Docket No. SA-520

Exhibit No. 7-A

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Structures Group Chairperson's
Factual Report of Investigation

(54 Pages)

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D. C. 20594

November 9, 2000

Structures Group Chairperson's Factual

DCA00MA023

A. ACCIDENT

Location:	Near Port Hueneme, California (Pacific Ocean)
Date:	January 31, 2000
Time:	1621 Pacific Standard Time (PST)
Airplane:	Boeing MD-83, N963AS Operated by Alaska Airlines

B. STRUCTURES GROUP

Chairperson:	Lorenda Ward National Transportation Safety Board Washington, D. C.
Member:	Rolando Domingo[1] Boeing Company Long Beach, California
Member:	Ken Umeda[2] Boeing Company Long Beach, California
Member:	A. J. Borodayko[3] Boeing Company Long Beach, California
Member:	Gerardo Hueto Alaska Air Seattle, Washington

[1] Attended the First On-Site and the Second On-Site visits only.
[2] Attended the Second On-Site visit, the dimensional check, and the first and second static quill shaft test.
[3] Present during the recovery operations and the development of the field notes.

Member:	Scott Patterson[4] Alaska Airlines Seattle, Washington
Member:	Ken Brown[5] Federal Aviation Administration Van Nuys, California
Member:	Mike Lee[6] Federal Aviation Administration Lakewood, California
Member:	John Scarola Air Line Pilots Association Seattle, Washington
Member:	Dave Eisenbrey Air Line Pilots Association Los Angeles, California
Member:	Louie Key[7] Aircraft Mechanics Fraternal Association Seattle, Washington
Member:	Earl Clark[8] Aircraft Mechanics Fraternal Association Oakland, California
Member:	Kurt Pagenkopf[9] Aircraft Mechanics Fraternal Association Seattle, Washington
Member:	Matt Schmidt[10] Aircraft Mechanics Fraternal Association Portland, Oregon

[4] Attended the recovery operations and the development of the field notes.
[5] Attended the first on-site and the second on-site visits.
[6] Present during the recovery phase and the development of the field notes, attended the second on-site visit, the dimensional check, and the first and second static quill shaft test.
[7] Present during the recovery phase, attended the first on-site and second on-site visits, the dimensional check, and the first static quill shaft test.
[8] Present during the recovery phase and attended the first on-site visit.
[9] Present during the recovery phase, attended the second on-site visit, and the second static quill shaft test.
[10] Present during the recovery phase and development of the field notes.

C. SUMMARY

On January 31, 2000, at about 1621 PST, Alaska Airlines flight 261 a Boeing MD-83, N963AS, crashed near Port Hueneme, California into the Pacific Ocean. The flight, from Puerto Vallarta, Mexico to Seattle, Washington with an intermediate stop in San Francisco, was operating under title 14 CFR part 121. All 83 passengers and 5 crewmembers were fatally injured and the aircraft was destroyed. Visual meteorological conditions prevailed at the time of the accident.

The structures group met from February 1 to March 15, 2000 to assist in the recovery, examination and documentation of the recovered wreckage. The group made a second trip to revisit the wreckage on May 2, 2000. The group also traveled to Seattle, Washington on July 21, 2000 to conduct a dimensional check of an Alaska Airlines MD-83, tail number N932AS. The group traveled twice, July 26 and October 2, 2000, to the Boeing facility in Huntington Beach, California to witness static load tests. On October 3, 2000 the group traveled to Long Beach, California to watch a presentation on Boeing's FEM of the jackscrew.

Supporting documentation, including a map of the crash site location, a map of the search areas, a major assembly diagram, fuselage stations diagram, wing stations diagram, horizontal stabilizer diagram, vertical fin stations diagram, and photographs is attached.

D. DETAILS OF THE INVESTIGATION

1.0 Wreckage Distribution and Recovery

The aircraft wreckage was located at Latitude 34 03.5 North, Longitude 119 20.8 West in a debris field roughly the size of a football field and at an approximate depth of 700 feet. The wreckage was resting in the National Oceanic and Atmospheric Administration's (NOAA) Channel Islands National Marine Sanctuary which is an environmentally protected area. The National Ocean Service (NOS) provided assistance to the National Transportation Safety Board (NTSB) in regards to the environmental issues related to the wreckage recovery.

The rescue effort was changed to a recovery effort on February 2, 2000. Floating debris was recovered through out the investigation. The cockpit voice recorder (CVR) was recovered February 2, 2000 and the flight data recorder (FDR) was recovered February 3, 2000. The U.S. Navy's Supervisor of Salvage and Diving conducted the side scan sonar and bottom mapping of the debris field. Also, they utilized a remotely operated vehicle (ROV) to video map the debris field. The structures

group reviewed the numerous video tapes of the underwater debris field and denoted the latitude and longitude of items of interest.

Initial recovery of the wreckage was accomplished by a ROV that surgically removed the selected pieces and loaded them into a basket on the ocean floor. Once the basket was full the load was brought up onto the M/V Independence. Even though the process was less intrusive than a bulk recovery, there was damage incurred by the manipulation arm and/or cable lift. There is video coverage of the ROV wreckage recovery. Once the pieces were on board the ship they were washed with bleach and water. After the recovered pieces were transferred to shore, the pieces were fresh water rinsed with a garden hose and then moved into the building 546 warehouse at Port Hueneme.

The first major piece recovered by the ROV was the horizontal stabilizer section with the upper portion of the jackscrew assembly still attached. The video of the this piece shows the jackscrew resting on the ocean floor. During the recovery of this section the cable released the assembly and it fell back to the ocean floor. The second attempt was successful in bringing the piece on board ship. This piece was brought to shore on February 8, 2000.

Approximately 75% of the airplane was recovered by the ROV method. The Sea Clipper, a commercial trawler, was sent out with sole nets and shrimp nets to recover the smaller pieces. Approximately 15% more wreckage was recovered by this method, for a total of 90%.

In the end, there were three search areas that were canvassed. The recovered wreckage came from search area #1, which contained the debris field. The two other search areas did not yield any accident airplane parts.

The NTSB finished the wreckage recovery portion of the accident investigation on March 15, 2000. The structures group chairperson traveled to Port Hueneme on two other occasions to examine metallic parts that were recovered by commercial fishermen. It was determined that the recovered parts were not from the accident airplane.

2.0 On-Site Structures Examinations

The structures group met from February 1 to March 15, 2000 to assist in the recovery, examination and documentation of the recovered wreckage. The initial area of focus was the empennage, with the main focus on the horizontal stabilizer and vertical stabilizer. A special study group was formed within the structures group to examine parts of the

empennage structure. This group met from February 14 to 24, 2000. Their observations are included in this report.

The group re-visited building 546 at Port Hueneme (warehouse) on May 2, 2000, to look at the empennage and the pressure bulkheads. This was a direct result of a meeting that was held at the Boeing facility in Long Beach on April 12, 2000. In attendance at that meeting were the Systems Group and Group Chairman, the Performance Group Chairman, the Structures Group Chairman, and additional representatives from Boeing. The NTSB had made a request of Boeing to provide a computer 3D model of the horizontal and vertical stabilizer. Boeing wanted to look at the recovered structure to check to see if their computer 3D model needed refining. The new observations are included in the text of this report.

In general, there was no evidence of any pre or post impact fire damage and most of the fractures were consistent with failures generated by a high-energy water impact, i.e.; bending, distortion, and tearing. There was no prevailing directionality to the failures, although the right hand side and the crown of the airplane exhibited more extensive damage than the rest of the airplane. None of the fracture surfaces examined showed any signs of pre-existing fatigue or corrosion damage. However, there was some light corrosion on a few parts where the primer and paint were missing. There was no evidence of foreign impact damage.

2.1 Fuselage

Description: The fuselage is approximately 121 feet long and is of all-metal construction consisting of a nose section, a center section and a tail section. For the purpose of this report the fuselage is divided into five sections: nose section, forward cargo area, mid cargo area, wing area, and the aft cargo area, refer to attached fuselage station diagram.

All external doors and emergency exits, with the exception of the forward airstair door, are plug-type and pressure sealed.

Findings: Approximately 85% of the fuselage was recovered with the largest sections being from below the floorline. The left and right passenger window belts, between longeron #11 and longeron #15, comprise the next largest identifiable portions. The upper crown structure recovered exhibited substantial compression damage and were broken into numerous small segments which were too fragmented to locate positively. Of note is the size of the recovered segments which generally are progressively larger when moving forward to aft. In the

different fuselage sections, if the recovered piece covered two sections the finding was put in the forward section.

2.1.1 Nose Section

Description: The nose section is from fuselage station seven to fuselage station 218. It includes the cockpit, electrical & electronics (E & E) bay, and the forward passenger entrance (L1) door. There are no passenger windows in this section.

Findings: Approximately 55% of the nose section was recovered and identified. The forward passenger entrance (L1) door (5.5 feet by 3 feet portion) and most of the structure of the door is in place. The forward upper portion of the door (26 inches by 15 inches) is ripped. Adjacent to the ripped portion is a 10 inch by 15 inch portion of the door structure which is bent and crushed approximately 90 degrees down and aft. The outside and inside door handles (with mechanism) are in place (closed position).

The left flight compartment upper window (eyebrow) was recovered with the window frame in place. The forward jamb structure (8.3 feet by 1.4 feet) of the forward passenger entrance door (L1) is attached to the window. Broken pieces of the inner & outer panes remain along the perimeter of the window frame. The skin plank joining the door jamb to the aft frame of the window is torn off from the aft frame and crumpled outward and around the upper portion of the door jamb structure. The upper section of the jamb structure from the forward corner radius extending approximately 16 inches down is bent/creased inward approximately 20 degrees.

A 5 foot by 3 foot section of the flight compartment structure has been recovered. This section includes the lower frame of the left aft window, the lower frame of the left sliding window and the vertical frame common to both windows. The lower frame of the sliding window is bent 80 degrees aft and 30 degree inboard. The skin structure included the latch hook-up for the forward passenger entrance door (L1). The lower frame of the aft window is in place. The two end pad attach bolts at its aft end are fractured. All the fasteners attaching the forward frame retainer of the aft window are fractured and pulled forward. The four end pad attach bolts at the upper end of the frame are fractured. The lower frame of the sliding (clearview) window is fractured at its outboard end and bent up approximately 45 degrees. The retainer for this frame is pulled outboard. The section of the fuselage outer skin adjoining this retainer has also been pulled outboard. The skin structure, 30 inches by

36 inches, below the lower frame of the aft window is in place but its inboard section is peeled outboard.

The center windshield, right windshield, right sliding (clearview) window, and the right upper (eyebrow) flight compartment window structure have been recovered (10.5 feet by 6.5 feet). The center windshield window panes are in place but shattered. Its top, bottom, and outboard retainers are in place. The right windshield has 70% of the panes but shattered. The lower frame of the right windshield window separated from the center windshield frame at the two connecting bolts (both bolts were severed at the threaded portions). The retainers for the right windshield panes are attached. The upper frame of the right windshield separated from the front frame of the sliding window at the two connecting bolts (both bolts were severed at the threaded portions).

The sliding window panes were not recovered along with their aft frame and retainer. The upper 50% of the retainer (for the sliding window) at the forward frame is peeled and bent 90 degrees forward from the top. The panes of the upper window are not recovered except for some broken pieces left under the retainer. The retainer for the upper window is in place as well as its frames. The skin and enclosure structure (connecting the upper window, side window, and the center window) are not recovered. The wreckage included the right wiper arm, its motor, and a 15 inch by 20 inch surrounding skin structure. The left aft windshield window was also recovered. Approximately 90% of the panes are in place but shattered. The retainers are also in place. The inboard retainer has all the fasteners pulled. The upper, lower, and aft frames are present. The inboard end of the lower frame is bent down approximately 10 degrees and outward 30 degrees. The web of the frame is fractured 4 inches from the inboard end extending out 11 inches. Both end pads of the lower frame are present. The inboard end pad has a fractured portion of the inner attachment bolt present in the hole. The outboard end pad has the fractured portion of both attachment bolts present. The 5 inch inboard end of the upper frame has been torn off. The aft frame included a 10 inch section of the enclosure lower frame that is fractured across its web 2.5 inches above the attachment point for the lower frame of the windshield window. This aft frame also included a 7 inch length of upper enclosure frame. A 13 inch long by 5.5 inch wide section of intercostal is still attached to the aft frame of the windshield window but pulled from the upper frame.

A 6 foot by 3.8 foot portion of the slant/horizontal pressure panel of the flight compartment has been recovered encompassing station 69 to station 101, x = 12 to the inside mold line of the fuselage skin. The web of the slant panel from station 41 to station 53 shows compression

deformation in the forward to aft direction as well as the beam at x = 24 which is bent 90 degrees to the left (of the aircraft). The web of the slant panel is severed at station 53 from x = 24 to x = 36, and at x = 24 from station 41 to station 69. The two front intercostals (parallel to the floor beams), the two outboard longitudinal beams and the two bottom stiffeners (parallel to the floor beams) are in place with minimal damage. The caps are still attached to the web structure with all fasteners in place at the horizontal pressure panel at x = 12 and x = 24.

The beam of the horizontal panel at x = 36 (most outboard beam) is still attached at the forward end to the beam of the slant panel but is severed from its cap along the web of the horizontal panel from station 75 to station 101. The web of the horizontal panel broke off at x = 12, station 101, x = 36, and station 69. The front end of the ripped web (horizontal panel) from x = 36 to fuselage skin is still attached to the slant panel splice. The bottom fuselage frames at station 69 (10 inches long) and station 57 (8 inches long) are still attached to the structure. The frames are bent approximately 45 degrees outboard and aft. Four pieces of the center section of the pressure panel were also recovered (2 feet by 2 feet, 1 foot by 1 foot, 2.5 feet by 2 feet, 2 feet by 1 foot) with both nose landing gear wheel spin brakes included. The four pieces exhibit severe crushing.

