Aircraft Rescue and Firefighting Strategies and Tactical Considerations for New Large Aircraft

April 2013

Final Report

This document is available to the U.S. public through the National Technical Information Services (NTIS), Springfield, Virginia 22161.

This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov

U.S. Department of Transportation
Federal Aviation Administration
NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof. The United States Government does not endorse products or manufacturers. Trade or manufacturer’s names appear herein solely because they are considered essential to the objective of this report. The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the funding agency. This document does not constitute FAA policy. Consult the FAA sponsoring organization listed on the Technical Documentation page as to its use.

This report is available at the Federal Aviation Administration William J. Hughes Technical Center’s Full-Text Technical Reports page: actlibrary.tc.faa.gov in Adobe Acrobat portable document format (PDF).
<table>
<thead>
<tr>
<th>1. Report No.</th>
<th>DOT/FAA/TC-13/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Government Accession No.</td>
<td></td>
</tr>
<tr>
<td>3. Recipient's Catalog No.</td>
<td></td>
</tr>
<tr>
<td>4. Title and Subtitle</td>
<td>AIRCRAFT RESCUE AND FIREFIGHTING STRATEGIES AND TACTICAL CONSIDERATIONS FOR NEW LARGE AIRCRAFT</td>
</tr>
<tr>
<td>5. Report Date</td>
<td>April 2013</td>
</tr>
<tr>
<td>6. Performing Organization Code</td>
<td></td>
</tr>
<tr>
<td>7. Author(s)</td>
<td>Jack Kreckie</td>
</tr>
<tr>
<td>9. Performing Organization Name and Address</td>
<td>ARFF Professional Services, LLC</td>
</tr>
<tr>
<td></td>
<td>11 Lantern Lane</td>
</tr>
<tr>
<td></td>
<td>Milford, MA 01757</td>
</tr>
<tr>
<td>10. Work Unit No. (TRAIS)</td>
<td></td>
</tr>
<tr>
<td>11. Contract or Grant No.</td>
<td>DTFACT-10-D-00008</td>
</tr>
<tr>
<td>12. Sponsoring Agency Name and Address</td>
<td>U.S. Department of Transportation</td>
</tr>
<tr>
<td></td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td></td>
<td>Airport Engineering Division (AAS-300)</td>
</tr>
<tr>
<td></td>
<td>800 Independence Avenue SW</td>
</tr>
<tr>
<td></td>
<td>Washington, D.C. 20591</td>
</tr>
<tr>
<td>13. Type of Report and Period Covered</td>
<td>Final Report</td>
</tr>
<tr>
<td>14. Sponsoring Agency Code</td>
<td>AAS-300</td>
</tr>
<tr>
<td>15. Supplementary Notes</td>
<td>The Federal Aviation Administration Aviation Research Division COR was Keith Bagot.</td>
</tr>
<tr>
<td>16. Abstract</td>
<td>The evolution of aircraft design and construction has brought about new challenges to Aircraft Rescue and Firefighting (ARFF) personnel. The New Large Aircraft (NLA) entering the market have introduced increased passenger capacities, fuel loads, hydraulic pressures, and the use of advance composite materials. The most significant change is the introduction of the full-length, upper-passenger deck on the Airbus A380 with certification for up to 853 total passengers. The B-747-8 was just beginning flight service in the United States as this report was being developed. A supplement to this report will be issued following additional research specific to the B-747-8.</td>
</tr>
<tr>
<td>17. Key Words</td>
<td>NLA, Composite, Tactics, Strategies, ARFF, A380, VLTA, B-747-8, IAV, HRET, Evacuation, Ventilation, New Generation Aircraft</td>
</tr>
<tr>
<td>18. Distribution Statement</td>
<td>This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov</td>
</tr>
<tr>
<td>19. Security Classif. (of this report)</td>
<td>Unclassified</td>
</tr>
<tr>
<td>20. Security Classif. (of this page)</td>
<td>Unclassified</td>
</tr>
<tr>
<td>21. No. of Pages</td>
<td>138</td>
</tr>
<tr>
<td>22. Price</td>
<td></td>
</tr>
</tbody>
</table>

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

The author acknowledges the following people as intrinsic to the writing of this report:

- Herbert Gielen, Airport Safety Manager, Airbus
- Robert Mathis, Deputy Fire Chief, Boeing Fire Department
- Gerry Moore, Station Manager, JFK International Airport, Emirates
- Dominic Demerets, Assistant Station Manager, JFK International Airport, Air France
- Ralph Strafaci, Assistant Station Manager, JFK International Airport, Korean Air
- Christopher Michaels, JFK International Airport Duty Station Manager, Lufthansa German Airline
- Dana Larsen, Los Angeles City Fire Department, Los Angeles International Airport
- Keith Bagot, Airport Safety Specialist, FAA Airport Research and Technology Branch
- Nick Subottin, Airport Research Specialist, FAA Airport Research and Technology Branch
- Patricia R. Kreckie, President, ARFF Professional Services, LLC
### TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>xvii</td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. FIREFIGHTING AGENT QUANTITY CONSIDERATIONS</td>
<td>2</td>
</tr>
<tr>
<td>3. EVACUATION SLIDES</td>
<td>6</td>
</tr>
<tr>
<td>3.1 Evacuation Slide Assistance</td>
<td>6</td>
</tr>
<tr>
<td>3.2 Mechanical Factors</td>
<td>7</td>
</tr>
<tr>
<td>3.3 Large Aircraft Evacuation</td>
<td>8</td>
</tr>
<tr>
<td>3.4 Obstruction to ARFF Operations</td>
<td>8</td>
</tr>
<tr>
<td>4. INTERIOR ACCESS VEHICLE</td>
<td>10</td>
</tr>
<tr>
<td>5. HISTORICAL REVIEW—B-747 AND A380 EVACUATIONS</td>
<td>12</td>
</tr>
<tr>
<td>5.1 The B-747 Incidents</td>
<td>12</td>
</tr>
<tr>
<td>5.2 The A380 Incidents: Singapore Changi Airport</td>
<td>14</td>
</tr>
<tr>
<td>5.2.1 Singapore Changi Airport: Singapore Airlines Flight 221</td>
<td>14</td>
</tr>
<tr>
<td>5.2.2 Singapore Changi Airport: Qantas Flight 32</td>
<td>15</td>
</tr>
<tr>
<td>5.3.2 The Finkenwerker Plant A380 Evacuation Test</td>
<td>17</td>
</tr>
<tr>
<td>6. HUMAN FACTORS</td>
<td>17</td>
</tr>
<tr>
<td>6.1 Passenger Demographics and Behavior</td>
<td>17</td>
</tr>
<tr>
<td>6.2 Emergency Responders</td>
<td>18</td>
</tr>
<tr>
<td>7. VENTILATION</td>
<td>19</td>
</tr>
<tr>
<td>7.1 Ventilation Objectives</td>
<td>19</td>
</tr>
<tr>
<td>7.2 Ventilation Strategies</td>
<td>20</td>
</tr>
<tr>
<td>7.3 Ventilation Methods</td>
<td>20</td>
</tr>
<tr>
<td>7.3.1 Horizontal Ventilation</td>
<td>20</td>
</tr>
<tr>
<td>7.3.2 Vertical Ventilation</td>
<td>20</td>
</tr>
<tr>
<td>7.3.3 Positive Pressure Ventilation</td>
<td>21</td>
</tr>
<tr>
<td>7.3.4 Hydraulic (or Forced) Ventilation</td>
<td>21</td>
</tr>
<tr>
<td>7.3.5 Oxygen Deprivation</td>
<td>21</td>
</tr>
<tr>
<td>7.3.6 Multideck Aircraft Ventilation Design</td>
<td>22</td>
</tr>
<tr>
<td>8. AIRCRAFT ACCESS</td>
<td>24</td>
</tr>
</tbody>
</table>
9. EXTERIOR FIRES
   9.1 Overall Size
   9.2 Passenger Capacity
   9.3 Obstructions to Exterior Streams

10. INTERIOR FIREFIGHTING OPERATIONS
    10.1 Access
    10.2 Avionics Bays
    10.3 Lavatory Fires
    10.4 Lower-Deck Spaces Designed for Occupancy
    10.5 Galleys
    10.6 Main Cabin Fires
    10.7 Initial Entry
    10.8 Consideration for Interior Fire Attack

11. THE HRET OPERATIONS
    11.1 The HRET Design and Capability
    11.2 Using HRET for Remote Access to Aircraft Cabin
    11.3 Using FLIR Cameras and TICs
    11.4 Upper-Deck Piercing
    11.5 Fires in Lower Deck (Belly Compartments)

12. CARGO COMPARTMENT DOORS

13. LANDING GEAR AND BRAKE HAZARDS
    13.1 Brake Overheat
    13.2 Wheel Fires
    13.3 Landing Gear Extension and Retraction System
    13.4 Braking Systems
    13.5 Steering

14. HYDRAULIC AND COOLING SYSTEMS

15. CONSTRUCTION MATERIALS
    15.1 Composite Material Use
    15.2 Advanced Composite Materials on the A380
    15.3 Effects of Fire on Composite Materials
    15.4 Extinguishment
    15.5 Protection

16. AUXILIARY POWER UNIT

17. FUEL SYSTEM
18. THE U.S. AIRPORTS SERVING NLA
   18.1 Cabin Configuration
   18.2 First-Class Suites

19. THE B-747-800 SERIES AIRCRAFT

20. SUMMARY

21. REFERENCES

22. ADDITIONAL DOCUMENTATION

APPENDICES

A—Seating Charts for the A380
B—Firefighting Practices for New Generation Commercial Composite Structures
C—Galden HT135 Fluid MSDS and Safety Data Sheet
D—ARAC ARFF Recommendations Working Group—Final Recommendation for Quantity of Agent for NLA
E—Fuel Weight/Volume Conversion
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper-Deck Evacuation Slide Deployment Lengths</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>The A380 TCA/PCA Areas With Evacuation Slides Deployed</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>Approach of ARFF Vehicles With Slides Deployed</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Slide Emergency Evacuation of a B-747-438—View 1</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Slide Emergency Evacuation of a B-747-438—View 2</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>Singapore Airlines Flight 221, A380 Off Pavement</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>Gear of SQ Flight 221, A380 Off Pavement</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>Deplaning Passengers From QF Flight 32</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>Number 2 Engine of QF Flight 32</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>Forward Stairway Between Decks on Air France A380</td>
<td>22</td>
</tr>
<tr>
<td>11</td>
<td>Rear Stairway Between Decks on Air France A380</td>
<td>23</td>
</tr>
<tr>
<td>12</td>
<td>Service Elevator on A380</td>
<td>23</td>
</tr>
<tr>
<td>13</td>
<td>The ML4 Door, Interior View; Type A Passenger Door With Slide Container</td>
<td>24</td>
</tr>
<tr>
<td>14</td>
<td>The ML1 Door A380, Exterior Operation View</td>
<td>24</td>
</tr>
<tr>
<td>15</td>
<td>Exterior Door Operation Demonstration—Step 6</td>
<td>25</td>
</tr>
<tr>
<td>16</td>
<td>Exterior Door Operation Demonstration—Step 7</td>
<td>26</td>
</tr>
<tr>
<td>17</td>
<td>Korean A380 With Two Jet Bridges Extended at JFK</td>
<td>28</td>
</tr>
<tr>
<td>18</td>
<td>Training to Shut Down and Secure the Aircraft</td>
<td>30</td>
</tr>
<tr>
<td>19</td>
<td>Cockpit Window Operation</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>Emirates A380 Business-Class Cabin</td>
<td>31</td>
</tr>
<tr>
<td>21</td>
<td>Avionics Bay Locations</td>
<td>33</td>
</tr>
<tr>
<td>22</td>
<td>Access Hatch From Forward Fuselage Left Side to Main Avionics Bay</td>
<td>33</td>
</tr>
<tr>
<td>23</td>
<td>Access to the Upper Avionics Bay From the Landing at the Top of the Forward Stairs</td>
<td>34</td>
</tr>
</tbody>
</table>
24 Upper Avionics Bay With Leaning Rail Raised, Exposing the Locked Door
25 Access to Upper-Deck Avionics From Lounge/Seating Area
26 Access Point to Upper-Deck Avionics Through the Lavatory
27 Typical Labels Seen on Compartments Used to Store Fire Extinguishers and Hoods
28 Upper-Deck Lavatory on Emirates A380
29 First-Class Lavatory/Shower on Emirates A380
30 Lavatory Door Locks
31 Lower-Deck Cabin Crew Rest Area, Individual Bunk (Air France)
32 Access Door From Main Deck to Lower-Deck Crew Rest Area
33 Access Ladder to Lower-Deck Crew Rest Area
34 Airtight Hatch Door to Lower-Deck Crew Rest Area
35 Lower-Deck Crew Rest Area, A380
36 Lower-Deck Crew Rest Area Lavatory, Lufthansa A380
37 Secondary Exit From Lower-Deck Crew Rest Area, Lufthansa A380
38 Emergency Exit Hatch From Lower-Deck Crew Rest Area, Lufthansa A380
39 Lower-Deck Crew Rest Area Fire Detection and Suppression
40 Main Deck Flight Crew Rest Areas Located Aft of Cockpit
41 Flight Crew Rest Areas Located Immediately Aft of the Flight Deck, in Air France, Qantas, Lufthansa, and Korean Air Configurations
42 Cabin Crew Rest Areas (Emirates)
43 Crew Rest Area on Main Deck Aft (Emirates)
44 Galley Trash Compactor
45 Midship Galley Ovens
46 Galley Refrigerators
47 Galley Service Elevator
48 Galley Electrical Panel, Including Emergency Power Shutoff
Gate at Top of Stairway

Rear Spiral Staircase

Gate and Curtain Stowed Position, Main Stairs

Gate in Operational Position, Top of Main Stairs

Folded Bed Storage in Lufthansa A380

Privacy Curtain in Operational Mode

The HRET Boom Used as a Waterway

Obstructions to Direct Attack Through Entry Doors

Fire Attack Resulting in Horizontal Ventilation During ARFF Training

Depth of Each Seat Row

Normal Cabin View With Good Visibility

Same Cabin Through a TIC

Overhead Compartments Located Over Every Seated Position

The HRET Using Boom Hydraulics for Penetration

The HRET Using Hydraulic Accumulators for Penetration

Discharge Pattern of ASPN on HRET

Testing the FAA HRET

The FLIR Cameras Identifying Heat Signatures

The Best Guidance for Piercing Locations

Testing to Understand the Effect of Piercing the Overhead Bin

Window Removal Using an HRET

Standoff Position and Approach for Upper-Deck Piercing

Piercing an Upper Deck, Angled Down

Proper Piercing Angle on Steeper Slope of Fuselage

Positioning With Increased Standoff Distance
<table>
<thead>
<tr>
<th>Page</th>
<th>Image Description</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>74</td>
<td>Forward Portion of Aft Cargo Compartment, Known as the Tunnel</td>
<td>68</td>
</tr>
<tr>
<td>75</td>
<td>Lower Cargo Compartment Configuration</td>
<td>69</td>
</tr>
<tr>
<td>76</td>
<td>Cheek Area Inside Rear Cargo Compartment (42 in.)</td>
<td>69</td>
</tr>
<tr>
<td>77</td>
<td>Flare of Faring Between Cargo Compartment and Wing</td>
<td>70</td>
</tr>
<tr>
<td>78</td>
<td>Outside View of Wing Faring Flare</td>
<td>70</td>
</tr>
<tr>
<td>79</td>
<td>Aft Cargo Compartment With Cargo Net Separating the Bulk Cargo Compartment</td>
<td>71</td>
</tr>
<tr>
<td>80</td>
<td>A ULD in Position in Lower Cargo Compartment</td>
<td>72</td>
</tr>
<tr>
<td>81</td>
<td>Cargo Offloading Operations</td>
<td>72</td>
</tr>
<tr>
<td>82</td>
<td>Philadelphia Fire Fighters Attempt Forcible Entry on a DC-8 Cargo Door</td>
<td>73</td>
</tr>
<tr>
<td>83</td>
<td>Bulk Cargo Door Operation</td>
<td>74</td>
</tr>
<tr>
<td>84</td>
<td>Forward Cargo Door Operation</td>
<td>74</td>
</tr>
<tr>
<td>85</td>
<td>Aft Cargo Door Operation</td>
<td>75</td>
</tr>
<tr>
<td>86</td>
<td>The A380 WLG and BLG–View From Front</td>
<td>77</td>
</tr>
<tr>
<td>87</td>
<td>Landing Gear Numbering System</td>
<td>77</td>
</tr>
<tr>
<td>88</td>
<td>Increased Use of Composite Materials</td>
<td>81</td>
</tr>
<tr>
<td>89</td>
<td>Construction of B-787</td>
<td>81</td>
</tr>
<tr>
<td>90</td>
<td>The ARFF Information on a B-747-8I</td>
<td>82</td>
</tr>
<tr>
<td>91</td>
<td>Composite Materials and Locations on the A380</td>
<td>82</td>
</tr>
<tr>
<td>92</td>
<td>The GLARE Locations on the A380, Highlighted</td>
<td>83</td>
</tr>
<tr>
<td>93</td>
<td>Comparison of GLARE and Aluminum Penetration Forces</td>
<td>84</td>
</tr>
<tr>
<td>94</td>
<td>The APU Emergency Shutdown Locations</td>
<td>85</td>
</tr>
<tr>
<td>95</td>
<td>Refuel/Defuel Panel</td>
<td>86</td>
</tr>
<tr>
<td>96</td>
<td>The APU Emergency Shutdown Controls in the Refuel/Defuel Panel</td>
<td>86</td>
</tr>
<tr>
<td>97</td>
<td>Nose Gear APU Panel</td>
<td>87</td>
</tr>
<tr>
<td>98</td>
<td>First-Class Suite: Emirates</td>
<td>89</td>
</tr>
<tr>
<td>Page</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>99</td>
<td>First-Class Cabins: Qantas (left) and Air France (right)</td>
<td>90</td>
</tr>
<tr>
<td>100</td>
<td>Raised Partition Around First-Class Seat on Lufthansa A380</td>
<td>90</td>
</tr>
<tr>
<td>101</td>
<td>Korean Air First-Class Seat</td>
<td>90</td>
</tr>
<tr>
<td>102</td>
<td>Emirates First-Class Shower</td>
<td>91</td>
</tr>
<tr>
<td>103</td>
<td>Emirates First-Class Lavatory Window</td>
<td>91</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>The FAA ARFF Index Comparison to ICAO and NFPA</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Agent/Quantity Comparison</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Category 10 Aircraft–Agent/Chassis Comparison</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Slide Failures Listed in the ACRP Study</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Sill Heights</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Fire Classes (U.S.)</td>
<td>31</td>
</tr>
<tr>
<td>7</td>
<td>International Comparisons Fire Classes</td>
<td>32</td>
</tr>
<tr>
<td>8</td>
<td>Hose Line Characteristics</td>
<td>54</td>
</tr>
<tr>
<td>9</td>
<td>Hydraulic Systems Operation</td>
<td>79</td>
</tr>
<tr>
<td>10</td>
<td>Airports Serving NLA</td>
<td>88</td>
</tr>
<tr>
<td>11</td>
<td>The U.S. Airports With MoSs in Place for B-747-8</td>
<td>93</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>ACRP</td>
<td>Airport Cooperative Research Program</td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>Airport Emergency Services</td>
<td></td>
</tr>
<tr>
<td>AFFF</td>
<td>Aqueous film forming foam</td>
<td></td>
</tr>
<tr>
<td>ARAC</td>
<td>Aviation Rulemaking Advisory Committee</td>
<td></td>
</tr>
<tr>
<td>ARFFRWG</td>
<td>ARFF Requirements Working Group</td>
<td></td>
</tr>
<tr>
<td>ARFF</td>
<td>Aircraft Rescue and Firefighting</td>
<td></td>
</tr>
<tr>
<td>ASPN</td>
<td>Aircraft skin penetrating nozzle</td>
<td></td>
</tr>
<tr>
<td>APU</td>
<td>Auxiliary power unit</td>
<td></td>
</tr>
<tr>
<td>BLG</td>
<td>Body landing gears</td>
<td></td>
</tr>
<tr>
<td>CAG</td>
<td>Changi Airport Group</td>
<td></td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
<td></td>
</tr>
<tr>
<td>CFRP</td>
<td>Carbon fiber-reinforced plastic</td>
<td></td>
</tr>
<tr>
<td>COF2</td>
<td>Carbonyl fluoride</td>
<td></td>
</tr>
<tr>
<td>EASA</td>
<td>European Aviation Safety Agency</td>
<td></td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
<td></td>
</tr>
<tr>
<td>FLIR</td>
<td>Forward Looking Infrared</td>
<td></td>
</tr>
<tr>
<td>GLARE</td>
<td>Glass-reinforced aluminum laminate</td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td>Hydrogen fluoride</td>
<td></td>
</tr>
<tr>
<td>HRET</td>
<td>High-Reach Extendable Turret</td>
<td></td>
</tr>
<tr>
<td>IAP</td>
<td>Incident Action Plan</td>
<td></td>
</tr>
<tr>
<td>IAV</td>
<td>Interior Access Vehicle</td>
<td></td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
<td></td>
</tr>
<tr>
<td>IFSTA</td>
<td>International Fire Service Training Association</td>
<td></td>
</tr>
<tr>
<td>JFK</td>
<td>John F. Kennedy International Airport</td>
<td></td>
</tr>
<tr>
<td>LEHGS</td>
<td>Local Electro-Hydraulic Generation System</td>
<td></td>
</tr>
<tr>
<td>LGERS</td>
<td>Landing Gear Extension and Retraction System</td>
<td></td>
</tr>
<tr>
<td>MoSs</td>
<td>Modifications of Standards</td>
<td></td>
</tr>
<tr>
<td>MSDS</td>
<td>Material Safety Data Sheet</td>
<td></td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
<td></td>
</tr>
<tr>
<td>NLA</td>
<td>New Large Aircraft</td>
<td></td>
</tr>
<tr>
<td>NLG</td>
<td>Nose Landing Gear</td>
<td></td>
</tr>
<tr>
<td>NTSB</td>
<td>National Transportation Safety Board</td>
<td></td>
</tr>
<tr>
<td>PCA</td>
<td>Practical Critical Area</td>
<td></td>
</tr>
<tr>
<td>PPE</td>
<td>Personal protection equipment</td>
<td></td>
</tr>
<tr>
<td>PPV</td>
<td>Positive pressure ventilation</td>
<td></td>
</tr>
<tr>
<td>Q1</td>
<td>The quantity of water required to obtain a 1-minute control time in the PCA.</td>
<td></td>
</tr>
</tbody>
</table>
Q2 The quantity of water required for continued control of the fire after the
first minute, for complete extinguishment of the fire, or both.
Q3 The quantity of water required for interior firefighting.
QF Qantas Flight
SCBA Self-Contained Breathing Apparatus
SIN Singapore Changi Airport
SQ Singapore Airlines
SOG Standard Operating Guidelines
TCA Theoretical Critical Area
TIC Thermal imaging camera
U.S. United States
USAF United States Air Force
VLTA Very-Large Transport Aircraft
WLG Wing landing gear

Control—of a fire is considered to be achieved when the intensity of the fire is reduced by 90%.

Flashover—The nearly simultaneous ignition of combustible materials in an enclosed space.
Flashover occurs when the material in an enclosed space is heated to their auto-ignition
 temperatures.

Practical Critical Area (PCA)—An area equal to 2/3 the size of the Theoretical Critical Area.

Rollover—Often precedes a flashover. As fire gases are heated, the super-heated gases rise to the
 overhead portion of an enclosed area. As the gases bank off the ceiling it appears as flames
 rolling across the ceiling. Rollover often precedes a flashover.

Size-Up—The initial evaluation of an incident, conducted to develop a determination of
 immediate hazards to responders, other lives and property, and also what additional resources
 may be needed.

Theoretical Critical Area (TCA)—The theoretical area adjacent to an aircraft in which fire must
 be controlled for the purpose of ensuring temporary fuselage integrity and provide an escape area
 for its occupants.

Ventilation—The exchange of the interior atmosphere of a structure with the outside atmosphere.
EXECUTIVE SUMMARY

Airport Rescue and Firefighting (ARFF) services personnel at commercial airports worldwide commonly respond to and train for incidents involving large aircraft carrying numerous passengers. The introduction of aircraft with two full decks of passengers has increased the challenges and the stakes presented to aircraft rescue firefighters. Before the introduction into service of the Airbus A380 by Singapore Airlines in the fall of 2007, the only aircraft to have an upper deck was the Boeing 747, and that has only limited upper-deck seating. The full-length, upper-deck passenger compartments allow for a dramatic increase in passenger capacity.

