No. 2

KLM, B-747, PH-BUF and Pan Am, B-747, N736, collision at Tenerife Airport, Spain, on 27 March 1977. Report dated October 1978, released by the Subsecretaría de Aviación Civil, Spain, in both Spanish and English.

1.- INVESTIGATION

1.1 History of the flight

The KLM Boeing 747, registration PH-BUF, took off from Schipol Airport (Amsterdam) at 0900 hours on 27 March 1977, en route to Las Palmas de Gran Canaria. This flight was part of the Charter Series KL 4805/4806 Amsterdam-Las Palmas (Canary Islands)-Amsterdam operated by KLM on behalf of the Holland International Travel Group (H.I.N.T.), Rijswijk-Z.H.

The Boeing 747 registration N736PA, flight number 1736, left Los Angeles International Airport, California, United States, on 26 March 1977, local date, at 0129Z hours, arriving at John F. Kennedy International Airport at 0617Z hours. After the aeroplane was refuelled and a crew change effected, it took off for Las Palmas de Gran Canaria (Spain) at 0742Z.

While the aeroplanes were en route to Las Palmas, a bomb exploded in the airport passenger terminal. On account of this incident and of a warning regarding a possible second bomb, the airport was closed. Therefore, KLM 4805 was diverted to Los Rodeos (Tenerife) Airport, arriving at 1338Z on 27 March 1977. For the same reason, PAA 1736 proceeded to the same airport, which was its alternate, landing at 1415.

At first the KLM passengers were not allowed to leave the aeroplane, but after about twenty minutes they were all transported to the terminal building by bus. On alighting from the bus, they received cards identifying them as passengers in transit on Flight KL 4805. Later, all the passengers boarded KLM 4805 expect the H.I.N.T. Company guide, who remained in Tenerife.

When Las Palmas Airport was opened to traffic once more, the PAA 1736 crew prepared to proceed to Las Palmas, which was the flight's planned destination.

When they attempted to taxi on the taxiway leading to runway 12, where they had been parked with four other aeroplanes on account of the congestion caused by the number of flights diverted to Tenerife, they discovered that it was blocked by KLM Boeing 747, Flight 4805, which was located between PAA 1736 and the entrance to the active runway. The first officer and the flight engineer left the aeroplane and measured the clearance left by the KLM aircraft, reaching the conclusion that it was insufficient to allow PAA 1736 to pass by, obliging them to wait until the former had started to taxi.

The passengers of PAA 1736 did not leave the aeroplane during the whole time that it remained in the airport.

KLM 4805 called the tower at 1656 requesting permission to taxi. It was authorized to do so and at 1658 requested to backtrack on runway 12 for take-off on runway 30. The tower controller first cleared the KLM flight to taxi to the holding position for runway 30 by taxiing down the main runway and leaving it by the (third) taxiway to its left. KLM 4805 acknowledged receipt of this message from the tower, stating that it was at that moment taxiing on the runway, which it would leave by the first taxiway in order to proceed to the approach end of runway 30. The tower controller immediately issued an amended clearance, instructing it to continue to taxi

to the end of the runway, where it should proceed to backtrack. The KLM flight confirmed that it had received the message, that it would backtrack, and that it was taxiing down the main runway. The tower signalled its approval, whereupon KLM 4805 immediately asked the tower again if what they had asked it to do was to turn left on taxiway one. The tower replied in the negative and repeated that it should continue on to the end of the runway and there backtrack.

Finally, at 1659, KLM 4805 replied, "O.K., sir."

At 1702, the PAA aeroplane called the tower to request confirmation that it should taxi down the runway. The tower controller confirmed this, also adding that they should leave the runway by the third taxiway to their left. At 1703:00, in reply to the tower controller's query to KLM 4805 as to how many runway exits they had passed, the latter confirmed that at that moment they were passing by taxiway C-4. The tower controller told KLM 4805, "O.K., at the end of the runway make one eighty and report ready for ATC clearance."

In response to a query from KLM 4805, the tower controller advised both aeroplanes - KLM 4805 and PAA 1736 - that the runway centre line lights were out of service. The controller also reiterated to PAA 1736 that they were to leave the main runway via the third taxiway to their left and that they should report leaving the runway.

At the times indicated, the following conversations took place between the tower and the KLM 4805 and PAA 1736 aeroplanes.

Times taken from KLM CVR.

1705:44.6
KLM 4805: The KLM four eight zero five is now ready for take-off and we are waiting for our ATC clearance. (1705:50.77).

1705:53.41
Tower: KLM eight seven zero five you are cleared to the Papa Beacon, climb to and maintain flight level nine zero, right turn after take-off, proceed with heading four zero until intercepting the three two five radial from Las Palmas VOR. (1706:08.09).

1706:09.61
KLM 4805: Ah - Roger, sir, we are cleared to the Papa Beacon, flight level nine zero until intercepting the three two five. We are now (at take-off). (1706:17.79).

1706:18.19
Tower: O.K..... Stand by for take-off, I will call you. (1706:21.79).

Note: A squeal starts at: 1706:19.39
The squeal ends at: 1706:22.06

1706:21.92
PAA 1736: Clipper one seven three six. (1706:23.39).

1706:25.47
Tower: Ah - Papa Alpha one seven three six report the runway clear. (1706:28.89).

1706:29.59
PAA 1736: O.K., will report when we're clear. (1706:30.69).

1706:31.69
Tower: Thank you.

Subsequently, KLM 4805, which had released its brakes to start take-off. run 20 seconds before this communication took place, collided with the PAA aeroplane.

The control tower received no further communications from PAA 1736, nor from KLM 4805.

There were no eyewitnesses to the collision.

Place of accident

The accident took place on the runway of Tenerife Airport (Los Rodeos) at latitude 28° 28' 30" N and longitude 16° 19' 50" W. The field elevation is 2 073 ft (632 m).

Date

The accident occurred on 27 March 1977, at 17 hours 06 minutes 50 seconds GMT.

1.2 Injuries to persons

1.2.1 KLM 4805

Injuries	Crew	Passengers	Others
Fatal	14	234	-
Non-fatal	-	-	-
None	-	-	

1.2.2 PAA 1736

Injuries	Crew	Passengers	Others
Fatal	9	317	-
Non-fatal	7	61*	2**
None	-	-	

* 9 of these passengers subsequently died as a result of injuries received.