A 12.6 foot by 18.2 foot section of left fuselage structure has been recovered encompassing station 133 to station 351 and longeron #18 left to longeron #30. The forward airstair door and handle are in place and do not appear to have structural damage. There is a 4 foot by 2.7 foot floor panel and outboard seat track still attached adjoining the L1 door location. A 4 foot long by 1 foot wide area of the aft door jamb structure remains attached and appears to conform to the fuselage contour. The fuselage skin plank aft and below the forward airstair door is crushed. This piece included the crushed toilet bowl and sink of the forward lavatory with several wire harnesses and one cabin lights circuit breaker panel.

2.1.2 Forward Cargo Area

Description: The forward cargo area is from fuselage station 218 to fuselage station 541. It includes the forward cargo compartment. There are thirty-four passenger windows in this section.

Findings: Approximately 75% of the forward cargo area was recovered and identified. A 6.3 foot by 4.5 foot section of the forward upper fuselage has been recovered encompassing station 218 to station 294 left and longeron #18 left to longeron #11 left. There are three

passenger windows and one plug in this section. The passenger window between station 275 & station 294 still has the outer pane and seal in place. The window plug at station 229 is in place. The lower skin plank fractured off at longeron #18 left, the top fractured off at longeron #11 left, and the forward and aft ends appear to have been ripped and torn off. The front end is bent inward (approximately 80 degrees from skin contour) diagonally from station 237 longeron #18 left to station 256 longeron #11 left.

A 9 foot by 5 foot section of the left lower fuselage structure has been recovered, encompassing station 233 to station 341 and longeron #17 left to longeron #28 left. The forward lavatory service panel is in place and still attached along with access door, ducting, and remote dump cable. The upper portion of the wreckage was broken off at the cusp line (longeron #18 left) for most of its length. The tearing for most of the finger doubler scallops above longeron #18 skin splice is in the forward and up direction.

A 10.8 foot by 8.8 foot section of the forward lower fuselage structure has been recovered encompassing station 313 to station 427 and longeron #18 left to longeron #24 right. The structure includes the lower portion of the forward cargo compartment door cutout (lower sill area) and is in place with the adjoining cargo floor panel and supports at the entry area. The skin and longerons are fractured at station 313. The right front skin structure up to the forward jamb is crushed downward and folded outward. The jamb is fractured at longeron #26 right. The frame at station 427 was severed at longeron #28 right. A 56 inch by 46 inch section of the forward cargo door aft jamb structure was also recovered. The jamb structure is bent inward 5 inches along 27 inches of span between longeron #23 right and longeron #24 right. The skin aft of the jamb is severely torn and wrinkled. This wreckage was brought in underneath a large tangled bundle of wire harnesses, ductings, control cables, aileron torque tube/override mechanism, co-pilot sheet metal seat frame, and electrical power center (EPC) mostly from the avionics compartment and cockpit area of the aircraft.

A 21.2 foot by 7.4 foot section of the upper fuselage structure has been recovered encompassing station 334 to station 588 and longeron #6 left to longeron #18 left. There are ten passenger windows. The window belt structure is in place. The lower edges of the skin panels sheared off along the splice at longeron #18 left from station 334 to station 465, and longeron #17 from station 465 to station 588. The top edges of the skin panels appear to have been ripped off along longeron #11 left (top of window belt) from station 560 to station 465 and then torn off from longeron #15 left to longeron #6 left, station 465 to station 386. The

wreckage shows predominantly two longitudinal wrinkles (i.e., compression deformation impact in a fore to aft direction) and creases in the vertical direction at 3 places. The first wrinkle is 33 inches high along a span of 80 inches, from station 370 to station 465. The second wrinkle is 26 inches high along a span of 60 inches from station 465 to station 522.

A 6 foot by 4.8 foot section of the upper forward fuselage has been recovered encompassing station 294 to station 365 and longeron #11 left to longeron #16 left. There are four passenger windows. The wreckage shows diagonal creasing with the lower ends showing tearing along the splice at longeron #11 left. The tear direction appears downward evidenced by the elongation of the finger doubler holes at the lobes.

A 11.8 foot by 4.3 foot section of the upper fuselage has been recovered encompassing station 446 to station 588 and longeron #17 left to longeron #23 left. The potable water service panel at station 530 and the ground flood light at station 477 are in place. The skin plank is bent inside out along station 522 (skin plank from station 522 to station 588 is bent out & forward 160 degrees). The top edges of the wreckage sheared off from station 579 to station 522 along longeron #17 left. The aft end of the wreckage broke off along the circumferential fuselage skin splice at station 588. The front end and the top end of the wreckage show ripping of the skin planks. The forward lower skin 26 inches tall by 27 inches long is torn and bent aft 45 degrees.

2.1.3 Mid Cargo Area

Description: The mid cargo area is from fuselage station 541 to fuselage station 786.5. It includes the mid cargo compartment. There are twenty-six passenger windows in this section.

Findings: Approximately 75% of the mid cargo area was recovered and identified. A 18.4 foot by 14.3 foot section of the lower fuselage structure has been recovered encompassing station 541 to station 762 and longeron #18 left to longeron #18 right. The structure includes the lower portion of the mid cargo compartment door cutout (lower sill area) and appears intact with the adjoining cargo floor panel and supports at the entry area. The forward pressure relief valve at station 626 is in place while the aft pressure relief valve at station 702 is completely detached. The butterfly doors for both valves are still attached to the structure. The aft end of the wreckage shows the skin plank severely wrinkled and folded up and forward. The left and right primary static ports are in place. The aft door jamb is creased between longeron #25 right and longeron #2 right. The door jamb is bent aft and inboard approximately

15 degrees between longeron #24 right to longeron #18 right. The floor beam and the frame are fractured at longeron #18 right. There is a vertical skin fracture at station 636 and longitudinal skin fracture at longeron #26 left. The lower skin at station 560 is folded down 90 degrees. The forward jamb is fractured between longeron #25 right and longeron #24 right.

A 6.3 foot by 4.8 foot section of the upper fuselage has been recovered encompassing station 579 to station 655 left and longeron #18 left to longeron #11 left. There are three passenger windows. The front end of the wreckage is broken off along the skin splice at station 588 and from longeron #18 left to longeron #16 left. The lower edge of the wreckage separated along the splice at longeron #18 left. The aft end of the skin from longeron #18 left through longeron #16 left is bent inboard 90 degrees from station 655 to station 636.

A 5.2 foot by 7.3 foot section of the lower fuselage has been recovered encompassing station 753 to station 815 and longeron #22 left to longeron #26 right. The structure between longeron #22 left to longeron #26 right and station 769 to station 817 is in place. The pneumatic anti-ice duct of the left side is still attached. The right skin severed at longeron #26 from station 769 to station 817. The keel beam joining fittings at longeron #29 left, longeron #30, and longeron #29 right are in place. The four joining bolts are in place in the fittings and severed at the threaded area of the bolts. A portion of the outboard keel beam fitting end pad is still attached at longeron #29 left and longeron #29 right. The lower surface does not show evidence of pillowing. The longerons from longeron #29 right to longeron #26 right are bent inward in varying degrees up to approximately 75 degrees. The left forward end of the structure, longeron #29 to longeron #22, is bent outward approximately 30 degrees. Two feet of the left wing-to-body fillet is in place at the forward end.

2.1.4 Fuselage Over Wing Area

Description: The fuselage over wing area is from fuselage station 786.5 to fuselage station 1007. There are twenty-two passenger windows in this section.

Findings: Approximately 60% of the fuselage over wing area was recovered and identified. A 5 foot by 3.3 foot section of the right upper fuselage structure has been recovered encompassing station 859 to station 918 and longeron #8 right to the window belt area. This section includes the upper structure areas of the over wing emergency exit

doors. A 5 foot long portion of the left side of the frame at station 905 is still attached.

A 31.5 foot by 14.5 foot section of the aft fuselage lower structure has been recovered. It encompasses the lower body area from station 946 to station 1322 and from longeron #18 left to longeron #24 right. The longerons, skin panels, and most of the frames are in place. The left wing-to-body fillet is still attached. There is no evidence of cusp membrane decompression on the left hand side. The left gear door is in place and attached at its inboard hinge to the keel beam. The cargo compartment forward bulkhead (just forward of station 1003) is in place except where it intersects the lower fuselage skin structure. The bulkhead assembly broke off along its lower edge as evidenced by the bulkhead cap flanges still attached to the fuselage skin structure. A 5 foot length of wheel well horizontal closure panel and associated support structure, station 946 to station 1003, are attached along the entire top of the bulkhead. A 1 foot outboard section of the structure is detached at the right hand side from station 946 to station 1003. The right section of this piece, 20 inches outboard and 27 inches inboard of the outer track, is bent down approximately 60 degrees. The web in this section showed evidence of ripping and tearing. This portion of the wreckage did not show evidence of fatigue and multi-site damage.

The wheel well centerline panel is severely deformed/crushed aft and to the right. The forward and aft jambs are detached from the lower door sill area. The forward jamb of the aft service door is severed from 5 inches above longeron #18. The aft jamb of the aft service door is severed at longeron #15 and bent outward approximately 10 degrees. The keel beam structure is in place but bent down approximately 15 degrees. The right aft and outboard end of the keel beam is fractured at the wing skin. The aft outboard end pad fitting is fractured and still attached to the frame at station 1003. All the other tension bolts in the remainder of the fitting are not present.

A 12 foot by 5 foot section of floor panels, floor beams, two outboard seat tracks, and associated structure are still attached along the left hand side by the aft service (L2) door area. The left aft skin plank has both the cabin airflow butterfly valve, nozzle valve, toilet service panel, and associated mechanisms and ductings are still attached. The aft auxiliary tank (580 gal) although separated from its hanger supports and drag links is in place, along with the fuel probes and bladders. There is a 1.5 foot by 1.5 foot puncture hole at the aft right wall with ripping along the remainder of the right wall.

2.1.5 Aft Cargo Area

Description: The aft cargo area is from fuselage station 1007 to fuselage station 1463. It includes the aft cargo compartment, aft service (L2) door, engine pylons, and the aft pressure bulkhead. There are twenty-two passenger windows in this section.

Findings: Approximately 85% of the aft cargo area was recovered and identified. A large piece of recovered fuselage for the aft cargo area is described in the fuselage over wing area due to the forward end extending to fuselage station 946.

Aft Pressure Bulkhead. The aft pressure bulkhead (APB) was recovered in five segments equaling approximately 95% of the total. The rear entry door was recovered approximately 95% intact and is detailed in another section.

The largest section recovered was 12 feet by 8.8 feet overall and was primarily above the floor level and contains the aft cabin door frame and extends circumferentially from longeron #18 left through longeron #1 around to longeron #16 right. The upper and left door frame segments are complete. The right frame includes 54 inches from the top and is deformed vertically in a bowed manner and forward. Reinforcements for the two upper corners and lower left corner are attached with all fasteners in place. The door frame upper door pin engagement receptacle is torn out of the frame in the forward direction. The door frame corners showed no evidence of failure.

The right side web section is deformed progressively in a forward direction approximately 20 inches, near longeron #3 right, to 32 inches near longeron #12 right. Additional deformation exists at the circumference from longeron #12 right to longeron #15 right. The break at longeron #17 right exhibits a rearward bow near the mid-span, with an approximate 6 inch depth and continues vertically up to longeron #12 right.

The upper circumference and web, from longeron #2 right to longeron #2 left, is torn and compressed inward toward radial center and aft. The remaining left web section, longeron #2 left to longeron #15 left, exhibits heavy compression damage vertically and horizontal tearing inward toward the left door frame. Small fuselage skin segments adjacent to the butt joints are attached to the left and top APB "Tee". Numerous systems cables, wiring, and plumbing remain attached.

A 33 inch by 42 inch segment matching the larger segment breaks, extending from longeron #15 left down to longeron #18 left, shows similar compression and tearing.

The lower right segment, 75 inches by 54 inches, extends from longeron #18 right to longeron #23 right. Attached to this section is the lower right 12 inches and bottom threshold of the door frame. The negative pressure relief valve is attached and free to operate but exhibits hydrodynamic damage. The portion of APB web below the floorline is bent aft. The upper right section of this segment is folded forward. Hydrodynamic damage is evident.

The bottom segment, 64 inches by 36 inches overall, extends from longeron #23 right to a few inches past longeron #23 left. There is a section of fuselage skin adjacent to and including the tail jack point fitting that is attached to the bulkhead "Tee". The segment extends up to and includes the lower left corner of the negative pressure relief valve frame. The web section exhibits compression damage and is buckled and bent at a 45 degree angle to center. A 10 inch section of the upper finger doublers are pulled up and 45 degrees left. A 3 foot by 11 inch section of the station 1338 lower frame is still attached to the APB lower "Tee" section. The vertical frame is bent aft 90 degrees and right 30 degrees near the half way point.

The lower left segment, 32 inches by 29 inches overall, remains connected to a 4 foot by 8 foot section of fuselage structure. The APB segment extends from longeron #18 left to longeron #23 left. A portion of auxiliary power unit (APU) ducting and related components are attached. The upper edge at longeron #18 left is separated at the floorline splice along its length. The floorline splice "Tee" has pulled away from the web. The web portion is buckled and torn consistent with the other APB segments.

A 5 foot by 6 foot section of the aft lower fuselage has been recovered. It encompasses the APU compartment area, station 1343 to station 1401 and longeron #23 left to longeron #24 right. The entire auxiliary power unit (components, ductings, air inlet door panel, and support box) is attached to the fuselage structure. The access door for pneumatic air ground connection and the access door for the stair control are both in place.