By definition, New Large Aircraft (NLA) are so categorized due to the increase of passenger capacities, fuel loads, overall size, and the use of advanced materials. NLA being developed today are taller, heavier, and carry more passengers than any aircraft recognized by the International Civil Aviation Organization (ICAO) Rescue Fire Fighting Panel at the time that the Theoretical Critical Area/Practical Critical Area (TCA/PCA) formulas were first developed. These TCA/PCA formulas have never been recalculated to take into account the full upper deck and additional height of these NLA. Certain portions of the A380 and B-747-8 commonly referenced under the NLA category are constructed with composite materials. These aircraft have double-deck passenger configurations and increased quantities of fuel and passengers.

Much of this report focuses on the A380. This aircraft represents the biggest changes because it is the first aircraft with a full upper deck. It has the largest passenger capacity and the greatest fuel capacity. Many tactics and strategies described in this report are applicable on other sizes and types of aircraft. In fact, there are a number of aircraft that have entered the market, or are currently in development, that offer different passenger cabin configurations, advanced composites, and increased fuel loads. ARFF departments can take applicable information from this report and apply it to other newer aircraft in service to their airports. The A340, B-777, B-787, A380, and B-747-8 are all part of the broader category of New Generation Aircraft, which may be a more appropriately categorized for new technologies and challenges to ARFF created by the evolution of these aircraft. When this report was completed, the next generation B-747, the 800 series, was just beginning passenger service in the United States. Deeper analysis into concerns for firefighting tactics and strategies for that aircraft will be covered in a follow-on report.

This report provides a discussion of the primary topics pertinent to strategies for NLA firefighting. These topics include agent quantity, aircraft systems, and components. Information from previous reports, regulatory data, and historical reviews related to NLA firefighting are presented in this report. Also discussed are configurations and aspects of NLA layouts, which require strategic consideration and could influence ARFF tactical decisions and response preplanning. Recommendations for best practices in NLA firefighting strategies are offered throughout this report.
1. INTRODUCTION.

Aircraft rescue and firefighting (ARFF) personnel require a great deal of information to make informed tactical decisions during aircraft incidents. Preplanning for such incidents saves precious time in the deployment of firefighting assets and personnel. During preplanning, the differences in aircraft size, composition, passenger loads, fuel quantities, as well as the use of composites and advanced materials, change certain tactics and strategies that may lack the capacity to be equally effective on New Large Aircraft (NLA).

The following topics were researched during the preparation of this report:

- Quantities of firefighting agent
- Evacuation slides
- Interior access vehicles (IAV)
- Historical review of evacuations
- Ventilation
- Interior and exterior fires
- High-Reach Extendable Turret (HRET) operations
- Access to cargo compartments
- Landing gear
- Hydraulic systems
- Construction materials
- Auxiliary power units (APU)
- Fuel systems
- NLA cabin configurations

The purpose of this report was to determine what, if anything, has remained the same from previous generations of aircraft, and what has changed. Changes required further study to determine if modified procedures or new technology may be appropriate to improve tactics and strategies for access to NLA or in firefighting evolutions.

The development of NLA brings fundamental changes that are different from aircraft that flew previously. These changes are what classify these aircraft as New Generation Aircraft. Educating emergency responders as to how these changes impact existing firefighting tactics and strategies is important to the safety and success of emergency management involving NLA. These factors include:

- Increased aircraft size
- Increased hydraulic pressures
- Increased use of advanced composite materials
- Increased passenger loads
- Increased fuel loads
- Unique uses or configuration of space
- Multideck configuration
• Sill height for accessing upper decks
• Crew rest areas on lower level (below main deck)

2. FIREFIGHTING AGENT QUANTITY CONSIDERATIONS.

The Federal Aviation Administration (FAA) serves as the United States (U.S.) Government’s advocate with the International Civil Aviation Organization (ICAO), a United Nations specialized agency created to achieve safe, secure, and sustainable development of civil aviation throughout the world. In that role, the FAA provides significant resources to support the ICAO and its goal to establish a global aviation system through cooperation, partnership, and harmonization of requirements.

ICAO Circular 305-AN/177, “Operation of Newer Larger Aeroplanes at Existing Aerodromes,” [1] was released on March 14, 2005. It is important to understand the relevant information included in the circular, and consider applying the intent and approach in any study of NLA.

It is interesting to note that the U.S. uses the phrase New Large Aircraft, whereas the ICAO definition is New Larger Aeroplanes. The following quoted text was taken directly from Circular 305 [1]. Note that the conversions to feet from meters were not in the original ICAO text.

“Foreword

In the early 1990s, the major aeroplane manufacturers announced that plans were in hand to develop aeroplanes larger than the Boeing B747-400 — currently the largest passenger aeroplane in commercial service — capable of carrying more than 500 passengers.

In response to the stated need for appropriate ICAO provisions to facilitate aerodrome development for these new larger aeroplanes (NLAs), ICAO undertook a study with the participation of several States, selected international organizations and aeroplane manufacturers. The results of that study led to Amendment 3 to Annex 14 — Aerodromes, Volume I — Aerodrome Design and Operations, which was adopted by the ICAO Council in March 1999. A new aerodrome reference code letter F to cover aeroplanes with wingspans from 65 m (213.25 feet) up to but not including 80 m (262.46 feet), and an outer main gear wheel span from 14 m (45.93 feet) up to but not including 16 m (52.49 feet) was established. Consequent new specifications on aerodrome physical characteristics for these aeroplanes were also developed. The new code F specifications in Annex 14, Volume I, became applicable from 1 November 1999. Aerodrome rescue and fire fighting (RFF) specifications for aeroplanes with maximum fuselage widths in excess of 7 m, (22.96 feet) and lengths greater than 76 m (249.34 feet) RFF category 10, had already been developed and included in the Annex. (ICAO Circular 305-AN/177)”
In 2004, the Aviation Rulemaking Advisory Committee (ARAC) ARFF Requirements Working Group (ARFFRWG) released a report [2] that, among other things, looked at certain issues relative to NLA. Findings and conclusions documented by this working group are integrated throughout this report, e.g., section 2.

Tables 1 through 3 were derived from information provided in the ARAC report [2]. The primary relative points illustrated in this comparison chart are the additional ICAO and National Fire Protection Association (NFPA) categories created for aircraft longer than 249 ft (76 m), up to 295 ft (90 m). In addition, both the ICAO and NFPA use a maximum fuselage width, as well as overall length. Title 14 Code of Federal Regulations (CFR) Part 139 [3] uses only overall length in Index determination, and Index E is for all aircraft greater than 200 ft (61 m) long.

Table 1. The FAA ARFF Index Comparison to ICAO and NFPA

<table>
<thead>
<tr>
<th>FAA Index</th>
<th>Aircraft Length (ft)</th>
<th>ICAO Category</th>
<th>Aircraft Length up to but not Including (ft)</th>
<th>Width up to but not Including (ft)</th>
<th>NFPA Category</th>
<th>Aircraft Length up to but not Including (ft)</th>
<th>Width up to but not Including (ft)</th>
<th>Sample Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA-1</td>
<td>NA</td>
<td>1</td>
<td>29 (9 m)</td>
<td>6.6 (2 m)</td>
<td>1</td>
<td>30 (9 m)</td>
<td>6.6 (2 m)</td>
<td>Cessna 182</td>
</tr>
<tr>
<td>GA-1</td>
<td>NA</td>
<td>2</td>
<td>39 (12 m)</td>
<td>6.6 (2 m)</td>
<td>2</td>
<td>39 (12 m)</td>
<td>6.6 (2 m)</td>
<td>Cessna Caravan</td>
</tr>
<tr>
<td>GA-2</td>
<td>NA</td>
<td>3</td>
<td>59 (18 m)</td>
<td>9.8 (3 m)</td>
<td>3</td>
<td>59 (18 m)</td>
<td>9.8 (3 m)</td>
<td>Cessna 404</td>
</tr>
<tr>
<td>A</td>
<td>&lt;90</td>
<td>4</td>
<td>78 (24 m)</td>
<td>13.1 (4 m)</td>
<td>4</td>
<td>78 (24 m)</td>
<td>13.0 (4 m)</td>
<td>EMB120</td>
</tr>
<tr>
<td>A</td>
<td>&lt;90</td>
<td>5</td>
<td>91 (28 m)</td>
<td>13.1 (4 m)</td>
<td>5</td>
<td>90 (28 m)</td>
<td>13.0 (4 m)</td>
<td>CRJ-200, Saab 340</td>
</tr>
<tr>
<td>B</td>
<td>90-126</td>
<td>6</td>
<td>127 (39 m)</td>
<td>16.4 (5 m)</td>
<td>6</td>
<td>126 (39 m)</td>
<td>16.4 (5 m)</td>
<td>DC-9, A320</td>
</tr>
<tr>
<td>C</td>
<td>126-159</td>
<td>8</td>
<td>160 (49 m)</td>
<td>16.4 (5 m)</td>
<td>7</td>
<td>160 (49 m)</td>
<td>16.4 (5 m)</td>
<td>B-757-200, B-767-200ER</td>
</tr>
<tr>
<td>D</td>
<td>159-200</td>
<td>8</td>
<td>200 (61 m)</td>
<td>22.9 (7 m)</td>
<td>8</td>
<td>200 (61 m)</td>
<td>23.0 (7 m)</td>
<td>A300, B-757-300</td>
</tr>
<tr>
<td>E</td>
<td>&gt;200</td>
<td>9</td>
<td>249 (76 m)</td>
<td>22.9 (7 m)</td>
<td>9</td>
<td>250 (76 m)</td>
<td>23.0 (7 m)</td>
<td>A340-600; B-777</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>295 (90 m)</td>
<td>26.2 (8 m)</td>
<td>25.0 (8 m)</td>
<td>10</td>
<td>295 (90 m)</td>
<td>25.0 (8 m)</td>
<td>AN-225, A380</td>
</tr>
</tbody>
</table>
Table 2. Agent/Quantity Comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Index</th>
<th>ICAO</th>
<th>FAA</th>
<th>NFPA Q1 and Q2</th>
<th>NFPA Q1, Q2, and Q3</th>
<th>Example Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GA-1</td>
<td>61</td>
<td>—</td>
<td>120</td>
<td>120</td>
<td>Cessna 206</td>
</tr>
<tr>
<td>2</td>
<td>GA-1</td>
<td>177</td>
<td>—</td>
<td>200</td>
<td>200</td>
<td>Cessna 414</td>
</tr>
<tr>
<td>3</td>
<td>GA-2</td>
<td>317</td>
<td>—</td>
<td>370</td>
<td>670</td>
<td>Beech 1900</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>634</td>
<td>100</td>
<td>740</td>
<td>1,340</td>
<td>DHC-8-100</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>1427</td>
<td>100</td>
<td>1510</td>
<td>2,760</td>
<td>ATR-72</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>2087</td>
<td>1500</td>
<td>2490</td>
<td>3,740</td>
<td>B-737-300; Emb-145</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>3197</td>
<td>3000</td>
<td>3630</td>
<td>4,880</td>
<td>B-757</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>4808</td>
<td>4000</td>
<td>5280</td>
<td>7,780</td>
<td>A300; B-767-300</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>6419</td>
<td>6000</td>
<td>7070</td>
<td>9,570</td>
<td>B-747-200; A340-400</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>8533</td>
<td>—</td>
<td>9260</td>
<td>14,260</td>
<td>AN-225; A380</td>
</tr>
</tbody>
</table>

Note: Q1 is the quantity of water required to obtain a 1-minute control time in the Practical Critical Area. 
Q2 is the quantity of water required for continued control of the fire after the first minute, or for complete 
extinguishment of the fire, or for both. 
Q3 is the quantity of water required for interior firefighting.

Table 3. Category 10 Aircraft–Agent/Chassis Comparison

<table>
<thead>
<tr>
<th>Reference</th>
<th>Gallons for Q1-Q2</th>
<th>Chassis</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAA</td>
<td>6000</td>
<td>3</td>
</tr>
<tr>
<td>ICAO</td>
<td>8533</td>
<td>3</td>
</tr>
<tr>
<td>NFPA</td>
<td>9260</td>
<td>4</td>
</tr>
</tbody>
</table>

Of the three references (FAA, ICAO, and NFPA), only the FAA does not calculate additional water for aircraft over 250 ft (76 m) long or over 23 ft (7 m) wide. The ICAO has increased water quantities for Category 10 aircraft over the quantities required for Category 9 aircraft by 2114 gallons (8002 liters) or 33%. Without factoring in Q3 water for interior firefighting, the NFPA has increased water quantities for Category 10 aircraft over the quantities required for Category 9 aircraft by 2190 gallons (8290 liters) or 31%.

The ARAC report points out that accepted formulas for Theoretical Critical Area (TCA) and Practical Critical Area (PCA)*, as defined in NFPA 403, are flawed when used to calculate minimum agent requirements for multideck aircraft. These formulas are based on the aircraft length and width and do not take into account the greater aircraft height, larger fuselage surface area, greater fuel quantities, or increased fuselage footprint to accommodate the longer slides.

---

* TCA is the area adjacent to an aircraft where fire must be controlled for the purpose of ensuring temporary fuselage integrity and provide an escape area for its occupants. PCA is an area equal to 2/3 the size of the TCA.
The A380 is not significantly longer, nor is the fuselage appreciably wider, than other aircraft in its Index. As a result, the agent requirement for an A380 only increases by 138 gallons when using the current TCA/PCA formulas. The fuel capacity of the A380 is 44% greater than the B-777 and 42% greater than the B-747-400. The larger fuel quantity increases the potential size of a pool fire under the aircraft.

Another issue is the increased area that must be protected on a multideck aircraft for the footprint of the evacuation slide deployment. Since the upper-deck evacuation slides are now higher, their lengths have been increased to achieve a safe sliding angle. The upper-deck evacuation slides touch the ground 12 ft further from the fuselage on each side than those deployed from the main deck of the B-777. In order to protect the area that the slide touches the ground, additional foam would need to be calculated for 12 additional feet on each side, a total of 24 ft for the length of the fuselage, as shown in figure 1.

![Figure 1. Upper-Deck Evacuation Slide Deployment Lengths](image)

The rationale recommended by the ARAC ARFFRWG increases the PCA by 12 ft on either side to accommodate safe escape paths for passengers coming down the upper-deck evacuation slides. Using this calculation, 2977 gallons are required for Q1, and 5656 gallons for Q2. Combined water for aqueous film forming foam (AFFF) proportioning for Q1 and Q2 for an A380 is 8633 gallons, using the ARAC ARFFRWG approach [2]. This does not increase the agent quantities to include Q3, but rather to satisfy the FAA’s implied goal of maintaining escape paths, or as Gage-Babcock described that goal, “allow ambulatory occupants to exit the aircraft within tolerable heat conditions and move to a safe area” [4].

A published report by Hughes Associates, Inc. [5] for the FAA reviewed the formula to calculate agent quantities, the history behind the formula, and the purpose of each Q quantity and the time when they are to be delivered. It also considered the amount of agent to protect egressing passengers from a pool fire. This report proposes that, based on the justifications for the quantities, those required in NFPA seem most adequate to meet the actual need.
3.  EVACUATION SLIDES.

The first priority in an aircraft fire or significant incident is to evacuate or deplane passengers and crew. Emergency evacuations of aircraft from heights above 6 ft from the ground require the use of emergency evacuation slides. FAA certification of an aircraft requires a full-scale demonstration where a full complement of passengers and crew deplane through half of the emergency exits in the dark of night in 90 seconds or less. It is not unusual for slides to fail to operate or become damaged or unusable due to emergency conditions present as a result of the incident, hence the requirement for the evacuation test using half of the exits.

A safety study conducted by the National Transportation Safety Board (NTSB) [6] reviewed 46 evacuations involving 2651 passengers from September 1, 1997 through June 1, 1999. In these cases, 6% of the aircraft occupants suffered minor injuries, and 2% suffered serious injuries. Slide technology has evolved with the new aircraft being built. Certain slides onboard the aircraft have the Tribrid Inflation System, which is connected to a sensing system within the door. Activation of this system occurs if the door is opened in the emergency mode at an abnormal attitude. The slide will inflate normally, and in addition, several feet of additional slide will inflate to increase the chance for the slide to reach the ground.

A ramp slide is an evacuation slide with a small platform or landing between the exit and the slide itself. Ramp slides are installed on aircraft primarily when the proximity of the exit to an engine requires the slide to be angled away from the engine. Ramp slides are used for the over-wing exits on A310, A340-60, A380, and B-747 aircraft. For certification of the A380, dual-lane slides were required. These double-width slides can transport up to 70 passengers a minute.

Slides are typically constructed of urethane-coated nylon that is sprayed with grey aluminized paint. The reflective paint is added to reflect heat from a nearby fire, extending its operation time when adjacent fires are present for at least the 90 seconds of required slide use. The slides must deploy in 6 seconds in temperatures ranging from -65° to 160°F. The slides should be capable of deploying and remaining useable in winds up to 25 knots.

The first priority of ARFF is the safety of the occupants of the aircraft. Slides facilitate evacuation of the aircraft when conditions warrant and therefore contribute to the safety of the occupants. The effectiveness of the slides is affected by certain human factors and mechanical shortcomings. The increased number of slides from NLA also adds a level of difficulty and increased tasking for ARFF.

3.1  EVACUATION SLIDE ASSISTANCE.

There is no FAA requirement for dedication of emergency personnel to staff the base of evacuation slides, steady them in high winds, or assist passengers at the bottom of the slides. Aircraft cabin crews may assign passengers to provide assistance at the base of slides. The vast majority of passengers evacuating an aircraft during an emergency are doing so for the first time. The hazards associated with evacuation are complicated by a number of factors, as identified in an NTSB safety study, “Emergency Aircraft Evacuation Study,” [6] and an Airport Cooperative Research Program (ACRP) study, “Evaluation and Mitigation of Aircraft Slide Evacuation Injuries” [7].
According to the ACRP study [7], “Wind had an adverse effect on slide use in 12.4 percent of the accidents. In these cases, the wind blew the inflatable slides up against the sides of the aircraft, preventing slide use. In the evacuation events where the slides were unusable, the mean wind speed varied from 13 to 20 knots.” The report claims “historical data shows that when the wind’s mean speed does not exceed 25 knots and one individual holds down the slide, the inflatable evacuation slide remains stable. (NTSB 2000; Van Es and Post 2004).”

3.2 MECHANICAL FACTORS.

The NTSB study [6] indicates that 37% (7 of 19) of the evacuations with slide deployments in the study cases had at least one slide fail to operate. Redundancy of exits is included in the safety margin, as per the requirement of evacuating 100% of the passengers using 50% of the exits in 90 seconds or less. However, a failed slide adds to passenger anxiety and will delay at least those passengers who were planning on evacuating through the exit with the failed slide. Slide failures occur for a variety of reasons, as presented in table 4, which was extracted from the ACRP study [7].

<table>
<thead>
<tr>
<th>Identified Problem</th>
<th>Amount (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slide did not inflate</td>
<td>28.1</td>
</tr>
<tr>
<td>Aircraft attitude</td>
<td>15.7</td>
</tr>
<tr>
<td>Other</td>
<td>13.5</td>
</tr>
<tr>
<td>Wind</td>
<td>12.4</td>
</tr>
<tr>
<td>Slide burnt</td>
<td>11.2</td>
</tr>
<tr>
<td>Incorrect rigging</td>
<td>7.9</td>
</tr>
<tr>
<td>Slide ripped</td>
<td>6.7</td>
</tr>
<tr>
<td>Unknown</td>
<td>4.5</td>
</tr>
</tbody>
</table>

The ACRP study looked at 142 emergency evacuation events for the period of January 1, 1996 through June 30, 2006. The data illustrated that during this time period approximately 50% of emergency evacuations result in injuries, 90% of which were minor. This finding is considered to be consistent with the aforementioned NTSB study [6], which looked at 46 incidents over 21 months (September 1997–June 1999); the percentage of minor injuries was the same, i.e., 90%.

The ACRP study [7] demonstrated that human reactions in situations requiring emergency evacuation include panic and confusion. Some interviews indicated competitive behavior among passengers trying to exit the aircraft. The ACRP made recommendations for the first responders to (1) practice the initial stabilization and proper orientation of the slide, particularly during windy conditions, and (2) realize that continued stabilization may be needed under such conditions.
3.3 LARGE AIRCRAFT EVACUATION.

In addition, the ACRP study looked at the emerging issue (at the time of the study) of emergency evacuation of Very Large Transport Aircraft (VLTA). Recorded evacuations involving B-747 aircraft and the certification test of A380 aircraft were included in the analysis. A mathematical model was developed to study the relative speed at which a passenger travels down an evacuation slide. The conclusion of the analysis shows that the rate and speed of a passenger traveling down an evacuation slide from an upper deck of an A380 is the same as from an upper-deck slide on a B-747.

Additional papers were written to further evaluate emergency evacuations from upper decks of VLTA. One such paper was presented at the 2001 International Aircraft Fire and Cabin Safety Research Conference in Atlantic City, New Jersey, by Jungermann and Colleagues [8]. Jungerman concluded that there was a need for further research, as a difference in hesitation time between individuals evacuating from the upper deck and individuals evacuating from the main deck was determined.

3.4 OBSTRUCTION TO ARFF OPERATIONS.

Evacuation slides are the primary means of egress of passengers from an aircraft. The protection of these slides, as part of the escape path, is one of the primary concerns during the initial attack response of the ARFF. During the critical period of evacuation and until confirmation is received that all occupants are off the aircraft, the slides must be protected and preserved in usable condition. Situations may require an attendant to stand at the base of the slide to maintain a connection with the ground or to assist passengers to their feet and direct them to safety as they exit the slide. Aircraft with two passenger decks have more exits than those with a single deck. Additional slides increase the number of escape paths to protect, as well as the number of attendants that may be required to assist with the slides. Passengers may be assigned by cabin crews or voluntarily position themselves at the base of evacuation slides. In some scenarios, this is a practical solution. In other scenarios, particularly those involving pooled fuel or fire, it is not prudent to allow persons without personal protection equipment (PPE) to remain in the affected area.

While deployed, the slides serve as obstructions to ARFF activities that will prevent foam streams from being used to control a fuel fire or to cover a fuel spill. The 16 evacuation slides create an intricate web; 6 are from the upper deck. All slides are two lanes wide, as shown in figure 2. If the slides are intact, and the pool of fire is under control, hand lines will be necessary for application and reapplication of a foam blanket.
Providing ARFF personnel to stabilize slides during an emergency evacuation will likely reduce the number and severity of injuries. It will also likely reduce delays in passengers jumping into the slides, as the anxiety of the event will be decreased at the sight of emergency responders at the bottom of the slides to assist them.

With 16 evacuation slides, deployed access is restricted for ARFF operations. The slides from the upper deck extend beyond the PCA, the area by which foam quantity calculations are derived.

The slides from a two-deck aircraft, like an A380, block access to the majority of the occupiable portion of the fuselage. Winds can raise or twist slides. Ramp slides from the A380 wing actually route passengers under the midship upper-deck two-lane slide, putting that evacuation point out of sight from emergency personnel who are outboard of the slides, as shown in figure 3.

Approach of ARFF vehicles for the points aft of the wing is limited. The over-wing ramp slide exit disappears from view behind the upper-deck, double-lane slide. Each slide on the A380 is equipped with a re-entry line, installed to provide direct access for ARFF crews to both the main and upper decks. This may be a physically challenging method of access, but it is an available feature. Each evacuation slide is also equipped with three emergency lights.
4. INTERIOR ACCESS VEHICLE.

Mobile stair vehicles (also called air stairs), when correctly deployed, provide a safe and stable platform for enplaning or deplaning passengers. Most airlines or fixed-base operators have such vehicles in their fleet; however, availability during emergency operations cannot be guaranteed. The majority of stair vehicles are designed to accommodate the sill heights of aircraft ranging from a B-727 to an A340, which is 5.5 to 19 ft (1.7 to 5.8 m). The A380 upper-deck sill height can be as high as 26.25 ft (8 m) in a normal aircraft attitude. Sill heights for normal, tail up, or tail down attitudes are referred to as Normal Sill Height, Minimal Sill Height, or Maximum Sill Height, as shown in table 5.

