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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

July 31, 2001

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

A. ACCIDENT: DCA00MA026

Location: Rancho Cordova, CA
Date: February 16, 2000
Time: 1951 Pacific Standard Time
Aircraft: Emery Worldwide Airlines Flight 17, Douglas Model DC8-71F, N8079U

B. AIRWORTHINESS GROUP

Chairman: Kevin M. Pudwill
National Transportation Safety Board
Washington, DC

Member: T.R. Proven
Federal Aviation Administration
Washington, DC

Member: William C. Steelhammer
The Boeing Co.
Longbeach, CA

Member: Michael Huhn
Air Line Pilots Association
Herndon, VA

Member: Jim Owens
Emery Worldwide Airlines
Vandalia, OH

C. SUMMARY

On February 16, 2000, at 1951 Pacific Standard Time, a Douglas[1] Model DC8-71F, N8079U, operated by Emery Worldwide Airlines (Emery), as flight 17, a cargo flight departing from Mather Field (MHR) in Rancho Cordova, California to Dayton International Airport (DAY) in Dayton, Ohio, crashed into an auto salvage yard while attempting an emergency return to MHR. Three crew members onboard received fatal injuries and the aircraft was destroyed.

[1] Now known as The Boeing Company (Boeing).

A review of the data downloaded from the Flight Data Recorder (FDR) revealed that the Elevator parameter incorrectly portrayed the position of the Elevators consistently throughout the FDR recording. The review further revealed that the recorded Elevator trace never indicated travel below the neutral position of the Elevators, at any time during the accident flight, including during the "Taxi" and "80 knot" Elevator checks, even though the Control Column trace indicated that the Columns were positioned well forward of their neutral position the majority of the flight. Refer to Section 4.0 for further details.

A detailed wreckage examination of the Elevator flight control systems revealed a missing bolt at the right Elevator Control Tab crank fitting, where the Control Tab pushrod is normally attached. Although the pushrod was recovered separately, the pushrod and fitting remained structurally intact at the missing bolt location of each respective assembly. In addition, numerous indications of contact damage were noted on the forward edges of the crank fitting. Refer to Section 8.0 for further details, including a description of the DC-8 Elevator flight control system.

A review of the Maintenance Records for this aircraft revealed that the Elevator assemblies, including their Control Tabs, had been replaced with overhauled assemblies during the most recent "D" Check, that was completed on November 17, 1999. A review of the Work Cards and the applicable Maintenance Manual (MM) reference, related to the installation of the Control Tab, revealed that no hardware requirements were specified by the instructions provided for the missing bolt location (noted above). In addition, no specific instructions related to the inspection requirements associated with this installation were provided. Refer to Section 9.0 for further details.

Testing was performed on the Elevator flight controls of an exemplar DC-8 aircraft, to identify the effects of a free pushrod when disconnected from its Control Tab (crank fitting). This testing revealed that the disconnected Control Tab would result in a mismatch between the left and right Control Tabs of approximately 25°, throughout the available range of Control Column travel. The testing further revealed that the disconnected Control Tab would be deflected approximately twice as far, and in an opposite direction to, the functional Control Tab, even with the Control Columns commanded full forward (i.e. aircraft nose down). Refer to Section 11.0 for further details.

D. DETAILS OF THE INVESTIGATION

1.0 Wreckage Distribution

The accident occurred approximately 2 miles due east of the approach to runway 22L (MHR), northwest of the intersection between Sunrise Boulevard and Douglas Road, at the Insurance Auto Auction salvage yard and the Allstate Claims Service Center. The Insurance Auto Auction is located at 11499 Douglas Road, Rancho Cordova, California, 95742. The Allstate Claims Service Center is located at 11535 Douglas Road, Rancho Cordova, California, 95742. Refer to Attachment I for a map depicting the location of the accident site in relationship to MHR.

The aircraft was found oriented on a magnetic heading of approximately 295 degrees, coincident with a debris path along the same heading, that spanned an area approximately 500 yards in length by 150 yards wide. Refer to Attachment II, Photo 1, for an aerial photo of the wreckage site.

The center of the main wreckage (i.e. intersection of the fuselage and wings) was found at the following geographic coordinates: 38 degrees, 33 minutes, 45.05 seconds North Latitude; 121 degrees, 15 minutes, 11.32 seconds West Longitude. The local ground elevation at the crash site was determined to be approximately 140 feet above mean sea level.[2]

The airframe had broken up into several sections. The cockpit was found to the south of the main wreckage, the fuselage section forward of the wings was located to the west, a section of the right wing to the north, and the rear fuselage and empennage to the southeast. A debris field of aircraft parts extended towards the southeast and consisted of the engines, engine components, nacelles, pylons, landing gear assemblies, flight control surfaces, sections of each wing, the stabilizers, the fuselage tail cone, and numerous systems components.

All major sections of the aircraft were accounted for in the wreckage. However, the majority of the airframe, its associated systems, and onboard cargo were heavily damaged and /or consumed by fire subsequent to the accident. Refer to Attachment II for general photographs of the wreckage.

2.0 Structures

2.1 Fuselage

The main flight deck (cockpit) was found inverted approximately 30 feet south of the center of the main wreckage, along with portions of the fuselage nose section. The entire cockpit area was consumed by fire. The shell that remained measured approximately 6 feet by 8 feet by 3 feet in height and included the left, center and right windshield frames, numerous pieces of each pilots sliding clear view windows, a section of the fuselage crown immediately above the cockpit, and a section of the cockpit floor.

The forward left section of the fuselage between station (STA) 25 and 560 (i.e. aft of the cockpit), between the crown and cusp line, was located approximately 80 feet directly forward of the main wreckage and was oriented perpendicular to the longitudinal axis of the remaining fuselage. The cargo door remained attached to this section and was found closed and latched, with its actuator and hinges intact. The 9g net attachment fittings remained attached to this section of the fuselage, just aft of the crew access door to the cockpit.

A similar section of the right forward fuselage, immediately aft of the cockpit, measuring approximately 15 feet in length, was located nearby the forward left section of the fuselage. The 9g net attachment fittings remained attached to this section of the fuselage as well.

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[2] Geographic coordinates and ground elevation provided by the California Highway Patrol (CHP), Valley Division, Multidisciplinary Accident Investigation Team (MAIT), that performed a survey of the accident scene on February 18th and 19th, 2000.

Several small pieces of the 9g net webbing were recovered. However, the majority of the net was destroyed by fire. Likewise, the 9g net center attachment ring was also severely damaged by fire.

The majority of the fuselage aft of the wing center section was consumed by fire, with the exception of a section of the left fuselage measuring approximately 8 feet fore and aft of the number (No.) 3 door, that extended from the main cargo deck to the crown, and the structure immediately surrounding the No. 4 (right) door. A much smaller section of the left rear fuselage, measuring approximately 12 feet in length, surrounding the No. 4 (left) door was found adjacent to the fuselage section described above. The structure at or below the main cargo deck throughout the rear fuselage, including the floor boards, floor beams, seat tracks, cargo hardware, and lower fuselage were heavily damaged due to extreme deformation, heat and /or fire. All surfaces that remained were burned, charred and sooted.

Note: The rear fuselage was found layered upon sections of the left wing and several salvage yard automobiles. The belly of the aircraft was deformed and conformed to the irregular shapes of these various obstructions between the wing center section and tail.

2.2 Wings

The left wing was found fractured in a chord-wise direction approximately 15 feet outboard of the fuselage, as measured along the front spar. Portions of the rear spar and lower wing skin remained. However, the remaining structure in this area (i.e. ribs, front spar, stringers, upper skin panels, systems, leading and trailing edges) were consumed by fire.

Approximately 22 feet of the left (outer) wing, from the No. 2 (inboard) pylon outboard, was found directly beneath the wreckage of the rear fuselage. The No. 2 pylon was found inverted and immediately forward of the horizontal stabilizer. The mating section of the wing was also found inverted, oriented such that the rear spar was facing the left side of the fuselage and the outboard section spanned forward of this point. The upper wing skin was basically intact. However, the lower wing skin assembly (that was in contact with the lower fuselage) was consumed by fire. The No. 2 pylon sustained heavy damage due to fire. Portions of the left wing upper surface trailing edge remained intact, however exhibited substantial fire damage. The left wing inboard and outboard flap actuators were recovered in this area. The left aileron actuator and aileron linkage assembly were also recovered in this area. The aileron actuator was found extended approximately 8 inches.

The wing center section torque box upper surface (i.e. skin assembly) was consumed by fire. The wing center section was filled with cargo debris from the rear fuselage, including portions of two different pallets believed to be from position No. 17 and 18.

