Japan Airlines 706 Accident Investigation Report

Japan Airlines McDonnell Douglas MD-11 JA8580

Over Shima Peninsula, Mie Prefecture, Japan

8 June 1997

ALPA Japan Technical Support Team

Japan Airlines Captain Association

Contents

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SUMMARY OF THE ACCIDENT

The McDonnell Douglas MD-11 belonging to and operated by Japan Airlines, registration JA8580, departed Hong Kong as JL706 for Nagoya on 8 June 1997. Before departing Kei Tak Hong Kong International Airport at 07:38 UTC[1], it was confirmed that there were no matters that would affect the flight. The flight proceeded to Nagoya in accordance to the flight plan on airway G581 at FL370. As the JL706 was descending through approximately 17,000 ft over the Shima Peninsula, Mie Prefecture, for an approach to Nagoya, the aircraft experienced abrupt and abnormal attitude changes, that injured 5 passengers and 7 crewmembers. The abrupt and abnormal attitude changes continued for approximately 15 seconds, after which, the flight crew reestablished the normal descent attitude of the aircraft and landed at Nagoya International Airport at 11:14. There was no damage to the airworthiness of the airframe but damage was found to the ceiling and to cabin service equipment in the aft galley.

1. FACTUAL INFORMATION

1.1.1 History of the flight

On 8 June 1997, JA8580 departed Hong Kong International Airport as JL706 at 07:38 UTC and cruised at FL370 on G581. As it approached 20 NM southwest of KEC (Kushimoto) VORTAC, it received a clearance from Tokyo Control to descend and maintain FL290. JL706 initiated descent to comply with the clearance. The turbulence information that the flight crew of JL706 had received from Japan Airlines Nagoya Operations prior to descent indicated that on the flight route from the south, there was light turbulence between 22,000 to 15,000 ft due to changes in the wind velocity.

As JL706 descended past FL300, the captain reported approaching FL290 and requested ATC clearance to descend to a lower altitude. ATC reissued a clearance to maintain FL290 to which JL706 complied by leveling off at FL290 and reducing speed to 260 knots.

Thereafter, JL706 was cleared to descend and maintain 9,000 ft and to cross XMC (Kowa) VORTAC at 9,000 ft. JL706 initiated descent to comply with the clearance and set 350 knots in accordance to AOM procedures.

The atmospheric conditions in the area, indicated by the applicable emagrams, showed that there was an inversion layers in the vicinity over the Cape Shionomisaki at 11,000 ft and over Tateno, Ibaraki Prefecture at 20,000 ft.

The PIC turned on the seatbelt sign, at approximately 10:45, 3 minutes before the turbulence began. All the cabin attendants were either in the galley or in the aisles continuing their assignments while the seatbelt sign was turned on to the time of the accident. All the passengers that were injured either did not have their seatbelts fastened or had their seatbelts loosely fastened.

According to the DFDR/ADAS[2] records, after leaving 29,000 ft, the aircraft accelerated to the preset speed of 350 kts, where at about 10:47:30, it stabilized at an approximate pitch attitude of –3°. The aircraft showed a slight deceleration tendency at 10:47:58, and at about 10:48:07 it slowed to 343 kts at a pitch attitude of –4° degrees. The pitch decreased further to –4.6° at 10:48:12, thereafter it started to show a gradual tendency to recover airspeed. However, passing 17,800 ft at 10:48:13, the aircraft started to accelerate rapidly, passing 351 kts at 10:48:15 and reaching 368 kts at 10:48:24, exceeding the Vmo[3] speed of 365 kts. The aircraft gradually started to increase pitch from 10:48:15 to 10:48:21,

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[1] All times will be UTC unless otherwise noted

[2] DFDR/ADAS: Digital Flight Data Recorder/Auxiliary Data Acquisition System

[3] Vmo: maximum operating speed

where it stabilized at approximately -3° until 10:48:23. A rapid increase in pitch started at 10:48:23 and at 10:48:27 reached an initial peak of +7.4°.

Spoiler deployment started at 10:48:20 and they were fully extended at 10:48:25. Vertical G recordings registered+1.3G at 10:48:25, +2.2G at 10:48:26 and a maximum of +2.78G at10:48:27. "AP2"[4] was recorded by ADAS at 10:48:26 but then "OFF" was recorded at 10:48:27. The throttle levers were at idle at 10:48:26 but started to move to increase thrust at 10:48:27. From 10:48:15 to 10:48:24, the sensor that records a pressure on the control column (CWS) indicated approximately10 lbs of pressure in the nose up direction except for momentary 21 lbs at 10:48:18.

No large changes in the control column and elevator positions were registered until 10:48:24. At 10:48:23 to 24, the right inboard elevator, controlled by AP2, moved 2.5° in a nose down direction. However, the right outboard elevator at 10:48:24 moved 1.1°, the left inboard and the left outboard elevators moved 3.6° in the nose up direction from 10:48:24 to 25 in spite of the fact that they should have moved with the right inboard elevator. The control column stayed in the vicinity of +1.8° (from neutral position), the normal descent range until 10:48:25, when it moved a further 2.3° in the nose up direction. Thereafter, at 10:48:26, it moved in the nose down direction, moving between +3.4° to –5.8° (from neutral position), mainly in the nose down direction until 10:48:41.

The aircraft attitude oscillated five times in 15 seconds from 10:48:23 at a amplitude of approximately 8° at a frequency of 3 seconds between 0° to 9° gradually increasing the null point of oscillation in the nose up direction. The vertical G force varied between +2.78G to –0.45G and started to show a converging tendency from 10:48:36. AP1[5] was engaged at 10:48:41 with the aircraft reestablishing descent attitude at 10:48:48.

The horizontal stabilizer position was at an approximate 0.7 ANU[6] position until 10:48:20, after which its position varied until 10:48:48 when it stabilized between the values of 0.2 to 0.3 ANU.

The senior cabin attendant came to the flight deck to report that three cabin attendants were on the floor in the aft galley of the aircraft. Injuries included lumps to the head and bleeding. Moaning was the only response that could be gotten to attempts to ascertain their condition. There were several injured passengers but none seemed to be incapacitated. The senior cabin attendant also indicated that he wanted a physician to be waiting shipside. The captain consented and told him that they would be landing in about 10 minutes. The senior cabin attendant indicated that since the galley was in disorder a 10 minute holding of the aircraft would be required to tidy things up. The captain consented to this request.

After requesting a 10 minute hold over KCC VORTAC, the captain accepted the ATC offer to be radar vectored for 10 minutes instead of the holding.

He then instructed the first officer to contact Japan Airlines Nagoya to have a physician standing by at shipside because of the injuries from the oscillation of the aircraft. JAL Nagoya informed them that there was no physician at the airport at that time and instead suggested calling several ambulances. They therefore requested that arrangement be made to have ambulances standing by at shipside.

JL706 was radar vectored for the VORDME A approach to runway 16. At 11:10, on a 7 DME final at 1,900 ft, the captain disengaged the autopilot for landing. At this time "LSAS CHAN FAIL" and "YAW DAMPER CHAN FAIL" messages appeared. The aircraft landed uneventfully at Nagoya at 11:14 and blocked in to spot number 4 at 11:16.

It required time for the ambulances to reach shipside since they had been waiting outside the airport when the flight blocked in at spot number 4. The cabin attendant that sustain the head injury was taken to a hospital on an ambulance at 12:05, 49 minutes after JL706 blocked in.

1.1.2 The testimony of the captain on the sequence of events of the flight

The captain was assigned to JL705 (NGO-HKG) and JL706 (HKG-NGO) of 8 June 1997. The

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[4] AP2: Autopilot-2

[5] AP1: Autopilot-1

[6] ANU: Aircraft Nose Up

preflight briefing received after showing up at JAL Nagoya Flight Operations indicated that the low pressure system over the island of Kyushu[7] would move to the Chubu[8] area at the time JL706 would be approaching the Nagoya area. The weather was forecast to be deteriorating, with a wind direction change to the south in the evening and a possible chance of precipitation. At the time of departure from Nagoya, there was no turbulence expected in the terminal area or enroute, however, there was a possibility of turbulence during descent on the return arrival to Nagoya due to the low pressure that was to move over the Chubu area. There was no significant turbulence experienced on JL705 from Nagoya International Airport to Kei Tak Hong Kong International Airport.

JL706 departed Kei Tak Hong Kong International Airport at 07:38 and proceeded on G581 at FL370 in accordance to the filed flight plan. As they were approaching Dempa point, they complied with the ATC clearance that instructed them to proceed directly to KEC (Kushimoto) VORTAC.

When a cabin attendant came to the cockpit at 10:15 on a routine visit to get arrival information, the captain informed her that descent would start at about 10:40 (19:40 JST[9]) and that there was a chance of turbulence. He further instructed them to clean everything up before the start of descent and that everybody should be seated when the seatbelt sign was turned on.

Thereafter, prior to descent at approximately 10:20, the following ACARS message came from JAL Nagoya Flight Operations:

> “NGO APO INFO AS OF 08 JUN/1900I, USING RWY16, VOR DME「A」APP, RWY COND/BA DRY, APP/DEP AREA SOUTH 22T-15T LT TURB DUE WIND VEL CHG, WEST 22T-18T CHPY OCNL LT TURB 24T N 33T-35T CHPY.”

On receiving this information, the captain told the cabin attendants at 10:25 that information from JAL indicated that the flight would encounter turbulence about 19:48 JST (10:48) and instructed them to be seated as soon as the seatbelt sign was turned on. The time of turbulence was based on the time and descending altitude between Owase point and Shima Victor point.

When the senior cabin attendant visited the cockpit at 10:35 to report that the cabin was almost in order, the captain conveyed the same ACARS information to him.

At 20 NM[10] to KEC, slight before the normal point of descent, ATC issued a clearance to descend and maintain FL290. As the aircraft approached the path calculated by the onboard computer to cross XMC VORTAC at 9,000 ft, a clearance restriction often issued by ATC, and passing FL300, the captain reported to ATC that JL706 was approaching FL290 and requested further descent. However, ATC instructed them to maintain FL290 for 10 (or 15) more nautical miles.

Due to this constraint, JL706 reduced its airspeed to 260 kts to assure adequate time and distance necessary for descent since it was past the descent point for this altitude.

ATC instructed a frequency change to JL706 at 60 NM southwest of XMC. On changing frequency, the new sector instructed JL706 to descend and maintain 9,000 ft and to cross XMC at 9,000 ft. JL706 accepted this clearance and started descent to comply with it.

The 350 kts descent speed was selected in compliance with AOM[11] 4-15-7 on late descent. To establish the initial descent attitude, the Vertical Speed mode was selected on the autopilot and set to 5,000 fpm[12]. The more stable speed mode of Flight Level Change was then selected as the airspeed approached the selected value. The Vertical Speed mode was selected because the pitch attitude of the aircraft reacts more quickly than other modes. Thereafter, active use of the Vertical Speed mode was employed in lieu of the Flight Level Change mode when it became necessary to make fine adjustment to the pitch of the aircraft.

At 10:45, passing FL250, the seatbelt sign was turned on. Since a cabin attendant had already

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[7] Kyushu: the most southwestern of the four major islands of Japan

[8] Chubu: the area of Japan where Nagoya is located

[9] JST: Japan Standard Time

[10] NM: nautical mile

[11] AOM: Aircraft Operating Manual

[12] fpm: feet per minute

started to make an announcement to the passengers to fasten their seatbelts, the captain forewent his planned announcement on the fastening of seatbelts.

When the aircraft showed a deceleration trend as it passed 300 kts during descent, the Vertical Speed mode of the autopilot was again employed followed by the reengagement the Flight Level Change mode as the descent rate increased. The auto throttle was disengaged and the thrust was set to idle.

The aircraft stabilized at 350 kts briefly, then showed a slight deceleration tendency, after which, it suddenly went into an acceleration condition. The captain selected the Vertical Speed mode on the autopilot and rotated the Pitch Wheel several times in the reduce descent rate direction (aircraft nose up direction) since no change could be seen as the aircraft passed its selected speed of 350 kts. This control input did not result in the indication of the Selected Vertical Speed Bug in the Vertical Speed Indicator or the display of the selected descent rate in the V/S-FPA[13] Display Window and the aircraft did not respond as anticipated. The spoilers were deployed to 1/3 position in an effort to decelerate, however, acceleration continued, so the spoiler deployment was increased to 2/3 then to the fully deployed position.

As the spoilers were deployed to full open, the airspeed reached Vmo, the airspeed indication turned red and the Overspeed Warning activated. A shock was felt at the same time the aircraft reached Vmo. The first shock, a upward thrust, was similar to that felt when a car hits a pock mark in the road. The following experience was like that being tossed around during a rodeo ride. Several large thrusts were experienced. The confusion from the large G forces and noise resulted in not being able to monitor the flight instruments. The crew was momentarily at a loss as to what had occurred. Thereafter, as the crew realized that the control column was moving aft and that the aircraft was pitching up, the autopilot disconnected. As the captain lowered the nose to stabilize the aircraft, he ordered the first officer to reengage the autopilot.

The captain reported that the feel of the control column was abnormally lighter than normal. He notes that at no time was any pressure applied to the control column to counter act the autopilot or were the thrust levers moved at the time of the first shock. He also has no clear recollection of why or when the spoilers were retracted.

Shortly afterwards, the captain monitored on the interphone system, the cabin attendants talking about people down on the floor in the aft galley. He cut into the party line system and asked if they had had their seat belts fastened. The cabin attendants remained silent to this question. He then asked them to report on the situation in the cabin compartment.

After a while, the senior cabin attendant came to the flight deck to report that three cabin attendants were on the floor in the aft galley. Injuries included lumps to the head and bleeding. Moaning was the only response that could be gotten to attempts to ascertain their condition. There were several injured passengers but none seemed to be incapacitated. The senior cabin attendant also indicated that he wanted a physician to be waiting shipside at the destination. The captain agreed and told him that they would be landing in about 10 minutes. The senior cabin attendant indicated that since the galley was in disorder he would like the aircraft to hold for about 10 minutes.

The captain consented to this request and requested to hold over KCC VORTAC for 10 minutes. He accepted the ATC offer to radar vector the aircraft for 10 minutes instead of the holding.

He then instructed the first officer to contact Japan Airlines Nagoya to have a physician standing by at shipside because of the injuries from the turbulence. JAL Nagoya informed them that at that time there was no physician at the airport and instead suggested calling ambulances. They therefore requested arrangements be made to have ambulances standing by at shipside.

The senior cabin attendant reported several minutes later that landing preparations in the cabin were completed and that the cabin was ready for approach. The captain reported that they were ready for approach to ATC. As a result, not much time was lost for landing preparations.

JL706 was cleared for the VORDME A approach to runway 16 and was radar vectored to the final

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[13] V/S-FPA: vertical speed / flight path angle

course. When the autopilot was disengaged as the aircraft approached 7 DME on final at 1,900 ft, the "LSAS CHAN FAIL" and "YAW DAMPER CHAN FAIL" messages appeared and the Master Caution light illuminated. Since the captain wanted to land the aircraft as soon as possible to care for the injured and since he did not feel anything out of normal in the flight controls, he did not execute the required Non Normal Procedures in response to the warning light. The aircraft landed at Nagoya at 11:14 and blocked in at spot number 4 at 11:16.

1.1.3 The testimony of the senior cabin attendant

The senior cabin attendant was briefed on the following items by the captain during the preflight briefing at Hong Kong:

1. There was a possibility of turbulence during climb from Hong Kong, in the vicinity of Okinawa and during descent to Nagoya. The captain suggested that arrival preparation should be completed early.
2. When the seat belt sign was turned on, everybody was to be seated with "no exception."
3. If a situation arose requiring someone to leave their seat, they were to receive permission from the captain.
4. Time might be required to permit someone from leaving their seat depending on the situation. The captain would make a cabin announcement in such circumstances.

The senior cabin attendant, around 10:15 to 20, received information concerning arrival and on the probability that there would be turbulence during descent from the captain. He conveyed this information to all the cabin attendants. At 10:35, he reported to the captain that all cabin service had been completed. At that time he was informed by the captain that there might be turbulence during descent and instructed him to complete all cabin preparation early. He conveyed this information on the interphone system to all the cabin attendants.

The seatbelt sign was turned on at about 10:48. The turbulence started around 10:50 although he could not tell where it occurred. The cabin attendants had to check the passengers' seatbelts and lavatory and could not be seated immediately after the belt sign was turned on. The galleys were being cleaned up when the seatbelt sign illuminated. The situation in the cabin had not changed when the turbulence began. He experienced strong G forces to his body and had to support himself by holding onto the handrail in the galley. He was not conscious of how the aircraft was reacting.

The cabin attendants that were in his vicinity were in the midst of completing sales related activities. They were being rocked back and forth but he did not recollect any being tossed into the air. Going to the aft galley, he found objects scattered on the floor and three cabin attendants collapsed on the floor. All three were either bleed from the face or head and lumps were beginning to form. Some could only moan while others were barely able to communicate. Two cabin service carts had fallen over on the floor.

He reported to the captain, at about 11:00, on the situation, requesting that a physician be waiting at the arrival gate and asked for some time to clean up the cabin for landing. He reported to the captain that the cabin was ready for landing at 11:05.

1.1.4 Cabin attendant court testimony

The cabin attendants testified that in spite of the illumination of the seatbelt sign, if the turbulence was not that great, they would continue their work. It was up to their discretion to access the turbulence and decide whether to interrupt their work and be seated. They understood that the instruction from the captain was an order but would continue their work when it was necessary. They added that they had never asked the captain for permission in such cases before.

1.1.5 Report by the Nishikasugai East Fire Fight Company

- □ At 11:05 (20:05 JST) the Nishikasugai East Fire Fight Company received a 119 call from Nagoya International Airport.
- □ At 11:12 Ambulance No. 2 arrived at the lobby of Nagoya International Airport and stood by.

- At 11:26 additional request for Ambulance No. 4 was coordinated with the hospital.
- At 11:34 Ambulance No. 4 arrived at Nagoya International Airport
- At 11:45 the actual request for ambulance medical assistance was made and they arrived by the aircraft at 11:54.
- Ambulance activities started at 11:54 and were completed at 12:07
- Ambulance No. 2 departed the airport at 11:56 and arrived at the hospital at 12:04.
- Ambulance No. 4 departed the airport at 12:05 and arrived at the hospital at 12:13.

The ambulance paramedics reported that they advocated caring for the most seriously injured first but the JAL ground staff insisted that the passengers be given priority.

1.2 Injuries to persons

	Crew	Passengers	Others
Fatality	0	0	0
Serious Injury	3	1	0
Slightly Injured/None	4 / 4	4 / 164	0

1.3 Damage to aircraft

Slight damage was found to the ceiling interior of the aft galley. Two cabin service carts had been thrown out of their storage bin, one being severely deformed, while the other received only light damage. The service cart lock within the cart storage bin, although not damaged, was in the unlocked, horizontal position.

1.4 Other damage

None

1.5 Personal information

1.5.1 Flight crew qualifications

All the flight crewmembers were fully qualified and current in their qualifications.

1.5.2 Flight crew duty

The flight crew operated JL 705 and JL706 as a single day round trip flight pattern starting from Nagoya, Japan to Hong Kong Kei Tak Airport then back again to Nagoya. The nine flight attendants that took duty on JL705 were relieved of their duty, as scheduled, at Hong Kong Kei Tak Airport and nine new flight attendants, who had flown in on the previous day, took on duty for JL706.

The flight crew flew a one day round trip from Nagoya, Japan to Manila, Philippines as JL743 and 744 on 6 June and were off duty on 7 June. The flight crew left their hotel accommodations in Nagoya at 22:50 (07:50 JST) to showed up at JAL Flight Operations Nagoya at 23:40 (08:40 JST) for JL705 and JL706 as duty crew for a one day round trip from Nagoya to Hong Kong Kei Tak Airport and back.

1.6 Aircraft information

1.6.1 Weight and balance information

JL706 operated within its certified weight and center of gravity operating limitations. The Japan Aircraft Accident Investigation Commission puts the weight of the aircraft at 414,500 lbs and the center of gravity at 29.5% MAC[14] and according to the FPAL (Flight Plan and Log), the remaining fuel is estimated to be approximately 54,000 lbs at the time of accident.

