

AIRCRAFT ACCIDENT FINAL REPORT

AIR FRANCE

AIRBUS A 300 B4, F-BVGK

SANA'A AIRPORT (YEMEN ARAB REPUBLIC)

MARCH 17, 1982

Prepared and distributed by

BUREAU ENQUETES-ACCIDENTS
246, rue Lecourbe 75732 PARIS - France

On behalf and after approval on July 1984 by the

Chairman
CIVIL AVIATION AND METEOROLOGICAL AUTHORITY
YEMEN ARAB REPUBLIC
P.O. BOX 1042 - SANA'A

JULY 1984



YEMEN ARAB REPUBLIC

CIVIL AVIATION & METEOROLOGY AUTHORITY

SANA'A

الجمهورية العربية اليمنية
الهيئة اليمنية العامة للطيران المدني والارصاد
منعاه

Date 18.7.1984

Ref 1604

File

التاريخ

الرقم

الملف

Mr. J. P. Bonny
Le Chef du Bureau Enquest Accidents
Ingenieur General de L'Aviation Civile
246 rue Lecourbe 75732
Paris, Cedex 15-France

Subject:- A300, F-BVCK ACCIDENT FINAL REPORT DISTRIBUTION

Dear Mr. Bonny,

Reference your letter No.0276-IGCEM/EA dtd 2 July 1984.

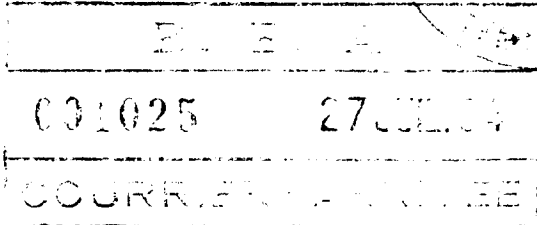
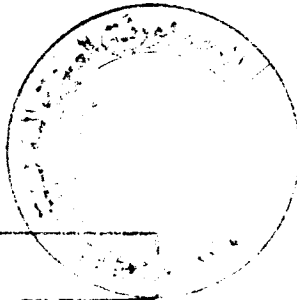
We appreciate your proposal of distribution of copies of the complete final report related to A300, F-BVCK accident, and we do agree on that the distribution of the said copies can be done by you on our behalf.

Availing the opportunity, I would like to thank you for your valued cooperation and assure you of our highest considerations at all times.

Yours faithfully,

M. M. Al-Ansi
Chairman

Civil Aviation & Meteorology Authority



- S U M M A R Y -

1 -	<u>SYNOPSIS</u>	Page	1
2 -	<u>ORGANIZATION AND PROGRESS OF THE INVESTIGATION</u>		2
3 -	<u>INVESTIGATIONS</u>		5
3.1	- History of the flight		5
3.2	- Injuries to persons		6
3.3	- Damage to aircraft		7
3.4	- Other damage		7
3.5	- Crew information		7
3.6	- Aircraft information		11
3.7	- Meteorological information		13
3.8	- Aids to navigation		13
3.9	- Communications		13
3.10	- Aerodrome and ground facilities		14
3.11	- Flight recorders		15
3.12	- Wreckage		17
3.13	- Medical and pathological information		19
3.14	- Fire		19
3.15	- Survival aspects		20
3.16	- Tests and research		22
3.16.1	- Powerplants investigations		22
3.16.2	- Test bed trials - Disassembly and inspection of APU		30
3.16.3	- Examination of tyres and wheels		33
3.16.4	- Studies concerning fire resistance and white smoke's origin		38
3.17	- Additional information : turbine disk FPI survey		42
4 -	<u>ANALYSIS</u>		44
4.1	- Origin of the accident		44
4.2	- Secondary damage		49
4.3	- Survival aspects		51
5 -	<u>CONCLUSIONS</u>		56
5.1	- Findings		56
5.2	- Causes		58
6 -	<u>SAFETY RECOMMENDATIONS</u>		59

APPENDICES

1 SYNOPSIS

Date and time of the accident

March 17th 1982 at 05.10 am UT (*)

Place of the accident:

Runway 36, Sana'a international airport (North Yemen)
Elevation : 2.100m

Nature of the flight :

Regular public passenger transportation
Flight AF 125 - Sana'a - Cairo - Paris

Aircraft

Airbus A300 B4 S/N 70
registration : F.BVGK

Owned and operated by :

Compagnie Nationale Air France
1, square Max Hymans
75015 PARIS -France

Persons on board :

Captain : JANIAC Bogdan
plus 2 flight crew members
and 10 cabin attendants
111 passengers.

Summary of the accident :

During the acceleration for take-off, at approx. 95 kt, a high pressure turbine (HPT) disk of the RH engine desintegrated, which resulted in heavy impacts damage, fuel leaks and a fire. The crew carried out an acceleration - stop procedure.

The airport fire crews reacted very quickly and efficiently. The aircraft was evacuated. However, due to fire damage, the aircraft was irreparable.

Conséquences :

Persons on board			Aircraft	Cargo	Property damage
	killed	injured			
Crew	-	-	irreparable aircraft	recovered	slight damage to the runway and one building
Passengers	-	1			

(*) UT : universal time

Three hours must be added to obtain the standard time at the place of the accident.

2 - ORGANIZATION AND PROGRESS OF THE INVESTIGATION

On March 18th 1982, the North Yemen Civil Aviation Authority (CAMA) constituted an investigation committee whose chairman was M. Mohamed AL MADAGHI - Manager of the Airworthiness Department - appointed as the "Investigator in charge".

In accordance with the ICAO (International Civil Aviation Organization) procedure (annex 13), France appointed authorized representatives in order to participate in the investigation.

The on-site preliminary investigation resulted in the creation of 7 investigation groups placed under the authority of a managing committee, supervised by M. Mohamed AL MADAGHI, whose members were :

Mr R.C. DURGEAT, investigator at the BEA (French Bureau Enquêtes-Accidents)

M. V. FAVE, investigator at the BEA

as accredited representatives sent by France and assisted by :

M. J. BETHEUIL, acting for the General Inspection of Air France,

M. G. SERRA, chief engineer at the Direction du Materiel of Air France,

as advisers and experts.

This managing committee coordinated the activities of the following seven groups :

- Operations
- Structures/Airframe
- Powerplant
- Airport authority
- Technical reports (recorders)
- Witnesses
- Legal matters

Several Air France representatives, one Airbus Industrie representative, and in a second stage, two General Electric Company representatives actively participated in the tasks of these various groups.

In the preliminary phase of the investigation, the Committee was assisted in its work by many experts, from both Yemenia Airways and Air France as well as from Airbus Industrie and General Electric, allowing the preparation of preliminary reports in good conditions.

The works of the groups mainly dealt with :

- The investigation of the damaged engine, the recovery of the main parts projected during the explosion, the preparation of a map showing the distribution of the debris, their transfer to a hangar,
- The investigation of the main wreckage and the survey of the various impacts which followed the uncontained explosions, and
- All information enabling the flight history and the circumstances of the accident to be reconstituted, including the analysis of the available recorded data.

The flight recorders read-out, digital flight data recorder and cockpit voice recorder (CVR), was carried out in France under the responsibility of French experts, in the presence of M. Mohamed AL BAHR, group manager.

In accordance with the International Civil Aviation Organization procedure (annex 13), the French Authorities accepted the proposed delegated tasks in order to carry out the analysis and expertise activities concerning points which were described in a delegation letter.

The Yemen Civil Aviation Authority followed the progress of the analysis and expertise tasks carried out in France, through M. Ahmed EL MAKALEH, who stayed in France until the main results were known.

In order to achieve the various activities mentioned above, several experts in addition to those of the French "B.E.A.", were requested to co-operate : "Centre d'Essais en Vol" in Breigny (Flight Test Centre), Air France, "Aérospatiale-Laboratoire Central d'Analyses" (Central Laboratory), Airbus Industrie, General Electric, National Transportation Safety Board and Atlas partners.

These activities concerned the following points (in the sequence in which they are mentioned in the delegation letter) :

- experts' report concerning tyres
- experts' report concerning various parts removed from the aircraft, such as cabin floor panels, forward cargo compartment wall panels, portions of air conditioning ducts and insulating lining, and
- experts' report concerning both engines and the auxiliary power unit (APU).

The various tasks mentioned are documented in notes and reports. Furthermore, some considerations were further investigated in order to evaluate the consequences of an uncontained explosion on the pursuance of the flight if it had occurred beyond V 1.

As proposed by the Yemen authorities, the partial delegation given to France was extended in a subsequent stage to the preparation of the whole draft of the final report.

3 - INVESTIGATIONS

3.1 - HISTORY OF THE FLIGHT

On Wednesday, 17 March 1982 with a slight delay from schedule, the Airbus registrated F.BVGK providing commercial flight AF 125 from Sana'a to Cairo (Paris being its final destination) initiated its take-off roll at 05.10 a.m. U.T. (08.10 local time).

The Sana'a International airport (El Rahaba) has one runway which is 3,250 meters long, with a north-south orientation, at an elevation of 7,237 ft, i.e. 2,205m.

The aircraft was cleared to roll for a take-off to the north. The weather conditions were good. The indicated wind was calm at first, and then 150°/8kt, just before the clearance for take-off. Visibility was good ("daylight" conditions). The operational parameters (resulting from runway characteristics, weather conditions and operating conditions of the day) did not result in any particular limitation and the situation did not call for any remark, until the take-off power was set.

The pilot at the controls was the first officer, seated on the right hand seat. At about 95 kt, an explosion was felt in the cabin. In the cockpit the crew perceived a "shimmy" and vibrations. The captain thought that it was a tyre burst and decided to abort take-off. In fact, the explosion was due to the "uncontained" desintegration of a stage one HPT disk of the RH engine. The number 2 fire warning immediately sounded, as fuel started to leak through the punctures in the wing tank and ignited.

The fire first spread towards the rear part of the aircraft on the right hand side, especially under the line of windows (a long burning torch hung on the engine) ; it was also noted that the APU flamed-out and that the horizontal stabilizer and the tail cone were damaged in some place.

The aircraft came to a stop approx. 1,350 meters from the end of the runway, after a relatively moderate braking, using the thrust reverse (on the LH engine).

The fuel still leaking the fire rapidly developed under the aircraft towards the whole left forward part.

The firemen, who were on the side of the runway during the take-off, reached the aircraft without delay and got the fire under control within a few minutes.

The emergency evacuation was carried out successfully, mainly with the LH rear slide.

3.2 - INJURIES TO PERSONS

Injuries	Crew members	Passengers	Other persons
Fatal	-	-	-
Severe	-	1	-
Slight	1 (*)	-	

(*) suffered during a relatively long time from the inhalation of smoke in the cabin.

3.3 - DAMAGE TO AIRCRAFT

The aircraft was very heavily damaged by the fire, and was rapidly considered as irreparable.

3.4 - OTHER DAMAGE

The runway sustained minor damage : the asphalt was burnt at several places, and many metallic components were spread over the bitumen and stuck into the runway.

The two HP turbine disks were found more than one kilometer away from the runway. One of them had gone through an inhabited house, without injuring anybody.

