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NATIONAL TRANSPORTATION SAFETY COMMITTEE

AIRCRAFT ACCIDENT REPORT

Garuda Indonesia Flight GA 880
Boeing B747-200 PK-GSD
In flight (21 minutes after takeoff from Denpasar, Bali)
23 November 2001

NATIONAL TRANSPORTATION SAFETY COMMITTEE
DEPARTMENT OF COMMUNICATIONS
REPUBLIC OF INDONESIA
2003

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This report has been prepared based upon the investigation carried out by the National Transportation Safety Committee in accordance with Annex 13 to the Convention on International Civil Aviation, UU No.15/1992 and PP No. 3/2001.

This report was produced by the National Transportation Safety Committee (NTSC), Gd. Karsa Lt.2 Departemen Perhubungan dan Telekomunikasi, Jalan Medan Merdeka Barat 8 JKT 10110 Indonesia.

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CONTENTS

GLOSSARY OF ABBREVIATIONS

ATPL	Air Transport Pilot License
BSI	Boroscope Inspection
CAAS	Civil Aviation Authority of Singapore
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
CY	cycles
DFDR	Digital Flight Data Recorder
DGAC	Directorate General of Air Communications
EDS	Energy Dispersive Spectrometry
EPR	Engine Pressure Ratio
F/E	Flight Engineer
FAA	Federal Aviation Administration
FDR	Flight Data Recorder
FEL	Flight Engineer License
FH	flight hours
FL	flight level
FOD	foreign object damage
HB	Brinell hardness number
HPT	High Pressure Turbine
HRC	Rockwell C hardness number
hrs	time (24 hour clock)
LH	left hand
LPT	Low Pressure Turbine
mm	millimetre(s)
NGV	Nozzle Guide Vane
NTSB	National Transportation Safety Board
NTSC	National Transportation Safety Committee
°C	degrees Celcius
P/N	part number
PIC	Pilot-In-Command
RH	right hand
RPM	Revolutions Per Minute
SAIB	Special Airworthiness Information Bulletin
S/N	Serial number
SEM	Scanning Electro Microscope
TOC	take-off climb
TSN	Time Since New
TSR/CSR	Time since removed/Cycles since removed
TT/TC	Total Time/Total Cycle
UTC	Universal Time Co-ordinated

SYNOPSIS

On 23 November 2001, a Garuda Indonesia Boeing B747-200 aircraft registration PK-GSD was on a scheduled passenger flight from Denpasar to Jakarta. At 14.26 UTC, approximately 21 minutes after takeoff from Ngurah Rai Airport, the aircraft experienced an engine failure on the #2 engine. The flight crew decided to descend from FL390 to FL310 and proceed with N-1 condition to Jakarta, where an uneventful landing was accomplished. No injuries to crew or passengers were reported.

The National Transportation Safety Committee conducted the investigation according to the standards and recommended practices of Annex 13 to the Convention on International Civil Aviation.

On-ground inspection by the NTSC and Garuda Indonesia investigation team revealed that an uncontained engine failure had occurred on the #2 engine low pressure turbine. The debris ejected from the #2 engine had caused minor damages to the airframe and FOD to the #1 engine.

The #2 engine was sent to Pratt & Whitney Facilities in Middletown, Connecticut, where an engine tear down was conducted. The tear down was witnessed by an accredited representative from The US National Transportation Safety Board and advised by a US Federal Aviation Administration officer, a team from Pratt & Whitney and a team from the NTSC. Metallurgical analysis was performed on several parts of the 5th stage LPT disk, specifically on the web, at the NTSB headquarters in Washington, D.C.

The engine tear down revealed the blockage of the cooling air holes of the 5th stage rotating airseal by plasma coating material. This blockage has a significant impact on the 5th stage disk lives and resulted in uncontained disk fracture.

Further investigations found that the process sheet of Windsor Airmotive Asia in Singapore where the airseal was repaired did not include the caution not permitting plasma coat in airseal holes. NTSC immediately issued recommendations to the Department of Communications and notified the Civil Aviation Authority of Singapore. The US FAA also issued a SAIB concerning the blockage of the 5th stage airseal cooling air holes, followed by an All Operators Wire from Pratt & Whitney.

This final report contains the factual information, analysis, conclusions and recommendations from the accident investigation. An additional information on engine malfunction identification is attached as an appendix.

1 FACTUAL INFORMATIONS

1.1 History of Flight

On 23 November 2001, a Garuda Indonesia Boeing B747-200 aircraft registration PK-GSD took off from Denpasar, Bali to Jakarta at 14.05 UTC. The aircraft was climbing as it approached FL390 when a loud bang (explosive sound) was heard, approximately at 14.26 UTC. The purser reported to PIC that a flight attendant saw flame accompanied the bang on the portside. The flight crew saw increased EGT of #2 engine momentarily following the bang, and then all #2 engine parameters dropped. The flight crew then performed the checklist for ENGINE FAILURE/SHUTDOWN, reported to ATC and descent to FL310. Considering no other anomalies found on other engine parameter indicators and no vibrations observed, the flight crew decided to proceed with N-1 condition to Jakarta. The rest of the flight was normal and the landing was uneventful, although when the aircraft flared during touchdown, the thrust was reduced significantly that the flight crew felt a sudden drop of the speed. No injuries to crew or passengers were reported.

On-ground inspection revealed that an uncontained engine failure had occurred on the #2 engine low-pressure turbine, and the liberated debris had caused FOD on the #1 engine and airframe (see Figure A10).

1.2 Injuries to Persons

There were no injuries to the 19 crew members or 128 passengers reported.

1.3 Damage to Aircraft

The #2 engine had experienced an uncontained engine failure on the low pressure turbine module, with the following damages:

- Damages on outboard engine cowling and outer casing (see Figures A1, A2).
- Rupture on LPT casing, i.e. 5th and 6th stage outer airseal at 6 – 10 o'clock[1] position (see Figure B2).
- Damages on LPT 5th stage stator vanes.
- The 5th stage low pressure turbine disk rim was liberated. The 5th stage rotor blades were fractured through airfoils, generally adjacent to the root platforms. Some of the blade roots were found in the disk rim slots, while others have been liberated. Two pieces of 5th stage turbine disk rim that had separated from the web were recovered (85 attachment slots out of 110).
- The 6th stage stator vanes were detached and missing at 6 to 12 o'clock[1] position (see figure.
- The LPT 6th stage rotor blades were fractured transversely outboard of the platform.
- Minor damages on the tailcone and flange bolt recess cavities.
- Severe impact damages on the turbine exhaust case and exhaust guide vanes (see Figures A3-A6).

The #1 engine fan blades, spinner cone, side cowling and fan case had sustained damages (FOD) due to debris from the #2 engine (see Figures A11-A16).

[1] O'clock position refers to radial clockwise position, as viewed to the direction of flight.

The ejected debris from the #2 engine had also caused these following damages on **the airframe** (see Figures A17-A22):

- Damages on lower surface of LH inboard aileron.
- Damages on LH inboard flap
- Damages on flap canoe #1 and #2.
- Damages on fix fairing near LH refueling panel.
- Damages on engine #1 pylon upper fairing.
- Skin scratches on engine #1 pylon RH side.
- Skin scratches on engine #1 hydraulic bay RH panel.

1.4 Other Damage

There was no report of other damages caused by ejected debris from #2 engine.

1.5 Personnel Information

	PIC	**Co-pilot**	**Flight Engineer**
Gender	Male	Male	Male
Date of birth	3 December 1954	11 April 1970	26 March 1959
Nationality	Indonesia	Indonesia	Indonesia
Marital status	Married	Single	Married
Date of joining company	12 September 1978	21 March 1995	1 April 1980
License	ATPL 2473	ATPL	FEL 332
Validity period of license	23-04-2002	11-07-2002	
Type rating	B747-200	B747-200	F/E B747-200
Date of last medical	23-10-2001	11-01-2001	06-08-2001
Last line check	23-09-2001	14-01-2001	
Last proficiency check	26-09-2001	03-10-2001	21-11-2001
FLIGHT TIME			
Total time	13,600	4,728	8,000
This make & model		1,348	
Last 90 Days	140.00	42.00	70.00
Last 72 Days	100.00	36.00	42.00
Last 24 Hours	1.45	-	20
This flight	0.20	0.20	0.20

1.6 Aircraft Information

1.6.1 Aircraft Data

Registration Mark	:	PK-GSD
Manufacturer	:	Boeing Commercial Airplane Group
Country of Manufacturer	:	United States of America
Type/ Model	:	B747-200
Serial Number	:	22249
Date of manufacture	:	1980
Certificate of airworthiness	:	Valid until October 18, 2002
Issued	:	19 October 2001
Certificate of registration	:	Valid until August 26, 2002
Issued	:	27 October 2001
Category	:	Transport
Crew (Cockpit /Cabin)	:	3/16
Pax seats	:	38 C/360Y
Time Since New	:	73921 FH
Cycles Since New	:	18932 CY
Last Inspection	:	A-check FA11 at 73778 FH/18908 CY
Next Inspection	:	A-check FA12 at 74328 FH
Hours since last inspection	:	143 hrs
Cycles since last inspection	:	24 cycles

1.6.2 Engine Data

Engine Type	:	Turbofan
Manufacturer	:	Pratt & Whitney
Type/ Model	:	JT9D-7Q
Serial Number #1	:	P 702247
▪ **TSN**	:	55,421 FH
▪ **CSN**	:	14,286 CY
▪ **TSI**	:	2790 FH
▪ **CSI**	:	538 CY
Serial Number #2	:	P 702424
▪ **TSN**	:	46,154 FH
▪ **CSN**	:	11,527 CY
▪ **TSI**	:	1,470 FH
▪ **CSI**	:	374 CY

1.6.2.1 Maintenance History

Engine #2 5th stage inner rotating airseal (P/N 760659, S/N KJ7386)

Historical records of the airseal are as follow:

Date	TT/TC	Installed on	
		LPT Module S/N	Engine S/N
2 April 1986	9083/2634	S/N D02446	S/N P702446
2 December 1986	9794/2793 TSR/CSR: 0/0	S/N D02446	S/N P702246
7 January 1988	13399/3812	S/N D02446	S/N P702403
21 February 1992	24478/6535 TSR/CSR: 0/0	S/N D02446	S/N P702201
24 May 1994	30431/7780	S/N D02446	S/N P702244
16 November 1995	33125/8313	S/N D02446	S/N P702425
2 June 1998	37409/9163 TSR/CSR: 0/0	S/N D02445	

The airseal was inspected and repaired by Windsor Airmotive Asia on 25 April 1997, received by Eagle Services Asia on 5 May 1997 and installed on LPT module D02445 on **2 June 1998**.

Engine #2 LPT Module (P/N 808808, S/N D02445)

On 29 October 1997, the LPT module P/N D02445 was removed from Engine S/N P702412 by Eagle Services Asia. This module was refurbished, disassembled and its 5th stage inner airseal was repaired outhouse (Windsor Airmotive Asia).

The LPT module was installed on Engine S/N P702231 and returned to service on 13 November 1998 and removed again on 16 October 2000 for a repair. In this repair, the module was disassembled to replace the 3rd stage airseal but the 5th stage rotor was not disassembled.

This module was then installed on Engine S/N P702424 on **15 January 2001**.

Engine #2 S/N P702424

The engine was installed on PK-GSD on **2 June 2001**. On 12 October 2001, a borescope inspection revealed a crack on 1st stage NGV. The engine continued to be in-service with reduced BSI interval (from 500 hours to 250 hours).

There were several problems on engine #2 recorded in the maintenance logbook from 14 October 2001 to 28 October 2001, consisted of higher ground idle parameters and faster spin up (compared to three other engines), high fuel flow, thrust lever #2 manual power adjustment problems and auto throttle problem.

1.6.3 Weight and Balance

Not relevant.

1.7 Meteorological Information

It was reported that during the time of the accident the weather was clear.

1.8 Aids to Navigation

Not relevant.

1.9 Communications

Not relevant.

1.10 Aerodrome Information

Not relevant.

1.11 Flight Recorders

1.11.1 Flight Data Recorder

Flight Data Recorder was secured and the read-out was done at Aviation Safety Council, Taipei, Taiwan on 7-10 January 2002.

The database document of the DFDR (P/N 981-6009-014 S/N 3272) contains several errors of the EPR, oil temperature, altitude, etc. Due to noisy tape signal, it was difficult to read-out 100% of E/U data. Therefore, the read-out analysis could not be carried out accordingly.

1.11.2 Cockpit Voice Recorder

The CVR (P/N 980-6005-076 S/N 9221) was not analyzed because the event recording had been erased due to continued flight to Jakarta (more than 30 minutes).

1.12 Wreckage and Impact Information

Not relevant.

1.13 Medical and Pathological Information

Not relevant.

1.14 Fire

There was a report of flame seen from portside by a flight attendant at the time the explosive sound was heard. There was no evidence of fire found on the #1 and #2 engines.

1.15 Survival Aspects

Not relevant.

1.16 Test and Research

1.16.1 Engine tear down

The #2 engine tear down was conducted on 8-10 January 2002 at Pratt & Whitney facilities in Middletown, Connecticut involving air safety investigators from NTSC, US NTSB, US FAA, Pratt & Whitney and engineers from Pratt & Whitney. Details from the teardown process are attached as Appendix D (NTSB Engine Teardown Field Notes).

1.16.1.1 Engine #2 LPT module

a). The 5th stage disk P/N 753421, S/N K15178

The rim of the disk was detached from the web (Fig. B12). The recovered rims consist of two broken pieces, which include 85 slots (out of 110 slots). These two pieces were recovered at Garuda Engine shop in Jakarta, and directly sent to NTSB Laboratory in Washington DC. The web of the disk shows different colors on both faces, the forward face has gray-blue color (Fig. C1), while the aft face has brown-red color (Fig. C2). The fracture surfaces of the disk show 90-degree plane on both faces connected by a 45-degree plane (Fig. C3, C4, C5 and C6).

b). The 5th inner airseal P/N 760659C, S/N KJ7386

The 5th airseal has 60 holes for the cooling air passage. During the teardown, fifty-six of the 60 (>90%) cooling holes were found blocked by plasma coating material. The four that were found partially blocked were exposed because of chipped coating (Fig. B9 and B10).

1.16.1.2 Borescope Inspection of Engine #2 HPT Module

Borescope inspection was conducted to 8th, 9th and 11th stage compressors and through AP8 and AP9 for combustion chambers and 1st NGV. No anomalies were found, other than metal burning and some crack found on the trailing edge of 1st NGV at 2 o'clock position. This has already been observed on the last inspection.

1.16.2 Metallurgical Examinations

Metallurgical examinations were conducted at Metallurgical Laboratory, US National Transportation Safety Board, Washington D.C. on 14-17 January 2002 by NTSB and NTSC. Metallurgical examinations were performed on the disk, specifically on the web. Factual report from the NTSB metallurgist is attached as Appendix H of this report.

1.16.2.1 Visual observation

Overall visual inspection showed that the length of the 90^{o} fracture surface is about 14 inches long on the forward face and 9.5 inches long on the aft face of the web. This type of fracture surface is located approximately 7 inches from the forward inner spacer snap diameter (or 13 inch radius from the disk centerline) or 0.5 inch from live rim. The 45^{o} fracture surface occurred continuously circumferentially. This 45^{o} fracture surface has a jagged form circumferentially (i.e. from 7 to 7.5 inches).

The 90^{o} fracture surface emanating from the aft and forward disk surfaces are associated with the normal tensile stress, while the 45^{o} fracture surface is associated with the shear stress acting on the plane of fracture.

Secondary cracks were also observed intermittently around 7 inches from the forward inner spacer snap diameter (or 13 inch radius from the disk centerline).

Deformation due to bending was observed near the tip of the fracture in the forward direction.

The aft face surface has a red-brown appearance, while the forward face shows bluish-gray tint. Cleaning with water and soap revealed randomly distributed red-brown deposits on the aft face.

1.16.2.2 Binocular Fractography

a) 5th stage LPT web

Binocular microscope examination was performed on a segment cut from the disk containing the deepest 90^o-fracture surface. The binocular examination revealed the grainy nature of the 90^o fracture surfaces and the smooth nature of the 45^o-shear fracture plane.

b) 5th stage live rim

There are two broken pieces of the live rim recovered. Close examination reveals that all of end fracture surfaces show shear type fracture.

1.16.2.3 SEM Fractography and EDS

a) 5th stage LPT web

Prior to SEM examination, the sample was cleaned with ultrasonic cleaner. This operation caused a large portion of the deposit of the aft face to detach, indicating that the deposit is of loose nature (not adherent).

SEM examination was done on the fracture surface revealed the intergranular nature of the 90^o fracture surface and smooth sheared surface of the 45^o fracture surface (Fig. C13). On the 90^o fracture surfaces the intergranular nature is more distinct at locations away from the disk face. Intergranular cracks were also observable at these locations. The less prominent intergranularity near the disk face is due to oxide formation (Fig. C16).

Dimples showing shear movement were observed on the 45^o fracture surface (Fig. C15).

SEM observation on the face showed a circumferential intergranular crack (Fig. C16). Similar feature of fracture surface was observed in the secondary crack, due to oxide formation indicating longer exposure to gases.

SEM observations performed on the aft face showed typical oxide morphology.

Further EDS analysis on this particular oxide layer confirmed that it was metal oxide, as described by the spectrum. As a comparison, an EDS analysis was performed on the metal.

In the region of oxides, a distinct feature was observed, i.e. the presence of oxygen and at some cases Phosphorus peak. The presence of oxygen indicates oxide formation. The Phosphorus might have originated from the mist of the lubricants (oil) of the bearing. No sulfur element was found in the spectrum, indicating that there was no fuel contamination.

SEM examination/EDS analysis was continued for microanalysis of un-etched sample, i.e. on a section near the fracture surface. On the forward and aft face, the oxides layer was not of uniform thickness, varied from nil to about 9 micrometer. On the outer edge of the fracture surface, the oxides were thicker, and became thinner toward the inner direction.

EDS on the oxide reveals spectrum having peaks with different intensities. At a location, it shows a predominant Fe (with much lower content in Cr and Ni) At other location it has high content of Cr, Ni, Ti and Fe, forming metallic compounds.

During SEM examination, the sample part for metallography was selected.

b) Plasma coating material

A sample of the material of the plasma coating was examined to determine whether it complies with the specification or not. The standard requires plasma coating material to contain 95% Ni and 5% Al. EDS analysis spectrum shows that the material contains high percentage of Ni and smaller percentage of Al, which is an indication that the plasma coating material complies to the standard.

1.16.2.4 Optical metallography

a) 5th stage LPT web section near the fracture surface

- Un-etched specimen

  A sample for metallography was prepared on a section taken from the segment that has been observed by SEM. The un-etched surface shows the nature of the cracks and secondary cracks on the forward and aft side. More specifically, there were thicker oxide layers at the outer fracture and becomes thinner towards inner location. The intergranularity of the 90^o fracture was also confirmed by the metallography examination. There were secondary cracks on the forward side and the aft side. These secondary cracks were "filled" with oxides.

  Deformation occurred in the forward direction. No pitting corrosion was observed on the forward as well as aft side.

- Etched specimen

  The grain size of the section near the fracture surface was found to be 6 ASTM Grain Size.
  Higher magnification (1000x) reveals that the grain boundaries consist of small discrete carbide precipitates. There are no detrimental phases/features observed at the grain boundaries, such as:
  - no creep voids;
  - no continuous film of carbide precipitates;
  - no blocky carbides.

b) 5th stage LPT web section near the bore

Metallographic examination performed on a sample taken from a location near the bore. This sample shows also that oxide layers were formed on forward and aft faces.

The grain size of the web near the bore was found to be between 5 to 6 ASTM Grain Size.

Higher magnification reveals microstructure that is similar to that of the web near the fracture surface.

c) 5th stage LPT live rim

The grain size of this region was found to be between 5 to 6 ASTM Grain Size. The microstructure observed at high magnification (1000) is similar to that of the web.

1.16.2.5 Hardness Measurement

Rockwell C measurement on the forward and aft face of the rim results in an average of 33 HRC (without grit paper cleaning), and 31 HRC (after grit paper cleaning). These values are in the range stated in the material specification PWA1029, i.e. 248–342 HB (equivalent to 24-37 HRC).

1.16.3 Evaluation of the Process Sheets

The process sheet/component repair traveler (listing the steps for the repair process and also containing the certification record) for 5th stage turbine airseal issued by Windsor Airmotive Asia was correct and in accordance with the engine manual #72-52-16. The deburring of the cooling holes was specified and final inspection was required to be carried out and certified after the plasma spray process. However the caution note in the engine manual stating "NO PLASMA COAT IS PERMITTED IN AIRSEAL HOLES OR ON HOLE EDGE BREAKS" was not reflected on the component traveler.

The caution was included in the Pratt & Whitney JT9D Engine Manual 777210 #72-52-15 Repair-04 for 4th stage turbine airseal and #72-52-16 Repair-04 for 5th stage turbine airseal.

Eagle Services Asia did not issue any process sheets for the 5th stage turbine airseal because the airseal was repaired out-house. But for the 4th stage rear snap diameter plasma spray repair, the process sheets also did not include the caution, until it was revised in 21 February 1997.

1.16.4 Interview of the Inspector

The final inspection column after the plasma spray operation was certified by an internal authorized inspector of Windsor Airmotive Asia. He had the required training to carry out this inspection and proper procedures were followed before the internal authorization was issued to him. In a statement that was taken from him by the CAAS, he said that he did inspect the cooling air holes and found them clear.

1.17 Organizational and Management Information

1.17.1 PT Garuda Indonesia

Aircraft Owner	:	PT Garuda Indonesia
Address	:	Jalan Merdeka Selatan 13 Jakarta Pusat
Aircraft Operator	:	PT Garuda Indonesia
Address	:	Jalan Merdeka Selatan 13 Jakarta Pusat

1.17.2 Eagle Services Asia and Windsor Airmotive Asia

Eagle Services Asia and Windsor Airmotive Asia are located in Singapore, and their headquarters are in the United States. Windsor Airmotive Asia is an aerospace workshop holding CAAS Certificate of Approval permitting them to carry out repairs on aircraft engine components. The shop also holds FAA, JAA and Indonesian DGAC repair station approvals.

1.18 Other Information

The airseal was released by a US FAA Form 8130-3 airworthiness approval tag and not by a Singapore approved release certificate CAAS(AW)95. Eagle Services Asia was visited by CAAS to check their stock of serviceable airseals that had been repaired by Windsor Airmotive Asia. A 5th stage airseal that had been repaired by Windsor Airmotive Asia was found to have 2 holes partially blocked. It was also noted that this air seal was also released on an FAA Form 8130-3 and not a CAAS(AW)95. There had reportedly been only one technician who performed the plasma spray work and he had left the company (Windsor Airmotive Asia).

