

ORIGINAL

NO.HQCAA/1901/215/SIB



**CIVIL AVIATION AUTHORITY
PAKISTAN**

AIRCRAFT INCIDENT INVESTIGATION

M/S PAKISTAN INTL AIRLINES

BOEING -747 REG.NO,AP-AYW WHICH OCCURRED

ON 22ND DECEMBER, 1996

AT

QUAID-E-AZAM INTERNATIONAL AIRPORT.

KARACHI

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KARACHI, PAKISTAN

AIRCRAFT INCIDENT INVESTIGATION

INVESTIGATION IN RESPECT OF INCIDENT TO
M/S PIAC BEOING-747 REG NO. AP-AYW OCCURRED ON
22ND DECEMBER, 1996 AT QIAP KARACHI .

Authority:- Director General Civil Aviation Authority
Memorandum No. HQ CAA/1901/215/SIB dated
29th December , 1996 (Ref Appendix 'A').

Composition Of Investigation Team

- | | | |
|-----|--|-----------------------|
| (a) | Air Cdre(R) Rashid A. Bhatti
President SIB CAA | Investigator Incharge |
| (b) | Wg Cdr (Rtd) Sajjad Ahmed
Technical Investigator, SIB CAA | Investigator |

1. AIRCRAFT INFORMATION

- | | | |
|------|--|---|
| 1.1. | Aircraft type | : B-747 |
| 1.2. | Reg. NO. | : AP-AYW |
| 1.3. | Engine types, airframe
positions & S.Nos. | : CF6-50C2, POSN. 1 - 455339
POSN. 2 - 528-154 |
| 1.4 | Certificate of Registration | : No. 561 |

- 1.5 Certificate of Airworthiness No. & date of expiry, and flight manual No. : 064/04-08-1997
CAA-462 (Rev-1)
- 1.6 Certificate of Safety date & time (GMT) of issue and period of validity. : C of M 25.03.1996
- 1.7 Date of construction of airframe. : February, 1979
- 1.8 Name address of Owner. : M/S PIAC Karachi
- 1.9 Airframe history. (Give flying times since manufacture, last overhaul and last periodic check. List also essential modifications completed. : On 15.08.1996. T.S.N. - 43706-29
Last check B done at 42556-38 T-hrs/25.03.96.
Last Base check at 34341-00 T-Hrs/ 13.01.1993
- 1.1 Engine history. (Give flying time since manufacture, last overhaul and last periodic check. List also essential modifications completed). : No.1 S.No.455-339 TSN-44744- /CSN-17899
No.2 S.No.528-154 TSN-25045-13/CSN-11120.

2. CREW INFORMATION

- 2.1 Not required.

3. SUMMARY

- 3.1. On 22nd December, 1996 at about 1545 hours M/s PIAC Boeing-747 aircraft Reg No. AP-AYW had a ground fire incident in which APU Compartment at the tail caught fire after APU was started for aircraft towing operation. Subsequent to normal APU start-up and stabilization of its rpm at 100 percent the APU audio(bell) and video(light) /warning

warning signals came on simultaneously. In response to the situation the operator in the cockpit pulled the 'Fire Handle' of "Fire Extinguishing Bottle" and thereafter the fire warnings went 'OFF'. While no personal injury was caused the aircraft tail structure was severely burnt.