Table 5. Sill Heights

<table>
<thead>
<tr>
<th>Sill Height</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>U1, U2, U3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>17.06 ft (5.2 m)</td>
<td>17.06 ft (5.2 m)</td>
<td>17.06 ft (5.2 m)</td>
<td>17.06 ft (5.2 m)</td>
<td>17.06 ft (5.2 m)</td>
<td>26.25 ft (8.0 m)</td>
</tr>
<tr>
<td>Maximum</td>
<td>31.82 ft (9.7 m)</td>
<td>26.25 ft (8.0 m)</td>
<td>--</td>
<td>20.01 ft (6.1 m)</td>
<td>23.29 ft (7.1 m)</td>
<td>32.48 ft (9.9 m)</td>
</tr>
<tr>
<td>Minimum</td>
<td>7.87 ft (2.4 m)</td>
<td>10.50 ft (3.2 m)</td>
<td>--</td>
<td>8.53 ft (2.6 m)</td>
<td>5.25 ft (1.6 m)</td>
<td>20.34 ft (6.2 m)</td>
</tr>
</tbody>
</table>

Note: M1-M5 refers to Main Deck, Door Positions 1-5. U1-U3 refers to Upper Deck Door Positions 1-3.

The FAA ARFF Research Program made use of the FAA’s Civil Aerospace Medical Institute evacuation simulation programs [9] to study how making closed exits available using an IAV
could improve evacuation times. The results of the study indicate that, in a total evacuation, an IAV could significantly impact evacuation times, especially in double-aisle aircraft.

Currently, there are no U.S.-based manufacturers offering IAVs with the ability to reach upper-deck cabin sill heights. Rapid access to the aircraft may be critical to successful mitigation of an onboard incident. Gaining access to emergencies onboard, whether the event is a medical emergency, fire, investigation, or law enforcement incident, is, as a practical matter, the first step upon arrival at the aircraft to deal with the problem. For airports serving multipassenger deck aircraft, having equipment that can reach the sills of upper decks should be a primary consideration when planning a purchase. If the mobile stair vehicle can also be equipped with agent or equipment to better facilitate the ARFF mission and satisfy the Index requirements, the vehicle can be used in the initial mitigation of the aircraft emergency rather than to be called out afterward. The FAA ARFF Research Program is working with the aviation community to develop a model for a piece of equipment that can provide immediate access to the aircraft to gain access for emergency responders or to provide a safe exit for passengers. In addition, the IAV may serve as a chassis/platform to provide firefighting agent and equipment to complement agent carried on traditional ARFF vehicles.

The IAV has great merit and provides additional important roles to ARFF and the airport community. In November 2009, the FAA conducted tests and practical evolutions to determine the best methods for gaining forcible entry to an aircraft for which the doors are no longer operable. The first challenge in these events is to gain control of a suitable work platform from which to launch such an effort; a wide mobile stair platform has the necessary features. The IAV research should include a chassis with the ground clearance and mobility to reasonably operate off road, as would be the case for an aircraft that is off pavement.

In addition, the IAV can serve the airport during weather diversions and events that cause aircraft to be remotely parked with passengers onboard. Access to these aircraft for medical emergencies and other events often are delayed, as the airlines’ equipment and personnel are already in high demand during such events. An IAV controlled by ARFF would be available for such responses, as well as support to law enforcement, thereby minimizing delays in emergency management.

Singapore Changi Airport (SIN) was the first airport outside of Europe to host the A380. It arrived in November 2005 for airport compatibility verification tests. The A380’s inaugural commercial flight departed from SIN in 2006.

Preparation for A380 service at SIN began in 2003 and included several infrastructure improvements that supported the A380 operations. ICAO Annex 14, Aerodromes, Volume I Aerodrome Design and Operations, Chapter and ICAO Circular 305 [1]entitled “Operation of NLA at Existing Aerodromes” provides the regulatory and guidance material used to prepare for conducting flight operations with NLA. Circular 305 recognizes that the aerodrome infrastructure recommendations made in Annex 14 do not cover all of the specific needs to safely accommodate specific aircraft types at airports.
In terms of emergency services, SIN Airport Emergency Services (AES) conducted a needs analysis and developed plans to satisfy the ICAO regulations and guidance, as well as to satisfy SIN goals for NLA emergency preparedness.

In 2006, SIN AES procured two Rosenbauer rescue stair vehicles. Each is equipped with a firefighting package, including 264 gallons (1000 liters) of water and a hose connection at the top of the platform for rapid access to either NLA deck for interior firefighting. The standard response for an incident involving an A380 at SIN calls for a response of six ARFF appliances, including AES 2 (rescue stair vehicle).

5. HISTORICAL REVIEW—B-747 AND A380 EVACUATIONS.

For the purpose of this study, only evacuations from upper decks were researched. The research was conducted searching only for evacuations on B-747 and A380 aircraft.

5.1 THE B-747 INCIDENTS.

The NTSB lists 271 incidents or accidents involving B-747s. Only eight incident narratives report that an evacuation was conducted. None of the narratives indicate that passengers were evacuated directly from the upper deck.

From the 142 slide emergency evacuation events identified for the ACRP study [7], only 2 of those events involved B-747 aircraft.

- August 19, 2005, Agana, Guam. A B-747-200 landed with its nose gear retracted and an emergency evacuation was initiated. Two minor injuries occurred during the evacuation and no reports of the upper-deck evacuation slides being used.

- May 1998, Tokyo, Japan. This event involved a B-747-400. There were no reports of the upper-deck evacuation slides being used.

An article was published in the July–August 2005 issue of Flight Safety Australia, titled “Evacuate. Evacuate. Evacuate” [10]. The article describes a B-747-438 slide emergency evacuation event that occurred in Sydney, Australia, on July 2, 2003. The captain ordered the evacuation upon hearing the report that the aircraft’s brakes were smoking.

During the B-747-438 evacuation, the L2 and R4 slides did not deploy. The upper-deck, right-slide deployed, but it was reported to be blocked by a vehicle. Ground crews freed the slide from the vehicle and turned it to the correct position in reference to the ground. Upper-deck passengers used the stairway to the main deck and evacuated via the main deck slides. The copilot evacuated from the upper-deck, right-side slide and was carrying a 6.6-lb fire extinguisher. The copilot reported he could not control his ascent, and he let go off the fire extinguisher while sliding. He landed heavily on his shoulder and fractured his collar bone. There were a total of 350 passengers and 14 crewmembers onboard. Four serious injuries occurred, including one to a crewmember during the emergency evacuation. Figures 4 and 5 show the slide deployment after the Sydney evacuation. In figure 5, a deflated ramp slide is visible. The slide deflated 32 seconds after it was inflated. The failure occurred while a woman
wearing high-heeled shoes was on the slide. She fractured a vertebra when she landed hard on the concrete apron. The Transportation Research Board was not able to conclusively determine the cause of the slide failure, but did confirm that it was used successfully by several passengers before the failure occurred.

Figure 4. Slide Emergency Evacuation of a B-747-438—View 1
(Photo Source: Australian Transport Safety Bureau)

Figure 5. Slide Emergency Evacuation of a B-747-438—View 2
(Photo Source: Australian Transport Safety Bureau)
5.2 THE A380 INCIDENTS: SINGAPORE CHANGI AIRPORT.

There have been two cases reporting a need to evacuate or deplane passengers as a result of an incident or accident involving an A380. Both incidents occurred at SIN. Neither incident involved passengers being deplaned via slides or air stairs directly from the upper deck. In both cases, the passengers came down the interior stairs from the upper deck to the main deck to exit the airplane.

5.2.1 Singapore Changi Airport: Singapore Airlines Flight 221.

The first A380 evacuation on record occurred at SIN. On January 10, 2010, Singapore Airlines (SQ) Flight 221 became disconnected prematurely from a push-back tractor, and the aircraft rolled off pavement and into the soft turf adjacent to Terminal 3. The aircraft was deplaned and recovered from the grass strip, as shown in figures 6 and 7.

![Figure 6. Singapore Airlines Flight 221, A380 Off Pavement](image1)

![Figure 7. Gear of SQ Flight 221, A380 Off Pavement](image2)
5.2.2 Singapore Changi Airport: Qantas Flight 32.

The second evacuation of an A380 also occurred at SIN. The incident on November 4, 2010, unfolded as Qantas (QF) Flight 32 left Singapore bound for Sydney, Australia. The A380 suffered an uncontained engine failure of its Number 2 engine just 6 minutes into the flight. The engine failure and subsequent flying shrapnel cut electrical cables and hydraulic lines in the wings. The wing’s forward spar was damaged, and two wing fuel tanks were ruptured. As fuel leaked out, an imbalance was created between the wings. The electrical problems meant the pilots were unable to transfer fuel forward, and the aircraft became tail heavy. The pilots struggled to maintain balance and keep the A380 from losing lift, which would cause the aircraft to stall, while fielding 54 alarms of system failures or impending failures in the cockpit. The flaps and landing-gear doors were inoperable, and the Number 2 engine was on fire. The pilots were able to use gravity to lower the landing gear.

During landing, the brake temperature exceeded 1650°F (900°C), causing four flat tires. The possibility of the leaking fuel reaching the hot brakes was a significant threat of fire development. The pilots rolled out the plane the full length of the runway so it would be close to ARFF vehicles to facilitate the application of foam under the aircraft. Upon landing, the crew was unable to shut down the Number 1 engine. SIN AES were forced to discharge high volumes of foam into the engine, which choked the engine and forced it to shut down.

The events that unfolded in this incident certainly would have justified the pilot to order evacuation by slides; however, in spite of the combination of events, he elected to deplane the passengers over air stairs provided by the Changi Airport Group (CAG) AES, on the scene, as shown in figures 8 and 9.
The following media statement was issued by CAG:

“An A380 Qantas flight, QF 32, bound for Sydney, Australia, departed Singapore Changi Airport at 0956 hours today. For technical reasons, the aircraft turned back to Changi and landed safely at 1146 hours.

Changi Airport Group’s Airport Emergency Service (AES) responded with six fire vehicles, in accordance with standard operating procedure for such incidents. In response to the pilot’s request, checks were conducted on the aircraft by AES. Once the checks were completed, passengers and crew began disembarking from the aircraft at Runway 2. Buses were arranged to ferry them to the airport terminal. Disembarkation of all 469 passengers and crew on board was completed by 1340 hours.”

SIN AES Emergency Stair Unit (ES2) was capable of reaching the upper deck of the A380. When the decision was made to disembark all passengers from the A380, ES2 was positioned at the MR-2 door. During this evacuation, a determination was made to deplane all passengers from the main deck since there were far fewer passengers on that deck (business class) and all were capable of climbing down the interior stairs. The main deck had a number of elderly passengers and children. Had it been necessary, ES2 could have reached the upper deck just as easily. Take note of the diversity in age and physical characteristics of the sampling of passengers in the figure 8. An evacuation slide exit, if not required by the situation, puts some passengers at risk more than others. The evacuation of the 469 passengers and crew on the aircraft took nearly an hour because there were only two buses used to ferry passengers from the aircraft.

A great deal is known about the frequency of evacuations, percentage and types of injuries, effects of wind, and passenger behavior during evacuations.
The ACRP study “focused on slide emergency evacuations from upper decks of very large transport aircraft” [7]. Several initial parameters were changed to see the effect they had on the velocity of an individual as a function of position on the slide. The graphs in this study show and compare the results between sliding down from the upper deck of the Airbus A380 versus the B-747.

5.3.2 The Finkenwerker Plant A380 Evacuation Test.

According to a first-hand account of the evacuation test published in *Flight International* on April 6, 2006 [11], over 1000 volunteers were assembled at Airbus’s Finkenwerker Plant in Hamburg on March 26, 2006, for the A380 evacuation test. Approximately 50% of the volunteers were Airbus employees and 50% were members from a local gym. Prior to being approved to participate, an agility test was conducted, which was designed to cull out the very elderly or clinically infirm. Prior to boarding the aircraft for the evacuation test, warm up exercises were conducted with the group.

The passenger loading for the A380 Maximum Capacity Simultaneous Evacuation Trial included 315 passengers and 7 crew on the upper deck, 538 passengers and 11 crew on the main deck, and 2 crew in the cockpit. For this test, the aircraft was not equipped with a main deck crew rest area.

6. HUMAN FACTORS.

Certification requirements are based on a single evacuation trial. The subjects used to conduct the evacuation test were prepared for the evacuation and were properly dressed for an evacuation. The European Aviation Safety Agency (EASA) and the FAA regulations require that 35% of the participants must be over age 50, a minimum of 40% must be female, and 15% must be female and over 50.

- One common report during emergency evacuations was that passengers insist on retrieving their personal belongings, such as luggage and briefcases. Injuries have been documented associated with this action [6].
- There is a noted hesitation by passengers evacuating via upper-deck evacuation slides versus main-deck slides [6].
- The most serious evacuation-associated injuries occurred when occupants jumped out the exits and off the wings [6].

6.1 PASSENGER DEMOGRAPHICS AND BEHAVIOR.

Obviously, to use a more diverse profile of age, condition, and health would put the occupants at a higher risk for injuries. From the standpoint of emergency responders, it is unlikely that, with passenger loads anticipated on large aircraft, all passengers would be fit enough to self-evacuate in 90 seconds or less using half of the exits. The demographics standardized by the FAA and EASA set a standard for evacuation testing for aircraft certification, but they do not accurately describe the typical passenger load, which would nearly always include infants, small children,
elderly, handicapped, and obese passengers. Some passengers or cabin crewmembers will almost certainly be occupied assisting those unable to evacuate on their own. The delays caused by those who may block an aisle trying to self-evacuate or by those assisting others will contribute to some occupants spending longer periods of time in the aircraft. There are multiple references to human factors in each study evaluated that impact evacuation in actual emergencies. The actions, reactions, and decisions made by each passenger will have an effect on the overall process.

The height of the upper-deck slide is likely to cause apprehension in some passengers, thus causing them to turn around once reaching the door and refusing to jump, particularly if the emergency condition prompting the evacuation is not visible to the passenger. Jumping into the slide may seem like a greater danger than staying onboard. This may contribute to the migration of passengers from the upper deck to the main deck using the interior connecting stairway. This action will increase the time to evacuate the upper deck, and disrupt the evacuation process underway on the main deck. The cabin crew is responsible to coordinate, communicate, and direct all passengers. The large number of passengers in an A380 or B-747 may increase the anxiety and panic level of the passengers.

Beyond the initial certification test, there can be no prediction as to how aircraft crews or passengers will react in an evacuation. Statistically, it is very common for aircraft doors or slides to malfunction during evacuations; this gauge prompted the requirement for completing the evacuation test in 90 seconds or less using half of the exits. The unknown is which door(s) will be located in areas of the aircraft safe for evacuation and whether or not those doors are found to be operational when needed.

6.2 EMERGENCY RESPONDERS.

Emergency responders must be prepared with any combination of scenarios and respond and react to overcome each challenge, regardless of the cause. Whether an evacuation slide malfunctions due to airframe damage or improper packing and installation, the effect on passenger evacuation is the same. The responders’ first priority is the safety of the passengers. The strategy for protecting the passengers may require removing them from the aircraft, or perhaps creating a safe environment inside the aircraft. The condition of doors, evacuation slides, and access or egress points to the aircraft will be taken into consideration in the development of an Incident Action Plan (IAP).

Gaining rapid access to the interior of the aircraft is essential to the assessment of interior conditions, assisting with evacuation, treatment of the ill or injured, and mitigation of the emergency condition. Equally important to gaining access is that the entry must never restrict the flow of passengers coming off the aircraft. In the case of the A380 or B-747, additional decks mean additional access points.

Fire commanders or entry teams need to quickly assess the aircraft to determine the best location to gain entry. By having an IAV capable of reaching every deck, the greatest number of opportunities is available. The IAV can be used to gain access, to assist passengers left onboard, and to launch interior fire attack.
The additional access points on these NLA also create obstructions for gaining access. Deployed evacuation slides block the approach to doors and must be deflated or removed prior to positioning an IAV at a door.

Positioning of the IAV should be done such that support for the greatest number of anticipated missions is provided. If passengers are evacuating through main deck doors only, then positioning the IAV on the upper deck will provide access for rescue or entry teams without obstructing an exit. If passengers are all evacuating through forward doors, positioning the IAV at an accessible rear door follows a similar strategy. Positioning an IAV at a door at which the slide failed to deploy creates an access point or exit not previously available.

If an IAV is not capable of reaching the upper deck, the versatility of the device is significantly reduced.

7. VENTILATION.

In every aspect of firefighting, ventilation is a key factor in fire development, as well as control. Ventilation is the exchange of the interior atmosphere of a structure with the outside atmosphere. Buildings are designed to breathe, and the exchange is continuous and ongoing. When on the ground, aircraft move air in the same way through open doors and outflow valves. This process is ongoing in all structures and does not normally involve heat, smoke, and toxic products of combustion (gases).

When a fire occurs in the fuselage of an aircraft, ventilation involves supply of air (oxygen) to the fire and exhaust of smoke and hot gases from the fire. This description is what is occurring at the fire itself. The scale of this ventilation process is different (scalable) based on the size, fire load, and location. During assessment of a fire in an aircraft, if smoke is observed, ventilation is taking place. Each time the amount of ventilation or the position of the ventilation changes, it will have an effect on the fire. The change or extent of that effect may occur as a result of tactical steps taken in firefighting, such as opening a door to gain access, removal of a window, or as a result of burn through of the fuselage.

The operative point is that ventilation is occurring if there is a fire. Ventilation extent and effect will change throughout the event, whether it is done intentionally as part of a ventilation strategy, accidentally as a byproduct of intentional tactical operations, or naturally as a result of fire growth. ARFF personnel must be aware of the ventilation occurring and be able to anticipate the effects of ventilation changes incurred by the actions of ARFF crews.

7.1 VENTILATION OBJECTIVES.

Before determining the need, strategy, or method of ventilation, the objective for ventilation must be clear. Ventilation is performed for one of the following reasons.

- Life—If there are occupants in the aircraft, or if fire fighters must make entry, ventilation is performed to improve conditions in the aircraft by removing heat, smoke, and gases while introducing fresh air.
• Fire—Opening doors, windows, or creating openings in the aircraft to control fire direction or growth may be used as part of an attack strategy while advancing hand lines or using aircraft skin-penetrating nozzles (ASPN).

• Safety—Used when the risk analysis indicates that entry is not warranted as part of a defensive firefighting operation.

7.2 VENTILATION STRATEGIES.

In any aircraft fire, there are two general strategies that may be employed to manage a change in ventilation.

• Tactical Ventilation—Planned implementation of methods designed to remove heat, smoke, and gases while introducing fresh air (such as opening doors and removing windows.)

• Tactical Oxygen Deprivation—Planned implementation of methods designed to trap heat, smoke, and gases while excluding introduction of fresh air (such as closing doors and blocking windows.)

If the change in ventilation is not planned or managed, an unplanned change in ventilation will occur.

7.3 VENTILATION METHODS.

Ventilation during aircraft fire attack is necessary regardless of the size of the aircraft. NLA, with multiple decks, more doors, windows, stairways, etc., provides additional opportunities for introducing ventilation as well as complications created by those same opportunities. Sections 7.3.1 through 7.3.7 describe the ventilation methods.

7.3.1 Horizontal Ventilation.

On an intact aircraft, horizontal ventilation is the easiest to achieve. To be effective, it may actually require a combination of tactical ventilation (opening doors or removing windows) and tactical oxygen deprivation (as described in section 7.3.5). If the aircraft has been evacuated, most doors will be open. The air flow provided through the open doors on multiple decks with interior staircases between the main deck and the upper deck on A380 and B-747 aircraft will influence fire behavior. By selecting which doors to open and which to close, ventilation can help to control fire behavior.

7.3.2 Vertical Ventilation.

On an intact aircraft, vertical ventilation is the most labor intensive. Structural fire fighters employ vertical ventilation by opening roof scuttles and skylights or making roof cuts. It is essential to release superheated smoke and gases that are trapped in the higher deck of a structure, particularly in a stairwell, to reduce the temperatures to a safe level for entry to the upper decks. If the aircraft is in normal orientation, there are no hatches or scuttles on the
aircraft roof over the main cabin. Roof cuts on the top of a fuselage are difficult and dangerous for fire fighters. The level of effectiveness of a roof cut for vertical ventilation will vary based on a number of factors. If the aircraft is configured for passengers, the roof cut will open into a compartment above the upper deck passenger compartment. Between the fuselage and the cabin, there are a number of obstructions including but not limited to, ventilation ducts, electrical wiring, insulation, and interior finish (ceiling). If the ceiling is intact at the time of the roof cut, the majority of the heat and smoke may be trapped below the ceiling. If the fire is on the lower deck, a roof cut may actually encourage the fire to travel toward the source of fresh air being introduced through the roof cuts. If the fire is left unabated, it will eventually breach the overhead and self-vent vertically.

7.3.3 Positive Pressure Ventilation.

This method involves using mechanical fans to force air into the fuselage and direct the air toward an outlet vent opening. The intention is to rapidly release heat and smoke. Many airports mount positive pressure ventilation (PPV) fans on their mobile stair trucks or IAVs. Some airports have large truck-mounted PPV fans of sufficient capacity to ventilate an entire aircraft deck on a wide-body aircraft. PPV methods and strategies are very effective if used correctly. The effectiveness of the PPV is dependent upon the amount of air moved being sufficient to have the desired effect in the aircraft. Ventilating a larger space or attempting to move air a greater distance will require larger-capacity PPV fans. An open door, window, or access panel can significantly reduce the effectiveness of a PPV ventilation strategy. These challenges are greater on larger, multideck aircraft.

7.3.4 Hydraulic (or Forced) Ventilation.

This method can be used to supplement vertical and horizontal ventilation. All that is required is a charged hand line and a fog nozzle. As an immediate follow up to knocking down the fire, forced ventilation can be used to quickly improve the conditions and visibility in the aircraft cabin. Fire fighters position themselves inside the cabin near an open door. The hand line is then positioned a few feet from the door opening, and the nozzle is set to a wide fog pattern. The nozzle is opened, and the fog stream is positioned so it covers most of the opening. At this time, heat and smoke are drawn into the stream and forced out of the aircraft. Rotating the nozzle may increase the Venturi effect of the spray and draw out the heat and smoke faster. This method works well through an open window, but the larger door opening is more efficient. This method is not recommended until after the fire is knocked down. If a high heat condition still exists, this method will produce steam, which can be dangerous to fire fighters.

7.3.5 Oxygen Deprivation.

This method confines the fire to a given area by closing openings, limiting fire travel paths, and restricting the additional introduction of oxygen. European fire fighters have seen great success in employing oxygen deprivation methods in structures. There are a number of factors that determine the long-term effectiveness of oxygen deprivation in an aircraft. However, if there are no occupants, oxygen deprivation is a reasonable method to use if interior attack teams are not immediately available. When interior attack teams are available, oxygen deprivation becomes
part of the tactical ventilation strategy. Doors that are selected to be open or closed should be based upon the needs of the attack team and the intent of the tactical ventilation strategy.

### 7.3.6 Multideck Aircraft Ventilation Design

The unique configuration that includes an upper deck of an A380 or a B-747 aircraft provides a circulation of air between decks on the aircraft. There are no doors to separate or isolate the upper-deck cabin from the main-deck cabin. If the aircraft has power, and the aircraft doors and windows are closed, the A380 ventilation system is designed to pressurize the stairs and cabins in a way that limits any travel of smoke between decks. When the smoke exceeds the capacity of the ventilation system, when power is lost, or when doors are open, smoke from a fire on either deck will enter both cabins. The PPV system on the A380 is designed for use in flight. Conditions on the ground with doors open and power secured will not allow the system to operate as designed. An understanding of this system is important for fire commanders and fire fighters. A report from the pilot in flight may indicate that smoke is contained to one area, passengers have been relocated, and they are perhaps even calm. That condition may change rapidly once the doors are opened. If smoke rushes through the cabin as a result of the aircraft PPV system being overcome by conditions, the survivability of the atmosphere, as well as the level of anxiety of the passengers, may dramatically change.

The B-747-400 has ten exit doors and a crown escape hatch in the cockpit. The B-747 has one passenger stairway connecting the main-deck cabin with the upper-deck cabin. The A380 has 16 door openings and interior stairs connecting the main- and upper-deck cabins located forward and aft, as shown in figures 10 and 11. Both aircraft have operable escape windows in the cockpit. The A380 also has service elevators located in the middle and rear galleys, as shown in figure 12. Ventilation occurs at all times on these aircraft. Controlling the airflow as part of the ventilation strategy will be an essential component to successful interior firefighting operations.

![Figure 10. Forward Stairway Between Decks on Air France A380](image)
Figure 11. Rear Stairway Between Decks on Air France A380

Figure 12. Service Elevator on A380
8. AIRCRAFT ACCESS.

The A380 is equipped with:

- Six type A upper-deck passenger doors
- Eight type A main-deck passenger doors with slide containers (figure 13)
- Two type A main-deck emergency exits without slide containers

The designations for the doors have a prefix of M for main-deck doors, or U for upper-deck doors. Hence, the forward door on the main-deck left side is designated ML1 (figure 14), and the rear door on the upper deck on the right side is designated UR3.