3.5 - CREW INFORMATION

3.5.1 - Flight crew members

Captain : M. JANIAK Bogdan, born on 6.9.31 at St LUPIEN (Aube)
(France)

Certificates and licences, validity :

- A.T.P.L. n° 1590 dated 12.01.70
- A300 type rating obtained on : 7.03.1979
- other type ratings obtained previously : captain on SE210 and B727, pilot on DC 3, BR 763, DC 4, SE 210
- date of the last medical check-up : november 26, 1981
- date of the last flight check : 24.02.82 (simulator and
28.08.81 (line check)
- instructor's qualification

Flight hours, working and rest times :

- total flight hours : 14.728 hrs
- on type : 1.594 hrs
- during the month preceding that of the accident : 34 hrs
- during the last 30 days : 24 hrs
- during the last 90 days : 142 hrs
- during the previous 12 months : 494 hrs
- 28 hrs of rest before he started his duty
- 10 days of rest in March and 14 days in February
- past medical records : none. No medical restriction
- previous accidents : none

First officer : M. BIGEARD Yves, born on 7.5.48 at l'Isle Jourdain
(Vienne) - France

Certificates and licences :

- A.T.P.L. n° 2501 dated 18.05.80
- A300 type rating obtained on 5.03.82
- other type ratings obtained previously : SE210 and B 727
- date of the last medical check-up : november 5, 1981
- date of the last flight check : Feb. 15 1982 Airbus type
rating after line check on march 5, 1982

Flight hours, working and rest times

- total flight hours : 3.721 hrs
- on type : 68 hrs
- flight hours during the last 30 days : 54 hrs
- during the last 90 days : 68 hrs
- during the previous 12 months : 414 hrs
- 28 hrs of rest before he took his duty, 8 days of rest in
March 1982
- past medical records, no medical restriction
- previous accidents : none

Flight engineer : M. VERGNE Jean-Marie, born on 6.01.46
at Chartier-Herrière (Corrèze) - France

Certificates and licences :

- flight engineer's licence n° 1984 date 22.7.74
- validity of the licence : medical : 9.8.82, technical : 24.9.82
- A300 type rating obtained on april 8, 1980
- other type ratings obtained previously : SE 210

Flight hours, working and rest times :

- total flight hours : 4.304 hrs, including 1.032 on type
- 22 flight hours and 17 days of rest in Feb. 82
- 28 hrs of rest before he took his duty
- past medical records : none, no medical restriction
- previous accidents : none

3.5.2 - Cabin attendants

The minimum number of cabin attendants required on the Airbus for the flight considered (111 passengers) was 4 cabin attendants. This condition was largely met, due to the presence of the following six cabin attendants :

Chief purser : M. OUDART Gaëtan

- CSS (1) obtained on 12.3.59
- last CSS training : 26.8.81
- check out on Airbus on : 11.3.82
- check out on other aircraft : B 707, B 747

Purser : Mrs EMAN Branda

- CSS obtained on 16.7.73
- last CSS training : 18.12.81
- check out on Airbus on 3.2.81
- check out on other aircraft : B 707 and B 747

Purser : Mrs ROVELLI Monique

- CSS obtained on : 20.7.70
- last CSS training : 14.9.81
- check out on Airbus on 4.5.81
- check out on other aircraft : B 707, B 727 and B 747

Steward : M. LOISY Bernard

- CSS obtained on : 16.5.79
- last CSS training : 19.2.82
- check out on Airbus on 24.11.81
- check out on other aircraft : B 707, B 747

(*) CSS : "Certificat de Sécurité Sauvetage"
(flight safety certificate)

Steward : M. PENNE Jean-Christophe

- CSS obtained on : 3.11.81
- last CSS training : 24.4.81
- check out on Airbus on 3.11.81
- check out on other aircraft : B 727, B 747

Steward : M. SALIOU Jean-Jacques

- CSS obtained on : 10.6.80
- last CSS training : 23.2.82
- check out on Airbus on 25.5.81
- check out on other aircraft : B 727, B 747

Furthermore, four additional cabin attendants who were following a training or a check out on the Airbus took also part in this flight :

Hostess : Miss PARIS Brigitte

- CSS obtained on : 21.1.82
- check out on Airbus 3.12.81
- check out on other aircraft : B 707, B 747

Hostess : Miss PRIEUR Joëlle

- CSS obtained on : 3.7.70
- check out on Airbus 30.10.81
- check out on other aircraft : B 727

Steward : M. BIANCONI Jean-Pierre

- CSS obtained on : 2.2.78
- last CSS training : 29.1.82
- check out on other aircraft : B 707, B 747

Hostess : Miss VETILLARD Monique

- CSS obtained on : 23.3.79
- last CSS training : 4.11.81
- check out on other aircraft : B 707, B 747

3.6 - AIRCRAFT INFORMATION

3.6.1 - Airframe

Owned and operated by :

- Compagnie Nationale Air France
1, square Max Hymans - 75015 PARIS - France

Manufactured by :

- Airbus Industrie, 12 bis Avenue Bosquet 75007 PARIS - France

Type : A 300 B4 - 203

S / N : 70

date of the first flight : 22.2.79

date of delivery : 27.4.79

registration : F.BVGK

registration certificate : n° 16323 on 26.4.79

Compagnie Nationale Air France : registration cancelled on
May 7, 82

Airworthiness certificate : n° 31939 dated 19.4.79
validated until april 27, 1982

Total flight hours since manufacturing : 9.053

Total number of take-off : 3.376

Last periodical inspection on march 15, 1982 - V3

type inspection result : good

Previous accidents : none

3.6.2 - Engines

Manufacturer :

- General Electric Company - Cincinnati - Ohio - USA

Type : CF 6 - 50 - C2

	Position 1 (LH)	Position 2 (RH)
Serial number	455,896	455,777
total operating hours	6,318	15,350
total number of cycles	3,212	5,369
operating hours since last inspection	2,637	2,832
number of cycles since last inspection	892	958

Fuel used : A1 jet fuel

3.6.3 : Weight and balance

Fuel on board :	27,200 kg
Freight :	6,225 kg
Passengers :	7,990 kg
MTOW :	132,915 kg
C.G.	24.8 %

3.6.4 - Equipment

The aircraft was equipped in accordance with the French regulation and according to standards at least equivalent to the international standards applicable for public transportation.

3.7 - METEOROLOGICAL INFORMATION

The take-off took place under daylight conditions, the visibility and the other weather conditions were good.

Temperature was 19°C ; QFE : 787 mb, QNH : 1025 mb

The wind announced was calm at first and then 150°/8Kt during alignment i.e. very light RH tail wind during the application of the take-off power.

3.8 - AIDS TO NAVIGATION

Not applicable

3.9 - COMMUNICATIONS

The transcription of the CVR recordings gives the detailed communications exchanged between the flight crew and the air traffic control services (see appendix).

No particular problem or difficulty is to be noted.

3.10 - AERODROME AND GROUND FACILITIES

The main characteristics of the airport facilities have already been mentioned in § 3.1. The safety services were positioned along the runway at the time of take-off.

The fire department is based in a building located at 1.200m from the threshold of runway 36.

The firemen, who heard the explosion and saw the fire starting immediately reacted before being given the order by the tower and without waiting for a request for help from the aircraft.

The first trucks reached the aircraft approx. 15 - 20 seconds after it had stopped.

The fire-crash rescue service has a total of 4 vehicles at its disposal, 3 of them are very modern trucks equipped with foam spraying. According to the firemen's report, the fire was subdued within less than 3 minutes, and completely extinguished within 4 minutes and 40 seconds.

3.11 - FLIGHT RECORDERS

In compliance with French regulations in force, the aircraft was equipped with two recorders - a Sunstrand 573 parameters recorder and a Sunstrand V 557 voice recorder.

The two recorders were removed from the aircraft the day after the accident. From the outside, they did not appear to be damaged by the accident. The YEMEN authorities decided to entrust the work of examining them to the French Bureau Enquêtes-Accidents.

The FDR was read at the Brétigny Flight Test Center and the CVR was read in the facilities of Bureau Enquêtes-Accidents. The readout of the FDR was normal until the moment when the plane reached the speed of 95 kt when accelerating during take-off. Parameters were normal up to this point.

From this point onwards the recorder supplied three seconds of unsynchronized data before restituting data that were 25 hours old and related to the take-off on march 15 at 1610 hours from Roissy-Charles de Gaulle of flight AF 487 for Cairo and Kartoum. The deceleration phase had therefore not been recorded on the FDR.

The CVR was read and the readout is enclosed as an appendix. The conversation in French between the crew members are given in French and are followed by their English translation. Intelligibility of the CVR is not of good quality although it is not bad. It has not been possible to transcribe a number of passages recorded by the cockpit area microphone when the sound level of the words spoken was hardly greater than that of the background noise.

The contents of the CVR that follows the first stop or recording of the FDR at 95 kt has been the subject of a spectral analysis that shows a noise, at the start, that must be the noise caused by disintegration of engine 2 to which is given the time of 0 second followed by :

- o - 0.12 s : noise of disintegration of engine 2
- * 0.25 - 0.62 s : no signal
- 0.75 - 3.25 s : a new signal, the pilot pronounces the words
"accélération-arrêt" ("rejected take-off")
- * 3.37 - 3.62 s : no signal
- 3.75 : the signal is back

The FDR is connected to the 3 XP bus normally fed by alternator 1 while the CVR is connected to the 4 XP that is normally fed by the same alternator when the A/C ESS BUS selector is in the NORM position.

The FDR stopped at 95 kt at the very moment when the CVR was recording a blank. This corresponds to the loss of alternator 1. Because the disintegration of engine n°2 was not recorded on the FDR, it may be assumed that alternator 1 was lost at the same time that engine 2 stopped. The two recorders were then supplied with power from the APU for 2.5 seconds ; this is in fact the recording time of both recorders between the two blanks noted on the CVR tape.

When the APU stopped, the 3 XP bus from which the FDR was fed was no longer carrying power and the FDR therefore finally stopped working at that moment, while the 4 XP emergency bus from which the CVR was fed with power was supplied with standby power from the static inverter and the CVR was thus able to continue working after the FDR stopped.

It may be added that loss of alternator 1 is due to the differential protection 1. The DP 2 would, have in fact caused a standby power supply to be provided by the APU for only 250 milliseconds on buses 3 XP and 4 XP. This conclusion is corroborated by the damage to electric cables seen in the engine n°1 pylon.

(*) This no signal duration is a minimal duration, the actual duration may be slightly longer, but could not be determined precisely with the recorders

3.12 - WRECKAGE

3.12.1 - Main wreckage

The aircraft, at the end of its acceleration-stop stopped about 1,900m from the runway threshold (1,350 from the end).

The investigation of the main wreckage led to a detailed report made by the "structures/Airframe group".

The following summary can be recorded :

The aircraft was severely damaged by fire, and the most affected zones were : the whole lower lobe of the fuselage below the line of windows, the zone of the right-hand wing between the engine and the fuselage, the RH main landing gear wheel well and the RH main landing gear itself, the LH forward zone up to and including the cockpit, with repercussions on frames and stringers, which began to melt.

The RH main landing gear wheel well was severely damaged and several wires located inside were destroyed. The cabin floor was attacked as far it presented then abnormal flexibility, detectable in the cabin.

Secondary damage subsequent to the ejection of many parts during the uncontained disintegration was noticed on the wing, the moving surfaces of the flight controls, the engine pylons, the horizontal stabilizer and, less severely, the fin and one wheel of the LH main landing gear.