1.6.2 Characteristics of the MD-11

The MD-11 is a derivative that evolved from the DC-10 airframe. The two major characteristics of

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[14] MAC: mean aerodynamic chord

the MD-11 are:

1. The area of the horizontal stabilizer is approximately 30% smaller in comparison to the DC-10 to reduce the drag and weight from this structure.
2. Fuel is transferred to the stabilizer tank in the horizontal stabilizer to intentionally maintain a more aft CG[15] during cruise. This results in the reduction of the negative (downward) lift required by the horizontal stabilizer to balance the aircraft, reducing the lift required by the wing to maintain level flight and thus reducing the overall induced drag of the aircraft.

The aircraft is also outfitted with winglets and the trailing edge of the wings have been curved slightly downward to resemble the form of a super critical wing.

These alterations in design made the MD-11 consume less fuel on the one hand but the small horizontal stabilizer and aft CG reduced the stability of the aircraft. At high altitude and high speed, the control feel to raise and lower the nose was very light and the same control input would result in a larger reaction in the MD-11 than other aircraft. According to McDonnell Douglas (see Attachment-4), at normal cruise speed, stick force per G required on the MD-11 was 44 lbs, in comparison it was 64 lbs on the B747. Similarly, at Vmo it was 39 lbs on this aircraft while the B747 required 67 lbs. A function of the FCC[16], LSAS[17], was used to compensate for this sensitive reaction of the aircraft due to the light control feel of the control column. In other words, the FCC functioned as the autopilot and during manual flight, its LSAS function maintained the aircraft pitch attitude when control column pressures were below 2 lbs. Due to the accidents that had occurred because of abrupt pitch changes during manual flight reported since the MD-11 became operational, a refit was made to prevent large pitch changes. LSAS software was modified in 1996 and a pitch rate damper function that was continuously operational at and above 15,000 ft was added. (See Attachment-4, Fig 2)

McDonnell Douglas information shows that in the flight control system, there was a 0.2 second time delay from the time that the control column was moved to flight control surface movement. This is comparable to the US military handling quality MIL Spec Level-2 rating. A NASA research report indicates that a “increased pilot workload/mission degradation” could result in control difficulties under certain flight conditions.

The flight spoiler system is comprised of ten spoilers, five on each wing. In flight speed brake use results in a maximum of 30° deployment of all these ten spoiler panels.

1.6.3 Autopilot (FCC) Characteristics

1.6.3.1 Autopilot

Operation

The MD-11 is equipped with a dual FCC system, FCC-1 controlling Autopilot-1 and FCC-2 controlling Autopilot-2, and an AUTOFLIGHT switch that engages the autopilot. When electrical power is initially supplied to the aircraft, either FCC-1 or FCC-2 is arbitrarily armed to the autopilot depending on the timing. If both FCC are normal, the FCC armed to the autopilot at the time of power supply will command the aircraft when the AUTOFLIGHT switch is depressed. When Autopilot-1 is controlling the aircraft, FCC-2 will become active and Autopilot-2 will control the aircraft when the AUTOFLIGHT switch is depressed. FCC-1 will revert to armed condition at that time. Each time the AUTOFLIGHT switch is depressed, the command FCC and armed FCC are interchanged.

Each autopilot controls the pitch of the aircraft through a specific elevator. There are four elevator control surfaces on the MD-11, with FCC-1 controlling the left inboard elevator (LIB) and FCC-2 controlling the right inboard elevator (RIB). The other remaining elevators are not directly connected to either FCC and move through a linkage mechanism with the either LIB or RIB that is controlled by the active FCC.

Evaluation/Assessment

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[15] CG: center of gravity

[16] FCC: Flight Control Computer

[17] LSAS: Longitudinal Stability Augmentation System

There are two opposing assessments of the MD-11 autopilot system. One, asserted by McDonnell Douglas after the accident, that stated that there was a danger of an abrupt change in the aircraft attitude if there was pressure applied to the control column when the autopilot was disengage. After the JL706 accident, Japan Airlines amended the MD-11 AOM to reflect this, "*If any inadvertent autopilot disconnect occurs, the pilot must smoothly stabilize the aircraft attitude, releasing the flight control, if necessary, until the aircraft motion dampens out*"

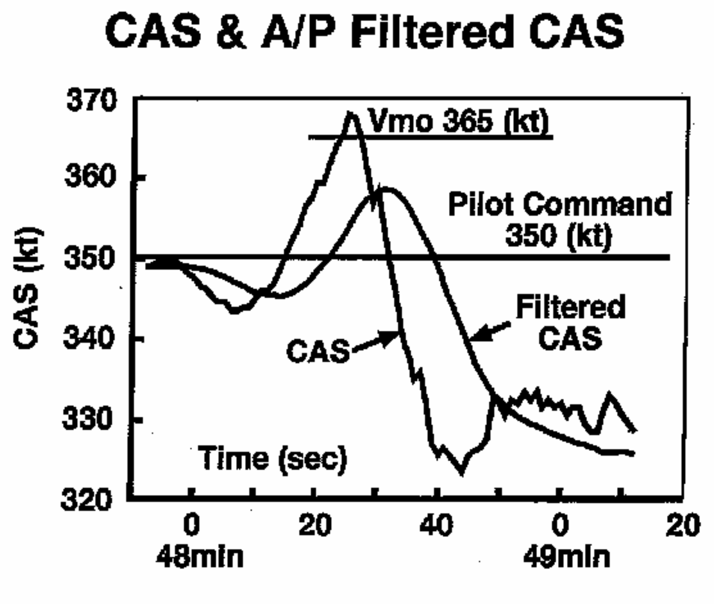
According to the Japanese Airworthiness Examination Regulatory Manual, "Recovery should be demonstrated either by overpowering or by manual use of an emergency quick disconnect device after the appropriate delay. The pilot should be able to return the airplane to its normal flight attitude under full manual control without exceeding the loads or speed limits defined in 3-1-3 and without engaging in any dangerous maneuvers during recovery."

The other assessment stems from the a report, based on research from manufacturer information of over 30 active commercial airline aircraft, including the MD-11, issued in June 2001 by the FAA in reply to a NTSB[18] recommendation made in 1999. The research was on what happen if the autopilot was manually overridden or if there were abrupt changes in aircraft attitude immediately after the autopilot being overridden. The NTSB issued a recommendation of design change (NTSB Recommendation A-99-41, 42 on 25 May 1999) to address abrupt "upsets" in aircraft attitude by the autopilot based on studies made on several MD-11 accidents. Negotiations with the FAA resulted in the NTSB concluding that the present autopilot of the MD-11 was "not acceptable." McDonnell Douglas objected to this assessment and advocated that the autopilot of the MD-11 was comparable to that of other commercial aircraft. With this difference in evaluation, however, there is no provision in commercial aircraft made by Boeing to release pressure from the control column when the aircraft responds in an abrupt manner.

The use of filtered airspeed in the autopilot

The MD-11 Autopilot System uses a filtered airspeed signal to smooth out the signal and prevent the FCC from responding too sensitively to momentary airspeed changes. This results in a delayed autopilot response to rapid changes in airspeed. According to McDonnell Douglas reference material, shown in the figure on the right, it can be assumed that there was a noticeable difference between the indicated airspeed and the filtered airspeed signal.

The MD-11 flight crew of Japan Airlines were never informed of the fact that the FCC uses a filtered airspeed signal, nor is there any indicator in the cockpit that displays this filtered airspeed or the dissociation of between the two signals.



FCC speed control capability

The MD-11 incorporates "G control" to govern the attitude of aircraft during descent. During Profile mode and Flight Level Change mode, the vertical G force to the airframe is controlled within a tolerance of ±0.07G, while during Vertical Speed mode it is limited 0.2G. These figures indicate that this aircraft is slower than other commercial airliners in responding to changes in airspeed. A 1 kt per second wind

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[18] NTSB: National Transportation Safety Board (U.S.A.)

speed change is said to be the maximum that the autopilot system is capable of correctly responding to. JL706 encountered a wind speed change of between 1.5 to 2.8 kts per second.

Overspeed protection function

The Overspeed Protection function of the MD-11 autopilot will activate when Vmo is exceeded and will reduce the airspeed to Vmo. Once reduction to Vmo is accomplished, it will automatically maintain Vmo. The Autothrottle will automatically engage and advance to provide the required thrust to maintain this speed.

Automatic autopilot disengagement

The JAL AOM states the following conditions for automatic disconnection of the Autopilot:

1. Vertical G forces exceeds 1 ± 0.6 G ～ 1 ± 1.4 G
2. Roll Rate exceeds 10°/ sec
3. Bank Angle exceeds 60°
4. When the Autopilot detects a discrepancy between its control commands and the position of the control surfaces due to pilot override control or other reasons. This function is known as Command Response Monitor or CRM.

The CRM monitors whether the elevator control surfaces are responding normally to the control commands of the FCC. The CRM activates when there is a 4° or more difference between the FCC commanded position and the actual elevator deflection. The CRM will recognize this as a FCC system fault, if this difference continues for a given period of time (difference x time ≥ 4° second; minimum of ⅔ seconds) and is designed to disconnect the autopilot for preventing a hardover.

McDonnell Douglas indicates that this CRM feature that monitors the overriding of the autopilot by the pilot, as safety backup function, to enable disengagement of the autopilot when the control wheel Autopilot Disengage switch cannot be used. An overriding force of 50 lbs (22.5 kgs) must be exerted on the control column to accomplish this. Air Data Signal anomalies and the use of the Manual Stabilizer Trim are other conditions for the automatic disconnection of the autopilot.

The President of the Flight Operations Engineering Department testified at the trial that there is McDonnell Douglas technical information indicating that during autopilot use, the autopilot would maintain the pitch of the aircraft even if 20 lbs of force was applied to the control column. Changes to the aircraft pitch would occur when the force exceeded 20 lbs and the CRM function would start operation at approximately 50 lbs. This has been confirm in the simulator.

Horizontal stabilizer control

The FCC also controls the horizontal stabilizer. The horizontal stabilizer is controlled to relieve the displacement of the FCC controlled elevator when a travel of more than ±1.35° from neutral continues for 3 seconds or more. During the flight of JL706, ADAS records indicate that the average neutral position of the elevators to be estimated at +0.503°. There was no movement of the horizontal stabilizer on this flight, in spite of the fact that the RIB elevator was beyond this value of 1.35° for 9 seconds from 10:47:59 to 10:48:08 and for 7 seconds from 10:48:17 to 10:48:24.

1.6.3.2 LSAS (Longitudinal Stability Augmentation System)

McDonnell Douglas installed the Longitudinal Stability Augmentation System (LSAS) on the MD-11 to supplement the pitch stability of the aircraft. The major functions of LSAS are, Pitch Attitude Hold, Pitch Attitude Limiting, Pitch Rate Damping, Automatic Pitch Trim, Speed Protection and Stall Protection, and it is only active during manual flight. Pitch Attitude Hold and Automatic Pitch Trim functions operate when the force on the control column is 2 lbs or less. There are two LSAS channels in each FCC. During manual flight, the two FCCs control the four elevators simultaneously, with LSAS-1A and LSAS-1B of FCC-1 controlling ROB[19] and LIB[20] elevators respectively, and LSAS-2A and LSAS-2B of FCC-2 controlling LOB[21] and RIB[22] elevators respectively.

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[19] ROB: right outboard

[20] LIB: left inboard

[21] LOB: left outboard

Improvements to the handling quality of the aircraft during manual flight have been implemented since the aircraft entered operation. The Pitch Rate Damping function was added in 1996 to prevent large G forces to the aircraft during manual flight. When the system detects a pitch rate change beyond a defined value, LSAS will control the elevators to moderate the rate of pitch change. This improved function has been recognized to greatly reduce the chance of over controlling the aircraft during manual flight. LSAS elevator travel is limited to within 5° however there is no feedback to the control column.

1.6.4 Fault record of the accident aircraft

The FCC fault message , “Elevator Command Response Monitor” (E-CRM) was recorded at 10:48 on the accident aircraft. Additionally, when the PIC disengaged Autopilot-1 on final approach to fly manually, he reported that the “LSAS CH[23] FAIL” and “YAW DAMPER CH FAIL” Alert messages appeared. However, maintenance records on the Fault Indication Systems showed only the FCC-1 Fault Review at 11:10, LSAS COM MON INV[24], CPU1B[25], CPU2, and CPU3 messages. There was no Yaw Damper related recording.

1.7 Meteorological information

Sunset was at 10:05 (19:05 JST) and the Moon Phase was 3 for the Chubu area at the time of the accident. The general weather indicated that the low pressure system that was over the Kyushu Area in the morning had moved east and was approaching the Kii Peninsula. According to the composite radar echo chart of 1997.6.8.12 UTC, the west side of the Kii Peninsula was covered with clouds that did not accompany precipitation, however, the east coast where the accident occurred had only weak echo returns.

The 1997.6.8.12 UTC Emagram showed a layer of discontinuity accompanied by an inversion layer over the Shio Peninsula, between the altitudes of 12,000 to 13,000 ft. A wind direction change from 300° to 220° and a velocity change from 35 to 10 kts occurred in this area. At the same time, a layer of discontinuity accompanied by an inversion layer existed over Hamamatsu at around 20,000 ft with an sharp temperature change from -9° to -14°C. A wind change occurred below 18,000 ft. The inversion layer over Hamamatsu was termed by meteorological forecasters as very striking and observed very rarely. During this period there was a layer of discontinuity accompanied by an inversion layer over Tateno, Ibaraki Prefecture, at 24,000 ft.

The cross section chart of 12:00 indicated a prominent area of wind shear between 15,000 to 20,000 ft over the Chubu area. The Tsu[26] Meteorological Observatory issued warnings concerning thunderstorm, strong wind, high wave and fog for southern Mie Prefecture at 21:00 JST 8 June.

The airport weather at the time of landing, 11:00 (20:00 JST), was as follows:
14015 KT 9999 FEW030 SCT120 OVC150 21/16 Q1009 RMK 1CU030 3AC120 8AS150 A2982.

1.8 Aids to navigation

There were no reported abnormalities concerning aviation supporting facilities that would have contributed to the accident.

1.9 Communications

There were no reported abnormalities concerning aviation communication facilities that would have contributed to the accident.

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[22] RIB: right inboard

[23] CH: channel

[24] LSAS COM MON INV: LSAS command monitor invalid

[25] CPU: central processing unit

[26] a city situated on the western shore of the Ise Bay south of Nagoya

1.10 Aerodrome information

The VORDME-A approach to runway 16 was in use at the time of landing. There were no NOTAMs that would have affected the flight.

1.11 Flight recorders

There was no damage to the Digital Flight Data Recorder. ADAS recordings were used to augment the DFDR information. CPU data overflowed for one second between ISFC[27]12326 to 12327 and was lost.

1.12 Wreckage and impact information

There was no damage to the aircraft from impact with other objects.

1.13 Medical and pathological information

Serious injuries

1. Passenger A: Walking on the aisle. Fracture of the transverse lumbar vertebrae and a bruise to the face.
2. Cabin Attendant A: Cleaning up the service equipment in the aft galley. Fracture of the pelvic bone and open fracture of the left thumb.
3. Cabin Attendant B: On returning from the forward galley for cabin sales accounting. Fracture of the pelvic bone, fracture of a lumbar vertebra, fracture of the right arm.
4. Cabin Attendant C: Working in the aft galley. Cerebral contusion and pelvic bone fracture. Died on 16 February 1999.

Minor Injuries

1. Passenger B: In the lavatory.
2. Passenger C: Resting while seated with the seat belt fastened loosely.
3. Passenger D: Resting while seated with the seat belt not fastened.
4. Passenger E: In the process of being seated after returning from the lavatory.
5. Cabin Attendant: D: Cabin sales accounting in the forward galley.
6. Cabin Attendant E: Conducting tax-free goods documents accounting in the forward galley.
7. Cabin Attendant F: Working in the forward galley.
8. Cabin Attendant G: Working in the forward galley.

1.14 Fire

There was no fire.

1.15 Survival aspects

No death were attributed to the accident in accordance to ICAO standards. Cabin Attendant C, who was seriously injured, died 20 months after the accident from multiple organ failure.

1.16 Tests and research

1.16.1 Meteorological investigation

The DFDR indicates that the aircraft under went a sudden wind change between 1.5 to 2.8 knots per second. Several other aircraft that flew in the same area at the time of the accident reported turbulence. There were no clouds or turbulence below the altitude where the accident occurred. A high probability of CAT[28] can be anticipated where there is wind shear and large temperature change. The following is a chart is based on information in the Japan Airlines Weather Handbook concerning CAT occurrence.

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[27] ISFC: Time Scale Input Subframe Counter

[28] CAT: clear air turbulence

	International Meteorological Standard	**Domestic Meteorological Standard**	**ICAO**	**United States Military**
VWS (knot / 1000 ft)	≥ 6	≥ 10	≥ 6	≥ 10
HWS (knot / 60 NM)	Unknown	≥ 20	≥ 20	≥ 33
Wind Speed (knot)	Unknown	≥ 190	≥ 110	Unknown
Temperature Change (° C / 120 NM)	Unknown	Large	≥ 5	Unknown

In the book "New Aviation Weather" edited by the Japan Weather Association, it is noted that low altitude wind shear occur where there is a temperature inversion. A marked change in wind speed will occur near this inversion layer and a wind shear area forms along the border of this inversion layer plane. When an aircraft flies into this layer, it will encounter turbulence, changes in indicated airspeed due to changes in the wind and changes in lift as a result of this.

1.16.2 The atmospheric condition at the time of the accident based on ADAS data.

At 10:48:00, according to the ADAS data, the atmosphere in the area of the accident was just about at standard conditions. A constant temperature layer existed between 10:48:00 (18,208 ft) to 10:48:13 (17,405 ft), the change in altitude was not accompanied by a change in temperature. From 10:48:13 to 10:48:24 (16,709 ft) there was an inversion layer, where the temperature decreased with the decrease in altitude. There was a turbulent layer from 10:48:24 to 10:48:44 (17,200 ft), another inversion layer between 10:48:44 to 10:48:50 (16982 ft) and another constant temperature layer to 10:49:00 (16,607 ft), below which standard atmospheric condition existed.

1.16.3 Autopilot disconnection by overriding force on the control column

Tests were made on the MD-11 simulator to determine whether it was possible to inadvertently disconnect the autopilot by applying force to the control column. It was found that a conscious effort using both hands to apply approximately 50 lbs of pressure was required and that it was not possible to unconsciously apply enough force to accomplish this. It was determined that during a 350 kts descent, a gradual application of force would result in a control column displacement of approximately 3.5 cm (comparable to CCP displacement of 2.7°) or a rapid control column movement of 17 cm (CCP displacement of 13.4°) to disconnect the autopilot by forced override.

It was discovered that when the autopilot is disconnected by a overriding force on the control column, there was a possibility of both the Automatic Cut Off (ACO) and CRM functioning. As indicated in Attachment-5, a relatively rapid application of force results in a G limit exceedance disconnection occurring after 2 to 10 seconds. This leaves a "ACO" CFDS[29] fault record, while a gradual application of force of approximately 10 seconds that does not exceed the G limit will cause the CRM function to disengage the autopilot leaving a "E-CRM" CFDS fault record.

1.16.4 Temporary FCC malfunction and autopilot disengagement

A study on the MD-11 simulator was made on what would happen if a malfunction occurred in the FCC during autopilot use. A RIB LSAS failure, which simulates a RIB elevator hydraulic shutoff valve malfunction, was entered into the simulator while Autopilot-2 (FCC-2) was in use. After approximately 3 seconds, the autopilot disconnected, leaving the "ELEV ACT-RIB" and "EL CMD RESPONSE" fault messages in the CFDS. These are the same messages that were displayed on JL706. When these faults occur, the LSAS channel fail warning light will not illuminate for 6 seconds after the LSAS has failed and will not leave any CFDS recordings. However, after these 6 seconds, the overhead panel LSAS channel fail warning light will illuminate and simultaneously record a CFDS fault.

If a fault occurs in the armed FCC during autopilot operation, there will be no fault message displayed until the armed FCC starts operation as the active LSAS system when the operating autopilot is

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[29] CFDS: Centralized Fault Display System

replaced by it. The LSAS channel fail message appeared when the autopilot was disengaged. The LSAS fault time recorded in the CFDS was the time of LSAS Channel Fail warning light illumination and not when that of LSAS failure.

