SA-379 File No. 1-0006

CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

ADOPTED June 27, 1966 **RELEASED.** July 1, 1966

EASTERN AIR LINES, INC
DOUGLAS DC-8, N8607
NEW ORLEANS, LOUISIANA
FEBRUARY 25, 1964

SYNOPSIS

Eastern Air Lines, Inc., Flight 304, a DC-8, N8607, crashed in Lake Pontchartrain, Louisiana, approximately 19 miles northeast of the New Orleans International Airport, at approximately 0205 c.s.t., February 25, 1964. All 51 passengers and the crew of seven were fatally injured

The flight, scheduled from Mexico City to New York City, with several intermediate stops, had just departed New Orleans at 0200. Three minutes later the captain acknowledged a request to change radio frequencies, but no further communications were received from the flight At 0205:40 the radar target associated with Flight 304 had disappeared from the scopes of both the radar controllers who were observing the flight. Moderate to severe turbulence existed in the area at the time of the accident.

The Board determines the probable cause of this accident was the degradation of aircraft stability characteristics in turbulence, because of abnormal longitudinal trim component positions

1. INVESTIGATION

1.1 History of the flight

Eastern Air Lines (EAL) Flight 304 (N8607) originated in Mexico City and had intermediate stops scheduled at New Orleans, Atlanta, and Washington prior to the destination of New York City Aircraft N8607 arrived in Mexico City at 2212[1] on February 24, 1964. The captain of the inbound crew reported that ". the only exception to normality was that the PTC (pitch trim compensator) was inoperative, with a fix scheduled for the next morning at Kennedy Airport."

The captain of Flight 304 filed an Instrument Flight Rules (IFR) flight plan for a reduced airspeed, in accordance with company procedures for dispatch under these conditions. The flight attendants, who were scheduled for a crew change, and the deplaning passengers at New Orleans indicated that this segment of the flight

1/ All times herein are central standard based on the 24-hour clock was routine except for light to moderate turbulence experienced during the last 30 minutes. One flight attendant also stated that the captain was flying the aircraft. The landing was made at New Orleans International (Moisant) Airport at 0051.

Following a normal U. S. Customs inspection of the aircraft and baggage, all passengers for the continuing flight boarded the aircraft. The aircraft computed takeoff gross weight of 213,871 pounds was less than the 215,000 maximum allowable for the airport, and the center of gravity (c.g.) of 25.2 percent was within the allowable limits of 16 5 to 32 percent.

At 0159 46 the local controller in the tower observed Flight 304 commence the takeoff (See Attachment A). The lift-off appeared normal, and at approximately 0201 he advised the flight to contact Departure Control, which was acknowledged. He estimated that the flight was two or three miles north of the airport when the lights disappeared into the overcast Voice communication and radar contact were established immediately between the flight and the departure controller who advised them to ". . turn right heading 030, be a vector north of J-37 (the planned route of flight) " While the flight continued on this vector, the departure controller contacted the New Orleans Air Route Traffic Control Center (ARTCC) The radar target was identified five miles north of the New Orleans VORTAC, and a radar handoff was effected at 0202 38. Flight 304 was instructed to " . . contact New Orleans Center radar, frequency 123.6 now." At 0203 15 the crew replied, "OK". This was the last transmission from the flight. At 0205 40, when no transmissions had been received from the flight, the center controller contacted the departure controller to verify that proper instructions had been given. During this conversation both controllers confirmed that the radar target associated with the flight had disappeared from both scopes, and emergency procedures were initiated shortly thereafter. The last position noted by the controllers was approximately eight miles from the New Orleans VORTAC on the 030-degree radial. The aircraft crashed at 14.5 miles on the 034-degree radial, in Lake Pontchartrain

Statements were obtained from 29 witnesses, 14 of whom were located on the north shore of the lake, closest to the crash site Eleven of these reported hearing an explosive rumble, and three described a tornado - like sound or terrible scream. Three also stated they saw a fire-like glow in the vicinity of the lake.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	7	51	0
Non-Fatal	0	0	0
None	0	0	0

1 3 Damage to aircraft

The aircraft was destroyed at impact.

1 4 Other damage

None

1.5 Crew information

Captain William B Zeng, age 47, held airline transport pilot certificate No. 22015-40 with ratings for DC-3, DC-4, DC-6/7, DC-8, Martin 202/404, Lockheed Constellation, and Lockheed L-188, and commercial privileges for airplane single engine land. He had a total pilot time of 19,160 hours, including 916 hours in the DC-8. He had been rated in the DC-8 on January 8, 1962, and passed his last proficiency check on January 24, 1964. His FAA first-class medical certificate was dated August 27, 1963

First Officer Grant R. Newby, age 39, held airline transport pilot certificate No. 380237 with ratings in the Martin 202/404 and commercial privileges for airplane single engine land. He had total pilot time of 10,734 hours, including 2,404 hours in the DC-8. His last proficiency check was accomplished on December 4, 1963, and his FAA first-class medical certificate was dated January 28, 1964. He was the first officer and flying another DC-8, N8603, which was upset near Houston, Texas on November 9, 1963. On that occasion control of the aircraft was lost at approximately 19,000 feet but recovery was accomplished by approximately 5,000 feet. He was restored to flying status on November 21, 1963, and flew 214 hours on 20 separate trips since then.

Pilot/Engineer Harry Idol, age 39, held airline transport pilot certificate No. 385961 with ratings in the Martin 202/404, and commercial privileges for airplane single engine land and multi-engine sea. He was a certificated flight instructor and also held flight engineer certificate No. 1546386. He had accumulated a total pilot time of 8,300 hours, including 1,069 in the DC-8 as pilot/engineer. His FAA first-class medical certificate was dated September 23, 1963.

Flight Attendant Grover W. Flowers, age 36, was employed on October 9, 1950, and received his last recurrent training on December 22, 1963.

Flight Attendant Barbara D Norman, age 21, was employed on November 30, 1962, and received her last recurrent training on January 2, 1964.

Flight Attendant Tove E. Jensen, age 24, was employed on April 5, 1963, and received her last recurrent training on May 23, 1963.

Flight Attendant Mary Ann Thomas, age 21, was employed on July 26, 1963, and received her last recurrent training on August 3, 1963.

The flight crew arrived in Mexico City at 2205 on February 23, after accumulating 5 42 hours flight time and 8:35 hours duty time Following a layover of 24 55 hours they originated Flight 304. The four flight attendants boarded the aircraft at New Orleans.

1.6 Aircraft information

The aircraft was a Douglas DC-8-21, S/N 45428, which was delivered to EAL on May 22, 1960 with a total aircraft time of 12.30 hours. At the time of the accident the aircraft had been flown 11,340 hours, and had four Pratt & Whitney JT4A-9 engines installed as follows:

Position	Serial No.	TSO	TT
1	610631	2,590 hours	6,766 hours
2	611786	4,151 hours	7,876 hours
3	610636	3,927 hours	6,857 hours
4	611573	734 hours	6,320 hours

The aircraft can be controlled longitudinally by use of the elevators or variable incidence horizontal stabilizer. The elevators are operated by movement of either control column through two independent cable systems to elevator control tabs. The elevators are connected together by a torque tube at the rear spar of the horizontal stabilizer. The friction tolerance in this system is ± 5 to 6 pounds. Tabs on the trailing edge provide aerodynamic boost to control inputs. Most of the pilot's stick force2/ is provided by a load feel mechanism with two opposing preloaded springs which establish a neutral point of the elevator control system. Resistance of these springs to motion of the control column is greatest near the neutral point (See Figure 1, Attachment C).

The nosedown pitching moment encountered in high speed flight is offset in the DC-8 by the Pitch Trim Compensator (PTC) system which applies noseup control through the elevator system. Operation of the PTC is also required in the low altitude, high speed regime below mach effect to improve stick force characteristics as speed increases. This system consists of an electrical computer, an electrical actuator, spring loaded linkages, and a mechanical indicator. The computer senses mach effect at high altitude and dynamic pressure below 20,000 feet, and provides the electrical signals to the actuator which actually moves the copilot's control column. The actuation begins at either Mach 70 or 310 knots and increases in displacement and rate up to Mach 88 or 410 knots. The maximum input is 36 pounds of stick force Actuation of the PTC is indicated by the extension of a plunger from a flexible cable housing attached to the left side of the copilot's control column. There is no measurable correlation between the amount of indicator showing and the degree of actuator extension. A three-position switch located on the left side of the control pedestal permits normal operation, testing of the system in the spring-loaded test position, and an override position which may be used to retract the actuator in the event of a malfunction.

Longitudinal trimming of the aircraft is accomplished by hydraulic or electric actuation of the horizontal stabilizer The hydraulic motor trims at a rate of 1/2 degree/second through a range of 10 degrees aircraft noseup (ANU) to two degrees aircraft nosedown (AND), and is actuated by manipulation of dual toggle switches on either control column, or by split "suitcase" handles mounted side by side on the center console. The electric motor trims at a rate of 1/17 degree/second, and is actuated by dual toggle switches3/ on the center console, or by the autopilot Both motors provide power through differential gearing to a drive shaft

2/ Stick force is the most often used of several terms, including "column force" and "wheel force," to describe the pull and push forces required of the pilot to operate the elevator control whether it be a stick, column and wheel, or shaft and wheel.

3/ Simultaneous operation of any set of dual switches or handles is required to actuate the system.

on which a dual sprocket assembly is mounted. The sprockets are connected to the common drive shaft by shear rivets, and each transmits rotation of the drive unit through roller chains to an irreversible jackscrew. Failure of either set of shear rivets freezes the stabilizer in the last selected position, and further operation is impossible. The indication of stabilizer position is provided by fore and aft movement of a small "bug" along a scale on the left side of the center console.

Longitudinal control of the aircraft may also be accomplished through the autopilot which utilizes elevator displacement to initially retain the selected attitude. An automatic trim coupler senses elevator servo torque information and generates stabilizer trim commands when torque of a given value or time interval is encountered. Any "runaway" or contradiction in the system results in the interruption of power to the autopilot and the illumination of a warning light.

Attitude information in N8607 was provided by a Collins 105 Approach Horizon through movement of the "miniature airplane" in reference to the all-black face of the instrument. It has no indices for the degree of pitch, and the displayed rate of pitch change varies as follows

Attitude Range	Display Ratio
0-20 degrees	0.033 inch/degree change
20-70 degrees	0.012 inch/degree change
70-85 degrees	0.006 inch/degree change

Thus it is possible for the instrument to indicate a reduced rate of pitch when attitude changes through 20 degrees of pitch, even though the actual rate of change is constant. In a corresponding manner if the attitude has exceeded 20 degrees, the displayed rate of aircraft response to control inputs will be slower than the actual response.