On 18 January 2002, CAAS directed Windsor Airmotive Asia to take the following steps: (1) To stop the plasma spray process immediately; (2) Withdraw the internal approval A008 of the inspector who carried out the final inspection; (3) Carry out a review of in house process sheets, to incorporate all caution notes; (4) Inform all affected customers to check for blockage of all air seals repaired by Windsor and revert to CAAS with progress reports.

The QA Manager from the USA headquarters of Windsor Airmotive Asia had conducted an audit of the Asia plant. To ensure no future occurrences, the company had taken the following preventive measures:

(a) The plasma spray process had been halted.

(b) Internal approval A008 had been withdrawn.
(c) The work sheets have been amended to require the inspector to sign off the specifically the inspection of the cooling holes.
(d) Carried out intensive training for plasma operators and inspectors on work instruction revisions and plasma masking and inspection techniques.
(e) Carried out a review of all their component work travelers documentation to ensure that all caution statements in the engine manual are properly reflected.
(f) All affected customers had been informed by phone and fax to check for blockage of the air seal cooling holes. To date there were no new cases of cooling air holes that were found blocked.
(g) A thorough audit was carried out by Windsor Airmotive Asia head office of all in-house processes to determine the root cause.
(h) Incorporated compulsory attendance of human factor courses for all certification personnel.

There was no further report of any blocked airseal holes from the affected customers. The plasma spray process of Windsor Airmotive Asia was reinstated by CAAS on 22 February 2002. The Approval of the inspector A008 can be reinstated only after the retraining on procedures, documentation and human factors.

A letter of caution dated 25 February 2002 was issued by CAAS to the organization for not fully reflecting the caution statement of the engine manual and allowing blockages of the air seal cooling holes to occur. The letter was to remind the company to be vigilant in drawing up its maintenance worksheets so as to fully reflect the manufacturer's procedures and caution notes. The company should also diligently ensure that various corrective measures are carried out on a sustained basis in future.

The US FAA has issued a Special Airworthiness Information Bulletin SAIB No. NE-02- 21 dated March 15, 2002 advising owners, operators and engine repair stations of Pratt & Whitney JT9D engines to inspect the incoming parts and post-repaired parts to ensure the cooling holes on the 5th stage LPT airseal, P/N760659, are not blocked. The FAA also advised all repair facilities involved in JT9D airseal repair that the only currently acceptable process is to follow the instruction of JT9D Engine Manual (P/N777210) to ensure "**NO PLASMA SPRAY IS PERMITTED IN AIRSEAL (COOLING) HOLES OR ON HOLE EDGE BREAKS"**.

On April 9, 2002, Pratt and Whitney issued an All Operator Wire recommending airlines to continue to inspect their shelf stock of LPT 4th and 5th Stage Rotating Airseals to evaluate whether any of the cooling holes are blocked. The AOW also reminds airlines, overhaul and repair facilities about the caution notes and informs that inspection is added to the LPT 4th and 5th stage rotating airseal INSP/CHECK-01 section to inspect the cooling holes for blockage during every part inspection. Pratt & Whitney has also issued the revisions to JT9D manuals, which also require the removal of affected parts from service.

Another SAIB was issued on June 3, 2002 by the US FAA (SAIB No. NE-02-30), concerning recommendation for owner/operators/repair facilities to continue to inspect the incoming part and post-repaired part of the 4th and 5th stage LPT airseals. The FAA Engine Certification Office also advises that if a 4th or 5th stage LPT airseal has service time with more blocked holes than are permitted, the airseal, disk and blades associated with the airseal should be scrapped.

2 ANALYSIS

2.1 The Failure and Absence of Defenses

There are two important defenses that should have been able to prevent the occurrence of the accident but had failed or did not exist. Those missing defenses are:

(1) The absence of the caution note in the process sheet/component traveler of the 5th stage rotating airseal issued by Windsor Airmotive Asia.

Although the shop's 5th stage rotating airseal process sheet included finish machining, hand dressing to remove excess overspray and final inspection, the absence of the caution note was a procedural lapse. The caution note should be incorporated in the process sheet as it will increase the awareness of the employee performing the plasma spray.

(2) Failure of the inspection procedure to detect the blockage of the cooling air holes in the concerned 5th stage rotating airseal and the absence of inspection procedure in the Engine Manual (ref. JT9D Engine Manual Turbine Airseal (stage 5) – Inspection-01 #72-52-16 Apr 15/98).

According to the CAAS report, in the airseal that was found in Eagle Services Asia, "the 2 holes that were partially blocked was very slight and could be missed". The cooling air holes are about 2 mm in diameter, and there are 60 holes in every airseal, hence, the inspection can be considered as a tedious work requiring intense concentration. The caution note and an understanding of the consequences of the blockage will increase the inspector's awareness in performing such inspection. Using a special inspection tool can reduce this tedious work.

2.2 The Effect of Cooling Air Holes Blockage

The temperature chart and the LPT flow map of the engine is shown in Appendix F. The cooling air holes on the 4th and 5th stage inner airseals provide streams of cooling air on to the live rim. When the streams of the cooling air is undisturbed, the temperature difference between the bore and the rim of the 5th stage disk during acceleration ranges begin from 200^{o}F (at idle) to an approximately 450^{o}F (at the end of takeoff). During deceleration, it ranges from 300^{o}F (at the beginning of descent) to around 100^{o}F (at idle).

The flow map shows that blocked cooling air holes at the 5th stage inner airseals enables gas path air to ingest into the 5th disk live rim and this will cause the live rim temperature to start approaching gas path temperatures. A significant increase in temperature gradient between the bore and the live rim will occur as shown in the charts, especially during acceleration. During acceleration, the temperature difference between the rim and the bore ranges begin from 250^{o}F (at idle) to an approximately 850^{o}F (at the end of take off), while during deceleration, it ranges from 450^{o}F (at the beginning of descent) to 150^{o}F (at idle). The increase of thermal gradient between the bore and the live rim will induce thermal stress along the radial direction of the disk.

In normal condition the disk temperature near the live rim will be around 875^{o}F. When the blockage occurs, the live rim temperature may reach gas path temperature, which is around or higher than 1265^{o}F (note that the precipitation heat treatment was performed at temperatures 1300 - 1400^{o}F for 16 hours followed by heating at 1200^{o}F for 12 hours).

Although there was no evidence that the operational loads ever reached the yield strength of the metal, the service life would be shortened at an elevated temperature environment. Elevated temperature might cause creep phenomenon at subjected metal. The elevated temperature for Nickel-base alloys begins approximately at 1200°F.[2] Therefore, when the live rim temperature reaches 1265°F, it experienced a creep phenomenon.

At 1.16.2.3, it is said that the 90° fracture surfaces of the 5th stage disk are of intergranular fracture, as at high temperature grain boundaries are weaker than grains, and deformation and fracture are largely intergranular.[3] While, the 45° fracture surface of the 5th stage disk is of shear type, which developed in a fast manner during the final stage of the disk failure.

Meanwhile, the SEM on 5th stage LPT web [1.16.2.3] showed that the oxide formation on the fractured surface became thinner toward the inner direction. This evidence is consistence with the thermal fatigue theory. The theory says while the outer metal surface is hotter than inside, the cracks will initiate along the surface and progress inward. Because the crack initiates externally, the amount of corrosion or oxidation along the surface of a thermal fatigue crack is inversely proportional to the depth of the crack.[4]

It is concluded that, the air-cooling blockage made the disk rim area subjected to its elevated temperature environment, which enabled the creep phenomenon to happen. Beside mechanical vibration, this higher rim temperature also added more to the thermal stress between bore to rim. The higher thermal stress gradient on the part lead to shorter thermal fatigue life. The combination of creep-fatigue (thermal + mechanical) caused a weakening on the 5th stage disk, which lead to the crack and the uncontained disk fracture.

2.3 Uncontained Engine Failure Identification

In this occurrence, following the **EGT surge**, the **loud bang** and **then the dropped all #2 engine parameters**, the flight crew identified the event as engine failure. The flight crew considered the #2 engine had quitted and decided to choose the checklist for ENGINE FAILURE/SHUTDOWN.

In assessing the damage caused by the failure, the flight crew relied on the remaining engines' parameter indicators and other system indications. The crew stated that visual assessment was not possible due to lack of illumination (nighttime operation). Moreover, in this event the primary damage was not visually accessible from cabin window (the damage of the engine was on the outboard side). Although the purser reported that there was **flame** on the port side, no further action was taken by the flight crew because there was no fire warning and also because the flame was short-lived. The absence of vibrations on the remaining engines and no aircraft performance degradation while en route made the crew believe that there was no additional damage on the aircraft.

During the remaining of the flight, the damages on #1 engine [1.3] were unsuspected and unable to be detected by the flight crew. Although when the aircraft flared during touchdown, the thrust was reduced significantly that the flight crews felt a sudden drop of the speed.

If in such condition, a go-around need to be executed, the crew might face handling difficulties since they were unaware of the severe damage in #1 engine. Considering such risk, an information on the uncontained engine failure event became quite critical to the crews to take a proper decision and preparation.

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[2] American Society for Metals. *Metals Handbook® 9th Edition Volume 11: "Failure Analysis and Prevention"*. 1986. p.263-297.

[3] Ibid.

[4] Ibid.

ENGINE FIRE, SEVERE DAMAGE OR SEPARATION

- ▶ Thrust Lever . . . . CLOSE
- ▶ Start Lever . . . . CUTOFF
- ▶ Engine Fire Switch . . . . PULL

If engine fire switch remains illuminated :

- ▶ Fire Bottle . . . . DISCHARGE
- ▶ Autothrottle . . . . OFF
- ▶ After 30 seconds if fire switch remains illuminated :

Other Fire Bottle . . . . DISCHARGE

If high vibration occurs and continuous after engine is shutdown:
Without delay, reduce airspeed and descend to a safe altitude which results in an acceptable vibration level. If high vibration level returns and further airspeed reduction and descent is not practical, increasing airspeed may reduce the vibration.

- Autothrottle (if desired) . . . . ON

If engine fire continues :

- Do not extend flaps or speed brakes unless emergency landing imminent.
- Land at nearest suitable airport.

-------------------**WHEN TIME PERMITS**-------------------

- Engine Driven Hydraulic Pump . . . . SUPPLY OFF
- Ignition Switch(s) . . . . OFF
- Nacelle Anti-Ice . . . . OFF
- Autothrottle (if desired) . . . . ON
- Autopilot (affected system) . . . . OFF
- Air Pump . . . . OFF or CONTINUOUS
- Max. Crosswind 20 kt. Tailwind 5 kt.
- Procedure completed.
  (See REFERENCE below)

NOTE: *If performance requirement demand immediate weight reduction, perform memory items of the FUEL DUMPING procedure. (EAC-6)*

ENGINE FAILURE / SHUTDOWN

- ▶ Thrust Lever . . . . CLOSE
- ▶ Start Lever . . . . CUTOFF
- ▶ Autothrottle . . . . OFF

----------------- **WHEN TIME PERMITS** -----------------

- Ignition Switch(s) . . . . OFF
- Nacelle Anti-Ice . . . . OFF
- Autothrottle (if desired) . . . . ON
- Air Pump . . . . AUTO or CONTINUOUS
- Fuel Control Unit Cooling . . . . 3 min/HOUR
- Max. Crosswind 20 kt. Tailwind 5 kt.
- Procedure completed.
  (See REFERENCE below)

REFERENCE

- Engine Failure Enroute . . . . AOM II 2.3.6 – 3
- Three Engines Cruise Setting . . . . AOM III 3.7.1
- Inflight Diversion Long Range Cruise . . . . OM 23.20.03

31 JUL 01 EAC-1

Figure 1. Garuda's B747-200 Emergency Checklist for Engine Fire, Severe Damage of Separation and Engine Failure/Shutdown

3 CONCLUSIONS

3.1 Findings

a. The process sheet issued by Windsor Air Motive for 5th stage turbine airseal repair was correct and in accordance with the JT9D engine manual #72-52-16 Repair-04, but the caution note in the engine manual stating “NO PLASMA COAT IS PERMITTED IN AIRSEAL HOLES OR ON HOLE EDGE BREAKS” was not reflected on the process sheet.

b. There was no inspection procedure for cooling air holes in the Engine Manual (ref. JT9D Engine Manual Turbine Airseal (stage 5) – Inspection-01 #72-52-16 Apr 15/98).

c. The 5th inner airseal has 60 holes for the cooling passage. During teardown, fifty six of the 60 cooling holes were found blocked by plasma coating material. The four that were partially blocked were exposed because of chipped coating.

d. The quality assurance system of Eagle Services Asia and/or Windsor Airmotive Asia had failed to detect the blockage of the 5th stage inner airseal cooling holes.

e. The air-cooling blockage made the disk rim area subjected to its elevated temperature environment, which enabled the creep phenomenon to happen. Beside mechanical vibration, this higher rim temperature also added more to the thermal stress between bore to rim. The higher thermal stress gradient on the part lead to shorter thermal fatigue life. The combination of creep-fatigue (thermal + mechanical) caused a weakening on the 5th stage disk, which lead to the crack and the uncontained disk fracture.

f. The failure of the 5th stage disk had caused an uncontained engine failure, which induced additional damages to the airframe and FOD to the #1 engine.

g. No elaboration of procedure in the AOM regarding additional damage assessment following engine failure en-route specifically for uncontained engine failure event.

h. The crew was not completely informed of the symptom of uncontained engine failure in their organization of executing the appropriate checklist procedure.

3.2 Causes

a. The fracture of the disk is originated from the web, about 13 inches radius from the disk centerline. In thickness-wise, this crack has propagated to about 60 percent of the thickness (for both faces), and reached approximately 9.5 - 14 inches circumferentially before final failure occurred.

b. The failure mode is of creep-fatigue (thermal + mechanical) combination.

c. The root cause of the accident is the blockage of the cooling air holes on the 5th stage inner airseal, which made the disk rim area subjected to its elevated temperature environment. The blockage is due to a non-compliance operation of the plasma coating of the airseal.

3.3 Safety Threats

a. An uncontained engine failure that occurs in-flight, may inflict subsequent damages to the outboard engines, control surfaces, fuel tanks and fuselage, which could result in an adverse flight condition.

b. The uncontained engine failure event was failed to be identified during the flight.

4 RECOMMENDATIONS

A. The National Transportation Safety Committee recommends the DGAC to take proper actions to the followings:

1. to ensure that all pertaining maintenance facilities which hold DGAC AMO perform repair on such airseals as per repair manual, with careful attention to the cautions (ref. Pratt & Whitney JT9D Engine Manual – Turbine Airseal (Stage 5) – Repair – 04, Subtask 72-52-16-34-002).
2. to ensure that DGAC AMO has Company Maintenance Procedure Manual which contain detailed description of the scope of work undertaken by the AMO; and details of the AMO's procedures to ensure that reference, whenever necessary, is made to the manufacturer's inspection standards for the maintenance of any article.[5]
3. to ensure that no airseal, disk and blades associated with the 4th or 5th stage LPT airseal that has service time with more blocked holes than are permitted being used by the owner/operator.
4. to ensure that the operator in performing, or making an arrangements with other maintenance facilities to perform maintenance as provided in operator's continuous airworthiness maintenance program and operator's maintenance manual.[6]
5. to ensure the operator in cooperation with the aircraft manufacturer elaborate an adequate procedures for identifying an uncontained engine failure en route in their AOM.
6. to ensure that the operator is aware of the safety threats of a possibility of severe damage to the airplane in following an uncontained engine failure event.

B. The National Transportation Safety Committee recommends the US FAA to take proper actions to the followings:

7. to require the engine manufacturer to include inspection procedure for cooling air holes of the 4th and 5th stage turbine airseal in the engine manual.[7]
8. to ensure the aircraft manufacturer elaborate an adequate procedures for identifying an uncontained engine failure en route in their AFM.

C. The National Transportation Safety Committee recommends the CAAS to take proper actions to the followings:

9. to trace whether similar operations have been conducted by Windsor Airmotive Asia to other similar engines.[8]

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[5] In parallel to Civil Aviation Safety Regulation Part 145 Rev. 1 paragraph 145.45(l)

[6] In parallel to Civil Aviation Safety Regulation Part 121 Rev. 2 paragraph 121.379(a)

[7] Pratt and Whitney has issued revisions to the pertaining engine manuals.

[8] This has been done by the CAAS and Windsor Air Motive.

APPENDIXES

APPENDIX A – DAMAGES ON AIRCRAFT

Figure A1. Damage on Engine #2 casing (1)

Figure A2. Damage on Engine #2 casing (2)

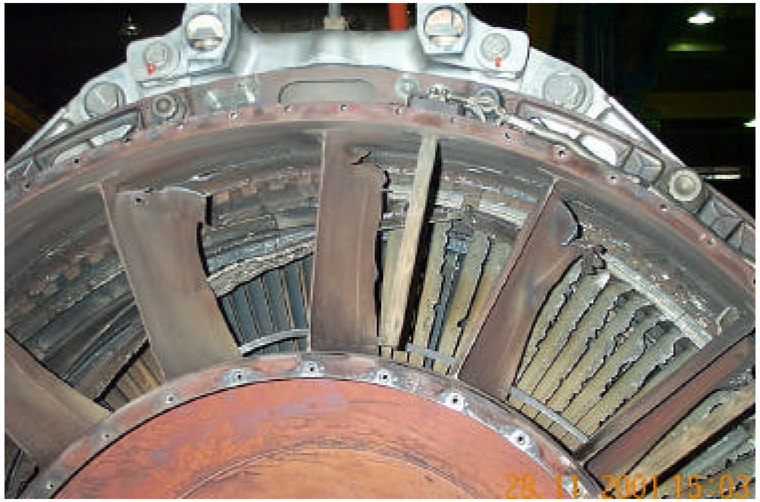


Figure A3, A4, A5, A6. Engine #2 EGV

Figure A7. Engine #2 LPT Module, 5th and 6th stage (1)

Figure A8. Engine #2 LPT Module, 5th and 6th stage (2)

