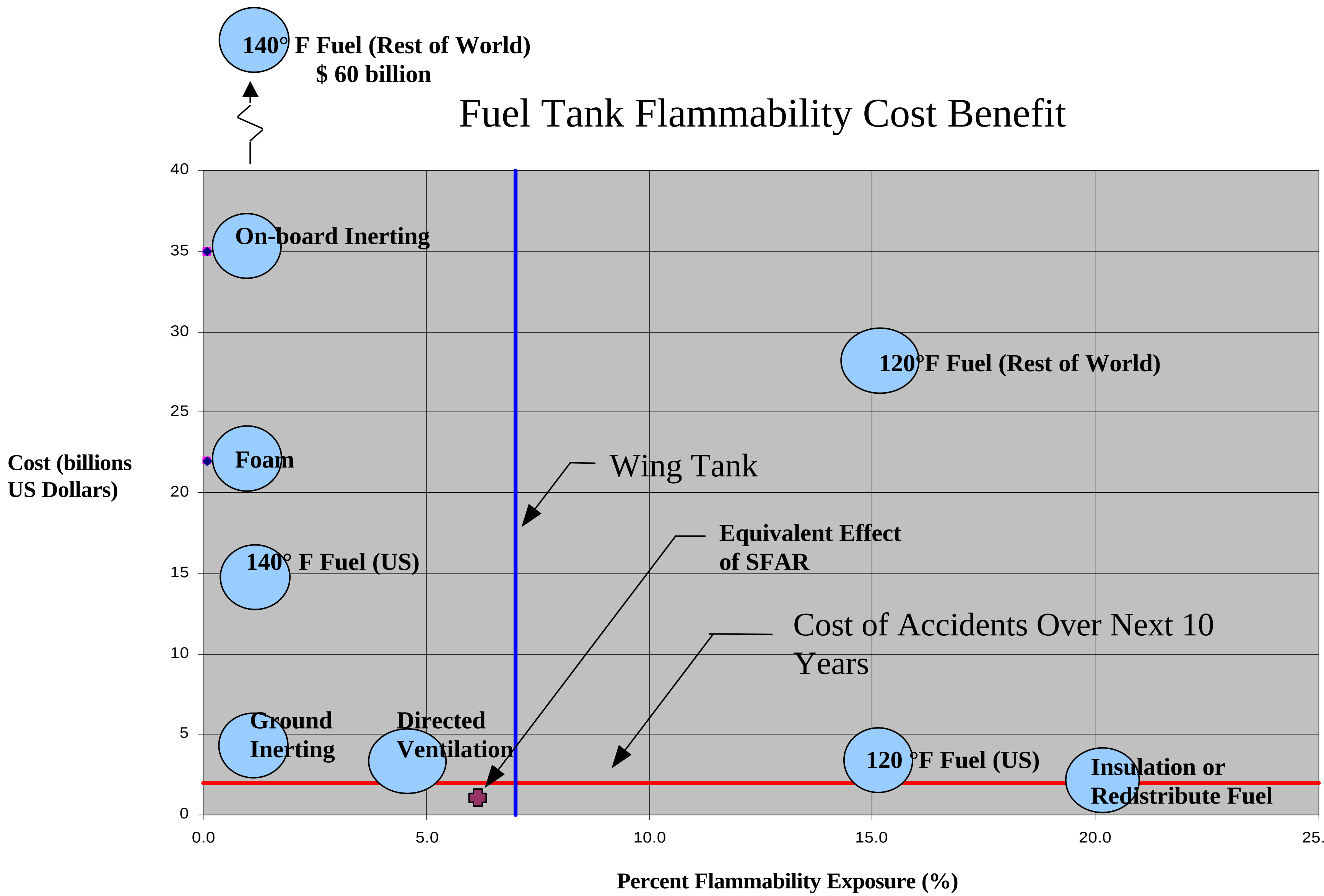
- Techniques such as on board fuel tank inerting or installation of foam in the tanks would also achieve the goal, but at a cost estimated to be at least $20 billion over the next ten years and would be very difficult to retrofit in current airplanes. Ground inerting, wherein specific tanks are made inert prior to flight, at specific airports, is an option that needs future study to determine; (a) the logistical costs of such a system and, (b) if retrofit installation of the distribution system internal to the airplane could be achieved in a cost effective manner.

- The Working Group considered several concepts that were determined to be insufficiently advanced technically at this time, for transport airplane fuel tank use. These included ullage sweeping and explosion suppression systems.

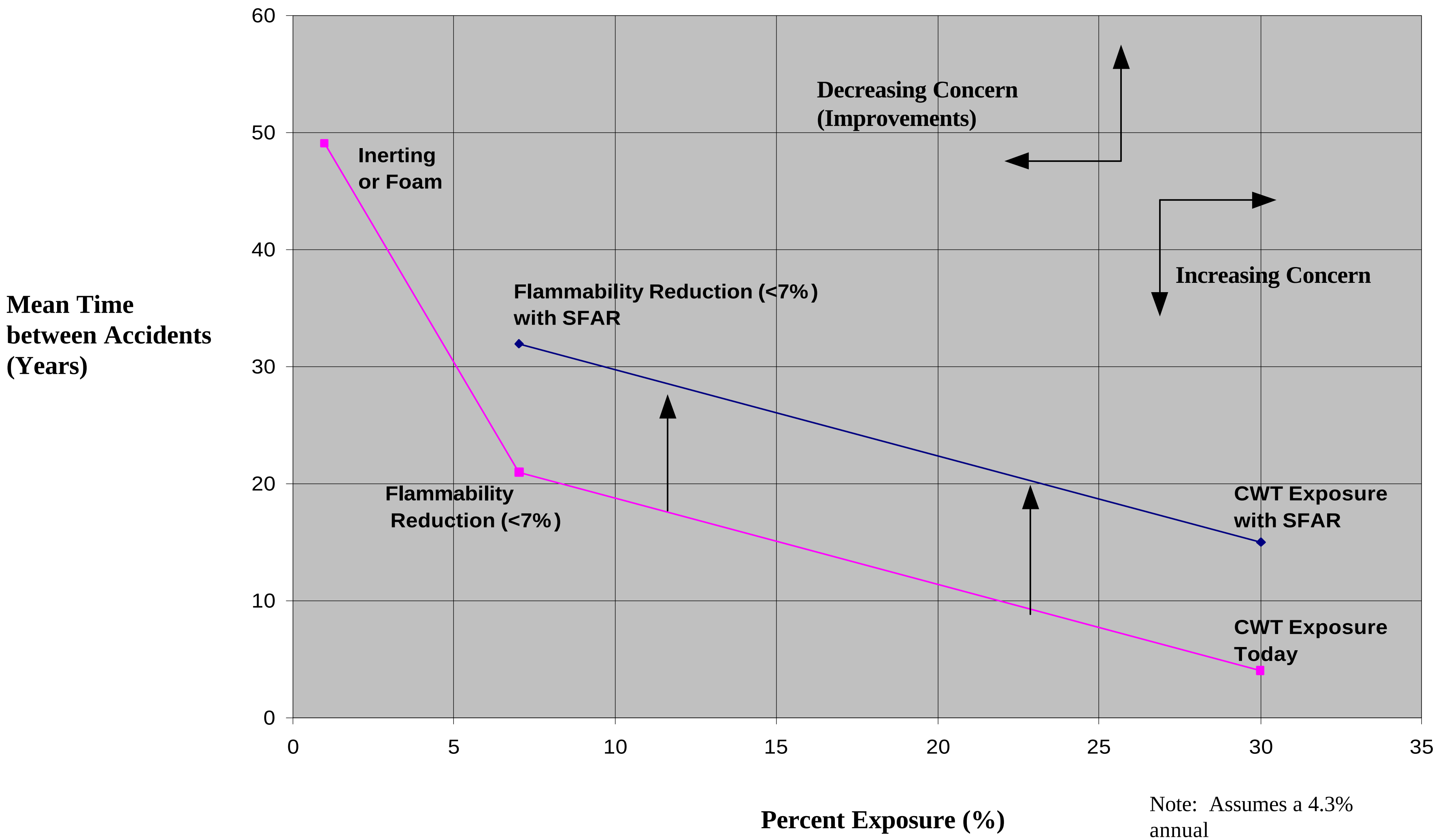
An initial estimate provided by the FAA for the cost of future events is $2 billion over the next ten years, if no changes are made in the fleet. The flammability reduction techniques studied by the group have an economic impact greater than this, and therefore careful consideration must be given to determine which avenue to pursue.