Figure 13. The ML4 Door, Interior View; Type A Passenger Door With Slide Container

Figure 14. The ML1 Door A380, Exterior Operation View
The exterior door operations/steps are as follows:

1. Verify the cabin pressure status. If the red indicator light is flashing in the window, the cabin is still pressurized. If the cabin is still pressurized, communications with the cockpit is the best method for de-pressurization. If the cockpit crew is unresponsive (overcome) the outflow valves can be forcibly opened.

2. Verify the emergency evacuation slide status by looking through the window indicator.

3. Push the outer door flap and grab the door control handle.

4. Lift the door control handle. This will lift the door and expose the OPEN/CLOSE buttons.

5. Press and hold the OPEN button. The door will start swiveling.

6. Lift the handle fully and ensure it is lined up with the green bar, as shown in figure 15. The handle should stay in that position when released.

7. With the handle raised, the door is unlocked and the OPEN/CLOSED buttons are fully exposed, as shown in figure 16.

Figure 15. Exterior Door Operation Demonstration—Step 6
9. EXTERIOR FIRES.

The greatest risk involving fires on the exterior of any aircraft is fuel. Certainly, there are other areas at risk for fire, but as individual events, they are not much different on NLA than on other aircraft. Fires involving engines, APUs, wheels, etc., are approached with tactics and strategies similar to those used for the same type of fire on a different type of aircraft. Familiarization of each aircraft providing service to an airport is required for all ARFF members.

Fuel quantities on larger aircraft are greater than in smaller classes of aircraft. The large quantity of fuels carried is not limited to B-747-8 or A380 type aircraft. Other aircraft (listed below) that have been in service for a number of years also carry large quantities of fuel that raise the risk profile of a ground emergency involving fuels.

- B-777-300 ER—47,890 gallons
- A340-600—51,750 gallons
- B-747-400—63,500 gallons
- B-747-8I (Intercontinental)—64,055 gallons
- A380—83,290 gallons
- B-787—33,528 gallons

The trend is toward larger aircraft with greater carrying capacity and greater fuel capacities. From a tactical fire attack standpoint, the B-747 and the A380 offer the greatest challenges. The greatest risk is based on the quantities of fuel carried (see above). There are three other important considerations: overall size, passenger capacity, and obstructions to exterior streams.
9.1 OVERALL SIZE.

The overall size, not just the length of aircraft, has increased. The height of an aircraft is not factored into traditional TCA/PCA formulas used to calculate minimum agent requirements. The sill height is increased for the upper deck and tends to be beyond the reach of many traditional stair trucks, which is generally less than 20 ft.

- Upper-deck sill height for B-747—25.60 ft
- Upper-deck sill height for A380—26.25 ft

9.2 PASSENGER CAPACITY.

Compliance with the weight and balance limits of any aircraft is critical to flight safety. Operating an aircraft above the maximum weight limitation compromises its structural integrity and adversely affects its performance. For this reason, the certified maximum number of passengers will never be combined with the maximum fuel capacity. These numbers must be adjusted to satisfy maximum allowable weights for safe flight. On a shorter route, the quantity of fuel carried can be reduced, thereby allowing a larger passenger load. As fuel is reduced, the passenger-carrying capacity increases and range decreases.

- B-747-400—416 passengers on two decks
- B-747-8—467 passengers on two decks
- A380—certified maximum of 853 passengers/555 typical maximum

9.3 OBSTRUCTIONS TO EXTERIOR STREAMS.

Protection of the passenger evacuation path is a primary requirement for ARFF crews. This protection is crucial when fuel has been released under an aircraft or if fuel released under the aircraft is involved in fire.

Burning fuel under the aircraft poses an immediate hazard to the integrity of the evacuation slides and evacuating passengers and crew. Application of AFFF from ARFF vehicle-mounted turrets and/or hand lines is used to knock down, control, and extinguish the fire. Once controlled or extinguished, the foam provides a vapor-sealing blanket on the surface of the fuel. Complete coverage of the spill area for initial application, as well as re-application, is required to prevent the escaping fuel vapors from finding an ignition source. The foam water mixture also provides cooling to hot aircraft components that may serve as an ignition source to escaping flammable vapors.

An aircraft away from the gate that is being evacuated due to a ground emergency will have some, or all, evacuation slides deployed. The evacuation slides are a critical safety component of the aircraft and absolutely essential to rapidly evacuate passengers, particularly on a large aircraft with hundreds of passengers.

These evacuation slides are at risk from the effects of heat, direct-flame impingement, wind, and the force of water and foam streams being used to fight the fire or provide a protective blanket of
foam over the fuel. Operators of turrets, extendable turrets, and hand lines have to deal with the obstructions of the evacuation slides. When the slides are coming from two passenger decks, the obstruction is greater. In the case of an A380, 14 separate evacuation slides extend outward from the fuselage creating a great deal of obstruction to streams, as well as the conditions under the aircraft. The over-wing slide uses a ramp slide and reaches the ground behind an upper-deck slide, completely blocking the view of passengers evacuating on that slide.

AFFF is very slippery, and it will accelerate the speed of passengers if it is on the slide’s surface. Also, the ground at the base of the slides, as well as the entire area around the aircraft, becomes very slippery for evacuating passengers and ARFF crews.

An NLA at the gate may have additional encumbrances blocking accessibility for ARFF vehicles. The left side of the aircraft may have one to three jet bridges attached to the aircraft. One jet bridge blocks a significant area for access by ARFF vehicles. That blocked area is proportionately increased with the typical A380 boarding arrangement, which uses two jet bridges, one for each deck. An example of two jet bridges extended to an A380 illustrates (figure 17) the restricted access by ARFF to the left side of the aircraft. Airbus reports that 11 airports in the world that already have or plan to have A380 service are considering plans to add a third jet bridge to certain gates. These airports are Heathrow (LHR), Suvarnabhumi (BKK), Singapore Changi (SIN), Dubai (DXB), Charles de Gaulle (CDG), Johannesburg (JNB), John F. Kennedy (JFK), Shangai Pudong (PVG), Beijing Capital (PEK), Kansai (KIX), and Hong Kong (HKG).

Figure 17. Korean A380 With Two Jet Bridges Extended at JFK

In addition to the jet bridges, access around an A380 is severely restricted. Most airports have had to make a number of adjustments to provide gate space large enough to accommodate the A380 and all support vehicles required to provide service. If the aircraft is being serviced at the
gate, and the adjacent gates are occupied, there will be very limited access to the area adjacent to the aircraft for ARFF operations.

10. INTERIOR FIREFIGHTING OPERATIONS.

Interior firefighting operations on NLA offer additional challenges not found on single-deck aircraft. In preplans, a number of factors must be considered. The NLA configuration varies significantly by carrier, and ARFF crews are required to become familiar with each type of aircraft with service to the airport. An understanding of the configuration of each carrier flying that particular type of aircraft is essential for ARFF crews, since each carrier makes different use of the space.

The B-747 has been flying since January 1970, so the concept of a second (upper) deck is something that Index E airports have been dealing with for over 40 years. The B-747 has grown over the years, become more sophisticated, and increased its fuel and passenger payload, as well as its use of composite materials.

The A380 is the first aircraft to have a full-length, upper passenger deck. In addition, some carriers are using the lower deck (below the main deck) for a crew rest area. The options for lower-deck crew rest area configurations provide more than one area for rest. For ARFF firefighters, this means there are potentially three occupied decks on certain A380s. Familiarization of unique carrier configurations will ensure that, during training and prefire planning, ARFF crews know all the areas where occupants may be located, rather than after an incident during search, rescue, and recovery.

10.1 ACCESS.

Gaining safe and rapid access to the aircraft for immediate intervention of the risk or hazard is important. When away from the jet bridge, these mammoth aircraft have no convenient access points. Airline mobile air stairs or IAVs are necessary tools for gaining access with ARFF personnel and equipment.

Approaching the aircraft with an IAV or attempting to board by any other means must be coordinated and approved by the Pilot in Command. This will also help to coordinate with the cabin crew who, if still onboard, can often assist with opening doors to make entry or to assist with evacuation.

If the cockpit is unattended, or if the flight crew is no longer in command of the aircraft, it should be ensured that the aircraft is secured in position before approaching to gain access. Airline personnel may be helpful in providing wheel chocks or installing pins in the landing gear, if appropriate.

Once onboard, if the aircraft is still running but no longer occupied, it may be necessary to make entry to the cockpit to shut down the aircraft’s engines and power. This may include pulling back on the engine throttles, shutting off the battery switches, and setting the parking brake. If the fire involves engines or APUs, ARFF personnel should activate engine fire suppression systems prior to securing the batteries. Once the batteries have been secured, lighting and
powered controls for doors, etc., will be inoperable. An illustration of the cockpit’s many electrical components is shown in figure 18.

Aircraft familiarization training in the cockpit should also include window operation, as shown in figure 19. ARFF fire fighters may need to open or close cockpit windows as part of a ventilation strategy. The cockpit escape equipment associated with the windows should also be reviewed in the event that the fire fighter needs an emergency exit point. With the assistance of a cockpit certified trainer, learning to operate the seats would be extremely helpful if trying to perform rescue of a member of the cockpit crew. Releasing the five-point seat belt, sliding the seat back to keep the crewmember’s feet from getting caught on pedals, and reclining the seat make removal of a crewmember much easier. It will never be easy, especially in a smoke-filled cockpit, but practice will help to sharpen the skill.

Figure 18. Training to Shut Down and Secure the Aircraft

Figure 19. Cockpit Window Operation
Cockpit familiarization should be completed by all ARFF members. Finding switches and controls to secure the aircraft in a dark, smoke-filled cockpit without prior training will be time consuming and potentially dangerous.

Most interior fires on intact aircraft can be expected to be in avionics, galleys, lavatories, or areas housing electrical equipment. There is a tremendous amount of electrical equipment in the interior cabins of the aircraft, primarily in the personal entertainment system components, as shown in figure 20. The heat generated by normal operation of this equipment on the A380 requires using air conditioning on the upper deck to maintain the comfort levels of passengers.

![Figure 20. Emirates A380 Business-Class Cabin](image)

Fires are categorized in four different classes in the U.S., as listed in table 6. In a major fire, water and foam can be used for all these classes since they are the agents that are available in the largest quantity on the fire apparatus. In smaller fires affecting individual components, it may be necessary to use specific agents designed for the particular class of fire being fought. In the U.S., the following table represents the different classes of fires.

<table>
<thead>
<tr>
<th>Fire Class</th>
<th>Description</th>
<th>Typical Extinguishing Agent Carried by ARFF Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Ordinary combustibles, wood, paper, cloth, some plastics</td>
<td>Water</td>
</tr>
<tr>
<td>B</td>
<td>Flammable Liquids (jet fuel, aviation gas)</td>
<td>Foam, dry chemical, Halon 1211, Halotron™</td>
</tr>
<tr>
<td>C</td>
<td>Electrical Equipment</td>
<td>CO₂, dry chemical, Halon 1211, Halotron</td>
</tr>
<tr>
<td>D</td>
<td>Combustible Metals</td>
<td>Class D-rated dry powder</td>
</tr>
</tbody>
</table>
After securing power to the aircraft or the affected circuit, isolated electrical fires should be fought using Class C agents, and full PPE must be worn. Electrical fires may spread to other areas, including structural components. These changes in fire loads must be evaluated during assessment and firefighting efforts to determine if additional or different classes of agent are required. Most Class C agents are also rated for Class A and B fires.

It is important to recognize that fire classes are not universal internationally. It is possible that a fire extinguisher found onboard an aircraft of European, Australian, or Asian origin may be labeled for a class of fire recognized in that country, but different from the classes recognized in the U.S. Table 7 provides a comparison of those fire classes.

<table>
<thead>
<tr>
<th>U.S.</th>
<th>European</th>
<th>Asia-Australia</th>
<th>Type of Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Class A</td>
<td>Class A</td>
<td>Ordinary combustibles</td>
</tr>
<tr>
<td>Class B</td>
<td>Class B</td>
<td>Class B</td>
<td>Flammable liquids</td>
</tr>
<tr>
<td>Class C</td>
<td>Class C</td>
<td>Class C</td>
<td>Flammable gases</td>
</tr>
<tr>
<td>Class D</td>
<td>Class F/D</td>
<td>Class E</td>
<td>Electrical equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class D</td>
<td>Combustible metals</td>
</tr>
</tbody>
</table>

10.2 AVIONICS BAYS.

The A380 has three avionics bays (main, upper, and aft), as shown in figure 21.

- The main avionics bay contains most of the aircraft computers and the electrical power center. This bay can be accessed from three locations: the forward cargo compartment, through the floor hatch in the cockpit, and the exterior of the fuselage. Figure 22 shows the exterior access hatch to the avionics bay.

- The upper avionics bay contains the emergency electrical power center, the network server, and the majority of the in-flight entertainment systems. The bay is accessible through a door in the bulkhead on the upper deck at the top of the forward stairs. In some configurations, a hinged portion of the leaning rail must be lifted to access the space.

- The aft avionics bay is only accessible through a hatch on the outside of the aircraft. Equipment in the aft avionics bay includes the trolley lift control center.

All three avionics bays and the in-flight entertainment centers are monitored by smoke detectors, but have no automatic suppression systems. All three avionics bays have ventilation systems that take air from the cabins and discharge it through the extract valve or the outflow valve when in flight. On the ground, the air is discharged through the overboard valves.
Figure 21. Avionics Bay Locations
(Compliments of Airbus)

Figure 22. Access Hatch From Forward Fuselage Left Side to Main Avionics Bay
The upper avionics bay is large enough for entry, and the entire space is not visible from the access door on the upper deck. There are a multitude of systems, lines, and wire bundles that could easily get caught on while crawling through this space. The space has smoke detection but no suppression. It has ventilation that will vent the majority of any smoke created in the space outside the aircraft, if the ventilation is still running.

The access points to the upper avionics bay are always in the same location aboard the aircraft, but due to the different configurations, they are not easily identifiable. The access point is on the right side of the aircraft on the upper deck. If ascending the forward staircase, turn left at the top of the stairs. The space in front of that access door is used for different functions in every configuration. It may be a lounge area, a rest room, or detailed for any function that suits the needs of the air carrier. Figures 23 and 24 show the access door in a lounge area. There is a leaning rail around the entire space. This railing is hinged in front of the door and needs to be raised to open the door. There is no method for locking the rail in the open position, so the railing will drop back in place when released. Figure 25 shows the access door in a lounge not equipped with the rail, and figure 26 shows the access door inside a lavatory. Once inside the upper avionics bay, the equipment mounting will be almost identical on all A380s.

Figure 23. Access to the Upper Avionics Bay From the Landing at the Top of the Forward Stairs

Figure 24. Upper Avionics Bay With Leaning Rail Raised, Exposing the Locked Door
Figure 25. Access to Upper-Deck Avionics From Lounge/Seating Area

Figure 26. Access Point to Upper-Deck Avionics Through the Lavatory

10.3 LAVATORY FIRES.

All lavatories have smoke detectors, as well as automatic fire-extinguishing systems in the waste bin. These systems use Halon 1211 or DuPont™ FE 36™, which is a low-toxicity, low ozone-depleting, clean, firefighting agent. Most lavatory fires are caused by a passenger sneaking a cigarette and disposing of it in the waste bin. The waste bin suppression system should handle this type of fire. Cabin crews are trained in the use of portable fire extinguishers to deal with lavatory fires. There are portable fire extinguishers and smoke hoods located throughout the cabins, as shown in figure 27.
There are up to 17 lavatories on the A380; 10 on the main deck, and 7 on the upper deck. As an added comfort feature for passengers, some lavatories that are against the fuselage have a window, as shown in figure 28. This is important to keep in mind for penetration considerations. Emirates Airlines include two showers for their first-class customers, as shown in figure 29. These are located on either side of the forward part of the first-class cabin, but they do not have windows like the lavatories do. If a lavatory fire exceeds the ability of waste bin suppression system or occurs on the ground when the cabin is not attended, it should be treated as any small interior fire. The size of an aircraft lavatory could be compared to a residential closet, and locking mechanisms are shown in figure 30. The spread of a lavatory fire into the cabin is reviewed in section 10.6.

Lavatory doors have privacy locks comparable to residential privacy locks in a home. As shown in figure 30, raise the panel above the indicator to expose the lock release on the A380.
Airbus offers a wide variety of A380 configurations. In addition to the main- and upper-deck cabins, additional spaces in the lower deck may be occupied. Currently, Qantas and Air France are using the lower-deck cabins for crew rest areas, as shown in figure 31. While these compartments are not expected to be occupied during takeoff and landing, it is important to note
that there have been numerous incidents of aircraft fires at the gate area that require fire
departments to do a complete search of the aircraft for occupants. In these situations, it is very
possible that crewmembers or cleaning personnel could be located in these crew rest areas during
a fire emergency.

![Image](image1.jpg)

Figure 31. Lower-Deck Cabin Crew Rest Area, Individual Bunk (Air France)

As new aircraft are built, this space may be used for additional functions. The crew rest areas
may be crew rest modules installed in the forward portion of the aft cargo compartment, or in the
aft portion of the forward cargo compartment. Primary access is from the main deck through a
locked door, as shown in figure 32. Inside the door, is a steep set of stairs (best if used as a
ladder) leading into the crew rest area, as shown in figure 33.

![Image](image2.jpg)

Figure 32. Access Door From Main Deck to Lower-Deck Crew Rest Area
Airbus offers a number of options for configuration on each of the three decks. Aircraft familiarization training for each carrier conducting service is the only way for ARFF to understand the layout and the challenges for access, rescue, or firefighting.

In preparation for the A380, ARFF crews can check the carriers’ websites to view the use of space. The carriers should also be contacted to get individual crash charts of the A380 in that carrier’s configuration.

When the lower-deck crew rest area is not installed or in use, this airtight hatch door is closed and locked, as shown in figure 34. This access door is opposite door M3R on this particular aircraft.
The lower-deck crew rest area (figure 35) includes 12 sleeping areas, which are protected by seven smoke detectors and a fixed fire-extinguishing system. Some lower-deck crew rest areas may be equipped with a small lavatory, as shown in figure 36.

Figure 35. Lower-Deck Crew Rest Area, A380

The secondary exit from the lower-deck crew rest area is designated by an exit sign, as shown in figure 37. The overhead panels in a designated bunk area are removable to access the escape hatch leading into the main deck cabin.

Figure 36. Lower-Deck Crew Rest Area Lavatory, Lufthansa A380
To use the emergency exit from the lower-deck crew rest areas, the overhead access panel must be removed. These panels and the directions for removal are clearly identified with instructional labels.

If the lower-deck crew rest area is located in the forward portion of the aft cargo compartment space, as in the Air France and Korean Air configurations, the access hatch ends up in the center seating area. It eliminates one seat to ensure the hatch is accessible. The row numbers will also vary depending on the seating configuration used by each carrier.

If the lower-deck crew rest area is located in the aft portion of the forward cargo compartment, as in the Lufthansa configuration, the escape hatch will be located in the middle of the left aisle floor, as shown in figure 38. Lufthansa uses a red outline on the carpet around the hatch to make it more visible, as shown in figure 38.
The lower-deck crew rest areas are protected by smoke detectors and a fire suppression system, as shown in figure 39. A fire in the lower-deck rest area that is not controlled by the fixed suppression system will need to be fought from the inside. Before advancing hand lines down the main access ladder, the escape hatch in the main deck will need to be opened with horizontal ventilation to an open door to relieve smoke in the main cabin. Familiarity with these spaces learned during aircraft prefire planning is essential to prepare entry teams.

Figure 39. Lower-Deck Crew Rest Area Fire Detection and Suppression

It would be impractical to advance a handline larger than 1.75 inches into this area due to the narrow ladder, tight turns, and narrow passageway. Ventilating this space will be critical to relieve the heat and smoke trapped in the space.

If the deck hatch in the main cabin is open, and fire and heat are not a factor at the entry door to the lower-deck crew rest area, advancing a dry handline is much easier and less fatiguing than a charged handline. If heat or fire is evident from the entry point, entry with an uncharged handline is not an option. Fire fighters positioned to feed the hose through the main cabin positioned at corners and pinch points will be necessary to allow the fire attack team to do their job in the lower cabin. A backup handline should be positioned to support the attack team operating in the lower cabin.

Without an understanding of configurations like this, a search in heavy smoke conditions would be very confusing. This lower-deck crew rest area has difficult access for fire fighters wearing full PPE and carrying equipment, due to the size of the entrance ladder and the limited circulation space. Rescuing up to 12 people from this space would be very challenging.
Most carriers have their flight crew rest areas just aft of the cockpit, within the secured area of the secure cockpit door, as shown in figures 40 and 41.

Figure 40. Main Deck Flight Crew Rest Areas Located Aft of Cockpit

Figure 41. Flight Crew Rest Areas Located Immediately Aft of the Flight Deck, in Air France, Qantas, Lufthansa, and Korean Air Configurations (Compliments of Airbus)
In the Emirates configuration, both the flight and cabin crew rest areas are together in the aft of the main deck, as shown in figures 42 and 43.

Figure 42. Cabin Crew Rest Areas (Emirates)

Figure 43. Crew Rest Area on Main Deck Aft (Emirates)
A crash axe is provided for the crews to use if they are unable to egress through the door.

It should also be noted that there is no fixed fire suppression system in these main deck crew rest areas, but they do have smoke detectors and a portable fire extinguisher.

10.5 GALLEYS.

There are at least two galleys on each A380, regardless of cabin configuration. Typically, one galley is aft near the rear stairway, and the second is midship. The galleys include trash compactors (figure 44), ovens (figure 45), and refrigerators (figure 46). Each galley has a service elevator (figure 47) to move carts between decks. A galley fire is likely to be electrical. If the aircraft is still energized, there are local power panels (figure 48) in each galley. The emergency power shutoff on the galley electrical panel should be secured before any firefighting effort. Thermal imaging cameras (TICs) or hand-held infrared thermometers are excellent tools for identifying the source of an odor or smoke in a galley.

Figure 44. Galley Trash Compactor
Figure 45. Midship Galley Ovens

Figure 46. Galley Refrigerators
Figure 47. Galley Service Elevator

Figure 48. Galley Electrical Panel, Including Emergency Power Shutoff
10.6 MAIN CABIN FIRES.

A fire in the main cabin that is confined to an individual space, such as a galley, lavatory, rest area, or bar is comparable in size to a one-room fire in a commercial structure. Entry teams should receive reports from flight crews or air traffic control, prior to making entry. These reports should be used to perform assessments and make tactical decisions for entry and fire attack. Fire fighters should check for fire extension and work with aircraft maintenance to isolate power and other hazards associated with the event. If in service, the aircraft positive-pressure ventilation system will handle a good deal of the smoke issues until the aircraft lands and doors are opened. An electrical failure will also cause the PPV system to shut down.

Recommended steps for fire fighters to take for a reported cabin fire on an NLA would include the following:

- If available, establish communications with the aircraft via radio enroute to the aircraft position.
- If the aircraft is said to be occupied, activate internal and external procedures to provide manpower and equipment necessary to evacuate or deplane passengers and crew as well as for their transportation or safe harbor.
- Upon arrival, establish command and begin populating Command Post.
- Upon arrival, if evacuation is in progress, assist in the evacuation/deplaning.
- Upon arrival, establish water supply and ready the attack line.
- With the entry team in full PPE, make entry with firefighting agent or tools sized for the reported threat and intelligence gathered through assessment.

10.7 INITIAL ENTRY.

It is not necessary or prudent to drag a fire hose into an aircraft cabin each time an odor or smoke condition is reported. It can actually delay intervention for the majority of the incidents that occur on aircraft. Frequently, the cause of the heat that caused an odor or smoke condition is already secured through a tripped circuit breaker or actions by the aircraft crew. A tool box, portable fire extinguisher, and a TIC are normally appropriate tools for initial entry for a report of an odor of smoke. An ARFF vehicle capable of deploying an attack line should be positioned at an appropriate entry point.

While the initial entry is in progress, ARFF vehicles on the exterior should be set up to protect the aircraft, provide reports of thermal scans conducted using fixed forward-looking infrared (FLIR) cameras on the ARFF vehicles, and be prepared to advance an attack line should the event escalate.

If the interior of the cabin is on fire, the attack will be entirely different. Evacuation and rescue should always be the first consideration. The assessment will determine if ventilation or oxygen
deprivation tactics are necessary. This tactic will be based on the number of doors open or closed, their position relative to the fire, and wind direction or other environmental factors. Interior fire loads in the cabin consist of a variety of materials. In many cases, the areas under the seats, as well as the overhead bins, will contain personal effects. The furnishings, partitions, and decorative finishes consist of a great deal of plastics.

The cabins are separated by partitions and curtains. All furnishings, partitions, galleys, lavatories, etc., serve as an obstruction for firefighting streams. Conducting a search of these cabins can be extremely labor intensive. Advancing hose lines around all the obstructions will be challenging due to the number of things on which the line can get caught.