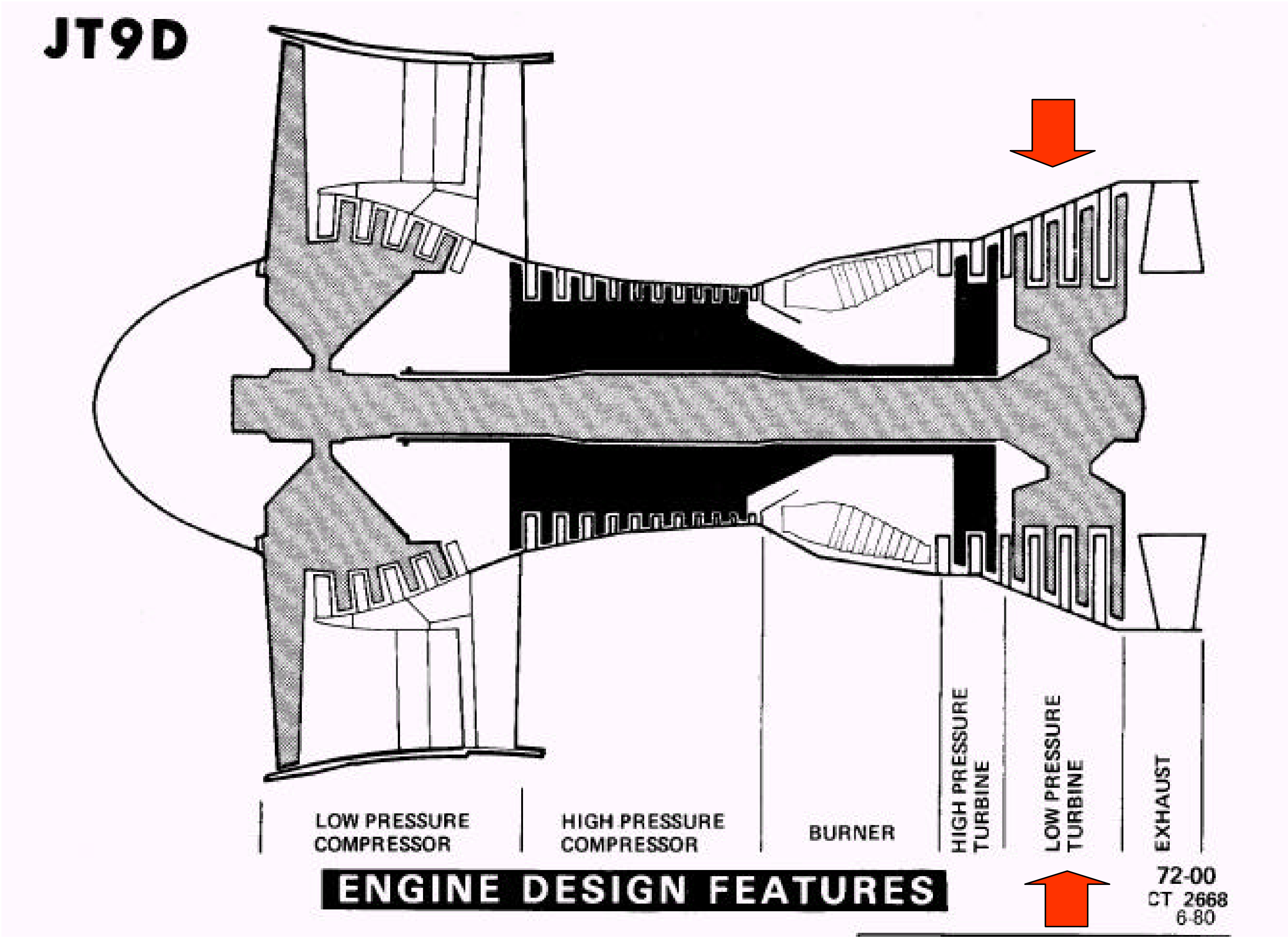


Figure A9. JT9D-7Q Diagram

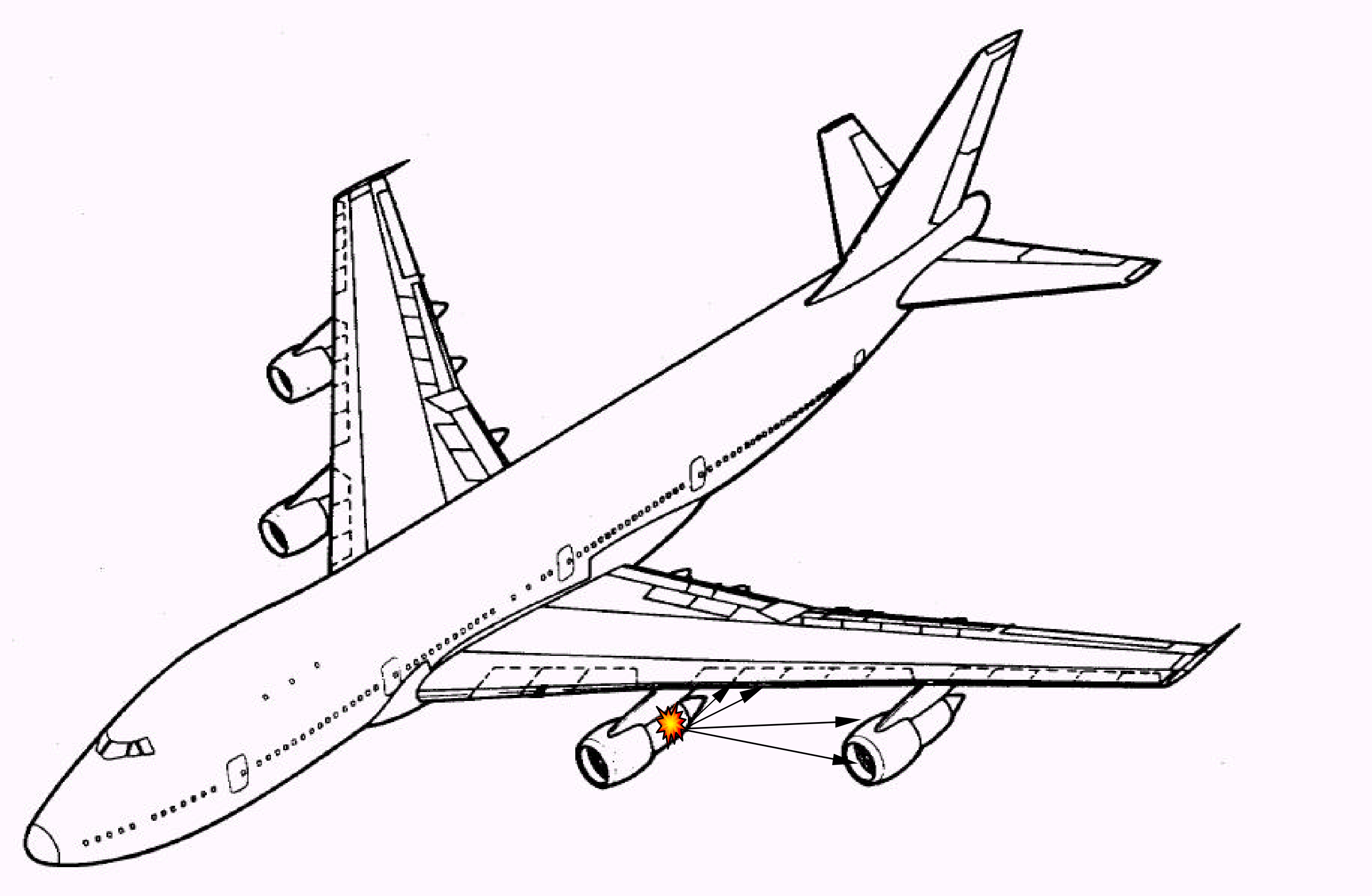


Figure A10. Sketch of ejected debris path from engine #2

Figure A11. FOD on Engine #1 fan (1) – tagged debris

Figure A12. FOD on Engine #1 Fan (2)

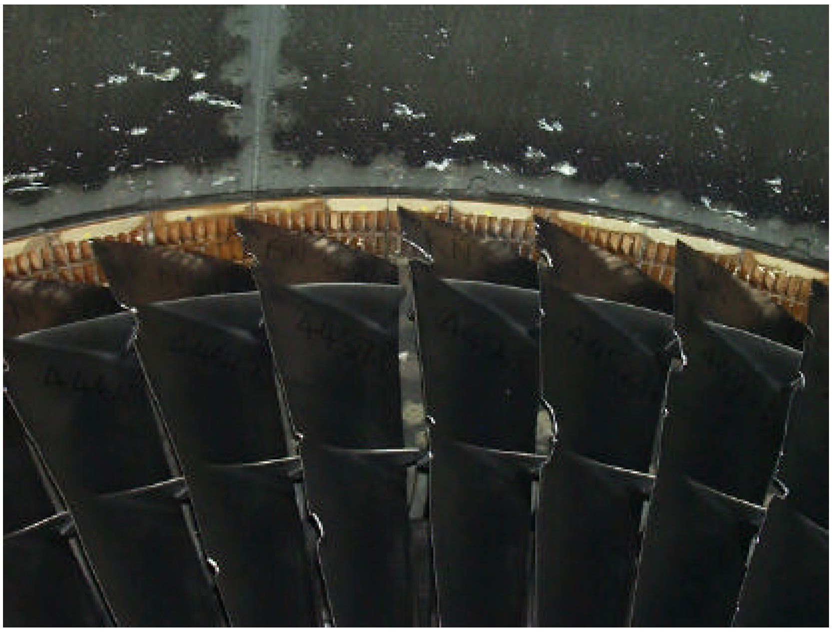


Figure A13. FOD on Engine #1 Fan/Fan Blades (2)

Figure A14. FOD on Engine #1 inner cowling

Figure A15. FOD on Engine #1 RH reverse cowl (1)

Figure A16. FOD on Engine #1 RH reverse cowl (2)

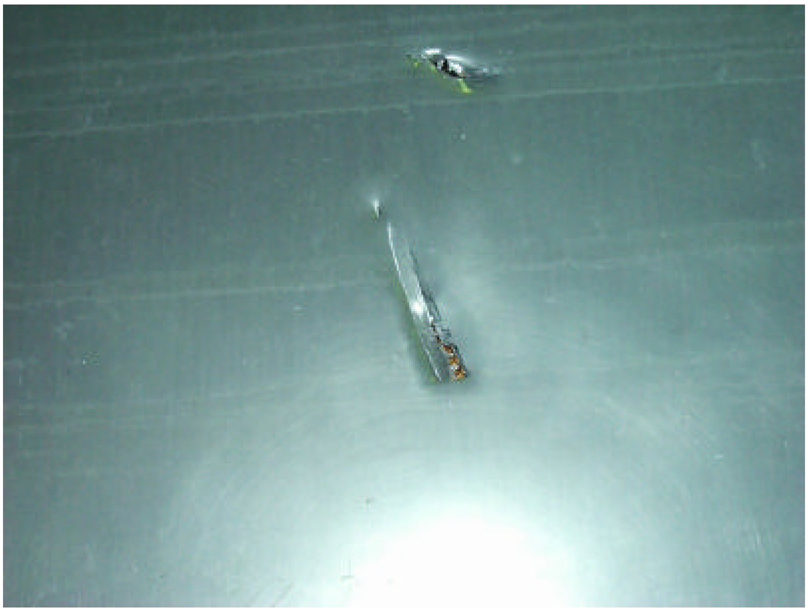


Figure A17.

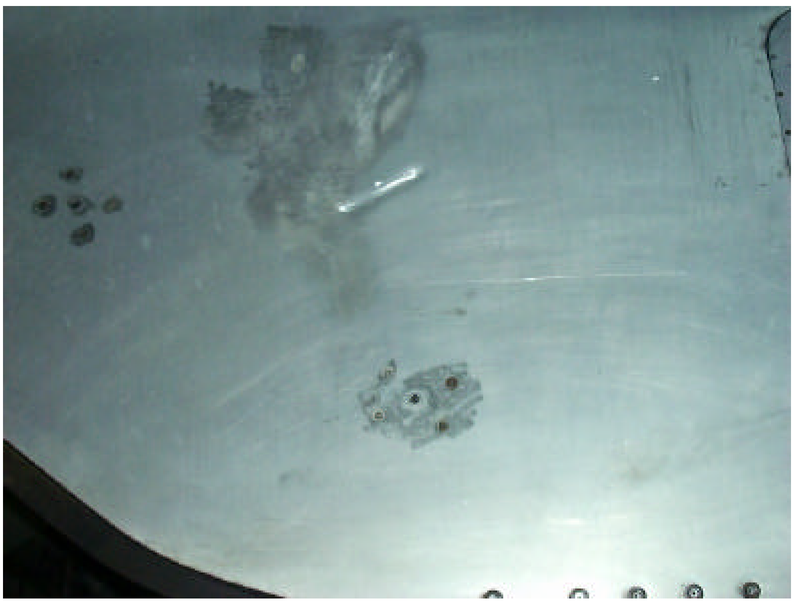


Figure A18. Engine #1 LH Pylon

Figure A19. Damage on LH low speed aileron and flap track fairing – tagged debris

Figure A20. Damage on LH low speed aileron – tagged debris

Figure A21. LH flap track fairing

Figure A22.

APPENDIX B – ENGINE TEAR DOWN

Figure B1. Engine #2 LPT Module (1) – 6th stage disc on top

Figure B2. Engine #2 LPT Module (2)

Figure B3. Engine #2 LPT Module

Figure B4. Engine #2 LPT Module – 5th stage disc revealed

Figure B5.

Figure B6.

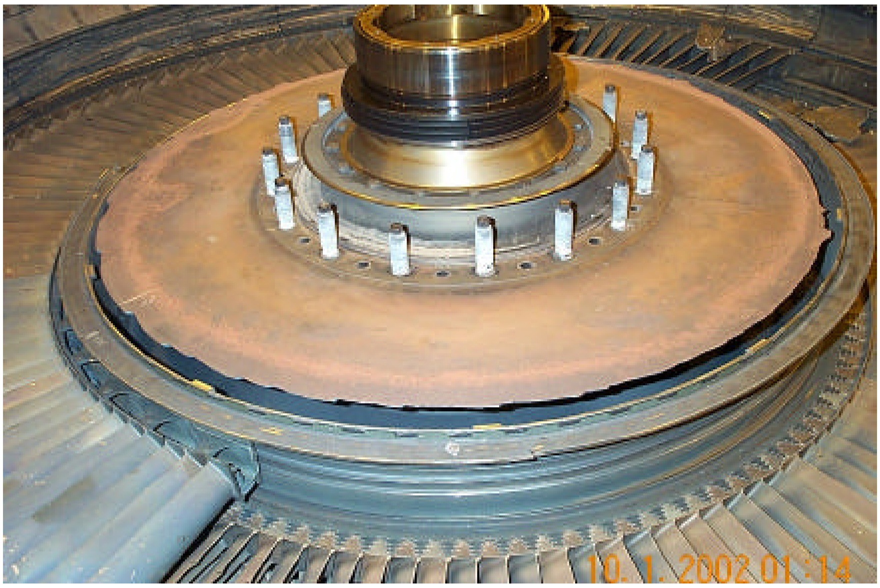


Figure B7. 5th stage disc web

Figure B8. 5th stage inner airseal

Figure B9. 5^{th} stage inner airseal cooling air holes – three holes partially opened

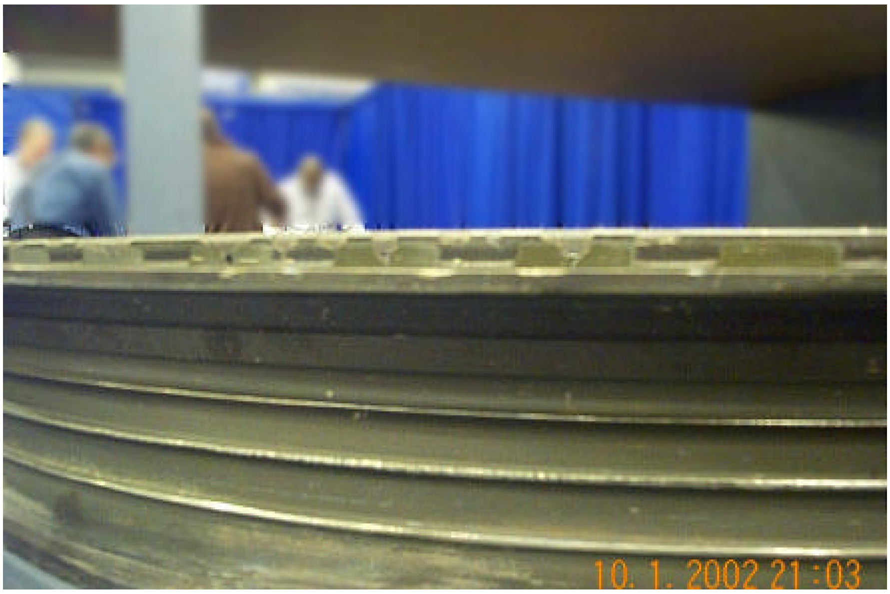


Figure B10. 5^{th} stage inner airseal cooling air holes – blocked holes

Figure B11. 4th stage inner airseal – discoloration due to cooling air passing through cooling air holes, not found on 5th stage inner airseal

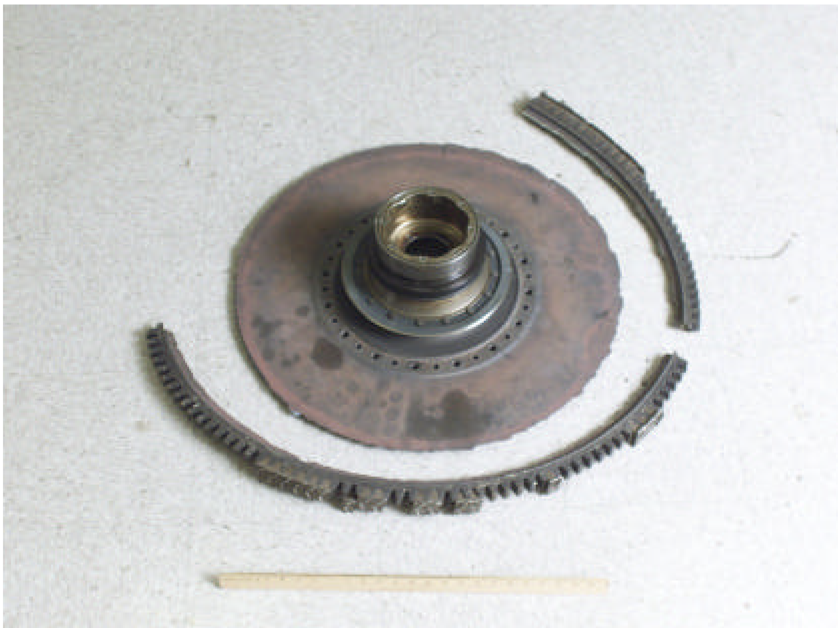
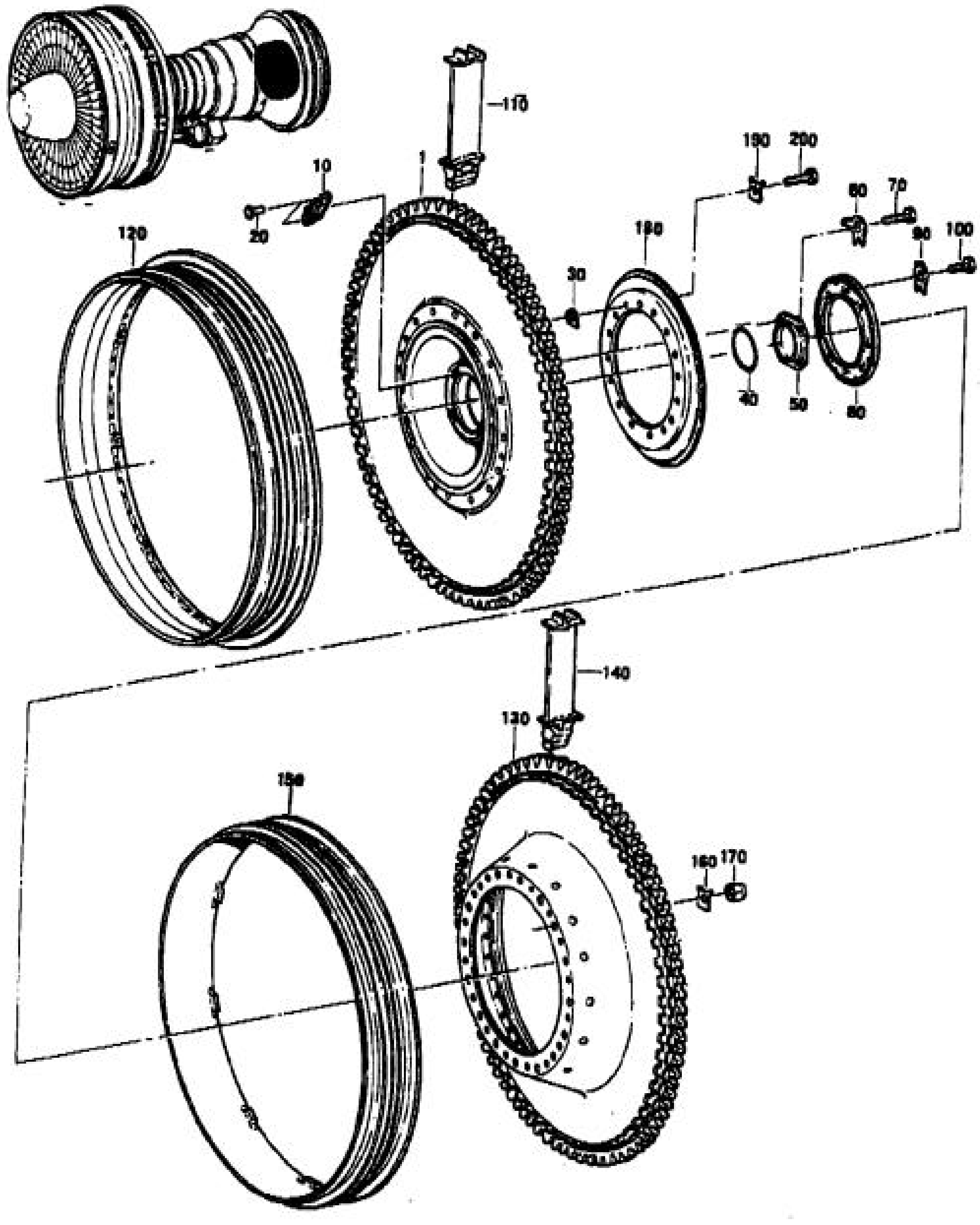


Figure B12. 5th stage disc – web and two portions of recovered rims



DISKS AND BLADES-FIFTH AND
SIXTH STAGE TURBINE
FIGURE 3

72-52-00

FIG 3
PAGE 0
JAN 15/92

Figure B13. Illustrated parts – 5th and 6th stage turbine disks and airseals

APPENDIX C – Photographs from Metallurgical Analysis

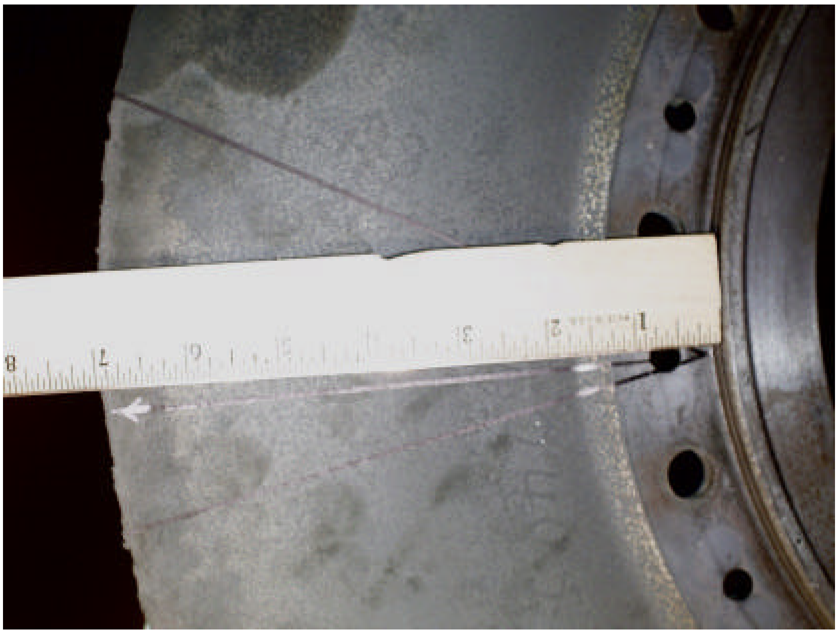


Figure C1. Location of fracture origin on 5th stage disc web, measured from bore – forward face

Figure C2. Location of fracture origin on 5th stage disc web, measured from bore – aft face

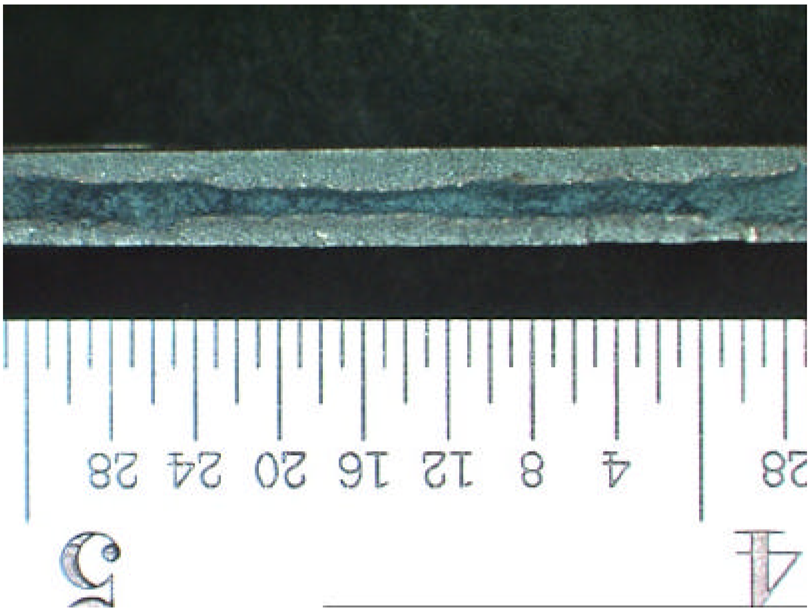


Figure C3. 5th stage disc web fracture origin surface (1)