The inboard section of the right wing remained partially attached to the main wreckage and spanned from its root to a point approximately 9 feet outboard of the No. 4 (outboard) pylon. The basic structure throughout this section was almost totally consumed by fire. Only the lower skin assembly, portions of the front and rear spars, and the pylons remained. Aluminum, that was completely molten at one time and later re-solidified, covered an area on the ground that extended aft of the rear spar approximately 6 feet and spanned the entire

length of the right wing. Numerous sections of composite trailing edge panels and rear spar attachment fittings were also found along the rear spar.

The right wing flap (inboard and middle) actuators were found separated from their respective rear spar attachments due to significant fire damage. The right flap (outboard) actuator remained partially attached to the rear spar. The inboard, middle, and outboard actuator cylinders were found extended approximately 12 inches, 10 inches, and 8 inches respectively.

The right wing aileron actuator remained attached to the rear spar with its cylinder extended approximately 6 inches. The damper assembly, normally attached to the outboard section of the aileron, was found intact but detached from the rear spar due to fire damage.

A section of the right wing upper skin panel assembly, measuring approximately 16.5 feet long by 5.5 feet wide, was found approximately 30 feet directly forward (north) of the right wing. This majority of this section of the wing had melted down during the post crash fire and was found draped over the vehicle(s) beneath.

The left and right wing flaps (inboard and outboard sections) were found scattered throughout the debris field as were sections of the left and right spoiler panels. Sections of the left aileron were also found in the debris field along with its damper assemblies.

2.3 Empennage

The horizontal stabilizer center section and surrounding tail structure were located aft of the rear fuselage and exhibited heavy fire damage. Portions of the vertical stabilizer rear spar were found separately, immediately adjacent to the tail. However, the remaining structure of the vertical stabilizer and rudder were consumed by fire.

The horizontal stabilizer jackscrews and associated drive mechanisms (i.e. sprockets, chains, reduction gear box and drive motors) were heavily damaged due to fire. Both jackscrews were found extended approximately 28 inches, i.e. the distance measured between the drive sprocket and centerline of the pin attaching each jackscrew to its respective horizontal stabilizer actuating arm. The Boeing Co. later confirmed that this position (extension) of the jackscrews corresponds to the full aircraft nose down trim position of the horizontal stabilizer.

The majority of the left horizontal stabilizer and approximately 50% of the left Elevator and its Tabs (i.e. Control Tab, Geared Tab), were consumed by the post crash fire. Those sections that were recovered from the debris field were sooted and heavily damaged due to impact.

The right horizontal stabilizer was recovered from the debris field and was found essentially intact. The Elevator was fractured into several sections; however, the majority of the outboard sections were consumed by post crash fire. The right Control Tab and the inboard end of the Geared Tab remained attached to the inboard section of the Elevator, but had suffered severe heat and fire damage. All surfaces were sooted and heavily damaged due

to impact.

2.4 Landing Gear

The nose landing gear assembly was found approximately 11 feet to the left of the No. 2 pylon. The strut appeared to be fully extended with the drag brace broken off. The nose wheel steering cylinders were not attached. The nose gear retract actuator was not recovered. The upper strut of the nose gear cylinder was fractured about 1 foot above the actuator. The nose gear tires were consumed by fire.

The left main landing gear truck assembly was found separated from the wing and located in the debris field approximately 30 feet from its upper main strut assembly. One tire assembly remained attached along with two partial wheel hubs.

The right main landing gear truck assembly and gear strut were found separated from the right wing and were located in the debris field. Three tire assemblies and one brake assembly remained attached.

3.0 Systems

3.1 Cockpit

The flight instruments and the flap position indicator were recovered with the main cockpit wreckage previously described. All the instruments were destroyed due to mechanical damage and /or fire. When the remaining section of the cockpit floor was removed from the cockpit debris, the control column torque tube, the Pitch Trim Compensator (PTC)[3] motor and actuator, throttle quadrant, throttle handles, flap handle, spoiler handle, and thrust reverser levers were also recovered.

The PTC actuator was found in its retracted position. The throttle quadrant was intact with its levers bent into various directions. However, the throttle handles were found aligned with each other. The flap handle was found with its lever latched in the third detent aft of its stowed position that corresponds to a flap extension of 15 degrees. The flap position gauge was recovered but was unreadable due to mechanical /fire damage. The spoiler handle was found in its retracted position. The thrust reverser levers were found in their respective stowed positions.

The Flight Engineer's panels were located nearby the pilots' instrument panel and to the right of the cockpit windshield, approximately 25 feet from the main aircraft wreckage. The fuel select levers and crossover levers were found in their normal takeoff position. The Flight Engineer's instruments were found damaged and unreadable. The circuit breaker panel and its associated breakers were heavily damaged.

[3] Refer to Section 8.1 for a description of the PTC system.

The radio rack equipment was found forward of the main cockpit wreckage, draped over an automobile. The cockpit radios, a transformer rectifier, and miscellaneous electronic debris were found in the immediate vicinity and were all destroyed due to fire.

3.2 Flight Control Cables

Continuity of the flight control cables, including those that control the Elevator Control Tabs, could not be established due to the severe breakup of the aircraft and post crash fire.

4.0 Flight Data Recorder

A review of the data downloaded from the FDR, for the accident and previous flights of N8079U, revealed that the presentation of the recorded data associated with the Elevator parameter, based upon the initial conversions provided by Emery, incorrectly portrayed the position of the Elevators consistently throughout the FDR recording. The review further revealed that the recorded Elevator trace never indicated travel below the neutral position of the Elevators, at any time during the accident flight, including during the "Taxi" and "80 knot" Elevator checks, even though the Control Column trace indicated that the Columns were positioned well forward of their neutral position the majority of the flight, i.e. positions that would normally correspond to trailing edge down (TED) Elevator positions.

The recorded data associated with the previous flight (i.e. takeoff from Reno, NV) indicated that the Elevators were deflected approximately 14 degrees trailing edge down (TED), during climb, 15 seconds following rotation, while the Control Columns were positioned near their rigged neutral position, 13.5 degrees forward of vertical (-13.5 degrees). However, the neutral position of the Control Columns (in flight) normally corresponds to the neutral position of the Elevators (i.e. 0 degrees). Refer to Attachment III-1 for a plot of the FDR data associated with this takeoff. Note the commanded rotation at FDR Subframe 1220, i.e. Control Column motion aft, corresponding Elevator response in the trailing edge up (TEU) direction, and increase in aircraft pitch attitude, followed shortly thereafter by Control Column motion forward and corresponding Elevator movement to a stabilized position near 14 degrees TED at FDR Subframe 1235.

Further review of the FDR data indicated that the Elevators were deflected 11 degrees TED whenever the Elevator Gust Lock[4] was engaged. However, since the Elevators are physically locked in their neutral position when the Gust Lock is engaged, the data revealed that the Elevator trace was actually offset by 11 degrees from its true position. Refer to Attachment III-2 for a plot of the FDR data associated with the accident flight, including taxi. Note the position of the Elevator at FDR Subframe 200, while the Gust Lock is engaged. Further note the addition of a dashed line that indicates this Elevator reference (neutral) position throughout the FDR data presented.

Finally, a review of the accident flight data (Attachment III-3, FDR Subframes 685 through

[4] Operated by a Gust Lock lever located on the right side of the pilot's center control pedestal. When the lever is moved to its aft (down), latched position, the Elevator and Rudder surfaces are locked and a throttle interlock system limits the movement of the throttles.

890), with the understanding that the recorded Elevator trace is offset by 11 degrees, revealed the following: 1) during the "80 knot" Elevator checks (FDR Subframe 750), the recorded Elevator trace did not indicate travel below the neutral position of the Elevators as would normally be expected; 2) although the Control Column trace indicated that the Columns were commanded forward of their rigged neutral position, at FDR Subframe 765, the Elevator trace indicated that the Elevators were deflected approximately 5.5 degrees above their neutral position (i.e. TEU), and the aircraft rotated as indicated by the increasing pitch attitude of the aircraft; and 3) the Elevator trace indicates that the Elevators remained TEU throughout the accident flight, although the Control Columns were positioned well forward of their neutral position the majority of the flight, i.e. positions that normally correspond to TED Elevator positions.

5.0 Manufacturer Service Bulletins

A review of McDonnell Douglas Corporation (Douglas) Service Bulletins (SB) revealed that several bulletins have been issued related to the Elevator flight controls of the Douglas Model DC-8. The bulletins listed below are those directly related to abnormal Elevator travel during preflight rollout checks and /or incidents where an aircraft became uncontrollable in the aircraft nose up direction during takeoff.

