No: 11/92 **Ref: EW/C92/6/1** **Category: 4**

Aircraft Type and Registration:	Douglas Aircraft Company MD-11, N1754	
No & Type of Engines:	3 General Electric CF6-80C2D1F turbofan engines	
Year of Manufacture:	1992	
Date & Time (UTC):	4 June 1992 at 1052 hrs	
Location:	22 nm south-east of Pole Hill on Airway B4	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 15	Passengers - 165
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Nil	
Commander's Licence:	Airline Transport Pilot's Licence (American)	
Commander's Age:	54 years	
Commander's Flying Experience:	15,300 hours	
Information Source:	AAIB Field Investigation	

The aircraft departed from London (Heathrow) Airport at 1032 hrs on a scheduled flight to Chicago, United States of America. During the later stage of the climb, a problem was experienced with the electronic display units; this had largely been resolved when, at 1051 hrs, the aircraft levelled at FL330, at about 0.83M. Almost immediately, a moderate airframe buffet was experienced. The commander reported that the aircraft started a slow pitch up to about 7.7° and rolled slowly to the right. He instructed the first officer to guard the combined slat/flap lever while he manually lowered the nose to the level flight attitude and levelled the wings. The autoflight system was disconnected. Both the commander and the third pilot noticed a SLAT DISAGREE caption; the third pilot also noticed that the master caution illuminated. After a short time the vibration ceased and the aircraft was returned to straight and level flight.

At 1052 hrs, the crew reported to ATC that they had encountered some flight control difficulties and wished to return to London (Heathrow) Airport. The aircraft had just passed Pole Hill on airway B4 and the controller gave a heading of 200° to take it towards Wallasey, where about 15 minutes of fuel jettison was to be carried out. At 1058 hrs, the aircraft entered the holding pattern at Wallasey at FL330. The procedure had been completed by 1116 hrs and clearance was given to descend to FL250. The flight progressed without incident and, at 1138 hrs, when the aircraft was at FL90, the

speed was reduced to 220 kt and a control check was carried out. No problems were experienced and radar vectors were given to the ILS approach to runway 27R. The aircraft landed without further incident at 1200 hrs.

Flight Recorders

The Flight Data Recorder (FDR), a Sundstrand UFDR was removed and sent to the US National Transportation Safety Board in Washington D.C. for readout. The data was also supplied to the AAIB. Figure 1 shows some of the parameters during the incident, the aircraft was at 33,000 feet, with an airspeed of 297 kt CAS and 0.83M.

Slat position is sampled from the left inboard and left and right outboard once per second, the position is recorded as retracted, in transit or deployed. Figure 1 shows the inboard slats started to extend at time T = 14 seconds (from an arbitrary datum), this co-incided with the slat disagree warning, and the inboard slats were fully deployed within 3 seconds. The outboard slats then started to extend at T = 16 seconds and were fully deployed in 6 seconds. The inboard slats started to retract at T = 24 seconds, and were fully retracted within 8 seconds. The outboard slats started to retract at T = 31 seconds, and were fully retracted in 7 seconds.

At T = 18 seconds the aircraft started to pitch up, initially at T = 21 seconds to an attitude of 6.3° nose-up, there was also a slight roll to 8° right wing down, and a peak value for normal acceleration of 1.2g. The autopilot was disconnected at T = 21 seconds. The minimum pitch attitude during the recovery was 2.1° nose-up with a minimum normal acceleration of 0.56g. The maximum recorded value of alpha was 6.15°, and the stall warning operated for one second at T = 21 seconds. There was also a slight roll to 8° right wing down.

There followed two more pitch up and recoveries the second of which was more severe. During the first pitch up the peak attitude recorded at T = 25 seconds was 7.4° nose-up and a normal acceleration of 1.39G, the minimum pitch attitude during the recovery was 1.75° nose-up and a normal acceleration of 0.53G. The maximum alpha recorded was 7.9°, the stall warning operated for 3 seconds. The autothrottle was disconnected at T = 28 seconds.

The maximum pitch attitude recorded during the final pitch up at T = 29 seconds was 8.1° nose-up and 1.5g normal acceleration, and the minimum pitch attitude during recovery was 1.75 deg nose-up and a normal acceleration of 0.5g. The stall warning again operated for 4 secs at T = 29 seconds, the maximum alpha was 8.6°.