The report of the "Powerplant group" describes the damage on the right hand engine and the turbine disks in detail. The distribution of the metallic parts projected during the uncontained disintegration is given in appendix.

The most probable sequence of the various events which followed the explosion is the following : explosion of one tyre of the LH landing gear (point + 850 m), beginning of the melting process which affected some metallic parts of the fuselage due to fire (at aprox. + 1,200 m), loss of the RH anti-skid systeme, associated with the destruction of cable bundles by fire, and/or ejections of various parts, subsequent explosion of the tyres of the RH landing gear and, after stop, rapid progression of fire towards the forward part of the aircraft (and particularly on the LH side).

3.13 - MEDICAL AND PATHOLOGICAL INFORMATION

Not applicable.

No medical investigation was justified.

3.14 - FIRE

(Quotations taken from the firemen's intervention report)

The fire/crash rescue-Department had the following equipment at their disposal :

- 2 "Patroller" vehicles (capacity of 10,000 l ; foam/water) operated by a team of 3 persons.
- 1 "Pathfinder" vehicle (capacity of 13,000 l ; foam/water) operated by a team of 4 persons.
- 1 dry chemical truck (capacity : 2,000 kg) operated by a team of 3 persons.
- 1 command car with an officer assisted by 3 persons.

(Note : the first 3 trucks are very modern and equipped with foam guns).

The actions achieved consisted of applying a large quantity of foam and water to the fuselage by means of fire hose nozzles and foam guns in order to protect the passengers, who were evacuating. Simultaneously, rescue teams entered into the aircraft (by ladders placed in the vicinity of some doors) in order to facilitate the evacuation.

The firemen's report mentions the following figures :

- duration of the evacuation : 2 minutes 15 seconds
- fire under control after 2 minutes 45 seconds
- fire completely extinguished after 4 minutes 40 seconds
- 2,000 kg of powder consumed
- 28,860 l of water ("AFFF light water") consumed.

3.15 - SURVIVAL ASPECTS

As it has already been said before, the first teams of the fire/crash rescue department arrived on the spot 15 to 20 seconds after the aircraft had stopped on the runway. This action, rapid and efficient has been decisive for the success of the emergency evacuation. The firemen carried out actions both to subdue the fire and to facilitate the evacuation (ladders were placed at some doors) and to help passengers.

According to several passengers' statements, the fire was practically extinguished at the end of the evacuation. The firemen's intervention report evaluated the duration of this evacuation at 2 minutes and 15 seconds. It was during a premature evacuation, carried out with a hand baggage and against the will of the cabin attendant responsible for safety in the zone concerned that one passenger and only one, was seriously injured.

The fire did not penetrate the cabin, and the absence of toxic gases emission was also a favourable factor. However, this evacuation was hindered by some other factors :

- penetration into the cabin of a heavy black smoke as soon as doors were opened (particularly the forward RH door), which reduced visibility (less than one meter at some places), and made the coordination of the actions conducted by crew members more complicated (the megaphones were used only at the end of the evacuation).
- destruction of a few slides after their inflation, due to either a direct contact with fire (1 RH) or a contact with zones of the aircraft skin which had reached very high temperatures (4 RH).
- no functioning of one slide (3 LH). Furthermore, the slide of the LH n°2 door, which was opened after the end of the evacuation, did not inflate.
- temporary impossibility of opening 2 doors (mechanically blocked possibly due to deformations caused by the temperatures reached). These doors operated normally after a sufficient

cooling time, after the evacuation.

- confusion, due to misunderstanding, of some addresses with evacuation orders (preparation/accomplishment).

The captain made address by means of the "public address", (the EVAC signal was not used, but this fact does not seem to have delayed the evacuation).

The evacuation, which was oriented to the forward part of the cabin in a first step was then oriented to the rear part, due to the fire development at the front of the aircraft. The progression of fire outside was appreciated differently by the crew members, depending on whether they were at the front or at the rear of the aircraft : as this external situation evolved, it was not possible to get a global appreciation.

- the evacuation of almost all the passengers through the LH aft door was carried out in slightly more than 2 minutes. The other passengers were evacuated through the front RH n°1 door by means of a ladder placed by the firemen.

3.16 - TESTS AND RESEARCH

3.16.1 - Power plants investigations

3.16.1.1 - Introduction

The engine in position 2 (series n° 455.777) which had, at the time of the accident, 20,580/6,911 hours/cycles since manufacture and 2,832/958 hours/cycles since the last workshop inspection, have been subject to an uncontained disintegration of a high-pressure turbine. A seven dovetail post section of stage 1 HPT rotor disk rim was found in the left wing, inside the fairing of the track beam of flap n° 3. The remainder of disc n° 1 and the whole disc n° 2 was found outside the airport perimeter by the YEMEN authorities ; the disks were found at a distance between 1,100 to 1,300 meters east of the runway.

With regard to the engine in position 1 (series n°455.896) internal damages was observed that necessitated complete dissassembly.

3.16.1.2 - ESN 455.777 (n°2 position) investigation

The failure sequence of this engine, based upon the physical evidence, indicated that the failure event was initiated by separation of a stage 1 HPT disk rim segment spanning a length of seven dovetail posts. All other damage was secondary following this initiating event.

All fractures examined during the engine teardown investigation at Orly were secondary damage, no evidence of fatigue was found.

The primary failure event including the separation of both stage 1 and 2 HPT disk from the engine occurred within a time span of a few milliseconds.

No other anomalies were found within the engine which were contributory to the failure.

Factual observations of the engine damage showed significant similarities to previous stage 1 HPT disk separation events (ref. § 4.1.2).

Exclusive of the stage 1 HPT disk deposits, all deposits found on the exposed surfaces of the components and broken fragments of the engine during teardown investigation which were analyzed were found to be normal engine dust accumulation representative of operation in dusty or sandy environment or metallic and other debris which resulted from the primary failure event or exposure to the environment after liberation from the engine.

3.16.1.3 - ESN 455.777 stage 1 HPT disk fractography,
material/dimensional inspection,
analysis of disk deposits

This disk was serial n° (S/N) MPOA0489, Part n° (P/N) 9045M34P07.

Separation of a disk rim segment spanning a length of seven dovetail posts resulted from initiation and propagation to critical crack size of a low cycle fatigue crack (one load cycle per flight) in the aft inner radius of disk embossment n°7.

The results of fractography in combination with the propagation analysis on the fracture surface of disk embossment n°7 (the failure origin) estimated the time from crack initiation to disk rim separation to be 3,700 flight cycles (considering that one load cycle generates one striation when propagation is in the transgranular mode).

Similar low cycle fatigue cracks were noted propagating in the the aft inner radii of several other disk embossments of the same disk.

These cracks initiated and propagated first in a predominantly transgranular fracture mode. The deeper cracks changed to an intergranular propagation mode.

No fatigue cracks were noted in the disk other than at the aft embossment radii.

All fatigue cracks originated at the surface of the aft inner radius of the embossments.

The analytic transgranular crack propagation rate, using average material properties data, correlated well with the propagation rates determined from fractographic examination of cracked embossments.

Note : Fractographic examination were performed on embossment n°40 by both the Centre d'Essais des Propulseurs (CEPr) à Saclay (France) and the General Electric Company laboratories.

Minor differences in total cycle counts were found between these two laboratories when the fracture was examined using the Scanning Electron Microscope (SEM).

However, analysis made by the Transmission Electron Microscope indicated that more cycles may have been present within the transgranular region than was indicated in the SEM analysis.

Because the SEM analysis is more conservative, in the direction of increasing safety margin, and since the major portion of the fractographic analysis was performed using the SEM technique, the SEM results were used in formulating the conclusions presented in this report.

The stage 1 disk material properties were examined in accordance with the workscope. All material properties were within specification.

The stage 1 disk was dimensionally inspected in accordance with the workscope requirements. All dimensions were within blueprint tolerance limits.

Chemical analysis of debris found on the stage 1 disk, exclusive of the "adherent debris" on embossment fracture surfaces, indicated an accumulation of normal engine dust representative of operation in dusty or sandy environment.

In addition, secondary debris deposits, particularly in the forward disk rim embossment pockets, resulted from the separation of the disk from the engine and travel across the airport surface.

o

o

o

As distinctly different from the other foreign material deposits on the disk, there were local regions of adherent material on the surfaces of some of the exposed embossment fractures as well as on fracture surfaces of some cracks which had not progressed to separation breaks. These "adherent debris" regions on the fracture surfaces had two physical characteristics.

First, the regions strongly charged and glowed under the electron beam in the SEM. Secondly, these regions gave the appearance of debris having flowed into the fracture crevices and interstices and forming a partially fused or sintered mass on the fracture surface.

The adherent debris on the fracture surfaces was importantly involved in determination of the crack depth present at the time of the last disk inspection.

The crack which ultimately led to failure of the disk, and several of the larger cracks present in the disk at the time of failure, were present and of a size approximately 2.5 mm deep at the time of the last disk inspection.

Using the analytic intergranular crack propagation curve for the stage 1 disk and the measured dimension of the portion of crack depth corresponding to the region of adherent debris from the fracture surfaces of 12 cracked embossments, the analytical-ly predicted number of cycles since last inspection was 1,013. By comparison, the actual number of flight cycles was 958.

Micro-chemical analysis was conducted on the adherent debris deposits found on the crack surface of embossment n° 40 and the primary separation fracture surface of the disk, embossment n°7.

The presence of the aluminum-phosphorous particles only in the adherent debris regions of cracks n°7 and 40, and the absence of these particles in samples of engine dust and debris from the disk, suggests that they are the result of penetrant in these cracks.

°

°

°

Combining the results of the fractography, propagation analysis and microchemical analysis, the following summary can be made :

Estimated crack initiation to separation time at embossment n°7 (failure origin) was 3700 flight cycles. The last shop visit was 958 cycles previous.

Propagation analysis establishes a positive correlation between the crack depth region containing the adherent debris and the number of cycles since the last shop visit.

Adherent debris which were found in the cracks existing at the time of the last shop visit did not continue to flow as the cracks subsequently progressed in depth. The adherent debris appeared to give an image of the cracks dimensions at the time of the last shop visit.

Cracks which initiated subsequent to the time of the last shop visit show evidence of debris which were not adherent.

The chemistry and morphology of the adherent debris showed differences from the loose debris or engine dust.

Therefore, something was added to engine dust in the cracks existing at the time of the last shop visit to make it adherent. Tests indicate that was fluorescent penetrant inspection (FPI) fluid.

In this connection it is pertinent to note that the stage 1 HPT disk from engine position n°1 had aft embossment cracks, and these cracks contained loose debris or engine dust. The debris was not adherent, indicating that these (somewhat smaller) cracks had formed subsequent to the last disk inspection with FPI penetrant.

3.16.1.4 - Engine S/N 455.896 n° 1 position

The question was raised by the investigating authorities as to whether the n°1 engine would have been capable of producing take off thrust in the event the failure of n° 2 engine had occurred above V1 speed where the pilot was committed to continue the take off. The question presumes that the foreign object damage (FOD) sustained by n°1 engine was the direct result of the n°2 engine failure. The primary emphasis of the teardown investigation of the n°1 engine and analysis of other operational data was directed to this point.

Documentation of the damage to ESN 455.896 and analysis of the soot deposits found in the engine was also conducted.