The respective elevator hydraulic shutoff valve electrical power source is shown in Attachment 7-2. The electrical power is shutoff when the continuous BIT[30] equipment of the respective FCC units detects any of the following faults, resulting in the hydraulic shutoff valve becoming inoperative.

☐ Input Data
☐ CPU
☐ Memory
☐ Digital/Analog & Analog/Digital Converters
☐ ARINC[31]
☐ LVDT & Synchro
☐ Output Discretes
☐ Time Magnitude Monitor
☐ CWS[32]

This stops the supply of hydraulic power to the control valve of the Elevator Power Control Unit (PCU). When this power is cutoff, the PCU will not be able to respond to the command from the controlling FCC, resulting in a disagreement between the commanded position and elevator displacement position resulting in the CRM function starting to operate.

1.16.5 Mode change during autopilot use

Autopilot mode changes were examined on the actual MD-11. This study on an operational aircraft showed that no matter how fast the pitch wheel was turned during autopilot operation in Flight Level Change mode, a change to the Vertical Speed mode would occur.

1.16.6 Simulator evaluation of flight performance

☐ The simulator was set to the parameters of the aircraft at the time of the accident: aircraft weigh 414,500 lbs, CG[33] 29.5%, ZFW[34] 359,100 lbs, ZFW CG 27.5%, fuel 55,400 lbs.

☐ AP2 was used from FL220 and Flight Level Change mode at 350 kt was used with the respective environmental conditions entered in to FL170 when stable conditions resumed.

1) Pitch Attitude during Normal Descent
   When the FCC is operating normally, the 350 kt normal descent attitude is –2.5°.
2) Changes that occur when the Over Speed Protection Function activates
   It was discovered that when the over speed protection mode activates, a mode reversion process takes place, i.e. Flight Level Change mode changes to V/S[35] mode and then reverts back to Flight Level Change mode. The Flight Level Change mode remains active during an over speed condition until the over speed protection function intervenes and it is still possible to use the V/S mode through the pitch wheel.
3) The Wind Change Effect on Pitch Attitude
   Increasing the wind at FL170 by 30 kts in 10 seconds, resulting in the aircraft pitch increasing from –2.5° to –1.5°.
4) The Horizontal Stabilizer Effect on Pitch Attitude
   The typical horizontal stabilizer position during a constant 350 kt descent is 0.4 ANU. According to ADAS data, the horizontal stabilizer position of the accident aircraft was at 0.7 ANU position and

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[30] Continuous BIT: continuous built in test

[31] ARINC: Aeronautical Radio Incorporation data exchange specifications

[32] CWS: control wheel sensor

[33] CG: center of gravity

[34] ZFW: zero fuel weight

[35] V/S: Vertical Speed

therefore it may have been slightly out of trim. The simulator horizontal stabilizer trim was fixed at this value to re-create this condition but no noticeable change to the aircraft attitude resulted when the autopilot was disengaged, using the disengage switch.

5) The Effect of Spoiler Extension on Pitch Attitude
Attitude change for spoiler extension during both autopilot control and normal LSAS manual control flight was from –2.5° to +2.5°. During this autopilot operation study, the control column moved approximately 1 cm in the nose down direction (equivalent to approximately 1° CCP movement). In this study to simulate the momentary failure of the pitch control function of the FCC, the LSAS and the autopilot were turned off. This change in pitch attitude was studied by setting the flight conditions to those of JL706. The spoilers were extended in an identical manner and the simulator exhibited a similar increase in pitch attitude, as illustrated in the figure.

6) The Simultaneous Effect of Wind Change, Horizontal Stabilizer Change and Spoiler Extension
The pitch attitude changed from –2.5° to +5.0° when, as in the accident aircraft, the horizontal stabilizer was set to 0.7 ANU, the wind increased by 30 kt in 10 seconds and the spoilers fully extended. Shortly after this change, the RIB and LOB LSAS fail light illuminated, followed by all LSAS fail and an abrupt increase in pitch to approximately +30°.

7) The Effect of the Change of Outside Air Temperature (OAT) on the Indicated Air Speed (IAS)
A temperature decrease of approximately 5°C at FL170 was used to study the effect of the change of OAT induced by an inversion layer. The IAS increased between 4 to 5 kts in spite of the fact that the true air speed (TAS) remained nearly constant.

8) The Deceleration Effect of Spoiler Extension when the Flight Level Change Mode Selected Speed is Exceeded
A study was made on how long the aircraft would take to decelerate to 350 kts in Flight Level Change mode, with and without the use of the spoilers, after it accelerated from 350 to 365 kts as a consequence of encountering a 30 kt increase of headwind in a duration of ten seconds. The deceleration took 20 seconds without spoilers and 13 seconds with the use of spoilers. It was confirmed that the Flight Level Change mode with the use of spoilers exhibited sufficient deceleration characteristics when the selected speed was exceeded.

9) The Response of the Aircraft when the Autopilot is Manually Overridden by the Application of Force on the Control Column
When 20 lbs of force was applied and maintained on the control column in the nose up direction during autopilot operation, there was no change to the aircraft attitude. The Autopilot did not disconnect after this condition was maintained for more than one minute. When 40 lbs of force was applied to the control column in three seconds, there was a momentary increase of 1° in pitch but it returned to its original value. The autopilot, again, did not disconnect after this condition was maintained for more than one minute.

10) The Reaction of the Aircraft when the Autopilot is Disconnected by Overriding It
The study indicated that there was no great change to the aircraft attitude by overriding the autopilot and disconnecting it.

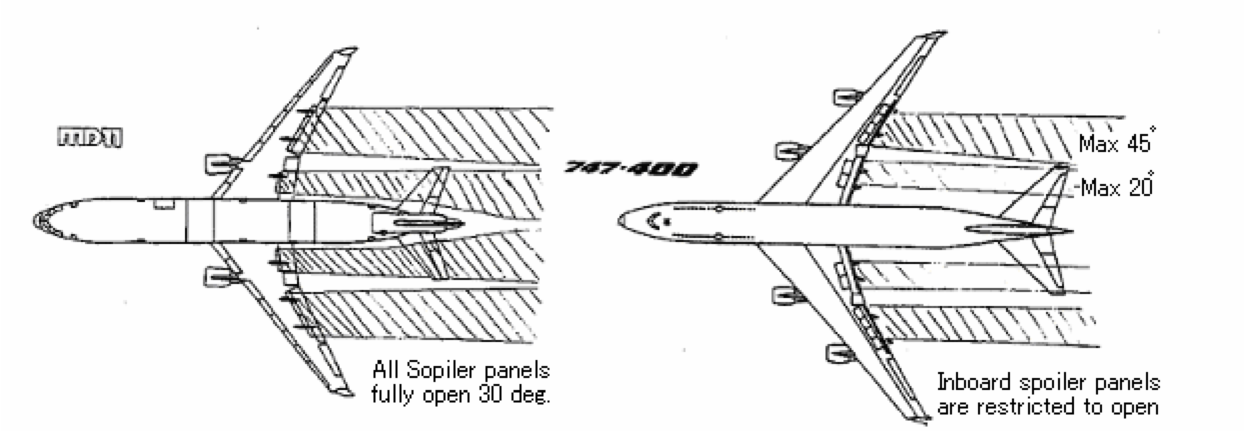
11) The CFDS Records when the Autopilot was Disconnected by an Overriding Force
A study was made on disconnecting the autopilot by applying an overriding force. It was found that it was not possible to disconnect the autopilot within 2 seconds by applying an overriding force. The autopilot was completely able to maintain aircraft attitude if the force was 20 lbs and that it did not affect the flight at all. Twenty more experiments were conducted using more than 20 lbs of force to find out the relationship between the time to autopilot disconnection after the application of more than 20 lbs of force and the logic of that caused the autopilot disconnection. The 14 autopilot disconnections that took place between 2 to 13 seconds were ACO disengagements, a result of G exceedances. Six CRM autopilot disconnections were recorded for disconnection that took place 14 seconds or more after the application of force. (See Attachment-5)

12) The Possible Forces that could be applied on the Control Column during Flight
The forces that the control column is subject to during normal flight was verified on the simulator.

It was found that a 170 cm pilot sitting in the left seat would apply a force of 4 to 8 lbs of pitch up force on the control wheel when the pilot raised his back from his seat and leaned forward to reach for the pitch wheel control. When the spoilers were extended, the autopilot, momentarily exerted a nose down force on the control column. When the pilot was holding the control column, this resulted in the pilot exerting a 10 to 12 lb force in the nose up direction, but this did not result in the autopilot disconnecting.

13) The Overriding Force Required to Disconnect the Autopilot
    Instruments were used to measure the manual overriding force required to disconnect the autopilot. It was found that a force of 50 lbs was required to disconnect the autopilot. However, although it was not impossible to exert such a force with only the left hand, it required a large amount of concentration and that such force was very difficult to put on the control column while performing normal procedures.
14) The Possibility of Causing Pitch Oscillation during Manual Flight
    Tests were conducted on the simulator to reproduce the five nose up and down oscillations that were recorded in the DFDR. It was found that, even with a conscious determined effort, it was not possible to continuously oscillate the nose up and down due to the LSAS Pitch Rate Damping function intervening and that such pitch oscillation ended after about two cycles.

1.16.7 Spoilers



Inflight speed brake

The spoiler system on the MD-11, functions as speed brakes during flight, with all the spoiler panels opening to an angle of 30°. In comparison, the spoiler panels close to the fuselage on the B747 are limited in travel, which prevents the wake from these inboard spoilers from adversely affecting the horizontal stabilizer aerodynamically. Spoiler wake is usually not considered a problem and evaluation on the simulator did not reveal anything to the contrary. However, when the angle of attack undergoes large fluctuations during flight in vertical vortices, the downwash from the wing may be in a different position from normal and possibly cause the wake from the spoilers to adversely affect the horizontal stabilizer.

1.17 Organizational and management information

1.17.1 Cabin attendant department policy

The Cabin Attendant Department promotes the sales of items during the flight as a measure to efficiently increase revenue. As shown in Attachment-8, a sales target is set for each route and the 100% attainment of this objective on each flight is strongly encouraged. Each group of 10 cabin attendants assigned to a senior cabin attendant is scored in accordance to the achievement of this goal and a graph representing their standing is displayed in the Cabin Attendant Department. Groups that have attained their objects are rewarded with prizes and cash. Individuals not associated with these groups that have attained their 100% objectives may be disadvantaged in their promotion.

1.17.2 Regulations for seat belt sign illumination

Japanese civil aviation regulations

Article 73: Captain Authority

The pilot-in-command (any person who performs the duty of the pilot-in-command whenever the pilot-in-command cannot perform such duties, hereafter the same shall apply) shall direct and supervise those who perform their duties on board the aircraft.

Japan Airlines operation manual

9-2-3 Seat Belts and Shoulder Harness

2. Cabin Attendant
   (1) During takeoff and landing and when the seatbelt sign is turned on, each cabin attendant shall take his/her assigned seat with his/her seatbelt fastened.
   (2) When, in-flight, the cabin attendants' leaving his/her seat is unavoidable while the seatbelt sign is on, he/she shall leave his/her seat with the PIC's[36] approval

9-3-2 Seatbelt Sign and the Use of Seatbelts by Passengers

1. The PIC shall turn the Seatbelt Sign on in the following cases
   (1) During takeoff and landing.
   (2) Flying in turbulent air conditions and when turbulence is expected.
   (3) In cases the PIC deems it necessary.
2. (2) When flying in turbulent air conditions or when the seatbelt sign is turned on, cabin attendants shall make passenger announcements to encourage passengers to comply with the sign. Furthermore, during cruise, if the sign is on for an extended period, cabin attendants shall, at proper intervals, encourage passengers with the instructions.

Cabin attendant manual（CAM）

Quoted directly from OM 9-2-3.

Cabin service bulletin supplement 123 issued 11 December 1991

This Cabin Service Bulletin Supplement issued by the Cabin Service Department of the Cabin Attendants Department was titled "Seatbelt Sign Procedures in the Operation Manual to be Revised"

1. The illumination of the "Seatbelt" sign is an indication that there is a high possibility of injury if people are not seated with their seatbelt securely fastened.
2. When the "Seatbelt" sign is illuminated during turbulence, cabin attendants should not directly check that the passengers are seated and have fastened their seatbelts but should use the PA system to announce to the passengers to do so.

With the issuance of this bulletin, the illumination of the seatbelt sign was revised from being a "warning" to the principle that all cabin attendants were to be seated and to have their seatbelts fasten. This was to be accomplished as soon as they had secured all dangerous items in the galley, had the passengers return to their seats and had taken other necessary minimum safety measures. However, when ample time is given in advance during cruise, or if there is no danger of turbulence during descent, cabin attendants are to visually check that all passengers had been seated and had fastened their seatbelts.

1.18 Additional information

1.18.1 Similar cases to the accident aircraft in Japan Airlines

1) JL724 (MD-11, JA8580) after taking off from Narita, in May 1995, displayed the "LSAS CH FAIL (LOB & RIB) alert message. The alert message disappeared after Autopilot-1 was engaged. Subsequent maintenance action replaced FCC-2 and the captain's side RCWS[37] sensor.

2) On 8 March 1998, the autopilot disconnected and JL724 (MD-11, JA8580) abruptly pitched up when the autopilot switch was pushed during cruise. The message "E-CRM" in FCC-2 was recorded in the

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[36] PIC: pilot in command

[37] RCWS: roll control wheel steering

Fault Display System but subsequent maintenance action could not find the fault. FCC-2 was replaced for troubleshooting.

3) On 18 March 1998, Autopilot-1 disengaged and JL708 (MD-11, JA8580) abruptly pitched up when the autopilot switch was pushed. The message "E-CRM" in FCC-2 was recorded in the Fault Display System but subsequent maintenance action could not find the fault. FCC-2 was again replaced for troubleshooting.

According to Japan Airlines, the number of FCC removed from its fleet of MD-11 in 2001 was 31 units. Of these 31 FCC units, the cause of the fault could only be determined in 2 of the units.

1.18.2 The Characteristics of the MD-11 flight control system

Dr. Ralph A. Harrah, a research engineer for NASA, has published a report on the reaction time delay of flight control systems and controllability of aircraft. It is stated that the time delay from the initial pilot input to the control column to actual control surface movement is the principle cause of APC (Aircraft-Pilot Coupling) or PIO (Pilot Induced Oscillation).

> The result of a small amount of dynamic distortion (for example, a modest delay of 0.10 to 0.15 seconds between the pilot's control input and the control surface output typical for today's aircraft) may cause a momentary loss of control during an aggressively flown recovery from an upset. The pilot's impression this APC encounter will be that the incident may have been the result of an external disturbance, or pilot over control. From a hull loss perspective, such instances of momentary loss of control would be catastrophic only if there was contact with the ground or another aircraft, or the structural limits were exceeded. However, passenger discomfort/injury is likely, particularly if passengers are unbelted.
>
> The results of substantial dynamic distortion (caused by a delay of greater than 0.2 of a second between the pilot's control input and the control surface output) can result is such discordant aircraft responses to the pilot's control input that the pilot becomes convinced that the control is broken. Substantial dynamic distortion is the result of the pilot "over driving" the cockpit control beyond the surface actuator (or software) rate limit and/or the control surface deflection (or software) limit. Such "over driving" might be expected during a flight saving recovery to counter a large upset in close proximity to the ground, or an impending mid air collision.

APC has been experienced on many modern aircraft and occur in spite of the fact that sufficient training based on the lessons learned in the past and extensive use of the simulator have been implemented. This problem can be solved if the problem of APC was acknowledged.

In December 1988, APC test flights were conducted by 7 test pilots and 5 flight test engineers from the FAA. These tests were conducted on an actual aircraft that could simulate changes to the flight control system. In spite of the fact that all participants had been thoroughly taught and undergone simulator training, several of the test flights almost crashed. The safety pilot had to intervene and return the flight control system to normal in order to recover from the situation.

It should be realized that time delays should be less than 0.15 seconds and that there is a potential danger in delays of 0.2 seconds.

Due to the fact that the problem of APC in accident statistics has not been determined yet, 50% of accidents are still attributed to "pilot error." Similarly, APC could account for some of the causes in the 30% "cause unknown" category. To determine the cause as APC related, it is necessary to increase the data rate of information. A solution is possible if APC is recognized as a causal factor. On the other hand, if APC is not recognized and "pilot error" is chosen as the default cause, the true cause of these accidents will remain hidden.

Handling Qualities	Time Delay	Control Characteristics
Level 1	0.10 sec	Adequate Control Characteristics
Level 2	0.20 sec	Degraded Control Characteristics
Level 3	0.25 sec	Pilot not able to respond adequately

The JAAIC JL706 Accident Report indicates that McDonnell Douglas information determined the time delay in the MD-11 to be approximately 0.2 seconds, putting this aircraft in the Handling Quality Level 2 category. PIO occurs when a pilot endeavors to control the aircraft attitude, but it is necessary that the pilot is integrated into the closed loop dynamics of the aircraft control system. In other words, it is necessary that the conditions for the pilot to be able to determine the attitude of the aircraft and adequately apply corrective control to the aircraft be satisfied.

1.19 Useful and effective investigative techniques

None

2. ANALYSIS

2.1 Meteorological analysis

1) Summary

The accident aircraft was descending at approximately 3000 fpm until slightly after 10:48:25 when it started a slight climb. From 10:48:25 to 10:48:43, the aircraft climbed approximately 500 feet in altitude after which, at 10:48:44, it started to descend again. Changes to the OAT[38] and wind direction and speed started to occur from 10:47:55. The OAT best depicts the atmospheric conditions of this area. Within a layer, 1500 feet thick, the atmosphere showed remarkable change as it switched from standard lapse rate to constant temperature, to inversion, to turbulent, to inversion, to constant temperature and then back to standard lapse rate.

To compare the atmospheric condition until 10:47:57 and after 10:48:59, an adiabatic calculation of the air masses to mean sea level was made. The difference of the air masses can be seen in the difference in temperature, the former being 30.4°C and the latter 25.4°C.

2) Atmospheric Conditions until 10:47:57 (Normal Lapse Rate)

The atmosphere was approximately close to standard, with a lapse rate of about 2°C per 1000 ft (standard lapse rate), until about 10:47:57.

3) Atmospheric Conditions after 10:47:57

10:47:57 (18,352 ft): changes start to occur in the wind direction and speed

The wind direction changes 60° in the counter clockwise direction in 30 seconds. The wind speed increases 5 kts in 8 seconds.

10:48:00 (18,298 ft): constant temperature layer (13 seconds)

The atmosphere temperature increased at the standard lapse rate until 10:48:13 when it stopped increasing and remained constant through an atmospheric layer of approximately 900 feet.

10:48:10 (17,617 ft): the wind remains constant at 37 kts for 5 seconds

10:48:13 (17,405 ft): inversion layer (11 seconds)

The atmospheric temperature lapse rate reverses from temperature increase with the decrease in altitude to an inversion layer where the temperature decreases with descent. This was recorded until 10:48:24, through an altitude layer of approximately 700 feet.

10:48:24 (16,709 ft): turbulent layer (20 seconds)

The aircraft starts a slight climb after descending constantly until this time. An 18 second duration of rapid changes, temperature inversion, decrease in wind speed and changes in wind direction occur.

10:48:37 (17,057 ft): The OAT increases at 1.4°C/second, equivalent to a lapse rate of 25°C/1000 ft when standard atmosphere dictates 0.1°C/second. It is inferred that a vertical vortex formed due to the mixing of warm and cold air. The wind direction and speed went through abrupt changes, with the direction stabilizing after the change.

10:48:38 (17,085 ft): The peak height of the aircraft's climb is recorded about 7 seconds later.