There were five discrepancies on the continuous maintenance log (1) Fuel totalizer reading wrong, (2) Outer pane center windshield heat inoperative, (3) No. 3 engine ejector light blinks, (4) No 3 main fuel gauge reads 2-4,000 pounds high, and (5) PTC inoperative.

1.7 Meteorological information

The U. S. Weather Bureau (USWB) aviation area forecast, valid 0100-1300, indicated a surface wave off the Louisiana coast was expected to move eastward at 30-35 knots, with ceilings at 400-800 feet and moderate to occasionally heavy rain. A north-south line of showers and embedded thunderstorms north of the wave crest was expected to produce moderate to severe turbulence in the thunderstorms and heavier showers, and moderate or greater clear air turbulence was forecast from 24,000 to 40,000 feet, throughout the area. The EAL system forecast, valid 0000-1200, predicted ceilings below 1,000 feet, light rain in the Pensacola-New Orleans area, improving to 1,200-2,500 feet as the low center moved eastward. Turbulence[4]

4/ EAL utilizes a numerical scale to delineate the severity of turbulence within a given classification, i.e , 4-6 is moderate, 7-9 is severe, and 10 is extreme.

was forecast at scale 6 in occasional thunderstorms, and light to moderate wind shear turbulence above 14,000 feet.

The 0146 New Orleans Radar weather observation showed an area of scattered echoes containing light rain showers, with the closest showers at 260 degrees, 60 miles. The top of detectable moisture was 18,000 feet. The 0210 Moisant special surface weather observation was Ceiling measured 1,000 feet overcast, visibility 7 miles, wind direction 020 degrees at 12 knots. Unofficial surface wind observations recorded on Lake Pontchartrain at the north and south draw bridges indicated gusty winds from the north and northeast at 24 and 26 knots respectively at the approximate time of the accident. There was no observation of winds aloft at New Orleans because of the overcast condition, however, the official USWB 0516 winds aloft observation at Burrwood, Louisiana, 70 miles southeast of New Orleans indicated

Altitude	Direction	Velocity
3,000 feet	290 degrees	41 knots
4,000 feet	290 degrees	48 knots
5,000 feet	290 degrees	55 knots
6,000 feet	280 degrees	44 knots
7,000 feet	270 degrees	34 knots
8,000 feet	270 degrees	43 knots
9,000 feet	270 degrees	57 knots

The freezing level at Burrwood was reported to be 12,400 feet.

Two flights departed New Orleans at approximately the same time as Flight 304. The first, a C-46 took off at 0146 and proceeded on a similar departure pattern toward the northeast. This crew reported moderate to severe turbulence from lift-off to 9,000 feet. The airspeed fluctuated 15-20 knots, and heading varied approximately 10 degrees, however, no loss of control was experienced. The second aircraft, a large jet, departed at 0202 and was vectored to the northwest. The captain of this flight observed Flight 304 make a "normal" takeoff and disappear into the overcast at approximately 1,200 feet. He also said that, "We entered the overcast at approximately 1,200 feet and . . . noticed light to moderate turbulence almost immediately This condition persisted until we broke out on top at approximately 5,000 feet. At the time we entered the overcast I recall our speed to be approximately 200 knots indicated We reduced power shortly thereafter and maintained this approximate speed until breaking out on top." The existing turbulence was also confirmed by the readout of the flight recorder tape from this flight.

1.8 Aid to navigation

A Notice to Airmen advised that the VOR portion of the New Orleans VORTAC was inoperative from 2259 to 0458 However, maintenance workers reported that the malfunction was in the monitoring system, and the facility was actually operating normally throughout the period

1.9 Communications

There were no discrepancies in air-ground communications, except the failure of Flight 304 to contact the center. No emergency or distress was exhibited in any transmissions. It was determined from recordings of transmissions that the first officer made all ground transmissions, and the captain made all those after takeoff.

1.10 Aerodrome and ground facilities

Not applicable.

1.11 Flight recorder

The aircraft was equipped with a Fairchild Model 5424 flight data recorder. The recorder magazine, with the record spool, and approximately 50 feet of loose unused tape were recovered. The last readable portion of the tape was 150 minutes of flight, encoded as Flight 304 of the 24th, ending at a point which appears to be the landing approach to New Orleans. The takeoff portion of the tape was not recovered

1.12 Wreckage

Initial attempts to locate the wreckage of Flight 304 were conducted by helicopter. The discovery of an oil slick and floating debris on the lake prompted a systematic dragging operation commencing simultaneously in this area and also at the point of last radar contact. This search rapidly assumed enormous proportions as additional electronic and sonic underwater detection gear became available. Discovery of the wreckage was finally confirmed late in the afternoon, March 13. Salvage operation commenced immediately and continued on a 24-hour basis until April 16, at which time approximately 60 percent of the wreckage, by weight, had been recovered. The operation involved raising the pieces from deep in the mud and silt bottom of the lake, and placing them on a barge. The parts were examined and the condition noted by Board investigators. After being washed, all parts were then transferred to shuttle barges, and taken to a hangar at the New Orleans Lakefront Airport where a layout was made for further study.

Portions of all extremeties of the aircraft were recovered from the main impact area. The general pattern of breakup showed extreme fragmentation of all structure with the largest piece being the upper five feet of rudder. The flaps and landing gear were determined to be in the up position. Detailed examination of all structure recovered revealed no evidence of in-flight fire, explosion, or structural failure.

The Nos. 1 and 2 powerplants were recovered approximately 45 feet from the Nos. 3 and 4. All four received similar damage, and evidenced severe disintegration at impact. The diffuser and combustion cases of all four engines accordioned between the 3 and 9 o'clock positions, and the ejector assemblies were extended. No evidence of pre-impact operating distress was found. The recovered reverser assemblies indicated use of reverse thrust at impact.5/ The fuel system was capable of functioning normally.

Although none of the aircraft systems was recovered completely, there was no indication of fire or heat damage on the components available. The left and right stabilizer jackscrews were within one turn of the full AND trim setting. This

5/ Reverse thrust is used in flight as a speed brake.

setting is equivalent to the stabilizer being in the full AND position.

Examination of the drive gear assembly of the stabilizer drive unit revealed normal wear patterns on the planetary gears and the male spline extension which transmits power down to the dual sprocket assembly In addition, another wear pattern was found 1/4 inch below the normal engagement point of the extension. This abnormal wear pattern continued to the end of the splined shaft. The flanks of the splines in this area were highly polished around the entire periphery of the shaft, indicating the wear occurred over an extended period of time, and could not have occurred during breakup. There was also considerable spalling of the case hardened surface at the end of the splined shaft. The mating female splines, in the top of the dual sprocket assembly portion of the stabilizer drive unit, exhibited a similar severe wear pattern. The wear had produced convex surfaces lengthwise on both flanks and left a lune-shaped area on the crest of each tooth. This damage from misalignment of the mating splines resulted from oscillation of the sprocket assembly since the planetary gears at the top of the shaft had no abnormal wear. The case hardened male splines at the bottom of the shaft did not develop the lune-shaped wear. A bearing seat at the top of the dual sprocket assembly also exhibited the abnormal wear from a 1/4 inch displacement, and oscillation of the assembly. The lower support bushing P/N2652666 for the sprocket shaft, which supports the sprocket assembly in the vertical plane for proper spline engagement and also restrains it in the lateral direction, was not recovered. Other sprocket assemblies used for comparison showed bright polishing on the lower shaft where it fits into the lower bearing support bushing and showed polishing on the bottom sprocket hub where it rests on and is supported by this same bushing The sprocket and shaft assembly from N8607 showed none of this. The lower support bushing has a flange on its outer circumference and when installed properly (flange up) it overlaps the lower bearing and thus provides the vertical and lateral support for the sprocket shaft assembly. The three rivets attaching the lower sprocket to the assembly sheared circumferentially from loads applied in the ANU direction, but the needle bearings from this sprocket scored the shaft axially as the sprocket and shaft separated.

No portion of the PTC actuator was recovered.

1.13 Fire

There was no evidence of in-flight fire.

1.14 Survival aspects

The extreme disintegration of the aircraft structure precluded any crash/injury study The crash was non-survivable.

1.15 Maintenance records

The flight maintenance logs for N8607 were reviewed back through May 22, 1960, the date of delivery to EAL. They revealed that on August 20, 1963, the aircraft was subjected to abnormal flight conditions during flight in severe turbulence. A Severe Turbulence Mechanical Check of the aircraft at that time revealed only minor damage. On September 11, 1963, the stabilizer jammed in the full ANU position during a landing at San Juan, Puerto Rico. An inspection at that time revealed that power from the drive unit was not transmitted through the sprockets to the jackscrews. The dual sprocket assembly was replaced, but the rivets sheared again during the ground test operation. It was noted that the shearing occurred without contacting the stop in either direction, so both the jackscrews and sprocket assembly were replaced this time. One of the removed jackscrews had a rusted thread and the lubrication on the bearing was poor. The mechanic who performed this work, an authorized inspector, reported that ". . . it is the custom in EAL Maintenance to change the complete assembly and not (disassemble) the sprocket housing. Line Maintenance procedures require the replacement of units, not parts, to keep from overhauling units on the line." There was no further maintenance work recorded on the stabilizer drive unit of N8607 until the accident.

The review of the aircraft records disclosed a recent history of PTC difficulties. The PTC computer on this aircraft had been changed eight times, four had been used during the last week of operation. On February 18, although the PTC was reported as operative, the indicator failed to show extension. There was no maintenance performed on the indicator mechanism following this writeup. Computer S/N 268D, installed at the time of the accident, had been removed from various aircraft 15 times, beginning in April, 1960. Six of these removals were for unwanted extensions. No discrepancies were ever found during the shop inspection of this component. Following the accident it was discovered that functional tests by EAL and other operators could not detect certain computer malfunctions. This was demonstrated when a serviceable unit in EAL stock failed to pass the manufacturer's complete test procedures. Two other instances were discovered at other operators The PTC computer of N8607 was changed the last time on February 24, in Miami The aircraft was flown to Philadelphia and no flight crew complaints on the PTC were entered in the log. The flight engineer on the outbound flight to Mexico City, noted that the PTC failed to check on the ground. Maintenance personnel performed a ground check of the system and confirmed the engineer's findings. The check performed was activation of the test circuit and watching for movement of the indicator or control yoke. No inspection of the actuator position or operating capability of the indicator system was made. The aircraft was dispatched with a request that the crew check the PTC operation during the flight. This check was performed at cruising speed and altitude between Washington and Atlanta. It was determined that the PTC was inoperative.