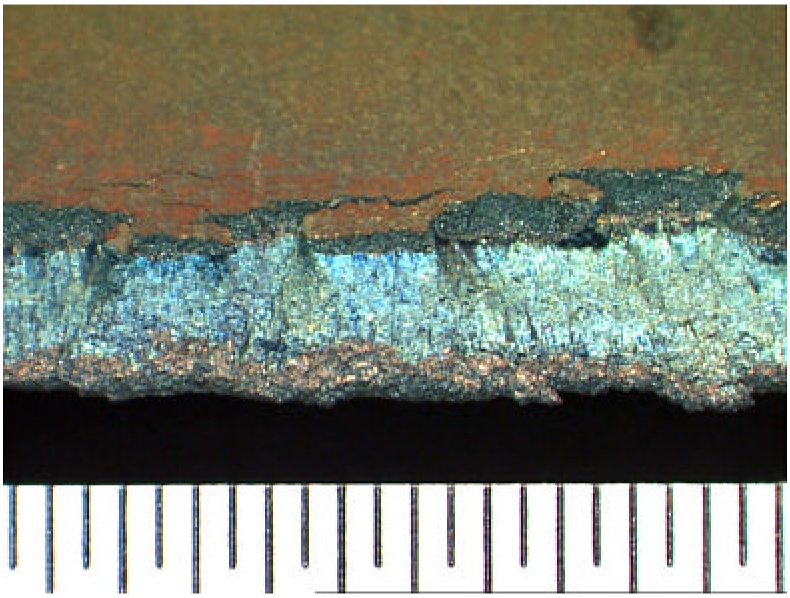


Figure C4. 5th stage disc web fracture origin surface (2)

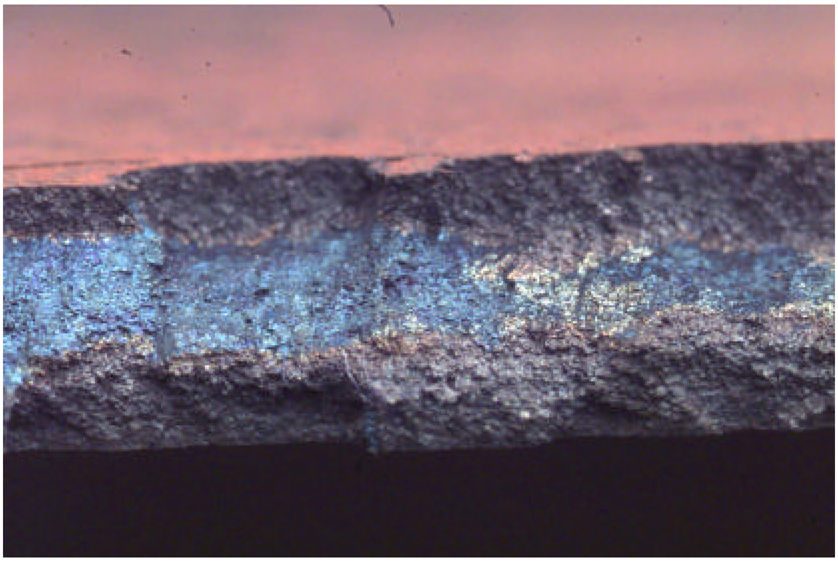


Figure C5. 5th stage disc web fracture origin surface (3)

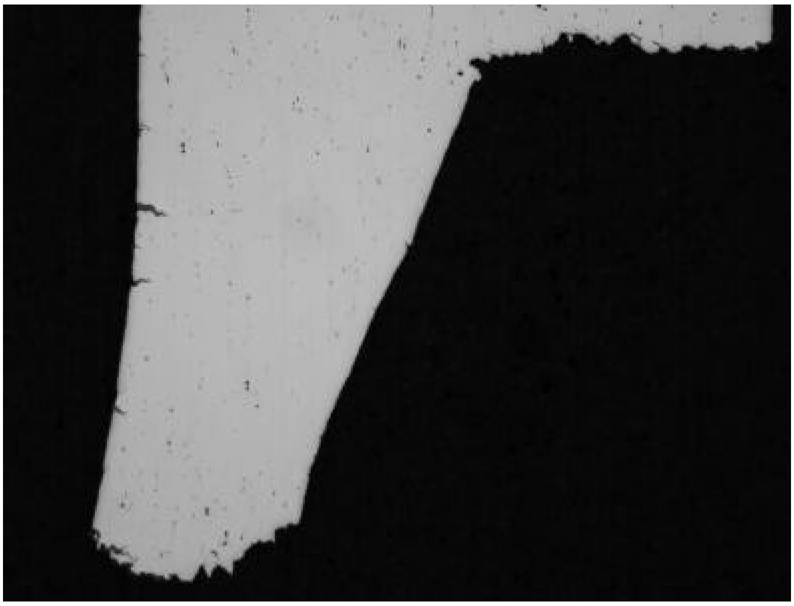


Figure C6. Radial metallographic section through fracture origin showing forward and aft face of web. Forward face is on left side.

Figure C7. Fracture origin on aft face of web (aft face on right side)

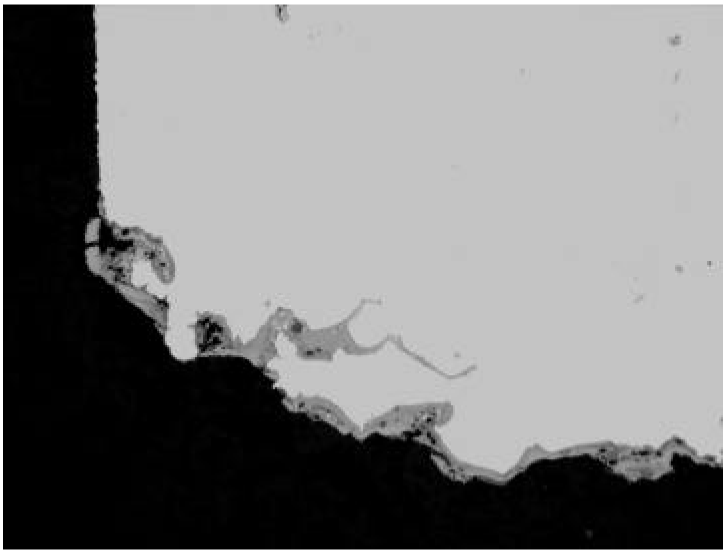


Figure C8. Fracture origin on forward face of web (forward face is on left side)

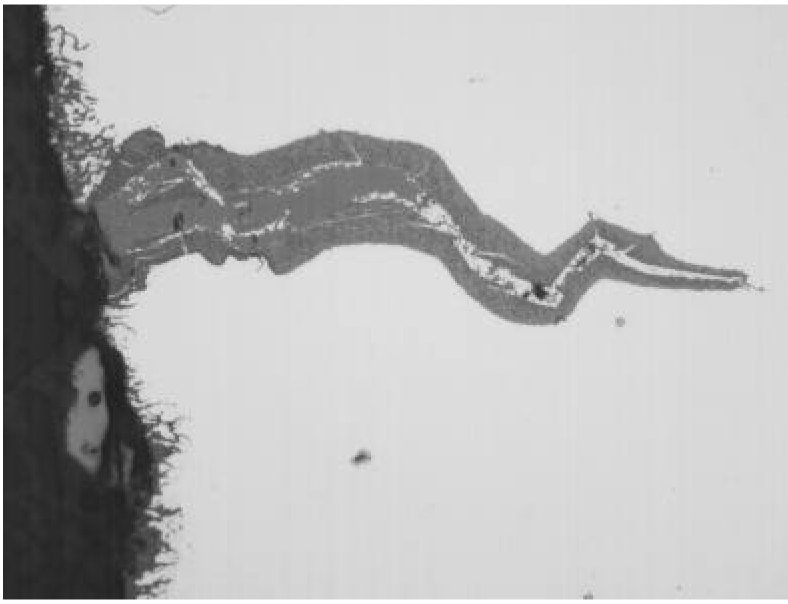


Figure C9. Secondary intergranular crack on forward face (left side)

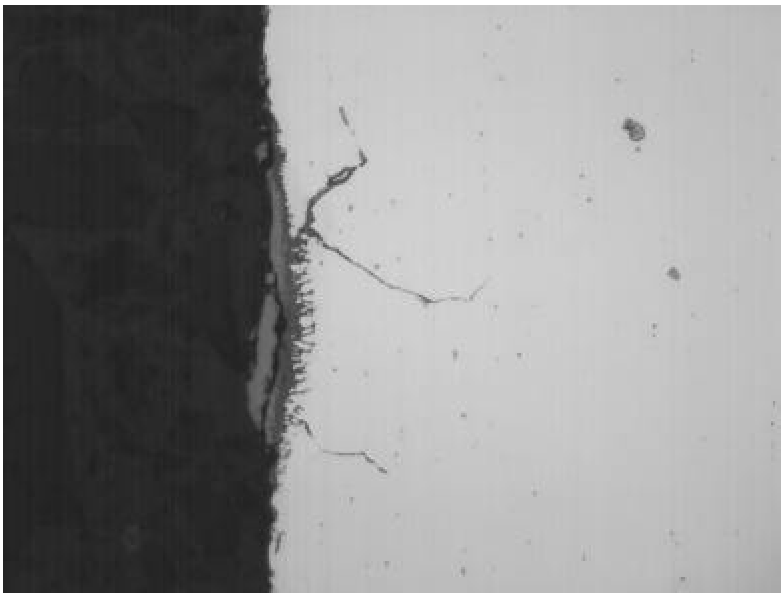


Figure C10. Secondary crack on forward face (left side)

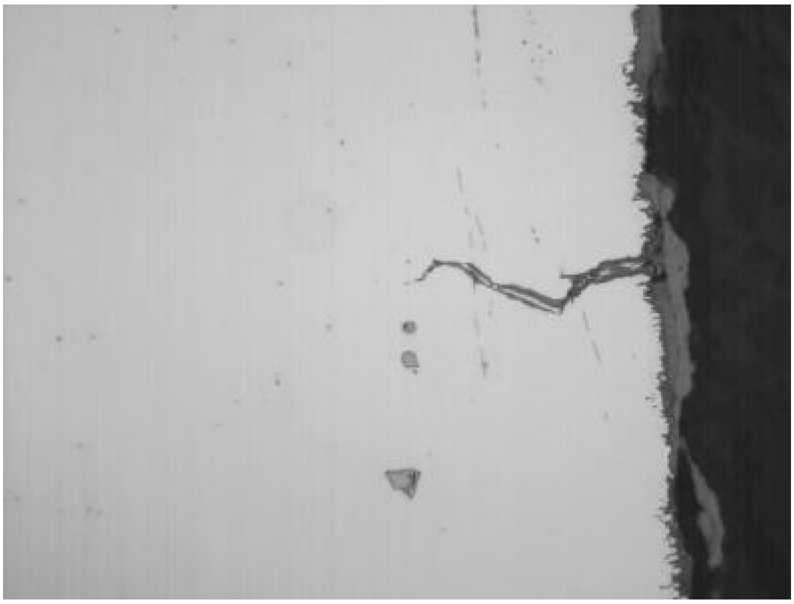


Figure C11. Secondary intergranular crack on aft face (right side)

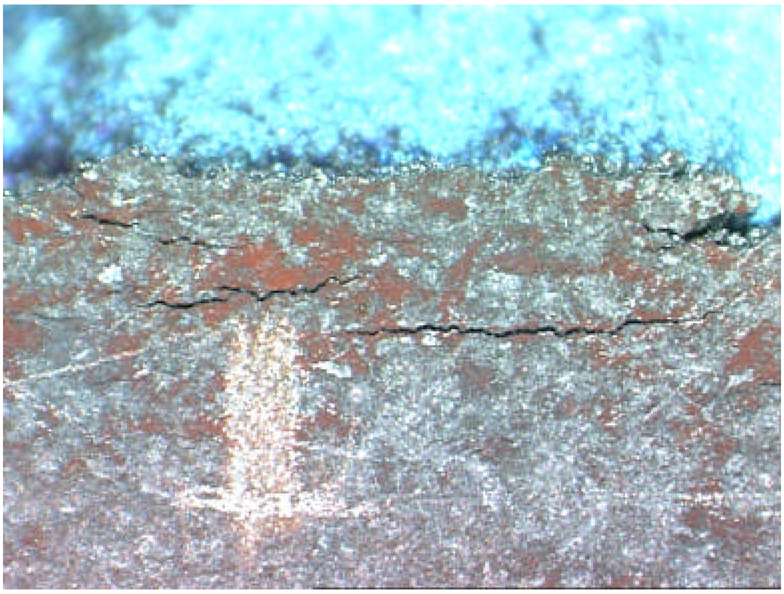


Figure C12. Secondary crack on aft face of web

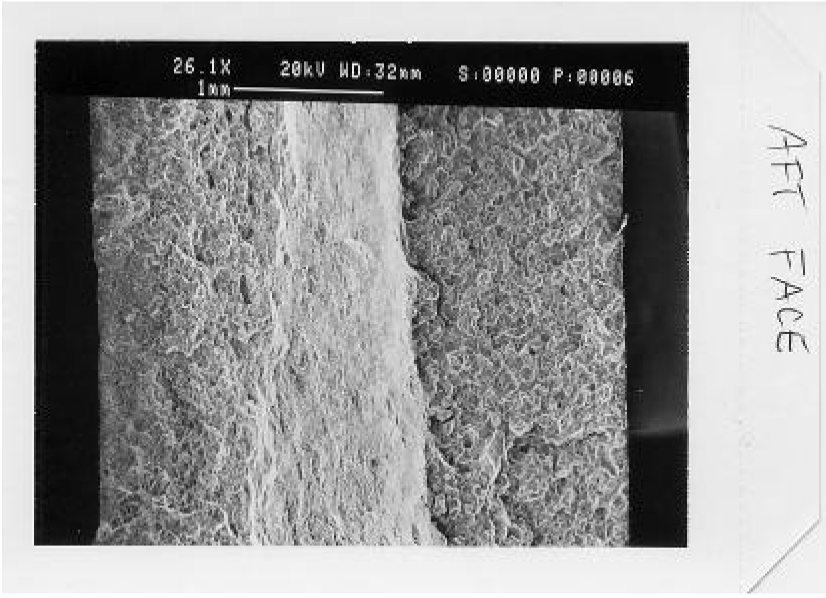


Figure C13. SEM Photo of fracture origin area

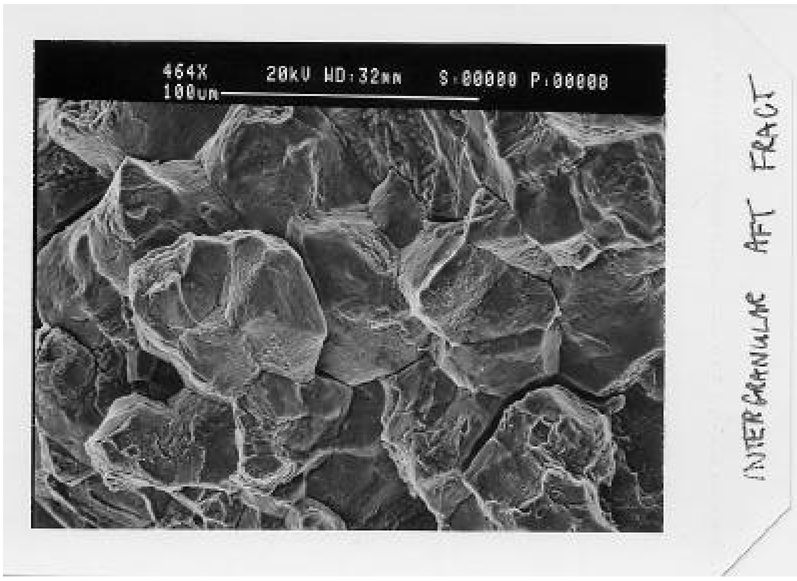


Figure C14. Intergranular fracture – aft face

Figure C15. Ductile dimples indicating shear fracture in the middle section of the fracture origin surface

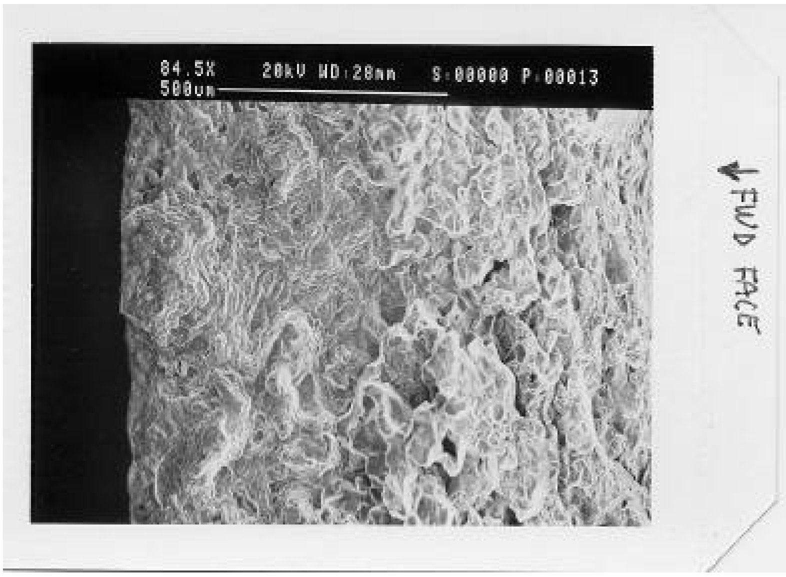


Figure C16. Severely oxidized intergranular fracture on left side (forward face)

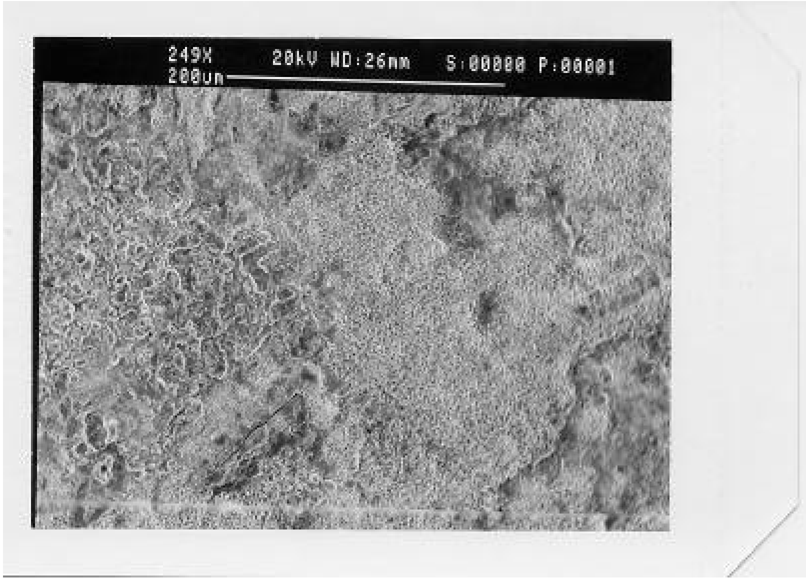


Figure C17. Close up of aft face showing oxidized surface (red oxide appears as fine feature)

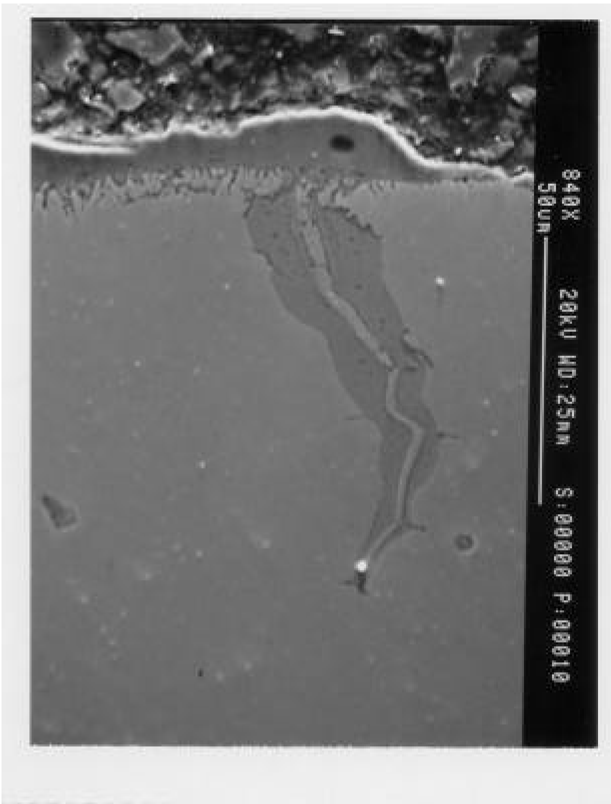


Figure C18. SEM photo of secondary intergranular crack (forward face)

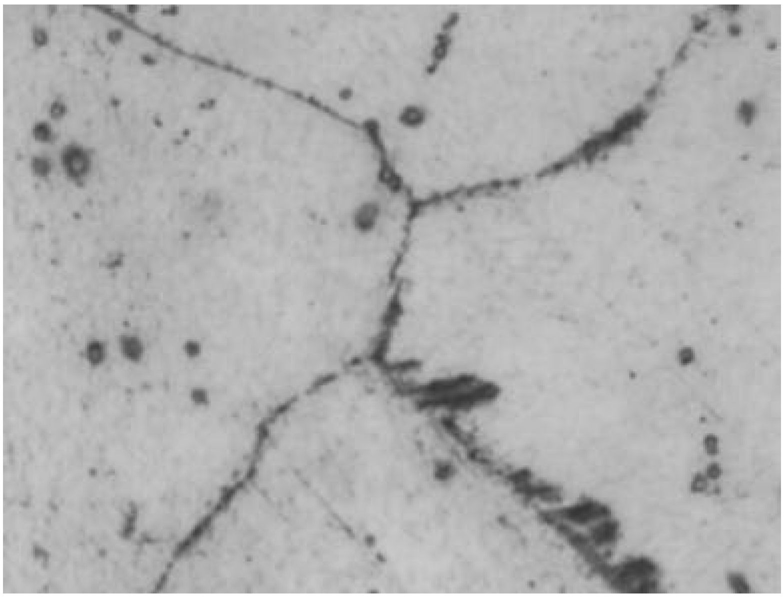


Figure C19. Microstructure next to fracture origin area

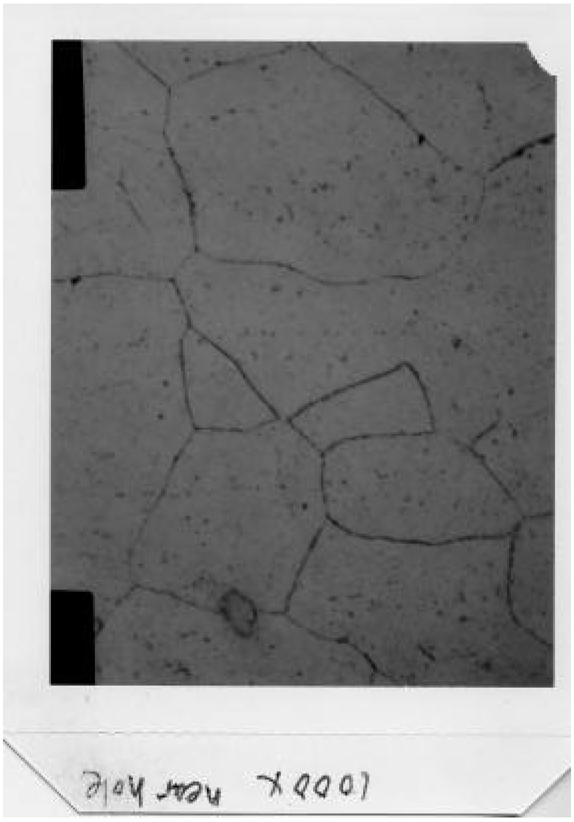


Figure C20. Microstructure next to hole area

APPENDIX D – NTSB ENGINE TEAR DOWN FIELD NOTES

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

Date January 11, 2002

POWERPLANTS GROUP FIELD NOTES

NTSB ID No.: ENG02RA003

A. INCIDENT

Location:	En route to Jakarta, Indonesia
Date:	November 23, 2001
Time:	Not reported
Aircraft:	Boeing 747-200

B. POWERPLANTS GROUP

Accredited Representative:	Carol Horgan National Transportation Safety Board Washington, D.C.
Advisor:	Jason Yang Federal Aviation Administration Burlington, MA
Advisor:	Jim Sunamoto Pratt & Whitney East Hartford, CT
Advisor:	Bernard A. Andrews Pratt & Whitney East Hartford, CT
Advisor:	Ryan Snyder Pratt & Whitney East Hartford, CT
Advisor:	Jim Peretto Pratt & Whitney East Hartford, CT

C. SUMMARY

On November 23, 2001 Garuda Airlines B 747-200 tail number PK-GSD experienced a number 2 engine flameout while en route from Dempasar (DPS) to Jakarta (CGK), Indonesia. The incident occurred while in cruise flight, approximately 21 minutes after takeoff. The pilot accomplished the emergency checklist procedure and the flight continued to Jakarta, where an uneventful 3-engine landing was made. There were no reports of injuries to the passengers or the crew members.