5.1 SB 27-254

On March 5, 1975, Douglas issued SB 27-254, titled "Flight Controls – Elevator and Tabs – Install Position Indicator," that recommended Operators install an Elevator Position Indicator (EPI), in addition to an Elevator position transmitter and associated circuitry.

Douglas indicated that this bulletin had been released due to two instances of insufficient or abnormal Elevator travel that had been reported during preflight rollout checks. Douglas further indicated, that their investigation of these events had revealed, that an EPI would aid flight crews in detecting restricted Elevator movement in the event of foreign object interference between the Elevator surface and trailing edge of the horizontal stabilizer.

Note that SB 27-254, instructed Operators to install the EPI on the First Officer's instrument panel, in a location selected by the Operator, such that the First Officer's view of the indicator was not obstructed by the full forward position of the Control Column.

5.2 SB A27-262

On April 28, 1977, Douglas issued Alert SB A27-262, titled "Flight Controls – Elevator and Tab – Inspect Elevator Geared Tab Mechanism and Gust Lock Crank Assembly," to provide Operators with information and inspection procedures related to an incident whereby, during takeoff, at approximately 80 knots, a DC-8 aircraft became uncontrollable in the nose up direction, the takeoff was aborted, and the aircraft departed the runway.

According to Douglas, the investigation revealed that the left Elevator Geared Tab drive (crank) arm assemblies, part number (P/N) 4710541 (inboard) and P/N 4710542 (outboard) had failed, likewise the Elevator Gust Lock crank assembly had failed. The SB indicated

that Douglas had not determined when the Gust Lock crank assembly failed; however, they suspected that the failure of the Geared Tab crank arms occurred when the aircraft was parked, in gusty conditions, with the Gust Lock disengaged or inoperative.

Based upon their findings, Douglas strongly recommended that Operators engage the Elevator Gust Lock, at all times, whenever an aircraft is parked. The SB informed Operators that when the Gust Lock is engaged, its position (condition) is readily determined from outside the aircraft, since the Elevators are held in their neutral position. The SB further advised Operators that any Elevator not held in its neutral position, when the Gust Lock is engaged, indicates a system malfunction and therefore requires that the inspection identified within SB A27-262 be performed prior to the next flight of the aircraft.

Douglas further recommended that the inspection requirements identified within the SB be accomplished at the first convenient maintenance check, not to exceed 30 days from the date of its issuance. The SB instructions included a visual inspection of the left and right Elevator Geared Tab (inboard and outboard) crank arm assemblies and the Gust Lock assembly for failure and /or cracks. The SB indicated that failed or cracked parts must be replaced immediately, that Operators should verify that adequate clearance exists between the Geared Tab crank arm assemblies and the horizontal stabilizer throughout the range of Elevator travel, and that Operators should notify Douglas of all inspection findings.

5.3 SB A27-264

On May 14, 1977, Douglas issued Alert SB A27-264, titled "Flight Controls – Elevator and Tab – Check Elevator Control Surface for Proper Response in Relation to Up and Down Elevator Inputs," to provide Operators with additional information regarding the incident discussed in SB A27-262 and implement operating procedures related to the performance of Elevator flight control checks.

Through SB A27-264, Douglas informed Operators that the investigation, related to the incident identified by SB A27-262, revealed that an Elevator control surface was blocked in the aircraft nose up direction due to a failed Elevator Geared Tab crank arm. Douglas further advised Operators that, in their opinion, had SB 27-254 (Refer to Section 5.1 above) been accomplished on the aircraft involved, the flight crew would have determined that the Elevator surfaces were not moving normally.

SB A27-264 advised Operators that Elevator flight control checks must be performed with the aircraft turned into the wind. Douglas also informed Operators, that if it was not possible to check the Elevator controls with the aircraft turned into the wind, than an optional procedure could be used during the initial takeoff roll (60 – 80 knots), i.e. by checking the response of the aircraft in relation to small up and down Elevator inputs. Douglas added that this optional procedure should not be used when takeoffs are made on wet or icy runways or when moderate crosswind conditions exist.

SB A27-264 also advised Operators that the incorporation of SB 27-254, i.e. the installation of an EPI, was considered terminating action for this SB.

5.4 SB 27-262

On July 15, 1977, Douglas issued SB 27-262, titled "Flight Controls – Elevator and Tab – Modify Elevator Geared Tab Mechanism," that provided instructions related to the modification of the left and right Elevator Geared Tab (inboard and outboard) operating mechanisms. Refer to Attachment IV, for a copy of this SB, specifically Figure 1 (Sheet 2 of 7) for an illustration of the Elevator Geared Tab mechanisms. Refer to Figure 1 (Sheet 5 of 7) for illustrations of the Geared Tab (outboard) mechanism in relationship to various positions of the Elevator throughout its full range of travel.

This SB presented two options for incorporation by the Operator. Modification in accordance with Option I essentially improved the clearances between the Geared Tab mechanism (i.e. drive crank arm, link assembly) and surrounding structure (i.e. horizontal stabilizer, Elevator) at each location, and at the Operator's convenience, replaced the left and right Elevator Geared Tab inboard and outboard crank arm assemblies. Whereas, modification in accordance with Option II simply improved the clearances between the Geared Tab mechanisms and surrounding structure addressed in Option I.

Option I allowed Operators to replace the existing aluminum Geared Tab crank arm assemblies (P/N 4710541 and 4710542), inboard and outboard respectively, with like parts, or install new crank assemblies (P/N 3802767-1 and 3802768-1) forged from stainless steel. Note that the installation of new (steel) crank assemblies required that the Elevators be rebalanced and that balance weights be removed to compensate for the added weight of the new assemblies.

Option II allowed Operators to accomplish the majority of the work outlined by Option I without having to remove the left or right Elevators.

In this SB, Douglas informed Operators that the replacement of existing aluminum Geared Tab crank arm assemblies, with steel crank assemblies, and the improvement of crank assembly clearances would minimize the possibility of crank failures when an aircraft is parked in gusty conditions.

Douglas recommended that the modification to provide clearance between each Geared Tab mechanism and its surrounding structure, in accordance with Option I or II, be accomplished within 12 months from the issue date of this SB. Douglas further recommended that Elevator Geared Tab crank arm assembly replacements be accomplished, in accordance with Option I, at the Operator's convenience.

6.0 FAA Airworthiness Directives

A review of Federal Aviation Administration (FAA) Airworthiness Directives (AD), applicable to McDonnell Douglas DC-8 Series aircraft, revealed two AD related to the SB noted above.

AD 77-10-12, Amendment 39-2906, effective May 26, 1977, mandated the inspection requirements identified within Douglas SB A27-262, to detect cracks and prevent failure or

jamming of the Elevator Geared Tab crank arm and Gust Lock assemblies. The AD required that these inspections were to be complied with within 300 flight hours or 30 days, whichever occurred first.

AD 78-01-15, Amendment 39-3198, effective June 1, 1978, mandated that Operators incorporate the modifications identified within Douglas SB 27-262, within 12 months, to prevent failure of the Elevator Geared Tab crank arms and therefore jamming of the Elevators. However, in line with the recommendations that Douglas had made, the AD indicated that compliance with the requirements related to the installation of steel Geared Tab crank arms was optional. This AD further mandated the installation of an EPI system in accordance with Douglas SB 27-254, within 18 months, unless already accomplished.

Note that AD 78-01-15 also included a provision that allowed Operators to operate an aircraft with an inoperative EPI system, provided that, prior to each takeoff, proper operation of the Elevators be verified by a ground observer, and by utilizing the Elevator flight control check procedure identified within Douglas SB A27-264.

7.0 History of DC-8 Restricted Elevator Events

7.1 NTSB Investigations

A review of NTSB accident investigations, related to Douglas DC-8 aircraft and restricted Elevator movement, revealed Aircraft Accident Report No. NTSB-AAR-71-12, adopted August 18, 1971, titled: Trans International Airlines Corp., Ferry Flight 863, Douglas DC-8-63F, N4863T, J.F. Kennedy International Airport, New York, September 8, 1970. In that investigation, the Safety Board determined (in part) that the probable cause of the accident was a loss of pitch control caused by the entrapment of a pointed (asphalt-covered) object between the leading edge of the right Elevator and horizontal stabilizer. The Safety Board further concluded that this restriction to Elevator movement, caused by an unknown condition, was not detected by the crew in time to reject the takeoff successfully.

In view of their findings related to this investigation, the Safety Board issued the following recommendations to the FAA:

1) All DC-8 operators be advised of the hazardous condition that can be created by foreign object jamming of the aircraft's elevators.

