07
85/
33

COPY 1

DOT/FAA/CT-85/33

FAA TECHNICAL CENTER
Atlantic City Airport
N.J. 08405

Galley and Overhead Compartment Experiment Results - Full-Scale Transport Controlled Impact Demonstration

FEDERAL AVIATION ADMINISTRATION
MAY 5 1986
LIBRARY
N.J. 08405

Roger M. Lloyd
RMS Technologies, Incorporated
Trevose, Pennsylvania

Dick Johnson
Federal Aviation Administration Technical Center

December 1985

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-85/33	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Galley and Overhead Compartment Experiment Results - Full-Scale Transport Controlled Impact Demonstration		5. Report Date: December 1985
		6. Performing Organization Code
7. Author(s): Roger M. Lloyd, Richard A. Johnson		8. Performing Organization Report No.
9. Performing Organization Name and Address: RMS Technologies, Inc. One Neshaminy Interplex, Suite 306 Trevose, Pennsylvania 19047		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFA03-81-C-00040
12. Sponsoring Agency Name and Address: Federal Aviation Administration Technical Center Atlantic City Airport, NJ. 08405		13. Type of Report and Period Covered: Final June 1981 - December 1985
		14. Sponsoring Agency Code: ACT-300

15. Supplementary Notes

16. Abstract

On December 1, 1984, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA), conducted an air-to-ground impact test demonstration with a remotely piloted transport category airplane. This joint program, identified as the Full-Scale Transport Controlled Impact Demonstration Program (CID), was the culmination of the four years of effort by the two agencies. The main thrust of this effort included activities involved in the development and subsequent demonstration of an antimisting fuel experiment and experiments relating to improvements in cabin fire safety and structural impact protection. This report documents the results of structural experiments associated with two onboard galleys and overhead stowage compartments. During the impact demonstration, both compartments remained in place without spillage of their internal contents, while the post-crash fire resulted in minor galley damage and total destruction to the overhead compartments.

17. Key Words	18. Distribution Statement		
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

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

PREFACE

This report describes the results of onboard galley and overhead stowage compartment experiments that were conducted by RMS Technologies, Inc., as part of a joint Federal Aviation Administration/National Aeronautics and Space Administration transport airplane controlled impact demonstration under FAA Technical Center Contract DTFA03-81-C-00040. The technical monitor for the FAA Technical Center was Mr. Richard Johnson, FAA Transport Program Manager. The contractor's technical monitor was Mr. Roger Lloyd, Program Manager.

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	ix
INTRODUCTION	1
Purpose	1
Design Criteria	1
Studies	2
Controlled Impact Demonstration Experiments	3
Objective	4
EXPERIMENT DESCRIPTION	4
Test Aircraft	4
Instrumentation	5
Data Acquisition System	6
Galley Installation	6
Overhead Compartment Installation	8
CID FLIGHT	8
RESULTS	9
Galley	9
Overhead Compartment	9
CONCLUSION	11
REFERENCES	12
APPENDICES	
A — Laboratory Analysis	
B — Distribution	

LIST OF ILLUSTRATIONS

Figure		Page
1	Planned CID Impact Scenario	13
2	Test Aircraft Floor Plan	13
3	Structural Experiment Instrumentation	14
4	Data Acquisition System	14
5	Experiment Locations	15
6	Galley Upper Attachment Fitting	15
7	Forward Galley Installation	16
8	Aft Galley Instrumentation	16
9	Galley Front Floor Attachment Fitting	17
10	Galley Rear Floor Attachment Fitting	17
11	Galley Loaded With Plates, Trays, Etc.	18
12	Simulated Hazardous Cargo	18
13	Overhead Compartments	19
14	Upper Support Links	19
15	Lower Support Link	20
16	Upper Support and Drag Links	20
17	Strain Gages Upper Support Links	21
18	Strain Gage Lower Support Link	21
19	Overhead Compartment Installation	22
20	Left Wing Impact	22
21	Fuselage Impact	23
22	Impact With the Wing Cutter	23
23	Post-Crash Fire	24
24	Foward Galley Post-Crash	24
25	Floor Displacement At Aft Galley	25

Figure		Page
26	Aft Galley Forward Track Stud	25
27	Aft Galley Aft Track Stud	26
28	Aft Galley China Post-Crash	26
29	Aft Galley China, Trays Post-Crash (Lower)	27
30	Aft Galley China, Trays Post-Crash (Upper)	27
31	Forward Overhead Compartment Post-Crash	28
32	Aft Overhead Compartment Post-Crash	28
33	Support Link Data With Expanded Time Scale	29
34	Overhead Compartment Normal Acceleration	29
35	Overhead Compartment Longitudinal Acceleration	30
36	Overhead Compartment Transverse Acceleration	30
37	Overhead Compartment Upper Support Link Force	31
38	Overhead Compartment Lower Support Link Force	31
39	Normal Accelerations During Ground Impact	32
40	Normal Accelerations During Obstacle Impact	32
41	Longitudinal Accelerations During Ground Impact	33
42	Longitudinal Accelerations During Obstacle Impact	33
43	Transverse Accelerations During Ground Impact	34
44	Transverse Accelerations During Obstacle Impact	34
45	Resultant Accelerations On Overhead Compartment	35
46	Resultant Accelerations On Overhead Compartment	35
47	Lower Support Link Force Comparison With Transverse Acceleration	36

LIST OF TABLES

Table		Page
1	Aircraft Specification	4
2	CID Instrumentation Summary	5
3	Lower Aft Galley Contents	7
4	Lower Forward Galley Contents	7

EXECUTIVE SUMMARY

On December 1, 1984, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA), conducted an air-to-ground impact test demonstration with a remotely piloted transport category airplane. This joint program, identified as the Full-Scale Transport Controlled Impact Demonstration Program (CID), was the culmination of four years of effort by the two agencies. The main thrust of this effort included activities involved in the development and subsequent demonstration of an antimisting fuel experiment and experiments relating to improvements in cabin fire safety and structural impact protection. This report documents the results of structural experiments associated with two onboard galleys and two overhead stowage compartments.

The objective of the CID galley and overhead compartment experiments was to evaluate the effectiveness of transport cabin compartment retention means under severe-survivable impact conditions. An onboard camera and installed strain gage and accelerometer instrumentation were used to monitor the performance of the compartments during the demonstration.

At impact, one of two overhead compartment doors opened. While both the galley and overhead compartment modules remained in place without spillage of their internal contents at impact, post-crash examination revealed that the resulting fuel fire caused minor galley damage and total destruction of the overhead compartments.

INTRODUCTION

On December 1, 1984, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA), conducted an air-to-ground impact test demonstration with a remotely piloted transport airplane. This joint program, identified as the Full-Scale Transport Controlled Impact Demonstration Program (CID), was the culmination of four years of effort by the two agencies. The main thrust of this program included experiments involved in the development and demonstration of non-flammable antimisting fuel. The program also provided for experiments associated with improvements in occupant and cabin equipment restraint system protection. This report covers a description and results of the cabin equipment restraint system experiments as related to the retention of mass items, galleys, and overhead stowage compartments. Results obtained from the other experimental activities are being reported under separate documentation.

PURPOSE

The purpose of the CID galley and overhead compartment experiments was to validate technology that could be used to evaluate cabin restraint system protection on transport airplanes.

Design Criteria

The Code of Federal Regulations Title 14, Chapter I, Part 25.787 specifies that each compartment for the stowage of cargo, baggage, carry-on articles, and equipment must be designed for its placarded maximum weight of contents and for the critical load distribution at the appropriate load factors corresponding to the specified flight and ground loading conditions, and to the emergency landing conditions of Part 25.561(b). The overhead compartments are required to be completely enclosed if there are more than 10 passenger seats. In addition, Part 25.789 specifies that each item of mass (that is a part of the airplane type design) in a passenger compartment or galley must be prevented from becoming a hazard by shifting under the appropriate maximum load factors corresponding to the specified flight and ground loading conditions, and the emergency landing conditions of Part 25.561(b). The ultimate inertia forces acting separately relative to the surrounding structure specified in Part 25.561(b) are: 2.0 G upward, 9.0 G forward, 1.5 G sideward, 4.5 G downward or any lesser force that will not be exceeded when the airplane absorbs the landing loads resulting from impact with an ultimate descent velocity of 5 feet per second at the design landing weight.

Studies

During the early 1980's, several investigative studies were initiated by both the FAA and other Government/industry organizations to determine the adequacy of existing cabin baggage/equipment restraint system designs on transport airplanes. Of particular concern were recent increases in the amount of passenger carry-on baggage and the variance of cabin stowage facilities between airplane models. In addition, there was equal concern with the number of reported failures associated with existing restraint systems and the hazardous effect of unretained mass items relative to occupant injuries and/or evacuation performance during survivable crash occurrences.

In September 1981, the National Transportation Safety Board (NTSB), issued a special study on cabin safety in large transport aircraft (reference 1) which reported overhead panels, racks and passenger service units failed on 77.8 percent of the cases they examined. They found that the basic design or failures of overhead compartments allowed items in them to become missiles during the crash sequence causing injuries to the passengers and impediments to evacuation. This study claimed that components of galley equipment failed in about 62 percent of the cases examined. In almost all cases, food, eating utensils, and waste material were thrown from open storage areas or containers and drawers that did not remain latched. The drawers were often released. The NTSB concluded that since the galleys are usually located near exits, occupant egress could be hindered, and if a major component or the entire galley is displaced, the exit could be partially or completely blocked. Also, the flight attendants are often located near the exits and galley during a crash and therefore were prone to injuries caused by failures, which could be debilitating and seriously compromise the flight attendant's ability to assist passengers during the evacuation of the aircraft.

Several examples of cabin interior restraint system failures were cited in an investigative study by the FAA of crash injury protection in survivable transport accidents (reference 2). There were 30 accidents between 1970 and 1978 in which cabin furnishings failed during survivable impact conditions causing injuries and the blocking of emergency exits. In another contracted industry study of 153 survivable transport accidents between 1959 and 1979, a joint report by the FAA and NASA addressed the dynamic performance of fuselage structure and related cabin restraint systems (reference 3). Cabin interior restraint system failures were involved in 45 of these accident cases. These failures included equipment separation, spillage of contents, evacuation blockage and injury to occupants. The interior

systems were a major factor in 12 cases affecting evacuation. Failures of the overhead storage compartments were known to have caused injuries in 5 accidents and probably in 3 additional cases.

Controlled Impact Demonstration Experiments

The CID experiments addressed under this report represented an outgrowth of the aforementioned FAA/NASA studies. While the demonstration was originally planned as an air-to-ground impact test to demonstrate technology associated with an FAA program involving non-flammable antimisting fuel, it was recognized during early 1981, that additional structural experiments could be accommodated without compromising the performance and results of either of the experimental areas. Therefore, in conjunction with the antimisting fuel demonstration, and as individual structural experiments appropriate to the needs of both the FAA and NASA organizations, a combined fuel and structural safety demonstration was implemented under the CID program (reference 4). As depicted under figure 1, the demonstration represented a severe, survivable air-to-ground impact occurrence in which the dynamic response to the structure and cabin restraint system could be assessed. The selected structural experiments and objectives, including the galley/stowage compartment experiments discussed under his report, are as follows:

a. Structure (fuselage, wing, floor) - Examine structural failure mechanisms and correlate analytical predictions; provide baseline metal crash data to support FAA and NASA composite crash dynamics research; and, define dynamic floor pulse for related seat/restraint system studies.

b. Seat/Restraint System - Evaluate performance of existing, improved, and new lightweight seat concepts; and, evaluate performance of new seat attachment fittings.

c. Galley/Overhead Compartment - Evaluate effectiveness of existing retention means.

d. Analytical Modeling - Verify predicted crash test impact loads and validate FAA "KRASH" and NASA "DYCAST" models for transport aircraft.

e. Flight Data and Cockpit Voice Recorders - Demonstrate/evaluate performance of new FDR/CVR system and demonstrate system usefulness for accident investigation analysis.

f. Flight Incident Recorder/Emergency Locator Transmitter - Demonstrate/evaluate performance of the ejectable type United States Navy/Naval Air Test Center (NATC) systems.

g. Hazardous Materials Package - Demonstrate performance of package designs in an impact environment.

h. Post-Impact Accident Investigation Analysis - Assess adequacy of current NTSB forms and investigation procedures.

OBJECTIVE

The objective of the CID galley and overhead compartment experiements was to evaluate the effectiveness of existing transport cabin compartment retention means under severe, survivable impact conditions.

EXPERIMENT DESCRIPTION

Test Aircraft

The aircraft selected for use in the subject CID program was a Boeing 720 4-engine jet typical of aircraft entering airline service in the mid 1960's. The aircraft (N18066) was purchased new by the FAA in 1960 for use in training the agency's maintenance and operational inspectors. During its FAA career, more than 20,000 hours and over 54,000 takeoffs and landings were logged. A general B-720 aircraft specification list is contained under Table 1.

