Carbon/Graphite Fiber Risk Analysis and Assessment Study

An Assessment of the Risk to Douglas Commercial Transport Aircraft

H. C. Schjelderup, et al

McDonnell Douglas Corporation
Douglas Aircraft Company
Long Beach, California 90846

CONTRACT NAS1-15508
JANUARY 1980
# DOCUMENT RELEASE AUTHORIZATION

To be completed by responsible NASA Program Officer: Technical Monitor, or designee.

<table>
<thead>
<tr>
<th>Return to:</th>
<th>NASA Scientific and Technical Information Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.O. Box 8757</td>
<td>B.W.I. Airport, Maryland 21240</td>
</tr>
<tr>
<td>Cognizant NASA Center:</td>
<td>Langley Research Center</td>
</tr>
<tr>
<td>Office Code:</td>
<td>M/S 231</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date Signed</th>
<th>September 23, 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone No.</td>
<td>(804) 827-2591</td>
</tr>
</tbody>
</table>

## I. DOCUMENT IDENTIFICATION

<table>
<thead>
<tr>
<th>Title</th>
<th>Carbon/Graphite Fiber Risk Analysis and Assessment Study: An Assessment of the Risk to Douglas Commercial Transport Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>H. C. Schieldrup, et al.</td>
</tr>
<tr>
<td>Originating Organization</td>
<td>McDonnell Douglas Corporation</td>
</tr>
<tr>
<td>Contract/grant/interagency agreement No.</td>
<td>NAS-15508</td>
</tr>
<tr>
<td>Report Date</td>
<td>January 1980</td>
</tr>
</tbody>
</table>

**Document Security Classification:**

- [ ] C
- [ ] S
- [ ] CRD
- [ ] SRD

**Title Classification:**

- [ ] C
- [ ] S
- [ ] CRD
- [ ] SRD

**NASA CR:** 159212

**NASA TM:**

---

## II. DOCUMENT CHARACTERIZATION

### A. TYPE OF DOCUMENT

- [ ] Final (termination) report
- [ ] Topical Report
- [ ] Progress report required by contract/grant
- [ ] Interim report
- [ ] Other (specify) ________________

### B. PUBLICATION

- [ ] This document is to be printed as a NASA Formal Series report and is being coordinated with the Center technical publications office or Headquarters Code: NST-43

### C. METRIC UNITS OF MEASUREMENT

- [XX] Report meets SI Unit requirements in accordance with NPD 2220.4
- [ ] SI Unit requirements are waived

---

## III. DISTRIBUTION (Consider separately from announcement or nonannouncement, for which check Part IV)

### A. TYPE OF DISTRIBUTION

- [XX] Publicly available (no restrictions on provision to domestic or foreign requestors)
- [ ] May be exempt from public disclosure under Freedom of Information Act (NMI 1382.2). May only be distributed to group checked below. (Also check here if appropriate for security classified report)
  - [ ] Government agencies and their contractors
  - [ ] Government agencies
  - [ ] Government agencies and NASA contractors
  - [ ] NASA Headquarters and Center personnel
  - [ ] Other limitations (specify) ________________

- [XX] FEDD (For Early Domestic Dissemination) (Available to domestic U.S. requesters in accordance with NMI 2210.1)

- [XX] Security classified (available to all certified for equivalent level of security access: for additional restriction, check also the appropriate group above)

---

## IV. BIBLIOGRAPHIC PROCESSING

- [XX] May be announced in STAR (or LSTAR if classified or if a limited availability is checked in Part III.)
- [ ] May not be announced in STAR or LSTAR but may be entered into bibliographic series (see explanation of series on back of form)
- [ ] May not be announced in STAR or LSTAR but may be entered into record series (see explanation of series on back of form)
- [ ] May not be processed by Facility into information system because (Please provide a brief statement to be used in answering requests for this document)

---

## V. BLANKET RELEASE

- [ ] All documents issued on this contract/grant/interagency agreement/project may be processed and distributed as indicated above

**Signature:**

Barnett W. Peters, Jr.
Chief, STIPD

**Office Code:** M/S 180A

**Date Signed:** September 23, 1980

**Telephone No.:** (804) 827-2591

---

**NOTE:** Forward this completed form to your local Field Installation Representative for Document Release.
CARBON/GRAPHITE FIBER RISK ANALYSIS
AND ASSESSMENT STUDY
AN ASSESSMENT OF THE RISK TO DOUGLAS
COMMERCIAL TRANSPORT AIRCRAFT

January 1980

Prepared Under Contract NAS1-15508
for
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

by

Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California
PREFACE

This final report was prepared by cognizant personnel at the Douglas Aircraft Company, a division of the McDonnell Douglas Corporation, under NASA Contract No. NAS1-15508. The contract was administered by the NASA Langley Research Center. Mr. J. L. Humble of NASA was the Douglas Aircraft Technical Monitor and Mr. R. J. Huston was the overall Program Manager for NASA.

The work was performed under the general supervision of Dr. H. C. Schjelderup. The following Douglas personnel made significant contributions to the program:

- Electrical/Electronic Component Characterization - C. Q. Cook, E. Snyder
- Fiber Transfer Functions - B. Henning
- Potential Equipment Exposure - J. Hosford
- Equipment Vulnerability Assessment - D. L. Gilles, C. W. Swanstrom

iii
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2 SUMMARY AND CONCLUSIONS</td>
<td>3</td>
</tr>
<tr>
<td>3 DC-9/DC-10 ELECTRICAL/ELECTRONIC COMPONENT CHARACTERIZATION</td>
<td>5</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>5</td>
</tr>
<tr>
<td>3.2 Selection of Equipment for Categorization</td>
<td>5</td>
</tr>
<tr>
<td>3.3 Component Data Sheets</td>
<td>5</td>
</tr>
<tr>
<td>3.4 Observations/Recommendations</td>
<td>9</td>
</tr>
<tr>
<td>4 FIBER TRANSFER FUNCTIONS</td>
<td>19</td>
</tr>
<tr>
<td>4.1 Introduction</td>
<td>19</td>
</tr>
<tr>
<td>4.2 DC-10 Transfer Function</td>
<td>20</td>
</tr>
<tr>
<td>4.3 DC-9 Transfer Function</td>
<td>23</td>
</tr>
<tr>
<td>4.4 Discussion of Data</td>
<td>25</td>
</tr>
<tr>
<td>4.4.1 Main Engine Data</td>
<td>25</td>
</tr>
<tr>
<td>4.4.2 APU Data</td>
<td>25</td>
</tr>
<tr>
<td>4.4.3 Pneumatic and Conditioned Air Carts</td>
<td>26</td>
</tr>
<tr>
<td>4.4.4 Air-Conditioning Packs</td>
<td>26</td>
</tr>
<tr>
<td>4.4.5 Settling, Re-Entrainment, and Crack Capture</td>
<td>26</td>
</tr>
<tr>
<td>4.4.6 Data Summary</td>
<td>27</td>
</tr>
<tr>
<td>5 TRANSPORT AIRCRAFT EQUIPMENT POTENTIAL FOR EXPOSURE TO CARBON FIBERS</td>
<td>33</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>33</td>
</tr>
<tr>
<td>5.1.1 Inputs to Risk Analysis Models</td>
<td>33</td>
</tr>
<tr>
<td>5.1.2 Aircraft Operations on Airport</td>
<td>35</td>
</tr>
<tr>
<td>5.2 Data</td>
<td>36</td>
</tr>
<tr>
<td>5.2.1 Gate Times</td>
<td>36</td>
</tr>
<tr>
<td>5.2.2 Number of Operations</td>
<td>37</td>
</tr>
<tr>
<td>5.2.3 Aircraft at Maintenance Facility and Overnight Aircraft</td>
<td>38</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------</td>
</tr>
<tr>
<td>5.2.4 Operating Modes</td>
<td>39</td>
</tr>
<tr>
<td>5.2.5 Transfer Functions</td>
<td>41</td>
</tr>
<tr>
<td>5.3 Analysis</td>
<td>41</td>
</tr>
<tr>
<td>5.3.1 Expected Number of Aircraft at the Gate</td>
<td>41</td>
</tr>
<tr>
<td>5.3.2 Average Number of Aircraft per Airport</td>
<td>53</td>
</tr>
<tr>
<td>5.3.3 Potential Exposure per Aircraft</td>
<td>55</td>
</tr>
<tr>
<td>5.4 Future Changes in Aircraft Operation</td>
<td>55</td>
</tr>
<tr>
<td>5.5 Summary</td>
<td>58</td>
</tr>
<tr>
<td>6 EQUIPMENT VULNERABILITY ASSESSMENT</td>
<td>59</td>
</tr>
</tbody>
</table>
### TABLES

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-1</td>
<td>ATA Index (3-Digit)</td>
<td>6</td>
</tr>
<tr>
<td>3-2</td>
<td>DC-10 Data Sheets/Chapter Breakdown</td>
<td>7</td>
</tr>
<tr>
<td>3-3</td>
<td>DC-9 Data Sheets/Chapter Breakdown</td>
<td>8</td>
</tr>
<tr>
<td>3-4</td>
<td>Typical Fiber Effects</td>
<td>10</td>
</tr>
<tr>
<td>3-5</td>
<td>DC-10 Open Units Operating Regime</td>
<td>11</td>
</tr>
<tr>
<td>3-6</td>
<td>DC-9 Open Units Operating Regime</td>
<td>12</td>
</tr>
<tr>
<td>3-7</td>
<td>DC-10 Test Candidate Determination</td>
<td>13</td>
</tr>
<tr>
<td>3-8</td>
<td>DC-9 Test Candidate Determination</td>
<td>17</td>
</tr>
<tr>
<td>4-1</td>
<td>Transfer Function for CF to The Avionics and CAC Compartments of DC-10.</td>
<td>22</td>
</tr>
<tr>
<td>4-2</td>
<td>Transfer Function for CF to The Avionics Compartment of DC-9.</td>
<td>28</td>
</tr>
<tr>
<td>4-3</td>
<td>DC-10 Avionics Compartment Overall Transfer Function</td>
<td>29</td>
</tr>
<tr>
<td>4-4</td>
<td>DC-10 Center Accessory Compartment Overall Transfer Functions</td>
<td>30</td>
</tr>
<tr>
<td>4-5</td>
<td>DC-9 Avionics Compartment Overall Transfer Function</td>
<td>31</td>
</tr>
<tr>
<td>5-1</td>
<td>Average Scheduled Gate Times (Minutes)</td>
<td>36</td>
</tr>
<tr>
<td>5-2</td>
<td>Percent of Time per Operating Mode</td>
<td>40</td>
</tr>
<tr>
<td>5-3</td>
<td>Transfer Functions</td>
<td>42</td>
</tr>
<tr>
<td>5-4</td>
<td>Potential Exposure Factor</td>
<td>43</td>
</tr>
<tr>
<td>5-5</td>
<td>Chicago-O'Hare (ORD) Aircraft in Scheduled Service - August 1978.</td>
<td>44</td>
</tr>
<tr>
<td>5-6</td>
<td>New York City-Kennedy (JFK) Airport in Scheduled Service - August 1978.</td>
<td>45</td>
</tr>
<tr>
<td>5-7</td>
<td>St. Louis-Lambert (STL) Aircraft in Scheduled Service - August 1978.</td>
<td>46</td>
</tr>
<tr>
<td>5-8</td>
<td>New York City-La Guardia (LGA) Aircraft in Scheduled Service - August 1978.</td>
<td>47</td>
</tr>
<tr>
<td>Number</td>
<td>Table Title</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>5-9</td>
<td>Boston-Logan (BOS) Aircraft in Scheduled Service - August 1978.</td>
<td>48</td>
</tr>
<tr>
<td>5-10</td>
<td>Philadelphia (PHL) Aircraft in Scheduled Service - August 1978.</td>
<td>49</td>
</tr>
<tr>
<td>5-12</td>
<td>Atlanta-Hartsfield (ATL) Aircraft in Scheduled Service - August 1978.</td>
<td>51</td>
</tr>
<tr>
<td>5-13</td>
<td>Miami International (MIA) Aircraft in Scheduled Service - August 1978.</td>
<td>52</td>
</tr>
<tr>
<td>5-14</td>
<td>Average Number of Aircraft per Airport.</td>
<td>54</td>
</tr>
<tr>
<td>5-15</td>
<td>Potential Exposure per Airport (Expected Number of Aircraft) (Potential Exposure Factor).</td>
<td>56</td>
</tr>
<tr>
<td>6-1</td>
<td>DC-10 Failure Rate and Cost Assessment - Category A - Carbon Fiber Study.</td>
<td>60</td>
</tr>
<tr>
<td>6-2</td>
<td>DC-10 Failure Rate and Cost Assessment - Category B - Carbon Fiber Study.</td>
<td>61</td>
</tr>
<tr>
<td>6-3</td>
<td>DC-10 Failure Rate and Cost Assessment - Category C - Carbon Fiber Study.</td>
<td>61</td>
</tr>
<tr>
<td>6-4</td>
<td>DC-9 Failure Rate and Cost Assessment - Category A - Carbon Fiber Study.</td>
<td>62</td>
</tr>
<tr>
<td>6-5</td>
<td>DC-9 Failure Rate and Cost Assessment - Category B - Carbon Fiber Study.</td>
<td>63</td>
</tr>
<tr>
<td>6-6</td>
<td>DC-9 Failure Rate and Cost Assessment - Category C - Carbon Fiber Study.</td>
<td>64</td>
</tr>
</tbody>
</table>
SECTION 1
INTRODUCTION

The use of carbon/graphite composite material in aircraft structure is increasing every year and the increase is expected to continue for the foreseeable future. Concern has been expressed recently over the potential hazard to electrical and electronic devices should there be a release of free fiber due to a crash and fire. NASA established a comprehensive study program to estimate the expected dollar loss due to accidental release of carbon/graphite fibers. Work programs were conducted by a variety of firms and Government agencies to acquire data as to exposure and equipment sensitivity in order to provide data for a risk analysis.

This report presents the results of the following studies assigned to Douglas:

- DC-9/DC-10 Electrical/Electronic Component Characterization
- DC-9 and DC-10 Fiber Transfer Functions
- Potential for Transport Aircraft Equipment Exposure to Carbon Fibers
- Equipment Vulnerability Assessment.
SECTION 2
SUMMARY AND CONCLUSIONS

This report was prepared under contract to NASA and contains information necessary to evaluate the risk—to Douglas-manufactured commercial jet aircraft—caused by the accidental release of free carbon/graphite fibers from composite material. Detailed data from this report and similar reports prepared by Boeing Commercial Airplane Company and Lockheed California Company have been used by Arthur D. Little Inc. and Operations Research Institute Inc. to determine their estimate of the national risk factor.

Since the major threat would be to the aircraft avionics, the first two tasks undertaken were to determine entry path and filtration to the avionics compartment, and to classify the avionics equipment as to its vulnerability. Further tasks included an assessment of the average number of aircraft on the ground at selected airports during the day and at night and the vulnerability configuration of these aircraft, i.e., the probability of avionic equipment failure, the cost of maintenance, and the hazard to the aircraft.

Considerable interface with NASA risk analysis contractors, Arthur D. Little Inc., and Operations Research Institute Inc., is evident, and the use of their input is gratefully acknowledged.

This study established that there is only a negligible increase in risk, either now or projected to 1993, for the DC-9 and DC-10 fleets due to accidental release of free carbon/graphite fibers.
SECTION 3
DC-9/DC-10 ELECTRICAL/ELECTRONIC COMPONENT CHARACTERIZATION

3.1 Introduction

The identification, tabulation, and categorization of the DC-9 and DC-10 electrical and electronic components for carbon fiber (CF) risk assessment was accomplished in compliance with NASA Contract NAS1-15508.

3.2 Selection of Equipment for Categorization

The preliminary DC-9 Master Component List and the DC-10 Master Component List identifies all Line Replaceable Units (LRU) that have reliability, maintenance, or cost significance. The components evaluated by this study were obtained from these lists and are identified on the Component Data Sheets. The Component Data Sheets were assembled by ATA Chapters which are identified in Table 3-1. Reflected in Tables 3-2 and 3-3 are the number of data sheets and the number of units open/closed for the DC-10/DC-9 aircraft. These data sheets were previously submitted to NASA via letters CI-091-ACEE-537, dated 9 November 1978 and CI-091-ACEE-153, dated 26 March 1979 and are not included herein.

3.3 Component Data Sheets

The information contained in the data sheets relates primarily to internal and external box construction, ventilation, voltage and power requirements, and location of the equipment in the aircraft. Sheets containing this data were completed for those components whose enclosure construction was open, particular care for completeness being given to those units regarded as candidates for CF testing. The data sheet form utilized was reviewed by NASA.