Curtains and gates are used during flight to discourage passengers from passing between decks. Figure 49 depicts a gate that may be installed at the top of the rear stairway. (The rear stairs ascend spirally.) If approaching the stairs from the lower (main) deck, they will turn to the left before reaching the upper deck. As shown in figure 50, looking up the rear stairs from the lower deck will not provide a visual of conditions on the upper deck without climbing the stairs.

Figure 49. Gate at Top of Stairway
The forward stairs are also equipped with a gate and a curtain. These are primarily used to discourage passenger movement between decks. As shown in figure 51, when not in use, the gate and curtain are secured in the open position at the top of the stairs on the right side when looking from the bottom of the stairs. As shown in figure 52, when open, the gate locks securely in place, and the curtain opens to block the view between decks. All gates and curtains should be in the open and secure stowed position during taxi, takeoff, and landing.
Some A380s might have another curtained area to provide privacy for an ill passenger. As shown in figure 53, in the Lufthansa configuration, a bed is folded and stored in the overhead compartment over the seats in row 21. The bed can be installed over a row of seats in a designated location. Once installed, a curtain can be pulled to give the person in the bed privacy, as shown in figure 54.
The typical length of an attack line on an ARFF vehicle seldom exceeds 200 ft. The selected entry point for interior attack lines should be carefully selected. If entering through a forward door (which is the most likely position for a jet bridge or stair truck to be positioned during normal aircraft operations), it is quite possible that a 200-ft hose line will not be long enough to reach the opposite end of the cabin. If the attack line is coming from a structural pumper rather than an ARFF vehicle, this may not be a factor. Consideration should be given to using additional lengths of hose, commonly referred to as a “high-rise pack,” which could be attached to the penetrating nozzle discharge or other elevated water source at the door to allow for longer reaches inside. As shown in figure 55, the HRET boom can be used as a waterway. Entering through the door (or doors) located a safe distance from the area involved in fire while keeping the largest uninvolved portion behind the interior attack team will protect that larger portion of the cabin.
10.8 CONSIDERATION FOR INTERIOR FIRE ATTACK.

There is no typical fire in any aircraft cabin. The decision to take an offensive or defensive approach is a matter for on-scene incident commanders and safety officers. A risk analysis must be conducted as part of the size-up to determine if an interior fire attack is appropriate. This guidance is not directing a method but rather serves as guidance, using accepted firefighting tactics if it is determined to be prudent.

The same initial decisions made by structural fire fighters every day are present in the decision-making process to establish an IAP. Departments should have Standard Operating Guidelines (SOG) in place to assist crews in this initial action. Safety is always the primary factor in the decision-making process. There are certain fire scenarios (e.g., small fires within easy reach of an accessible entry point) that, if acted upon quickly, could be stopped upon arrival with minimal water, thus minimizing damage. Without such SOGs, preplanning, and training, this type of “fast stop” is less likely.

A fire that is beyond that scope, particularly one in a wide-body, multideck aircraft, should not be approached without adequate resources, planning, and training. The determination of what is adequate is the subject of preplanning.

A B-747 or an A380 is a multideck structure with up to three decks designed for occupancy. The two primary decks have no suppression systems in the cabins. Each of those decks has multiple obstructions and two aisles. Due to the obstructions of the seats, lavatories, business and first-class seating pods, first-class suites in some configurations, crew rest areas, and the size of the cabins themselves, a single attack hose line is not sufficient for a well-involved cabin fire, see figure 56. Advancing hose lines through the cabin will require planning for hose line size and manpower to man the nozzle, as well as to advance lines through pinch points and around corners and bulkheads. The size of the hose line is a consideration that has been well defined in structural firefighting.

![Figure 56. Obstructions to Direct Attack Through Entry Doors](image-url)
If an interior fire attack team enters through this door, obstructions eliminate the possibility of an immediate direct attack from the entry door position, unless the fire is in this immediate area. If the fire is accessible for a direct attack from the door position, fire fighters should stay low, allowing the smoke and heated gases to escape through the top portion of the open door.

Hose line selection should be based on the flow rate required, the reach of the stream required, the size of the space involved, and the size/intensity of the fire.

The following guidelines are provided by the International Fire Service Training Association (IFSTA) *Essentials of Fire Fighting*, 5th edition [12], and are modified here to reflect a scenario on a multideck aircraft. On a wide-body aircraft with two aisles, the recommended hose line applies to each aisle, see table 8. If the fire is beyond the “small developing fire” stage, or is located a distance from the closest access point, an appropriately sized line should be advanced simultaneously in each aisle.

### Table 8. Hose Line Characteristics

<table>
<thead>
<tr>
<th>Size Inches (mm)</th>
<th>GPM (LPM)</th>
<th>Reach Maximum Feet (m)</th>
<th>When Used</th>
<th>Effective Area (Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 (38)</td>
<td>40-125 (160-500)</td>
<td>25-50 (8-15)</td>
<td>Small developing fire. Anticipated to be easy stop.</td>
<td>One to three cabins on same deck.</td>
</tr>
<tr>
<td>1.75 (45)</td>
<td>40-175 (160-700)</td>
<td>25-50 (8-15)</td>
<td>Quick attack when ratio of fuel load to area is relatively light.</td>
<td></td>
</tr>
<tr>
<td>2 (50)</td>
<td>100-250 (400-1000)</td>
<td>40-70 (12-21)</td>
<td>When intensity or size of fire exceeds capability of smaller line. When larger water volume or longer stream reach are required. Requires adequate manpower and water supply.</td>
<td>One deck or more with heavy fire load.</td>
</tr>
<tr>
<td>2.5 (65)</td>
<td>125-350 (500-1400)</td>
<td>50-100 (15-30)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: GPM = Gallons per minute. LPM = Liters per minute

Regardless of the type of attack, ventilation is an essential element to relieve the heat and gases from the space, making it safe for fire fighter entry. Opening a door on the end of the aircraft toward which the interior attack teams are advancing, along with the water stream, will help ventilate the fuselage through the open doors. This is known as horizontal ventilation. In
figure 57, fire fighters demonstrate horizontal ventilation by initiating fire attack through the rear door and forcing the smoke out the front door.

The selected method of agent application should be based on the fire conditions, manpower, hose line size, flow rate, and length available. The properties of water are used to cause a change in the properties of fire. Water absorbs heat and therefore cools the fire and the space around it. Water also can isolate or dilute oxygen, which has a smothering effect on a fire. When water has absorbed enough heat to boil, it is converted to steam. When water is heated to its boiling point (212°F), it expands 1700 times. A single drop of water that has expanded 1700 times its original volume occupies 1700 times as much volumetric space, allowing it to displace more hot gases and absorb more heat. This steam conversion and expansion can be very effective in cooling and ventilating a fuselage. It can also be very dangerous to occupants and fire fighters in the space.

In general, steam conversion is part of fire extinguishment. There is a significant increase in the amount of heat absorbed when the expansion occurs through steam conversion. Fire fighters in an interior attack need to possess a thorough understanding of this characteristic of water and how to manage it during an interior fire attack.

The heat created by the fire, which is trapped and building in the aircraft cabin, may make entry for fire fighters too dangerous. With an enclosed interior fire, thermal layering of gases occurs according to temperature. The hottest gases rise to the highest levels and form the top layer.
Cooler gases form the lower layer. This leaves the lower levels safer for fire fighters. Improper application of water to unventilated areas disrupts the thermal balance that has been created and causes smoke and steam to circulate in all levels of the space. This disruption creates a significant burn hazard to fire fighters.

The interior environment must be made tenable for entry teams. If the thermal balance is disrupted, forced ventilation is required to reduce temperatures to safe levels for entry. If the balance has not been disrupted, fire fighters may still be able to operate beneath the thermal layering to initiate fire attack, depending on the location of the fire.

A direct attack may not be possible, as the fire will likely be shielded by bulkheads, seats, and other obstructions. In this case, if entry crews enter the fuselage, they will be working directly below the hot gas layer. This is extremely dangerous, as the conditions overhead may transition to a flashover or rollover at any time. To make safe entry, gas cooling should be accomplished. From the doorway, fire fighters can set their nozzles to a 40- to 60-degree fog pattern, and discharge short, 1- to 2-second bursts into the overhead gas layer. This effort is designed to cool the gases, allowing for safe entry, not to convert large quantities of steam. When water droplets fall down from the overhead, it is an indication that the gas layer has been cooled. This method may need to be repeated, as interior attack teams advance into the cabin. In narrow areas, the discharge pattern may need to be tightened. In wide open areas, the pattern may need to be opened wider.

A direct attack is considered the most efficient use of water on a fire. Water should be discharged directly into the burning products in short bursts using solid or straight streams. This technique is called “penciling.” The visual indicator that the method is working is when the fire darkens down. Another direct attack method called “painting” can be used to cool the hot surfaces of the fuel by applying a lighter spray over the hot material. This discharge should not be constant, because it tends to produce more steam in the area occupied by fire fighters.

The cabin of a jumbo aircraft is very long; the length of the aircraft is a long crawl when dragging a hose. During that time, fire fighters must remain aware of hazards. If the entry team is conducting search and rescue, a TIC is highly recommended. Although the straight aisles are easy to follow and maintain direction and orientation, the depth of the rows of seats, particularly the center section shown in figure 58, make a hand search very time-consuming, and perhaps beyond the capability of a single self-contained breathing apparatus (SCBA) bottle. If ventilation and other efforts have not improved visibility, a TIC in each aisle will significantly reduce the time required for a full search of the aircraft. The TIC is also helpful in finding hot spots.

Due to the depth of each seat row, a search in a smoke-filled environment is very time-consuming. A search should be conducted from both aisles between members who have communications with each other and with the incident commander, with coordinated progression clearing one row at a time. More manpower can be used to coordinate a faster search.
In a dark, smoke-filled cabin, visibility is zero. Figure 59 provides the view of an aircraft cabin in normal visibility. In a fire condition, the same space would simply be black. Figure 60 provides the view of the same cabin through a TIC when blacked out with smoke. When using a TIC, thermal images of anything with a heat signature different from the ambient temperatures become apparent.
The overhead storage bins are fastened directly to structural components and are designed to carry the weight of the contents, as shown in figure 61. A hard landing, structural damage, weight shift, introduction of additional weight from water, or exposure to fire, may affect the integrity of the mounting system. Fire fighters must remain aware of this possibility on any aircraft; if the mounting system fails, the loaded overhead bin would certainly cause injury if it landed on a fire fighter or occupant. Fortunately, the design of the cabin builds in a relative level of protection. The seat backs will likely absorb most of the energy of a falling overhead bin. Contents may spill out, potentially striking a fire fighter or occupant; the addition of the bins and the spilled contents will complicate passage in the aircraft. Fire fighters in the aisle, particularly in a crawling position, would have a fair amount of protection from a falling bin. An exception is when the compartments are over the center section seating pods, as in some carriers’ business-class and first-class cabins.
11. THE HRET OPERATIONS.

A great deal of information on HRETs has been released by the FAA. Advisory Circular 150-5210-23, “ARFF Vehicle and High Reach Extendable Turret (HRET) Operation, Training and Qualifications” [13] provides operational information, tactical guidance, and training and proficiency guidance. The FAA also released an ARFF Training DVD on HRETs, which has been distributed to all certificated airports. Copies may be requested from the FAA Airports Regional Offices.

HRETs provide an opportunity to introduce firefighting agent into an aircraft without having firefighters enter a potentially hazardous environment. Interior entry and firefighting is labor intensive and certainly not without risk. A properly trained and equipped entry team may be able to make a quick stop with an aggressive interior attack. An evaluation of resources available will include a review of the specialized equipment available, as well as manpower and water supply. Interior fire attack may require multiple platforms for boarding, or to open or close doors as part of a ventilation strategy. Incident commanders must make decisions as to each action taken by ARFF crews for each incident. Factors in the decision-making process include knowledge of the aircraft, preplanning experience, SOGs, conditions present, and resources available.

If the HRET is to be deployed as the primary method of applying agent, or as part of an interior fire attack strategy, these factors must be considered in the preplanning and in the IAP development.

The use of HRETs and ASPNs to introduce agent is an advanced technology method of interior firefighting. It affords fire fighters the opportunity to launch a direct attack without making entry. The attack must be choreographed to include the required method of ventilation and monitoring. The HRET, in the hands of a skilled operator, can be deployed quickly. If the area involved in fire is known, and proper tactics are employed, a fast stop of fire progression is possible.

11.1 THE HRET DESIGN AND CAPABILITY.

Piercing technologies have been developed to provide an opportunity for an ARFF vehicle operator to pierce an aircraft fuselage and introduce agent through an ASPN. Currently approved HRETs use an extendable boom mounted on the top of an ARFF vehicle. The boom can be controlled and positioned by the driver or the operator in the right-hand seat.

HRETs are available in various lengths. The FAA does not differentiate the need for longer or shorter booms, but rather, identifies the performance requirements necessary to pierce the tallest aircraft with service at the airport. There are currently two different types of piercing technology available for use on ARFF vehicles. The first uses boom hydraulics, with the piercing tip aligned with the boom, as shown in figure 62. Once in position, the boom is extended forward and the ASPN pushes through the fuselage. Once fully through the fuselage skin and interior trims, the discharge holes on the ASPN are exposed to the interior of the fuselage and provide a wide spray pattern inside the aircraft to extinguish the fire.
The second technology uses hydraulic accumulators, as shown in figure 63. In this application, the boom, which does not have to be aligned with the piercing tip, fires the tip quickly through the skin and interior trims rather than pushing through. The ASPN is stored within a tube prior to firing.

Both types of technology provide a very similar discharge pattern through the ASPN, as shown in figure 64. This pattern inside an enclosed fuselage covers a large area and provides a great deal of cooling.
11.2 USING HRET FOR REMOTE ACCESS TO AIRCRAFT CABIN.

The HRET can be positioned at an aircraft door for interior firefighting. On certain doors, HRETs can be positioned inside the aircraft using the boom-mounted lighting, optics, and turret for evaluation and interior firefighting, as shown in figure 65.

11.3 USING FLIR CAMERAS AND TICs.

One of the most valuable tools used in evaluating fire conditions onboard an aircraft is the FLIR camera. The heat created by the fire onboard may present as a bright spot or “bloom” on the FLIR camera’s display. If visible, this bloom will identify the location and relative intensity of the fire.
FLIR cameras were originally installed on ARFF vehicles to aid in low-visibility responses. The cameras are able to see heat signatures at distances up to 1200 ft. They can assist drivers to more safely drive in heavy fog or other periods of restricted visibility by picking up heat signatures of runway lights, vehicles, personnel, and aircraft. TICs are usually hand held and are designed for portable use during interior operations. These cameras read temperatures at a lower scale and may be able to see heat signatures on the aircraft exterior not visible through a FLIR camera.

This technology is more likely to be helpful on passenger aircraft, as the heat is more easily transferred through the aircraft window than through the solid fuselage of a freighter aircraft. FAA testing has indicated that the shielding of heat through the aircraft skin, insulation, and cargo liner may block as much as 800°F of heat.

By combining the available technologies of FLIR cameras, TICs, and ASPNs, the greatest benefits can be achieved by identifying the location and relative intensity of the fire inside the aircraft. Using the heat signatures, as well as knowledge of aircraft construction, the ideal piercing location can be selected.

FLIR cameras or TICs provide the advantage of monitoring the effectiveness of any action taken. If the image provided through the camera indicates the firefighting efforts are not having the desired effect (the bloom is not reducing in size despite the agent application), re-evaluation will be necessary because it is likely the agent is not reaching the fire. On the other hand, if the bloom is not growing in size or intensity and/or is diminishing in size or intensity, this indicates that the action taken is having the desired effect upon the fire.

A thermal scan of an aircraft will identify all heat signatures on the exterior of the aircraft, as shown in figure 66. Also visible in the scan is absorbed heat on the steel mockup, reflective heat on the ground, and heat from the apparatus engine. Training helps develop an understanding of normal heat signatures. As an assessment tool, a thermal scan of a closed compartment adds valuable data to the risk analysis performed prior to decisions to open doors or pierce spaces.

![Figure 66. The FLIR Cameras Identifying Heat Signatures](image)
It is important to recognize visual reference points (such as cabin windows) and use the FLIR cameras or TICs to identify heat signatures and possible piercing locations, as shown in figure 67.

As a rule of thumb, when piercing into a passenger aircraft fuselage, the operator should try to avoid any rivet lines and be approximately 10” to 12” above the top of the window. This location should put the piercing tip above the seat backs and below the overhead bin. Piercing lower on the passenger aircraft will result in the passenger seats blocking 50% or more of the stream’s available discharged pattern from the ASPN.

Piercing into the overhead storage bins will reduce the effectiveness of the spray pattern. In tests conducted by the FAA, piercing into the overhead compartment still provided the introduction of agent into the aircraft cabin; however, the pattern and effectiveness were significantly reduced. In each test, the storage compartment door was opened, or partially opened, either by the force of the stream or by the contents being pushed against the door by the piercing tip, as shown in figure 68.

Figure 67. The Best Guidance for Piercing Locations
(Graphic Compliments of Crash Rescue)

Figure 68. Testing to Understand the Effect of Piercing the Overhead Bin
The piercing tip can be used very effectively in the removal of aircraft cabin windows. Positioning the piercing tip and slowly extending the tip and pushing the window will cause the window mounting clips to break, forcing the window to drop into the aircraft cabin. Although the windows can be penetrated rather easily on most aircraft, as shown in figure 69, the seats can block 50% or more of the effective fog spray. A removed window could be used as part of a ventilation strategy or, if deemed appropriate, as an element of an indirect fire attack.

Figure 69. Window Removal Using an HRET

11.4 UPPER-DECK PIERCING.

Some HRETs with ASPN are capable of reaching the required height, gaining the proper angle, and piercing into upper-deck cabins above the seats and below the overhead bins necessary for NLA. However, this maneuver is much more challenging than piercing a lower deck. The reasons are largely based on visibility and visual perception. To be within range of the boom to reach the required elevation to pierce the upper deck, the ARFF vehicle must be positioned fairly close to the aircraft. The piercing heights for the three A380 decks are:

- Lower deck: 13.6 ft
- Main deck: 23 ft
- Upper deck: 31 ft

The standoff position is the distance between the front bumper of the ARFF vehicle and the fuselage, as shown in figure 70. To pierce higher on a fuselage, as may be required for the upper deck of a B-747 or A380, the ARFF vehicle must be positioned closer to the fuselage. A vehicle positioned closer to the aircraft is said to have a “reduced” standoff position. From this reduced standoff position, the operator’s view is significantly reduced. The reference points for positioning and alignment are achieved by looking up at 50–60 degrees through the top of the windshield. The piercing location for upper-deck piercing uses the same reference points as for
main-deck cabin piercing. The ideal position is between the top of the seat backs and the overhead storage bins. The reference point is 10” to 12” above the top of the upper-deck cabin window. This reference point is on the steeper angle of the fuselage curve, and beyond the widest point or midpoint of the fuselage. As the standoff position of the ARFF vehicle reduces, so does the view of the operator of this piercing location. FAA testing has found that, not only does the view of that piercing location diminish, but due to the steeper angles of the curve, the driver’s perception to determine when the ASPN is level is nearly impossible.

Some ASPNs have a tendency to skip or slide along the fuselage when on the curve. Positioning the ASPN on an angle perpendicular to the surface curve will improve the chances of a successful penetration, but the “bad angle” will impact the effectiveness of the spray pattern.

When piercing a cabin on a passenger aircraft, regardless of which deck, the ASPN should be level and enter the aircraft between the top of the seats and the bottom of the overhead bin. This position will allow the most effective spray pattern without being blocked by the seats. The view and perception of the ASPN angle is affected by the reduced standoff position and the inability to visually reference beyond the curve of the fuselage.

Figures 71 and 72 show the angle of the ASPN during FAA piercing tests where a skilled operator repeatedly pierced at this angle, although confident that the orientation of the ASPN was level. The downward angle reduced the effectiveness of the pattern, and the seats block about 50% of the spray.
Positioning the ARFF vehicle at the greatest distance from the aircraft that the HRET can be effective increases the driver's view and accuracy in piercing position and angle. Figure 73 shows an ARFF vehicle with HRET operating at the furthest possible point of the recommended standoff position. The driver has achieved greater safety through distance and a full view of the piercing operation. Developing proficiency in positioning the vehicle in the proper standoff position required repetitive training.
11.5 FIRES IN LOWER DECK (BELLY COMPARTMENTS).

The lower deck of the A380 is divided into three cargo compartments. The compartments on the lower cargo deck are also referred to as belly bays or cargo holds. The most aft compartment is the bulk cargo compartment (or bay). Loose freight or baggage that is not stored in ULDs is kept in this compartment. The aft compartment begins aft of the main landing gear and ends just forward of the bulk cargo compartment. The forward cargo compartment begins forward of the main gear and ends just aft of the main avionics bay. On some A380s, the aft cargo compartment extends forward into what the airlines refer to as a tunnel. As shown in figure 74, the tunnel is narrower than the aft main cargo compartment. It will accommodate freight pallets, which must be turned sideways on the rollers to fit into the narrower tunnel. Attempts to pierce into the freight tunnel using current ASPNs on HRETs will not be effective. An ARFF vehicle’s approach to that portion of the fuselage will be obstructed by wings and engines and make access nearly impossible. If access could be made, the wing-to-body fairing, the cheek area, and the additional bulkhead in the tunnel create a 74-in. distance from the exterior skin. To effectively penetrate the tunnel with the discharge holes of the ASPN exposed to allow full-rated flow pattern, the piercing tip would need to be 82 to 84 in. long.

Cargo containers and cargo pallets are known as Unit Load Devices (ULD). The forward cargo compartment has a loading door on the right side in the forward 1/3 of the cargo compartment. This compartment can carry up to 22 LD-3 cargo containers or 7 cargo pallets. The aft cargo compartment has a loading door on the right side in the aft portion of the cargo compartment. The aft cargo compartment can carry up to 16 LD-3 cargo containers or 6 cargo pallets.
The bulk cargo compartment is the furthest aft portion of the aft cargo compartment, and carries hand-loaded cargo, not cargo containers or ULDs. Both the bulk cargo compartment portion and the aft cargo compartment are ventilated with recycled air from the cabin. The temperature in the bulk cargo compartment is also regulated. Access to the bulk cargo compartment is available through the aft cargo compartment and vice versa. There is also a dedicated bulk cargo door located aft of the aft lower-deck cargo door on the right side of the aircraft.

The cargo compartments are equipped with smoke detectors that are monitored in the cockpit. The cockpit crew can activate the cargo compartment extinguishing system controlled by the Cargo Smoke panel in the cockpit. If the affected compartment is a ventilated cargo compartment, the ventilation is automatically isolated.

Fires in cargo compartments equipped with detection and suppression systems have proven to be quite effective. Typically, the fire suppression system uses a clean agent to flood the cargo compartment. Opening the cargo door prematurely may provide oxygen to the oxygen-starved fire, and allow re-ignition. FLIR cameras and TICs may be helpful in checking the heat in the compartment before cargo doors are opened. The flight crew and the aircraft maintenance group should be involved in the decision making with respect to actions to be taken after the fire-suppression system has been activated in a cargo compartment, unless obvious fire conditions are present.

The cargo compartments are isolated from the walls of the fuselage by bulkheads. These bulkheads provide a clean space with vertical walls in a round space, separating the freight area from the fuselage walls and the systems that are attached to them. The voids created between the fuselage and the cargo compartments are called the cheek areas. These cheek areas are fairly deep in large aircraft, i.e., 42 in. at the narrowest point on an A380. The cheek area locations are shown in figure 75. The cheek areas contain wiring, piping, and other aircraft components.
Figure 75. Lower Cargo Compartment Configuration

Piercing through the cheek area for a fire in the lower cargo compartment is not an effective strategy because the ASPN is not long enough to pass through the cheek area and into the cargo compartment. Figure 76 shows a measurement of the cheek area immediately inside the rear cargo compartment door. At that position, the cheek area is 42 in. at the narrowest point on the A380. However, if the fire is in the cheek area, an HRET with an ASPN may be very effective. It may be difficult to determine whether a fire is burning in the cargo compartment or in the cheek area. One of the best indications would be blistering paint or other signs of heat on the skin.

Figure 76. Cheek Area Inside Rear Cargo Compartment (42 in.)

From the position between the rear cargo door and the wing root, the wing fairing flares out on the exterior of the aircraft. This increases the distance between the exterior skin and the open cargo compartment. This is not a suitable area for piercing for three reasons.
• The distance is far greater than the length of ASPNs on HRETs.