The results of the investigation clearly indicate that the significant FOD sustained by the n°1 engine occurred near the end of the take off abort sequence, either in reverse or forward thrust, but at low engine power. Findings supportive of this result are summarized below.

- Engine n°1 FOD did not result from impact damage to the inboard side of the nacelle which was sustained at the time of the n°2 engine failure. Fragments liberated from n°2 engine at the time of failure did rebound from the runway and impact/penetrate regions of the inboard nacelle, pylon and the n°3 flap track flairing. However, no fragments entered the n°1 engine at this time which would have been of sufficient size to produce the internal high pressure (HP) compressor damage noted.

- There was extensive FOD in the aft stages of the HPC ; the damage was of such extent that the engine could not have been normally accelerated to or run at high power without a compressor stall. This conclusion is substantiated by damage experience during service operations with the CF6 compressor.

- Engine n°1 operated normally at take off power for several seconds after the n°2 engine failure, responded normally to the "interrupted deceleration-acceleration" transient of the rejected take-off sequence, and sustained high power reverse thrust down to low forward aircraft speed. This finding is supported by the fact that the flight crew did not report any malfunction or anomalies in n°1 engine operation and by the absence of high power engine stall indications in the HP compressor or turbine hardware.

- Evidence of the foreign material ingestion was found in the fan inlet and subsequently in the internal HP compressor and compressor rear frame casing areas of the engine.

A bolt head fragment found in the fan inlet area was identified as the stage one nozzle inner support fastener from the high pressure turbine area. This fragment must have originated from the n°2 engine, probably in the latter stages of the abort sequence while the n°1 engine was operating in the reverse thrust mode.

The source of the foreign elements found internally in the n° 1 engine (other than soot) was not identified.

- The sooting and apparent fire extinguishing agent ingestion occurred at low engine power operating conditions as evidenced by contamination of internal piping which flows only at idle or near idle conditions.

The soot ingestion occurred either after the FOD event or continued after the FOD event as evidenced by soot contamination of FOD surfaces on the HP compressor airfoils.

°

°

°

Based upon the foregoing evidence, all of the indications support the finding that n° 1 engine was capable of producing take-off power without time limitations had the n° 2 engine failure event occurred at or above V1 speed.

3.16.2 - TEST BED TRIALS - DISASSEMBLY AND INSPECTION OF APU P 80-154

3.16.2.1 - Summary

In addition to a visual inspection conducted in the Air France workshops at Orly, at the request of the investigators, a trial on a test bed was conducted on 26 May 1982 followed by complete disassembly at the Alitalia maintenance workshops in Rome (the accredited repair shop of the Atlas group) on 27 and 28 May 1982. Before proceeding with the trial, the FIM and the ECB were examined and found to be in good condition.

3.16.2.2 - Alitalia inspection before test

Because of the large quantities of black deposit (a mixture of oil and dust) in the cooling air ducts, a special inspection was carried out. The cooling air inlet system was found to be 40% clogged.

No cleaning was done before the test run.

3.16.2.3 - Test Bed trial

APU : P/N	380 944-1	total hours	8,689 H
	S/N P80-154	since overhaul	1,957 H
		hour counter	562 H

During the test that lasted one hour with an OAT of 23°C. all the data registered were in the usual running range.

3.16.2.4 - Observations after disassembly

The disassembly of the APU which followed the test bed trial confirmed that there was considerable clogging of the cooling air in the air inlet ducts.

Compressor section : a dark thick deposit was found on all stages of both rotor and stator vanes probably due to flames drawn into the inlet section.

Internal air passages exhibited unusually high ingestion of sand.

The abradable shrouds of the compressor section show normal wear for the number of running hours.

Turbine section : the high-pressure turbine rotor disks are in excellent condition as are the rotors and blades of the low-pressure stages.

3.16.2.5 - Conclusions

As indicated by the entirely satisfactory results on the test bed, no defect was found that could explain the auto-shutdown of the APU.

Examination of the test bed results showed that any marginal operation of the APU under varying load conditions could not have caused the automatic shutdown of the APU at SANA'A for there existed a sufficiently large temperature margin to ensure undoubtedly the correct operation of the APU.

Moreover hot gases ingestion into the air inlet circuits was confirmed. First effects of this ingestion are a temporary decrease of the turbine and generator speeds.

Finally, it must be noted that a drop of about 10% of the 400Hz frequency current causes an instantaneous cut-off and that such a drop of frequency occurs as soon as the rotation speed of the APU drops to about 10%.

The shutdown trials carried out during the APU certification have shown that a speed decrease of approximately 10 % is observed within two seconds when fuel is cut-off.

The general opinion is that ingestion of hot gases has a similar effect to cutting off fuel.

The 400 Hz power supply from the APU lasted 2.7 seconds after the failure of the n°2 engine with a very short interruption during this period, which is fully compatible with the above observations.

The final conclusion of the expertise is that the APU shutdown was due to the ingestion of hot gases after the failure of n°2 engine, causing air starvation, that resulted in a drop of RPM, leading to automatic cutoff of the 400 Hz current.

3.16.3 - EXAMINATION OF TYRES AND WHEELS3.16.3.1 - Information on the tyres of the
main landing gears (MLG)

Positions :



1 □ 2 3 □ 4
5 □ 6 7 □ 8

Left MLG

Right MLG

Two makes of tyre are used on the MLG

GOOD YEAR and DUNLOP :

model 49 x 17 - 32 PR 225 MPH 36 skid

Pos.	Mark	P/N	S/N	Number of retreads	Number of landings	
					since new	since last retread
1	GY	V 2446	118 NJ 0104	1	278	172
2	GY	V 2446	117 NJ 0085	1	310	172
3	GY	V 2241	B27 NJ 0036	8	1233	121
4	GY	V 2441	B25 NJ 0301	6	756	88
5	GY	V 2446	118 NJ 0208	1	412	172
6	DU	V 2221	340 10950	1	341	154
7	GY	V 2442	B50 NJ 0311	5	1007	144
8	DU	V 2221	339 23905	3	489	154

3.16.3.2 - Company operating inspection procedures
regarding pressure and cuts on MLG tyres

34.

Inflation pressure :

- 13.4 bars to 12.8 bars : normal pressure
- 12.8 bars to 12.2 bars : admissible daily loss,
reinflate to 13.4 bars
- 12.2 bars to 11.6 bars : reinflate to 13.4 bars, note on the
mechanical log book and replace wheel
the next day if pressure loss is the
same
- 11.6 bars to 10.4 bars : replace wheel
- 10.4 bars to 0 bars : replace wheel and companion wheel

Cuts in tyres :

Maximum permissible depth of cut : 12 mm from bottom of the
nearest groove or 8 mm from the surface, if the groove
has disappeared

Length : no limit if the depth is not below bottom of groove ;
replace wheel when length is greater than 25 mm and
depth is below bottom of groove.

3.16.3.3 - Information supplied by mechanical log book

On the mechanical log book, dated 13.3.82 to 16.3.82, no loss of
tyre pressure was noted ; on 14.3.82, a cut on tyre n° 1, within
limits was noted.

3.16.3.4 - Result of examination

Out of 8 tyres fitted on the two MLG, only the carcasses of tyres at positions 2, 3, 4, 6, 7 and 8 were brought back to France and examined. The debris separated from those carcasses were left at SANA'A along with tyres 1 and 5 that are still on the wreckage. It is noteworthy that after the accident, tyre number 1 was deflated and number 5 was not.

Left M.L.G.

The tyres at positions 2 and 6, left MLG, have less damage than those on the right MLG.

Position 2 : the tyre remains entire. Its outside appearance is correct. It is regularly worn and it remains a tread depth of 2 mm. There are a number of shallow cuts on a sidewall. A cross-through cut of 70 mm long is noted on the tread and caused by a piece of turbine blade.

Position 6 : the 3/4 of tread is separated. The tyre has burst, two pieces of carcass about 800 x 650 mm and 650 x 530 mm are missing and left in SANA'A. there are several shallow cuts in a sidewall.

Right M.L.G. : Tyres and wheels

Tyres

The 4 tyres of the right MLG are all damaged in a similar mode.

Position 3 : the tyre is burnt on the outside, there is an X-shaped burst on a flat worn spot in the tread crossing through out all plies and, at the same level, there is a flat worn spot on a sidewall that extends up to the plies turnup. A large piece of carcass, about 500 x 370 mm, is missing. A non cross-through cut, about 14 mm long, is noted on the sidewall opposite the serial number. Wear is regular and it remains a tread depth of 4 mm.

Position 4 : the tyre is burnt on the outside, there is an X-shaped burst on a flat worn spot in the tread crossing throughout all plies and, at the same level, a flat worn spot on a sidewall. Several non cross-through cuts, 23, 16 and 12mm long, are noted on the tread and on both sidewall. Wear is regular and it remains a tread depth of 5 mm.

Position 7 : the tyre is burnt on the outside, there is an X-shaped burst on a flat worn spot in the tread crossing throughout all plies and, at the same level, a flat worn spot on the sidewall that extends up to the bead heel. The bead is worn down on a length exceeding 360 mm. No cut is noted. Wear is regular and it remains a tread depth of 3 mm.

Position 8 : the tyre is burnt on the outside, there is an X-shaped burst on a flat spot worn on the tread crossing throughout all plies and, at the same level, a flat worn spot on the sidewall that extends up to the bead heel ; the bead is worn down on a length exceeding 430 mm. No cut is noted. Wear is regular and it remains a tread depth of 3 mm.

Wheels

Made by Hispano-Messier, P/N 2890.2.10.32

Position	S/N	Number of landings since new
3	1050	1,657
4	1120	549
7	1150	217
8	1067	1,334

Each of those 4 wheels has a flat worn area on the rim flange caused by scraping on the runway.

3.16.3.5 - Conclusions

The similarity of the damage noted on the 4 tyres of the right MLG, in particular flat spots worn at the same level, shows that the damage is due to brakes locking on this MLG while tyres were still inflated.

From the study of the tyres marks on the runway, the brakes-locking apparently occurred first on the inner wheel or wheels of the right MLG a little before 1400 meters and then on the outer wheel or wheels of this MLG at about 1450 meters. The bursting of the inner tyre or tyres occurred towards 1550 meters followed, a few tens of meters later, by the bursting of the outer tyre or tyres.

It is noteworthy that, after the accident, investigators found a bundle of electric wires in the right wing root including the anti-skid wires which had been destroyed by fire. The non-operation of the anti-skid systems on the right MLG is very probably due to the short circuiting of electric wires and led to brakes locking.

The experts believe that the damage that was caused to the right MLG tyres is consequential to non-operation of the anti-skid and to cuts provided from foreign objects off the right-hand engine. Brakes-locking and tyres destruction led the wheels rim flange to rub down against the runway.

The MLG tyres, positions 2 and 6, were deflated by cuts provided from debris of the same engine.

It appears that none of the damage observed on the tyres and the wheels results from any malfunction prior to the accident.

3.16.4 - STUDIES CONCERNING FIRE RESISTANCE AND WHITE SMOKE ORIGIN

3.16.4.1 - Introduction

The various parts, brought back from SANA'A to FRANCE (see list in appendix) in order to determine the origin of the observed white smokes and to verify the fire resistance capability of some cabin and cargo compartment materials, have been the subject of necessary tests, either in the laboratories of the CEPr at Saclay, or in the central laboratory of Aerospatiale at Suresnes ; their results are summarized below.