Data sheets for equipment whose enclosure construction was regarded as sealed were not completed in detail although exceptions are found. While sealed equipment is not regarded as being subject to CF influence, component
<table>
<thead>
<tr>
<th>Code</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-00</td>
<td>AIR CONDITIONING</td>
</tr>
<tr>
<td>29-00</td>
<td>FUEL SYSTEM</td>
</tr>
<tr>
<td>35-00</td>
<td>OXYGEN</td>
</tr>
<tr>
<td>57-00</td>
<td>WING</td>
</tr>
<tr>
<td>20</td>
<td>DISTRIBUTION</td>
</tr>
<tr>
<td>28-00</td>
<td>STORAGE</td>
</tr>
<tr>
<td>30</td>
<td>CREW</td>
</tr>
<tr>
<td>71-00</td>
<td>AUXILIARY STRUCTURE</td>
</tr>
<tr>
<td>30</td>
<td>PRESSURIZATION CONTROL</td>
</tr>
<tr>
<td>20</td>
<td>DISTRIBUTION</td>
</tr>
<tr>
<td>40</td>
<td>DUMP</td>
</tr>
<tr>
<td>30</td>
<td>PORTABLE</td>
</tr>
<tr>
<td>50</td>
<td>FLIGHT SURFACES</td>
</tr>
<tr>
<td>40</td>
<td>COOLING</td>
</tr>
<tr>
<td>40</td>
<td>INDICATING</td>
</tr>
<tr>
<td>70</td>
<td>POCKET</td>
</tr>
<tr>
<td>60</td>
<td>TEMPERATURE CONTROL</td>
</tr>
<tr>
<td>22-00</td>
<td>HYDRAULIC POWER</td>
</tr>
<tr>
<td>20</td>
<td>MAIN</td>
</tr>
<tr>
<td>50</td>
<td>NACELLES/PYLONS STRUCTURE</td>
</tr>
<tr>
<td>30</td>
<td>AUXILIARY INDICATING</td>
</tr>
<tr>
<td>73-00</td>
<td>ENGINE FUEL AND CONTROL</td>
</tr>
<tr>
<td>20</td>
<td>DISTRIBUTION</td>
</tr>
<tr>
<td>40</td>
<td>INDICATING</td>
</tr>
<tr>
<td>74-00</td>
<td>IGNITION</td>
</tr>
<tr>
<td>30</td>
<td>WATER/WASTE</td>
</tr>
<tr>
<td>30</td>
<td>POTABLE</td>
</tr>
<tr>
<td>74-00</td>
<td>ELECTRICAL POWER SUPPLY</td>
</tr>
<tr>
<td>00</td>
<td>AIR</td>
</tr>
<tr>
<td>40</td>
<td>AIR SUPPLY</td>
</tr>
<tr>
<td>33</td>
<td>DISTRIBUTION</td>
</tr>
<tr>
<td>00</td>
<td>ENGINE ANTI-ICING (SERIES 20 ONLY)</td>
</tr>
<tr>
<td>00</td>
<td>IGNITION/STARTING</td>
</tr>
<tr>
<td>50</td>
<td>OIL</td>
</tr>
<tr>
<td>10</td>
<td>DOORS</td>
</tr>
<tr>
<td>52-00</td>
<td>MAIN ENGINES AND DOORS</td>
</tr>
<tr>
<td>10</td>
<td>PASSenger/Crew</td>
</tr>
<tr>
<td>10</td>
<td>CARGO</td>
</tr>
<tr>
<td>10</td>
<td>SERVICE</td>
</tr>
<tr>
<td>10</td>
<td>Fixed interior</td>
</tr>
<tr>
<td>10</td>
<td>DOOR WARNING</td>
</tr>
<tr>
<td>10</td>
<td>LANDING GEAR</td>
</tr>
<tr>
<td>70</td>
<td>EXHAUST</td>
</tr>
<tr>
<td>80</td>
<td>OIL</td>
</tr>
<tr>
<td>23-00</td>
<td>COMMUNICATIONS</td>
</tr>
<tr>
<td>10</td>
<td>HIGH FREQUENCY (HF)</td>
</tr>
<tr>
<td>20</td>
<td>VERY HIGH FREQUENCY (VHF)</td>
</tr>
<tr>
<td>40</td>
<td>PASSENGER ADDRESS AND ENTERTAINMENT</td>
</tr>
<tr>
<td>30</td>
<td>AUDIO INTEGRATING</td>
</tr>
<tr>
<td>50</td>
<td>CENTRAL WARNING SYSTEMS</td>
</tr>
<tr>
<td>50</td>
<td>EXTERNAL POWER</td>
</tr>
<tr>
<td>32-00</td>
<td>LANDING GEAR</td>
</tr>
<tr>
<td>60</td>
<td>MAIN ENGINES AND DOORS</td>
</tr>
<tr>
<td>20</td>
<td>NOSE GEARS AND DOORS</td>
</tr>
<tr>
<td>20</td>
<td>EXTENSION AND RETRACTION</td>
</tr>
<tr>
<td>20</td>
<td>WHEELS AND BRAKES</td>
</tr>
<tr>
<td>20</td>
<td>STEERING</td>
</tr>
<tr>
<td>20</td>
<td>POSITION AND WARNING</td>
</tr>
<tr>
<td>20</td>
<td>LIGHTS</td>
</tr>
<tr>
<td>53-00</td>
<td>FUSELAGE</td>
</tr>
<tr>
<td>50</td>
<td>AERODYNAMIC FAIRINGS</td>
</tr>
<tr>
<td>80</td>
<td>STARTING</td>
</tr>
<tr>
<td>82-00</td>
<td>WATER INJECTION (P&amp;W)</td>
</tr>
<tr>
<td>20</td>
<td>STORAGE</td>
</tr>
<tr>
<td>33</td>
<td>DISTRIBUTION</td>
</tr>
<tr>
<td>30</td>
<td>INDICATING</td>
</tr>
<tr>
<td>60</td>
<td>FUEL SYSTEM</td>
</tr>
<tr>
<td>30</td>
<td>STORAGE</td>
</tr>
<tr>
<td>30</td>
<td>AUXILIARY STRUCTURE</td>
</tr>
<tr>
<td>20</td>
<td>FLIGHT SURFACES</td>
</tr>
<tr>
<td>50</td>
<td>FLIGHT SURFACES</td>
</tr>
<tr>
<td>40</td>
<td>FLIGHT SURFACES</td>
</tr>
<tr>
<td>30</td>
<td>FLIGHT ENVIRONMENTAL DATA</td>
</tr>
<tr>
<td>30</td>
<td>ATTITUDE AND DIRECTION</td>
</tr>
<tr>
<td>30</td>
<td>LANDING AND TAXING AIDS</td>
</tr>
<tr>
<td>30</td>
<td>INDEPENDENT POSITION DETERMINING</td>
</tr>
<tr>
<td>30</td>
<td>POSITION DETERMINING</td>
</tr>
<tr>
<td>30</td>
<td>POSITION COMPUTING</td>
</tr>
<tr>
<td>30</td>
<td>CABIN</td>
</tr>
<tr>
<td>30</td>
<td>DOOR</td>
</tr>
</tbody>
</table>

**TABLE 3-1**
ATA INDEX (3-DIGIT)
<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>DATA SHEETS</th>
<th>UNITS OPEN</th>
<th>UNITS CLOSED</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 AIR CONDITIONING</td>
<td>38</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>22 AUTO FLIGHT</td>
<td>28</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>23 COMMUNICATIONS</td>
<td>30</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>24 ELECTRICAL POWER</td>
<td>35</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>25 EQUIPMENT/FURNISHINGS</td>
<td>11</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>26 FIRE PROTECTION</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>27 FLIGHT CONTROLS</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>28 FUEL SYSTEM</td>
<td>13</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>29 HYDRAULIC POWER</td>
<td>17</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>30 ICE AND RAIN PROTECTION</td>
<td>12</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>31 INSTRUMENTS</td>
<td>16</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>32 LANDING GEAR</td>
<td>14</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>33 LIGHTS</td>
<td>8</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>34 NAVIGATION</td>
<td>56</td>
<td>23</td>
<td>33</td>
</tr>
<tr>
<td>35 OXYGEN</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>36 PNEUMATIC</td>
<td>10</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>38 WATER/WASTE</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>49 AIRBORNE AUXILIARY POWER</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>52 DOORS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>53 FUSELAGE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>54 NACELLES/PYLONS STRUCTURE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>55 STABILIZERS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>56 WINDOWS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>57 WING</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>71 POWER PLANT</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>72 ENGINE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>73 ENGINE FUEL AND CONTROL</td>
<td>10</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>74 IGNITION</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>75 AIR</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>76 ENGINE CONTROLS</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>77 ENGINE INDICATING</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>78 EXHAUST</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>79 OIL</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>80 STARTING</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>82 WATER INJECTION (P&amp;W)</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>359</strong></td>
<td><strong>72</strong></td>
<td><strong>287</strong></td>
</tr>
<tr>
<td>CHAPTER</td>
<td>DATA SHEETS</td>
<td>UNITS OPEN</td>
<td>UNITS CLOSED</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td>21 AIR CONDITIONING</td>
<td>21</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>22 AUTO FLIGHT</td>
<td>16</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>23 COMMUNICATIONS</td>
<td>26</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>24 ELECTRICAL POWER</td>
<td>20</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>25 EQUIPMENT FURNISHINGS</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>26 FIRE PROTECTION</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>27 FLIGHT CONTROLS</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>28 FUEL SYSTEM</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>29 HYDRAULIC POWER</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>30 ICE AND RAIN PROTECTION</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>31 INSTRUMENTS</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>32 LANDING GEAR</td>
<td>7</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>33 LIGHTS</td>
<td>11</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>34 NAVIGATION</td>
<td>64</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>35 OXYGEN</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>36 PNEUMATIC</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>38 WATER/WASTE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>49 AIRBORNE AUXILIARY POWER</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>52 DOORS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>53 FUSELAGE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>54 NACELLES/PYLONS STRUCTURE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>55 STABILIZERS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>56 WINDOWS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>57 WING</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>71 POWER PLANT</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>72 ENGINE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>73 ENGINE FUEL AND CONTROL</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>74 IGNITION</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>75 AIR</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>76 ENGINE CONTROLS</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>77 ENGINE INDICATING</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>78 EXHAUST</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>79 OIL</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>80 STARTING</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>82 WATER INJECTION (P&amp;W)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

| Total                         | 226         | 54         | 172          |
data sheets for these equipments were included in the report, both for report completeness and to provide visibility into the number and range of the equipment examined.

3.4 Observations/Recommendation

The study shows 20 percent of the DC-10 components and 23 percent of the DC-9 components examined have open construction. Most of these are found in Chapter 23, Communication; Chapter 24, Electrical Power; and Chapter 34, Navigation.

The guidelines of NASA Technical Memorandum 78788 were used to categorize these open units. This memorandum, "A Summary of Data Related to the Carbon/Graphite Fiber Electrical Hazard Resulting from Accidental Release from Aircraft (U)," dated November 1978, states that in general the nature of the hazard is determined by the voltage and power level at which the equipment operates. Equipment operation is broken down into three broad regimes: low voltage, medium voltage, and high voltage. Table 3-4, received from NASA during Douglas/NASA discussions, summarizes the voltage regimes and the typical effect that carbon fibers are likely to cause. The open units from the Douglas study are identified and categorized in Tables 3-5 and 3-6 in accordance with this voltage/power criteria; hence, the equipment in the principal problem areas of low-voltage, low-power; medium-voltage, high-power; and high-voltage, high-power categories is readily identified.

Tables 3-7 and 3-8 identify by chapter each component determined by the study to have open construction, thereby warranting consideration for CF testing. In addition to the internal/external box construction, ventilation, and installation location, the recommendation of a unit as a test candidate also considered representation from various voltage and power regimes, type of equipment and its use, ease of testing, and any unique feature of a unit such as internal fan, conventional wiring, etc. Tables 3-7 and 3-8 identify those units thought to be representative of test candidates.
### TABLE 3-4
#### TYPICAL FIBER EFFECTS

<table>
<thead>
<tr>
<th>VOLTAGE RANGE</th>
<th>LOW POWER (UP TO 100W)</th>
<th>HIGH POWER (ABOVE 100W)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0 TO 30 VOLTS)</td>
<td>SUSTAINED SHORTS</td>
<td>SUSTAINED SHORTS</td>
</tr>
<tr>
<td></td>
<td>FIBER NOT BURNED</td>
<td>FIBER NOT BURNED</td>
</tr>
<tr>
<td></td>
<td>MALFUNCTIONS</td>
<td>NO EQUIPMENT DAMAGE</td>
</tr>
<tr>
<td></td>
<td>NO LOCAL DAMAGE</td>
<td></td>
</tr>
<tr>
<td><strong>MEASURED</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(30 TO 1000 VOLTS)</td>
<td>SPARKING OR SHORTS</td>
<td>SOME SUSTAINED ARCS</td>
</tr>
<tr>
<td></td>
<td>POSSIBLE FIBER BURN</td>
<td>FIBER BURNS</td>
</tr>
<tr>
<td></td>
<td>TRANSIENTS</td>
<td>TRANSIENTS</td>
</tr>
<tr>
<td></td>
<td>BLOWN FUSES</td>
<td>BLOWN FUSES</td>
</tr>
<tr>
<td></td>
<td>STRESSED COMPONENTS</td>
<td>STRESSED COMPONENTS</td>
</tr>
<tr>
<td></td>
<td>LOW DAMAGE POTENTIAL</td>
<td>DAMAGE USUALLY REPAIRABLE</td>
</tr>
<tr>
<td><strong>HIGH</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&gt;1000 VOLTS)</td>
<td>SPARKS, NO SUSTAINED ARCS</td>
<td>SUSTAINED ARCS</td>
</tr>
<tr>
<td></td>
<td>LOW VOLTAGE CORONA</td>
<td>CORONA</td>
</tr>
<tr>
<td></td>
<td>TRANSIENTS</td>
<td>FLASHOVER</td>
</tr>
<tr>
<td></td>
<td>INTERRUPTIONS</td>
<td>MAY BE SEVERE DAMAGE</td>
</tr>
<tr>
<td>TABLE 3-5</td>
<td>DC-10 OPEN UNITS OPERATING REGIME</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>LOW VOLTAGE — LOW POWER</strong></td>
<td><strong>HIGH VOLTAGE — HIGH POWER</strong></td>
<td></td>
</tr>
<tr>
<td>CABIN ALT WARN — ANEROID PRESSURE SWITCH</td>
<td>WEATHER RADAR INDICATOR</td>
<td></td>
</tr>
<tr>
<td>CARGO COMPARTMENT TEMP SENSOR</td>
<td>POWER SOURCE</td>
<td></td>
</tr>
<tr>
<td>ZONE TEMP INDICATOR SENSOR</td>
<td>SMOKE DETECTOR</td>
<td></td>
</tr>
<tr>
<td>DUCT TEMP INDICATOR SENSOR</td>
<td>VOR/ILS RECEIVER</td>
<td></td>
</tr>
<tr>
<td>VHF TRANSCEIVER (2)</td>
<td>VHF TRANSCEIVER</td>
<td></td>
</tr>
<tr>
<td>PASSENGER ADDRESS AMPLIFIER</td>
<td>WEATHER RADAR R/T UNIT</td>
<td></td>
</tr>
<tr>
<td>HANDSET</td>
<td>CONTROL DISPLAY UNIT (RNAV)</td>
<td></td>
</tr>
<tr>
<td>AUDIO CONTROL PANEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWITCH ASSEMBLY, ROLLER CONTROL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATTERY/LIGHT, EVAC EQUIPMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMOKE DETECTOR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMOKE DETECTOR INDICATOR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THERMAL SWITCH, ANTI-ICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROXIMITY ELECT UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARN AND CAUTION CONTROLLER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HORIZONTAL SITUATION INDICATOR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARKER BEACON RECEIVER (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INERTIAL SENSOR DISPLAY UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOR/ILS RECEIVER (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADF RECEIVER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIGHT SWITCH</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MEDIUM VOLTAGE — LOW POWER</strong></td>
<td><strong>MEDIUM VOLTAGE — HIGH POWER</strong></td>
<td></td>
</tr>
<tr>
<td>TAPE ANNOUNCEMENT REPRODUCER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAIN MULTIPLIER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUB MULTIPLIER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERHEAD DECODER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATTERY VENT PUMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLIGHT DATA ENTRY PANEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLIGHT DATA ACQUISITION UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEIGHT AND BALANCE COMPUTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDICATOR/CONTROL PANEL (WT AND BAL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENTRAL AURAL WARNING UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANTI-SKID CONTROL UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VERTICAL GYRO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STANDBY ATTITUDE INDICATOR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILS RECEIVER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RADIO ALTIMETER R/T UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GROUND PROXIMITY WARNING COMPUTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOR RECEIVER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLIGHT DATA STORAGE UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTROL SWITCH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FUEL FLOW ELECTRONICS UNIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENGINE IGNITION SWITCH</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HIGH VOLTAGE — LOW POWER</strong></td>
<td><strong>HIGH VOLTAGE — HIGH POWER</strong></td>
<td></td>
</tr>
<tr>
<td>WEATHER RADAR INDICATOR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POWER SOURCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PRINCIPAL AREAS OF CONCERN</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**TABLE 3-6**
DC-9 OPEN UNITS OPERATING REGIME