2) Until adequate procedures are developed for positive check of elevator position, all DC-8 operators be advised that takeoff should be aborted whenever premature or unacceptable rotation of the aircraft occurs during takeoff.

3) The DC-8 flight control system be evaluated by the FAA in the interest of developing a standard procedure for checking the system from the cockpit. The Procedure should provide for positive detection of a jammed elevator.

4) Consideration be given for a requirement to install an elevator position indicator in the cockpit of all DC-8 aircraft.

7.2 Service Difficulty Reports

A review of Service Difficulty Reports (SDR), submitted during the last five years, related to DC-8 Elevators, indicates that several Geared Tab crank arm failures have been reported. While one such report indicated that the problem was noted during an Elevator Check on the ground, another indicated that the problem occurred in flight and caused a full down Elevator.

Four reports, from this same period in time, indicate that takeoffs were aborted due to abnormal aircraft and/or Elevator response (including one instance of a jammed Elevator) during Elevator checks. Three of the four SDR indicate that these Elevator checks were performed at 80 knots.

Refer to Attachment V for a copy of the SDR related to these events.

7.3 Manufacturer Reports

At the request of the NTSB, Boeing provided information regarding the abnormal Elevator events that have been reported by DC-8 Operators, including the following; binding /jammed Elevators, broken Geared Tab crank arms, Gust Lock related events, and abnormal Elevator indications during takeoff. The information that Boeing provided on January 10, 2001, dates back to September 8, 1970, and includes the NTSB investigation noted in Section 7.1 (above).

Refer to Attachment VI for a table of the abnormal Elevator events identified by Boeing. Note that three events involved foreign objects, that were found (or suspected) to have been lodged between the Elevator and horizontal stabilizer. Further note that five events involved broken (aluminum) Geared Tab crank arms.

8.0 Detailed Wreckage Examination (Elevator Flight Control System)

Following the review of the FDR (Refer to Section 4.0), members representing the FAA, Boeing, Emery, and the Air Line Pilots Association (ALPA) met in Sacramento, California, on February 7th and 8th, 2001, to perform a detailed wreckage examination of the flight 17 Elevator flight control systems. The purpose of the examination was to search for evidence that might be related to a problem with the Elevator flight control systems during the accident flight. Refer to Section 8.1 (below) for a general description of the DC-8 Elevator flight control systems identified in this document.

Refer to Attachment VII for sketches of the Horizontal Stabilizers, Elevators, and Tabs, that were recovered and examined. Note that these sketches also include the applicable station locations referenced throughout the following sections.

8.1 Description of DC-8 Elevator Flight Control Systems

The following system description is based upon information found in Chapter 27 of the

DC-8 MM and the Emery DC-8 Aircraft Operating Manual. Refer to Attachment VIII for a schematic of the Elevator Control System.

The DC-8 Elevator flight control system consists of two Elevators, two Control Tabs, two Geared Tabs, two Control Columns, dual flight control cables, and a load-feel and centering device that provide longitudinal control of the airplane about its lateral axis.

The left and right Elevators are hinged to the rear spar of the horizontal stabilizer, and are interconnected by a torque tube so that they operate in unison. The Elevators travel approximately 27° up and 16.5° down from their faired (neutral) position with the stabilizer.

A Control Tab is hinged to the inboard trailing edge of each Elevator. A crank fitting, installed at the inboard end of each Control Tab, is connected by mechanical linkage (i.e. pushrod, crank arm, and bell crank assembly) to a flight control cable system that is routed through the aircraft to the respective Control Column on that side. The Control Tabs travel approximately 8.5° up and 26.5° down from their faired position with the Elevator.

A Geared Tab is hinged to the trailing edge of each Elevator, immediately outboard of the Control Tab. Two pushrods, attached to the Geared Tab (one at each end), connect the Geared Tab to the rear spar of the horizontal stabilizer via a Geared Tab drive linkage (i.e. crank arm, link assembly). The Geared Tabs are rigged to be faired with the Elevators when the Elevators are in their neutral position. The Geared Tabs travel approximately 4.75° up and 26.75° down from their faired position, in a direction opposite to that of the Elevators.

Two Control Columns are located in the cockpit and are interconnected by a torque tube beneath the cockpit floor, so that they operate in unison. The Control Columns travel approximately 23.75° forward and 6.5° aft of a vertical reference line (i.e. perpendicular to the inboard seat track at the First Officer's station). Stops at the base of the left Control Column prevent travel beyond these deflections. The Elevator flight control cables are connected to the base of each Control Column. A load-feel and centering device assembly is connected to the base of the right Control Column and provides a simulated feel of aerodynamic flight loads. This assembly also acts as a centering device to return the Columns to neutral (approximately 15° forward of vertical) when no external forces are applied to the Columns.

An Elevator Position Indicator (EPI), mounted on the copilot's instrument panel, indicates the position of the Elevators. The indicator is marked with UP, DN (Down), and NEUT (Neutral) index markings. The UP index mark corresponds to an Elevator position of 27° TEU, whereas the DN index mark corresponds to an Elevator position of 16.5° TED. A narrow white band adjacent to the NEUT markings indicates an Elevator position between 0 and 5°.

Operation:

When either Control Column is moved forward or aft, the Control Column torque tube moves the opposite Column in the same direction, causing the cable systems and their associated mechanical linkages to drive the Control Tabs up or down (respectively). During

flight, aerodynamic forces exerted on the deflected Control Tabs drive the Elevators in the opposite direction. As the position of the Elevators change in relation to the horizontal stabilizer, the Geared Tab drive linkages move the Geared Tabs in the same direction as the Control Tabs, in effect providing an aerodynamic boost, to assist in moving the Elevators.

Viscous dampers installed in each Elevator leading edge, at the inboard hinge location, prevent flutter of the Elevators by applying a force directly proportional to the rate of Elevator movement.

The PTC [Pitch Trim Compensator] system applies a force to the First Officer's Control Column, to prevent an aircraft tendency to lower its nose at airspeeds above 310 knots, at altitudes below approximately 20,500 feet, and when operating between Mach 0.70 and 0.95, at altitudes greater than 20,500 feet. The operation of this system is automatic, when properly configured via its circuit breakers and switches. A computer controls the PTC motor, which drives (extends) its actuator, that is mechanically linked to the Control Column. Note that when the PTC actuator is in its retracted position, no force is applied to the First Officer's Control Column.

8.2 Right Horizontal Stabilizer /Elevator /Tabs

The majority of the right horizontal stabilizer was recovered intact. Essentially, the entire span of the stabilizer survived, with the exception of a section of the torque box directly forward of the rear spar, near the root of the stabilizer. Localized deformation was noted on the lower skin trailing edge in the vicinity of the geared tab outboard crank assembly installation. However, no other significant damage was noted along the span of the rear spar, nor the upper and lower trailing edge skins.

The geared tab inboard crank arm, manufactured from aluminum, was found fractured yet remained attached to its link assembly attached to the rear spar of the stabilizer. However, the link assembly was twisted and deformed. Witness marks were noted on the lower edge of the rear spar cutout, directly beneath the fractured crank arm, consistent with contact between the fractured crank arm and stabilizer.

Approximately 6.75 feet of the Elevator, between stations XE 149 and 221, primarily consisting of the leading edge forward of the front spar, remained attached to the mid section of the right stabilizer, via the geared tab outboard crank arm installation only. The associated geared tab crank arm and link assembly at this location were bent and twisted in several directions, yet had not failed. The crank arm was rusted and therefore determined to be steel.

The Geared Tab pushrod, at this outboard location, remained attached to its spline attachment at the leading edge of the Elevator, but was found bent approximately mid way between its spline attachment and aft end that was free.

The Elevator leading edge doubler, located at the outboard crank arm assembly described above, was found deformed inward near the upper inboard edge of its opening (slot) for the crank arm. The damage matched the contour of the crank arm when this section

of the Elevator was rotated to an abnormal position, above the surface of the stabilizer, as if being twisted and torn away from the stabilizer.

An Elevator hinge bracket remained attached to the rear spar of the stabilizer immediately outboard of this section of the Elevator.

The right Elevator was recovered in several sections, independent of the stabilizer, and with breaks at stations XE 149, 221, and 272. The inboard section, that spanned from the root of the Elevator to station XE 149 remained basically intact, however was sooted over its entire surface. The majority of the Elevator outboard of this location was consumed by fire. The remaining sections exhibited damage due to post crash fire and were heavily sooted. The section that spanned between station XE 149 and XE 221, remained attached to the stabilizer and is described above. The Elevator, between station XE 221 and XE 312 was recovered in two sections, separated at station XE 272. The leading edges of these two outer sections exhibited minor damage due to contact with other objects.