3.16.4.2 - Deck and walls elements fire resistance

It has to be recalled that the wheel well area is not classified as "fireproof" area, therefore, the fire resistance criteria was not to be taken into account in the certification requirements of the Airbus A 300 for the elements of this area.

So, the test of flame penetration have been performed on these panels as indication test, in order to determine the effective resistance in case of fire, particularly in the wheel well area.

Various tests of fire effect and resistance have been made on structural sandwich elements brought back from SANA'A to verify the resistance of the floor panels, and also on various new sample panels to determine their fire behaviour and resistance.

The tests have been performed in accordance with the Airbus Industrie specification ATS 1000 applied since 1979. By the time of the A 300 certification, the FAR 25 par.853a were the only ones in effect. The french regulations require, besides the FAR specifications, some tests related to smoke emission and chemical toxicity analysis.

Concerning the fire resistance, the cabin floor panel of the damaged aircraft and the new sample panels of the same type have similar characteristics and comply entirely with the FAR 25 requirements for elements located in "non fireproof" area, which is the case of the parts studied, and more severe conditions of Airbus Industrie ATS 1000 specification.

Toxicity measures have been performed on the smokes emitted ; these panels satisfy the requirements in this field too;

3.16.4.3 - Origin of the white smokes

In order to determine the origin of the white smokes observed in cabin, samples of white deposits covering some elements of the air conditioning system have been taken off in three places on the extraction circuit of the front bay.

After magnifying glass examination, various spectrographic, radiocrystallographic analysis and infra-red spectrometry were performed.

All the deposits examined are the results of "in-situ" degradation. They are produced by the thermic degradation of fiberglass gluing and impregnating products of the sleeve, and also of the silicone elastomer used to protect clamp collars.

Taking into account the previous experience we must admit that a large majority of synthetic and composite materials, when heated, release, during first step, white smokes (or fumes), first indication of the pyrolyse of this materials.

3.16.4.4 - Smokes path

To explain the penetration in cabin of the white smokes, study of the ventilation conditions of the cabin during an aborted take off for an Air France Airbus is needed.

During take off, the two air conditionning systems being closed, the air circulation is as follows :

- feeding of outer fresh air closed,
- doors closed,
- inner circulation ensured by forced air through two ventilators
output flow : approximately 1 m³/S per ventilator ; from which 550 l/s are taken off from the toilets and the galleys, the rest from the cockpit and the electronic compartment, and cargo compartments environment.

- During the aircraft acceleration

The auxiliary valve, allowing the introduction of outer air, located in an embossment under the fuselage forward of the air conditionning systems, forward of the wheel well, is closed (external air does not enter).

The four discharge valves are generally closed (in view to facilitate a slight pressurization).

The safety valve for differential pressure and recirculation is opened : air aspired by the ventilators come back into the cabin through the vents normally used for air extraction, located near the walls at the floor level.

- During the end of a normal deceleration

The auxiliary valve opens (flow of approximately 2 m³/s).

The four discharge valves open (1 m³/s to the front, 1 m³/s to the rear).

The safety valve remains closed.

- During the deceleration at SANA'A, the ventilators have been stopped as a result of the total loss of electric power supply (a few seconds after the failure of engine n°2), and the four discharge valves are shut mechanically.

As a conclusion, as long as the fans were running white smoke being in the cargo compartments penetrated into the cabin through the vents normally used for air extraction. The white smokes, observed by the hostess in station 3 left and some other people, have effectively seemed to emanate from extraction vents. It was the outbreak of the products of the pyrolysis of materials located around the right wheel well.

When the aircraft stopped and doors were opened black smokes coming from the outside of the airplane entered the cabin through the doors and possibly through the air conditioning circuit.

3.17 - ADDITIONAL INFORMATION - TURBINE DISK FPI SURVEY

3.17.1 - Following the discovery in laboratories of numerous cracks on the accidented disk, some doubts appeared as to the efficiency of the last FPI performed.

The Bureau Enquêtes-Accidents and interested French Authorities representatives (SFACT, STPA and Bureau Veritas), together have conducted a large survey of procedures used in european ATLAS and KSSU shops performing FPI on CF6-50 1st stage turbine disks.

BEA members had previously the opportunity to observe such an operation in GE facilities at Cincinnati.

Visits took place in facilities of Air France at Orly, Sochata-Snecma at Billancourt, KLM at Amsterdam, Lufthansa at Hambourg and, also of MTU at Munich, which controls only new disks, and never detected any crack.

3.17.2 - In relation with shops controlling disks in use, the observations made may be summarized as follow.

- the detailed procedure of control defined especially for this disk by GE seems to be correctly followed. Furthermore this manufacturer makes regular audits in the different shops, this audits never showed any significant deviation in the performance of the procedure.

- few minor variations in the practical execution of the process were noted, but can't affect notably the quality of the inspections performed.

- it is evident that effectiveness of the procedure depends mainly on the proficiency and ability of the operator and, also the quality of cleaning of the parts to be inspected.

3.17.3 - After the first disk ruptures, GE started advanced studies concerning the various processes to be used in crack detection (Eddy currents, ultrasonics). It has been established that for Inconel 718 part, with non finished surfaces and complicated geometry, the FPI gives the best results, without, of course, being able to offer total guaranty.

3.17.4 - Following the SANA'A accident, the FPI procedure defined by GE has not been modified in itself.

However, it has been decided to prescribe double inspection, each one being totally independant from the other ; by doing so, the influence of human error was greatly reduced and, at the same time, the quality of surface cleaning was improved.

In other respects, the acceptance criteria in pin points interpretation has been changed in a conservative manner ; this, in conjunction with availability of the new design disks has led to increase in the number of old disks rejected since the new directives have been enforced.

4 - ANALYSIS

4.1 - ORIGIN OF THE ACCIDENT

4.1.1 - Origin

The investigation clearly showed that the origin of the accident was the fracture of the stage one HPT disk of the RH engine of the aircraft.

A seven dovetail post segment of the stage one HPT disk rim was separated due to the progression of a low cycle fatigue crack (one striation per engine cycle) caused by a stress concentration and initiating in the aft inner radius of one of the disk embossments.

The very severe dynamic unbalance caused by the separation of this part led to the fracture of the shaft after approx. half a revolution (within a few 1/1000 of a second), which liberated the two HPT disks.

These disks went through the casing and rebounded on the asphalt on the right hand side of the aircraft ; they were recovered approx. 1.5 km from the runway.

The portion which initially separated, as well as various parts of blades also rebounded on the runway and punctured different parts of the aircraft, which immediately caused severe damage : in particular a significant fuel leak which immediately burnt and the failure of the electrical power supply given by the LH engine.

These events were first perceived as an explosion by the crew, who initially thought that it was a tyre burst.

4.1.2 - Background

Stage one HPT disk fractures had previously occurred on CF6-50 engines.

- On June 9, 80, on a DC-10 of Philippine Airlines, shortly after take-off from Bahrain, engine S/N 517.173 was shut down in emergency. After a successful landing, the factual inspection showed that an eight dovetail post segment of the stage one HP turbine disk rim was missing. It had left a hole in the casing of about 65 x 23 cm.

This portion was never recovered, but the disk (MTU 0009), which had 4,941 cycles and 18,295 hours, was examined by G.E. who attributed this fracture to a fatigue crack propagation.

Before this accident, G.E. has observed cracks on two HPT disks subjected to factory endurance tests : for the first one, after 15,050 cycles, the crack origin was attributed to a tool mark induced during manufacture, for the second, after 10,096 cycles, the crack was due to a production defect.

After the accident of 1980, during the systematic inspection of the disks, G.E. reported 6 cases of cracked disks, 5 for the MTU production, and 1 for the G.E. production.

- On July 3, 81, on an Airbus A300 of Thai Airways International, during take-off roll on the Hong Kong runway, at approx. 120 kt (before V1), engine S/N 455 161 breached in its diameter due to the separation of two HP disks (MTU production) which rolled into the sea. The initiated fire was extinguished with the engine extinguishers. The aircraft stopped and taxied to the runway threshold by itself.

In spite of very long investigations, it was not possible to find these two disks.

4.1.3 - Investigations

The disk which failed at SANA'A was a G.E. (MPO) production, and had reached 6,911 cycles and 20,580 hours since new when the accident occurred. It had reached 958 cycles and 2,837 hours since its last inspection by AF. This inspection took place on February 19.81 according to the procedures defined by G.E. and in accordance with the ADs issued by the FAA after the accident of June 1980.

The very complete investigation to which this disk was subjected, in particular the investigation of all the cracks detected and the deposits observed, in the G.E. laboratories in the United States under the control of NTSB and BEA representatives and partially duplicated by the CEPr laboratories of Saclay in France, showed that the crack which was at the origin of the fracture (at embossment n°7) had approx. 3,700 cycles.

Consequently, this crack already existed at the time of the last shop visit at Air France, It was concluded that at that time it was already open, and approx. 2.5 mm deep.

These investigations, as well as those which were also done by G.E. on other disks on which cracks had been found during inspections after the SANA'A accident, enabled the crack initiation and propagation process proposed by General Electric to be confirmed and conservative measures to be determined, in order to keep the engines in service until all current design disks were replaced by new configuration disks, with much greater embossment radii in sensitive zones, so as to reduce the surface stresses very significantly.

As the crack which was at the origin of the accident had not been detected during airline inspection, the BEA carried out a detailed examination of the fluorescent penetrant inspection procedure both at Air France and in the other airlines shops of the Atlas group, as well as at the SNECMA and MTU.

In all these shops, the inspection process defined seemed to be correctly applied. It had never been intrinsically modified. G.E. carries out regular "audits" and has never questioned the agreements given.

4.1.4 - Corrective measures

Following the first accident (june 9, 1980), the FAA issued AD 80-16-51 on july 18, 1980, requiring stage one HPT disks manufactured by MTU, which had more than 3,500 cycles, to be subjected to an additional fluorescent penetrant inspection which had to be repeated every 2,500 cycles of operation up to the approved limit of 8000.

- On February 18, 1981, a new AD, 81-05-51, extended the mandatory inspection to the MPO disks (G.E. production) which had reached more than 5,400 cycles.

Following studies done by G.E. on disks on which cracks had been found during inspections, the FAA issued a third AD in February 82, which made these inspections compulsory for the MTU disks after 2,500 cycles, and then every 1,500 additional cycles, and for the MPO disks after 4,000 cycles, and then every 1,500 additional cycles.

After the SANA'A accident, a 4th telex A.D. on april 9th, 1982 prescribed new measures, mainly :

- compulsory duplication of fluorescent penetrant inspections (two independant sequential inspections)

- reduction of the authorized numbers of cycles progressively from April to October 1982 from 1,500 to 750 cycles for the MTU disks which had more than 2,000 cycles and for the MPO disks which had more than 3,200 cycles.

- re-installation of the present disks prohibited after Feb. 1st, 1984, and replacement by a disk of a new design.

No principle modification to the inspection process defined by G.E. has been made. However, it appears that the workshops responsible for the inspections have become more severe in the appreciation of the detected defects, and in particular they almost systematically reject the disks which show only pin points (which in principle are not similar to a crack).

