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NASA CR 137690

AN ANALYSIS OF AIRCRAFT ACCIDENTS INVOLVING FIRES

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May 1975

Prepared under Contract No. NAS2-8535 by
STANFORD RESEARCH INSTITUTE
Menlo Park, California

for

AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR 137690		

4. Title and Subtitle

AN ANALYSIS OF AIRCRAFT ACCIDENTS INVOLVING FIRES

5. Report Date
May 1975

6. Performing Organization Code

7. Author(s)
G.V. Lucha, M.A. Robertson, and F.A. Schooley

8. Performing Organization Report No.

9. Performing Organization Name and Address
Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, CA 94025

10. Work Unit No.

11. Contract or Grant No.
NAS2-8535

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, CA 94035

13. Type of Report and Period Covered
Contractor Report
10-22-74 thru 5-22-75

14. Sponsoring Agency Code

15. Supplementary Notes
Technical Monitor, Dr. Domenick Cagliostro, Chemical Research Projects Office, NASA Ames Research Center, Moffett Field, CA

16. Abstract

All U.S. Air Carrier accidents between 1963 and 1974 were studied to assess the extent of total personnel and aircraft damage which occurred in accidents and in accidents involving fire. Published accident reports and NTSB investigators' factual backup files were the primary sources of data. Although it was frequently not possible to assess the relative extent of fire-caused damage versus impact damage using the available data, the study established upper and lower bounds for deaths and damage due specifically to fire.

In 12 years there were 122 accidents which involved airframe fires. Eighty-seven percent of the fires occurred after impact, and fuel leakage from ruptured tanks or severed lines was the most frequently cited cause.

A cost analysis was performed for 300 serious accidents, including 92 serious accidents which involved fire. Personal injury costs were outside the scope of the cost analysis, but data on personnel injury judgements as well as settlements received from the CAB are included for reference.

17. Key Words	18. Distribution Statement
Aircraft Accidents, Aircraft Incidents, Aircraft Fires, Crash Fires, Fuel Fires, Accident Costs	Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	147	

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AN ANALYSIS OF AIRCRAFT ACCIDENTS INVOLVING FIRES

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I SUMMARY

Published accident briefs and reports, NTSB coded data, and investigators' factual backup files were studied to assess the extent of total personnel, aircraft, and property damage in accidents and accidents involving fire for U.S. Air Carriers between 1963 and 1974. A secondary objective, which was to determine the degree to which more fire-resistant or less toxic materials could reduce injuries, fatalities, and aircraft damage costs, could not be fully met because the accident data studied did not describe in sufficient detail propagation of fires within the cabin, injuries or fatalities due to toxic gases, or relationships between fire characteristics and interior materials. Upper and lower bounds for the number of deaths and damage costs specifically due to fire were determined.

During the twelve year period studied there were 122 accidents with fires involving the airframe and 36 additional engine or wheel nacelle fires. Eighty-seven percent of the airframe fires occurred after impact, and a majority of the listed causes involved ruptured fuel tanks, severed fuel lines, and other fuel related factors. The fires which followed more than half of the severe impacts destroyed or seriously damaged the wreckage, indicating that improved fire hardening should probably accompany any efforts to improve passenger impact survivability.

Accident data specifically ascribed 320 of the 2530 reported aircraft accident fatalities to fire and its effects. It is highly likely, however, that up to 555 of the deaths were due to this cause.

Aircraft damage in 300 serious aircraft accidents exceeded $500,000,000 between 1963 and 1974. Approximately $285,000,000 of this damage occurred in 91 serious accidents which involved fire. It was not possible to definitely apportion impact damage and fire damage costs for accidents where both types of damage were present. Specific fire-caused damage costs were between $42,000,000 and $149,000,000 over the twelve years.

II INTRODUCTION

This is the final report of "An Analysis of Aircraft Accidents Involving Fires" conducted by the Stanford Research Institute (SRI) under Contract NAS2-8535 with the National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California. This report documents all research activities conducted during the study, which extended from October 22, 1974 through May 22, 1975.

A. Background

This study is one of several being sponsored by the NASA-Ames Chemical Research Projects Office as part of its Aircraft Interior Fire Protection Program. Other studies in the series include an evaluation of combustion detectors, mass spectroscopic analysis of pyrolysis and combustion processes, as well as full-scale fire testing.

B. Objectives

The purpose of this study was to provide a basis for assessing the extent of total personnel, aircraft, and property damage occurring in accidents on U.S. commercial aircraft in the period 1963-1974 and to assist in determining the degree to which materials with improved fire resistance and/or decreased toxicity could reduce injuries, fatalities and aircraft damage costs.

C. Definitions and Scope

The study concerns U.S. Air Carriers* comprising the U.S. Certificated Route and Supplemental Air Carriers which perform scheduled and nonscheduled passenger and cargo services, both domestic and international. Only fixed wing aircraft were included which, as of December 1974, included 2,464 aircraft, 95% of which were turbine-powered. Another group of carriers flying large jets--the "Commercial Operators," such as PSA--was

*Non-U.S. Air Carrier accidents, such as the Varig 707 near Paris in July 1973, are not included in this study; two are mentioned briefly in Appendix F, however.

examined, but because of the minor degree of fire involvement, this group is not included in the results.

The study has examined all reported accidents and incidents involving fire between 1963 and 1974. Data for 1974, however, are still incomplete pending final determination of causal factors of 23 accidents (including 7 fatal accidents) by the National Transportation Safety Board (NTSB). Therefore, all tables purporting to show 1974 data should be interpreted with care, and the phrase "1974 incomplete" is repeated frequently throughout the report as a reminder.

The term "ACCIDENTS" as used in this study has a precise definition and is distinguished from "incidents" and "occurrences."

Briefly,

> "Aircraft Accident" means an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or the aircraft receives substantial damage.*

"INCIDENTS" are specific occurrences, such as an inflight fire, for which reports are required by NTSB/FAA. Incidents occur with parked aircraft nearly as often as in moving aircraft; this is not the case for "accidents." (A listing of reportable incidents appears in Appendix A, Definitions.)

This study uses the term "OCCURRENCES" to refer to any other situation besides an accident or an incident which concerns fire and U.S. Air Carrier aircraft. Some of these are required to be reported to the FAA under the Federal Aviation Regulations and are known to the FAA as "Service Difficulty Reports." The following section of the report will describe such occurrences in more detail. Others are fire occurrences

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*Bone fractures are considered serious injuries. The full definition of the terms "serious injury" and "substantial damage" is included in Appendix A, Definitions.

which did not appear in the FAA's SDRs but were found in the files of the National Fire Protection Association. These are only a few, usually on parked, empty aircraft and with no injuries.

Other terms will appear in the report from time tc time with brief definitions in the text and more extensive descriptions in Appendix A.

D. Method of Approach and Data Sources

The study was organized into three major tasks. Task 1 was the collection of most of the accident data and the preparation of a number of statistical summaries describing the frequency of accidents and the frequency of accidents involving fires, along with a series of severity and accident typology comparisons. This work was basic to the entire study but results are primarily reported in Chapter III.

Task 2 involved detailed examination of the individual reports of each fire-involved accident using published data and detailed case files for the 1970-1974 accidents which were made available to our researchers by the National Transportation Safety Board (NTSB). The NTSB case files for pre-1970 accidents were stored in separate archives and could not be obtained in time to be used for this study. For these accidents the needed detail was obtained from published information and from NTSB computer files. The case files were examined particularly for the effects of fire on passengers and crew, timing and opportunity of escape and the injuries and fatalities specifically attributed to burns and toxic fume inhalation, as well as to those injuries from airframe damage. The results of these analyses are reported in Chapters IV and V and in several appendices.

Task 3 is a cost analysis designed to determine the monetary impact of both fire and non-fire accidents and is reported in Chapter VI.

At the beginning of Task 1, a listing was requested from NTSB for all accidents and incidents involving U.S. Air Carriers from 1963-1974 under the following fire codings:

Fire or explosion--inflight
Fire or explosion--on ground
Fire after impact

Cases involving fires restricted to engines or wheel nacelle areas were separated out, and the study focuses on a remaining 122 accidents and 27 incidents. A data collection form was designed to reflect data from CAB and NTSB accident briefs, from 64 NTSB-published Aircraft Accident Reports and from the in-depth files (factual reports by NTSB investigators) maintained by the NTSB in Washington, D.C. Files at the National Fire Protection Association (NFPA), Boston, were used to supplement the accident information.

A computer printout of all flame and smoke reports involving U.S. Air Carriers from 1970-1974 (the only machine readable data period available) was obtained from the FAA Maintenance Analysis Center (MAC) in Oklahoma City. Fires occurring in the cabin were divided into three groups: cabin, lavatory and galley fires. These reports are required by Federal Aviation Regulations, Part 121 (Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft), Section 121.703, Mechanical Reliability Reports (MRR), and Section 121.705, Mechanical Interruption Summaries (MIS). The FAA MAC has recently combined the MRRs and MISs and called them Service Difficulty Reports (SDR). It is required that the following, among others, be reported: fires during flight, smoke vapor, or toxic or noxious fumes in the crew compartment or passenger cabin during flight and aircraft structure that requires major repair.* (See Appendix A for the full citations.) SDRs reflect occurrences which might have become fire incidents or accidents but which were located and arrested. Although not included in the original scope of the study, some of the statistics from the SDRs are presented to supplement the accident data and provide a further index of the occurrence of fires in airframe accidents.

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*In addition, 121.7[illegible](c) states that "In addition to the reports required by paragraph (a) of this section, each certificate holder shall report any other failure, malfunction, or defect in an aircraft that occurs or is detected at any time if, in its opinion, that failure, malfunction, or defect has endangered or may endanger the safe operation of an aircraft used by it."

One other set of data obtained through the NFPA files involved aircraft which were parked with engines not operating. (Some of these may have resulted in SDRs (see below) but they were not in FAA-MAC's computerized file begun in 1970. Also, some of the 1963 occurrences may have been "incidents" for which NTSB data were not available.)

The major study effort was carried out in Task 1: locating data sources and extracting and assembling a large number of detailed accident and fires accident/incident statistics from available published material and files. Task 2 presents and compares the assembled statistics from the following points of view:

- Flight purpose: passenger, cargo or ferry/training
- Phase of operation when "accident/incident" occurred: while aircraft static (with or without engines operating), taxiing, taking off, inflight, or landing (each phase has several subphases)
- Aircraft damage: from impact and from fire
- Injury severity: fatal, serious, minor/none and number due to fire
- Type of accident: 59 categories, 32 of which contain fire involved accidents/incidents.
- Aircraft make and model.

The cost analysis effort of Task 3 involved obtaining aircraft and accident cost data, developing average cost indices for various crashes, and conducting a cost analysis of fires accidents related to the general accident picture. A more complete treatment of the costing methodology is contained in Chapter VI.

E. Acknowledgements

The project staff gratefully acknowledges the assistance provided by the following organizations and personnel in opening their files to data collection or providing data used in this study:

National Transportation Safety Board, Washington, D.C.
Office of General Manager
Accident Inquiries and Records Section
James Constantine, Jr. and David Parker

and

Information Systems Branch/Bureau of Aviation Safety
Gene Koski and Dennis Grossi

National Fire Protection Association, Boston
Fire Analysis Department
John Ottoson and James Lathrop

Federal Aviation Administration
Maintenance Analysis Center, Oklahoma City
Bill Chandler

Civil Aeronautics Board, Washington D.C.
Office of the General Counsel
Peter Schwartzkopf

Contact was also made with the Flight Safety Foundation, the Air Transport Association, Airline Pilots Association, American Airlines, United Airlines, FAA-Flight Standards Service Accident Investigation Staff, and FAA-Airport Services to find previous studies that may have been done concerning aircraft fires and with McDonnell Douglas, Boeing, Lockheed, and General Dynamics/Convair to obtain aircraft characteristics.

III AIRCRAFT ACCIDENTS AND ACCIDENTS INVOLVING FIRES, 1963-1974

A. Introduction

The results of Task 1 of the study are presented in this chapter. Task 1 was an aircraft accident data review designed to develop summary statistics contrasting the frequency of aircraft accidents involving fires with the frequency of other types of aircraft accidents. The summary tables which follow are for aircraft flown by U.S. Air Carriers (defined in Chapter II), unless otherwise stated; more detailed tabulations have been placed in Appendix B. The reader is again cautioned that these tables do not show 23 1974 accidents not yet released by the NTSB.

B. Accident Summary Statistics

The data review yielded a reported 713 accidents for U.S. Air Carriers between 1963 and 1974 with 158 (22%) of these involving some degree of fire. Thirty-six of the 158 fires, however, were limited to the engines or wheel nacelles and are not of primary interest to this study. Thus, the remaining 122 accidents involve fires in the airframe and represent 17 percent of total reported accidents; these will be emphasized. In addition, 168 of the 713 reported accidents were non-crash accidents with injuries due only to turbulence.* These are excluded from some comparisons and from the reported total, resulting in 545 accidents, 122 of which involved fire in the airframe. Table 1 summarizes these comparisons.

*An inflight aircraft encounters clear air turbulence and a standing occupant falls and fractures a bone, a serious injury. This, therefore, by definition becomes an "accident;" no collision is involved.

Table 1

Comparison of Fire-Involved U.S. Air Carrier Accidents with All Accidents, 1963-1974 (1974 Incomplete)

Category	No. of Accidents	Percent of Total
U.S. Air Carrier Accidents 1963-1974*	713	100%
Above Accidents Involving Fire	158	22%
Above Accidents Involving Fires in Airframe	122	17%
No. of non-Turbulence Accidents	545	100%
Above Accidents Involving Fire in Airframe	122	22%

*1974 data are preliminary and exclude 23 accidents pending NTSB determination of the cause.

C. Fatality and Injury Summary Statistics

While only 22 percent of all non-turbulence accidents involved airframe fires, the majority of the fatal accidents did. As shown in Table 2, 75 percent of the fatal accidents involved some degree of airframe fire. However, these accidents seem to involve fires as a byproduct of their severity rather than deriving their severity due to the fire. As shown in the following table, only 14 percent of all fatal accidents had deaths specifically noted as being fire caused and only 13 percent of the people killed in fatal accidents were reported to have died due to burns, fumes and other effects of the fire. Chapter IV includes additional data addressing the question of fire-related fatalities occurring in otherwise survivable accidents.

Examining injuries and injury accidents, 33 percent of seriously injured people were involved in fire accidents, and at least two percent of those injured were reported injured as a direct result of the fire

(smoke, burns, etc.). Others were injured as an indirect result of a fire while evacuating the aircraft, for example.

The following table compares the severity of accidents involving fires with all accidents in terms of whether the accidents resulted in deaths or injuries.

Table 2

Comparison of Fatal and Injury U.S. Air Carrier Accidents with Fire and Without Fire, 1963-1974 (1974 Incomplete)

Category	No. of Accidents of Given Severity	Percent of Total
Fatal Aircraft Accidents	95	100%
Fatal Aircraft Accidents with Fire	71	75%
Accidents with specifically identified fires-caused deaths	13	14%
Persons Killed in Aircraft Accidents	2530	100%
Killed in Aircraft Fires Accidents	2116*	84%
Deaths specifically attributed to fires	320	13%
Serious Injury Accidents (excluding turbulence, engine and wheel nacelle accidents)	103	100%
Above Accidents with Fire	16	16%
Persons Seriously Injured in Aircraft Accidents	1265	100%
Seriously Injured in Aircraft Fires Accidents	414	33%
Injuries specifically noted as fire caused	31	2%

*Most were killed in the impact. Further discussion is included in Chapter IV.

Table 3 examines accident injury level as a function of flight purpose. The Cargo and Ferry/Training flights are significant in terms of damage and accident totals if not in terms of injuries and fatalities. Table 3 shows the numbers of accidents and numbers of accidents with fires and, for fatal accidents, the number of accidents with fatalities due to fire.

Table 3

Comparison of Fire-Involved U.S. Air Carrier Accidents (Excluding Non-Crash Turbulence, Engine and Wheel Nacelle Fire Accidents) with all Such Accidents 1963-1974 (1974 Incomplete) According to Flight Purpose

Flight Purpose	Maximum Severity Level					
	Fatal		Serious Injury		Minor/No Injury	
	All	Fire	All	Fire	All	Fire
Passenger	67	49(11)*	90	9	250	20
Cargo	19	16(1)	8	5	62	10
Ferry/Training	8	6(1)	5	2	36	5
Totals	94†	71(13)	103	16	348	35

*Numbers in ( ) are accidents with fatalities specifically cited by NTSB to be caused by fire. A few others not specifically cited may have included fire-caused deaths.

† This value differs from that shown in Table 2 because one non-crash turbulence accident involved a passenger fatality.

Sixty-two percent of U.S. Air Carrier accidents from 1963-1974 (1974 incomplete) which caused serious injury (as the greatest degree of injury) were non-crash turbulence accidents, in which an aircraft encountered clear air turbulence and a standing occupant fell and usually fractured a leg or arm. These accidents are not included in Table 3. Serious injury also frequently occurs during evacuation of an aircraft because of the threat or reality of fire; occupants jump off wings, for example, and fracture legs. This is discussed in Chapter IV.

D. Damage Summary Statistics

The number of aircraft destroyed in accidents with fire and the number of aircraft destroyed due to fire are shown in Table 4. (Non-impact turbulence accidents are excluded from the table.)

Table 4

Comparison of Aircraft Damage in Fire-Involved U.S. Air Carrier Accidents with All Accidents (Excluding Non-Crash Turbulence), 1963-1974 (1974 Incomplete)

Category	No. of Accidents	Percent of Total
Number of Non-Turbulence Accidents	545	100%
Number of Aircraft Destroyed	113	21%
Number Destroyed in Accidents Involving Fires	91*	17%
Number Destroyed by Fire	55*	10%

*Many of these had already been extremely damaged by impact.

As shown above in ten percent of the crashes fire destroyed the aircraft. The relative contributions of fire and impact will be further addressed in Chapters IV and VI.

Aircraft damage statistics for three categories of flight purpose are shown in Table 5. The damage severity in this table is based on the total effects of both impact-caused and fire-caused damage. Numbers shown in parentheses present aircraft damage severity specifically reported as due to the effects of fire alone. Thus, for example, 55 aircraft were destroyed by fire; some of which probably would have had some salvage value had the fire not occurred. There were 258 passenger aircraft with substantial damage. There were 25 aircraft with overall substantial damage in accidents involving fire and there were 12 accidents where the fire damage was substantial.

Table 5

Comparison of All U.S. Air Carrier Accidents with Fire Involved Accidents (Excluding Non-Crash Turbulence, and Engine and Wheel Nacelle Fire Accidents) by Aircraft Damage, 1963-1974 (1974 Incomplete) According to Flight Purpose

Flight Purpose	Aircraft Damage			
	Destroyed		Substantial	
	All	Fire Involved	All	Fire Involved
Passenger	68	53(28)	258	25(12)
Cargo	32	27(17)	53	4(5)
Ferry/Training	13	11(10)	35	2(1)
Totals	113	91(55)	346	31(18)

Note: Numbers in ( ) indicate number of accidents where fire caused the indicated damage severity.

E. Accident Involvement of Different Aircraft Models

The number of accidents and fire related accidents reported for each turbine powered aircraft type represented in the U.S. Air Carrier fleet are shown in Table 6 along with the number of aircraft-years each type was in service in the fleet over the same 12-year period as an index of exposure. Also shown in Table 6 are two involvement index values based on the ratio between the number of accidents or fires accidents and the number of aircraft service years for the same 12-year period.

$$\text{Involvement Index} = \frac{\text{Accidents}}{\text{Service Years}} \times 100$$

Additional data showing the number of accidents, fire- accidents and number of aircraft in the fleet for each calendar year 1963-1974 is presented in Table B-2, Appendix B.

An examination of Table 6 shows overall accident involvement to be relatively uniform across aircraft types. Readers may be tempted to view the figures in Table 6 as an index to the relative safety of different aircraft types, but extreme caution is urged in making such an interpretation. First, the accident totals include many minor accidents. Also, the accidents and exposure index are based on a different mixture of passenger and cargo aircraft for each aircraft type. The use of aircraft-years of service as the exposure index also introduces problems because this assumes each aircraft type has an equal utilization factor in terms of number of trips, aircraft miles, passenger miles, or other statistics which the analyst believes should be correlated with human accident exposure. The major value of Table 6 is that it shows the degree to which the aircraft fires problem cuts across different types or classes of aircraft. Data are available in Appendix B to repeat the analysis for each calendar year to examine temporal trends in the number of accidents or airframe fires; this analysis is left for the reader to perform if desired.

F. Accident Types

Fire-involved accidents occurred in 32 of 59 accident categories distinguished by NTSB, and eighty percent of the accidents involving the airframe fell into one of the 12 categories shown in Table 7.

Table 6

U.S. Air Carrier Accidents by Type of Aircraft, 1963-1974
(1974 Incomplete)

		Aircraft	No. of Accidents* in 12 Year Period	Fire Accidents†	Aircraft Service Years During Period	Accident Involvement Index	Fire Accident Involvement Index
4-Engine	Turbojet	Boeing 707	58	16	3606	1.6	0.4
		Boeing 720	22	2	1208	1.8	0.2
		Boeing 747	9	-	505	1.8	0
		Convair 880	7	2	474	1.5	0.4
		Convair 990	3	1	139	2.1	0.7
		McD D DC8	41	7	2445	1.7	0.3
	Turboprop	Lockheed 188	15	3	1104	1.4	0.3
		Lockheed 382	6	2	148	4.0	1.3
		Vickers 745	11	5	252	4.3	1.9
		V810,C144,AW650	9	4	247	3.6	1.6
3-Engine	Turbojet	Boeing 727	52	9	5616	0.9	0.2
		Lockheed 1011	3	1	133	2.2	0.8
		McD D DC10	4	-	271	1.5	0
2-Engine	Turbojet	Boeing 737	7	2	982	.7	0.2
		McD D DC9	32	12	2489	1.3	0.5
		BAC 111	6	2	506	1.2	0.4
		Caravelle	3	-	140	2.1	0
	Turboprop	Convair 580	12	4	514	2.3	0.8
		Con 600/640	9	2	138	6.5	1.4
		Fairchild F27	16	3	506	3.2	0.6
		Fairchild FH227	14	4	373	3.7	1.0
		YS-11	3	-	130	2.3	0
		Convair 240T	0	-	144	0	0
		Convair 340T	1	-	381	0.3	0
Other Turbine			17	2	208	8.1	0.9
Piston Powered			185	39	6408	2.8	0.6
Totals			545	122			

*Excludes non-crash turbulence

†Excludes engine and wheel nacelle fires

Table 7

Comparison of Major Types of Fire-Involved and Non-Fire Accidents, 1963-1974 (1974 Incomplete)

NTSB Accident Type Category	Fire Accidents		Non-Fire Accidents
	Airframe Fire Accidents	Engine or Wheel Fire Accidents	
Controlled Collision with Ground	18	0	6
Uncontrolled Collision with Ground	17	0	2
Undershoot	12	0	12
Collision with Trees	8	0	3
Engine Failure	8	12	22
Collision with Aircraft Inflight	7	0	8
Stall	5	0	2
Fire on Ground	5	9	0
Groundloop Swerve	5	2	30
Gear Collapsed	4	0	40
Collision with Other Objects	4	0	14
Fire Inflight	4	10	0
Total in These 12 Categories	97	33	139
Percent of All in Involvement Class	80%	92%	19%
Total in 20 Other Categories*	25	3	334
Percent of All in Involvement Class	20%	8%	47%
Total in Remaining 27 Categories*	0	0	83
Percent of All in Involvement Class	0%	0%	12%

*See Appendix B, Table B-3 for these 20 categories and a partial list of the remaining 27.

These 12 categories accounted for 97 of the 122 fire-involved accidents reported during the 12-year period studied. The remaining fire accidents are distributed among 21 other accident categories. Table B-3 showing all 32 accident classifications and a comparison with all accidents in the period was prepared and is shown in Appendix B. An analysis of these tables indicates that an overwhelming majority of the fires accidents have type classifications that involve collisions or abnormal contact with the ground. Only 19% of the non-fire accidents occur in these 12 categories; 47 percent more occur in the additional 20 categories where fire-involved accidents are found, but half of those were turbulence accidents. (Two turbulence accidents did involve airframe breakup and subsequent fire.) A remaining 34 percent of all non-fire accidents are distributed among 27 accident types. As will be shown in Chapter IV, 87 percent of fire-involved airframe accidents involved fires after impact. Only four of the 122 airframe accidents are listed in the fire-inflight initiation category.

G. Accident Involvement vs. Phase and Purpose of Flight

The occurrence of accidents and fires-accidents during various phases of operation is summarized in Table 8 below.

Table 8

Comparison of Airframe Fire Accidents with All U.S. Air Carrier Accidents (Excluding Non-Crash Turbulence) by Phase of Operation, 1963-1974 (1974 Incomplete)

Phase of Operation	No. of Non-Turbulence Accidents	Percent of Total	Airframe Fire Related Accidents	Percent of Airframe Fires
Static (On Ground)	39	7	3	2
Taxi	51	9	3	2
Takeoff	82	15	28	23
Flight	122	23	29	24
Landing	249	35	58	48
Not Reported	2	1	1	1
Total	545	100%	122	100%

As shown in Table 8, more than one-third of all accidents, and half of all airframe fires accidents, occur during landing. About three quarters of the accidents and airframe fires accidents occur at or near airports, and the remaining one fourth occur during flight.

The following table compares the phase of operation of fire involved accidents (excluding engine and wheel nacelle fires) with all U.S. Air Carrier accidents (excluding non-crash turbulence accidents) according to phase of operation and flight purpose.

Table 9

Comparison of All U.S. Air Carrier Accidents
(Excluding Non-Crash Turbulence) with Those Involving Fires
(Excluding Engine and Wheel Nacelle), 1963-1974 (1974 Incomplete)
by Flight Purpose

Flight Purpose	Phase of Operation										All Phase Totals	
	Static		Taxi		Takeoff		Flight		Landing			
	All	Fire	All	Fire	All	Fire	All	Fire	All	Fire	All	Fire
Passenger	37	2	39	2	56	15	101	22	172	36	405	77
Cargo	1	0	9	1	18	10	13	6	47	14	89	31
Ferry/Training	1	1	3	0	7	3	8	1	30	8	49	13
Totals	39	3	51	3	82	28	122	29	249	58	543*	121*
Percent Involving Fire at Phase of Operation		8%		6%		34%		24%		23%		22%

*For two accidents (one involving fire) the phase of operation was not shown in the report.

Excluding inflight non-crash turbulence accidents, 249 (46 percent) occurred during the landing phase of operation, with 23 percent involving fire. Eighty-two accidents occurred on takeoff, with 34 percent involving fires.

IV INJURIES, FATALITIES AND DAMAGE IN ACCIDENTS INVOLVING FIRE*

A. Introduction

This report section is devoted primarily to the results of Task 2, an analysis of the injuries, fatalities and aircraft damage resulting from fires. The statistics and discussion included and in Chapter V are are designed to improve the understanding of fires accident causes, occurrence and effects. The data are also necessary inputs to the cost analysis, described in Chapter VI, which will express the accident effects in monetary terms.

As mentioned in Chapter III, 158 of the 713 accidents reported during the 12-year study period (1963-1974) involved an aircraft fire of some type. The distribution of these 158 accidents in terms of flight purpose, fire occurrence and phase of operation when the accident occurred is shown in Table 10.

*Matrices describing each of the fire involved accidents, incidents, and occurrences in terms of damage, injuries and accident descriptors are provided in Appendix D.

Table 10

U.S. Air Carrier Accidents Involving Fire 1963-1974 (1974 Incomplete)

Flight Purpose	Fires Accidents	Engine or Wheel Fires	Airframe Accidents	Airframe Accident Occurrence					Airframe Accident Fire Occurrence		
				Static	Taxi	Takeoff	Flight	Landing	Ground	In-Flight	After Impact
Passenger	106	28	78	2	2	15	22	36	6	7	65
Cargo	34	3	31	0	1	10	6	14	0	1	30
Ferry/ Training	18	5	13	1	0	3	1	8	1	1	11
Totals	158	36	122	3	3	28	29	58	7	9	106

As can be seen in the table, 36 out of 158 (23 percent) of the accidents involved fire in only the engine or wheel nacelle area. Engine and landing gear fires rarely affect the airframe and thus are not discussed in further detail in this report. (A listing of these with a few of their characteristics is included in Table D-3, Appendix D.) The majority of reported data will reflect the incidence and effect of fire occurring in the airframe only. (Technically, the landing gear are part of the airframe but for this report, "airframe" shall refer to the wings, fuselage and tail sections only.) After eliminating the engine and wheel fires accidents, the fire-accident study population consisted of 122 airframe accidents. Table 10 shows that 64 percent of these were passenger-carrying flights, 25 percent were cargo, and 11 percent were ferry or training flights. These were distributed among the three listed fire occurrence situations as follows:

On Ground: 6%	Static (such as parked at terminal), taxiing, ground run for takeoff, etc.
In Flight: 7%	Cruise (lightning strike, turbulence breakup)
After Impact: 87%	Accident occurs upon takeoff (aborted and then object struck), inflight (mid-air collisions, descending and hitting mountain ridge), or on landing (mainly during final approach, too low, hitting trees)

The fact that 87 percent of the fire-involved accidents were accidents with fires after impact is of major importance and is discussed later and in Table C-2 of Appendix C.