The flight maintenance logs also revealed eleven autopilot malfunctions in the last 30 days of operation. Two discrepancies involved yaw, six referred to longitudinal control problems, and three reported automatic disconnects.

The review disclosed that both artificial horizons failed simultaneously on February 18, 1964. This was corrected by replacement of the instrument switching unit, which is a common point in the wiring of both instruments.

1.16 Tests and research

The Douglas Aircraft Company (DACO) performed a functional test of a stabilizer drive unit to determine what effect the omission of the drive sprocket support bushing P/N 2652666 would have on the operation of the unit. All parts were production items except the test sprocket drive gear assembly which did not have production shear rivets installed. Their report dated May 29, 1964, indicated that while full stabilizer trim capability existed, a comparable wear pattern was reproduced on the test assembly. On June 1, 1964, the FAA issued a telegraphic alert recommending, "(1) Operators perform a one-time inspection of stabilizer adjusting mechanism to determine proper installation of bushing P/N 2652666 and shim P/N 2648310, (2) Operators maintenance procedures be reviewed regarding adequate assembly and installation instructions of stabilizer drive mechanism. . . ." The DACO DC-8 Overhaul Manual instructions pertaining to the drive sprocket support bushing of the sprocket assembly were revised on August 1, 1964, to incorporate the additional information, "Make certain bushing (104) is installed with flange up."

During initial certification of the DC-8 satisfactory stability characteristics were demonstrated in high speed cruise (350 knots) configurations and also at the best rate of climb speed (220 knots). However, it was found in flight testing subsequent to the accident that with the aircraft trimmed at 300 knots in an aft c.g. climb configuration with maximum continuous thrust (MCT), and the PTC inoperative, the slope of the stick force curve remained essentially zero as the aircraft accelerated to 390 knots. This stick force relationship to airspeed conflicted with then existing regulations which specified that speed changes be perceptible to the pilot through a change in the stick force. The criterion generally used at that time was at least one pound of force/seven knots of airspeed change.

Further flight tests were conducted to evaluate the controllability of the aircraft with unprogrammed PTC extensions or retractions. The final determination was that adequate elevator control was available to overpower the PTC input even though the time delays for pilot response were actually longer than those used during autopilot "hardover" testing.

One of these later tests involved an aircraft loaded to an equivalent c.g. of 24 percent. The FAA test pilot stated that an interesting discovery was made, " . . . during maneuvering with a fully extended PTC at a velocity of approximatel 220 knots and the airplane trimmed to its previous extreme of full AND (2.0 degree It was observed that any attempt at maneuvering the airplane with the elevator system resulted in sharp reversals in the airplane's maneuvering stability. This was true in applying either noseup or nosedown control. A pilot with this condition existing during turbulent atmosphere would be presented with a very difficul control problem. When the nosedown trim was adjusted to the new limit of 0.5 degrees AND the airplane demonstrated less tendency toward maneuvering instability."

Another test pilot reported that flight testing of the DC-8 handling characteristics under abnormal conditions, i e., PTC extended to offset a 0.5 AND stabilizer setting, in a cruise configuration at 220 knots, revealed that, " . . . the aircraft exhibited no stick force stability. This lack of stick force is caused by a shifting of the stick neutral position to a very flat portion of the load feel spring when PTC is extended. The low gradient of the load feel spring in this area is masked by the control system friction which necessitates flying the aircraft by stick position only The aircraft is neutrally stable at small airspeed increments about the trim point in any normal attitude, including 45 degrees turning flight, and would maintain a 45-degree coordinated turn hands off until the speed was changed. With a change of ± 10 knots, the aircraft exhibited classic instability and would continue to increase or decrease, whichever the case may be, until restrained."

The investigation also focused on the aerodynamic stability of large swept-wing jet aircraft, with particular emphasi on the longitudinal natural frequenc

Data developed by an independent research agency, under government contract, revealed that the rate of response to elevator deflection has a profound effect on the behavior of the aircraft from the pilot viewpoint This mode of motion, the longitudinal short period mode, has a one to five second period and is involved in the maneuvering of the aircraft. As the short-period frequency decreases a slower response is experienced and the initial motion is not a good indicator of what the final response will be. They reported that this leads the pilot to over-correct, and consequently produce a pilot-induced oscillation (PIO). Flight testing demonstrated that with the frequency adjusted between 0.2 and 0.3 cycles per second (cps), with a damping ratio of 0.4 to 0.7, which is quite heavy, the aircraft could be flown with no difficulty as long as the pilot flew gently, accepting the slow response. If he attempted to force a more rapid response, as might be done in a gust disturbance, a short-period PIO resulted. The pilots quickly found this characteristic could be overcome by smaller corrections. However, it was disturbing to fly because one was never certain when a quick response might be needed. The optimum longitudinal short period frequency from a pilot standpoint was found to be 0.6 to 0.7 cps. The DC-8 has a longitudinal short period frequency of approximately 0.28 cps in cruise, with a damping ratio of 0.6. The first fuselage bending frequency is 3.78 cps.

During the investigation the Board discovered several incidents of misrigging in the longitudinal control system of other DC-8 aircraft, including some from other airlines. One incident involved an aircraft leased by EAL from January 15, 1964 through March 4, 1964. Pilot writeups on this aircraft resulted in the installation of a PTC actuator on February 13, and a new indicator on the following trip the same day. There was no further action by EAL in this area, and following 225 hours of accumulated flight time from this date, the aircraft was returned to the owner. The aircraft was then operated by the owner, from March 5 until March 31, when the pilot suggested that the elevator load-feel mechanism be checked for proper adjustment. He wrote that "It does not center control wheel with gust lock on and feel is not in proportion to other aircraft." Following a check of the load-feel mechanism and a visual inspection of the PTC the aircraft was cleared to continue. On April 1, the crew of a training flight reported that "At times it is necessary to crank trim to full nosedown and still necessary to hold forward control." A thorough examination of the various components of the system at this time revealed that.

1. The actuator arm of the PTC was extended 1/2 inch too far (this displaces the control column neutral, introducing a noseup input at all times). This was installed with zero time since modification by the manufacturer.

2. The pitch trim compensation spring (providing noseup control input when the PTC operates) was reset from 56 to 36 pounds. This adjustment bolt still retained the original DACO factory seal.

3. The right elevator control tab was found 3/8 inch out of rig in the nosedown direction. This item had last been adjusted by the owner on November 11, 1963.

4. The PTC indicator was found to have excessive play in the mechanical linkage which resulted in erroneous or no indication The indicator neutral position had also been displaced to indicate PTC retraction with 1/2 inch of actuator input into the system.

The aircraft had been flown 238 hours by the owner, including three training flights, following its return by EAL.

1.17 Modifications

Following this accident, and as a result of further testing of the DC-8, the FAA approved several aircraft modifications, and new maintenance and operating procedures. The AND travel limit of the horizontal stabilizer was reduced from two degrees to one-half degree to minimize the effects of mistrimming. The elevator load-feel and centering spring assembly was modified to properly adjust tolerances, and eliminate the possibility of a heavy compression spring in the assembly producing a preset in the assembly. The PTC actuator bellcrank arm was replaced to modify the aft force on the control column to provide an increase in longitudinal stability under all flight conditions, and an amber warning light was installed to warn of 80 percent of full extension. The operating procedures for the aircraft were also changed to restrict the climb speed to 250 knots maximum when the PTC was inoperative and the aircraft c g. exceeded 30 percent. Because trimming against an unwanted PTC extension will result in (1) decreasing the elevator available for landing, and (2) decreasing the stability of the airplane the procedure for overcoming this condition was changed to. ". . . the elevator should not be trimmed to zero, but the stabilizer should be positioned to maintain a slight push force (approximately 10 pounds). . ."

EAL has also modified their Collins 105 Approach Horizon to provide a more realistic presentation of attitude to the pilot.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

In this case there is a meager amount of information regarding the events immediately prior to the accident plus an immense collection of data and testimony of a general, or background nature. The Board has been faced with two basic questions, (1) Is there sufficient evidence as to conditions and circumstances of the flight on which to make causal determinations? (2) Are the background data too general to be applicable to this case or are they in reality symptoms of underlying factors which led to the accident?

Three factors contribute to the lack of specific information about the flight. First, air traffic was extremely light, negating the usual departure requirements of limiting altitudes, specified navigational fixes and constant radar surveillance. This reduced the radio conversations to the minimum; hence, no references were made by the crew to altitude, speed, or position at any given time following takeoff. Similarly, neither controller, ARTCC or Departure, had definitive information for the last one-third of the flight. and, of course, no altitude references at all. Second, the failure to recover certain meaningful components from Lake Pontchartrain has made it difficult to draw many positive conclusions. Third, the failure to recover the pertinent portion of the flight recorder tape eliminated perhaps the best means of accurately defining the final phases of Flight 304.

To properly assess the evidence at hand, the Board found it necessary to construct by analytical methods a facsimile of the type of plot normally gained from the flight recorder. This was done by utilizing a DC-8 flight simulator programmed to duplicate the weight and c.g of N8607 and the takeoff conditions of Moisant Airport at the time of takeoff. The simulated accelerations and climb data were corroborated by observations of actual DC-8 takeoffs. Integration of the data produced the plot shown in Attachment B. Unknown variations in the winds aloft and in pilot techniques are among several factors which prevent accurate depiction of the flight. It must, therefore, be recognized that the plot in Attachment B cannot be exact, but it does give an envelope within which this flight operated.

It should be noted that the maximum altitude which would have been attained at a point which still allows time for descent to the water is about 7,000 feet for a normal climb at 310 knots. It could have been lower depending on possible power and speed reductions because of turbulence and on the time of onset of difficulties, their nature, and the crew reaction thereto. Within certain limitations there is also latitude for variation in airspeed. An acceleration to, and climb at 310 knots, in the integrations for Attachment B, presented the most plausible appearing flight profile, however, the unaccountability of a period of 40 seconds, explained subsequently, allows for possible airspeed reduction. Such reduction could have been drastic, say to 220 knots, for a short period of time or to values in the order of 280 knots for a relatively prolonged period. Assuming impact to be as late as 0205 40, absolutely the latest time, and later than the Board believes the accident occurred, it can be shown that the average climb speed could not have been less than about 250 knots.

With the facsimile flight profile as a guide, and from the collected data concerning the weather, the flight, the aircraft, and crew, preliminary observations and conclusions can be made in preparation for the more important task of isolating causal areas for the disaster.