<table>
<thead>
<tr>
<th>* LOW VOLTAGE — LOW POWER</th>
<th>LOW VOLTAGE — HIGH POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHF TRANSCEIVER (2)</td>
<td>NAV INSTRUMENT FAILURE MONITOR</td>
</tr>
<tr>
<td>PA AMPLIFIER</td>
<td></td>
</tr>
<tr>
<td>CABIN SPEAKER</td>
<td></td>
</tr>
<tr>
<td>PILOT'S CALL BELL</td>
<td></td>
</tr>
<tr>
<td>MECHANIC CALL HORN</td>
<td></td>
</tr>
<tr>
<td>AUDIO PANEL</td>
<td></td>
</tr>
<tr>
<td>JACK PANEL</td>
<td></td>
</tr>
<tr>
<td>FLIGHT COMP SPEAKER</td>
<td></td>
</tr>
<tr>
<td>FLIGHT INTERPHONE AMPLIFIER</td>
<td></td>
</tr>
<tr>
<td>SMOKE DETECTOR</td>
<td></td>
</tr>
<tr>
<td>ANTI-SKID CONTROL BOX</td>
<td></td>
</tr>
<tr>
<td>PROXIMITY SW CONTROL</td>
<td></td>
</tr>
<tr>
<td>MASTER CONTROLLER</td>
<td></td>
</tr>
<tr>
<td>MARKER BEACON RECEIVER (2)</td>
<td></td>
</tr>
<tr>
<td>VOR/ILS RECEIVER</td>
<td></td>
</tr>
<tr>
<td>ADF RECEIVER (2)</td>
<td></td>
</tr>
</tbody>
</table>

**MEDIUM VOLTAGE — LOW POWER**

<table>
<thead>
<tr>
<th>TAPE REPRODUCER</th>
<th>LOW VOLTAGE — HIGH POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATTERY VENT FAN</td>
<td>WINDSHIELD TEMPERATURE CONTROLLER</td>
</tr>
<tr>
<td>INSTRUMENT AMPLIFIER</td>
<td>AC GENERATOR</td>
</tr>
<tr>
<td>VERTICAL GYRO</td>
<td>GENERATOR CONTROL PANEL</td>
</tr>
<tr>
<td>FLIGHT DIR ROLL COMPUTER</td>
<td>BUS CONTROL PANEL</td>
</tr>
<tr>
<td>FLIGHT DIR PITCH COMPUTER</td>
<td>AC REGULATOR</td>
</tr>
<tr>
<td>NAV COMPARATOR UNIT</td>
<td>AC RELAY</td>
</tr>
<tr>
<td>RATE-OF-TURN RACK</td>
<td>EMERGENCY INVERTER</td>
</tr>
<tr>
<td>STANDBY HORIZON INDICATOR</td>
<td>TRANSFORMER-RECTIFIER</td>
</tr>
<tr>
<td>RADIO ALTIMETER R/T (2)</td>
<td>BATTERY CHARGER</td>
</tr>
<tr>
<td>GROUND PROXIMITY WARNING COMPUTER</td>
<td>TOTAL AIR TEMPERATURE SENSOR</td>
</tr>
<tr>
<td>FLIGHT DIRECTOR COMPUTER</td>
<td>INSTRUMENT AMPLIFIER RACK</td>
</tr>
</tbody>
</table>

**HIGH VOLTAGE — LOW POWER**

<table>
<thead>
<tr>
<th>WEATHER RADAR INDICATOR (2)</th>
<th>* MEDIUM VOLTAGE — HIGH POWER</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>WEATHER RADAR INDICATOR (2)</th>
<th>* HIGH VOLTAGE — HIGH POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF TRANSCEIVER</td>
<td>WEATHER RADAR R/T UNIT</td>
</tr>
<tr>
<td>ATC TRANSPONDER (2)</td>
<td></td>
</tr>
<tr>
<td>DME INTERROGATOR</td>
<td></td>
</tr>
</tbody>
</table>

*PRINCIPAL AREAS OF CONCERN
## TABLE 3-7
DC-10 TEST CANDIDATE DETERMINATION

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>COMPONENT</th>
<th>TEST CANDIDATE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-31-05</td>
<td>STANDBY CABIN PRESSURE CONTROLLER</td>
<td>X</td>
<td>OPENING IS SCREENED AND FILTERED, REDUNDANT UNIT</td>
</tr>
<tr>
<td>21-33-03</td>
<td>ANEROID PRESSURE SWITCH (CABIN ALT WARN)</td>
<td>X</td>
<td>SWITCH ENCLOSED, TYPICAL EXTERNAL SCREW TERMINALS</td>
</tr>
<tr>
<td>21-41-02</td>
<td>CARGO COMPARTMENT TEMP SENSOR</td>
<td>X</td>
<td>CARGO COMPARTMENT HEAT – SIMPLE COIL SENSOR</td>
</tr>
<tr>
<td>21-64-02</td>
<td>ZONE TEMP INDICATOR SENSOR</td>
<td>X</td>
<td>COMPARTMENT HEAT SENSOR – SIMPLE COIL SENSOR</td>
</tr>
<tr>
<td>21-64-03</td>
<td>DUCT TEMP INDICATOR SENSOR</td>
<td>X</td>
<td>DUCT TEMPERATURE SENSOR – SIMPLE COIL SENSOR</td>
</tr>
<tr>
<td>22-11-01</td>
<td>FLIGHT GUIDANCE PITCH COMPUTER</td>
<td>X</td>
<td>DIFFICULT TO SIMULATE/TEST</td>
</tr>
<tr>
<td>22-12-01</td>
<td>FLIGHT GUIDANCE ROLL COMPUTER</td>
<td>X</td>
<td>DIFFICULT TO SIMULATE/TEST</td>
</tr>
<tr>
<td>22-13-01</td>
<td>FLIGHT GUIDANCE YAW COMPUTER</td>
<td>X</td>
<td>DIFFICULT TO SIMULATE/TEST</td>
</tr>
<tr>
<td>23-11-01</td>
<td>HF TRANSCEIVER</td>
<td>X</td>
<td>FORCED COOLING, HIGH VOLTAGE, HIGH POWER</td>
</tr>
<tr>
<td>23-21-01</td>
<td>VHF TRANSCEIVER (2 LISTED)</td>
<td>X</td>
<td>LOW VOLTAGE, LOW POWER, TYPICAL CONSTRUCTION</td>
</tr>
<tr>
<td>23-31-02</td>
<td>PASSENGER ADDRESS AMPLIFIER</td>
<td>X</td>
<td>PASSENGER ADDRESS</td>
</tr>
<tr>
<td>23-31-02</td>
<td>PA AMPLIFIER</td>
<td>X</td>
<td>PASSENGER ADDRESS</td>
</tr>
<tr>
<td>23-31-05</td>
<td>HANDSET</td>
<td>X</td>
<td>PASSENGER ADDRESS</td>
</tr>
<tr>
<td>23-32-01</td>
<td>REPRODUCER, TAPE; ANNOUNCEMENT</td>
<td>X</td>
<td>PASSENGER ADDRESS</td>
</tr>
<tr>
<td>23-33-01</td>
<td>MAIN MULTIPLEXER</td>
<td>X</td>
<td>PASSENGER ENTERTAINMENT</td>
</tr>
<tr>
<td>23-33-02</td>
<td>SUB MULTIPLEXER</td>
<td>X</td>
<td>PASSENGER ENTERTAINMENT</td>
</tr>
<tr>
<td>23-33-03</td>
<td>TIMER/DECODER, SECTION</td>
<td>X</td>
<td>PASSENGER ENTERTAINMENT</td>
</tr>
<tr>
<td>23-33-06</td>
<td>OVERHEAD DECODER</td>
<td>X</td>
<td>PASSENGER ENTERTAINMENT</td>
</tr>
<tr>
<td>23-51-05</td>
<td>AUDIO PANEL CONTROL</td>
<td>X</td>
<td>FLIGHT INTERPHONE</td>
</tr>
<tr>
<td>CHAPTER</td>
<td>COMPONENT</td>
<td>TEST CANDIDATE</td>
<td>REMARKS</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------</td>
<td>----------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>24-21-01</td>
<td>AC GENERATOR</td>
<td>X</td>
<td>ENGINE GENERATOR</td>
</tr>
<tr>
<td>24-24-01</td>
<td>1200 VA STATIC INVERTER</td>
<td>X</td>
<td>MEDIUM VOLTAGE, HIGH POWER – REPRESENTATIVE</td>
</tr>
<tr>
<td>24-25-01</td>
<td>TURBINE GENERATOR ASSEMBLY</td>
<td>X</td>
<td>IN FLIGHT USE ONLY — EMERGENCY HYDRAULIC POWER</td>
</tr>
<tr>
<td>24-31-01</td>
<td>TRANSFORMER/RECTIFIER POWER SUPPLY</td>
<td>X</td>
<td>MEDIUM VOLTAGE, HIGH POWER – CONVENTIONAL WIRING</td>
</tr>
<tr>
<td>24-34-03</td>
<td>BATTERY CHARGER</td>
<td>X</td>
<td>NOT USED CONTINUOUSLY</td>
</tr>
<tr>
<td>24-35-01</td>
<td>BATTERY VENT PUMP</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER – NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>24-41-03</td>
<td>GROUND POWER RECEPTACLE</td>
<td>X</td>
<td>GROUND OPERATION ONLY</td>
</tr>
<tr>
<td>24-51-01</td>
<td>TRANSFORMER, INSTRUMENT BUS</td>
<td>X</td>
<td>MEDIUM VOLTAGE, HIGH POWER – INSULATED WINDINGS</td>
</tr>
<tr>
<td>25-52-05</td>
<td>SWITCH ASSEMBLY, CONTROL, ROLLER</td>
<td>X</td>
<td>NOT CRITICAL, CARGO LOADING SYSTEM</td>
</tr>
<tr>
<td>25-61-06</td>
<td>BATTERY AND LIGHT</td>
<td>X</td>
<td>EVACUATION EQUIPMENT</td>
</tr>
<tr>
<td>26-14-01</td>
<td>SMOKE DETECTOR</td>
<td>X</td>
<td>CARGO COMPARTMENT, CASE OPEN, COMPONENTS SEALED</td>
</tr>
<tr>
<td>26-15-02</td>
<td>SMOKE DETECTOR INDICATOR</td>
<td>X</td>
<td>LIGHT</td>
</tr>
<tr>
<td>29-21-01</td>
<td>PUMP, ELECT MOTOR DRIVE</td>
<td>X</td>
<td>HYDRAULIC POWER BACKUP — CHECKED ON GROUND</td>
</tr>
<tr>
<td>30-22-05</td>
<td>THERMAL SWITCH</td>
<td>X</td>
<td>TYPICAL EXTERNAL SCREW TERMINAL CONNECTIONS</td>
</tr>
<tr>
<td>30-41-01</td>
<td>WINDSHIELD ANTI-ICING CONTROLLER</td>
<td>X</td>
<td>MEDIUM VOLTAGE, HIGH POWER</td>
</tr>
<tr>
<td>CHAPTER</td>
<td>COMPONENT</td>
<td>TEST CANDIDATE</td>
<td>REMARKS</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>31-31-04</td>
<td>FLIGHT DATA ENTRY PANEL</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER — NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>31-31-05</td>
<td>FLIGHT DATA ACQUISITION UNIT</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER — NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>31-41-01</td>
<td>WEIGHT AND BALANCE COMPUTER</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER — NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>31-41-02</td>
<td>INDICATOR/CONTROL PANEL (WT AND BAL)</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER — NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>31-51-01</td>
<td>CENTRAL AURAL WARNING UNIT</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER — NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>32-45-01</td>
<td>ANTISKID CONTROL UNIT</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER — NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>32-61-05</td>
<td>PROXIMITY ELECT UNIT</td>
<td>X</td>
<td>LOW VOLTAGE, LOW POWER, REQUIRED/CHECKED AT DISPATCH</td>
</tr>
<tr>
<td>33-11-04</td>
<td>LAMP DIMMER</td>
<td>X</td>
<td>LOCATED FLT ENG PANEL — INSTRUMENT LIGHT CONTROL</td>
</tr>
<tr>
<td>33-15-01</td>
<td>WARN AND CAUTION CONTROLLER</td>
<td>X</td>
<td>BASICALLY A SWITCHING BOX</td>
</tr>
<tr>
<td>34-16-01</td>
<td>CENTRAL AIR DATA COMPUTER</td>
<td>X</td>
<td>UNPROTECTED WIRE WRAP MOTHERBOARD</td>
</tr>
<tr>
<td>34-22-01</td>
<td>HORIZONTAL SITUATION INDICATOR</td>
<td>X</td>
<td>ESSENTIALLY PROTECTED</td>
</tr>
<tr>
<td>34-23-01</td>
<td>VERTICAL GYRO</td>
<td>X</td>
<td>ESSENTIALLY PROTECTED</td>
</tr>
<tr>
<td>34-28-01</td>
<td>STANDBY ATTITUDE INDICATOR</td>
<td>X</td>
<td>HAS FILTERS, BACK-UP UNIT</td>
</tr>
<tr>
<td>34-31-01</td>
<td>MARKER BEACON RECEIVER (2)</td>
<td>X</td>
<td>DRAW-THROUGH COOLING, METAL CHASSIS</td>
</tr>
<tr>
<td>34-32-01</td>
<td>ILS RECEIVER</td>
<td>X</td>
<td>TYPICAL RADIO CONSTRUCTION</td>
</tr>
<tr>
<td>34-41-01</td>
<td>WEATHER RADAR R/T UNIT</td>
<td>X</td>
<td>HAS FILTER, DIFFICULT TO TEST</td>
</tr>
<tr>
<td>34-41-03</td>
<td>WEATHER RADAR INDICATOR</td>
<td>X</td>
<td>HIGH VOLTAGE, LOW POWER — NON-CRITICAL CATEGORY, HARD TO TEST</td>
</tr>
<tr>
<td>34-42-01</td>
<td>RADIO ALTIMETER R/T UNIT</td>
<td>X</td>
<td>TYPICAL CONSTRUCTION, FORCED COOLING</td>
</tr>
<tr>
<td>CHAPTER</td>
<td>COMPONENT</td>
<td>TEST CANDIDATE</td>
<td>REMARKS</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------------------</td>
<td>----------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>34-43-03</td>
<td>INERTIAL NAVIGATION UNIT</td>
<td>X</td>
<td>HIGH COST ITEM; DIFFICULT TO TEST</td>
</tr>
<tr>
<td>34-43-11</td>
<td>INERTIAL SENSOR DISPLAY UNIT</td>
<td>X</td>
<td>REQUIRES INTERFACING EQUIPMENT TO TEST</td>
</tr>
<tr>
<td>34-45-01</td>
<td>GROUND PROXIMITY WARN COMPUTER</td>
<td>X</td>
<td>TYPICAL CONSTRUCTION</td>
</tr>
<tr>
<td>34-51-01</td>
<td>VOR/ILS RECEIVER (2)</td>
<td>X</td>
<td>TYPICAL CONSTRUCTION, DUAL FUNCTION</td>
</tr>
<tr>
<td>34-51-01</td>
<td>VOR RECEIVER</td>
<td>X</td>
<td>TYPICAL CONSTRUCTION, FORCED COOLING</td>
</tr>
<tr>
<td>34-52-01</td>
<td>DME (2)</td>
<td>X</td>
<td>FORCED COOLING, INTERNAL FAN</td>
</tr>
<tr>
<td>34-53-01</td>
<td>ADF RECEIVER</td>
<td>X</td>
<td>TYPICAL RADIO CONSTRUCTION</td>
</tr>
<tr>
<td>34-54-01</td>
<td>ATC TRANSPONDER</td>
<td>X</td>
<td>REPRESENTATIVE TEST UNIT</td>
</tr>
<tr>
<td>34-61-01</td>
<td>NAVIGATION COMPUTER</td>
<td>X</td>
<td>HIGH COST ITEM, DIFFICULT TO TEST</td>
</tr>
<tr>
<td>34-61-02</td>
<td>TAPE CARTRIDGE UNIT</td>
<td>X</td>
<td>REQUIRES INTERFACING EQUIPMENT TO TEST</td>
</tr>
<tr>
<td>34-61-03</td>
<td>CONTROL DISPLAY UNIT</td>
<td>X</td>
<td>REQUIRES INTERFACING EQUIPMENT TO TEST, HIGH COST</td>
</tr>
<tr>
<td>36-10-01</td>
<td>CONTROL SWITCH, PNEUMATIC</td>
<td>X</td>
<td>TYPICAL ROTARY SWITCH, EXTERNAL TERMINALS</td>
</tr>
<tr>
<td>36-23-04</td>
<td>LIGHT SWITCH</td>
<td>X</td>
<td>TYPICAL SWITCH</td>
</tr>
<tr>
<td>36-27-06</td>
<td>CONTROLLER, PNEUMATIC SYSTEM</td>
<td>X</td>
<td>REDUNDANT UNIT</td>
</tr>
<tr>
<td>73-31-03</td>
<td>FUEL FLOW ELECTRONICS UNIT</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER – NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>74-30-01</td>
<td>ENGINE IGNITION SWITCH</td>
<td>X</td>
<td>TYPICAL ROTARY SWITCH, EXTERNAL TERMINALS</td>
</tr>
<tr>
<td>CHAPTER COMPONENT</td>
<td>TEST CANDIDATE</td>
<td>REMARKS</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------</td>
<td>--------------------------------------</td>
<td></td>
</tr>
<tr>
<td>23-11-01 HF TRANSEIVER</td>
<td>X</td>
<td>ALSO A DC-10 CANDIDATE</td>
<td></td>
</tr>
<tr>
<td>23-21-01 VHF TRANSEIVER (2 LISTED)</td>
<td>X</td>
<td>ALSO A DC-10 CANDIDATE</td>
<td></td>
</tr>
<tr>
<td>23-31-02 PASSENGER ADDRESS AMPLIFIER</td>
<td>X</td>
<td>LOW VOLTAGE-LOW POWER, TYPICAL CANDIDATE</td>
<td></td>
</tr>
<tr>
<td>23-31-05 CABIN SPEAKER</td>
<td>X</td>
<td>PASSENGER ADDRESS</td>
<td></td>
</tr>
<tr>
<td>23-32-01 TAPE REPRODUCER</td>
<td>X</td>
<td>PASSENGER ENTERTAINMENT</td>
<td></td>
</tr>
<tr>
<td>23-41-02 PILOT CALL BELL</td>
<td>X</td>
<td>INTERPHONE</td>
<td></td>
</tr>
<tr>
<td>23-41-03 MECHANIC CALL HORN</td>
<td>X</td>
<td>INTERPHONE</td>
<td></td>
</tr>
<tr>
<td>23-52-01 AUDIO PANEL</td>
<td>X</td>
<td>INTERPHONE</td>
<td></td>
</tr>
<tr>
<td>23-52-02 JACK PANEL</td>
<td>X</td>
<td>INTERPHONE</td>
<td></td>
</tr>
<tr>
<td>23-52-03 FLIGHT COMPARTMENT SPEAKER</td>
<td>X</td>
<td>INTERPHONE</td>
<td></td>
</tr>
<tr>
<td>23-52-05 FLIGHT INTERPHONE AMPLIFIER</td>
<td>X</td>
<td>INTERPHONE</td>
<td></td>
</tr>
<tr>
<td>24-21-01 AC GENERATOR</td>
<td>X</td>
<td>ENGINE GENERATOR</td>
<td></td>
</tr>
<tr>
<td>24-21-02 GENERATOR CONTROL PANEL</td>
<td>X</td>
<td>PART OF POWER GENERATION SYSTEM</td>
<td></td>
</tr>
<tr>
<td>24-21-03 BUS CONTROL PANEL</td>
<td>X</td>
<td>PART OF POWER DISTRIBUTION SYSTEM</td>
<td></td>
</tr>
<tr>
<td>24-21-05 AC REGULATOR</td>
<td>X</td>
<td>PART OF ELECTRICAL POWER SYSTEM</td>
<td></td>
</tr>
<tr>
<td>24-21-06 AC RELAY</td>
<td>X</td>
<td>PART OF ELECTRICAL POWER SYSTEM</td>
<td></td>
</tr>
<tr>
<td>24-23-01 EMERGENCY INVERTER</td>
<td>X</td>
<td>MEDIUM VOLTAGE-HIGH POWER-ALSO A DC-10 CANDIDATE</td>
<td></td>
</tr>
<tr>
<td>24-31-01 TRANSFORMER-RECTIFIER</td>
<td>X</td>
<td>MEDIUM VOLTAGE-HIGH POWER-ALSO A DC-10 CANDIDATE</td>
<td></td>
</tr>
<tr>
<td>24-31-03 BATTERY CHARGER</td>
<td>X</td>
<td>MEDIUM VOLTAGE-HIGH POWER REPRESENTATIVE</td>
<td></td>
</tr>
<tr>
<td>24-31-08 BATTERY VENT FAN</td>
<td>X</td>
<td>MEDIUM VOLTAGE-LOW POWER, NON-CRITICAL REGIME</td>
<td></td>
</tr>
<tr>
<td>26-11-07 SMOKE DETECTOR</td>
<td>X</td>
<td>CASE OPEN, COMPONENTS SEALED</td>
<td></td>
</tr>
<tr>
<td>30-41-01 WINDSHIELD TEMPERATURE CONTROLLER</td>
<td>X</td>
<td>MEDIUM VOLTAGE-HIGH POWER REPRESENTATIVE</td>
<td></td>
</tr>
<tr>
<td>32-45-01 ANTI-SKID CONTROL BOX</td>
<td>X</td>
<td>LOW VOLTAGE-LOW POWER REPRESENTATIVE</td>
<td></td>
</tr>
<tr>
<td>32-61-01 PROXIMITY SWITCH CONTROL</td>
<td>X</td>
<td>LOW VOLTAGE-LOW POWER, REQUIRED, CHECKED AT DISPATCH</td>
<td></td>
</tr>
<tr>
<td>33-12-01 MASTER CONTROLLER</td>
<td>X</td>
<td>LIGHTING CONTROL</td>
<td></td>
</tr>
<tr>
<td>CHAPTER</td>
<td>COMPONENT</td>
<td>TEST CANDIDATE</td>
<td>REMARKS</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>34-18-03</td>
<td>TOTAL AIR TEMPERATURE SENSOR</td>
<td>X</td>
<td>HIGH POWER HEATING ELEMENT TEMPERATURE PROBE</td>
</tr>
<tr>
<td>34-21-05</td>
<td>INSTRUMENT AMPLIFIER RACK</td>
<td>X</td>
<td>MULTIPLE CHANNELS – DIFFICULT TO SIMULATE</td>
</tr>
<tr>
<td>34-22-03</td>
<td>INSTRUMENT AMPLIFIER</td>
<td>X</td>
<td>MULTIPLE CHANNELS – DIFFICULT TO SIMULATE</td>
</tr>
<tr>
<td>34-22-04</td>
<td>VERTICAL GYRO</td>
<td>X</td>
<td>ESSENTIALLY PROTECTED</td>
</tr>
<tr>
<td>34-24-03</td>
<td>FLIGHT DIRECTOR COMPUTER</td>
<td>X</td>
<td>TYPICAL TRANSISTORIZED ANALOG COMPUTER</td>
</tr>
<tr>
<td>34-24-07</td>
<td>FLIGHT DIRECTOR ROLL COMPUTER</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER, NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>34-24-08</td>
<td>FLIGHT DIRECTOR PITCH COMPUTER</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER, NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>34-26-02</td>
<td>NAV INSTRUMENT FAILURE MONITOR</td>
<td>X</td>
<td>LOW VOLTAGE, HIGH POWER, NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>34-26-02</td>
<td>NAV SMART RACK</td>
<td>X</td>
<td>DIFFICULT TO TEST</td>
</tr>
<tr>
<td>34-26-03</td>
<td>NAV COMPARATOR UNIT (2 LISTED)</td>
<td>X</td>
<td>MULTIPLE CHANNELS – DIFFICULT TO SIMULATE</td>
</tr>
<tr>
<td>34-26-04</td>
<td>SPEED COMMAND COMPARATOR</td>
<td>X</td>
<td>DIFFICULT TO TEST</td>
</tr>
<tr>
<td>34-28-02</td>
<td>RATE-OF-TURN RACK</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER, NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>34-29-01</td>
<td>STANDBY HORIZON INDICATOR</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER, NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>34-31-01</td>
<td>MARKER BEACON RECEIVER (2 LISTED)</td>
<td>X</td>
<td>ALSO DC-10 CANDIDATES</td>
</tr>
<tr>
<td>34-32-01</td>
<td>VOR/ILS RECEIVER</td>
<td>X</td>
<td>ALSO DC-10 CANDIDATE</td>
</tr>
<tr>
<td>34-33-05</td>
<td>ADF RECEIVER (2 LISTED)</td>
<td>X</td>
<td>ONE TYPE ALSO A DC-10 CANDIDATE</td>
</tr>
<tr>
<td>34-41-02</td>
<td>ATC TRANSPONDER (2 LISTED)</td>
<td>X</td>
<td>ONE TYPE ALSO A DC-10 CANDIDATE</td>
</tr>
<tr>
<td>34-42-02</td>
<td>DME INTERROGATOR</td>
<td>X</td>
<td>FORCED COOLING, CHASSIS TYPE CONSTRUCTION</td>
</tr>
<tr>
<td>34-43-02</td>
<td>WEATHER RADAR R/T UNIT</td>
<td>X</td>
<td>DIFFICULT TO TEST</td>
</tr>
<tr>
<td>34-43-04</td>
<td>WEATHER RADAR INDICATOR (2 LISTED)</td>
<td>X</td>
<td>HIGH VOLTAGE, LOW POWER, NON-CRITICAL REGIME</td>
</tr>
<tr>
<td>34-44-01</td>
<td>RADIO ALTIMETER R/T UNIT (2 LISTED)</td>
<td>X</td>
<td>TYPICAL CONSTRUCTION – FORCED COOLING</td>
</tr>
<tr>
<td>34-51-01</td>
<td>GROUND PROXIMITY WARN COMPUTER</td>
<td>X</td>
<td>MEDIUM VOLTAGE, LOW POWER, NON-CRITICAL REGIME</td>
</tr>
</tbody>
</table>
4.1 Introduction