** Company employees, sitting on the cockpit jumpseats, who had boarded the aeroplane in Tenerife.

1.3 Damage to aircraft

Damage to the aeroplanes was 100 per cent due to the impact and post-impact fire.

1.4 Other damage

The runway was damaged in the area of impact by the impact itself and by the subsequent fire. Cost of repairs thereto amounted to 16 005 464.22 pesetas.

1.5 Crew information

1.5.1 KLM crew

a) Captain

Nationality: Dutch
Date and place of birth: 5 February 1927, in Lisse, Netherlands

Licences:
Private Pilot's Licence issued 21.6.1947
Commercial Pilot's Licence issued 18.4.1950
Flight Navigator's Licence issued 6.8.1963
Airline Transport Pilot's Licence issued 19.10.1956 and valid until 16.6.1977
Flight Radio Telephone Operator's Licence issued 22.9.1952 and valid until 2.10.1980

Type ratings:

Douglas DC-3	28.9.1951	until	20.6.1962
Convair CV 240/340	23.8.1952	"	20.6.1962
Lockheed L749/1049	1.10.1952	"	20.6.1962
Douglas DC-6	12.2.1957	"	20.6.1962
Douglas DC-7C	6.6.1957	"	20.6.1962
V. Viscount 803	11.6.1959	"	21.7.1967
Douglas DC-9	16.3.1967	"	9.6.1971
Boeing 747	23.1.1971	"	16.6.1977

Flying experience:
Total flying time as of 27.3.1977: 11 700 hours
Flying time on Boeing 747 as of 27.3.1977: 1 545 hours

Last medical examination:
29.12.1976. Result: fit for ATPL

Last proficiency check:
25.1.1977: O.K.

b) Co-pilot (First Officer)

Nationality: Dutch
Date and place of birth: 12.2.1935 in Opperdoes, Netherlands

Licences:
Private Pilot's Licence issued 31.5.1958
Commercial Pilot's Licence issued 2.3.1960
Flight Navigator's Licence issued 20.4.1966 and valid until 26.6.1977
Flight Radio Telephone Operator's Licence issued 30.12.1957 and valid until 2.6.1981
Airline Transport Pilot's Licence issued 5.6.1970 and valid until 29.6.1977

Type ratings:

Beechcraft D13S	2.3.1960	until	11.7.1961
Fokker F-27	26.8.1966	"	2.7.1970
Douglas DC-8	13.12.1970	"	29.6.1977
Boeing 747	19.1.1977	"	29.6.1977

Flying experience:
Total flying time as of 27.3.1977: 9 200 hours
Flying time on Boeing 747: 95 hours

Last medical examination:
29.12.1967. Result: fit for ATPL

Last proficiency check:
17.1.1967. Result: O.K.

c) Flight Engineer

Nationality: Dutch
Date and place of birth: 30.8.1928 in Amsterdam, Netherlands

Licences:
Flight Engineer's Licence issued 12.5.1950 and valid until 3.9.1977
Flight Radio Telephone Operator's Licence issued 10.6.1970 and valid until 3.9.1977
Private Pilot's Licence issued 6.9.1973 and valid until 3.9.1977

Type ratings:

Douglas DC-3	12.5.1950	until	28.3.1958
Douglas DC-6	28.3.1958	"	24.10.1960
Douglas DC-7C	28.3.1958	"	24.10.1960
Douglas DC-8	24.10.1960	"	3.9.1976
Boeing 747	22.4.1976	"	3.9.1977

Flying experience:
Total flying time: 17 031 hours
Flying time on Boeing 747: 543 hours

Last medical examination:
16.8.1976. Result: fit for Flight Engineer

1.5.2 PAA crew

a) Captain

Nationality:	American
Date of birth:	18 May 1920
Total flying time:	21 043 hours
Total 747 hours:	564
Total last 30 days:	63:43
Total last 24 hours:	6:33
Total this flight:	0
Last medical examination:	23 March 1977
Certificates and ratings:	ATP, 747 and 707 ratings
Last proficiency check:	15.11.1976

b) Co-pilot (First Officer)

Date of birth:	14 September 1937
Total flying time:	10 800 hours
Total 747 hours:	2 796
Total last 30 days:	42:39
Total last 25 hours:	6:33
Total this flight:	0
Last medical examination:	13.1.1977
Certificates and ratings:	ATP, 747 and 707 ratings
Last proficiency check:	17.1.1977

c) Flight Engineer

Date of birth:	12 December 1930
Total flying time:	15 210 hours
Total 747 hours:	559
Total last 30 days:	52:01
Total last 24 hours:	6:33
Total this flight:	0
Last medical examination:	25 June 1976
Certificates and ratings:	Flight Engineer, Turbojet rating

1.6 Aircraft information

1.6.1 KLM 4805

Aircraft type:	Boeing 747-206B
Registration:	PH-BUF
Serial No.:	20400
Year of manufacture:	1971
Manufacturer:	The Boeing Company, Seattle, Washington, U.S.A.
Airworthiness Certificate:	No. L1877
Date of first issue:	19 October 1971 (as Certificate of Validation, valid for three months) issued by the Department of Civil Aviation, Aeronautical Inspection Directorate
Date of definitive first issue:	13.12.1971
Date of last renewal:	15.11.1976
Date of expiry:	13.2.1977

Maintenance record

Total airfame hours as of 27.3.1977:	21 195
Total number of landings:	5 202
Last major overhaul/inspection:	January 1975, at 13 200 hours total aircraft time
Last periodical inspection:	18 March 1977; D-11 check at 20 898 hours total aircraft time
Maintenance Release:	No. 6076 of 18 March 1977

Engines

Number of engines: four (4)
Engine type: Pratt and Whitney JT-9 D-7

Engine position	Serial No.
Position 1	663056
" 2	685641
" 3	662694
" 4	662800

On the day of the accident, engine no. 1 had accumulated 15 080 total flying hours; no. 2 had accumulated a total of 16 677 hours; no. 3, 6 716 hours; and no. 4, 13 692 hours. The corresponding number of cycles was as follows: no. 1: 3 340 cycles; no.2: 3 337 cycles; no.3: 1 637 cycles; and no. 4: 3 399 cycles.

1.6.2 PAA 1736

Aircraft type:	Boeing 747-121
Registration:	N736PA
Serial No.:	19643, manufactured in January 1970 under a Standard Airworthiness Certificate, Transportation Category
Total hours:	TT: 25 725 TC: 7 195 (These hours and cycles go up to 27.3.1977 in JFK Airport)
Owner:	Pan American (PAA)
Flight number:	1736

Maintenance record

The aeroplane was equipped with an instrument flying panel in accordance with airline requirements under CFR 14, U.S. Code Far 121 and 25.