The slat disagree indication on the DFDR lasted for 22 seconds and ended at T = 37 seconds.

Description of the MD-11 Flap/Slat System

The design of the MD-11 flap/slat system is broadly similar to the earlier DC-10 aircraft from which it was derived. It is essentially a simple hydro-mechanical system in which movement of a combined flap/slat lever on the centre pedestal initially extends the slats and, with further movement, progressively extends the trailing edge flaps. Cables running aft from the lever mechanism move the inboard slats control valve via a spring coupler (see Figure 2). When the inboard slats are partially extended, a follow-up mechanism on the inboard slat drive drum opens the outboard slat control valve and the outboard slats extend. During retraction, the inboard slats retract first, followed by the outboard slats. It can be appreciated that there is no electrical signalling involved in the normal operation but, associated with the stall protection system, is an "Autoslat" feature which extends the *outboard slats only* should the flight control computers sense an impending stall. This system is, however, inhibited at the high Mach number or IAS at which this aircraft was operating.

Single lever operation of the flaps and slats is achieved by a cam mechanism in the centre pedestal (see Figure 3). Rearward movement of the lever (not shown) from the 0°/0° retracted detent rotates a cam plate anti-clockwise. A roller forming part of a cam follower is thus moved downwards until, at the 0°/ext detent, the slats are extended and further rearward movement of the lever causes no further vertical motion of the follower. It is this vertical motion which is transmitted to the cable system and thence to the inboard slats control valve and it should be noted that there is no proportional movement of the slats. At a point during travel of the cam the slat control valve is given a signal to commence and fully complete the extension cycle, although the motion can be reversed at any point in the cycle if the lever is moved back to retract. Consideration of the cam and follower geometry shown in Figure 3 shows that the rigging of the follower roller is highly critical since small variations in the rigged position have a very large effect when the roller is moving in the slat operating part of the cam. The significance of this should become evident later.

It is also necessary to describe the operation of the flap/slat lever detents and gates. When the crew select the slats to extend, they must *lift* the lever out of the 0°/0° detent and pull it aft before allowing it to drop into either the 0°/ext (no flap, slats extended) detent or into one of the flaps extended detents. When retracting the slats, the crew must *push down* on the lever so that the detent pin pushes past the spring-loaded zero gate and springs back into the 0°/0° detent. Studies arising from the previous incidents of inadvertent slat deployment (see following paragraph) suggested that, with a combination of friction forces and the presence of the extend bias spring, the detent pin could sit in a "false detent" created by the profile of the gate and detent hardware (see Figure 3). Disturbance of the lever could

allow the pin to open the gate and extend the slats. The extend bias spring, fitted as an FAA and JAA certification requirement, is intended to ensure that the slats will remain extended if the control cable circuit is disrupted but has the effect of applying a tension on the extend cable and hence the lever will move towards the extend position if not securely located in a detent. Position of the flap/slat lever is signalled by a microswitch located on the cable quadrant beneath the pedestal and is used only as an input to the indication logic. Since any disparity between the position of the slats and the position of the handle would bring on an amber caution and the caption SLAT DISAGREE, a time delay is incorporated to prevent this occurring every time the slats are in transit following a deliberate selection although the FDR records all slat disagree messages without delay.

Previous Incidents of Inadvertent Slat Deployment

Information supplied by the manufacturer showed that the first case of airborne inadvertent slat deployment occurred in April 1991 followed by a further incident in July and two in December. In one of the December incidents the crew reported it as an encounter with severe turbulence during the cruise which injured five passengers. It was only when the manufacturer requested a readout of the FDR that it became clear that it had actually been a slat deployment with a consequent pitch-up to 20° followed by a rapid pitch-down. The other three incidents were correctly reported by the crews who stated that they had immediately pushed the flap/slat handle fully forward and the slats retracted again. The manufacturer's response to the first incident was to issue an All Operators Letter (AOL) advising of the occurrence and cautioning crews to ensure that the flap/slat handle was firmly stowed in the UP/RETRACT (0°/0°) detent. At the same time, a modification was devised to re-profile the gate and detent assembly to obviate the "false detent" possibility. This was issued as Service Bulletin (SB) 27 - 18 on 30 August 1991 with accomplishment recommended "at the earliest practical maintenance period". The December occurrences led to a further All Operators Telex advising of the incidents and recommending incorporation of the SB. N1754 had the modification incorporated during manufacture.