The aircraft only climbed about 50 feet, the OAT rose 1.5°C and then at 10:48:47, passing

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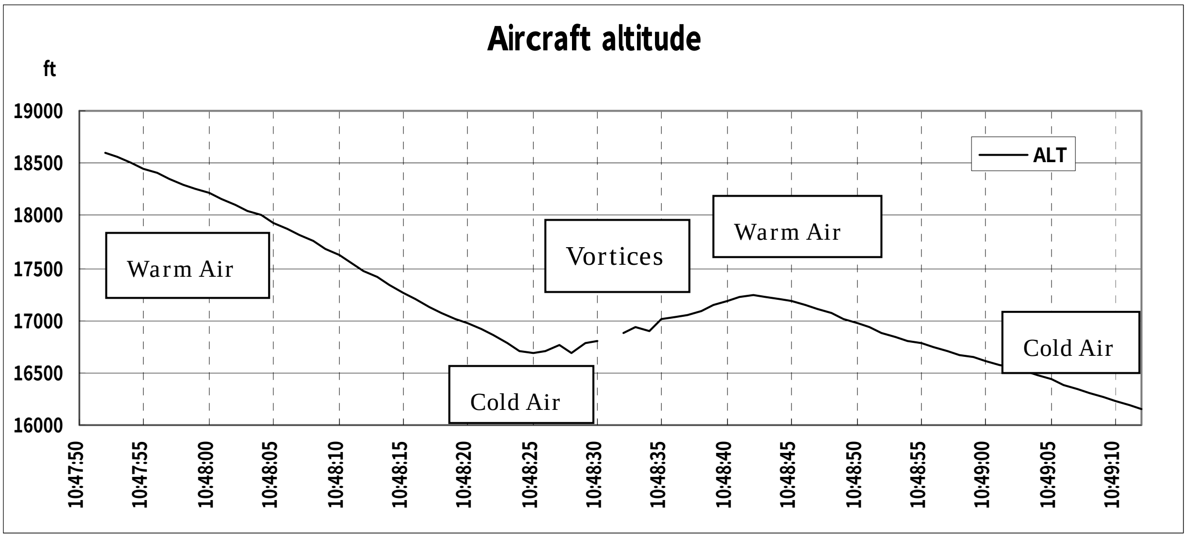
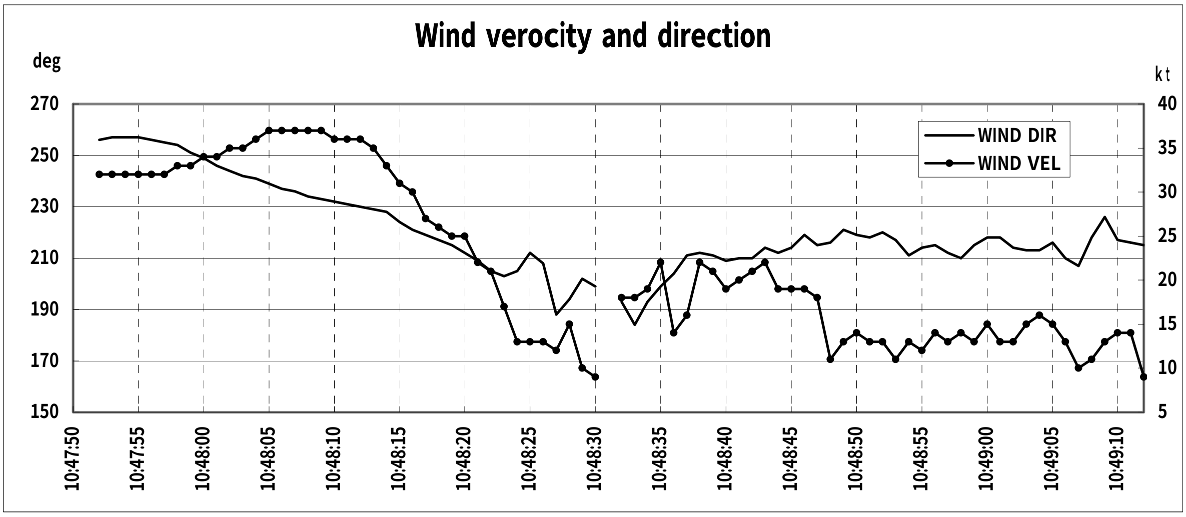
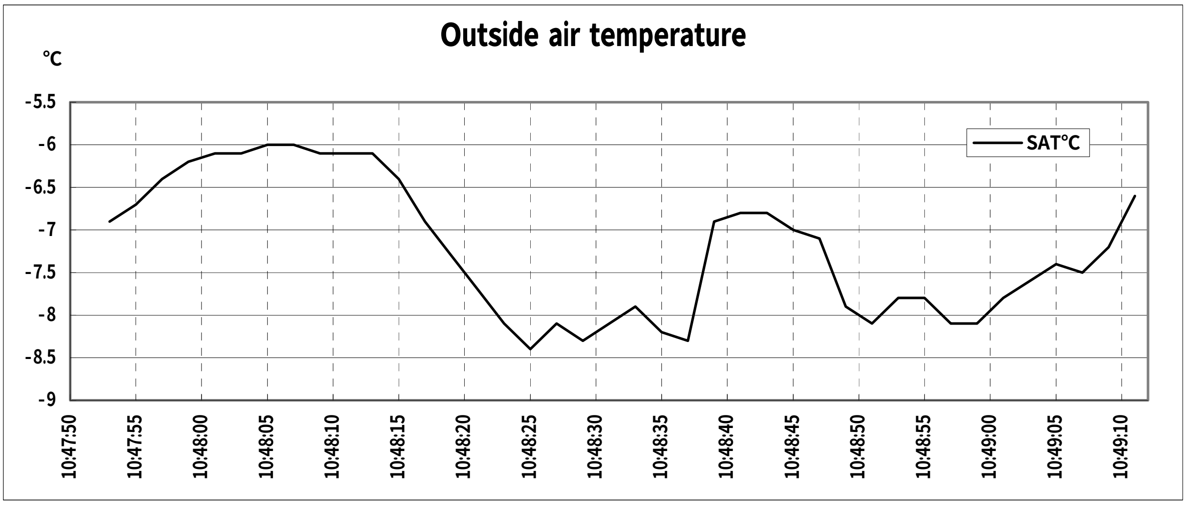
[38] OAT: outside air temperature







Warm Normal layer	Constant Temp layer	Temp Inver. layer	Turbulent layer	Tmp Inv lyr	Const Temp layer	Cold Normal layer

through 17,111 feet, decreased 0.8°C in one second. This is an indication that warm air was flowing into the area above approximately 17,100 feet.

10:48:42 (17.233 ft): The aircraft reached the peak of its climb here and the changes in wind direction and speed seems to stop here. However, it can be deduced that the boundary between the warm air and the cold air below is in this area.

10:48:44 (17,200 ft): Inversion Layer (6 seconds)

The OAT decreased after which the rate of change dropped. At 10:48:59, the aircraft entered a layer of constant temperature and then for the remainder of the descent, a condition very close to the standard lapse rate was recorded.

This condition of the atmosphere on the route of descent was caused by the low pressure system that was approaching the Kii Peninsula, causing the warm air that it brought with it from the Kyushu/Chugoku area to rise above the cold air that existed over the Kinki/Chubu area. This indicates that there was an area of atmospheric discontinuity brought about by the very prominent temperature difference of the converging air masses along the air route above the Shima Peninsula between the altitudes of 18,200 to 16,600 feet.

2.2 The rapid increase in indicated air speed

The following conditions were deduced from a comparative study of the route of descent of JL706 and the data on the atmospheric conditions at the time.

1) Although there were slight changes in the wind direction and speed, the atmospheric condition could be considered stable during this part of the descent until 10:48:00.
2) The aircraft entered a constant temperature zone from about 10:48:00 but a change in the wind direction increased the head wind component and increased the calculation burden on the FCC.
3) From 10:48:10 the aircraft entered an inversion layer where the OAT decreased and causing an IAS[39] increase. In addition, a decrease in the wind speed caused a loss in the tail wind component and further increased the IAS. The FCC could not keep up with this sudden change in IAS and was temporarily unable to function properly.
4) About 10:48:24, the aircraft entered an area of turbulence and experienced a large G force due to a vertical vortex, which also caused abrupt irregular changes to the angle of attack. These variations caused the down wash from the wing to change their course, causing the turbulent wake from the spoilers to change their path of flow.
5) The aircraft lost stability as it flew this turbulent area. It affected the aircraft aerodynamically and with the degradation in the performance of the FCC, caused it to pitch oscillate five times. At about 10:48:40, the aircraft left the turbulent layer and entered the inversion layer. Here, the air mass was less turbulent and with the spoilers retracted, the pitch oscillation started to converge and the flight crew was able to determine the attitude of the aircraft.
6) The aircraft attitude settled down as, from 10:48:45, it flew through an inversion layer, then a constant temperature layer and then into a normal air mass at an interval of several seconds each. This is recorded as a gradual decrease in the oscillation of the nose and a transition to normal descent parameters.

The change in the tail wind component to the aircraft at 10:48:10 (17,700 ft) from 9 kts to a head wind component of 15 kts at 10:48:25 (16,750 ft) caused Vmo to be exceeded. The airframe was subjected to a vertical wind shear (VWS) of 25 kts/1000 ft.

The filtered air speed that the autopilot uses starts to diverge away from the actual air speed when the MD-11 autopilot encounters a wind component change that exceeds 1 kt per second,. At the time of the accident, the head wind component varied from 1.7 to 2.8 kts/second and in spite of the fact that the IAS should have been about 360 kts at 10:48:21, the filtered air speed was about 350 kts. This resulted in the aircraft autopilot not being able to cope with this increase in IAS in a timely manner.

---

[39] IAS: indicated air speed

2.3 The initial pitch up of the aircraft

The flight path of JL706, took the aircraft through a constant temperature zone from 10:48:00 to 10:48:13, an inversion layer from 10:48:13 to 10:48:24 and a unstable layer from 10:48:24 to 10:48:45. At the same time, although the wind was relatively stable in terms of direction and speed between 10:47:57 to 10:48:23, they varied irregularly from 10:48:23 to 10:48:36. This unstable state of the atmosphere indicates the possible existence of an exceptional vertical vortex in the area. The changes in OAT, wind direction and speed, the angle of attack, the IAS and G limit probably overwhelmed the computation capability of the FCC. Therefore, the FCC was unable to accomplish the necessary calculations and had momentarily failed. (See Attachment-6)

The assumption of a temporary failure of the FCC can be seen from the following facts:

□ The Flight Level Change mode has a G Control function designed into it to maintain the vertical G of the aircraft to within the tolerance of ±0.07G. The ADAS recordings indicate that from 10:48:15 to 10:48:20, the aircraft had exceeded this 0.07G limit for five seconds.

□ Just prior to autopilot disconnection, for two seconds from about 10:48:23.5, the G on the aircraft diminished to 0.77G. however, in spite of this, the autopilot did not move the elevators to raise the nose to increase the G value to within the acceptable parameters, but instead had moved them in the opposite direction of pitching the nose down to exasperate the situation.

□ At 10:48:15, the autopilot did not react when the PIC tried to pitch the nose of the aircraft up by turning the pitch wheel several times to counter the rapid increase in IAS. The fact that the autopilot does not respond to the Pitch Wheel when it is in the overspeed protection mode, but, according McDonnell Douglas information, between 10:48:15 to 10:48:20, when the pitch wheel was used, using filtered airspeed signal the FCC was receiving data below the overspeed protection threshold of Vmo-3 kts or 362 kts should be noted. This phenomena suggests that the overspeed protection mode had not activated but instead that the FCC was not able to sense the signal from the pitch wheel. The movement of the horizontal stabilizer of the accident aircraft was studied using ADAS data. The RIB elevator position angle of the FCC controlling the aircraft, for nine seconds from 10:47:59 to 10:48:08 and for seven seconds from 10:48:17 to 10:48:24, was out of its neutral position ±1.35° for over 3 seconds each time.

The temporary failure of the FCC is apparent from this state of the aircraft. When the spoilers were extend in the simulator with the FCC disabled, it displayed a strong resemblance in the rate of pitching up to the accident aircraft. The autopilot was strongly suspected not to be able to make the necessary correction to the pitch up that started at 10:48:23.5 due to the temporary failure of the FCC. It is presumed that it was not able to overcome the nose up displacement of the horizontal stabilizer, the sudden increase in head wind component and the pitch up tendency caused by the extension of the spoilers.

2.4 Autopilot disconnection

The conditions for automatic disconnection of the autopilot according to the MD-11 AOM are:

1. Vertical G forces exceeds 1 ± 0.6 G ～ 1 ± 1.4 G
2. Roll Rate exceeds 10°/ sec
3. Bank Angle exceeds 60°
4. When the autopilot detects a discrepancy between its control commands and the position of the control surfaces due to pilot override control or other reasons.

Conditions 2. and 3. of the above will not be considered because they are not applicable to this accident.

When the aircraft exceeded 1.6G between 10:48:25 to 10:48:26, according to the flight recorder and condition 1., the autopilot should have automatically disconnected. Therefore to consider the probability of an autopilot disconnection due to exceeding the defined G limit is a possible, the CFDS autopilot disconnection record should have been “ACO” but it was “E-CRM” on JL706. Consequently, disconnection was not due to G exceedance.

The E-CRM function, condition 4. of the above, monitors the autopilot and disconnects it when it malfunctions. This is the function that disconnects the autopilot when there is a discrepancy between the elevator position and the FCC commanded elevator position signal of 4° or more for a defined duration of time (difference x time ≥ 4° second; minimum of ⅔ seconds). When the autopilot is over ridden by the pilot exerting force on the control column, the elevator is forced away from its FCC commanded position and presumably leaving the fault record of "CRM." However, the PIC of JL706 testified that he did not over ride the autopilot. When the autopilot disconnects, 2 to 3 seconds, after an effective pressure is applied to the control column, the cause should be a G exceedance ACO and not CRM. Therefore, the cause of the autopilot disconnection on JL706 is not the activation of CRM due to an overriding force.

From the fact that since at the time of the accident, FCC-2 was not functioning properly, the FCC continuous BIT function sensed an abnormality in the input data, CPU, memory, D/A & A/D converters, AC/DC power supplies, LVDT & synchro, output discrete, time magnitude monitor, or CWS, and shutoff the hydraulic supply to the control valve in the PCU and stopped the elevators from following the FCC commands. It can be presumed that when this occurred, the difference in the actual position of the elevator and FCC control signal exceeded defined conditions and the CRM function disconnected the autopilot. (Attachment-7)

2.5 The pitch oscillation of the aircraft

A characteristic of the Super Critical wing on the MD-11 is that its aerodynamic center moves with changes in flight conditions, such as, the creation of a shock wave due to the airspeed increase, spoiler extension, or the separation of the airflow over the wing occurring due to abrupt changes in the attack angle of the wing.

The fact that the MD-11 has inboard spoilers close to the fuselage and that open to the full inflight angle of 30° and that the wake from the spoilers can, depending on the aircraft attitude, have an aerodynamic effect on the horizontal stabilizer should be noted. Under such conditions, with the elevators exposed to this wake, their effectiveness can be reduced and make control of the aircraft very difficult.

Some attribute the five pitch oscillations that occurred to JL706 as result of PIO (pilot induced oscillation) but this phenomena is the result of the pilot recognizing the response of the aircraft and intervening to correct the situation. In other words, the pilot is in the control structure loop and recognizes the aircraft attitude, and over controls the aircraft with excessive inputs in an effort to neutralize the pitch changes. PIO can be ruled out in the case of JL706 because identification of the instruments was not possible due to the large G changes that the PIC were experiencing, and that it was after sunset, the area was covered with clouds exasperating recognition of the situation. It was therefore not possible to attempt to administer the corrective control inputs necessary to satisfy the definition of PIO.

The pitch rate damper function of LSAS, always in the aircraft control system loop during manual flight, reduces the G forces by sensing the pitch rate change to the aircraft. A close study of the pitch changes and elevator movements that occurred after autopilot disconnection, shows that the elevators moved in the pitch up direction shortly after the large pitch rates recorded during the pitch down movements of 10:48:27 to 28, 10:48:30 to 31, 10:48:34 and 10:48:37, and that they moved in the opposite pitch down direction when the aircraft showed large pitch rates in the up direction at 10:48:29, 32 and 35. This is a very strong indication that the pitch rate damper function was controlling the elevators. In other words, the LSAS pitch rate damper was trying to control the pitch rate when it sensed the abrupt pitch changes after it started functioning when the AP-2 disconnected during an abrupt aircraft pitch up.

The pitch rate damper function, which is designed to suppress the pitch oscillation of the aircraft, was unable to effectively do so because the horizontal stabilizer was in the wake of the spoilers during this period and the elevators lost their aerodynamic effectiveness in this turbulent wake. As the pitch increases, the horizontal stabilizer goes down below the turbulent wake, the elevators enter the regular airflow, become effective and the aircraft pitches down causing the horizontal stabilizer to re-enter the turbulent wake and lose its aerodynamic effectiveness. The aircraft is believed to have pitched up again due to the fact that the horizontal stabilizer might have rose above the turbulent wake and the elevators that the pitch rate damper was controlling became effective again and/or due to the pitch up moment from the extension of the spoilers.

The clear difference in the fifth pitch oscillation from 10:48:38 to 41, compared to the preceding four, indicates that after the spoilers were retracted after 10:48:37, the pitch moment of the spoilers and their turbulent wake ceased. It can be assumed that the horizontal stabilizer regained its effectiveness as a result and the controllability of the aircraft restored.

2.6 Regulations concerning the fastening of seatbelts in the cabin

The regulations stipulating immediate seating and the fastening of the seatbelt when the Fasten Seatbelt sign is illuminated are the same for both the Cabin Attendants and Flight Crew. However, Cabin Service Bulletin Supplement 123, distributed to the cabin attendants indicates the following:

> Cabin attendants should, in principle, be seated as soon as the minimum safety measures are taken. However, if information has been received during cruise that there is ample time before the turbulence or that there is no turbulence forecast on the route for arrival, then a visual confirmation, as previously conducted, should be made to verify that the passengers have fastened their seatbelts.

This explanation is a source of confusion among the cabin attendants because it can be interpreted as if the captain has given permission for the cabin attendants to leave their seats. Also the phrase concerning a forecast seatbelt sign and a sudden illumination of the seatbelt sign during cruise is not differentiated and ambiguous.

The Cabin Attendant Department, as a means to increase revenue, conducts inflight sales of items. A sales target is set for each route and each cabin attendant group is graded on the attainment of this objective with the results being displayed in the department. Highly ranked groups receive cash rewards and individuals associated with these groups are promoted. This type of scheme fosters a climate where individual cabin attendants interpret this sales policy as a very high priority item during the flight.

Additionally this scheme presents an additional burden on the cabin attendants because when a customer submits a claim, even though the illumination of the seatbelt sign had prevented adequate cabin service, they are required to submit a report to their superior or are interviewed personally by them. This practice of the cabin department organization and managers encourages cabin attendants to take risks in continuing cabin services under unacceptable conditions rather than obeying the safety instructions from the captain of the flight.

2.7 Emergency response

The transportation of the injured was delayed due to the fact that in spite of the request for the ambulances being made to have them waiting at “shipside”, they were standing by outside of the airport. The fact that the cabin attendant that had received serious injury to her head was transported out of the airport, 49 minutes after arrival, may have contributed to the complications in her medical condition.

3. CONCLUSION

3.1 Cause of injuries

It can be presumed that the cause of the injuries was a result of the turbulence that the flight encountered. It can also be presumed that the fact that the injured had not obeyed the safety instructions from the captain on the anticipated turbulence and did not have their seatbelts fasten properly was a major factor. It should be especially noted that all the cabin attendants were continuing their tasks as normal and were not seated with their seatbelts fastened. The cabin department policy of promoting inflight sales, rewarding such activity and using these results in the evaluation of the individual cabin attendant was a contributing factor. This policy cultivated a culture where instead of obeying the captain's safety instructions they feared complaints from passengers that might be made if adequate cabin service was not accomplished in spite of the seatbelt sign was on. This was exasperated by the policy that if such a claim was made by a customer, the cabin attendant would be required to submit a written report or be interviewed by a superior concerning the details of the failure to satisfy the customer. This culture of placing a greater weight on inflight sales and fulfilling the services that the passengers wanted over the captain's safety instructions and regulations bred this climate that undervalued the importance of safety over other issues.

The Operations Manual, the highest priority regulatory document within the company, stipulates that when the fasten seatbelt sign illuminates during flight all crewmembers are to be seated and to secure their seatbelts. This Operations Manual paragraph is quoted in the Cabin Attendants Manual. On the other hand, the document that was distributed to all the cabin attendants to explain seatbelt procedures says,

> "When minimum safety precautions, such storing items that might be a cause of injury and securing cabin service carts in their storage bins, have been accomplished, the cabin attendants are to be seated immediately."