Analyses of weather conditions in the accident area indicate that Flight 304 entered a broken to overcast layer of fractostratus clouds at approximately 1,000 feet, and that the tops of the clouds were between 5,000 feet and 6,000 feet. These clouds were associated with a sharp, inverted trough lying across the accident area, oriented northwest-southeast at approximately 5,000 feet. This trough originated from a closed low at that altitude, lying about 55 miles southeast of the accident scene. A regular low pressure trough was oriented north-south at 10,000 feet somewhat west of the area. The freezing level at the accident site would have been at 9,000 feet.

In view of the weather situation that prevailed, pronounced vertical and horizontal wind shear existed in the accident area. Therefore, it is believed that moderate and probably severe wind shear turbulence was encountered by Flight 304 while in the clouds below 6,000 feet. An analysis of the flight recorder of the jet which departed New Orleans immediately after Flight 304, substantiates the severity of the turbulence in the area. Accelerations to +0.2 and +1.9-g between 2,000 and 6,000 feet, recorded on this tape indicate severe turbulence. Since, known or forecast turbulence along the climb path is the prime criterion for selection of the climb speed, it is probable that the crew of Flight 304, unconcerned about turbulence below 14,000 feet, chose 310 knots rather than the lower rough airspeeds depicted in their flight manual.

The records indicate that the members of the flight crew were properly certificated and qualified to operate the equipment, that they had had sufficient rest prior to originating the flight at Mexico City, and they had not exceeded the maximum allowable monthly flight time.

Company records indicate that the aircraft was within allowable gross weight and c.g. limits.

The takeoff was observed to be normal, and at 0202 38, when the flight was five miles north of the VORTAC, a radar handoff from Departure Control to the Center was effected. The recordings of transmissions from Flight 304 failed to reflect any apprehension on the part of the captain. At 0203 15 he acknowledged instructions to contact the Center, however, he never complied with this instruction. It is therefore believed that at approximately this time or very shortly thereafter an emergency occurred. The facsimile profile indicates that at this time the flight should have accelerated to or near en route climb speed, traveled approximately 12 miles, and reached an altitude of about 4,000 feet. The center controller stated that he last observed the radar target at eight miles on the 030-degree radial of the VORTAC. Since the aircraft was found 6.5 miles northeast of this position, it is obvious that there was a time lapse between this observation and his inquiry about the flight at 0205 40. At this time both controllers had lost radar contact. Allowing for controller recognition and time for the radar target to fade, it is probable that Flight 304 crashed at approximately 0205. While the time plot in Attachment B has been styled to an impact time of 0205, it is interesting to note that in developing this profile, any attempt to use 0205 40 as the end point, associated with normal climb speeds, resulted in an excess of 35-to 40-seconds.

The recovery of all powerplants and portions of all extremities of the aircraft from a closely confined area indicates that the aircraft was structurally intact at the time of contact with the water. Based on the Board's observations over the years that the attitude of a diving aircraft tends to flatten between the times of nose and wing contact, it can be assumed that N8607 struck the water at some dive angle in excess of the 20-degree indication in the damage pattern of the powerplants. The fact that the engines were being operated in the reverse thrust regime is in itself indicative of an attempt by the crew to recover from a diving attitude. The first officer of Flight 304, in his testimony following a previous upset into a steep dive, attributed the successful recovery to the use of reverse thrust which, in addition to providing drag forces, produces a noseup pitching moment. Furthermore, it can be concluded from the symmetry of the powerplant damage pattern and from the small wreckage area that the aircraft was essentially level, laterally, at impact.

Examination of the horizontal stabilizer lower sprocket failure reflects that the sprocket rivets sheared during rotation of the sprocket in the sense of ANU. The Board can easily attribute the axial, non-rotational scoring of the sprocket shaft by the needle bearings, to impact damage. It cannot, however, accept the rotational pattern of rivet shear or the previously mentioned abnormal, displaced wear pattern of the unit as being associated with crash forces. These latter indications along with the discovered positions of the two irreversible-action stabilizer jackscrews reflect that the stabilizer drive unit had been operating in an abnormal condition over a period of time, then failed while being operated in an ANU direction from the full, or near full, AND position.

The Douglas tests indicate that the unit in this abnormal condition would be capable of operating throughout the normal required range. However, since the test rig had no means to introduce appropriate air loads, neither the torque forces required to start and sustain rotation of the unit, nor the actual rate of drive were realistic when compared with the normal design values. It is believed that operation of the unit varied from these normal values, however, the variation would be nominal. The geometry of the drive system and the wear patterns in evidence strongly suggest a unit which would not attract attention to its abnormal condition until it failed completely.

Based on the evidence contained in the recovered horizontal stabilizer drive unit, and the tests performed by DACO, the Board concludes that the drive unit was installed by EAL maintenance personnel in September 1963, with the support bushing in the inverted position. This would allow the bushing to fall free at some point in time after installation and the drive shaft to drop down from its normal position. In this instance it dropped 1/4 inch and was operated in this position for an extended period of time. Since the wear rate would be dependent on the number of actuations, as well as the associated loads imposed, there is no way to determine the exact point in time of the commencement of this condition.

It is logical to assume that the drive unit was functioning prior to departure from New Orleans since the crew would have to position the stabilizer for takeoff. If the drive unit failed prior to takeoff, the crew would have had the difficulty corrected. The EAL DC-8 Flight Manual in use at the time of the accident indicated a stabilizer setting of one degree ANU for takeoff and since a normal trim correction toward AND is experienced as the aircraft is rotated and then "cleaned up," the drive unit was operating after the aircraft became airborne and started to climb to the assigned cruise level.

The stabilizer position of two degrees AND, whether placed there intentionally or unintentionally by the pilot, or by malfunction, is symptomatic of an abnormal flight condition. Consequently, the Board has focused on the possible reasons for the stabilizer position and the attendant conditions produced by this setting.

On at least two occasions tobacco tar, dust, and other material from the cabin have collected in the fairleads of DC-8 rear pressure bulkheads On these occasions when actuation of the stabilizer was initiated by the pilot, the cables stuck in the fairleads and the pilot was unable to stop the stabilizer at an intermediate position. Once the full nosedown or noseup position was reached he was then able to actuate the control in the opposite direction. This also resulted in the control running to the full travel position. The rear pressure bulkhead of N8607 was not available for examination so the Board must rely solely on maintenance records which show that this area was cleaned a week before the accident. If the stabilizer cable fairleads were in fact cleaned at that time, and there is no reason to suspect otherwise, it is doubtful that the full AND position was produced by fairlead contamination

Testimony by a DACO Aerodynamicist revealed that the extreme AND range of the stabilizer was provided to allow pilots, who so desire, to maintain a pull force under certain loading conditions during acceleration after takeoff. While it is doubtful that the 2-degree position would normally have been reached following the takeoff at New Orleans, the Board believes that the history of this aircraft reflects a possible condition which could have caused trim positions more AND than usual. To see how this could come about, it is first necessary to examine the history and characteristics of another DC-8 which was leased to Eastern Air Lines from January 15 to March 4, 1964.

On April 1, 1964, twenty-seven days after return of the leased DC-8 to the owner, the crew of a training flight noted control difficulties following takeoff. An inspection of the control system subsequently revealed that the PTC actuator on installation had been adjusted so that it was extended 1/2 inch when at its most retracted position. Normally this amount of extension would have caused the indicator on the first officer's column to be partially extended. In this case the sleeve from which the indicator plunger extends, had been raised to the degree that it was flush with the plunger at the minimum position of the actuator as installed. Additionally, because of a mechanical malfunction in the linkage as found, the indicator was inoperative. A check into the maintenance records showed that on February 13, while the aircraft was on lease to EAL, the PTC actuator was replaced because of a failure of the installed unit, a new actuator was obtained by EAL from the owner's stock, and installed in the aircraft by EAL maintenance personnel at Kennedy International Airport.

The EAL foreman in charge of this work testified to the Board on his activities in this regard. He stated that he had examined the old and new units, assuring that the replacement actuator measured the same as the old one with respect to "eye-bolt to eye-bolt" length and to number of threads showing on the rod end-fittin Investigation has revealed, however, that both of these conditions could not exist simultaneously since the old unit, DACO P/N17989-2, and the new one, DACO P/N17989- differed in configuration. With the same number of threads showing on a -2 as on a -3, the eye-bolt to eye-bolt distance will differ by about 1/2 inch, the -3 being the longer. So installed, the fully retracted position would be the equivalent of the programmed extension for 386 knots EAS 6/ below 20,000 feet or at 0.84 Mach number at higher altitudes.

It is extremely interesting to note the effects this misrigged PTC system had on the aircraft. Pilots commented that nosedown trim was required following takeoff to the point that the warning light was illuminated. 7/ There was no reference made to how much additional AND trim was used. Also of interest is the fact that the c.g. was at 26 percent, or approximately the same as that of N8607. The weight was considerably higher, however, weight effects on trim are minimal.

The Board discovered a parallel to the above case in the history of N8607. The PTC actuator in the aircraft at the time of the accident had been installed

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6/ "Equivalent airspeed" means the calibrated airspeed of an aircraft corrected for adiabatic compressible flow for the particular altitude.

7/ This warning light is peculiar to this company's aircraft and is illuminated at about one degree AND.

on May 6, 1963, as a replacement for a malfunctioning actuator. As with the leased DC-8, the new unit was a -3, whereas the one removed was a -2, and the change had likewise been accomplished by EAL maintenance personnel. With reference to the PTC problems encountered at Philadelphia on the day before the accident, the Board can find it nowhere indicated that anyone, either maintenance or flight personnel, ascertained that the actuator was in fact retracted. The only determination made was that the unit was inoperative and an election was made to utilize the airplane in that condition until the following day. Failure to positively ascertain the true position of the actuator was most probably brought on by its inaccessibility, removal of the first officer's seat was necessary to view the actuator. (This has since been corrected by the installation of an access panel in the nose wheel well.) The captain of the flight to Mexico City testified that the PTC was also checked in flight after departure from Washington and found to be still inoperative. While this information further verifies the static condition of the system, it offers no enlightenment on the PTC actuator position.