On 17 March 1977, at 25 726 hours total aircraft time, the aircraft received a Pre-flight Inspection in accordance with the PAA FAA-Approved Maintenance Programme.

Engines

Engines: Pratt and Whitney JT 9 D-7CN

No. 1 - Serial no. P 662403 CN:	total hours:	14 364
	total cycles:	4 234
No. 2 - Serial no. P 662996 CN:	total hours:	13 350
	total cycles:	2 824
No. 3 - Serial no. P 662256 CN:	total hours:	18 511
	total cycles:	6 666
No. 4 - Serial no. P 662307 CN:	total hours:	16 281
	total cycles:	4 838

Note.- Not included are the flying hours from JFK (John F. Kennedy Airport in New York to Tenerife, i.e., 6:33 hours).

1.7 Meteorological information

At Los Rodeos Airport, this is provided by:

1. A weather observation tower located at about 400 m southwest of the approach end of runway 30.

2. Another tower located at about 200 m northeast of the approach end of runway 12.

3. A visibility transmissometer located at about 70 m south of the runway 30 approach.

4. A ceilometer located in the same place.

5. Barometric pressure, temperature and dew point recording equipment.

6. Teletype for route weather information.

7. Visibility is reported by the tower controller when the approach to the runway in service is in sight. Otherwise, this is done by an observer in the weather observation tower.

8. Runway visual range (RVR) is not reported.

9. The following visibility values are given:

   - Horizontal and slant approach

   - Runway

   - Taxiway

Pertinent weather observations (QAM) as from 1630 hours were as follows:

QAM at approach end of runway 30 at 1630 hours

Approach horizontal visibility:	10 km
Runway visibility:	3 km
Approach slant visibility:	7 to 8 m
Present weather:	Intermittent light rain and fog at distance
Cloud coverage:	1/8 at 0 m, 2/8 at 30 m, 2/8 at 120 m, 2/8 at 180 m
Field altimeter setting (QNH):	1023 mb (30.21 Hg)
Sea level barometric pressure (QFE) Runway 30 approach end:	949 mb
Temperature:	14°C
Dew point:	13°C

QAM at approach end of runway 30 at 1645 hours

Approach horizontal visibility:	8 to 10 km
Runway visibility:	2 to 3 km
Approach slant visibility:	7 to 8 km
Present weather:	Intermittent light rain and fog patches
Cloud coverage:	2/8 at 0 m, 2/8 at 30 m, 2/8 at 90 m, 2/8 at 150 m
Field altimeter setting (QNH):	1023 mb (30.21 Hg)
Sea level barometric pressure	
(QFE) Runway 30 approach end:	951 mb
A.D.:	948 mb
Runway 12 approach end:	949 mb
Temperature:	14°C
Dew point:	13°C

QAM at approach end of runway 30 at 1650 hours

Approach horizontal visibility:	2 to 3 km; intermittent 8 km
Runway visibility:	2 to 3 km
Approach slant visibility:	2 km; intermittent to 7 km
Present weather:	Light rain and fog patches
Cloud coverage:	4/8 at 0 m, 2/8 at 30 m, 2/8 at 60 m

QAM at approach end of runway 30 at 1702 hours

Approach horizontal visibility:	500 m; intermittent to 5 km
Runway visibility:	300 m
Approach slant visibility:	500 m; intermittent to 5 km
Present weather:	Light rain and fog patches
Field altimeter setting (QNH):	1023 mb (30.21 Hg)
Sea level barometric pressure	
(QFE) Runway 30 approach end:	951 mb
A.D.:	948 mb
Runway 12 approach end:	949 mb
Temperature:	14°C
Dew point:	13°C

QAM at approach end of runway 30 at 1710 hours

Approach horizontal visibility:	4 to 5 km; intermittent 7 km
Runway visibility:	1 km
Approach slant visibility:	4 to 5 km; intermittent to 6 km
Present weather:	Intermittent light rain and fog patches
Cloud coverage:	5/8 at 0 m, 2/8 at 30 m, 2/8 at 90 m

QAM at approach end of runway 30 at 1725 hours

Approach horizontal visibility:	1 km, intermittent 3 km
Runway visibility:	300 m
Approach slant visibility:	1 km; intermittent 3 km
Present weather:	Light rain and fog patches
Cloud coverage:	7/8 at 0 m, 1/8 at 30 m

QAM at approach end of runway 30 at 1925 hours

Approach horizontal visibility:	100 m
Runway visibility:	100 m
Approach slant visibility:	100 m
Present weather:	Light rain and fog patches
Cloud coverage:	8/8 at 0 m
Field altimeter setting (QNH):	1022 mb (30.19 Hg)
Sea level barometric pressure	
(QFE) Runway 30 approach end:	950 mb
A.D.:	948 mb
Runway 12 approach end:	948 mb
Temperature:	13°C
Dew point:	13°C

1.8 Aids to navigation

1.8.1 KLM 4805

The aircraft was equipped with the following aids to navigation:

VOR/ILS:

Bendix RNA-26C	108-117, 95	MHz	3 systems
Marker Beacon:			
Bendix MKA-28C	75	MHz	1 system
ADF:			
Collins 51Y-7	190-1750	kHz	2 systems
DME:			
Collins 860 e-3	1000	MHz	2 systems
ATC Radar Beacon:			
Collins 621A-3	1030-1090	MHz	2 systems
Weather Radar:			
Bendix RDR-1F	9375	MHz	2 systems
Radio Altimeter:			
Collins 860F-1	4300	MHz	3 systems
Inertial Navigation System:			
Delco Carousel IV			3 systems
Emergency Radio Beacon:			
Garret Rescue-99	121.5/243	MHz	4 systems

1.8.2 PAA 1736

The aircraft was equipped with the following aids to navigation:

Description	Make	Model	No. of systems
ADF	Collins	51Y4	2 systems
DME	Collins	621A-3	2 systems
VOR/ILS	Collins	51RV2B	2 systems
Radar	(AVQ-30X) RCA	MI-592041	2 systems
Radio Altimeter	Bendix	ALA-51A	2 systems
Radar Beacon	Collins	621A-3	2 systems
Inertial Navigation System	Delco Elect	7883450-041	3 systems