The tail skid fitting is in place with the safety wire of the sensor indicating lever in place. The APU shroud is still attached with ripping at both outboard ends. The upper half portion of the APU shroud is crushed in a down and aft direction. The left and right closure panels outboard of

the APU support box are detached and both appear to have been broken off at the hinges. There is no evidence of pillowing.

2.1.6 Miscellaneous Fuselage

There were sections that were identified as fuselage but the exact airplane location could not be determined due to the size of the piece and/or lack of identifying numbers on the piece. These pieces were sorted and placed in storage boxes that were labeled fuselage-white paint, fuselage-multi-paint and fuselage-green paint. A table with the description of the pieces is attached. The total percentage of the recovered fuselage that was classified as miscellaneous is approximately 30%.

2.2 Wings

Description: The wings are 56.5 feet long. The wing as described in the MD-80 Maintenance manual follows. The wings are an all-metal, fully cantilevered, sweptback, double-dihedral single-unit mounted through the lower section of the fuselage. Each wing has leading edge slats, ground spoiler, inboard and outboard spoilers, inboard and outboard flaps, aileron, aileron control tab, aileron trim tab, integral fuel tanks and supporting structure for the main landing gear. Refer to the attached wing station diagram for station locations, i.e. xcw, xrs, xfls, xw.

The main frame consists of a front spar, rear spar, chordwise ribs and bulkheads, and skin panels with spanwise stiffeners. The main frame forms a structural box extending from wingtip to wingtip. The integral fuel tanks are located within the structural box sections of the wing. The front and rear spars provide the main supporting structure for the main landing gear and flight control surface attach fittings.

The secondary structure of the wing is the area forward of the front spar and aft of the rear spar except for the control surfaces. The wing leading edge consists of a fixed portion and extendable full span slats. The slats extend the length of the leading edge of the wing. The slats are independently lowered to the takeoff position during initial extension of the flaps.

The secondary structure includes the wingtips, leading edge, and the trailing edge. The leading edge is attached with permanent-type fasteners. Wingtips are removable for inspection and maintenance.

The fixed leading edge consists of skin and formers and contains frictionless rollers that completely cage the slat tracks for extension and

retraction of the slats. The leading edge slats consists of six segments supported on tracks and rollers. The upper surface and nose section of the slats are of double skin construction attached to chordwise ribs which incorporate thermal anti-icing.

The wingtip is a faired assembly that completes the contour of the outer wing. The tip is of all-metal construction consisting of ribs, channels, doublers, gussets, and plating. The landing light, logo light, position lights, and strobe lights, and compass flux valve are housed within the wingtip. The compass flux valve is attached to the wing structure and extends into the wingtip.

The wing trailing edge is constructed of aluminum honeycomb panels and aluminum sheets supported by ribs. The lower surfaces aft of the rear spar and forward of the flaps have hinged panels.

Articulated bent up trailing edge (BUTE) panels are installed on the lower surface of each wing as the aft portion of the hinged trailing edge panels. The BUTE panels are hinged near the center of the trailing edge panels and deflect upwards against stops as the flaps are extended. The panels deflect back to the faired position as the flaps are retracted.

A vortilon (aerodynamic fence) is installed on the lower surface of each wing. The vortilon is constructed in two removable sections joined together with a connecting access fairing. The sections are attached with screws to formers outboard of the landing gear.

2.2.1 Left Wing

Findings: The left wing was recovered in three major portions: from xcw=104 to xrs=164 (inboard portion); from xrs = 164 to xrs = 353 (mid portion); and from xrs = 353 to the wing tip (outboard portion), refer to the attached wing station diagram. Approximately 90% was recovered and identified.

Inboard portion. The lower wing skin fractured at approximately xcw = 104, from front spar to rear spar. The fracture line runs chordwise parallel to the xcw = 104 bulkhead and the lower skin is bent down 80 degrees. Most stringers failed at the same approximate location with the skin, except for stringers #16, #19, and #21 where the upper flanges of the "J" section fractured approximately 1 foot inboard of the skin fracture line.

The rear spar is deformed aft inboard of xcw = 104, but it was not completely severed at that location, a section of spar extending inboard

to xcw = 58.6 is attached to this portion of wing. The main landing gear attach fitting, trapezoidal panel, main landing gear piston and wheel assemblies and fixed side linkage remain attached to this portion of rear spar.

The wing bulkheads at xcw = 104, xcw = 121, xrs = 69, xrs = 91, and xrs = 111.5 are attached to the lower wing skin and rear spar. The front spar web and upper cap are detached, except for a portion of web extending from xcw = 121 to xrs = 91, which is folded forward. Outboard of xrs = 91, the front spar web is severed span wise along the upper edge of the lower spar cap vertical leg.

At the outboard end of this portion, the lower wing skin fractured in two sections: the aft plank (from the rear spar plane to stringer #17) is severed chordwise at approximately xrs = 137, and the forward plank (from stringer #17 to the front spar plane) is severed chordwise at approximately xrs = 164. The aft skin plank has its fractured edge slightly bent up, whereas the forward skin plank is deformed down and aft 45 degrees.

The rear spar upper cap is severed near the radius between the horizontal and vertical legs. The rear spar web is severed just outboard of xrs = 111.5, where the four bolts that provide support for the flap hinge fitting are fractured just aft of the rear spar plane. The main landing gear upper attach fitting support doubler (surfboard) is severed spanwise near the rear spar plane.

The lower surfboard doubler has a chordwise fracture line at its aft inboard edge, where approximately 3 inches of the doubler is detached. The main landing gear attach fitting is attached to both the upper and lower doublers and the rear spar. The left hand main landing gear assembly is still attached to its fitting at or near its stowed position.

The left hand trapezoidal panel is displaced inboard at its aft end. The main landing gear fixed side link brace is slightly bent down around its mid-section, with its inboard attachment pulled out of the trapezoidal panel. The fixed side link inboard attach nut was wedged behind the trapezoidal panel.

A section of upper wing skin corresponding to this inboard left wing was recovered. It extends from approximately xcw = 79 to xrs = 209. The forward skin plank is detached from xcw = 79 to the stringer splice at xcw = 121. The front spar upper cap upper leg is attached to the forward edge of the skin from approximately xrs = 111 to xrs = 209. The rear spar upper cap upper leg is also attached to the skin from

approximately xcw = 104 to xrs = 209. There is a 5 foot section of spar cap that extends outboard from the chordwise fracture line at xrs = 209. The fracture extends between the rear spar plane and stringer #2.

Mid portion. The mid portion consists of sections of upper and lower skin, spars and internal structure extending approximately from xrs = 137 to xrs = 353. The lower wing skin aft plank is severed chordwise and bent down 20 degrees at xrs = 137. The lower skin forward plank is severed chordwise at approximately xrs = 164. Both lower skin forward and aft planks are severed chordwise just outboard of xrs = 353 and both are bent up varying degrees up to 90 degrees. The forward lower skin plank has a chordwise tear at approximately xrs = 240. There is a section of front spar extending approximately from xrs = 200 to xrs = 353, the web is separated from the upper and lower spar caps and bent aft 45 degrees at the inboard end over a span of approximately 5 feet.

The upper skin forward and aft planks are severed chordwise at xrs = 214, with the forward plank separated from stringer #5 at its aft end over a span of approximately 5 feet.

At xrs = 353 both upper skin planks are severed, with portions in the mid-chord area folded up past 90 degrees from its original shape. The rear spar web and lower cap separated from the wing skins from xrs = 164 to xrs = 267. From xrs = 267 to xrs = 353, the spar is attached to both skins. The flap hinge fittings at xrs = 267 and xrs = 353 are still attached to the rear spar. The flap hinge fitting at xrs = 164 is still attached to the rear spar and a 2 feet portion of the wing bulkhead at that station, which separated from the skins. Parts of the trailing edge support structure remain attached to the rear spar from xrs = 164 to xrs = 353.

Outboard portion. The outboard portion of the recovered left wing extends from 1 foot inboard of xrs = 383 to the wing tip. The upper and lower skins exhibit several span wise and diagonal fracture lines from xrs = 414 to their outboard end. The outboard portion of the lower wing skin is severed chordwise at xrs = 509 approximately, and it is bent down 90 degrees between xrs = 545 and xw = 536. The wing tip is crushed and exhibits evidence of water impact on its upper skin. The rear spar has all four aileron hinges still attached, together with the trailing edge panels from xrs = 509.5 to xw = 560. The trailing edge panels exhibit multiple tears and bends in their upper and lower surfaces.

The front spar has portions of the leading edge attached to it from the slat track #12 to approximately xrs = 531, the portion of spar

between xrs = 509 and xrs = 531 is bent up and aft approximately 45 degrees. The slat track #13 is still attached to the spar.

Flap. The left flap assembly was recovered in three sections. The first section extends from the flap inboard end (xcw = 58) to the flap flex joint at xw = 138. The vanes are still attached to this section, with the outboard vane severed chordwise in two locations, with both fracture lines approximately 2 inches inboard of the flap vane support fittings. The inboard flap track is still attached to the flap assembly, and exhibits a dent on its upper inboard flange at the 0 degree position. The upper skin exhibits chordwise and spanwise fractures at xifo = 69. The xrs = 111 flap hinge bracket and hinge are still attached to the flap assembly.

The second section extends from the flap flex joint to the skin splice at xfls = 235. The corresponding flap vanes are still attached and fractured chordwise close to xfls = 212. A portion of the flap upper leading edge skin also fractured chordwise at this location and is attached to the third recovered section of flap. This second section of flap is attached to the wing rear spar by the flap hinge bracket and flap hinge fitting at xrs = 164.

The third recovered section of the left flap extends from xfls = 235 to the outboard end (xw = 351). The outboard end is bent up 90 degrees over 1 foot with a chordwise crease and several tears in the upper and lower skins. The flap vanes are still attached and fractured in two locations: at xfls = 235 and at xfls = 350. This section of flap remains attached to the wing rear spar by the flap hinge brackets and fittings at xrs = 267 and xrs = 353.

Spoilers. None of the spoilers were recovered complete, but there were nine spoiler sections ranging in size from 3 feet to 5 feet spanwise. A 1 foot long (spanwise) section of spoiler is attached to its hinge and the wing rear spar at xte = 297.114.

Aileron. The recovered portions of the left aileron comprise its outboard end (xa = 411) and total three sections spanning approximately 8 feet. The control tab is severed chordwise at its inboard hinge location. The trim tab is fractured chordwise at the inboard and mid-hinge points. All aileron hinge fittings are attached to the wing rear spar.

Slats. The recovered portions of slats were comprised of 90 % of slat #0, all of slat #1, the inboard foot of slat #2, all of slat #3, all of slat #4, and all of slat #5.

Slat #1 was separated chordwise 3 feet inboard. Slat #2 exhibits a chordwise fracture 1 foot outboard of track #7. Slat #3 is complete. Slat #4 is severed chordwise in two locations, both within 1 foot of slat track #11.

All slats exhibit apparent water impact damage on their upper surfaces.

Fourteen slat track assemblies (out of a total of 15) were recovered, two of them (#9 and #10) are attached to an approximate 10 foot section of wing leading edge that separated from the wing front spar. Three slat track assemblies (#11, #12, and #13) are still attached to the wing front spar and portions of wing leading edge. Only slat track #14 was not recovered.

2.2.2 Right Wing

Findings: Seven major portions of the right wing were recovered with numerous smaller sections of internal structure and fittings. All of the recovered parts exhibit more severe damage than the left wing. Approximately 80% was recovered and identified.

The first portion comprises an inboard section of lower wing skin forward and aft planks extending from approximately xcw = 20 to xrs = 157. All wing bulkheads are detached except for a 2 foot by 1 foot portion of the xcw = 79 bulkhead which is still attached to the skin just aft of stringer #17. The forward skin plank is folded aft 130 degrees and down behind the front spar plane in its inboard section. Outboard of xcw = 121 the forward skin plank is folded aft and inboard diagonally 100 degrees.

Along xcw = 104, both lower skin planks are bent down chordwise about 45 degrees. The main landing gear lower attach fitting external doubler (surfboard) is still attached to the skin at this location. All stringers are severed along xcw = 104.

The lower skin aft plank has the rear spar lower cap still attached to it. The spar cap and the skin are bent up 20 degrees at the inboard fracture line xcw = 20, down 45 degrees at xcw = 104, and slightly bent up again at the outboard fracture line at xrs = 157. The section of skin aft of the rear spar at xcw = 121 has the main landing gear auxiliary spar lower cap attached to it.

The second portion is a section of the lower outboard wing skin's forward and aft plank. This section extends from approximately xrs =

111 to xw = 560, and it is fractured chordwise at xrs = 477. At the inboard end, the section aft of stringer #15 fractured chordwise at xrs=157. All wing bulkheads are detached, except for an approximate 1 foot chordwise section at xrs=383. The rear spar lower cap lower flanges and the front spar lower cap lower flanges are still attached to the wing skin along the span of the recovered portion.

All ten lower wing outboard fuel tank access doors are attached to the skin. The BUTE piano hinges are attached to the rear spar lower cap aft flange, and two 3 feet long sections of the forward BUTE panels remain attached to the hinges at the outboard end.

An approximate 5 foot spanwise section of front spar web is attached to the outboard end of the recovered wing panel. This spar section contains the slat track shroud corresponding to the #12 slat track.

The outboard end of the lower wing skin, from xrs = 477 to xw = 560, is detached due to a chordwise fracture at xrs = 477. The section of xrs = 477 to xw = 560 of lower wing skin is slightly bent up and aft, and its leading edge has several irregular fracture lines from xrs = 531 to xw = 536. All the spanwise stiffeners and access panels are in place.