The first chart below depicts the relative costs and flammability exposure benefits of various options studied. The fuel tank inspections, the service bulletins for wiring improvements, and the anticipated SFAR for ignition sources (which the FAA is studying independently of this effort) should reduce the hazard from ignition to a level equivalent to a 6% flammability exposure. The estimated cost for the anticipated SFAR is between $1-2 billion. This is depicted on the chart as a cross to differentiate it from the options studied by the Working Group.

The second chart below depicts the impact on the fuel tank explosion accident frequency predicted for fuel system enhancements in flammability reduction and in ignition source mitigation.


140° F Fuel (Rest of World)
$ 60 billion
Fuel Tank Flammability Cost Benefit
Cost (billions US Dollars)
40
35
30
25
20
15
10
5
0
On-board Inerting
120°F Fuel (Rest of World)
Foam
Wing Tank
Equivalent Effect of SFAR
140° F Fuel (US)
Cost of Accidents Over Next 10 Years
Ground Inerting
Directed Ventilation
120 °F Fuel (US)
Insulation or Redistribute Fuel
0.0
5.0
10.0
15.0
20.0
25.0
Percent Flammability Exposure (%)

Effect of Fuel Tank Enhancements



Note: Assumes a 4.3% annual

The Working Group evaluated potential regulatory actions and concluded that the most effective action would be a revision of FAR 25.981 to address both ignition source prevention and flammable fuel-air mixture exposure in a single regulation, consolidating the major aspects of preventing tank explosions into one rule.

Recommendations

The ARAC Working Group recommends that the FAA/JAA pursue a cost effective approach to enhance fuel tank safety.

The following specific recommendations are made:

1. Adopt the proposed new regulatory action on new aircraft designs.

2. Continue to investigate means to achieve a cost-effective reduction in flammability exposure for the in-service fleet and newly manufactured aircraft.

3. Pursue the studies associated with directed ventilation and ground-based inerting systems to improve their cost effectiveness.

4. If a practical means of achieving a cost effective reduction in flammability exposure can be found for the in service fleet, either at the level specified in the rule or at some intermediate level (recommendations 2 and 3 above), consider application of that solution, in combination with other actions (e.g. SFAR).

5. If a practical means of achieving a cost effective reduction in flammability exposure can be found for newly manufactured aircraft, either at the level specified in the rule or at some intermediate level (recommendations 2 and 3 above), consider application of that solution, in combination with other actions (e.g. SFAR).

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8) Task Group 6/7 – Fuel Properties and Its Effects on Aircraft and Infrastructure Final Report
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CHAPTER 1 GENERAL CONSIDERATIONS AND PROPOSED RULE

1.1 Introduction

1.1.1 Background

On July 17, 1996 TWA Flight 800, a Boeing model 747-131, exploded in flight shortly after takeoff from Kennedy International Airport in New York. The accident investigation led by the National Transportation Safety Board (NTSB) has not, as of this date, determined the primary cause for the accident. Evidence gathered from the accident site indicates that the center wing tank exploded, but an ignition source has not been identified.

The NTSB sent four recommendations for regulatory changes to the Federal Aviation Administration (FAA) on December 13, 1996. The NTSB had recommended that the FAA require the development and implementation of design or operational changes intended to eliminate, significantly reduce or control explosive fuel-air mixtures in fuel tanks of transport category airplanes.

On April 3, 1997, the FAA issued a public notice soliciting comment on the feasibility of implementing the NTSB recommendations. To support this request, airplane manufacturers and airline operators initiated a comprehensive review of fuel system design and operational practices.

Their report, issued July 30, 1997, concluded that the overall level of safety and reliability of commercial airplane fuel systems was very high and any changes must be carefully studied so that additional risks are not introduced. Net safety benefits must be documented.

The industry further recommended that an international fuel tank group be established to develop aircraft inspection programs to verify the integrity of wiring and grounding straps, the condition of fuel pumps, fuel lines and fittings and the electrical bonding of all equipment, to verify the design and assure that no ignition sources could exist in fuel tanks.

Subsequent to this recommendation, airlines and airframe manufacturers initiated a joint program to examine the condition of aircraft fuel tank wiring and bonding. This program is called Aircraft Fuel System Safety Program (AFSSP) and the group plans to issue a final report by the year 2000. The FAA participates in the leadership of the AFSSP.

Late in 1997, the FAA announced the decision to develop a Special Federal Aviation Regulation (SFAR) with the purpose of reducing the risk of ignition sources in fuel tanks through design reviews and improved maintenance programs.

In December 1997, the FAA/JAA announced the decision to initiate the Aviation Rulemaking Advisory Committee (ARAC) Fuel Tank Harmonization Working Group (FTHWG).

1.1.2 Scope

The historical approach to fuel system safety has been to control the risk of ignition sources. All current regulation and commercial aircraft design is based upon this philosophy. The ARAC FTHWG was tasked to recommend new rulemaking to eliminate or significantly reduce the risk of exposure to flammable fuel-air mixtures in fuel tanks.

1.1.3 Charter of the ARAC Fuel Tank Harmonization Working Group

The charter of the ARAC Fuel Tank Harmonization Working Group was:

1. To analyze:
    - The history of the world transport aircraft fleet
    - The safety status of the existing fleet
    - Various means of reducing exposure to flammable fuel vapors
    - Means to eliminate the resultant hazard if ignition does occur
2. To recommend regulatory text for new rulemaking aiming at controlling flammability of fuel vapors in fuel tanks.
3. To assess the cost benefit of those means.
4. To assess the effect of the new rule on other sections of the industry.
5. To follow the rules for ARAC harmonization working groups.
6. To issue a final report within six months after publication of the Terms of Reference (TOR).

1.1.4 Terms of Reference

The National Transportation Safety Board has concluded from the accident investigation that an explosive fuel-air mixture existed in the center wing tank of TWA Flight 800.

The FAA has identified 10 transport airplane hull loss events since 1959, which involved fuel tank explosions. The investigation of TWA Flight 800 and the number of fuel tank explosions which have occurred in service has led the FAA to question the adequacy of transport airplane certification requirements relative to fuel tank design, specifically with respect to environmental considerations and the adequacy of steps to minimize the hazard due to potential ignition sources, both in initial design and over the life of the airplanes.

The FAA further believes that one of the approaches to improve fuel tank explosion safety is the prevention or reduction of the occurrence of a flammable fuel-air mixture in the tanks through some means of inerting, cooling/insulation, modified fuel properties, installation of foam or fire suppression systems.

The task for the ARAC FTHWG was to prepare a report to the FAA/JAA that provides specific recommendations and proposed regulatory text, that will eliminate or significantly reduce the hazards associated with explosive vapors in transport category airplane fuel tanks. Proposed regulatory text should ensure that new type designs, in-production airplanes and the existing fleet of transport airplanes are designed and operated so that during normal operation the presence of an explosive fuel-air mixture in all fuel tanks is eliminated, significantly reduced or controlled to the extent that there could not be a catastrophic event.

The report should include the following:

1. An analysis of the threat of a fuel tank explosion due to internal and external tank ignition sources.

2. An analysis of various means of reducing or eliminating exposure to operation of transport airplane fuel tanks with explosive fuel-air mixtures or eliminating the resultant hazard if ignition does occur.