B. Injuries

Further analysis of the 122 airframe fires accidents showed that 414 persons were seriously injured in accidents involving fire, with at least 31 of the injuries definitely attributable to fire. Fifty-eight of the serious injuries occurred in 16 accidents with no fatalities, and the remaining serious injuries occurred in 24 accidents which also

had fatalities. The serious injuries are often broken limbs incurred during emergency evacuation of the aircraft while jumping off the wing. NTSB defines broken bones as a serious injury. The injury severity breakdown for the 122 accidents in the study population is shown below.

Table 11

Accident Injury Classes by Flight Purpose, 1963-1974 (1974 Incomplete)

Flight Purpose	No. of Accidents with Maximum Severity Shown			Totals
	Fatal	Serious	Minor/None	
Passenger	49	9	20	78
Cargo	16	5	10	31
Ferry/Training	6	2	5	13
Totals	71	16	35	122

C. Fatalities

There were 95 fatal accidents in the 12 years of data, 71 of which occurred in accidents involving some degree of fire. Nearly all of the fire-involved fatal accidents (65 out of the 71) involved after-impact fires. The six exceptions occurred inflight and involved a lightning strike, airframe breakup in turbulence, airframe plenum chamber fire also involving hydraulic fluid, fire in baggage compartment or cabin, improperly packaged nitric acid (cargo flight), and an unknown cause.

1. Cause of Death

The 71 fatal fire-related accidents represent 58 percent of all airframe fire-accidents and account for 2116 of the 2530 total U.S. Air Carrier fatalities between 1963-1974.* Of these 2116 fatalities in

*It is noted that 370 fatalities occurred in 1974 in seven fatal accidents for which NTSB has not yet determined cause and which are not included in the above totals; it is unknown how many of those accidents involved fire or how many fatalities may have been due to fire alone.

fire-involved accidents, only 320 or 15 percent, were reported as definitely due to fires according to NTSB reports (based on post-mortem examinations, autopsy and toxicological tests). The remaining 1796 deaths in the fire-involved accidents were not identified in the investigators' reports as being fire-caused, and thus it is believed that many if not all of these deaths were caused by impact rather than by the subsequent fire. From the designations recorded in published NTSB accident reports or in the NTSB factual investigation files, the 71 fatal accidents involving fire were grouped into three classes:

- 39 fatal accidents that were not impact-survivable* with 1377 deaths
- 13 fatal impact-survivable accidents in which some (320) of the fatalities were definitely caused by the fire†
- 19 fatal accidents with impact and not specifically designated as impact survivable or non-survivable with 419 deaths.

This third category is subject to more uncertainty than the other two. All but one of the 19 accidents involved after-impact fires, and the number of fatalities for this group totaled 419. This means that there were 739 potential fire-caused deaths (320 definitely due to fire plus the 419 in the third group) if all of the undesignated accidents were in fact impact-survivable. A minimum of 320 were fire-caused deaths if none of the 19 accidents were impact-survivable. In an attempt to reduce the

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*A "survivable" accident is defined by NTSB as one in which the fuselage remains relatively intact, crash forces do not exceed the limits of human tolerance, there are adequate occupant restraints and sufficient escape provisions. In 28 of the 39 accidents the "non-survivable" designation was stated as such in the published Aircraft Accident Report. The remaining 11 were designated as such by the SRI analyst, based on an "impact severity" code of "extreme" in the NTSB computer records as well as NTSB's definitions for these terms when published designations could not be located. (Section A.5 of Appendix A has a discussion of the codes.)

†These thirteen accidents and the number of persons killed by the fires were identified from data recorded on the NTSB "Aircraft Accident Analysis Sheet" Form 6120.12. Data on serious injuries due to fire were taken from published accident reports where available or factual backup material (1970-1974 only) and thus are available in less detail.

uncertainty each of the 19 accidents was further analyzed according to its impact severity code and fire severity codes and then grouped according to these codes. The results are shown in Table 12. First, three accidents that were very probably not impact-survivable were removed from the undesignated group. One of these aircraft disintegrated inflight and the other two had extreme to severe impact codes and minor and no fire damage, respectively. Next, three undesignated accidents were removed because reports ascribed their fatalities to impact. This reduced the maximum number of fire-caused deaths to 555.

Table 12

Impact Survivability Estimates for Undesignated Cases

Group	No. of Accidents	No. of Deaths	Remaining No. of Possible Fires Deaths If Accidents were Non-Impact Survivable
Total Undesignated	19	419	739 (maximum)
Probably No Fire Fatalities: Impact was coded severe to extreme and fire damage was minor or none or the report ascribed fatal injuries to impact	6	184	555 (probable maximum)
Possible Non Impact Survivable: Impact was severe, fuselage was destroyed by fire	4	96	459
Impact Survivability Unknown*	9	139	320 (minimum)

*Three accidents had 47 survivors in addition to 34 fatalities.

It is believed from the above that a maximum of 26 of the accidents could have been survivable (13 specifically designed in the second group, plus the 13 undesignated accidents remaining after the above analysis). It is also estimated that no more than 555 of the fatalities could have been due to the fire--from burns or from inhalation of combustion products. Table 13 gives some characteristics of the 13 impact-survivable accidents with definite fire-caused deaths. All the fires occurred after impact, three occurring during takeoff, one in flight, and nine upon landing (six during the final approach). There were survivors in all but one case. In that case, a training flight, one of the four persons killed probably would have survived had there been no fire. Among the survivors in the other 12 accidents, 188 were injured seriously, at least 17 by the fire itself, and there were 306 persons with minor or no injuries (in 8 accidents). Of the 417 who died in these 13 accidents, 320, or 77 percent, died from fire while the others apparently died from impact.

2. Crashworthiness

The preceding subsection suggests that in 45 of the 71 fatal fire-involved accidents it was immaterial from a fatality standpoint whether or not the fire occurred. Most of these accidents were so severe as to be totally non-survivable from an impact standpoint. The issue, however, in these nonsurvivable cases, is that if the aircraft structure had been more crashworthy--and at present there are ongoing research programs dealing with crashworthiness--the fire threat is still present and many of the occupants might then have died from ensuing fires. In 20 of the 39 nonsurvivable accidents in the first group, the aircraft was ultimately destroyed by fire and in an additional six cases the aircraft suffered substantial fire damage.

Table 13

CHARACTERISTICS OF IMPACT-SURVIVABLE ACCIDENTS WITH DEFINITE FIRE CAUSED DEATHS

File No.	Date	Location	Aircraft	Fire Damage	Injuries*			Phase of Operation	Fire Factors
					Fatal	Ser.	M/N		
Passenger:									
1-0080	11-23-64	Rome	TWA 707-331	D	48(44)	11	14	Takeoff 3	Fuel line tore free on impact; spewing fuel was ignited; fuel from right wing tip surge vent burned; fire spread to center fuselage tank, exploded
1-0032	11-11-65	Salt Lake	United 727	S	43(43)	35	13	Landing 3	Ruptured fuel line and sparks
1-0033	12- 4-65	Carmel, NY	Eastern L1049C	D	4(2)	34	16	Inflight 2	Ground fire
1-0001	4-22-66	Ardmore, OK	Amer. Fly L188C	D	83(12)	15		Landing 1	Struck hill
1-0062	6-13-68	Calcutta	Pan Am 707	D	6(6)		56	Landing 8	Collided with trees
1-0026	12-28-70	St. Thomas VI	Trans Carib 727	D	2(2)	11	42	Landing 4	Left wing root, explosion, small fire
1-0025	11-27-70	Anchorage	Capitol DC8	D	47(47)	49	133	Takeoff 3	Fire left side during first impact
1-0006	6- 7-71	New Haven CT	Allegheny CV580	D	28(27)	3(3)		Landing 3	Hit buildings, power lines; wing fixed; spilled fuel ignited
1-0017	12-20-72	Chicago	No. Central DC9	D	10(10)	9(9)	26	Takeoff 2	After impact fire in rear cabin
1-0048	12- 8-72	Chicago	United 737	D	43(27)	12	6	Landing 3	Struck electric line, houses
1-0001	1-30-74	Pago Pago	Pan Am 707-321B	D	95(95)	5(5)	--	Landing 3	Fire outside on right; flaming fuel trailing wing edge
Cargo:									
1-0003	2- 3-63	San Francisco	Slick L1049H	D	4(4)	4		Landing 3	Ground fire
Training:									
1-0003	5-30-72	Ft. Worth	Delta DC9	S	4(1)	-	--	Landing 3	Ruptured right wing fuel tank (wing hit runway); friction

*Figures in ( ) are injuries or fatalities due to fire.

Fire Damage: D, destroyed; S, substantial; Ser., serious; M/N, minor/none; Phase of Operation: *Takeoff* 2, initial climb; 3, aborted; *Inflight* 2, cruise; *Landing* 1, in traffic pattern; 3, final approach; 4, level off/touchdown; 8, other.

Table 13 - Continued

File No.	Evacuation Factors					Fuel Type	Remarks
	Emerg Exits	Assis-tance	Exit Loc.	No. Evac	Evac Time		
Passenger:							
1-0080	C		GHL	46	31-60 sec.	?	Aircraft stopped 20 sec. after impact; first explosion 40 sec. after impact; 2nd exp. 60 sec.; COHb on-board fatals averaged 23%; lethal agent was extremely short exposure fire with fire blast
1-0032	C	Too late	GHI	50	61-90 sec.	?	Fire on board throughout evacuation; elevation 4,300 ft; altitude hypoxia problem
1-0033						?	
1-0001						?	
1-0062	C	Effective		57		?	
1-0026		Effective	GK	53	31-60 sec.	Kerosene Type A	
1-0025			C	182		JPI Type A	
1-0006	A	Available but unable	H	3	0-30	JPI	Fire and smoke from burning houses and aircraft fuel outside aircraft; cabin filled rapidly with smoke; only attendant probably incapcitated by impact forces
1-0017			GHI	36		Jet A Kerosene	
1-0048		Too late	EK	18	Over 2 min		
1-0001	C	Too late	HK	10	?	Kerosene Type A	
Cargo:							
1-0003			DH			Octane AVGAS	
Training:							
1-0003						Jet A	

Emergency Exits: A, functioned normally, used; C, would not open (one or more); Exit Locations: C, main doors, fore and aft; D, auxiliary door, forward; E, auxiliary door, aft; F, auxiliary door, other; G, both main and auxiliary doors (one or more of each); H, emergency window exit(s); I, cockpit window; K, break in fuselage; L, thrown clear.

3. Evacuation

The inability of passengers to accomplish self evacuation appeared to be a major cause of fatalities in post-impact fires in many of the accounts of such fires read during the present study. The importance of evacuation was also underscored by some of the accident statistics. Although most people killed in aircraft accidents die from force of impact, in all but one of the 13 impact-survivable crashes, some occupants were able to evacuate successfully. Others, however, died from the effects of fire in these crashes and it seems clear that more would have been saved if they had been able to evacuate sooner.

A second major factor implied by the accident data is that the evacuation process itself can be the cause of injury in accidents involving fires. In some of the less serious fires, all of the serious injuries happened during evacuation and the fires can be said to have been an indirect rather than a direct cause of the injury. For example, in the 122 airframe fire-involved accidents, 16 accidents (13 percent) had serious injuries as the greatest severity and in the 36 accidents with engine/wheel nacelle fires, 10 accidents (28 percent) were in the serious injury severity class. Each of the 21 serious injuries in these 10 engine/wheel nacelle accidents happened during evacuation and probably at least 15 of the injuries in the airframe accidents were due to evacuation.

Although a detailed discussion of evacuation problems is beyond the scope of this report, the reader is referred to publications listed in Appendix E, particularly to the report by Snow et al. which includes a human factors discussion of two of the fire accidents (Rome, 11-23-64 and Salt Lake City, 11-11-65).

D. Aircraft Damage

NTSB Aircraft Accident Reports are coded for overall aircraft damage; impact severity (from a human factors point of view); impact damage severity to the cockpit, forward, center and aft cabin; and damage by fire.

"Impact severity" and "damage severity (impact)" are coded according to the following classification and definitions:*

extreme--nonsurvivable

severe--slightly less than extreme where there is extensive damage and the aircraft is demolished but survival is a fact or could have been

moderate or minor--investigator's judgment based on investigative evidence

none--none

Fifty-eight of the 122 aircraft in the airframe fires accident population had impact and/or damage severity coded as "extreme" or "severe." These, therefore, were demolished even without the effects of fire. Thirty-five of these 58 aircraft were subsequently destroyed by fire. In 21 accidents with moderate, minor, or no impact damage at all, the following fire damage was reported:

8 aircraft destroyed by fire

8 received substantial fire damage

5 had minor, no or unknown fire damage

Some of these 21 accidents are examples of situations where a fire suppression or inerting system may have reduced property loss.

Impact and fire-caused damage for the 122 accidents between 1963-1974 involving airframe fire are shown in Table 14. The same information for each of 21 different models of aircraft has been included in Table C-1, Appendix C. As can be seen in Table 14, the aircraft were destroyed by fire in 56 of the 122 airframe fire-involved accidents. At least 35 of these had extreme or severe impact damage, and thus the damage done by fire in these 35 cases probably did not increase substantially human or monetary costs already incurred. Unfortunately, impact damage or severity were not coded for 43 accidents, and the relative importance of fire damage in those cases could not be deduced.

*These definitions are from the Bureau of Aviation Safety, Safety Analysis Division, National Transportation Safety Board, Analyst's Handbook, revised January 1973. See Section A.5, Accident Codes--Severity and Damage, of Appendix A for further discussion.

Table 14

Impact Damage and Fire Damage in U.S. Air Carrier Accidents Involving Fire
1963-1974 (1974 Incomplete)

Flight Purpose		Impact Damage																														
		Extreme					Severe					Moderate					Minor					None					Unknown				
		Fire Damage					Fire Damage					Fire Damage					Fire Damage					Fire Damage					Fire Damage				
		D	S	M	N	?	D	S	M	N	?	D	S	M	N	?	D	S	M	N	?	D	S	M	N	?	D	S	M	N	?*
Passenger	78	9	4	3		6	10	2	1	1		3	1	1			4	1					4	1	1		4	1	6	2	13
Cargo	31	7			1		5		1	1	2		1	1		1						1				4	3	1		2
Ferry/ Training	13	2					2	1													1					5		1		1
Totals	122	18	4	3	1	6	17	3	2	2	2	3	2	2	0	1	4	1	0	0	0	1	5	1	1	0	13	4	8	2	16

Fire Damage Key: D=Destroyed; S=Substantial; M=Minor; N=None; ?=Unknown

*Note: 16 cases do not have impact damage, impact severity or fire damage coded separately but overall aircraft damage was coded as follows: Passenger, 5 destroyed, 8 substantial damage; Cargo, 2 destroyed; Ferry/Training, 1 substantial damage.

E. Comparison with 1955-1962 Data

In March 1966 the Bureau of Safety of the Civil Aeronautics Board issued a report entitled "A Study of United States Air Carrier Accidents Involving Fire, 1955-1964" (BOSP 7-6-3). This report provided statistical and analytical data on 155 accidents caused by or resulting in fire. After removing from this data 21 accidents which occurred in 1963 and 1964 (an overlap with the present study) and five helicopter accidents, the following table was prepared to describe the aircraft fire accident picture for the eight years preceding our selected time frame.

Table 15

Aircraft Accidents Involving Airframe Fires 1955-1962 (CAB Study)

Fire Occurrence	Total Accidents*	No. of Fatal Accidents	Fatalities	No. of Serious Accidents	No. of Minor/ None Accidents
In Flight	14	11	218		3
After Impact	89(10)	53(10)	1428(243)	9	
On Ground	3				3
Total	106(10)	63(10)	1646(243)	9	3

*An additional 23 accidents were engine or wheel well fire accidents, only two of which involved serious injuries.

Figures in parentheses indicate those specifically due to fire rather than impact.

The 10 accidents with fatalities due to fire occurred during landing and takeoff operations and for the following aircraft types:

Year	Aircraft	Remarks
1957	DC6A	Crashed after takeoff in instrument weather
1958	DC3	Struck trees during single engine climbout; training
1958	CV240	Struck ground short of runway during instrument approach
1959	L049	Slid down embankment from slick runway
1960	DC6B	Hit mountain shortly after takeoff
1960	C46	Lost control during takeoff and crashed
1961	DC8	Thrust reversal failure on landing; hit runway construction
1961	L049	Crashed short of runway
1962	L1049H	Struck ground short of runway during instrument approach
1962	DC7	Struck ground during attempted go-around

Five occurred during landing, four occurred during takeoff and one (slick runway) is unknown. All but one of these aircraft were piston-powered.

Thus, of 106 accidents and 63 fatal accidents, 10 resulted in deaths from fire. Of 1646 fatalities, 243 or 15 percent were due to fire. Of the 106 accidents, 14 occurred in flight, 89 occurred after impact, and three took place on the ground. These findings are compared with the 1963-1974 time frame of the present study in Table 16 below.

Table 16

Accidents Involving Airframe Fires 1955-1962 and 1963-1974 Compared (1974 Incomplete)

Study	Fire Occurrence			Fatal as Percent of All Fire Accidents	Percent due to Fire	
	Inflight	After Impact	On Ground		Fatal Accidents	Fatalities
CAB 1955-1962	13%	84%	3%	59%	16%	15%
1963-1974	7%	87%	6%	58%	18%	15%

The eight recommendations in the 1966 CAB report included the following: "the increased strength of environmental structures and occupant restraint systems to withstand the impact forces that are tolerable to man," "further improvement and development of integral fuel inerting, fire suppression and fire extinguishing systems," and "the suppression or elimination of toxic fumes that originate from burning fabrics and interior furnishings." Almost ten years later, these three conclusions are still airline safety issues.

F. Aircraft Fire Etiology

In this section the causes, origins, and reasons for many of the aircraft fires studied will be presented and briefly discussed.

Fire causes were stated definitely or could be confidently assumed from the information available in investigators' reports for 49 of the 122 accidents involving airframe fires. However, no specific details concerning the fires could be obtained in the remaining 73 cases. Table 17 compares the characteristics of the 49 accidents with known fire causes with characteristics of the group for which causal information was lacking. Most of the latter occurred between 1963 and 1969, the period for which the NTSB backup reports are in archives and which could not be made available in time to be studied.

Causes for the 49 accidents for which this information was available are tabulated in Table 18. Based on these reported cases, fuel-related factors predominate. In 11 cases fuel tanks ruptured, often after a wingtip hit the runway and friction sparks ignited escaping fuel. In eight more cases, fuel lines were severed during impact and the fuel ignited. Fuel was also a factor in seven other cases. There were also three cases in which the aircraft exploded on impact. The reasons behind the remaining 20 fires are varied and may be seen in Table 18.

One may also infer something about fire causes by studying the incident data. These fires did not become accidents because they were controlled before serious injury or death could result. However, any of the incidents discussed here could have become accidents in different

Table 17

Characteristics of Fire Involved Accidents with Known vs. Unknown Causes, 1963-1974 (1974 Incomplete)

Characteristic		Cause Known*		Cause Unknown	
		Number	Percent	Number	Percent
Total Number		49	100 %	73	100 %
Phase of Operation	Static	2	4	1	1
	Taxi	2	4	1	1
	Takeoff	10	20	18	25
	Inflight	11	22	19	26
	Landing	24	49	34	47
Fire Damage	Destroyed	18	37	38	52
	Substantial	15	31	4	5
	Minor	8	16	8	11
	None	1	2	4	5
	Unknown	7	14	19	26
Injury Index	Fatal	28(8)†	57(16)	43(5)	59(7)
	Serious	8	16	9	12
	Minor/None	13	27	21	29
Fire Occurrence	Inflight	8	16	1	1
	On Ground	5	10	2	3
	After Impact	36	73	70	96

*Causes listed in Table 8

† Figures in ( ) indicate fatalities due to fire

circumstances and thus studying them could help to avert future accidents. There were 27 incidents involving fuselage fires, and the causes are known for 13 of these. Unlike the accident data, no single cause predominates. The distribution of incident causal factors for the 27 incidents for which the cause was stated is shown below in Table 19.*

Table 19

Fire Incident Causal Factors

No. of Cases	Fire Cause or Starting Point
4	Electrical
3	Oxygen system
1	Lavatory refuse container
1	Incendiary device
1	Paper (in heater duct)
1	Chemical cargo
2	Refueling on ground
14	Cause not staced

There were also seven fire "occurrences" in the National Fire Protection Association files for 1963. These may have all been incidents, but no 1963 list of CAB/NTSB incidents could be found to verify this. An additional five occurrences of cabin fires were found in the NFPA files for 1965-1972, and these are summarized in the narrative below.

In one case, aliphatic naphtha was being used for spot cleaning vinyl plastic and, as the maintenance man shifted positions, static electricity caused the rug to burst into flames. The aircraft was destroyed by the fire.

In one case, electrical arcing (a short caused by water) was the cause of a fire in the galley area.

In one case, an electrical fault in a razor outlet caused a fire which was enhanced by the venting of oxygen cylinders in the hat racks.

In another, an oxygen bottle exploded in the cockpit.

In the last case, a fire was caused by a malfunction as a result of heat by friction or electrical short circuit in the recirculating air unit.

*A listing of all fire related incidents, 1964-1974, is in Appendix D-2.

Table 18

FIRE CAUSAL FACTORS FOR 49 ACCIDENTS WITH REASONS STATED

Reason For Fire	Date	Aircraft	Phase of Operation	Non-Survivable?	Fatals Due to Fire	Fire Damage	Remarks
Fuel Tank Ruptured:	7- 2-63	M404	Takeoff			Destroyed	
	8-10-68	FH227	Landing			Destroyed	
	12-27-68	CV440	Landing			Substantial	Fuel contacted engine parts
	6- 7-71	CV580	Landing		27	Destroyed	
	9-27-73	CV600	In Flight	Yes		Substantial	Hit Mountain
	12-29-72	1011	In Flight	Yes*		Substantial	
	5-18-65	DC6A	Landing			Substantial	
	3-21-68	727	Takeoff			Destroyed	
	3-18-71	GA382B	Landing			Substantial	
	5-30-72	DC9	Landing	Yes	1	Substantial	
	5- 3-68	L188	In Flight†	Yes		Unknown	Right wing failed in turbulence; fuel released, fire.
Fuel Line Severed:	11-23-64	707-331	Takeoff		44	Destroyed	
	11-11-65	727	Landing		43	Substantial	
	11-27-73	DC9	Landing			Substantial	
	11- 6-67	707	Takeoff			Minor	Ground fire at R wing separation and #3, 4 engines
	10-28-73	737	Landing			Minor	R engine separated
	9-12-66	DC7C	Takeoff			Substantial	Engine came to rest under empennage and started fire
	2-10-67	L1049H	In Flight†			Minor	#2 engine and prop separated
	11- 8-65	727	Landing			Destroyed	#1,3 engine separated at impact, intense ground fire; flame at cabin rear
Other Fuel	12- 8-63	707	In Flight†	Yes		n.a.	Lightning strike caused fire
	5-18-72	DC9-31	Landing			Destroyed	Fuel ignited on hot engine
	6-29-72	CV580	In Flight (mid-air)	Yes		Substantial	Fuel splatter burning (mid-air collision then impact with ground)
	12-17-73	DC9	Takeoff			Minor	Fire both engs; fuel spill beneath
	1-30-74	707-321B	Landing		95	Destroyed	Flaming fuel at wing; rt. eng. on fire
	8-24-70	L188	Takeoff			Destroyed	Wind blew fire from wing to tail; fuel spill
	9- 4-71	727	Landing	Yes		Substantial	All fuel containers disintegrated on impact
Explosion On Impact:	8-16-65	727	In Flight	Yes		Minor	Into Lake Michigan, fire and explosion on impact
	11-20-67	CV880	Landing			Destroyed	Explosion after impact
	3-31-71	720	Landing	Yes		Destroyed	Exploded on impact
Hydraulic Fluid:	1-16-74	707	Landing			Destroyed	Nose wheel steering hydraulic line fractured; friction of tires + runway ignited.
	6-23-67	1-11	In Flight †	Yes		n.a.	Fire progressed to vertical fin, started in plenum chamber

Table 18-Continued

Reason For Fire	Date	Aircraft	Phase of Operation	Non-Survivable?	Fatals Due To Fire	Fire Damage	Remarks
Electrical	5-10-72	DC9	Static‡			Substantial	Electrical short, cabin row 19
	12-24-68	CV580	Landing			Minor	Severed electrical wire bundle in right wing
	8-16-71	PC6H2	Landing			n.a.	Electrical fire at strut puncture
	8- 8-71	V745D	Taxi‡			Substantial	Left nickel-cadium battery thermal runaway
Miscel-laneous:	7-23-65	CV440	Takeoff			Destroyed	Engine failure; flash fire during skid
	1- 6-69	CV440	Landing			None	Flash fire + fuel puddles
	8- 6-66	1-11	In Flight†	Yes		n.a.	Airframe failure due to turbulence; flash in sky, fell flaming
	5-28-63	L1049	Landing			Destroyed	Wing and fuselage fuel tanks
	12-28-70	727	Landing		2	Destroyed	Wing root
	7-31-67	V745D	In Flight				Nose wheel penetrated fuselage cargo compartment; luggage ignited
	12-20-72	DC9	Takeoff (collided on runway)		10	Destroyed	Fire in right engine indicated; flame in rear cabin
	7- 9-64	V745D	In Flight†	Yes		Destroyed	Px hydrocarbon?; cabin or baggage fire
	12- 8-72	737	Landing		27	Destroyed	Chimney effect of house shell; hit electrical lines, houses
	3-19-72	DC9	Takeoff‡			Minor	Fire at buffet; engine compressor parts penetrated fuselage
	11- 3-73	707	Landing†	Yes		n.a.	Improperly packaged nitric acid in cargo
	6-10-72	727	Static‡			Minor	O_2 bottle exploded; contaminated bottle
	3-25-65	CV440	Taxi‡			Substantial	Mail bag in baggage contacted light
	3-26-65	707	Landing			Substantial	Dragged wing tip

*but 77 survivors (99 fatals)

†Fire occurred while in flight

‡Fire occurred while on ground

Note: Those cases not footnoted as per above two footnotes had fire occurring after impact.

n.a. = not available

To conclude this section on fire causes, attention is directed to a recent study of airport firefighting services needs which included a discussion of fire causation, propagation, and occupant survivability. Excerpts from this treatment of aircraft fire problems have been included as Appendix F.

V AIRCRAFT CABIN FIRES

A. Cabin Fire Accidents, Incidents, and Service Difficulty Reports

The following discussion is limited to 1970-1973, a period for which complete data from three different sources coincide. The sources of cabin flame or smoke occurrences are the following:

- NTSB Accident Reports
- NTSB Incident Reports
- FAA Service Difficulty Reports (SDR).

The majority of the "fire" occurrence data are Service Difficulty Reports (Mechanical Reliability Reports and Mechanical Interruption Summary Reports) covering problems of relatively minor nature which do not cause substantial damage or safety because they are discovered and controlled. Most of these are smoke/fume reports; only 48 (38 percent) actually cite "flame" as the condition present.

The next largest cabin fire occurrence data base is "accidents," most of which occur after impact. These resulted in destruction of the aircraft by fire in 16 cases; substantial fire damage, 9; minor fire damage, 5; and unknown fire damage in 4 cases.

Finally, there were 9 "incidents" resulting in substantial fire damage in 3 cases, minor in 3 cases, and none in 3 cases (2 cases where portable oxygen generators ignited and burned and 1 where a defective auxiliary power unit atomizer ignited and then was extinguished).

The following figures show the numbers of flame or smoke occurrences for different portions of the cabin.