On-ground inspection revealed that the JT9D-7Q, ESN P-702424 engine had experienced an uncontained low pressure turbine (LPT) disk fracture event. The 5th stage LPT disk rim was separated and there was damage to the outboard engine cowling.

The No. 1 engine had sustained minor damage attributed to liberated debris from the No. 2 engine. Garuda reported the airframe sustained damage to the left hand high speed aileron (inboard aileron) and canoe fairing.

Two pieces of the 5th disk rim were recovered, accounting or 85 of 110 blade attachment slots.

The engine was shipped to Pratt & Whitney's Middletown, CT facility for investigation. The engine teardown investigation was conducted January 8-11, 2002 by the Powerplant team.

The recovered 5th stage disk rim pieces were shipped to the NTSB Materials Lab in Washington, DC.

D. ENGINE EXAMINATION

1.0 External Inspection

There was no evidence of fire on any engine hardware.

LPT Module data plate D02445.

The low rotor spool was seized. There was slight visible motion of the 4th stage low pressure turbine (LPT) rotor when rotation was attempted at the fan.

A rupture in the low pressure turbine case extended from 6:00 to 10:00 o'clock[1] in plane with the 5th stage turbine rotor. The rupture spanned 50 bolt holes of the rear[2] flange of the LPT case ("P" flange); a 23-bolt hole section (about a 25" circumferential section) of the LPT case was missing. A 4-ft. loop of the 6th stage

[1] O'clock locations refer to approximate radial clockwise locations, viewed from the rear of the engine looking forward.
[2] All references to position are aft looking forward unless otherwise noted.

outer air seal had extruded out of the case rupture site. It was severely mangled, battered, and had an axial fracture. The 6th stage stator lock also protruded from the case rupture site. The stator lock was mangled and battered. The 4th stage outer air seal damper was fractured at the case rupture site and a 16" segment was protruding from the case.

The 5th stage disk rim, blades, and attachments were missing in the viewable area. Visible portions of the 5th and 6th stage rotating inner air seals were intact. The space normally occupied by the 5th stage disk assembly was occupied by the 5th and 6th stage inner air seals.

The 6th stage vanes between 6 and 12 o'clock were missing. There was heavy damage to the OD trailing edge of the 6th stage vanes.

The 6th blade airfoils were all fractured transversely just outboard of the platform. There was one blade attachment missing.

A 25 inch circumferential section of a 5th stage outer air seal damper was missing and fractured at the case rupture locations.

There was no obvious fan blade damage. Visual examination of externals and the right hand side of the engine found no anomalies. Except for P-flange, all flange bolts were intact/secure.

The exit nozzle was removed and inspected. There were random small surface dents on its inside diameter. There was some discoloration underneath a dessicant bag found sitting in the nozzle at 6 o'clock.

The tailcone had minor impact damage and there were two small punctures in the flange bolt recess cavities.

A 1 -inch axial tear was noted in the turbine exhaust case (TEC) just forward of the #2 TEC strut. The case surface was bulged outward at this site. There was a 2 ¼-inch circumferentially oriented inner to outward case puncture forward of the # 15 strut. The maximum width of the puncture was 3/8-inch.

All 15 of the struts showed severe impact damage consistent with the direction of low rotor rotation, with material torn away from the outer diameter stand off weld joint in a forward-to-aft direction. A small amount of metallic debris had collected at 6 o'clock in the TEC.

Borescope inspection was performed through the 8th, 9th, and 11th compressor and AP8 and AP9 combustion chamber ports; no anomalies were found.

The main gearbox sump, No. 3 bearing and No. 4 bearing chip detectors, and the main oil filter were inspected with no anomalies noted. There was no debris found in the No. 3-4 bearing oil strainer.

The main fuel pump filter element was inspected and no abnormality was found.

The high rotor was found to rotate freely. The fan/LPC rotate freely once the LPT was removed.

2.0 Turbine Exhaust Case and Front Compressor Drive Turbine Disassembly

No. 4 Bearing Cover.

The No. 4 bearing cover was in good condition

No. 4 Bearing.

The No. 4 bearing was intact and cursory inspection found it to be in good condition. The carbon seal was cracked axially in one location. A small piece had broken off.

Turbine Exhaust Case.

There was heavy damage to the convex side of all 15 turbine exhaust case (TEC) struts, consistent with the direction of spool rotation. Thirteen struts had partially detached from their outboard casing strut stand off welds and curled aft in the direction of rotation. There were two struts completely separated from their outer strut stand offs. There was only minor damage to the concave sides, and all struts remained attached at their inner diameter strut stand off with the case; there was one strut that was partially separated at the inner diameter strut stand off. There was severe smearing and gouging 360° around the inner diameter of the forward section of the TEC. The forward rail was buckled between 10:00 and 11:00 o'clock and the outboard strap was fractured about 12:00 o'clock. The aft rail was undamaged. A 2 1/4 inch (circumferential) by 3/8-inch (axial) ID to OD puncture centered about two inches aft of the rear face of the "P" flange was located at about 11:30 o'clock. There was a 1.0 inch axial tear located forward of the No. 2 strut between the circumferential weld and the front rail. There was a 3/8-inch outer surface tear located centered about 3/4" aft of the rear flange aft face near the 9:30 o'clock location. There was heavy 360° scoring damage to forward 60% of the labyrinth seal land base. Wire-like debris consistent with debris found on 6th stage disk aft face was present. On the front of the No. 4 bearing housing, there was evidence of coking at 12 o'clock .

Turbine Tie Rods. All tie rods (16) were intact and tight. The tie stretch was recorded as follows:

Location[3]	calculated stretch(inch)
1	0.004
2	0.004
3	0.003
4	0.011
5	0.006
6	0.012
7	0.017
8	0.008
9	0.013
10	0.013
11	0.021
12	0.011
13	0.016
14	0.009
15	0.006
16	0.009

6th Stage Turbine Vanes. Three blade attachments were found on the aft face of the 6th stage vanes. Eighteen of the 38 3-vane clusters remained in position within the LPT case. These vane clusters were located from 12:30-5:30 o'clock; all others were missing, including two single vanes. The remaining vanes displayed significant impact damage.

6th Stage Turbine Disk. Metal shavings and fragments were found on the aft side of the 6th stage disk. The metal shavings were consistent with damage found to the TEC labyrinth seal land base material. No obvious source for the metal fragments was identified.

There were minor nicks and scrapes orientated, primarily in a circumferential direction, on the aft rim, web, and bore surfaces. Four balance weights were attached to the balance flange. One 6th stage blade attachment was missing at slot #71.

The forward side of the disk conical section and web displayed some spotty discoloration. There was fresh (shiny) galling damage on the airseal snap[4] and anti-rotation tab forward edges, consistent with damage to radially coincident surfaces of the 6th stage rotating air seal.

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[3] .Tiebolt location was counted clockwise from the rear, from the 12 o'clock position.

[4] A snap, as utilized on P&W engines, is a diametric feature on a part that engages to a diametric feature on an adjacent part. The diameters of the two features are machined to slightly different dimensions, typically between 0.005 to 0.010 inches to create an interference fit in order to align and lock the parts together.

6th Stage Turbine Blades . All blades were fractured transversely across the airfoil 1/8-inch to one inch above the blade root platform.

6th Stage Turbine Air Sealing Ring Support.
The ring support was fractured at two locations. The 7 – 12 o'clock section was missing.

6th Stage Turbine Stator Lock. The stator lock was broken, mangled and battered. A portion was found protruding from the LPT case rupture.

6th Stage Turbine Rotating Inner Air Seal The aft face of the 6th stage outer air seal rear snap and anti-rotation tabs exhibited galling damage consistent with that seen on the 6th stage disk. The forward snap showed fresh galling on the OD and ID. The OD galling is consistent with galling on the aft ID of the 5th stage air seal. The ID galling is axially consistent with the high points of the 5th stage disk fracture surface.
All three knife edges showed heavy rub damage and circumferential rubbing was evident between knife edges. The blade retention wing on the rear of the air seal showed signs of rubbing on the forward OD side

6th Stage Turbine Inner Shroud
Five of 38 pins on the forward flange were damaged. Both forward and rear flanges have localized areas of deflection. The rear face of the forward flange has local areas of missing coating material. The honeycomb inner diameter sealing surface shows multiple off-center wear patterns, and penetration between 11 – 2 o'clock.

5th Stage Turbine Outer Air Seal Damper. The 5th stage outer air seal damper was fractured and was missing a 25-inch section at 7-10 o'clock location.

5th Stage Turbine Outer Air Seal Segments The segments showed damage to the honeycomb and honeycomb attachment. Fourteen out of 29 were missing. Four segments were jammed into the LPT case. The remaining dampers were fractured and distorted.

5th Stage Turbine Vane Clusters. Twenty of 40 3-vane clusters remained with the engine; 20 3-vane clusters and one single vane were lost. Of the 20 clusters remaining, four have extensive damage to airfoil TE near OD platform. 16 have minor to heavy TE damage. The inner honeycomb seals show heavy rub.

5th Stage Turbine Rotating Inner Air Seal (P/N 760659C, S/N KJ7386) The three inner air seal (IAS) knife edges were worn and rolled over, 360°. The forward face of blade retention wing was damaged consistent with damage on the 5th stage vane cluster inner segments. Sections of the blade retention wing over a 40° arc were missing. The blade retention wing also showed one radial crack about 180° from the missing wing section. The aft and ID faces of all 10 anti-rotation lugs were worn consistent with wear seen on the 6th inner air seal.

The OD and aft face of the rear snap were coated and exhibit light to moderate chipping. The OD rear snap displayed witness marks of intermittent snap contact from the 5th stage disk snap. Fifty-six of the 60 rear snap cooling holes are covered at the OD with coating material. Four rear snap cooling holes appear only as a result of chipped coating. The forward snap of the air seal shows galling on both inner and outer diameters.

The coating material from 5 airseal holes was removed by the Powerplant Group for metallurgical evaluation at NTSB, Washington, DC.

5th Stage Turbine Disk Assembly
P/N 753421, S/N K15178 (from records)
The 5th stage disk was missing the entire rim just inboard of the web-to-rim transition. The aft web face showed brownish discoloration. The disk was shipped to the NTSB, Washington, DC, for metallurgical evaluation.

Low Pressure Turbine Case

The LPT case had a hole between 7:30 and 9:00 o'clock. The maximum hole size is about 12 inches in axial length (which includes a missing section of P-flange[5]), by 26 inches in the circumferential direction. The forward end of the LPT case fractured adjacent to a circumferential weld under the 4th stage vane. At the upper hole edge, the case fracture continued adjacent to the circumferential weld. The fracture continued 22 ¼-inch to about 11:00 o'clock. The upper case segment deformed outward. At the bottom hole edge a 4 ½-inch circumferential fracture adjacent to the rear edge of the 5th vane foot, turned axially forward to about ½-inch aft of the 4th vane rear foot support. It traversed an additional 2 ½-inch circumferentially to about 6:00 o'clock. The bottom case segment was also distorted outward. The "P" flange bolts were missing from about 6:00 to 11:00 o'clock. There was a 360° weld about 5 inches from the front LPT case flange from a previous repair. A portion of the fracture occurred along this weld.

4th Stage Turbine Rotating Outer Air Seal. The 4th stage air seal was in generally good condition. Some circumferential rubbing was evident on the forward face of the blade retention wing, consistent with rubs seen on the aft side of the 4th stage vane inner air seal honeycomb segments.

4th Stage Turbine Vanes
All 42 vane clusters were accounted for. There was no LE airfoil damage. Airfoil trailing edges and outer shrouds displayed various degrees of metal splatter. There was moderate to severe rub on the rear face of the inner and outer shrouds from 8-10 o'clock. The inner air seal segment rivet and the rear face of the air seal segment wear patterns were normal.

4th Stage Turbine Disk.
The rear snap aft face is galled, consistent with the rub on the 4th stage air seal front snap. No other anomalies noted.

[5] The P-flange is connecting joint between the LPT case to the turbine exhaust case (TEC)

4th Stage Turbine Blades.
All 4th stage blades remained in the rotor. All blades had light to severe impact damage to the trailing edges. About 40% exhibited material missing from the trailing edges. 100% of the forward knife edges are rolled over or missing; all of the aft knife edges are missing. There was rub damage LE seen at the ID and OD of all blade airfoils.

3rd Stage Turbine Blades. All third stage blades remained in the rotor. Most of the outer shroud front knife edges were damaged. 34 blades have missing front knife edge material; 7 have missing rear knife edge material. There was no leading or trailing edge damage.

3rd Stage Turbine Vanes
All 3rd stage turbine vanes were found in good condition.

3rd Stage Turbine Disk. There was no damage evident on front or rear surfaces of the 3rd stage disk. There was some spotty discoloration on the front web surface.

3rd Stage Inner Rotating Air Seal No damage was noted to the 3rd stage air seal.

Turbine Rotor Spacer.
No distress or damage was noted to the turbine rotor spacer.

Low Pressure Turbine Shaft. The shaft forward of the shaft rear flange front face exhibited three light score marks in the same circumferential position, at 9 o'clock.

distance forward of shaft flange(inches)	*length (inches)*
6	4
15	4 ½
23 ½	2 ¾

There was a ¾ -inch wide (axial) by 1 ¾ -inch polished area just forward of the center score.

TURBINE AIRSEAL (STAGE 5) - REPAIR-04

1. Task 72-52-16-30-004: Rear Snap Diameter Plasma Coat Repair

A. See Task 72-52-16-99-001 (Repair-00) for part number applicability.

B. Equipment And Materials - None

C. Procedure

See Figure 901.

Subtask 72-52-16-33-018-002

CAUTION: IF AIRSEAL HAS BEEN PREVIOUSLY PLASMA COAT REPAIRED, ENSURE ALL PLASMA IS REMOVED.

(1) If applicable, remove all plasma coating from the rear snap diameter one of these (machine the coating off only if necessary):

NOTE: SPOP 48 or 50 will remove plasma coat repairs from airseal surfaces which have them. To prevent unwanted plasma coat removal from these areas, use SPOP 36 masks.

Subtask 72-52-16-33-018-002
(a) SPOP 48

Subtask 72-52-16-33-019-003
(b) SPOP 50

Subtask 72-52-16-33-048-001
(c) SPOP 322.

Subtask 72-52-16-32-003

CAUTION: AIRSEAL REAR FACE DIMENSION INDEX 3 OF FIGURE 901 MUST BE MET. AIRSEALS NOT MEETING THIS DIMENSIONAL REQUIREMENT MUST BE REPAIRED PER REPAIR-05 PRIOR TO ACCOMPLISHING THIS REPAIR.

(2) Machine the airseal rear snap diameter (Index 2) to remove all coatings and all worn or damaged areas. Hold the spacer diameter to the maximum possible.

TURBINE AIRSEAL (STAGE 5) - REPAIR-04

Subtask 72-52-16-34-013-004

(3) Prepare the repair surface by SPOP 170. See the Standard Practice Manual, Section 70-46-01.

NOTE: Use masks as necessary to keep blasting grit and plasma coat in the repair area. Shotpeen out of the repair area is optional and may be incomplete, but no rolled edges or sudden changes of contour are permitted on knife-edges or surfaces where the shotpeen will cause damage to the finish.

Subtask 72-52-16-34-002

CAUTION: NO PLASMA SPRAY IS PERMITTED IN AIRSEAL HOLES OR ON HOLE EDGE BREAKS.

(4) Plasma coat the area shown in the figure by PWA 53-37 to a thickness sufficient for finish machining. Coat outside of the area shown is not permitted. Thickness of coat after finish machining must be 0.003 - 0.015 inch (0.08 - 0.38 mm).

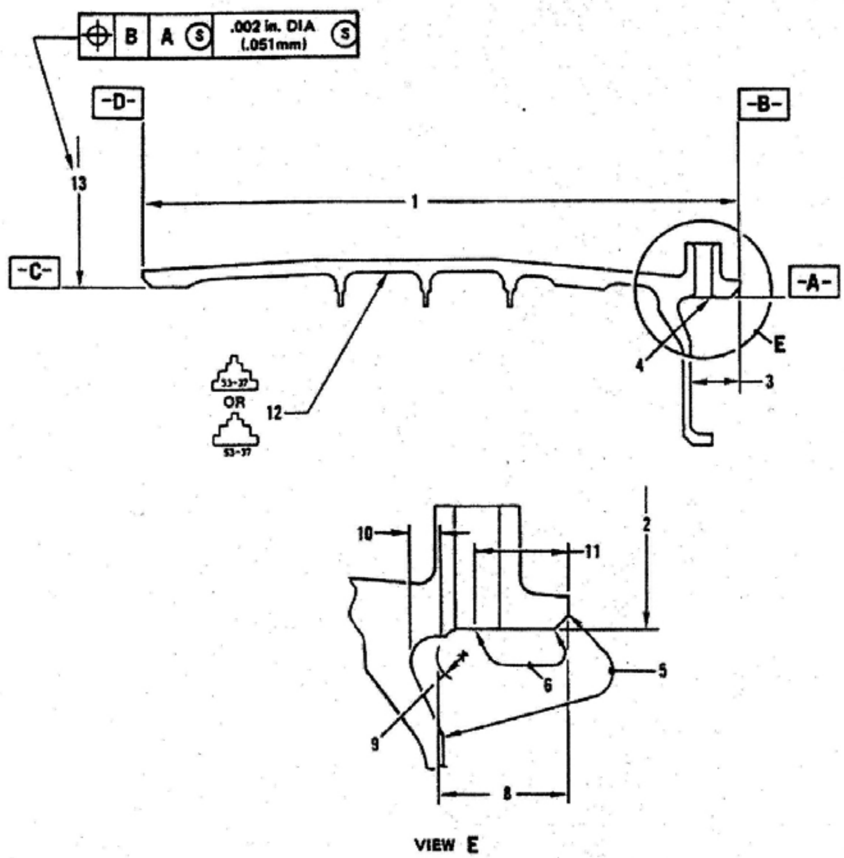
Subtask 72-52-16-32-004

(5) Finish machine the coated area as shown in the figure.

(8 Make a beehive symbol mark on the part in the area shown by the approved vibration peen method.

Subtask 72-52-16-22-000

(6) Do an inspection of the airseal by Task 72-52-16-22-000, (Inspection-01).



L-H2809 (0000)

Rear Snap Diameter
Repair (Stage 5)
(Task 72-52-16-30-004)
Figure 901

TURBINE AIRSEAL (STAGE 5) - REPAIR-04

1. 3.841 - 3.843 Inches (97.562 - 97.612 mm)

).76 mm) 60 Places. Break Edge | 4. 0.005 - 0.030 Inch (0.13 - (

Text. | 5. Shotpeen Enclosed Area Per T

er Text. | 6. Plasma Coat Enclosed Area Pe

7. Not Used.

3.64 mm) | 8. 0.320 - 0.340 Inch (8.13 - 8

1.98 mm) Radius | 9. 0.047 - 0.078 Inch (1.19 - 1

10. 0.078 Inch (1.981 mm) Minimum

11. 0.240 Inch (6.096 mm) Minimum

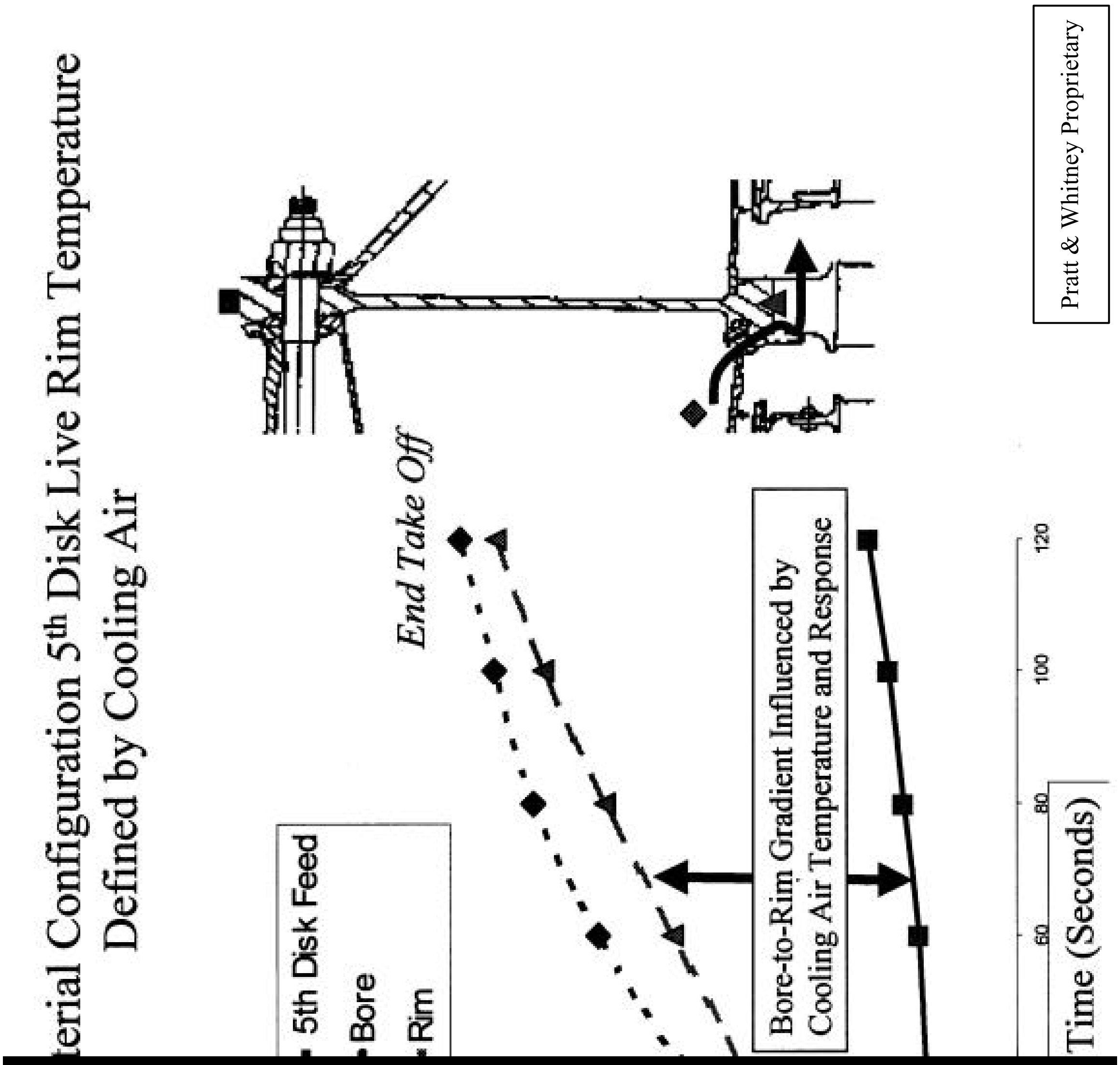
12. Beehive Symbol Marking Area, For Plasma Coat Repair.