3. An analysis of the cost/benefit of modified fuel properties that reduce exposure to explosive vapors within fuel tanks. Factors that may enhance the benefits of modified fuels, such as cooling provisions incorporated to reduce fuel tank temperatures, should be considered and cost information for the various options should be developed.

4. Review comments to the April 3, 1997 Federal Register Notice such that validated cost benefit data of a certifiable system is provided for the various options.

5. Recommend objective regulatory actions that will eliminate, significantly reduce or control the hazards associated with explosive fuel-air mixtures in all transport airplane fuel tanks.

In addition to this task, the ARAC FTHWG should support the FAA/JAA in evaluation of application of the proposed regulation to the various types of transport airplanes and any impact on small businesses.

The activity was tasked for a 6-month time limit to complete the tasks.

1.2 Development of the ARAC FTHWG

A public notice was issued in the Federal Register by the FAA on January 23, 1998 surveying industry and regulatory agencies for potential members for this Working Group. Over 75 responses were received. Of those responses, over 45 Task Group members were selected to become part of the FTHWG.

Members were selected based on background, expertise, and affiliation with a variety of industry and regulatory groups. The FAA/JAA wanted to ensure that the regulatory recommendations were developed by a broad-based group of stakeholders who would be impacted by these changes. The FAA/JAA also wanted to access the wide-ranging expertise that industry brings to this subject. ARAC operating procedures were used throughout the process.

The 6-month timeframe specified by the FAA/JAA to complete this analysis was very aggressive and unprecedented. Members selected for the FTHWG had to be available on a nearly full-time basis for the 6-month period.

Due to the extensive amount of work currently taking place throughout industry in harmonizing FAA and JAA regulations, the FAA/JAA also tasked the FTHWG with ensuring that the regulatory recommendations developed were the product of a consensus of the FAA, JAA and industry members.

The FTHWG was co-chaired by representatives of Aerospace Industries Association (AIA) and The European Association of Aerospace Industries (AECMA) and made up of representatives from:

Air Transport Association (ATA)

Air Line Pilots Association (ALPA)

International Air Transport Association (IATA)

Federal Aviation Administration (FAA)

Joint Aviation Authorities (JAA)

General Aviation Manufacturers Association (GAMA)

American Petroleum Institute (API)

1.2.1 FTHWG Organization

The members selected to participate in this project were divided into seven Task Groups. Due to the short time frame of the project, several assignments had to take place concurrently. Each assignment was given to a Task Group, with the entire project being overseen by the nine-member FTHWG. An ‘Organization Chart’ of this arrangement is attached. Much care was taken to balance the Working Group membership so that it represented all aspects of industry and regulatory agencies. Care was also taken to balance each individual Task Group.

1.2.2 Charter and Deliverable of Each Task Group

Several tasks were undertaken simultaneously at the inception of the FTHWG. These tasks fell into five main categories:

1) A review of service history;
2) A thermal analysis to quantify the current fleet exposure to flammable fuel-air mixtures;
3) A detailed analysis of means to reduce exposure to flammable fuel-air mixtures (such as fuel property changes, fuel tank inerting, ullage sweeping, ullage washing, temperature control);
4) A detailed cost/benefit analysis of means to suppress explosions (such as foam);
5) A set of proposed regulatory material.

Task Group charters and objectives are summarized below.

<u>Task Group 1: Service History/Fuel Tank Safety Level Assessment</u>
Prepare a detailed analysis of previous tank explosion events. Carry out a flammability review of the current range of fuel system designs and tank configurations. Develop a safety analysis tool to evaluate the safety impacts of any proposed (design) changes.

<u>Task Group 2: Explosion Suppression</u>
Research the industry for existing technologies and systems specifically designed to actively monitor, detect, react to and suppress an explosion event before the event can produce catastrophic results.

<u>Task Group 3: Fuel Tank Inerting</u>
Provide a feasibility analysis of fuel tank inerting systems. Focus on reducing or eliminating exposure to explosive mixtures for transport airplane operations. Prepare a cost/benefit analysis.

<u>Task Group 4: Foam</u>
Provide a feasibility analysis of foam systems. Also included is an analysis of expanded metal products. Prepare a cost/benefit analysis.

Task Group 5: Fuel Vapor Reduction
Quantify the exposure of fuel tanks to flammable vapor. Analyze means to reduce that exposure. Prepare a cost/benefit analysis for each of the means.

Task Group 6/7: Fuel Properties and Its Effects on Aircraft and Infrastructure
Assess the feasibility of using jet fuel with a higher flash point in the transport airplane fleet as a means of reducing exposure of the fleet to explosive fuel-air mixture. Include an assessment of the impact of modified fuel properties on both the infrastructure and the aircraft and its operations. Include a cost/benefit analysis.

Task Group 8: Evaluation Standards and Proposed Regulatory Action Advisory Group
Provide a common set of definitions to the other Task Groups so there is consistency in the data used by all groups. Define a proposed regulatory action.

1.2.3 Time Schedule

A milestone schedule was developed at the first FTHWG meeting in February 1998. The FTHWG agreed to meet together for a two-day period each month. Task Groups were instructed to meet as often as necessary. The final report was due 23 July 1998.

1.3 Standards Applied

A common set of standards was necessary to achieve consistent results in performing cost benefit studies. To achieve this consistency, Task Group 8 was chartered to provide a common set of definitions to the other Task Groups.

1.3.1 Assumptions Made

A spreadsheet was developed to provide a common source of data to be used by the task groups in order to ensure that the potential methods were evaluated using consistent data and assumptions. Data were included in the spreadsheet for six generic airplane types: small, medium and large transports, regional turbofans, regional turboprops and business jets. The data included summaries for each airplane type, such as fleet size, weights, fuel volumes and flight distributions. Mission profile data such as weight, altitude, Mach number, fuel remaining in each tank and body angle as a function of time was included for each generic airplane type. Temperature profiles ranging from cold to extremely hot were also included in the mission profiles. Performance trades and cost trades were also included to allow the consistent calculation of performance and cost impacts. Details of the standards and assumptions can be found in the Task Group 8 report.

1.4 Service History/ Review of Past Accidents

The service history of the transport airplane fleet (including turbofan and turboprop airplanes) over the last forty years was examined, and information regarding known instances of fuel tank explosion (other than those caused by post-impact crash events) was assembled. The starting point was the table of events contained in the FAA Notice on Fuel Tank Ignition Prevention Measures published in the Federal Register on April 3, 1997. The data sources used were accident and incident reports provided by investigating organizations, regulatory authorities, and original equipment manufacturers' safety-related databases. The level of details reported in the early events was sometimes limited depending on the event location and the type of event (whether it involved an internal or external ignition source).

The attached service history report by Task Group 1 contains a detailed description of each event and the findings of the investigating authority, followed by a description of the mitigating actions taken subsequent to the event. The events have been separated into operational events and refueling and ground maintenance events. They are grouped by cause (lightning, engine separation, refueling, maintenance, etc.), and are then categorized by operational phase, ignition source, type of fuel tank involved, and fuel type. The mitigating actions taken after each event are summarized and any recurring events are identified.

From the analysis, certain patterns emerge:

- Of the 16 fuel tank events examined, 8 involved wing tanks, 8 involved center or fuselage tanks;
- There were 9 operational events and 7 refueling and ground maintenance events.
- There were only 2 explosions due to lightning strike, with 396 million flight hours accumulated since the last event in 1976;
- In the wing tank events, 5 out of 8 involved the use of wide-cut fuel (JP-4/Jet B);
- In the wing tank events, 5 out of 8 occurred in-flight;
- All the wing tank events involved external ignition sources - there were no known wing tank explosions due to internal ignition sources in the 40 years of commercial jet aviation history;
- All the center tank events involved the use of Jet A/Jet A-1 fuel;
- In the center tank events, 6 out of 8 occurred on the ground;

The data suggests that there is a difference in the respective safety levels between wing tanks and center tanks.