The operating modes of the DC-10 and DC-9 were analyzed with respect to CF environment and the following modes defined as those during which the aircraft will be vulnerable to CF ingestion:

1. Main engines supplying bleed air to the air-conditioning packs and through the cockpit or cabin to the avionics compartments. Air can be extracted from either low- or high-stage bleed port depending on engine power setting.

2. Auxiliary Power Unit (APU) supplying bleed air to the air-conditioning packs.

3. Pneumatic ground cart(s) supplying air to the packs (cockpit windows and passenger doors may be open or closed).

4. Conditioned air cart(s) supplying air directly to the cockpit and cabin distribution ducting (windows and passenger doors open or closed).

5. Open cockpit windows and/or passenger doors open and avionics cooling fan drawing air into avionics compartments.

6. Avionics compartment door(s) open and the avionics cooling fan drawing air directly into the avionics compartment (conditioned air may or may not be supplied by packs or carts).

Operating modes 1 and 2 above can occur with the aircraft either static (parked) or moving during taxi, takeoff, or low-level flight and results given are applicable to any of these conditions. Operating modes 3, 4, 5 and 6 apply only to aircraft which are parked.
The transfer function for the passage of CF through the aircraft defines the ratio of the weight concentration of CF at a given point within the aircraft \( (C_I) \) to the weight concentration of CF in the ambient air outside the aircraft \( (C_o) \). This function is dependent both on the aircraft operating mode and the point within the aircraft under consideration. In order to simplify the analyses and provide maximum flexibility in the use of results, each operating mode was analyzed and an overall transfer factor (OTF) was established for that mode from the relationship:

\[
OTF = (1 - n_1)(1 - n_2)(1 - n_3)
\]

where \( n_1 \) is the CF extraction efficiency of the first element in the flow paths of the CF-laden air and \( n_2, n_3, \) etc. are successive elements in the flow path up to the point of interest within the aircraft.

The overall transfer factors may be considered single mode transfer functions and CF concentration during a given operating mode may be determined from:

\[
C_I = C_o(OTF)
\]

The following sections develop the extraction efficiencies and overall transfer factors for all modes of interest which in the aggregate define transfer functions for the DC-9 and DC-10 aircraft. A more detailed analysis is presented in McDonnell Douglas Report MDC J8320.

4.2 DC-10 Transfer Function

The overall transfer factors for the DC-10 can be calculated from:

\[
OTF = (1 - n_e)(1 - n_p)(1 - n_c)
\]

where:
- \( n_e \) is extraction efficiency of the air supply source,
- \( n_p \) is the extraction efficiency of the air-conditioning packs, and
- \( n_c \) is the filtering effect of cockpit and cabin furnishings.
This expression applies to the avionics compartment and the center accessory compartment (CAC) of the DC-10 with extraction efficiencies as shown in Table 4-1. The expression defines the transfer of fibers to the air in the compartments. The effects of the "black box" enclosures and individual cooling techniques are not included. They are discussed in detail in McDonnell Douglas Report MDC J8320. It will be noted that there are some differences in OTF between the two compartments when no air-conditioning is being supplied. These differences are caused by variations in the cooling system operation for these modes. Specifically, the avionics cooling system will draw outside air into the compartment while the CAC system will recirculate air within the aircraft with little or no outside air entering the compartment.

The values of $\eta_e$ for main engines were derived from the results of dirt ingestion tests conducted with coarse Arizona road dust. The specific values given are for the P&WA JT9D engine and include the effects of switching bleed ports and varying power settings. A comparison of bleed port configuration and service experience with the GE CF6 engine indicates that these values will also apply to that engine. The value of $\eta_e$ for the APU was likewise derived from test data which indicated that the particle removal characteristics of this engine are negligible.

The values of $\eta_e$ for ground carts were determined by contacts with cart suppliers and airline users. Both these groups also stated that these units are used infrequently on the DC-10 because of the availability of the APU.

The values of $\eta_p$ were calculated for packs with a water separator bypass configuration* for both a hot day and a cold day situation to define maximum and minimum values. Water separator bag filtering efficiency was assumed to be 0.9 after contact with bag suppliers, and comparison with known filter media.

The value of $\eta_c$ was calculated from the known settling rate (0.2m/s) of composite fibers and the airflow velocities through the cockpit and cabin. Both re-entrainment and crack-capture effects have been ignored due to lack

*This is the configuration of the domestic, short-range DC-10-10.
<table>
<thead>
<tr>
<th>NO.</th>
<th>OPERATING MODE</th>
<th>AVIONICS COMPARTMENT</th>
<th>CENTER ACCESSORY COMPARTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\eta_e$</td>
<td>$\eta_p$</td>
</tr>
<tr>
<td>1</td>
<td>MAIN ENGINES</td>
<td>(3)</td>
<td>0.957</td>
</tr>
<tr>
<td></td>
<td>70 PERCENT TAKEOFF POWER (8TH STAGE BLEED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3)</td>
<td>0.962</td>
</tr>
<tr>
<td></td>
<td>90 PERCENT TAKEOFF POWER (8TH STAGE BLEED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3)</td>
<td>0.9956</td>
</tr>
<tr>
<td></td>
<td>GROUND IDLE (HIGH STAGE BLEED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>APU OR PNEUMATIC CART</td>
<td>(3)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>PNEUMATIC CART</td>
<td>(3)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CONDITIONED AIR CART</td>
<td>(4)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>OPEN COCKPIT WINDOWS AND PASSENGER DOORS</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>OPEN AVIONICS COMPARTMENT AND CAC DOORS</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(1) FOR AIRCRAFT WHICH DRAW AIR FROM CABIN.
(2) FOR AIRCRAFT WHICH DRAW AIR FROM UNDER THE CABIN FLOOR.
(3) IF TRANSFER FUNCTION IS DESIRED FOR FIBERS GREATER THAN 1 MM, THIS VALUE BECOMES 1.0 AND OTF = 0. SEE BIOEATICS DATA (REFERENCE NASA CONTRACTOR REPORT 159183).
(4) FOR THE SAME CONDITIONS AS NOTE 3, THIS VALUE SHOULD BE 0.50 AND OTF = 0.35.
of data which would apply to aircraft interiors. It should be noted that these two factors tend to cancel each other and the effect of ignoring them may not significantly affect the final answers.

The settling of fibers in both the avionics compartment and the CAC was considered to be negligible because of high air velocities and turbulence in these compartments which should cause substantial re-entrainment. The avionics compartment has a large recirculating fan which draws air from the forward left side of the compartment and discharges it into various areas of the compartment at velocities up to 1400 m/min (4600 fpm). Most aircraft also have three inertial navigation cooling fans dumping into the compartment at 370 m/min (1224 fpm). These fans are in addition to the fan which draws air through the compartment.

The CAC has a large fan which draws air from the upper cabin on early aircraft and from below the cabin floor on later versions. This fan discharges into the compartment at a velocity of approximately 1140 m/min (3745 fpm). In addition, when conditioned air is being supplied to the cabin with cabin doors closed, approximately 57 percent of the conditioned air passes through the CAC prior to exhausting overboard. It is expected that these air flow mechanisms will prevent significant settling in these compartments.

4.3 DC-9 Transfer Function

The overall transfer factors for the DC-9 can be calculated from:

\[ OTF = (1 - \eta_e)(1 - \eta_p)(1 - \eta_c)(1 - \eta_s) \]

where:

- \( \eta_e \) is the extraction efficiency of the air supply source,
- \( \eta_p \) is the extraction efficiency of the air-conditioning pack (which includes a centrifugal cleaner),
- \( \eta_c \) is the filtering effect of cockpit and cabin furnishings, and
- \( \eta_s \) is the settling effect in the avionics compartment.
This expression defines the transfer of the fibers to the air of the DC-9 avionics compartment with extraction efficiencies as shown in Table 4-2. This approach does not define the effects of "black box" enclosures or the various cooling methods which are used with these units.

