3 CONCLUSIONS

3.1 Findings

1. The engine and pylon assembly separated either at or immediately after liftoff. The flightcrew was committed to continue the takeoff.

2. The aft end of the pylon assembly began to separate in the forward flange of the aft bulkhead.

3. The structural separation of the pylon was caused by a complete failure of the forward flange of the aft bulkhead after its residual strength had been critically reduced by the fracture and subsequent service life.

4. The overload fracture and fatigue cracking on the pylon aft bulkhead's upper flange were the only preexisting damage on the bulkhead. The length of the overload fracture and fatigue cracking was about 13 inches. The fracture was caused by an upward movement of the aft end of the pylon which brought the upper flange and its fasteners into contact with the wing clevis.

5. The pylon to wing attach hardware was properly installed at all attachment points.

6. All electrical power to the No. 1 a.c. generator bus and No. 1 d.c. bus was lost after the pylon separated. The captain's flight director instrument, the stall warning system, and the slat disagreement warning light systems were rendered inoperative. Power to these buses was never restored.

7. The No. 1 hydraulic system was lost when the pylon separated. Hydraulic systems No. 2 and No. 3 operated at their full capability throughout the flight. Except for spoiler panels No. 2 and No. 4 on each wing, all flight controls were operating.

8. The hydraulic lines and followup cables of the drive actuator for the left wing's outboard leading edge slat were severed by the separation of the pylon and the left wing's outboard slats retracted during climbout. The retraction of the slats caused an asymmetric stall and subsequent loss of control of the aircraft.

9. The flightcrew could not see the wings and engines from the cockpit. Because of the loss of the slat disagreement light and the stall warning system, the flightcrew would not have received any electronic warning of either the slat asymmetry or the stall. The loss of the warning systems created a situation which afforded the flightcrew an inadequate opportunity to recognize and prevent the ensuing stall of the aircraft.

10. The flightcrew flew the aircraft in accordance with the prescribed emergency procedure which called for the climbout to be flown at V_3 speed. V_3 speed was 6 KIAS below the stall speed for the left wing. The deceleration to V_3 speed caused the aircraft to stall. The start of the left roll was the only warning the pilot had of the onset of the stall.

11. The pylon was damaged during maintenance performed on the accident aircraft at American Airline's Maintenance Facility at Tulsa, Oklahoma, on March 29 and 30, 1979.

12. The design of the aft bulkhead made the flange vulnerable to damage when the pylon was being separated or attached.

13. American Airlines engineering personnel developed an ECO to remove and reinstall the pylon and engine as a single unit. The ECO directed that the combined engine and pylon assembly be supported, lowered, and raised by a forklift. American Airlines engineering personnel did not perform an adequate evaluation of either the capability of the forklift to provide the required precision for the task, or the degree of difficulty involved in placing the lift properly, or the consequences of placing the lift improperly. The ECO did not emphasize the precision required to place the forklift properly.

14. The FAA does not approve the carriers' maintenance procedures, and a carrier has the right to change its maintenance procedures without FAA approval.

15. American Airlines personnel removed the aft bulkhead's bolt and bushing before removing the forward bulkhead attach fittings. This permitted the forward bulkhead to act as a pivot. Any advertent or inadvertent loss of forklift support to the engine and pylon assembly would produce an upward movement at the aft bulkhead's upper flange and bring it into contact with the wing clevis.

16. American Airlines maintenance personnel did not report formally to their maintenance engineering staff either their deviation from the removal sequence contained in the ECO or the difficulties they had encountered in accomplishing the ECO's procedures.

17. American Airline's engineering personnel did not perform a thorough evaluation of all aspects of the maintenance procedures before they formulated the ECO. The engineering and supervisory personnel did not monitor the performance of the ECO to insure either that it was being accomplished properly or if their maintenance personnel were encountering unforeseen difficulties in performing the assigned tasks.

18. The nine situations in which damage was sustained and cracks were found on the upper flange were limited to those operations wherein the engine and pylon assembly was supported by a forklift.

19. On December 19, 1978, and February 22, 1979, Continental Airlines maintenance personnel damaged aft bulkhead upper flanges in a manner similar to the damage noted on the accident aircraft. The carrier classified the cause of the damage as maintenance error. Neither the air carrier nor the manufacturer interpreted the regulation to require that it further investigate or report the damages to the FAA.

20. The original certification's fatigue-damage assessment was in conformance with the existing requirements.

21. The design of the stall warning system lacked sufficient redundancy; there was only one stickshaker motor; and further, the design of the system did not provide for crossover information to the left and right stall warning computers from the applicable leading edge slat sensors on the opposite side of the aircraft.

22. The design of the leading edge slat system did not include positive mechanical locking devices to prevent movement of the slats by external loads following a failure of the primary controls. Certification was based upon acceptable flight characteristics with an asymmetrical leading edge slat condition.

23. At the time of DC-10 certification, the structural separation of an engine pylon was not considered. Thus, multiple failures of other systems resulting from this single event was not considered.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the asymmetrical stall and the ensuing roll of the aircraft because of the uncommanded retraction of the left wing outboard leading edge slats and the loss of stall warning and slat disagreement indication systems resulting from maintenance-induced damage leading to the separation of the No. 1 engine and pylon assembly at a critical point during takeoff. The separation resulted from damage by improper maintenance procedures which led to failure of the pylon structure.

Contributing to the cause of the accident were the vulnerability of the design of the pylon attach points to maintenance damage; the vulnerability of the design of the leading edge slat system to the damage which produced asymmetry; deficiencies in Federal Aviation Administration surveillance and reporting systems which failed to detect and prevent the use of improper maintenance procedures; deficiencies in the practices and communications among the operators, the manufacturer, and the FAA which failed to determine and disseminate the particulars regarding previous maintenance damage incidents; and the intolerance of prescribed operational procedures to this unique emergency.