Galley:

56 SDRs (28 flame)

Lavatories:

1 incident
11 SDRs (9 flame)

Remainder of cabin:

8 incidents (3 ground, 5 flight)
34 accidents (4 ground, 2 flight, 28 after impact)
58 SDRs (11 flame)

There were a total of 168 reported flame or smoke occurrences involving aircraft cabins between 1970-1973. To place this figure in perspective, there were approximately five million departures per year during the same time frame.* The rate of occurrence of cabin fires is thus exceedingly low on a per departure basis. The approximate figures are:

6 cabin, galley, lavatory SDRs per million departures
1.7 airframe fire accidents per million departures
0.4 fire incidents per million departures

B. Service Difficulty Reports

1. Lavatories

The flame and smoke reports from the FAA Maintenance Analysis Center showed 26 occurrences in lavatories from 1970-1974, three percent of all occurrences reported for that period. These were distributed as follows (figure in parentheses indicates flame reports):

19(11) in lavatory space (12 in disposal containers)
1 in lavatory light system
6 in lavatory flush motors

The aircraft concerned were the following:

DC8	5	707	3	DC9	3
727	6	737	2	1011	1
747	3	DC10	2	188A	1

The 11 flame and 15 smoke occurrences were during the following phases of operation:

Cruise	18
Inspection/Maintenance	3
Climb	2
Approach	1
Descent	1
Taxi/Ground Handling	1

*The exact figures are given in Appendix B.4

Of 12 fire or smoke reports involving wastepaper containers, eight noted the presence of a cigarette. One other report noted chaffed wires as the problem. Five occurred in 1970, 4 in 1973 and 3 in 1974. The 12 involved 3 DC8s, 3 747s, 3 727s, and 1 each DC10, DC9 and 707.

2. Galleys

The flame and smoke reports showed 95 occurrences in galleys from 1970-1974 (12 percent of those reported), 36 flame and 59 smoke. These were distributed as follows (figure in parentheses indicate flame reports):

12(5) in buffet/galley area
49(24) in ovens
27(5) in coffee makers
1 in equipment/furnishings
1 in communications equipment
2(1) in electrical power
1 in light system
1(1) in drinking water system
1 smoke in galley from engine flameout.

The aircraft concerned were the following:

727	23	DC10	11	737	5	CV580	3
747	13	DC8	10	720	5	CV880	1
707	12	DC9	9	1011	3	DC6	1

The occurrences were during the following stage of flight:

Cruise	70
Taxi/Ground Handling	7
Inspection/Maintenance	5
Climb	5
Takeoff	4
Descent	2
Approach	2

Fire and smoke occurrences in the buffet/galley area which did not concern coffee makers or ovens included problems such as refrigerator compressors, water pump fuses, hot cup overheating, fan motors, burned resistors.

3. Cabin

The flame and smoke reports showed 97 occurrences in the cabin from 1970-1974 (13 percent of those reported), 14 flame and 83 smoke. These were distributed as follows (figures in parentheses indicate flame report):

10(7) equipment/furnishings (seats, etc.)
11(1) lights
41 air conditioning
8(1) airborne auxiliary power
8(1) engines
5(1) communications (movie projectors, etc.)
3(2) oxygen
3 pneumatic
2(1) water/waste
2 electrical power
1 fuel
1 navigation
1 bleed air
1 engine oil

The aircraft concerned were the following:

DC9	20	727	10	707	5	1011	2	CV880	1
CV580	13	DC10	10	737	4	CV600/640	2	1-11	1
747	10	DC8	7	L188	2	F27	2	Other	8

The occurrences were during the following stages of flight:

Cruise	42
Taxi/Ground Handling	15
Climb	10
Takeoff	9
Approach	8
Descent	6
Inspection/Maintenance	2
Landing	1
Unknown	4

Occurrences involving the air conditioning system include problems such as smoke from oil in the engine driven compressor (EDC) duct and other EDC problems (15 occurrences), coalescer bag problems, fan problems, etc. The equipment/furnishings occurrences included fires in the arm rests, light cove overtemperatures, air vent overheats, elevator motor burned out. Seven of the 14 flame reports occurred in equipment/furnishings.

4. Other Flame and Smoke Reports

547 other flame and smoke reports occurred from 1970-1974 but did not involve the cabin area. These occurred mainly in engines (116) and the air conditioning system (74), electrical power (56), landing gear (59), lights (40), airborne auxiliary power (32) and engine fuel and control systems (32). These, along with those mentioned in lavatories, galleys and cabin, accounted for over 75% of the reports during the time period. The remaining reports were distributed among 26 other systems. (See Appendix C.3 for a listing of all systems and the number of reports in each.)

C. Additional Occurrences

Eight occurrences from 1965-1972 were found in the NFPA files but not on the NTSB incident or SDR lists. These involved seven parked aircraft and one landing aircraft. Causes were as follows: three electrical arcing, one static electricity with cleaning fluid, one oxygen bottle explosion, one broken propeller parts, two cleaning solvent at wheel well with sparks.

Also in the NFPA files were seven occurrences in 1963 which may have been classified as "incidents." NTSB has not computer coded the 1963 incidents and a listing of them was not found elsewhere; therefore, this cannot be confirmed. Causes of those seven fires, six occurring while the aircraft was parked and one in flight, were sparks from taxiing aircraft, fuel sprayed on hot engine during refueling, cigarettes in cabin (during cleaning in two cases), electrical, oxygen system contaminated, and unknown.

There were four 1974 occurrences in the files; these may turn out to be NTSB "incidents" also; the NTSB will not complete cause determination for the 1974 incidents until later in 1975. Three of these occurred during takeoff and one inflight; two involved the engine and no further details were available. In one, the cause was electrical, and in the other (wheel nacelle fire), friction from blown tires ignited leaking hydraulic fluid.

VI COST ANALYSIS

A. Introduction

The objective of the cost analysis was to determine the economic impact of airline fire related aircraft accident damages and to compare the result with airline total accident damage. The cost impact of personal injury and fatality occurrences was beyond the scope of the investigation. However, preliminary information on personnel injury passenger recoveries (both judgements and settlements) was obtained and will be reported in this section.

The accident population for the cost analysis differed in two respects from the population reported in the two preceding chapters, and, therefore, the accident totals reported here may be slightly different than those reported earlier. First, since 95 percent of the present U.S. air carrier fleet is turbine powered, only turbine powered aircraft types were considered in the cost analysis. Also, foreign made aircraft were not costed and the few accidents involving U.S. carriers flying foreign made aircraft were not analyzed. Included, however, were engine and wheel nacelle fire accidents which had been removed for most of the previous analyses.

The procedure used in obtaining information on aircraft damage costs involved the following steps:

1. Conduct a literature review of all current and historical publications relating to the general subjects of aircraft accident occurrence, aircraft damage and aircraft repair costs as well as specific accident descriptions and reports.

2. Review the aircraft accident reports prepared by the National Transportation Safety Board (NTSB) on each specific accident investigated between 1963 and 1974.

3. Determine the cost of aircraft and equipment purchased by certified carriers during a recent two-year period (September 1971 through September 1973).

4. Adjust the aircraft costs to include communications and other miscellaneous equipment. Develop a cost factor for each turbine powered (Turbo-fan, Turbo-jet and Turbo-prop) aircraft in service on commercial airlines as of January 1, 1973.

5. Supplement the NTSB reports by obtaining additional information and reports on specific accidents from the National Fire Protection Association in Boston.

6. Obtain information on aircraft takeoff weights and develop a cost-estimating formula based upon the cost/weight relationship using a standard computerized least squares curve fit technique.

7. Select accident reports from fire related and U.S. turbine powered aircraft accidents involving substantial damage and/or total aircraft destruction.

8. Develop the costs of fire related turbine powered aircraft damage (substantial and total destruction) by reviewing the appropriate damage report and applying the cost factors and cost/weight relationship developed in steps #4 and #6 above.

9. Estimate the cost of total aircraft damage by comparing the total number of turbine powered accidents by degree of damage with similar data on fire related accidents annually for a 12-year period (1963 thru 1974).

10. Compare the cost of total aircraft damage with that of fire related damage by using average cost factors both for destroyed and for substantially damaged turbine powered aircraft.

It would have been desirable to specifically isolate fire-caused accident damage from total damage, but because of the nature of the accident reports this could not be done accurately. Typically, aircraft damage occurs on impact, fire occurs following impact, and often no

specific report is made separating and isolating the magnitude and extent of each type of damage (impact versus fire). Therefore, instead of a single damage cost, we place upper and lower bounds on the cost of fire damage. This has been done by subtracting the cost of 34 impact-destroyed aircraft in accidents involving fire from the total costs of destroyed and substantially damaged aircraft in these accidents. This sets an upper bound on fire-caused damage. (Even if impact accounted for none of the damage in the remaining accidents the fire caused damage could not have exceeded this upper bound.) A lower bound on fire-caused damage was set by estimating the cost of the 13 survivable accidents in the 12-year data base which involved extensive fire damage but only moderate to minor impact damage to set a lower bound. (At least that much damage was definitely fire caused.)

B. Cost Factors

Early in the study data concerning air carrier unit costs was obtained from the Civil Aeronautics Board. The results derived from this data are shown in Table 20 on the following page. The table indicates the airframe average cost, and engine average cost over a two-year period based on 176 airframe purchases by 13 certificated carriers (Braniff, Continental, Delta, Eastern, Frontier, Piedmont, Air West, Southern, North Central, National, Northwest, Western, and TWA) over a two-year period beginning in September 1971.

The airframe cost figures were adjusted upward by 10 percent to cover the cost of engines and other necessary equipment. The resulting Airframe Adjusted Cost factors shown in Table 20 are roughly equivalent to those under Cost Less One Year's Depreciation in Table 21. The factors shown on Table 20 were used, therefore, along with a cost/weight formula derived in Section D to estimate annual accident costs.

Table 20

COST OF TURBINE-POWERED AIRCRAFT AND EQUIPMENT PURCHASED BY CERTIFIED CARRIERS DURING THE TWO-YEAR PERIOD ENDING SEPTEMBER 30, 1973

Aircraft Type	Airframe Average Cost*	Airframe Adjusted Cost	Engine Average Cost
B-707 Aircraft			
B-707 - 100B	$ 5,961,218	$ 6,557,000	$ 280,000
B-707 - 300	4,406,609	4,847,000	182,513
B-707 - 300B	6,635,847	7,299,000	280,000
B-707 - 300C	7,872,578	8,660,000	360,000
B-707 Average	$ 6,220,000	$ 6,842,000	$ 276,000
B-720 Aircraft			
B-720 - 000	$ 3,921,881	$ 4,314,000	$ 170,425
B-720 - 000B	5,253,388	5,779,000	239,850
B-720 Average	$ 4,590,000	$ 5,049,000	$ 205,000
B-727 Aircraft			
B-727 - 100	$ 1,823,876	$ 2,006,000	$ 117,173
B-727 - 100C	4,674,149	5,142,000	264,343
B-727 - 100QC	4,952,941	5,448,000	239,913
B-727 - 200	5,742,073	6,316,000	405,461
B-727 Average	$ 4,300,000	$ 4,730,000	$ 256,723
B-737 - 200	$ 3,147,617	$ 3,462,000	$ 193,480
B-747	$19,575,206	$21,533,000	$ 806,203
BAC 1-11-200	$ 868,545	$ 1,403,000	$ 125,935
CV-580	$ 629,282	$ 692,000	$ 42,494
CV-600	$ 529,019	$ 581,000	$ 98,403
CV-880	$ 2,222,013	$ 2,444,000	$ 90,350
DC-8-20	$ 3,000,000	$ 3,300,000	$ 125,000
DC-8-30	$ 2,161,913	$ 2,377,000	$ 150,000
DC-8-50	$ 1,220,000	$ 1,342,000	$ 154,318
DC-8-61	$ 6,976,349	$ 7,673,000	$ 275,000
DC-8-62	$ 8,957,150	$ 9,853,000	$ 306,049
DC-8-63	$ 9,418,976	$10,360,000	$ 294,649
DC-9-10	$ 1,238,600	$ 1,362,000	$ 270,004
DC-9-30	$ 3,786,011	$ 4,165,000	$ 415,000
DC-10	$15,264,235	$16,791,000	$ 809,705
F-27A	$ 224,210	$ 247,000	$ 18,300
FH-227	$ 992,114	$ 1,091,000	$ 82,867
FH-227B	$ 1,138,017	$ 1,252,000	$ 66,470
L-1011	$14,351,166	$15,786,000	$ 1,158,212
YS-11A	$ 1,307,445	$ 1,438,000	$ 40,000

*Averages exclude the cost of aircraft communications equipment, propellers, and overhaul expenditures.

Source: Local Service Air Carriers Unit Costs, Volume II, Civil Aeronautics Board Year Ended September 30, 1973.

Table 21

Annual Amount for Depreciation and Investment Required per Aircraft by Type, Twelve Months Ended September 30, 1973 (U.S. Commercial Carriers)

Aircraft Type	Cost of Airframes	Cost of Engines	Cost of Propellers	Cost of Communications Equipment	Total Cost of Aircraft	Annual Amount for Depreciation	Cost Less One Year's Depreciation
B-707-100B	5,961,218	1,120,000	0	0	7,081,218	495,685	6,585,533
B-707-300	4,406,609	730,052	0	0	5,136,661	487,983	4,648,678
B-707-300B	6,635,847	1,120,000	0	0	7,755,847	542,909	7,212,938
B-707-300C	7,872,578	1,440,000	0	0	9,312,578	651,880	8,660,698
B-720-000	3,921,881	681,700	0	0	4,603,581	437,340	4,166,241
B-720-000B	5,253,388	959,400	0	0	6,212,788	434,895	5,777,893
B-727-100	1,983,876	494,019	0	66,802	2,544,697	156,954	2,387,743
B-727-100C	4,674,149	793,029	0	0	5,467,178	382,702	5,084,476
B-727-100QC	4,952,941	719,739	0	0	5,672,680	397,088	5,275,592
B-727-200	5,902,073	1,336,383	0	66,802	7,305,258	491,768	6,813,490
B-737-200	3,307,617	528,172	0	127,464	3,963,253	256,343	3,706,910
B-747	19,575,206	3,224,812	0	0	22,800,018	1,282,500	21,517,518
BAC 1-11 200	974,545	339,160	0	97,818	1,411,523	85,276	1,326,247
CV-580	653,282	129,780	63,000	90,990	937,052	73,802	863,250
CV-600	564,019	226,806	46,812	42,600	880,237	69,295	810,942
CV-880	2,222,013	361,400	0	0	2,583,413	245,424	2,337,989
DC-8-20	3,000,000	500,000	0	0	3,500,000	332,500	3,167,500
DC-8-30	2,161,913	600,000	0	0	2,761,913	262,382	2,499,531
DC-8-50	1,220,000	617,272	0	0	1,837,272	128,609	1,708,663
DC-8-61	6,976,349	1,100,000	0	0	8,076,349	565,344	7,511,005
DC-8-62	8,957,150	1,224,196	0	0	10,181,346	712,694	9,468,652
DC-8-63	9,418,976	1,178,596	0	0	10,597,572	741,830	9,855,742
DC-9-10	1,361,933	631,454	0	84,077	2,077,464	130,388	1,947,076
DC-9-30	3,866,011	900,000	0	245,000	5,011,011	340,271	4,670,740
DC-10	15,264,235	2,429,115	0	0	17,693,350	995,251	16,698,099
F-27A	284,210	58,000	15,800	26,300	384,310	25,747	358,563
FH-227	1,064,114	196,964	35,542	84,744	1,381,364	108,641	1,272,723
FH-227B	1,238,017	180,940	56,228	165,404	1,640,589	126,870	1,513,719
L-1011	14,351,166	3,474,636	0	0	17,825,802	1,002,701	16,823,101
YS-11A	1,407,445	130,000	50,456	184,954	1,772,855	137,943	1,634,912

Data Source: Volume II, Attachment C, Part 3 of CAB Report, Local Service Air Carriers Unit Costs--Year Ended, September 30, 1973.

C. Cost-Weight Formula

There is a high correlation between aircraft cost and takeoff weight. A standard computerized least squares curve fitting technique was used to investigate the relationship. It was established that 96 percent of the variation in costs could be explained by changes in aircraft weights.

Figure 1 on the following page shows a least squares fit of the weight and cost data for 10 popular turbine powered aircraft (see also Table 22). The resulting linear formula takes the form:

$$X = (y-A)B$$

where X = aircraft cost in 1973 dollars
y = aircraft take-off weight in pounds
A = 34,160 lbs.
B = $31.294

As shown in Table 22 the accuracy of the formula improves when applied to the larger most recently developed aircraft models but variations above plus or minus 20 percent can occur on older/smaller models. This formula was used to compute the cost for aircraft types not listed in Tables 20 or 21.

D. Individual Accident Report Analysis

Following the development of cost factors and the cost-weight formula a detailed review of each accident involving fire was undertaken to estimate the costs of aircraft damage. First, the description of each accident was placed on a data collection form using individual case reports or backup reports in the NTSB files. Then the accident cost was estimated based on this description and total costs of the involved aircraft. The accidents found in "briefs" for which there were no data sheets were estimated based on available data.

The results of the accident review are shown in Table H-1 for aircraft destroyed in accidents involving fire and in Table H-2 in Appendix H for aircraft substantially damaged by fire. Both tables are for turbine powered U.S. Air Carrier Fire-Related accidents.

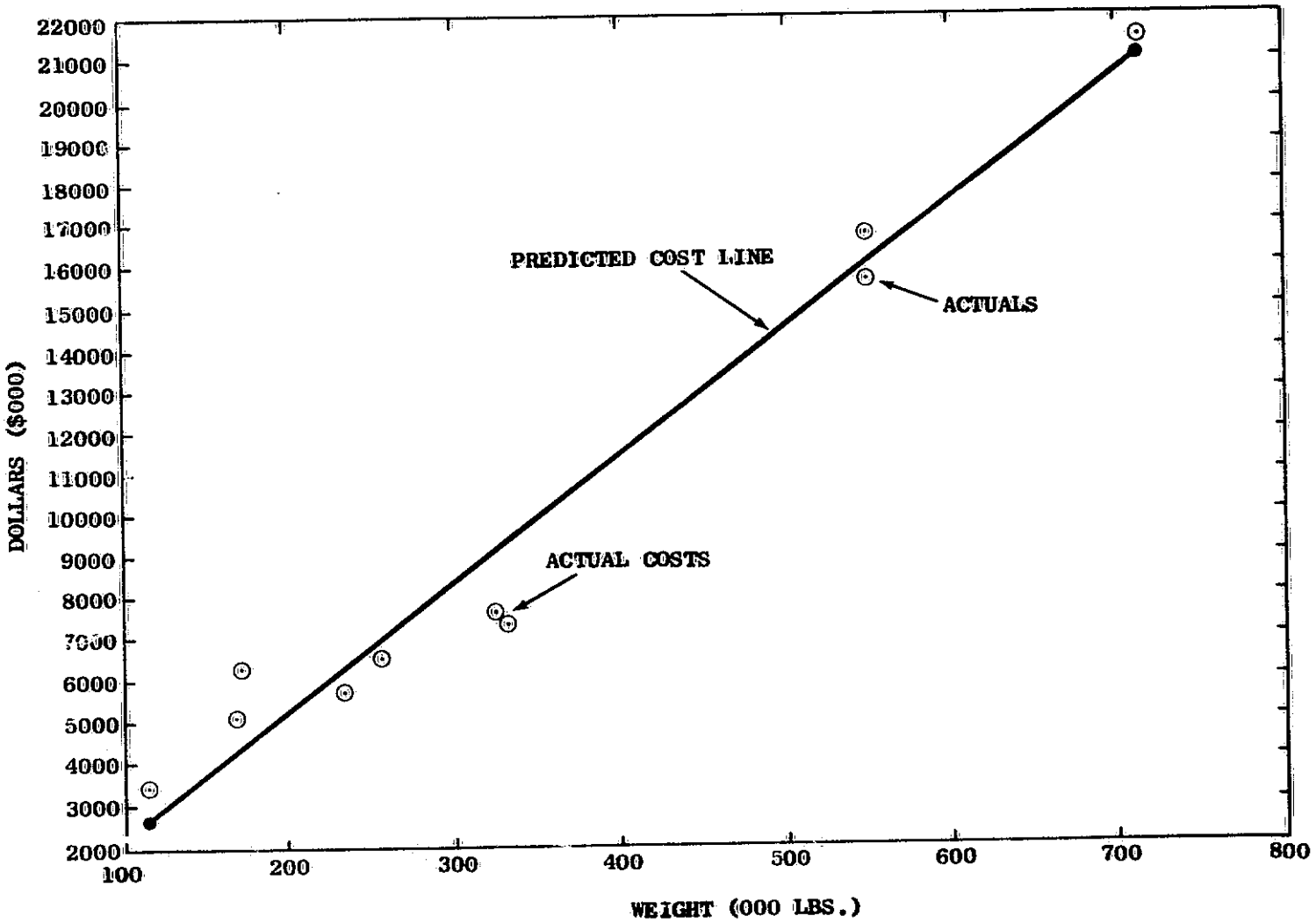

FIGURE 1. AIRCRAFT COSTS VS. TAKE OFF WEIGHTS

Table 22

PREDICTED VERSUS ACTUAL TURBINE POWERED AIRCRAFT COSTS
(1973 Dollars)

Aircraft Type	Weight (000 lbs)	Actual Cost 1973 Dollars ($000)	Predicted Costs Based Upon Formula ($000)	Percentage Variation Actual Vs. Predicted
Boeing 707-100B	257.0	$ 6,557	$ 6,974	5.4%
Boeing 707-300B	333.6	7,299	9,370	24.7%
Boeing 720-000B	234.0	5,779	6,254	6.9%
Boeing 727-100C	169.0	5,142	4,220	-14.8%
Boeing 727-200	172.0	6,316	4,314	-27.1%
Boeing 737-200	114.5	3,462	2,514	-20.9%
Boeing 747	710.0	21,533	21,150	- 1.6%
DC-8-61	325.0	7,673	9,101	16.3%
DC-10	555.0	16,791	16,299	- 2.7%
L1011	550.0	15,786	16,143	2.1%

Many of the accidents where aircraft were destroyed, were considered impact non-survivable. As a rule these involved severe impact damage such that all occupants should have died from impact stresses. These accidents, 34 in number, are identified by an * in Table H-1. The individual accident costs developed in this section will be grouped and compared in Section E.

E. Cost Analysis Results

1. Introduction

Table 23 presents the cost of fire-related damage annually and in total for the 12 years studied. From 1963 through 1974 the cost of turbine powered aircraft accidents where the aircraft was totally destroyed averaged $4,339,000 and the cost of accidents involving substantial damage averaged $897,000. Accident costs have risen through the past 12 years reflecting the trend toward the use of larger and more costly aircraft by the commercial carriers.

As can be seen in Table 23, damage in 92 accidents involving fire between 1963-1974 totalled $285,614,000.

2. Fire-Related and Total Accident Costs

Tables 24 and 25 summarize the numbers of accidents and fire related accidents involving total aircraft destruction or substantial aircraft damage. The figures show that 75 percent of the accidents which destroyed the aircraft involved fires, while only 15 percent of the substantial damage accidents did. There were 78 totally destroyed aircraft and 223 substantially damaged aircraft during the 12-year period.

The data necessary to compare fire involved costs and total accident costs is summarized in Table 26. The costs for accidents involving fire are taken from Table 23. The costs for accidents without fire were computed by estimating average costs per accident and multiplying by the number of non-fire accidents. For destroyed aircraft the average costs per accident are assumed to be equal whether or not fire was involved. For substantially damaged aircraft, the cost per accident was estimated at $700,000 or about three-fourths the costs for aircraft substantially damaged when there was fire involved in the accidents.

Table 23

Turbine Powered Aircraft Damage Cost Estimates Where Aircraft were Destroyed or Received Substantial Damage (Fire Related Accidents--U.S. Commercial Carriers) 1963-1974 (1974 Incomplete)

Aircraft Condition	Year												Totals
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	
Destroyed													
Accidents #	3	4	5	4	7	8	3	6	5	6	6	2	59
Cost ($000)	$13,336	$10,154	$13,604	$5,771	$23,869	$31,320	$20,272	$40,487	$24,744	$29,270	$33,517	$9,660	$256,004
Substantial													
Accidents #	3	2	2	1	6	3	2	3	3	3	5	0	33
Cost ($000)	$ 3,500	$ 3,000	$ 1,800	$ 700	$ 2,360	$ 2,100	$ 950	$ 280	$ 820	$ 7,100	$ 7,000	$ 0	$ 29,610
Totals													
Accidents #	6	6	7	5	13	11	5	9	8	9	11	2	92
Cost ($000)	$16,836	$13,154	$15,404	$6,471	$26,229	$33,420	$21,222	$40,767	$25,564	$36,370	$40,517	$8,660	$285,614

Table 24

NUMBER OF TURBINE POWERED AIRCRAFT ACCIDENTS
INVOLVING TOTAL DESTRUCTION
(U.S. COMMERCIAL CARRIERS)

	Year												Total	Percent of Total
	63	64	65	66	67	68	69	70	71	72	73	74		
Fire Related Accidents	3	4	5	4	7	8	3	6	5	6	6	2	59	75.6
Non Fire Relat. Accidents	1	1	2	1	0	3	4	3	0	2	1	1	19	24.4
Totals	4	5	7	5	7	11	7	9	5	8	7	3	78	100.0%

Note: 1974 data are preliminary.

Table 25

NUMBER OF TURBINE POWERED AIRCRAFT ACCIDENTS
INVOLVING SUBSTANTIAL AIRCRAFT DAMAGE
(U.S. COMMERCIAL CARRIERS)

	Year												Total	Percent of Total
	63	64	65	66	67	68	69	70	71	72	73	74		
Fire Related Accidents	3	2	2	1	6	3	2	3	3	3	5	0	33	14.8
Non Fire Relat. Accidents	13	18	18	24	16	18	23	14	13	19	10	4	190	85.2
Totals	16	20	20	25	22	21	25	17	16	22	15	4	223	100.0

Note: 1974 data are preliminary

Table 26

Damage Costs

Category	No. of Aircraft	Average Cost per Accident ($000)	Total Cost ($000)
Destroyed Aircraft			
Accidents with fire	59	$4,339*	$256,004
Accidents with no fire	19	4,339	82,441
Destroyed TOTAL	78		$338,445
Substantial Damage			
Accidents with fire	33	$ 897*	$ 29,610
Accidents with no fire	190	700	133,000
Substantial Damage TOTAL	223		$162,610
Impact Non-Survivable (Included in Destroyed-Fire figures above)	34		$135,829

*Rounded

With the above figures we are prepared to perform the accident cost comparison. Three figures will be considered:

- Total cost of all U.S. Air Carrier accidents substantially damaging or destroying the aircraft
- Cost of above accidents involving fire
- Cost of damage due to fire.

Computation of the first two values is straightforward. Computation of the damage due to the effects of the fires will not be possible but an estimate of the upper and lower bounds of this damage will be made instead.

a) Cost of 300 serious accidents, 1963-1974

78	Destroyed	$338,445,000
222	Substantial	162,610,000
	Total	$501,055,000

b) Cost of 92 serious accidents involving fire, 1963-1974

59	Destroyed	$256,004,000
33	Substantial	29,610,000
	Total	$285,614,000

c) Cost due to the fires

Computing this cost requires that the incremental accident costs due to the fire be isolated from accident costs that would have resulted had there been no fire. Because of the nature of the accident data, separating the two damage increments quantitatively can only be done in an approximate way. The limited objective of the following analysis is to be able to determine a range within which fire-caused damage costs must fall. When the costs of aircraft known to have been destroyed by impact stresses are removed from the fire related accident costs the result is an upper limit on the costs due to fire.

Cost of 92 Accidents Involving Fire:	$285,614,000
Cost of 34 Impact-Destroyed Aircraft:	135,829,000
Maximum Cost of Fire-Caused Damage 1963-1974 (57 accidents)	$149,785,000

Next, the lower bound on fire damage cost will be computed. The lower bound must be at least the cost of the 13 accidents listed in Table 27. These are the accidents where impact damage was slight, overall damage severe and where accident reports specifically identified deaths from fire damage. The lower bound on fire damage costs is $42,336,000 based upon these reports. Thus, it is estimated based on the above that the cost of aircraft damage caused by fire during the 12 years probably falls within the range $42,336,000 to $149,785,000. The average fire loss per year, therefore, ranges from $3.5 million to $12.4 million and this is the material loss subject to reduction by improved fire hardening of aircraft.

F. Personal Injuries and Fatalities (Judgements and Settlements)

Although the cost impact of personal injuries and fatalities was beyond the scope of the study, the information on personnel injury judgements and settlements shown in Tables 28 and 29 obtained from the Office of the General Counsel of the Civil Aeronautics Board are included here as a matter of interest. As shown in Table 28, "Passenger Death Recoveries--U.S. Carriers," the average passenger death settlement in 1974 was $233,210 (non Warsaw).* This amount compares with an average of only 49,000 in 1964 reflecting an average 16 percent increase per year over the period 1964 through 1974.

Similarly, the cost of serious injury settlements have also had a dramatic increase. As shown in Table 29, "Passenger Serious Injury Recoveries--U.S. Carriers," the average passenger serious injury settlement increased from $34,740 in 1964 to $171,323 in 1974.