1.9 Communications

1.9.1 KLM 4805

The aircraft was equipped with the following communication instruments:

HF COM:			
Collins 61 8T-2	2-30	MHz	2 systems
VHF COM:			
Collins 618M-2B	118-135.97	MHz	3 systems
Selcal:			
Motorola NA-135	1 Dual Decoder		
Cockpit Voice Recorder (CVR):			
Sundstrand AV-557B			1 system

1.9.2 PAA 1736

The aircraft was equipped with the following communication instruments:

Description	Make	Model	No. of systems
VHF	King	KTR-9100A	2 systems
HF	Collins	61T82	2 systems
Audio-Interphone	Ford	1-X00-185-3	1 system
Selcal	Motorola	NA-126AV	1 system

1.10 Aerodrome and ground facilities

Los Rodeos (Tenerife) Airport is located at an elevation of 632 m (2 073 ft). The 12/30 runway is 3 400 m (11 155 ft) long, and has two stopways of 60 m. It is 45 m wide. The elevation at the approach end of runway 30 is 2 001 ft and that

of runway 12 is 2 064 ft. The highest point of the airport is near the intersection of taxiway 3.

Because of its altitude and location in a sort of hollow between mountains, the airport has distinctive weather conditions, with frequent presence of low-lying clouds.

The Los Rodeos Airport was equipped with the following radio aids to navigation at the time of the accident:

VOR/DME, TFN 112.5 Mc	Normal operation
ILS 110.3 Mc	" "
FP Beacon, 243 kc	" "
NDB, TX, 410 kc	" "
NDB, LD, 370 kc	Out of service (NOTAM II 573/76)

Los Rodeos Airport was equipped with the following visual approach aids at the time of the accident:

Approach lights	In service
VASIS	" " (that of runway 12 was being tested)
Flashers on runway 30	" "
Precision approach lighting	" "
Runway centre line indicated	

The airport was equipped with the following beacon marking system at the time of the accident:

Lighting of the flight runway	In service
Lighting of the taxiway	" "

The runway centre line lights were out of service (NOTAM II 92/77).

The air-ground communication radio frequencies in service at the time of the accident were as follows:

- 119.7 Mc for Approach

- 118.7 Mc for Taxiing

The following NOTAMs were in force at the time of the accident, with regard to the Los Rodeos Airport radio aids and air-ground visual and communication aids:

1. On 15.3.1977, NOTAM I, National no. 643, International No. 382, contained the following text: "Runway 12/30 centre line lights out of order until further notice." (This NOTAM was changed to NOTAM II-A, no. 92/77 on 15.3.1977.)

2. On 19.3.1977, NOTAM I, National no. 791, International no. 463, contained the following text: "Frequencies 121.7 and 118.7 MHz being tested." (On 25.3.1977, this NOTAM was changed to NOTAM II-A, no. 108/77).

1.10.1 Magnetophone recording points in the Tenerife control tower equipment

Radio

a) Radio channels recording

The radio channels recording is performed by operator posts in the following manner.

The reception signals heard over the loudspeaker are recorded immediately after the loudspeaker line amplifier at the point indicated in the "Rx loudspeaker record" diagram.

The reception signals heard by earphones are recorded immediately after the earphone line amplifier at the point indicated in the "Rx earphone" diagram.

The transmission signals are recorded immediately before the transmission line amplifier at the point indicated in the "Tx record" diagram.

All these signals are appropriately mixed in order to be fed into the magnetophone recording channels in the following manner:

Operator Post	A	Channel 7
" "	B	Channel 8
" "	C	Channel 9
" "	D	Channel 10
" "	E	Channel 11

b) General radio recording

All the signals received by the Tower receivers, whether coming from aircraft or from the airport's own ground transmitters, are recorded at a point immediately before the radio control system, indicated in the "Rx lines record" diagram.

These signals coming from all the receivers are conveniently mixed and fed into Channel 12 of the magnetophone.

Telephony

Telephone transmissions and messages received are also recorded by Operator posts and taken from the points indicated on the diagram as "telephone record" and "L.C. loudspeaker record", being conveniently mixed and fed into the magnetophone in the following manner:

Operator Post	A	Channel 2
" "	B	Channel 3
" "	C	Channel 4
" "	D	Channel 5
" "	E	Channel 6

Channel 1 of the magnetophone records the time signals.

1.11 Flight recorders

1.11.1 KLM 4805

KLM Boeing 747, registration PH-BUF, flight number 4805, was equipped with a digital flight data recorder (DFDR) and a cockpit voice recorder (CVR).

Digital flight data recorder (DFDR)

This was a Sundstrand model 573 A with 41 parameters. The box was considerably damaged by the impact and fire. The front aluminium panel was missing, so that the tape covering could be seen. Therefore, no serial number was immediately available, and this was obtained from the KLM records.

1.11.2 PAA 1736

Boeing 747, registration N736PA, belonging to Pan American World Airways Company, flight number 1736, was equipped with a digital flight data recorder (DFDR) by Lockheed Aircraft Service Co. (LAS), Model 209-E, serial number 375. The DFDR was not damaged by fire and suffered only sight damage due to the impact.

It was also equipped with a cockpit voice recorder (CVR), model Fairchild A-100, serial number 504.

Both recorders were transported, duly sealed, by the Spanish Civil Aviation Authorities to the N.T.S.B. in Washington for transcription.

1.12 Aircraft wreckage

A 1:2 000 scale plan showing the position of the wreckage of the KLM aeroplane, PH-BUF, and of the Pan Am aeroplane, N736PA, is herewith attached.

1.13 Medical and pathological information

On account of the magnitude of the disaster, the Spanish, Dutch and American medical authorities, as well as the Spanish Judicial Authority, agreed that the pathological teams should work together on the tasks of identification, embalming and possible autopsies.

It was not possible to perform autopsies on the members of the KLM crew on account of the state of the bodies.

1.14 Fire

1.14.1 Alarm and mobilization of the fire fighting team

The weather conditions, with fog patches at 0 m, prevented the accident from being immediately and directly visible from the control tower, where they only heard one explosion followed by another, without being able to localize them or ascertain their cause.

Moments later, an aircraft located on the parking apron advised the tower that it had seen a fire, without specifying the exact place nor its cause.

The tower immediately sounded the fire alarm for the fire service, informing them that there was a fire and that they should be prepared for an urgent departure. The tower had not yet been able to locate the fire.