Three more incidents of inadvertent slat deployment occurred in 1992 prior to the incident to N1754. On two of these it was assumed that SB 27-18 was not incorporated but the other aircraft was known to have been modified. However, its Captain apparently reported that he had depressed the zero gate whilst explaining the mechanism to the First Officer and that this had initiated the event. This crew seems also to have had difficulty in recovering the situation since the aircraft experienced pitch angles causing load factors up to 2.1g and pre-stall buffet for an extended period of time causing separation of an outboard elevator skin. This remains the only report of structural damage occurring as a result of this problem.

Reports were also received of two ground incidents of uncommanded slat deployment, but no details have been obtained.

Examination of the Aircraft and Subsequent Actions

The apparent coincidence of the Display Unit malfunction and the slat deployment dictated that the aircraft was initially subjected to component changes and checks centred around the Autoslat/stall warning system, since this was the only apparent interface between the aircraft avionics and the slat extension mechanism. Accordingly, both Flight Control Computers, No's 1 and 2 Display Electronics Units (DEU's, which drive the cockpit Display Units) and No.1 DU were removed and despatched to their manufacturer for testing and interrogation of their non-volatile memory. In addition, the stick shaker and Autoslat extend motors were checked and a structural inspection of the elevators was carried out. No abnormalities were found as a result of these latter checks. The FDR was removed and despatched to the US National Transportation Board for initial read-out (see preceeding paragraph).

Following the series of checks and component changes the aircraft embarked on a test flight and was then ferried back to the airline's main base at Dallas/Fort Worth in the United States for further investigation. During the course of this investigation the airline reported to the manufacturer that the rigging of the flap/slat control system had been found to be out of tolerance. Some confusion existed when it was thought that the airline was not aware of revised rigging procedures which had been adopted by the manufacturer but not yet promulgated by revision of the Maintenance Manual. However, evidence was produced which showed that the "as found" rig was incorrect even to the revised standard. Referring to Figure 4 it can be seen that the original design called for the system to be rigged with the cam follower concentric with the rigging sighting hole. The revised rigging position had the centre of the follower level with the aft edge of the sighting hole (this was in response to crew complaints of difficulty in stowing the lever in the 0°/0° detent). N1754 had the forward surface of the follower level with the aft edge of the hole as shown. Two other components of the system, the input pushrod and the input clapper, were also found out of adjustment in the extend sense. Tests by the manufacturer on a deliberately misrigged aircraft showed that, in this configuration, the slat handle became extremely sensitive and minor disturbances, even when stowed in the 0°/0° detent, could result in accidental full deployment of the slats.

Following extensive testing and simulations, the DU manufacturer could not confirm any fault which would have caused the initial reported DU malfunction. They speculated that DEU 2 could have been forced into a reset mode due to an (unresolved) internal fault, but the flight crew recycled the DEU 2

circuit breaker before DU 2 could be reset. The tests also confirmed that there could have been *no* connection between the slat deployment and any fault in the units examined

On 23 June Douglas issued a telex Alert Service Bulletin No. A27-29 recommending checks on the slat control rigging within 30 days and on 25 June circulated an AOL describing the procedures to be adopted by flight crews to restow the slats should deployment occur with or without lever movement.

However, on 28 June a further case of inadvertent slat deployment occurred on an MD-11 which led to at least three cases of injury to occupants. Inspection of the slat control system revealed similar out-of-rig conditions to those found on N1754 (the aircraft was one fuselage later in the production sequence from N1754). On 29 June the FAA issued Emergency Airworthiness Directive T92-14-51 mandating SB A27-29 with a compliance time of 10 days, and which expressed their concern about the possibility of structural damage occurring to the elevators. Yet another case of inadvertent initiation of slat extension occurred on 16 July but in this case the crew reported that there had been accidental movement of the lever out of the 0°/0° detent followed by an immediate restow. No injuries or damage occurred.

On 13 August Douglas issued letters to all operators advising them of the inadvertent slat extension incidents and Douglas' Flight Operations published an interim procedure to avoid such deployments by verifying that the flap/slat lever is properly stowed. This interim procedure cautions crews to avoid coming into contact with the lever unless flap/slat extension is required.