The values of $\eta_e$ given for the P&WA JT8D main engines are judgmental in nature due to the paucity of usable test data. Although numerous tests have been conducted, no data was uncovered to relate contamination at the bleed ports to that at the engine inlet. Values of $\eta_e$ were therefore selected after careful consideration of pack nozzle erosion experience and a comparison of bleed air extraction features with those of the DC-10 engines. The values chosen are intended to represent a "worst case"; i.e., largest possible amount of CF being left in the bleed air.

From the DC-9 APU, no data applicable to this study was uncovered. It was therefore assumed that this machine is equivalent to the DC-10 and neither concentrates nor extracts CF prior to being bled. Likewise, ground carts for pneumatic air and conditioned air are assumed to have characteristics identical to those used on the DC-10.

The value of $\eta_p$ includes the effects of the Centrisep bleed air cleaner and water separator bag filtering as a function of air being bypassed on hot and cold day situations. Performance of the Centrisep cleaner is well documented by test data and service experience. Water separator bag filtering efficiency was again assumed to be 90 percent, based on comparison with other filter construction.

The value of $\eta_c$ was calculated from the known characteristics of the DC-9 cockpit and cabin volumes and airflow rates with a CF settling rate of 0.2 m/s. This factor does not include the effects of re-entrainment or "crack-capture."

The DC-9 avionics compartment should experience some settling of CF fibers because of relatively low velocities in the compartment. The value of $\eta_s$ was therefore determined from compartment volume and airflow rates without
compensation for re-entrainment or "crack-capture." The value of $\eta_s$ represents the average settling in the compartment; i.e., midway in the compartment between the air inlet and exit.

4.4 Discussion of Data

4.4.1 Main Engine Data

Test data on the P&W A JT9D provides a high level of confidence in analysis associated with this engine. The uncertainties involve the assumption that CF density of 1.7 gm/cm$^3$ is sufficiently close to "Arizona Road Dust" density of 2.4 gm/cm$^3$ so that both mediums will behave in the same manner while passing through the engine. It was also assumed that CF fibers would break into relatively short segments analogous to the 5- to 15-micron dust category when passing through high-speed axial and centrifugal compressors and fans. This is basically substantiated by the data supplied by Bionetics on simulated turning vanes.

These data associated with the GE CF6 engine presented some uncertainties but it is believed that this engine is at least as good as the JT9D in foreign matter rejection from the bleed ports. The data used for this engine are therefore conservative.

The values used to the P&W A JT8D are substantiated only by comparison to the JT9D. Since these two engines are substantially different in size and construction, this comparison does not provide a high level of confidence in these numbers.

4.4.2 APU Data

Test data on the DC-10 APU had some argumentative aspects but the results appear to be substantiated by in-service pack nozzle erosion data.

No data was available on the separation efficiency of the DC-9 APU. However, pack nozzle erosion data tends to support the value chosen.
4.4.3 Pneumatic and Conditioned Air Carts

Ground cart manufacturers could provide no data other than judgment as to the filtering to be expected from this equipment. It is expected that pneumatic carts would exhibit a wide range of values due to the various designs used for this task.

4.4.4 Air-Conditioning Packs

The filtering effects of the water separator bags and the centrifugal bleed air cleaner used in the analysis are the same as those in McDonnell Douglas Report MDC J8320, and were based on particulate data of the actual air cleaner and on comparative data for the water separator. The data supplied by Bionetics indicate a higher separation efficiency, for both the water separator and air cleaner, than the values used in this analysis. However, the data were for CF sizes of 1, 3, and 10 mm and it is expected that the CF sizes will be less than 1 mm before reaching the air-conditioning packs. This is substantiated by the Bionetics data on simulated turning vanes which show the carbon fibers are broken up (<1 mm) for air velocities that are present in both the engines and APUs. Therefore, it is believed that the values obtained in MDC J8320 are more representative of the actual case.

4.4.5 Settling, Re-entrainment, and Crack Capture

The interior of an aircraft is a complex maze of wire bundles, cables, structures, equipment racks, seats, carpeting, avionics units, ducts instrumentation, etc., with many airflow origination points and flow paths coupled with the effects of human movements. In addition, settling, re-entrainment, and crack capture will be affected by the length of the carbon fibers. As previously stated, CF passing through high-speed rotary equipment is assumed to be "chopped" while CF passing into avionics areas through open windows and doors will be as initially disseminated.

Since there were no data applicable to this type of construction and environment, the approach used in defining settling, re-entrainment, and crack capture effects was to establish a "worst case" for the combination of the three factors. The actual condition to be encountered on an aircraft may be
somewhat better than the values used, but a significant change in values is not expected because the effects of settling and crack capture are opposed by re-entrainment.

4.4.6 Data Summary

The various operating conditions (1 through 6 of Tables 4-1 and 4-2) were sufficient to determine the transfer functions for all operating conditions to be considered. However, the data are reorganized into Tables 4-3, 4-4, and 4-5 to better present the functions considered in the other sections of this report.
### Table 4-2

**Transfer Function for CF to the Avionics Compartment of the DC-9**

<table>
<thead>
<tr>
<th>NO.</th>
<th>Operating Mode</th>
<th>$\eta_e$</th>
<th>$\eta_p$</th>
<th>$\eta_c$</th>
<th>$\eta_s$</th>
<th>OTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Engines</td>
<td>(1) -1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8th Stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold Day</td>
<td>0.987</td>
<td>0.454</td>
<td>0.293</td>
<td>0.01255</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hot Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13th Stage</td>
<td>(1) 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold Day</td>
<td>0.987</td>
<td>0.454</td>
<td>0.293</td>
<td>0.00251</td>
<td>0.06485</td>
</tr>
<tr>
<td></td>
<td>Hot Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>APU or Pneumatic</td>
<td>(1) 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold Day</td>
<td>0.987</td>
<td>0.454</td>
<td>0.293</td>
<td>0.00502</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ground Cart</td>
<td>(1) 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold Day</td>
<td>0.664</td>
<td>0.454</td>
<td>0.293</td>
<td>0.12970</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Conditioned Air Cart</td>
<td>(2) 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold Day</td>
<td>0</td>
<td>0.454</td>
<td>0.293</td>
<td>0.38602</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Open Cockpit Windows and Passenger Doors</td>
<td>0</td>
<td>0</td>
<td>0.454</td>
<td>0.293</td>
<td>0.38602</td>
</tr>
<tr>
<td>6</td>
<td>Open Avionics Compartment Door</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.293</td>
<td>0.70700</td>
</tr>
</tbody>
</table>

(1) If transfer function is desired for fibers greater than 1 mm in length, this value becomes 1.0 and OTF = 0.0. See Bionetics Data (Reference NASA Contractor Report 159183).

(2) For the same conditions as Note (1), this value should be 0.5 and OTF = 0.19,
## TABLE 4-3
DC-10 AVIONICS COMPARTMENT
OVERALL TRANSFER FUNCTION

<table>
<thead>
<tr>
<th>AIRCRAFT POWER</th>
<th>AVIONICS DOOR</th>
<th>PASSENGER DOORS</th>
<th>AVIONICS DOOR</th>
<th>PASSENGER DOORS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OPEN</td>
<td>CLOSED</td>
<td>OPEN</td>
<td>CLOSED</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Хот</td>
<td>Хот</td>
<td>COLD</td>
</tr>
<tr>
<td>ENGINE 70 PERCENT TAKEOFF (8TH STAGE BLEED)</td>
<td>1</td>
<td>1</td>
<td>0.00136</td>
<td>0.00421</td>
</tr>
<tr>
<td>90 PERCENT TAKEOFF (8TH STAGE BLEED)</td>
<td>1</td>
<td>1</td>
<td>0.00120</td>
<td>0.00372</td>
</tr>
<tr>
<td>GROUND IDLE (HIGH STAGE BLEED)</td>
<td>1</td>
<td>1</td>
<td>0.00014</td>
<td>0.00043</td>
</tr>
<tr>
<td>APU OR PNEUMATIC CART</td>
<td>1</td>
<td>1</td>
<td>0.03162</td>
<td>0.09796</td>
</tr>
<tr>
<td>AIR CONDITIONING CART</td>
<td>1</td>
<td>1</td>
<td>0.69000</td>
<td>0.69000</td>
</tr>
<tr>
<td>GROUND ELECTRIC</td>
<td>1</td>
<td>1</td>
<td>0.69000</td>
<td>0.69000</td>
</tr>
<tr>
<td>NONE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
## TABLE 4-4

**DC-10 CENTER ACCESSORY COMPARTMENT**  
**OVERALL TRANSFER FUNCTIONS**

<table>
<thead>
<tr>
<th>AIRCRAFT POWER</th>
<th>CENTER ACCESS DOOR</th>
<th>CENTER ACCESS DOOR</th>
<th>CENTER ACCESS DOOR</th>
<th>CENTER ACCESS DOOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OPEN</td>
<td>CLOSED</td>
<td>OPEN</td>
<td>CLOSED</td>
</tr>
<tr>
<td></td>
<td>HOT</td>
<td>COLD</td>
<td>HOT</td>
<td>COLD</td>
</tr>
<tr>
<td>ENGINE 70 PERCENT TAKEOFF (8TH STAGE BLEED)</td>
<td>(1) 0.69000</td>
<td>(2) 0.69000</td>
<td>0.00136</td>
<td>0.00421</td>
</tr>
<tr>
<td>GROUND IDLE (HIGH STAGE BLEED)</td>
<td>0.69000</td>
<td>0.69000</td>
<td>0.00014</td>
<td>0.00043</td>
</tr>
<tr>
<td>APU OR PNEUMATIC CART</td>
<td>0.69000</td>
<td>0.69000</td>
<td>0.03162</td>
<td>0.09796</td>
</tr>
<tr>
<td>AIR CONDITIONING CART</td>
<td>0.69000</td>
<td>0.69000</td>
<td>0.69000</td>
<td>0.69000</td>
</tr>
<tr>
<td>GROUND ELECTRIC</td>
<td>0.69000</td>
<td>0.69000</td>
<td>0.69000</td>
<td>0.69000</td>
</tr>
<tr>
<td>NONE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(1) AIRPLANES PRIOR TO 242 THAT DRAW AIR FOR THE CAC FAN FROM THE CABIN  
(2) AIRPLANES 242 AND SUBS THAT DRAW AIR FOR THE CAS FAN FROM THE SIDE TUNNELS
<table>
<thead>
<tr>
<th>AIRCRAFT POWER</th>
<th>AVIONICS DOOR OPEN</th>
<th>AVIONICS DOOR CLOSED</th>
<th>AVIONICS DOOR OPEN</th>
<th>AVIONICS DOOR CLOSED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PASSENGER DOORS</td>
<td>PASSENGER DOORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OPEN</td>
<td>CLOSED</td>
<td>OPEN</td>
<td>CLOSED</td>
</tr>
<tr>
<td></td>
<td>HOT</td>
<td>COLD</td>
<td>HOT</td>
<td>COLD</td>
</tr>
<tr>
<td>ENGINE 8TH STAGE</td>
<td>0.70700</td>
<td>0.70700</td>
<td>0.01255</td>
<td>0.32425</td>
</tr>
<tr>
<td>13TH STAGE</td>
<td>0.70700</td>
<td>0.70700</td>
<td>0.00251</td>
<td>0.06485</td>
</tr>
<tr>
<td>APU OR PNEUMATIC CART</td>
<td>0.70700</td>
<td>0.70700</td>
<td>0.00502</td>
<td>0.12970</td>
</tr>
<tr>
<td>AIR CONDITIONING CART</td>
<td>0.70700</td>
<td>0.70700</td>
<td>0.38602</td>
<td>0.38602</td>
</tr>
<tr>
<td>GROUND ELECTRIC</td>
<td>0.70700</td>
<td>0.70700</td>
<td>0.70700</td>
<td>0.70700</td>
</tr>
<tr>
<td>NONE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
SECTION 5
TRANSPORT AIRCRAFT EQUIPMENT POTENTIAL FOR EXPOSURE TO CARBON FIBERS

5.1 Introduction

NASA-Langley is assessing the national risk caused by the release of carbon fibers (CF) following accidental fires on aircraft utilizing graphite epoxy composite structural materials. This activity includes contracts to estimate the damage cost of CF exposures at specific sites. NASA also has contracts with the three major domestic airframe manufacturers to evaluate the equipment failures in commercial aircraft exposed to CF releases. The expected number of aircraft in potentially vulnerable operating modes in the vicinity of an accidental CF release incident is required for this evaluation. This report presents the aircraft manufacturers' consolidated estimate of that required data for nine domestic airports.

5.1.1 Inputs to Risk Analysis Models

The risk analysis models to estimate the damage cost of a CF fire are to be used at the following airports:

Chicago O'Hare (ORD)
New York City Kennedy (JFK)
St. Louis Lambert (STL)
New York City LaGuardia (LGA)
Boston Logan (BOS)
Philadelphia International (PHL)
Washington, D.C. National (DCA)
Atlanta Hartsfield (ATL)
Miami International (MIA)

It has been determined that aircraft in flight and aircraft on the ground with all doors closed, operating with no power on or on normal engine power, have an effective transfer function of zero to equipment locations, and need not receive further consideration in the risk analysis. Therefore, major...
input to these models is the expected number of aircraft on the ground in other operating modes at each of these airports; this input is to be specified according to:

**Time of day:**
- Daytime (0600-2059)
- Nightime (2100-0559)

**Aircraft type (only jet aircraft considered)**
- Large (over 250 seats)
- Medium (150 to 250 seats)
- Small (under 150 seats)

**Location on the airport:**
- At gate being serviced
- At maintenance facility (being serviced or parked)

The probability that a CF cloud will short aircraft electronic equipment is dependent upon the transfer function to the various equipment locations, characterized by the following door status and the aircraft power sources.

**Avionic doors:**
- open
- closed

**Passenger and/or cargo doors:**
- open
- closed

**Power Source:**
- Auxiliary power unit
- Engines running
- Air cart
5.1.2 Aircraft Operations on the Airport

There are three basic locations at an airport where an aircraft is parked with its avionic, passenger, or cargo doors open. These are: passenger terminal, cargo terminal, and maintenance facility. The passenger and all cargo aircraft are analyzed separately, but the results are combined to give the total number of aircraft being serviced at the gate.

An aircraft is being serviced at a gate if it is:

- Being prepared for a flight origin
- Being serviced during an en route stop
- Being serviced after a flight termination

An aircraft has an en route stop if its departure flight number is the same as its arrival flight number. Most flight terminations will stay at the gate and become flight origins; however, many will be towed to a maintenance facility for scheduled work.

An en route stop usually requires less time than a turn (flight destination plus flight origination) because fewer services (particularly cabin cleaning) are performed. Other factors which significantly impact time at the gate include:

- Galley service
- Customs clearance on international flights
- Ground crew availability
- Buffer time to allow for airport delays

The gate times for scheduled service include time for maintenance tasks normally performed during en route and turn operations and for minor problems that keep the aircraft at the gate for a longer time period than planned. In addition, there are often aircraft at the gate during nighttime hours for scheduled or unscheduled maintenance. This includes the extensive overnight
cabin cleaning which often requires more than two hours. The aircraft being maintained at the gate during nighttime hours is added to nighttime scheduled service to give the total number of aircraft at the gate. It is assumed that there is no maintenance performed at the gate during the day.

The average number of aircraft at the separate maintenance facility during the daytime and during nighttime has been determined for each airport based upon data from the airlines, airport authorities, and aircraft manufacturers' field representatives. These data are used directly to define the number of aircraft in the maintenance facility.

5.2 Data

5.2.1 Gate Times

Gate time data was obtained from the following airlines: United, American, Ozark, Western, Continental, Delta and Trans World. These data ranged from actual scheduled gate times, to planning guidelines, to discussions of how gate time is impacted by customs, cabin cleaning, or food service. The airline data defined the operations as turns or en route stops.

Table 5-1 presents the average scheduled gate time as a function of aircraft type and type of operation. Gate times for supersonic and two-engine narrow-body aircraft were estimated without any airline data. Gate times for international passenger and all cargo flights were assumed to be five minutes longer than domestic turns.

<table>
<thead>
<tr>
<th>TYPE FLIGHT</th>
<th>TYPE SERVICE</th>
<th>TYPE OPERATION</th>
<th>DOMESTIC PASSENGER</th>
<th>INTERNATIONAL PASSENGER OR FREIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARRIVAL</td>
<td>DEPART</td>
</tr>
<tr>
<td>SUPERSONIC</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 ENGINE WIDE-BODY</td>
<td></td>
<td></td>
<td>23 MIN</td>
<td>38 MIN</td>
</tr>
<tr>
<td>3 ENGINE WIDE-BODY</td>
<td></td>
<td></td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>2 ENGINE WIDE-BODY</td>
<td></td>
<td></td>
<td>21</td>
<td>30</td>
</tr>
<tr>
<td>4 ENGINE NARROW</td>
<td></td>
<td></td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>3 ENGINE NARROW</td>
<td></td>
<td></td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>2 ENGINE NARROW</td>
<td></td>
<td></td>
<td>19</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 5-1

AVERAGE SCHEDULED GATE TIMES (MINUTES)
5.2.2 Number of Operations

Data on the number of aircraft operations was obtained from the August 1978 Official Airline Guide (OAG) computer tape. These data were extracted to give the number of operations for all combinations of the following:

Airport: each of the nine airports

Time of day:
- Daytime (0600-2059 hours)
- Nighttime (2100-0559 hours)

Aircraft type:
- Supersonic (only at JFK)
- 4-Engine Wide-Body (B747)
- 3-Engine Wide-Body (DC-10, L-1011)
- 2-Engine Wide-Body (A300)
- 4-Engine Narrow-Body (DC-8, B707)
- 3-Engine Narrow-Body (B727)
- 2-Engine Narrow-Body (DC-9, B737, BAC 1-11)

Type of flight:
- Passenger Aircraft
  - Domestic (to or from U.S. airport)
  - International
- All Cargo Aircraft

Type of operation:
- Arrival
- Departure

All four- and three-engine wide-body aircraft are classified as large aircraft (over 250 seats). The two-engine wide-body aircraft and 36.4 percent of the four-engine narrow-body aircraft are classified as medium aircraft.
(150 to 250 seats). All other aircraft are classified as small aircraft (under 150 seats). In August 1978, there were 717 daily departures by four-engine narrow-body aircraft with over 150 seats and 1254 daily departures by four-engine narrow-body aircraft with less than 150 seats; hence, 36.4 percent of the four-engine narrow-body aircraft are medium-sized.