• The wing box structure is among the strongest components on the aircraft. Piercing through that material is not an option.

• The wings and engines present an obstruction to positioning the ARFF vehicle.

The flare of the wing fairing, looking forward from the rear cargo compartment, is shown in figure 77, and the outside view is shown in figure 78.

![Figure 77. Flare of Faring Between Cargo Compartment and Wing](image)

![Figure 78. Outside View of Wing Faring Flare](image)

If the fire is in the lower cargo compartment and the onboard suppression system did not succeed in extinguishing the fire, the ASPN may be used to pierce through the cargo door itself. The thickness of the cargo door is well within the ability of the ASPN to pass through. The edges of the door and the door frame, attachments, and locking mechanisms should be avoided, as they
are the most heavily reinforced points on the aircraft. A position should be chosen that is toward the center of the door to avoid rivet lines or door controls. This is the best area to successfully introduce agent into the lower cargo compartment with the ASPN.

FAA research has shown that Halotron has promising effects on fires in sealed cargo compartments when used as a flooding agent through the ASPN. Typically, there are vents in these compartments that are open when the aircraft is on the ground. Normal landing procedures and depressurization opens the vents and outflow valves. If the cockpit crew is still onboard, it may be possible to close the vents to reduce Halotron leakage. It is also possible to block the outflow valves to reduce the leak rate.

Access into the lower rear cargo compartment can be achieved through the bulk cargo compartment, which is the furthest aft door on the right side of the aircraft. This compartment is used for hand-loaded luggage, and it is equipped with a door that easily opens manually. Once inside, it may be necessary to remove luggage, but the door and compartment allow direct access into the lower rear cargo compartment. The bulk cargo compartment and the aft cargo compartment are separated by a cargo net, as shown in figure 79.

Figure 79. Aft Cargo Compartment With Cargo Net Separating the Bulk Cargo Compartment

12. CARGO COMPARTMENT DOORS.

For a fire in the cargo compartment, careful consideration must be given to determine if there are benefits in gaining access to the space. Cargo compartments are typically full of freight. The freight is first loaded into ULDs or pallets, which are metal trays equipped with nets that hold the freight in place. There is no circulation space or aisles where fire fighters can gain access to a burning ULD. Figure 80 shows a ULD loaded in a lower cargo compartment. Removing the ULDs to gain access to another ULD is not a good option. Maintaining the load and balance of
an aircraft is critical to the safety of any operation. Removing a ULD in the wrong order could cause the aircraft to tail tip, jeopardizing the safety of everyone involved. Unloading an aircraft requires specialized equipment and training. Fire fighters who have not had special training in unloading aircraft would be endangering themselves, others, and the aircraft. Allowing the airline workers to unload the aircraft would require authorizing them to be in the hot zone. Cargo offloading operations are shown in figure 81.

Figure 80. A ULD in Position in Lower Cargo Compartment

Figure 81. Cargo Offloading Operations

Once a decision has been made to access the cargo compartment, options for entry must be considered. The easiest way to gain access to any structure is through the normal entries using the same methods and controls that are used during nonemergency situations. This may be an option depending on what power is still on in the aircraft and what damage has been caused by
the fire. Aircraft familiarization and preplanning are the best times to determine the options available for opening doors. Airline representatives can provide technical guidance during the emergency. Crash charts and the ARFF Working Group ARFF database can provide detailed instructions for opening doors electrically, hydraulically, and manually.

Forcible entry on a cargo door is not an option. The construction, locking mechanisms, and the size and weight of the door make it impractical. In February 2006, Philadelphia, PA, fire fighters were challenged with forcible entry on the main cargo door on a Douglas DC-8 (UPS 1307), which landed at Philadelphia International Airport with a cargo fire onboard. The rescue company’s attempts to force the door by cutting the locking mechanisms proved futile, see figure 82. The A380 door is larger, heavier, and just as formidable as the DC-8 door.

![Figure 82. Philadelphia Fire Fighters Attempt Forcible Entry on a DC-8 Cargo Door](image)

The doors can be operated hydraulically with the toggle switches available on the cargo door control panel, which is located to the right of the forward and aft cargo door. If the power to the aircraft has been secured, electric operation of the door is not an option. The bulk cargo door can be manually operated; procedures are shown on the fuselage or adjacent to the door, as shown in figures 83 through 85.
Bulk Cargo Door Operation—Door Opening
1. Press Push Button to release handle.
2. Move Handle to “UNLATCHED”, and open door partially.
3. Move Handle to “LATCHED”.
4. Open Door Until Latched and Push Handle into Recess.

Figure 83. Bulk Cargo Door Operation

ENSURE RED WARNING LIGHT INDICATING PRESSURIZED CABIN IS NOT FLASHING
1. Push in Flap to Grasp Handle.
2. Pull Handle to UNLATCHED/UNLOCKED.
4. Push Toggle Switch to OPEN Position until the Green Light is On.

Figure 84. Forward Cargo Door Operation
Same Operation as Forward Door.
ENSURE RED WARNING LIGHT INDICATING PRESSURIZED CABIN IS NOT FLASHING
1. Push in Flap to Grasp Handle.
2. Pull Handle to UNLATCHED/UNLOCKED.
4. Push Toggle Switch to OPEN Position until the Green Light is On.

Figure 85. Aft Cargo Door Operation

Opening the cargo door on a loaded cargo compartment will only provide access to the cargo containers immediately inside the door. Again, airline representatives should be consulted prior to attempting access to these spaces. If removal of cargo containers is necessary, the aircraft representatives must be on hand to oversee operations and safety.

A cargo loading platform may provide the best access to a cargo compartment. It will provide a safe platform from which to work if access is necessary. A cargo loading platform is designed to span the width of the door, and can be raised and lowered, as needed. Caution must be taken because of the rolling casters located on the deck surfaces within the cargo compartments. Airline personnel should be consulted for safe operation. These cargo loading platforms are very large. They move very slowly and have no off-road capability and are designed to operate on paved, level surfaces. If the aircraft is on or adjacent to a cargo ramp, these vehicles may be nearby and using one may be a viable option. If the aircraft is located off the hard surface or at a great distance from the cargo ramp, other options should be explored.

13. LANDING GEAR AND BRAKE HAZARDS.

Emergencies involving landing gear, wheels, brakes, and tires on NLA have the same types of concerns as all other large aircraft. There are, however, certain differences of which emergency responders should be aware. This section identifies specific guidance and procedures for issues related to the undercarriage of the A380.
13.1 BRAKE OVERHEAT.

The following guidance regarding brake overheats was provided by an Airbus representative:

- Brake overheats can be caused by:
  - Aborted takeoff
  - Emergency braking
  - Frequent use of brakes
  - Braking system fault
  - Overweight or short landing

- High brake temperatures may cause damage to gear, struts, and axles.

- Hot brakes, if not treated properly, pose significant risk of tire explosion and rim disintegration.

- Hot brakes, combined with hydraulic leak or grease build up, can cause an undercarriage fire.

- Brake temperatures are monitored from the cockpit. ARFF communications with the cockpit should be attempted to gain the pilot’s interpretation of the conditions.

- If fusible plugs have melted and the tire(s) deflated, the wheels should be approached from forward or aft, and water mist should be used to cool the wheels.

- After brake temperatures drop (approximately 1 hour), when struts and axles are no longer in danger of warping, brake fans or PPV may be used to aid in cooling.

  CAUTION: Carbon fibers created in the brakes during braking may become airborne when brake fans or PPV are activated. Full PPE, including SCBA, must be maintained during this operation. Fan placement and downwind effects of airborne carbon fiber should be considered.

13.2 WHEEL FIRES.

If wheels are burning, the danger of fire extension exists. ARFF personnel should not wait for tires to deflate if fire attack can be launched safely. The preferred attack is from an ARFF vehicle, which will provide some protection for firefighters in the event the wheel or tire disintegrates. Attack the wheel fire by applying a blanket of AFFF using the turrets from a forward or aft position to the aircraft. In addition to the physical protection offered by the truck, the turret provides greater range and standoff distance from the fire and hazards presented.

The A380 has 22 wheels, as shown in figure 86, and:

- One set of nose landing gear (NLG)
Two sets of wing landing gear (WLG)

Two sets of body landing gear (BLG)

Figure 86. The A380 WLG and BLG–View From Front
(Photograph taken from right side of aircraft)

What fire fighters commonly refer to as the main gear are specifically called wing and body landing gear. WLG and BLG wheels are numbered for identification. Nose gear wheels are not numbered. For the WLG and BLG, the numbering starts from the left side (just like engines), and then moves aft. The first row of gear on the A380 is the WLG. From left to right, the wheels are referred to as 1, 2, 3, and 4, as shown in figure 87. The next row of WLG starts with 5 on the left side, followed across as 6, 7, and 8. The BLG rows follow suit, with numbering starting on each row at the left.

Figure 87. Landing Gear Numbering System
The following systems are associated with the gear: landing gear extension and retraction system (LGERS), braking system, and steering. The tire pressure, brake temperature, and landing gear shock-absorber pressures are monitored from the cockpit.

Certain specific information relative to the operation of the landing gear and brakes are important for ARFF personnel, based on the way pilots typically report failures. On the A380, a pilot is likely to report a failure of the GREEN Hydraulic System or the YELLOW Hydraulic System. An understanding of what is controlled hydraulically or electrically better prepares ARFF personnel for potential effects of the reported anomaly.

As a quick reference:

- **GREEN** Hydraulic System controls NLG, including steering and WLG, and associated gear doors.
- **YELLOW** Hydraulic System controls BLG, including BLG steering and associated gear doors.

Sections 13.3 through 13.5 provide more detailed descriptions of these systems.

**13.3 LANDING GEAR EXTENSION AND RETRACTION SYSTEM.**

Normally, the landing gear on an A380 extends and retracts hydraulically. The unlocking function, which allows it to release from its up and locked position, is controlled electrically. The GREEN Hydraulic System controls the NLG and WLG and the associated gear doors. The YELLOW Hydraulic System controls the BLG and the associated gear doors. In the event of a failure that does not allow normal use of the LGERS, a gravity-assisted landing gear extension may be performed. This is accomplished electrically through two free-fall control modules.

**13.4 BRAKING SYSTEMS.**

The A380 has 16 carbon brakes. There is one brake on each WLG wheel, and one brake on each of the four forward-most wheels on each BLG. There are no brakes on NLG or on the rear two wheels on each BLG. In normal braking, the GREEN Hydraulic System powers brakes in the WLG. The YELLOW Hydraulic System powers brakes in the BLG.

In addition, there is a Local Electro-Hydraulic Generation System (LEHGS), which serves as an independent hydraulic power source. The LEHGS has its own electrically powered hydraulic pump, hydraulic reservoir, and controller. In abnormal braking scenarios, the LEHGS are used as well as the hydraulic accumulators.

**13.5 STEERING.**

The A380 has steering systems for the nose wheels and for the rear four body wheels. Normally, the nose wheel steering is powered by the GREEN Hydraulic System, which is backed up by the LEHGS and nose wheel steering accumulators. The body wheel steering is powered by the YELLOW Hydraulic System.
14. HYDRAULIC AND COOLING SYSTEMS.

While the B-747-8 Intercontinental still makes use of a 3000-psi hydraulic system, which is the typical hydraulic pressure on aircraft, the A380 includes eight engine-driven hydraulic pumps rated at 5000 psi. There are two hydraulic systems on the A380; they are designated as the GREEN Hydraulic System and the YELLOW Hydraulic System, as shown in table 9. Four engine-driven pumps, two per engine, power each hydraulic system. Two engine-driven pumps are sufficient to pressurize one hydraulic system. The pumps on the Number 1 and 2 engines power the GREEN Hydraulic System. The pumps on the Number 3 and 4 engines power the YELLOW Hydraulic System.

Table 9. Hydraulic Systems Operation

<table>
<thead>
<tr>
<th>System</th>
<th>Number 1 and 2 Engines</th>
<th>Number 3 and 4 Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLG/doors</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>BLG/doors</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>WLG brakes</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>BLG brakes</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Nose wheel steering</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Body wheel steering</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Slats and flaps (redundant)</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

The hydraulic systems operate constantly and power the landing gear systems, flight controls, and cargo doors. The landing gear system includes braking and steering.

During emergency operations, ARFF should avoid cutting pressurized hydraulic lines. The pressure of a rupture in a pressurized hydraulic line is dangerous to personnel. The fluid can cause severe skin and eye irritation and degrade protective clothing properties. Airbus lists three approved hydraulic fluids on their qualified manufacturers list, e.g., Exxon Mobil HyJet® IV APlus, HyJet V, and Skydrol LD-4. These are phosphate-based hydraulic fluids. Both hydraulic systems (YELLOW and GREEN) contain 145 gallons (550 liters) each, for a total capacity of 290 gallons (1100 liters) per aircraft.

There is a cooling system that runs between both A380 decks to supply the chillers in the galleys. Since it runs as one system between the decks, it too has a high pressure of 5000 psi. The fluid used is Galden™ HT135; a Material Safety Data Sheet (MSDS) and Safety Data Sheet, provided by the manufacturer, are included in appendix C. Historically, Airbus has used Galden HT135 in other aircraft besides the A380. At temperatures above 572°F (300°C), this fluid can break down and, after prolonged heating or fire exposure, degrade, liberating hydrogen fluoride (HF) and carbonyl fluoride (COF2). It should be noted that, according to the company, this fluid does have FM Approval Standard 6930 [14] approval as having no flash or fire point and no explosion hazards.
To meet the changing demands of the market the use of advanced materials and technologies in aircraft design has increased. The A380 is an excellent example of the evolution and use of these materials. The materials selected for each component of the aircraft are specifically chosen to satisfy the need of the component, provide high strength, and provide resistance to the typical causes of fatigue, damage, stability, and corrosion. The weight of the material is an important factor, as weight is directly related to the cost of operating the aircraft. Production costs and availability are also factors.

For the A380, the proportion of structural materials by weight still shows that aluminum alloys make up the largest proportion (61%). A number of new construction practices were engaged on the A380. Some made use of new alloys, while others used different sizes and runs of conventional materials to reduce seams and fasteners to lighten the aircraft without compromising strength.

Some of these changes involving metals include:

- Aluminum lithium extrusions, used on main deck cross beams
- 7085 aluminum alloy for wing spars and ribs
- Titanium alloys in place of steel; the percentage of titanium by weight on the A380 increased 2% in the A380 over previous Airbus models in the pylons and landing gear alone.

A380 construction materials by weight are as follows:

- 61% aluminum
- 22% composite materials
- 10% titanium and steel
- 3% glass-reinforced aluminum laminate (GLARE)
- 2% surface protections
- 2% miscellaneous

Increased use of composites is not only present on A380s and other NLA, but is also a part of the evolution of aircraft construction in general. The Boeing Company has significantly increased the quantity of composites in newer aircraft, as shown in figure 88.
The B-787 is constructed of 50% composite materials by weight, as shown in figure 89. These advanced materials offer new challenges to ARFF personnel, and a great deal still needs to be learned. The FAA is conducting research to gain a better understanding of these advanced materials and develop best practices for piercing and cutting them. The B-747-8I (Intercontinental) design does not include the same increase in proportion of composite materials. Composites on the B-747-8I are located primarily on control surfaces, pylons, fairings, and cowls, as shown in figure 90.
15.2 ADVANCED COMPOSITE MATERIALS ON THE A380.

The increased use of carbon fiber reinforced plastic (CFRP) laminates has allowed the most drastic weight reduction in the A380. The A380 has a CFRP composite center wing box, which is a first in commercial aviation. In addition, the upper-deck floor beams, fin box, rudder, horizontal stabilizer elevators, and rear-pressure bulkhead are made of CFRP. The CFRP has replaced aluminum on lateral panels and secondary ribs. CFRP has also been introduced in mid and outer flaps, flap track fairings, spoilers, and ailerons, as shown in figure 91.

Figure 90. The ARFF Information on a B-747-8I
(Compliments of The Boeing Company)

Figure 91. Composite Materials and Locations on the A380
(Compliments of Airbus)
Although the A380 includes GLARE fiber metal laminate in the overall construction of the fuselage skin, the skin of the cheek areas for both the forward and aft cargo compartments is aluminum alloy. GLARE is composed of several very thin layers of aluminum interspersed with layers of glass fiber pre-preg bonded with a resin matrix.

GLARE panels are used for two sections of the skin, and they cover almost 5400 sq ft of the aircraft fuselage, as shown in figure 92. GLARE has significantly better burnthrough resistance than traditional aluminum used for aircraft skins. According to reference 15, tests have shown that the burnthrough time for 0.039-in. (1-mm)-thick aluminum skin is 30 seconds, but GLARE has resisted burnthrough for over 15 minutes. Where GLARE is not installed on the underside of the aircraft, fire-resistant thermoacoustic insulation is used to meet the 5-minute burnthrough resistance requirement, but the burnthrough time of the skin from direct flame impingement of a pooled fuel fire will not significantly change. Fire exposure from the exterior of the A380 in the GLARE-protected areas may increase the period of survivable temperatures inside the aircraft. The increased burnthrough resistance of GLARE will also increase the resistance to breaching the fuselage from a fire burning inside the cabin.

![Figure 92. The GLARE Locations on the A380, Highlighted (Compliments of Airbus)](image)

Laboratory-scale experiments have compared the force to penetrate GLARE and CFRP to traditional aluminum alloy as used for aircraft skins. Though this work is ongoing, initial results indicate that GLARE takes more force to penetrate, but the force of retraction is greater for aluminum, as shown in figure 93. This force on the ASPN should not cause any operational problems, as long as the ASPN is withdrawn at the same angle and position as it was during the piercing.

A concern has been raised anecdotally that, after piercing a GLARE panel, the GLARE material may tend to bind on the ASPN due to the ASPN changing its angle during penetration. As opposed to aluminum, which will continue to split once penetrated if the ASPN angle changes, the greater strength of the GLARE from the fiber reinforcement prevents that. Planned full-scale tests by the FAA will assess the potential for this to occur once the laboratory-scale experiments are complete. It should be noted that this has not been observed in any of the laboratory-scale experiments, but the ASPN being used travels in a very precisely controlled motion. In the field, the boom has a lot of sway, and the ASPN can shift its angle due to the joints and flexibility built into the system.
15.3 EFFECTS OF FIRE ON COMPOSITE MATERIALS.

A burning aircraft presents the effects of combustion on every aircraft component and the goods being carried. A burning aircraft is a hazardous material incident and must be treated as such. For ARFF personnel, understanding the unique characteristics of each product or material used, both in construction and carried on the aircraft in fire conditions, is an important aspect in emergency management and scene safety. Protection required and firefighting tactics do not significantly differ from those for aircraft without composites. The highest level of protection for fire fighters and the exposed population must be employed for all aircraft fires.

The components of advanced composite materials are all affected by fire. Resins and epoxy will burn, particularly in the presence of an aviation fuel fire. Where aluminum will melt at 1220°F (660°C), generally composites will burn between 572°F (300°C) and 932°F (500°C) but will maintain their structural integrity during burning. Resins will ignite at 400°-600°F (204°-315°C). Products of composite combustion will contribute to the toxicity of the smoke plume.

Carbon fibers combust at 1000°F (538°C), and burn with a glowing red color at 1400°F (760°C). Kevlar® fibers combust at 800°-900°F (427°-482°C). Glass fibers do not support combustion, but they will melt and possibly form glass beads.

A composite material in a confined space may be very difficult to extinguish based on the experiences of the United States Air Force (USAF). Currently, FAA research is working to evaluate this evidence. USAF guidance on composite material hazards in their Technical Order 00-105E-09 [16] instructs ARFF to continuously apply water to cool smoldering composites and to ensure they are cooled below 300°F (149°C). Cooling sufficiently is very important, as is ensuring that all smoldering areas have been adequately overhauled to prevent reignition. Hose-stream attack on smoldering composite structures may cause the release of superheated steam.
15.4 **EXTINGUISHMENT.**

Class B foam is the preferred agent to use for composite material fires; however, water can be used to cool deep-seated, smoldering epoxy composites since large volumes may be needed. Pooled fuel fires should be controlled first, then burning composites. Smoldering composites have a tendency to reflash if not sufficiently cooled.

15.5 **PROTECTION.**

Full PPE, including SCBA, is required for extinguishing composite material fires or if composite fibers are airborne. Proper decontamination of PPE is necessary after exposure to these fires or airborne fibers. ARFF should ensure areas downwind are protected from exposures of smoke and airborne fibers. The Boeing Company has provided guidance to the ARFF industry in “Firefighting Practices for New Generation Composite Structures,” which is provided in appendix B.

16. **AUXILIARY POWER UNIT.**

The APU is located in the tail of NLA. The APU emergency shutdown switches are located in the cockpit, the maintenance nose gear panel, and the refuel/defuel panel, as shown in figures 94 through 97. The APU fire-extinguishing system is designed to activate automatically when a fire is detected if no action is taken or if the aircraft is left unattended.

![Figure 94. The APU Emergency Shutdown Locations](Provided by Airbus)
Figure 95. Refuel/Defuel Panel

Figure 96. The APU Emergency Shutdown Controls in the Refuel/Defuel Panel
17. FUEL SYSTEM.

According to the A380 ARFF Chart provided by Airbus [17], the A380 has a fuel capacity of up to 83,290 gallons (315,289 liters) of usable fuel. In addition to wing fuel tanks, there is a trim tank, which holds 6,260 gallons (23,700 liters) in the horizontal stabilizer. If the pilot reports that the aircraft must dump fuel prior to landing, fuel can be jettisoned at the rate of 49,254 gallons (186,446 liters) per hour.

This information is helpful when considering that the maximum gross takeoff weight for an A380 is 1,234,588 pounds (560,000 kilograms), and that the maximum gross landing weight is 850,984 pounds (386,000 kilograms) for a fully loaded A380 that just departed and needs to return due to a problem. Prior to consuming fuel for taxi and takeoff, that aircraft was 383,604 pounds (174,000 kilograms) above its maximum landing weight. To land within weight restrictions, the A380 may need an hour or more to jettison fuel prior to landing. If there is a fire onboard, an hour is a long time to delay landing. If the aircraft lands at a weight above maximum gross landing weight, a greater risk for damage to the aircraft exists, which will likely result in a release of fuel upon landing. Fuel released upon heavy landing could potentially find an ignition source in the landing gear.

An incident of this nature occurred at JFK Airport on July 30, 1992. When TWA Flight 853, an L-1011, aborted takeoff, it was loaded to gross departure weight. The aircraft came down hard on the runway causing some structural damage to the aircraft, which resulted in fuel being released from the wing tanks. The leaking fuel found an ignition source, and the aircraft was consumed by fire after all 292 passengers and crew escaped without serious injury.
18. THE U.S. AIRPORTS SERVING NLA.

The list of NLA deliveries continues to grow, as do the routes and destinations. There are hundreds of airports in the world that are in the process of completing modifications to accommodate the NLA. The list in table 10 will continue to evolve as routes are approved and aircraft are delivered.

Table 10. Airports Serving NLA

<table>
<thead>
<tr>
<th>U.S. Airport</th>
<th>Aircraft Type</th>
<th>Operators</th>
<th>Current or Planned Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hartsfield–Jackson Atlanta International (ATL)</td>
<td>A380</td>
<td>Korean Air</td>
<td>2013</td>
</tr>
<tr>
<td>San Francisco International (SFO)</td>
<td>A380</td>
<td>Lufthansa and Air France</td>
<td>Current</td>
</tr>
<tr>
<td>George Bush Intercontinental (IAH)</td>
<td>A380</td>
<td>Lufthansa</td>
<td>Current</td>
</tr>
<tr>
<td>Miami International (MIA)</td>
<td>A380</td>
<td>Lufthansa</td>
<td>Current</td>
</tr>
<tr>
<td>Los Angeles International (LAX)</td>
<td>A380</td>
<td>Singapore, Korean, Qantas, Lufthansa, Air France</td>
<td>Current</td>
</tr>
<tr>
<td>Dulles International (IAD)</td>
<td>A380</td>
<td>Air France, Lufthansa</td>
<td>Current, Current</td>
</tr>
<tr>
<td>O’Hare International (ORD)</td>
<td>B-747-8F</td>
<td>British Airways</td>
<td>Current</td>
</tr>
</tbody>
</table>

18.1 CABIN CONFIGURATION.

Each operator that purchases an A380 has the opportunity to customize the design of their cabin in terms of both seat style and seating arrangement. Currently, eight carriers operate A380s, and two operate B-747-8s. Each carrier has its own design, layout, and configuration. While economy and business class seats are more stylish, and sometimes larger than those on all other passenger aircraft, they are nothing more than new designs of current seats. Where the actual design of the seat is significant to ARFF is in first class. Airbus has enhanced the first-class experience so dramatically that passengers do not purchase a seat in first class, but a rather a pod that serves as a private suite. These pods provide obstructions to fire streams and increase the level of effort required for search and rescue. ARFF departments that protect airports serving as primary or alternate destinations for A380 service must be familiar with the configurations of each carrier. These pods are not unique to A380 aircraft; they also exist on other aircraft including certain B-777s. Carriers may also reconfigure aircraft at any time. This makes it critical to ARFF to maintain communications with air carriers to stay current on aircraft layout.
and passenger loads. Section 18.2 provides descriptions of some first-class configurations being used at the time of this report.