TABLE 1. AIRCRAFT SPECIFICATION

Length	136.7 Feet
Wing	130.9 Feet
Empty Weight	106,000 Pounds
Maximum Landing Weight	175,000 Pounds
Gross Takeoff Weight	203,000 Pounds
Fuel Capacity	12,189 Gallons
Flight Crew	(3)
Passengers	(124) Normal
	(113) CID Configuration

The test aircraft was delivered to NASA in June 1981 to prepare for the CID program. Interior materials, floor, and side panels were subsequently removed to allow access and the installation of accelerometers, strain gages, and instrumentation/power cabling within the aircraft cabin and fuselage structure. In some areas,

selected side panel and materials were not replaced; i.e., cargo compartment, fuselage ceiling, etc. The galleys, overhead stowage compartments and other onboard experimental systems were installed in the otherwise empty cabin. The flight deck, flight control and avionics systems were modified for the Edwards Air Force Base operations, remote piloted vehicle, and instrumentation needs. In addition, the fuel and propulsion system were modified to support an Antimisting Kerosene (AMK) degrader system, instrumentation, and operations.

Instrumentation

The floor plan of the test aircraft is shown in Figure 2. Instrumentation hardware consisted of two Data Acquisition System (DAS) pallets (located fore and aft), four power pallets, ten cameras, and associated camera lights. In addition to the identified galley and overhead compartment experiments, other onboard experiments included seats and flight data/cockpit voice recorders. Accelerometers and strain gage instrumentation appropriate to these cabin experiments and other fuselage structural experiments are shown in Table 2.

TABLE 2. CID INSTRUMENTATION SUMMARY

Accelerometers

Dummies		52
Seats		75
Structure		178
Overhead Compartments	3	
Wing pylons	4	
Wing other	14	
Floor near seats	43	
Frames	109	
CG	3	
Tail	2	
Total		305

Bending Bridges

Wing	4
Fuselage	8
Total	12

Load Cells

Overhead Compartments	3
Lap Belt	26
Shoulder Harness	4
Total	33

Total channels	350

The structural experiment instrumentation layout of the aircraft is shown in Figure 3. Basically, seven major frames distributed along the length of the fuselage were instrumented from belly to crown to measure load transmission during the impact. The cross-sectional views show the distribution at a particular frame. Eight bending bridges along the fuselage near the major frames were installed to obtain the variation of vertical bending moment during impact. While not shown, the wings and engine pylons were also instrumented per Table 2.

Data Acquisition System

The DAS included two independent systems each capable of collecting and processing data from 180 sensors (Figure 4). The signal conditioning units used in the DAS had 30 channels per unit. There were six of these systems in each DAS for a total of 180 channels of which 176 were used for data and the balance for system monitoring. The signal conditioning units provided the input to the pulse code modulation system (PCM).

The PCM data from each DAS was transferred directly to two onboard 14-channel tape recorders. The PCM data, while being recorded onboard, was being transmitted redundantly air-to-surface via four telemetry transmitting systems and recorded at the ground receiver control station.

Galley Installation

The two experimental galley modules were acquired from a Boeing 720 airplane located at Davis Monthan AFB. These galleys, which were made by the REF Company in Mineola, New York, were used as original equipment in many Boeing 720's, and therefore, were considered appropriate for a demonstration of their crashworthiness performance and content retention. Both galley modules, along with their interfacing structural members, were installed in the test aircraft in the location corresponding to those of the original installation. The forward galley was located at station 382 on the right side of the aircraft just forward of the galley service door. The aft galley was located at station 482 on the right side and just aft of the door (figure 5). An example of the upper attachment fittings is shown in figure 6. There were two upper attachment fittings on each galley located on the outboard top of the galley. They attached to the aircraft structure as shown in figures 7 and 8. The bottom of the galley was attached to the floor track by four studs near the corners of the galley which slid into the track and were held in place by a plate and retaining nut on the inside of the galley (figures 9 and 10).

The forward and aft galleys were loaded to simulate in-service conditions. In the aft galley (forward facing) the above counter section was left empty while the lower individual food service modules were filled with actual trays, dishes, and silverware (no food) as identified under Table 3 (Figure 11). These contents weighed approximately 96.6 pounds. In the forward galley (aft facing), a coffee pot was placed in the above counter heating unit. However, the lower food service module area was not loaded with the normal food service equipment. Instead, the contents included a series of special "hazardous material" packages manufactured by the Lawrence Packing, Eli Lilly, and Dow Chemical companies (Figure 12). These packages are identified under Table 4. The total weight of these packages was approximately 147 pounds. (NOTE: The "hazardous material packages" contained non-hazardous jelled material and represented an experiment to determine the adequacy of such packages in resisting high impact conditions).

TABLE 3 - LOWER AFT GALLEY CONTENTS

Type of Equipment	Gross Weight	Number of Items	Total Wt/lbs.
Food Trays	9 1/4 oz.	41	23.7
Casserole Dishes	8 oz.	101	50.5
Plates	8 oz.	41	20.5
Silverware (Sets)	3 oz.	10	1.9
	TOTAL	193	96.6

TABLE 4 - LOWER FORWARD GALLEY CONTENTS

Type of Packages	Inner Container Size	Outside Dimensions	Gross Weight	Number Packages In Test	Total Wt/lbs.
Dow	Quart	10"x10"x14"	7	3	21
Dow	Pint	9"x 9"x11"	5	3	15
Lawrence	Quart	9"x 9"x13"	8	3	24
Lawrence	Pint	6"x 6"x10"	3	3	9
Exception	Power	13"x13"x 9"	26	3	78
			TOTAL	15	147

Neither of the galley modules was instrumented because of the limited number of channels available in the DAS and because of the higher instrumentation priorities placed upon other experiments. The nearby floor and fuselage structure area were instrumented for the purpose of measuring impact loads and accelerations.

Overhead Compartment Installation

Similar to the galley modules, two enclosed type overhead stowage compartments were acquired from the same Boeing 720 located at Davis-Monthan AFB. The compartments and their structural hardware were installed in the test aircraft at locations corresponding to those of the original installation. This greatly facilitated the installation and allowed a realistic mounting scheme. The compartments were mounted on the right side of the aircraft just aft of the galleys (see figure 13). As shown in figures 14 through 16, the compartments were attached to the airframe by four sets of three support links and two drag links. One set of the support links was strain gaged to measure the forces in the supports during the crash. The stain gaged links are shown in figures 17 and 18.

The forward compartment was instrumented with 3 accelerometers attached to a tri-axial mount. They were mounted in such a way that with the door closed, they aligned with the longitudinal, vertical and transverse axes of the aircraft. The mount was fastened to a 75 pound steel plate which was attached to the door (and acting floor) of the compartment to simulate maximum placarded loading at 2 pounds per inch (see figure 19). The aft bin was similarly loaded with an identical steel plate. However, it was not instrumented due to the shortage of instrumentation channels. In addition to the accelerometer and strain gage instrumentation, the performance of both overhead compartments was monitored during impact by one onboard high-speed camera.

CID FLIGHT

The CID flight was remotely controlled by a ground-based NASA test pilot. The test aircraft was accompanied by a chase aircraft in case an abort landing was required. Two helicopters and an Orion P-3 over the impact area provided photographic coverage along with over 50 ground-based cameras. A final calibration of the instrumentation was performed before takeoff.

On final approach to the impact site, the aircraft had a speed of 152 knots, a sink rate of 17 ft/sec, and a 0 degree pitch attitude. Prior to impact, the aircraft experienced alignment problems which when corrected caused the left outboard engine to touch the ground first, 410 ft. short of the target as shown in figure 20. This initiated a left yawing motion of the aircraft. The forward portion of the fuselage (approximately B.S. 540) then touched down (figure 21) and the aircraft continued to yaw as it slid through the wing openers (figure 22). A fire erupted when a wing opener impacted the right inboard engine. The right wing, having been failed by the obstacles, separated, lifted upward as the aircraft continued to slide (figure 23), then plummeted to

the ground and slid under the fuselage. In the meantime, fuel entered the cargo area of the aircraft through holes left by the wing openers and began burning. Since the crash fire team was concentrating on saving the contents of the cabin, it was not discovered until much later that a major source of the fire was in the cargo area. The main fire damage occurred where the fire burned up through the floor, into the cabin, then out through the roof.

RESULTS

Galley

Both of the galley modules withstood the crash impact forces with no structural damage except for post-impact damage caused by the fire crew when they used fire axes to get to the simulated hazardous material containers. These containers, located in the bottom of the forward galley, started to burn due to the entry of fire from the lower cargo compartment (figure 24). The inboard studs of the aft galley floor attachment became disengaged from the floor track when the floor collapsed due to fire and the weight of the DAS located at about the same station on the other side of the aircraft. Neither the track nor the studs were broken or deformed as may be seen in figures 25 through 27. The studs may not have been adequately tightened or the floor could have shifted enough to allow the studs to disengage from the track. However, both galleys remained attached to the airframe and the supports did not appear to be overly stressed. There were no popped rivets or deformed structures.

Post-test examination of the galley modules also revealed that the interior latching devices and exterior sliding galley restraint doors, performed satisfactorily without loss of interior contents and equipment. The galley interior and container equipment showed evidence of smoke residue due to the fire. Also, minor chips on some of the dishes were noticed. the forward galley performed equally well. Notwithstanding that the hazardous material packages were ignited by the lower cargo compartment fire and that some of the packages were damaged by the fire crew, there appeared to be no evidence of prior impact damage to the forward galley or interior contents (see figures 28 through 30).

Overhead Compartment

A post-crash examination of the onboard high-speed camera film revealed that the forward compartment door remained closed during impact while the aft compartment door opened almost instantaneously. Unfortunately, the cause of the door opening could not be determined because of the fire damage. From the interior movies, it was determined that the overhead compartments

remained in place during the crash and slide out. However, both compartments were found in the lower cargo area severely damaged by fire when the aircraft was entered after the crash. As may be seen in figure 31 and 32, the compartments were heavily damaged by fire. There are some questions about the failures of the support links. The remains of the support links were examined by the metallurgy laboratory at the Naval Air Development Center, Warminster, PA., to determine if the failures were due to the heat from the fire and/or if they could have failed structurally during the crash. The laboratory report is included as Appendix A to this report. The laboratory results concluded that all of the failures were due to the fire. However, there is some evidence indicating that some of the support links may have broken during the initial impact, while not to the extent that would have allowed separation of the compartments.

In figure 33, an identification of the pre and post-impact loads across the upper (channel 348) and the lower (channel 349) instrumented support links are shown. Notwithstanding that the identified loads in the lower link are undetermined due to a drift in the data (cause unknown), the relative variation of loads in the upper link after the crash is about 60 percent greater than before the crash. it is believed that this increase in load as carried by the upper link could have been contributed by failures of one or more of the other support links. (NOTE: Due to a scaling factor error under figure 25 (channels 348 and 349), the exact magnitude of peak loads are not correctly identified. The qualitative assessment of upper link performance was therefore, based upon the relative change in load.) Another indication of possible link failure may be seen by comparing the general forms of the compartment mass accelerations and link load data in figures 34 through 38. In figures 34 through 37, the range of the accelerations or loads are roughly the same before and after the implanted obstacle impact at about 4000 milliseconds. In figure 38, the range is much larger after impact than it was prior to impact. Again, either some links broke or the instrumentation on the lower support links failed at that time. Unfortunately, the fire devastated the area and made absolute determinations impossible.

The peak accelerations obtained from the restrained compartment mass item during both the initial ground impact and subsequent obstacle impact are shown in figures 33 through 38. Figures 39 and 40 depict vertical accelerations during the initial and obstacle impact which peaked at approximately 5 and 9 G's respectively, with each having a duration of 30 - 40 milliseconds. The appropriate longitudinal accelerations are shown in figures 41 and 42 at values of approximately 5 to 6 G's with durations of 60 - 75 milliseconds. Figures 43 and 44 provide transverse accelerations of 9 to 10 G's with duration in

the 50 milliseconds range. Figures 45 and 46 identify the resultant compartment mass accelerations which were analytically derived from the individual accelerometer data. The maximum resultant G measured in the compartment was approximately 11.0 G during the ground impact stage, 10.5 at the implanted obstacle impact and 13.7 G during the slide out over the railroad bed rock.

The stress in the lower support link was almost completely due to transverse accelerations of the overhead compartment. Figure 47 shows the overhead compartment transverse accelerations with the lower support link forces with reverse polarity superimposed. They are an almost perfect match. The upper support link stresses were due to a combination of accelerations and did not display any such direct similarities.

CONCLUSION

Both visual inspection and instrumentation show that neither the air-to-ground impact nor obstacle impact applied sufficient inertia loading to deform and/or fail the experimental galleys and overhead compartments.

Data obtained from these instrumented overhead compartments demonstrates some dynamic capability of current designs. Notwithstanding that the peak accelerations in the 14G range were measured (in excess of the current FAR static inertia load requirement), such accelerations were applied for rather short durations of time and not to the extent that significant damage would have occurred. One of the two overhead compartment doors did open under low level accelerations (as observed from onboard film). However, because both compartments were completely destroyed by fire, a post-crash examination of the door latching mechanism was not possible.