It is noted that at least 320 deaths were specifically ascribed to fire in Chapter IV and a minimum of 256 deaths were found due to fire in turbine powered aircraft in Table 27 (using a slightly different accident population). Multiplying this number of deaths by the $233,000 average 1974 death settlement, it is seen that fatality costs are comparable to damage cost estimates made in the previous section. Of course, if injury settlements were also added the human costs would exceed the damage costs.

*Appendix I defines the terms "Warsaw" and "Non-Warsaw" which relate to an agreement limiting liability for claims arising out of international transportation.

Table 27

Cost of Turbine Powered Aircraft Damage in Accidents
with Moderate, Minor or no Impact Damage
but Aircraft Destroyed or Substantially Damaged by Fire

Accident Date	Aircraft Model Number	Damage Estimate ($000)	Fatalities Per Accident	
			Total	Fire Caused
Fatal Accidents:				
1-30-74	707-321B	$ 8,660	96	95
6- 7-71	CV580 (modified from CV440)	692	28	27
11-27-70	DC8-63F	10,360	47	47
11-11-65	727-22		43	43
11-23-64	707-331	8,660	48	44
9-13-65	CV880	2,444	--	--
	TOTALS	$30,816	262	256
Other Accidents:				
3-18-71	L382B (Turboprop)	$ 500	--	--
8- 8-71	V745D	20	--	--
5-10-72	DC9-31 Stretch	6,000	--	--
11-27-73	DC9-32	2,000	--	--
3-26-65	707-321	1,000	--	--
1-16-74	707-131B	1,000	--	--
5-18-72	DC9-31	1,000	--	--
	TOTALS	$11,520		
	Total Accident Cost Involving Destruction Plus Substantial Damage	$42,336		

Table 28

Passenger Death Recoveries (Including Both Judgements and Settlements) in Warsaw and Non-Warsaw Cases--U.S. Carriers

Settlement Year	No. of Settlements	Total Settlements	Average per Death
	NON-WARSAW		
1964	1	$ 49,000	$ 49,000
1965	23	1,384,724	60,205
1966	46	4,708,476	102,358
1967	29	1,793,546	61,846
1968	117	13,366,488	114,243
1969	128	18,000,079	140,625
1970	112	18,518,524	165,343
1971	170	21,035,249	123,736
1972	165	20,189,129	122,358
1973	99	14,676,136	148,243
1974	141	32,882,650	233,210
Totals	1031	146,604,001	142,195
	WARSAW		
1964	2	17,567	8,783
1965	39	369,102	9,464
1966	24	223,216	9,300
1967	13	182,093	14,007
1968	11	721,685	65,607
1969	29	1,791,996	61,792
1970	17	1,003,690	59,040
1971	30	1,477,766	49,258
1972	16	706,996	44,187
1973	28	6,143,020	219,393
1974	13	715,918	55,070
Totals	222	13,353,049	60,148

Source: Civil Aeronautics Board, Office of the General Counsel

Table 29

Passenger Serious Injury Recoveries
Warsaw and Non-Warsaw Cases--U.S. Carriers

Year	No. of Settlements	Total Settlements	Average per Serious Injury
		NON-WARSAW	
1964	6	$ 36,748	$ 6,124
1965	11	77,488	7,044
1966	25	1,018,857	40,754
1967	23	1,115,930	48,518
1968	25	977,422	39,096
1969	35	1,476,851	42,195
1970	38	2,411,662	63,464
1971	41	973,187	23,736
1972	25	717,119	28,684
1973	37	1,939,096	52,408
1974	75	12,849,250	171,323
Totals	341	23,593,610	69,189
		WARSAW	
1964	1	60	60
1965	8	37,089	4,636
1966	5	48,882	9,776
1967	1	750	750
1968	2	1,750	875
1969	5	27,704	5,540
1970	8	98,421	12,302
1971	31	199,777	6,444
1972	46	955,765	20,777
1973	23	805,600	35,026
1974	22	1,074,303	48,831
Totals	152	3,250,101	21,382

Source: Civil Aeronautics Board, Office of the General Counsel

320 x $233,000 = $74,560,000 — Estimated Fatality Cost due to Fires, 1963-1974.

A copy of the CAB document entitled, "Levels of Recoveries on Account of Passenger Deaths and Serious Injuries in Airplane Accidents," with respect to accidents occurring in calendar years 1960 through 1969 is included in Appendix I. Appendix J contains four tables obtained from the CAB updating the data shown in the earlier report covering settlement data for the years 1970 through 1974.

VII RESULTS AND CONCLUSIONS

A. General Remarks

The object of this study was to provide a basis for assessing the extent of total personnel, aircraft and property damage occurring in accidents and in accidents involving fire in U.S. commercial aircraft for the period 1963-1974. A further objective was to assist in determining the degree to which materials with improved fire resistance or decreased toxicity could reduce injuries, fatalities and aircraft damage costs.

The study concerned only fixed wing aircraft operated by U.S. Certificated Route and Supplemental Air Carriers, scheduled and non-scheduled, domestic and international. "Accidents" (which involve death, serious injury, or substantial damage by NTSB definition) as well as generally less serious "incidents" involving fire were studied. Other reported flame and smoke occurrences were also noted and discussed.

The approach adopted was to collect all available accident and incident reports involving fire inflight, on the ground and after impact. Data sources included CAB and NTSB accident briefs, NTSB-published Aircraft Accident Reports, NTSB coded accident data, investigators' factual reports made available from the NTSB's Washington files, and files maintained by the National Fire Protection Association. A printout showing all 1970-1974 flame and smoke reports (Service Difficulty Reports--SDRs) involving U.S. Air Carriers was obtained from the FAA to supplement the accident and incident data.

The analysis involved detailed examination of the individual reports of each fire-involved accident, extracting and assembling statistics comparing these from several points of view, and a cost analysis which compared damage costs for serious accidents with damage costs for the serious accidents involving aircraft fires.

The data obtained during the study were sufficient to allow the extent of personnel, aircraft and property damage in U.S. commercial aircraft between 1963-1974 to be assessed. However, data concerning the propagation of fires within the cabin, details concerning injuries and fatalities caused by toxic gases, and information relating reported fire factors to aircraft interior materials could not be obtained in spite of intensive searching. These probably do not exist, and controlled experimentation may, therefore, be necessary to study these factors adequately. The cost impact of personal injuries was outside the scope of the study, but some data bearing on these costs were obtained and reported.

B. Summary of Results

A great many detailed accident and cost statistics were developed during the study. A few of the major results are summarized below:

1. Between 1963 and 1974* there were 713 U.S. Air Carrier "accidents". Excluding non-crash turbulence-injury accidents there were 545 accidents, an average of about 45 per year. Fire destroyed the aircraft in approximately 10 percent of these cases.

2. There were 158 U.S. Air Carrier accidents involving fire during 1963-1974 and 122 of these, approximately 10 per year, involved the airframe. The rest were engine or wheel nacelle fires.

3. A minimum of 31 of the 1265 serious injuries in aircraft accidents were ascribed to fire effects in the accident reports.

4. A minimum of 320 of the 2530 reported fatalities in aircraft accidents were ascribed to fire effects in the accident reports, but 2116 of the deaths occurred in fire-related accidents.

*1974 data are incomplete pending NTSB determination of cause for 23 accidents. These have not been included in any of the reported results.

5. An overwhelming majority of the 122 airframe fire accidents were characterized by collision or abnormal contact with the ground. Only 4 of the airframe accidents were assigned to the inflight fires accident type by the NTSB.

6. Half of the airframe fire accidents occurred during the landing phase.

7. More than half of the aircraft accident deaths in fire-related accidents occurred in 39 accidents designated non-survivable. An additional six accidents were believed probably non-survivable. Fire ultimately destroyed the aircraft or caused substantial damage in 26 of these 45 accidents but their deaths and damage would have occurred even without the fires.

8. The ability of passengers to evacuate in time to avoid becoming incapacitated by fire or its effects was important in at least 12 fatal accidents.

9. In at least 21 accidents, improved fire suppresion systems and/or fuel inerting could have reduced property losses. Impact damage was relatively light and fire damage severe in these cases.

10. Approximately 85 percent of the fires involving the airframe were after-impact fires. A similar result was reported in a CAB study covering accidents from 1955-1962.

11. Fuel related factors account for more than half of the fires in the 49 accidents where fire cause was known. Fuel was not a major factor in reported "incidents."

12. In addition to accidents and incidents there were 218 flame or smoke occurrences involving aircraft cabins in the 5 years 1970-1974: 26 occurred in the lavatories; 95 in the galleys (including 49 in ovens and 27 in coffeemakers); and 97 in the remainder of the cabin (41 in the air conditioning system, 11 in the lights and 10 in equipment and furnishings, such as seats). There were an additional 547 flame and smoke reports which did not involve the cabin area.

13. There were approximately five million departures per year of the aircraft studied, and, therefore, a rate of approximately 1.7 airframe fire accidents per million departures. There were also 0.4 fire incidents per million departures and 6 flame and smoke cabin SDRs per million departures. (Data period 1970-1973).

14. Damage costs in 300 serious turbine-powered aircraft accidents (both fire and non-fire) averaged $1,665,000 per accident. Damage costs in 92 serious turbine-powered aircraft accidents involving fire averaged $3,105,000 per accident.

15. It was not possible to determine the cost of damage specifically due to fire because the relative contributions of impact and fire to overall damage could not be determined for many cases. Instead, upper and lower bounds on costs due to fire have been established: Fire-caused damage was established as falling between $42,336,000 and $149,785,000 during the 12 years studied.

16. Turbine-powered aircraft damage* in 300 serious accidents, 1963-1974, studied for the cost analysis are summarized below:

Damage in all 300 serious accidents	$501,000,000
Damage in 92 serious accidents involving fire	$286,000,000
Damage caused by fire	$ 42,000,000 to $150,000,000

C. Conclusions

1. Based on 12 years of accident data (1974 incomplete), approximately 60 reportable aircraft accidents can be expected per year. Approximately 15 of these will be non-crash events involving inflight turbulence, and about 10 accidents per year will involve fires affecting the airframe.

*Average domestic death recovery was approximately $142,000 per fatality over the study period.

2. The incidence of inflight fires leading to a crash has been quite rare. Since 1963, eighty-seven percent of the fires involving the airframe occurred after impact, with fuel the major factor in these fires.

3. The potential benefits from fire hardening aircraft are limited by severity of impact. Historically, 65 percent of the fatalities in fire-related accidents have occurred in crashes which were judged to be impact-nonsurvivable. Assuming the same rate, fire hardening at best can be expected to influence the survival, on the average, of approximately 60 persons per year. Improving the impact survivability of aircraft, however, would result in a greater number of people threatened by a subsequent fire. More than half of the impact-nonsurvivable accidents also involved substantial damage or total destruction in a subsequent fire.

4. Existing accident data probably do not support an analysis of the mode of propagation of fires within the aircraft cabin. This is probably better studied through controlled experimentation.

5. Serious aircraft accidents will cost at least $42,000,000 in aircraft damages per year, and accidents involving fire are expected to approximate $24,000,000 of these costs per year. Based on 1974 average domestic death recoveries, the settlement costs for fatalities expected in all accidents could reach $49,000,000 per year (1974 dollars), and the deaths due to fire related accidents would represent $41,000,000 of this cost. Personal injury costs are also expected to be about $70,000,000 annually (1974 dollars).

6. The average U.S. accident personal injury payment as a result of commercial carrier death settlements and/or court judgements has increased over 16% since 1964 ($49,000 in 1964 to $233,210 in 1974). These settlements now represent about half of the total cost of aircraft accidents and should be studied in-depth. It is recommended that more specific information be obtained

to discover the cost of fire-related personal injury settlements and judgements and to compare these costs with total settlements and judgements from all accidents. This analysis would require extensive contacts with individual airline companies, insurance carriers, the CAB, and the Airline Transportation Association, in order to obtain detailed information on each settlement or judgement and to determine the extent of fire-related damages, injuries and deaths. Although the effort would be arduous, it would provide a more definitive analysis of the total cost of aircraft fires aboard commercial carriers and is essential to complete the analysis of fire related costs.

APPENDICES

Appendix A

DEFINITIONS

This appendix defines some of the terms used in this report. In particular, "accident" as used by NTSB refers to a specific event occurring within a specific "time" relating to flight. It should not be confused with a "crash" or "collision."

"Service Difficulty Reports," a term used by the FAA Maintenance Analysis Center to refer to Mechanical Reliability Reports, MRRs, and Mechanical Interruption Summary Reports, MISs, are defined by Federal Aviation Regulations 121.703 and 705 which are included here. Data for 1970-1974 is computer coded and was used in that format for this report.

"Flight purpose" and "phase of operation" are discussed briefly.

"Severity and impact codes" as used in the analysis were taken from data furnished for each accident on the "Aircraft Accident Analysis Sheet," NTSB Form 6120.12. The codes and their definitions are discussed here.

A.1 Accidents and Incidents

a. *Aircraft Accident* means an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or the aircraft receives substantial damage.

b. *Fatal Injury* means any injury which results in death within 7 days.

c. *Operator* means any person who causes or authorizes the operations of an aircraft, such as the owner, lessee, or bailee of an aircraft.

d. *Serious Injury* means any injury which:

1) Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received;

2) Results in a fracture of any bone (except simple fractures of fingers, toes or nose);

3) Involves lacerations which cause severe hemorrhages, nerve, muscle, or tendon damage;

4) Involves injury to any internal organ; or,

5) Involves second or third degree burns, or any burns affecting more than five percent of the body surface.

e. *Substantial Damage* means:

1) Except as provided in subparagraph (2) of this paragraph, substantial damage means damage or structural failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component.

2) Engine failure, damage limited to an engine, bent fairings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades, damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wing tips are not considered "substantial damage" for the purpose of this part.

f. *Incidents.* Procedures for NTSB/FAA participation in incident investigations will be the same as in accident investigations. For the purpose of notification, investigation and reporting in accordance with this handbook the following will apply:

1) In-flight fire.

2) Rapid decompression, requiring emergency action.

3) Unwanted or asymmetrical reversal.

4) Flight control system malfunction or failure.

5) Inability of any required flight crewmember to perform his normal flight duties as a result of injury or illness.

6) During ground operations of an aircraft with engine(s) functioning without the intention of flight any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or the aircraft receives substantial damage.

7) Turbine engine rotor failures excluding compressor blades and turbine buckets.

8) Aircraft collide in flight.

9) Any occurrence related to aviation safety. This includes, but is not necessarily limited to, such items as near midair collisions, parachute jumping injuries, or threats or acts of sabotage.

Source: HANDBOOK: AIRCRAFT ACCIDENT INCIDENT INVESTIGATION AND REPORTING. Handbook 8020.1A. Washington: Federal Aviation Administration, September 18, 1968 (4/70 reprinted to include changes 1 through 3), pp. 1-2.

A.2 Service Difficulty Reports

§ 121.703. Mechanical Reliability Reports.

a. Each certificate holder shall report the occurrence or detection of each failure, malfunction, or defect concerning--

1) Fires during flight and whether the related fire-warning system functioned properly;

2) Fires during flight not protected by a related fire-warning system;

3) False fire warning during flight;

4) An engine exhaust system that causes damage during flight to the engine, adjacent structure, equipment, or components;

5) An aircraft component that causes accumulation or circulation of smoke, vapor, or toxic or noxious fumes in the crew compartment or passenger cabin during flight;

6) Engine shutdown during flight because of flameout;

7) Engine shutdown during flight when external damage to the engine or airplane structure occurs;

8) Engine shutdown during flight due to foreign object ingestion or icing;

9) Engine shutdown during flight of more than one engine;

10) A propeller feathering system or ability of the system to control overspeed during flight;

11) A fuel or fuel-dumping system that affects fuel flow or causes hazardous leakage during flight;

12) A landing gear extension or retraction or opening or closing of landing gear doors during flight;

13) Brake system components that result in loss of brake actuating force when the airplane is in motion on the ground;

14) Aircraft structure that requires major repair;

15) Cracks, permanent deformation, or corrosion of aircraft structures, if more than the maximum acceptable to the manufacturer or the FAA; and

16) Aircraft components or systems that result in taking emergency actions during flight (except action to shut down an engine).

b. For the purpose of this section "during flight" means the period from the moment the aircraft leaves the surface of the earth on take-off until it touches down on landing.

c. In addition to the reports required by paragraph (a) of this section, each certificate holder shall report any other failure, malfunction, or defect in an aircraft that occurs or is detected at any time if, in its opinion, that failure, malfunction, or defect has endangered or may endanger the safe operation of an aircraft used by it.

d. Each certificate holder shall send each report required by this section, in writing, covering each 24-hour period beginning at 0900 hours local time of each day and ending at 0900 hours local time on the next day, to the FAA maintenance inspector assigned to its operations. The report must be delivered to him by 0900 hours local time on the following day. However, a report that is due on Saturday or Sunday may be delivered on the following Monday and one that is due on a holiday may be delivered on the next workday.

e. The certificate holder shall transmit the reports required by this section in a manner and on a form that is convenient to its system of communication and procedure, and shall include in the first daily report as much of the following as is available:

1) Type and identification number of the aircraft.

2) The name of the operator.

3) The date, flight number, and stage during which the incident occurred (e.g., preflight, takeoff, climb, cruise, descent, landing, and inspection).

4) The emergency procedure effected (e.g., unscheduled landing and emergency descent).

5) The nature of the failure, malfunction, or defect.

6) Identification of the part and system involved, including available information pertaining to type designation of the major component and time since overhaul.

7) Apparent cause of the failure, malfunction, or defect (e.g., wear, crack, design deficiency, or personnel error).

8) Whether the part was repaired, replaced, sent to the manufacturer, or other action taken.

9) Whether the aircraft was grounded.

10) Other pertinent information necessary for more complete identification, determination of seriousness, or corrective action.

f. A certificate holder that is also the holder of a Type Certificate (including a Supplemental Type Certificate), a Parts Manufacturer Approval (PMA), or a TSO authorization, or that is the licensee of a Type Certificate, need not report a failure, malfunction, or defect under this section if the failure, malfunction, or defect has been reported by it under § 21.3 or § 37.17 of this chapter or under the accident reporting provisions of Part 430 of the regulations of the National Transportation Safety Board.

g. No person may withhold a report required by this section even though all information required in this section is not available.

h. When a certificate holder gets additional information, including information from the manufacturer or other agency, concerning a report required by this section, it shall expeditiously submit it as a supplement to the first report and reference the date and place of submission of the first report.

§ *121.705. Mechanical Interruption Summary Report.*

Each certificate holder shall regularly and promptly send a summary report on the following occurrences to the Administrator:

a. Each interruption to a flight, unscheduled change of aircraft en route, or unscheduled stop or diversion from a route, caused by known or suspected mechanical difficulties or malfunctions that are not required to be reported under § 121.703.

b. The number of engines removed prematurely because of malfunction, failure or defect, listed by make and model and the aircraft type in which it was installed.

c. The number of propeller featherings in flight, listed by type of propeller and engine and airplane on which it was installed. Propeller featherings for training, demonstration, or flight check purposes need not be reported.

Source: Federal Aviation Regulations, Part 121: Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft (published April 1974)

A.3 Flight Purpose

The accidents were divided according to purpose of flight, that is passenger, cargo and ferry or training flights. This was done to keep perspective on numbers of persons involved in the accidents. In cargo flights, an average of 3 persons were aboard and the aircraft type included planes which did not show up among passenger flights, such as C46 and GA382B (Hercules). Another fact of interest was that 16 of the 31 cargo flights were military contract flights. (Only 5 of the 78 passenger flight accidents involved military contracts.)

Five flights were ferry and 8 were training flights. Again these involved fewer people, an average of 6 each for the ferry flights and 5 each for the training flights. The training flights are often involved in

practicing landing maneuvers and in 2 cases, the accidents occurred during a missed approach practice.

The remaining 78 accidents occurred with passenger flights and thus involved a much larger number of people.

A.4 Phase of Operation

Each accident or incident occurs during a specified "phase of operation." The five major phases were used in the analysis and subphases were included in the discussion of "after impact" fires to better understand when the accident occurred. The phases are as follows:

Static	Starting engine, idling, engine runup
Taxi	To take off, from landing
Takeoff	Ground run, initial climb, aborted
Inflight	Climb, cruise, descending, holding
Landing	In traffic pattern, initial approach, final approach, level off/touchdown, rollout, go-around, missed approach

A.5 Accident Codes--Severity and Damage

In addition to the aircraft accident "briefs" for all and the published "Aircraft Accident Reports" for 64 of the 122 fire involved accidents, certain coded information was received from NTSB for each accident. This data consisted of information from the "Aircraft Accident Analysis Sheet," NTSB Form 6120.12, prepared for each accident. In particular data from Card No. 20, Human Factors, and Card No. 21, Fire Information, was received and the following elements were used and appear on the tables describing each accident in Appendix D:

Card	Column	Codes*	Definitions†
20 Human Factors	23 Impact Severity	A Minor B Moderate C Severe D Extreme	Generally extreme will be related to non-survivable accidents. Severe--slightly less than extreme where damage is extensive and aircraft demolished, but survival is fact or could have been fact. Moderate and minor should be easily determined from investigative evidence. In this and other human factors areas the analyst must equate the circumstances to the values using his/her personal experience and judgment as the yardstick.
	32-35 Damage Severity Cockpit, Forward, Center and After Cabin	A Extreme B Severe C Moderate D Minor E None	[No comments given; assumed similar to above]
	44-46 Deaths Resulting From Fire After Impact		Code on all fatal accidents when Fire After Impact, Card No. Ø1, column 35 is coded.
21 Fire Information	19 Location of Fire	A Powerplant B Baggage compartment C Passenger cabin D Cockpit E Wheel nacelle F Wing G Empennage Y Other Z Unknown/not reported	For columns 17 thru 29, code all applicable items for accidents involving fire, both pre-impact fire and fire after impact.
	27 Fire Damage	A Destroyed B Substantial C Minor D None Z Unknown/not reported	[No comments given but are same categories as overall aircraft damage, only comment for that refers to missing aircraft.]

Additional codes were examined but not used in this report's analysis.

*Code from Manual of Code Classifications

†Definitions from NTSB Bureau of Aviation Safety, Safety Analysis Division, Evaluation Branch, ANALYST'S HANDBOOK, PART II: GUIDE FOR USING THE MANUAL OF CODE CLASSIFICATIONS, revised 1973.

Appendix B

DETAILED ACCIDENT SUMMARY STATISTICS

The tables in this appendix give numbers of all fixed wing U.S. Air Carrier accidents with various characteristics from 1963-1974 (1974 incomplete) by year, by aircraft type by year, and by accident type. Fire accidents are included in the last two tables as comparisons.

Data for all accidents were taken from accident briefs and/or summary tables from the following sources:

1963	Computer printout of "Briefs of Accidents/Incidents, U.S. Air Carriers Over 12,500 lbs., 1963" (unpublished) from NTSB, Information Systems Branch, Bureau of Aviation Safety (received April 1975).
1964-1969	A STUDY OF U.S. AIR CARRIER ACCIDENTS, 1964-1969, Report NTSB AAS-72-5, Washington, D.C.: National Transportation Safety Board, May 1972.
1970-1972	ANNUAL REVIEWS OF AIRCRAFT ACCIDENT DATA, U.S. AIR CARRIER OPERATIONS, 1970-1972, Report NTSB-ARC-74-1, Washington, D.C.: National Transportation Safety Board, April 1974.
1973	ANNUAL REVIEWS OF AIRCRAFT ACCIDENT DATA, U.S. AIR CARRIER OPERATIONS, 1973, Report NTSB-ARC-74-2. Washington, D.C.: National Transportation Safety Board, October 1974.
1974	Computer printout of "Briefs of Accidents, U.S. Air Carriers--Includes Only Accidents in Which a Causal Determination Has Been Made, 1974" (unpublished) from NTSB, Information Systems Branch, Bureau of Aviation Safety (received January 1975).

One additional table gives number of departures of U.S. Air Carrier Certificated Route Carriers for 1970-1973 and departures and all accidents and fire accidents for 1972-1973 by turbine powered aircraft by type.

Table B-1

ALL U.S. AIR CARRIER ACCIDENTS (FIXED WING), 1963-1974 (1974 Incomplete)
(Non-Crash Turbulence Accidents in Parentheses)

	Flight Purpose			Phase of Operation						Aircraft Damage				Injury Index				Turbulence
Year	PX	CG	F/T	St	Tx	TO	Ft	Ln	Ot	Des	Sub	Min	Non	Fat	Ser	Min	Non	
1963	48			3	2	3	21(13)	18	1	6	25	2(2)	15(11)	6	19(13)	1	22	13
		12			3	1	4	4		3	9			3	1		8	
			5		1		1	3		2	3			3			2	
Total		65		3	6	4	26(13)	25	1	11	37	2(2)	15(11)	12	20(13)	1	32	
1964	57			1	3	10	18(9)	25(1)		7	36(1)	3(2)	11(7)	8(1)	16(9)	7	26	10
		16			1	5	1	9		5	11			4			12	
			3	1			1	1			3					1	2	
Total		76		2	4	15	20(9)	35(1)		12	50(1)	3(2)	11(7)	12(1)	16(9)	8	40	
1965	64			1	5	8	29(13)	21		8	36	2	18(13)	7	22(13)	6	29	13
		12		1			6	5		4	7		1	2			10	
			4			2		2		2	2				1		3	
Total		80		2	5	10	35(13)	28		14	45	2	19(13)	9	23(13)	6	42	
1966	53			2	4	5	23(11)	18	1	5	33	1	14(11)	5	18(11)	6	24	11
		10			1	3	1	5		7	3			2	2	2	4	
			6				4	2			5		1		1	1	4	
Total		49		2	5	8	28(11)	25	1	12	41	1	15(11)	7	21(11)	9	32	
1967	53				2	5	27(13)	19		7	27	3(1)	16(10)	3	22(13)	4	19	13
		9			2	1		6		2	6		1	2			7	
			7		1		1	5		1	6			1			6	
Total		69			5	6	28(13)	30		10	39	3(3)	17(10)	11	22(13)	4	32	
1968	55			6	2	1	30(19)	16		9	18(1)	3(1)	25(17)	9	29(19)	6	11	19
		6				3	1(1)	5		3	5	1(1)		1	3(1)	1	4	1
			6			2		4		2	4				1		5	
Total		70		6	2	6	31(20)	25		14	27(1)	4(2)	25(17)	10	33(20)	7	20	20
1969	55			6	8	6	25(20)	10		6	20	5(2)	24(18)	6	27(20)	2	20	20
		2				1		1			1		1				2	
			7		1	1	1	4		2	5			1			6	
Total		64		6	9	8	26(20)	15		8	26	5(2)	25(18)	7	27(20)	2	28	
1970	44			4	4	4	20(16)	12		4	17	6(4)	17(12)	3	23(16)	5	13	16
		6				4		2		5	1			2	1	1	2	
			4			1		3		2	2			1	2		1	
Total		54		4	4	9	20(16)	17		11	20	6(4)	17(12)	6	26(16)	6	16	
1971	42			5	2	3	21(14)	11		3	17	4(1)	18(13)	3	21(14)	3	15	14
		5				1	1	3		1	4			1	2		2	
			1					1		1				1				
Total		48		5	2	4	22(14)	15		5	21	4(1)	18(13)	5	23(14)	3	17	
1972	45			6	5	5	17(13)	12(1)		6	17	5(2)	17(12)	5	21(14)	3	16	14
		2						2			2						2	
			3					1		1	2			1			2	
Total		50		6	5	5	17(13)	17(1)		7	21	5(2)	17(12)	6	21(14)	3	20	
1973	34			1	1	4	20(12)	8		5	11	1	17(12)	6	20(12)	4	4	12
		6			2			4		2	3		1	2			4	
			3			1		2			3						2	
Total		43		1	3	5	20(12)	14		7	17	1	18(12)	8	20(12)	5	10	
1974*	24			2	1	2	14(11)	5(1)		2	3	5(1)	14(11)	2	18(12)	1	3	12
Prelim		1						1			1						1	
			0															
Total		25		2	1	2	14(11)	6(1)		2	4	5(1)	14(11)	2	18(12)	1	4	
1963-1974 Total	574	90	49	37 1 1 39	39 9 3 51	56 19 7 82	265(164) 14(1) 8 287(165)	175(3) 47 30 252(3)	2	68 32 13 113	260(2) 53 35 348(2)	40(18) 1(1) 41(19)	206(147) 4 1 211(147)	68(1) 19 8 95(1)	256(166) 9(1) 5 270(167)	48 4 3 55	202 58 33 293	167 1 168
		713																

*1974 Incomplete: 7 fatal, 12 serious and 4 no injury accident causes yet to be determined; total 23 accidents.

Key: PX, passenger; CG, cargo; F/T, ferry or training; St, Static; Tx, taxi; TO, takeoff; Ft, flight, Ln, landing; Ot, other; Des, destroyed; Sub, substantial; Min, minor; Non, none; Fat, fatal; Ser, serious.