Minor damage was also noted along the leading edge of the Elevator that spanned between its root and station XE149. The right control tab remained attached to this section of the Elevator and moved freely about its hinges. In addition, approximately two feet of the Geared Tab remained attached to this section of the Elevator immediately outboard of the Control Tab.

The geared tab inboard crank arm, manufactured from aluminum, was found fractured at a location just inside the leading edge of this section of the Elevator. Continuity of the geared tab pushrod assembly was verified by the noted deflection of the Geared Tab during rotation of the remaining portion of the fractured crank arm.

The right Elevator Control Tab crank (clevis) fitting was found structurally intact and remained attached to the Control Tab inboard hinge fitting, at the inboard end of the Elevator. However, numerous indications of contact damage (i.e. wear, gouge marks and indentations) were noted across the forward edges of the clevis fitting lugs and on the external face of the outboard lug. Refer to Attachment II, Photo 2, for a digital photograph of the Control Tab clevis fitting, as recovered. Refer to Photos 5 and 6, for digital photographs of the Control Tab clevis fitting, following its removal from the Elevator, that depict the contact damage noted on the forward edges of the clevis fitting.

Although the Control Tab clevis fitting lugs had not failed and both Control Tab pushrod attachment bushings were present, with no visible signs of internal damage or deformation, the bolt that normally secures the Control Tab pushrod to this clevis fitting was missing and not recovered. Refer to Attachment IX for a figure depicting the location of this missing bolt.

Note: According to the Douglas Aircraft Company DC-8 Overhaul Manual (OHM), Chapter 27-16-1, Figure 2 (Page 13/14), the hardware required to secure the Control Tab pushrod to the Tab crank fitting at this location includes; an NAS464P5L14 bolt, 2704013-516L washer, AN320-5 castellated nut, and an AN381-2-8 cotter pin. Further note that the missing NAS464P5L14 bolt has a double shear strength of approximately 14,600 lb_f.

Portions of the Control Tab pushrod (upper) fairing remained attached to this section of the Elevator and Control Tab; however, much of the fairing was consumed by fire. The sections that remained exhibited severe heat and fire damage and were deformed. The aft section of the fairing, that remained attached to the Control Tab, was deformed such that it matched the approximate shape (contour) of the upper end of the Control Tab crank fitting, when the Control Tab was deflected to a position approximately 30 degrees TED.

The Control Tab pushrod was recovered separately from the inboard section of the Elevator and Control Tab. A portion of the Control Tab drive crank assembly, the drive arm, remained secured to the forward rod end of the pushrod with an NAS6305-10D bolt, washer, AN 320-5 castellated nut, and cotter pin. The tab drive crank assembly had fractured into two sections and separated from the Elevator hinge line tab control shaft (i.e. torque tube)[5], internal to the Elevator. However, the tab drive crank assembly attachment bolt, castellated nut, and cotter pin remained attached to the torque tube assembly and the shaft rotated freely. The remaining section of the tab drive crank assembly, the stop arm, was recovered from inside this section of the Elevator, near its leading edge.

The Control Tab pushrod forward (adjustable) rod end jam nut was found slightly loose and the pushrod rotated approximately 90 degrees from its normal orientation in relationship to the drive arm. Although the pushrod was recovered separately from the Control Tab crank (clevis) fitting, its aft rod end and associated bearing, that normally attach the pushrod to the clevis fitting, were found intact. Witness marks (i.e. contact damage, deformation) were noted on the circumference, shoulders, and exposed perimeter edges of the rod end. Refer to Attachment II, Photos 3 and 4, for digital photographs of the right Control Tab pushrod, including a close up of its (intact) aft rod end.

One arm of the right Control Tab bell crank assembly was recovered separately, along with approximately 20 feet of flight control cable. The cable and its turnbuckle remained attached to the bell crank and the required bolt, nut, and cotter pin were found intact.

The right Elevator hinge line bearing housing was cracked at two or more locations and was slightly displaced due to the breakup of the aircraft.

The right Elevator damper assembly, that had previously been removed from the leading edge of the Elevator, was found intact with the damper drive linkage still attached to its crank arm and its horizontal stabilizer rear spar attachment fitting, that had separated from the stabilizer. The rivets that attach the crank arm to the rotor were found sheared; however, the rotor /disk assembly (internal to the damper) rotated freely.

8.3 Left Horizontal Stabilizer /Elevator /Tabs

The majority of the left horizontal stabilizer was consumed by fire. However, two sections, representing approximately 25% of the stabilizer, were recovered near the tip of the

[5] The position of the Elevator hinge line tab control shaft, and therefore the tab drive crank assembly, is controlled by the Elevator flight control cable bell crank assembly and /or the position of the Elevator, when the fixed Control Tab stops (internal to the Elevator) contact the tab crank assembly stop arm.

stabilizer. No significant damage was noted along the rear spar, nor the upper or lower trailing edges of these sections.

The sections of the left Elevator and Control Tab, that spanned inboard of station XE77, including the left Control Tab clevis fitting, were consumed by fire. However, the left Control Tab pushrod, normally installed in this area, was recovered.

The pushrod aft rod end, normally attached to the Control Tab clevis fitting, was fractured and approximately ¾ of the rod end, and its associated bearing, were missing. Likewise, the forward end of the pushrod was fractured at the aft rivet attachment holes for the forward rod end. The pushrod was found bent approximately 90 degrees midway between each end. No fire damage was noted on the pushrod assembly.

A six foot section of the left Elevator, that spanned between hinge stations XE77 and XE149, was recovered. The outboard 4 feet of the Control Tab and inboard 3 feet of the Geared Tab remained attached to this section of the Elevator. The leading edge of the Elevator was dented inward at several locations and heavy fire damage was noted near the outboard end.

The Geared Tab inboard fairing remained attached to this section of the Elevator and exhibited minor damage. The Geared Tab crank arm at this location, manufactured from aluminum, was found fractured at approximately the same location as the Geared Tab inboard crank arm on the right Elevator. The doubler surrounding the crank arm opening on the leading edge of the Elevator was not damaged. However, minor gouges, measuring approximately 0.5" wide by 0.375" long, were noted on the skin directly beneath the crank arm opening. Continuity of the Geared Tab pushrod assembly was verified, by the noted deflection of the Geared Tab, when the remaining portion of the crank arm was rotated.

The left Geared Tab outboard crank arm and push rod assembly were recovered separately. The crank arm was rusted and therefore manufactured of steel. The associated Elevator leading edge crank arm (slot) doubler was also recovered with the Geared Tab crank arm /pushrod assembly. Melted aluminum from the Elevator leading edge remained attached to the inner surfaces of this steel doubler, trapped beneath its associated nut plates.

A second section of the left Elevator was recovered further outboard. The section spanned between hinge station XE 221 and a point approximately 18 inches outboard of hinge station XE 272, and was heavily damaged due to impact. The leading edge of the Elevator between the hinge cutouts in this section was also gouged. However, no penetration of the leading edge or visible sign of interference with the rear spar of the matching horizontal stabilizer section (identified above) was noted in this area.

9.0 Maintenance Records

Based upon the evidence noted in Section 8.2 (above), i.e. related to the missing bolt and associated hardware at the right Elevator Control Tab crank fitting (pushrod attachment), a review of the Maintenance Records for N8079U was performed to determine when /where this installation was last worked on.

A review of the Maintenance Records, revealed that the Elevators and their associated Tabs were replaced with overhauled assemblies during the most recent "D" Check, that was completed on November 17, 1999, by Tennessee Technical Services (TTS), located in Smyrna, TN. Refer to the Maintenance Group Chairman's Factual Report for general information related to Emery Worldwide Airline's Maintenance Program, including the flight hours /cycles on the aircraft at the time of this "D" Check.

A review of the "D" Check Work Cards, provided by Emery to TTS, revealed the following:

The original right hand (R/H) Elevator and its Tabs, were removed in accordance with Work Card (W/C) Number (No.) 3103D, titled "Remove R/H Elevator and Tabs." This W/C provided instructions to remove the R/H Elevator, Control Tab, and Geared Tab, and to bag and attach all parts (interpreted to mean hardware) to their respective sub assemblies. Refer to Attachment X for a copy of this W/C, in addition to the other W/C references identified within this section.