18.2 FIRST-CLASS SUITES.

First-class suites are quite intricate, with a variety of detail features to improve comfort and privacy for the passenger. Figure 98 shows the Emirates first-class suite.

![Figure 98. First-Class Suite: Emirates](image)

Singapore Airlines, Lufthansa, and Emirates are among the operators currently using first-class suites with partitions that passengers can close for privacy. This same configuration is used in Singapore Airlines B-777s employed on longer routes in business- and first-class cabins. By closing the partition and raising a divider that separates adjoining suites, the passenger enjoys what amounts to a personal suite, complete with widescreen television, cold drinks, vanity mirror, fold-out table, bed, and an assortment of comfort controls. Qantas, Korean Air, and Air France chose designs that are closer to the traditional style of first-class seats, as shown in figure 99. They have seats that convert to beds as well as many comfort controls and features, but the suites do not have closing partitions and, therefore, are more open. Search and rescue operations may be hampered by the need to reach into each seating pod to check for incapacitated victims. To that end, each partition is electronically controlled, rendering them inoperable if the aircraft power is disconnected. No information is available regarding whether the doors can be forced open with the power off. It is possible to look over the walls of the suite, but this requires the firefighter to stand up into heat and heavy smoke normal to a fire condition. All carrier-specific information is subject to change as airlines modify configurations and update furnishings. These descriptions and photographs are provided to serve as examples of potential configurations. Aircraft familiarization visits are essential for ARFF crews.

Cabin configurations may be unique to each aircraft. In some cases, carriers are using different configurations on like aircraft based on the route and seating class designs for each route. Figures 99 to 103 highlight the difference in first-class cabins, as well as show the amenities available that would pose considerable hindrance to ARFF crews.
Figure 99. First-Class Cabins: Qantas (left) and Air France (right)

Figure 100. Raised Partition Around First-Class Seat on Lufthansa A380

Figure 101. Korean Air First-Class Seat
Figure 102. Emirates First-Class Shower

Figure 103. Emirates First-Class Lavatory Window
Familiarization with each carrier’s configuration will prevent the potential for penetrating into a lavatory or a first-class suite, either of which will reduce or eliminate the effectiveness of the penetration and interior fire-suppression effort. Singapore, Emirates, Lufthansa, and Qantas have first-class seats and suites that can effectively block the ASPN spray pattern. It is also important to note that while Qantas and Singapore have their first-class cabins on the main deck, Emirates and Lufthansa have theirs on the upper deck. Korean Air has 94 business-class seats on the upper deck, yet has kept first class on the main deck. There is no such thing as a standard seating configuration on the A380.

19. THE B-747-800 SERIES AIRCRAFT.

While writing this report, The Boeing Company began deliveries of the B-747-800 series aircraft. As of this report publication date, the following carriers are flying B-747-8 aircraft in one of three models:

- B-747-8I
- B-747-8F
- B-747-8 VIP

The carriers who have taken delivery thus far include:

- AirBridge Cargo Airlines: B-747-8F
- Atlas Air (operating for British Airways): B-747-8F
- Boeing Business Jets: B-747-8 VIP
- Cathay Pacific Airways: B-747-8F
- Cargolux Airlines International: B-747-8F
- DAE Capital: B-747-8F
- Korean Air Boeing: B-747-8F
- Lufthansa: B-747-8I
- Nippon Cargo Airlines: B-747-8F

As of the publication of this report, only one U.S. airport has scheduled passenger service of the B-747-8I. Lufthansa has service from Dulles International Airport (IAD) to Frankfurt International Airport (FRA).

Currently, B-747-8 freighters have a larger presence at U.S. airports than B-747-8 passenger service.

The airports listed in table 11 have Modifications of Standards (MoSs) in place for B-747-8 operations [18]. These airports are authorized to conduct flight operations of B-747-8 aircraft based on established criteria for ICAO Code F/FAA Group VI design groups [1].
Table 11. The U.S. Airports With MoSs in Place for B-747-8 [18]

<table>
<thead>
<tr>
<th>Airport (Location Identifier)</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston Logan International Airport (BOS), Massachusetts</td>
<td>New England</td>
</tr>
<tr>
<td>Chicago O’Hare International Airport (ORD), Illinois</td>
<td>Great Lakes</td>
</tr>
<tr>
<td>Chicago Rockford International Airport (RFD), Illinois</td>
<td>Great Lakes</td>
</tr>
<tr>
<td>Dallas/Fort Worth International Airport (DFW), Texas</td>
<td>Southwest</td>
</tr>
<tr>
<td>Detroit Metropolitan Wayne County Airport (DTW), Michigan</td>
<td>Great Lakes</td>
</tr>
<tr>
<td>Denver International Airport (DEN), Colorado</td>
<td>Northwest Mountain</td>
</tr>
<tr>
<td>Hartsfield-Jackson Atlanta International Airport (ATL), Georgia</td>
<td>Southern</td>
</tr>
<tr>
<td>Honolulu International Airport (HNL), Hawaii</td>
<td>Western-Pacific</td>
</tr>
<tr>
<td>Houston George Bush Intercontinental Airport (IAH), Texas</td>
<td>Southwest</td>
</tr>
<tr>
<td>Huntsville International Airport (HSV), Alabama</td>
<td>Southern</td>
</tr>
<tr>
<td>Indianapolis International Airport (IND), Indiana</td>
<td>Great Lakes</td>
</tr>
<tr>
<td>John F. Kennedy International Airport (JFK), New York</td>
<td>Eastern</td>
</tr>
<tr>
<td>Los Angeles International Airport (LAX), California</td>
<td>Western Pacific</td>
</tr>
<tr>
<td>Miami International Airport (MIA), Florida</td>
<td>Southern</td>
</tr>
<tr>
<td>Newark Liberty International Airport (EWR), New Jersey</td>
<td>Eastern</td>
</tr>
<tr>
<td>Orlando International Airport (MCO), Florida</td>
<td>Southern</td>
</tr>
<tr>
<td>San Francisco International Airport (SFO), California</td>
<td>Western-Pacific</td>
</tr>
<tr>
<td>Seattle-Tacoma International Airport (SEA), Washington</td>
<td>Northwest Mountain</td>
</tr>
<tr>
<td>Ted Stevens Anchorage International Airport (ANC), Alaska</td>
<td>Alaskan</td>
</tr>
<tr>
<td>Toledo Express Airport (TOL), Ohio</td>
<td>Great Lakes</td>
</tr>
<tr>
<td>Washington-Dulles International Airport (IAD), Washington D.C.</td>
<td>Eastern</td>
</tr>
</tbody>
</table>

20. SUMMARY.

This report provides an in-depth view into the various challenges, hazards, and unique characteristics of NLA. It is evident that as the world’s aircraft evolve in size, sophistication, and capability, the knowledge base, technology, and skill sets required for ARFF must evolve as well. Knowledge is among the greatest tools the ARFF commanders and fire fighters possess.

The size, fuel-carrying capacity, passenger loads, cabin configurations, and increased footprint of NLA with evacuation slides deployed are the issues that require the most attention as ARFF crews plan, prepare, and train for NLA incidents.

The passenger capacity is the primary reason that the A380 was developed. The current average of 525 passengers in a three-class configuration is already a staggering load to manage during emergency operations. Responders need to plan for this number to increase as airlines look for ways to capitalize on the capability of this aircraft to carry over 800 passengers. Plans for mass casualty, evacuations, transportation, and shelter that were developed for B-747-400s need to be doubled if this aircraft starts flying with the total number of passengers that it is certified to carry.
NLA are capable of carrying 80,000 gallons of fuel, which is the equivalent of approximately nine tractor trailer tankers full of jet fuel. This fuel is stored in various locations on the aircraft, i.e., above, below, and alongside the fuselage, which seats hundreds of passengers. Improved fire-resistant qualities of cabin finishes, improved burnthrough times offered by advanced composites, and increasingly sophisticated technology aboard these aircraft certainly increase overall safety for passengers. However, there is still a risk of an incident wherein fuel escapes from the tanks, pools under the aircraft, and finds an ignition source. ARFF fire fighters need to plan for the worst-case scenario, which would require controlling an 80,000-gallon fuel fire under an aircraft carrying 550 or more passengers. This will require rapid response by qualified ARFF fire fighters with sufficient equipment, quantities of foam, water, and techniques to quickly provide protection to the occupants. This must be done before the temperature becomes unbearable, or products of combustion entering the passenger cabin become an immediately dangerous situation. Most ARFF fire fighters will never fight an 80,000-gallon fuel fire. An event of this magnitude with an occupied aircraft would be the first in history. Prudent planning and training are the only tools available to achieve success.

Evacuation slides play a vital role by providing passengers and crew a rapid method of escape from a dangerous incident. Master streams from primary turrets and HRETs are needed to quickly make the area safe. ARFF personnel must prioritize and balance the needs of emergency operations. Initial priorities include extinguishing fires in rescue/escape paths and assisting passengers as they evacuate the aircraft. Stabilizing the evacuation slides will increase safety during evacuation. Using hand lines to apply a protective blanket of foam under and around the web of slides will use less agent than turrets and allow for a more precise application in the areas where the slides block access to the area under the fuselage. Turrets may damage the slides, which are at risk for being moved by the force of the streams. The slippery foam will increase the speed of a person on the slide, as well as increase the risk of falling on the ground. Hand lines provide more precise placement of the foam and do not usually disrupt slides. The lower pressure and volume of the hand lines, the reduced range of the pattern, and the personnel that must be committed to deploy the lines all negatively impact the planning of an efficient operation with finite resources during this critical stage of an emergency. These complications are reality and must be factored into preplans by ARFF departments.

The sheer size of these NLA adds a level of difficulty for ARFF fire fighters during emergency operations. Available technology can reduce the impact of these challenges if available and properly deployed. HRETs can reduce the time and increase the efficiency of an interior attack. Use of cameras on the tip of the device can provide remote monitoring of conditions and increase fire fighter safety with the ability to operate the device from outside the aircraft. IAVs can provide a safe work platform, a point of access for fire fighters to conduct interior operations, and a means of supporting passenger evacuation and deplaning. Training, maintaining proficiency, and well-thought deployment plans are critical components to the efficient use of these tools.

Adequate supplies of firefighting agents with consideration to the increased footprint created by upper-deck slide deployment should be factored into incident planning. Planning and coordination for additional agent and supplies (Q3) quantities required for interior fire attack must be determined in planning exercises and drills, not on the fire ground.
Preplanning for each NLA configuration is necessary in preparing for mitigation of an incident or accident involving NLA. Areas of these aircraft designed for occupancy vary and will affect planning for fire attack, rescue, and search and recovery. These plans must be dynamic, as airlines may change these configurations based on passenger loads, routes, and the market demands.

The challenges created by NLA continue to test the resourcefulness and capabilities of first responders. Along with ARFF professionals who have the primary responsibility to protect these aircraft, mutual aid responders must be included in aircraft familiarization, incident planning, mass casualty, agent resupply, and every task that depends on those off-airport resources for successful operations.

21. REFERENCES


22. ADDITIONAL DOCUMENTATION.

The following documents were specifically used for compiling information during the writing of this report.

APPENDIX A—SEATING CHARTS FOR THE A380

1. Singapore Airlines

AIRBUS 380

Diagram showing seating arrangements for the Airbus A380, including suites, business class, and economy class seating.
2. Air France
3. Emirates

Emirates Aircraft - Seat Configuration

Airbus A380-800 (3 Class)

Main Deck

Upper Deck

Economy Class: Rows 43-88

First Class: Rows 1-3

Business Class: Rows 6-26

KEY

X = Baby Bassinet  Arrow Inward = Passenger Door  Arrow Outward = Emergency Exit
4. Qantas
5. Korean Air
6. Lufthansa

Airbus A380-800
Upper Deck

(385)
Main Deck

First Class 8 Sitz/Sitze

Economy Class 420 Sitz/Sitze

Business Class 90 Sitz/Sitze

Bordküche/Galley
Toiletten/Lavatory
Telefon/Television

Technische Daten/Technical specifications

Flugzeuglänge: 78,6 km
Füllänge: 80,9 m
Langstrecke: 77,2 km / 236.11 in
Wasserabfluss: 35,8 km / 222.11 m
Max. Pegelgewicht: 560,079 kg
Max. Startgewicht: 256,079 kg
Max. Betriebsgeschwindigkeit: 397,079 km/h
Max. Flughöhe: 15,300 m
Max. Betriebsleistung: 43,000 lb
Reichweite/Rang: 12,600 km / 7,800 Miles
Telefonie/Telefon: 4 * Priva, Phera

A-6
Firefighting Practices for New Generation Commercial Composite Structures

Boeing has received a number of inquiries from the airport fire community and airport operators related to the fire behavior associated with the increased usage of composite materials in the main structure of the 787 aircraft.

In reference to the composite structure, Boeing is not recommending any major changes to the standard way of fighting an aircraft fire. Extensive testing has been conducted in regards to combustibility and toxicity related to the composite structure. The tests have proven very successful and warrant the basis of our position. The structure is monocoque in its design with multiple layers of uni-dimensional woven fabric. This design not only adds to the strength of the product, but also makes it a good barrier to fire and heat. The structure does not aid in the spread of fire and acts as a barrier creating greater difficulty for an exterior fire to penetrate an intact fuselage. From a toxicity perspective, the composite structure during fire testing poses no greater hazard than an aluminum fuselage aircraft. Also, note that the burnthrough time on the composite structure is significantly longer than with the aluminum fuselage which may inherently provide greater safety to both the rescue fire responders and passengers in some scenarios.

Upon approach of a fire involving a 787 aircraft, the rescue fire services should deploy their standard tactics as if they were addressing an aircraft with an aluminum fuselage. This may be through the use of turrets or handlines, depending on the situation. Initial fire engagement should include foam to knock down the flames and suppress any fuel vapor that may be on the ground around the accident scene.

Gaining access to the 787 for rescue purposes should be in accordance with the local rescue fire service procedures. Our testing concludes that cutting the composite structure is much easier than cutting the aluminum fuselage. Testing has been conducted with the typical rescue tools: circular saw, air chisel, and chainsaw. The most effective method to cut through the composite structure is to utilize a circular saw with either a carbide tip blade or diamond tip blade.

When performing handline operations and rescue activities, personnel should be in full protective clothing with bunker gear and self-contained breathing apparatus (SCBA). The same level of personal protective equipment (PPE) with SCBA should be worn regardless of aircraft material.

All aircraft accidents involving fire should be considered a hazardous materials incident whether the situation involves an aluminum fuselage or composite fuselage. With respect to this,
hot, warm, and cold zones should be established and maintained through the completion of the accident investigation. Personnel entering to investigate the accident after the scene has been stabilized, should be monitored, tracked, and checked to ensure they have appropriate protection equipment, i.e. coveralls, gloves, hoods, and respirators are common PPE for these types of situations.

Additional Information:

The Air Force has additional information available related to Military derivative composites and provides information that may be helpful. Access to the link provided is through enrollment. [http://www.dodfirecert.com/00-105E-9/index.cfm](http://www.dodfirecert.com/00-105E-9/index.cfm) Chapter 3. Hazardous Material and Mishap Hazards and 3.5 Composite Material Hazards is where the appropriate data resides. NOTE: This data does not depict, nor indicate, the behavior of the new generation composite being used on the 787 and is only provided as a resource for review.

The Federal Aviation Administration has done recent testing on more current composite materials similar in design to the new commercial aircraft. These data are closer to the information gleaned from our toxicity testing. These test data can be accessed at: [http://www.fire.tc.faa.gov/pdf/TN07-15.pdf](http://www.fire.tc.faa.gov/pdf/TN07-15.pdf)

Note: Boeing test data, as well as other data sources, reference that the composite material itself does not usually burn, but the resin used to bond the carbon material will melt and may ignite. When the surface area of the composite structure is exposed to heat and/or flame, it will maintain its structure though it may be weakened. However, the composite structure will not melt as with aluminum fuselages. Because of this, rescue fire personnel must use caution when traveling across the surface area of the composite structure. Make sure to test the surface area if suspected exposure to heat and flame are present.

Additional questions regarding issues related to Aircraft Rescue and Fire Fighting (ARFF) and Boeing aircraft can be directed to either of the following:

Boeing Fire Department  
Attn: Robert Mathis, Captain – Training & Safety P.O.  
Box 3707, MC 17-WE  
Seattle, Washington USA 98124  
206-491-4005 (Cell)  
[robert.c.mathis@boeing.com](mailto:robert.c.mathis@boeing.com)

or

Boeing Airport Technology  
P.O. Box 3707, MC 67-KR  
Seattle, Washington USA 98124  
425-237-1004  
[AirportTechnology@boeing.com](mailto:AirportTechnology@boeing.com)
1. PRODUCT AND COMPANY IDENTIFICATION

1.1. Identification of the substance or mixture

Product name: GALDEN(R)
HT LOW-BOILING Product grade(s): HT55; HT70; HT90; HT110; HT135

Structural formula: CF3-O-(C3F6O)n-(CF2-O)m-CF3
Molecular Weight: Range of values: 350 - 650

1.2. Use of the Substance/Mixture

Recommended use: - Heat transfer medium
- For industrial use only.

1.3. Company/Undertaking Identification

Address: SOLVAY SOLEXIS, INC.
10 LEONARD LANE
WEST DEPTFORD NJ 08086
United States

1.4. Emergency and contact telephone numbers

Emergency telephone: 1 (800) 424-9300 CHEMTREC ® (USA & Canada)
Contact telephone number (product information): (856) 853-8119 (Product information)

2. HAZARDS IDENTIFICATION

2.1. Emergency Overview:

NFPA: H= 1  F= 0  I= 0

General Information

Appearance: liquid
Colour: colourless
Odour: odourless

Main effects
- Not hazardous in normal conditions of handling and use
- Ecological injuries are not known or expected under normal use.
- Thermal decomposition can lead to release of toxic and corrosive gases.

2.2. Potential Health Effects:

Inhalation
- No known effect.

Eye contact
- Contact with eyes may cause irritation.
- Redness

Skin contact
- Symptoms: Redness, Irritation.

Ingestion
- Ingestion may provoke the following symptoms:
  - Symptoms: Nausea, Vomiting, Diarrhea.

Other toxicity effects
- See section 11: Toxicological Information

2.3. Environmental Effects:
- See section 12: Ecological Information

3. COMPOSITION/INFORMATION ON INGREDIENTS

1-Propene, 1,1,2,3,3,3-hexafluoro-, oxidized, polymd.
CAS-No. : 69991-67-9
Concentration : >= 99.9 %

4. FIRST AID MEASURES

4.1. Inhalation
- Move to fresh air in case of accidental inhalation of fumes from overheating or combustion.
- Oxygen or artificial respiration if needed.

4.2. Eye contact
- Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes.
- If eye irritation persists, consult a specialist.

4.3. Skin contact
- Wash off with soap and water.
- If symptoms persist, call a physician.

4.4. Ingestion
- Drink 1 or 2 glasses of water.
- Do NOT induce vomiting.
- If symptoms persist, call a physician.

5. FIRE-FIGHTING MEASURES

5.1. Suitable extinguishing media
- Water
- powder
- Foam
- Dry chemical
- Carbon dioxide (CO2)

5.2. Extinguishing media which shall not be used for safety reasons
- None.

5.3. Special exposure hazards in a fire
- The product is not flammable.
- Not explosive
- In case of fire hazardous decomposition products may be produced such as: Gaseous hydrogen fluoride (HF), Fluorophosgene

5.4. Hazardous decomposition products
- Gaseous hydrogen fluoride (HF).
- Fluorophosgene

5.5. Special protective equipment for fire-fighters
- Wear self-contained breathing apparatus and protective suit.
- When intervention in close proximity wear acid resistant over suit.

5.6. Other information
- Evacuate personnel to safe areas.
- Approach from upwind.
- Protect intervention team with a water spray as they approach the fire.
- Keep containers and surroundings cool with water spray.
- Keep product and empty container away from heat and sources of ignition.

6. ACCIDENTAL RELEASE MEASURES

6.1. Personal precautions
- Ensure adequate ventilation.
- Material can create slippery conditions.
- Sweep up to prevent slipping hazard.
- Prevent further leakage or spillage if safe to do so.
- Keep away from open flames, hot surfaces and sources of ignition.
- Refer to protective measures listed in sections 7 and 8.

6.2. Environmental precautions
- Should not be released into the environment.
- The product should not be allowed to enter drains, water courses or the soil.
- In case of accidental release or spill, immediately notify the appropriate authorities if required by Federal, State/Provincial and local laws and regulations.

6.3. Methods for cleaning up
- Soak up with inert absorbent material.
- Suitable material for picking up
- Dry sand
- Earth
- Shovel into suitable container for disposal.

7. HANDLING AND STORAGE

7.1. Handling
- No special handling advice required.
- Ensure adequate ventilation.
- Use personal protective equipment.
- Keep away from heat and sources of ignition.
- To avoid thermal decomposition, do not overheat.
- Take measures to prevent the build up of electrostatic charge.
- Clean and dry piping circuits and equipment before any operations.
- Ensure all equipment is electrically grounded before beginning transfer operations.

7.2. Storage
- No special storage conditions required.
- Keep away from heat and sources of ignition.
- Keep in properly labelled containers.
- Keep away from combustible material.
- Keep away from incompatible products

7.3. Packaging material
- glass
- Plastic material

7.4. Other information
- Provide tight electrical equipment well protected against corrosion.
- Refer to protective measures listed in sections 7 and 8.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1. Exposure Limit Values
Remarks:
- Threshold limit values of by-products from thermal decomposition
  
  Hydrogen fluoride anhydrous
Carbonyl difluoride
- US. ACGIH Threshold Limit Values 2009 time weighted average = 2 ppm
- US. ACGIH Threshold Limit Values 2009 Short term exposure limit = 5 ppm
- US. OSHA Table Z-1-A (29 CFR 1910.1000) 1989 time weighted average = 2 ppm time weighted average = 5 mg/m³
- US. OSHA Table Z-1-A (29 CFR 1910.1000) 1989 Short term exposure limit = 5 ppm Short term exposure limit = 15 mg/m³
- US. OSHA Table Z-2 (29 CFR 1910.1000) 02 2006 time weighted average = 2.5 mg/m³ Remarks: Dust
- US. OSHA Table Z-1 Limits for Air Contaminants (29 CFR 1910.1000) 02 2006 Permissible exposure limit = 2.5 mg/m³ Remarks: as F
- US. Tennessee. OELs. Occupational Exposure Limits, Table Z1A 06 2008 time weighted average = 2 ppm time weighted average = 5 mg/m³
- US. Tennessee. OELs. Occupational Exposure Limits, Table Z1A 06 2008 Short term exposure limit = 5 ppm Short term exposure limit = 15 mg/m³

8.2. Engineering controls
- Provide local ventilation appropriate to the product decomposition risk (see section 10).
- Refer to protective measures listed in sections 7 and 8.
- Apply technical measures to comply with the occupational exposure limits.
- For additional information, consult the current edition of The Guide to the Safe Handling of Fluoropolymers published by the Society of Plastics Industry, Inc. (SPI) Fluoropolymer Division.

8.3. Personal protective equipment
8.3.1. Respiratory protection
- No personal respiratory protective equipment normally required.
- Wear self-contained breathing apparatus in confined spaces, in cases where the oxygen level is depleted, or in case of significant emissions.
- Use only respiratory protection that conforms to international/national standards.
- In case of decomposition (see Section 10), wear a suitable respirator with a combination filter for organic vapor and particulate.
- Use NIOSH approved respiratory protection.
- Comply with OSHA respiratory protection requirements.

### 8.3.2. Hand protection
- Rubber or plastic gloves
- Latex gloves
- Take note of the information given by the producer concerning permeability and break through times, and of special workplace conditions (mechanical strain, duration of contact).

### 8.3.3. Eye protection
- Safety glasses with side-shields
- If splashes are likely to occur, wear: Tightly fitting safety goggles

### 8.3.4. Skin and body protection
- Lab coat

### 8.3.5. Hygiene measures
- Ensure that eyewash stations and safety showers are close to the workstation location.
- When using do not eat, drink or smoke.
- Wash hands before breaks and at the end of workday.
- Handle in accordance with good industrial hygiene and safety practice.