Furthermore, G.E. re-opened detailed researches on other inspection processes (eddy current, ultra sonics). It proved that it was particularly difficult to apply such methods to parts with a complex geometry (e.g. disks), and that the fluorescent penetrant inspection process presented the best reliability.

4.1.5 - Conclusions

The F.A.A. noted during an industrial meeting (after various investigations) definition of the inspection intervals elaborated within continuing airworthiness purpose was not sufficient to guarantee operation safety as based on an inappropriate concept : the probability of detecting a crack of a given size.

In fact, it is necessary to consider both the importance of the human factor in the periodical inspection process used, and the probability (which is not evaluated) of severe damage due to the dispersion of debris in the event of a disk fracture. Consequently, the reference basis should be the risk probability of non-detection of a crack, likely to lead to the fracture with the number of cycles authorized between inspections.

Finally, due to the extreme difficulty to practically protect aircraft against damage, it seems necessary to take better preventive actions against the risk of a fractured disk by conducting systematically in the future real fatigue tests of disks within the framework of the engines certification.

4.2 - SECONDARY DAMAGE

4.2.1 - Mechanical damage

The metallic debris projected by the RH engine after the fracture of the shaft (many of which rebounded on the runway) caused the following damage :

- four significant punctures in the main tank of the RH wing, resulting in a large fuel leak which burnt immediately.
- the wing was damaged in several places : minor damage to the leading edge slats, more severe damage to the trailing edge near the root, more particularly at the inboard flap, which was later on severely damaged by fire.
- the fuselage was punctured in various places of the pressurized zone (even in the cushion of a cabin seat) without causing injuries to the passengers.
- at least one tyre was punctured (LH landing gear).
- punctures in the LH engine nacelle without penetration of the inlet duct. The portion of the turbine disk rim penetrated the pylon and several electrical cables were severed, which resulted in an electrical power supply failure (engine n°2). This portion subsequently lodged in the n°3 flap track fixed fairing of the LH wing.
- some impacts without repercussions on the fin.

4.2.2 - Fire damage

The fire which immediately started on the right hand wing first resulted in the APU rapid shut-down (after about 6 seconds) due to a lack of oxygen, which caused the DFDR to stop since all the electrical power supplies other than the batteries had disappeared.

This fire then affected various zones of the aircraft, and as soon as the aircraft stopped, the whole lower lobe, owing to the fuel leak.

The damage can be summarized as follows :

- damage to the RH inboard flap and guide tracks
- severe damage to the RH landing gear wheel well ; destruction of the spoiler controls and the RH landing gear anti-skid system which became inoperative.
- severe damage to the RH landing gear wheel well panels with damage to the lower part of the cabin floor.
- melting of the fuselage skin in several zones (which resulted in temporary blocking of doors), particularly in the LH forward zone, where frames and stringers started to melt (the pilot's windshield became opaque). The lower surface of the horizontal stabilizer burnt ; penetration of white and subsequently black smoke.

It must be noted that the most severe fire damage occurred after the aircraft had come to a stop on the runway, due to the accumulation of fuel under the aircraft.

It can also be said that the slight tail wind which was blowing at this time, the use of the thrust reverse (at least in the ultimate phase) and the fire fighting started on the RH rear part of the aircraft may have facilitated the propagation of fire towards the LH forward part by the bottom of the aircraft.

4.2.3 - Conclusions

The secondary mechanical damage was not only due to direct impacts but also to many parts which had rebounded on the runway, which is difficult to take into consideration within the aircraft certification. However, this aspect of the conditions of the accident gave rise to manufacturer development.

As far as secondary damage due to fire the consequences of the penetration of a significant quantity of burning fuel into the RH main landing gear wheel well must be noted. It may be considered that wheel wells although not classified as a "fire zone" according to the regulations, remain a "sensitive zone" in the event of a severe fire. Thermal protection was provided by a shield which was not designed for this purpose, but which avoided the penetration of fire into the cabin during the firemen's intervention.

4.3 - SURVIVAL ASPECTS

4.3.1 - Fire Fighting

The firemen's intervention was specially rapid and efficient. They reached the aircraft within 15 to 20 seconds after it had stopped on the runway, they fought the fire without delay and completely subdued it within less than 4 minutes.

In fact, it was the first time that such a fire sustained by a wide-body aircraft on the ground was subdued so successfully. A less rapid or less spontaneous action might have enabled the fire to penetrate the cabin and compromised the rescue of the occupants.

4.3.2 - Emergency evacuation start

The importance of the fire, its rapid and unexpected progression towards the front of the aircraft on the left hand side in particular, and an important emission of black smoke did not allow the flight and cabin crew members to get rapidly a global appreciation of the evolution of the actual outside situation.

It can be considered that as soon as the aircraft had stopped, the situation was such that an observer standing inside the aircraft could draw different (and even contradictory) conclusions, depending on whether he was at the front or at the rear of the cabin, or in the cockpit.

Due to the appraisal factors which were available at the end of the deceleration, the captain using the "public address" gave in a first step instructions for an emergency evacuation preparation.

The end of this address was received and interpreted by most cabin crew members as a real order of evacuation through the forward door (... "RH side forward not rear"), where as the captain stated he intended to direct the evacuation towards the front in a first step, and then towards the rear (the quality of the recordings does not enable doubt to be removed) ; the flight attendants responsible for the aft zone could think that their zone was more appropriate to an emergency evacuation (opening of the LH n°4 door, as soon as the aircraft had stopped)

The penetration of a heavy black smoke through the first opened doors (RH n°1 and LH n°4 doors) made the situation more confused, and helped creating a conflict in the cabin between two groups of passengers moving in opposite directions.

When it became obvious that the evacuation could not take place through front doors (explosion of the RH n°1 slide, LH n°1 and n°2 doors blocked by the fire) a physical action of the cabin attendants was necessary, in addition to the orders shouted by the chief purser to finally direct the evacuation towards the rear.

The EVAC signal was not activated. Most of the cabin attendants did not use or attempt to use the service interphone network to exchange information between the rear and the front zones of the cabin. The loud-hailers, accessibility of which seems questionable, were generally not used. They appeared to have a difficult access and low efficiency inside a smoky cabin.

4.3.3 - Evacuation progress

It took approximately 30 seconds before any confusion ended, and the evacuation definitely directed to the rear. Almost all the passengers moved back to the rear without any excessive panic movement.

The evacuation took place mainly through the LH aft door, but some passengers who had seen that the fire had been subdued preferred to be evacuated through the RH forward door, helped by the firemen.

The duration of the evacuation through the rear can be estimated between 2 and 3 minutes. The few passengers who went to the front were the last to be evacuated.

In addition to the lack of coordination between the crew members, which has already been mentioned the following factors must be considered :

- presence of black smoke in the cabin, which reduced visibility to less than one meter in some places, and which led half the cabin attendants to use their oxygen equipment.
- reduced illumination of the "sortie - exit" panels and the no activation of the emergency ceiling lights.
- difficult communications between cabin attendants and no instructions to passengers (with loud-hailer and/or "public address")
- passengers hesitation to jump two by two into the double slide

- one single assist handle at each door for the cabin attendants
- temporary no functioning of some doors and destruction or no inflation of some slides.

4.3.4 - Operation of doors and slides

Out of the 8 doors of the Airbus, 6 can be considered as main passenger cabin access doors, the two number 3 doors are only emergency exit doors not provided with a pneumatic opening system.

- During the evacuation, the opening of the RH n°3 and LH n°2 doors was voluntarily not attempted.

- The RH n°1 and n°4 doors, as well as the LH n°3 and n°4 doors were opened as soon as the evacuation started.

The RH n°1 and n°4 slides operated normally, but exploded (when in contact with fire for the first one, and, for the second one, when in contact with the airframe, which had reached excessively high temperatures). The LH n°3 slide did not extend due to the presence of a safety pin which had not been removed from the inflation bottle during maintenance.

The LH 4 slide inflated normally and permitted the evacuation of most of the passengers.

- The LH 1 and RH 2 doors could not be opened when hot, but operated normally at the end of the evacuation after the fire had been subdued ; they operated perfectly well during all the subsequent tests conducted at normal temperature. The slides of these doors operated correctly.

- The LH n°2 door was opened at the end of the evacuation and its slide did not extend : the investigation concluded that this was most probably due to a wrong routing of the inflation pipes.

4.3.5 - Miscellaneous questions

In the event of an "emergency evacuation", the rule at Air France is to take no action from memory, which necessitates reading a check list.

Rules in this field are very diversified when considering the doctrines of the various international airlines or manufacturers.

According to Airbus Industrie, the check-list "fire on the ground" comprises three actions from memory (underlined items).

In the present case, this solution might have been preferable to that of some manufacturers who do not require that actions be taken from memory under similar circumstances.

Furthermore, when considering various reflexions and analyses which took place during the investigation, it seems that a particular attention should be paid to the following two points :

- possibility of re-closing the main access doors after the automatic opening procedure
- improvement of the accessibility of the escape slide emergency percussion handle.

5 - CONCLUSIONS

5.1 - FINDINGS

The investigation showed that :

- the crew had the certificates, licences and ratings required by the regulations to fulfill the functions for which they were responsible on the type of aircraft and the route considered. Furthermore, the requirements concerning their rest periods before the flight had been met.
- the aircraft was certified, equipped and operated in accordance with the French regulations and according to standards at least equivalent to the international applicable standards. Its weight and balance were within the authorized limits.
- communications with the ground services were normal and satisfactory
- weather conditions were good
- the take-off started correctly, and the operation of the aircraft, of its engines and the onboard systems was normal up to approx. 95 kt when an uncontained disintegration of the RH engine took place
- the decision to abort take-off was taken and announced by the captain immediately after this explosion (which was first felt by the crew as a tyre burst). Taking account of the great margin due to the speed which was still relatively low when the event took place, the braking was moderate and the aircraft came to a stop after running approx. 2/3 of the runway.

- the uncontained explosion resulted in punctures in several places of the RH inboard tank, the fuel of which immediately burnt and then largely spilled onto the ground under the aircraft at a stop, which caused stringers and frames to melt. Secondary damage also severely affected the tyres (bursts), the LH engine and its pylon, as well as the fuselage and the control surfaces (impacts and punctures). Furthermore, the A.P.U. shut-down (due to air starvation), the loss of the electrical power supply (emergency batteries not affected) and the loss of the RH main landing gear anti-skid system were also reported.

- Engine n°1 was capable of producing take-off power without time limitations had the n°2 engine failure event occurred at or above V1 speed.

- the evacuation initiated as soon as the aircraft had stopped, took place under difficult conditions :
 - . presence in the cabin of smoke coming from outside, necessity due to the unexpected progression of severe fire outside, of reversing to the aft after approx. 30 seconds the evacuation flow which in a first step had been oriented to the front.

 - . failure of two slides due to fire, extension without inflation of another slide (abnormal presence of a safety pin), difficulties encountered with two doors which could not be opened immediately (deformations possibly due to the heat caused by fire), non utilization of the public address and loudspeakers to coordinate actions : consequently, most occupants were evacuated through one single door (LH n°4).

- the rapid and efficient intervention of firemen was determining : reaching the aircraft within 15 to 20 seconds after it had stopped they subdued the fire within less than 4 minutes and their action greatly facilitated the evacuation, the overall duration of which can be estimated at 3 1/2 minutes. (it must be noted that the only injured passenger - broken leg - had hustled the cabin attendant in order to exit before being given the order).