The OAG data give the number of arrivals and departures per hour for domestic passenger flights, international passenger flights, and all cargo flights. The data extracted did not identify whether the flight was a turn or en route stop. It was assumed that: JFK, MIA and BOS have 90-percent turns, ORD, DCA, ATL and LGA have 60-percent turns, STL and PHL have 20-percent turns. It was also assumed that an additional two minutes per operation was scheduled for ORD and LGA to give an additional buffer time for airport runway delays.

5.2.3 Aircraft at Maintenance Facility and Overnight Aircraft

The average number of aircraft at the maintenance facility during the daytime and nighttime was obtained from the airlines, airport authorities, and aircraft manufacturers' representatives.

The average number of aircraft which overnight at the gate is used to compute the expected number of exposed aircraft at the gate during nighttime. These numbers are calculated from the total number of aircraft which overnight at the airport and the number of aircraft in the maintenance facility during the daytime and nighttime. The total number of aircraft which overnight are obtained from an analysis of the OAG data and contacts with airlines, airport authorities, and aircraft manufacturers' field representatives.

Data on the number of aircraft at the maintenance facility during the daytime and nighttime and the total number of overnight aircraft were obtained by a coordinated effort of the three aircraft manufacturers. Each manufacturer obtained these data for three airports:
5.2.4 Operating Modes

The probability that a CF cloud will damage aircraft electronic equipment is dependent upon the aircraft's power source and whether the passenger or avionic bay door is open. The aircraft power source and door status (or operating mode) was determined by interviewing airline maintenance and operations personnel, and by on-site surveys to determine the percent of the aircraft in each operating mode.

The percent of the time the aircraft spent in each operating mode was determined by Boeing and Lockheed for the following conditions:

Boeing Commercial Airplane Company
- Gate position daytime
- Gate position nighttime

Lockheed-California Company
- Maintenance facility

The operating mode data are summarized in Table 5-2.
<table>
<thead>
<tr>
<th>AIRPORT LOCATION AND TIME PERIOD</th>
<th>AIRCRAFT POWER SOURCE</th>
<th>AVIONIC DOORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GATE, DAY</td>
<td>Aux power unit</td>
<td>OPEN</td>
</tr>
<tr>
<td></td>
<td>Engines</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Air cart</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ground electric</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td>GATE, NIGHT</td>
<td>Aux power unit</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Engines</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Air cart</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ground electric</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td>MAINTENANCE</td>
<td>Aux power unit</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Engines</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Air cart</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Ground electric</td>
<td>72.7</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Table 5-2**

PERCENT OF TIME PER OPERATING MODE
5.2.5 Transfer Functions

Boeing and Lockheed determined the transfer functions presented in Table 5-3, Boeing developed the transfer functions for small aircraft, and Lockheed developed the transfer functions for medium and large aircraft. All three manufacturers have reviewed these data and have agreed that they adequately characterize their fleets.

Table 5-4 presents the potential exposure factors for the aircraft sizes, equipment location on the aircraft, and aircraft location on the airport. These potential exposure factors were obtained by multiplying the fraction of the time per operating mode by the transfer function for that operating mode and then summing for all operating modes.

5.3 Analysis

5.3.1 Expected Number of Aircraft at the Gate

The expected number of aircraft at the gate is equal to the number in active service (being prepared for a flight origin, during an en route stop, or after a flight destination) plus the number of aircraft receiving extensive maintenance or cabin cleaning at the gate (this only occurs during nighttime). Table 5-5 (one page per aircraft) contains the data and basic calculations to determine the expected number of aircraft at the gate.

The top part of Tables 5-5 through 5-13 presents the OAG data and the calculated gate hours. The OAG data gives the total daily (average day in August 1978) scheduled operations for all combinations of:

- Time period (daytime, nighttime)
- Type of operation (arrival, departure)
- Type of flight (domestic passenger, international passenger or freight)
- Aircraft type (seven types)

The gate hours per aircraft type and time period are obtained by multiplying the number of operations by the gate time per operation (Table 5-1) and summing for all types of operations.
### TABLE 5-3
TRANSFER FUNCTIONS

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE CLASS</th>
<th>ELECTRONIC EQUIPMENT LOCATION</th>
<th>AVIONIC DOORS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>OPEN</td>
</tr>
<tr>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>APU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GR EL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td>MED/LARGE</td>
<td>FLIGHT DECK</td>
<td>APU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GR EL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>FLIGHT STATION</td>
<td>APU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GR EL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>PASSENGER CABIN</td>
<td>APU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GR EL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>FESC/MESC</td>
<td>APU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GR EL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td>AIRCRAFT SIZE</td>
<td>ELECTRONIC EQUIPMENT LOCATION</td>
<td>AIRPORT LOCATION AND TIME PERIOD</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GATE DAYTIME</td>
</tr>
<tr>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>0.703</td>
</tr>
<tr>
<td></td>
<td>FLIGHT DECK</td>
<td>0.7</td>
</tr>
<tr>
<td>MED/LARGE</td>
<td>FLIGHT STATION</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>FESC/MESC</td>
<td>0.0128</td>
</tr>
</tbody>
</table>
### TABLE 5-5
CHICAGO O'HARE (ORD)
AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978

<table>
<thead>
<tr>
<th>HOURS</th>
<th>STATISTIC</th>
<th>SCHEDULED OPERATIONS</th>
<th>GATE HOURS</th>
<th>SCHEDULED OPERATIONS</th>
<th>GATE HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>DAYTIME 0600-0759</td>
<td>NIGHTTIME 0700-0859</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
<td>I, F</td>
<td>D</td>
<td>I, F</td>
<td>D</td>
</tr>
<tr>
<td>SUPersonic</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 engines wide-body</td>
<td>9.3</td>
<td>9.1</td>
<td>12.3</td>
<td>9.6</td>
<td>33.3</td>
</tr>
<tr>
<td>3 engines wide-body</td>
<td>89.0</td>
<td>3.6</td>
<td>92.3</td>
<td>3.7</td>
<td>114.5</td>
</tr>
<tr>
<td>2 engines wide-body</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 engines narrow</td>
<td>65.3</td>
<td>21.7</td>
<td>66.2</td>
<td>23.4</td>
<td>116.0</td>
</tr>
<tr>
<td>3 engines narrow</td>
<td>352.1</td>
<td>11.1</td>
<td>347.8</td>
<td>11.1</td>
<td>373.6</td>
</tr>
<tr>
<td>2 engines narrow</td>
<td>177.0</td>
<td>2.0</td>
<td>177.8</td>
<td>2.0</td>
<td>172.9</td>
</tr>
</tbody>
</table>

### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>34</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>LARGE</td>
<td>6</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>
## TABLE 5-6
### NEW YORK CITY KENNEDY (JFK)
#### AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978

<table>
<thead>
<tr>
<th>HOURS</th>
<th>DAYTIME 0600-2059</th>
<th>NIGHTTIME 2100-0559</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SCHEDULED OPERATIONS</td>
<td>GATE HOURS</td>
</tr>
<tr>
<td>ARRIVALS OR DEPARTURES</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
<td>I, F</td>
</tr>
<tr>
<td>SUPersonic</td>
<td>–</td>
<td>2.4</td>
</tr>
<tr>
<td>4 Engine Wide-Body</td>
<td>11.3</td>
<td>46.5</td>
</tr>
<tr>
<td>3 Engine Wide-Body</td>
<td>21.5</td>
<td>11.3</td>
</tr>
<tr>
<td>2 Engine Wide-Body</td>
<td>3.0</td>
<td>–</td>
</tr>
<tr>
<td>4 Engine Narrow</td>
<td>32.3</td>
<td>58.8</td>
</tr>
<tr>
<td>3 Engine Narrow</td>
<td>51.3</td>
<td>9.0</td>
</tr>
<tr>
<td>2 Engine Narrow</td>
<td>24.0</td>
<td>10.9</td>
</tr>
</tbody>
</table>

#### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>20</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>LARGE</td>
<td>9</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>
### TABLE 5-7
**ST. LOUIS LAMBERT (STL)**
**AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978**

<table>
<thead>
<tr>
<th>HOURS</th>
<th>DAYTIME 0600-2059</th>
<th>NIGHTTIME 2100-0559</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATISTIC</td>
<td>SCHEDULED OPERATIONS</td>
<td>GATE HOURS</td>
</tr>
<tr>
<td>ARRIVALS OR DEPARTURES</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
<td>I, F</td>
</tr>
<tr>
<td>SUPersonic</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 Engine Wide-Body</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3 Engine Wide-Body</td>
<td>9.0</td>
<td>10.0</td>
</tr>
<tr>
<td>2 Engine Wide-Body</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 Engine Narrow</td>
<td>23.9</td>
<td>0.7</td>
</tr>
<tr>
<td>3 Engine Narrow</td>
<td>89.7</td>
<td>0.4</td>
</tr>
<tr>
<td>2 Engine Narrow</td>
<td>94.3</td>
<td>–</td>
</tr>
</tbody>
</table>

### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>14</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LARGE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### TABLE 5-8
NEW YORK CITY LAGUARDIA (LGA)
AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978

<table>
<thead>
<tr>
<th>HOURS</th>
<th>DAYTIME 0600-2059</th>
<th>NIGHTTIME 2100-0559</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATISTIC</td>
<td>SCHEDULED OPERATIONS</td>
<td>GATE HOURS</td>
</tr>
<tr>
<td>ARRIVALS OR DEPARTURES</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
<td>I, F</td>
</tr>
<tr>
<td>SUPersonic</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 ENGINE WIDE-BODY</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3 ENGINE WIDE-BODY</td>
<td>9.9</td>
<td>1.0</td>
</tr>
<tr>
<td>2 ENGINE WIDE-BODY</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 ENGINE NARROW</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3 ENGINE NARROW</td>
<td>167.6</td>
<td>10.7</td>
</tr>
<tr>
<td>2 ENGINE NARROW</td>
<td>85.6</td>
<td>–</td>
</tr>
</tbody>
</table>

### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>50</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LARGE</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### TABLE 5-9
**BOSTON LOGAN (BOS)**
**AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978**

<table>
<thead>
<tr>
<th>HOURS</th>
<th>DAYTIME 0600-2059</th>
<th>NIGHTTIME 2100-0559</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STATISTIC</strong></td>
<td><strong>SCHEDULED OPERATIONS</strong></td>
<td><strong>GATE HOURS</strong></td>
</tr>
<tr>
<td><strong>ARRIVALS OR DEPARTURES</strong></td>
<td><strong>A</strong></td>
<td><strong>D</strong></td>
</tr>
<tr>
<td><strong>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</strong></td>
<td><strong>D</strong></td>
<td><strong>I, F</strong></td>
</tr>
<tr>
<td><strong>SUPersonic</strong></td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 ENGINE WIDE-BODY</td>
<td>2.7</td>
<td>5.0</td>
</tr>
<tr>
<td>3 ENGINE WIDE-BODY</td>
<td>12.4</td>
<td>3.4</td>
</tr>
<tr>
<td>2 ENGINE WIDE-BODY</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 ENGINE NARROW</td>
<td>16.6</td>
<td>9.4</td>
</tr>
<tr>
<td>3 ENGINE NARROW</td>
<td>85.8</td>
<td>5.9</td>
</tr>
<tr>
<td>2 ENGINE NARROW</td>
<td>59.9</td>
<td>6.0</td>
</tr>
</tbody>
</table>

### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>DAY</strong></td>
<td><strong>NIGHT</strong></td>
</tr>
<tr>
<td>SMALL</td>
<td>51</td>
<td>2.2</td>
<td>13</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LARGE</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
## TABLE 5-10
PHILADELPHIA (PHL)
AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978

<table>
<thead>
<tr>
<th>STATISTIC</th>
<th>SCHEDULED OPERATIONS</th>
<th>GATE HOURS</th>
<th>SCHEDULED OPERATIONS</th>
<th>GATE HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DAYTIME 0600-2059</td>
<td></td>
<td>NIGHTTIME 2100-0559</td>
<td></td>
</tr>
<tr>
<td>ARRIVALS OR DEPARTURES</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
<td>I, F</td>
<td>D</td>
<td>I, F</td>
</tr>
<tr>
<td>SUPersonic</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 Engine Wide-Body</td>
<td>2.7</td>
<td>–</td>
<td>2.7</td>
<td>–</td>
</tr>
<tr>
<td>3 Engine Wide-Body</td>
<td>17.7</td>
<td>1.0</td>
<td>17.7</td>
<td>1.0</td>
</tr>
<tr>
<td>2 Engine Wide-Body</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 Engine Narrow</td>
<td>16.1</td>
<td>2.0</td>
<td>18.1</td>
<td>2.7</td>
</tr>
<tr>
<td>3 Engine Narrow</td>
<td>56.4</td>
<td>1.3</td>
<td>61.4</td>
<td>2.3</td>
</tr>
<tr>
<td>2 Engine Narrow</td>
<td>66.3</td>
<td>1.0</td>
<td>72.0</td>
<td>–</td>
</tr>
</tbody>
</table>

### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>22</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LARGE</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
TABLE 5-11
WASHINGTON NATIONAL (DCA)
AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978

<table>
<thead>
<tr>
<th>HOURS</th>
<th>DAYTIME 0600-2059</th>
<th>NIGHTTIME 2100-0559</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STATISTIC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ARRIVALS OR DEPARTURES</td>
<td>SCHEDULED OPERATIONS</td>
</tr>
<tr>
<td></td>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>SUPersonic</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>4 Engine Wide-Body</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>3 Engine Wide-Body</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2 Engine Wide-Body</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>4 Engine Narrow</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>3 Engine Narrow</td>
<td>155.2</td>
</tr>
<tr>
<td></td>
<td>2 Engine Narrow</td>
<td>82.0</td>
</tr>
</tbody>
</table>

AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>27</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LARGE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HOURS</td>
<td>STATISTIC</td>
<td>DAYTIME 0600-2059</td>
<td>NIGHTTIME 2100-0559</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td></td>
<td>SCHEDULED OPERATIONS</td>
<td>GATE HOURS</td>
<td>SCHEDULED OPERATIONS</td>
</tr>
<tr>
<td>ARRIVALS OR</td>
<td></td>
<td>A, D</td>
<td></td>
</tr>
<tr>
<td>DEPARTURES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOMESTIC OR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERNATIONAL</td>
<td>Plus Freight</td>
<td>D, I, F</td>
<td>D, I, F</td>
</tr>
<tr>
<td>SUPersonic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 ENGINE WIDE-BODY</td>
<td>0.1 -</td>
<td>0.1 -</td>
<td>0.1</td>
</tr>
<tr>
<td>3 ENGINE WIDE-BODY</td>
<td>43.7, 2.0</td>
<td>49.7, 2.0</td>
<td>59.6</td>
</tr>
<tr>
<td>2 ENGINE WIDE-BODY</td>
<td>2.0 -</td>
<td>2.0 -</td>
<td>2.6</td>
</tr>
<tr>
<td>4 ENGINE NARROW</td>
<td>23.4, 5.2</td>
<td>26.6, 4.2</td>
<td>37.1</td>
</tr>
<tr>
<td>3 ENGINE NARROW</td>
<td>204.2, 2.3</td>
<td>226.5, 2.3</td>
<td>223.1</td>
</tr>
<tr>
<td>2 ENGINE NARROW</td>
<td>217.6 -</td>
<td>229.4 -</td>
<td>214.0</td>
</tr>
</tbody>
</table>

**AIRCRAFT IN MAINTENANCE**

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>24</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LARGE</td>
<td>6</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
### TABLE 5-13
MIAMI INTERNATIONAL (MIA)
AIRCRAFT IN SCHEDULED SERVICE – AUGUST 1978

<table>
<thead>
<tr>
<th>HOURS</th>
<th>DAYTIME 0600-2059</th>
<th>NIGHTTIME 2100-0559</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SCHEDULED OPERATIONS</td>
<td>GATE HOURS</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>ARRIVALS OR DEPARTURES</td>
<td>D</td>
<td>I, F</td>
</tr>
<tr>
<td>DOMESTIC OR INTERNATIONAL PLUS FREIGHT</td>
<td>D</td>
<td>I, F</td>
</tr>
<tr>
<td>SUPersonic</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4 ENGINE WIDE-BODY</td>
<td>2,6</td>
<td>0,1</td>
</tr>
<tr>
<td>3 ENGINE WIDE-BODY</td>
<td>20,1</td>
<td>11,9</td>
</tr>
<tr>
<td>2 ENGINE WIDE-BODY</td>
<td>2,0</td>
<td>2,9</td>
</tr>
<tr>
<td>4 ENGINE NARROW</td>
<td>4,8</td>
<td>25,5</td>
</tr>
<tr>
<td>3 ENGINE NARROW</td>
<td>95,2</td>
<td>17,4</td>
</tr>
<tr>
<td>2 ENGINE NARROW</td>
<td>42,4</td>
<td>26,1</td>
</tr>
</tbody>
</table>

### AIRCRAFT IN MAINTENANCE

<table>
<thead>
<tr>
<th>AIRCRAFT SIZE</th>
<th>NO. OF OVERNIGHT AIRCRAFT</th>
<th>AVERAGE NO. OF AIRCRAFT AT MAINTENANCE FACILITY</th>
<th>AVERAGE NO. OF OVERNIGHT AIRCRAFT AT GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DAY</td>
<td>NIGHT</td>
</tr>
<tr>
<td>SMALL</td>
<td>54</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>LARGE</td>
<td>7</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
The bottom part of Tables 5-5 through 5-13 presents the data on the average number of aircraft which overnight at the airport and the average number of aircraft at the maintenance facility during the daytime or nighttime. The average number of aircraft being maintained at the gate during nighttime is based upon the following:

1. The number of aircraft at the gate during nighttime equals the number of aircraft which overnight at the airport minus the difference in the (nighttime and daytime) number of aircraft at the airport's maintenance facility.