Table B-2

Total U.S. Air Carrier Accidents, Fire Accidents and Fixed Wing Aircraft in the Fleet
by Aircraft Type and Year, 1963-1974 (1974 Incomplete)
(Non-Crash Turbulence and Engine and Wheel Nacelle Fire Accidents Excluded)

	Aircraft	Accident Totals		1963			1964			1965			1966			1967			1968			1969			1970			1971			1972			1973			1974		
		All	Fire	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt	Accidents T	Accidents F	Flt
4-Engine Turbojet	B707	58	16	3	1	136	5	2	160	10	2	191	3		245	4	2	388	7	2	393	6	1	428	2	1	406	3	1	365	4		342	6	2	316	5	2	286
	B720	22	2	4	1	104	4		112	4		121	4		129	1		135	1		134			127	3		115	1	1	106			57			45			23
	B747	9	0			-			-			-			-			-			-			1	1		79	4		104	3		106			111	1		104
	GV880	7	2	1		46	2		48	1	1	47			46	2	1	45			41			41			41			41	1		41			37			?
	GV990	3	1			19			19	1		18	1		17			14			11	1		6	1	1	5			8			8			8			6
	DC8	41	7	4	1	107	3		117	5		134	2		149	3	1	173	4	1	237	7	1	283	4	2	285	3		265	2		256	3	1	233	1		206
4-Engine Turboprop	L188	15	3	1		126	1		126			126	4	1	125	1		125	5	1	114			73	1	1	69			60	2		57			53			50
	L382	6	2			-			-			-	1		5	1		9			13			18	2	1	22	1	1	21	1		21	1		20			19
	V745	11	5			49	2	1	48			48	1		44	6	3	38			19	1		3			3	1	1*	-			-			-			-
	V810,C144, AW650	9	4	3	1	39	3		39	1	1	41	2	2	36			24			21			17			16			7			-			-			-
3-Engine	B727	52	9			-			88	5	3	173	5	1	287	3	1	510	8	1	543	10		628	5	1	659	5	1	665	5	1	683	4		733	2		747
	L1011	3	1			-			-			-			-			-			-			-			-			-	2	1	17	1		48			68
	DC10	4	0			-			-			-			-			-			-			-			-			13	1		59	2		91	1		108
2-Engine Turbojet	B737	7	2			-			-			-			-	1		76			147	1		149	1		155	1	1	153	3	1	152			150		
	DC9	32	12			-			-			4	2	1	56	1	1	148	2		266	6		327	3	1	337	7	1	341	7	5	335	4	3	340			335
	BAC 1-11	6	2			-			-	1		17	1	1	54	1	1	57	1		60	1		60	1		59			62			58			43	1		36
	Caravelle	3	0			20	1		20	1		20	1		20			20			20			20			-			-			-			-			-
2-Engine Turboprop	240T	0	0			-			1			2			28	1		29			36			24			24			-			-			-			-
	CV340T	1	0			-			4			18			42	1		85			113			119			-			-			-			-			-
	CV580	12	4			-			-			-			-	1		-	4	2	-			-	2		108	2	1	106	2	1	104	1		105			91
	CV600/640	9	2			-			-			-	2		-	2	1	-			-	1		-	1		10			33	2		34	1	1	32			29
	F27	16	3	4		50	4	2	54	4		63	2		64	1	1	49	1		48			38			37			34			29			25			15
	FH227	14	4			-			-			-			16	2		58	2	2	55	4	1	53	1		47			48	4		32	1	1	31			33
	YS-11	3	0			-			-			-			3			2			9	1		17	2		21			21			22			23			21
Other Turbine†		17	2			3	2		4	2		14	4		12	2	1	29	1		30	3		18	1		18	1	1	27	1		22			15			16
Piston Powered		185	39	32	7	1360	39	8	1221	34	10	1067	23	5	873	24	5	642	11	4	331	3	1	224	7		153	5		146			133	4		137	1		121
TOTALS		545	122	52	11	2059	66	13	2061	68	17	2104	57	11	2251	56	18	2430	48	13	2570	43	4	2672	38	8	2663	34	8	2628	38	9	2569	31	9	2598	12	2	2464

Source of Fleet Data: 1963-1973 taken from tables of "Composition of U.S. Air Line Fleet..." (given as of January 1 for each year but used as of December 31 of preceeding year for this table), from Aerospace Industries Association of America, Inc., Aerospace Facts and Figures, New York: Aviation Week and Space Technology, various years. 1974 from FAA Flight Standards Technical Division Aircraft Utilization and Propulsion Reliability Report, February 1975 (data as of December 1974)

*Accident in August 1971, fleet count as of end of year.

†Other turbine includes G159, Nord 262, DHC-6, SC-7, PC-6A/B

Key: T = Total; F = Fire; Flt = Fleet

Introduction to Table B-3: Accident Types

Fire-involved accidents occurred in 32 of the 59 accident categories used by NTSB. The following table gives the total for all accidents and for fire-involved accidents for each of the 32 categories. (An additional 83 non-fire accidents are distributed among 27 categories not shown on the table; these include collision with aircraft/both on ground, collision with parked aircraft (engines not running), propeller accident to person, airframe failure on ground, bird strike, and so forth.)

Note that the largest category of accidents is "turbulence." Most involve clear air turbulence with a standing occupant falling and breaking a bone (serious injury). However, two of the fire accidents resulted from turbulence and ensuing airframe failure and collision with the ground; therefore, the turbulence category is included.

Table B-3

U.S. Air Carrier (Fixed Wing) Accidents 1963-1974 (1974 Incomplete) by Total Number Accidents, Total Fire Involved Accidents, Airframe Fire Accidents, and Engine/Wheel Nacelle Fire Accidents by First Type of Accident (32 Categories)

Type of Accident*	All	Non-Fire	Fire			
			Total	Fire as Percent of All	Air-frame	Eng/ Wheel
Groundloop,swerve	37	30	7	19%	5	2
Dragged wingtip	2	1	1	50%	1	
Wheels-up landing	23	22	1	4%	1	
Gear collapsed	44	40	4	9%	4	
Gear retracted	17	15	2	12%	1	1
Hard landing	29	26	3	10%	3	
Overshoot	18	17	1	6%	1	
Undershoot	24	12	12	50%	12	
Collision w/aircraft, inflight	15	8	7	47%	7	
Collision w/aircraft, one airb.	1	0	1	100%	1	
Collision w/ground, controlled	24	6	18	75%	18	
Collision w/ground,uncontrolled	19	2	17	89%	17	
Collision w/trees	11	3	8	73%	8	
Collision w/residences	1	0	1	100%	1	
Collision w/fences	1	0	1	100%	1	
Collision w/electronic towers	1	0	1	100%	1	
Collision w/runway/approach lights	6	5	1	17%	1	
Collision w/ditches	2	0	2	100%	2	
Collision w/dirt bank	1	0	1	100%	1	
Collision w/other objects	18	14	4	22%	4	
Stall	7	2	5	71%	5	
Fire in flight	14	0	14	100%	4	10
Fire on ground	14	0	14	100%	5	9
Airframe failure in flight	9	7	2	22%	2	
Airframe failure on ground	7	6	1	14%	0	
Engine failure	42	22	20	50%	8	12
Propeller failure	5	2	3	60%	2	1
Turbulence	170	168	2	1%	2	
Lightning strike	4	3	1	25%	1	
Evasive maneuver	14	13	1	7%	1	
Miscellaneous/other	49	48	1	2%	1	
Undetermined	1	0	1	100%	1	
Totals (32 categories)	630†	472	158		123	36

*Where two types of accidents were listed, each accident was counted once using the first listed.

†88% of the 713 fixed wing accidents for the period

Introduction to Tables B-4 and B-5: Number of Departures of U.S. Air Carrier Certificated Route Carriers

Many analyses use miles and hours flown as comparative indices for accident rates. SRI feels that a more useful index for the present study is the total number of departures, defined as "an aircraft takeoff made at an airport." This is particularly useful since the takeoff and landings seem to be the most critical part of the flight operation and, indeed, involve 15 percent and 46 percent of the non-turbulence accidents, respectively. Data from the FAA and CAB is presented in the two following tables.

Table B-4

Number of Departures of U.S. Air Carriers (Certificated Route), Scheduled and Nonscheduled, Domestic and International by Year, 1970-1973

Year	Departures
1970*	5,070,117
1971*	4,754,684
1972†	5,097,804
1973†	5,184,236
Total	20,106,841

*Includes helicopters, number of departures unknown.
Data from Table 2.5, Departures and Overs at FAA Air Route Traffic Control Centers: 1962-1971, FAA STATISTICAL HANDBOOK OF AVIATION, 1972 Edition.

† Includes helicopters, 79,979 departures in 1972 and 83,152 in 1973; does not include supplemental air carriers.
Data from Table 1, Summary of Aircraft Departures...by Air Carrier, in CAB/FAA's AIRPORT ACTIVITY STATISTICS OF CERTIFICATED ROUTE AIR CARRIERS, 12 months ended December 31, 1972 and 1973.

Table B-5

Departures of Scheduled and Nonscheduled Turbine Powered Aircraft of Certificated Route Air Carriers and Accidents, 1972-1973

Aircraft			1972	1973	Departures in Two Years	Number of Non-Turbulence Accidents 1972-1973			
						All	Acc.per 100,000 Depart.	Fire	Acc.per 100,000 Depart.
4-Engine	Turbojet	B707	375,254	320,881	696,135	10	1.43	2	0.28
		B720	94,290	66,570	160,860	0	0	0	0
		B747 †	88,339	96,897	185,236	3	1.62	0	0
		CV880	62,685	56,966	119,651	2	1.67	0	0
		DC8 †	299,355	280,410	579,765	5	0.86	1	0.17
	Turbo-Prop	L188 †	20,896	22,149	43,045	2	4.65	0	0
		L382 †				2			
3-Engine	Turbojet	B727 †	1,377,959	1,494,933	2,872,892	9	0.31	1	0.03
		L1011	5,042	22,441	27,483	4	14.55	1	3.64
		DC10 †	42,044	101,819	143,863	3	2.08	0	0
2-Engine	Turbo-jet	B737	354,612	380,660	735,272	4	0.54	2	0.27
		DC9 †	1,165,819	1,161,170	2,326,989	11	0.47	8	0.34
		BAC 1-11	120,581	128,360	248,941	0	0	0	0
	Turboprop	CV580	449,713	427,512	877,225	4	0.45	1	0.11
		CV600/640	86,593	76,486	163,079	3	1.84	1	0.61
		F27	62,187	74,218	136,405	0	0	0	0
		FH227	143,630	105,528	249,158	5	2.01	1	0.40
		YS-11	92,404	87,860	180,264	0	0	0	0
Other Turbine*			43,270	36,993	80,263	1	0.12	0	0
Total Turbine			4,884,673	4,941,853	9,826,526	68	0.69	18	0.18
Total Piston			213,131	242,383	455,514	4	0.88	0	0
TOTALS			5,097,804	5,184,236	10,282,040	72	0.70	18	0.17

*PC6B, DHC6, and SC7

†Supplemental air carriers also fly these aircraft but numbers of departures are not included in these data.

Source of Data: Civil Aeronautics Board and DOT/FAA AIRPORT ACTIVITY STATISTICS OF CERTIFICATED ROUTE AIR CARRIERS, 12 Months Ended December 31, 1972 and 1973, Table 7 in each report.

Appendix C
FIRE ACCIDENT STATISTICS

The table in C.1 below gives type of impact and fire damage by aircraft type for turbine-powered aircraft from 1963-1974. Full definitions of both damage category designations can be found in Section A.5, Accident Codes--Severity and Damage, of Appendix A.

C.2 is a brief discussion of fires after impact; 87 percent of the 122 accidents involving fire were fires occurring after impact.

C.3 is a listing of service difficulty report locations by aircraft system from 1970-1974 (1974 incomplete).

Table C-1

Impact Damage and Fire Damage for Turbine-Powered U.S. Air Carrier (Fixed Wing) Accidents Involving Fire for Each Aircraft Type, 1963–1974 (1974 Incomplete)

Aircraft	Total	Impact Damage																														
		Extreme					Severe					Moderate					Minor					None					Unknown				
		Fire Damage					Fire Damage					Fire Damage					Fire Damage					Fire Damage					Fire Damage				
		D	S	M	N	?	D	S	M	N	?	D	S	M	N	?	D	S	M	N	?	D	S	M	N	?	D	S	M	N	?
707	16	3				2	1*					2*		1			1*						1				2				3
DC9	12	3				1	1*	1*					1				1						1						2		1
727	9	1	1	1			3*				1							1*						1							
DC8	7	1					2					1*															2				1
V745	5	1													1								1						1		1
CV580	4				1			1				1*			1																
FH2.7	4				1		2																				1				
F27	3		1			1			1																						
L188	3						1																				1*				1
720	2	1																													1
CV880	2	1																				1									
L382	2	1											1																		
737	2						1*																						1		
1-11	2	1				1																									
CV600/640	2		1																										1		
PC6	2																														2
C..4	2								1																		1				
CV990	1																										1				
L1011	1		1																												
AW650	1														1																
V810	1						1																								
Total	83	13	4	3	0	5	12	2	2	0	1	4	2	1	2	1	2	1	0	0	0	1	3	1	0	0	8	0	5	0	10

Fire Damage Key: D = destroyed; S = substantial; M = minor; N = none; ? = unknown.

Note: 10 cases do not have impact damage, impact severity or fire damage coded separately but they do have an overall aircraft damage coded as follows: 4 destroyed, 6 substantial damage.

*1 each accident had fatalities due to fire

Introduction to Table C-2: Fires After Impact

In 106 (87 percent) of the 122 accidents which involved fire, the fire occurred after impact. Fatalities occurred in 65 (61 percent) of the 106 accidents with fire after impact. In the 13 accidents in which fatalities were due to fire directly, these fires also occurred after impact. The first of the following two tables presents details of the accidents with fire after impact.

The second table indicates during which subphase of the four phases of operation the accident leading to the impact occurred. The largest number of accidents occurred during final approach; the next largest group, 12 accidents, occurred during initial climb after takeoff. The landing accident types include controlled and uncontrolled collisions with the ground, undershoot, and collision with other objects such as trees. They often occur during adverse weather conditions.

Table C-2

U.S. Air Carrier Accidents (Fixed Wing) Involving Fire After Impact 1963-1974 (1974 Incomplete)

Flight Purpose	Totals	Aircraft Damage							Number Accidents by Injury Type		
		Overall		Due to Fire					Injuries		Fatal due to Fire
		Des	Sub	Des	Sub	Min	Non	Unk	Fat	Ser	
Passenger	65	47	18	27	9	11	4	14	44	7	11
Cargo	30	26	4	17	5	2	1	5	15	5	1
Ferry/ Training	11	11	0	10	1	0	0	0	6	2	1
Totals	106	84	22	54	15	13	5	19	65	14	13

Flight Purpose	Totals	Phase of Operation															
		Taxi to TO	Takeoff			Inflight					Landing						
			Gd Run	Int Clmb	Aborted	Clmb	Crse	Des	Unc Desc	Other	In TfPt	Int App	Fnl App	Lvl Off	Roll	Misd Ap	Other
Passenger	65		4	4	4	3	4	5	3	2	1	4	19	8	2		2
Cargo	30	1	1	7	2	1	4	1				3	7	1	2		
Ferry/ Training	11		1	1	1						1		5			2	
Total	106	1	6	12	7	4	8	6	3	2	2	7	31	9	4	2	2
Phase Total		Taxi: 1 (1%)	Takeoff: 25 (24%)			Inflight: 23 (22%)					Landing: 57 (54%)						

Key: TO, takeoff; GdRun, ground run; Int Clmb, initial climb; Clmb, climb; Crse, Cruise; Des, Descending; Unc Des, Uncontrolled descent; In TfPt, in traffic pattern; Int App, initial approach; Fnl App, final approach; Lvl Off, level off/touchdown; Roll, rollout; Misd App, missed approach.

Introduction to Table C-3: Service Difficulty Reports, SDRs

A computer printout of SDRs was obtained from the FAA Maintenance Analysis Center. This showed 765 flame or smoke occurrences in U.S. Air Carrier aircraft from 1970-1974. The occurrences were distributed by aircraft system as shown in the following table. Over 50 percent occur in four aircraft systems.

Table C-3

Number of Flame and Smoke Occurrences in Service Difficulty Reports 1970-1974 by Aircraft Systems

Number	Aircraft System	Number	Aircraft System
123	Equipment/Furnishings (e.g., galley, lavatory, cabin,etc.)	9	Water/Waste
116	Engines	8	Starting
115	Air Conditioning	7	Engine Oil
60	Electrical Power	6	Fire Protection
59	Landing Gear	6	Propellers
42	Lights	6	Power Plant
40	Airborne Auxiliary Power	5	Engine Exhaust
32	Engine Fuel & Control	4	Bleed Air
22	Hydraulic Power	2	Auto Flight
18	Flight Controls	2	Indicating/Recording Systems
17	Navigation	2	Structures
12	Oxygen	2	Ignition
12	Pneumatic	2	Remote Gear Boxes (Eng Dr)
11	Communications	1	Doors
10	Fuel	1	Fuselage
10	Ice and Rain Protection	1	Engine Controls
		1	Turbines (Reciprocating Eng)
		1	Water Injection

There were no flame or smoke occurrences in the following eight systems: Vacuum/Pressure, Electrical/Electronic Panels and Multipurpose Components, Nacelles/Pylons, Stabilizers, Windows, Wings, Rotors, and Engine Indicating.

Appendix D

FIRE FACTORS MATRICES

The following four tables list details for the 122 airframe fire accidents, 105 incidents (both airframe and engine/wheel nacelle), 36 engine/wheel nacelle accidents, and 19 other occurrences. In the first three tables, the NTSB file number is included with its date for use by anyone wishing to look up the accident brief. The fourth table is composed of data taken from the files of the National Fire Protection Association (NFPA) and thus has no file numbers.

The tables list the date, location of the accident, airline, aircraft type, and period of fire occurrence (whether in flight, on the ground, or after impact).

Damage is presented from several points of view. Overall aircraft damage is taken from the aircraft accident/incident brief. Three other damage types are taken from computer coded data described in Appendix A.5: fire damage, fuselage impact damage (given for the cockpit, forward, center and aft cabin), and impact severity, oriented to the human occupants.

Nonsurvivable is coded "yes" where accidents were described as such in the published Aircraft Accident Report or deduced from coded impact severity and fuselage impact damage data, as indicated in the footnote for Section C.1, Chapter 4, of this report. Phase of operation and accident type are also included for each accident.

Data for incidents and engine/wheel nacelle accidents is presented in Tables D-2 and D-3 in a similar manner. "Evac" is given to indicate "evacuation" of aircraft wherever it was coded by NTSB.

Limited information was found in the National Fire Protection Association (Boston) files on 19 other occurrences not found elsewhere and is presented in Table D-4.

C. 2

Table D-1

122 U.S. Air Carrier (Fixed Wing Aircraft) Accidents Involving Fire, 1963-1974 (1974 Incomplete)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage: Overall	Damage: Fire	Fuselage Impact Damage: Cabin Cp	Cabin Fw	Cabin Ct	Cabin Af	Imp Sev	Non-Surv	Injuries: Fatal	Serious	Min/None	Phase of Operation	Type of Accident
Flight Purpose: Passenger																		
1-0002	1-29-63	Kansas City, MO	Continental	V810(812)	AI	D	D					Sv		8			Landing	Ground/Uncontrolled
1-0006	2-12-63	Nr. Miami, FL	Northwest	720B	AI	D							(Yes)	43			Inflight 2	Airframe Fail/Inflight
1-0007*	5-28-63	Manhattan, KS	Standard	L1049G	AI	D	D	Mo	Mo	Mo	Mo	Mo			1	69	Landing 3	Propeller Failure
1-0008	7- 2-63	Rochester, NY	Mohawk	M404	AI	D	D					Sv		7	30	6	Takeoff 2	Ground/Uncontrolled
1-0009*	6- 3-63	Nr. Annetu Is., AK	Northwest	DC7C	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	101			Unknown	Undetermined
1-0015	12- 8-63	Nr. Elkton, MD	Pan Am	B707-121	F	D		Ex	Ex	Ex	Ex	Ex	Yes	81			Inflight 4	Lightning
1-0049	8-21-63	Orlando, FL	Eastern	DC8	AI	S										28	Landing 4	Wheels Up
1-0004	3-12-64	Miles City, MT	Frontier	DC3C	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	5			Landing 3	Ground/Controlled
1-0007	5- 7-64	San Ramon, CA	Pacific	F27	AI	D		Ex	Ex	Ex	Ex	Ex	Yes	44			Inflight 2	Misc,Ground/Uncontrolled
1-0025	5- 4-64	Rochester, NY	United	DC6B	AI	S	No	No	No	No	No	Mi				29	Takeoff 1	Gear Collapsed
1-0033	7- 9-64	Parrotsville, TN	United	V745D	F	D	D	Ex	Ex	Ex	Ex	Ex	Yes	39			Inflight 3	Fire/Inflight
1-0040	7-17-64	Richmond, VA	Eastern	DC7	AI	S										76	Landing 3	Undershoot
1-0043	8-26-64	Kansas City, MO	TWA	707-331C	AI	S										138	Landing 3	Undershoot
1-0066	11-15-64	Las Vegas, NV	Bonanza	F27	AI	D	Mi	Ex	Ex	Sv	Sv	Ex	Yes	29			Landing 2	Ground/Controlled
1-0080	11-23-64	Rome, Italy	TWA	707-331	AI	D	D	Mi	Mi	Mi	Mi	Mi		48(44)	11(5)	14	Takeoff 3	Ground-Loop-Swerve
1-0001	2- 8-65	Jones Beach LI, NY	Eastern	DC7B	AI	D		Ex	Ex	Ex	Ex	Sv	Yes	84			Inflight 1	Evasive Maneuver
1-0008	3-25-65	Albany, NY	Mohawk	CV440	G	S	S	No								43	Taxi 2	Fire/On Ground
1-0010	1-21-65	Weyers Cave, VA	Piedmont	M404	AI	S	Mi	No	No	No	No	Mi				28	Landing 3	Undershoot
1-0017	5-29-65	Nikolski, AK	Aleutian	DC3	AI	S	Mi									5	Takeoff 2	Stall
1-0022	7-23-65	Montorsville, PA	Allegheny	CV440	AI	D	D	Sv	Sv		Mo	Sv			23	17	Takeoff 2	Engine Failure
1-0030	8-16-65	Lake Michigan, IL	United	B727-22	AI	D	Mi	Ex	Ex	Ex	Ex	Sv	Yes	30			Inflight 3	Ground/Water/Controlled
1-0031	11- 8-65	Nr. Constance, KT	American	B727-23	AI	D	D	Ex	Sv	Sv	Sv	Sv		58	4		Landing 3	Ground/Controlled
1-0032	11-11-65	Salt Lake City, UT	United	B727-22	AI	D	S	Mi	Mi	Mi	Mi	Mo		43(43)	35	13	Landing 3	Undershoot
1-0033	12- 4-65	Carmel, NY	Eastern	L1049C	AI	D	D							4(2)	34	16	Inflight 2	Aircraft/Inflight
1-0049*	3-26-65	Saigon, Vietnam	Pan Am	707-321	AI	S	S	No	No	No	No					170	Landing 4	Dragged Wingtip
1-0063	10-16-65	Charlotte, NC	Eastern	DC7	AI	S	S									62	Landing 4	Undershoot
1-0078	10-17-65	Huntsville, AL	United	DC6	AI	S										16	Takeoff 1	Gear Retracted
1-0082	9-17-65	Montserrat BWI	Pan Am	707-121B	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	30			Inflight 3	Ground/Controlled
1-0001*	4-22-66	Ardmore, OK	Amer. Flyers	L188C	AI	D	D							83(12)	15		Landing 1	Ground/Uncontrolled
1-0008	8- 6-66	Falls City, NE	Braniff	1-11/203	F	D		Ex	Ex	Ex	Ex	Ex	Yes	42			Inflight 2	Airframe Fail/Inflight
1-0015	10- 1-66	Wemme, OR	West Coast	DC9-10	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	18			Inflight 3	Ground/Controlled
1-0043	7-27-66	Gallup, NM	Frontier	DC3	AI	S									3	13	Takeoff 1	Ground/Loop/Swerve
1-0044	8-21-66	Juneau, AK	Al. Coastal	G21A	AI	D								9			Inflight 5	Ground/Uncontrolled

Note: See end of table for abbreviations

Table D-1 (Continued)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage: Overall	Damage: Fire	Fuselage Impact Damage: Cabin Cp	Cabin Ew	Cabin Ct	Cabin Af	Imp Sev	Non-Surv	Injuries: Fatal	Injuries: Serious	Injuries: Min/None	Phase of Operation	Type of Accident
Passenger (Continued)																		
1-0002	3- 9-67	Urbana, OH	TWA	DC9	AI	D		Ex	Ex	Ex	Ex	Ex	Yes	25			Inflight	3 Aircraft/Inflight
1-0004	6-23-67	Blossburg, PA	Mohawk	1-11	F	D		Ex	Ex	Ex	Ex	Ex	Yes	34			Inflight	1 Fire/Inflight
1-0005	7-19-67	Hendersonville, NC	Piedmont	B727-22	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	79			Inflight	1 Aircraft/Inflight
1-0007	3-10-67	Klamath Falls, OR	West Coast	F27	AI	D	S	Ex	Ex	Ex	Ex	Ex	Yes	4			Inflight	Ground/Uncontrolled
1-0019	6-26-67	Kalskag, AK	No. Cons.	PC6A	AI	S										2	Landing	4 Ground/Loop/Swerve
1-0029	11- 6-67	Erlanger, KY	TWA	707-131	AI	D	Mi	Mo	Mo	Mo	Mo	Mo		1*	1	34	Takeoff	3 Gear Collapsed
1-0033	11-20-67	Constance, KY	TWA	GV880	AI	D	D	Ex				Sv		69	13		Landing	3 Undershoot
1-0036	6-26-67	Grand Rapids, MI	United	V745D	AI	S	Mi								1	32	Takeoff	3 Gear Collapsed
1-0037	7-31-67	Honolulu, HI	Aloha	V745D	F	S										38	Inflight	2 Fire/Inflight
1-0047	1-23-67	San Juan, PR	Caribb.-Atl.	CV640	AI	S	Mi									28	Landing	3 Undershoot
1-0058	11-28-67	Raleigh-Durham, NC	United	V745D	AI	S	No								1	42	Landing	5 Gear Collapsed
1-0068	9- 9-67	Frankfurt, Germany	Pan Am	707	G	S									2	172	Takeoff	1 Engine Failure
1-0003	5- 3-68	Nr. Dawson, TX	Braniff	L188		D							Yes	85			Inflight	2 Turb.(Airframe/Inflight)
1-0014	8-10-68	Charleston, WV	Piedmont	FH227B	AI	D	D							34	2		Landing	3 Undershoot
1-0024	10-25-68	Hanover, NH	Northeast	FH227	AI	D	D	Sv	Sv		Mo	Mo		32	8	2	Inflight	3 Ground/Controlled
1-0028	6-24-68	Sioux Falls, SD	North Central	GV580	AI	S	No									22	Landing	2 Electronic Tower Collision
1-0033	12-24-68	Bradford, PA	Allegheny	GV580	AI	D	Mi	Ex	Ex	Ex	Sv	Sv		20	12	15	Landing	3 Trees Collision
1-0040	12-27-68	Chicago, IL	North Central	CV440	AI	D	S	Ex	Ex	Sv	Sv	Sv		27	16	2	Landing	3 Ground/Uncontrolled
1-0062	6-13-68	Calcutta, India	Pan Am	B707	AI	D	D					Sv		6(6)		56	Landing	Trees Collision
1-0001	1- 6-69	Bradford, PA	Allegheny	CV440	AI	D	No	Sv	Sv		Sv	Sv		11	14	3	Landing	2 Trees Collision
1-0026	11-19-69	Glen Falls, NY	Mohawk	FH227B	AI	D	D	Sv	Sv			Ex	Yes	14			Inflight	5 Ground/Uncontrolled
1-0023	11-14-70	Huntington, WV	Southern	DC9-31	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	75			Landing	3 Trees Collision
1-0025*	11-27-70	Anchorage, AK	Capitol	DC8-63F	AI	D	D	Mo	Mo	Mo	Mo	Sv		47(47)	49	133	Takeoff	3 Ditch Collision
1-0026	12-28-70	St. Thomas, VI	Trans Caribb	727-200	AI	D	D	Sv	Sv	Sv	Sv	Sv		2(2)	11	42	Landing	4 Hard Landing
1-0005	6- 6-71	Duarte, CA	Air West	DC9-31	AI	D							Yes	49			Inflight	1 Aircraft/Inflight
1-0006	6- 7-71	New Haven, CT	Allegheny	CV580	AI	D	D	Sv	Mo	Mo	Mo	Mo		28(27)	3(3)		Landing	3 Residence Collision
1-0008	9- 4-71	Juneau, AK	Alaska	727-193	AI	D	S	Ex	Ex	Ex	Ex	Ex	Yes	111			Landing	2 Ground/Controlled
1-0013	8- 8-71	Honolulu, HI	Aloha	V745D	G	S	S	No								22	Taxi	2 Fire/On Ground
1-0035	8-16-71	Akiak, AK	Wien Consol.	PC6H2	AI	S										2	Landing	5 Object Collision
1-0002	5-18-72	Ft. Lauderdale, FL	Eastern	DC9-31	AI	D	D	Mi	Mi	Mi	Mi	Mo			3	7	Landing	4 Ground/Controlled
1-0005	6-29-72	Appleton, WI	No. Central	GV580	AI	D	S	Ex	Ex	Sv	Sv	Ex	Yes	5			Inflight	2 Aircraft/Inflight
1-0011	3-19-72	Atlanta, GA	Delta	DC9-32	G	S	Mi									85	Takeoff	1 Engine Failure
1-0016	12-29-72	Miami, FL	Eastern	1011-385-1	AI	D	S	Ex	Ex	Ex	Ex	Ex	Yes	99	60(14)	17	Inflight	5 Ground/Uncontrolled
1-0017	12-20-72	Chicago, IL	No. Central	DC9-31	AI	D	D	Sv	Sv	Sv	Mo	Sv		10(10)	9	21	Takeoff	2 Aircraft/One Airborne
1-0018	5-10-72	Atlanta, GA	Eastern	DC9-31	G	S	S	No								4	Static	1 Fire/On Ground
1-0048	12- 8-72	Chicago, IL	United	737-222	AI	D	D	Ex	Ex	Sv	Sv	Sv		43(27)	12	6	Landing	3 Stall
1-0049	6-10-72	Flushing, NY	American	727-100	G	Mi	Mi	No							2	75	Static	1 Fire/On Ground

Note: See end of table for abbreviations.