The third portion is a section of front spar and upper wing skin extending form approximately xrs = 415 to xw = 560. Sections of wing leading edge, totaling approximately 10 feet spanwise, are attached to the wing front spar. These leading edge sections exhibit multiple tears and missing portions, mostly on the upper skin. Several slat mechanism control pulleys and sections of slat control cables are attached to this leading edge section. Slat tracks #13, #14, and #15 are also attached to the front spar. A section of slat #5, approximately 30 inches spanwise, is attached to slat track #15. The upper wing skin exhibits a spanwise fracture along stringer #11, except for a small 2 foot section of skin inboard of xw = 536, where the whole chordwise width of the skin is present.

The fourth major portion that was recovered consists of a section of wing rear spar from approximately 3 feet inboard of xcw = 58 to xrs = 91. This section contains a portion of the upper wing skin (from the rear spar to stringer #4) that extends outboard to xrs = 111, aft of the rear spar upper cap. The main landing gear attach fitting auxiliary spar upper cap is still attached to the upper wing skin. The inboard end of the auxiliary spar upper cap is still attached to the main landing gear attach fitting upper outboard flange.

A 6 foot portion of the bulkhead at xcw = 104 is still attached to the wing skin and rear spar forward of the main landing gear attach fitting. The forward end of the bulkhead is bent inboard at 90 degrees from its original position. The main landing gear attach fitting is attached to the wing rear spar and a portion of its upper support doubler (surfboard). The main landing gear cylinder is attached to the main landing gear attach fitting.

The trapezoidal panel is attached to the rear spar, the fixed side brace link, and the ski fitting. The ski fitting is severed spanwise at approximately the rear spar plane.

The fifth major recovered portion of the right wing consists of three sections of wing rear spar. The two inboard sections are approximately 22 feet long when put together, and consists of the rear spar upper cap and portions of the web on the inboard end. These two sections have portions of upper trailing edge panels attached to the spar upper cap. Two outboard flight spoiler hinge fittings are also attached to the spar with sections of the spoilers still attached to the hinges. The third section is an 8 foot spanwise portion of the wing's rear spar that extends to the spar outboard end at xw = 560. The trailing edge panels, which exhibit multiple tears in the skin, are still attached to the aft edge of the wing rear spar. The right wing tip and its inboard support bulkhead are attached to the outboard end of this rear spar section. The forward upper end of the wing tip has more impact damage than the rest of the wing tip assembly.

The sixth recovered portion of the right wing is the upper inboard wing skin containing the area from stringer #3 to stringer #8 and from xcw = 58 to approximately xrs = 90. The upper skin is fractured chordwise just inboard of xcw = 58 and bent down 30 degrees. There are no internal ribs attached to this section of skin. The stringers are fractured at various lengths inboard and outboard of the production splice at xcw = 121 and are bent down and aft 60 degrees. Both wing upper access doors along stringer #7, inboard and outboard of xcw = 121 were attached to this skin section. The section of skin outboard of the xcw = 121 stringer splice is bent up 30 degrees and aft at the fracture at the outboard end at approximately xrs = 90. The forward section of the main landing gear upper attach fitting external surfboard doubler at xcw = 104.5 is attached in the area of stringer # 3 through #5.

The seventh recovered portion of the right wing is a section of upper wing skin with portions of stringers that is approximately 22 feet long, extending from xrs = 164 to xrs = 414.

The upper skin forward plank is severed chordwise at approximately xrs = 164 and it extends to its outboard splice along stringer #5, ending at xrs = 353. The forward horizontal leg of stringer #5 is still attached to this forward skin plank. The front spar upper cap is still attached to this skin along its forward edge.

The upper skin aft plank is severed chordwise at approximately xrs = 295 and at the outboard end (xrs = 414). There are multiple fracture lines, both chordwise and spanwise, in the area between stringers #1 and #4. The front spar upper cap is attached to this portion of aft skin plank from xrs = 353 to xrs = 414. There are no wing internal bulkheads attached to this section of skin.

Flap. The inboard right flap was separated chordwise at xifi=35.5. The remainder of the inboard and outboard flaps are connected at the flex joint area. An approximate 22 inch by 22 inch section of the inboard flap removable trailing edge is torn out between xw = 47.45 and xifo = 64.224.

The outboard flap trailing edge skins are fractured in several locations between stations xfls = 187.406 and xfls = 241.125. The outboard section of flap at xfls = 304 is fractured and bent down 45 degrees and aft 20 degrees. This section is missing most of the upper flap skin on the removable trailing edge wedge and is missing a section of the lower skin from station xw = 333.148 to the outboard end.

The inboard 40 inches of the inboard flap was recovered separate from the main flap section discussed above. As in the recovered left inboard flap, the flap track and lower flap fairing remained attached to the flap's inboard closing rib. This section is severed chordwise at approximately xifi = 35.5. The fractured area is bent down 10 degrees and slightly aft in the leading edge section. The lower aft skin of the removable trailing edge wedge is torn approximately 30 inches spanwise just aft of the flap spar. A section of flap vane spanning approximately 40 inches is attached to the flap leading edge. The outboard edge of this flap vane section is severed in line with the fracture of the main flap at xifi=35.5.

All the flap vanes were recovered. The inboard flap's, outboard vane was severed chordwise 50 inches outboard from its most inboard end. The outboard piece of this vane is attached to the flap. The inboard piece of this outboard flap vane as well as the remaining vanes were recovered separate from the main flap section. All vanes are damaged with multiple tears, dents and wrinkles on their upper surfaces. All flap vane attach brackets are bent in an inboard direction.

All four flap aft hinge brackets were attached to the flaps at their respective attach locations. The hinge brackets at station xrs = 111.5 and xrs = 164 were attached to the hinge fittings which were attached to an approximate six foot section of wing rear spar from station xrs = 91.5 to xrs = 164. Both hinge fittings at xrs = 111.5 and xrs = 164 remain attached to this section of rear spar by the two lower mount locations on each fitting. Both fittings are pulled down and aft from their upper mount locations. The upper mount studs for the fitting at xrs = 111.5 are attached to the upper spar cap and a section of the wing internal bulkhead. The two studs are fractured in an aft and down bending orientation. The upper studs at station xrs = 164 are detached along with the surrounding upper spar cap and web section. Both forward and aft hinge fairings are attached at these locations.

The hinge bracket at station xrs = 267 is attached to the forward fitting which is attached to the aft 18 inches of the internal wing bulkhead at xrs = 267. All four mounting studs and attach bolts remain attached. The aft fairing is attached to the bracket, the forward fairing has sections missing. The most outboard bracket at xrs = 353 is attached to the flap, the left attach lug of the forward fitting remains bolted to the pivot lug of the aft fitting.

Spoilers. Pieces of each of the three spoilers were recovered, ranging in size from 10 inches to 45 inches. The inboard (ground) spoiler hinge fitting was not recovered. The two flight spoiler hinge fittings have segments of the spoilers attached and were recovered attached to a section of the wing rear spar.

Ailerons. The right aileron was recovered in multiple pieces. The inboard 3.5 feet of the right aileron was still attached to the inboard hinges. The inboard hinges are attached to a 65 inch section of the right wing's rear spar web. The remaining 104 inches that was recovered had multiple chordwise breaks. There is a 27 inch piece of the aileron nose only. The control tab and trim tab are detached. The inboard 17 inches of the trim tab was recovered separate from the aileron.

Slats. Approximately 20% of the slat structure from the right wing has been recovered. There is an approximate 30 inch section of the #5 slat that is attached to the wing structure at the #15 slat track which has the inboard end bent up at 45 degrees. Eleven of the fifteen slat tracks were recovered and of the eleven, three (#13, #14, and #15) were still attached to the front spar structure on the right wing. The remaining eight (#1, #3, #4, #6, #8, #9, #10, and #11) were recovered individually mounted on the leading edge machined ribs with local

portions of the slats and leading edge skins attached. Slats tracks #2, #5, #7, and #12 were not recovered.

2.2.3 Wing Center Box

Findings: The recovered wing center box structure consists of a large section of the lower skin and two sections of the upper skin. Approximately 40% of the wing center box was recovered and identified.

Lower skin. The lower skin section is approximately 10 feet spanwise and approximately 9.5 feet chordwise. The boundaries encompass the front and rear spar and spanwise from xcw = 20 right to xcw = 100 left. The right section of wing skin and stringers fractured in the same area, 10 to 20 inches outboard of the wing centerline splice. The edges of the skin are bent down 30 degrees. On the left side the wing skin and horizontal legs of the stringers are fractured at xcw = 100. The vertical legs of the stringers are fractured at xcw = 79. Portions of the center box bulkheads at xcw = 0, xcw = 20 and xcw = 42 are attached to the lower wing skin and bent to the left.

The forward portion of the lower wing skin was bent up approximately 45 degrees in the area of stringer #23. The lower skin is fractured in several areas along the bendline. The aft left hand corner of this section has a slight downward bend starting at stringer #15.

The keel box that attaches to the lower wing skin is still attached to the skin. The horizontal legs of the upper attach angles are fractured from the vertical legs that attach to the keel box and are bent up with the wing skin approximately 45 degrees).

Upper skin. The two sections of upper skin recovered consist of a large piece of skin and stringer from stringer #11 upper to the rear spar and xcw = 58 right to approximately xcw = 86 left, and a smaller skin and stringer piece on the left hand side from xcw = 20 to xcw = 58 and stringer #9 to stringer #14 upper. None of the two skin sections contain any attached wing internal bulkhead sections.

The larger section contains both the upper right and left fuel tank access panels between xcw = 20 and xcw = 42 and the auxiliary fuel aft tank transfer mount between stringers #2 and #1. The right side has a slight downward bend from xcw = 42 to the fracture at xcw = 58. The left side has a spanwise fracture in the skin between stringers #6 and #5 and extends from the outboard chordwise fracture at xcw = 58 inboard to xcw = 20. The skin section aft of the spanwise break is bent up

approximately 60 degrees. The outboard fracture of the skin at xcw = 58 has a slight downward bend.

The smaller section of upper skin contains the forward auxiliary fuel tank transfer mount between stringers #12 upper and #14 upper and between xcw = 20 and xcw = 42.

2.2.4 Miscellaneous Wing

Findings: There were pieces of structure that were recovered and identified as being from the wing but the exact wing location could not be determined due to the lack of a part number and/or size of the piece. Approximately 10% of the recovered wing is classified as miscellaneous and is documented in the attached table.

2.3 Empennage

Description: The empennage consists of the horizontal stabilizer and vertical stabilizer. The horizontal stabilizer is approximately 40 feet long. Both sides of the horizontal stabilizer have an elevator with an anti-float tab, geared tab, and an elevator control tab. The vertical stabilizer has the rudder and rudder control tab and is approximately 18 feet long.

The vertical and horizontal stabilizers are fully cantilevered sections of the empennage. The vertical stabilizer is attached to the aft fuselage and the horizontal stabilizer is mounted at the top of the vertical stabilizer.

Findings: Approximately 85% of the empennage was recovered and identified.

2.3.1 Horizontal Stabilizer

Description: The description of the horizontal stabilizer per the MD-80 maintenance manual follows. The horizontal stabilizer is removable as a unit and consists of a center section and right and left outboard sections. The horizontal stabilizer is hinged to the vertical stabilizer rear spar, and serves as a movable control surface for longitudinal trim. The leading edge sections are removable. Aerodynamically balanced elevators are hinged to the outboard sections of the horizontal stabilizer. Refer to the attached horizontal stabilizer diagram for station locations, i.e. xe, xhs, xh.

Findings: The retrieved horizontal stabilizer structure is in several segments. The major segment consists of the center box, the left and right outer constant sections, a 13.5 foot segment of the left outer section, the root portion of the right outer section, the inboard 20 inches of the right elevator and control tab. The upper 20 inch portion of the vertical stabilizer structure (except for a longer strand of vertical stabilizer rear spar cap) is attached to the horizontal stabilizer pivot lugs. The upper portion of the horizontal stabilizer control mechanism with jackscrew was attached to the horizontal stabilizer. The acme screw had what appeared to be thin, spiral metallic material attached to it. The bottom of the quill shaft was fractured. The control mechanism (jackscrew assembly) was removed from the horizontal stabilizer for detailed analysis. The lower stop collar was recovered separately and was also sent to the NTSB metallurgical lab for analysis. Refer to the NTSB Materials Laboratory Factual Report No. 00-145.

The second segment is an 8 foot section of the left outboard horizontal stabilizer, which includes the horizontal stabilizer tip.

The third segment consists of the right outer section except for the inboard 3 feet of the structure, which was recovered separately. For the purpose of this report, the sections will be described individually.

Center Section. The front spar upper cap forward tang has small pieces broken off. The front spar lower cap forward tang, has a 1.5 inch semi-circular indentation approximately 3.5 inches left of centerline. A thread impression is visible.

The side plates where the jackscrew attaches are bent approximately 1.25 inches to the left. The bottom section of the side plate lugs are fractured and the tops are bent. The forward upper panel has a 0.5 inch by 2 inch hole in the aft right corner of the panel. The remaining upper panels appear damage free and with only minor scuffing of the corrosion protection film. The forward lower panel exhibits some downward bulging and upward buckling of the integral stiffeners, which is more prevalent at the right forward corner of the lower surface. No buckling was noticed on the upper stiffeners.

Both left hand and right hand inboard ends of the horizontal stabilizer outboard constant section front spar upper cap exhibit similar fractures which appear to be a mirror image of each other. On the right hand and left hand side of the front spar upper cap outboard of the fracture, there is a witness mark that matches the deformation found in the lower edge of the vertical stabilizer tip fairing. The inboard end of the

constant outer section rear spar lower cap aft tang is fractured and bent up ¾ inch in both the left hand and right hand sides.

The rear spar of the center box appears undamaged. The elevator control mechanism (sectors and supports) and hydraulic components are attached to the rear spar.