4. **INJURY TO PERSONS**

4.1. No personnel injury was caused.

5. **DAMAGE TO AIRCRAFT**

5.1. Aircraft tail section was severely burnt and APU was damaged.

6. **OTHER DAMAGES**

6.1. None

7. **METEOROLOGICAL CONDITION**

7.1. Not relevant.

8. **NAVIGATIONAL & LANDING AIDS**

8.1. Not relevant.

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9. **COMMUNICATIONS**

9.1. Not relevant.

10. **AERODROME AND GROUND FACILITIES**

10.1. Not relevant.

11. **FLIGHT RECORDERS**

11.1. Not relevant.

12. **WRECKAGE & IMPACT INFORMATION**

12.1. Not relevant.

13. **FIRE**

13.1. Fire was caused due to the incident.

14. **SURVIVAL ASPECTS**

14.1. Not relevant.

15. **TEST & RESEARCH**

15.1. Nil

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16. OBSERVATIONS

16.1. No fire extinguisher was available in the close vicinity of the aircraft at the time of incident.

16.2. ATC was not informed about the physical fire for timely deployment of fire tenders.

17. WITNESSES

17.1 Statement of witnesses are given at appedix 'F1' to 'F5' to this report.

INVESTIGATION

18. At about 1545 hours on 22nd December, 1996 Boeing-747 aircraft Reg No. AP-AYW was to be towed from Line Maintenance-1 to Bay No.61 for operating PK-731. The Cockpit was manned by Senior Technician Badi-ud-Din and Engineering Officer Muhammad Ayub was manning the walkie-talkie out side the aircraft. In order to build-up hydraulic pressure for aircraft brakes operation the Auxiliary Power Unit (APU) was started after carrying out necessary checks. During start-up the APU operation was normal and at about 30 percent rpm its EGT rose to about 840 deg C but came down to 340 deg C as rpm stabilized to 100 percent. After about 2 to 3 minutes the APU fire warning audio(bell) and video (light) signal came 'ON' and Senior Technician Badi-ud-Din received a call from Engineering Officer Muhammad Ayub on wakie-talkie that aircraft tail Section was on fire. At this stage Mr. Badi-ud-Din pulled the 'Fire Handle' and also discharged the 'Fire Bottle' of APU. Soon after the APU fire was extinguished and the APU fire warning light went 'OFF'. However, during this process Mr. Badi-ud-Din didn't inform ATC about the occurrence for

/obtaining

obtaining Fire Tenders support which was essentially required to counter any further damage to the aircraft in case fire was not extinguished.

19. **Post Incident Scene.** During post incident examination the APU Compartment was found severely burnt and aircraft tail skin in the adjoining area had evidence of over heat. The tail skin was buckled at several places and its normal white painted appearance had turned yellowish brown due to fire heat. Additionally, the skin sheet and lining were found burnt making two holes at 1 and 2 O' Clock positions measuring 20 x 30 and 80 x 100 inches respectively (Ref App B1 to B3). Internally, the APU compartment ribs supporting APU and three frames were burnt at locations corresponding to about 2 O' Clock position. Moreover, the compartment walls had evidence of soot deposits at some locations. (Ref Appendix B4 to B15).

20. **APU External Examination.** During external examination of the APU following evidence was observed:

20.1. Turbine Housing and Containment Ring was burnt through at about 2 O' Clock position, making an uneven hole measuring about 4 to 5 square inches (Ref. Appendix B17).

20.2. The rotor was ceased.

20.3. T1 Turbine Stator vanes were burnt more severely as compared to T2 turbine stator vanes. (Refer Appendix B18).

20.4 T1 Turbine visible rotor blades were intact, however; the blades tips had marks due to rubbing against the

/APU

APU abradable coating.

20.5 Rear side of the combustion zone and the front turbine area was slightly bulged out.

20.6 Local Hot Spots and over heat discoloration marks near damaged area.

20.7 APU Harness Assembly wires outer rubber skin deteriorated due to overheat.

21. **APU Shop Examination.** During strip examination of subject APU, evidence of damage was observed on various parts like Compressor, Combustion Chamber, Turbine, Rotor and Stator Assemblies etc the details of which are given at Appendix 'C' to this report.

22. **APU Components Test.** In order to ascertain serviceability of Primary and Secondary fuel manifolds, Fuel Metering valve, Electronics Turbine Control and Thermo Couple Harness a bench test at respective accessories shop was carried out. The test reports revealed that except for the Secondary Fuel Manifold all other APU parts referred above were serviceable. The test reports details in respect of subject parts are given at Appendix 'D' to this report.

23. **Secondary Fuel Manifold.** The test report of Secondary Fuel Manifold Pt No. 3609557-4 S NO. 277/85 revealed that out of a total of eight Nozzles one Nozzle was defective and its flow was five times greater than the average discharge rate (166CC) of rest of the Nozzles. Additionally, it was observed that the defective Nozzle had no spray pattern and had a tap-like flow. In order to Isolate

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the defective Nozzle Assembly, it was replaced with a new serviceable Nozzle Assembly and the performance of Secondary Fuel Manifold was found within acceptable limits as stipulated in the Maintenance Manual.