- the investigations showed that the first stage HP turbine disk had burst due to the propagation of a low cycle fatigue crack in an embossment of the disk rim. This crack was anterior to the last shop inspection conducted by airline in accordance with the inspection methods defined by the manufacturer at that time.

- This type of fracture was the third to occur on a CF6-50 GE engine. The investigations of the previous cases, as well as the measures taken after the accident by the manufacturer and the certification authorities (new airworthiness directives resulting in a modification of the intervals between inspections and their duplication, new design of the disk and progressive replacement), allow to conclude that the in service disk limit life validation methods used at that time were still insufficient.

5.2 - CAUSES

The accident directly resulted from the uncontained explosion of a first stage high pressure turbine disk of the right hand engine. The propagation of a low cycle fatigue crack on one of the embossments of the disk rim was at the origin of the disk fracture.

This cracks, which existed before, had not been detected during the inspection conducted in the operator's workshops, according to the method defined by the manufacturer and in accordance with the requirements of the airworthiness authority. The investigations showed that it was necessary, not only to reduce the intervals between the inspections of these disks and conduct two independent sequential inspections, but also to modify the design and make sure they were progressively replaced by the new type. It seems obvious that the limit life validation methods used at the time of the accident, were still insufficient, as far as the probability of non-detection of cracks was concerned.

6 - SAFETY RECOMMENDATIONS

The analysis of this accident put in sight various points of general interest valid not only for this particular case but also of worldwide importance :

Recommendation 1 : Turbine disk :

It is recommended that airworthiness regulations for turbo engines be modified in such a way that effective endurance tests be mandatory instead of mathematical models only.

Recommendation 2 : Wheel well :

It is recommended that transport category aircraft airworthiness regulations be modified in such a way that wheel wells be considered as "fire sensitive" areas.

Recommendation 3 : Access door :

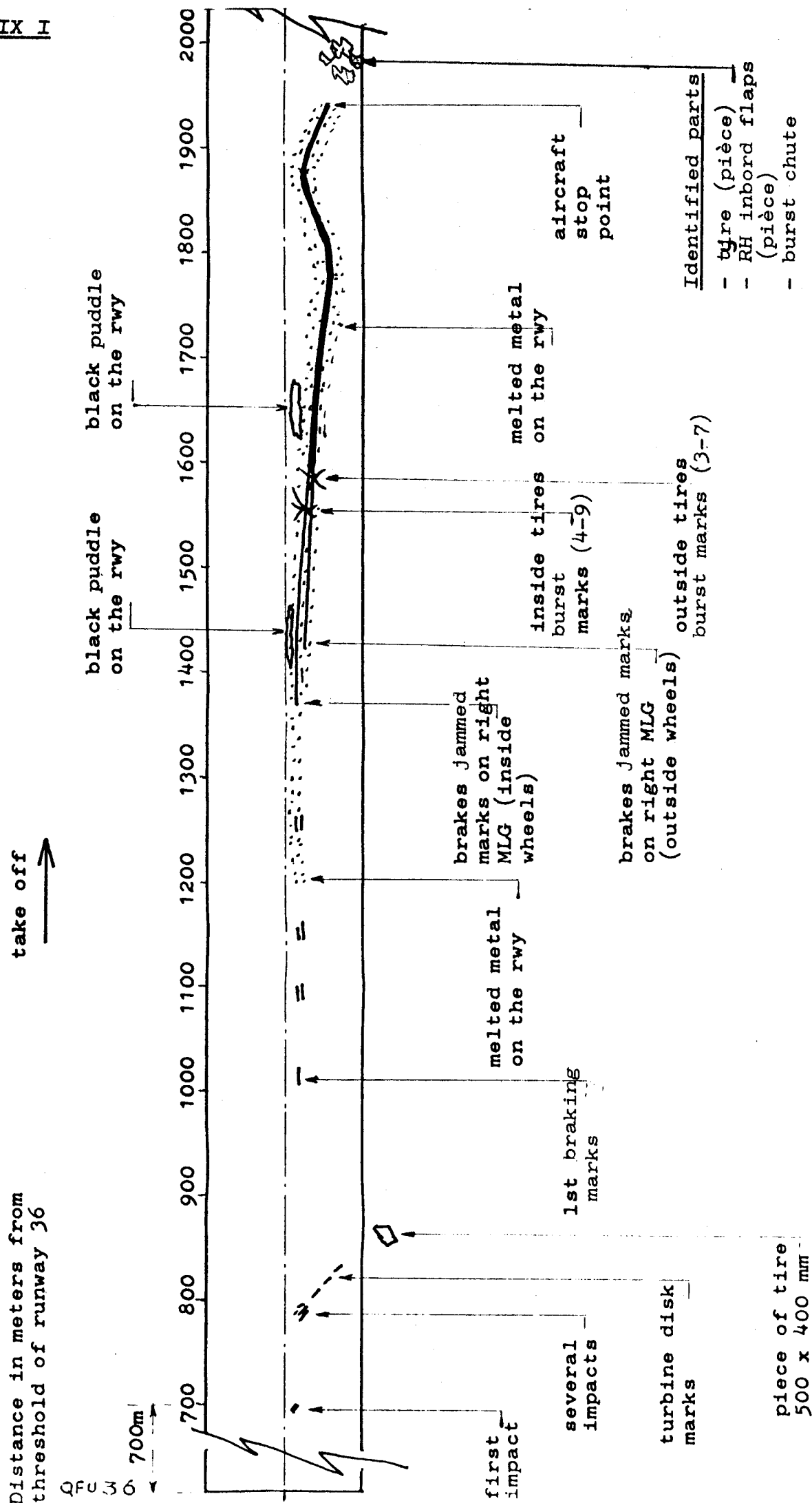
It is recommended that all access doors (mechanically assisted or not) be equipped with two structural handles, one on each side of the door frame.

Recommendation 4 : Chute :

It is recommended that chute design and manufacture be revised to avoid any defectuous inflation resulting of an always possible poor folding and, in particular, that the inflation pipes routing includes the necessary mandatory "way points".

A P P E N D I C E S

DIAGRAM OF MARKS ON THE RUNWAY



APPENDIX II

List of parts brought back to France

	delegation * reference
1 - Air conditionning duct (bended sleeve), to electrical equipments frames 32/33 - IPC : 21-21-02 F2 160 P/N A21273 493 00000	3
2 - Air conditionning duct (flexible sleeve) to electrical equipments frames 32/33 - IPC : 21-21-02 F2 70 P/N A212 000 222 600	3
3 - Air conditionning duct to electronic equipments frames 32/33 P/N : A212 73492 00000	3
4 - Air conditionning mixing chamber, passanger cabin area 2 frames 33/34 IPC : 21-61-02 P8 470 P/N : A212 737 76 00000	3
5 - Insulation blanket of cabin area 2 air duct frames 33/34 IPC : 21-62-02 PI 220 P/N A212 733 07 00200	4 c
6 - Insulation blanket of cockpit air duct frames 32/33 - stringers 27/29 P/N A212 733 22 00000	4 b
7 - Floor panel of passanger cabin IPC : 53-21-21 - 35A - item 70A P/N A 53 28 00 63 00 300	2
8 - Forward cargo compartment floor panel IPC : 53-21-30 - 2 - item 110 A P/N A532 727 98 00000	4 d
9 - Forward cargo compartment wall panel (forward) IPC : 25-51-22 - 8A - item 20 P/N A25 57 036 000 000	4 d
10 - Wheel well protection panel IPC : 29-15-03-62 - item 20 P/N A25 53 20 25 00 300	4 e

* item number in the letter of delegation of march 24 th, 1982

APPENDIX III

Legend

CAM	Cockpit area microphone or sound source
RDO	Radio transmission from accident aircraft
PA	Public address system
INC	Intercom
- 1	Voice identified as Captain
- 2	Voice identified as first officer
- 3	Voice identified as flight engineer
- 4	Voice identified as purser
- 5	Voice identified as flight attendant
- 6	Voice identified as ground mechanic
SANAA	Sana'a tower control
*	Unintelligible word
()	Questionable text
(())	Editorial insertion
.....	Pause

NOTE :-All times are expressed in GMT time.
-Intra-cockpit communications in french are printed normally.
The translation in english is printed in capitals after the
the statement in french.

TIMES SOURCE	INTRA-COCKPIT	TIMES SOURCE	AIR GROUND COMMUNICATIONS
CAM 1 0458 : 35	Tu as demandé l'autorisation ? DID YOU ASK FOR THE AUTHORIZATION ?	0458:55 RD02	AF 125, start up clearance to Cairo
CAM 2 0458 : 39	Non NO	0459:03 SANAA	AF 125, clear start
CAM1	Tu l'as demandée ? DID YOU ASK FOR IT ?	0459:05 RD02	OK clear to start
CAM ?	Ouais YES		
CAM 3 0459:08	Avant mise en route *ISS sur NAV* BEFORE START *ISS ON NAV*		
CAM ? 0459:15	Tu crois qu'on peut, oui ready nav YOU BELIEVE WE CAN ? YES READY NAV		
CAM 3 0459:22	*Frein de park pression *ZFW* *PARKING BRAKE PRESSURE *ZFW*		
CAM 3 0459:50	Non, c'est pas ça, 105 tonnes 7 NO, IT'S NOT THAT, 105,7 TONS		
CAM 3 0500:15	Pompes carburant/oui FUEL PUMPS /YES		
CAM 3 0500:18	L'enregistreur de vol/oui FLIGHT RECORDER/YES		

CAM 3 0500:20	*Voyants portes *DOORS INDICATOR LIGHTS		
CAM ? 0503 :44	J' entends rien du tout-hein I HEAR NOTHING		
CAM ? 0503 :48	OUI Yes		
CAM ? 0503:56	Au revoir GOOD BYE		
CAM 5 0505:17	Le temps de vol ? THE FLIGHT DURATION ?		
CAM 1 0505:52	Chef pilote de Yémen Airways YEMEN AIRWAYS CHIEF PILOT		
CAM 0505:59	Enchanté NICE TO MEET YOU	INC 6 0506:01	Fermé le cargo en 5 *des armes* oui CARGO IN 5 CLOSED *ARMS* YES
CAM ? 0506:16	*ça va, autrement, on est paré* *OK, OTHERWISE WE ARE READY		
CAM ? 0507:15	Au décollage, au décollage, oui AT TAKE OFF, AT TAKE OFF, YES	INC 1 0507:03	Allo, le sol ALLO, THE GROUND

CAM 2 0507:34	Vanne ouverte VALVE OPEN	INC 1 0507:13	Le sol ? GROUND ?
CAM 3 0507:36	Pression d'air correcte AIR PRESSURE CORRECT	INC 6 0507:15	Oui, j'écoute, voilà, ça se précise ; la soute 5 refermée par moi-même.L'avion dégagé - les câbles en place, donc paré, le 2 quand vous voudrez. YES, LISTENING, IT BECOMES CLEAR, CARGO DOOR 5 CLOSED BY MYSELF AIRPLANE CLEAR, THE CHOCKS IN POSITION, SO READY, NUMBER 2 WHEN YOU WANT.
CAM 1 0507:43	10%	INC 1 0507:13	OK - On y va au 2 OK - WE GO WITH NUMBER 2
CAM 3 0507:51	Pression hydraulique HYDRAULIC PRESSURE	INC 6 0507:44	Paré au 2 READY FOR NUMBER 2
CAM 1 0508:07	280 (Fuel flow) Allumage IGNITION		*Rotation du 2 *NUMBER 2 ROTATING

CAM 2	12 secondes		
	12 SECONDS		
CAM	30%		
0508:08			
CAM 3	Pression d'huile		
	OIL PRESSURE		
0508:15			
CAM 2	Vanne fermée		
	VALVE CLOSED		
0508:23			
		INC 1	Démarrage du 1
		0508:25	START UP OF NUMBER 1
		INC 6	Paré au 1
			READY FOR NUMBER 1
		INC 2	Vanne ouverte, rotation N1
		0508:28	VALVE OPEN, ROTATION N1
CAM 1	10%		
0508:35			
CAM ?	Allumage		
	IGNITION		
0508:53			
CAM ?	30%		
0509:00			
CAM 2	45 - Vanne fermée		
	45 - VALVE CLOSED		
0509:17			

INC 1
0509:19
Bon, le démarrage est terminé. On mettra le bloc à 10. A tout de suite.
WELL, THE START UP IS OVER. WE WILL PUT BLOCK TIME AT TEN. SEE YOU SOON

INC 6
OK. A tout de suite.
OK. SEE YOU SOON

CAM ?
0509:51
C'est terminé ?
IS IT OVER ?