Subsequently, a member of the CEPSA Co. arrived at the fire station parking lot, where the firemen were all ready and prepared, and told them that there was a fire "to the left to the parking area" .

This was the first, though vague, indication regarding the location of the fire. The firemen immediately communicated this information to the tower, and set out at the greatest possible speed, which nevertheless was very low because the weather conditions resulted in a serious risk of collision with persons, vehicles and aeroplanes, in view of the fact that they had to cross the very congested parking apron diagonally.

Finally, they saw a bright light through the fog and when they came closer, although they were as yet unable to see the flames, they suffered the effects of strong heat radiation.

When there was a slight clearing, they saw for the first time that there was a aeroplane totally envelopped in flames, its only visible part being the rudder.

After they began to fight the fire, a greater clearing opened in the fog and they saw a bright light further away, which they thought at first was a part of the same aeroplane that had broken off and was also burning.

They divided up the fire trucks and, on approaching what they thought was only a second focal point of the same fire, they discovered a second aeroplane on fire. They immediately concentrated their main efforts on this second aeroplane because the first was already totally irrecoverable.

As a result of this action, they were able - in spite of the tremendous range of the fire in this second aeroplane - to save the left side, from which between fifteen and twenty thousand kg of fuel were subsequently removed.

Meanwhile, because of the dense clouds surrounding it, the tower was still unaware of the exact location of the fire and whether one or two aeroplanes had been involved in the accident.

1.14.2 The impact, start of and extinguishing of the fire

There is no indication of any failure prior to the impact. The distance from the approach end of runway 30 to the Pan Am wreckage was about 1 385 m. From here to the main KLM wreckage there was a distance of about 450 m.

The Pan Am aeroplane was at an angle of about 45 degrees relative to the centre of the runway, *i.e.*, at about 75 degrees magnetic. It is possible that it continued to move after the impact.

Apparently, the KLM no. 1 engine only grazed the tip of the Pan Am aeroplane's right side; the nose and front landing gear overshot the latter aeroplane and the main landing gear smashed against it in the area of its no. 3 engine. (See Appendix 4 showing the position of the two aeroplanes at the moment of impact).

The KLM aeroplane was already entirely airborne when the impact took place. Its tail drag had scraped the runway in an excessive rotation for a distance of 65 ft; the tracks on the runway began about 300 ft before the place of impact.

Some sections of the right side of the Pan Am aeroplane were found near the KLM one, indicating that there was indeed an impact there.

The KLM fuselage skidded over the Pan Am aft fuselage, destroying it and shearing off the empennage. The KLM aeroplane continued in flight, hitting the ground about 150 m further on and sliding another 300 m on the runway. It caught fire suddenly and violently.

The four available turret trucks, with their corresponding crews, were initially used for extinguishing the fire. Later, all the airport Fire Service vehicles, except one which was out of service and the two first-aid Land Rovers, were added. Likewise, within a few minutes, fire fighting units from La Laguna and Tenerife joined in, with three tank trucks. The fire was not totally extinguished until 0330 on March 28.

Five thousand kilograms of foam (Tutogene) and about 500 000 L of water were used in order to put out the fire.

1.14.3 Fire fighting equipment

a) The Tenerife Airport Fire Fighting Unit had the following equipment available at the time of the accident:

- 2 Walter Yankee 4 200 L water and 840 kg foam Turret Trucks
- 2 Walter Yankee 4 200 L water and 800 kg foam Turret Trucks
- 1 Walter Yankee 3 550 L water and 660 kg foam Turret Truck
- 1 Walter Yankee 12 000 L water truck
- 1 International 5 886 L water and 600 kg foam truck
- 1 International 750 kg foam truck (dry chemical)
- 2 Land Rover 250 kg powder first-aid vehicles

One Walter Yankee turret truck was out of service, as indicated in the NOTAM.

b) Training of fire fighting team

Theoretical training takes place practically every day, in the form of classes and explanations regarding deployment, using the wall-mounted visual displays in the fire station.

All equipment is tested and personnel are drilled three times a month with fire-pit exercises and dry runs, with a constant view to achieving optimum readiness as well as maximum efficiency and rapidity of response.

Eight men are regularly kept partially suited during peak airport traffic periods. In practice, two men are ready at all times and all the fire station trucks are ready to roll within 30 to 45 seconds after the alarm sounds.

1.14.4 Rescue and survival

There were no survivors in the KLM aircraft, even though the impact both against the Pan Am aeroplane and against the ground could not have been excessively violent. However, an immediate and raging fire must have prevented adequate emergency operations because all the aircraft's evacuation doors remained shut even though the fuselage was not significantly deformed.

In the Pan Am aircraft, the first-class lounge disappeared as a result of the impact, as well as nearly the whole of the top of the fuselage. The lounge floor gave way, which meant that the crew had to jump to the first-class section and get out through a hole in the left wall, behind the L.1 exit. This hole was the main escape route for the passengers located in the forward part of the aircraft. None of those in the first-class lounge survived.

According to the survivors, the shock of impact was not excessively violent, leading them to believe that the cause was an explosion. They jumped to the ground through openings in the left side, or through door L.2 which was duly opened, from a height of 20 ft (6 m). The left engines were still turning and there was a fire under the wing on this side. A large number of passengers escaped off this wing, jumping from it to the grass. Explosions were already taking place, and the ambulances appeared almost immediately.

At the centre and aft of the aeroplane, the accumulation of wreckage and twisting of metal sheets of the fuselage must have been such that, apart from the fire which suddenly broke out, it formed a kind of trap, preventing forward exit of the passengers.

Total evacuation time is estimated to have been about one minute. The crew and "extra crew" helped effectively in the evacuation. Subsequently, airport personnel and even private individuals who happened to be there also provided effective help. There were five ambulances in the airport at the time of the accident.

The general plan of evacuation worked very much in accordance with what had been planned in case of emergency. In general, it was carried out very rapidly and there was a free traffic flow between the airport and the hospitals. This operation was directed by the Civil Guard for Traffic.

Local radio transmitters requested that anyone who could help should go to the airport. This appeal, which undoubtedly was made with the best of intentions. nevertheless had negative consequences because, when most of the people arrived, the PAA injured had already been evacuated, and a traffic jam occurred which could have made the providing of further help more difficult.

There were large-scale blood donations. All the injured were promptly and duly taken care of in the Santa Cruz hospitals, so that it was not necessary to make use of the three surgical teams and 89 hospital beds made available in Puerto de la Cruz.