24. **Examination Of Defective Nozzle.** During examination of the defective Nozzle Assembly Pt No. 968605-4 fig Index 56/ 1 Allied Signal Maint Manual (Ref. Appendix 'D') removed from the Secondary Fuel Manifold of subject APU the nozzle inside the Shroud was found loose and also the Nozzle tip was protruding out as compared to other nozzles installed on subject fuel manifold. On removal of the Nozzle Shroud following evidence was observed :-

- 24.1. Fuel Nozzle Tip was loose and was out by about two threads.
- 24.2 Hexagonal Nozzle body was free to rotate without turning the triangular locking lugs of the Tab Washer Pt No. 698266-1. Maint Manual Allied Signal GTCP 660-4
- 24.3. Corners of the Nozzle hexagonal surfaces had rubbing shinning marks at three places.
- 24.4. Triangular locking lugs of the Tab Washer were protruding outward and were not butting with the hexagonal faces of the nozzle body.
- 24.5. Tab Washer Triangular locking lugs inner surface had no scratch marks.
- 24.6. Rectangular slot in the Nozzle body designed to hold positively the rectangular locking lug of

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the Tab Washer had no evidence of any scratch or rubbing marks.

24.7. Tab washer Rectangular locking lug had no evidence of rubbing or scratching on its internal surface.

24.8. Tab washer Triangular locking lugs inner surface had no scratch or rubbing marks, however; both lugs had shinning rubbing marks at the lower inner surface at the base.

Location Of Defective Nozzle. The position of defective fuel Nozzle Assembly of Secondary Fuel Manifold was checked when installed on the APU. The location of subject nozzle was observed to be at 2 O' Clock position around which most of the damages to APU and aircraft had occurred.

Defective Nozzle History The Board observed that the Secondary Fuel Manifold S.No. P277/85 having defective nozzle was removed from APU No. P38091 on 4th April, 1996 when APU S.No. P38091 was received in the APU Shop for a maintenance defect: APU not starting. Subject SFM was handed over to the Accessory Shop for maintenance vide M/s PIAC maint continuation sheet Form No. 9-17-765 Ref No. PIA/JE/1428/96 dated 16th april, 1996. (Ref Appendix 'E'). During the recovery maintenance Five Shrouds Pt No.871362-3 were found worn out and were replaced by Officer Engineering Muhammad Bashir and supervisory check was carried out by Acft Engr Sultan Ali Bukhari. Subject nozzle was released as serviceable after its operation was found satisfactory by Quality Inspector Mr. Kahlid Iqbal QC No. Q3-40/650 on 7th July, 1996. Subsequent to Quality check the secondary Fuel Manifold was kept in storage till the time it was installed on APU SNO P37802 .

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27. History of APU SNO. 037802. APU 37802 was removed from aircraft Reg No. AP-BCM on 4th September, 1996 at 19591 operating hours since new and 493 hours since overhaul. The APU was disassembled, its gas turbine section was overhauled, tested on 15th November, 1996 and was installed on aircraft Reg No. AP-AYW on 21st December, 1996. At the time of incident the APU had logged 6 hours including 2 hours on the test bed.

ANALYSIS

APU Components

28. The satisfactory test results of Fuel metering valve and Electronic Turbine Control indicated that the fuel supply system of the APU was within the design parameters. Moreover, Thermo-couple Harness test results confirmed serviceability of the thermo couple harness and validity of the fact that EGT signal was received at Electronic Turbine Control. Furthermore, serviceability of Primary Fuel Manifold logically isolates the Secondary Fuel Manifold as the main problem area to which localized heating can be attributed to. Subject inference was validated by the Secondary Fuel Manifold flow test which showed one of the nozzle flow was about 5 times more than the average of rest of the seven nozzles which is far out of the permissible limits. Additionally, the defective nozzle had no flow pattern and the fuel flow was in the form of streaks. Moreover, the location of the damage area in and around APU was confined to same area ie 2 O' Clock which conforms to the defective nozzle position.
29. From the foregoing evidence the Board is of the opinion that while the metering valve was supplying metered fuel, one single nozzle was pouring 5 times more fuel than others. Moreover, with no fuel spray pattern the design flame pattern and flame cooling provided

/by

by the secondary air blanket was not being achieved, instead a streak of unauthorised fuel burning occurred at one location on the APU hardware causing excessively high temperature in a small area persistantly. Although, it cannot be conclusively determined as to how long in terms of operating hours subject condition prevailed but it did prevailed long enough to damage the turbine hardware, T1 Stator, T2 Stator and APU casings considerably during last six hours of operations.

ETC Auto-Shut Down.