### 9. PHYSICAL AND CHEMICAL PROPERTIES

#### 9.1. General Information

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Liquid</td>
</tr>
<tr>
<td>Color</td>
<td>Colorless</td>
</tr>
<tr>
<td>Odor</td>
<td>Odorless</td>
</tr>
</tbody>
</table>

#### 9.2 Important health safety and environmental information

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point/Boiling Range</td>
<td>55 – 135°C (131 - 275°F)</td>
</tr>
<tr>
<td>Flash Point</td>
<td>Not Flammable</td>
</tr>
<tr>
<td>Flammability</td>
<td>Not Flammable</td>
</tr>
<tr>
<td>Explosive Properties</td>
<td>Not Explosive</td>
</tr>
<tr>
<td>Oxidizing Properties</td>
<td>Non Oxidizing</td>
</tr>
<tr>
<td>Vapor Pressure</td>
<td>7.7 – 300 hPa</td>
</tr>
<tr>
<td>Relative Density/ Density</td>
<td>1.65 – 1.72 g/cm³ Temperature: 25°C (77°F)</td>
</tr>
<tr>
<td>Solubility</td>
<td>Water Insoluble</td>
</tr>
<tr>
<td>Fluorinated Solvents</td>
<td>Insoluble</td>
</tr>
<tr>
<td>Viscosity</td>
<td>ca. 0.7 – 1.7 mPa.s</td>
</tr>
</tbody>
</table>

#### 9.3. Other data

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Point/Range</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Decomposition Temperature</td>
<td>&gt; 290 °C (554°F)</td>
</tr>
</tbody>
</table>
10. STABILITY AND REACTIVITY

10.1. Stability
- Stable under recommended storage conditions.
- Metals promote and lower decomposition temperature.
- In presence of titanium and its alloys, the decomposition temperature decreases to 260°C.

10.2. Conditions to avoid
- To avoid thermal decomposition, do not overheat.
- Keep away from flames and sparks.
- Keep at temperature not exceeding: 290 °C (554 °F).

10.3. Materials to avoid
- Combustible material, Flammable materials
- Non-aqueous alkalis
- Lewis acids (Friedel-Crafts) above 100°C
- Aluminum and magnesium in powder form above 200°C

10.4. Hazardous decomposition products
- Gaseous hydrogen fluoride (HF), Fluorophosgene

11. TOXICOLOGICAL INFORMATION

Toxicological data

Acute oral toxicity
- LD50, rat, > 5,000 mg/kg

Acute inhalation toxicity
- LC50, rat, > 1,826 mg/l

Acute dermal irritation/corrosion
- LD50, rat, > 2,000 mg/kg

Skin irritation
- Rabbit, No skin irritation

Eye irritation
- Rabbit, No eye irritation

Sensitisation
- Guinea pig, Did not cause sensitization on laboratory animals.

Chronic toxicity
- Oral, 28-day, rat, NOEL: > 1000 mg/kg/day, Remarks: Subacute toxicity

Genetic toxicity in vitro
- Not mutagenic in Ames Test.
- Chromosome aberration test in vitro, negative

Remarks
- Description of possible hazardous to health effects is based on experience and/or toxicological characteristics of several components.
- Thermal decomposition can lead to release of toxic and corrosive gases.
- Exposure to decomposition products
- Causes severe irritation of eyes, skin and mucous membranes.

12. ECOLOGICAL INFORMATION

12.1. Ecotoxicity effects

Acute toxicity
- Remarks: no data available

12.2. Mobility
- Remarks: no data available

12.3. Persistence and degradability
Abiotic degradation
- Result: no data available

Biodegradation
- Remarks: no data available

12.4. Bioaccumulative potential
- Result: no data available

12.5. Other adverse effects
- no data available

12.6. Remarks
- Ecological injuries are not known or expected under normal use.

13. DISPOSAL CONSIDERATIONS

13.1. Waste from residues / unused products
- Do not dump into any sewers, on the ground, or into any body of water. All disposal methods must be in compliance with all Federal, State/Provincial and local laws and regulations. Regulations may vary in different locations.
- Waste characterizations and compliance with applicable laws and regulations are the responsibility of the waste generator.
- Can be incinerated, when in compliance with local regulations.
- The incinerator must be equipped with a system for the neutralisation or recovery of HF.

13.2. Packaging treatment
- Empty containers can be landfilled, when in accordance with the local regulations.

13.3. RCRA Hazardous Waste
- Listed RCRA Hazardous Waste (40 CFR 302) - No

14. TRANSPORT INFORMATION

- Sea (IMO/IMDG)
  - not regulated
- Air (ICAO/IATA)
  - not regulated
- U.S. Dept of Transportation
  - not regulated
- It is recommended that ERG Guide number 111 be used for all non-regulated material.
- Canadian Transportation of Dangerous Goods
  - not regulated

15. REGULATORY INFORMATION

15.1. Inventory Information

<table>
<thead>
<tr>
<th>Substance control list</th>
<th>Compliance status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxic Substance Control Act list (TSCA)</td>
<td>In compliance with inventory.</td>
</tr>
<tr>
<td>Australian Inventory of Chemical Substances (AICS)</td>
<td>In compliance with inventory.</td>
</tr>
<tr>
<td>Canadian Domestic Substances List (DSL)</td>
<td>In compliance with inventory.</td>
</tr>
<tr>
<td>Inventory of Existing Chemical Substances (China) (IECS)</td>
<td>In compliance with inventory</td>
</tr>
<tr>
<td>Korea Existing Chemicals Inv. (KECI) (KECI (KR))</td>
<td>In compliance with inventory.</td>
</tr>
<tr>
<td>Japanese Existing and New Chemical Substances (MITI List) (ENCS)</td>
<td>In compliance with inventory</td>
</tr>
<tr>
<td>New Zealand Inventory (in preparation) (NZ)</td>
<td>In compliance with inventory.</td>
</tr>
<tr>
<td>Philippine Inventory of Chemicals and Chemical</td>
<td>In compliance with inventory</td>
</tr>
</tbody>
</table>

C-7
Substances (PICCS)

| EU list of existing chemical substances (EINECS) | not applicable, Product falls under the EU-polymer definition. |

15.2. Other regulations

**US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 302**
- Extremely Hazardous Substance (40 CFR 355, Appendix A)
  - not regulated.

**SARA Hazard Designation (SARA 311/312)**
- Acute Health Hazard: No.
- Chronic Health Hazard: No.
- Fire Hazard: No.
- Reactivity Hazard: No.
- Sudden Release of Pressure Hazard: No.

**US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 313 Toxic Chemicals (40 CFR 372.65) - Supplier Notification Required**
- not regulated.

**US. EPA CERCLA Hazardous Substances (40 CFR 302)**
- not regulated.

**US. New Jersey Worker and Community Right-to-Know Act (New Jersey Statute Annotated Section 34:5A-5)**
- not regulated.

**US. Pennsylvania Worker and Community Right-to-Know Law (34 Pa. Code Chap. 301-323)**
- not regulated.

**US. California Safe Drinking Water & Toxic Enforcement Act (Proposition 65)**
- This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm..

**OSHA Hazard communication standard**
- This material is non-hazardous as defined by the American OSHA Hazard Communication Standard.

15.3. Classification and labelling

- Does not contain a controlled product

Remarks: This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.

16. OTHER INFORMATION

Ratings:

**NFPA (National Fire Protection Association)**
- Health = 1  Flammability = 0  Instability = 0
Further information

- Update
- Distribute new edition to clients

Material Safety Data Sheets contain country specific regulatory information; therefore, the MSDS's provided are for use only by customers of the company mentioned in section 1 in North America. If you are located in a country other than Canada, Mexico or the United States, please contact the Solvay Group company in your country for MSDS information applicable to your location.

The previous information is based upon our current knowledge and experience of our product and is not exhaustive. It applies to the product as defined by the specifications. In case of combinations or mixtures, one must confirm that no new hazards are likely to exist. In any case, the user is not exempt from observing all legal, administrative and regulatory procedures relating to the product, personal hygiene, and integrity of the work environment. (Unless noted to the contrary, the technical information applies only to pure product).

To our actual knowledge, the information contained herein is accurate as of the date of this document. However, neither the company mentioned in section 1 nor any of its affiliates makes any warranty, express or implied, including merchantability or fitness for use, or accepts any liability in connection with this information or its use. This information is for use by technically skilled persons at their own discretion and risk and does not relate to the use of this product in combination with any other substance or any other process. This is not a license under any patent or other proprietary right. The user alone must finally determine suitability of any information or material for any contemplated use in compliance with applicable law, the manner of use and whether any patents are infringed. This information gives typical properties only and is not to be used for specification purposes. The company mentioned in section 1 reserves the right to make additions, deletions or modifications to the information at any time without prior notification.

Trademarks and/or other products of the company mentioned in section 1 referenced herein are either trademarks or registered trademarks of the company mentioned in section 1 or its affiliates, unless otherwise indicated.

Copyright 2009, Company mentioned in Section 1. All Rights Reserved.
Galden HT 135

SOLVAY SOLEXIS, Inc.
10 Leonards Lane
Thorofare, NJ 08086
856-853-8119

Section 1 - Chemical product and Company information

Date Revised: May 24, 2005
Product Name: Galden HT 135
Chemical Name: Propene, 1,1,2,3,3,3-hexafluoro, oxidized, polymerized
Chemical Family: Fluorocarbons, Perfluorinated polyethers
Synonyms: None
Emergency Telephone: 800-424-9300 (CHEMTREC, 24 hours)
856-853-8119

Emergency Overview:
Clear, colorless liquid. Thermal decomposition will generate hydrogen fluoride (HF), which is corrosive.

Section 2 - Compositional information

Name: Propene, 1,1,2,3,3,3-hexafluoro, oxidized, polymerized
CAS# 69991-67-9
Approximate Weight (%)
100

Section 3 - Potential Health Effects

Effects of Overexposure:
Eye Contact
Eye contact may cause slight irritation.

Skin Contact
Skin contact may cause slight irritation.

Inhalation
Inhalation of vapors or mists may cause respiratory tract irritation.

Ingestion
No ill effects are expected.

Section 4 - First Aid Measures

Eye Contact:
Flush eyes for 15 minutes with copious amounts of water, retracting eyelids often. Seek medical attention if irritation persists.

Skin Contact:
Wash skin thoroughly with mild soap and water. Flush with lukewarm water for 15 minutes.

Inhalation:
If symptoms of irritation, discomfort or overcome by exposure, remove affected person to fresh air. Give oxygen or artificial respiration as needed.

Ingestion:
If conscious, drink three to four 8 ounce glasses of water or milk. Call a physician. If unconscious, immediately take affected person to a hospital. Do not give anything by mouth to an unconscious person.

Section 5 - Fire Fighting Measures
Flash Point: Not Applicable
Lower Explosive Limit: Not Applicable
Upper Explosive Limit: Not Applicable
Autoignition Temperature: Not Applicable
Extinguishing Media: Water (spray or fog), foam, dry chemical or carbon dioxide (CO2).

Unusual Fire Hazards:
Fluoropolymers will degrade upon prolonged heating or in a fire, liberating hydrogen fluoride (HF) and carbonyl fluoride (COF2). This gas is toxic if inhaled or it comes into contact with moist skin. HF has an ACGIH PEL TLV (8hr TWA) of 0.5ppm and a ceiling limit of 2 ppm (1.7mg/m3). COF2 has an ACGIH TLV of 2 ppm (5.4 mg/m3) and an OSHA PEL TWA of 2 ppm (5 mg/m3).

Fire Fighting Procedures:
Use self-contained breathing apparatus (SCBA) and skin protection for acid gas exposure. Do not enter fire area without proper protection. Fight fire from safe distance. If possible, air monitoring should be performed.

Section 6 - Accidental Release Measures
Releases: In case of a release or spill, absorb material onto vermiculite or similar inert absorbent. Use Perfluorosolv0 PFS-1 as an aid in cleaning. Place spilled material into covered container for disposal. Dispose of according to applicable local, state and federal regulations. Extinguish all ignition sources and evacuate the area. Exercise caution; spill area may be slippery.

Section 7 - Handling and Storage
Wash hands after use and before handling food or applying cosmetics. Do not use tobacco products in the immediate area. Keep containers closed. Keep away from heat, sparks and flames. Do not store near combustible materials.

Section 8 - Exposure Controls/Personal Protection
ACGIH Threshold Limit Value (8 hr. time weighted average): None established
OSHA Permissible Exposure Limit Value (8 hr. time weighted average): None established

Engineering Controls: Ventilation Requirements:
Local Exhaust: Vent vapors or mists generated by processing away from operating personnel. Local exhaust ventilation at a rate of 50 feet per minute.

Personal Protective Equipment: Respiratory Protection:
No occupational exposure standards have been developed for this material. In situations where exposure to vapors or mists is likely, NIOSH/MSHA approved respirators are recommended. Respirator use limitations made
by NIOSH/MSHA or the manufacturer must be observed. Respiratory protection programs must be in accordance with 29 CFR 1910.134.

**Eye Protection:**
Eye/Face Protection: ANSI Z87.1 approved safety glasses with side shields or equivalent.

**Skin Protection:**
Rubber or latex recommended but not necessary.

### Section 9 - Physical and Chemical Properties
- **Appearance:** Clear liquid
- **Color:** Colorless
- **Odor:** Odorless
- **Vapor Pressure:** 8 torr
- **Vapor Density (Air=1):** Not available
- **Boiling Point:** 135 °C
- **Melting Point:** Not available
- **Specific Gravity:** 1.7-1.9
- **Solubility in Water:** Insoluble
- **% Volatile by Volume:** 0

### Section 10 - Stability and Reactivity
**Stability:**
This material is stable.

**Reactivity:**
This material is not reactive.

**Conditions to Avoid:**
Heat, sparks, flames, and other ignition sources; avoid heating above 290 C/554 F.

**Materials to Avoid:**
Strong or non-aqueous alkali and Lewis acids above 100 C/212 F.

**Hazardous Decomposition Products:**
Thermal decomposition of this product will generate hydrogen fluoride (HF), which is corrosive, causing burns on contact with skin and other tissue.

**Incompatibility (Materials to Avoid):**
Alkali metals and halogenated compounds.

### Section 11 - Toxicological Information
- **Rat oral LD50:** greater than 25.65 g/kg
- **Rat intraperitoneal LD50:** greater than 25 g/kg
- **Rat dermal LD50:** greater than 2 g/kg
- **Rabbit skin irritation:** not irritating
- **Rabbit eye irritation:** not irritating
- **Guinea pig sensitization:** not a sensitizer

Solvay Acceptable Exposure Limit 1000ppm
Section 12 - Ecotoxicological Information
No ecotoxicological information is available for this material.

Section 13 - Disposal Considerations
Waste Disposal: Material, as supplied, is not a hazardous waste. Landfill according to current federal, state and local regulations, or incinerate in a high-temperature incinerator designed to burn fluorine-containing materials. Processing, use or contamination may make this information inaccurate or incomplete.

Section 14 - Transportation information
Shipping Class: Not regulated by DOT.

Section 15 - Regulatory information
All components of this product are listed on the Toxic Substances Control Act (TSCA) Section 8(b) Chemical Inventory and the Canadian Environmental Protection Act (CEPA) provisional domestic substances list (DSL). This product is not a "hazardous substance" as defined by OSHA Hazard Communication Standard (29 CFR 1910.1200). This product is not a "controlled product" as defined by the Canadian Workplace Hazardous Materials Information System (WHMIS).

SARA Section 302 Extremely Hazardous Substances: Not listed

SARA 311/312:
- Acute: No
- Chronic: No
- Fire: No
- Reactivity: No
- Sudden Release of Pressure: No

SARA Section 313 Toxic Chemicals: Not listed

Section 16 - Additional Information
NFPA Ratings (Scale of 0-4): Health = 1
- Fire = 0
- Reactivity = 0

Material Safety Data Sheets contain country-specific regulatory information; therefore, the MSDS’s provided are for use only by customers of Solvay Solexis, Inc. in North America. If you are located in a country other than Canada, Mexico or the United States, please contact the Solvay Group company in your country for MSDS information applicable to your location.

The previous information is based upon our current knowledge and experience of our product and is not exhaustive. It applies to the product as defined by the specifications. In case of combinations or mixtures, one must confirm that no new hazards are likely to exist. In any case, the user is not exempt from observing all legal, administrative and regulatory procedures relating to the product, personal hygiene, and integrity of the work environment. (Unless noted to the contrary, the technical information applies only to pure product).

To our actual knowledge, the information contained herein is accurate as of the date of this document. However, neither Solvay Solexis, Inc. nor any of its affiliates makes any warranty, express or implied, or accepts any liability in connection with this information or its use. This information is for use by technically skilled persons at their own discretion and risk and does not relate to the use of this product in combination with any other
substance or any other process. This is not a license under any patent or other proprietary right. The user alone must finally determine suitability of any information or material for any contemplated use, the manner of use and whether any patents are infringed.

Trademarks and/or other Solvay Solexis, Inc. products referenced herein are either trademarks or registered trademarks of Solvay Solexis, Inc. or its affiliates, unless otherwise indicated.

Solvay Solexis, Inc. All rights reserved. Copyright 2004
For instance, the new A380 has a fuel capacity 44% greater than a B777 and 42% greater than a 747-400. Because of this there is a greater potential for a larger 2-D fuel fire from a ruptured fuel tank. However the current calculations for the agent quantities Theoretical Critical Area / Practical Critical Area (TCA/PCA) would only require an additional 138 gallons of agent. This is due to the fact that the multiple passenger level aircraft are not significantly larger in length and fuselage width but increase in height and fuel load. Both factors are not figured into TCA/PCA.

Compounding this problem is the increase in number of emergency escape slides on these aircraft. The upper level escape slides will deploy 12’ further on each side than the B777. This will increase the area which will need to be protected to maintain an adequate escape path for the occupants. With the additional slide deployments and the increased length of the upper level slides it will be harder to make an effective fire attack on a 2-D fire that is under the fuselage jeopardizing the integrity of the aircraft. The figure below illustrates the additional slide deployment length.

Before Guyer’s (BG) large fire test Gage-Babcock determined what area needed fire protection and how big the area needed to be. The area needing fire protection was an area around the aircraft which would allow ambulatory occupants to exit the aircraft within tolerable heat conditions and move to a safe area. Dimensions were then determined (TCA-PCA) around the aircraft that would allow a clear escape path. With a known area to extinguish, TCA, Guyer’s large fire tests were then conducted.

- The Airbus 380 is unique and challenging due to the amount of upper deck occupants and their need to evacuate when necessary.
- The Airbus 380 upper deck slide extends further from the fuselage than the largest single-deck airplane, the Boeing 777.
• The early work of Gage-Babcock continues to be relevant to post-crash occupant safety. The goal is not how large of an area of fire can be extinguished by a given quantity of extinguishing agent but how can we assure an area around the aircraft that would “allow ambulatory occupants to exit the aircraft within tolerable heat conditions and move to a safe area”. That being our mission the slide length does become a new and different challenge as the Airbus 380 enters service at our airports.

The following calculations demonstrate a method of using the NFPA accepted K factor table and modifying it with an additional factor to accommodate multiple passenger level aircraft.

**K Factor Modification:**

\[
Q = Q_1 + Q_2 + Q_3
\]

Where \(Q_1\) = water requirement for control of PCA

\(Q_2\) = water requirement to maintain control or extinguish the remaining fire or both

\(Q_3\) = water requirement for interior firefighting

The method for calculating the values for each component of \(Q\) are presented below.

\[
Q_1 = \text{PCA} \times R \times T
\]

Where PCA = \((0.67) \times TCA\),

\[
TCA = L \times (K + W)
\]

\(L\) = length of aircraft

\(W\) = width of fuselage

\(R\) = application rate of selected agent: AFFF = 0.13 gpm/ft²

\(T\) = time of application (1 minute)

\(K\) = values shown below:

<table>
<thead>
<tr>
<th>Feet</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 39</td>
<td>39 where (L) = less than 39</td>
</tr>
<tr>
<td>39-59</td>
<td>46 where (L) = 39 up to but not including 59</td>
</tr>
<tr>
<td>59-79</td>
<td>56 where (L) = 59 up to but not including 79</td>
</tr>
<tr>
<td>&gt; 79</td>
<td>98 where (L) = 79 and over</td>
</tr>
</tbody>
</table>
The current values of $Q_2$ as a percentage of $Q$ have been determined to be as shown:

<table>
<thead>
<tr>
<th>Airport Category</th>
<th>$Q_2$% $Q_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>75</td>
</tr>
</tbody>
</table>

100%

Sample Calculation for A380 and Aqueous Film Forming Foam (AFFF)

$TCA = L \times (K + W)$

$= 239 \times (98 + 21) = 28441 \text{ ft}^2$

$PCA = \frac{2}{3} \times TCA = \frac{2}{3} \times 28441 \text{ ft}^2 = 19055 \text{ ft}^2$

$Q_1 = 0.13 \text{ gpm/ft}^2 \times 19055 \text{ ft}^2 \times 1 = 2477 \text{ gal}$

$Q_2 = 190\% \times Q_1 = 1.9 \times 2477 = 4707 \text{ gal}$

$Q_3 = \text{add 5,000 gallons}$

Sample Calculation for A380 w/ additional 24' slide and AFFF

$TCA = L \times (K + W)$

$= 239 \times (98 + 21 + 24) = 34177 \text{ ft}^2$

$PCA = \frac{2}{3} \times TCA = \frac{2}{3} \times 34177 \text{ ft}^2 = 22898 \text{ ft}^2$

$Q_1 = 0.13 \text{ gpm/ft}^2 \times 22898 \text{ ft}^2 \times 1 = 2977 \text{ gal}$

$Q_2 = 190\% \times Q_1 = 1.9 \times 2977 = 5656 \text{ gal}$

$Q_3 = \text{add 5,000 gallons}$

Sample Calculation for A380 w/ modified K factor and AFFF

$TCA = L \times (K + W)$

$= 239 \times (122 + 21) = 34177 \text{ ft}^2$

$PCA = \frac{2}{3} \times TCA = \frac{2}{3} \times 34177 \text{ ft}^2 = 22898 \text{ ft}^2$

$Q_1 = 0.13 \text{ gpm/ft}^2 \times 22898 \text{ ft}^2 \times 1 = 2977 \text{ gal}$

$Q_2 = 190\% \times Q_1 = 1.9 \times 2977 = 5656 \text{ gal}$

$Q_3 = \text{add 5,000 gallons}$

New 5th K factor:

$K = 122$ where $L = 79$ and over with multiple passenger cabin levels. The new K factor is based on the increased slide area, which would need to be protected.
APPENDIX E—FUEL WEIGHT/VOLUME CONVERSION

(Conversion Factors: 6.7 lb/gal – 3.04 kg/gal)

<table>
<thead>
<tr>
<th>POUND</th>
<th>GALLONS</th>
<th>KILOGRAMS</th>
<th>GALLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000 lbs</td>
<td>300 gal</td>
<td>2,000 Kg</td>
<td>658 gal</td>
</tr>
<tr>
<td>5,000</td>
<td>746</td>
<td>5,000</td>
<td>1,645</td>
</tr>
<tr>
<td>10,000</td>
<td>1,492</td>
<td>10,000</td>
<td>3,290</td>
</tr>
<tr>
<td>15,000</td>
<td>2,239</td>
<td>15,000</td>
<td>4,934</td>
</tr>
<tr>
<td>20,000</td>
<td>2,985</td>
<td>20,000</td>
<td>6,579</td>
</tr>
<tr>
<td>25,000</td>
<td>3,731</td>
<td>25,000</td>
<td>8,224</td>
</tr>
<tr>
<td>30,000</td>
<td>4,478</td>
<td>30,000</td>
<td>9,868</td>
</tr>
<tr>
<td>35,000</td>
<td>5,224</td>
<td>35,000</td>
<td>11,513</td>
</tr>
<tr>
<td>40,000</td>
<td>5,970</td>
<td>40,000</td>
<td>13,158</td>
</tr>
<tr>
<td>45,000</td>
<td>6,716</td>
<td>45,000</td>
<td>14,803</td>
</tr>
<tr>
<td>50,000</td>
<td>7,463</td>
<td>50,000</td>
<td>16,447</td>
</tr>
<tr>
<td>100,000</td>
<td>14,925</td>
<td>100,000</td>
<td>32,895</td>
</tr>
<tr>
<td>150,000</td>
<td>22,388</td>
<td>150,000</td>
<td>49,342</td>
</tr>
<tr>
<td>200,000</td>
<td>29,850</td>
<td>200,000</td>
<td>65,789</td>
</tr>
<tr>
<td>250,000</td>
<td>37,313</td>
<td>250,000</td>
<td>82,237</td>
</tr>
</tbody>
</table>