All the wing tank events have been due to known, external ignition sources (lightning strikes, over-wing fire, refueling, maintenance error). There were no known internal ignition sources in 520 million hours of commercial transport fleet operation that resulted in a tank explosion. Corrective actions to prevent recurrence of these wing tank events have been in place for many years, and have been demonstrated to be effective.

However, in the two most recent center tank events the ignition sources have not yet been identified. While corrective actions to identify and eliminate potential ignition sources are being put in place, the investigation of flammability reduction is warranted since the efficacy of these actions has yet to be proven.

Over the years, center tanks have accumulated considerably fewer operating hours than wing tanks (for example, a typical twin-engine transport has two wing tanks and one center tank, and therefore accumulates wing tank hours at twice the rate of center tank hours). Since the equipment in wing and center tanks is very similar, i.e. there are similar types and numbers of potential ignition sources, one might expect there to be significantly fewer center tank events than wing tank events. Actually, the numbers of events are equal. This suggests that these tanks have not yet reached the safety level attained by wing tanks, and that action to further reduce the flammability levels in center tanks should be considered.

It might be argued that the reason for this disparity is that components in the wing tanks are more often submerged than those in the center tanks, which empty prior to wing tanks. However, this may be an over-simplification. There are several pieces of electrical equipment inside wing tanks, which routinely operate in the vapor space. The disparity may be the result of the center wing tanks being significantly more flammable than wing tanks. Therefore, altering the flammability level in center tanks equivalent to wing tank levels appears to be a worthwhile target.

The absence of explosions in wing tanks due to lightning strike supports this view. Lightning strikes frequently occur. On average, every aircraft in the world fleet experiences one strike per year. Yet, the data shows that there are only two explosions due to lightning strike in a database spanning 40 years, with the last event occurring 22 years ago. However, both involved the use of wide-cut fuel (JP-4), which has a much higher volatility than kerosene fuel (Jet A/A-1) and whose flammability envelope coincides much more closely with the normal flight ranges of altitude and ambient temperature. The phasing-out of wide-cut fuel from commercial airline use means that for a large proportion of the flight envelope the wing tank ullage is non-flammable.

In the last 20 years (when Jet A/A-1 has been the predominant fuel), there have been five fuel tank explosion events involving center/fuselage tanks, and two wing tank events. The continuing incidence of center tank explosions (all of which involved Jet

A/A-1 fuel) indicates that these tanks have not yet reached the safety level attained by wing tanks, and that action to further reduce the flammability levels in center tanks should be considered.

This study identified and analyzed 16 known instances of fuel tank explosions (other than those following impact with the ground) over the past 40 years of transport aircraft operations worldwide. The following conclusions have been drawn:

- There is a close relationship between the incidence of explosions in wing tanks and the use of wide-cut fuel.
- Wing tanks operating with Jet A/A-1 fuel have demonstrated an acceptable safety record.
- Center tank and fuselage mounted tanks have also shown a low probability of explosions, but there is some evidence that they are more vulnerable to explosion in the presence of ignition sources.
- Apart from the two most recent events, which involved Center Wing Tank with thermal inputs to the tanks, (1990/Manila & 1996/New York), the causes of all the other events have been addressed by actions designed to prevent or minimize their recurrence.
- The Safety Level Performance of wing tanks has been identified as a target for the technologies applied to center wing tanks and their safety level performance.

1.5 Safety/Risk Assessment Methodology

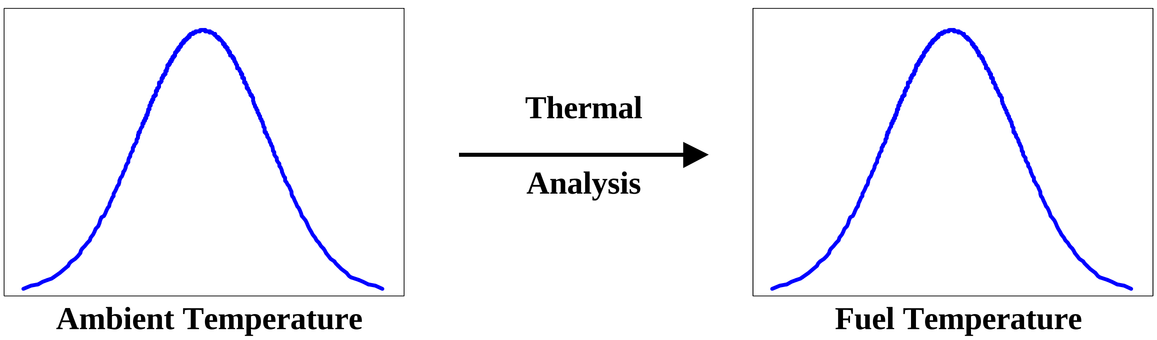
A safety/risk assessment methodology was developed to quantify the current fleet exposure of fuel tanks to flammable fuel vapors, and then to predict the reduction in exposure achievable by implementation of various methods. The additional risks that may be introduced as a result of implementation of a method must be taken into account in the net safety assessment. This methodology was used as the benefit half of the cost/benefit analysis.

1.5.1 Thermal Analysis

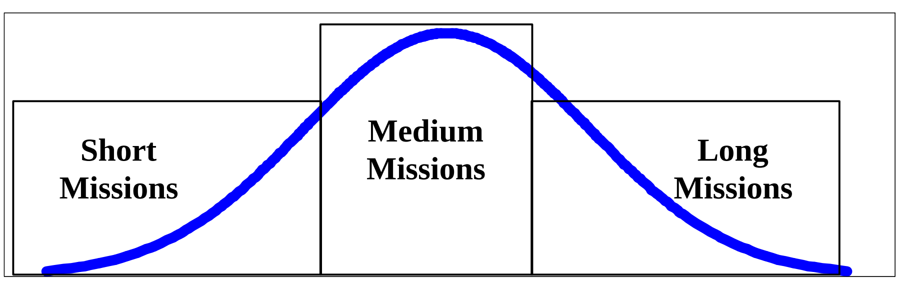
To define the current fleet of fuel tanks, the methodology was to study different fuel tank configurations on airplanes over a wide range of size. Tank configurations analyzed included several wing tanks and several center tanks, some with and some without adjacent heat sources. Representative airplanes from each of the generic size categories were chosen for the analysis (large, medium, and small transports, regional jets and business jets.)

To define the exposure to flammable fuel vapors, the methodology was to quantify the amount of time that the fuel temperature is above the flash point of the fuel over the mission profile. The analysis therefore has three main variables; fuel temperature, mission profile, and flash point.

Fuel temperature – In order to quantify the fuel temperature for each fuel tank configuration, thermal analysis of the fuel tank was required, including the affects of adjacent heat sources. Because airplanes operate in a wide range of environments, thermal analysis over a wide range of ambient temperatures was required. Ground and in-flight atmospheric data was used to define the range of ambient temperatures and flight route/frequency data was used to define the probability of a flight encountering a particular ambient condition. From this distribution, representative ambient temperature profiles were chosen as the inputs to the thermal analysis to produce a range of fuel temperature profiles with a defined distribution.

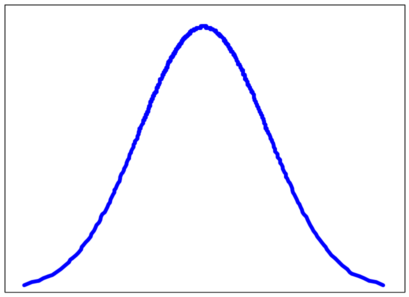


Mission profile – Airplanes operate over a wide range of missions. For each airplane, flight range/frequency data was used to define the distribution of mission lengths. Three mission profiles were chosen to be representative of typical, short, medium and long flights.