30. The APU has an auto shut down device to prevent damage to the APU in case excessive EGT condition prevails. However, in subject case due to inefficient/off-design combustion process, average EGT signal around the thermo couples located in the exhaust, would have been slightly lower than what it should have been under normal operating conditions. Therefore, the auto-shut down action of ETC did not occur under the circumstances.

Torching Effect.

31. Constant impinging of raw fuel, directly on the turbine hardware, generated intense heat which led to thermal distress of the T1 stator, T2 stator and APU casing. Once punctured the EGT signal at thermo couples became even lower due to leakage of hot gases from the inner shell through the punctured turbine casing. Subsequently, the out going flame caused burning of the APU compartment.

Defective Nozzle.

32. During investigation it was observed that the defective fuel Nozzle tip was touching the outer shroud and was free to rotate inside. On
/removal

removal of the Nozzle Shroud it was observed that the Nozzle tip had unscrewed by about 2 turns and its locking Tab Washer Pt No. 6982661 Allied Signal Over Haul Manual Page 389 Oct 31/94 (Ref Appendix 'D') was not restricting the movement of hexagonal face of the Nozzle tip. The hexagonal tip of the Nozzle is screwed to its Nozzle body by applying 40 in-lb torque. Additionally, the Tab Washer has one rectangular and two triangular locking lugs which are butted against the Nozzle surface respectively when the washer is correctly locked after tightening the Nozzle. While observing the Tab Washer the Board didn't observe that the locking lugs had any evidence of scratching or rubbing. Therefore, the Board is of the opinion that the Tab Washer lugs were not properly butted with the surface of the nozzle tip and under the circumstances no restriction was imposed to prevent unscrewing of Nozzle tip. Although, the Nozzle tip is tightened by applying 40 in-lb torque the APU System is exposed to vibration ranging from 4000 to 38500 rpm at 67 to 645 (cps) frequency respectively. Therefore, the Board is of the opinion that under such conditions a large probability exists for unscrewing of the Nozzle Tip, if the Tab Washer lugs are not locked properly.

Unauthorised Tampering Of Nozzle.

33. While the nozzle tip is screwed and locked it is also covered by cylindercal Nozzle Shroud Pt No. 871362-3 Fig Index No. 56/10 (Ref Appendix 'D') which is also locked by Shroud pin Fig Index 56/5, that can only be removed by a special punching tool. Hence, unscrewing of fuel nozzle tip by external source during transit has a low probability. However, to probe into any possibility of unscrewing of fuel nozzle due to inadvertant or unauthorized tampering following possibilities were probed :-

33.1. Tampering Of The Nozzle During Storage. The /nozzle

nozzle prior to its installation on APU NO. P-37802 was removed from APU NO. P-38091 for rectification at Fuel Accessory Shop on 16th April, 1996 where its five worn out Shrouds were replaced and the nozzle was released as serviceable for storage on 4th July, 1996. Subsequently, the nozzle was installed on APU No. 37802 in the month of November, 1996. As such, the nozzle remained in transit for about 120 days. Therefore, probability of its unauthorised tampering exists, though small, which cannot be ruled out.

33.2 Experiment On The Nozzle. The possibility of unauthorized fuel Nozzle tampering by use of spanner was also probed. An experiment conducted to unscrew the locked hexagonal nozzle tip revealed same evidence in terms of signatures on the locking lugs of the Tab Washer that were observed on the original Nozzle assembly. In that, the triangular Tab Washer lugs were protruding out to some what the same degree, had similar scratch marks at the inner surface at the base and the hexagonal corners of the nozzle had similar type of shining rubbing evidence as compared to that observed on the Nozzle involved in the incident.

34. Keeping the above evidence in view the Board is of the opinion that an effort was made to open the hexagonal tip of the nozzle with a spanner at some stage between the period it was tested and prior to its installation on the APU.

/serviceability

Serviceability Of The Secondary Fuel Manifold

35. Acft Engr Soomro stated that the SFM Nozzle had a serviceable Tag at the time it was received for installation on the APU some time in November, 1996. However, Officer Engineering Fazil Amir of APU Shop stated that subject secondary fuel manifold was received without a S/A Tag from the Planning Section and was installed after validating its last test record. Moreover, subject SFM was not tested despite the fact that it had no serviceable Tag. Additionally, Acft Engr Sultan Ali Bukhari informed the Board that he prepared a duplicate S/A Tag for subject SFM nozzle record when he was approached by Acft Engr Rafiq-uz-Zaman and Eng-Off. Fazal Amir on 24th December, 1996 after subject incident on 22nd December, 1996. Therefore, the Board is of the view that the nozzle didn't carry S/A Tag at the time it was received from the Planning Section for installation on the APU No. 37802 and the Board attributes a large probability to the fact that the Nozzle was unserviceable at the time of its installation on the APU involved in the incident.