There is no explicit explanation of the requirement to be seated immediately when the seatbelt sign goes on in cases where turbulence conditions are forecast and when there is time to make preparations prior to the turbulence. There was probably a confused understanding of situation and when the seatbelt sign is illuminated without prior warning. Members of the Cabin Department probably presumed that the cabin attendants were permitted to continue their required procedures before being seated. As a result, there is a high probability that the Flight Crew Department's interpretation that everybody was to be seated with their seatbelts fasten when the fasten seatbelt sign was illuminated was not understood in the same manner in the Cabin Department.

3.2 Pitch oscillation of the aircraft

It can be assumed that the abnormal pitch attitude changes following the increase in airspeed during descent was a result of the compound reaction of the following:

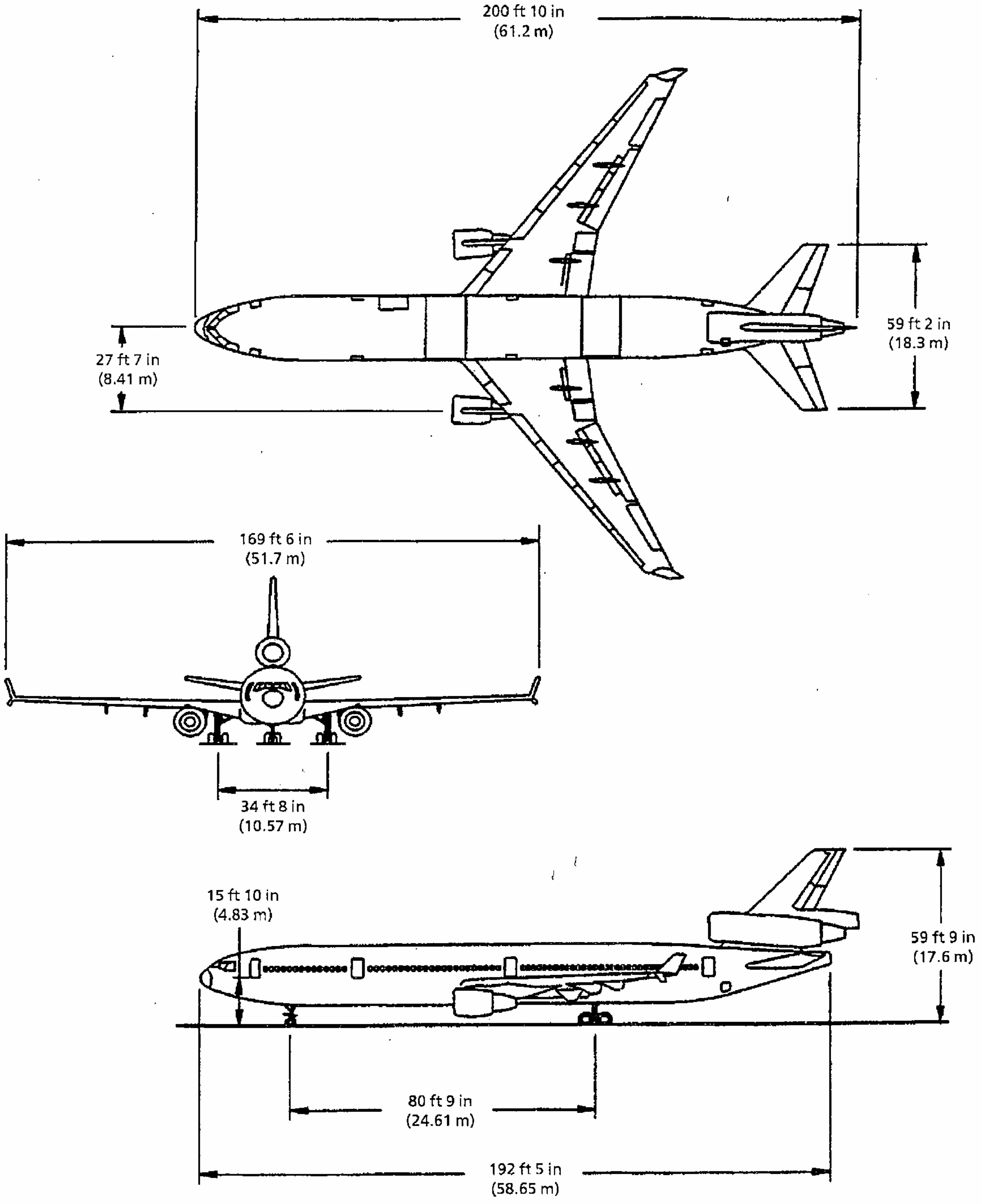
1. The aircraft was in a stable descent of 350 kts at an attitude of -3° until about 10:47:58 when it start to decelerate due to a wind change. The autopilot pitched down to a -4.5° pitch attitude to accelerate to the commanded speed and the indicated airspeed ceased to decelerate at 10:48:07, after which it started to increase. As the airspeed returned to its commanded value, the autopilot gradually started to pitch back up to -3° but during this process, at 10:48:13, the tail wind component decreased abruptly resulting in a sudden increase in the indicated airpseed.
2. The autopilot was not able to manage this increase in airspeed by controlling the pitch angle of the aircraft due to the fact that:
   a. The G control function of the autopilot prevented it from expeditiously increasing the pitch angle of the aircraft.
   b. The "filtered" airspeed that the autopilot was using prevented it from sensing the abrupt increase in airspeed that caused it exceed Vmo. The "filtered" airspeed fed to the autopilot was substantially lower than the actual airspeed that would have caused the autopilot to increase pitch to decelerate.
   c. The complex changes, due to the inversion layer, that the outside air temperature, wind direction and speed that the atmosphere underwent, cause the FCC to intermediately suffer malfunctions that prevented the autopilot from functioning normally.
3. The fact that the autopilot was not able to respond to the pitch wheel input during the rapid acceleration was due to the FCC momentarily not being able to function during the flight through the inversion layer in the unstable atmosphere.
4. The aircraft pitch increase that started at 10:48:23.5 was a result of the horizontal stabilizer being in a slightly pitch up position, the pitch up moments induced by the extension of the spoilers and rapid increase in the indicated airspeed. At 10:48:00, the rapid changes that the atmosphere

underwent caused the FCC to partially or intermittently malfunction preventing the autopilot from coping with this increase in pitch attitude.

5. The autopilot disconnected because the FCC E-CRM function had sensed that the difference in the FCC commanded elevator signal position and the actual elevator displacement had exceeded the defined limit. This was due to the malfunctioning of the FCC that shutoff the hydraulic power to the elevator PCU and prevented the elevators from moving to their commanded position.
6. The five pitch oscillations that followed the initial pitch up resulted from the captain not being able to steady the control column due to the aircraft being tossed around by the turbulence. The LSAS pitch rate damper function controls the elevators so as to dampen the G forces on the aircraft. Not only were these elevators, which were moving in and out of the turbulent wake produced by the extended spoilers, not able to adequately control the pitch of the aircraft but the situation was compounded by the fact that the pitch rate damper was contributing to the pitch oscillation of the aircraft.
7. The retraction of the spoilers stabilized the aircraft attitude at 10:48:40 because it eliminated the turbulent wake that the spoilers were producing, allowing the elevators to become effective again and control the aircraft. Also, the departure of the aircraft from the unstable atmospheric layer enabled the flight crew to determine the proper aircraft attitude.

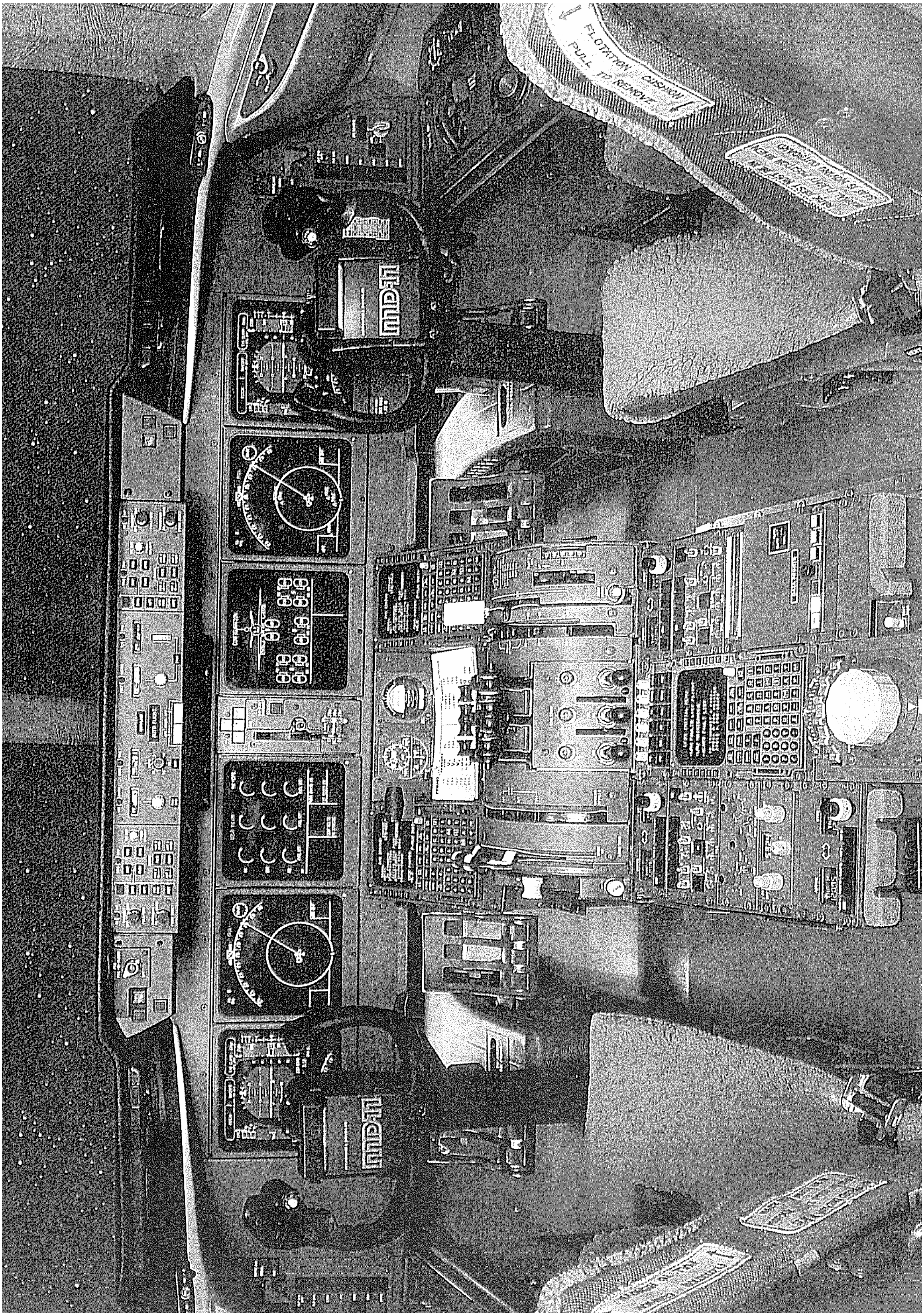
Appendix 1-1

DIMENSION

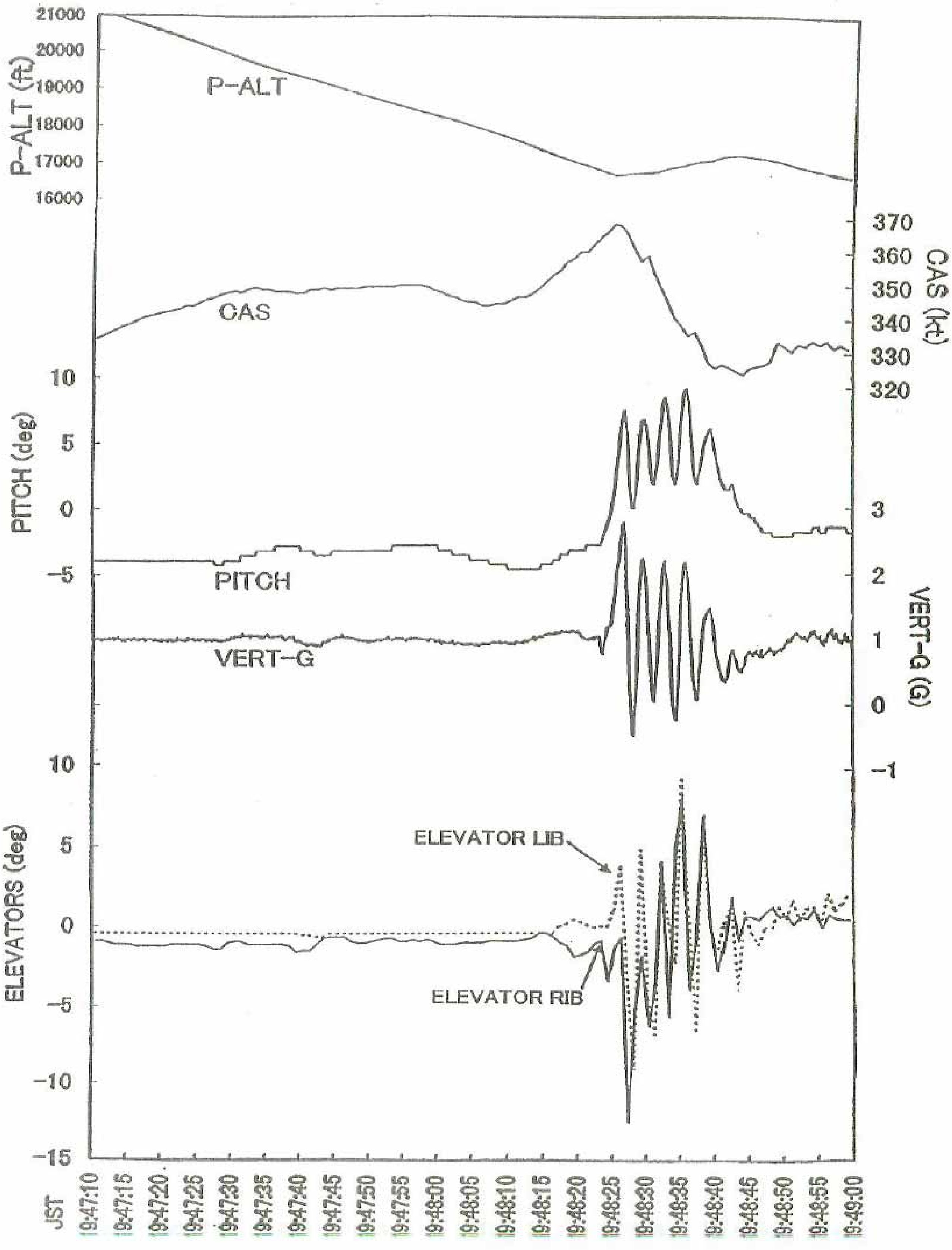


MD-11

Appendix 1—2

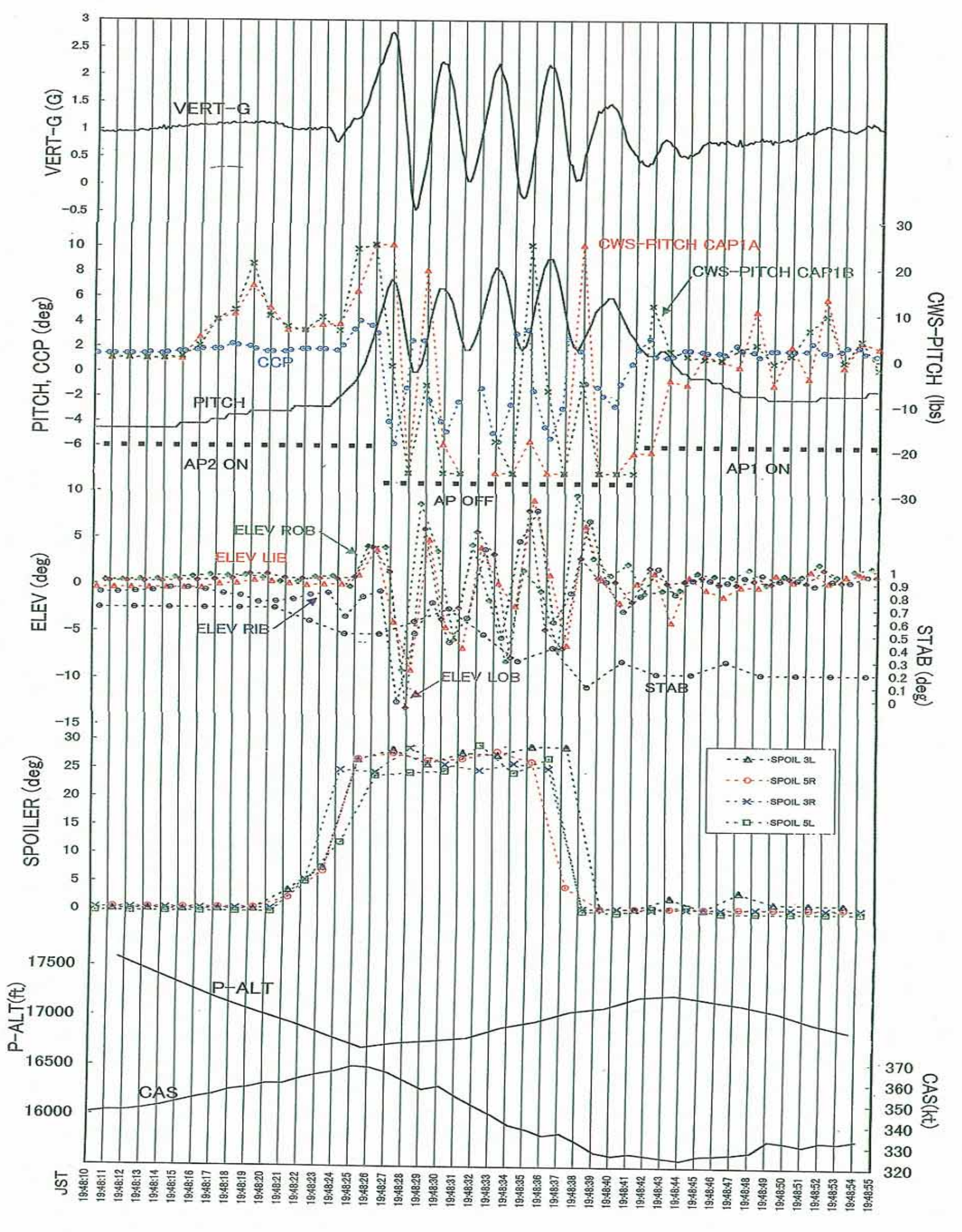


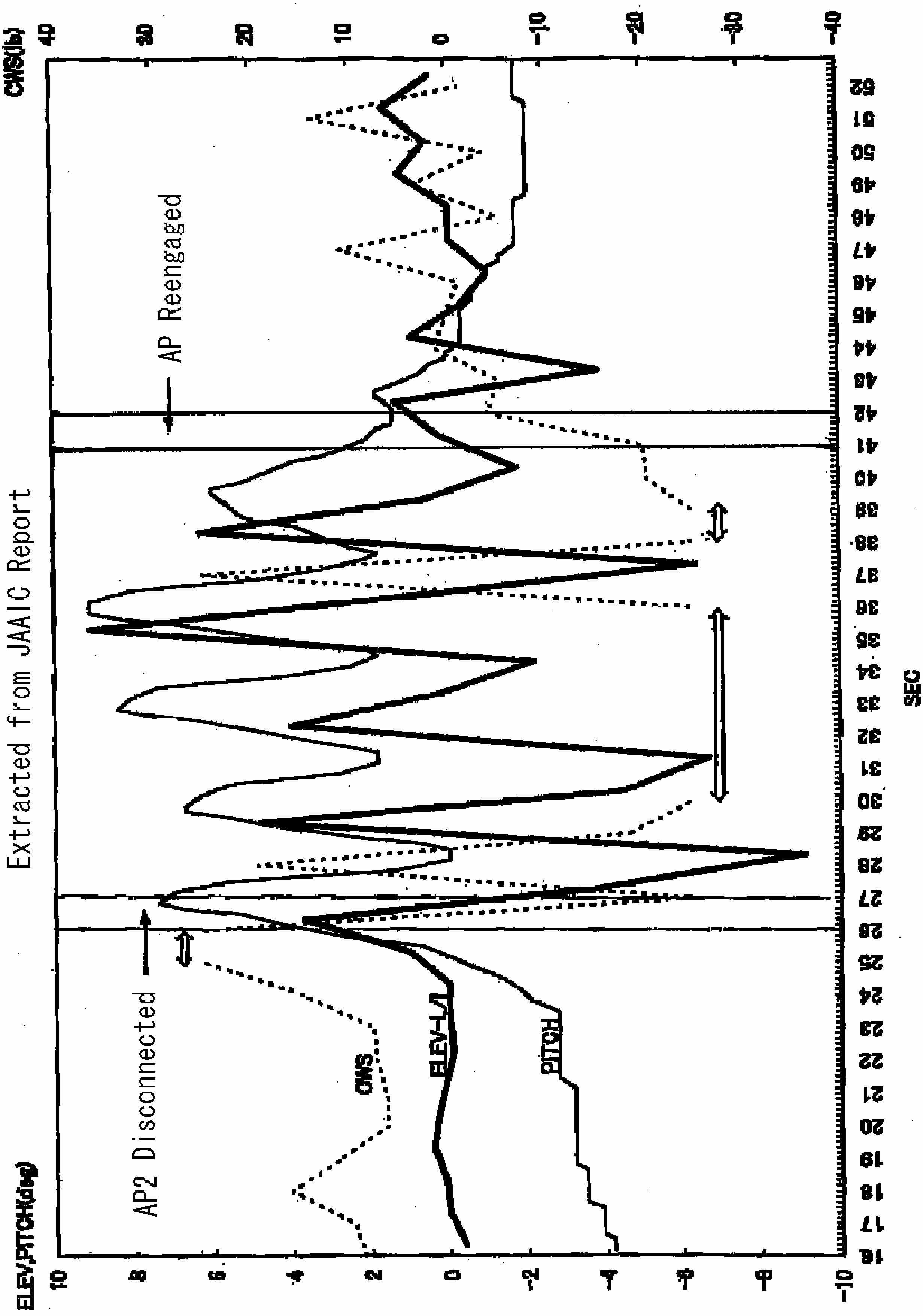
DFDR Records (Extracted from JAAIC Report)