13. 28.654 - 28.658 Inch (727.812 - 727.913 mm) Average Diameter C

<u>NOTE</u>: Dimensions apply when Surface B and Surface D and flat within 0.001 inch (0.025 mm) and Diameter C and Diameter A maintain a clearance envelope of 28.659 inch (727.939 mm) basic diameter and 28.851 inch (732.815 mm) basic diameter respectively in free state or constrained. Constraint contact allowed only on Surfaces B and D and Diameters C and A.

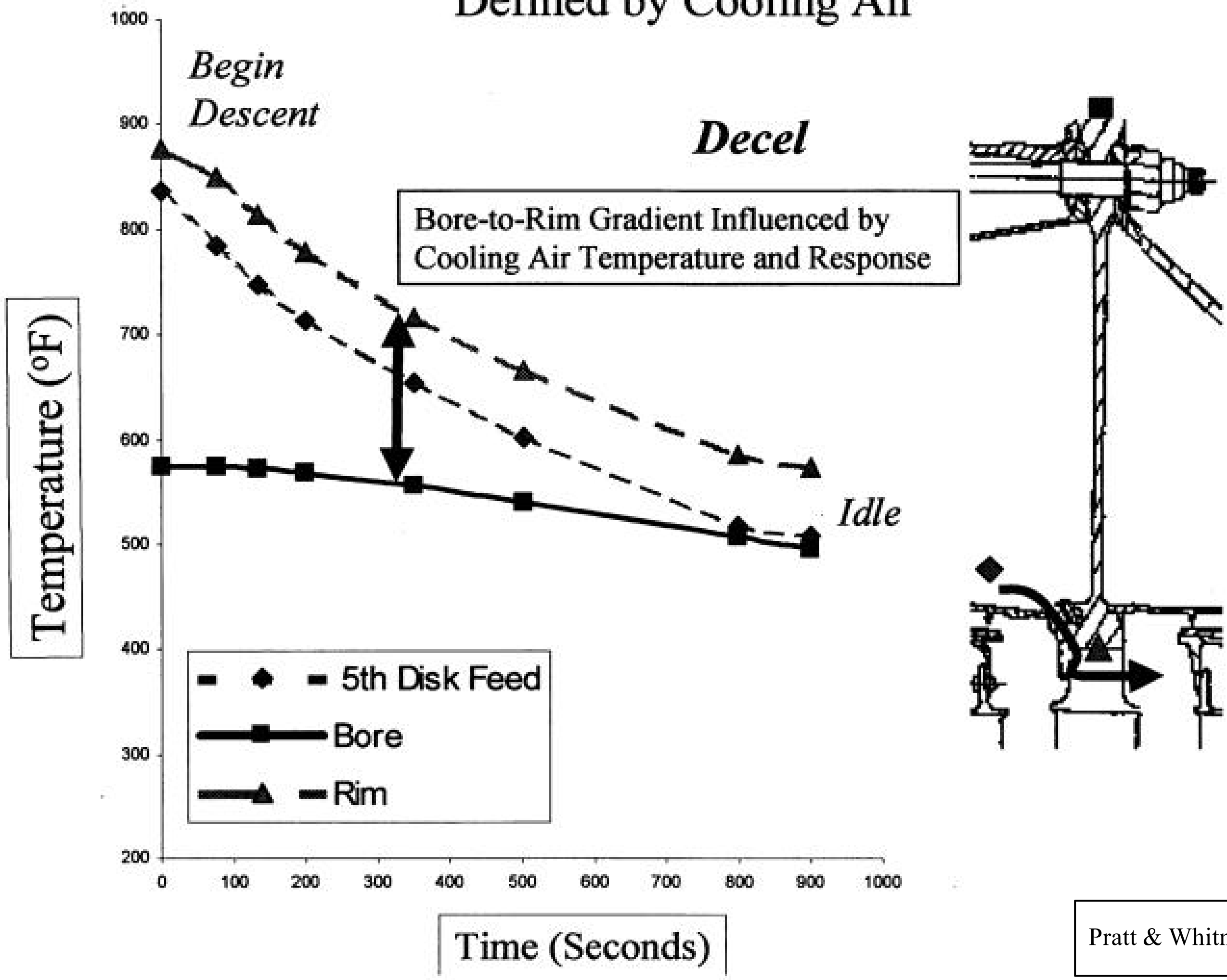
Key To Figure 901

APPENDIX F – TEMPERATURE CHART AND FLOW MAP



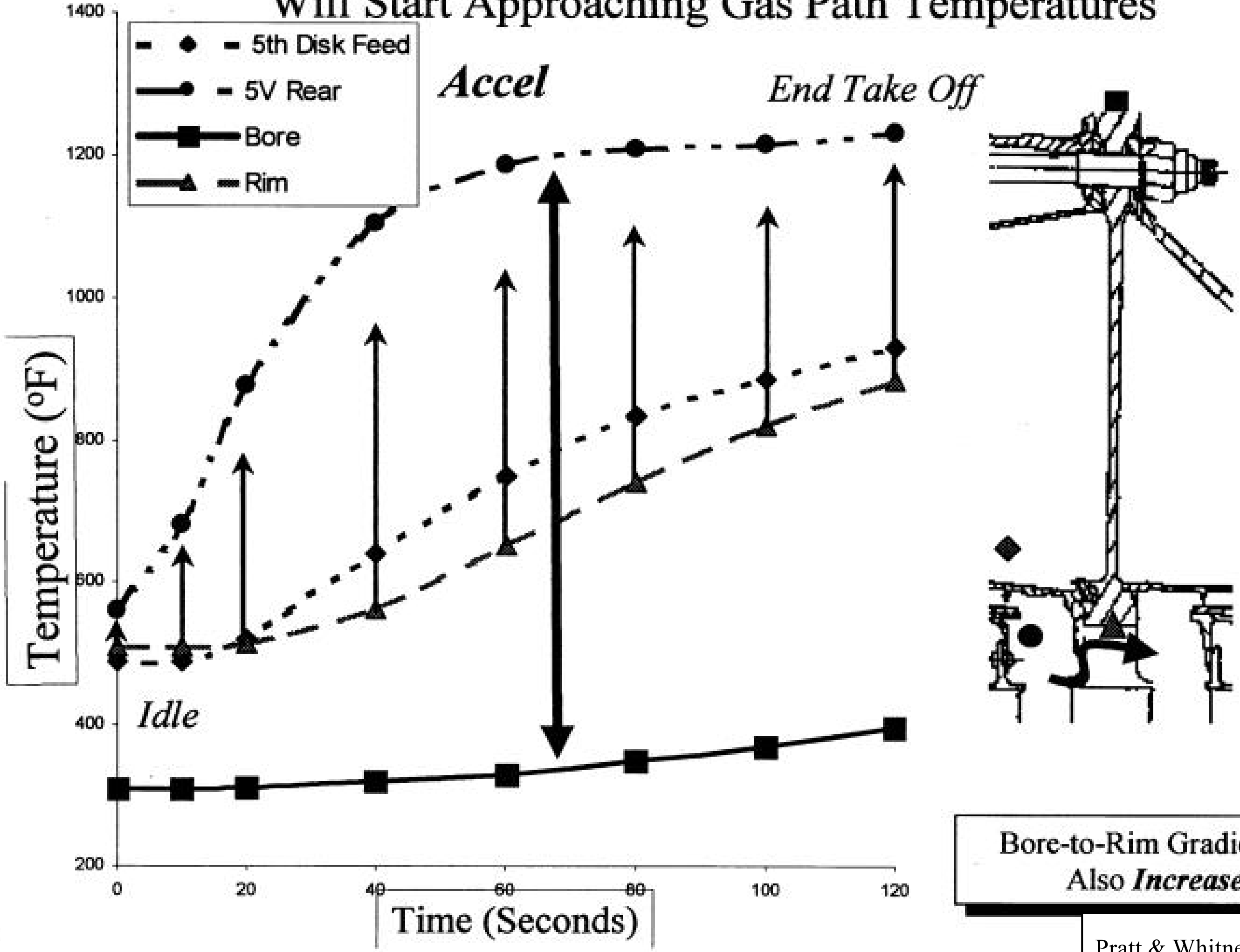
[redacted]

In the Bill of Material Configuration 5th Disk Live Rim Temperature Defined by Cooling Air



Pratt & Whitney Proprietary

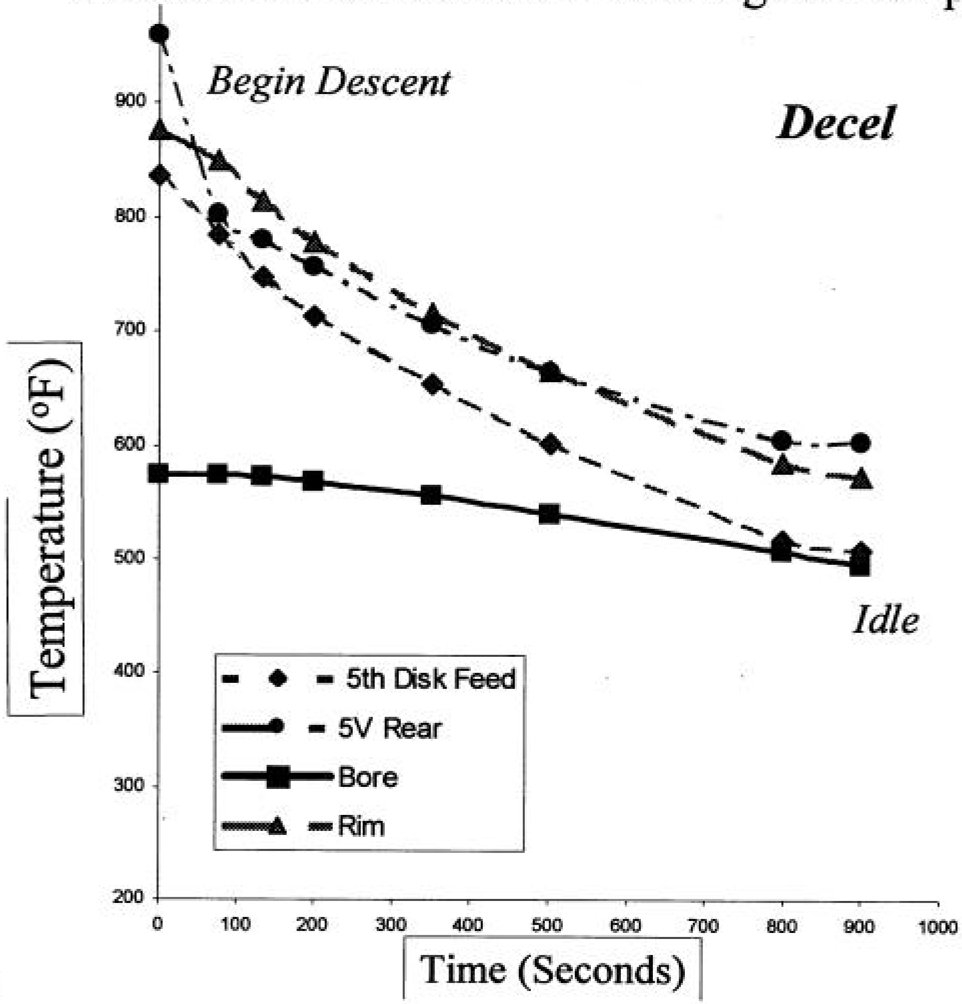
When the Live Rim Cooling Air is Blocked, Live Rim Temperatures Will Start Approaching Gas Path Temperatures

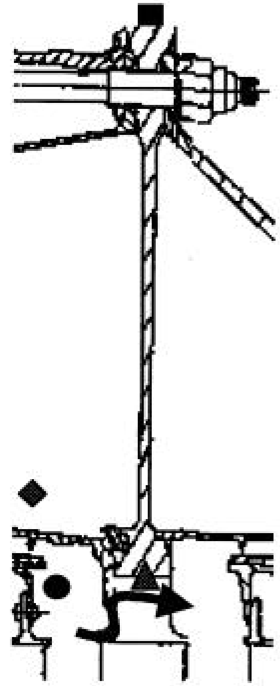


Bore-to-Rim Gradient Will Also ***Increase*** !!

Pratt & Whitney Proprietary

When the Live Rim Cooling Air is Blocked, Live Rim Temperatures will Increase Due to Increase in Cooling Air Temp – Not as Severe as Accel

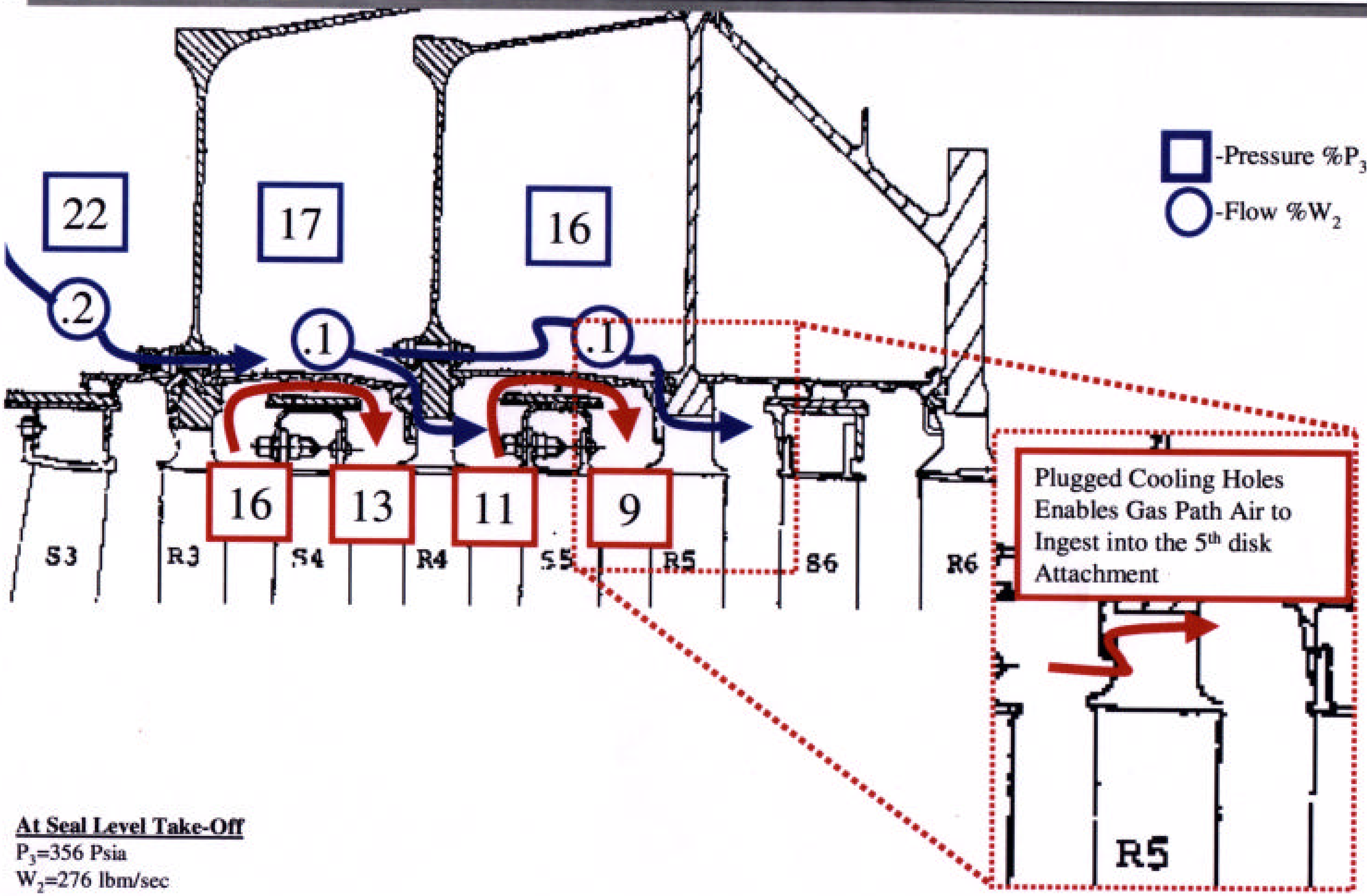




Bore-to-Rim Gradient Will Also ***Increase*** !!

Pratt & Whitney Proprietary

Plugging 4-5 Inner Air Seal Cooling Holes Will Increase Live Rim Temperatures at 5th disk



At Seal Level Take-Off
P_3=356 Psia
W_2=276 lbm/sec

Pratt & Whitney Proprietary

APPENDIX G – AOW AND SAIB

Please distribute this all operator wire to your cognizant airline personnel.

JT9D All Operator Wire

To: All JT9D Operators

Subject: LPT 4th and 5th Stage Rotating Airseals – JT9D Series Engines

Date: 09 APRIL 2002

Applicability: JT9D-59A, -70A, -7Q, -7Q3 Series Engines

This is: JT9D/72-52/CTS:RKS:4-09-02-1

(A) Wire Contents:

This wire provides information on a LPT 5th stage airseal, PN 760659, found with blocked cooling holes, and the predicted effect on associated LPT 5th stage disk life. LPT 4th or 5th stage rotating airseals with blocked cooling holes can potentially cause uncontained 4th or 5th stage disk fractures. Airline inspection results for blocked cooling holes per reference 1 are summarized. Enhancements to Pratt and Whitney engine manuals are explained to highlight actions Pratt and Whitney has undertaken to help prevent and identify improperly repaired airseals.

(B) Reference(s):

1. AOW JT9D/72-52/CTS:RKS:1-25-02-1 – provided initial information and recommendations for a LPT 5th stage airseal with blocked cooling holes.
2. FAA Special Airworthiness Information Bulletin (SAIB), No. NE-02-21, dated March 15, 2001 – provides information and recommendations on LPT 5th stage rotating airseal blocked cooling holes.
3. JT9D-7Q and –7Q3 Engine Manual 777210, Section 72-52-15, Repair 5, - Rear Snap Diameter Plasma Repair for the LPT 4th Stage Rotating Airseal.
4. JT9D-7Q, and –7Q3 Engine Manual 777210, Section 72-52-15, Inspection 01, - Turbine Airseal Stage 4.
5. JT9D-7Q, and –7Q3 Engine Manual 777210, Section 72-52-16, Repair 4, - Rear Snap Diameter Plasma Repair for the LPT 5th Stage Rotating Airseal.
6. JT9D-7Q, and –7Q3 Engine Manual 777210, Section 72-52-16, Inspection 01, - Turbine Airseal Stage 5.
7. JT9D-59A, -70A Engine Manual 754459 HM 72-52-06 Check-01 – Turbine Airseals (Stages 3, 4, 5 and 6 Rotating).
8. JT9D-59A, -70A Engine Manual 754459 OH 72-52-06 Repair-05 - Rear Snap Diameter Plasma Repair for the LPT 4th Stage Rotating Airseal.

9. JT9D-59A, -70A Engine Manual 754459 OH 72-52-06 Repair-07 Rear Snap Diameter Plasma Repair for the LPT 5th Stage Rotating Airseal.

(C) Discussion & Background Information:

Reference 1 provided information on a LPT 5th stage rotating airseal, PN 760659, found with cooling holes completely blocked by plasma coating as a result of an improper repair. This airseal was removed from an engine that experienced an uncontained LPT 5th stage disk fracture. Thermal and structural analysis, completed since the release of reference 1, shows that blocked cooling holes in the LPT 5th stage rotating airseal resulted in a significant reduction in the associated LPT 5th stage disk life and contributed to fracture of the LPT 5th stage disk. These findings were announced in reference 2, included here.

(Attachment 1 – FAA SAIB)

Reference 1 also requested that airlines conduct a one-time inspection of shelf stock to identify any additional LPT 4th or 5th stage seals with blocked cooling holes. A combined total of 48 LPT 4th and 5th stage seals were reported inspected and none were found with plasma completely blocking the holes. However, a total of 5 seals had very minor blockage from plasma overspray in the cooling hole edge breaks. Another 2 seals were found each with one hole blocked with a rubber masking plug, suspected to be part of a rear snap plasma repair. The inspected seals had been previously repaired by a variety of repair sources. Several of the inspected seals were repaired by the same repair source as the LPT 5th stage rotating airseal with completely blocked cooling holes and at about the same time as the airseal with blocked cooling holes. Additionally, the same person who performed the repair on the LPT 5th stage rotating airseal with blocked cooling holes repaired a total of only three 5th stage rotating airseals. All three of these seals have been inspected and are included in the above results. We conclude from these inspection results that there is minimal potential of having an additional LPT 5th stage rotating airseal with completely blocked cooling holes.