The center trailing edge ribs are installed in the aft side of the horizontal stabilizer rear spar at xh = 7.234 on the left and right sides. These ribs provide support for the aft end of the upper and lower horizontal stabilizer movable fairings (banana fairings). Both ribs have two production holes through their webs: the forward production hole allows routing of hydraulic lines and the aft production hole allows the elevator control shaft to pass through the rib.

The center trailing edge left rib is still attached to the banana fairing support fitting, but fractured along the forward edge that attaches to the horizontal stabilizer rear spar. The left rib's aft production hole is torn and elongated at the 2 o'clock position (looking outboard at the rib). This tear extends approximately 2 inches beyond the original hole diameter. The width of the tear is approximately the same as the diameter of the elevator control shaft.

The center trailing edge right rib is still attached to the horizontal stabilizer rear spar. The banana fairing support fitting is attached to this rib. The right rib's aft production hole is elongated at the 8 o'clock position (looking outboard at the rib). The elongation is approximately ½ inch beyond the original hole diameter. The width of the elongation matches the diameter of the elevator control shaft. This is similar to the elongation on the left rib.

The two brackets in the lower forward panel are for the anti-float tab control system. The tear out of the attach hardware through the bracket lugs is downward. The lugs are also bent to the left approximately 30 degrees.

The horizontal stabilizer pivot joint is present (i.e. sleeves, retainers, thru bolts and nuts). The lugs of the pivot fitting house a grease fitting on the bottom side of each lug. Both lug edge surfaces are scraped and the grease fittings sheared off. The adjacent vertical stabilizer pivot structure shows contact marks in line with the grease fitting location with the horizontal stabilizer rotated 90 degrees leading edge up. The horizontal stabilizer center section pivot lugs exhibit contact marks that appear to be caused by the aft edge of the vertical stabilizer

hinge plates. These marks are oriented at 40 degrees approximately from the lower surface of the horizontal stabilizer.

The vertical stabilizer tip fitting (L-shaped fitting spanning left to right pivot lugs) exhibits a torsional deformation and fracture. The fracture is indicative of the horizontal stabilizer rotating clockwise, when looking down, relative to the vertical stabilizer.

A 3 inch by 2.5 inch piece of rudder material was imbedded against the upper right horizontal stabilizer movable fairing in the rear spar area adjacent to the right side elevator control sector assembly.

The left and right elevator anti-float control sector shafts are attached to their respective side plates of the horizontal center section.

Right Outer Constant Section. The upper panels are severed at the root aft of the front spar and continuing approximately 3 feet chordwise and peeled up and aft approximately 30 degrees.

The lower panels are bent up approximately 15 degrees (chordwise) with local buckling between stringers. The outboard side plate is not recovered except for the aft 16 inches near the rear spar.

The front spar web was not recovered. The rear spar and elevator inboard hinge support structure is attached. The elevator inboard hinge fitting was fractured. The inboard 20 inches of the elevator and elevator control tab are attached by the control rod and linkage.

Left Outer Constant Section. The forward upper panel is severed at the root and bent up laterally approximately 1 inch. There are some wrinkles in the forward panel and the adjacent aft panel. The forward lower panel has a spanwise tear just aft of the front spar. The front spar web is bent aft approximately 45 degree with respect to the center section. A 16 inch by 15 inch piece of front spar lower cap with leading edge skin attached (upper forward corner) is lodged in the cavity of the outer constant section toward the forward end. The rear spar and elevator inboard hinge support structure are attached. The inboard elevator hinge fitting was not recovered.

Right Outer Section. The right outer section is separated into several pieces. Only the stringers, varying in length from 6 inches to 4 feet, are attached to the outer right section of the horizontal stabilizer.

A portion of the right horizontal stabilizer front spar and lower skin panels was recovered in five separate pieces.

The major piece is 12 feet long and consists of a section of front spar lower cap and web, with portions of the lower skin and stringer panel attached to the spar cap. The skin and stringer panel is approximately 2 feet chordwise at its widest point and exhibits multiple spanwise fracture lines with two major chordwise fractures approximately 50 inches apart. The upper flanges of the machined stringers are severed along their base radii and separated from the skin along the majority of their span. Multiple buckles can be observed in both skin and stringers. The forward 6 inches of skin in the vicinity of the front spar lower cap are bent up along the entire span, ranging from 30 degrees to 90 degrees. A 7 foot section of spar web is also attached to the lower spar cap, starting 3 feet outboard from the inboard end of the cap. This web section exhibits multiple bends and tears, its inboard 2 feet are bent forward approximately 80 degrees.

There is a separate 9 foot section of front spar web that extends inboard of the web portion described above. The front spar upper cap vertical leg is attached to this web section. The inboard 5 feet of web has its lower edge bent aft approximately 80 degrees.

Two pieces of skin and stringer panel approximately 55 inches by 16 inches each were recovered separately. These sections correspond to the lower skin and stringer panel just aft of the front spar. Both pieces exhibit twisting and spanwise buckling over their entire length. The integral machined stringers have multiple spanwise fractures along their vertical legs, and are separated from the skin.

A 5 foot spanwise by 14 inch chordwise section of horizontal stabilizer forward spar lower cap and skin panel was recovered separately. This section constitutes the outboard remainder of the 12 feet long section, and extends approximately to the outboard end of the horizontal stabilizer spar. The spar cap vertical leg is bent aft approximately 45 degrees at its inboard end. The machined stringers are detached, having fractured along their vertical legs over their whole span. The attached portion of skin is bent up aft of the spar cap, ranging from 90 degrees at its inboard end to approximately 130 degrees in the mid-span and outboard sections.

A piece of right outer section structure is severed approximately 3 feet from the inboard end. The lower skin panels of the main box are detached. The outboard portion was not recovered. The most outboard end of rear spar (approximately 7 feet) was attached. Two outboard elevator hinge assemblies, xe = 225.834 and xe = 204.114, were attached to the rear spar. Looking outboard, the rear spar appeared to be rotated 40 degrees counterclockwise. Four feet outboard, there is an 8 foot

section of the leading edge box attached. The anti-ice panels with some surrounding skin were recovered separately.

A 5.5 foot section of horizontal stabilizer rear spar was recovered separately. This portion extends from approximately xhs = 104 to xhs = 158 and contains the elevator hinge at xhs = 158. The elevator hinge fitting and a 10 inch portion of elevator front spar are still attached to the hinge bolt. A 2 foot chordwise section of horizontal stabilizer hinge support rib is also attached to this section of spar at xhs = 158 (outboard end). The upper spar cap is severed chordwise 10 inches from its inboard end. The fracture line in the spar cap coincides with a fracture and chordwise wrinkle in the horizontal stabilizer upper skin. The lower spar cap has its horizontal flanges separated from the vertical leg and is bent down approximately 25 degrees along its inboard 20 inches. An 8 inch wide section of lower skin panel is attached to the spar cap along its inboard 30 inches. The rear spar web is fractured in 2 locations: 20 inches and 10 inches from its inboard end. The web separated in 3 sections, however they remained attached to each other by the spar cap's vertical legs. The outboard fracture line in the web is also coincident with a fracture in the horizontal stabilizer upper skin. The inboard 20 inches of web are bent down approximately 80 degrees at the outboard fracture line, and then up approximately 80 degrees at the inboard fracture line, resulting in an almost Z-shaped deformation of the web. The elevator geared tab pushrod support fitting and part of the linkage are attached to the horizontal stabilizer rear spar at approximately xhs = 104.

The right tip of the horizontal stabilizer was recovered separately. There is localized damage at the hinges. Nineteen inches outboard from the xe = 204.115 hinge there is a buckle in the upper and lower skin. The spar caps are separated from the web over a span of 15 inches. The majority of the upper skin to rear spar fasteners are pulled through the skin.

The leading edge of the 20.5 feet section contained severe spanwise buckling damage. The leading edge lower skin is folded up and aft onto the upper skin over the entire span of 8 feet. This compression damage extends chordwise from the forward edge of the skin panel to an area located at least 16 inches aft of the forward edge of the skin panel. The upper skin panel in several areas along the span contains wrinkle marks consistent with the skin bending up. The outboard end of the horizontal stabilizer, together with the aft spar piece contains deformation consistent with the leading edge moving up and aft, whereas, the aft end was moving down. The upper skin behind the front spar has a spanwise wrinkle.

Left Outer Section. The left outer section is in two pieces. One piece is still attached to the horizontal stabilizer and is fractured 13.5 feet outboard. The second piece is separate and is 8 feet in length.

Approximately 3 feet outboard from the constant section chordwise splice the lower skin panel of the main box exhibits an upward chordwise buckling spanning 34 inches. There is no evidence of scratches on the exterior surface in the buckled area.

The horizontal stabilizer upper left skin panel is formed by three skin planks (forward, mid, aft) with integrally machined stringers. All three planks are attached to the outer end of the left horizontal stabilizer constant section. The mid skin plank has a spanwise fracture that extends for 14 feet, starting 2 feet outboard of the constant section. This skin plank is bent up approximately 30 degrees along the outboard 6 feet of this fracture line. Along the inboard 8 feet of the fracture line, the aft side of the skin is separated and moved up approximately 3 inches. Another spanwise fracture exists in this skin, it is located 5 inches forward of the fracture described above, it is 4 feet long and starts approximately 4 feet outboard of the skin inboard end. The aft skin plank has a spanwise fracture located approximately 8 inches forward of its trailing edge, and starting 6 feet outboard of the skin inboard end. The length of this fracture totals 9 feet, and the aft skin is bent up 30 degrees over its outboard 4 feet. All three skin planks are bent down approximately 10 degrees (chordwise, like a dihedral break) approximately 4 feet outboard of their inboard end. The bend line is not parallel to the airstream, and runs in a direction perpendicular to the rear spar. There is a 3 foot long diagonal wrinkle in the aft skin plank located approximately 5.5 inches outboard of the skin inboard end and extending forward and outboard from that point. This wrinkle extends across the full width of the aft skin plank.

In addition, the leading edge is pushed up approximately 16 inches and aft against the front spar. This area covers a span of approximately 4 feet from the oval anti-ice access door on the inboard side to the turnbuckle and anti-ice door at the outboard side. The leading edge structure (from 5 feet outboard continuing to the outboard end) is pushed up 2 inches and exhibits localized buckling.

The outboard end is severed at the leading edge manufactured splice.

The forward flange of the lower front spar cap at the outboard end, is severed for a span of 10 feet and remains attached to the aft edge of the leading edge skin.

On the 8 foot outer section of the left horizontal stabilizer, the forward flange of the lower spar cap (40 inches from the inboard end) is torn and remains attached to the leading edge skin. The leading edge lower surface is bent up and aft along the entire length, reducing in severity moving from inboard to outboard. The left horizontal stabilizer tip cap is bent down 90 degrees.

At the fracture line, the deformation of bending is constant with the horizontal stabilizer left tip bending up. The rivet fracture at the leading edge splice is at an angle of 45 degrees outboard and aft. The inboard 3 feet of the front and rear spars are bent down 30 degrees and aft while the upper and lower skin panels as well as the leading edge are bent up 70 degrees.

Elevator Hinges. Hinge at xe = 2.29 : The horizontal stabilizer hinge fitting is separated from the horizontal stabilizer structure and is attached to the elevator hinge fitting by the hinge bolt. A section of horizontal stabilizer lower trailing edge (10 inches spanwise) and the lower cap of the horizontal stabilizer hinge support rib (8 inches chordwise) are still attached to the horizontal stabilizer hinge fitting.

Hinge at xe = 49.72 : The horizontal stabilizer hinge fitting is separated from the horizontal stabilizer rear spar. The two upper attach bolts as well as the lower inboard attach bolt are not present. The upper attach holes are elongated at approximately the 8 o'clock position looking forward at the rear spar. Both hinge fittings are attached to the elevator.

Hinge at xe = 103.816 : The horizontal stabilizer hinge fitting is separated from the horizontal stabilizer rear spar. The upper attach bolt as well as its nut are present. The lower attach bolt is severed at approximately the rear spar plane. Both hinge fittings, as well as a portion of elevator front spar are not present.

Hinge at xe = 157.911 : Both the horizontal stabilizer fitting and the elevator fitting are attached to the horizontal stabilizer rear spar.

Hinge at xe = 204.114 : The horizontal stabilizer hinge fitting is separated from the horizontal stabilizer rear spar, and is still attached to the elevator hinge fitting via the hinge bolt. Both attach bolts and their respective nuts are attached to the horizontal stabilizer rear spar.

Hinge at xe = 225.834 : The horizontal stabilizer hinge fitting is attached to the rear spar and severed approximately 2 inches aft of the rear spar plane in its upper leg, which is bent inboard 45 degrees. The

lower leg of the fitting is severed approximately 1 inch aft of the rear spar plane and is bent slightly inboard.

Movable Fairing and Support Structure. The upper left movable fairing (banana fairing) is attached to the horizontal stabilizer support fitting, with the forward 30% flattened. Pieces of the mating support fittings are attached to the fairing at the forward and aft ends.

The two remaining support fittings are attached to the fairing and are complete except for a tear on the lower end of the forward fitting. The aft fitting is still attached to the trailing edge rib. An anti-float tab pulley bracket is attached to this fitting as well.

The upper right banana fairing has multiple bends and twisting. The aft 2 feet end is bent outboard approximately 30 degrees. On the upper right banana fairing, the two forward brackets were not recovered except for a small piece of web of the #1 bracket (from the front) with shims was attached to the fairing. The #2 bracket web and shims are attached with the upper tip of the web and upper shims bent inboard approximately 30 degrees. The outer skin of the fairing has a 3 inch long horizontal tear approximately 4 inches aft of the #2 bracket. Approximately 2 inches aft of the #2 bracket, a 2 inch by 2 inch piece of the inner skin was torn down.

There are several locations of primer transfer marks on the outer skin of the upper right banana fairing. The forward support fitting is fractured just below the lower edge of the fairing. Only the aft 20 inches of the lower banana fairings are attached.