Table D-1 (Continued)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage: Over-all	Damage: Fire	Fuselage Impact Damage: Cabin Cp	Cabin Fw	Cabin Ct	Cabin Af	Imp Sev	Non-Surv	Injuries: Fatal	Injuries: Serious	Injuries: Min/None	Phase of Operation	Type of Accident
Passenger (Concluded)																		
1-0011	7-31-73	Boston, MA	Delta	DC9-31	AI	D	D	Ex	Ex	Ex	Sv	Ex	Yes	88	1		Landing	3 Object Collision
1-0017	9-27-73	Nr. Mena, AR	Texas Int'l	GV600(240D)	AI	D	S					Ex	Yes	11			Inflight	Ground/Controlled
1-0019	10-28-73	Greensboro, NC	Piedmont	737-200	AI	S	Mi									96	Landing	4 Overshoot
1-0028	11-27-73	Chattanooga, TN	Delta	DC9-32	AI	S	S	Mi	Mi	Mi	Sv	Mo			3	37	Landing	3 Undershoot
1-0035	12-17-73	Greensboro, NC	Eastern	DC9-31	AI	S	Mi									89	Takeoff	1 Engine Failure
1-0038	7-22-73	Papeete, Tahiti	Pan Am	707	F	D								79			Takeoff	2 Ground/Uncontrolled
1-0041	7-23-73	St. Louis, MO	Ozark	FH227B	AI	D	Mi	Ex	Ex	Ex	Ex	Ex	Yes	38	6		Landing	3 Ground/Controlled
1-0001	1-30-74	Pago Pago, Samoa	Pan Am	707-321B	AI	D	D	Sv	Mi	Mi	Mi	Mo		96(95)	5(5)		Landing	3 Undershoot
1-0012	1-16-74	Los Angeles, CA	TWA	707-131B	AI	D	D	No	Mo	No	No				3	63	Landing	4 Hard Landing
Flight Purpose: Cargo																		
1-0003	2- 3-63	San Francisco, CA	Slick	L1049H	AI	D	D					Sv		4(4)	4		Landing	3 Runway or Approach Lights
1-0004*	2-16-63	Puyallup, WA	Zantop	C46F	AI	D	D					Sv			2		Inflight	1 Propeller Failure
1-0073*	12- 7-63	Nr. Nederland, CO	Zantop	C46A	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	3			Inflight	2 Ground/Controlled
1-0003	3-10-64	Boston, MA	Slick	DC4	AI	D		Ex	Ex	Sv	Sv	Ex	Yes	3			Landing	2 Ground/Uncontrolled
1-0044	9-22-64	San Juan, PR	Carrib Atl.	DC3	AI	S	Mi	Mi	Mo	Mi	Mi	Mo				2	Takeoff	2 Stall
1-0064	12-24-64	San Francisco, CA	Flying Tiger	L1049H	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	3			Takeoff	2 Ground/Controlled
1-0067	11-20-64	Inkster, MI	Zantop	C46A	AI	D										2	Takeoff	2 Stall
1-0004*	5-18-65	Knob Noster, MO	Aaxico	DC6A	AI	D	S	No	No	No	No	Mo				3	Landing	3 Trees Collision
1-0077*	10-14-65	Piqua, OH	Zantop	AW650	AI	D		Mi	Mo	Mo	Mo	Mo				3	Inflight	3 Engine Failure
1-0080	12-15-65	Alamosa, CO	Flying Tiger	L1049	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	3			Inflight	2 Ground/Controlled
1-0013	3-21-66	Norfolk, VA	Flying Tiger	GL44D	AI	D	Mi					Sv				6	Landing	4 Hard Landing
1-0016*	9-12-66	Tokyo, Japan	Airlift Int.	DC7C	AI	D	S								1	3	Takeoff	3 Fence Collision
1-0051	7-28-66	Port Elizabeth, NJ	Zantop	C46F	AI	D	No	Sv	Sv	Ex	Mo	Sv			1	1	Takeoff	2 Engine Failure
1-0061	6-16-66	Columbia City, IN	Zantop	C46	AI	D								2			Inflight	2 Aircraft/Inflight
1-0073	11-15-66	Nr. Berlin, Germany	Pan Am	B727-21	AI	D						Sv	Yes	3			Landing	2 Undetermined
1-0074*	12-24-66	Nr. Tourene Vietnam	Flying Tiger	GL44	AI	D	D							4			Landing	3 Ground/Controlled
1-0008*	3-23-67	Travis AFB, CA	Universal	DC7B	AI	S	S									3	Taxi	1 Object Collision
1-0028	12-21-67	Denver, CO	Frontier	DC3C	AI	D	D						Yes	2			Takeoff	2 Ground/Uncontrolled
1-0064*	1-31-67	San Antonio, TX	Saturn	DC6A	AI	D	D	Ex	Ex	Ex		Sv		3			Landing	3 Trees Collision
1-0067*	6-22-67	Nr. Saigon, Vietname	Airlift Int.	1049H	AI	D	D							7			Landing	3 Aircraft/Inflight
1-0023	3-21-68	Chicago, IL	United	B727-22QC	AI	D	D					Sv			1	2	Takeoff	3 Ditches Collision
1-0041*	9-27-68	Cherry Pt., NC	Universal	DC7C	AI	D	D					Sv			1	2	Landing	3 Ground/Controlled
1-0044*	7- 2-68	Philadelphia, PA	Universal	DC7BF	AI	S	S									3	Landing	5 Ground/Loop/Swerve
1-0045*	12-26-68	Anchorage, AK	Pan Am	B707-321C	AI	D	D	Ex	Ex	Ex	Ex	Sv	Yes	3			Takeoff	2 Ground/Uncontrolled

Note: See end of table for abbreviations.

Table D-1 (Concluded)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage: Overall	Damage: Fire	Fuselage Impact Damage: Cp	Fw	Ct	Af	Imp Sev	Nonsurv	Injuries: Fatal	Serious	Min/None	Phase of Operation	Type of Accident
Cargo (Concluded)																		
1-0027 *	8-24-70	Hill AF Base, UT	Universal	L188	AI	D	D	Sv	Sv			Sv				3	Takeoff	2 Ground/Uncontrolled
1-0028 *	10-10-70	Wrightstown, NJ	Saturn	L382B	AI	D	D					Ex	Yes	3			Landing	3 Trees Collision
1-0054	11-30-70	Tel Aviv	TWA	707	AI	D	D									3	Takeoff	1 Object Collision
1-0020*	3-18-71	Wichita, KS	Saturn	L382B	AI	S	S					Mo				4	Landing	5 Ground/Loop/Swerve
1-0025	7-25-71	Manila, PI	Pan Am	B707-321C	AI	D	D								4		Landing	2 Ground/Controlled
1-0018*	9- 8-73	Nr. King Cove, AK	World	DC8-63F	AI	D	D					Ex	Yes	6			Inflight	2 Ground/Controlled
1-0026	11- 3-73	Boston, MA	Pan Am	707-321C	F	D		Ex	Ex	Ex	Ex	Ex	Yes	3			Landing	3 Ground/Uncontrolled
Flight Purpose: Training and Ferry (Training denoted by @)																		
1-0017	11-29-63	Morgantown, WV	Purdue Aero.	DC3	AI	D	D							1	1	1	Landing	3 Trees Collision
1-0015@	1- 5-64	Miami, FL	Pan Am	DC3A	G	S										2	Static	2 Fire/On Ground
1-0021@	9-13-65	Kansas City, MO	TWA	CV880	AI	D	D	No	No	No	No	Mo				4	Takeoff	1 Engine Failure
1-0003@	3-30-67	Kenner, LA	Delta	DC8-51	AI	D	D						Yes	6			Landing	3 Ground/Uncontrolled
1-0059	2-10-67	Nr. Da Nang, Vietnam	Flying Tiger	L1049H	F	S	Mi									4	Inflight	2 Fire/Inflight
1-0009@	4-28-68	Atlantic City, NJ	Capitol	DC8-31	AI	D	D								2	2	Landing	1 Engine Failure
1-0013	1- 1-68	Oxford, MS	Southern	M404	AI	D	D									3	Landing	3 Undershoot
1-0017@	7-26-69	Pomona, NJ	TWA	707-331C	AI	D	D	Ex	Ex	Ex	Ex	Ex	Yes	5			Landing	7 Ground/Uncontrolled
1-0058@	10-16-69	Stockton, CA	Sea. World	DC8-63F	AI	D	D					Sv				5	Takeoff	3 Dirt Bank Collision
1-0011	9- 8-70	Jamaica, NY	Trans. Int.	DC8-63F	AI	D	D	Ex	Ex	Sv	Sv	Ex	Yes	11			Takeoff	2 Stall
1-0051	8- 8-70	Acapulco, Mex	Mod Air Trans	CV990	AI	D	D								8		Landing	3 Undershoot
1-0002@	3-31-71	Ontario, CA	Western	B720-047B	AI	D	D					Ex	Yes	5			Landing	7 Ground/Uncontrolled
1-0003	5-30-72	Ft. Worth, TX	Delta	DC9-14	AI	D	S	Ex	Sv	Sv	Mo	Ex	Yes	4(1)			Landing	3 Turbulence

COLUMN HEADINGS: Cp, cockpit; Fw, forward cabin; Ct, center cabin; Af, aft cabin; Imp Sev, impact severity; Nonsurv, nonsurvivable; Min/None, minor/none

DATA: Fire Occurrence: AI, after impact; F, inflight; G, on ground; Damage Codes: D, destroyed; S, substantial; Mi, minor; No, none; Fuselage Impact Damage Codes: Ex, extreme; Sv, severe; Mo, moderate; Mi, minor; No, none. Injuries: Figures in ( ) indicate number of fatal or seriously injured due to fire. Phase of Operation: *Static* 1, starting engine; 2, idling; 3, engine runup; *Taxi* 1, to take off; 2, from landing; *Takeoff* 1, ground run; 2, initial climb; 3, aborted; *Inflight* 1, climb; 2, cruise; 3, descending; 4, holding; *Landing* 1, in traffic pattern; 2, initial approach; 3, final approach; 4, level off/touchdown; 5, rollout; 6, go-around; 7, missed approach.

*Military contract flight

Table D-2

105 U. S. Air Carrier (Fixed Wing Aircraft) Incidents Involving Fire, 1964-1974 (1974 Incomplete)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage Over-all	Damage Fire	Injuries Minor/None	Phase of Operation	Fire Location	Remarks
Flight Purpose: Passenger											
(1963 listing not available)											
4-0001	1-22-64	Philadelphia, PA	Eastern	DC8	F	No	No	51	Inflight 1	Engine	
4-0015	8- 3-64	Tulsa, OK	American	L188A	G	Mi	Mi	17	Static 1	Engine	Oil leaking into tail pipe
4-0022	8-26-64	Dallas, TX	Delta	DC8	AI	S	Unk	135 evac	Landing 5	Wheel nacelle	
4-0023	6-26-64	Philadelphia, PA	Allegheny	M202A	G	Mi	No	33	Takeoff 1	Engine	
4-0024	6-14-64	San Juan, PR	Pan Am	121	G	Mi	Mi	165 evac	Static 1	*Refueling*	Wind blew escaping fuel onto hot engine
4-0025	2-13-64	San Juan, PR	Eastern	DC8	F	No	No	94	Inflight 1	Engine	
4-0026	9-19-64	San Juan, PR	Carib-Atl	CV340	F	No	No	57	Takeoff 2	Engine	
4-0028	5-30-64	Washington, DC	Eastern	L188	G	No	No	18	Static 1	Engine	
4-0030	9-22-64	Miami, FL	National	DC8	F	No	No	30	Inflight 2		
4-0043	10-15-64	New York, NY	Eastern	L1049C	F	No	No	76	Inflight 3	Engine	
4-0045	11- 5-64	N. Harrisburg, PA	United	745	F	Mi	No	25 evac	Inflight 2		Smoke in cockpit
4-0046	11-25-64	N. Newark, NJ	United	Caravelle	F	Mi	Mi	54	Inflight 2	*Cabin*	
4-0055	11-25-64	N. Hampton Roads, VA	United	V745D	F	Mi	No	14	Inflight 2	Engine	
4-0062	11-25-64	New York, NY	United	DC6	G	Mi	Mi	39 evac	Taxi 2	*Cabin*	
4-0073	2-17-64	N. San Juan, PR	Eastern	DC8B	F	Mi	Mi	69	Takeoff 2	Engine	
4-0001	1- 4-65	Salt Lake City, UT	Western	B720B	G	Mi		82	Static 2		
4-0006	1- 9-65	Roanoke, VA	Piedmont	M404	G	Mi	Mi	13	Taxi 1	Wheel nacelle	
4-0022	8-19-65	Corpus Christ, TX	Braniff	1-11	F	No	No	16	Landing 3	*Other*	
4-0025	7-12-65	N. Jamaica, NY	Eastern	DC8	F	Mi	Mi	117	Inflight 1	Engine	
4-0034	11-18-65	N. Los Angeles, CA	Delta	CV880	F	Mi	No	65 evac	Inflight 1	Engine	
4-0036	4-26-65	Miami, FL	Eastern	B727	AI	Mi			Static 1		
4-0039	6-14-65	Santiago, Chili	PanAm-Grace	DC8	AI	Mi	Mi	55 evac	Landing 5	Wheel nacelle	Airframe failure on ground
4-0040	11-15-65	N. McChord AFB,WA	United	DC8	F	No	Mi	12 evac	Inflight 2	Engine	
4-0005	2- 7-66	N. Little Rock, AR	Braniff	B720	F	Mi		105 evac	Inflight 2	Engine	
4-0016	4-17-66	Charlotte, NC	Eastern	L188	F	Mi	Mi	90	Inflight 2	*Baggage compar.*	Smoke in cockpit, fumes in cabin
4-0026	6-22-66	El Dorado, AR	Trans-Texas	DC3	F	Mi		3	Inflight 2	Engine	
4-0030	8-27-66	Buffalo, NY	United	727	F	Mi		39	Inflight 2	Engine	#3 11th stage compressor disc failed; inboard cowl panel burned thru
4-0033	9-26-66	N. Nassau, Bahamas	Pan Am	707	F	Mi	Mi	71	Inflight 1	Engine	#2 fire
4-0039	11-23-66	Newark, NJ	Mohawk	FH227	G	No	No	45	Landing 5	*APU*	Generator failed
4-0052	5-11-66	N. Norfolk, NE	North Central	DC3	F	Mi	Mi	18 evac	Landing 3	Engine	Wheels up; under investigation
4-0001	1- 3-67	N. Miami, FL	Pan Am	B720B	F	No		16	Inflight 2	Engine	Extinguished in air
4-0009	4- 8-67	Jamaica, NY	Eastern	DC8-21	F	No	No	113 evac	Takeoff 2	Engine	Fuel & oil lines severed; ignited by disintegrating eng compressor parts and escaping combustion flame
4-0024	6- 2-67	Washington, DC	Eastern	B727	F	Mi	No	67	Takeoff 2	Engine	#6 fuel nozzle leak; powerplt outer casting. Elec. wall heat blanket ignited
4-0027	9-14-67	Phoenix, AZ	American	707	F	Mi	Mi	106	Inflight 3	*Cabin*	
4-0032	3- 6-67	N. Port of Spain, WI	Pan Am	DC8	F	Mi		25	Inflight 3	Engine	#4; fuel fed fire
4-0033	7- 2-67	Chicago, IL	United	727	G	S	Mi	80 evac	Takeoff 1	Engine	
4-0038	6-17-67	Convington, KU	Delta	DC8	AI	S	S	142	Landing 5	Brakes	R brake truck locked on touchdown due control valve by-passing fluid

Table D-2 (Continued)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage Over-all	Damage Fire	Injuries Minor/None	Phase of Operation		Fire Location	Remarks
Flight Purpose: Passenger (Continued)												
4-0005	2-16-68	Elmira, NY	Mohawk	FH227	G	No	No	6	Taxi	1	Engine	
4-0013	8- 7-68	Chicago, IL	TWA	880	F	Mi	Mi	44	Takeoff	2	Engine	14th stage disc failed; engine cowl damaged
4-0014	8- 1-68	Champaign, IL	Ozark	FH227	F	No	No	30	Inflight	2	Engine	Compressor interstage bearing disintegrated
4-0016	11-19-68	Denver, CO	Continental	707-320C	F	Ni	Mi	81	Inflight	3	*Lavoratory*	Px set fire in R aft (incendiary device); extinguished; fumes in cabin; O_2 masks dropped (heat activated sensors); fume evacuation
4-0027	12-23-68	Newark, NJ	Eastern	DC8	AI	NI	No	46	Landing	3	Wheel nacelle	Collided with lights; #3, #7 wheels RMLG damaged; #7 separated
NFPA	7-25-68	Morgantown	Allegheny	CV580	AI	S	S	43 evac	Landing	?	Engine area	Fuel lines ruptured by right inside wheel coming off on landing and striking right prop; fuel ignited by burner cans in engine
4-0008	4-12-69	Raleigh, NC	United	727	G	No		52 evac	Static	1	*Air cond. pack*	Overheat
4-0011	3-23-69	Wash Natl Apt, DC	National	727	G	No		101 evac	Taxi	2	*Cooling ducting*	Intermittent circuit in ground cooling fan heated ducting when APU started
4-0038	5- 5-69	N. Miami, FL	Eastern	720	F	Mi	Mi	28	Inflight	2	Engine	
4-0043	12-14-69	Nashville, TN	Allegheny	DC9	F	Mi	Mi	13	Inflight	1	Engine	#6 stage of N1 compressor failed; hole in engine cowling
4-0045	10- 9-69	Jamaica, NY	United	DC8	G	No		78 evac	Taxi	2	Engine	
4-0024	4-22-70	Indianapolis, IN	TWA	707-131	G	S	S	0	Static	1	*Cabin*	Unattended a/c cove light capacitor port side seat 25 failed due to thermal runaway
4-0030	6-26-70	Jamaica, NY	TWA	747	G	No		201 evac	Landing	5	Engine	
4-0032	9-19-70	Jamaica, NY	TWA	747	G	Mi	Mi	324 evac	Static	2	Engine	Torched; fire damage in area of #1 tail pipe
4-0035	9-23-70	Kankakee, IL	American	727	F	Mi	Mi	80	Inflight	1	Engine	Failed; extinguished
4-0038	7-22-70	N. Newark, NJ	United	737	F	No	No	53	Inflight	3	*APU*	Atomizer defective; extinguished
4-0041	10-20-70	N. Wheeling, WV	Allegheny	CV580	F	Mi	Mi	20	Inflight	2	*Cabin*	Burned paper in duct; smoke/sparks from heater vents
4-0045	9-18-70	San Francisco, CA	American	747	F	Mi	Mi	132	Takeoff	2	Engine	Stress rupture of 1st stage turbine blades
4-0046	3-28-70	Las Vegas, NV	United	720	AI	Mi	No	124 evac	Taxi	1	RMLG	Truck beam failed, fatigue fracture
4-0051	8-26-70	San Francisco, CA	TWA	747	F	Mi	Mi	200	Inflight	1	Engine	Engine #2 quit, machine bolt failed; #4 ignited, oil sprayed access section
4-0060	12-05-70	Lynchburg, VA	Piedmont	737	G	No	No	16 evac	Takeoff	1	L Engine	First stage fan blade failed; severed ext oil lines caused fire
4-0062	10-27-70	London, England	Pan Am	747	G	Mi	Mi	107 evac	Taxi:Other		Engine	Fuel ctl rotary actuator failed, caused fire (2 escape slides malfunctioned)
4-0066	12-13-70	London, England	Pan Am	747	F	No	No	102	Inflight	1	Engine	#3 bearing, turbine section failed
4-0080	12-31-70	Washington,D.C.	United	737	G	S	S	3	Static	1	*Cabin*	O_2 servicing/fire started at filter element with filter valve inlet nipple; O_2 fed fire

Table D-2 (Continued)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Over-all	Fire	Injuries Minor/None	Phase of Operation	Fire Location	Remarks
Flight Purpose: Passenger (Concluded)											
4-0002	1-12-71	Baltimore, MD	United	720	F	Mi	Mi	64	Inflight 1	Engine	8th stage compressor blade failed; fire bottle inoperative
4-0004	4- 5-71	Flushing, NY	American	1-11	F	Mi	Mi	58	Inflight 1	Engine	Constant speed drive started overheated; burned hole in case
4-0005	5-13-71	Honolulu, HI	Northwest	B747	F	Mi	Mi	42	Takeoff 2	Engine	Fatigue crack in turbine air seal
4-0021	7-21-71	Dallas, TX	American	707	G	Mi		113	Takeoff 1	Engine	Fatigue fracture; debris damaged #4, R fuselage, R wing
4-0027	4- 2-71	Charlotte, NC	Piedmont	YS11	F	Mi		25	Inflight 3	Engine	1st stage impeller shaft roller bearing failed
4-0036	6- 3-71	N. Washington, D.C.	Piedmont	YS11A	F	Mi		45	Inflight 2	Engine	Bolt from inlet guide vane loose; caused milling thru backing plate; impeller failed
4-0040	8-24-71	Los Angeles, CA	Pan Am	747	F	Mi	Mi	158	Takeoff 2	Engine	Sensor attach filling failed; diffuser case ruptured, eng cowling sep
4-0050	11- 8-71	Jamaica, NY	Eastern	747	F	S	S	215	Takeoff 2	Engine	Diffuser case ruptured near #5 borescope boss
4-0052	12- 4-71	Dulles Int Apt, DC	United	DC10	G	Mi	Mi	109	Landing 5	L wheel area	Parking brake cable binding due poor design
4-0012	5-24-72	Boston, MA	Pan Am	747	G	Mi		92	Landing 5	Engine	Fuel ctl valve malfunctioned; torched; heat damage to flap and wing panel
4-0013	5-23-72	Jamaica, NY	TWA	707-331C	G	Mi	Mi	0	Static 1	*Cargo cmpt*	2 pkg chemical broke open, caught fire
4-0003	1- 8-73	Baltimore, MD	Delta	DC9	G	Mi	No	62 evac	Takeoff 1	Wheel	R MLG outbd tire blew; debris cut brake line, caused ground fire
4-0005	1-10-73	N. Grand Junction, CO	TWA	1011	F	Mi		79	Inflight 2	Engine	Fan disc failed, fan assembly separated; #1, 3 and airframe damaged by debris
4-0010	5- 1-73	N. Atlantic Ocean	American	707	F	No		84	Inflight 2	*Cabin*	Portable O_2 generator ignited
4-0013	7- 8-73	Dallas, TX	American	DC10	F	No		130	Inflight 2	*Cabin*	Portable O_2 generator; contents burned thru entr canister unit
4-0018	6-22-73	Spokane, WA	Air West	DC9	G	Mi	Mi	108 evac	Takeoff 1	Wheel	#3 and 4 tires failed
4-0020	9- 5-73	N. Memphis, TN	American	707-323	F	Mi	Mi	51	Inflight 2	*Lavatory*	L aft refuse container; dig.; extinguished by crew; circuit breaker for 3 phase aft lav heater popped before flight attendant reported fire
4-0005	3-17-74	N. Atlantic Ocean	TWA	747	F	Mi	Mi	163	Inflight: Other	*Cabin*	Coffee maker malfunctioned
4-0010	4-19-74	East Boston, MA	TWA	1011	G	D	D	Unocc	Static 1	*Cabin*	FS267 aft to FS1792;electrical floor heating blanket
(px,mil) 4-0023	3-23-74	Travis AFB, CA	Airlift Int	DC8	G	D	D	4	Static 1	*Wing*	Fuel fumes exploded in #1 tank area due undet elec source
4-0025	11-17-74	N. Honolulu, HI	Pan Am	747	F	Mi	Mi	172 evac	Inflight 1	Engine	#3 bearing cavity; penetrated to access drive gr box (5 escape slides malfunctioned)

Table D-2 (Concluded)

File No.	Date	Location	Airline	Aircraft Type	Fire Occur.	Damage Over-all	Damage Fire	Injuries Minor/None	Phase of Operation		Fire Location	Remarks
Flight Purpose: Cargo												
4-0010	6- 8-64	N. Vero Beach, FL	Eastern	1049C	F	Mi	MI	3	Inflight	2	Engine	
4-0013	5-24-65	Altus, OK	Zantop	DC6A	F	S		3	Takeoff	2	Engine	
4-0030	11-19-67	Munich, Ger	Pan Am	DC8	F			30	Takeoff	2	Engine	
4-0031	2-22-69	Jamaica, NY	Flying Tiger	DC8F	G	Mi	No	4	Takeoff	1	Wheel nacelle	Forward L main tires blew out
4-0040	8-27-70	Jamaica, NY	Airlift Int.	DC8	G	Mi	Mi	3	Takeoff	1	Wheel nacelle	L front MLG tires blew out, both wheels failed
4-0008	4-24-73	Jamaica, NY	Airlift Int.	DC8	G	Mi	Mi	3	Takeoff	1	Wheel nacelle	L LG failed; debris dislodged L wing fuel drain plug, aided fire
Flight Purpose: Ferry/Training (@ indicates ferry)												
4-0007	2-13-65	Fresno, CA	Pan Am	707	AI	Mi	Mi	4	Landing	4	Engine	Dragged wingtip
4-0026	7- 9-65	Winston Salem, NC	Piedmont	M404	F	Mi	Mi	3	Inflight	2	Engine	
4-0043	11-23-65	N. Chicago, IL	Delta	DC8	F	Mi	No	6	Inflight	2	Engine	Stall recovery maneuver; suspect fatigue tie-bolt hole area
4-0032@	9- 1-66	Miami, FL	Modern Air T.	DC7C	G	Mi	Mi	9	Taxi	1	Engine	Loose primer line B nut allowed fuel to contact #3 engine
4-0037	10-18-66	Miami, FL	Eastern	L1049	G	S			Static	1	*Wing*	Refueling; tug ruptured fuel line
4-0043	8-30-66	Mojave, CA	Flying Tiger	707	AI	S	No	4	Takeoff	1	Wheel nacelle	All 4 R MG tires blew out; pilot aborted
4-0020	4-30-67	Denver, CO	Continental	B720B	F	Mi	Mi	7	Landing	4	Engine	Engine contacted runway/fire/self extinguished
4-0058	5-26-70	Salina, KS	Northwest	747	F	Mi	Mi	7	Landing	3	Engine	Fuel line connecting main manifold w/ fuel nozzle seaprated at solder joint
4-0059	6-11-70	Salina, KS	Northwest	747	F	Mi	Mi	6	Inflight	1	Engine	Weld in diffuser case borescope boss failed; eng accessory cowling separated
4-0001	5- 2-72	Tucson, AZ	Continental	DC10	F			9	Inflight	4	Engine	High temp area set off air-oil mixture formed from released oil
4-0011	6-13-72	Miami, FL	Eastern	DC8-61	F	Mi		4	Inflight	1	Engine	3rd stage turbine disc failed; debris damaged pylons and L wing
4-0023@	10-18-73	Spokane, WA	Capitol Int.	DC8-63F	G	S	S	3	Static	3	*Refueling*	a/c and fuel trucks improperly grounded; fire originated under fuel truck parked partially under L wing
4-0006@	4- 7-74	Sagwon, AK	Airlift Int.	GA382B	F	Mi	Mi	4	Inflight	1	Engine	
Flight Purpose: Other												
4-0061	9-18-64	Indianapolis, IN	Lake Central	DC3	G	No	No	1	Static	2	Engine	Fatal prop accident to person
4-0001	1-30-69	Roanoke, VA	Piedmond	737	G	S	S	6 evac	Taxi:other		Wheels,Brakes	
4-0064	8- 7-70	Jamaica, NY	Overseas Natl	DC8	G	Mi		1	Static	1	LMLG cyl	Exploded during maint/refueling due to water in airstart chamber
4-0016	6-24-72	St. Louis, MO	American	727	AI	Mi		7	Static:other (hijack) taxied - parepared to take off		MLG nose	Vehicle driver rammed gear to prevent hijack takeoff; small ground fire

DATA: Fire Occurrence: AI, after impact; F, inflight; G, on ground. Damage Codes: D, destroyed; S, substantial; Mi, minor; No, none. Phase of Operation: *Static* 1, starting engine; 2, idling; 3, engine runup; *Taxi* 1, to take off; 2 from landing; *Takeoff* 1, ground run; 2, initial climb; 3, aborted; *Inflight* 1, climb; 2, cruise; 3, descending; 4, holding; *Landing* 1, in traffic pattern; 2, initial approach; 3, final approach; 4, level off/touchdown; 5, rollout; 6, go-around; 7, missed approach. Fire Location: *Italics* indicate incidents with fire in other than engine or wheel nacelle.