Douglas had already initiated a design review of the MD-11 slat control system in conjunction with the FAA and it is understood that a comprehensive redesign of several components in the system is urgently underway. Additionally, the FAA noted that the flight and ground crew training simulators did not accurately replicate the forces required to move the flap/slat lever and were therefore requiring that training on flap/slat operation be accomplished on an aircraft. Douglas advise that all MD-11 simulators worldwide have now been modified to accurately represent flap/slat handle forces.

FIGURE 1

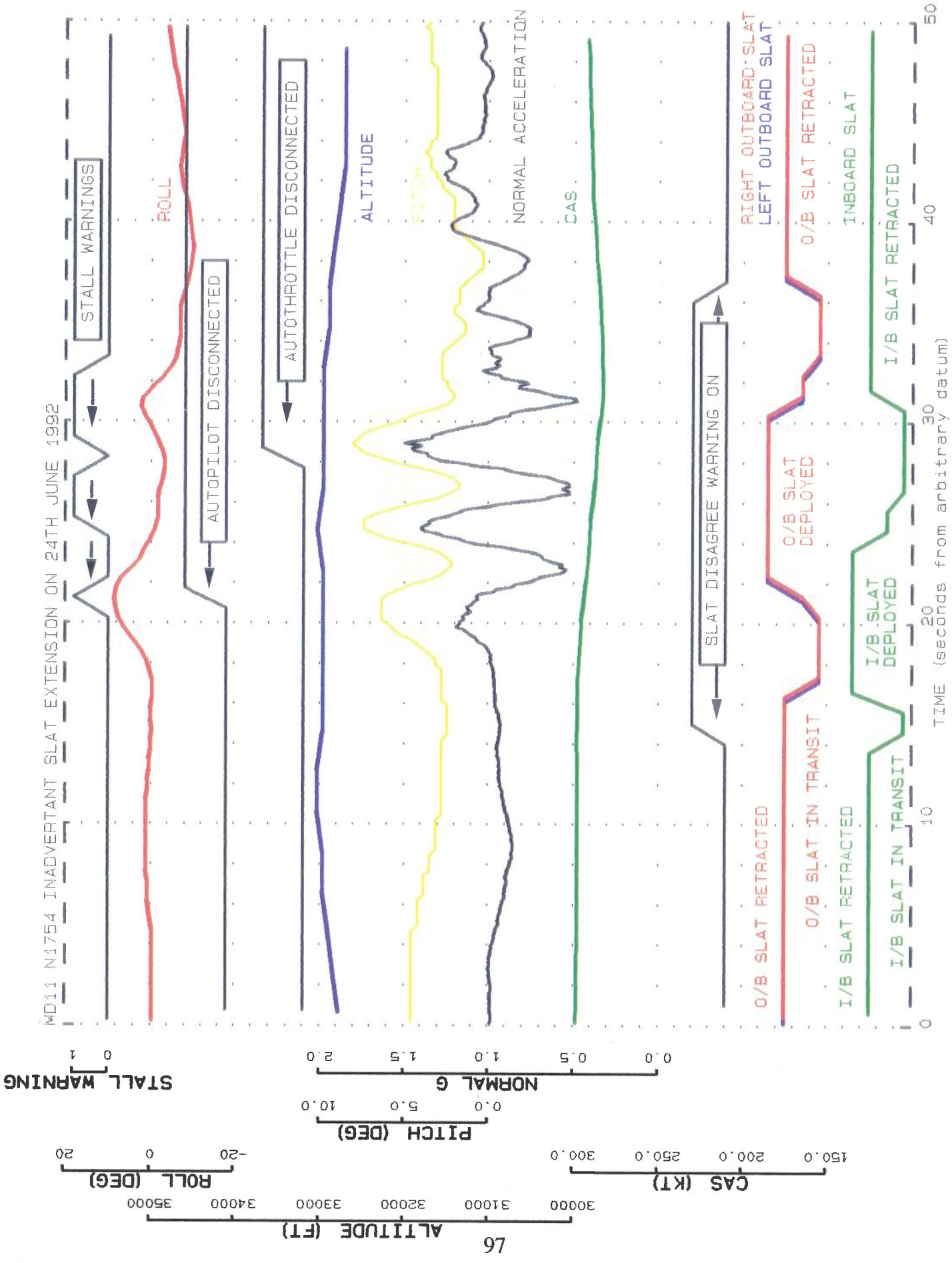
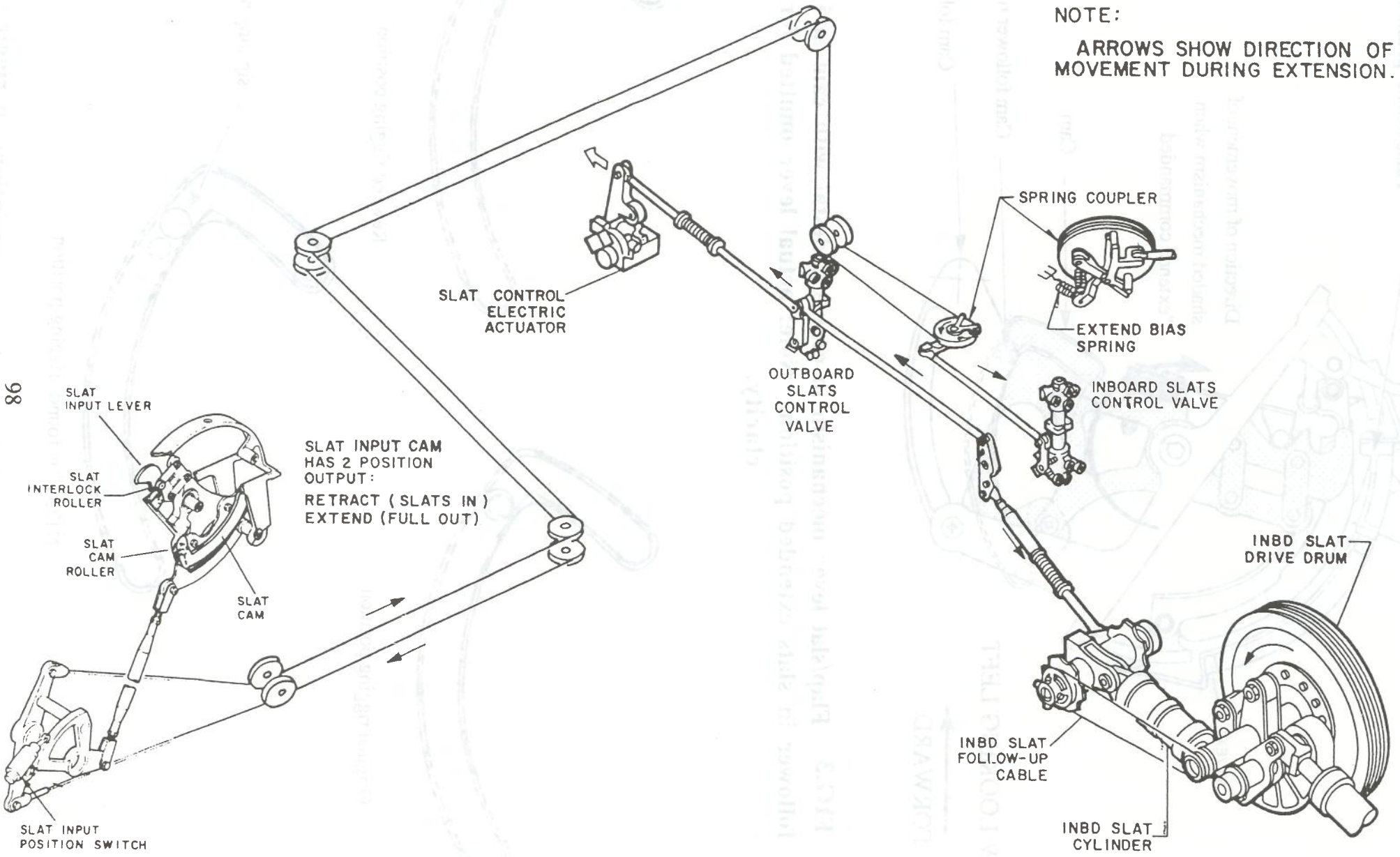