CAM 2
0510:01
Check list après mise en route.
Commande carburant HP sur ON, panneau central d'alarmes ?
AFTER START CHECK LIST. HP FUEL LEVER ON, MASTER WARNING PANEL.

CAM ?
0510:05
Oui
YES

CAM 2
0510:07
Sélecteur démarrage/crank start abort, servocommandes/ IM en ligne, fenêtre fermée à droite, dégivrage/sans objet, panneau électrique/ vérifié, panneau hydraulique/ vérifié, check list terminée
START SELECTOR/CRANK START ABORT, SERVO CONTROLS, MAGNETIC INDICATOR IN LINE, WINDOW CLOSED ON THE RIGHT, DEICING/ NO OBJECT, ELECTRIC PANEL/CHECKED, HYDRAULIC PANEL/CHECKED, CHECK LIST COMPLETED.

CAM 1
0510:34
Combien on est à bord
HOW MANY ARE WE ON BOARD ?

CAM 2
111 + 13

CAM ?
0511:01
Check list terminée
CHECK LIST COMPLETED

RDO1
0511:07
Sana'a, AF 125, taxi clearance please

SANA'A 125
0511:10
Taxi to the holding with runway 36,
wind calm, Q N H 1025 mb, go ahead

RDO1
0511:19
Runway 36, Q N H 1025 mb, AF 125

CAM 1
0512:09
On fait l'essai des commandes ?
WE DO THE FLIGHT CONTROLS CHECK ?

CAM ?
0512:11
Ailerons descendus
AILERONS DOWN

CAM 3
0512:14
*30 cabré
30 UP

CAM 3
0512:33
*20,*zéro

CAM 3
0512:45
Direction
YAW

CAM 2
0512:52
Check list roulage
TAXI CHECK LIST

CAM 3
0513:01
Index vitesse ? Alors 142 -148*
SPEED BUGS ? THEN 142- 148*

CAM 2
Affichés à droite, à gauche et au
centre
SET TO THE RIGHT, TO THE LEFT AND
TO THE MIDDLE

CAM 3
*direction, gauchissement, profondeur
*YAW, ROLL, PITCH

CAM 2	0,0,*		
CAM 3 0513:20	Spoilers sol GROUND SPOILERS		
CAM 1	Désarmés DIS ARMED		
CAM 3 0513:22	Becs, volets SLATS, FLAPS		
CAM 1	*16,krug		
CAM 3 0513:26	Commandes de vol FLIGHT CONTROLS		
CAM 1	Vérifiées CHECKED		
CAM 3	Compass COMPASS		
CAM 1	280 trois fois 280 THREE TIMES		
		SANAA 0613:39	AF 125, kindly give number, passagers number and crew on board ?
		RDO1 0513:45	Passengers we have 111 passengers and crew members 13
		SANAA 0513:55 RDO1 0513:56	Please say again Passengers 111, crew members 13, total on board 124

CAM ? 0514: 44	*Décollage* *Take off*		
CAM 2 0514: 54	*Après V1, c'est dans l'axe 700 pieds- virage à droite sur le 030 du VOR (VREF + 80) et ensuite virage à gauche pour revenir sur le VOR*		
	AFTER V1, SAME HEADING TO 700 FEET- TURN TO THE RIGHT ONTO THE 030 FROM THE VOR (VREF + 80) AND THEN TURN TO THE LEFT BACK TO THE VOR		
CAM 2 0515:12	*(Montée) sur le radial 20 du VOR *(CLIMB) ON THE RADIAL 020 OF THE VOR		
CAM 4 0515:22	Cabine parée CABIN READY		
CAM 2 0515:24	*Virage à gauche pour revenir sur le VOR *TURN TO THE LEFT TO COME BACK ON THE VOR		
CAM 2 0515:33	Briefing terminé BRIEFING COMPLETED	SANAA 0516:27	AF 125, clear by Djeddah Control to FL 280
		RDO1 0516:33	AF 125 Clear 280 by Yemen Control

By Addis, correction by Djeddah Control,
280
Roger, 280, *Djeddah Control
AF 125, clear into position and hold
125, clear into position and hold

SANAA
0516:40
RDO1
0516:42
SANAA
0517:36
RDO1
0517:38

PA 1
0517:44
Pour votre information, décollage dans
quelques instants
FOR YOUR INFORMATION, TAKE OFF IN A
MOMENT

CAM 1
0518:03
Check list avant décollage, dès que
tu es prêt
BEFORE TAKE OFF CHECK LIST AS SOON AS
YOU ARE READY

CAM 3
0518:06
Check list avant décollage
BEFORE TAKE OFF CHECK LIST

CAM 3
Paramètres décollage, trim
TAKE OFF PARAMETERS, TRIM

CAM 2
0518:10
*Alors les volets 8*confirmé
*THEN THE FLAPS 8,*CONFIRMED

CAM 3
0518:14
Température freins/80°, transpondeur,
VOR-DME,
BRAKES TEMPERATURE/80°, TRANSPONDER,
VOR-DME,

CAM 3
Panneau central d'alarmes
MASTER WARNING PANEL

CAM 1 Rappelé, inhibé
RECALL, INHIBIT

CAM 3 Allumage/continuu, projecteurs, strobe/ marche,
0518:26 sélecteurs pack valves fermés check list ter-
minée
IGNITION/CONTINUOUS, LIGHTS, STROBE/ ON,
PACK VALVE SELECTORS/CLOSED, CHECK LIST
COMPLETED

SANAA AF 125, wind check is 150/08, clear for
0519:23 take off

RD 01 125, taking off
0519:30

CAM 1 Poussée décollage
0519:39 TAKE OFF THRUST

CAM 2 Poussée décollage
TAKE OFF THRUST

CAM 3 80%
0519: 45

CAM 1 Badin
0519:59 SPEED

CAM 2 A droite
0520:00 ON THE RIGHT

CAM 3 Paramètres corrects
0520: 07 PARAMETERS CORRECT

((MEANS : CROSS CHECK ON THE RIGHT))

0520:07 ((SOUND RECORDED BY CAM, PROBABLY DESINTEGRATION
OF ENGINE N° 2 AND TOGETHER LOSS OF SYNCRO ON
DFDR))

CAM 1 Accélération-arrêt
0520:08 REJECTED TAKE OFF

0520:09 ((SOUND RECORDED BY CAM, AT FIRST NOT EVIDENTLY
THE ENGINE FIRE ALARM, BUT TWO SECONDS LATER
VERY RECOGNIZABLE AS THE ENGINE FIRE ALARM))

CAM 1 Doucement sur les freins, doucement sur les
0520:12 freins, c'est bon
GENTLY ON THE BRAKES, GENTLY ON THE BRAKES, IT'S
OK

0520:13 ((DEFINITIVE LOSS OF DATA ON DFDR))

CAM 1 Feu moteur droit, arrêt GTR hein
0520:17 RIGHT ENGINE ON FIRE, SHUT THE ENGINE HUH

CAM 3 Arrêt GTR
0520:19 ENGINE SHUT OFF

RDO1 Sana'a tower, AF 125, request firemen
0520:26 assistance, we have right engine
on fire

CAM 1 Continue
0520:30 GO ON

SANAA Roger, fire engine is coming
0520:33

CAM 1
0520:37 Continue, continue, continue,
GO ON, GO ON, GO ON

CAM 2
Je ne peux pas
I CAN'T

CAM 2
On arrête (là/pas), hein
WE STOP (HERE/NOT)

CAM 2
Je ne peux pas
I CAN'T

PA 1
0520:44 Chef de cabine, le commandant de bord,
restez à votre place. Préparez-vous à une
évacuation. Nous avons les préparez-
vous à une évacuation sur le côté droit
PURSER, CAPTAIN SPEAKING, STAY IN
POSITION, PREPARE TO AN EVACUATION. WE HAVE
THE PREPARE TO AN EVACUATION BY THE
RIGHT SIDE

CAM 2
0520:58 Du côté droit, et en avant
RIGHT SIDE, AND FOREWARD

PA1
0520:59 Côté droit, devant, pas à l'arrière, hein
TO THE RIGHT, FORWARD, NOT AFT, HUH

CAM ?
0521:13 Toutes les portes à droite
ALL THE DOORS ON THE RIGHT

CAM ?
0521:18 Par la droite
TO THE RIGHT

CAM ?
0521:23 Derrière, dégagez derrière
TO THE BACK, GO TO THE BACK

((PROBABLY RELATED TO STEERING DIFFICULTIES))

CAM ? Derrière
 TO THE BACK

SANAA AF 125, from SANA'A
0521: 33

CAM ? Par derrière... derrière ...
0521: 38 derrière
 THROUGH THE REAR... REAR... REAR... REAR PART...

CAM 5 Les masques... les masques... les masques
0521: 54 s'il vous plait
 THE MASKS... THE MASKS...
 PLEASE

CAM 5 Regarde ici si tu vois un masque
 LOOK HERE IF YOU SEE A MASK

CAM 5 Les masques... les masques... les masques
0522: 08 THE MASKS... THE MASKS... THE MASKS...

CAM 1 Ouvrez les portes, ouvrez les portes... les
0523: 08 portes pour aérer... les portes
 OPEN THE DOORS, OPEN THE DOORS... THE DOORS
 FOR FRESH AIR ... THE DOORS

SANAA AF 125, Sana'a
0523: 15

CAM ? Vas voir à l'arrière s'il y a une porte
0524: 37 GO AND SEE IN THE BACK IF THERE IS A DOOR

CAM ? Pardon ?
 PARDON ME ?

CAM ? Pars !
0524:40 GO !

CAM ? (C'est) terminé ?
0524:59 (IS'T) OVER ?

CAM ? Non, pas (encore)
 NO, NOT (YET)

CAM 5 Go to the back, go to the back
0525:04 go to the back, there is a door open
 ... go to the back

0525:30 ((SOUND ON THE FUSELAGE IN THE AREA OF
 THE FLIGHT DECK))

0527:10 END OF RECORDING