Table D-3

36 U.S. Air Carrier (Fixed Wing Aircraft) Accidents Involving Fire in the Engines or Wheel Nacelles, 1963-1974 (1974 Incomplete)

File No.	Date	Location	Airline	Aircraft Type	Damage All	Damage Fire	Injuries Serious	Injuries Min/None	Phase of Operation	Fire Location	Accident Type
Flight Purpose: Passenger											
*1-0062	11- 6-63	Boston, MA	Eastern	720	S	?	-	38	Takeoff	?	Fire In Flight
1-0069	12-12-63	New Orleans, LA	Eastern	720	S	?	-	16	Takeoff	?	Fire In Flight
†1-0038	7- 1-64	Jamaica, NY	American	720	S	None	-	12	Landing	Engine	Groundloop
1-0036	3-14-65	Ypsilanti, MI	United	Caravelle	S	S	1(evac)	53	Takeoff	Engine	Fire On Ground
1-0038	6- 9-65	San Francisco, CA	National	DC8	S	S	-(evac)	77		Engine	Fire In Flight
1-0006	2-13-66	Bornite, AK	Wien Alaska	Cess. 185	S	?	-	3	Inflight	?	Engine Failure
1-0007	2-13-66	Dallas, TX	Braniff	720	S	S	-(evac)	127	Landing	Engine	Engine Failure
1-0065	8-11-66	Martinsburg, WV	Lake Central	Nord 262		Min	-	17	Cruise	Engine	Engine Failure
1-0027	6-24-67	Newark, NJ	Delta	CV880	S	None	-	59	Flight	Engine	Engine Failure
1-0035	4- 8-67	Chicago, IL	Lake Central	Nord 262A	S	S	-	9	Takeoff	Engine	Fire In Flight
1-0048	7-23-67	Des Moines, IA	Braniff	CV340	S	S	-(evac)	9	Flight	Engine	Engine Failure
1-0055	4-25-67	San Juan, PR	Carib-Atl	CV640D	S	S	-	57	Landing	Wheel	Fire In Flight
1-0047	11-19-68	Martinsburg, WV	American	707	S	?	-	38	Flight	?	Fire In Flight
1-0007	2- 9-69	Berlin, W. Germany	Pan Am	727	S	?	2	114	Takeoff	?	Engine Failure
1-0054	11-28-69	Newark, NJ	Eastern	DC8	S	?	-	123	Takeoff	?	Fire On Ground
†1-0015	6- 3-70	Newark, NJ	Eastern	727	S	S		105	Static	Wing Root	Fire On Ground
1-0024	3- 2-70	Chicago, IL	United	720	No	None	1(evac)	94	Static	Engine	Fire On Ground
1-0029	6- 9-70	Bangor, ME	Trans Carib.	DC8F	Min	Min	2(evac)	226	Takeoff	Wheel	Fire On Ground
‡1-0036	5-18-70	Chicago, IL	United	727	No	None	1(evac)	71	Taxi	Wheel	Fire On Ground
†1-0053	9-29-70	Dallas, TX	Braniff	720	S	Min		54	Landing	Engine	Gear Retracted
1-0055	3-28-70	Nr. Annette Isl, AK	Western	720B	S	?	-	27	Flight	?	Fire In Flight
1-0017	7-23-71	Chicago, IL	United	747	Min	Min	1(evac)	198	Taxi	Engine	Engine Failure
1-0047	11-17-71	Nr. Milwaukee, WI	United	727	S	Min	-	36	Flight	?	Engine Failure
1-0013	9- 1-72	Jamaica, NY	TWA	747	Min	Min	8(evac)	345	Taxi	Wheel	Fire On Ground
1-0024	3- 3-72	Hilo, HI	United	DC8-61	No	?	1(evac)	128	Static	?	Fire On Ground
1-0038	11- 1-72	St. Louis, MO	TWA	707	Min	Min	1(evac)	80	Landing	Engine	Engine Failure
1-0015	6-20-73	Bangor, ME	Over. Natl.	DC8	Min	Min	3(evac)	258	Takeoff	Wheel	Airframe Failure
1-0039	8- 8-73	Washington, DC	Braniff	727	S	S	-(evac)	81	Inflight	Wheel	Fire In Flight
Flight Purpose: Cargo											
1-0051	10-10-64	Charleston, SC	Capitol	G46	S	Min	-	2	Takeoff	Engine	Engine Failure
1-0058	11-19-64	Gwinn, MI	Zantop	AW650	S	S	-	3	Landing	Other	Fire In Flight
1-0039	5-18-70	San Francisco, CA	Delta	GA382	S	S	-	3	Takeoff	Wheel	Engine Failure
Flight Purpose: Training and Ferry											
1-0039	6-17-66 T	Chicago, IL	No. Central	CV440	S	S	-(evac)	2	Inflight	Engine	Engine Failure
1-0055	8- 5-68 F	Travis AFB, CA	Flying Tiger	707	S	S	-	3	Landing	Engine	Fire On Ground
1-0010	3-19-72 F	Hill AFB, UT	Universal	L188	S	S	-	3	Inflight	Engine	Prop Failure
1-0014	2-16-72 T	Beaumont, TX	Texas Intl.	CV600	S	S	-	3	Landing	Engine	Engine Failure
† 1-0009	3- 5-73 F	Denver, CO	American	707	S	Min		3	Takeoff	Engine	Groundloop

Codes: Damage: S, substantial; Min, Minor; No, None. Injuries: Serious--Evac: emergency evacuation of aircraft specifically noted in NTSB codes; Min/None: minor or no injuries. Flight Purpose, Training and Ferry: T, training; F, ferry

*Fire Occurrence Inflight; †After Impact; ‡On Ground

Table D-4

19 U.S. Air Carrier (Fixed Wing Aircraft) Occurrences
Involving Fire, 1963-1974 (1974 Incomplete)

Date	Location	Airline	Aircraft	Injuries Minor/None	Phase of Operation		Fire Occur.	Fire Location	Ignition
5-30-63	Newark	American	GV990		Static	1	G	Cargo compartment Engines #1 and #2	Possibly sparks from exhaust of taxiing aircraft igniting ordinary combutibles through open cargo door
6- 6-63	Nashville	American	707B	13 evac			G	Engines #1 and #2	During refueling, fuel sprayed on engine
6-14-63	Los Angeles	American	720B		Static	1	G	Cabin	Cigarette butt wrapped in napkin placed in cabin seat pocket
6-18-63	Stuttgart	Pan Am	707-331				G	Lavatory D	Charred (low-light circuits) wire bundle; insufficient moisture resistance
8- 7-63	Cleveland	American	707B		Static	1	G	Cabin	Cigarette trays emptied into market bag; ignited; seat cushion burned
11-16-63	Miami	Eastern	720-025		Static	1	G	Cockpit	O_2 escaped under pressure; adiabatic compression downstream of valve resulted in ignition of valve components or fire caused by impurity in system.
12- 2-63	Nr. Miami	National	DC8		Inflight		F	Lavatory	
Note: 1963 occurrences may be "incidents" but listing unavailable.									
7-27-65	Atlanta	Delta	DC8	2 (1 burns)	Static	1	G	Right wing, fuselage, wheel well, interior carpet + smoke damage	Cleaning solvent ignited by lamp bulb on wheel well
3-12-66	Kansas City	TWA	707-331B	3	Static	1	G	Galley #3	Electrical arcing, shorted by water
12-31-66	Long Beach	(United) manufac.	DC8-61*	5 (1 burns)	Static	1	G	Cabin	Static electricity when man shifted; rug burst into flames; aliphatic naphtha for spot cleaning vinyl plastic.
6-30-67	Dallas	Braniff	727		Static	1	G	Left wheel well, fuselage, wing	Spark from APU in wheel well ignited solvent there from cleaning
5-16-68	Macuma Ecuador	Alaska	L382B	4	Landing	5	AI	Engine	#1 engine prop struck ground, breaking, throwing parts into #2 engine; fragments started fire
8- 7-69	Philadelphia	United	720		Static	1	G	Cabin	Electrical fault in razor outlet; O_2 cylinder in hat racks vented through safety valves aiding burning materials
7-27-71	Oakland	Saturn	L100	**	Static		G	Cockpit	O_2 bottle exploded
1-25-72	Seattle	Western	720B		Static	1	G	Cargo	Malfunction as result of heat by friction or electrical short circuit in recirc. air unit; unit aft of forward cargo compartment behind station 360 bulkhead; wiring compartment, floor of cabin above unit; smoke damage to entire cabin
8-30-74	Chicago	American	727	27 evac	Takeoff	1	G	Engine	
11-5-74	Boston	Allegheny	DC9	33 evac	Inflight	3	F	Cockpit	Cross tie relay area
4-24-74	Jamaica, NY	United	DC8	229	Takeoff	3	G	Wheel nacelle	Friction ccused by 2 blown tires on left MG and leaking hydraulic fluid
7-21-74		TWA	747	168 evac	Takeoff		F	Engine	
Note: 1974 occurrences may be "incidents"; listing is incomplete at time of this report.									

Note: All 19 occurrences found in National Fire Protection Association (Boston) files and not located on incident lists; 1971-1974 occurrences not located on SDR lists.

*Aircraft destroyed by fire

**3 were seriously injured due to fire.

Appendix E

BIBLIOGRAPHY OF PUBLICATIONS ON EMERGENCY EVACUATIONS

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Folk, Earl D., et al. (FAA Civil Aeromedical Institute). GPSS/360 COMPUTER MODELS TO SIMULATE AIRCRAFT PASSENGER EMERGENCY EVACUATION. AM-72-30. Washington: Federal Aviation Administration, September 1972.

Appendix F

DISCUSSION OF SURVIVABILITY AND CRASH FIRES FROM GAGE-BABCOCK STUDY

The findings of this study (and the CAB study covering 1955-1964) indicate that the greatest occurrence of fire accidents is after impact. The following material is quoted from two chapters, "Comments on Survivability" and "Crash Fires" of a study performed by B.M. Cohn and G.A. Campbell of Gage-Babcock Associates for the FAA/Airports Service in January 1971, "Minimum Needs for Airport Fire Fighting and Rescue Services" (Report AS-71-1, AD 720-512).

The first quote begins by pointing out that when an aircraft crashes, the crash location (off or on airport), the impact forces (high or low), and presence of fire are factors which can increase or decrease survival. Subfactors of concern for survivable accidents are the fuel system (ruptured or intact), cabin integrity (compromised or intact) and fire and rescue service (effective or ineffective). The following is quoted from Chapter IV, "Comments on Survivability" (pp. 32-34):

> Persons in aircraft involved in a crash fire will be exposed to hazardous environment which will impair their ability to escape and can cause serious or fatal injuries after sufficient exposure duration. The principal causes of injury or death will be:
>
> 1. Thermal conditions - radiant heat, hot gases, hot air and flame.
> 2. Products of combustion - carbon monoxide, carbon dioxide.
> 3. Pyrolysis products from interior furnishings, primarily, or from halogenated hydrocarbon extinguishing agents - HCl, Cl, Cl_2, $COCl_2$, HF, Br_2, COF_2, NH_3, HCN, etc.
>
> Experimental studies to date (9, 10) have indicated that the thermal conditions have been the limiting factors in escape and survival time....
>
> Impact damage to the fuel system is usually the cause of fatal aircraft fires. Ruptured fuel lines and tankage are the usual sources of fuel spills, with especially severe fires resulting when fuel booster pumps continue to operate following damage to fuel lines. While the type and quantity of fuel involved in a fire is a factor, it should be noted that even relatively small quantities of either high- or low-flash-

point fuel can quickly produce untenantable conditions in an aircraft cabin (11). In addition, the integrity of the cabin is of major importance to the survival of the occupants. Survival time may be essentially zero if the fuselage is opened by impact forces and a fire develops. Even if the cabin is intact following impact, it has been demonstrated that direct flame impingement on the aircraft skin can penetrate it in 10 to 50 seconds (9, 12).

Although the experimental studies had indicated thermal conditions would limit survival, actual crash experience indicates that toxic gases may be a frequent survival limit. The most critical toxic gas sources anticipated would be due to the combustion or/and pyrolisis (sic) of interior furnishings. The crash fire will heat the aircraft skin and the transfer of this heat will pyrolize or ignite interior materials at temperatures well below the point at which the aluminum fails. If the crash fire is impinging directly on the fuselage skin, the skin may fail in less than 10 seconds and fire can directly enter the fuselage. This fire will then ignite the interior combustibles.

It is also possible for fire and smoke to enter the aircraft cabin when the exits are opened. Once the cabin atmosphere becomes contaminated with dense smoke and hot, toxic gases, the occupants will be quickly incapacitated and not capable of accomplishing self-evacuation. Unconsciousness can result in 10 to 15 seconds, with death resulting shortly thereafter. Although fire-safe fuel systems and passenger survival in fire situations have been researched and studied extensively, little progress has been made in these areas. If meaningful reductions in the number of post-crash fire deaths are to be accomplished, they must come from improvements in these areas. They will not result from any ground firefighting and rescue systems, alone....

The FAA requires that the occupants of any aircraft be able to evacuate in 90 seconds or less, using only 50 percent of the plane's exits. Under ideal conditions, crash equipment might arrive at the scene within this time period; however, in most instances response time will be in excess of 90 seconds and, theoretically, evacuation will have been accomplished prior to the arrival of crash fire-fighting and rescue equipment. Where evacuation is hindered by injuries, lack of visibility, blocked exits, wreckage, or negative panic, effective firefighting can extend the survival time sufficiently to permit complete evacuation or eventual rescue.

Chapter VI, "Crash Fires", (pp. 41-43), discusses the problem of fuel spill due to line or tank rupture, and the mechanism of ignition and burning:

Since the elements of fire, fuel, ignition source and air are found in abundance in aircraft operations, a fire may result whenever the controlled separation of these elements is disturbed. Aviation fuel, either kerosene or gasoline, is the most prevalent combustible aboard an aircraft and, consequently, is the most likely to be involved in a crash fire. However, oil, hydraulic fluid, de-icing fluid, tires, magnesium components, cargo and baggage are other combustibles commonly present; ignition of these combustibles may either precede or succeed the ignition of the fuel.

A crash fire creates an immediate hazard to the aircraft and its occupants normally only when the aircraft fuel is spilled by rupture of fuel tanks or lines. These ruptures may occur as a result of:

Contact of the lines or tanks with a fixed obstacle.

Contact of the lines or tanks with a detached or displaced aircraft component.

Relative motion between aircraft components caused by impact loads.

Dynamic acceleration forces which generate internal loadings.

In addition, once a fire has started, whether it involves the fuel or another combustible, the lines or tanks may be ruptured as a result of fire exposure.

Most occurrences which produce fuel spillage will take place when the aircraft is in motion. Pressure and viscosity forces of the air tend to break up spilled liquid fuel into droplets or a fine mist. These droplets can move forward and spanwise from the source and will coalesce and drop down when they intercept a portion of the aircraft. As the aircraft slows down, the droplets increase in size, becoming a solid stream as the plane stops.

The droplets, mist and liquid fuel will wet the ground along the wake of the source; this wetting will deepen and broaden to the position where the aircraft comes to rest. The fuel which wets the ground in the wake of the aircraft will normally be a very thin layer. If ignited, it will burn away rapidly; if not ignited it may evaporate or soak into the ground quickly.

If the fuel mist is ignited, a large rapidly enveloping fire will result, which often leads observers to believe that the airplane exploded. However, this mist fire rises away from the aircraft and burns out in 15 to 20 seconds. The mist fire, although extremely spectacular, does not present a direct hazard to the aircraft or the occupants inside the aircraft (9). However, this mist fire will ignite liquid

fuel spilled on the ground, spilling from tanks, or on wetted surfaces. The intensity of the mist fire and its ignition capability are independent of fuel volatility, within the range used in aircraft.

If the mist fire does not occur, the spilled liquid fuel may be ignited by any of the numberous ignition sources present in an aircraft crash. If the spilled fuel is above its flashpoint, the fire will then propagate through the vapor-air mixture over the surface of the fuel at a rate of 700 to 800 ft./min. Both aviation gasoline and JP-4 have flashpoints well below zero, and in almost all accidents the fire may spread in this manner. However, kerosene and JP-5 fuels, with flashpoints of 110 and 140°F respectively, will frequently be below their flashpoints when spilled. The ignition source must then heat the liquid sufficiently to evaporate some liquid and then ignite the resultant vapor-air mixture. Once ignited, the flame heats adjacent layers of the liquid fuel and increases its evaporation rate so as to produce a combustible fuel-air mixture above the surface of the fuel. In this manner, the flame propogates slowly over the fuel surface at a rate of only 30 to 40 ft./min. When the temperature of a spilled fuel approaches its flashpoint, the rate of flame propagation over the liquid surface increases rapidly to a limiting value of about 740 ft./min. at a liquid temperature above the flashpoint. With high flashpoint fuels the flamespread can be slow, and it is much more sensitive to wind conditions.

Under some combinations of wind and temperature, the flame may not be able to propagate over the surface of high flashpoint fuels. However, whenever a fuel mist if formed and ignited, as is common in aircraft accidents, the flamespread is completely independent of the fuel volatility.

Once the fire is ignited, radiant heat from the fire plume warms and evaporates the liquid fuel in the pool. The vaporized fuel and air diffuse into the combustion zone above the surface of the liquid pool, where the burning reaction occurs. Gasoline will almost immediately attain a combustion rate of 0.15 in. of liquid depth per minute; kerosene fuels will burn more slowly at first but will reach a combustion rate of 0.13 in./min. in a period of two to three minutes. The temperatures of the plume ranges from about 1100°F at the edge to 1500-2000°F in the center; intermittent peak temperatures as high as 2200°F may occur (16). The height of the plume will be 1.5 to 2.0 times the diameter of the fire (17). The combustion gases and incandescent carbon particles in the plume will generate a radiant heat flux of 32,000 to 36,000 Btu/hr-ft^2. Radiation of the plume warms the surface of the liquid fuel; the surface temperature of burning kerosene will reach approximately 240°F.

The basic stages of a crash fire consist of:

1. An enveloping mist fire which occurs under the previously discussed conditions and persists for 15 - 20 seconds.
2. A residual fire involving spilled or/and spilling fuel which gradually increases in intensity. This developing fire may ignite other combustibles such as magnesium components, tires, oil, hydraulic flued (sic), cargo, etc.
3. In about 2 to 5 min. the developing fire reaches a level of maximum intensity.
4. The maximum intensity fire gradually decreases when the spilling fuel and spilled fuel is exhausted. This may not occur for a considerable time and may be quite slow.

The development of the fire may be accelerated or its maximum intensity may be increased by vapor-air explosions in confined spaces or by the sudden overpressure failure of the tankage under fire exposure. Interior aircraft fires may be increased in intensity by the relieving of oxygen cylinders.

An aircraft crash fire is primarily a two-dimensional spill fire. However, spilling fuel, fuel on aircraft structures, burning of other combustibles will add a third dimension to a portion of the fire. In addition, when fire is present inside compartments such as the fuselage, nacelles, wheel wells, etc., a three-dimensional interior fire will also exist. The dimensions of a crash fire are defined by the area in which significant quantities of liquid fuel have spilled or are spilling. The fuel that spilled in the wake of the aircraft or that flows some distance from the spillage source generally burns away quite quickly and does not create an exposure hazard or extinguishing problem. The area in which the fuel is spilled will depend on the sources of spillage and on the terrain at the crash site. If a crash occurs on an upslope, the fuel will flow down, enveloping the aft fuselage in the fire, while if it occurs on a downslope, the forward fuselage will be enveloped in a fire.

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Appendix G

TWO FOREIGN ACCIDENTS OF INTEREST

A study of foreign air carrier accidents, even on U.S. territory, is beyond the scope of this project. However, two accidents on foreign carriers outside the U.S. are interesting inflight aircraft fire accidents and are discussed here to illustrate a situation which can occur.

1. BOAC 707 Near Heathrow

On April 8, 1968, a BOAC 707-465 with 127 persons aboard (11 crew members and 116 passengers) was in the initial climb phase of takeoff when the number two engine experienced a mechanical fatigue failure of a fifth stage compressor wheel. The engine cowling separated, a fire occurred, and the aircraft began to return to the airport for an emergency landing. While the engine fire drill was carried out, the fuel shut-off valve was not closed. Fuel leaked into the jet efflux and the left wing fuel tank exploded. Either the engine extinguishing system was not used, or it was ineffective because of the missing cowling. During approach to the airport the engine fell off. Five people (one crew member and four passengers) succumbed to heat and smoke (suffocation); 38 passengers received nonfatal injuries (severity not noted). The aircraft was considered destroyed. In this case, an engine fire got out of control because the fuel shut-off was not closed after the main fuel feed pipe became disconnected, with fatalities due to the resulting fire.

2. Varig 707 Near Paris

On July 11, 1973, a Varig 707 with 134 persons aboard (17 crew members and 117 passengers) was in flight when a fire broke out in a rear lavatory. Two stewards tried to fight it unsuccessfully with fire extinguishers, and the fire spread rapidly due to the presence of plastics, forcing the

pilot to land while in the glide path, six miles from the airport. The steward said that, since he was sick from smoke, when the aircraft came to rest he was too weak to open the emergency door. He leaned against it and it opened, but it closed partially after he fell out. Rescue services had to search for the plane and arrived 16 minutes after the crash. They got the fire under control in five minutes and extinguished in 10 minutes. One passenger and nine crew members were rescued alive. Two crew members were uninjured and escaped unaided, but six crew members and 116 passengers succumbed to the effects of the fire. There apparently was no fuel fire and no metal fire; only the intense cabin fire contributed to the melting of the fuselage. Passengers died in flight due to asphyxiation, and only those who sought refuge in the cockpit survived.

The accident is still being studied and litigation is underway.

Appendix H

ESTIMATED DAMAGE COSTS IN FIRE-RELATED ACCIDENTS

Tables H-1 and H-2 give the estimated damage costs and several other factors for destroyed and substantially damaged turbine powered aircraft in fire-related accidents.

Note: Table H-2 includes the some engine and wheel nacelle accidents. Tables H-1 and H-2 exclude some foreign manufactured aircraft and other older turboprop aircraft for which cost data was not available.

Table H-1

Destroyed Turbine Powered Aircraft
U.S. Air Carrier--Fire-Related Accidents

Airline	Fire Phase	Date	Fatalities	Serious Injuries	Minor or No Injuries	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1963								
Pan Am	F	12- 8-63	81			81	707-121	$ 6,557*
Continental	AI	1-29-63	8			8	Vickers Viscount 812 Turboprop	1,000
Northwest	AI	2-12-63	43			43	720B	5,779*
1963 TOTALS			132			132		$ 13,336
1964								
United	F	7- 9-64	39			39	V745D	$ 1,000*
Pacific	AI	5- 7-64	44			44	F-27	247*
Bonanza	AI	11-15-64	29			29	F-27	247*
TWA	AI	11-23-64	48	11	14	73	707-331	8,660
1964 TOTALS			160	11	14	185		$ 10,154
1965								
United	AI	8-16-65	30			30	727-22	$ 2,006*
American	AI	11- 8-65	58	4		62	727-23	2,006
United	AI	11-11-65	43	35	13	91	727-22	2,006
Pan Am	AI	9-17-65	30			30	707 121B	5,142*
TWA (Ferry)	AI	9-13-65			4	4	CV-880	2,444
1965 TOTALS			161	39	17	217		$ 13,604

Table H-1(Continued)

Airline	Fire Phase	Date	Fatalities	Serious Injuries	Minor or No Injuries	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1966								
Braniff	F	8- 6-66	42			42	BAC 1-11/203 (2 eng. turbojet)	$ 1,403*
West Coast	AI	10- 1-66	18			18	DC9-10	1,362*
American Flyers	AI	4-22-66	83	15		98	L188C	1,000
Pan Am (Cargo)	AI	11-15-66	3	—		3	B727-21	2,006*
1966 TOTALS			146	15		161		$ 5,771
1967								
Mohawk	F	6-23-67	34			34	BAC 1-11	$ 1,400*
West Coast	AI	3-10-67	4			4	F-27	247*
Piedmont	AI	7-19-67	82			79	727-22	2,006*
TWA	AI	11- 6-67	1	1	34	36	707-131	6,557
TWA	AI	11-20-67	70	12		82	CV-880	2,444*
TWA	AI	3- 9-67	25			25	DC-9	1,362*
Delta (Ferry)	AI	3-30-67	6	—	—	6	DC-8-51	9,853*
1967 TOTALS			222	13	34	266		$ 23,869
1968								
Braniff	F	5- 3-68	85			85	Electra L188 (4 eng. turboprop)	$ 1,000*
Piedmont	AI	8-10-68	35	3		37	FH-227B	1,252*
Allegheny	AI	12-24-68	20	12	15	47	CV-580	692*
Northeast	AI	10-25-68	32	8	2	42	FH-227C	1,300
Pan Am		6-13-68	6		66	72	B707	6,557
United (Cargo)	AI	3-21-68		1	2	3	B727-220C	2,006
Pan Am (Cargo)	AI	12-26-68	3			3	B707-321C	8,660*
Capitol (Ferry)	AI	4-28-68	—	2	2	4	DC-8	9,853
1968 TOTALS			181	25	87	293		$ 31,320

Table H-1 (Continued)

Airline	Fire Phase	Date	Fatalities	Serious Injuries	Minor or No Injuries	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1969								
Mohawk	AI	11-19-69	14			14	FH227B	$ 1,252*
TWA(Training)	AI	7-26-69	5			5	707-331C	8,660*
Sea World (Training)	AI	10-16-69	—			5	DC8-63F	10,360
1969 TOTALS			19			24		$ 20,272
1970								
Southern	AI	11-14-70	75			75	DC9-31	$ 4,165*
Capitol Int.	AI	11-27-70	47	49	133	229	DC-8-63F	10,360
Trans Caribbean	AI	12-28-70	2	11	9	55	727-200	6,316
TWA (Cargo)	AI	11-30-70			3	3	707	6,842
Trans Int. (Ferry)	AI	9- 8-70	11			11	DC-8-63F	10,360*
Mod Air Trans (Ferry)	AI	8- 8-70	—	8	—	8	CV 990	2,444
1970 TOTALS			135	68	145	381		$ 40,487
1971								
Hughes Air West	AI	6- 6-71	49			49	DC9-31	$ 4,165*
Allegheny	AI	6- 7-71	28		1	31	CV 580 Turboprop	692
Alaska Airlines	AI	9- 4-71	111			111	727-193	5,448*
Pan Am (Cargo)	AI	7-25-71	4			4	B707-321C	8,660
Western (Ferry)	AI	3-31-71	5		—	5	B720-047B	5,779*
1971 TOTALS			197		1	200		$ 24,744

Table H-1 (Concluded)