MD11 N1754 INADVERTANT SLAT EXTENSION ON 24TH JUNE 1992
STALL WARNINGS
ROLL
AUTOPILOT DISCONNECTED
AUTOTHROTTLE DISCONNECTED
ALTITUDE
PITCH
NORMAL ACCELERATION
CAS
SLAT DISAGREE WARNING ON
RIGHT OUTBOARD SLAT
LEFT OUTBOARD SLAT
O/B SLAT RETRACTED
O/B SLAT IN TRANSIT
O/B SLAT DEPLOYED
O/B SLAT RETRACTED
I/B SLAT RETRACTED
I/B SLAT IN TRANSIT
I/B SLAT DEPLOYED
INBOARD SLAT
I/B SLAT RETRACTED
TIME (seconds from arbitrary datum)
0
10
20
30
40
50
STALL WARNING
0 1
NORMAL G
0.0 0.5 1.0 1.5 2.0
PITCH (DEG)
0.0 5.0 10.0
ROLL (DEG)
-20 0 20
ALTITUDE (FT)
30000 31000 32000 33000 34000 35000
CAS (KT)
150.0 200.0 250.0 300.0

FIG.2 Schematic layout of MD-11 leading edge slat operating system



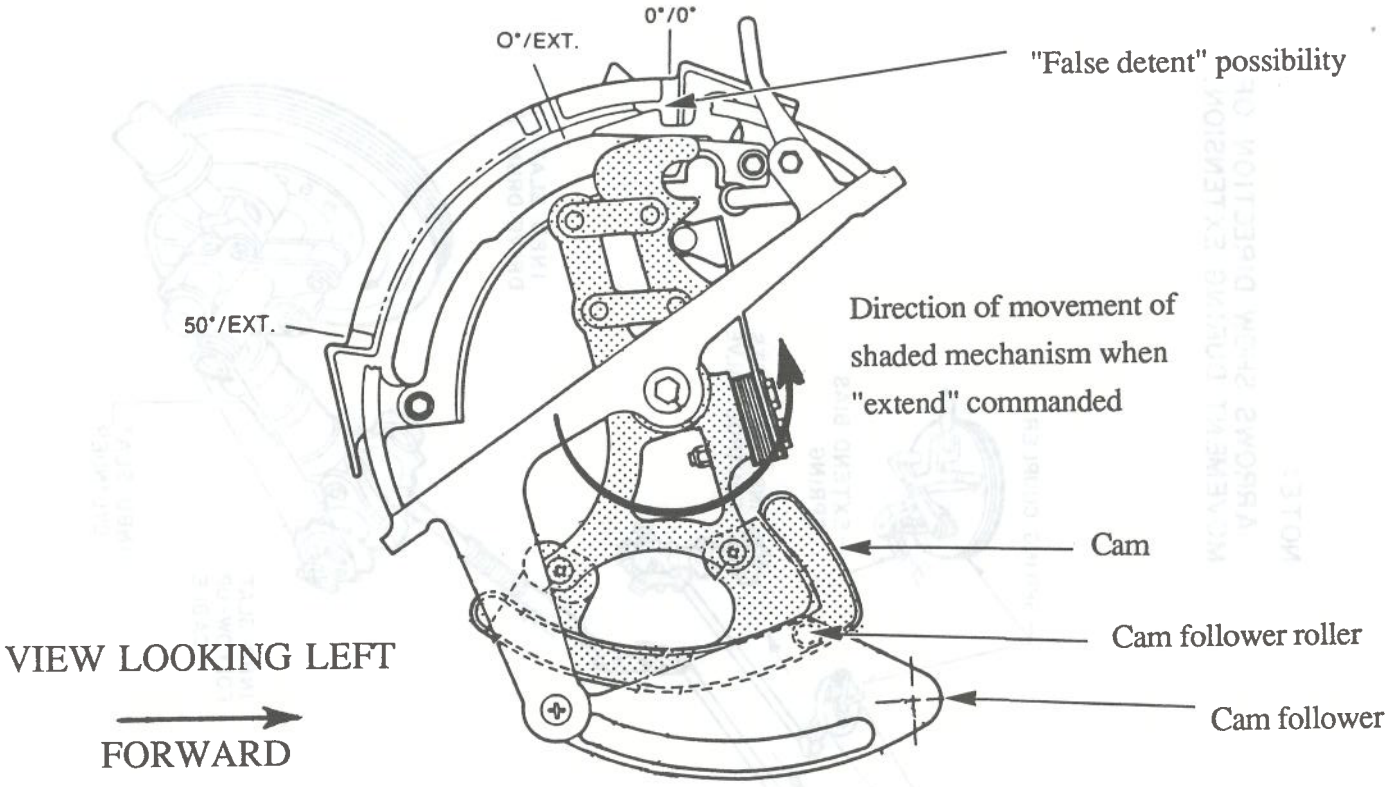


FIG.3 Flap/slat lever mechanism in centre pedestal with cam and follower in slats extended position. Note: actual lever omitted for clarity.