Appendix　2－2

DFDR&ADAS Records (Extracted from JAAIC Report)

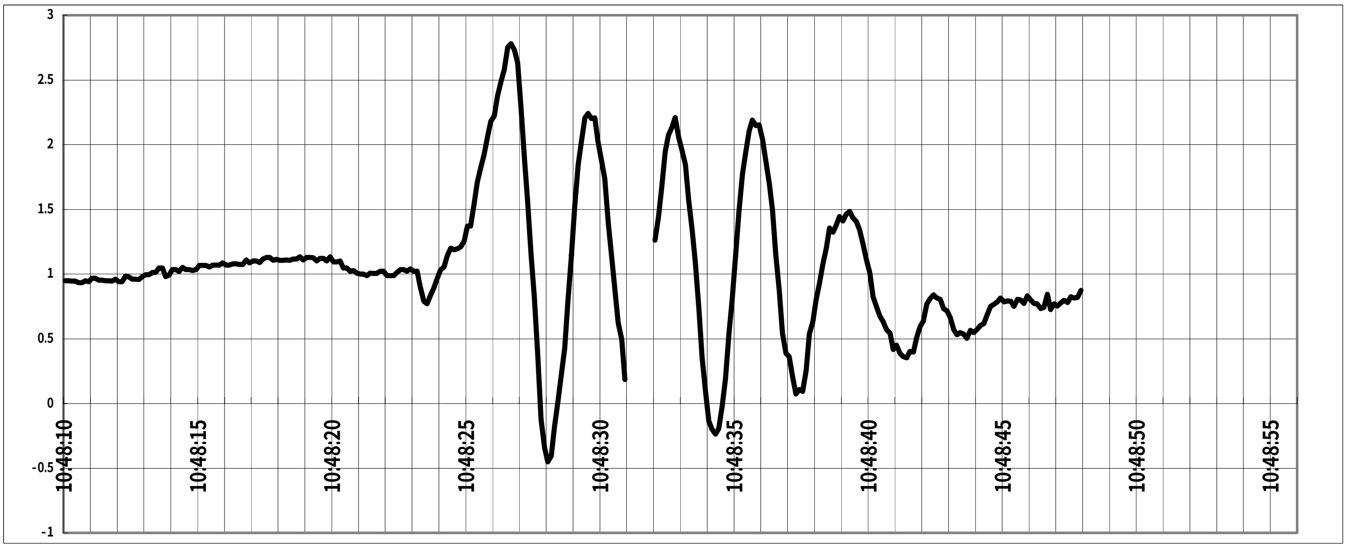




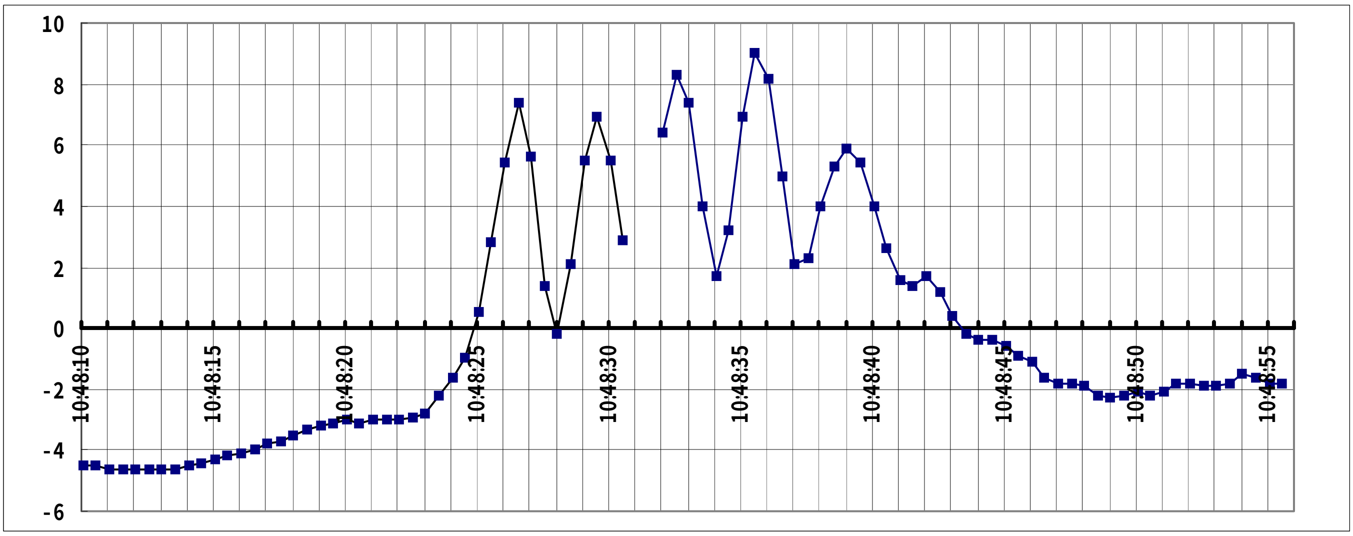
CWS ELEV-L/1 PITCH

Extracted from JAAIC Report

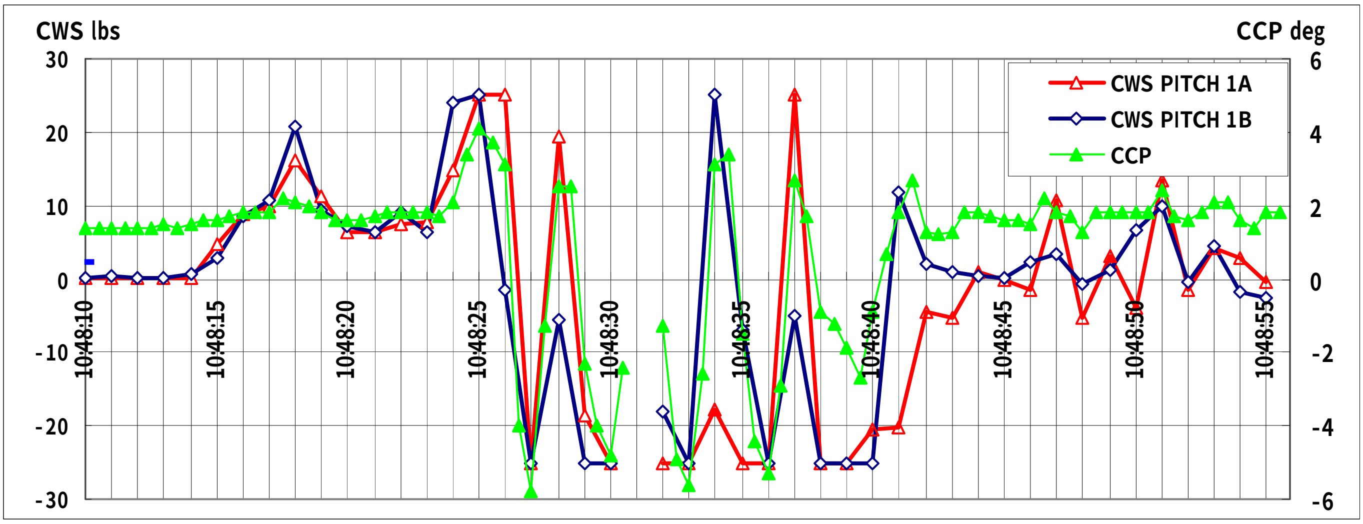
Vertical G



Pitch

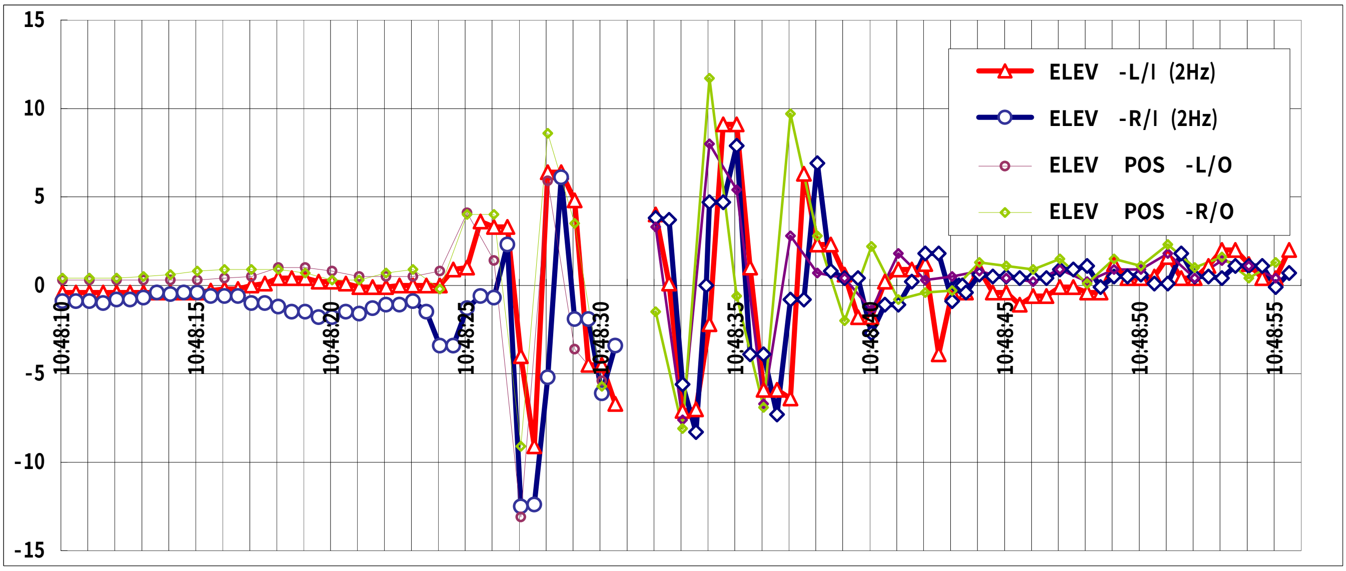


CWS, CCP

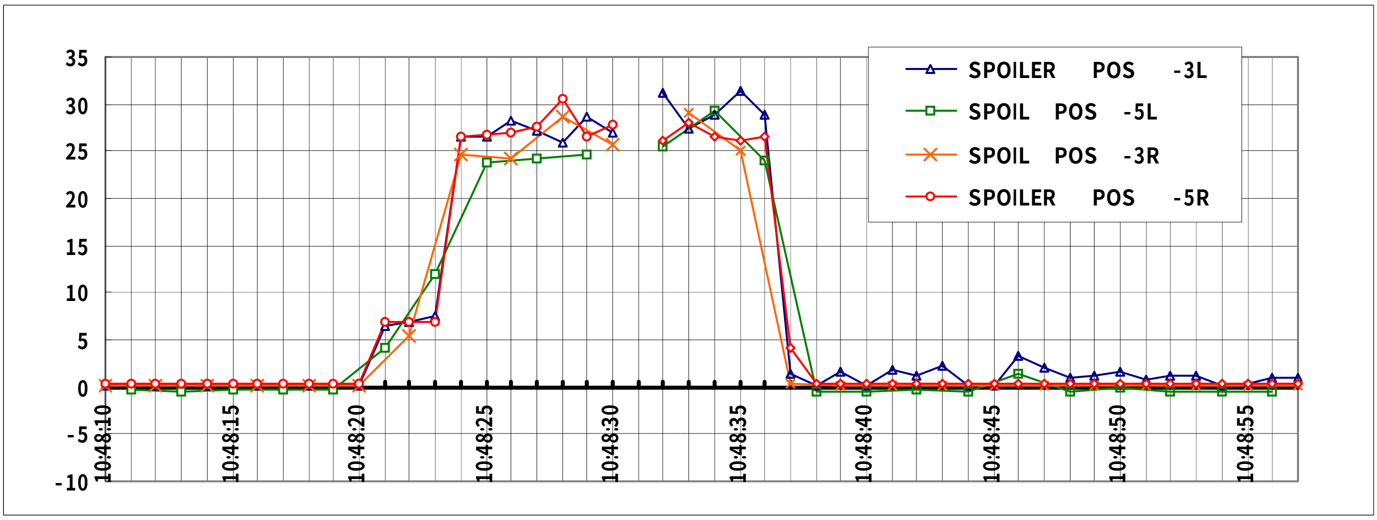


Appendix 2－5

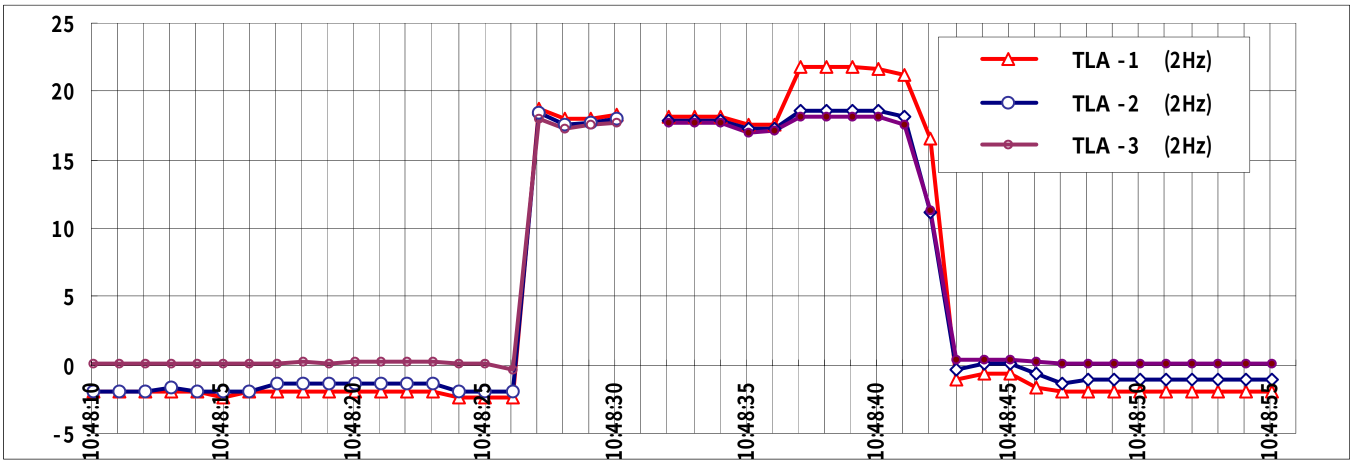
Elevator



Spoiler



Throttle Lever Angle



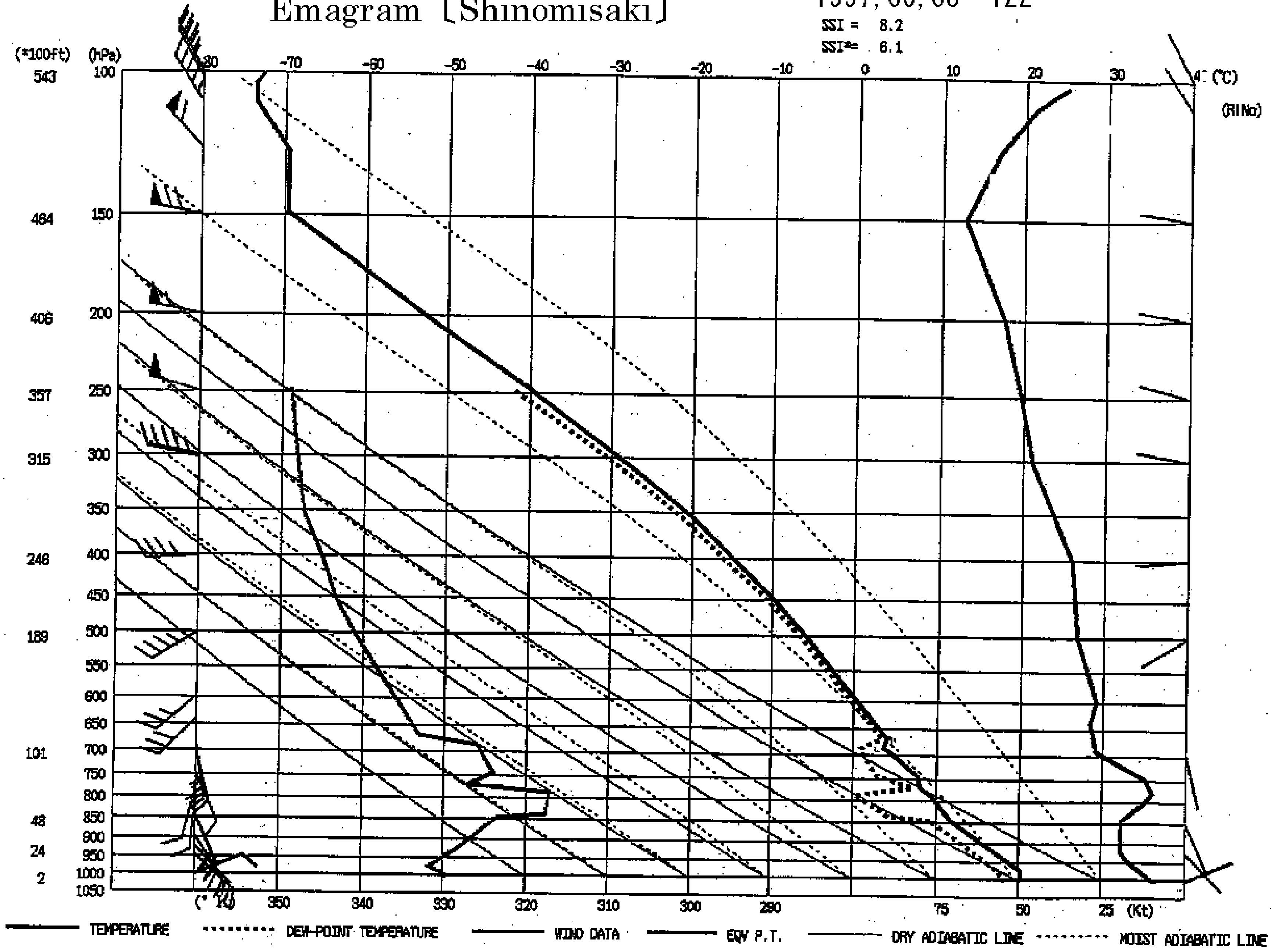
Appendix 3－1

Emagram 〔Shinomisaki〕

1997,06,08　12Z

SSI = 8.2

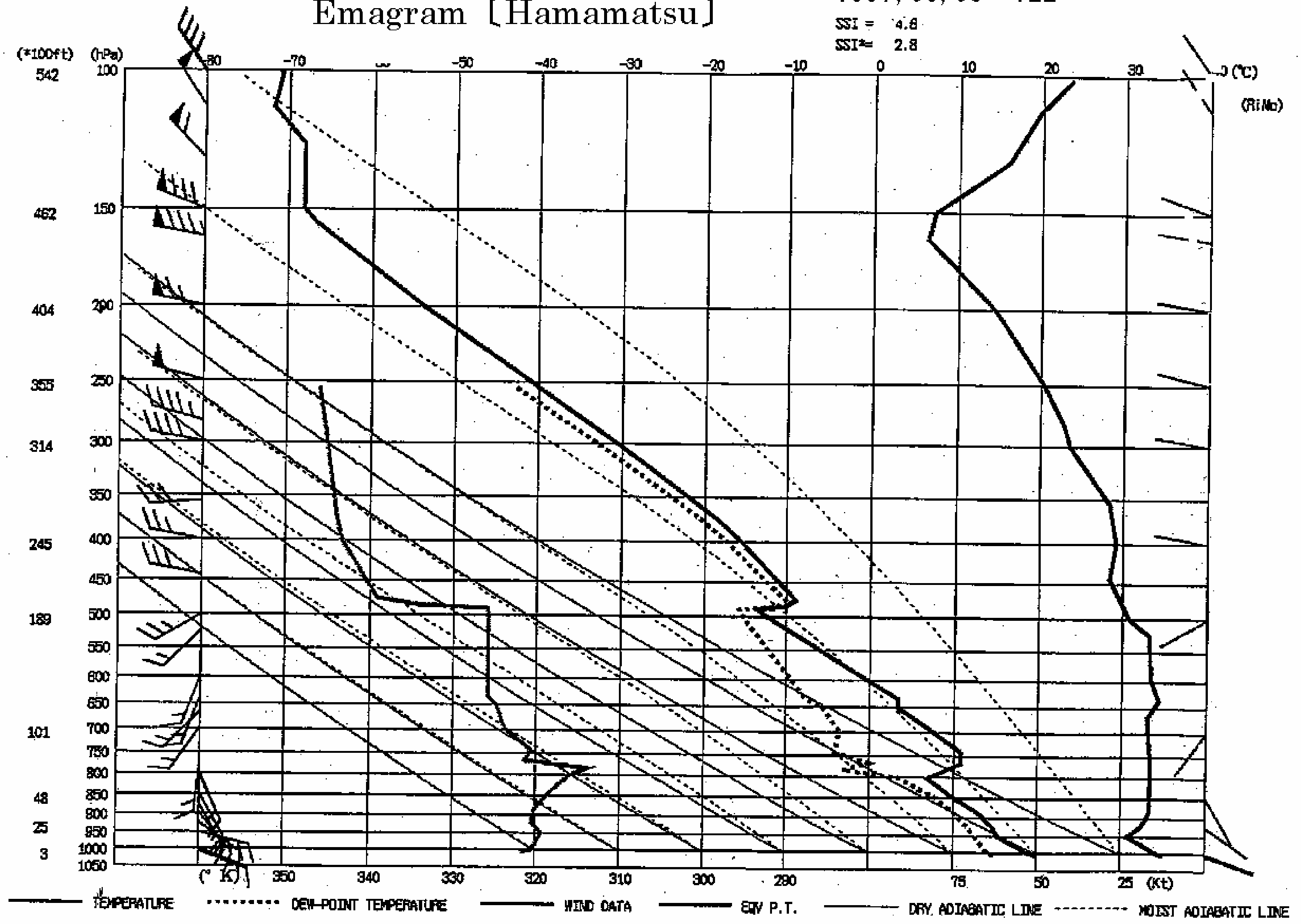
SSI* = 6.1



Emagram [Hamamatsu]

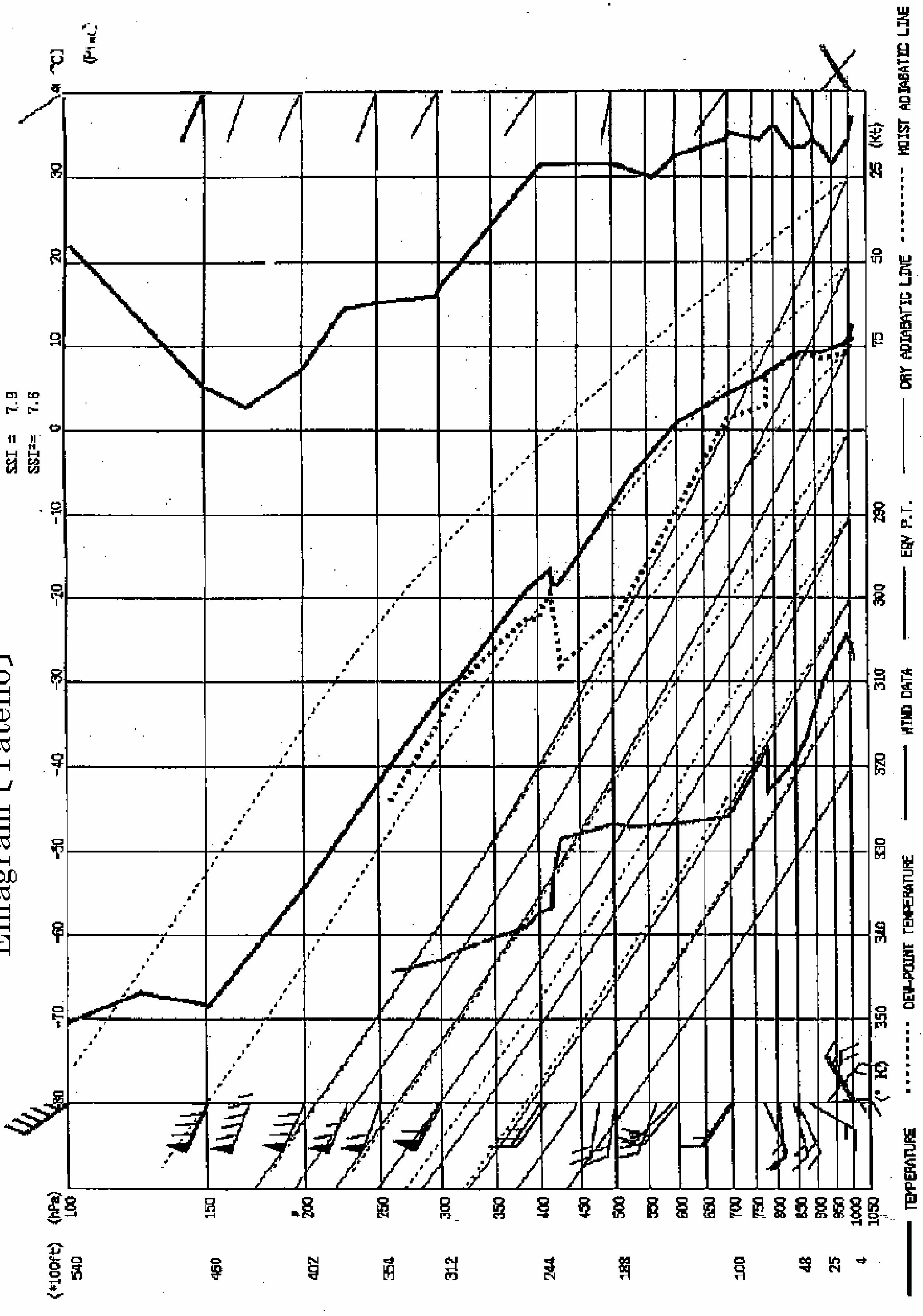