Elevators. The elevator is of all-metal construction except for a fiberglass trailing edge. The elevator is constructed with a spanwise spar, chordwise ribs, formers, and skin with bonded doublers. Control tabs of all-metal aluminum honeycomb construction are attached to the elevator trailing edge.

The right hand elevator, S/N 53125, is separated into five sections. The control tab, geared tab and anti-float tab were recovered. The inboard 22 inches of the elevator is still attached to the horizontal stabilizer. The leading edge close out box is separate. The elevator hinge attachment lug is ovalized in the 11 o'clock position looking inboard. The outboard portion of the lug is attached to the separated leading edge section. The lower stop has smearing on the upper outboard portion of the bolt. The upper stop has normal wear. The outboard portion of the formed hinge is fractured 45 degrees.

The leading edge skin is severed through the center of the rivet holes. The leading edge portion of the inboard ribs are bent to the left 90 degrees, 45 degrees and 90 degrees respectively. Approximately 14 inches of the inboard end of the control tab is attached to this section of the elevator. The control tab push rod is bent inboard 30 degrees and is broken at the forward lug. The broken forward lug is jammed in the vertical position.

The next section of the elevator is approximately 4 feet long. There is a 4 foot section of the rear spar of the horizontal stabilizer still attached with the hinge. The hinge has contact marks on the upper side of the fitting, but not on the bottom. The upper stop has contact damage. The inboard upper skin in this area is pulled up and inboard 180 degrees. The leading edge cap of the inboard 22 inches of the elevator is attached to this section. Nine inches of the upper skin is pulled up 80 degrees and aft 20 degrees. The leading edge is crushed back 1.5 inches. Approximately 22 inches of the leading edge is crushed back 9 inches. The outboard edge of this piece is crushed with a 1 foot by 9 foot section partially torn from the trailing edge.

The inboard section is opened up. Four inches from the inboard edge the lower skin is pulled through chordwise which coincides with the inboard hinge for the control tab. The lower skin has chordwise compression damage.

The third section of recovered elevator is approximately 41 inches long and is separated chordwise at xe = 49.72 and xe = 106.191. The right geared tab push rod is separated 1 inch from the aft lug. The push rod is bent inboard and is not jammed. The forward separated section is attached to the horizontal stabilizer. The inboard fractured surface is pulled up 20 degrees. The inboard end of the spar is pushed aft 60 degrees. The outboard closing rib of the main spar and continuing 7 inches back is torn from the upper and lower skin. The rib is pushed aft and creased. The upper skin in this area is pulled aft 120 degrees. The geared tab is not attached. The outboard (control) tab hinges are pulled from the structure.

The fourth piece is a 9.7 foot section that is separated chordwise at the xe = 103.816 and xe = 225.834 stations. The xe = 103.816 hinge is attached to the horizontal stabilizer. There are contact marks on the upper part of the hinge but not the lower. The upper skin has compression damage from the inboard section to the hinge at xe = 157.911. The xe = 157.911 hinge is attached to the horizontal stabilizer. The fitting has contact marks on the upper surface but not the lower surface. The outboard flange has a deep gouge parallel to the fitting.

The geared tab outboard pushrod is fractured at the aft eyebolt. The rod is deformed inboard 20 degrees and twisted up 30 degrees. The rod also has witness marks 1 inch forward of the lug. This is the location where the elevator would make contact with the pushrod if it over rotated. There are witness marks on the upper portion of the elevator in this area. Five inches of skin is pulled aft for 8 inches, at the hinge point.

The leading edge is compressed aft to the main spar, starting at the hinge for 1 foot moving outboard. The upper and lower skin on the leading edge close out cap is compressed 0.5 inch from the xe = 157.911 hinge to the outboard edge.

There is a tear in the upper skin at the xe = 204.114 hinge. The skin in this area is separated and the inboard section is pulled up 70 degrees and left. The outboard portion of skin is pulled up 110 degrees and right. The xe = 204.114 hinge is separated from the elevator but remains with the horizontal stabilizer. There are contact marks on the upper surface of the hinge but not on the lower surface. The outboard hinge has more damage.

The outboard tip has separated chordwise at the xe = 225.834 hinge. The leading edge upper skin close out section is compressed 0.5 inch.

Right Elevator Control Tab. The control tab is separated chordwise into three pieces. There are four hinges that connect the control tab to the elevator. The inboard 14 inches are attached to the inboard portion of the elevator.

The middle piece is 4 feet long and a rectangular-like puncture due to recovery 17 inches from the inboard edge. A mid hinge is attached to the control tab and the elevator. The inboard hinge is only attached to the control tab with the 4 inches of the rear close out of the elevator attached. The inboard hinge is connected to the elevator but not the control tab.

The outboard piece is 28 inches with half of the outboard hinge attached. There is a 1 inch by 3 inch skin disbond. This piece had compression damage on both the upper and lower skins. A 3 foot section separated chordwise at both ends.

All right control tab hinges are deformed outboard 30 degrees.

Right Elevator Geared Tab. The geared tab is separated chordwise, 1.5 inches inboard, into two pieces. The inboard flange on the two

inboard hinges remains with the elevator. The outboard hinge remains with the elevator. There is compression damage on the upper and lower skins of the outboard piece.

Right Elevator Anti-float Tab. The anti-float tab is in one piece. There is compression damage on the upper and lower skin. There are four hinges. The three inboard hinges are still attached to the anti-float tab. The most inboard hinge is only attached to the elevator.

Left Elevator. The identification tag reads: DeHavilland LTD, P/N (Illegible) - 403, FSN 53124. The left elevator assembly was recovered in three pieces along with its control tab, geared tab, and anti-float tab. The elevator is severed through chordwise in two locations. The inboard location is approximately xe =103 and the outboard location is xe = 206. The total measured length of the recovered pieces is 207 inches. The upper skin is torn chordwise and folded aft in a 16 inch by 18 inch triangular shape, 79 inches from the elevator inboard end.

The upper aft leading edge skin is folded up over 10 inches at the inboard end. The inboard hinge at station xe = 2 has a portion of horizontal stabilizer lower aft trailing edge skin and reinforcing structure attached to it with the mechanical stops. The lower bolt has the inboard portion of the head "smeared" off. The upper stop area has a contact mark on the inboard lower lip. The cut-out for the elevator has been pushed aft at the upper outboard corner. The inboard forward edge has been pushed outboard 90 degrees. The hinge at xe = 53 is separated at the four attach locations from the horizontal stabilizer rear spar. The two upper attach bolts are severed but still in the hinge fitting. The upper surface of the fitting has contact marks in direct relation to the upper cap of the main spar. The web has impact marks on both the inboard and outboard upper corners. The upper cap is pushed up 15 degrees.

The control tab pushrod at xe = 82 is severed at the aft rod end. The piece is jammed 90 degrees up from its normal position. The rest of the control tab push rod was found separately. The aft eyebolt is pushed outboard. The hinge and elevator internal rib at xe = 103 are detached. This is the inboard location at which the elevator is torn through. There is an approximate 4 foot section of elevator not recovered, between hinge xe = 103 and hinge xe = 157.91.

The xe = 157.911 hinge is still attached to the horizontal stabilizer but the bathtub fitting is torn from the elevator. There are contact marks on the upper portion of the fitting that coincides with the upper portion of the bathtub fitting and rivet line. There is no impact damage on the bottom surface of the fitting.

The elevator is severed chordwise at the inboard side of the hinge at xe = 204.114. The hinge fitting is separated from the horizontal stabilizer rear spar mounting bolts and is still attached to the elevator. The bolt holes are split in half vertically. The bathtub fitting is pushed aft 45 degrees. There are contact marks on the upper bathtub fitting and upper skin.

The hinge fitting at xe = 225.834 is separated from the horizontal stabilizer rear spar and but is attached to the elevator. There are contact marks on the upper and lower surface of the fitting. The lower bathtub fitting is pushed down 30 degrees. The outboard tip is complete, including the balance weight horn, which is bent outboard and down. The outboard rib that supports the balance weight has its upper and lower chords severed.

Left Elevator Control Tab. The control tab is severed chordwise in three locations at 13 inches, 35 inches, and 56 inches from its inboard end. All control tab hinge fittings except for the inboard one are still attached to the elevator rear spar. The tab skin has disbonded from the aluminum honeycomb core at the two inboard locations.

Left Elevator Geared Tab. The geared tab has a chordwise tear and the outboard section was not recovered. The tear is located approximately 36 inches from the geared tab's inboard end. Two of the geared tab's hinge fittings are attached to the elevator rear spar.

Left Elevator Anti-Float Tab. The anti-float tab is severed chordwise at a location 21 inches from its inboard end. The skin has disbonded from the aluminum honeycomb core and peeled back over a 2 inches span at the tear location. The inboard pushrod fitting is attached to the tab with the pushrod severed approximately 1 inch forward of its pivot point. The two outboard hinge fittings are still attached to the elevator rear spar.

2.3.2 Vertical Stabilizer

Description. The description of the vertical stabilizer from the MD-80 maintenance manual follows. The vertical stabilizer is constructed as an integral part of the aft fuselage structure. A section of the leading edge and the tip fairing are removable. An aerodynamically balanced rudder is attached to the hinge brackets on the vertical stabilizer rear spar and aft fuselage structure. Refer to the attached vertical stabilizer station diagram for station locations, i.e. zrs, zfs.

The rudder is of all-composite construction. The rudder consists of a spar, chordwise ribs, and skin. A control tab is attached to the trailing edge. Mass balance for flutter prevention is employed in the rudder control tab. The rudder leading edge has fixed weights bolted to the skin.

Findings. The full left skin of the vertical stabilizer remains attached to the fuselage. The rear spar is severed 3 inches below the bottom rudder hinge fitting. The lower 5.7 feet of the rear spar remains attached to the rear spar bulkhead in the fuselage. The entire rear spar and bulkhead exhibits 45 degree clockwise rotation when looking down. The left vertical stabilizer skin and stiffeners are fractured horizontally forward of the horizontal stabilizer cutout, from above the roller rub strip to the edge of the cutout from the horizontal stabilizer.

The center spar of the vertical stabilizer is attached to the center spar bulkhead and exhibits the same rotational characteristics as the rear spar.

Both left and right center spar caps are severed approximately 20 inches above the intersection of the center spar with the fuselage skin. The right cap is rotated approximately 45 degrees counter clockwise (when looking down at the center spar). The left cap does not appear to have rotated. The web exhibits multiple fractures at the point where the spar caps are fractured, and it is bent aft approximately 90 degrees. The remainder of the left center spar cap (upper portion) remains attached to the left vertical stabilizer skin. The remainder of the upper portion of the right center spar cap is attached to a portion of the right vertical stabilizer skin and stringer panel that was recovered separately. This portion of skin (with the left center spar cap attached) extends from the rear spar to the center spar and is approximately 5 feet long, starting about 20 inches above the intersection of the vertical stabilizer with the fuselage skin. Fracture lines were matched along the aft edge of this skin (a portion of it is still attached to the vertical stabilizer rear spar) and along its lower edge. All internal stringers are attached to the skin, which is bent inboard approximately 90 degrees along its aft edge, and curled outboard approximately 160 degrees at its forward upper edge. Another portion of skin and stringer panel corresponding to the vertical stabilizer right side was recovered; it is 8 feet long (vertically) and extends up from the lower edge of the vertical stabilizer skin. Chordwise, it extends from the center spar to the front spar. This skin panel is deformed in a "U-shape" along its length, with the stringers on the internal side of the "U".

The front spar, including the upper end of the front spar bulkhead in the fuselage, is severed from the structure. The spar remains relatively

straight vertically, however, there is bulging along its entire length in the aft direction.

The upper 9 feet of the rear spar remains connected to the bottom section of the vertical by the elevator control cables. The three rudder hinge fittings on the aft side of the vertical rear spar remain attached to the rear spar along with the mating hinge fittings of the rudder. These hinges are attached to the 9 feet long section of the upper rear spar.

The lower hinge fitting has both bolts and nuts that attach it to the spar caps in place. The right hinge shroud has buckles in its horizontal flanges, and it is pushed inboard approximately 1 inch. A 3 inch by 1 inch section of the shroud is missing in its lower aft edge. The rudder side of the hinge is still attached to the hinge plate and bolt. The hinge rod is attached to the hinge fitting, with its forward lug severed. The forward 50% of the lug circumference is missing. A 2 inch portion of composite rudder front spar is attached to the rudder side of this hinge. All three hinge plate bearings move freely.

The middle hinge fitting has both bolts and nuts that attach it to the rear spar. The left area of the hinge fitting shows torsional deformation at its attachment point to the rear spar, approximately 25 degrees counter clockwise (looking forward at rear spar). The right hinge shroud horizontal flanges are buckled, and the shroud is pushed inboard approximately 1 inch. It is also displaced down approximately 0.5 inch. The hinge rod is attached to the hinge fitting, with approximately 50% of its forward lug missing. A 4 inch portion of rudder rear spar with small fragments of rudder skin is attached to the rudder side of this hinge. All three hinge plate bearings can be moved.

The upper hinge fitting is attached to the vertical stabilizer rear spar by its right attach bolt. The left bolt is severed almost flush with the rear spar plane. The left bolt hole in the vertical stabilizer rear spar cap is deformed (ovalized) down and outboard with the damage located at approximately 7 o'clock when looking forward at the rear spar. An adjacent rear spar cap attachment hole was torn up and out to the outboard edge of the rear spar web, with the tear located at the 10 o'clock position when looking forward at the rear spar. The left arm of the hinge fitting is deformed down about 2 inches.