CONCLUSION

36. APU SNO. 37802 installed on Boeing aircraft Reg No. AP-AYW caught fire soon after the APU was started for aircraft towing. The fire resulted due to out flow of hot gases from the inlet casing of the APU which was internally burnt due to high temperatures condition that prevailed at about 2 O' Clock position inside the APU Turbine Casing. Subject high temperature was confined to a small area around a defective Fuel Nozzle through which fuel in unautomised condition contineously dripped causing impinged burning thereby the turbine housing and allied APU parts were burnt.
37. The faulty Secondary Fuel Manifold nozzle was found loose and
/its

its lock washer Pt NO. 6982661 was not restricting the hexagonal faces of the Nozzle tip. The SFM was received from the store without S/A Tag and was not tested prior to its installation. Therefore, under the circumstances a large probability is attributed to the fact that the Secondary Fuel nozzle was faulty at the time it was installed on APU No. 37802.

Findings

38. The Board finds that:-

- 38.1 On 22nd December, 1996 Senior Technician Badi-ud-Din and Engineering Officer Muhammad Ayub were detailed to tow Boeing aircraft Reg No. AP-AYW from Line Maint-1 area to the International Bay.
- 38.2 Soon after normal start-up of aircraft APU for developing hydraulic pressure of the brake system prior to towing, the Fire Warning (video light) and Audio (Bell) signal came 'ON' and fire extinguishing agent was discharged from the APU 'Fire Bottle' and fire was extinguished.
- 38.3 Senior Technician Badi-ud-Din who was manning the Cockpit didn't give any call to ATC for obtaining back-up support for the emergency.
- 38.4 The aircraft tail section and the APU Turbine casing were severely damaged due to fire (Ref Appendix 'B').
- 38.5 The fire was caused due to faulty Nozzle Assembly Pt No.968605-5 of Secondary Fuel Manifold Part No. 3609557-4 SNO. 277/85 which was found loose.
- 38.6 Subject Secondary Fuel Manifold was installed on the affected APU in the month of November, 1996 during APU Overhaul at APU Shop M/s PIAC.
- 38.7 Prior to installation of subject Secondary Fuel Manifold on APU SNO. 37802 it was neither tested nor it carried any 'Tag' to validate its serviceability.

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- 38.8 Out of 8 fuel nozzles of subject Secondary Fuel Manifold one of the nozzle's flow was 5 times the average of other 7 nozzles which was far beyond the permissible limits stipulated in the Manufacturer's Maintenance Manual.
- 38.9 The hexagonal tip of Nozzle Assembly Tip was found loose by about 2 turns and was free to rotate as the Tab Washer locking lugs were bulging outward thereby imposing no restriction on hexagonal nozzle tip movement.
- 38.10 The evidence on Tab Washer showed that the Nozzle Tip was forcibly untorqued and the nozzle tip was left in the open position, however; it could not be established as to when it was untorqued.
- 38.11 Last Maintenance on subject Fuel Manifold was carried out at Fuel Accessory Shop in which its five shrouds Pt No. 871362-3 were replaced.
- 38.12 During the period from 4th July to November, 1996 subject Secondary Fuel Manifold remained in transit till it was installed on APU No. 37802 without testing under instructions from Acft Engr Altaf Ahmed despite the fact that it didn't carry a Tag to validate its serviceability.
- 38.13 APU SNo. 37802 was released for operation after overhaul without ensuring completeness of its Overhaul documentary record, in that it had no document to validate serviceability of Secondary Fuel Manifold which was installed on subject APU during Overhaul.
- 38.14 A duplicate serviceability Tag in respect of Subject Secondary Fuel Manifold was prepared on 24th December, 1996 after the incident on 22nd December, 1996 by Acft Engr Sultan Ali Bukhari on request of Officer Engineering Fazal Amir(P-41630) of APU Shop.
- 38.15 APU NO. 37802 had operated 6 hours after Overhaul including 2 hours on the test bed.