Further, the Board believes it sees in the possibility of a partially extended PTC, an explanation for the many autopilot difficulties which remained, for the most part, uncorrected. The pilot write-ups and maintenance records reflect that N8607 had been plagued with autopilot difficulties, many of which were longitudinal. Several write-ups had been for automatic disconnects. The autopilot trim system is limited in positioning the stabilizer in the AND sense (1.25 to about 1.5 degrees AND) and if more nosedown moment is required to keep the aircraft in trim while utilizing the autopilot, the attendant loads must then be carried by the elevator servo. The circuitry of the autopilot is such that if these holding loads by servos become excessive, the autopilot will automatically disengage. These disconnects occur along a force-time curve extending from heavy-load/short-time to light-load/long-time. The recorded history of the autopilot difficulties does not contain, for the purposes of this report, the detail necessary to arrive at specific values of any meaning, however, the recorded disconnects and other longitudinal problems, despite repeated autopilot component replacements, indicate a problem lying without the autopilot system.

In summary, the work performed by EAL maintenance personnel on the leased DC-8 and the similar change in actuator models in N8607 establish the possibility of a partially extended PTC actuator, and the autopilot difficulties in N8607 are symptomatic of this condition. Furthermore, if the indicator system failed, as occurred on the leased aircraft and on this one earlier in the day preceding the accident, it is also possible that the PTC actuator could have become inoperative at any position. Apparently the indicator was the only basis used at Philadelphia to determine that the actuator was retracted. Therefore, the Board must accept the possibility that N8607, at departure from New Orleans, as well as earlier, was being operated with a PTC actuator extension (although inoperative) ranging from 0.5 inch to 2.15 inches (normal full extension of 1.65 inches plus the 0.15 inch misrigging).

If this condition existed, it is very likely that full AND stabilizer could have been employed shortly after takeoff. Failure of the chain sprocket on the next attempt to trim noseup would result in ever increasing pull forces on the column as airspeed was accelerated toward en route climb. In its consideration of this as a causal factor, the Board has found reasons both to support and to reject the probability

The data available[8] indicate that for the 2-degree AND condition the stick forces necessary to hold the aircraft in steady-state 1-G flight range from 33 pounds (PTC retracted) and zero pounds (PTC extended) at 242 knots, to 55 pounds (PTC retracted) and 22 pounds (PTC extended) at 320 knots. Accordingly, the force characteristics should have become noticeable to the crew at speed above 220-240 knots, depending on extent of PTC extension, and they would not have accelerated much beyond this speed band. Rather, they would have elected to return to New Orleans and would have made their intentions known to departure control. The facsimile airspeed trace in Attachment B shows that this speed range would have been reached at about 0201 36 to 0201 46 and yet a simple acknowledgment of "OK" was made about a minute and a half later when, if not in difficulty the aircraft would have already reached en route climb speed. In this case, notwithstanding the unavailability of an operable PTC (the primary corrective measure for a jammed stabilizer), there were many avenues of trouble shooting available to the crew, each and all of which would be time consuming: Operation of the trim switches on both control wheels, checking, pulling and resetting circuit breakers; checking hydraulic quantity and pressure, trimming attempts with the secondary trimming devices, the "suitcase" handles, and use of the tertiary electric trim switch. The slow trim rate of 1/17 degree per second of the electric system could in itself consume as much as 15 seconds before giving the crew a positive indication of operating or not operating. There is, then, the possibility that the time interval between attainment of 220-240 knots and the radio transmission "OK" was a period of problem and troubleshooting, during which no decision had been reached as to whether the flight should continue or return to New Orleans. The difficulty could have degenerated to an emergency and, ultimately, to catastrophe after the final transmission.

However likely or remote the possibility, the Board found it difficult to conclude that this condition alone, PTC extension and AND stabilizer, could precipitate the complete loss of longitudinal control so obviously manifested by the condition of the wreckage. Exploration of the aircraft manuals, the testimony and investigative data shed some light in this regard. It was established that under any condition whereby the aircraft is placed in trim by using AND stabilizer to counteract unprogrammed PTC actuation, the overall effect is to shift the zero-force point of the control column away from its normal position in relation to the dual rate feel spring to a point where the stick force per g becomes relatively light. This is depicted in Figure 1 of Attachment C, wherein the characteristic force pattern is reflected. The values on the abscissa and ordinate will vary depending on speed, altitude, and c g. location, but the shape of the curve does reflect the pattern for any regime. Normally trimmed, the control column will be centered about Area A and any column displacement from that area will follow the curve shown so that reasonable and expected stick force per g[9] or per degree of surface deflection will be felt by the pilot. Excessive nosedown stabilizer positions, on the other hand, require up elevator to keep the aircraft in trim. The new column center position is in Area B where pilot inputs in the pull direction are at a considerably lower gradient. It must be pointed out here that the primary concern is with the gradient and not the actual force, itself. The gradient is the same whether the pilot holds the aircraft in

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8/ For 213,000 pounds, c.g. at 26 percent and MCT

9/ A measure of maneuvering stability

trim against an unwanted AND stabilizer position by applying a stick pull force, or the control forces are in balance through the medium of using AND stabilizer to counteract unprogrammed PTC, or extension of the PTC by use of the "test" position to balance out unwanted AND stabilizer settings. Of course, if it becomes necessary for the pilot to hold a pull force against AND stabilizer, the magnitude of the force necessary does become a factor insofar as physical capability and pilot fatigue are concerned.

One very interesting aspect in the leased aircraft occurrence was the discovery that one elevator control tab had been rigged in such a manner that it partially offset the effect of the PTC extension, i.e., the compensating stabilizer deflection moved the controls into or toward Area B (Attachment C), and the tab rigging tended to shift them back toward Area A, but to a lesser degree. Tabs misrigged in the opposite direction, or for that matter correctly rigged, would have worsened the control difficulties of the aircraft.

The variation of stick force per g versus speed for the 2-degree AND case, shown in Figure 2 of Attachment C, is also significant. It should be noted that while the stick force per g is light but at a reasonable level at 310 knots, it degenerates to about 13 pounds at 220 knots. This level of force gradient is extremely light[10/] and is to a large extent masked by the friction forces of the system which are about ± 5 to 6 pounds. Thus, at 220 knots a pilot could maintain a 1.5-g maneuver without feeling any resistive force, or he could hold limit load (2.5-g) by feeling out only about 14 pounds, considerably less than required for a similar maneuver in a military fighter aircraft.

The report to his superiors, and the testimony of a highly qualified FAA test pilot become significant here. He stated that under similar conditions he found the aircraft exhibited maneuvering instability. In his testimony he described that test, ". . . we left the PTC extended and that was at approximately 220 knots and I trimmed . . . two degrees aircraft nosedown. I started doing some nominal maneuvering with the airplane in this configuration. I found that any time I attempted to depart from my trim point, either in noseup or nosedown direction, that I received reversals in the airplane's maneuvering stability. The rate of pitch would increase and my stick force would go to the opposite direction to check the maneuver." He also indicated that after a few maneuvers the tests were discontinued because of the ". . . nervousness of all the crew."

The Board recognizes that the reported test flight was made in a non-instrumented (for test work) aircraft and also, that all available data indicate a positive, though weak, stick force gradient. The Board, however, submits that whether the aircraft under these conditions is in fact unstable or just feels that way to an experienced test pilot is a difference unworthy of further discussion.

10/ The Civil Air Regulations under which the DC-8 and other transport aircraft were certificated do not specify stick force per g values. For the superscripted statement the Board relies on general consensus of opinion and on MIL-F-8785 (ASG) which specifies maximum and minimum gradients by formula. Applying the formula to the DC-8, the stick force per g values are a maximum of 80 and a minimum of 30 pounds.

By presuming an acceleration after takeoff to speeds where stick forces against a jammed AND stabilizer would become noticeable and further hypothesizing some continued acceleration while trying to reactivate the stabilizer, say to 260 or 270 knots, one can account for the speed element necessary to place the aircraft near the region of the accident. Further, if the pilot now reduces his airspeed, e g. to 220 knots, to relieve the stick force necessary for trim and finds himself in a field of moderate to severe turbulence (as analysis of the weather has shown), he could conceivably, because of the low stick force gradient, overcontrol the aircraft to the extent that on one of the oscillations the aircraft reaches a nosedown attitude for which the altitude does not permit recovery

The nosedown attitude necessary to establish a non-recoverable position is not as steep as one might first imagine. Attachment D has been constructed from available data, principally DC-8, by superimposing on the altitude required to recover from given dive angles (utilizing a 2-g recovery), the altitude lost in getting from level to these dive attitudes. Not included is altitude dissipated during the time required for situation analysis, decision and reaction, and the time necessary to apply the stick force for a 2-g maneuver. Examination of the graph shows that recovery becomes problematical if a pushover to 30 degrees is initiated at any altitude below 5,000 feet If one considers the additional altitude losses referred to above, the limiting altitude would be considerably higher or, conversely, the maximum dive angle for recovery would be less Calculations based on flight recorder data of the DC-8 turbulence upset which occurred with the same first officer at the controls showed that the aircraft reached a nosedown attitude of about 40 degrees. It is known that 13,000 feet was required to recover level flight.

Against the argument that the PTC actuator had been in the aircraft for 10 months, and therefore, any irregularities would have been detected much earlier, the Board offers two comments. First, the leased DC-8 was operated by EAL for 20 days and subsequently made over 100 scheduled flights after being returned to the owner before the condition was discovered. (There were two minor write-ups by pilots but no corrective action was taken) Second, it must be remembered that N8607 was involved in a turbulence upset 11/ incident after the installation of the -3 actuator

The Board has devoted the last several pages to a discussion of a set of circumstances and a possible causal area largely unprovable This has been done for two very good reasons, first, the possibility of the above described situation cannot be completely discounted and, second, much of the foregoing development of handling characteristics are equally applicable to the next possibility to be discussed In fact, the previous possibility and the following one differ only in the manner in which the stabilizer operation and time of failure are introduced into the situation.

The Board, in its report of June 1, 1965, on the Northwest Airlines, Inc., Boeing 720B accident near Miami, Florida, discussed at some length the general nature of the man-machine-environment complex and the characteristic patterns shown in the simulation of turbulence flying A pertinent portion of that report states· "While the Board was still actively investigating this accident and,

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11/ EAL, DC-8, N8607, at Dulles International Airport, August 20, 1963 later, while awaiting the results of pertinent test, study, and research programs, several incidents and other accidents occurred under conditions bearing some similarity to the conditions associated with this accident. Not all of these cases involved the same aircraft model family, and several of the cases were at greatly different altitudes. Flight recorder readouts and crew statements were available for study in a few cases, while in others the crew did not survive and the recorder foil was destroyed or otherwise not available for study Not all of the involved aircraft were U. S Registered. The Board does not presume to judge any investigation that may have been completed or to prejudge any that is still under evaluation. It wishes only to note here that every possible avenue of investigation that could be explored was considered during its lengthy evaluation of this accident. Although in those cases where the crew survived to relate their experiences there were many dissimilarities in the occurrences, there were a few apparent common denominators. Turbulence of varying degrees, small and large, was involved in each case, the aircraft pitch attitude, airspeed, and altitude varied greatly in both positive-negative or increasing-decreasing directions. The crews indicated that large longitudinal control displacements of both stabilizer and elevator were used and required to maintain control. In some of these cases substantial altitude losses were experienced. Generalizing from a limited number of cases not fully evaluated or clearly understood is usually a technically unsound approach, yet it is still difficult to escape concluding that the phasing relationship between turbulence-induced aircraft motion with control inputs is at least a factor in these occurrences."