Post-crash examination of the two experimental galleys revealed no structural damage or spillage of the interior contents. The condition of both galleys and their contents indicated that they were exposed to fire but not to the extent of the overhead compartments. The experimental hazardous material containers in the forward galley showed no indication of structural damage caused by the crash impact loads. There was, however, damage caused by the subsequent use of fire axes. The inboard aft galley floor attachment studs became disengaged from the floor track, while neither the studs nor the track were broken or deformed. It was believed that the studs may not have been adequately tightened or that floor deformation (resulting from the fire) could have allowed the studs to pop out.

REFERENCES

1. Special Study - Cabin Safety in Large Transport Aircraft, National Transportation Safety Board, NTSA-AAS-81-2, Sept. 9, 1981.

2. Neri, L.M., Caiafa, C., Chandler, R.F., and Pollard, D.; Crash Injury Protection in Survivable Air Transport Accidents - United States Civil Aircraft Experience from 1970 through 1978 (incomplete), DOT/FAA/CT-82-118, March 1983.

3. Thomas, R.G., and Caiafa, C.; Structural Response of Transport Airports in Crash Situations; DOT/FAA/CT-83/42, November 1983.

4. Full-Scale Transport Controlled Impact Demonstration Program, Management Plan, DOT/FAA/CT-82/151, January 1984.

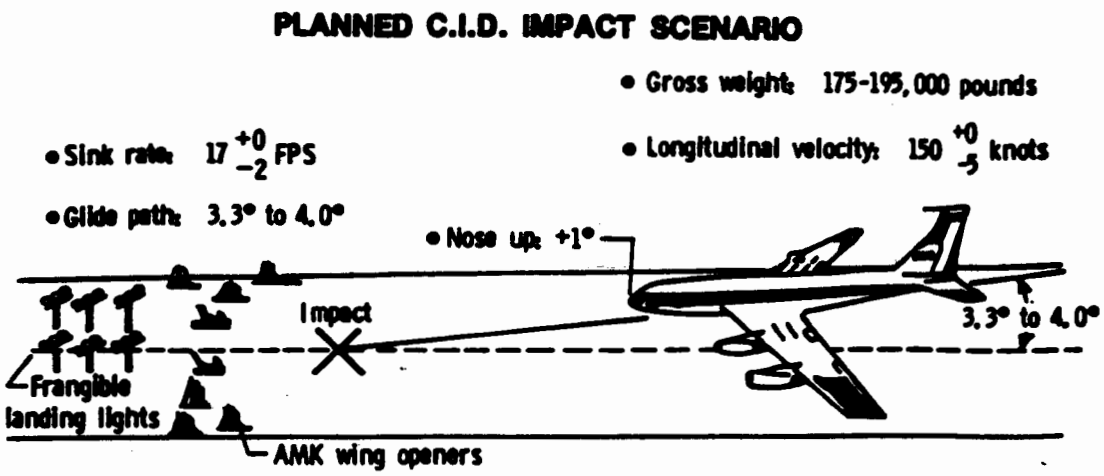


FIGURE 1. PLANNED C.I.D. IMPACT SCENARIO

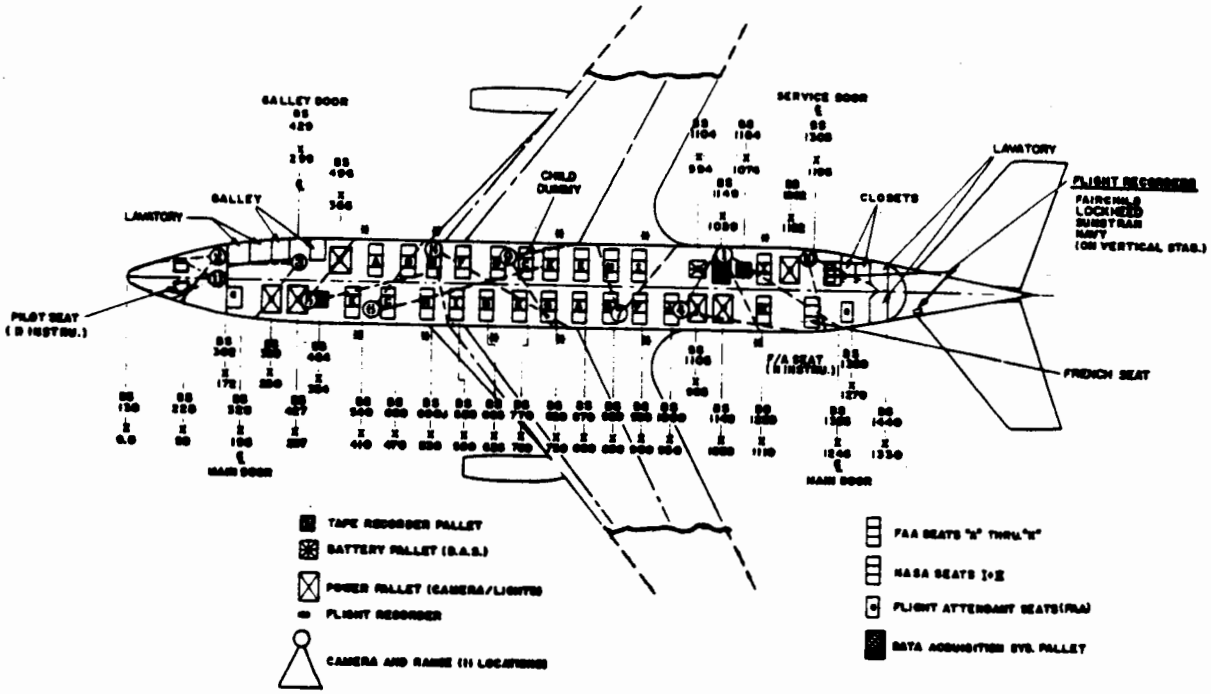


FIGURE 2. TEST AIRCRAFT FLOOR PLAN

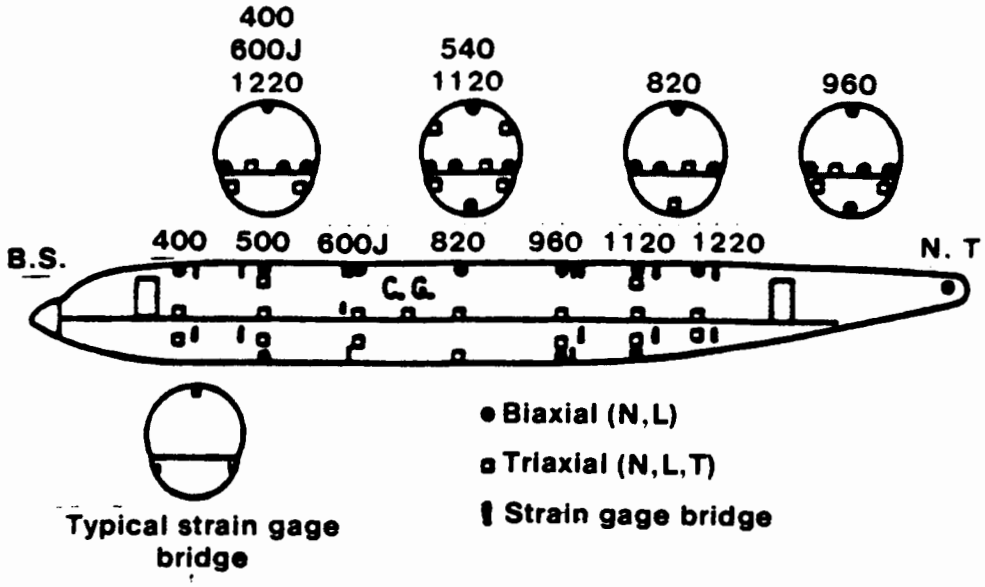


FIGURE 3. STRUCTURAL EXPERIMENT INSTRUMENTATION

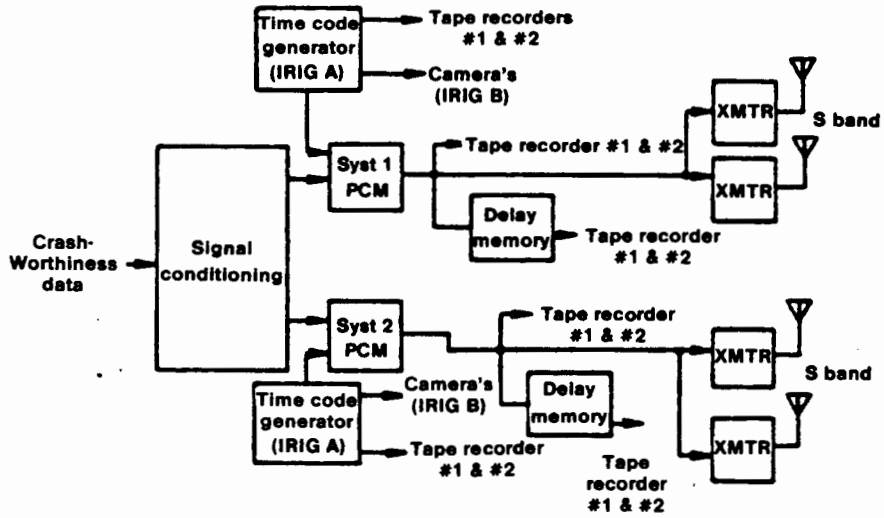


FIGURE 4. DATA ACQUISITION SYSTEM

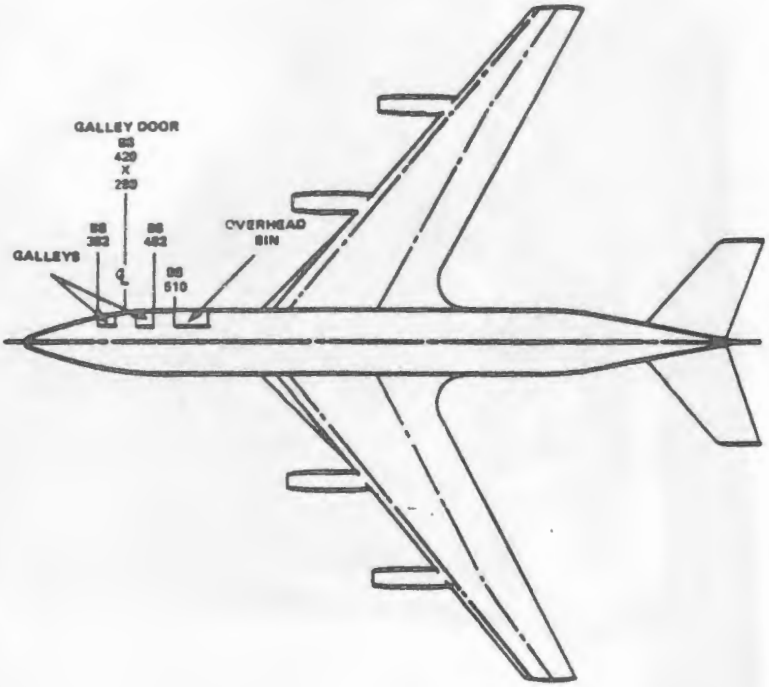


FIGURE 5. EXPERIMENT LOCATIONS

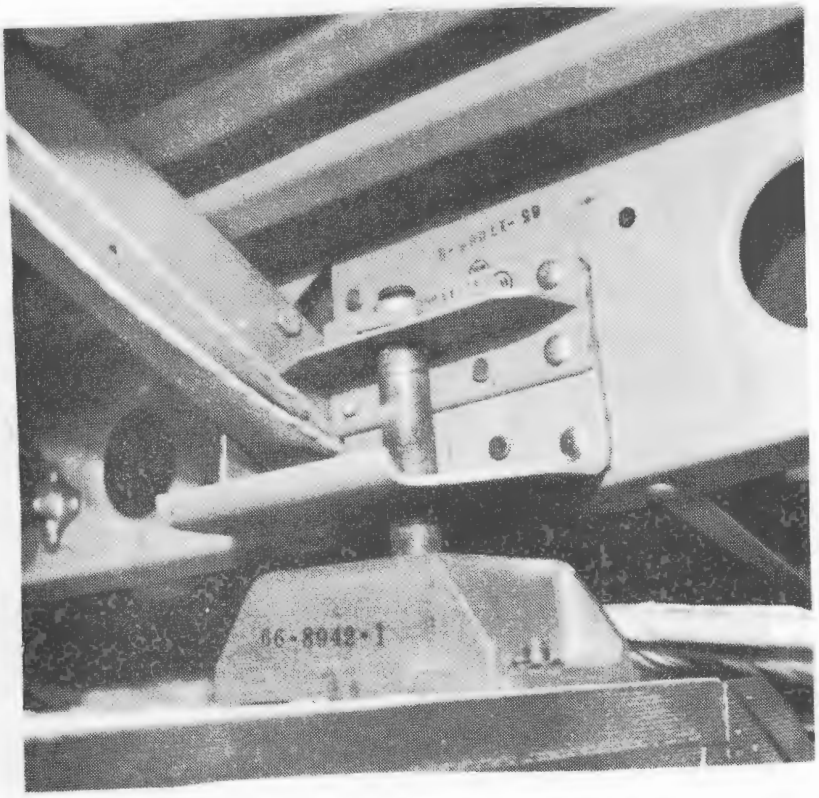


FIGURE 6. GALLEY UPPER ATTACHMENT FITTING

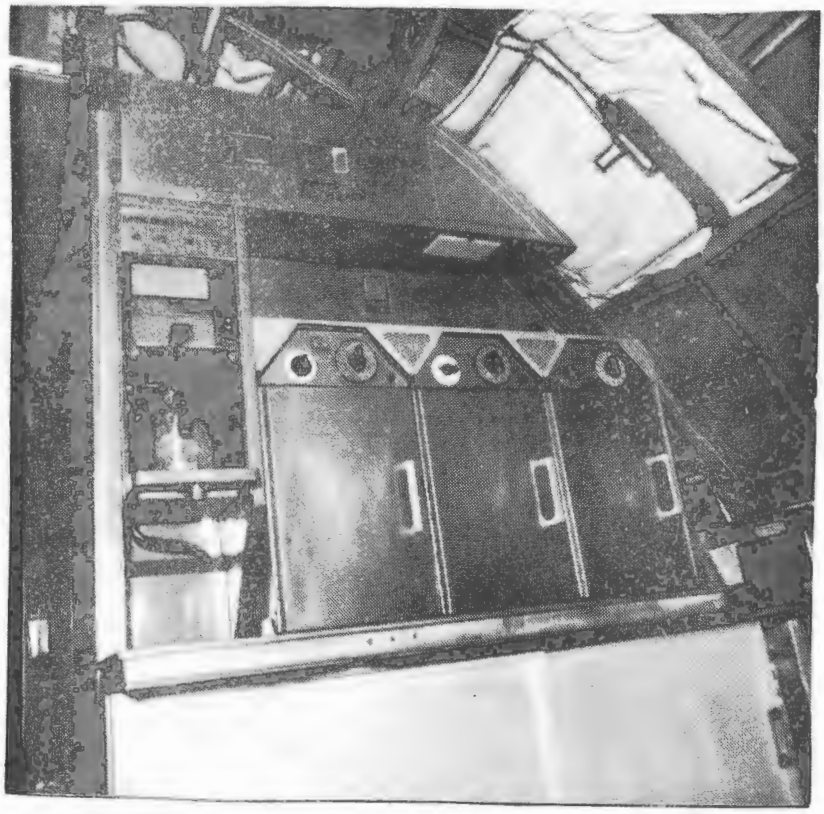


FIGURE 7. FORWARD GALLEY INSTALLATION

FIGURE 8. AFT GALLEY INSTALLATION

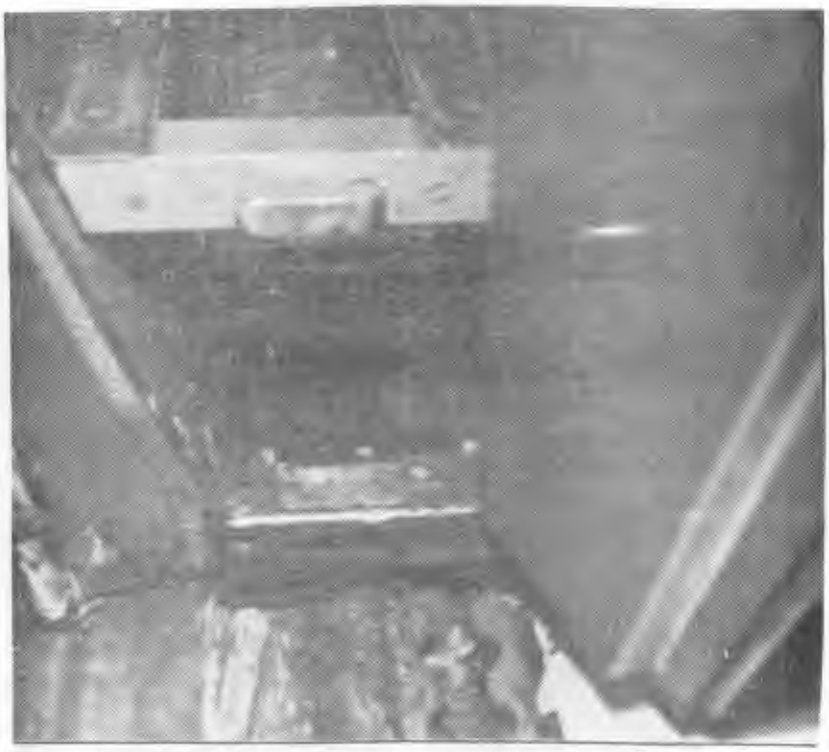


FIGURE 9. GALLEY FRONT FLOOR ATTACHMENT FITTING

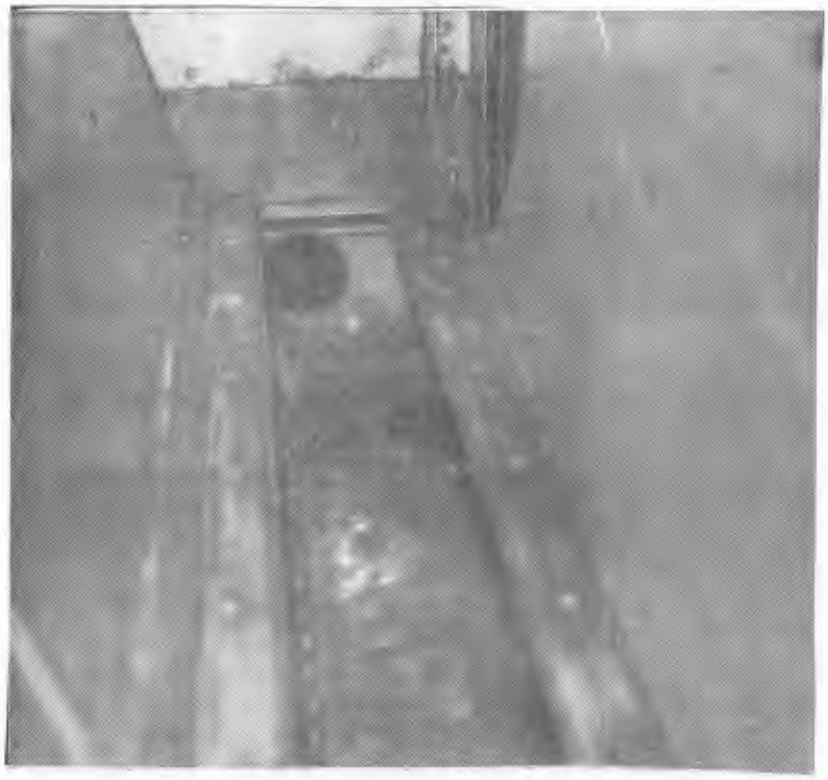


FIGURE 10. GALLEY REAR FLOOR ATTACHMENT FITTING

FIGURE 11. GALLEY LOADED WITH PLATES, TRAYS, ETC.