/causes

CAUSES

39. Following are the causes of the incident:-

- 39.1 Not testing the Secondary Fuel Manifold Pt No. 3604557-4 SNo. 277185 having no serviceable Tag prior to its installation on APU NO. 37802.
- 39.2. Not ensuring completeness of maintenance documents prior to release of APU SNo. 37802 as serviceable.

RECOMMENDATIONS

40. The Board recommends that:-

- 40.1. ATC must be informed for back up support in all cases of aircraft fires.
- 40.2 Supervisors must ensure that no component is installed without validating its serviceability.
- 40.3 Disciplinary action should be taken against Acft Engr. Altaf Ahmmd for authorizing installation of Secondary Fuel Manifold Pt No. 3609557 SNO. 277/85, carrying no serviceability Tag, without testing it on APU NO. 37802.
- 40.4 Disciplinary action should be taken against QC Inspector Aziz-ur-Rehaman for releasing APU NO. 37802 after overhaul without ensuring availability of S/A Tag of Secondary Fuel Manifold in the overhaul documentary record.

APP. B₁



BURNT TAIL SECTION. BETWEEN 2 TO 3 O'CLOCK POSITION.



APP. 'B₂'

BURNT SKIN CLOSE UP VIEW



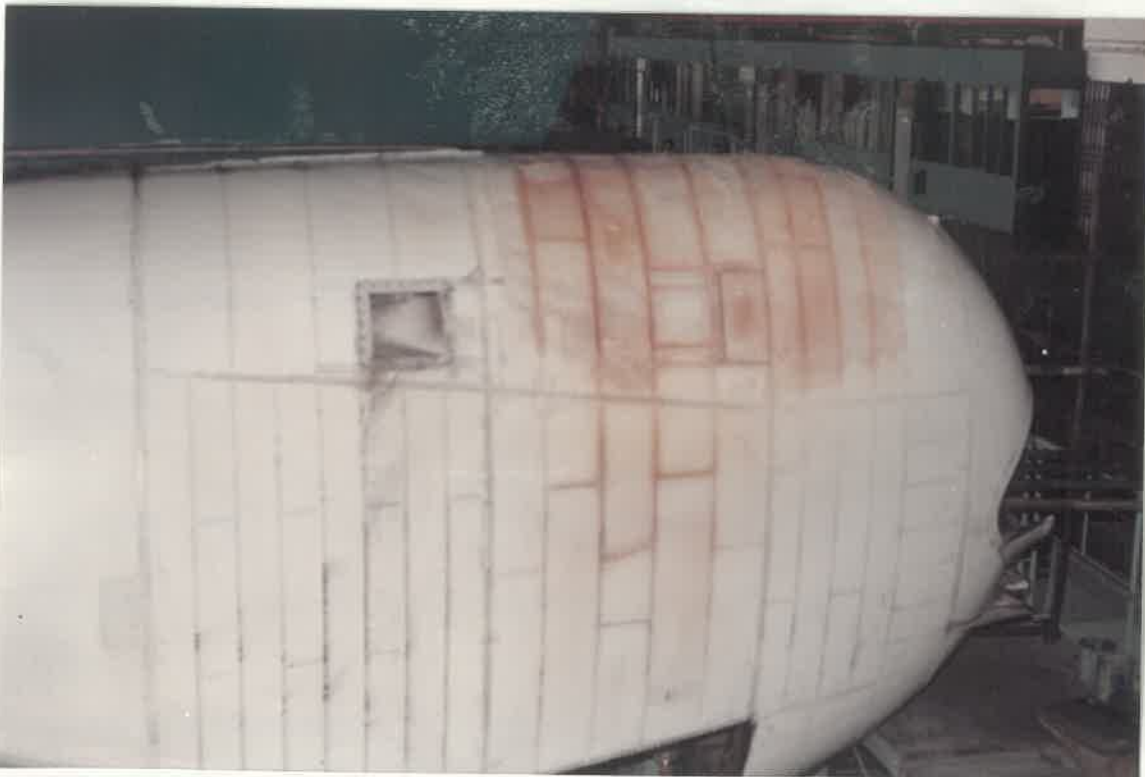
EVIDENCE OF BURNING AND BUCKLING OF TAIL SKIN

APP. 'B4'



EVIDENCE OF BUCKLED TAIL SKIN DUE TO HEAT

APP. 'B5'



EVIDENCE OF DISCOLORATION AND BUCKLING OF TAIL SKIN

APR 'B6'



FIRE DAMAGE TO TAIL SECTION INSIDE VIEW

APR 'B7'



FIRE DAMAGE EVIDENCE INSIDE VIEW

APP' B8'



EVIDENCE OF BURNING BUCKLING AND DISCOLORATION
DUE TO HI-TEMP.