1.15 Tests and investigations

1.15.1 In the investigation of this accident, the following tapes play a very important role: the two digital flight recorders (DFDR), one belonging to the Pan American Boeing 747, N736PA, and the other to the KLM Boeing 747, PH-BUF; the two cockpit voice recorders (CVR), one of which also belonged to each aeroplane; and the Tenerife Control Tower transmission tapes. The KLM DFDR and CVR were located in the aeroplane's tail section. The Pan Am DFDR was located in the tail section and the CVR in the cockpit.

1.15.2 KLM DFDR

The KLM DFDR box was considerably damaged by the impact and fire. The front aluminium panel was missing, so that the tape cover was visible. Therefore, no serial numbers were immediately available, and these had to be obtained from the KLM Company records. The unit's stainless steel cover was deformed and it could not be taken out of the structure. It had to be removed by opening the welded joint by means of a hammer and chisel. At first large scissors were used to try and cut the casing in order to open it, but this attempt failed. Once the casing had been removed, the shock-proof cover was separated from the electronic section by means of an iron

lever (the cover was attached to the electronic section with an anti-shock mounting). The lid bolts were removed from the shock-proof cover, and it was taken off. The DFDR heat insulation material had been singed and separated from the lid.

The teflon sheaths of the magnetic recording wire connectors were not burned and had kept their original colours. These would probably have been discoloured by temperatures above their MST temperatures of 400° to 478°F. The nylon cord used to tie the wire reels was discoloured. The MST for the nylon used is 250° to 300°F. There was no proof of melted welding, which indicates that the temperature did not reach 360°F. Therefore, it is probable that the temperature to which the cover was subjected was between 250° and 360°F.

Burn marks were found on the steel disc covering the upper reel, as well as on the reading head and on the reels themselves. The aluminium reels had a slightly golden colour. This shade of colour could have been caused by some material which gave off gases inside the cover during the fire.

The tape was found intact, without breakages. It was smudged and discoloured in the places where it was revolving around the reels and the heads at the moment that the recorder stopped working.

The mechanism had a burned area at its point of contact with the tape. It was possible to remove the heaviest bits from the tape by using alcohol, cotton and cotton tips. It was possible to read all the data on the tape after adequate cleaning.

The whole of the tape except for the last six meters was on the bottom reel. The accident data were on track 1.

DFDR tapes are made of a material called Vicalloy. They are 0.64 cm wide and 247 m long. Four tracks are recorded - two forward and two backward. Only one track records at a time and each track lasts approximately 6.25 hours, making a total time of 25 hours. There are two recording heads - one going forward and the other backward - as well as two playback and two eraser heads. The tape recording speed is 1.09 cm/sec and the playback speed is 14.2 cm/sec.

1.15.3 The Pan American DFDR

The PAA aircraft DFDR was not damaged by fire, and only slightly damaged by the impact. The inner and outer seals (dated 22 March 1977) were intact, as were the four screw seals for the box (S/N 1413).

The DFDR box is a shock-proof casing. The heat indicator is outside the tape cover. A temperature indicator (TEM PLATE) outside the tape cover showed a temperature of between 110° and 120°F, indicating that this was the highest temperature to which the box had been exposed.

When the tape covering was opened up, the tape was found to be intact, without any breakages and in excellent condition. On account of the strong impact to which this unit was subjected, the tape had come off the reel and two revolutions had fallen off the lower reel. The tape was handled carefully and replaced on the reels. Most of it was on the lower reel, with approximately 28 m remaining on the upper reel.

There was no problem with playback. The data were found between 105-113 m on track 3.

The DFDR LAS tape is based on Mylar, with an instrumentation grade 1.0 mm thick, 0.64 cm wide and approximately 145 m long (of which about 142 m are used for recording). Six tracks are registered, three forward and three backward. Only one track is recorded at a time and each one lasts approximately 4.2 hours, making a total recording time of 25 hours. There are two recording heads (one going forward and the other backward) and two playback heads. There are no eraser heads. The tape's recording speed is 0.94 cm/sec and the playback speed is 30 cm/sec.

1.15.4 Boeing 747, N736PA, cockpit voice recorder

As previously stated, the Pan American aeroplane's CVR was an A-100, with its identification plate missing. Pan American records show that the serial number was 504. This Fairchild CVR was only blackened. The tape was removed, copied and transcribed in accordance with normal procedures.

This CVR has four channels, which are recorded simultaneously. Recording is continuous, but only the last 30 minutes are kept. On one of the channels, that corresponding to the cockpit microphone area, all the latter's sounds are recorded. On the other three channels are recorded the communications from the Captain, First Officer and Flight Engineer, respectively.

Transcription of this flight recorder was carried out in the N.T.S.B. laboratories in Washington.

1.15.5 KLM Company Boeing 747, registration PH-BUF, cockpit voice recorder

It was not possible to transcribe this aeroplane's CVR at the N.T.S.B. because there was no reading equipment for this recorder in the N.T.S.B. laboratories, as the U.S. airline companies had not acquired this type of CVR. It was taken by a representative of the Spanish Civil Aviation Authorities to the Sundstrand equipment manufacturers in Seattle (U.S.A.) on 5 April 1977. Members of the N.T.S.B. and KLM accompanied this representative. When copies of the CVR were taken to the N.T.S.B., it was observed that there were noises and echoes, and for this reason the said representative returned to Sundstrand on April 7. New copies were made, partially suppressing the noises and echoes and obtaining recordings of satisfactory quality.

Like the Pan Am CVR, this CVR has four channels, which are:

- Channel 1: Flight Engineer's communications
- Channel 2: Co-pilot's communications
- Channel 3: Captain's communications
- Channel 4: Sounds in cockpit area.

The transcription of the said tapes on paper was carried out in the N.T.S.B. laboratories.

1.15.6 Tape of Tenerife Control Tower's communications

The Spanish Authorities made a cassette copy of the Tenerife Control Tower tape available. The original is in the hands and under the custody of said Authorities. A problem arose when an attempt was made to correlate the times of the tower tape with those of the Pan Am and KLM CVRs. The codified signal and the conversation in the tower were recorded simultaneously on the cassette and it was difficult to read the time signal. Moreover, the tape apparently changed speeds, making it difficult to correlate the time elapsed. Therefore, the Pan Am CVR was used as a basic time reference, being in perfect agreement with this aircraft's DFDR.