Mission Length

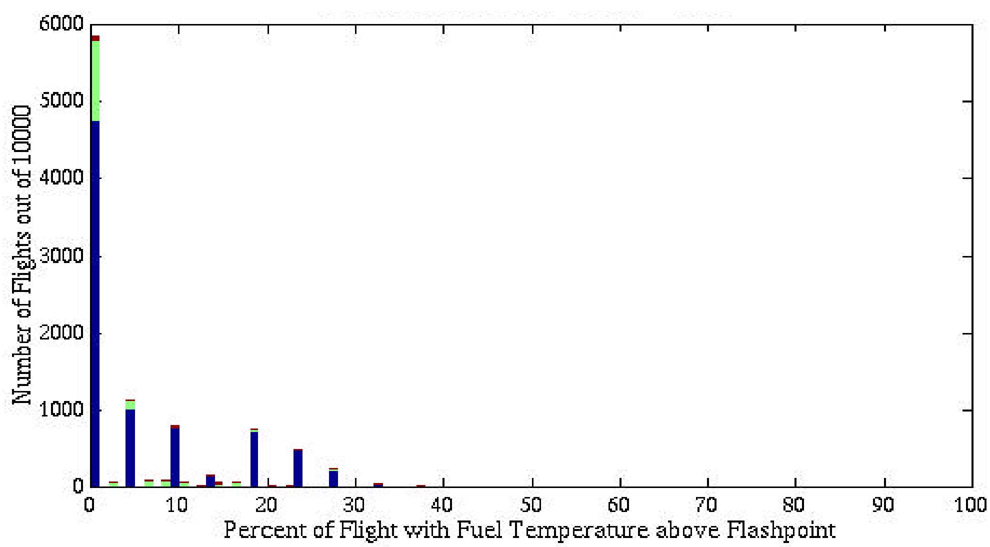
Flash point - To define the flash point of the fuel, the initial assumption was to use the specification limit of 100°F. However, as the objective was to define the exposure of the current fleet of airplanes as they actually operate, it was decided to increase the accuracy of the analysis by using the flash point of the fuel that is loaded onto the airplane. Task Group 6/7 collected data on the current distribution of flash points delivered worldwide and assigned probabilities of a specific mission being fuelled with a fuel at a specific flash point.



Fuel Flash Point

1.5.2 Exposure Analysis

To quantify the fleet exposure, a statistical analysis approach was applied to a statistically significant number (10,000) of randomly selected flights. The flights were then selected to be representative of the fleet using the defined distributions of the three variables. For example, flight one may be a short mission on a cold day with an average flash point fuel, and flight two may be a long mission on an average day with a low flash point fuel, and on and on until 10,000 flights have been defined in this manner. For every one of the 10,000 flights, the time that the fuel temperature was above the flash points was calculated. The results of the exposure analysis are best displayed in the form of a histogram like the example shown below.



Averaging the results for all 10,000 flights provides an average percentage of the flight time that any particular flight could be expected to be exposed to a fuel temperature above the fuel flash point. These fleet average exposure results are given for each airplane size and tank configuration in the table below.

Exposure Analysis Results

Wing Tanks				Center Tanks			
WITHOUT adjacent heat sources				WITHOUT adjacent heat sources		WITH adjacent heat sources	
large	small	regional turbofan	bizjet	small	regional turbofan	large	small
5%				5%		**30%**	

Once the current fleet exposures to fuel tanks with flammable vapors are calculated, the same method of thermal analysis / exposure analysis is used to systematically study methods to reduce the exposure in fuel tanks.

More information on the exposure analysis and thermal analysis can be found in the Task Group 5 report in sections 5.0 and 15.0. Results of the exposure analysis for each of the considered methods can be found in section 2.5 of this report, with more information in the Task Group 5 report.

1.5.3 Safety/Risk Assessment Methodology Conclusions

This safety/risk assessment methodology was developed to quantify the current fleet exposure of fuel tanks to flammable fuel vapors. Quantifying the exposure is a very complex task, so simplifying assumptions had to be made to complete the analysis in the tight time frame available, such as the use of generic airplane fuel tank configurations and typical flight profiles. To ensure confidence in the process, an independent third party audit was conducted by members of the API. The auditors agreed with the process as a valid method to quantify exposures. As discussed in the proposed advisory circular (Task Group 8 report), a simpler method of exposure analysis is currently under development.

1.6 Proposed Rule

The proposed rule was created to serve two purposes, firstly to provide a constant standard for the various task groups to use to develop solutions and to develop internally consistent comparisons, and secondly to provide the draft of a proposed rule to the FAA/JAA if the cost benefit analyses showed such a rule to be of overall benefit.

1.6.1 Methodology

The intent of the proposed rule is to achieve a level of safety that would reduce the probability of another fuel tank explosion event to a low enough level that one would not be expected to occur in the life of a given airplane type. The proposed rule was developed using the history of the fleet from Task Group 1 in conjunction with the analysis of Task Group 5 of the current flammability levels in the fleet today.

This approach was thus to look at the history for factors in explosion events, and then to look at the flammability modeling to see if there were matching factors. The other driver in looking at the proposed rule was to recognize that ignition prevention has been, and will continue to be, the primary protection technique for fuel system explosion prevention.

The group recognized that the FAA was pursuing a plan to address ignition source control through the SFAR process, and that the current rules, while being adequate at a high level, may not be specific enough at a detail level. To address all of these factors the group concluded that the proposed rule should address explosion prevention in one rule, with ignition source control being the first element and flammability control being the second.

The study concluded that fuel tank explosions were the result of unique circumstances at a single point in time, rather than circumstances that generate a continuous or intermittent ignition condition. The reasoning for this conclusion is that the flammability exposure of certain tanks was high (30% of fleet operating time) and therefore if circumstances created long duration ignition conditions, we would expect a far higher number of events than the fleet history shows. Based on this, it was concluded that the presence of an ignition source in any one tank was a very unlikely random event and the recommended way to further reduce the probability of an explosion is to limit the time during which the tank is in a flammable condition. It was concluded that total elimination of flammability is not required in as much as wing tanks operating with relatively low levels of flammability exposure have an excellent safety record.

In addressing the flammability section of the proposed rule, the group considered that total elimination of flammability was not required in as much as wing tanks operating with relatively low levels of flammability exposure have an excellent safety record. With this in mind, the group examined the flammability exposure of various tanks on a wide range of airplane types to determine how to define flammability exposure and how to select a suitable target to use in the rule. The Working Group determined from examination of various airplanes types that the exposure of wing tanks, without additional heat input from sources nearby, was below 6% of fleet operating time, while tanks exposed to heat input were flammable for up to 30% of the fleet operating time. The fleet history suggested that wing tanks with low flammability exposure had an excellent record, and thus a flammability limit that matched the wing tanks of most airplanes was selected for use in the proposed rule.

As noted above, the proposed rule was used to define a set of requirements to size and cost the various systems to satisfy the requirements. The cost benefit analysis provides the data to assess the reasonableness of adopting this rule versus focusing on ignition prevention as the means to reduce events to an acceptable level.

1.6.2 Proposed Rule

In order to enhance fuel system safety, the group recommends to the FAA/JAA the following action:

Create a revised paragraph FAR 25.981 to address fuel tank protection from airplane created threats that could prevent continued safe flight and landing. The proposed revision is as follows:

Section 25.981 Fuel Tank Ignition Prevention

The fuel system must be designed and arranged to prevent the ignition of fuel vapor within the tanks, or mitigate the effects of such an ignition by addressing:

(a) Ignition Sources

(a)1. *Place the current 25.981 requirement here*

(a)2. *Additional requirements in ignition source mitigation as defined by the FAA would be in section (a)2, (a)3, etc. as defined by the SFAR effort underway*

(b) Flammable Vapors

Limiting the development of flammable conditions in the fuel tanks, based on the intended fuel types, to less than 7% of the expected fleet operational time, or

Providing means to mitigate the effects of an ignition of fuel vapors within the fuel tanks such that any damage caused by an ignition will not prevent continued safe flight and landing.