The left hinge shroud is deformed down approximately 0.5 inch. There are contact marks on the upper outboard edge of the shroud. The right hinge shroud is pushed down about 2 inches with four attachments sheared off in its upper row of rivets. The upper horizontal flange of this shroud exhibits two sets of parallel contact marks. These marks match

the width of the elevator control pulley sector which is attached to the aft side of the horizontal stabilizer. There is a 2 inch tear in the shroud flange along the edge of the hinge area, the outboard side of the fracture is pushed down approximately 0.5 inch and slightly inboard. (Note: the elevator sector is fractured and attached to the vertical stabilizer via its control cable.)

There is a set of parallel contact marks located in the aft flange of the vertical stabilizer right spar cap approximately 1 inch above the hinge attach point. These marks are oriented in line with the marks in the hinge and also match the width of the elevator control pulley sector.

The right hinge arm is bent down approximately 10 degrees and rotated approximately 10 degrees counter clockwise, looking forward at the rear spar. The hinge plate is displaced down to its limit (contacting the lower aft edge of the hinge). All three hinge plate bearings are binding and hard to move. The rudder side of the hinge has its fitting deformed down approximately 0.25 inch in its right side. A 3 inch section of rudder spar and rudder rib are attached to the hinge. On the left of this hinge, there is a 5 inch by 3 inch portion of rudder skin. The signature paint line in this skin is 1.5 inches off from its continuation on the hinge shroud paint (the line in the shroud is below the one in the skin).

The upper end of the rear spar is torn. The vertical rear spar fracture faces appear to match the portion of stabilizer that remains attached to the horizontal stabilizer in the pivot lug area.

The aft portion of skin, with stringers attached, has an outward bend at the root and an inward bend at mid span.

The forward section of left skin is torn at the root and exhibits an outward bow. The two panels of leading edge that houses the Very High Frequency Omnidirectional Range (VOR) antennas remains attached to the vertical stabilizer.

Vertical Stabilizer Leading Edge. The ram air scoop, except for the lower 10.5 inches that remained with another section, is torn from the leading edge. The scoop is severely flattened and twisted. The elbow is bent forward approximately 90 degrees to the right.

A 10 foot segment of the lower leading edge contains the left and right leading edge stringer attach fittings, the leading edge skin less ram air scoop, and the lower right side VOR antenna. The skin panels have multiple tears and buckling, more severe on the right side.

A segment of the upper fuselage skin and frame are attached to the stringer attach fittings.

The fuselage frame segment extends 3 feet outboard (left and right) from the aircraft centerline.

Of note is the tear out of the stringer attach fittings which exhibit a counter clockwise rotation when looking down. The lower right leading edge stringer attach fittings are pulled aft (internal fuselage doubler).

Structure with Gimbal. The retrieved 10 feet by 6.6 feet structure consists of a segment of leading edge skin, main vertical stabilizer structure skin, the canted closing rib, gimbal support fitting (with gimbal attached), and the two ribs mating with the gimbal support fitting.

Gimbal Support Fitting. The gimbal is attached with pins to the support fitting. The gimbal is the lower portion of the horizontal stabilizer control mechanism that is attached to the vertical stabilizer. It contains the nut through which the jackscrew portion of the control mechanism travels.

On the left side of the gimbal, the horizontal leg of the fitting is severed approximately 6 inches from the pivot. On the right side of the gimbal, the horizontal leg of the fitting is complete and is attached to the left half of the mating vertical stabilizer rib. The vertical legs of the support fitting are complete and attached to the mating vertical stabilizer rib web. The support fitting lugs are in place with no apparent distortion.

The gimbal support fittings are attached to the horizontal and a vertical support ribs. The vertical support rib has both left and right caps severed at the intersection with the left and right vertical stabilizer skins (the left skin is not attached to this portion of wreckage). The horizontal support rib is fractured approximately along its centerline, with the left side torn away. The remainder of this rib is attached to the vertical stabilizer right skin and gimbal support fittings. It exhibits a downward buckle in its forward end (4th fastener row from forward end). This buckle is a 0.5 inch deep. This portion of rib together with the gimbal support fittings are displaced to the right side approximately 0.5 inch relative to the opening in the canted bulkhead. The aft end of the horizontal rib is deformed inboard over 5 inches at an approximate 45 degree angle.

The gimbal was free to rotate. The majority of the acme nut threads were missing from the bore. Consequently, the acme nut was

sent to the NTSB for metallurgical analysis. Refer to the NTSB Materials Laboratory Factual Report No. 00-145.

Canted Closing Rib. The canted closing rib has multiple tears with segments missing. The rib material aft of the front spar (approximately 12 inches) was not recovered. An additional 12 inch segment aft of the gimbal was not recovered. The right side rib cap has multiple tears at the fillet radius of the horizontal leg.

Approximately 12 inches aft of the gimbal, a 3.5 inch section of the rib web is bent down approximately 45 degrees from its normal position. The forward edge is a ragged tear. There is an approximate 1.5 inch semi-circular cut located two inches to the right of the center line in the free edge of the web.

Vertical Stabilizer Skin. The main skin with stringers attached has multiple tears and is bent and buckled inward. The bottom edge is torn on a line perpendicular to the rear spar in line with the bottom edge of the upper VOR antenna. The front and rear spar caps are not attached except for 1 foot of the front spar cap at the intersection of the front spar and canted closing rib.

The left side vertical stabilizer skin is torn along the rivet line of the center spar from the root and continues up 8.4 feet. From there the tear line proceeds forward to the front spar. A section of the left rub strip and internal support structure is deformed inboard at its upper 10 inches. There is a roller mark 5 inches below the upper attach screw. There is no apparent impact damage on the surface of the left vertical rub strip and adjacent skin.

Vertical Stabilizer Leading Edge Skin. A 5 foot by 2 foot segment of leading edge skin housing the upper VOR antenna is attached to the main structural skin. It has multiple tears and buckling. Small segments of the leading edge formers are attached. The upper VOR antenna is attached.

Vertical Stabilizer Tip Fairing. The retrieved structure of the tip fairing structure is in two segments. The front 25% was not recovered. The forward 3.5 feet segment of the two recovered pieces is the segment directly above the horizontal stabilizer center section. The forward end has been crushed from the bottom up and from the right. The deformation runs aft for about 10 inches. The right and upper sides are buckled vertically (approximately 1 inch deep) just aft of the vertical skin splice, with several tears and folds in the skin aft of the splice. These damaged areas (tears and folds) range from approximately 3 inches to 10

inches. The aft end is crushed inboard on the right side along its aft 11 inches. The forward section of this fairing is rotated to the right with respect to the aft section by about 10 degrees. There is a "V-shaped" mark on the right skin that matches the shape of the elevator inboard end.

The lower forward end of the fairing has its two attachments still in place. The lower edge of the fairing skin and internal leading edge former is crushed up, approximately 0.125 inch, symmetrically on both the left and right sides. There is a corresponding witness mark on both the right and left horizontal stabilizer front spar upper cap.

At this same location in the fairing, the internal former aft channel is fractured, bent slightly down, and is attached to the two fasteners in the fairing, on both the left and right sides. The internal vertical stabilizer leading edge fitting is fractured at approximately the same location (forward of the two fairing fasteners), the aft portion of this fitting is still attached to the two fairing fasteners. This is symmetrical on both the left and right sides.

On the horizontal rib in the aft section of the fairing, adjacent to the aft end of the fairing cutout, there is a set of parallel marks that match the size of the elevator control sector.

Both the left and right fairing skins are fractured 7.5 inches forward of the aft end of the horizontal stabilizer cutout. This location matches the position of the elevator control shaft.

Both the left and right inboard ends of the horizontal stabilizer outboard constant section front spar upper cap exhibit similar fractures which appear to be a mirror image of each other. On the right and left side of the front spar upper cap outboard of the fracture, there is a witness mark that matches the deformation found in the lower edge of the vertical stabilizer tip fairing. The inboard end of the constant outer section rear spar lower cap aft tang is fractured and bent up 0.75 inch on both the left and right sides.

The forward edge of the upper skin just forward of the elevator bell crank access door is folded down and aft into its inner surface. This fold matches a crease on top of the mid vertical stabilizer tip fairing. The mid and aft portions of the fairing were placed together and two fracture surfaces were matched. The relative position of the fairings when mating these fracture surfaces was mid fairing nose up approximately 80 degrees with respect to the aft fairing. The horizontal web of the tip fairing exhibits a downward bow. The aft end is severed at the forward

end of the elevator bell crank access door. A crease and fold approximately 8 inches forward of the aft edge suggests approximately an 80 degrees upward rotation. The primary and secondary trim motor wiring is attached to the fairing.

The aft 7 feet segment, containing aircraft marking 963, straddles the aft end of the horizontal stabilizer and is normally attached to the top of the vertical stabilizer. The aft most tip area (composite material) is severed. The lower forward end is crushed right and bent.

Rudder. Three major portions were recovered, along with several fragments of composite skin which vary in size from 4 inches up to 2 feet in length. One of the fragments is a 2 foot section of leading edge that contains three sets of balance weights.

The first major portion is 9 feet spanwise and 4 feet chordwise, and constitutes the lower section of the rudder. It is formed by sections of right skin, left skin, a 50 inch by 2 inch strip of leading edge, and the lower 60 inches of the rear spar. The lower 45 inches of the rudder tab are attached to the rear spar at the lower tab hinge point. The right skin is severed chordwise at zrs = 20 approximately and disbonded from the core over most of its area. The only internal rib attached to this skin is located at the zrs = 43 hinge point. Most of the skin to spar attachments at the aft edge of the skin have pulled out.

The second major portion is a mid-span section of the right rudder skin, extending 33 inches chordwise by 34 inches spanwise. A 3 inches section of rudder rear spar is attached to its internal surface. It exhibits two chordwise fractures, and a spanwise fracture aft of the front spar. Most of the skin is disbonded from the core.

The third major portion is the upper aft end of the rudder, and is 57 inches chordwise by 32 inches spanwise at its widest point. The lower edge has a diagonal fracture at approximately 45 degrees from the trailing edge that runs up and forward. The trailing edge has most of its attachments in place except for the upper 10 attachments, which are pulled out with the left skin deflected outboard approximately 10 degrees. The upper 5 inches of the trailing edge skin are torn off over a 4 inch span. The upper closing rib is attached. It contains a dataplate with the following numbers: "5955501-1", "456", and "Rev K". This rib exhibits multiple fracture lines and delamination, and is severed 35 inches forward of its aft end. There was a segment of this rib found wedged atop the horizontal stabilizer center box, in the aft support fitting for the right horizontal stabilizer upper movable fairing ("banana

fairing"). This segment was removed from the horizontal stabilizer and matched to the fracture line in the forward end of the rudder closing rib.

At the upper forward corner of this rudder portion there is a tear that runs aft from the forward edge, oriented approximately 40 degrees down from the upper edge of the skin. This tear extends aft 10 inches and it appears to match the diameter of the elevator pulley sectors shaft, which is installed in the center section of the horizontal stabilizer behind the rear spar.

On the right side of the skin there are a series of paint abrasions approximately 30 inches long vertically and 4.5 inches wide chordwise. The paint is abraded in a forward-aft (chordwise) direction and the marks seem to be caused by an object rotating along a large radius. Within these marks it is possible to discern at least two groups of abrasions with slightly different orientation and range of contact areas. Except for the upper 7 inches and the area in the vicinity of the fracture lines, the external left and right skins do not show signs of delamination or disbonds.

2.4 Landing Gear

Description: The MD-83 landing gear has a retractable tri-cycle landing gear configuration. The nose and main landing gear all have duel wheel and tire assemblies. The nose landing gear has the steering mechanism and the main landing gear has the brake assemblies.

2.4.1 Nose Landing Gear S/N CDI907

Findings: The nose landing gear of the aircraft has been recovered. Both wheels separated from the axle. Each tire is in place and remains mounted on its wheel. The outer half of one wheel has its rim fractured. The axle, torque links, and shock strut are in place. The shock strut piston is slightly bent towards the aircraft left. The exposed chrome area of the piston is 10 inches, measured between the bottom face of the cylinder and the upper edge of the torque link clevis.

The spring loaded pushrod, clevis, and yoke are in place. The support arm (connecting the link to the cable sector) is fractured at its base. The link and the cable sector are in place as well as the cables and follow on pulleys. Both steering cylinders are in place. The piston of the right steering cylinder is fractured at the bottom face of the cylinder. The right steering piston exposed chrome is 5.5 inches, measured from the bottom face of the cylinder to the center of the piston lug. The left

steering piston exposed chrome could not be accurately measured because the piston was free to rotate.

Both drag links and the forward door activating cranks are in place. The torque tube is fractured 12 inches from its right end. The nose gear cylinder side brace and nose gear actuating cylinders are in place. The piston exposed chrome of the nose gear actuating cylinder is 12.5 inches measured between the bottom face of the cylinder and the center of the piston lug. The overcenter link, bungee cylinder, and bungee springs are in place. The bungee springs are still attached at its bottom ends. The enclosure beams of the bungee cylinders broke off from the aircraft and remains attached to the nose gear. Portions of the torque tube beam fittings (bulkhead side) broke off from the aircraft and remained attached to both ends of the torque tube. A 9 inch by 10 inch section of the side bulkhead structure remains attached to the right side brace.

A large section of the left bulkhead is attached to the left side brace (up to 18 inches forward of the side brace attach point) including the beam structure support for the nose gear actuating cylinder. The entire left side of the pressure bulkhead at station 110 along with the skin structure (35 inches aft and 20 inches forward) remain attached to the wreckage. The right section of the bulkhead is 27 inches by 27 inches and has ripping and tearing and is pulled aft and left approximately 70 degrees. Approximately 70 percent of the station 110 bulkhead has been recovered. A separate section of the station 110 bulkhead was also recovered. It is a 33 inch by 12 inch section of the lower portion of the bulkhead, located at 17 inches left of and 17 inches right of the aircraft centerline. It included the battery charger unit. This section of structure showed insignificant damage.