The GMT time was determined by means of a transcription of the tower tape, whose chronology it was possible to ascertain with an acceptable degree of accuracy. This technique proved to be satisfactory as it was in agreement with the Pan Am and KLM CVR times. The PAA and KLM speeds were adjusted in such a way that the aeroplanes' 400 Hz energy was synchronized with the audio laboratory clock and, therefore, with the real time. The Pan Am CVR times were the most accurate during the initial period, on account of the Sundstrand B 557 B recording method. The degree of error is negligible. The Sundstrand tape is not continuous, but rather reverses its direction every 15 minutes.

The tape's basic time reference was determined by simultaneously recording the CVR and a digital watch on a video tape.

Subsequently the Spanish Authorities made copies of the control tower tape available; these did not give rise to time correlation problems.

1.16 Human factors

There is no evidence of contributory medical causes.

Socio-psychological causes

1. Limits on duty time of Dutch crews

Until a few years ago, the Flight Captain was able, at his own discretion, to extend the limit on his crew's activity in order to complete the service. However, this was recently changed in the sense of imposing absolute rigidity with regard to the limit of activity. The captain is forbidden to exceed it and, in case he should do so, may be prosecuted under the law.

Moreover, until December 1976, it was very easy to fix the said limit of activity by taking only a few factors into account, but this calculation has now been made enormously complicated and in practice it is not possible to determine it in the cockpit. For this reason it is strongly recommended that the Company be contacted in order to determine it.

This was the situation in Tenerife, and for this reason the captain spoke by HF to his company's operations office in Amsterdam. There they told him that if he was able to take off before a certain time it would seem that there would be no problems, but that if there was any risk of exceeding the limit they would send a telex to Las Palmas.

This uncertainty of the crew, who were not able to determine their time limit exactly, must have constituted an important psychological factor.

2. Those who serviced the KLM aeroplane in Tenerife stated that the crew appeared calm and friendly. Nevertheless, they perhaps felt a certain subconscious - though exteriorly repressed - irritation caused by the fact that the service was turning out so badly, with the possible suspension of the Las Palmas-Amsterdam flight and the resulting alteration of each person's plans, which would be aggravated by the existence of other possible sources of lateness such as ATC delays, traffic congestion in Las Palmas, etc.

3. Behaviour

3.1 *Care*. This can be divided into voluntary and involuntary, or subconscious. The increase in one brings with it a decrease in the other.

Visibility both before and during the accident was very variable. It changed from 1 500 to 300 m or less in very short periods of time. This undoubtedly caused an increase in subconscious care to the detriment of conscious care, part of which was already directed toward take-off preparation (completing of check-lists, taxiing with reduced visibility, decision to take off or to leave the runway clear and execute a difficult 180 degree turn with a 747 on a 45 m runway, in fog).

3.2 *Fixation.* Two kinds: a fixation on what is seen, with a consequently diminished capacity to assimilate what is heard, and another fixation on trying to overcome the threat posed by a further reduction of the already precarious visibility. Faced with this threat, the way to meet it was either by taking off as soon as possible, or by testing the visibility once again and possibly refraining from taking off (a possibility which certainly must have been considered by the KLM captain).

3.3 *Relaxation.* After having executed the difficult 180 degree turn, which must have coincided with a momentary improvement in the visibility (as proved by the CVR, because shortly before arriving at the runway approach they turned off the windscreen wipers), the crew must have felt a sudden feeling of relief which increased their desire to finally overcome the ground problems: the desire to be airborne.

4. Possible biometrical factors

4.1 *Fatigue.* Although within reasonable limits, fatigue began to be felt.

4.2 *Overload.* Problems were accumulating for the captain to a degree far greater than that of a normal flight. Likewise for the co-pilot, who did not have much experience in 747s.

4.3 *Low-frequency electromagnetic waves.* According to certain studies, these have a deleterious effect on man's intellectual performance (*e.g.*, 400-cycle alternative current waves in an aircraft).

4.4 *Noise and vibration.* Their level is quite high in a 747 cockpit.

5. Other possible causes

5.1 *Route and pilot-instruction experience.* Although the captain had flown for many years on European and intercontinental routes, he had been an instructor for more than ten years, which relatively diminished his familiarity with route flying. Moreover, on simulated flights, which are customary in flight instruction, the training pilot normally assumes the role of controller - that is, he issues take-off clearances. In many cases no communications whatsoever are used in simulated flights, and for this reason take-off takes place without clearance.

5.2 *Authority in the cockpit.* Although nothing abnormal can be deduced from the CVR, the fact exists that a co-pilot not very experienced with 747s was flying with one of the pilots of greatest prestige in the company who was, moreover, KLM's chief flying instructor and who had certified him fit to be a crew member for this type of aeroplane. In case of doubt, these circumstances could have induced the co-pilot not to ask any questions and to assume that this captain was always right.

2.- ANALYSIS AND CONCLUSIONS

2.1 Analysis

On 27 March 1977, a bomb exploded in the terminal building of Las Palmas Airport (Canary Islands), and for this reason the passenger terminal was evacuated. As there had been a threat of a second explosion, much of the traffic arriving at Las Palmas Airport was diverted to that of Los Rodeos on Tenerife Island. For this reason, the parking area at the latter airport was crowded with aeroplanes.

The KLM Boeing 747, PH-BUF, arrived at Los Rodeos Airport at 1338 and was parked at the end of the taxi runway next to a Breathens Boeing 737 (SAFE). Subsequently, a Sterling Boeing 727, a SATA DC-8 and the Pan American 747, N736, were parked in the same area.

The Pan Am Boeing 747, which arrived at Los Rodeos Airport at approximately 1415, was parked on the taxi runway next to the above-mentioned Breathens Boeing 737, Sterling Boeing 727, SATA DC-8 and the KLM Boeing 747, PH-BUF, which had arrived at Los Rodeos Airport at 1338.

Once Las Palmas Airport had been reopened, the Pan Am N736 aeroplane called the tower requesting permission to start up its engines; in reply, it was told that there was no ATC delay, but that it could have problems taxiing on account of the KLM aeroplane which was ahead of it, and that taxiing on the taxiway would not be possible on account of the aircraft congestion on the main apron.

Indeed, when the time came to taxi, the Pan Am aeroplane was forced, on account of the position of the KLM aeroplane which was blocking its way, to wait for the latter's departure. The three other aeroplanes parked there had already departed.