Blocked cooling holes in LPT 4th and 5th stage rotating airseals have a significant impact on the associated LPT 4th and 5th stage disk lives and can potentially result in uncontained disk fractures. As a result, Pratt and Whitney is enhancing the Engine Manuals to provide additional inspections to help prevent and identify improperly repaired LPT 4th and 5th stage rotating airseals. The following attachment summarizes the enhancements to the Engine Manuals.

(Attachment 2 – Engine Manual Enhancements).

(D) Maintenance Recommendations:

It is recommended that airlines continue to inspect their shelf stock of LPT 4th and 5th Stage Rotating Airseals, per reference 1, to evaluate whether any of the cooling holes are blocked. LPT 4th and 5th Stage Rotating Airseals with evidence of blocked cooling holes should be repaired to remove blockage prior to service.

Per Attachment 2, the Engine Manuals will be enhanced to add an inspection of the cooling holes as part of the LPT 4th and 5th stage rotating airseal rear snap diameter plasma repair so that the holes are not blocked during repair. Airlines, and overhaul and repair facilities are reminded of the existing caution in the LPT 4th and 5th stage rotating airseal rear snap diameter plasma repair stating, “NO PLASMA SPRAY (COATING) IS PERMITTED IN THE AIRSEAL HOLES OR ON HOLE EDGE BREAKS”. It is also noted that following plasma application on the rear snap diameter that hole edge breaks are required on the cooling holes, as specified in the repair.

Also per Attachment 2, an inspection is added to the LPT 4th and 5th stage rotating airseal INSP/CHECK-01 section to inspect the cooling holes for blockage during every part inspection. If a LPT 4th stage airseal has service time with blocked cooling holes as described in attachment 2, then the LPT 4th stage airseal and the 4th stage disks and 4th stage blades, all with service time associated with the affected 4th stage airseal must be scrapped. If a LPT 5th stage airseal has service time with blocked cooling holes as described in attachment 2, then the LPT 5th stage airseal and the 5th stage disks and 5th stage blades, all with service time associated with the affected 5th stage airseal must be scrapped.

It is no longer required to provide all inspection results to Pratt & Whitney as requested in reference 1. However, please notify Pratt & Whitney if any LPT 4th or 5th stage rotating airseal is found with blocked cooling holes. It is recommended that you remove any blockage of the cooling holes, if necessary, prior to returning a part to service.

Finally, Pratt & Whitney is **not** recommending disassembly of engines or LPT modules to inspect installed LPT 4th and 5th stage rotating airseals for blocked cooling holes. There is no borescope procedure that can be used to inspect the airseals for blocked cooling holes in assembled engines, as the cooling holes are in an inaccessible location. At an operator’s discretion, it is possible to borescope inspect for blocked LPT 4th and 5th stage rotating airseal cooling holes on LPT modules removed from engines. This can be accomplished with a 3mm right angle borescope via cooling holes in the LPT 3rd and 4th stage disks.

(E) Design Changes:

None.

(F) Federal Aviation Administration Actions:

The FAA has been notified of finding blocked cooling holes in a LPT 5th stage rotating airseal, PN 760659. The FAA is aware of the effect LPT 4th and 5th stage rotating airseal blocked cooling holes can have on 4th and 5th stage disk lives, and the potential for uncontained fractures of these disks.

The FAA has issued SAIB, No. NE-02-21, dated March 15, 2001 included in Attachment 1 above.

(G) Conclusion:

One instance of blocked cooling holes was found on a LPT 5th Stage Rotating Airseal used on JT9D-59A, 70A, -7Q, and 7Q3 series engines. Cooling holes are incorporated in the LPT 4th and 5th Stage Rotating Airseals in order for the corresponding LPT 4th and 5th stage disks to meet their chapter 5 lives. An uncontained fracture of these disks can potentially occur if the rotating airseal cooling holes are blocked.

Pratt & Whitney is enhancing the Engine Manuals per the above to include new inspections to help prevent and identify improperly repaired LPT 4^{th} and 5^{th} stage rotating airseals. Airlines, overhaul and repair facilities are requested to notify Pratt & Whitney if blocked cooling holes are found in any LPT 4^{th} or 5^{th} stage rotating airseals.

Airlines and overhaul and repair facilities are reminded of the existing caution in the LPT 4^{th} and 5^{th} stage rotating airseal rear snap diameter plasma repair stating, “NO PLASMA SPRAY (COATING) IS PERMITTED IN THE AIRSEAL HOLES OR ON HOLE EDGE BREAKS”, and to take appropriate corrective action per FAA SAIB, No. NE-02-21, dated March 15, 2001, to minimize the potential for future improperly repaired airseals.

If you have any questions regarding this subject, please do not hesitate to contact us.

United Technologies Corporation
Pratt & Whitney
Commercial Engine Business

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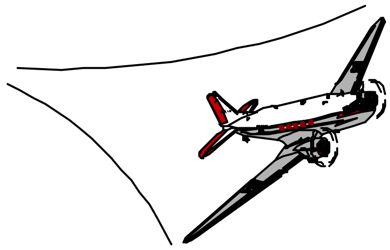
SPECIAL AIRWORTHINESS INFORMATION BULLETIN



U.S. Department of Transportation

Federal Aviation Administration

Aircraft Certification Service
Washington, DC

No. NE-02-21
March 15, 2002

We post SAIBs on the internet at "av-info.faa.gov"

This is information only. Recommendations are not mandatory.

Introduction

This Special Airworthiness Information Bulletin alerts you, owners or operators **of Pratt & Whitney (PW) JT9D series turbofan engines**, Repair Stations, and Principal Maintenance Inspectors in FAA's FSDOs to the possibility of an uncontained engine failure when 5^{th} stage LPT airseal cooling holes are blocked.

Affected Products

Pratt & Whitney JT9D -7Q, -7Q3, -59A, -70A

Background

During a recent FAA investigation of an uncontained failure of a JT9D-7Q 5^{th} stage low-pressure turbine (LPT) disk, we discovered that the LPT 5^{th} stage airseal cooling holes were completely blocked by plasma spray. The original 5^{th} stage airseal contains 60 holes to introduce cooling flow to cool the LPT 5^{th} stage disk web and disk rim. Blocking of the cooling flow results in unacceptable high temperatures on the disk which can cause the disk to crack and ultimately separate. Review of the JT9D Engine Manual indicates that plasma spray repair of the LPT 5^{th} stage airseal is permitted for the snap diameter, seal wing and face. Blockage of cooling holes may occur if proper repair procedures are not followed.

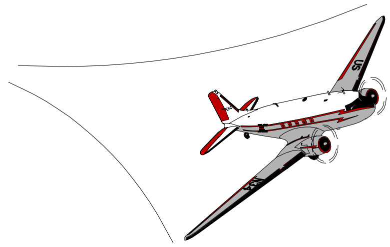
Recommendation

The FAA Engine Certification Office (FAA ECO) highly advises owners, operators, and engine Repair Stations to inspect the incoming parts and post-repaired parts to ensure the cooling holes on the 5^{th} stage LPT airseal, P/N760659, are not blocked. We highly recommend you remove any blockage of the cooling holes, if necessary. We also advise all repair facilities involved in JT9D airseal repair that the only currently acceptable process is to follow the instruction of JT9D Engine Manual (P/N777210) Turbine Airseal – Repair -4, and Inspection -01 to ensure "**NO PLASMA SPRAY IS PERMITTED IN AIRSEAL (COOLING) HOLES OR ON HOLE EDGE BREAKS**".

For Further Information, Contact

Jason Yang, FAA Engine and Propeller Directorate, Engine Certification Office, ANE-142, 12 New England Executive Park, Burlington, MA 01803-5299; phone: (781) 238-7747; email: Jason.Yang@faa.gov

SPECIAL AIRWORTHINESS INFORMATION BULLETIN



U.S. Department of Transportation

Federal Aviation Administration

Aircraft Certification Service
Washington, DC

No. NE-02-30
June 3, 2002

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This is information only. Recommendations are not mandatory.

Introduction
This Special Airworthiness Information Bulletin (SAIB) alerts owners, operators, and repair facilities of Pratt & Whitney (PW) JT9D series turbofan engines and Principal Maintenance Inspectors in FAA's FSDOsof the importance of performing an enhanced inspection of the cooling holes on LPT 4^{th} and 5^{th} stage rotating airseals. This SAIB also advises you to scrap certain disks that have service time with airseals with blocked cooling holes. An uncontained engine failure can potentially occur if the rotating airseal cooling holes are blocked.

Affected Products
Pratt & Whitney **JT9D -7Q, -7Q3, -59A, -70A**

Background
Investigation of an uncontained failure of a JT9D-7Q 5^{th} stage low-pressure turbine (LPT) disk revealed the LPT 5^{th} stage airseals were improperly repaired with excessive plasma spray which blocked the cooling hole on the airseal. Blocking of the cooling flow results in unacceptable high temperatures on the disk which can cause the disk to crack and ultimately separate. The FAA issued *SAIB NE-02-21 dated 03/15/02*, to recommend the inspection of the 5th stage LPT airseal cooling holes. Further investigation by Pratt & Whitney indicated blocking of the cooling holes on the LPT airseals of 4^{th} or 5^{th} stage disks would significantly reduce the lives of the LPT disks. Those disks, which have service time with airseals that have blocked cooling holes, should be scrapped in accordance with instructions described in JT9D Engine Manuals 777210 and 754459.

Recommendations
The FAA Engine Certification Office advises owner/operators/repair facilities to continue to inspect the incoming part and post-repaired part of the 4^{th} and 5^{th} stage LPT airseals. We also advise that if a 4^{th} or 5^{th} stage LPT airseal has service time with more blocked holes than are permitted, you should scrap the airseal, disk and blades associated with the airseal, as described in the P & W JT9D Engine Manuals 777210 and 754459.

For Further Information, Contact
Jason Yang, FAA Engine and Propeller Directorate, Engine Certification Office, ANE-142, 12 New England Executive Park, Burlington, MA 01803-5299; phone: (781) 238-7747; email: Jason.Yang@faa.gov

APPENDIX H NTSB MATERIALS LABORATORY FACTUAL REPORT

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

February 21, 2002

MATERIALS LABORATORY FACTUAL REPORT Report No. 02-12

A. INCIDENT

Place	: near Denpasar, Bali
Date	: November 23, 2002
Vehicle	: Boeing 747,
Operator	: Garuda Indonesia, Flight 880
NTSB No.	: ENG02RA003
Investigator	: Carol Horgan (AS-40)

B. COMPONENTS EXAMINED

Center portion of the 5th stage LPT disk, two portions of the rim, and several pieces of vanes and blades from a P&W JT9D engine.

C. DETAILS OF THE EXAMINATION

The metallurgical examination was performed between January 14 and 17, 2002 with the participation of the following individuals:

Frank Zakar	Senior Metallurgist, NTSB
Carol Horgan	Air Safety Investigator, NTSB U.S. Accredited Representative
Prof. Dr. Ir Mardjono S,	Investigator-in-Charge Air Safety Investigator, NTSC
Ir Saryani Asmayawati	Air Safety Investigator, NTSC
Ir Pudjiono,	Quality Assurance, Garuda Indonesia
Ir. V. Agung Prabowo	Power Plant Engineer, Garuda Indonesia
James Aufman	Service Investigations, Pratt & Whitney

1.0 Overall View

An overall view of the as-received portions of the 5th stage LPT disk (P/N 751505, S/N K15178), two portions of the rim, and several pieces of the vanes and blades, is shown in figures 1 and 2. Many of the blades and vanes had fractured through the airfoil sections and the majority of the outboard airfoil pieces were not submitted.

2.0 Fracture in the Web Portion of Disk

The disk fractured circumferentially through the web adjacent to the rim. Examination of the fracture with a magnifying glass revealed predominantly an angular (slant) fracture plane, with the following exceptions. The forward face of the web contained a continuous flat-fracture region (on a tangential plane) that extended approximately 14 inches around the web. The remaining portion of the forward face of the web contained isolated areas of flat fracture. The aft face of the web contained a continuous flat-fracture region opposite the flat-fracture on the forward face, except that it only extended approximately 9.5 inches around the web. The flat fracture regions had a dark blue-gray tint (see figure 3). The two flat fracture regions were at slightly different radial locations and were connected by a fracture on a slant plane. The fracture on the slant plane showed a blue tint. Figure 3 shows a photograph of a portion the fracture that contains the flat fracture regions. The fracture propagated circumferentially away from these two regions of flat fracture. The continuous flat fracture regions were located approximately 7 inches outboard of the inner snap diameter of the disk. The fractures located outside the continuous flat region were radially located between 7 inches and 7.3 inches outboard of the inner snap, and in shape appeared similar to the teeth on a saw.

The aft face appeared red-brown compared to the forward face, which had a blue-gray tint. Closer examination of the aft face after cleaning with soap and water disclosed that aft face contained randomly distributed red-brown deposit (see figure 4).

3.0 Scanning electron microscope

A pie shaped piece of the fracture face that contained flat fracture was excised from the web portion. The saw cuts were made through fracture face and intersected the inner snap hole. A saw cut was made about one inch below the fracture face to facilitate scanning electron microscope examination (SEM).

SEM examination of the excised portion of the fracture face revealed the flat fracture regions contained intergranular fracture features, see figure 5. The depth of each flat fracture region extended as deep as 40% [to a maximum depth of approximately 0.06 inches] of the wall thickness of the web, but the combined depth of both flat fracture regions at any one location did not exceed 75% of the thickness of the web, see figure 6. The slant fracture contained ductile dimple features typical of overstress separation, see figure 7. The intergranular fracture features near the disk surfaces were degraded (rounded and more flat) compared to the intergranular fracture features next to the transition to overstress fracture that were well defined (sharp edges). This effect was accompanied by the appearance of oxide on the fracture surface, which was progressively less severe with increasing distance from the disk surface. No evidence of pitting corrosion was noted on either face of the web or on the fracture face.

X-ray energy dispersive spectroscopy (EDS) analysis of the slant fracture face revealed a spectrum that contained major elemental peaks of iron (Fe), chromium (Cr) and nickel (Ni), and minor peaks of titanium (Ti), aluminum (Al), molybdenum (Mo), and silicon (Si), consistent with the composition of the specified alloy, PWA 1029 (similar to AMS 5732, an A286 stainless steel). Spectra from the intergranular regions contained a peak for oxygen

(O), consistent with an oxide, in addition to the elemental peaks found in the base metal. The forward and aft faces of the web also contained elemental peaks of phosphorus in addition to those for oxygen and the base metal elements.

4.0 Metallography

One of the pie-cuts through the web portion was oriented radially with respect to the axis of the disk, and it intersected the fracture face where the combined total depth of the flat fracture regions was the greatest. The metallurgical sections were prepared from the radially oriented saw cut face. A metallurgical section was excised from the web portion that incorporated the fracture area, and another metallurgical section was excised from the wall next the bore of the disc.

A third section was made through the mating rim portion of the disk. This metallurgical section was in the radial plane and encompassed a full blade attachment tang.

4.1 Metallurgical section through the web fracture

An as-polished metallurgical section that was made through the web portion of the disk incorporating the fracture is shown in figure 8. This section shows flat fracture regions at the forward and aft face of the web and the connecting slant (diagonal) fracture face. The flat fracture region adjacent to the forward face of the web was located approximately 0.3 inch outboard of the flat fracture region adjacent to the aft face of the web. Metallographic examination of the etched section (with Marble's reagent) disclosed generally equiaxed grain structure with a series of discrete carbide precipitates at the grain boundaries. No evidence of creep voids, continuous film, or delta (needle) phase was noted at the grain boundaries. The grain size at the web portion was approximately 6, within the range specified in PWA1029. Specification PWA1029 indicates that the grain size in the disk should be number 4 or finer. [1]

The section further disclosed the flat fracture regions were intergranular. The cracks along the grain boundaries near the fracture surface were filled with an oxide. Examination and study of the cracks were performed prior to etching. The forward and aft faces of the web contained a discontinuous layer of oxide. The aft face of the web contained longer segments of oxide layer compared to the layer on the forward face. The typical thickness of the oxide layers on each surface measured approximately 5 microns. Both forward and aft faces also exhibited intergranular secondary cracks that were filled with oxide (see figures 8, 9 and 10). The thickness of the oxide layer was greatest over the areas of a secondary crack (as much as 9 microns). The thickness of the oxide layer appeared to decrease toward the inboard direction. The secondary cracks measured as deep as 0.007 inch.

Detailed EDS analysis of oxide material in the secondary cracks revealed three visually-apparent types of oxidation, see figure 9. At the center of the crack was a layer of oxide that was Fe-rich (arrowed "1" in figure 9). Closer to the crack wall was a layer that contained Cr, Ti, Fe and Ni (arrowed "2" in figure 9). In the center region near the tip of the

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[1] Measured by comparison to ASTM chart. Higher numbers equate to small grains size.

crack was a light-appearing constituent that was very high in Fe, with some Ni and Cr (arrowed "3" in figure 9).

The oxide scale along the disk surfaces was Fe-rich, similar to one of the constituents found at the center of the cracks. "Finger-like" features extended below the scale, see figures 9 and 10. The fingers were enriched in Cr and Ti, with some Fe and Ni. The length of the fingers measured approximately 0.0002 inch

4.2 Metallurgical section adjacent to the bore for the inner snap of the disk

Microstructure of the polished and etched section from the bore area was similar to the web area except that no secondary cracks were found. The ASTM grain size at the transition region between the bore hole and the web portion typically was between 5 and 6.

4.3 Metallurgical Section through the Rim (Upper portion of Blade Attachment Tang)

Microstructure of the rim portion of the disk was similar to the web and bolt hole area. The grain size typically was between 5 and 6.

5.0 Hardness Testing

Specification PWA1029 indicates that the hardness of the disk material should be between 248 and 342 HB, which converts to a hardness range between approximately 24 and 37 HRC. Rockwell hardness measurements performed directly on the forward and aft faces of the rim, after cleaning with grit paper, produced an average hardness value of HRC 31. Hardness testing performed on the forward and aft faces of the web, without grit paper cleaning, produced an average hardness value of HRC 33. The hardness values were within the hardness range specified by the manufacturer, Pratt and Whitney.

6.0 Sample of Plasma Coating

Samples of plasma coating removed following disassembly at a Pratt & Whitney facility from the 5th stage air seal snap were submitted for elemental analysis. EDS analysis of the fractured ends of the plasma coating layer produced a spectrum that contained a major peak of nickel and minor peaks of aluminum and oxygen, consistent with PWA53-37 coating used for snap dimensional restoration.

7.0 Blade and Vane Pieces

The fracture face of the blade and vane pieces showed no evidence of a preexisting crack. They showed features typical of overstress separation.

Frank P. Zakar
Senior Metallurgist

Figure 1. As-received portions of the 5th stage LPT disk showing two pieces of the rim (right side of photograph), and several pieces of vane and blades.

Figure 2. As-received disk that fractured all around the web. The two rim pieces were postioned next to the web portion as if intact.

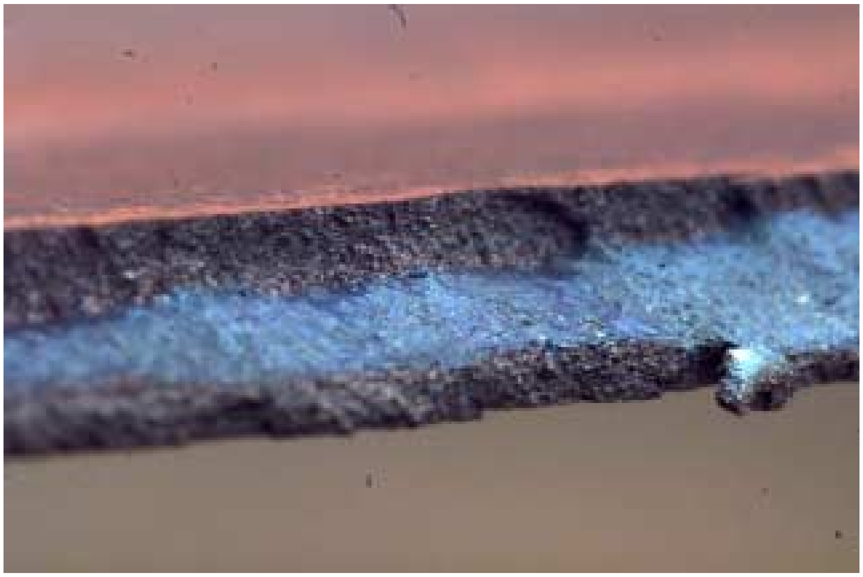


Figure 3. Optical photograph of a portion of the web fracture face. The flat fracture regions adjacent to each face of the web (appear gray-dark blue) are connected by a slant fracture (blue). The aft face of the web appears red-brown and is located on the upper side of the photograph. Photograph taken by P&W afte disassembly of the disk.

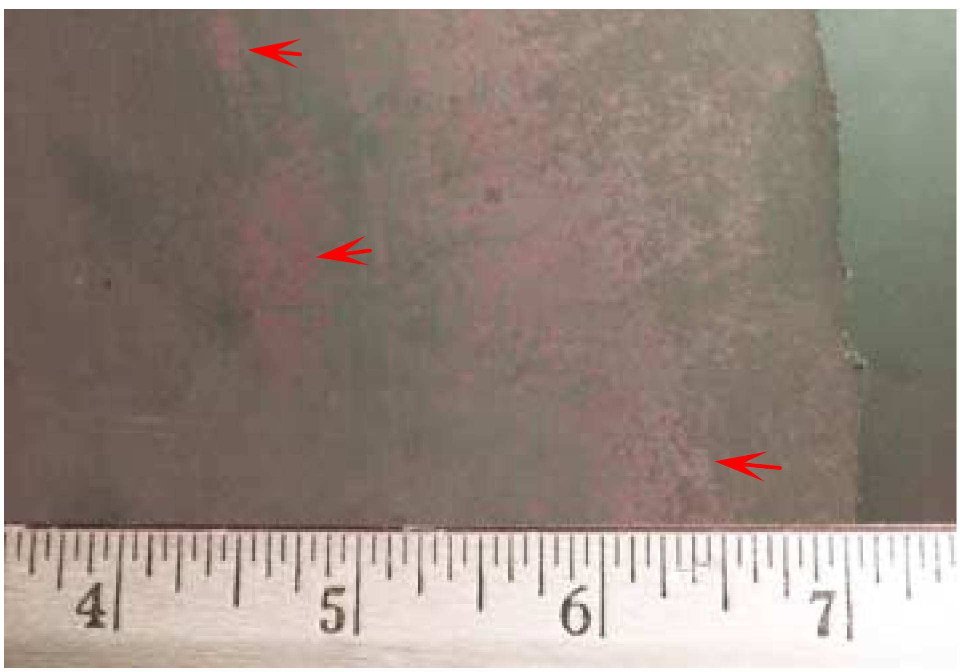


Figure 4. Area of the aft face of the web with some of the red-brown deposits indicated by unmarked arrows.