1997,06,08 12Z

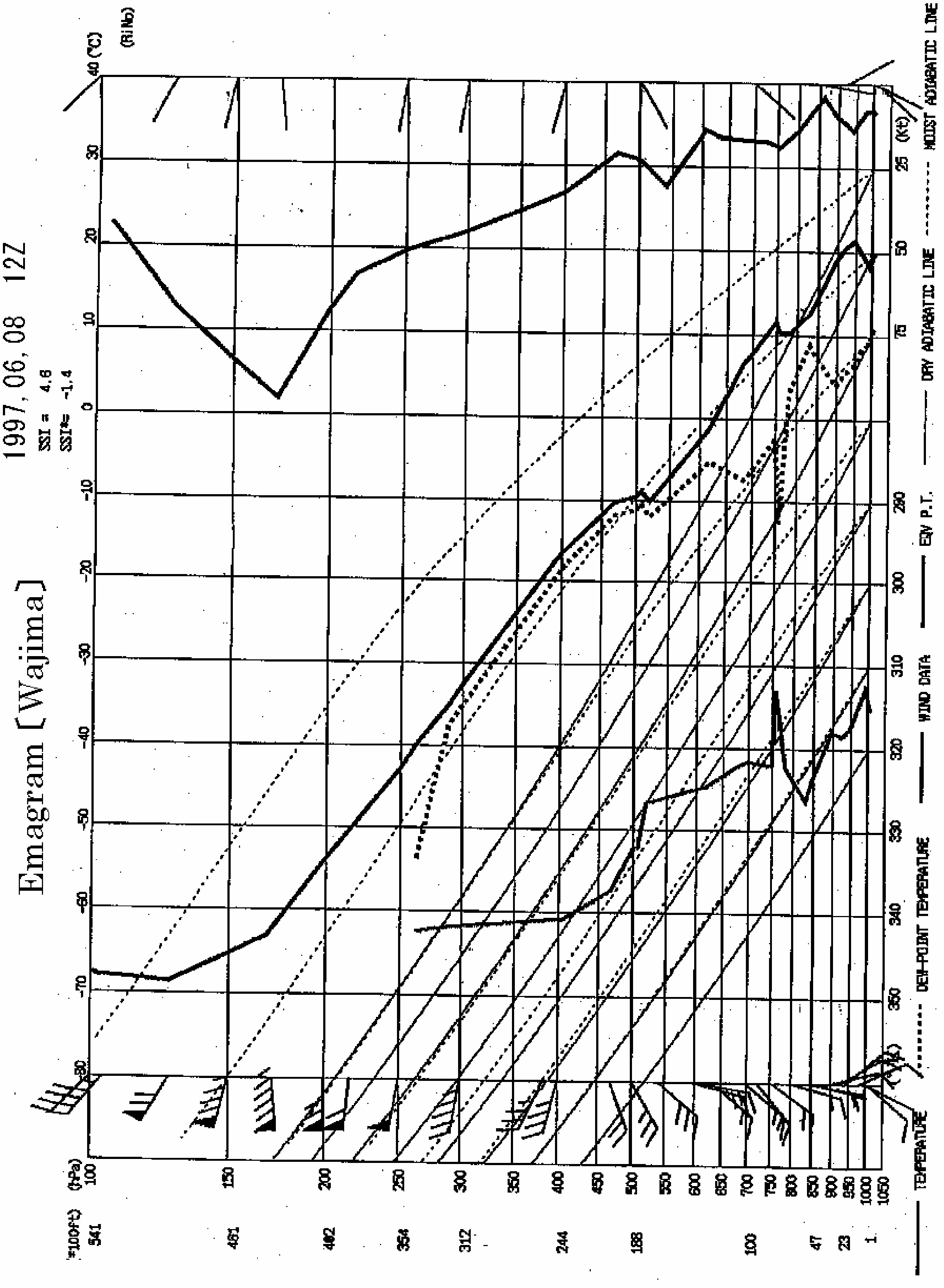
SSI = 4.8
SSI*= 2.8



Emagram [Tateno]

1997,06,08 12Z





Emagram [Wajima]

1997,06,08 12Z

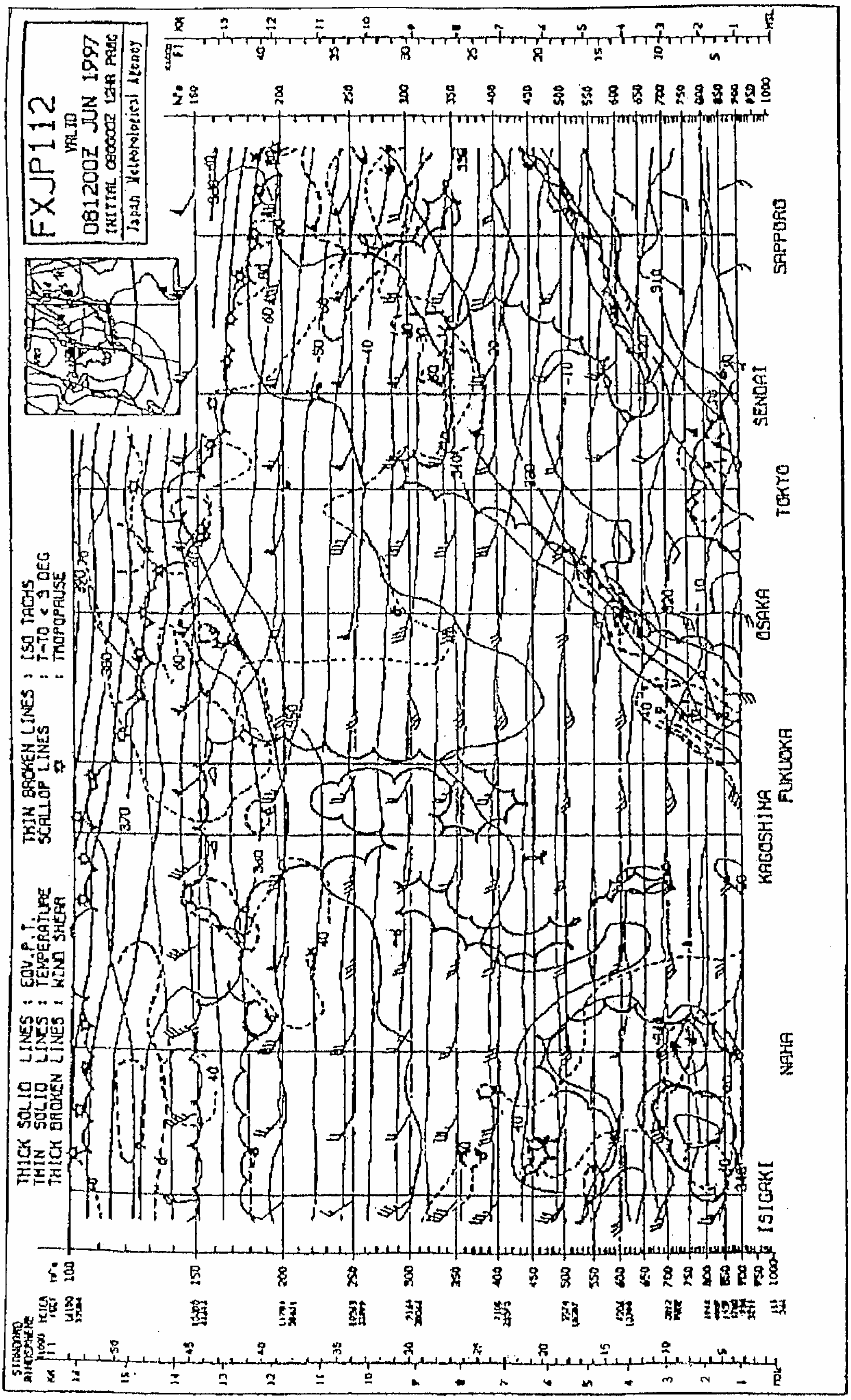

FXJP112
VALID
081200Z JUN 1997
INITIAL 080000Z 12HR PROG
Japan Meteorological Agency
THICK SOLID LINES : EQV.P.T.
THIN SOLID LINES : TEMPERATURE
THICK BROKEN LINES : WIND SHEAR
THIN BROKEN LINES : ISO TACHS
SCALLOP LINES : T-TD < 3 DEG
TROPOPAUSE
STANDARD ATMOSPHERE
ISIGAKI
NAHA
KAGOSHIMA
FUKUOKA
OSAKA
TOKYO
SENDAI
SAPPORO
hPa
FT
KM

Fig.1 Comparison of Pitch Stability

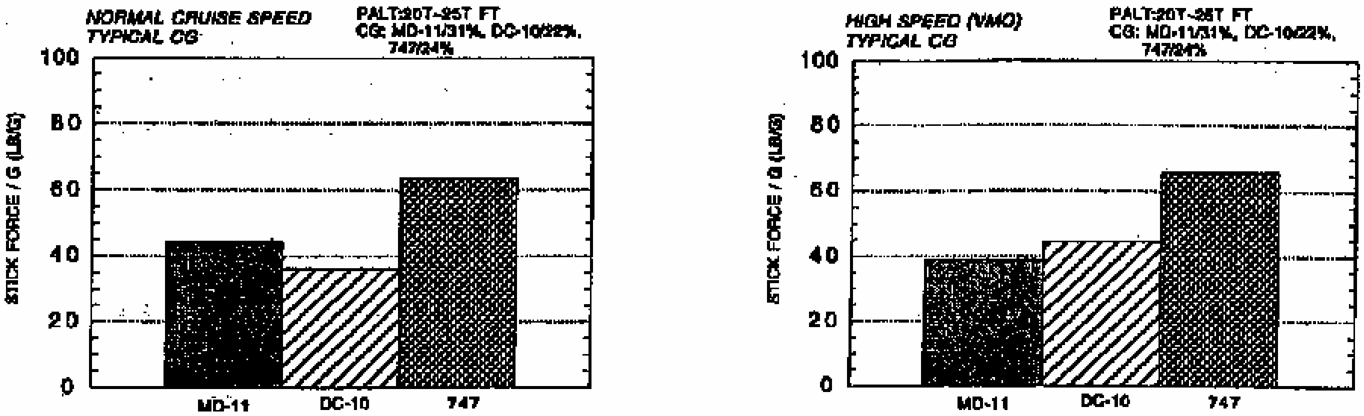
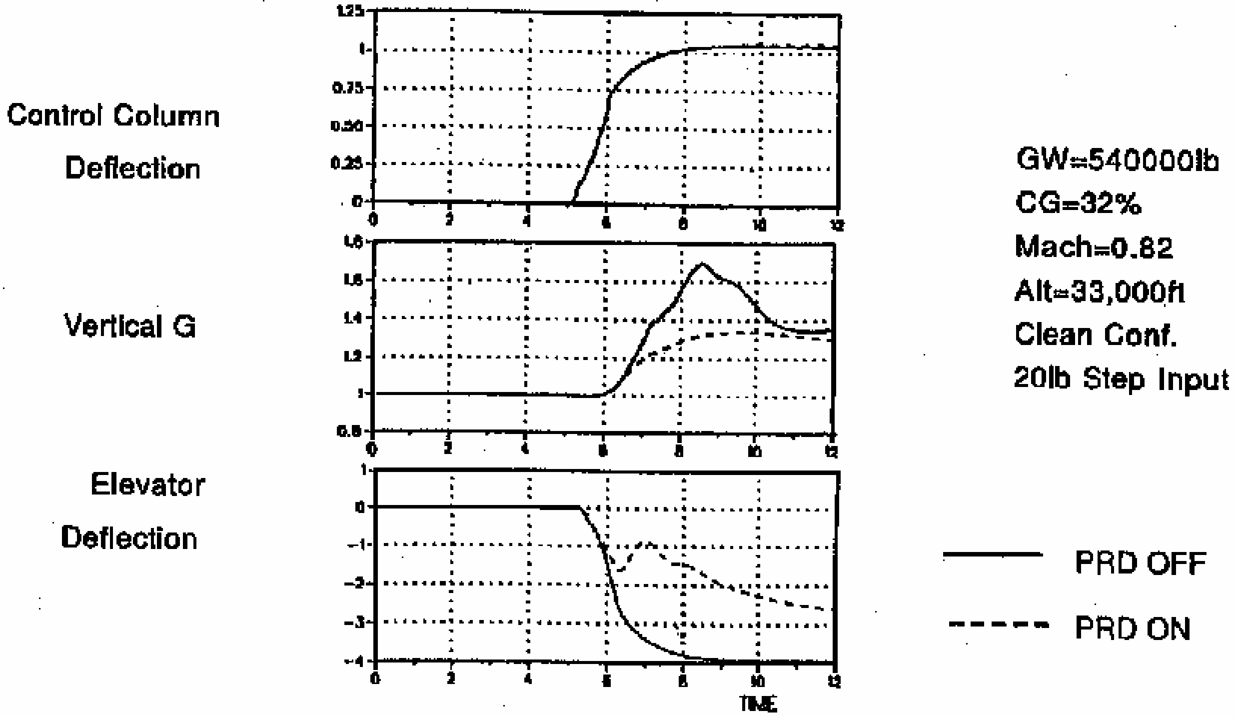