W/C No. 3502D, titled "Install Right Elevator Tabs," provided instructions to install an overhauled Control Tab on the Elevator, in addition to similar instructions to install an overhauled Geared Tab and related to the lubrication of the Tab hinge bearings. This W/C also included instructions for an Inspector to verify the Control and Geared Tab installation and security. A general note at the top of this W/C provided instructions to use the applicable DC-8 MM, Chapter 27, when performing this work. The completed W/C indicated that the installation of the Control Tab was signed off by a mechanic and TTS Inspector No. 20. The W/C also indicated that the final step, "Inspector verify control and geared tab installation and security," was signed off by TTS Inspector No. 2.

A review of the DC-8 MM (Chapter 27), provided by Emery and effective for N8079U, revealed that Chapter 27-32-06, titled "Tab, Elevator Control - Removal /Installation," was the applicable reference to perform this work. Refer to Attachment XI for a copy of this MM reference. Note that Section 3 "Removal /Installation," subpart D "Check Tab Clearances and Rig," step (2) provided instructions to connect the Tab pushrod to the Tab crank fitting and secure. However, no hardware requirements were specified by the procedure for this installation, within the section noted, nor within the associated installation illustration (Figure 1001) or the Illustrated Parts Catalog (i.e. parts list) provided. In addition, Section 3, subpart E "Operational Check," found directly beneath a heading titled "Inspector: Check Control Tab Installation, Security and Safeties," provided no specific instructions related to the inspection requirements associated with the installation of the Control Tab pushrod to the Control Tab crank fitting.

A review of the DC-8 Master MM and Illustrated Parts Catalog, applicable to Chapter 27, revealed similar findings, i.e. no reference to the hardware required to install the Control Tab pushrod to the Tab crank fitting. However, as previously indicated, a review of the DC-8 OHM, Chapter 27-16-1, did reveal the hardware required at this location.

W/C No. 3504D, titled "Install Right Elevator Assembly," provided instructions to install the Elevator assembly on the horizontal stabilizer. Once again, the instructions indicated to use the applicable DC-8 MM, Chapter 27, when performing this work. TTS Inspector No. 21 signed off step 1, "Inspection OK to install right elevator assembly to horizontal stabilizer." TTS

Inspector No. 19 signed off step 11, "Inspector check elevator assembly for proper installation and security." TTS Inspector No. 2 signed off the final step (step 12), "Rig R/H elevator assembly per DC-8 MM, Chapter 27."

W/C No. 3506D, titled "Functionally Check Right Elevator and Tab," provided instructions to perform Elevator and Tab travel checks, checks for excessive friction, mismatch checks between the left and right Elevators, Control Tabs, and Geared Tabs, and clearance checks. The W/C included a note to use the applicable DC-8 MM, Chapter 27, when performing this work and indicated that this W/C was to be worked in conjunction with W/C No. 3504D (identified above). TTS Inspector No. 2 signed off all steps (1-7) on this W/C, related to the inspection of each task.

10.0 Fleet Campaign Directive

At the request of the NTSB, Emery initiated a Fleet Campaign Directive (FCD), No. A27-8, dated March 16, 2001, titled "Elevator Push /Pull Rod End Bolt Installation Inspection," to inspect their fleet of 29 DC-8 aircraft, to ensure that the installation of each Elevator Control Tab push /pull rod (i.e. pushrod), at each rod end, was properly secured with a bolt, washer, nut, and cotter pin. This FCD also inspected each aircraft for damage to the pushrod, clearance between the Control Tab and Elevator, and orientation of the bolt used to attach the aft end of the pushrod to the Control Tab crank fitting. Refer to Attachment XII for a copy of this FCD.

The FCD included several steps with instructions regarding the specific inspections to be completed, including the requirement to make an aircraft logbook entry indicating compliance with this FCD. Step 5 of the work instructions, also included a note indicating that the correct installation for the aft end of the pushrod (i.e. at the Control Tab crank fitting) was with the bolt head facing inboard. Note: This is the same bolt orientation that is depicted within the DC-8 OHM, Chapter 27-16-1 (previously identified).

On May 21, 2001, Emery provided the NTSB with a summary of their findings associated with FCD A27-8. Those findings relevant to this investigation have been highlighted below.

The summary of the findings associated with the FCD, revealed that cotter pins were correctly installed on each aircraft Control Tab pushrod, at the forward rod end (i.e. Control Tab drive crank assembly) and aft rod end (i.e. Control Tab crank fitting) connections. However, these findings also revealed that bolts, installed at the aft connection, were oriented opposite to that depicted within the DC-8 OHM, Chapter 27-16-1, on eleven aircraft, five of which involved the left and right installations. In addition, the findings revealed that the orientation of the bolt installed at the forward rod end, was different than that depicted by the OHM on several aircraft. Three pushrods were replaced due to wear and /or suspected damage. One pushrod was found installed backwards.

11.0 Elevator Flight Control Testing

On April 11th and 12th, 2001, members representing the FAA, Boeing, Emery, and ALPA

met in Vandalia, Ohio, to perform testing of the Elevator flight control systems onboard an Emery DC8-71F (N8076U). This particular aircraft had accumulated 81,286:27 flight hours and 33,549 flight cycles at the time of this testing.

The basic outline for the testing that was performed was identified in "DC8-71F Test Plan (Flight Controls, Elevator /EPI)", dated April 11, 2001 (Refer to Attachment XIII). Note, however, that several steps of the identified procedure where either modified and /or deleted during the actual testing based upon the results that were witnessed. A summary of the significant test results has been included below.

The primary objective of this testing was to identify the effects of a disconnected /misaligned Control Tab pushrod (at the Control Tab crank fitting), by comparing the deflections of the left and right Control Tabs throughout the active range of Control Column and Elevator travel. In addition, several secondary objectives were included in an attempt to better understand the FDR data and physical evidence related to this accident.

The test plan included checks to determine the relationship between the travel of the Control Column, Elevator, and Tabs, with and without the right Control Tab pushrod connected. In addition, checks were included to determine the available forward range of motion of the Control Columns, assuming that Elevator travel was restricted at various TEU positions. Checks were also included to explore the Geared Tab (inboard) crank arm fractures, that were previously identified, in an attempt to identify where witness marks on the surrounding structure would be expected had these fractures occurred in flight and caused a restriction in Elevator travel. Finally, the test plan included checks to determine the response of the EPI (Elevator Position Indicator), during static conditions (i.e. with the aircraft at rest) and during the traditional "80 knot" Elevator Checks performed by Emery.

Prior to accomplishing the main objectives of this testing, baseline (conformity) checks were made of the Elevator flight control system to identify the travel of the Control Columns, Control Tabs, Elevators, Geared Tabs, and the EPI. Checks were also performed to identify any excessive friction within the Elevators, Control Tabs, or cable systems. In addition cable tension and stretch checks were performed on the Elevator flight control cables. The FDR was utilized during this phase of testing, such that its data could be compared to the physical measurements recorded.

Note: During normal operation of the DC-8 Elevator flight control system, the Control Columns, Control Tabs, Elevators, and Geared Tabs operate symmetrically between the left and right side. Therefore, unless stated otherwise, the positions of these flight controls identified below (left and right) are based upon angular measurements of the respective R/H flight control /surface.

All angular measurements recorded during the noted testing were taken using a Kell-Strom Pro 360 (Aero Angle) digital level. This instrument indicates angular measurements over a range of 360 degrees (i.e. 90 degrees x 4), with an accuracy of $\pm$ 0.2 degrees (maximum error), and weighs 289 grams (10.2 ounces).

11.1 Conformity Checks

The horizontal stabilizer (trim) setting was verified to be its neutral position, based upon the painted index markings on the aft fuselage and leading edge of the stabilizer, the Stabilizer Trim setting in the cockpit, and measurements between the inboard leading edge of the left Elevator and an index rivet on the tail used for rigging.

With the Elevator Gust Lock Engaged the right Control Column was measured to be 14.4° forward[6] of its vertical reference plane (i.e. perpendicular to the First Officer's outboard seat rail) and the EPI indicated that the Elevators were at neutral (0°).

The right Control Column was pulled aft (slightly) to 13.5° forward[7] of vertical and held. At this Column position, the right Control Tab faired with the right Elevator. However, the left Control Tab remained slightly above its faired position. When measured in relationship to the right side, the left Control Tab was found to be approximately 2.0° TEU, i.e. slightly mismatched. However, no mismatch was noted between the left and right Elevators or Geared Tabs during this step. Note that these surfaces remained faired with the horizontal stabilizer since the Elevator Gust Lock was engaged.

Upon release of the right Control Column, the Column returned to its original position of 14.4° forward of vertical (held by the centering device springs) and the Control Tabs deflected approximately 0.5" (2.0°) TEU as expected.