Some of the preliminary results of the extensive NASA intercenter rough air penetration studies were of considerable assistance to the Board in its assessment of both the Miami accident and this one. Of particular interest is NASA's finding that pilot workload, flight deck acceleration environment, aircraft characteristics, instrumentation displays, and piloting technique can all be factors in precipitating upsets in some cases. In the work completed it has been shown that the simulator, without any pilot control inputs, can fly through the most severe National Severe Storms Project (NSSP) gust/draft history without excessive g excursions, large airspeed variations or great altitude changes but with, in many cases, large changes in pitch attitude. The inherent or augmented stability of the simulated aircraft provides the restoring forces necessary to maintain the trim condition. In most of the trials with a pilot control input, the simulator could be flown successfully through the "storm" and the extent of the g, airspeed, and altitude excursions depended largely on how close the pilot tried to maintain the desired pitch attitude. Some of the trials revealed oscillations quite large in amplitude, indicating pilot control input out-of-phase with the simulator motions induced by the imposed gust/draft history In a few trials the oscillations became divergent and an upset occurred. When the pilot was told to deliberately ignore the pitch attitude display and to rely chiefly on controlling airspeed during the simulated penetration, large oscillations of all parameters invaribly resulted.

In line with the accepted concept that the attitude indicator becomes the primary instrument in turbulence flying, it is extremely interesting to recall the previously mentioned display characteristics of the Collins 105 instrument installed in this aircraft and others. The gearing of the pitch bar is such that when the aircraft is being rotated to high pitch attitudes (more than 20 degrees), the ratio of actual aircraft deck angle to indicated pitch attitude increases. The result, of course, is that unless the pilot is familiar with this phenomenon, he will view the aircraft in his mind's eye as being in a less severe attitude than it really is, or he may allow the aircraft to stray farther in pitch simply because his attitude instrument is presenting him with conservative data. If the attitude indicator presents "geared-down" pitch attitude information to the pilot, it likewise presents "geared-down" pitch rate information and could cause a degree of over-control when the pilot attempts to restore the aircraft to normal attitudes. Coupled with this, of course, is the small physical size of the instrument face. The Board does not wish to imply that, because of its small size, the instrument is unreadable, however, it must be accepted that it is more difficult to read and interpret than the larger indicators. Likewise, the solid black background does not display to the pilot the immediately interpretive picture of the two-colored instruments.

During the hearing in connection with this investigation, the Board heard testimony concerning the miscues presented to pilots by their flight instruments during turbulence flying. Additionally, there have been several papers written on the subject in the past several months. Generally conceded is the fact that airspeed, rate-of-climb, and altitude presentations can lack accuracy and, even more, can present completely erroneous information as to longitudinal attitude, i.e., trends exactly opposite to that expected of a given attitude. Now the Board finds that the one remaining instrument, the primary one, the attitude indicator, presents to the pilot information which, while not illogical, is certainly not optimum.

Previously this report dealt with the subject of maneuvering stability. Additionally, the Board gathered information in the form of testimony and reports, on the subject of speed stability.12/ Flight tests have shown that the DC-8 speed stability in the climb configuration approaches neutral at speeds above 300 knots when the PTC fails to extend the programmed amount. The FAA witness who testified on maneuvering stability also stated in regard to speed stability, "When I trimmed the airplane at 300 knots, I found that the static stick-free stability was positive when I departed to 85 percent of trim, but when I increased to 115 percent of trim, the static stability was within the friction band and, for all practical purposes, would be called neutral." Speed stability characteristics were explored with a research pilot who has considerable experience in experimentation with specially adapted variable stability aircraft. He indicated, as did other test pilots, that neutral speed stability in itself does not pose a serious problem to the pilot, and, in fact, under normal flying conditions ". . . it is actually quite a pleasant airplane to fly . . ." He further pointed out, however, "The thing that is dangerous about a situation like this is a distraction. If the pilot, for example, is distracted for any reason and allows the aircraft to start diverging from its trim condition, especially if he is in turbulence and he is faced with a fairly substantial change in his trim or his attitude, the tendancy usually is to make a large input, and this is where the trouble begins."

The Board conducted studies pertaining to aircraft characteristics in turbulence. This information revealed that turbulence has known energies broad enough to excite aircraft natural frequencies between 0.2 cps and 4.0 cps. An example

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12/ Speed or static stick-free, stability is the measure of the aircraft's ability to return to trim speed if momentarily disturbed to a lesser or greater speed. An aircraft which has positive speed stability will likewise require pull forces to maintain altitude if the speed decreases and push forces if the speed increases from trim speed.

of this is illustrated by the captain involved in the turbulence incident in N8607 at Dulles. He stated that ". . . we encountered the most violent jolt I have ever experienced in over 20,000 hours of flying.

"I felt as though an extremely severe positive, upward acceleration had triggered off a buffeting, not a pitch, that increased in frequency and magnitude as one might expect to encounter sitting on the end of a huge tunning fork that had been struck violently.

"Not an instrument on any panel was readable to their full scale but appeared as white blurs against their dark background.

"From that point on, it could have been 10, 20, 60 or 100 seconds, we had no idea of attitude, altitude, airspeed or heading. We were now on instruments with no visual reference and continued with severe to violent buffeting, ripping, tearing, rending crashing sounds. Briefcases, manuals, ash trays, suitcases, pencils, cigarettes, flashlights flying about like unguided missiles. It sounded and felt as if pods were leaving and the structure disintegrating.

"The objects that were thrashing about the cockpit seemed to momentarily settle on the ceiling which made it impossible to trust ones senses although I had a feeling that we were inverted as my seat belt was tight and had stretched considerable. As my briefcase was on the ceiling, I looked up and through the overhead (eyebrow) window and felt that I was looking down on the top of a cloud deck. (The first officer) later said he had the same impression at the same instant as we acted in unison applying as much force as we could gather to roll aileron control to the left. The horizon bar at this time started to stabilize and showed us coming back through 90 degrees vertical to a level attitude laterally. At this time, I had my first airspeed reading decaying through 250 knots. The air smoothed out and we gently leveled off at between 1,400-1,500 feet. . . ."

In further attempts to assess the combination of turbulence and handling characteristic elements of the man-machine-environment triangle, the Board found two other discussions by the research pilot significantly important "In our experience we find that slightly positive static margin . . is an area where pilots get into more difficulty than zero static margin, or even considering slightly unstable. What happens is that, especially in large aircraft, we have these slow response characteristics . . . as long as you fly an airplane and don't try to force it - you allow the airplane to respond well within its capabilities - you don't have any difficulty If you, however, try to force the airplane to respond faster than it wants to, then you can get into what we call a low frequency pilot-induced oscillation. It is nothing more, really, than over-controlling. You don't see the airplane respond immediately so you have the tendency to put a little more elevator in, and by this time the airplane has started to respond and you suddenly find the response is more than you wanted. So the tendency is to reverse the process. . . . I can see this situation can be quite critical in turbulence or possibly under IFR conditions plus turbulence where, let's say, you do have some large gusts which change your attitude appreciably If the pilot attempts to . . . maintain his attitude tightly, there is a possibility that he can get himself involved in a PIO." As amplification of this thought and in answer to a question concerning pilot comments, the witness, citing from a particular case, stated, "Here is a configuration in the short period, 0.2 cps and a damping ratio of 0.5. This particular pilot rated the aircraft a nine on the Cooper scale, which would be completely unacceptable. He says (quoting from the report) 'Trim ability extremely poor. Stick forces light initially, causes immediate response, wants to overshoot . . . The general feel is very bad, almost dangerous.' I think that comment is fairly respresentative."

Based on the information available to the Board, the DC-8 exhibits very low speed-stability characteristics, particularly at higher climb speeds when the PTC does not operate as programmed There was testimony at the hearing and depositions about whether these stability aspects were within the requirements of the Civil Air Regulations and much was made over the fact that the regulations do not address themselves to stability in the event of a mistrimmed condition or a system malfunction.13/ To the pilot the aircraft responds the same, whether or not it was required to meet any stability criteria for the condition in which he finds himself. What would be of primary interest to the pilot and is of primary interest in this report is the fact that at lower speeds (220 knots) the airplane can under certain mistrim conditions exhibit low to neutral stick force per g and stick force versus elevator deflection, and at the higher climb speeds (310 knots) it can have very low speed-stability.

Earlier the Board discussed the possibility of a partially or fully extended but inoperative PTC, and it should be pointed out here that this condition would contribute to reduced maneuvering stability at lower speeds but would improve to a small extent the speed stability at the higher speeds. On the other hand a retracted, inoperative PTC would have no effect at lower speeds but would produce marginal speed stability at speeds in excess of 300 knots. As stated before, the possibility exists that the PTC actuator was extended. This condition while it could worsen the situation, is not a necessary prerequisite to a PIO situation. The Board has investigated several PIO accidents and incidents in which the PTC was not involved, some involving aircraft which do not have this type of compensating system.

One element, however, common to almost all PIO occurrences has been the application of nosedown stabilizer trim at some point during the oscillatory cycles. The Board sees in this the results of forcing the aircraft, as described by the research pilot. In other words, the pilot, finding his aircraft in an excessively nose-high attitude, pushes the column forward and, when the aircraft does not respond to his satisfaction, he also actuates the trim switch. He then suddenly finds the aircraft responding more rapidly then he anticipated, and this motion could also have been aggravated by a gust reversal which becomes additive to the elevator and stabilizer inputs. At this point, in all probability, the PIO conditions have ended for all practical purposes, and the aircraft is in a dive The problem now becomes one of dive recovery.