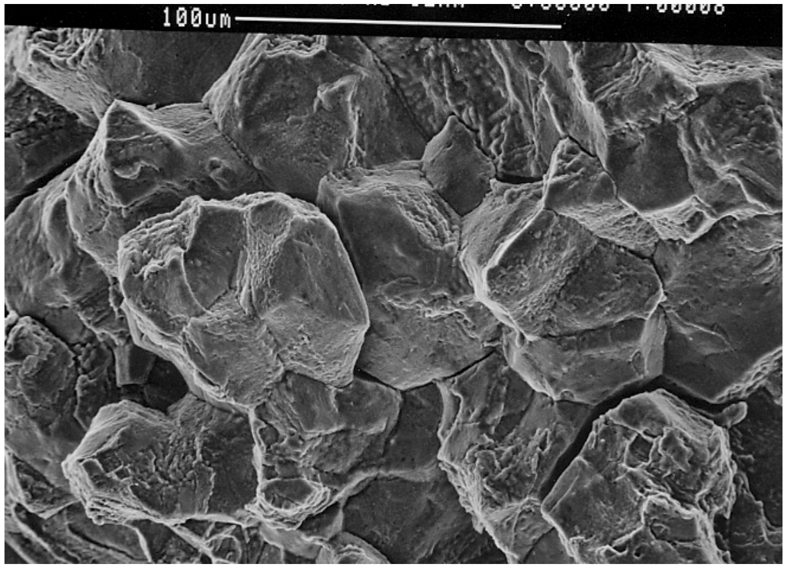


Figure 5. Scanning electon microcope photograph of typical intergranular fracture features that were found on the web portion of the disk. This photograph was taken on the flat fracture region that was located adjacent to the aft face of the web.

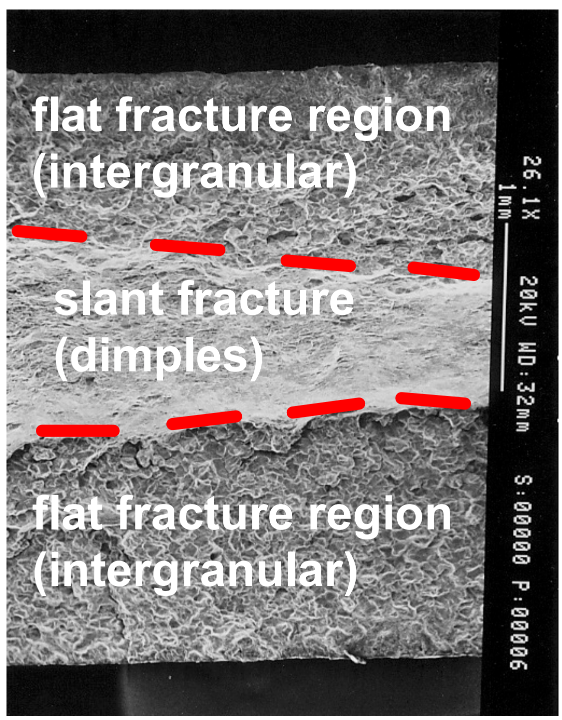


Figure 6. Scanning electron microscope (SEM) photograph of the fracture face located on the web portion of the disk. Flat fracture regions were situated adjacent to the forward and aft faces of the web. Aft face of the web is on the bottom side of photograph.

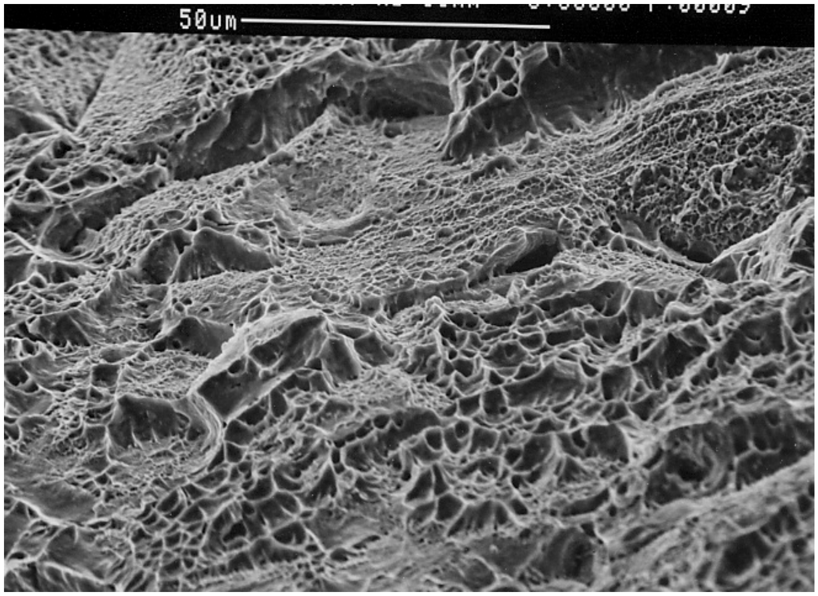


Figure 7. SEM photograph of typical ductile dimple features on the slant fracture.

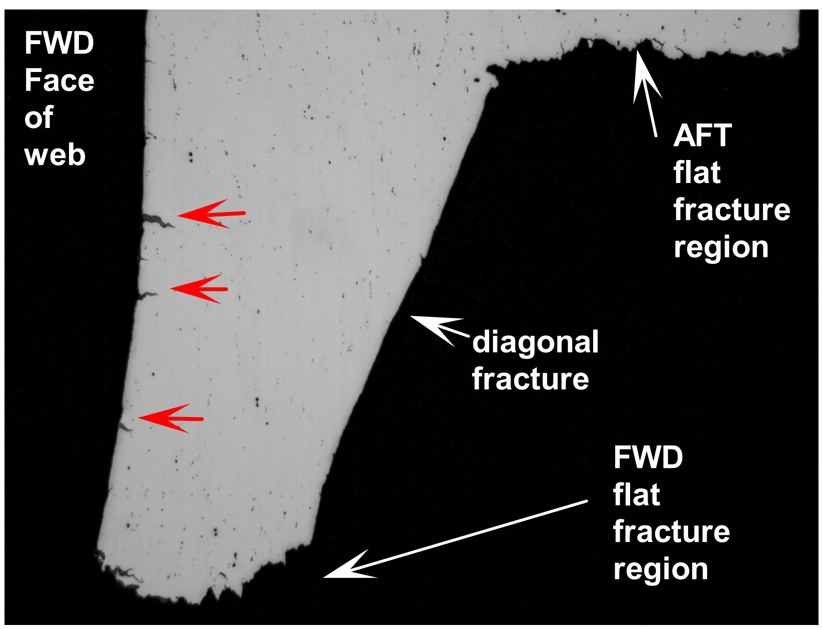


Figure 8. Metallurgical section radially through the fracture. The flat fracture regions on the forward and aft face of the web are connected by a diagonal (shear) fracture. Arrows indicate location of secondary cracks on the forward face of the web.

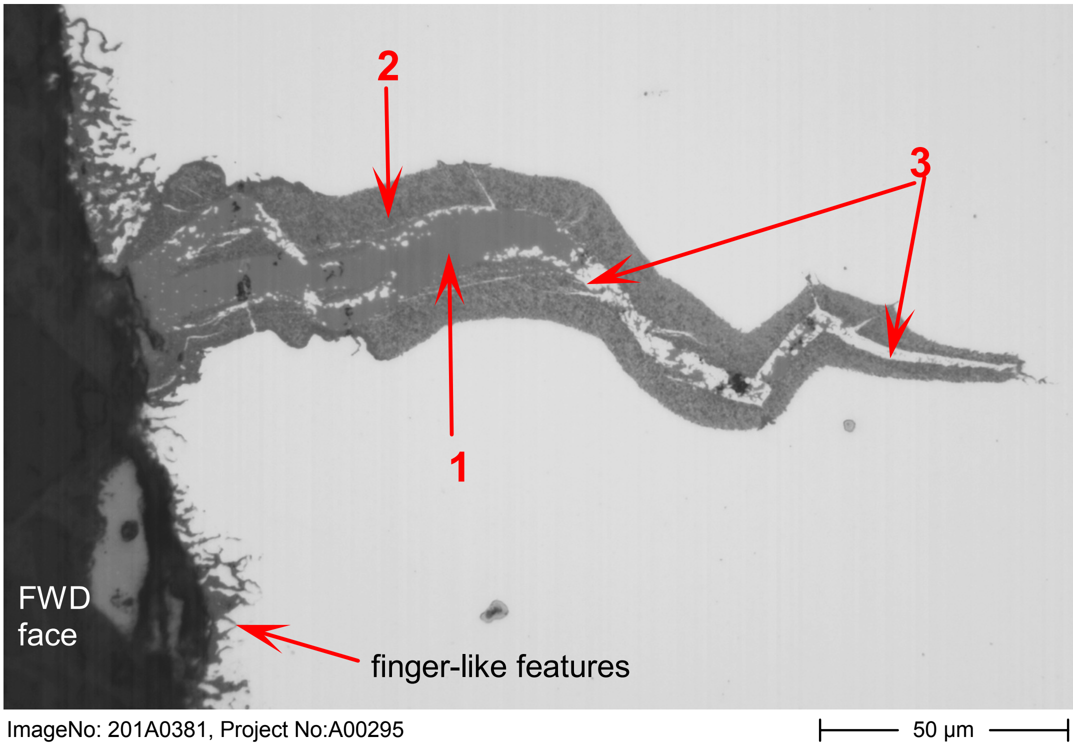


Figure 9. Polished section showing a crack that emanated from the forward face of the web. The crack is filled with three types of oxides, labelled "1" through "3".

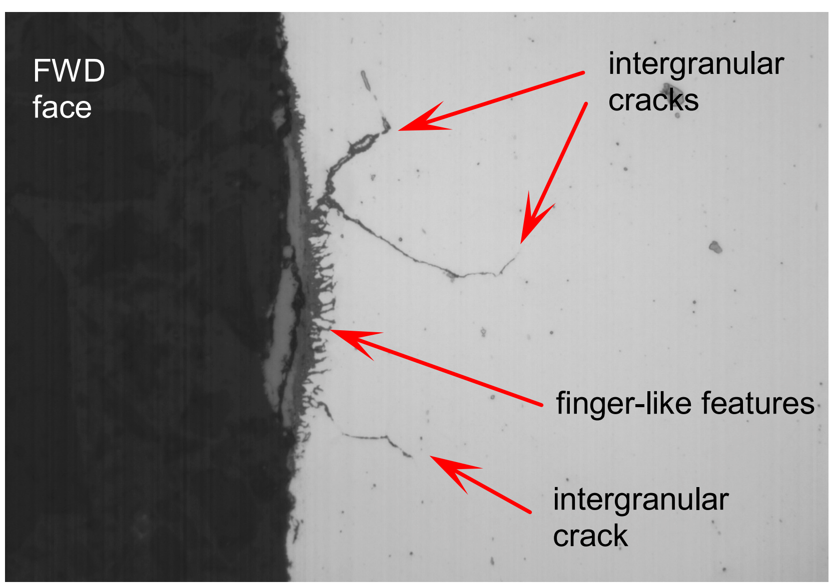


Figure 10. Portion of a polished section showing another crack that emanated from the forward face of the web. The crack is filled with oxides and it propagating along the grain boundaries.

APPENDIX I - TURBOFAN ENGINE MALFUNCTION INDENTIFICATION

The following text is taken from "AirplaneTurbofan Engine Operation and Malfunctions, Basic Familiarization for Flight Crews " by Pratt & Whitney. Although many failures may have similar symptoms, this table and the following illustration may help flight crew to choose the appropriate checklist.

	Engine separation	Severe damage	Surge	Bird ingestion/FOD	Seizure	Flameout	Fuel control problems	Fire	Tailpipe fires	Hot start	Icing	Reverser inadvertent deploy	Fuel leak
Bang	O	X	X	O	O						O		
Fire Warning	O	O		O				X					
Visible flame	O	O	O	O				O	X	O			
Vibration		X	O	X	O						X	X	
Yaw	O	O	O	O	O	O	O					X	
High EGT		X	X	O	O		X		O	X	O		
N1 change	X	X	O	O	X	X	X						X
N2 change	X	X	O	O	X	X	X						X
Fuel flow change	X	O	O		O	X	O	O					X
Oil indication change	X	O	O		O	X		O					
Visible cowl damage	X	X						O				X	
Smoke/odor in cabin bleed air		O		O	O								
EPR change	X	X	X	O	X	X	X						X

X = Symptom very likely
O = Symptom possible
Note: blank fields mean that the symptom is unlikely

Engine Stall/Surge

Event Description

Engine Stall or Surge is a momentary reversal of the compressor airflow such that high-pressure air escapes out of the engine inlet.

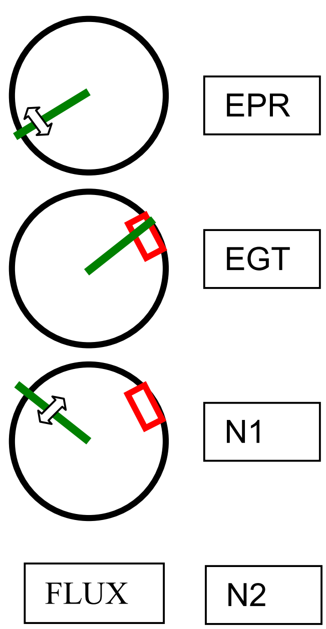
Corrective action

After stabilizing airplane flight path, observe engine instruments for anomalies. Stall/surge may be self-correcting, may require the engine to be throttled back, or may require engine shutdown, if the engine can be positively identified and the stall will not clear.

Symptoms

High power: Loud bang and yaw (may be repetitive). Flames from inlet and tailpipe. Vibration. High EGT/TGT. Parameter fluctuation

Low power: Quiet bang/pop or rumble.



POSSIBLE MESSAGES

ENG STALL

EGT OVERLIMIT

ENG FAIL

Flameout

Event Description

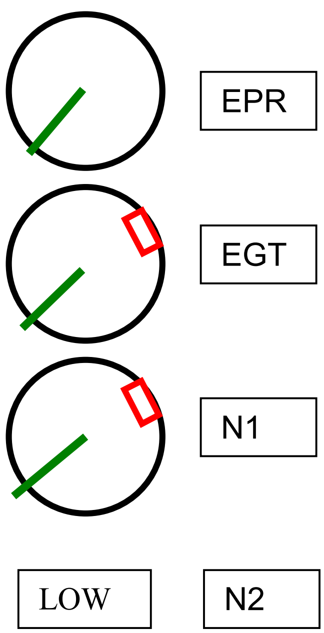
Engine Flameout is a condition where the combustor is no longer burning fuel.

Corrective action

After stabilizing airplane flight path, verify fuel supply to engine. Re-start engine according to AFM.

Symptoms

Single engine: Core speed, EGT, EPR all decay. Electrical generator drops off line; low oil pressure warning as core speed drops below idle. Multiple engines: As above, but also hydraulic, pneumatic and electrical system problems.



POSSIBLE MESSAGES

ENG FAIL

OIL LO PR

GEN OFF

BLD OFF

ALL ENG FLAMEOUT

Fire

Event Description

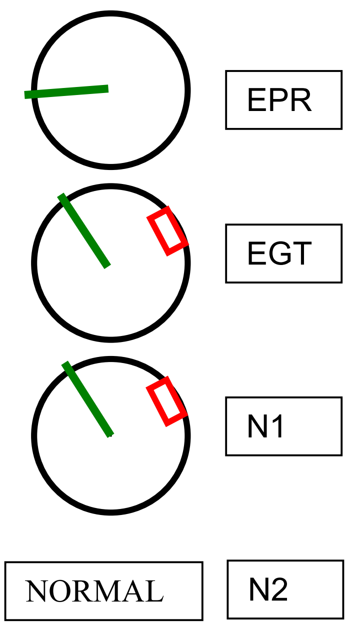
Engine fire is a fuel, oil or hydraulic fluid fire between the engine casing and the cowlings (or occasionally a metal fire). It could result from severe damage. Hot air leaks can also give a fire warning.

Corrective action

After stabilizing airplane flight path, shut the engine down and discharge extinguishant. Avoid restarting the engine.

Symptoms

Fire warning.
Flame or smoke may be observed.



POSSIBLE MESSAGES

ENG FIRE

PARAMETERS MAY LOOK NORMAL

Tailpipe fire

Event Description

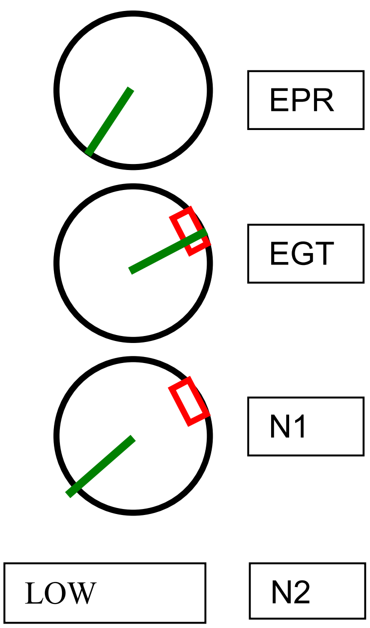
Fuel puddles in the tailpipe and ignites on hot surfaces.

Corrective action

Shut off fuel to the engine and dry motor it.

Symptoms

Observed flames and smoke. N**o fire warning.**



POSSIBLE MESSAGES

START FAULT

Bird Ingestion

Event Description

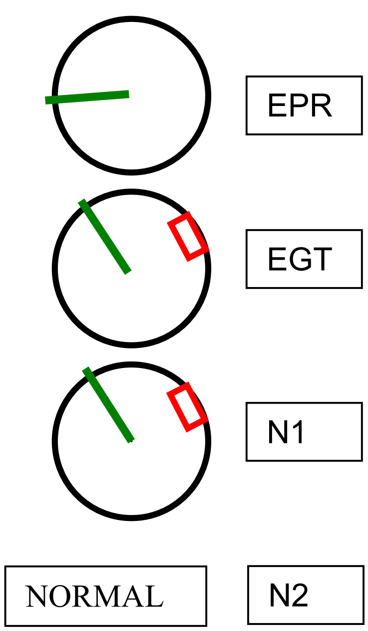
A bird (or other creature) is sucked into the engine inlet. Note: ingestion of ice slabs, blown tires, etc., will produce similar, but more severe, symptoms.

Corrective action

After stabilizing airplane flight path, watch engine instruments for anomalies. If the engine surges, throttle back or shut down as necessary. If multiple engines are affected, operate engines free of surge/stall to maintain desired flight profile.

Symptoms

Thud, bang, vibration. Odor in cabin. Surge may result from bird ingestion.



POSSIBLE MESSAGES

ENG STALL

EGT OVERLIMIT

VIB

PARAMETERS MAY LOOK NORMAL

Severe Engine Damage

Event Description

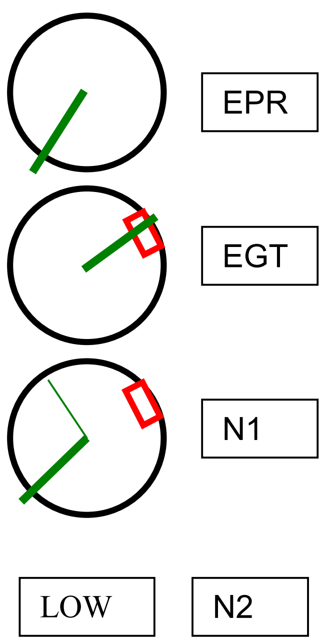
The engine hardware is damaged to the point where the engine is in no condition to run – such as bearing failure, major fan damage from ingestion of foreign objects, blade or rotor disk failures, etc.

Corrective action

After stabilizing airplane flight path, observe engine instruments for anomalies. Shut down engine.

Symptoms

Depending on nature of damage – surge/stall, vibration, fire warning, high EGT, oil system parameters out of limits, rotor speed and EPR decay, yaw.



POSSIBLE MESSAGES

ENG FAIL

EGT OVERLIMIT

ENG STALL

VIB

OIL LO PR

Engine Seizure

Event Description

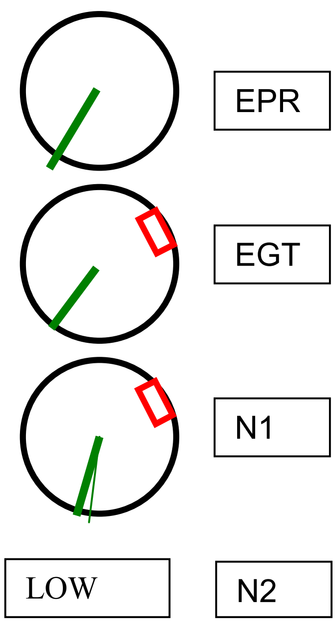
Engine seizure is the locking up of one or more rotors. It only happens after engines are shut down for severe damage.

Corrective action

Trim and adjust power for increased drag.

Symptoms

After shut down, zero speed on one of the rotors. Minor increase in required thrust for flight conditions.



POSSIBLE MESSAGES

ENG SHUT DOWN

Engine Separation

Event Description

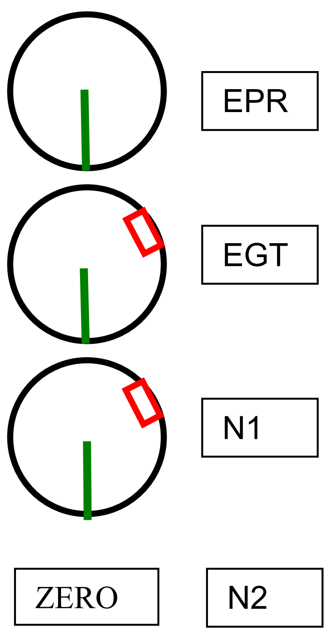
Engine Separation is the departure of the engine from the airplane due to mount or pylon failure.

Corrective action

After stabilizing airplane flight path, observe engine instruments for anomalies. Turn off fuel to appropriate engine.

Symptoms

Loss of all engine parameters. Hydraulic, pneumatic and electrical system problems



POSSIBLE MESSAGES

ENG FIRE

HYD OFF

GEN OFF

BLD OFF