FIGURE 12. SIMULATED HAZARDOUS CARGO

FIGURE 13. OVERHEAD COMPARTMENTS

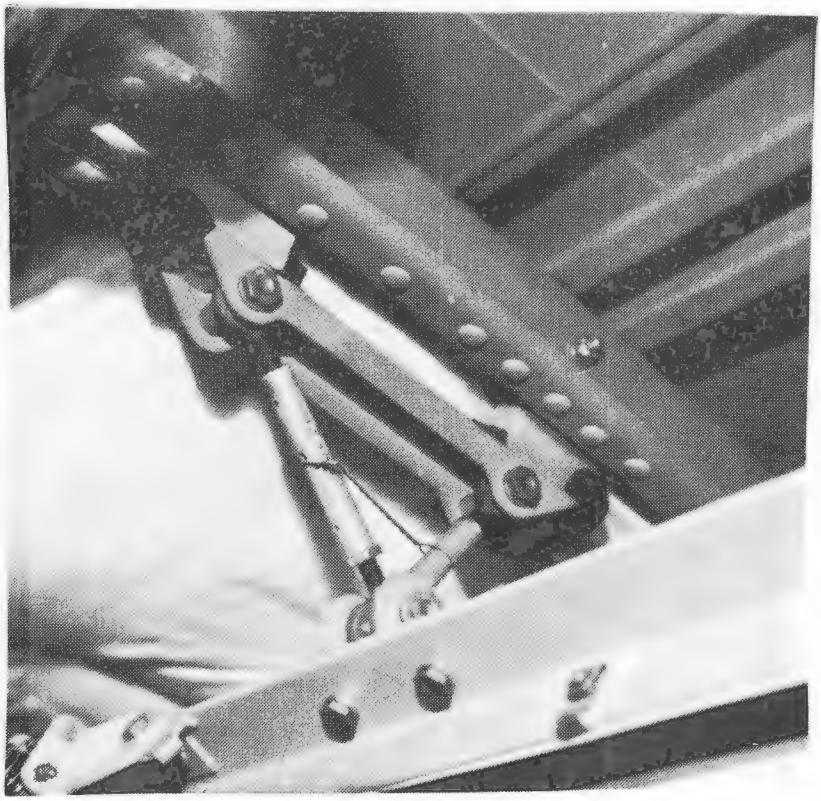


FIGURE 14. UPPER SUPPORT LINKS

FIGURE 15. LOWER SUPPORT LINK

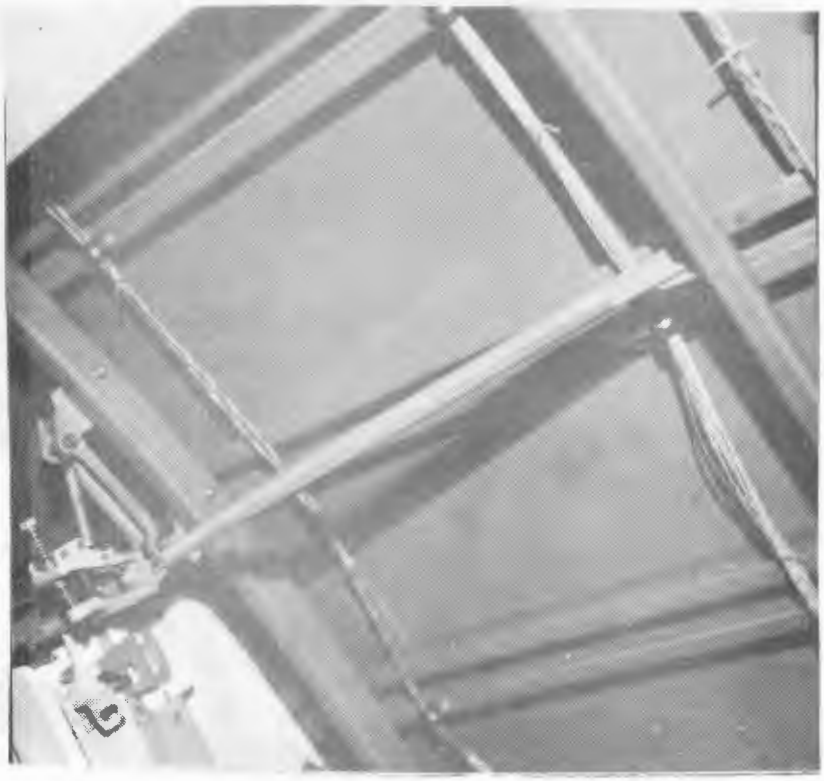


FIGURE 16. UPPER SUPPORT AND DRAG LINKS

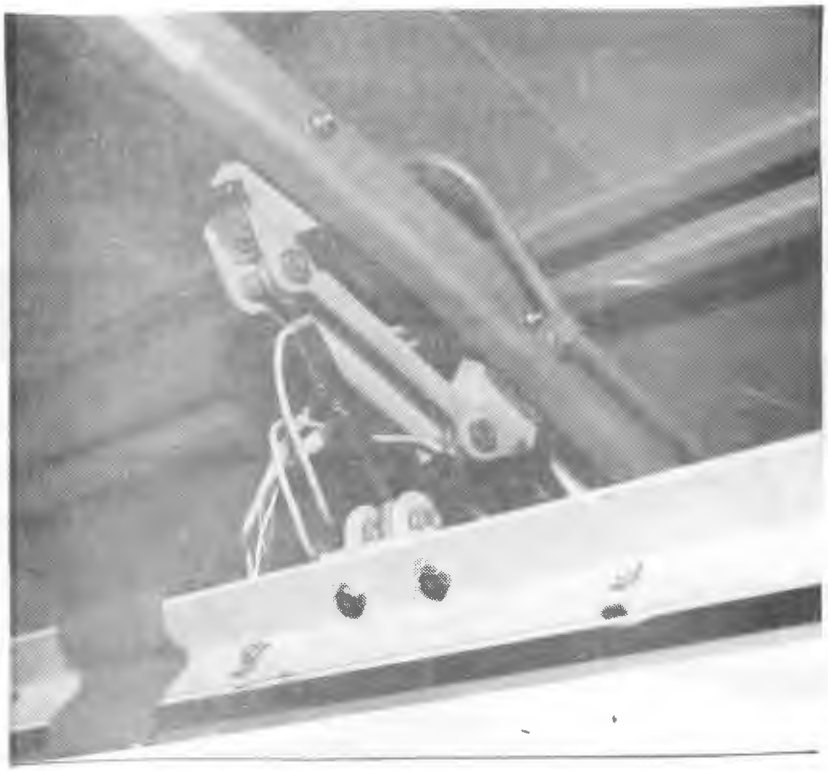


FIGURE 17. STRAIN GAGES UPPER SUPPORT LINKS

FIGURE 18. STRAIN GAGE LOWER SUPPORT LINK

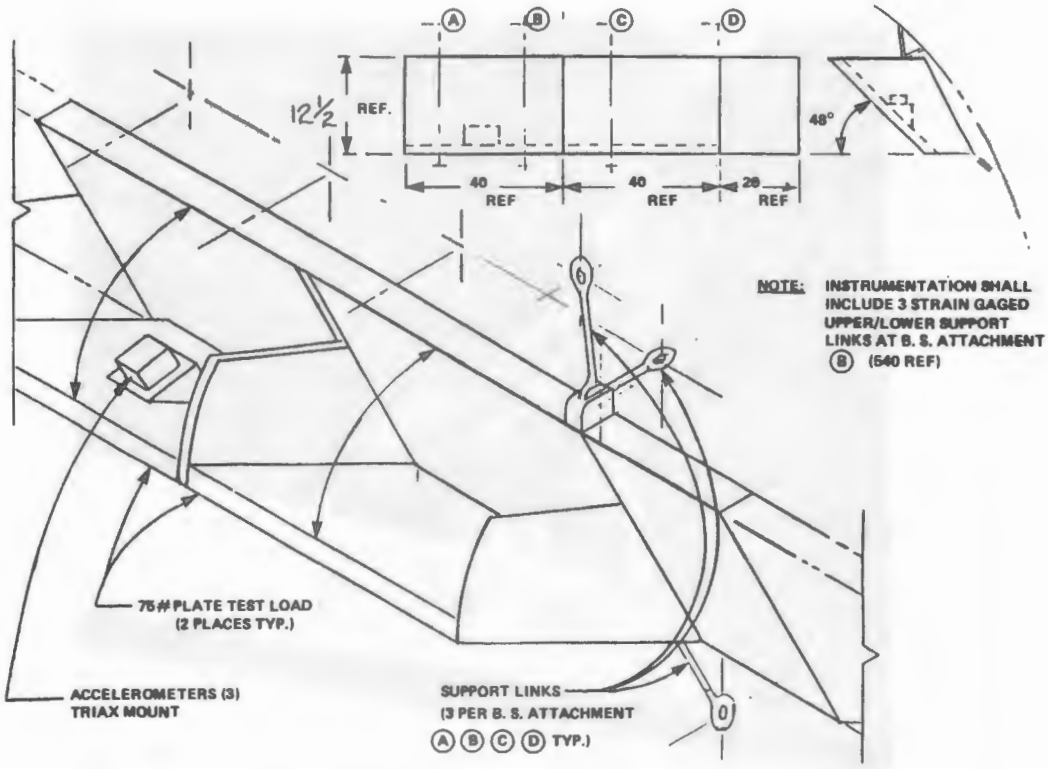


FIGURE 19. OVERHEAD COMPARTMENT INSTALLATION

FIGURE 20. LEFT WING IMPACT

FIGURE 21. FUSELAGE IMPACT

FIGURE 22. IMPACT WITH THE WING CUTTER

FIGURE 23. POST-CRASH FIRE

FIGURE 24. FORWARD GALLEY POST-CRASH

FIGURE 25. FLOOR DISPLACEMENT AT AFT GALLEY

FIGURE 26. AFT GALLEY FORWARD TRACK STUD

FIGURE 27. AFT GALLEY AFT TRACK STUD

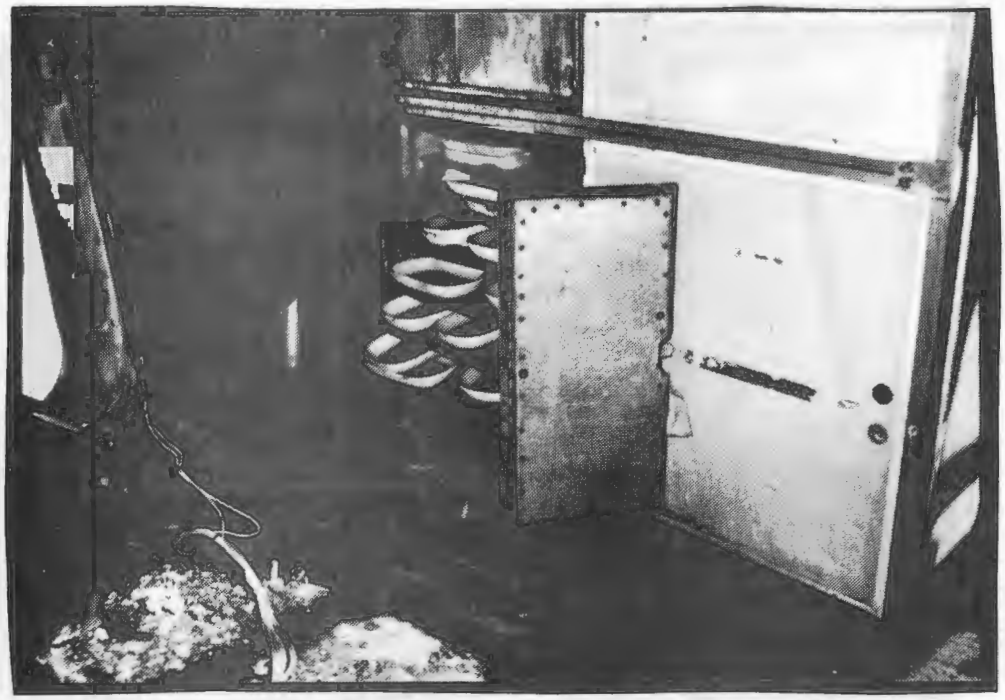


FIGURE 28. AFT GALLEY CHINA POST-CRASH

FIGURE 29. AFT GALLEY CHINA, TRAYS POST-CRASH (LOWER)

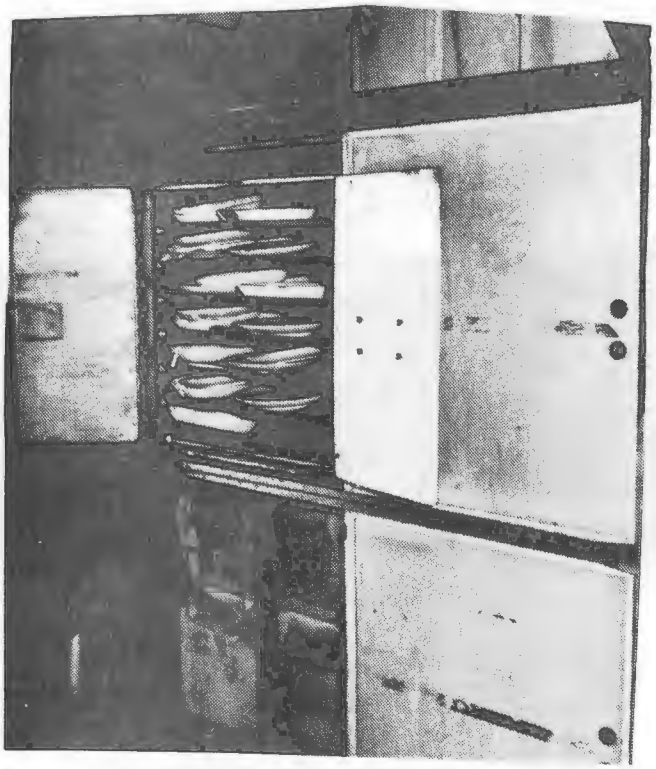


FIGURE 30. AFT GALLEY CHINA, TRAYS POST-CRASH (UPPER)