1.6.3 Discussion on the Intent of the Proposed Requirement

The proposed regulatory action provides a single regulation to address ignition prevention, thereby avoiding having several paragraphs which must be linked and interpreted in conjunction with each other. It provides the industry with a requirement that addresses all aspects of fuel tank ignition prevention/mitigation, which can be treated as a comprehensive requirement and addressed as one issue. The existing requirements set forth in sections 25.901, 25.954 and 25.981 are intended to preclude ignition sources from being present in airplane fuel tanks. As proposed, Paragraph (a) maintains these requirements, which have been, are, and should continue to be, the essential primary elements in fuel tank safety. Paragraph (b) provides a requirement to address flammability mitigation as a new layer of protection to the fuel system. The intent of the combined regulation is to prevent an applicant relying solely on ignition prevention or on flammability reduction as the means to protect the fuel system from ignition events.

1.6.4 Proposed Advisory Material

A proposed AC/ACJ 25.981 (b) is included in the Task Group 8 Report. This ACJ sets forth an acceptable method of compliance with the requirements of FAR/JAR 25.981(b). The guidance provided within this AC is harmonized with the FAA and JAA and is intended to provide a method of compliance that has been found acceptable.

CHAPTER 2 POSSIBLE COMPLIANCE METHODS

2.1 Introduction

This chapter summarises the findings of the Task Groups that investigated possible means to comply with the proposed rule.

Where possible, cost to the industry of each means is given.

Detailed reports of each Task Group's work are attached to this report.

2.2 Explosion Suppression

Task Group 2 has performed a search for reference material and documents concerning systems that have been specifically designed to suppress or extinguish an explosion within a fuel tank. This search quickly revealed that a great amount of research had been accomplished in this arena concerning military operations and the need to protect combat aircraft from external threats where fuel ignition could result.

From actual live-firing tests and system performance bench tests, a number of systems have demonstrated positive results in providing fuel tank and dry bay protection from fuel vapor explosions. The applicable technologies center around four separate methods of dispersing the suppressant:

- Inert Gas Generators
- Gas Generator driven Agent Dispersal
- Explosive Expulsion of Low Pressure Agent
- Explosive Release of High Pressure Agent

Four companies were contacted, and provided information pertinent to the above suppression methods.

From the review of the data presented by these companies, it is evident that the technology exists and is effective in suppressing the pressure effects of an explosion before those effects can become hazardous to the tank enclosure / structure. However, this technology is not yet fully mature and a significant amount of development is still required to understand to the specific requirements of fuel tank wet-bay protection.

No cost information is provided in this report due to the lack of maturity for fuel tank application.

2.3 Reticulating Foam and Expanded Metal Products

This report provides information on two types of materials available for installation inside aircraft fuel tanks to reduce the risks of aircraft hull losses in case of explosions:

- Reticulated polyether foam.

  This type of material has been used effectively on US military aircraft such as P-3 and C-130.

- Expanded metal products.

  This type of material is not widely used on transport aircraft.

Both have more than one application, and both will require FAA/JAA certification. Some will require extensive qualification tests. When installed inside fuel tanks both materials create their own disadvantages such as weight increase, fuel volume loss, increased pack bay temperatures, structural integrity degradation, Foreign Object Debris (FOD) and maintenance difficulties. Costs associated with using one alternative of each product have been estimated for generic center tanks, with adjacent heat sources. These estimates include total cost, i.e., designs, installations, and operations.

It is estimated that over a ten-year period it would cost the industry over 22 billion dollars to use expanded metal products and over 25 billion dollars to use foam.

The following two tables show the cost breakdowns in $US for the two classes of aircraft. Cost estimate totals are:

Per Aircraft Cost, In service aircraft, (Center Wing Tank only)

Aircraft Size	Foam Nonrecurring	Foam Annual	Exp Metal Nonrecurring	Exp Metal Annual
Large	$390,740	$1,584,121	$848,273	$1,329,017
Medium	$187,427	$653,497	$366,057	$538,951
Small	$64,161	$120,448	$112,605	$88,992

Per Aircraft Cost, Production Aircraft (Center Wing Tank only)

Aircraft Size	Foam Nonrecurring	Foam Annual	Exp Metal Nonrecurring	Exp Metal Annual
Large	$353,884	$1,584,121	$811,416	$1,329,017
Medium	$166,334	$653,497	$344,964	$538,951
Small	$54,636	$120,448	$103,081	$88,992

The findings from this Task Group have shown that foam or expanded metal products can be used effectively to prevent structural failure of fuel tanks as a result of an internal explosion. However, when installed, foam or expanded metal products will reduce aircraft payload and available fuel volume. These reductions are the two most important factors that could result in severe economic impact for operators along with possible health and safety risks, requiring fire prevention, storage and handling of these products in hangars.

2.4 Inerting

The Inerting Task Group studied the technologies offered by the respondents to the FAA's Request for Information. Several technologies for providing inert gas were reviewed including carbon dioxide in gaseous form and as dry ice, nitrogen in gaseous and liquid form, and exhaust gas.

The group analyzed the impacts of carrying an on-board inerting system versus a ground-based system. In addition, the group studied the cost and benefit of inerting the center wing tank only versus inerting all of the aircraft's fuel tanks. Finally, two methods of purging oxygen from the tank were reviewed i.e. "scrubbing" the fuel and "washing" the ullage space above the fuel.

A ground-based system that reduces flammability exposure below the 7% target provides the potential for the least costly (non-recurring cost) inerting system on the aircraft. However, it requires a substantial investment in ground equipment to supply inerting gas, plus the recurring costs of the inerting gas and operation of the equipment. Ground-based ullage washing is effective when considered in combination with the normal changes to fuel temperature during a flight. On average, the exposure to a flammable, non-inert ullage is approximately 1%.

Scrubbing fuel at the airport fuel farm, or on the aircraft during refueling, is the least effective form of tank inerting. The ullage is not inert during taxi, takeoff, and initial climb until inert gas evolves from the fuel. As fuel is consumed from a fuel tank, ambient air flows in to replace it and raises the oxygen concentration. The tank may only be inert for the latter portion of climb and the beginning of cruise. This is highly dependent on the initial fuel load. Clearly, this method provides little added protection to today's design. In addition, this method would provide no added protection for near empty fuel tanks.

On-board systems could provide inert gas throughout the flight and offer zero exposure to a flammable, non-inert ullage. There are several existing methods for providing nitrogen on board an aircraft. It can be stored as a gas in bottles or as a liquid in Dewar bottles, such as on the C-5. Either of these would require replenishment at an airport, which adds to the cost of the airport infrastructure.

An alternative to storing gases or liquids, On-board Inert Gas Generating Systems (OBIGGS) separate nitrogen from engine bleed air. Such systems exist on military aircraft today, notably the C-17 as well as some fighters and helicopters. All of these systems extract a performance penalty from the aircraft. A new aircraft design offers the best opportunity to minimize these penalties. Current production aircraft and the retrofit fleet may incur redesign and operational penalties that make them uneconomical to fly. Operational compromises will almost certainly be required. None of the airplanes analyzed have enough engine bleed air available to supply these systems.

Whichever type of inerting might be used, there are potential hazards to personnel. Gaseous inerting agents present a suffocation hazard and liquid nitrogen presents the additional hazard of freezing trauma to skin and eyes.

Several other on-board systems were reviewed. Exhaust gas from the jet's engines and auxiliary power unit (APU) was deemed infeasible primarily because the exhaust contains too much oxygen. Carbon dioxide in gaseous and solid (dry ice) form was also deemed infeasible. Except for nitrogen systems, none of the systems were mature enough to be considered for installation on commercial aircraft. Nitrogen is the best candidate at this time.