The Elevator Gust lock was disengaged and the Elevators allowed to position themselves to a stabilized position (TEU), due to their balance condition.[8] The Elevators deflected to 23.1° TEU, the Control Tabs deflected to 8.6° TEU, the geared tabs deflected to 21.7° TED. Note: These Control and Geared Tab positions, and all future Tab positions noted below, are in relationship to the position of the Elevators.

The Elevators were subsequently (manually) deflected in the TED direction until they reached their aircraft nose down (A.N.D.) stop,[9] while the right Control Column was simultaneously positioned to its forward (A.N.D.) stop. Note: The Elevators were held at 8.4° TED for approximately 10 seconds during this transition, to provide an FDR reference point.

Once the Elevators and Column were positioned to their respective stops, the position of the Column, Elevator, and EPI were recorded for comparison to their normal range of travel. The position of the Elevators was measured to be 16.3° TED, and the Control Column 21.2° forward[10] of vertical. Although the Elevators were at their A.N.D. stop, the EPI (needle)

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[6] Control Column position held by the load feel and centering device springs (N8076U), with no external forces applied to the Elevator flight control system. [This position is normally rigged to be at 15°].

[7] Neutral position of the Control Column, used during rigging, that normally corresponds to the faired positions of the Control Tabs when the Elevators are in their neutral position.

[8] The reported winds per KDAY (Dayton International Airport) ground control were 190° @ 7 knots. The magnetic heading of N8076U was 087°.

[9] Prevents further travel of the associated control or control surface.

[10] Max travel of the Control Column should be 23.75° forward of vertical.

indicated a position approximately 75% between its neutral position and down mark.[11]

The right Control Tab was deflected approximately 6.0° TEU, and the right Geared Tab approximately 2.8° TEU. However, the Control Tab had not completely traveled to its stop, due to the rigging (limited travel) of the Control Column noted above. When the Control Tab was fully deflected TEU by hand, a new reading of 7.3° TEU was recorded.

Note: When the Elevator flight control system, including the Control Columns, are rigged properly, the Control Tabs should travel 8.5° TEU and the Geared Tabs 4.75° TEU, when the Elevators are deflected 16.5° TED. The tolerance on these control surface positions is $\pm$ 0.5°.

Similar travel checks were performed with the Elevators (manually) deflected TEU until they reached their aircraft nose up (A.N.U.) stop, while the Control Column was positioned to its aft (A.N.U.) stop. The position of the Elevators was measured to be 27.3° TEU, and the Control Column 9.6° aft[12] of vertical. The EPI indicated a position approximately 95% between its neutral position and up mark.[13]

The right Control Tab was deflected approximately 26.4° TED, and the right Geared Tab approximately 29.1° TED. The travel of the Control Tab was found to be within limits, i.e. 26.5 $\pm$ 0.5°. However, the travel of the Geared Tab was found to be slightly beyond its limits of 26.75 $\pm$ 1.0°.

Note: The Geared Tab measurements recorded above slightly exceeded the travel limits expected. However, these measurements were taken at convenient locations based upon available access, and were not measured using the locations or methods specified in the MM while rigging the Elevator flight control system. These measurements were however, considered accurate enough for the purpose of this testing.

The Elevators and Tabs were checked for excessive friction, binding, or interference throughout their range of travel, none was noted. The Elevators were cycled at approximately 10 degrees per second, to determine the effects of the Elevator dampers. No appreciable restriction on the rate of Elevator travel was noted during this testing.

The Control Column was cycled forward of its neutral position and released, to check for excessive friction in the Control Column, cable, and Control Tab linkage system. During this test, and a similar test in the opposite direction, the Control Column returned to its neutral position, within 1/32" (0.2°) each time.

Elevator flight control cable tension checks were recorded using a Pacific Scientific tensiometer. The tension of the L/H cables was measured to be 68 lb_f, the R/H cables 80 lb_f. The ambient temperature was approximately 80°F during these checks.

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[11] The EPI down mark is calibrated to indicate an Elevator position of 16.5° TED.

[12] Max travel of the Control Column should be 6.5° aft of vertical.

[13] The EPI up mark is calibrated to indicate an Elevator position of 27° TEU.

Elevator flight control cable travel checks, measured in the tail forward of the bell crank assembly, revealed that the cables traveled approximately 8.0" when the Control Column was moved between its forward and aft stops.

Elevator flight control cable stretch checks revealed that the cables could be stretched equivalent to approximately 2.0° of Control Column travel, with moderate force applied to the Column(s). Note: The Elevator Gust Lock was engaged during this testing.

EPI checks performed on two other Emery DC-8 aircraft located at the airport, revealed that full Elevator nose up and down travel could be achieved during moderate tailwind and crosswind conditions. One aircraft was positioned with a heading of 010°, the other 280°. The winds were reported to be from a heading of 200° at 17 knots, gusting to 22 knots during these checks.

A review of the data recorded by the FDR during these Conformity Checks, revealed that the Elevator and Control Column parameters incorrectly identified the position of the Elevator and Column throughout this testing. This determination was made based upon a comparison of the physical measurements taken to those values produced by the FDR, using the conversions provided by Emery. Refer to Addendum I to the Digital Flight Data Recorder Factual Report, dated July 27, 2001, for tabular data and plots that illustrate the discrepancies noted with these two parameters. The plots included in Addendum I, have been modified to indicate the true position of the Control Column and Elevator parameters, based upon the physical measurements recorded during the Conformity Checks described above, in addition to the original values indicated by the FDR.

11.2 Disconnected Control Tab (Crank Fitting)

The Elevator Gust lock was disengaged and the Elevators allowed to position themselves to a stabilized position. The Elevators deflected to 20.0° TEU, the Control Tabs to approximately 8.5° TEU, and the Geared Tabs to 21.7° TED. The Control Column had positioned itself to 11.1° forward of vertical, due to the natural rotation of the Elevators. During these checks, the winds were reported to be from a heading of 200° at 11 knots.

The Elevators were subsequently (manually) rotated to their previously determined stop, i.e. 27.3° TEU. The Control Tabs remained deflected 8.5° TEU, and the Geared Tabs deflected to 29.0° TED. Likewise, the Control Columns moved slightly further aft to a position 8.8° forward of vertical.

Following these baseline tests, the Elevator Gust Lock was re-engaged so that the R/H Control Tab pushrod attachment bolt could be removed from the Control Tab crank (clevis) fitting. This joint was not manually dislocated. However, upon the careful removal of the bolt the Control Tab repositioned itself to a TED position, liberating the pushrod aft rod end (bearing) from the center of the clevis fitting.

The travel of the liberated Control Tab was interrupted due to interference between the outboard trailing edge of the Tab and the inboard Geared Tab linkage fairing. The Control Tab deflection at its maximum travel was measured to be 29.0° TED. The clearance

between the noted fairing and the Control Tab (when faired) was 9/32".

As the Control Tab deflected TED and the pushrod dropped away from the disconnected joint, the aft edge of the free rod end moved inboard and aligned itself with the inboard leg of the clevis fitting, as if preloaded in that direction. In this position, the free pushrod clearly obstructed the rotation of the Control Tab in the TEU direction.

Note: The Control Tab pushrod forward rod end is offset (canted) to accommodate the proper alignment of the pushrod between the Control Tab drive crank (assembly) and crank fitting. Therefore, improper installation could account for a preload on the pushrod. However, the orientation of the pushrod was inspected and found to be correct. Therefore, the reason for the preload on the pushrod (N8076U) was not identified. Similar findings were noted when the left Control Tab pushrod was disconnected from its Tab crank fitting.

The Elevator Gust lock was disengaged and the Elevators (manually) rotated to their upper stop, i.e. approximately 27.0° TEU. The Control Columns positioned themselves to 8.8° forward of vertical, and the Geared Tabs deflected to approximately 27.5° TED. The left Control Tab deflected to approximately 8.5° TEU, as expected. However, the (disconnected) right Control Tab was limited to a position of 15.9° TED, when manually raised to the point were the Tab clevis fitting contacted the free pushrod aft rod end. Further travel of the right Control Tab in the TEU direction was not possible, therefore this position corresponded to the minimum Control Tab deflection at this Elevator position.

Note: The mismatch between the left and right Control Tabs in this configuration was 24.4°. Further note that the left Control Tab was at its upper stop, i.e. full control authority in the A.N.D. direction, while the right Control Tab was deflected approximately twice as far in the opposite (A.N.U.) direction.