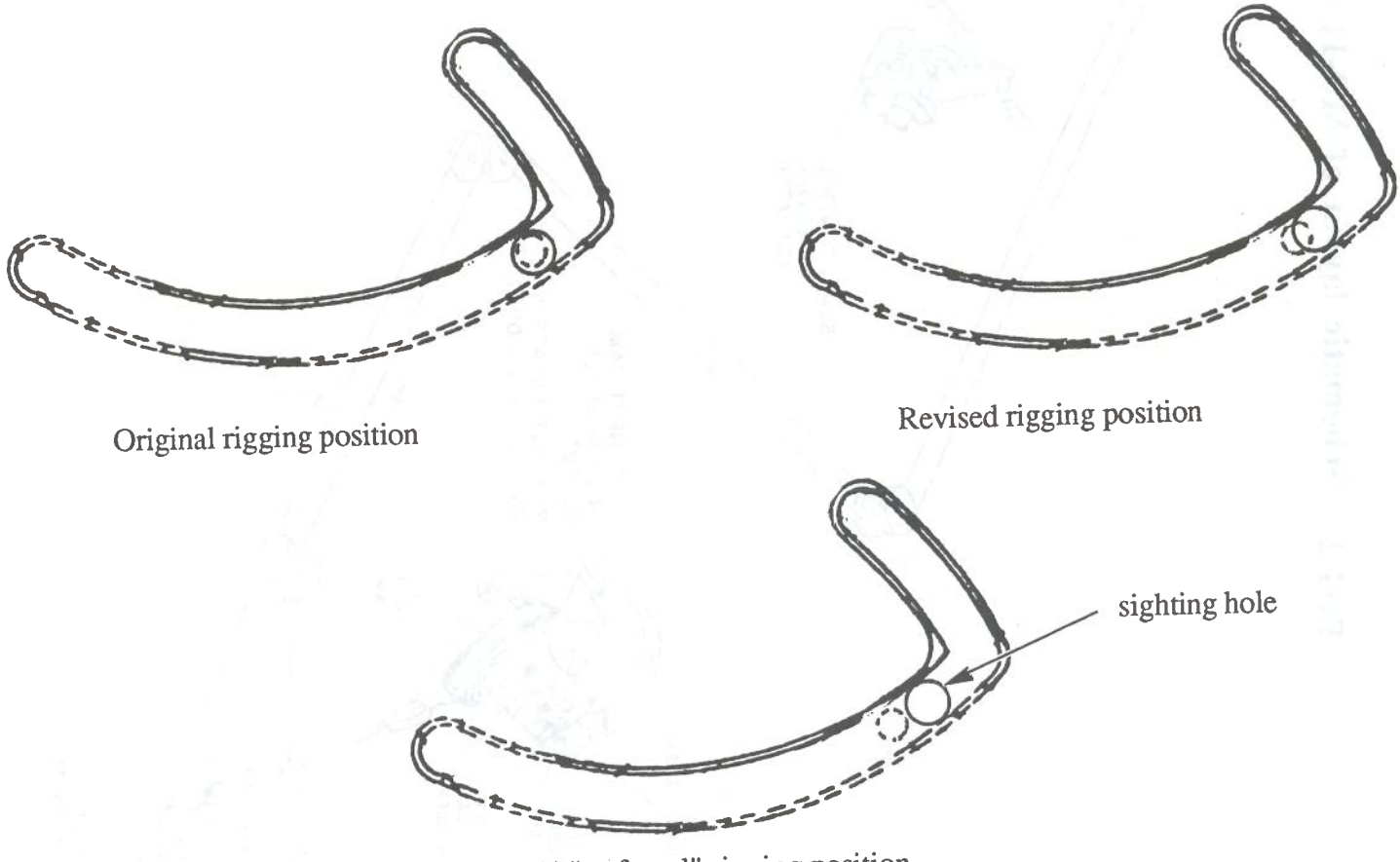


FIG.4 View of cam/cam follower showing variations in rigging.