Airline	Fire Phase	Date	Fatalities	Serious Injuries	Minor or No Injuries	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1972								
North Central	AI	12-20-72	10	9	26	45	DC-9-31	$ 4,165
Eastern	AI	12-29-72	99	60	17	176	L1011-385-1	15,786*
North Central	AI	6-29-72	5			5	CV 580	692*
United	AI	12- 8-72	45	17		62	737-222	3,462
Delta (Ferry)	AI	5-30-72	4			4	DC-9	4,165
Eastern	AI	5-18-72		3	7	10		1,000
1972 TOTALS			163	89	50	302		$ 29,270
1973								
Pan Am (Cargo)	F	11- 3-73	3			3	707-321C	$ 8,660*
Ozark	AI	7-23-73	38	6		44	FH227B	1,091*
Delta	AI	7-31-73	88	1		89	DC-9-31	4,165*
Texas Int.	AI	9-27-73	11			11	CV 600	581*
Pan Am	F	7-22-73	79			79	707	8,660
World Airways(Cargo)	AI	9- 8-73	6	—		6	DC-8-63F	10,360*
1973 TOTALS			225		7	232		$ 33,517
1974								
TWA	AI	1-16-74		3	5	5	707-131B	$ 1,000
Pan Am	AI	1-30-74	96	5	—	101	707-321B	8,660
1974 TOTALS			96	8	5	106		$ 9,660
				Total Cost of Destroyed Aircraft ($000)				$256,004
				Cost of Destroyed Impact Non-Survivable Aircraft Included Above ($000)				$135,829

Note: 1974 totals are preliminary
* Indicates impact non-survivable
Fire Phase Key: F = Inflight; AI = After Impact

Table H-2

Substantially Damaged Turbine Powered Aircraft
U.S. Air Carrier--Fire Related Accidents
(Including Engine/Wheel Nacelle Fires)

Airline	Fire Phase	Date	Fatalities	Serious Injury	Minor/ None	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1963								
Eastern	AI	8-21-63			28	28	DC8	$ 1,500
Eastern	F	11- 6-63			38	38	720	1,000
Eastern	F	12-12-63			16	16	720	1,000
1963 TOTALS					82	82		$3,500
1964								
American	AI	7- 1-64			3	12	720	$ 1,000
TWA	AI	8-26-64			138	138	707-331C	2,000
1964 TOTALS					141	150		$ 3,000
1965								
National	AI	6- 9-65			77	77	DC8	$ 800
Pan Am	AI	3-26-65			170	170	B707-321	1,000
1965 TOTALS					247	247		$ 1,800
1966								
Braniff	AI	2-13-66				127	B720	$ 700
1966 TOTALS								$ 700

Table H-2 (Continued)

Airline	Fire Phase	Date	Fatalities	Serious Injury	Minor/ None	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1967								
Caribbean Atlantic	AI	4-25-67				57	Convair 640D	$ 200
United	G	6-26-67		1	32	33	Viscount 745D	60
Caribbean Atlantic	AI	1-23-67			28	28	CV640	300
Pan Am	G	9- 9-67		2	172	174	707	1,500
No. Cons. Airline	AI	6-26-67			2	2	PC6A	200
Delta		6-24-67		—	59	59	CV880	100
1967 TOTALS				3	293	353		$ 2,360
1968								
North Central	AI	6-24-68			22	22	CV580	$ 300
Flying Tiger	G	8- 5-68				3	707	900
American	F	11-19-68			38	38	B707	900
1968 TOTALS					60	63		$ 2,100
1969								
Pan Am	G	2- 9-69		2	114	116	727	$ 800
Eastern	G	11-28-69			123	123	DC8	150
1969 TOTALS					237	239		$ 950

Table H-2 (Continued)

Airline	Fire Phase	Date	Fatalities	Serious Injury	Minor/ None	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1970								
Braniff	AI	9-29-70				56	720-027	$ 80
Western	F	3-28-70			27	27	720B	100
Delta		5-18-70			3	3	GA382	100
1970 TOTALS					30	86		$ 280
1971								
Aloha	G	8- 8-71				72	V745D Viscount	$ 20
Saturn	AI	3-18-71			4	4	GA382B	500
United		11-17-71			36	36	727	300
1971 TOTALS					36	108		$ 820
1972								
Delta	G	3-19-72				87	DC9-32	$ 1,000
Eastern	G	5-10-72				4	DC9-31 Stretch	6,000
Texas Intl.		2-16-72			3	3	CV600	100
1972 TOTALS					3	94		$ 7,100

Table H-2(Concluded)

Airline	Fire Phase	Date	Fatalities	Serious Injury	Minor/ None	Total Aboard	Aircraft Model	Estimated Damage Cost ($000)
1973								
Eastern	AI	12-17-73			1	89	DC9-31	$ 1,000
Delta	AI	11-27-73		3	39	79	DC9-32	2,000
Piedmont	AI	10-28-73			5	96	737-200	1,000
Braniff	F	8- 8-73			81	81	727	1,000
American	AI	3- 5-73			3	3	B707	2,000
1973 TOTALS				3	129	348		$ 7,000
					Total Cost of Substantially Damaged Aircraft ($000)			$29,610

Key: G=Ground; F=Flight; AI=After Impact

Appendix I

CAB REPORT ON LEVELS OF RECOVERIES ON ACCOUNT OF PASSENGER DEATHS (Accidents Occurring in Calendar Years 1960 through 1969)

Compiled by the Office of the General Counsel, in cooperation with the Data Processing Division, Bureau of Accounts and Statistics, Civil Aeronautics Board, from responses by U.S. certificated air carriers to a CAB Questionnaire (CAB Form T-109), circulated May 14, 1970.

SUMMARY

This report sets forth detailed information on financial recoveries by settlement or court judgment for passenger deaths and serious injuries arising from accidents occurring during U.S. air carrier operations during the period 1960 through 1969. It presents in tabular form the data compiled from responses from certificated U.S. air carriers to a questionnaire circulated by the Civil Aeronautics Board on May 14, 1970.

The tables indicate a striking increase in the level of individual recoveries in death cases settled between January 1968 and June 1970. The average level of recovery in domestic accidents, for example, has more than doubled, from below $90,000 before 1968 to nearly $200,000 in the first six months of 1970. The tables also indicate that the average time between accident and settlement for recoveries at various levels from $100,000 to $500,000 is running between 4 and 6 years.

SURVEY

The Civil Aeronautics Board requested all U.S. certificated carriers to furnish for each death or serious injury arising out of each accident occurring during the covered period,[1/] in addition to other information,

1/ The requests were based on reports of accidents furnished to the National Transportation Safety Board.

the amount,[2] and date of settlement,[3] if any, and the classification by nature of claim (non-Warsaw death, Warsaw death, non-Warsaw serious injury, Warsaw serious injury)[4] with respect to each claim. Responses were received from 33 carriers, providing information sufficient for compilation with respect to 166 accidents,[5] including 1186 recoveries for non-Warsaw deaths; 223 for Warsaw deaths; 200 for non-Warsaw serious injuries; and 25 for Warsaw serious injuries.[6] The responses further show pending

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2/ The amount requested was the gross amount paid; no adjustment has been made, and no information is available, as to the net recoveries by claimants.

3/ The term "settlement" as used herein refers to all recoveries whether by settlement or judgment.

4/ Warsaw claims include all claims arising out of international transportation subject to the Warsaw Convention (49 Stat. 3000; T.S. 876) whether or not the limit of liability provided therein was applied. With respect to passenger deaths or injuries the Convention provides for a liability limit of $8,300. However, since May 1966, the so-called "Montreal Interim Agreement" among carriers has provided a liability limit under the Warsaw Convention, for transportation to and from the U.S., of $75,000, with absolute liability (CAB Agreement 18900, approved by Board Order E-23680, May 13, 1966). Because Warsaw claims are subject to a liability limit and a different liability system, they have been compiled separately from claims not subject to the Warsaw Convention.

5/ No responses were received with respect to 13 accidents, involving 162 deaths and 29 serious injuries (including 2 accidents involving 78 and 41 deaths, respectively). In addition, responses with respect to 15 accidents, involving no deaths and 20 serious injuries, stated that data with respect to such accidents could not be obtained.

6/ The carrier responses included partial information, insufficient for compilation (except for the compilation included as paragraph 3 of the Appendix) with respect to 66 non-Warsaw death settlements; 75 Warsaw death settlements; 37 non-Warsaw serious injury settlements; and 24 Warsaw serious injury settlements. Twenty of these settlements represent a single recovery for more than one member of a family. The latter settlements have not been included in any compilation, but are separately compiled in paragraph 1 of the Appendix to this report.

unsettled claims as follows: 433 non-Warsaw deaths; 87 Warsaw deaths; 97 non-Warsaw serious injuries; and 16 Warsaw serious injuries.7/ The attached tables present pertinent compilations of the data received.8/

EXPLANATION OF TABLES

Tables I(A) through I(D) set forth the level of recoveries for non-Warsaw deaths, Warsaw deaths, non-Warsaw serious injuries, and Warsaw serious injuries, respectively, compiled on the basis of year of settlement for the period 1966 through 1970.9/ The total number and the percentage of settlements which exceed the stated levels of recovery are set forth. For example,

7/ A breakdown of pending claims by accident year and nature of claim is set forth in paragraph 2 of the Appendix.

8/ For purposes of comparison, paragraph 3 of the Appendix contains a compilation of the data on a ten-year basis in the form published by the ICAO Air Transport Committee from responses to State letter S 18/10-68/27, March 20, 1968, in AT-WP/1007, Revised 2/7/69, "Economic Information Relating to the Warsaw/Hague Liability Limits." (Reprinted in Volume I, Reports and Documentation, Subcommittee of the Legal Committee on Revision of the Warsaw Convention as amended by the Hague Protocol, 18-29 November 1960 and 2-19 September 1969, Doc. 8839-LC/158-1, at page 48.)

9/ The settlement year 1970 includes settlements made during the first six months of that year. The data reported for settlements made in the period 1960-1965 did not include settlements relating to accidents occurring prior to 1960. Because from 5% to 50% of settlements, depending upon the level of settlement, take six or more years to settle (see Time Elapsed Table III(A)), settlement data relating to settlement years 1960-1965 would be incomplete, and therefore have not been included.

Table I(A) indicates that in 1966 18.3% of the settlements were at a level over $150,000. In the first half of 1970, 58.1% of the settlements were over this level.

Table II shows the average of recoveries of the four categories (Warsaw and non-Warsaw, deaths and serious injuries) for the settlement years 1966 through 1970.[10/]

Tables III(A) and (B) provide a compilation, by number of years, of the time elapsed between the date of accident and the date of settlement, with respect to non-Warsaw death recoveries at various levels. Specifically, Table III(A) sets forth the percentage of such claims settled within the number of years stated, with respect to each recovery level category. Table III(B) sets forth essentially the same information, however, compiled on the basis of all claims exceeding the recovery levels of $100,000, $200,000, $300,000, and $500,000, respectively. In addition, Table III(B) includes an average elapsed settlement time for all such claims above these levels within the covered period. These Tables are based on recoveries relating to accidents occurring during the years 1960 through 1963.[11/]

10/ Earlier years have not been included for the reasons set forth in note 9 above.

11/ Because of the large proportion of claims taking more than 6 years to settle, the compilation does not include settlements relating to accidents in later years.

TABLE I (A)

NON-WARSAW DEATH SETTLEMENTS EXCEEDING STATED AMOUNT
(BY SETTLEMENT YEAR)

Recovery Amount	1966		1967		1968		1969		1970	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	110	95.7	67	96.8	160	100.0	157	99.6	117	100.0
10,000	94	81.8	50	72.2	152	95.3	152	96.4	115	98.2
50,000	47	41.0	24	34.6	69	43.3	98	62.2	86	73.4
75,000	39	34.0	18	25.9	63	39.5	86	54.6	80	68.3
100,000	32	27.9	14	20.1	54	33.9	75	47.6	74	63.2
125,000	28	24.4	13	18.7	48	30.1	69	43.8	70	59.8
150,000	21	18.3	12	17.3	45	28.2	61	38.7	68	58.1
200,000	12	10.5	8	11.5	30	18.8	43	27.3	57	48.7
250,000	5	4.4	3	4.3	20	12.5	31	19.7	42	35.9
300,000	3	2.7	2	2.9	12	7.5	16	10.2	28	23.9
500,000	2	1.8	0	0	1	.6	2	1.3	2	1.7
TOTAL SETTLE-MENTS (619)	115		69		160		158		117	

TABLE I (B)

WARSAW DEATH SETTLEMENTS EXCEEDING STATED AMOUNT
(BY SETTLEMENT YEAR)

Recovery Amount	1966		1967		1968		1969		1970	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	27	100.0	54	100.0	16	100.0	34	100.0	12	100.0
- 10,000	10	37.0	51	94.6	15	94.0	33	97.0	12	100.0
50,000	1	3.7	24	44.6	9	56.4	18	52.9	7	58.3
75,000	1	3.7	15	27.9	6	37.6	14	41.1	3	25.0
100,000	1	3.7	2	3.8	1	6.3	3	8.7	3	25.0
125,000	1	3.7	2	3.8	1	6.3	3	8.7	3	25.0
150,000	0	0	1	1.9	1	6.3	3	8.7	3	25.0
200,000	0	0	0	0	0	0	2	5.8	1	8.3
250,000	0	0	0	0	0	0	0	0	0	0
300,000	0	0	0	0	0	0	0	0	0	0
500,000	0	0	0	0	0	0	0	0	0	0
TOTAL SETTLE-MENTS (143)	27		54		16		34		12	

TABLE I (C)

NON-WARSAW SERIOUS INJURY SETTLEMENTS EXCEEDING STATED AMOUNT
(BY SETTLEMENT YEAR)

Recovery Amount	1966		1967		1968		1969		1970	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	28	90.2	25	92.5	35	92.0	37	78.8	13	92.8
- 10,000	12	38.6	18	66.6	28	73.6	19	40.5	7	49.0
50,000	3	9.6	11	40.7	13	34.2	6	12.8	6	42.8
75,000	3	9.6	8	29.6	9	23.7	3	6.4	4	28.5
100,000	2	6.4	6	22.2	3	7.9	3	6.4	1	7.1
125,000	2	6.4	5	18.5	3	7.9	3	6.4	1	7.1
150,000	2	6.4	3	11.1	3	7.9	2	4.3	1	7.1
200,000	2	6.4	2	7.4	1	2.6	2	4.3	0	0
250,000	2	6.4	0	0	1	2.6	2	4.3	0	0
300,000	1	3.2	0	0	0	0	2	4.3	0	0
500,000	0	0	0	0	0	0	0	0	0	0
TOTAL SETTLE-MENTS (157)	31		27		38		47		14	

TABLE I (D)

WARSAW SERIOUS INJURY SETTLEMENTS EXCEEDING STATED AMOUNT
(BY SETTLEMENT YEAR)

Recovery Amount	1966		1967		1968		1969		1970	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	6	100.0	0	0	1	100.0	3	75.0	1	100.0
10,000	4	66.7	0	0	1	100.0	0	0	0	0
50,000	0	0	0	0	1	100.0	0	0	0	0
75,000	0	0	0	0	1	100.0	0	0	0	0
100,000	0	0	0	0	1	100.0	0	0	0	0
125,000	0	0	0	0	1	100.0	0	0	0	0
150,000	0	0	0	0	1	100.0	0	0	0	0
200,000	0	0	0	0	0	0	0	0	0	0
250,000	0	0	0	0	0	0	0	0	0	0
300,000	0	0	0	0	0	0	0	0	0	0
500,000	0	0	0	0	0	0	0	0	0	0
TOTAL SETTLEMENTS (13)	6		1		1		4		1	

TABLE II

PASSENGER RECOVERIES (INCLUDING BOTH JUDGMENTS AND SETTLEMENTS)

IN WARSAW AND NON-WARSAW CASES - U.S. CARRIERS

SETTLEMENT YEAR	PASSENGER-DEATH NO. OF SETTLEMENTS	PASSENGER-DEATH TOTAL SETTLEMENTS	PASSENGER-DEATH AVERAGE PER DEATH	SERIOUS INJURIES NO. OF SETTLEMENTS	SERIOUS INJURIES TOTAL SETTLEMENTS	SERIOUS INJURIES AVERAGE PER SERIOUS INJURY
			N O N - W A R S A W			
1966	115	$9,775,379	$85,003	31	$956,887	$30,867
1967	69	$4,557,065	$66,044	27	$1,567,004	$58,037
1968	160	$16,829,175	$105,182	38	$1,801,490	$47,407
1969	158	$21,405,179	$135,475	47	$1,668,072	$35,490
1970	117	$22,866,877	$195,443	14	$641,972	$45,855
			W A R S A W			
1966	27	$502,330	$18,604	6	$70,641	$11,773
1967	54	$2,753,837	$50,996	1	$750	$750
1968	16	$1,022,485	$63,905	1	$172,500	$172,500
1969	34	$2,263,133	$66,562	4	$5,724	$1,431
1970	12	$959,078	$79,923	1	$6,000	$6,000

TABLE III (A)

NON-WARSAW DEATH SETTLEMENTS
TIME ELAPSED BETWEEN ACCIDENT AND SETTLEMENT
(BASED ON RECOVERIES FOR ACCIDENTS OCCURRING IN THE PERIOD 1960-1963)

SETTLED A/

RECOVERY AMOUNT	within 6 mos.		within 1 yr.		within 2 yrs.		within 3 yrs.		within 4 yrs.		within 5 yrs.		within 6 yrs.		within 7 yrs.		within 8 yrs.		within 9 yrs.		within 10 yrs.		TOTAL SETTLEMENTS
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
$1000 or less	9	15.2	36	61.0	41	69.4	41	69.4	47	79.6	50	84.7	56	94.9	59	100.0	-	-	-	-	-	-	59
1001-50,000	45	9.3	134	27.7	250	51.7	321	66.4	381	78.8	409	84.6	428	88.6	439	90.8	plus 44	100.0	-	-	-	-	483
50,001-75,000	1	2.5	8	20.5	14	35.8	17	43.5	23	58.9	31	79.4	33	84.6	36	92.3	-	-	-	-	plus 3	100.0	39
75,001-100,000	0	0	2	10.0	6	30.0	12	60.0	16	80.0	16	80.0	18	90.0	19	95.0	plus 1	100.0	-	-	-	-	20
100,001-200,000	1	1.2	2	2.5	13	16.6	24	30.7	52	66.6	61	78.2	69	88.4	75	96.5	plus 1	1/ 97.0	-	-	plus 2	100.0	78
200,001-300,000	0	0	0	0	1	2.6	5	13.1	19	50.0	19	50.0	26	68.4	34	89.4	-	-	plus 1	2/ 85.8	plus 3	100.0	38
300,001-500,000	0	0	0	0	0	0	0	0	2	10.0	3	15.0	10	50.0	18	90.0	-	-	-	-	plus 2	100.0	20
500,001 or above	0	0	0	0	0	0	1	33.3	3	100.0	-	-	-	-	-	-	-	-	-	-	-	-	3
TOTAL	56	7.5	182	24.5	325	43.9	421	56.8	543	73.3	592	80.0	643	86.8	683	92.2	729	98.5	730	98.6	740	100.0	740

A/ Numerical and percentage totals of settlements are cumulative, except as otherwise indicated.
1/ Percentage is based on the total settlements of 1960-1962 accidents only (67) because of the absence of an 8 year period to 1970 with respect to 1963 accidents.
2/ Percentage is based on the total settlements of 1960-1961 accidents only (21) because of the absence of a 9 year period to 1970 with respect to 1962 and 1963 accidents.

TABLE III (B)

NON-WARSAW DEATH SETTLEMENTS
TIME ELAPSED BETWEEN ACCIDENT AND SETTLEMENT
(BASED ON RECOVERIES FOR ACCIDENTS OCCURRING IN THE PERIOD 1960-1963)

RECOVERY AMOUNT	RECOVERIES ABOVE STATED AMOUNTS																						TOTAL SETTLEMENTS	AVERAGE NO. OF YEARS FOR SETTLEMENT
	within 6 mos.		within 1 yr.		within 2 yrs.		within 3 yrs.		within 4 yrs.		within 5 yrs.		within 6 yrs.		within 7 yrs.		within 8 yrs.		within 9 yrs.		within 10 yrs.			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
Above $100,000	1	.7	2	1.4	14	10.0	30	21.5	76	54.5	86	61.6	108	77.4	130	93.2	plus 1	1/ 93.7	-	-	plus 2	100	139	4.2
Above $200,000	0	0	0	0	1	1.6	7	11.4	25	40.9	25	40.9	39	63.9	55	90.1	-	-	plus 1	2/ 88.6	plus 3	100	61	5.4
Above $300,000	0	0	0	0	0	0	1	4.3	5	21.6	6	25.9	13	56.3	21	91	-	-	-	-	plus 2	100	23	6.5
Above $500,000	0	0	0	0	0	0	1	33.3	3	100	-	-	-	-	-	-	-	-	-	-	-	-	3	3.6

1/ Percentage is based on the total cumulative settlements of 1960-1962 accidents only (128) because of the absence of an 8 year period to 1970 with respect to 1963 accidents.

2/ Percentage is based on the total cumulative settlements of 1960-1961 accidents only (44) because of the absence of a 9 year period to 1970 with respect to 1962 and 1963 accidents.

PART III (B)

1. The following 20 settlements represent a single recovery for more than one member of a family and were not included in the compilation.

Recovery Amount	No. of Persons	Accident Year	Settlement Year
Non-Warsaw Deaths			
$600,000	2	1963	1969
495,000	2	1960	1966
367,000	2	1963	1970
350,000	2	1963	1969
275,000	2	1963	1969
170,000	2	1964	1966
150,000	2	1963	1970
95,000	2	1963	1965
76,000	2	1963	1969
75,000	2	1963	1969
68,500	2	1968	1969
65,000	2	1963	1965
65,000	2	1964	1970
50,000	2	1963	1970
10,000	2	1964	1966
Warsaw Deaths			
140,000	2	1964	1968
140,000	2	1964	1968
105,000	2	1964	1969
50,000	3	1968	1970
Warsaw Serious Injuries			
13,925	2	1965	1966

2. The following is a compilation of the 633 pending claims resulting from accidents occurring in the period 1960-1969.

Accident Year	Non-Warsaw Deaths	Warsaw Deaths	Non-Warsaw Serious Injuries	Warsaw Serious Injuries	Total Pending	Total Claims	% Pending
1960	11	0	0	0	11	448	2.4
1961	0	0	0	0	0	136	.0
1962	1	61	0	0	62	301	20.5
1963	0	0	2	0	2	251	.7
1964	10	2	1	0	13	190	6.8
1965	38	2	10	0	50	297	16.8
1966	14	0	4	0	18	75	24.0
1967	135	0	8	0	143	246	58.1
1968	123	19	46	4	192	343	55.9
1969	101	3	26	12	142	182	78.0
TOTAL	433	87	97	16	633	2,469	25.6

3. The following compilation corresponds to the Table published by the ICAO Air Transport Committee in AT-WP/1007, Revised 2/7/69, from State responses to ICAO State letter S 18/10-68/27, March 20, 1968.

PERCENT OF ALL JUDGMENTS AND SETTLEMENTS
FOR DEATHS WITHIN STATED LEVELS - U.S. CARRIERS
(Compilations based on all settlements for deaths or serious injuries for accidents occurring during the period 1960 through 1969.)

	Less than $17,001		$17,001 - $33,000		$33,001 - $50,000		$50,001 - $75,000		$75,001 - $100,000		Above $100,000		Total	
1960-1970	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Deaths														
Non-Warsaw	421	34.1	231	18.7	119	9.6	66	5.3	56	4.5	340	27.5	1233	100.0
Warsaw	106	47.3	33	14.7	23	10.2	20	8.9	32	14.2	10	4.4	224	100.0
Serious Injuries														
Non-Warsaw	134	56.5	29	12.2	22	9.2	16	6.7	16	6.7	20	8.4	237	100.0
Warsaw	33	94.2	1	2.8	0	-	0	-	0	-	1	2.8	35	100.0

Appendix J

LEVELS OF RECOVERIES ON ACCOUNT OF PASSENGER DEATHS AND SERIOUS INJURIES IN AIRPLANE ACCIDENTS--CAB DATA (Calendar Years 1970 through 1974)

NON-WARSAW DEATH SETTLEMENTS EXCEEDING STATED AMOUNTS
(By Settlement Year)

Recovery Amount	1970		1971		1972		1973		1974*	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	112	100	169	99.4	164	99.4	99	100	141	100
10,000	110	98.4	169	99.4	158	95.6	96	96.7	141	100
50,000	69	61.7	107	62.9	107	64.7	52	52.3	126	89.3
75,000	65	58.1	88	51.7	78	47.1	42	42.2	107	75.8
100,000	56	50.1	74	43.5	62	37.4	35	35.1	87	61.6
125,000	53	47.4	49	28.8	51	30.7	31	31.1	74	52.4
150,000	51	45.6	41	24.1	44	26.5	27	27.1	64	45.3
200,000	45	40.2	30	17.7	27	16.2	22	22.1	53	37.5
250,000	33	29.5	25	14.7	22	13.2	19	19.1	45	31.9
300,000	21	18.8	20	11.7	14	8.4	18	18.1	37	26.2
500,000	2	1.8	5	2.9	6	3.6	4	4.0	16	11.3
750,000	0	0	0	0	0	0	2	2.0	5	3.5
1,000,000	0	0	0	0	0	0	1	1.0	0	0
TOTAL SETTLE-MENTS (687)	112		170		165		99		141	

* First six months

WARSAW DEATH SETTLEMENTS EXCEEDING STATED AMOUNTS
(By Settlement Year)

Recovery Amount	1970		1971		1972		1973		1974*	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	17	100	28	93.3	16	100	28	100	13	100
10,000	17	100	28	93.3	16	100	28	100	12	92.3
50,000	8	47.1	6	20.0	3	18.8	22	78.6	8	61.5
75,000	3	17.7	4	13.3	1	6.3	15	53.6	1	7.7
100,000	2	11.8	4	13.3	1	6.3	14	50.0	1	7.7
125,000	2	11.8	3	10	1	6.3	14	50.0	0	0
150,000	2	11.8	3	10	1	6.3	14	50.0	0	0
200,000	1	5.9	0	0	0	0	7	25.0	0	0
250,000	0	0	0	0	0	0	7	25.0	0	0
300,000	0	0	0	0	0	0	7	25.0	0	0
500,000	0	0	0	0	0	0	5	17.9	0	0
750,000	0	0	0	0	0	0	1	3.6	0	0
1,000,000	0	0	0	0	0	0	0	0	0	0
TOTAL SETTLE-MENTS (104)	17		30		16		28		13	

* First six months

NON-WARSAW SERIOUS INJURY SETTLEMENTS EXCEEDING STATED AMOUNTS
(By Settlement Year)

Recovery Amount	1970		1971		1972		1973		1974*	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	32	84.2	37	90.2	24	96.0	32	86.5	75	100
10,000	14	36.8	23	56.0	16	64.0	21	56.7	73	97.3
50,000	9	23.6	5	12.1	6	24.0	7	18.9	51	68.0
75,000	7	18.3	2	4.8	2	8.0	5	13.5	38	50.7
100,000	5	13.0	1	2.4	1	4.0	4	10.8	32	42.7
125,000	4	10.4	1	2.4	1	4.0	3	8.1	29	38.7
150,000	4	10.4	1	2.4	0	0	3	8.1	24	32.0
200,000	3	7.8	1	2.4	0	0	3	8.1	21	28.0
250,000	2	5.2	0	0	0	0	3	8.1	19	25.3
300,000	2	5.2	0	0	0	0	2	5.4	16	21.3
500,000	1	2.6	0	0	0	0	0	0	7	9.3
750,000	1	2.6	0	0	0	0	0	0	1	1.3
1,000,000	0	0	0	0	0	0	0	0	0	0
TOTAL SETTLEMENTS (216)	38		41		25		37		75	

* First six months

WARSAW SERIOUS INJURY SETTLEMENTS EXCEEDING STATED AMOUNTS
(By Settlement Year)

Recovery Amount	1970		1971		1972		1973		1974*	
	No.	%	No.	%	No.	%	No.	%	No.	%
$ 1,000	5	62.5	25	80.6	37	80.4	23	100	22	100
10,000	3	37.5	3	9.6	17	36.9	15	65.0	14	63.5
50,000	0	0	1	3.2	5	10.9	4	17.3	5	22.6
75,000	0	0	0	0	2	4.4	2	8.6	2	9.0
100,000	0	0	0	0	1	2.2	1	4.3	2	9.0
125,000	0	0	0	0	1	2.2	1	4.3	1	4.5
150,000	0	0	0	0	0	0	1	4.3	1	4.5
200,000	0	0	0	0	0	0	0	0	1	4.5
250,000	0	0	0	0	0	0	0	0	1	4.5
300,000	0	0	0	0	0	0	0	0	1	4.5
500,000	0	0	0	0	0	0	0	0	0	0
750,000	0	0	0	0	0	0	0	0	0	0
1,000,000	0	0	0	0	0	0	0	0	0	0
TOTAL SETTLE-MENTS (130)	8		31		46		23		22	

* First six months