Fig.2 Response to 20lb Stick Force Input



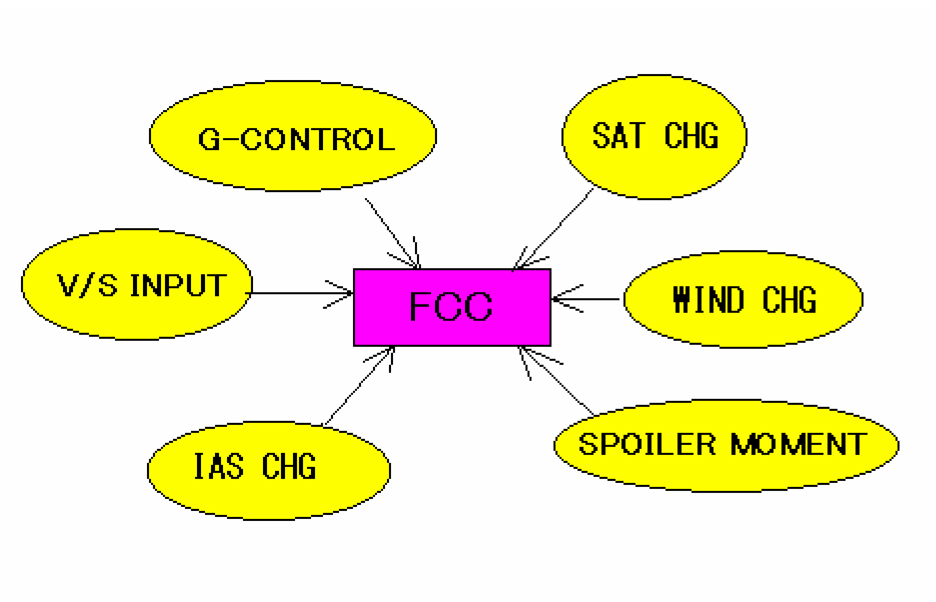
GW=540000lb
CG=32%
Mach=0.82
Alt=33,000ft
Clean Conf.
20lb Step Input

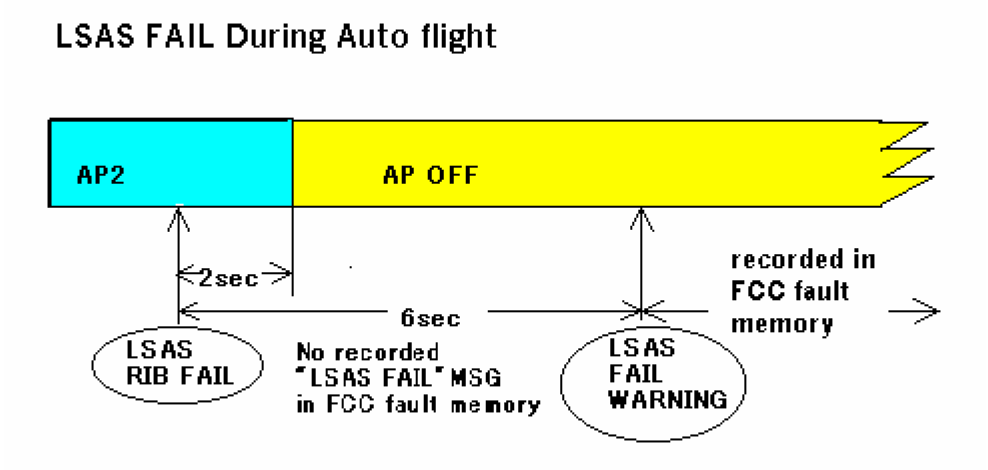
Time until autopilot disconnection by force override

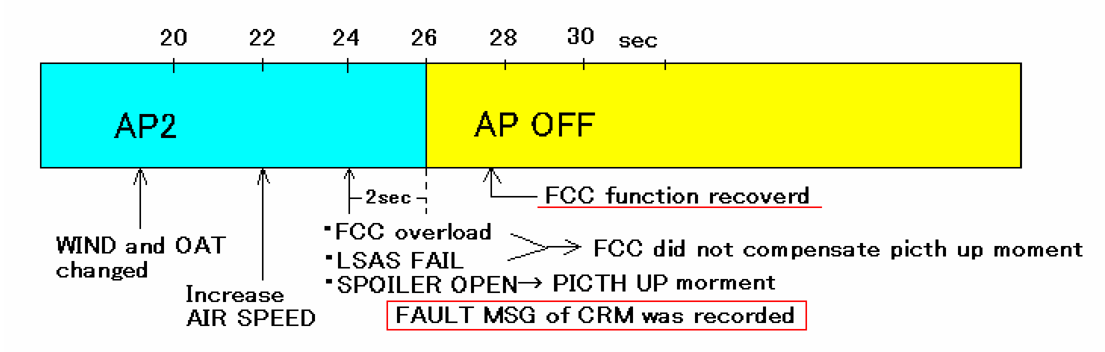
ACO（G）	Time until AP disconnection（sec）	CRM
	0	
	1	
●	2	
●	3	
●●●	4	
●●●	5	
●●	6	
	7	
●	8	
	9	
	1 0	
	1 1	
	1 2	
●●●	1 3	
	1 4	●●
	1 5	●
	1 6	
	1 7	
	1 8	●
	1 9	●
	2 0	●

Appendix 6

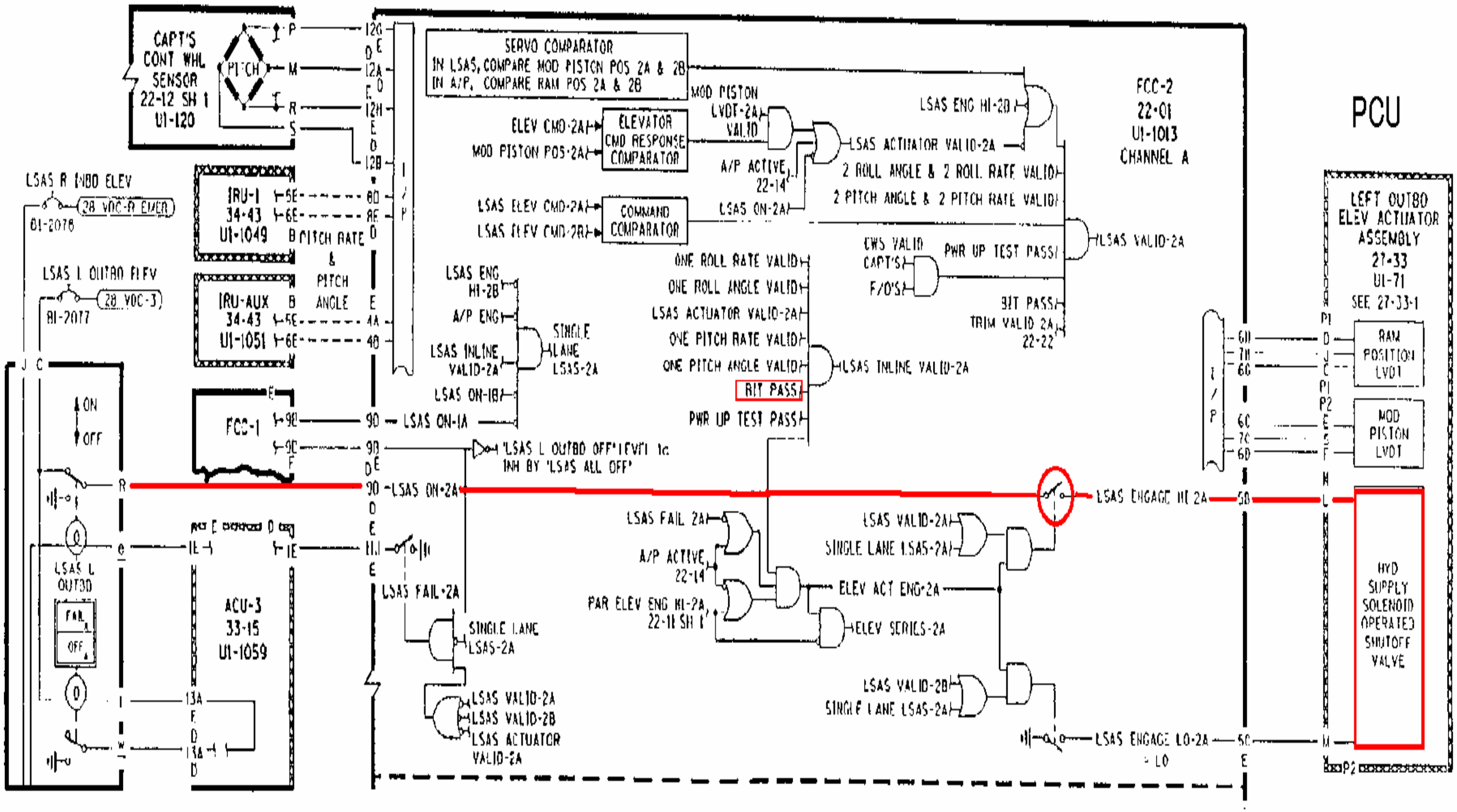
- FCC may pause calculation when CPU is overloaded.




LSAS FAIL During Auto flight



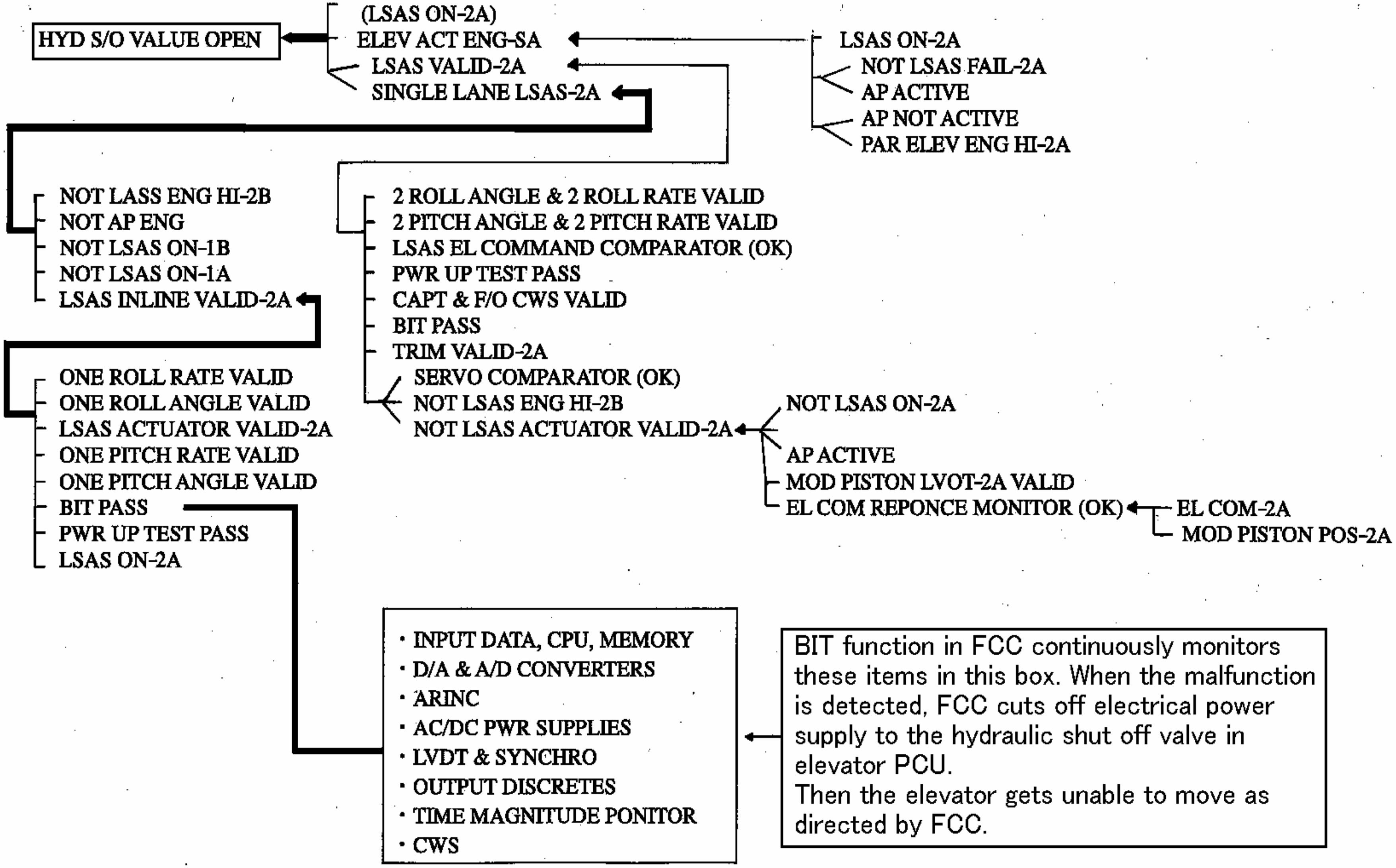
FCC controls the hydraulic shut off valve in elevator PCU



This chatr shows LOB elevator PCU, same as other elevator systems

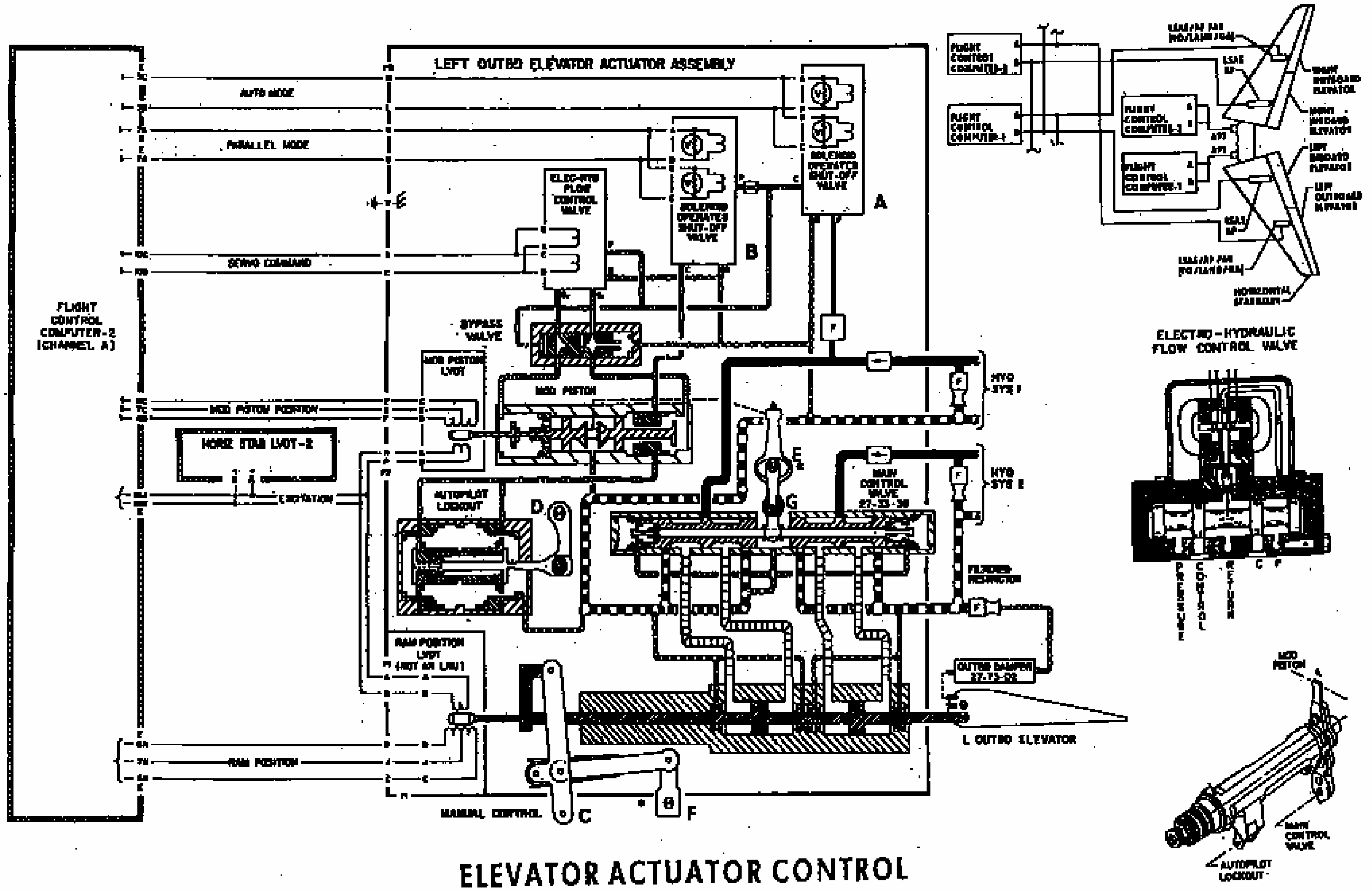
LSAS ENGAGE/DISENGAGE

FCC continuous BIT function diagram



BIT function in FCC continuously monitors these items in this box. When the malfunction is detected, FCC cuts off electrical power supply to the hydraulic shut off valve in elevator PCU.
Then the elevator gets unable to move as directed by FCC.

Elevator PCU



ELEVATOR ACTUATOR CONTROL

This chart shows LOB elevator PCU, same as other elevators

Sales target for each route per a cabin attendant

(The cabin attendant department of Japan Airlines)

HNL Route	OUTBOUNND	INBOUND	China Route	OUTBOUND	INBOUND
NRTHNL	10,000	32,000	NRTPEK	9,000	14,000
KIXHNL	8,000	31,000	KIXPEK	13,000	22,000
America Route	**OUTBOUND**	**INBOUND**	NGOPEK	6,000	8,000
NRTLAX	15,000	43,000	NRTPVG	11,000	17,000
KIXLAX	14,000	41,000	KIXPVG	10,000	-
NRTLAS	23,000	-	NRTDLC	13,000	20,000
NRTORD	22,000	47,000	KIXDLC	11,000	17,000
JFKGRU	8,000	6,000	NGOTSN	6,000	11,000
NRTJFK			NRTTAO	14,000	23,000
006/005	21,000	41,000	NGOPVG	8,000	14,000
048/047	11,000	23,000	NRTXMN	9,000	17,000
NRTSFO	14,000	33,000	**Asia (long dist) RT**	**OUTBOUND**	**INBOUND**
NRTYVR	18,000	37,000	NRTSIN		
YVRMEX	11,000	22,000	719/710	17,000	26,000
Euroupe Route	**OUTBOUND**	**INBOUND**	711/712	8,000	29,000
NRTCDG	19,000	42,000	KIXSIN	23,000	27,000
KIXCDG	20,000	46,000	NRTKUL	20,000	24,000
NRTLHR	15,000	31,000	NRTBKK	14,000	22,000
KIXLHR	16,000	33,000	NGOBKK	20,000	15,000
NRTZRH	28,000	55,000	KIXDPS	15,000	-
NRTMXP	27,000	48,000	CGKKIX	-	19,000
NRTAMS	24,000	42,000	NRTDPS	13,000	18,000
NRTFRA	21,000	36,000	NRTCGK	22,000	22,000
NRTSVO	25,000	25,000	KIXSGN	16,000	16,000
SVOFCO	5,000	33,000	NRTSGN	21,000	21,000
NRTFCO	25,000	51,000	NRTHAN	12,000	15,000
Oceania Route	**OUTBOUND**	**INBOUND**	NRTDEL	17,000	20,000
NRTBNE	11,000	37,000	**Asia (short dist) RT**	**OUTBOUND**	**INBOUND**
KIXBNE	10,000	-	NRTHKG	6,000	11,000
SYDKIX	-	39,000	KIXHKG	7,000	14,000
NRTSYD	10,000	32,000	FUKHKG	3,000	6,000
Other Route	**OUTBOUND**	**INBOUND**	NRTMNL		
Other	14,000	14,000	741/742	13,000	18,000
Domestic Route			745/746	6,000	13,000
All Route	2,200	-	NGOMNL	15,000	18,000