FIGURE 31. FORWARD OVERHEAD COMPARTMENT POST-CRASH

FIGURE 32. AFT OVERHEAD COMPARTMENT POST-CRASH

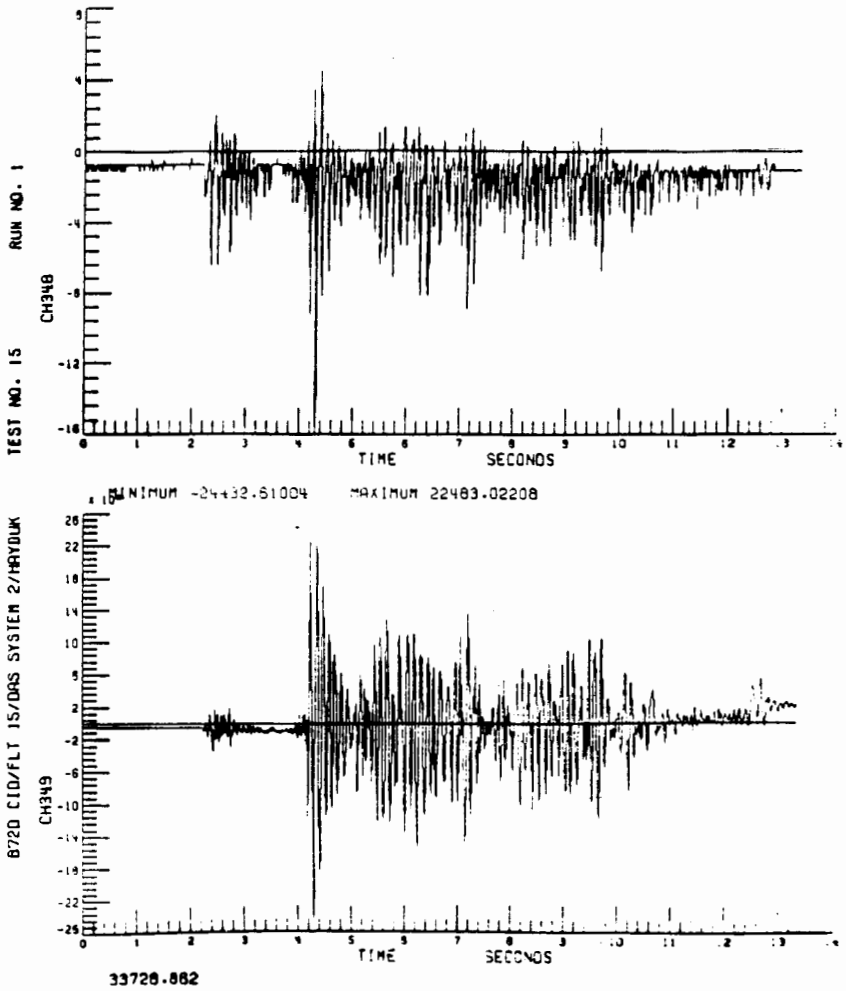


FIGURE 33. SUPPORT LINK DATA WITH EXPANDED TIME SCALE

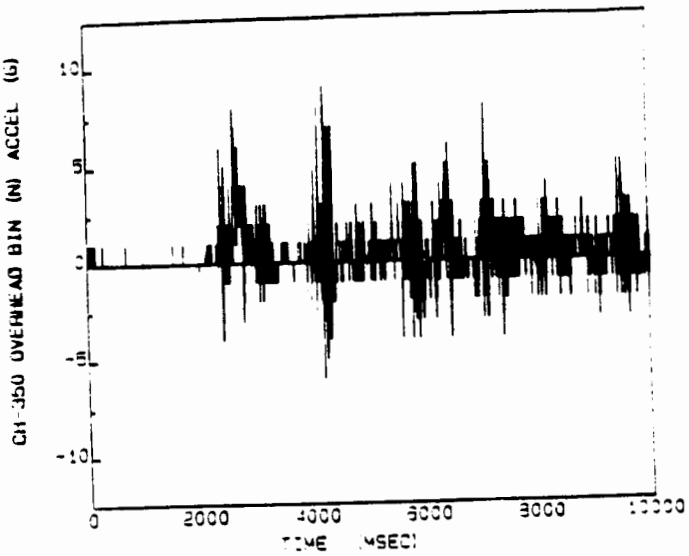


FIGURE 34. OVERHEAD COMPARTMENT NORMAL ACCELERATION

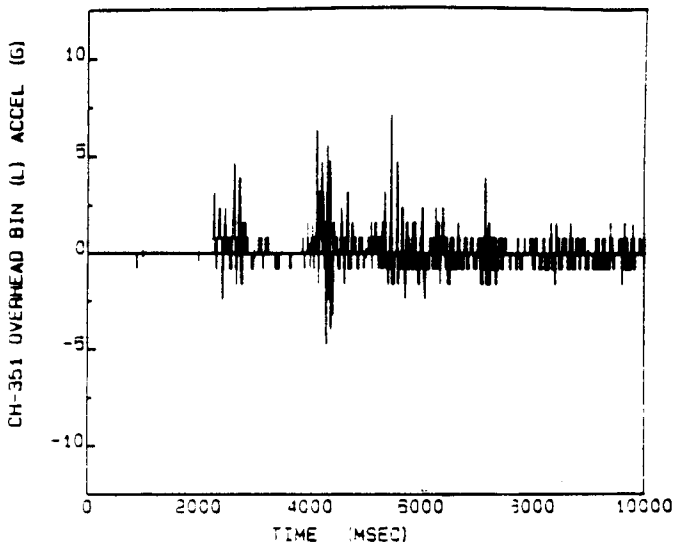


FIGURE 35. OVERHEAD COMPARTMENT LONGITUDINAL ACCELERATION

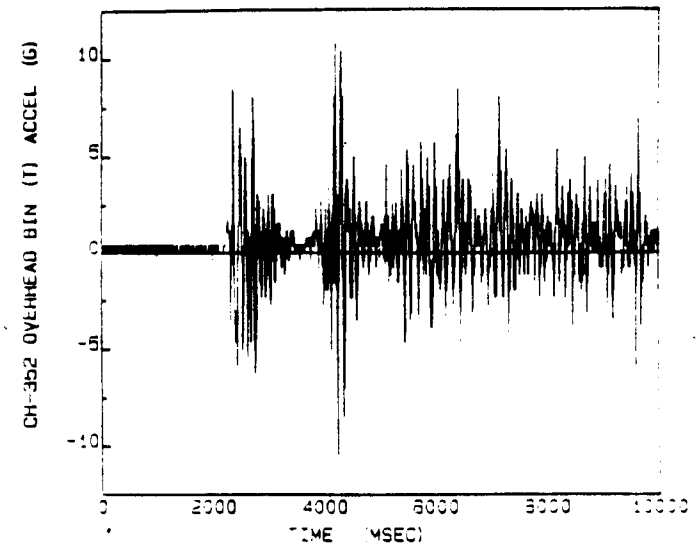


FIGURE 36. OVERHEAD COMPARTMENT TRANSVERSE ACCELERATION

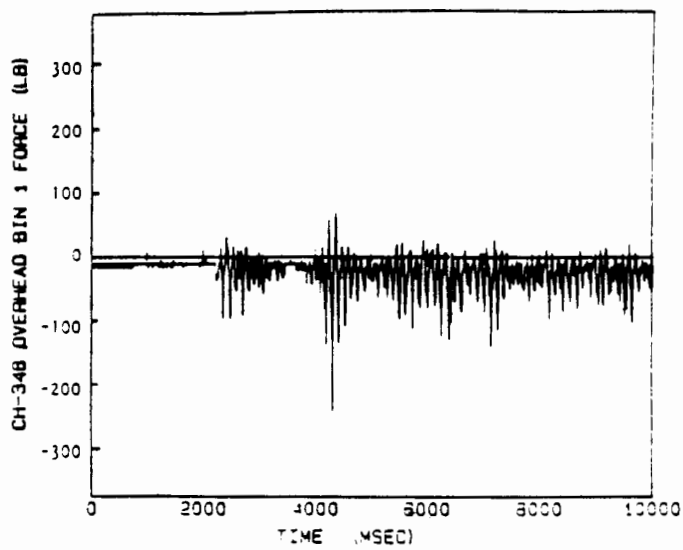


FIGURE 37. OVERHEAD COMPARTMENT UPPER SUPPORT LINK FORCE

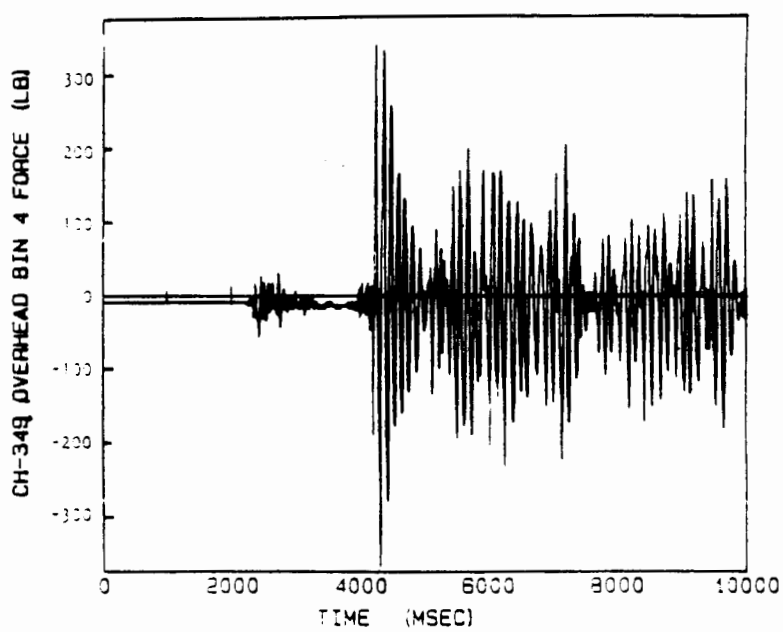


FIGURE 38. OVERHEAD COMPARTMENT LOWER SUPPORT LINK FORCE

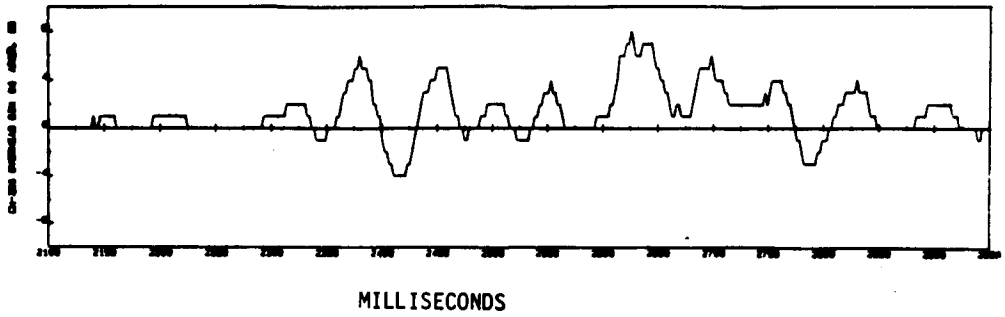


FIGURE 39. NORMAL ACCELERATIONS DURING GROUND IMPACT

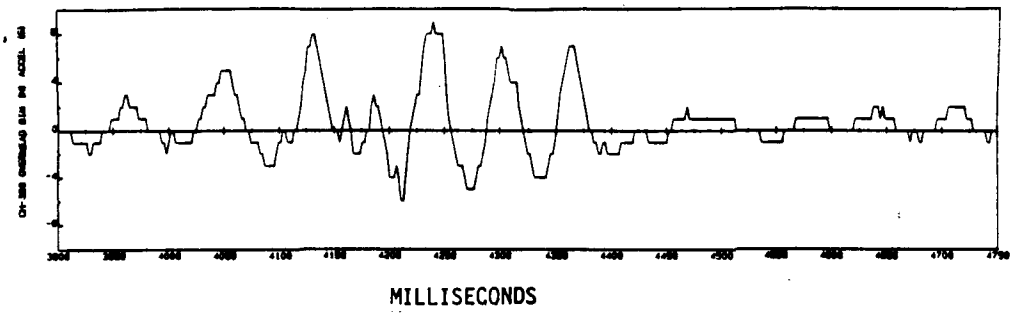


FIGURE 40. NORMAL ACCELERATIONS DURING OBSTACLE IMPACT

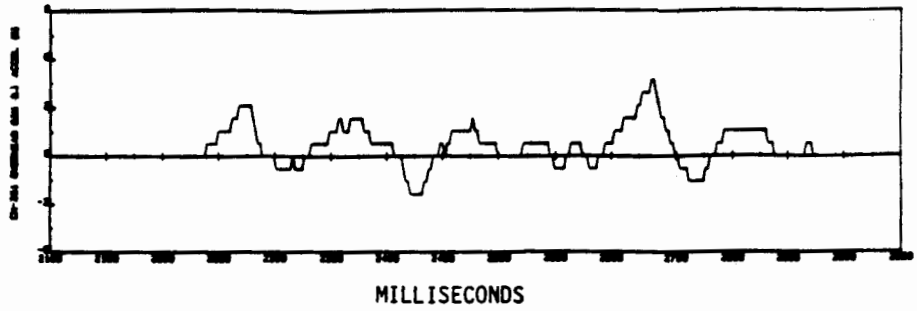


FIGURE 41. LONGITUDINAL ACCELERATIONS DURING GROUND IMPACT

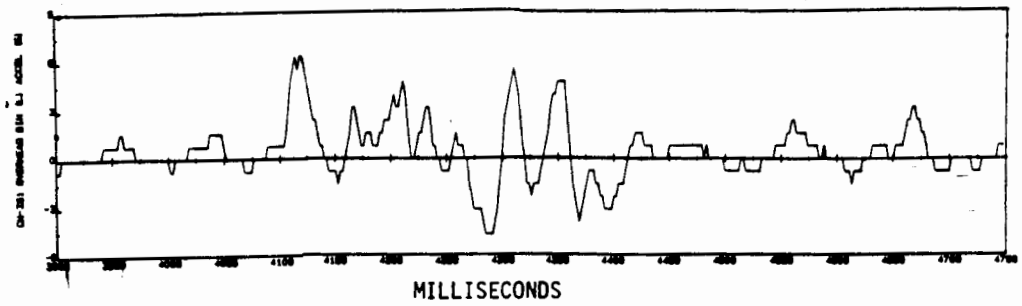


FIGURE 42. LONGITUDINAL ACCELERATIONS DURING OBSTACLE IMPACT

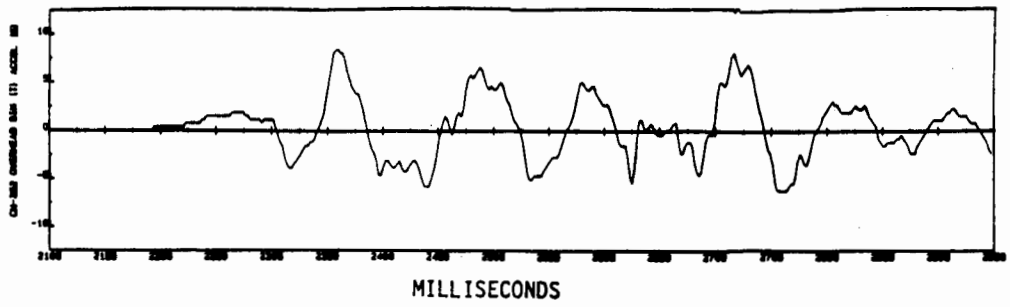


FIGURE 43. TRANSVERSE ACCELERATIONS DURING GROUND IMPACT

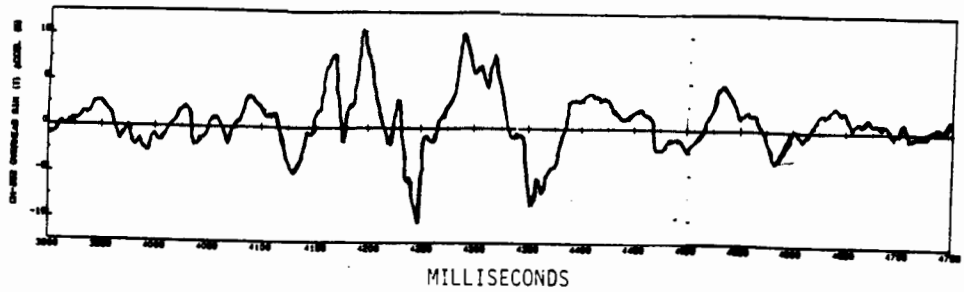


FIGURE 44. TRANSVERSE ACCELERATIONS DURING OBSTACLE IMPACT

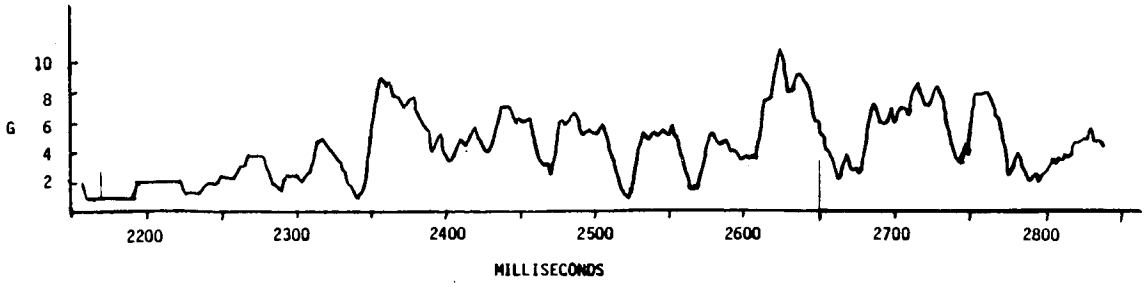


FIGURE 45. RESULTANT ACCELERATIONS ON OVERHEAD COMPARTMENT

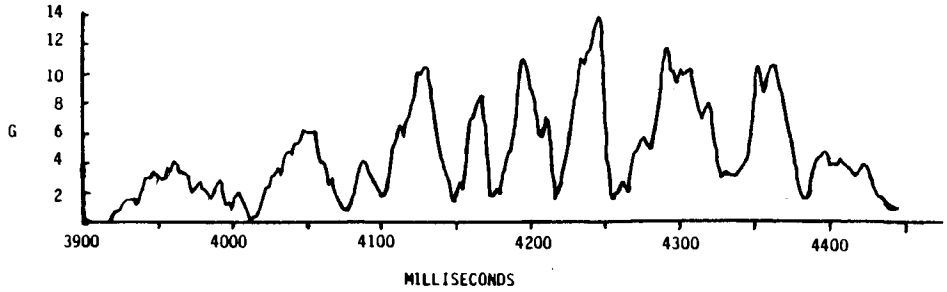


FIGURE 46. RESULTANT ACCELERATIONS ON OVERHEAD COMPARTMENT

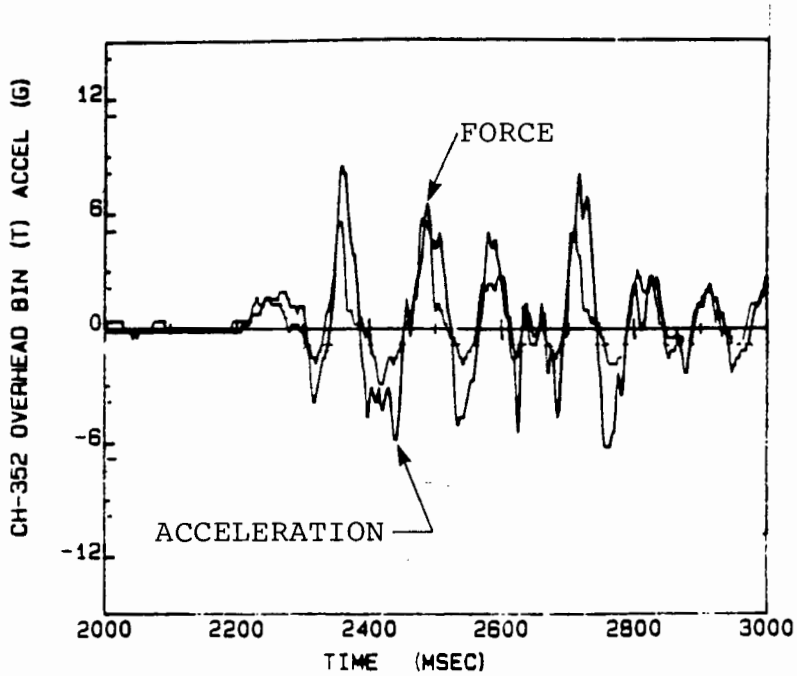


FIGURE 47. LOWER SUPPORT LINK FORCE COMPARISON WITH TRANSVERSE ACCELERATION

APPENDIX A

LABORATORY ANALYSIS

DEPARTMENT OF THE NAVY
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA. 18974-5000

4630
Ser 6063/8538
06 AUG 1985

From: Commander, Naval Air Development Center
To: Department of Transportation, Federal Aviation Administration, Technical Center, (R. Johnson) Atlantic City Airport, NJ 08405

Subj: FAILURE OF OVERHEAD STORAGE COMPARTMENT SUPPORT LINKS IN A BOEING 720 TRANSPORT PLANE

Ref: (a) PHONCON FAA R. Johnson/NAVAIRDEVCEN (Code 60634) R. Mahorter dtd 27 Feb 85

Encl: (1) NAVAIRDEVCEN Metallurgical Investigation of the Failure of Overhead Storage Compartment Support Links in a Boeing 720 Transport Plane dtd 22 Jul 85

1. A metallurgical investigation was performed, per reference (a), to determine the probable cause of the failure of overhead storage compartment support links from a Boeing 720 Transport plane used for a test program on passenger safety control impact demonstration.

2. The results of this investigation are presented in enclosure (1). The conclusions drawn from the final analysis in enclosure (1) indicate the failure of support links occurred due to overheating caused by the fire after the impact.

3. If there are any questions please contact Mr. R. Mahapatra, Code 60634, (215) 441-3687.

J. J. DE LUCCIA
By direction

Naval Air Development Center
Aircraft and Crew Systems Technology Directorate
Warminster, PA 18974-5000

6063
22 Jul 85

INVESTIGATION OF THE FAILURE OF SUPPORT LINKS OF AN OVERHEAD STORAGE COMPARTMENT IN A BOEING 720 TRANSPORT PLANE (USED IN A TEST PROGRAM ON PASSENGER SAFETY CONTROL FOR IMPACT DEMONSTRATION)