The Elevators were then manually positioned to various TEU deflections in order to compare the minimum right Control Tab deflection, associated with each position, to that of the left Control Tab while at its upper stop, i.e. with a forward force applied to the Control Columns. This testing simulated a restricted Elevator at each of the discrete positions noted, for comparison to the FDR during the accident flight. The recorded positions of the Control Columns define the available forward range of Control Column motion at each of the (restricted) Elevator positions identified, assuming no cable stretch. Refer to Table I (below) for the Control Column and associated Control Tab positions that correspond to the restricted Elevator positions evaluated.

Table I: Restricted Elevator vs. Control Column, Left & Right Control Tabs

Elevator	Control Column	L. Control Tab	R. (Disconnected) Control Tab
0.0°	17.0° forward	8.5° TEU	15.3° TED
4.1° TEU	15.9° forward	8.5° TEU	18.0° TED
7.0° TEU	15.7° forward	8.5° TEU	17.4° TED

10.2° TEU	15.3° forward	8.5° TEU	16.1° TED
15.7° TEU	13.8° forward	8.5° TEU	17.0° TED
20.3° TEU	13.0° forward	8.5° TEU	17.2° TED

Note: The average mismatch between the Control Tabs in Table I is approximately 25°. Although, the left Control Tab was at its upper stop, i.e. full control authority in the A.N.D. direction, the right (disconnected) Control Tab was deflected approximately twice as far in the opposite (A.N.U.) direction.

11.3 Control Tab Pushrod Interference Checks

Additional checks were performed to account for other possible interference modes, that might occur between a free pushrod and Control Tab clevis fitting, on other DC-8 aircraft. These checks assumed that a free pushrod would not necessarily displace itself inboard and align itself with the inboard leg of the clevis fitting as on N8076U. Rather, due to external forces experienced in flight, or other conditions related to its installation, the free pushrod may interfere with the travel of the Control Tab in a different manner.

The following checks were completed with the Elevator Gust Lock engaged. Therefore, the minimum Control Tab deflections associated with each interference mode were established based upon the available travel with the Elevators in their neutral position. The left Control Tab remained approximately 2.0° TEU throughout this testing, since no force was applied to the Control Columns.

The first interference position, used for reference purposes, was similar to that identified above, i.e. the aft edge of the pushrod (rod end) was aligned with the forward edge of the Control Tab clevis fitting. This testing included the positioning of the pushrod in front of each clevis fitting lug vs. just the inboard lug as initially seen on N8076U. When in either position, the minimum Control Tab deflection was measured to be 23.8° TED. Note: This interference position is considered to be the most likely to occur of all the conditions examined, due to the large frontal area of the clevis fitting.

The second interference position identified, placed the aft edge of the rod end between the lugs of the clevis fitting, in contact with the shoulder of either the inboard or outboard bushing (approximately 0.060" wide). When in either position, the minimum Control Tab deflection was measured to be 17.3° TED. Minimal force and /or pushrod movement was required to overcome the resistance of this interference position before the rod end reseated itself in the clevis fitting.

The third interference position identified, also placed the aft rod end between the lugs of the clevis fitting, however with contact between the forward edge of the clevis fitting lugs and the aft shoulders[14] of the rod end. In this position, the Control Tab could be deflected 3.2° TEU above its original position.

[14] Refers to the radii formed between either side of the rod eye and its shank, that is inserted into the pushrod (tube).

The final interference position identified, required that the pushrod be displaced outboard of the clevis fitting, with contact between the forward edge of the outboard lug and the (inboard) aft shoulder of the rod end. In this position, the Control Tab could be deflected 2.5° TEU above its original position.

Note: Inboard deflection of the pushrod was found to be restricted by the fairing structure above the Elevator, i.e. forward of the Control Tab clevis fitting, such that the pushrod would not clear the clevis fitting inboard leg.

The overall travel of the Control Tab pushrod (i.e. from stop to stop) was determined to be approximately 1.5 inches. Travel in the forward direction, i.e. from a neutral Control Tab position to its TEU (A.N.D.) stop measured approximately .375 inches.

11.4 Geared Tab Crank Arm Fracture /Interference Checks

The fractured Geared Tab (inboard) crank arm, recovered from the R/H Elevator of N8079U, was installed on N8076U for interference testing. With the Elevator Gust Lock disengaged, the Elevators were deflected TEU (full travel). Inspection of the clearance between the horizontal stabilizer and leading edge of the right Elevator revealed that the fractured (free) crank arm (now attached to the link assembly on the rear spar) could drop straight down, pass through the leading edge slot (opening) for this mechanism, and protrude beneath the lower surface of the stabilizer. In this configuration, subsequent rotation of the Elevators in the TED direction was obstructed (blocked) due to interference between the aft edge of the protruding crank arm and lower end of the leading edge opening in the Elevator. The travel of the Elevators was limited to positions greater than approximately 10.0° TEU.

A second interference position was noted where the free crank arm contacted the upper surface of the Elevator, just above and aft of its leading edge opening. This configuration precluded almost all Elevator travel in the TED direction.

Note: No evidence of damage was noted on the structure of N8079U, or the crank arms themselves, in the locations identified by the testing noted above.

A final interference position was identified where the fractured crank arm contacted its mating section that remained attached to the Elevator. However, Elevator travel restrictions were not considered in this configuration, since the fracture and adjacent surfaces of both the left and right Geared Tab (inboard) crank arms were not damaged.

Note: An examination of the fractured Geared Tab (inboard) crank arms was performed by a representative of the Safety Board's Materials Laboratory. No evidence of fatigue or stress corrosion cracking was noted during this examination. According to the metallurgist, the left and right crank arms contained no deformation and their fracture faces contained no features that would indicate the direction of their separation. However, the paint on the upper surface of the right crank arm (i.e. above the fracture) contained micro cracks, and thereby indicated that the crank arm was heavily stressed, as if the aft end of the crank arm (attached to the Elevator) was bending down relative to the forward end (attached to the rear spar link

assembly).

11.5 Elevator /EPI Checks

Static and dynamic Elevator checks were conducted on N8076U after the aircraft was returned to an airworthy condition following all previous testing. This phase of testing was performed by a flight crew (Captain, First Officer, and Flight Engineer), provided by Emery, and was witnessed by the NTSB and a representative of the FAA. The onboard FDR was utilized during this phase of testing.

During the static checks (i.e. Elevator checks performed before or during taxi) the EPI indicated that the Elevator traveled approximately 75% of the way between neutral and the down index mark on the indicator, i.e. 75% TED. During these checks, the aircraft heading was 060°, and the winds were reported to be from a heading of 230° at 34 knots, gusting to 41 knots.

Note: Previous testing indicated that this intermediate position of the EPI (N8076U) corresponded to the full travel of the Elevator in the TED direction, i.e. 16.3°.

During taxi to the active runway to perform the dynamic checks identified below, additional aircraft heading and EPI readings were recorded at various instances for future reference, related to the natural movement of the Elevators during headwind, tailwind, and crosswind conditions. The EPI (Elevator) deflections noted in Table II (below) were a direct result of the relative wind conditions present, and were not the result of forces applied to either of the Control Columns.

Table II: EPI (Elevator) deflections during Taxi

Winds	Heading	Ground Speed	EPI
230° @ 34 /G 41 knots	090°	Not Reported	50% TED
230° @ 34 /G 41 knots	150°	Not Reported	Neutral (0°)
230° @ 34 /G 41 knots	240°	25 knots (indicated by FMS)	30% TED

During the dynamic checks the Stabilizer trim setting was set to 1.7° (A.N.U.). The winds were reported to be from a heading of 250° at 23 knots, gusting to 31 knots. The objective of this testing was to command the Elevators to a position between 5 and 10° TED, as indicated by the positioning of the EPI to a point approximately mid-way between its neutral and down index markings.

The aircraft was accelerated to simulate a normal takeoff roll, with the intention of aborting the takeoff upon the successful completion of Elevator checks at 80 knots. At 60 knots, the flight crew called out "air speed alive," meaning that the aircraft had accelerated beyond the lowest airspeed indicated by the flight instrument. Moments later, the aircraft reached 80 knots, at which point the First Officer cycled his Control Column full forward

and the EPI immediately deflected to a position approximately 45% TED.[15] The throttles were retarded and the takeoff roll aborted at approximately 100 knots.

A review of the data recorded by the FDR during this testing, once corrected for the errors noted during the Conformity Checks, confirmed an Elevator deflection of approximately 10.0° TED during these dynamic ("80 knot") Elevator checks.

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[15] Corresponds to an Elevator deflection of approximately 9.8° TED, when corrected for the EPI error noted during the conformity checks, i.e. (.45 /.75) x 16.3° TED = 9.8° TED.