The following table provides a summary of the cost and benefit of each system.

Technology	**Exposure**	**Cost over 10 Years (US Dollars)**
On-board Liquid Nitrogen for All Tanks	< 1%	$35.7B
On-board Gaseous Nitrogen for All Tanks	< 1%	$33.9B
Air Separator Modules for All Tanks	< 1%	$37.3B
Air Separator Modules for the Center Tank	< 1%	$32.6B
Ground-based Ullage Washing with natural Fuel Cooling for Center Tank	1%	$4B with gaseous nitrogen $3B with liquid nitrogen

At this time, nitrogen appears to be the best inerting agent and there are several means of providing it to the aircraft. Ground-based ullage washing in combination with the drop in temperature within the tank reduces exposure to a flammable, non-inerted tank to approximately 1%. This is the most cost effective solution studied, with the cost over a 10 year period estimated at approximately $3 billion.

Present day aircraft do not have enough available engine bleed air, in most cases, to supply an OBIGGS type system. However, OBIGGS systems could be designed into future aircraft.

If a full-time inerting system were required for current production aircraft or retrofit airplanes then liquid or gaseous nitrogen storage could be placed on-board the airplanes. These systems tend to be a little heavier than OBIGGS and require additional airport infrastructure to support them. The overall cost for a 10 year period is similar to OBIGGS.

2.5 Fuel Vapor Reduction

Task Group 5 analyzed the exposure of fuel tanks to flammable vapor and evaluated methods to mitigate the exposure, considering the related impacts: safety, certification, environment, airplane design, operations and cost. Analysis has also been performed to assess the effects of ground inerting and changing the fuel flashpoint in mitigating the exposure to flammable vapors (see reports from Task Group 6/7 and Task Group 3 for the impacts of these modifications). This analysis has been completed for generic airplanes and therefore does not relate to any specific airplane design.

Thermal analysis has shown that all generic fuel tank designs have some exposure to flammable fuel vapor.

- Tanks without adjacent heat sources, independent of location, (wing or fuselage), have equivalent exposure of approximately 5%.
- Tanks with adjacent heat sources have exposure of approximately 30%.

Other factors affecting exposure are:

- Ambient temperature (of which control is not possible)
- Fuel loading (which is discussed further, see option 3)
- Altitude (which is not discussed within this report)

Thirteen methods of mitigating the effects of heat sources adjacent to fuel tanks have been analyzed. Only one eliminates exposure to fuel vapors. This is achieved by disabling the fuel tank and thus has severe operational consequences that can only be evaluated for individual airlines operations, and thus no conclusion is provided within this report.

Five options considered reduce the exposure to flammable fuel vapor, and have been evaluated for the small, medium and large transport airplanes:

1. Insulate the heat source adjacent to fuel tanks
2. Ventilate the space between fuel tanks and adjacent heat sources
3. Redistribute mission fuel into fuel tanks adjacent to heat sources
4. Locate significant heat sources away from fuel tanks.
5. Sweep the ullage of empty fuel tanks.

Options 2 and 4 have been shown to reduce the exposure of fuel tanks with adjacent heat sources to a level similar to fuel tanks without adjacent heat sources. (Option 4 is only applicable to new airplane designs).

Option 5 requires significant further research before a conclusion on its feasibility can be reached.

Table 2.5.1 summarizes the effects and impact of the five options.

Table 2.5.1 Summary of impacts and applicability of the five methods evaluated

Centre Wing Tanks With Adjacent Heat Sources Exposure to Flammable Vapours **30%**						
Fuel Tanks Without Adjacent Heat Sources Exposure to Flammable Vapors **5 %**						
OPTION **IMPACT**		1. Insulate Heat Sources	2. Ventilate (Directed)	3. Redistribute (Fuel)	4. Locate Heat Sources	5. Sweep Ullage
Estimated Exposure to Flammable Vapors after Modification		**20%**	**5%**	**20%**	**5%**	Not quantified
New safety Concerns		minor	none	medium	none	medium
Certification Impact		minor	minor	minor	none	major
Environmental Impact		none	none	none	none	yes
Airplane Impact		minor	medium	minor	major	medium
Operational Impact		minor	minor	major	minor	major
One Time Fleet Costs ($ Million)	Small	160	500	4	160	2,000
	Medium	50	60	2	50	650
	Large	100	300	3	100	1,200
Annual Fleet Costs ($ Million)	Small	10	170	7	?	370
	Medium	2	20	3	?	80
	Large	2	70	14	?	180
10 Year Fleet Costs ($ Million)		**450**	**3,500**	**250**	**?**	**10,000**
Applicability		most	most	most	new designs	most

In addition, the effects of ground inerting and changing the fuel flashpoint were assessed. Either method could reduce the exposure of fuel tanks with adjacent heat sources to a level similar to fuel tanks without adjacent heat sources.

Table 2.5.2 summarizes the effects on exposure of ground inerting, changing the flashpoint, and some potential combinations of modifications. This is not an inclusive list of all feasible combinations due to the time constraints involved in this project.

Table 2.5.2 Summary of the effects of changing the fuel flashpoint, ground inerting and combinations of different modifications.

Modification	**Wing Tanks Without heat sources**	**Center Tanks without heat sources**	**Center Tanks with heat sources**
Current Airplanes	5%	5%	30%
120°F Flashpoint Fuel	**< 1%**	**< 1%**	**10 to 20%**
130°F Flashpoint Fuel	**< 1%**	**< 1%**	**5 to 10%**
140°F Flashpoint Fuel	**< 1%**	**< 1%**	**1 to 5%**
150°F Flashpoint Fuel	**< 1%**	**< 1%**	**1%**
Ground Based Inerting of Fuel Tanks	Not applicable	< 1%	1%
Combinations of Modifications			
Ventilate (Directed) and 120°F Flashpoint Fuel	Not applicable	Not applicable	< 1%
Insulate and 120°F Flashpoint Fuel	Not applicable	Not applicable	5%
Insulate and 130°F Flashpoint Fuel	Not applicable	Not applicable	1%

2.6 Modified Fuel Properties

The purpose of this Task Group report is to evaluate the availability, cost, and risk associated with changing to a high flash point specification jet fuel for commercial aviation.

The Fuels Properties Task Group was charged with assessing the feasibility of using jet fuel with a higher flash point specification in the civil transport airplane fleet than required by current Jet A/Jet A-1 specification, as a means of reducing the exposure of the fleet to flammable/explosive tank vapors.

Raising the minimum flash point specification of jet fuel will result in a combination of changes to other fuel properties, such as viscosity. The magnitude of change is dependent on the magnitude of flash point increase. The engine and APU manufacturers have no experience base for such a modified specification, and are concerned about the risk and potential adverse impact on altitude relight and low temperature operations (especially Extended Twin Operations, ETOPS). Mitigating actions, including hardware modifications, fuel specification revisions, use of additives and revised operational limits, have also been reviewed. Laboratory, rig and/or full-scale engine testing on reference fuels may be required to quantify the impacts depending on the magnitude of change.

Raising the minimum flash point specification could also significantly raise the manufacturing cost and decrease the availability of the modified jet fuel. The reduced availability could have a significant impact on jet fuel price. Again, the higher the flash point, the more severe the effect.

The fuel impacts are most severe outside of the U.S. due to the differences in overseas refinery configurations and product demand. Some countries indicated that a change in flash point specification is not an option to which they would subscribe (Canada, New Zealand, Australia, Japan, United Kingdom, Russia and the Commonwealth of Independent States).