EVIDENCE OF BURNING AND BUCKLING OF TAIL SKIN - ANOTHER VIEW



BURNT TAIL SECTION - ANOTHER EXTERNAL VIEW

APP 'B11'



INTERNAL DAMAGE CAUSED DUE TO FIRE IN TAIL SECTION



TAIL SECTION BURNING INSIDE VIEW



TAIL SECTION INTERNAL DAMAGE - ANOTHER VIEW

APP. 'B14'



INTERNAL DAMAGE IN THE TAIL SECTION



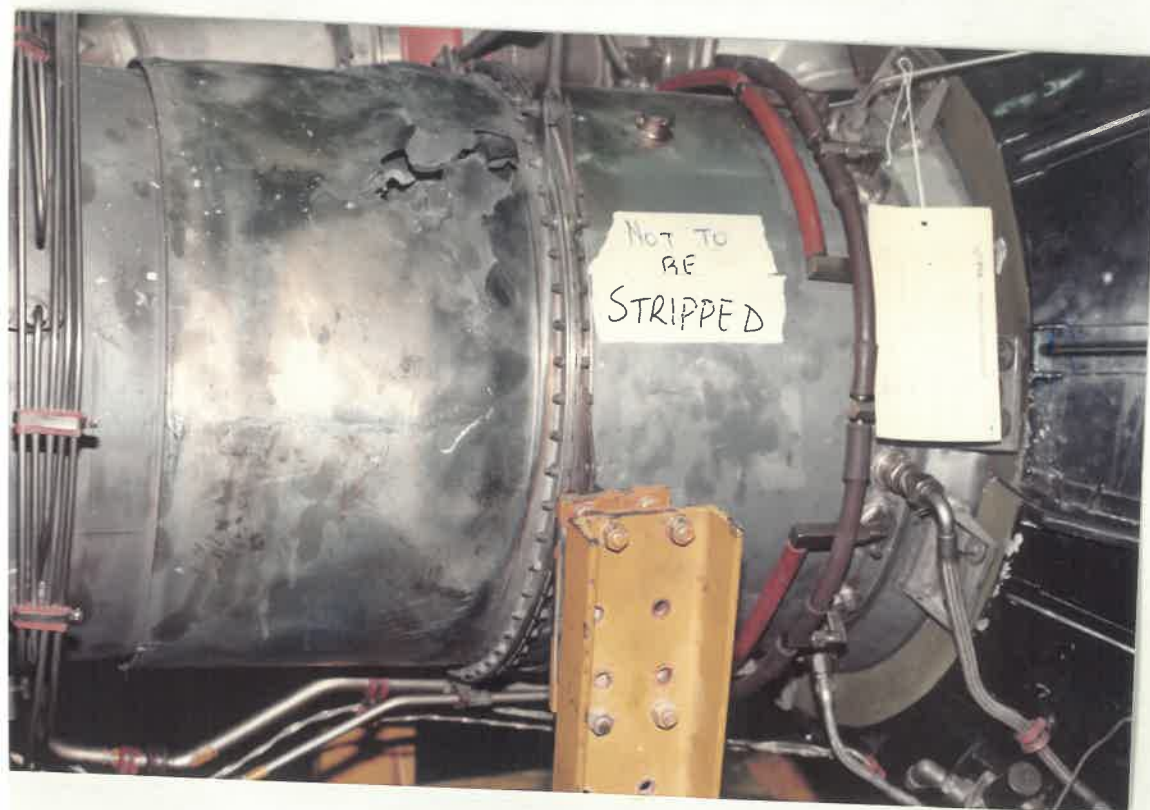
INSIDE VIEW OF DAMAGE CAUSED IN THE TAIL SECTION

APR. 'B16'



INSIDE VIEW OF TAIL SECTION DAMAGE - ANOTHER VIEW

APR. 'B17'



APU BURNT SKIN AT ABOUT 2 - 3 O'CLOCK POSITION

APP. B18



EVIDENCE OF OVERHEAT IN THE APU