Now a new set of factors comes into play, several of which are quite basic while others are more subtle and involved. As to whether or not the aircraft can be recovered to level flight, the basic considerations are dive angle and altitude, if the former is too great and the latter too small, recovery is obviously an unattainable goal. More subtle and difficult to assess, but greatly affecting the seriousness of angle and altitude, are pilot response

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13/ Under such conditions, the regulations require only that the aircraft be safely controllable.

times, his use of reverse thrust, whether he attempts to retrim and perhaps the most important of all, how much load he is willing or able to place on the airframe in the pullout.

This last factor deserves some additional discussion since the failed condition of the stabilizer drive system of N8607 suggests problems in this regard The failure of the stabilizer drive system at the full AND position automatically establishes a lower limit to the pilot's ability to recover from a diving condition, and here it should be recognized that it makes no difference whether the failure occurred during a PIO or earlier as previously hypothesized. The larger size of the stabilizer makes it approximately three times as powerful as the elevator, and therefore, about six degrees of up elevator is required to counteract the effect of an unwanted 2-degree AND stabilizer position. This amount of elevator deflection is lost insofar as recovery is concerned. Also, as speed increases, the ability to get any recovery action from the elevator diminishes, and disappears completely at about 470 knots. Other factors could also prolong the dive. The several PIO incidents established the fact, if not already know to pilots, that high stick forces (about 80 pounds or more) produce moments on the stabilizer which exceed the trim motor capability and that under these circumstances it is necessary to relax some of the pull force in order to reposition the stabilizer. The pilots in this case, if the drive system failed during a PIO rather than earlier, had no way of knowing the real reason for its failure to operate in the ANU direction. In the split seconds available to them for analysis they could easily have concluded that the failure was due to heavy stick forces. Reverse thrust, in addition to drag, produces a nose up pitching moment, a fact known to the first officer if not to the captain, and as indicated previously, they did employ this aid. It is also true that during the time, no matter how short, required to go from forward thrust to reverse, the noseup pitching moment of forward thrust has been removed and therefore contributes to the severity of the dive. Small as it may be, this factor becomes more significant at very low initiating altitudes.

There is an additional noteworthy element which is impossible to assess. It is most probable, based on voice identification and crew practices, that the first officer was at the controls during and following takeoff from New Orleans. Likewise, this same pilot was at the controls during the development of a longitudinal upset in another DC-8. There are still many unanswered questions concerning the exact mechanics of that earlier incident, but it is known that this pilot did not hesitate to apply full forward control column, and additional nosedown trim when faced with an unusual attitude in turbulence.14/ The result was a dive reaching about 40 degrees nosedown and from which about 13,000 feet were required for a recovery. The Board fully recognizes that what this pilot did in one situation at one time is not necessarily indicative of his actions in another, even similar, situation at another time. While the Board admits to the subjective nature of this information, it cannot ignore its existence.

Throughout this report the term "pilot-induced oscillation" has been used repeatedly, partially because it is reasonably descriptive but primarily because

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14/ Based on crew testimony, the amount of trim used in that case was probably less than the 2-degree AND limit.

it has been adopted generally by the aviation industry. It does, however, imply that the pilot may be solely responsible, and as sometimes used means exactly that. The Board has not intended this latter interpretation. It realizes that at least part of the input in a PIO is provided by the pilot as an integral part of the "control loop," but the fault certainly should not rest solely with him. Man characteristically is more adapted to a short period frequency of response about 0.6 to 0 7 cps, yet the industry is asking him to control under all tolerable situations a machine the natural frequency of which is 0.2 to 0.3 cps. This, of course, is not an impossible task as well demonstrated over the past several years, but it does introduce a measure of increased difficulty equally well demonstrated.

2.2 Conclusions

Based on the limited information available to it, the Board concludes that, although the exact time of trim failure cannot be established, such failure did occur and either contributed to the introduction of a PIO in turbulence or was contributory to the failure to recover therefrom, and that the inoperative PTC also contributed whether retracted or extended, and that there is a strong possibility that it was at least partially extended The exploration of the histories of this and other DC-8 aircraft suggests also that there could have existed some degree of control system misrigging which could have been additive to any other control difficulties.

At this point it would be appropriate to summarize the many factors with which the pilot may have been required to contend on the night of the accident. It should be noted that none of these factors in itself constitutes a hazard or even a serious situation, however, several or all of them in combination could create conditions under which control of the aircraft could be lost, partially or completely.

a. Findings

1. Night, instrument conditions prevailed.
2. Moderate to severe turbulence was encountered.
3. The PTC was inoperative and may have been partially or fully extended.
4 The stabilizer drive system failed in the 2-degree AND position at some time during the flight.
5. The attitude indicator, which was small with a solid black background, was difficult to interpret at night.
6 The pitch indication of the attitude indicator was "geared-down" but not indexed as to degrees.
7. The aircraft exhibited marginal to non-existent speed stability and a stick force per g characteristic which test pilots have interpreted as unstable.

b. Probable Cause

The Board determines the probable cause of this accident was the degradation of aircraft stability characteristics in turbulence, because of abnormal longitudinal trim component positions.

BY THE CIVIL AERONAUTICS BOARD.