2. Aircraft at the gate during nighttime have the doors open and/or power on for the following number of hours between 9:00 pm and 6:00 am:
   - Small aircraft - 3 hours
   - Medium aircraft - 4 hours
   - Large aircraft - 4 hours

5.3.2 Average Number of Aircraft per Airport

Table 5-14 summarizes the average number of aircraft per airport. The number of aircraft in maintenance are taken directly from the data at the bottom of Tables 5-6 through 5-13. The number of aircraft at the gate during daytime is based upon the daytime gate hours per aircraft type at the top of those tables. The number of aircraft at the gate during nighttime is based upon the nighttime gate hours per aircraft type at the top of Tables 5-6 through 5-13, plus the average number of active overnight aircraft at the gate from the bottom of those tables. The number of aircraft at DCA, ATL, and MIA are from analysis performed by Lockheed based on the March 1979 scheduled operations. This method estimates 8.5 percent more total aircraft at these three airports than would be calculated from the data in Tables 5-6 through 5-13.
<table>
<thead>
<tr>
<th>AIRPORT</th>
<th>AIRCRAFT SIZE</th>
<th>DAYTIME</th>
<th>NIGHTTIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GATE</td>
<td>MAINT</td>
<td>GATE</td>
</tr>
<tr>
<td>ORD</td>
<td>SMALL</td>
<td>41.4</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>2.8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>9.8</td>
<td>2.0</td>
</tr>
<tr>
<td>JFK</td>
<td>SMALL</td>
<td>40.7</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>3.8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>10.3</td>
<td>2.0</td>
</tr>
<tr>
<td>STL</td>
<td>SMALL</td>
<td>17.2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>LGA</td>
<td>SMALL</td>
<td>18.3</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>BOS</td>
<td>SMALL</td>
<td>14.9</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>2.3</td>
<td>0</td>
</tr>
<tr>
<td>PHL</td>
<td>SMALL</td>
<td>8.3</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>DCA</td>
<td>SMALL</td>
<td>16.1</td>
<td>0</td>
</tr>
<tr>
<td>ATL</td>
<td>SMALL</td>
<td>30.7</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>4.1</td>
<td>2.0</td>
</tr>
<tr>
<td>MIA</td>
<td>SMALL</td>
<td>19.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>2.6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>5.8</td>
<td>3.0</td>
</tr>
</tbody>
</table>
5.3.3 Potential Exposure per Airport

Table 5-15 summarizes the potential exposure for

- nine airports
- three aircraft size classes
- two (on small aircraft) or three (on medium and large aircraft)
  locations of the electronic equipment in the aircraft
- two time periods, and the daily average

The Table 5-15 data are the expected number of aircraft per airport (Table 5-14) times the potential exposure factor (Table 5-4) and summed for aircraft at the gate and at maintenance. The daily average potential exposure is weighted according to the length of the daytime and nighttime periods.

5.4 Future Changes in Aircraft Operations

It is expected that the following changes will occur before the end of the century:

1. There will be a small annual increase in aircraft operations. The magnitude of the increase is airport-dependent. The airports are sequenced as follows from the largest to the smallest expected increase: STL, MIA, PHL, ATL, BOS, JFK, ORD, LGA and DCA.

2. There will be a significant shift in aircraft power source from the auxiliary power unit (APU) to ground electrical power.

3. The 1978 aircraft mix at the nine airports by size category is approximately:

   - 80 percent small (under 150 seats)
   - 5 percent medium (150-250 seats)
   - 15 percent large (over 250 seats)
### TABLE 5-15
POTENTIAL EXPOSURE PER AIRPORT
(EXPECTED NO. OF AIRCRAFT)(POTENTIAL EXPOSURE FACTOR)

<table>
<thead>
<tr>
<th>AIRPORT</th>
<th>AIRCRAFT SIZE</th>
<th>ELECTRONIC EQUIPMENT LOCATION</th>
<th>TIME PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>DAYTIME</td>
</tr>
<tr>
<td>ORD</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>50.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>35.15</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>1.72</td>
</tr>
<tr>
<td>JFK</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>36.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>33.98</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>1.73</td>
</tr>
<tr>
<td>STL</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>13.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>13.41</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.01</td>
</tr>
<tr>
<td>LGA</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>12.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>12.88</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.01</td>
</tr>
<tr>
<td>AIRPORT</td>
<td>AIRCRAFT SIZE</td>
<td>ELECTRONIC EQUIPMENT LOCATION</td>
<td>TIME PERIOD</td>
</tr>
<tr>
<td>---------</td>
<td>---------------</td>
<td>--------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DAYTIME</td>
</tr>
<tr>
<td>BOS</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>12.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>11.94</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.03</td>
</tr>
<tr>
<td>PHL</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>6.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>5.95</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.02</td>
</tr>
<tr>
<td>DCA</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>11.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>11.27</td>
</tr>
<tr>
<td>ATL</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>30.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>28.35</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>1.65</td>
</tr>
<tr>
<td>MIA</td>
<td>SMALL</td>
<td>AVIONICS BAY</td>
<td>17.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLIGHT DECK</td>
<td>16.04</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>FLIGHT STATION</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>LARGE</td>
<td>FLIGHT STATION</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASSENGER CABIN</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FESC/MESC</td>
<td>2.47</td>
</tr>
</tbody>
</table>
There will be a significant decrease in the percent that are small aircraft, and the medium-sized aircraft will receive most of the growth.

5.5 Summary

Table 5-15 illustrates that the potential exposure per airport is not large, and that the potential exposure is predominantly to small aircraft. The small aircraft have the largest potential exposure because they constitute approximately eighty percent of all aircraft and because they have a significantly higher transfer function than medium/large aircraft. Table 5-4 shows that the potential exposure factor for small aircraft is approximately 70 times the potential exposure factor for the flight station and passenger cabin of medium or large aircraft, or for the forward or middle electronics service center of aircraft at the gate during daytime.
An investigation into electrical components potentially vulnerable to carbon fiber (CF) contamination was conducted for the DC-9 and DC-10 aircraft. These components, otherwise known as line replaceable units (LRUs) or black boxes (shortened to just "boxes"), have been categorized by type of design and vulnerability in accordance with NASA criteria.

Vulnerability to CF contamination in electrical/electronic equipment is determined by the type of equipment. For cooling purposes, some equipment is designed to be open so that air can flow through and vent the heat that is generated as the equipment is operated. Small carbon fibers released into the air may gain access to this type equipment with a probability of settling across unprotected terminals or uncoated terminal board leads, causing the equipment to malfunction.

Risk assessment is made by studying present-day aircraft safety and the cost of maintaining the vulnerable aircraft equipment under today's circumstances, and by comparing to corresponding future cost and safety when the use of composite materials becomes more widespread.

Tables 6-1 through 6-6 list the vulnerable LRUs for the DC-10 and DC-9 aircraft, respectively. These lists were categorized into open electrical/electronic boxes having:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Coated boards and unprotected terminals</td>
</tr>
<tr>
<td>B</td>
<td>Uncoated boards and protected terminals</td>
</tr>
<tr>
<td>C</td>
<td>Uncoated boards and unprotected terminals</td>
</tr>
</tbody>
</table>

The LRUs are further classified as to use:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Required for dispatch</td>
</tr>
<tr>
<td>E</td>
<td>Passenger convenience</td>
</tr>
<tr>
<td>F</td>
<td>Crew convenience (autopilot, etc.)</td>
</tr>
</tbody>
</table>

59
### TABLE 6-1

**DC-10 FAILURE RATE AND COST ASSESSMENT — CATEGORY A**

**CARBON FIBER STUDY**

**OPEN BOXES, COATED BOARDS, UNPROTECTED TERMINALS**

**DC-10 DAILY UTILIZATION = 8.56 HOURS (t)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Aircraft Removal Rate $\lambda_m/1000$</th>
<th>Average Repair Cost $\overline{\lambda}_m$ in $$/per removal</th>
<th>Average Repair Cost in $$/per 1000 FLT HOURS</th>
<th>Usage Classif.</th>
<th>QPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controller, Cabin Pressure, Stby</td>
<td>0.114</td>
<td>181.66</td>
<td>20.71</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Switch, Pressure, Aneroid</td>
<td>0.030</td>
<td>79.51</td>
<td>2.39</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Cargo Compt Temp Sensor</td>
<td>0.036</td>
<td>67.00</td>
<td>2.41</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Zone Temp Ind Sensor</td>
<td>0.039</td>
<td>93.00</td>
<td>3.63</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>Duct Temp Ind Sensor</td>
<td>0.030</td>
<td>91.60</td>
<td>2.75</td>
<td>F</td>
<td>5</td>
</tr>
<tr>
<td>Flight Guidance Pitch Computer</td>
<td>2.326</td>
<td>483.83</td>
<td>1125.39</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Flight Guidance Roll Computer</td>
<td>1.218</td>
<td>520.88</td>
<td>634.43</td>
<td>F</td>
<td>2</td>
</tr>
<tr>
<td>Flight Guidance Yaw Computer</td>
<td>0.676</td>
<td>236.75</td>
<td>160.04</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>HF Transceiver</td>
<td>1.242</td>
<td>137.33</td>
<td>170.56</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Amplifier, PA</td>
<td>0.854</td>
<td>161.19</td>
<td>137.66</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Reproducer, Tape ANCMT</td>
<td>0.964</td>
<td>81.41</td>
<td>78.48</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Main Multiplexer</td>
<td>0.312</td>
<td>188.13</td>
<td>58.70</td>
<td>E</td>
<td>1</td>
</tr>
<tr>
<td>Submultiplexer</td>
<td>0.442</td>
<td>412.91</td>
<td>182.51</td>
<td>E</td>
<td>2</td>
</tr>
<tr>
<td>Timer/Decoder Section</td>
<td>1.648</td>
<td>412.91</td>
<td>763.06</td>
<td>E</td>
<td>8</td>
</tr>
<tr>
<td>Overhead Decoder</td>
<td>1.305</td>
<td>82.36</td>
<td>112.42</td>
<td>E</td>
<td>39</td>
</tr>
<tr>
<td>1200-Va Static Inverter</td>
<td>0.020</td>
<td>197.38</td>
<td>3.95</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Battery Charger</td>
<td>0.193</td>
<td>50.00</td>
<td>17.00</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Battery Vent Pump</td>
<td>0.340</td>
<td>50.00</td>
<td>17.00</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Transformer, Instrument Bus</td>
<td>0.015</td>
<td>50.00</td>
<td>17.00</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Switch Assy Control, Roller</td>
<td>0.240</td>
<td>53.43</td>
<td>53.43</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Battery and Light</td>
<td>0.192</td>
<td>50.00</td>
<td>17.00</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Cabin Smoke Detection Ind</td>
<td>0.031</td>
<td>27.60</td>
<td>8.56</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Pump, Aux AC Elec. Motor Drive</td>
<td>0.190</td>
<td>121.11</td>
<td>60.71</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Switch, Thermal</td>
<td>0.054</td>
<td>68.00</td>
<td>3.67</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Flight Data Entry Panel</td>
<td>0.191</td>
<td>107.30</td>
<td>20.49</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Flight Data Acquisition Unit</td>
<td>0.200</td>
<td>179.61</td>
<td>35.92</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Antiskid Control Unit</td>
<td>0.009</td>
<td>220.12</td>
<td>68.02</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Lamp Dimmer</td>
<td>0.001</td>
<td>86.80</td>
<td>0.09</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>Controller, Warn and Caution</td>
<td>0.252</td>
<td>167.93</td>
<td>42.32</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Central Air Data Computer</td>
<td>1.042</td>
<td>169.18</td>
<td>176.29</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Horizontal Situation Indicator</td>
<td>2.336</td>
<td>570.83</td>
<td>1333.56</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Vertical Gyro</td>
<td>0.557</td>
<td>926.91</td>
<td>516.92</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Standby Attitude Indicator</td>
<td>0.233</td>
<td>361.14</td>
<td>84.15</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Receiver, ILS</td>
<td>0.836</td>
<td>202.49</td>
<td>168.28</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Weather Radar R/T Unit</td>
<td>2.304</td>
<td>133.73</td>
<td>133.73</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Weather Rad Ind</td>
<td>0.758</td>
<td>166.59</td>
<td>126.28</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Radio Altimeter R/T Unit</td>
<td>0.590</td>
<td>240.19</td>
<td>141.71</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Inertial Sensor/Navigation Unit</td>
<td>1.058</td>
<td>1300.00</td>
<td>1375.40</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Inertial Sensor Display Unit</td>
<td>0.181</td>
<td>1000.00</td>
<td>181.00</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Vor/Ils Receiver</td>
<td>1.352</td>
<td>151.81</td>
<td>205.25</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Vor/ils Receiver</td>
<td>0.920</td>
<td>278.70</td>
<td>256.40</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Vor Receiver</td>
<td>3.252</td>
<td>245.62</td>
<td>798.75</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Dme Interrogator</td>
<td>0.778</td>
<td>331.56</td>
<td>257.95</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>ADF Receiver</td>
<td>0.308</td>
<td>162.62</td>
<td>50.09</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>Atc Transponder</td>
<td>0.946</td>
<td>284.82</td>
<td>269.44</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Ails 70 Nav Computer</td>
<td>1.476</td>
<td>1500.00</td>
<td>2214.00</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Control Display Unit</td>
<td>1.470</td>
<td>1000.00</td>
<td>1470.00</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Switch, Control</td>
<td>0.081</td>
<td>306.40</td>
<td>24.82</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>Light Switch</td>
<td>0.081</td>
<td>24.60</td>
<td>1.99</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>Controller, Pneu Syst</td>
<td>0.936</td>
<td>274.01</td>
<td>256.47</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>Engine Ignition Switch</td>
<td>0.008</td>
<td>175.69</td>
<td>1.40</td>
<td>D</td>
<td>1</td>
</tr>
</tbody>
</table>

$$\Sigma_m = 35.182$$

$$\Sigma_n = 13995.34$$

$$t = 8.56 \text{ HOURS/DAY}$$

**Expected Number of Removals per Day per Aircraft**

$$\Sigma_m(t) = \frac{\Sigma_m t}{1000}$$

$$\Sigma_m(t) = 35.182 \times 8.56 = \frac{301.159}{1000} = 0.3012$$

**Expected Cost of Removals per Year per ACFT**

$$\frac{\Sigma \text{Repair Cost in } \$/\text{per 1000 FLT HOURS} \times 8.56 \times 365}{1000} = \frac{13995.34 \times 8.56 \times 365}{1000} = 43727.04$$

$$60$$
### TABLE 6-2
DC-10 FAILURE RATE AND COST ASSESSMENT — CATEGORY B
CARBON FIBER STUDY
OPEN BOXES, UNCOATED BOARDS, PROTECTED TERMINALS
DC-10 DAILY UTILIZATION = 8.56 HOURS (t)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>AIRCRAFT REMOVAL RATE λm/1000 FLIGHT HOURS</th>
<th>AVERAGE REPAIR COST IN $ PER REMOVAL</th>
<th>AVERAGE REPAIR COST IN $ PER 1000 FLT HOURS</th>
<th>USAGE CLASSIF</th>
<th>QPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASSENGER ADDRESS AMPLIFIER</td>
<td>0.908</td>
<td>161.19</td>
<td>146.36</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>AUDIO PANEL CONTROL</td>
<td>1.015</td>
<td>87.32</td>
<td>38.86</td>
<td>D</td>
<td>5</td>
</tr>
<tr>
<td>MARKER BEACON RECEIVER</td>
<td>0.162</td>
<td>110.99</td>
<td>4.77</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>SUM Σλm</td>
<td>2.085</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Σ= $189.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(t) = 8.56 HOURS/DAY