The left aft nose gear door remained attached (buckled in the forward to aft direction). Its forward end (8 inches in length) is bent outboard approximately 30 degrees.

Both nose gear forward doors were recovered. The left door broke in two pieces (chordwise), 15 inches and 32 inches. The aft piece fractured just forward of the door stop push rod rib support. Both forward doors show compression damage in the aircraft forward to aft direction. The nose landing gear was in the retracted position.

2.4.2 Right Main Landing Gear S/N MAL113.

Findings: The right main landing gear has been recovered. The two wheels (with tires) and brake assemblies are still attached to the lower

strut (piston). The outboard tire is punctured and torn from the outboard sidewall then diagonally across (approximately 45 degrees) to the inboard sidewall. The lower torque link is attached to the lower strut. It appears that the upper torque link separated from the lower torque link at their common hinge point. The upper lug of the lower torque link does not show any evidence of damage (i. e., tear out). The support links are still attached to the lower strut. The upper support link appears to have broken off from its top end.

All brake lines are severed. The entire lower strut (piston) is separated from the main gear strut (cylinder) but does not show sign of impact damage. The top flange wall of the lower strut is cracked at the outboard side. The crack starts from the top surface of the flange then downward approximately 0.5 inch and then splits in the forward and aft directions along the circumference of the strut (3 inches forward and 0.8 inch aft).

The right wing mounted main gear door has also been recovered. The door hinge shows that the hinge pin sheared off (portions of the sheared pin are still inside the hinge half). The forward drive rod lugs show evidence of tear out on both holes. Only the aft drive rod fitting is still attached and shows evidence of tension fracture.

The main gear upper strut (cylinder) was recovered attached to the main landing gear attach fitting along with its adjoining support structure. The main gear upper strut is in the retracted position. The upper torque link and the aft drive rod of the wing mounted door are still attached. The main gear actuating cylinder, the upper and lower side braces, the fixed side brace, and the over center linkage is in place and retracted. The inner wall of the cylinder shows buckling damage. The cylinder is bent forward a few degrees.

2.4.3 Left Main Landing Gear S/N MAL601

Findings: The left main landing gear was recovered attached to the center tank structure. The two wheels (with tires) and brake assemblies are still attached to the strut. The wing mounted gear door is only attached by the aft drive rod. The clevis fitting for the forward drive rod is completely broken off from the door at the base of the fitting. The forward drive rod and the door fitting remained attached to the main strut. Portions of the sheared off hinge pin remains attached to the door hinge half. The main landing gear wing mounted door assembly is in the retracted position. The main gear cylinder, the upper and lower side braces, fixed side brace, and the overcenter linkage are in place and retracted. The main landing gear fitting is attached to the rear spar.

Brake lines and system components are in place. The exposed chrome area of the piston is 17.5 inches, measured from the bottom face of the cylinder and the top of the lower strut axle.

3.0 Checks and Tests

In addition to the on-site examination of the wreckage, the structures group participated in a dimensional check of the rotational engagement clearances and interference's on the horizontal stabilizer of a MD-83 airplane and witnessed two quill shaft static load tests. The different activities are described below.

3.1 Dimensional Check

The structures group traveled to Seattle, Washington on July 21, 2000 to conduct a dimensional check of an Alaska Airlines MD-83, tail number N932AS. The dimensional check was to compare the rotational engagement clearance and interference values used by Boeing in their rigid body model of the horizontal stabilizer during upward travel.

The access panels to the jackscrew were removed before starting. A technician inside the cockpit of the airplane was radioed when to operate the horizontal stabilizer. The structures group was on the airplane's left side throughout the procedure.

The top measurements were taken first: the clearance from the motor to former, the spar cap to the cutout, and the elevator shaft to the cutout. Then the magic carpet was lowered and the bottom measurements were taken: the clearance from the mechanical stop to the gimbal nut and the elevator sector to the web lightening hole.

The horizontal stabilizer was zeroed out by lining up the rigging rivets (marked with crosshairs) on the vertical and horizontal stabilizers. Once the horizontal stabilizer was zeroed the measurements of the gap between the cutout and the spar cap were taken. A dimension of 2.8 inches was obtained. Boeing's model indicates 2.9 inches. The measurements were taken with a scale. A digital protractor was also zeroed and adhesively attached to the horizontal stabilizer to check the rotational angle. The clearance for the elevator shaft to the cutout was 2.85 inches. Boeing's model indicates 2.5 inches. This measurement has room for error due to the difficulty of reading/obtaining it, compared to the other measurements that were taken. The elevator sector to web lightening hole was 1.6 inches. Boeing's model indicates 1.3 inches. The mechanical stop to gimbal nut was 2.5 inches. Boeing's model indicates 2.4 inches.

The horizontal stabilizer was rotated up until the electrical stop was engaged. Inside the cockpit 1.9 degrees was indicated. The digital protractor indicated 2.0 degrees. Boeing's model indicates 2.1 degrees. The gap between the cutout and spar cap was 1.2 inches. Boeing's model indicates 1.2 inches. The elevator shaft to the cutout was 2.1 inches. Boeing's model indicates 1.7 inches. The clearance for the elevator sector to the web lightening hole was 0.86 inches. Boeings model indicates 0.6 inches. The gap between the mechanical stop and the gimbal nut was 0.94 inches. Boeing's model indicates 0.8 inches.

The horizontal stabilizer was rotated up till the mechanical stop was engaged. The digital protractor indicated 3.4 degrees minus a shift in the airplane of .4 degrees equals 3.0 degrees. A cockpit reading was unobtainable due to bypassing the sensor to engage the mechanical stop. The Boeing model indicates 2.6 degrees. The gap between the cutout and spar cap was .54 inches. Boeing's model indicates .8 inches. The difference here can be attributed to the fact that the horizontal stabilizer rotated 0.4 degrees farther thereby decreasing the amount of gap. The clearance for the elevator shaft to the cutout was 1.7 inches. Boeing's model indicates 1.5 inches. The clearance for the elevator sector to the web lightening hole was 0.42 inches. Boeing's model indicates .4 inches. The gap between the mechanical stop and the gimbal nut was .7 inches minus 0.5 for the height of the mechanical stop equals .2 inches. Boeing's model indicates 0.3 inches.

The quill washer and stop collar gap was .04 inches. The gaps for the primary motor cap to the top of the fairing were respectively 3.6 inches, 1.9 inches, and 1.3 inches. These are rough measurements since a straight edge was laid across the fairing and then a scale was positioned on the aft portion of the primary motor cap. Boeing's model indicates 3.8 inches, 2.0 inches, and 1.6 inches. The geometry of the fairing makes this measurement difficult. The fairing cover was not installed.

Position of Horizontal Stabilizer, degrees	Rotational Engagement Clearances, inches Actual/Boeing				
	Motor to Former	Cap to Cutout	Shaft to Cutout	Sector to Web	Stop to Nut
Neutral 0/0	3.6/3.8	2.8/2.9	2.9/2.5	1.6/1.3	2.5/2.4
Electrical Stop 2/2.1	1.9/2.0	1.2/1.2	2.1/1.7	0.9/0.6	0.9/0.8
Mech.Stop 3/2.6	1.3/1.6	0.54/0.80	1.7/1.5	0.42/0.40	0.2/0.3

3.2 Quill Shaft (Torque Tube) Static Load Test

The static load test of the quill shaft was to provide validation for the Boeing finite element model (FEM), compare fracture faces of the quill shaft (torque tube) to that of Flight 261 and to provide acoustical signature data. The threads of the gimbal nut are stripped, per NTSB specifications, so that the gimbal nut makes contact with the upper surface of the lower stop. This contact pushes the lower stop against the quill nut and quill washer with an offset load, thereby applying a bending and a tension load on the quill shaft.

3.2.1 First Test

The structures group traveled to the Boeing facility in Huntington Beach, California on 26 July 2000 to witness a static load test of a torque tube. The test utilized Alaska Airlines tail number N981AS hardware, except for: quill nut washer (new), quill nut (new), torque tube (new), lower stop (new), and the gimbal nut (different airplane). Before the testing began the gap between the washer and the stop was measured and was .040 inch.

There were basically two viewing areas. An area with plexiglass next to the test stand and another area that had a television and VCR set up that was fed by a digital camera. The VHS video did not have time on it. A grease pencil was used to mark on the television set the original position of the mechanical stop, lower stop, washer, torque tube, and quill nut.

The tension load was applied at a rate of .020 inch per minute. The torque tube and jackscrew were allowed to rotate. There was no braking action. The gap between the washer and lower stop closed quickly, by 10,000 lbs. At 12,000 lbs. the gimbal nut became flat against the lower stop. At 12,500 lbs. the deflection gages were no longer engaged. At 12,600 lbs. the aluminum alloy lower stop started to crush. At 13, 600 lbs. a piece of the lower stop separated.

At 28,900 lbs., the software ran out of stroke. The stroke was set for 0.75 inch. The load was held while the software was adjusted. The stroke was reset to 1 inch and the rate increased to .050 inches per minute.

The software again ran out of stroke at 63,000 lbs. At this point, the test was completely stopped and the load was removed. The test was restarted at 0 lbs. with a rate of .050 inch per minute. During this time

the digital camera was moved and a second tape was put into both the digital camera and the VCR.

The gimbal nut was sitting flat on the stop collar with no gap. There was a pop heard at 61,200 lbs. This was where another piece of the lower stop broke off but on the opposite side. The torque tube failed at 74,500 lbs. and released parts and a grease cloud.

Because the quill shaft failed in a tension mode, the decision was made to run a second test. The objective of the test was to provide an offset load to the quill shaft to produce a combined bending and tension load, which was not achieved.

Applied Load, lbs.	**Event**
Less than 10,000	Gap is closed on the washer and lower stop.
12,000	The gimbal nut became flat against the lower stop.
12,500	Deflection gauges were no longer engaged.
12,600	Crushing initiation on lower stop.
13,600	Piece of lower stop separated.
28,900	Ran out of stroke on software.
63,000	Ran out of stroke on software. Reset to 0 load.
61,200	Pop heard. Opposite piece of lower stop breaks off.
74,500	Torque Tube fractures.

3.2.2 Second Test

The structures group traveled to the Boeing facility in Huntington Beach, California on October 2, 2000 to witness the second static load test of a quill shaft for a MD-83 airplane. Once again, this static test was to provide validation for the Boeing FEM, compare fracture faces of the torque tube to that of Flight 261 and to provide acoustical signature data. Unlike the first test, the NTSB did not gather the acoustical signature data. Boeing recorded the acoustical signature data.

The test utilized Alaska Airlines tail number N981AS hardware for the quill nut washer, quill nut, torque tube, and the lower stop. The rest of the parts were parts supplied from TRIG Aerospace. Before the testing began the gap between the washer and the stop was measured and was .042 inch. The orientation of the gimbal nut was changed from the first test. A permanent marker was used to mark the jackscrew assembly on

the side where the gimbal nut (acme nut) makes contact with the stop collar and to line up the initial relative positions of the acme screw, stop collar, quill washer, quill nut, and torque tube at the start of the test.

The tension load was applied at a rate of 0.050 inch per minute. The gimbal nut and the jackscrew (acme screw) were restrained from rotation. This is different than the first test where both were free to rotate. Deflection wires were used for the second test to measure lateral deflection, ½ inch in either direction, and to move vertically with the quill shaft. Cross bars were added to the test platform to function as a guide to restrain the gimbal nut from rotating. The test platform was also stiffened.

By 2,500 lbs., the gap between the washer and lower stop on the loaded side closed quickly. Between 15,000 lbs. and 20,000 lbs. the opposite side gap was closed. The quill shaft failed at 25,576 lbs. and at a vertical stroke of .426 inch. The lateral deflection wires moved 0.12 inch and 0.11 inch, for maximum deflection.

3.2.3 Differences Between Test #1 and Test #2

First Test	**Second Test**
Acme Screw was free to rotate.	Acme Screw and gimbal nut were constrained from rotation.
Deflection push rods were used.	Deflection wires were used.
Gimbal nut position was positioned adjacent to the lower stop collar stop.	Gimbal nut was positioned on the lower stop collar stop.
NTSB and Boeing recorded acoustical signature data.	Boeing recorded acoustical signature data.
The load was applied at 0.020 inch per minute initially than 0.050 inch per minute later.	The load was applied at 0.050 inch per minute.
Ran out of stroke and had to reset machine (twice).	Did not run out of stroke.
Ran out of sampling space.	Did not run out of sampling space.
Crushed the lower stop.	Slight deformation on the lower stop
Tension failure at 74,400 lbs.	Bending/Tension failure at 25, 576 lbs.

3.2.4 Finite Element Model (FEM)

On October 3, 2000, the group traveled to Long Beach, California to watch a presentation on Boeing's FEM of the jackscrew. The FEM was

developed to analytically calculate the static capability of the quill shaft under an offset load produced by a combined bending and tension load.

The model is a non-linear static analysis. There are four contact surfaces: the splines of the quill shaft to the acme screw, the acme screw to the stop collar, the washer and the acme screw, and the stop collar and the washer. Boeing is on revision D for the FEM. The original model had only 8.5 inches of the acme screw modeled and was fixed at the center of the gimbal nut. Revision A modeled the contact of the splines. Revision B modeled the test case and was extended to 28.3 inches to idealize the full length of the acme screw. Revision B is the model that ran the different options for the position of the gimbal nut. There are 20,798 solid elements. Revision B at 12% ultimate strain failure generated a 25,000 lbs. failure. Revision C revised the stop collar idealization to detail the counterbores for the clamp-up bolts and 45 degrees stop ramp. At 10% ultimate strain failure the Rev C model predicted a 27,000 lbs. failure.

[redacted]

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11/20/00