/s/ CHARLES S MURPHY
Chairman

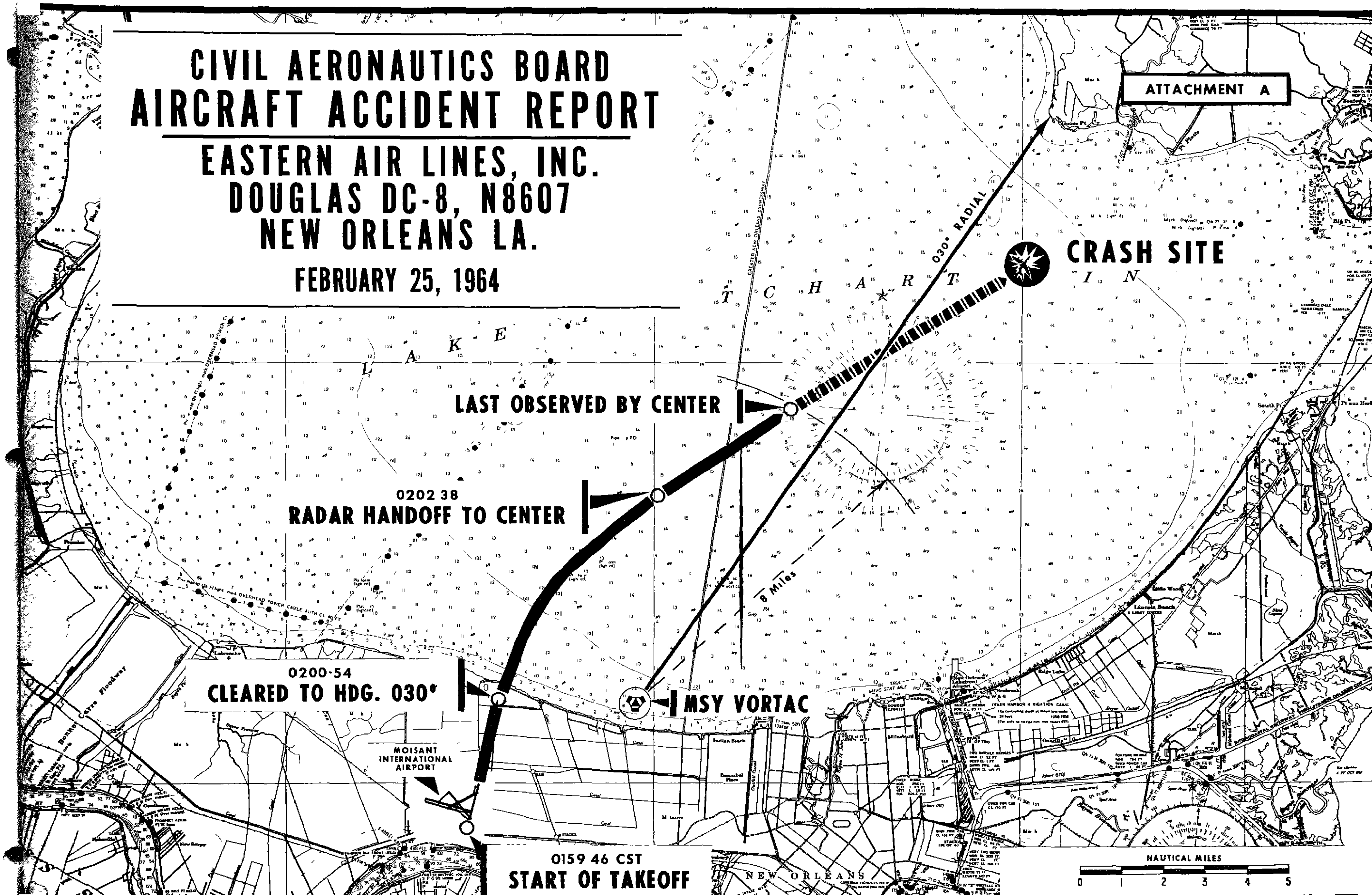
/s/ ROBERT T. MURPHY
Vice Chairman

/s/ G. JOSEPH MINETTI
Member

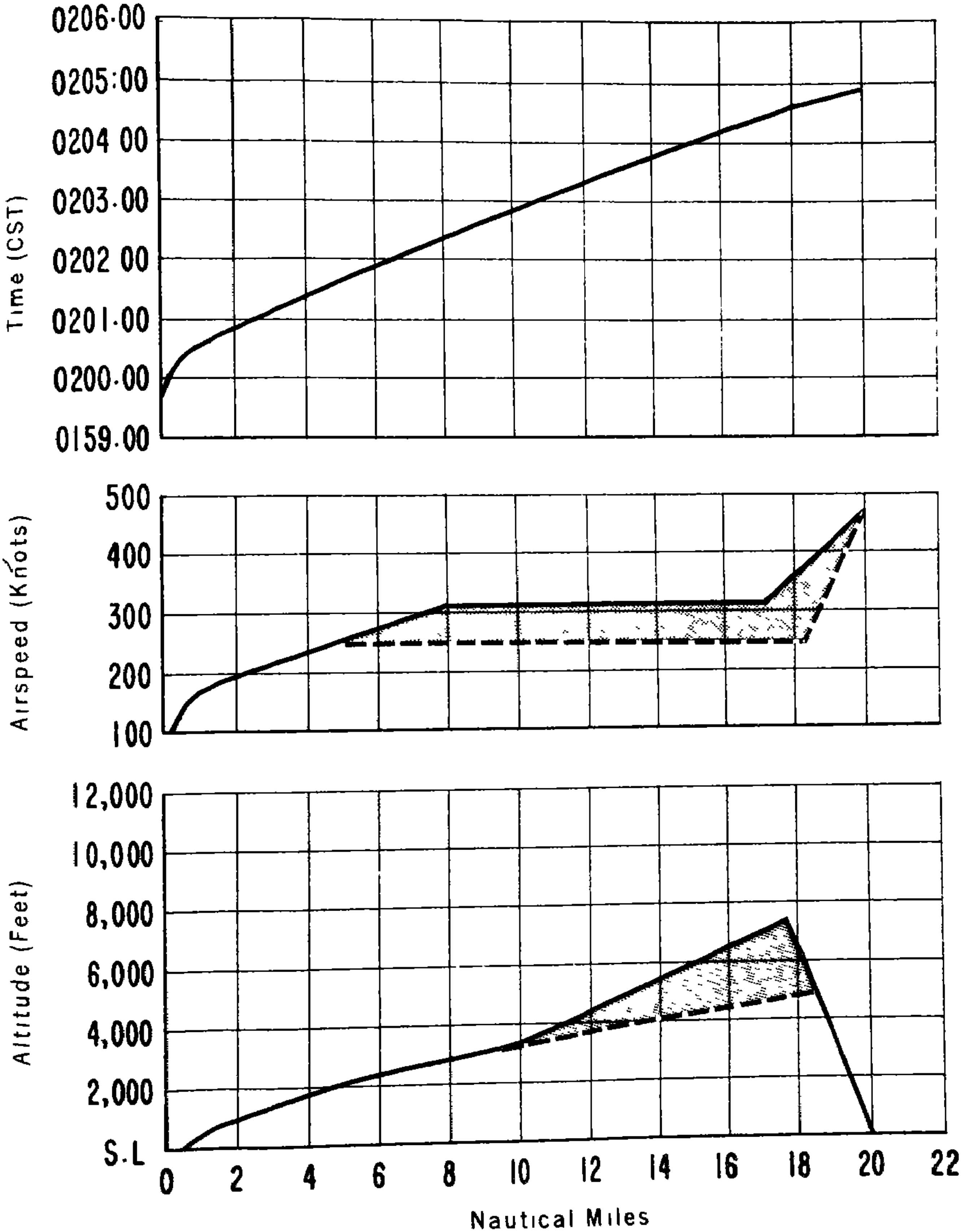
/s/ WHITNEY GILLILLAND
Member

/s/ JOHN G. ADAMS
Member

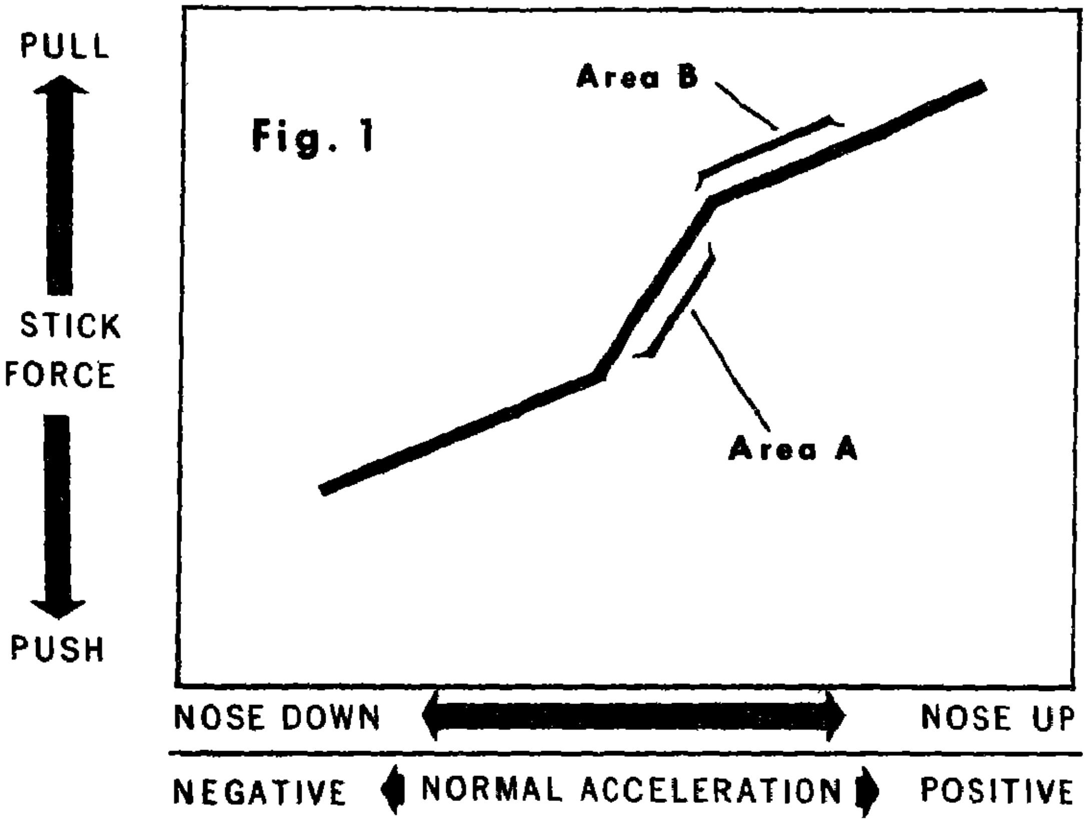
CIVIL AERONAUTICS BOARD
AIRCRAFT ACCIDENT REPORT
EASTERN AIR LINES, INC.
DOUGLAS DC-8, N8607
NEW ORLEANS LA.
FEBRUARY 25, 1964



ATTACHMENT B



ATTACHMENT C



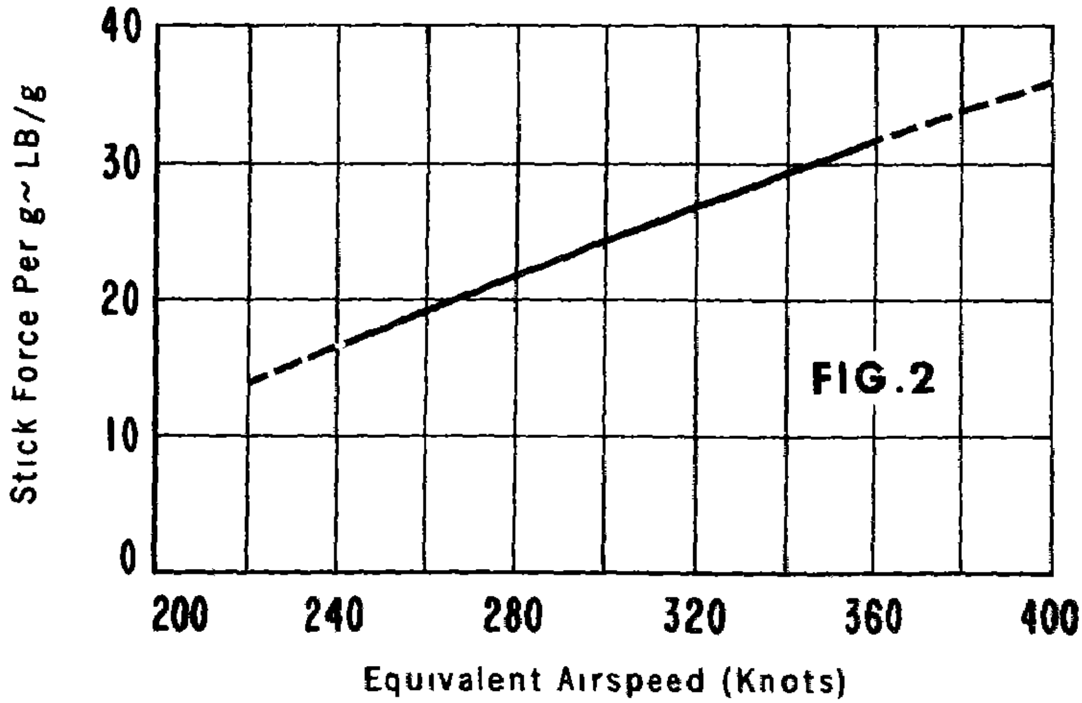
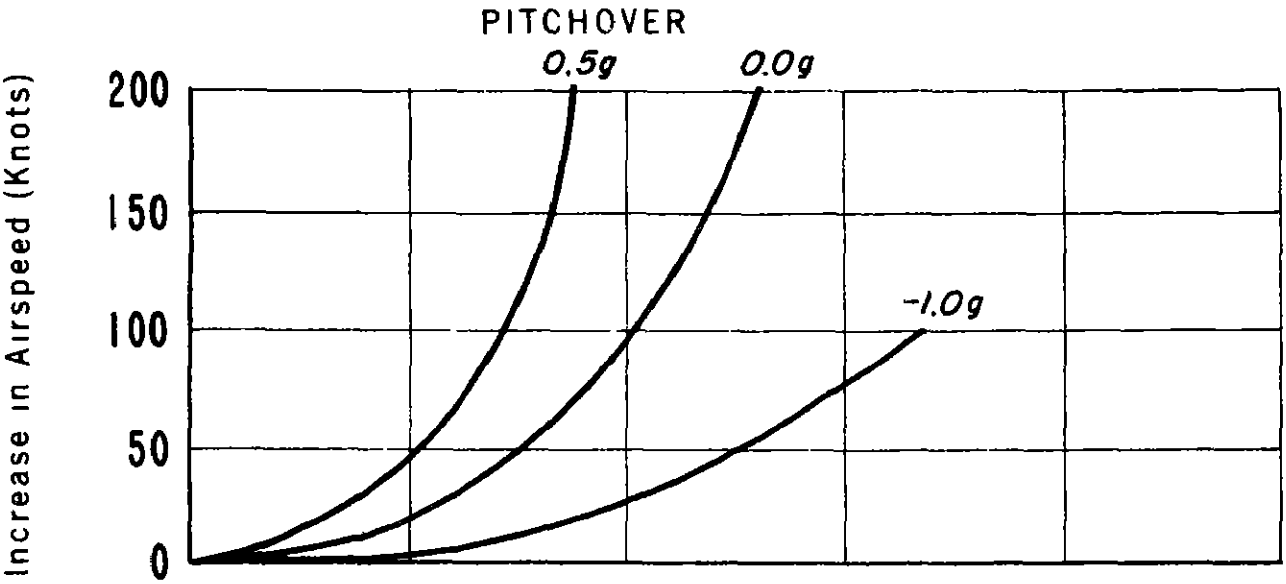


FIG.2

ATTACHMENT D



Airspeed Gained and Altitude Lost in a Pitchover Maneuver to a Dive Angle, Followed by a 2 0-g Pull-up to Level Flight