Conclusions of the group are:

An increase in the jet fuel flash point specification will result in shifts of fuel properties. At some increase in the flash point specification, a high flash Jet-A becomes a new fuel, never before used, with properties unlike any other fuel. The predicted fuel specification changes will result in a combination of fuel properties that can fall outside the current experience. The magnitude of property change and potential introduction of new molecules increases with increasing flash point.

Higher flash points could result in significant shortfalls of jet fuel availability and could require at least five years for industry to endeavor to meet jet fuel demand.

Estimated Refinery Shortfall For First 2 Years

Flash Point	In US	Outside US
120° F	5%	12%
150° F	20%	49%

The API survey results address jet fuel demand at 1998 levels. The survey does not address long-term changes in jet fuel demand, which is projected to grow by 6-15% more than other refined products by 2010. Environmentally driven reformulation of other fuels, (e.g., toward “light” diesel) will further increase demand for the jet fuel portion of the barrel. These pressures are likely to amplify the difficulties predicted for the 1998 level.

Requirements for higher flash point jet fuels could result in United States refinery production cost increasing 1.5-2.2 cents per gallon at 120 degrees and 6-7.5 cents per gallon at 150 degrees (assuming 7% ROI). Based on current U.S. jet demand, this translates into annual costs of $350-520 million at 120 degrees and $1.4-1.7 billion at 150 degrees. Outside the United States, requirements for higher flash point jet fuel will result in refinery production cost increasing 3-15 cents per gallon at 120 degrees and more than 20 cents per gallon at 150 degrees.

Cost Increase

Flash Point	Inside US	Outside US
120° F	1.5 – 2.2 Cents/gallon ($350-520M Annually)	3-15 Cents/gallon
150° F	6 – 7.5 Cents/gallon ($1.4 – 1.7B Annually)	>20 Cents/gallon

The potential for increased production cost and decreased capacity could dramatically impact the market price of jet fuel. Models have been used to calculate the increases in price that could occur for various combinations of capacity reductions and price elasticity. No substitutions for jet fuel were assumed to be available. Based on a price elasticity of 0.2, the annual cost is $4 to $13B.

CHAPTER 3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Overall Conclusions

The study concluded that each fuel tank explosion analyzed was the result of unique circumstances at a single point in time, rather than circumstances that generate a continuous or intermittent ignition condition. The reasoning for this conclusion is that the flammability exposure of certain tanks was high (30% of fleet operating time) and therefore if circumstances created long duration ignition conditions, we would expect a far higher number of events than the fleet history shows. Based on this, it was concluded that the presence of an ignition source in any one tank was a very unlikely random event and the recommended way to further reduce the probability of an explosion is to limit the time during which the tank is in a flammable condition. It was concluded that total elimination of flammability is not required in as much as wing tanks operating with relatively low levels of flammability exposure have an excellent safety record.

A maximum flammability exposure of 7% of expected fleet operational time was selected for use in the proposed rule. This exposure approximates that of wing tanks on most airplanes.

The proposed regulatory action provides the industry with a requirement that addresses all aspects of fuel tank explosion prevention/mitigation, which can be treated as a comprehensive requirement and addressed as one issue. The intent of the combined regulation is to ensure an applicant addresses both ignition prevention and flammability reduction to protect the fuel system.

A range of possible means to achieve this goal was evaluated for technical and economic merits. The following conclusions were reached:

- Explosion suppression technology is not yet fully mature. A significant amount of development is still required to refine the details to meet the specific requirements for fuel tank protection;

- Foam or expanded metal products can be used effectively to prevent structural failure of fuel tanks as a result of an ignition. However, foam or expanded metal products will reduce aircraft payload and available fuel volume. These reductions result in severe economic impact for the industry. There are also health and safety risks associated with storage and handling of these products;

- Nitrogen appears to be the best inerting agent at the present time. Ground-based ullage washing, in combination with the normal changes to fuel temperature during a flight, reduces exposure to approximately 1%. This is the most cost-effective inerting solution studied, with the cost over a 10-year period estimated at approximately $3 billion.

For on-board inert gas generating systems (OBIGGS), most in-service aircraft do not have enough engine bleed air supply. However, future aircraft could be designed to accommodate these systems. Liquid or gaseous nitrogen storage inerting system could be adapted for in-service aircraft. These systems tend to be heavier than OBIGGS and require additional airport infrastructure. The overall cost for a ten-year period is similar to OBIGGS and estimated at approximately $30 billion.

- For fuel vapor reduction, five of the options considered reduce the exposure to flammable fuel vapor. These are:

  - Insulate the heat source adjacent to fuel tanks;
  - Ventilate the space between fuel tanks and adjacent heat sources;
  - Redistribute mission fuel into fuel tanks adjacent to heat sources;
  - Locate significant heat sources away from fuel tanks;
  - Sweep the ullage of empty fuel tanks.

  Only directed ventilation and relocation of the significant heat sources reduce the exposure to an acceptable level. However, relocation is feasible only for new airplane designs. Directed ventilation for in service aircraft is estimated to have an overall cost for a ten-year period of $3.5 billion.

- To reach the goal by changing fuel properties, a minimum flash point specification of 140^{o}F would be required. A change of this magnitude falls outside of the current experience base and may require engine re-design/re-qualification. The overall fuel manufacturing cost increase for a ten year period is estimated at $15 billion in the USA and $60 billion for the rest of the world and could result in a significant shortfall of jet fuel.

Fuel tank explosions represent less than one percent of the accidents that occur in commercial aviation. The FAA has provided an estimate of the cost of future events to be $2 billion over the next ten years, if no fuel systems enhancements were made. The flammability reduction techniques studied by the ARAC Working Group have an economic impact far greater than this.

In addition, the FAA is conducting a thorough review of current design and maintenance practices, which will act to improve the safety of fuel tanks by addressing ignition source mitigation. The group concludes this approach will achieve a significant enhancement in safety.

3.2 Recommendation

The ARAC Working Group recommends that the FAA/JAA pursue a cost effective approach to enhance fuel tank safety.

The following specific recommendations are made:

1. Adopt the proposed new regulatory action on new aircraft designs.

2. Continue to investigate means to achieve a cost-effective reduction in flammability exposure for the in-service fleet and newly manufactured aircraft.

3. Pursue the studies associated with directed ventilation and ground-based inerting systems to improve their cost effectiveness.

4. If a practical means of achieving a cost effective reduction in flammability exposure can be found for the in service fleet, either at the level specified in the rule or at some intermediate level (recommendations 2 and 3 above), consider application of that solution, in combination with other actions (e.g. SFAR).

5. If a practical means of achieving a cost effective reduction in flammability exposure can be found for newly manufactured aircraft, either at the level specified in the rule or at some intermediate level (recommendations 2 and 3 above), consider application of that solution, in combination with other actions (e.g. SFAR).

Recommended Implementation Plan

Proposed Action	**In-Service Aircraft**	**New Production Aircraft**	**New Type Design Aircraft**
Flammability Reduction	Pursue practical means	Pursue practical means	Apply new rule
SFAR	Apply	Apply	Apply
AFSSP	Apply	Does not apply	Does not apply

Note:
The proposed ignition source prevention regulation (FAR/JAR 25.981 (a)), and supporting AC/ACJ, were outside the terms of reference of the ARAC Working Group and no effort was expended on these tasks. However, the group believes that the FAA/JAA should work with a similar group to finalize this action.

REFERENCE MATERIAL

ATTACHMENTS

1) TOR
2) Organizational Chart
3) Task Group 1 - Service History/Fuel Tank Safety Level Assessment Final Report
4) Task Group 2 - Explosion Suppression Final Report
5) Task Group 3 – Fuel Tank Inerting Final Report
6) Task Group 4 – Foam Final Report
7) Task Group 5 – Fuel Vapor Reduction Final Report
8) Task Group 6/7 – Fuel Properties and Its Effects on Aircraft and Infrastructure Final Report
9) Task Group 8 – Evaluation Standards and Proposed Regulatory Action Advisory Group Final Report