This investigation of failure involved the examination of the remnants of seven support links of an overhead storage compartment in a Boeing 720 transport plane used for a test program on passenger safety control for impact demonstration. The overhead storage compartment is supported by eight upper links and four lower links. Remnants of only seven links were provided for investigation. The examinations were performed using visual, macroscopic (10X), microscopic and other metallurgical techniques in order to identify the fracture mechanism and determine the probable cause of failure.

Visual/Macroscopic Examination: The remnants of seven support links were arranged in their relative positions in order to assess the loading and sequence of failure, as shown in Figures 1, 2, 3, and 4. Three links fractured in a plane perpendicular to the axial direction of the links through the holes in the unthreaded area. One link fractured in the same manner through the two small holes in the threaded area. In addition, two links failed through the eye-bolt attached to the threaded link. One of the seven links did not fail. The fractures in the failed links were relatively smooth and flat, as shown in Figure 5.

Microscopic Examination: A scanning electron microscopic (SEM) examination of the fracture surface was conducted to characterize the fracture mode involved in the failure. In most of the samples, significant fractographic features could not be discerned due to the presence of excessive amounts of oxidation products on the fracture surfaces, as shown in Figure 5. However, scanning electron microscopic examination of one sample relatively free of oxidation products revealed what appeared to be intergranular fracture, as shown in Figure 6. Subsequent metallographic examination of longitudinal sections in the area of fracture exhibits excessive grain growth and incipient melting at the grain boundary, as shown in Figure 7.

Chemical Analysis: The samples from the links were chemically analyzed and the chemical composition was similar to that of alloy 7075.

Test Program: A test program was conducted to provide pedigreed examples of room temperature and elevated temperature tension failures. The room temperature failure was characterized by

Enclosure (1)

prominent shear lips as shown in Figure 8. The elongated dimple rupture as shown in Figure 8 indicates that the material failed in a ductile manner at room temperature. The elevated temperature failure was flat and intergranular as shown in Figure 9. Comparison of the test program failure with the crash failures revealed that the crash fractures have characteristics that were most similar to the elevated temperature failures, as shown in Figure 6.

It should be noted that the pedigreed failures were conducted on samples of aluminum alloy 6061. The samples of support links were of aluminum alloy 7075. The material difference would have no major effect on failure modes or appearances.

Analysis of Results: The results of this investigation indicate that the probable cause of failure in the six broken links was due to overheating caused by the fire after impact. Evidence of incipient melting at the grain boundary in all samples indicates that these support links were subjected to a temperature very close to the melting point of the material.