EXPECTED NUMBER OF REMOVALS PER DAY PER AIRCRAFT = \( \frac{\Sigma \lambda m(t)}{1000} \)

\[ \Sigma \lambda m(t) = 2.085 \times 8.56 = \frac{17.848}{1000} = 0.018 \]

EXPECTED COST OF REMOVALS PER YEAR PER AIRCRAFT = \( \frac{\Sigma \text{REPAIR COST IN $ PER 1000 FLT HOURS} \times 8.56 \times 365}{1000} \)

\[ \frac{\Sigma \text{REPAIR COST IN $ PER 1000 FLT HOURS} \times 8.56 \times 365}{1000} = \frac{189.99 \times 8.56 \times 365}{1000} = 593.60 \]

### TABLE 6-3
DC-10 FAILURE RATE AND COST ASSESSMENT — CATEGORY C
CARBON FIBER STUDY
OPEN BOXES, UNCOATED BOARDS, UNPROTECTED TERMINALS
DC-10 DAILY UTILIZATION = 8.56 HOURS (t)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>AIRCRAFT REMOVAL RATE λm/1000 FLIGHT HOURS</th>
<th>AVERAGE REPAIR COST IN $ PER REMOVAL</th>
<th>AVERAGE REPAIR COST IN $ PER 1000 FLT HOURS</th>
<th>USAGE CLASSIF</th>
<th>QPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>HANDSET</td>
<td>0.332</td>
<td>52.13</td>
<td>17.31</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>MARKER BEACON RECEIVER</td>
<td>0.162</td>
<td>110.99</td>
<td>17.98</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>SUM Σλm</td>
<td>0.494</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Σ= $35.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPECTED NUMBER OF REMOVALS PER DAY PER AIRCRAFT = \( \frac{\Sigma \lambda m(t)}{1000} \)

\[ \Sigma \lambda m(t) = 0.494 \times 8.56 = \frac{4.229}{1000} = 0.004 \]

EXPECTED COST OF REMOVALS PER YEAR PER AIRCRAFT = \( \frac{\Sigma \text{REPAIR COST IN $ PER 1000 FLT HOURS} \times 8.56 \times 365}{1000} \)

\[ \frac{\Sigma \text{REPAIR COST IN $ PER 1000 FLT HOURS} \times 8.56 \times 365}{1000} = \frac{35.29 \times 8.56 \times 365}{1000} = 110.26 \]
# TABLE 6-4

**DC-9 FAILURE RATE AND COST ASSESSMENT — CATEGORY A**

**CARBON FIBER STUDY**

**OPEN BOXES, COATED BOARDS, UNPROTECTED TERMINALS**

**DC-9 DAILY UTILIZATION = 7.12 HOURS (t)**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>AIRCRAFT REMOVAL RATE $\lambda m/1000 FLIGHT HOURS$</th>
<th>AVERAGE REPAIR COST IN $ PER REMOVAL</th>
<th>AVERAGE REPAIR COST IN $ PER 1000 FLT HOURS</th>
<th>USAGE CLASSIF</th>
<th>QPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF TRANSCEIVER</td>
<td>1.100</td>
<td>282.00</td>
<td>310.20</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>CABIN SPEAKER</td>
<td>0.137</td>
<td>74.00</td>
<td>4.42</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>PILOT'S CALL BELL</td>
<td>0.002</td>
<td>102.00</td>
<td>0.20</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>MECHANIC'S CALL HORN</td>
<td>0.013</td>
<td>95.00</td>
<td>1.24</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>GENERATOR CONTROL PANEL</td>
<td>0.846</td>
<td>232.00</td>
<td>196.27</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>BUS CONTROL PANEL</td>
<td>0.598</td>
<td>288.00</td>
<td>171.65</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>AC REGULATOR</td>
<td>0.261</td>
<td>214.00</td>
<td>55.85</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>BATTERY VENT FAN</td>
<td>0.031</td>
<td>158.00</td>
<td>4.90</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>PROX SW CONTROL</td>
<td>0.215</td>
<td>146.00</td>
<td>31.39</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>VERTICAL GYRO</td>
<td>1.659</td>
<td>576.00</td>
<td>955.58</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>STANDBY HORIZON INDICATOR</td>
<td>0.226</td>
<td>338.00</td>
<td>76.39</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>VOR/ILS RECEIVER</td>
<td>1.950</td>
<td>232.00</td>
<td>452.40</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>ADF RECEIVER</td>
<td>0.876</td>
<td>172.00</td>
<td>151.02</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>ATC TRANSPONDER</td>
<td>0.642</td>
<td>282.00</td>
<td>181.04</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>WEATHER RADAR R/T</td>
<td>2.012</td>
<td>326.00</td>
<td>655.91</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>WEATHER RADAR INDICATOR</td>
<td>0.657</td>
<td>326.00</td>
<td>214.18</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>WEATHER RADAR INDICATOR</td>
<td>0.934</td>
<td>326.00</td>
<td>304.48</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>RADIO ALTIMETER R/T UNIT</td>
<td>0.936</td>
<td>204.00</td>
<td>190.94</td>
<td>D</td>
<td>2</td>
</tr>
</tbody>
</table>

\[
\Sigma \lambda m = 13.097, \quad \Sigma = \$3958.06, \quad 28
\]

(t) = 7.12 HOURS

EXPECTED NUMBER OF REMOVALS PER DAY PER AIRCRAFT = \( \frac{\Sigma \lambda m(t)}{1000} \)

\[
\Sigma \lambda m(t) = 13.097 \times 712 = \frac{93,251}{1000} = 0.093
\]

EXPECTED COST OF REMOVALS PER YEAR PER ACFT = \( \frac{\Sigma \text{REPAIR COST IN } \$ \text{ PER } 1000 \text{ FLT HOURS} \times 7.12 \times 365}{1000} = \frac{\$3958.06 \times 7.12 \times 365}{1000} \)

\[
= \$10,286.21
\]
### TABLE 6-5
DC-9 FAILURE RATE AND COST ASSESSMENT – CATEGORY B
CARBON FIBER STUDY
OPEN BOXES, UNCOATED BOARDS, PROTECTED TERMINALS
DC-9 DAILY UTILIZATION = 7.12 HOURS (t)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>AIRCRAFT REMOVAL RATE (λm/1000 FLIGHT HOURS)</th>
<th>AVERAGE REPAIR COST IN $ PER REMOVAL</th>
<th>AVERAGE REPAIR COST IN $ PER 1000 FLT HOURS</th>
<th>USAGE CLASSIF</th>
<th>QPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUDIO PANEL</td>
<td>0.664</td>
<td>90.00</td>
<td>59.76</td>
<td>F</td>
<td>4</td>
</tr>
<tr>
<td>JACK PANEL</td>
<td>0.057</td>
<td>90.00</td>
<td>5.13</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>FLIGHT COMPT SPEAKER</td>
<td>0.152</td>
<td>109.00</td>
<td>16.37</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>FLIGHT INTERPHONE AMPLIFIER</td>
<td>0.072</td>
<td>120.00</td>
<td>8.64</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>FLIGHT DIRECTOR COMPUTER</td>
<td>0.848</td>
<td>198.00</td>
<td>167.90</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>MARKER BEACON RECEIVER</td>
<td>0.213</td>
<td>120.00</td>
<td>25.56</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>ATC TRANSPONDER</td>
<td>0.642</td>
<td>226.00</td>
<td>145.09</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>DME INTERROGATOR</td>
<td>0.452</td>
<td>282.00</td>
<td>170.33</td>
<td>D</td>
<td>2</td>
</tr>
</tbody>
</table>

\[ \Sigma \lambda m = 3.100 \]

\[ \Sigma = 598.78 \]

(t) = 7.12 HOURS/DAY

EXPECTED NUMBER OF REMOVALS PER DAY PER AIRCRAFT = \[ \frac{\Sigma \lambda m(t)}{1000} \]

\[ \Sigma \lambda m(t) = 3.100 \times 7.12 = \frac{22.072}{1000} = 0.022 \]

EXPECTED COST OF REMOVALS PER YEAR PER ACFT = \[ \frac{\Sigma \text{REPAIR COST IN $ PER 1000 FLT HOURS} \times 7.12 \times 365}{1000} = \frac{598.78 \times 7.12 \times 365}{1000} \]

\[ = \$1556.11 \]
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>( \lambda m/1000 ) FLIGHT HOURS</th>
<th>AVERAGE REPAIR COST IN $ PER REMOVAL</th>
<th>AVERAGE REPAIR COST IN $ PER 1000 FLT HOURS</th>
<th>USAGE CLASSIF</th>
<th>OPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASSENGER ADDRESS AMPLIFIER</td>
<td>0.719</td>
<td>148.00</td>
<td>106.41</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>WINDSHIELD TEMP CONTROLLER</td>
<td>0.882</td>
<td>183.00</td>
<td>161.41</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>MARKER BEACON RECEIVER</td>
<td>0.326</td>
<td>120.00</td>
<td>43.44</td>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>ADF RECEIVER</td>
<td>0.812</td>
<td>226.00</td>
<td>183.51</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>( \Sigma \lambda m )</td>
<td></td>
<td>( \Sigma = 494.77 )</td>
<td></td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

\( (t) = 7.12 \text{ HOURS/DAY} \)

**EXPECTED NUMBER OF REMOVALS PER DAY PER AIRCRAFT**

\[ \frac{\Sigma \lambda m(t)}{1000} \]

\[ \Sigma \lambda m(t) = 2,739 \times 7.12 = \frac{19,502}{1000} = 0.020 \]

**EXPECTED COST OF REMOVALS PER YEAR PER ACFT**

\[ \frac{\Sigma \text{REPAIR COST IN $ PER 1000 FLT HOURS}}{1000} \times 7,12 \times 365 = \frac{494.77 \times 7,12 \times 365}{1000} \]

\[ = 1285.81 \]
Unscheduled removal rates \( (\lambda_m) \) have been determined for each LRU based on actual commercial airline experience. Column one, aircraft removal rate \( \lambda_m/1000 \) flight hours, represents the unscheduled removal rate of the LRU multiplied by the quantity per aircraft (QPA) shown in column five. Column one is summed for each of the categories to show the total unscheduled removal rate for the aircraft, as is column five to show the total number of LRUs involved in the assessment. A survey was conducted to determine the average repair cost involved in an unscheduled removal for each of the LRUs. The cost includes the labor cost to remove and reinstall the unit in the aircraft, the cost to transport to and from the repair facility, and the cost to test and repair the unit as necessary to be serviceable. These costs are listed for each LRU in the second column entitled average cost in dollars per removal and reflect a cost of $10.00 per hour labor and $18.00 per hour burden based on 1979 dollars. Multiplying column one and column two provides the average repair cost in dollars per 1000 flight hours for each LRU and is listed in column three. This column is again summed to show the total repair cost per 1000 flight hours for each category. Dividing through by 1000 flight hours shows the repair cost per flight hour.

The daily utilization (the average length of time per day the aircraft is actually flying) has been determined for the DC-9 as 7.12 hours, and for the DC-10 as 8.56 hours.

Multiplying the repair cost per flight hour by the daily utilization for 365 days per year provides the expected repair cost per year for each category. Summation of the repair cost per year for each category for each aircraft reveals that the annual repair cost for the DC-10 is $44,431, and for the DC-9 is $13,128. These are the costs requested by NASA to be provided to A. D. Little Inc. for use in their computer model to determine cost risk due to carbon fiber contamination. The average repair cost per unscheduled removal is $100.60 for the DC-10 and $120.87 for the DC-9.

During the investigation and identification of DC-9 and DC-10 components considered potentially vulnerable to the effects of CF fallout, an evaluation was made to determine whether any CF-caused failure of these components could result in a hazard on a subsequent flight, particularly any of a nature that
could not be coped with using established procedures for accommodating system anomalies. None were found. The reasons for this finding are discussed below.

1. Certification requirements established by the FAA and other regulatory agencies worldwide, as well as the in-house design standards of Douglas and other manufacturers, require that systems be tolerant of functional faults or provide for alternative methods to accomplish the function. All electronically dependent critical functions meet this requirement.

2. Contamination and moisture from various sources have always been present on aircraft and have been dealt with for many years. The sealing/coating protection developed and used on electrical and electronic equipment to control the more common types of contamination work equally well against CR as determined by NASA tests. NASA data show that avionics equipment with conformal coated circuit boards and protected terminals is not vulnerable to CF contamination.

3. NASA data also show that power-generating equipment is not essentially affected by CF contamination. Further, FAA regulations require multiple power sources, fault-clearing ability, and the ability for the aircraft to continue safe flight with all electrical power sources except the battery inoperative for a time sufficient to reconfigure or restart the engines, if that was the cause for electrical power loss. Although CF cannot cause such total loss, this requirement does ensure that the failure of any single electrical item or likely combination of items due to CF (or any other cause) can be tolerated and controlled.

4. No unique failure modes result from CF contamination. As part of the design and certification process, the effects of equipment failure modes are analyzed. Failure effects that are generated by CF fall within the possible failure modes that must be considered in the design of present equipment.
5. Prior to flight, a thorough checklist is completed by the flight crew. If an aircraft is exposed to CF and if any significant system anomaly results, it is unlikely that it would not be detected prior to the next flight.

Consequently, in our view there is no discernible additive risk associated with subsequent operation of an aircraft certified to FAR Part 25 after it has been exposed to CF fallout.

If some postexposure action is nevertheless felt to be prudent, a mandatory cleaning prior to further operation could be imposed. Such action might be shown to be cost-effective since it could reduce the likelihood of incurring subsequent maintenance costs of any vulnerable nonflight significant components. NASA data also indicate that the quantity of CF that must be present to result in a significant chance of affecting even very vulnerable devices would be visibly apparent and thus amenable to cleaning operations.
<table>
<thead>
<tr>
<th></th>
<th></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>Carbon/Graphite Fiber Risk Analysis and Assessment Study: An Assessment of the Risk to Douglas Commercial Transport Aircraft</td>
</tr>
<tr>
<td>5. Report Date</td>
<td>March 1980</td>
</tr>
<tr>
<td>6. Performing Organization Code</td>
<td></td>
</tr>
<tr>
<td>7. Author(s)</td>
<td>H. C. Schjelderup, et al</td>
</tr>
<tr>
<td>9. Performing Organization Name and Address</td>
<td>Douglas Aircraft Company</td>
</tr>
<tr>
<td>McDonnell Douglas Corporation</td>
<td></td>
</tr>
<tr>
<td>3855 Lakewood Blvd.</td>
<td></td>
</tr>
<tr>
<td>Long Beach, CA 90846</td>
<td></td>
</tr>
<tr>
<td>10. Work Unit No.</td>
<td></td>
</tr>
<tr>
<td>11. Contract or Grant No.</td>
<td>NAS1-15508</td>
</tr>
<tr>
<td>12. Sponsoring Agency Name and Address</td>
<td>National Aeronautics and Space Administration, Washington, DC 20546</td>
</tr>
<tr>
<td>13. Type of Report and Period Covered</td>
<td>Contractor Report - Final</td>
</tr>
<tr>
<td>16. Abstract</td>
<td>The use of carbon/graphite composite material in aircraft structures is increasing every year. However, concern has been expressed over the potential hazard to electrical and electronic devices should there be a release of free fibers due to a crash and fire; therefore, NASA established a comprehensive study program to estimate the expected dollar loss due to this problem. Work programs were conducted by a variety of firms and Government agencies to acquire exposure and equipment sensitivity data for a risk analysis. Results of the Douglas portions of this program are presented. They consisted of the following: DC-9/DC-10 Electrical/ Electronic Component Characterization, DC-9 and DC-10 Fiber Transfer Functions, Potential for Transport Aircraft Equipment Exposure to Carbon Fibers, and Equipment Vulnerability Assessment. Results reflect only a negligible increase in risk for the DC-9 and DC-10 fleets either now or projected to 1993.</td>
</tr>
<tr>
<td>17. Key Words (Suggested by Author(s))</td>
<td>Risk Analysis</td>
</tr>
<tr>
<td>Graphite</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td></td>
</tr>
<tr>
<td>Advanced Composites</td>
<td></td>
</tr>
<tr>
<td>Electrical Hazard</td>
<td></td>
</tr>
<tr>
<td>18. Distribution Statement</td>
<td>For U.S., Government Agencies and Their Contractors Only</td>
</tr>
<tr>
<td>19. Security Classif. (of this report)</td>
<td>U</td>
</tr>
<tr>
<td>20. Security Classif. (of this page)</td>
<td>U</td>
</tr>
<tr>
<td>21. No. of Pages</td>
<td>76</td>
</tr>
<tr>
<td>22. Price*</td>
<td></td>
</tr>
</tbody>
</table>

For sale by the National Technical Information Service, Springfield, Virginia 22161