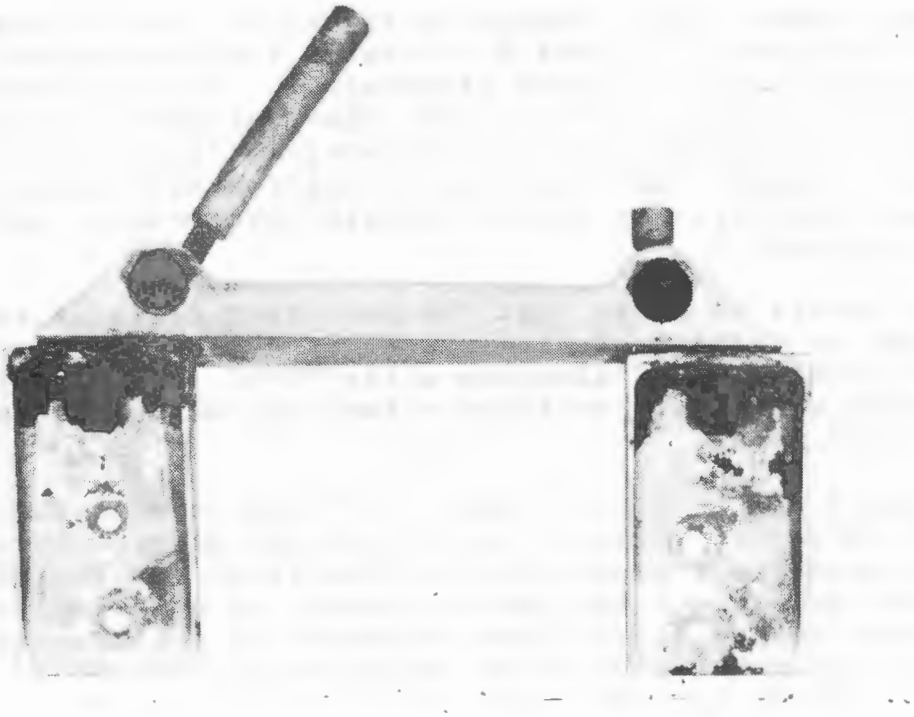


FIGURE A-1. FORWARD BIN, AFT UPPER SUPPORT BRACKET

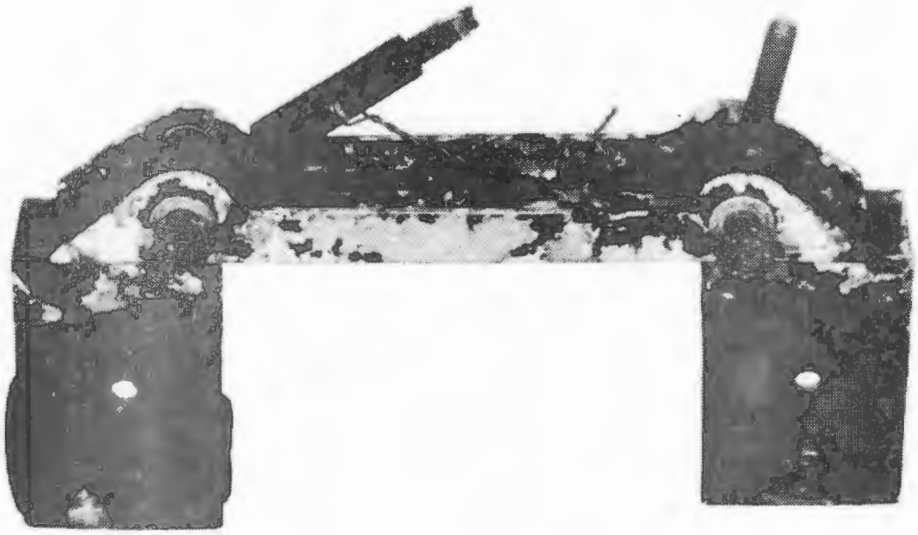


FIGURE A-2. FORWARD BIN, FORWARD UPPER SUPPORT BRACKET

FIGURE A-3. AFT BIN, AFT UPPER SUPPORT BRACKET

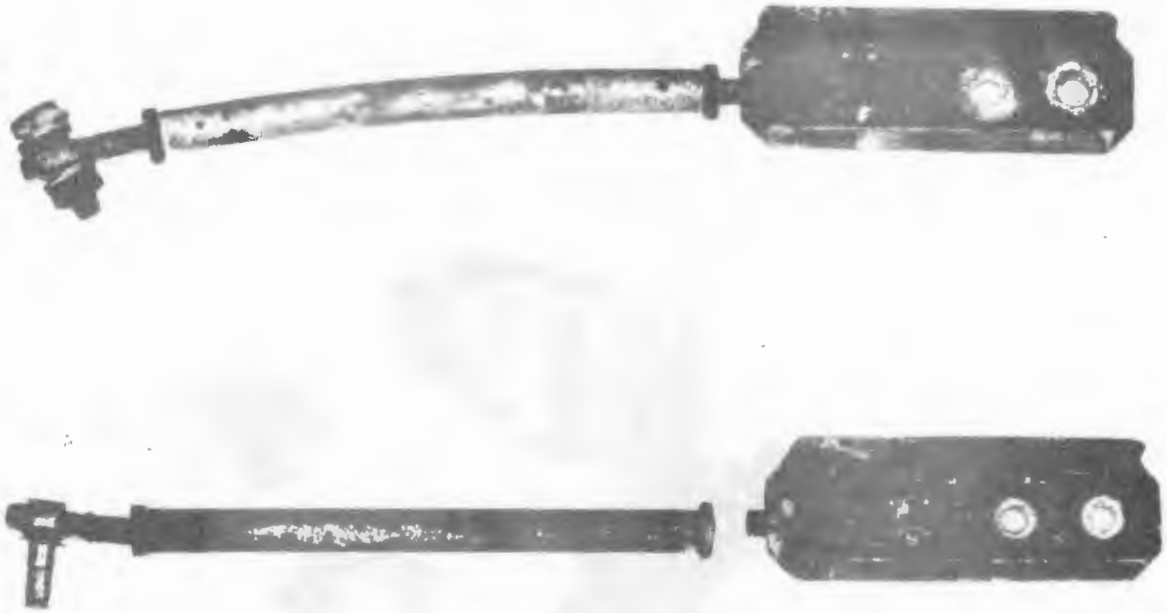


FIGURE A-4. AFT AND FORWARD LOWER SUPPORT LINKS

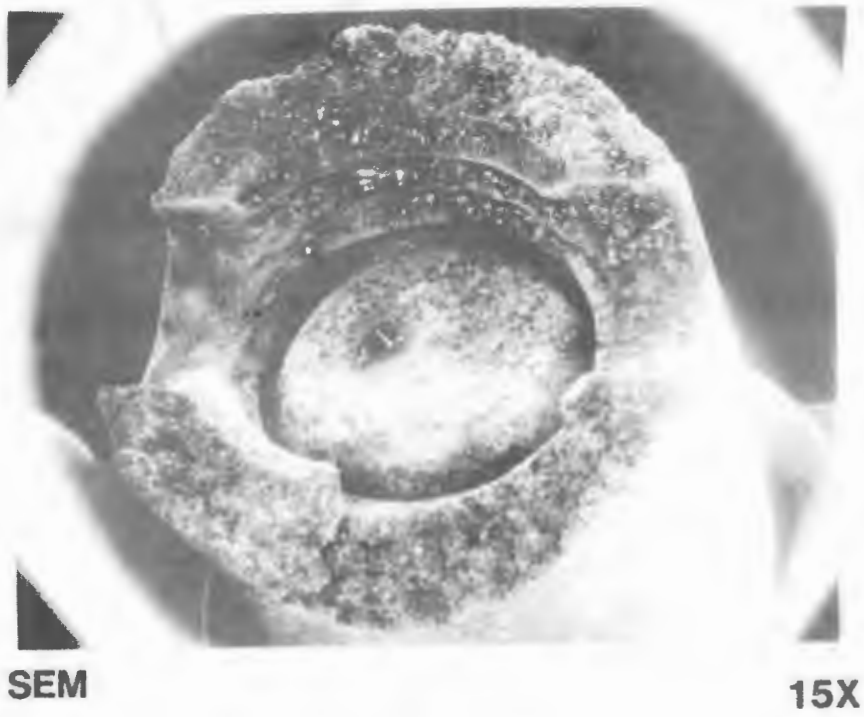
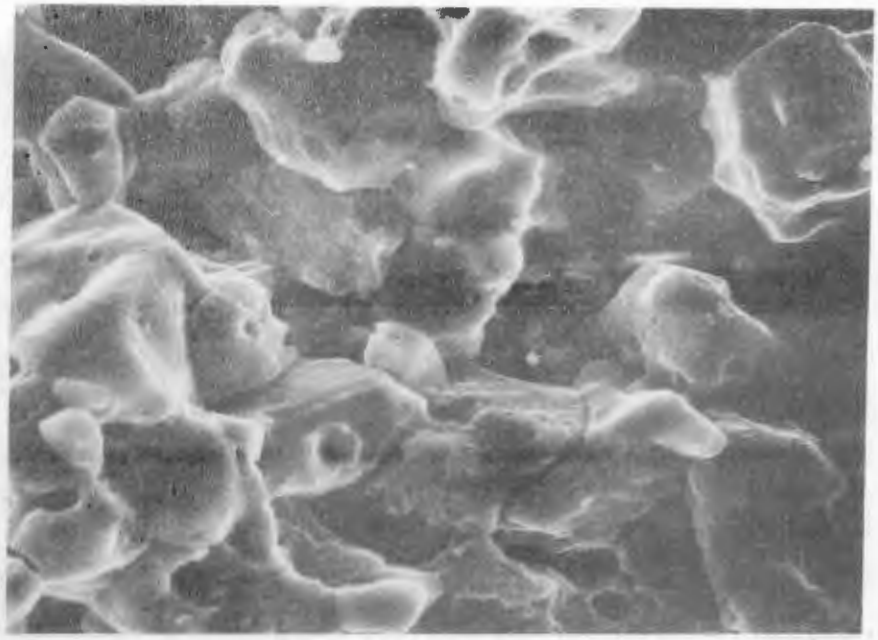


FIGURE A-5. TOPOGRAPHY OF FRACTURE SURFACE



SEM 2000X

FIGURE A-6. FRACTURE SURFACE OF FAILED LINK SHOWING INTERGRANULAR FAILURE

Keller's Reagent 400X

FIGURE A-7. MICROSTRUCTURE OF THE FAILED LINK SHOWING INCIPIENT MELTING AT GRAIN BOUNDRY

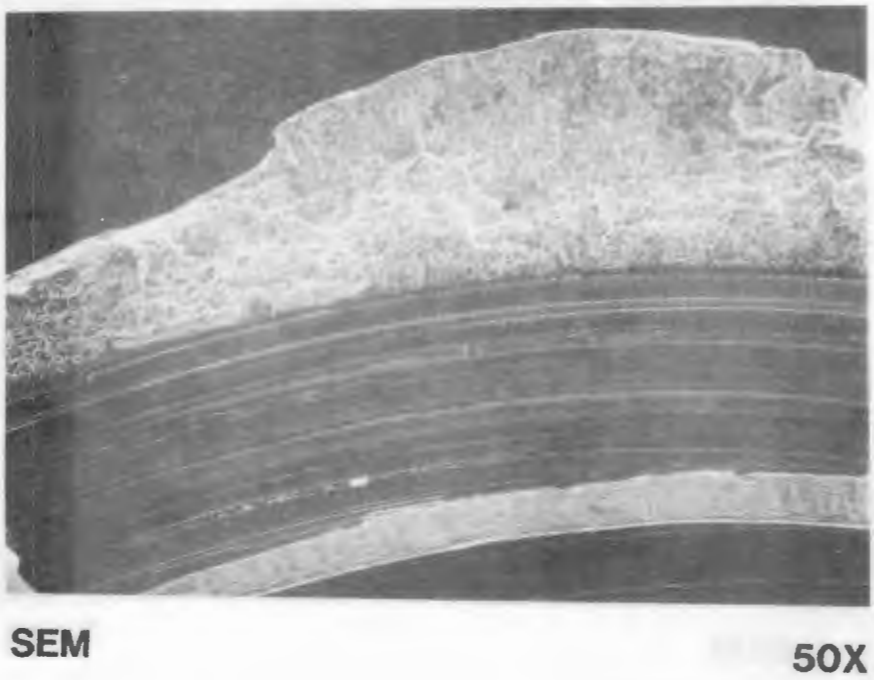


FIGURE A-8A. SURFACE AFTER FRACTURE AT ROOM TEMPERATURE SHOWING SHEAR LIPS

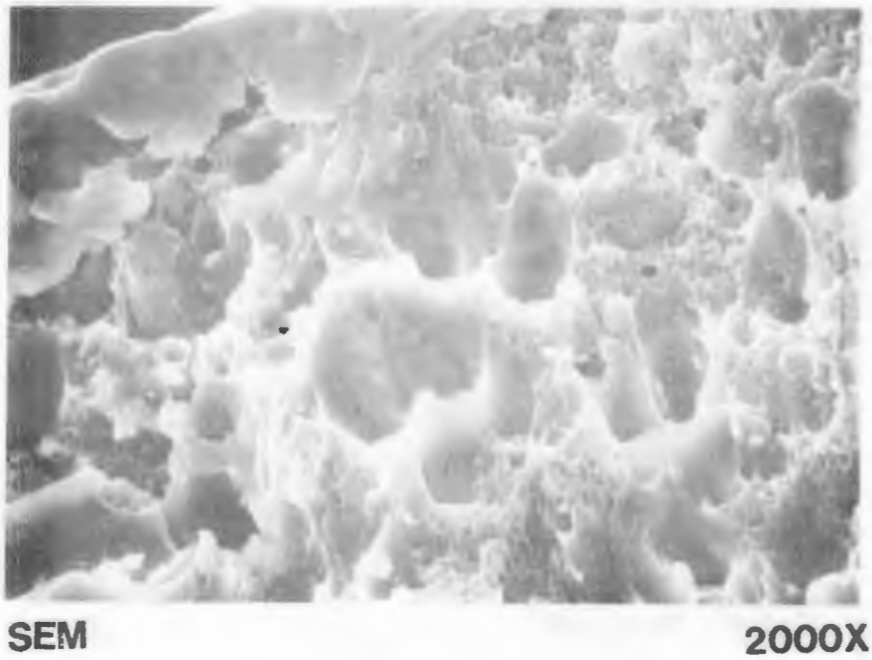
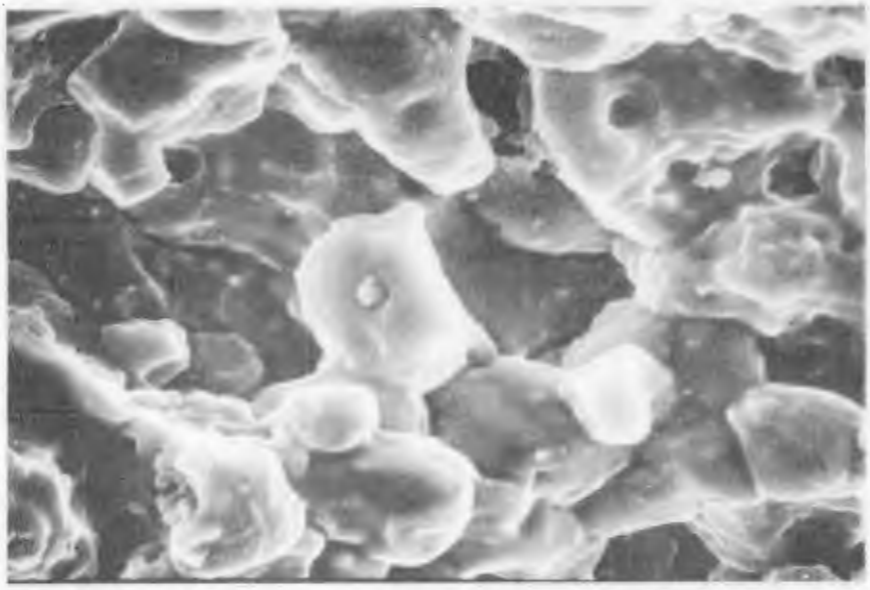


FIGURE A-8B. SURFACE AFTER FRACTURE AT ROOM TEMPERATURE SHOWING LONGATED DIMPLES



SEM 2000X

FIGURE A-9. SURFACE AFTER FRACTURE AT ELEVATED TEMPERATURE SHOWING INTERGRANULAR FAILURE

APPENDIX B

DISTRIBUTION

APPENDIX B

STANDARD DISTRIBUTION LIST

Region Libraries

Alaska	AAL-64
Central	ACE-66
Eastern	AEA-62
Great Lakes	AGL-60
New England	ANE-40
Northwest-Mountain	ANM-60
Western-Pacific	AWP-60
Southern	ASO-63d
Southwest	ASW-40

Center Libraries

Technical Center	ACT-64
Aeronautical Center	AAC-44.4

Civil Aviation Authority
Aviation House
129 Kingsway
London WC2B 6NN England

Embassy of Australia
Civil Air Attache
1601 Mass Ave. NW
Washington, D. C. 20036

Scientific & Tech. Info FAC
Attn: NASA Rep.
P.O. Box 8757 BWI Aprt
Baltimore, Md. 21240

DOT-FAA AEU-500
American Embassy
APO New York, N. Y. 09667

Headquarters (Wash. DC)

ADL-1
ADL-32 (North)
APM-1
APM-13 (Nigro)
ALG-300
APA-300
API-19
AAT-1
AWS-1
AES-3

OST Headquarters Library

M-493.2 (Bldg. 10A)

University of California
Sers Dpt Inst of Trsp Std Lib
412 McLaughlin Hall
Berkely, CA 94720

British Embassy
Civil Air Attache ATS
3100 Mass Ave. NW
Washington, DC 20008

Dir. DuCentre Exp DE LA
Navigation Aerineene
941 Orly, France

Northwestern University
Trisnet Repository
Transportation Center Lib.
Evanston, Ill. 60201

ADDITIONAL DISTRIBUTION LIST

R. Johnson	ACT-300
H. Brantidg	AWS-120
D. Schroeder	ADM-710
F. Lee	ANM-130L
S. Wallace	ANM-110
J. Starkle	ANM
D. Nelson	AWS-120
T. McSweeney	AWS-120
S. Soltis	ANW-100L
A. Hayes	AWS-120
D. Chandler	AAC-119

☆U.S. GOVERNMENT PRINTING OFFICE: 1986–606-637/27082