Approximately one hour later, KLM 4805 requested an estimated departure time. They said that they needed to refuel and that this would take approximately 30 minutes. They filled up with 55 500 L, while the passengers remained on board. Later the KLM aeroplane requested permission to start up its engines, and then clearance to taxi.

It was cleared to taxi towards the holding position of runway 12 and to change its surface frequency of 118.7 to the approach frequency of 119.7.

A few minutes later, the Pan Am aeroplane called again in order to request clearance to start up its engines, and was cleared to do so.

If we keep in mind that the Tenerife-Las Palmas flight is one of about 25 minutes duration, the taking on of 55 500 L of fuel leads us to suppose that the KLM captain thereby wished to avoid the difficulties of refuelling in Las Palmas, with the resulting delay, because a great number of aeroplanes diverted from Tenerife would be going there later. The aircraft could, in fact, have returned to Amsterdam with the fuel it had without refuelling in Las Palmas.

The conversations which took place between KLM 4805 and the control tower until the aeroplane started to taxi on the main runway were as follows. The times are those taken from the KLM CVR.

Time	Source	Content
1658:14.8	KLM 4805	Approach KLM four eight zero five on the ground in Tenerife.
1658:21.5	APP	KLM - ah - four eight zero five Roger.
1658:25.7	KLM 4805	We require back track on one two for take-off runway three zero.
1658:30.4	APP	O.K. four eight zero five... taxi... to the holding position runway three zero taxi into the runway and - ah - leave runway (third) to your left.
1658:47.4	KLM 4805	Roger, sir, (entering) the runway at this time and the first (taxiway) we, we go off the runway again for the beginning of runway three zero.

Time	Source	Content
1658:55.3	APP	O.K. KLM eight zero - ah - correction four eight zero five taxi straight ahead - ah - for the runway and - ah - make - ah - back track.
1659:04.5	KLM 4805	Roger, make a "back track".
1659:10.0	KLM 4805	KLM four eight zero five is now on the runway.
1659:15.9	APP	Four eight zero five roger.
1659:28.4	KLM 4805	Approach, you want us to turn left at Charlie one, taxiway charlie one?
1659:32.28	APP	Negative, negative, taxi straight ahead - ah - up to the end of the runway and make "back track".
1659:39.9	KLM 4805	O.K., sir.

At 1703:14.4, KLM 4805 asked the tower controller if the runway centre lights were in service because, as the weather conditions were becoming worse, he wished to have this information in connexion with the minimum required take-off conditions.

At 1704:58.7, the tower controller, after having checked, replied that the runway centre lights were out of service, while he also passed on this information to the PAA Clipper 1736.

At 1705:27.08, KLM 4805, which was already at the approach end of runway 30, completed the turn in order to face in the direction for take-off.

From this point on, see the diagram (Appendix 5) showing the time correlation between the tower, the KLM 4805 and the Clipper 1736 CVR tapes, as well as the data obtained from the KLM 4805 DFDR during the last 88 seconds.

At 1705:27.98, the engine braking begins and lasts for 2.54 seconds.

At 1705:36.7, the co-pilot finishes the take-off check-list and at 1705:41.22 (67.81 seconds before the impact), a slight forward movement due to opening of the throttle is observed (increase of continued EPR in the four engines). At 1705:41.5, the co-pilot says: "Wait a minute, we don't have an ATC clearance." To which the captain replies, "No, I know that, go ahead, ask."

At 1705:44.6, KLM 4805 tells the control tower: "Ah - the KLM four eight zero five is now ready for take-off, and we're waiting for our ATC clearance." This message ended at 1705:50.77. This communication was heard in the PAA 1736 cockpit.

At 1705:53.41, the controller gave KLM the following ATC instruction: "KLM eight seven zero five - uh - you are cleared to the Papa Beacon, climb to and maintain flight level nine zero ... right turn after take-off proceed with heading zero four zero until intercepting the three two five radial from Las Palmas VOR." The message ended at 1706:08.9. At 1706:07.39, i.e., 0.7 seconds before the message ended, the aircraft captain said, "Yes", and 44.31 seconds before the impact the nos. 3 and 4 engines slightly increased their EPR.

At 1706:09.61, the co-pilot repeated the ATC instructions given by the tower controller, at the following times and as follows:

Time	Source	Content
1706:09.61	KLM 4805 (RD 2)	Ah- Roger, sir, we are cleared to the Papa Beacon flight level nine zero, right turn out zero four zero until intercepting the three two five. We are now at take-off.

At 17:17.79, the co-pilot's repetition of the ATC instructions ended.

At 1706:11.08, the brakes of KLM 4805 were released. At 1706:12.25, the aircraft captain said, "Let's go ... check thrust", ending this sentence at 1706:16.11.

The following was ascertained from the DFDR data:

- 1706:11.70 (37.33 seconds before impact): it was deduced from the LONG that the aeroplane began to move with longitudinal acceleration.

- 1706:13.99 (35.04 seconds before impact): the EPR have risen above the figures for idling (1.12-1.12-1.14-1.14).

- 1706:14.94 (34.09 seconds before impact): the start of change of course was observed from the HEAD.

- 1706:17.17 (31.86 seconds before impact): from the VANE it can be ascertained that lift had begun. Value reached was 6.80°. Air speed was increasing (46.41). Direction straightened out.

From everything that happened during this time, it is seen that while the first officer was repeating the ATC instructions given by the controller, KLM 4805 had already started its ground run, while at 1706:14.00, moreover, the sound of engines starting to accelerate is observed.

At 1706:18.19, the controller replied to the read-back of his ATC clearance in the following way: "O.K.", and at 1706:20.08, *i.e.* 1.89 seconds later, added: "Stand by for take-off ... I will call you," ending said message at 1706:21.79.

During this time, at 1706:19.35, the KLM 4805 take-off EPR had already been reached and stabilized (1.39 to 1.42).

Simultaneously, in the Pan Am cockpit, on hearing this conversation, the pilot says "No, uh", and the co-pilot says, "and we are still taxiing down the runway, the Clipper one seven three six". This communication caused a shrill noise in the KLM cockpit, which started at 1706:19.39 and ended at 1706:22.06.

At 1706:25.47, the tower controller confirmed reception of the Pan Am message in the following way: "Papa Alpha one seven three six report runway clear." This was audible in the KLM cockpit. The message ended at 1706:28.89.

At 1706:29.59, the PAA replied: "O.K., will report when we're clear." This reply was audible in the KLM cockpit.

The control tower replied, "Thank you", and then the following sentences were spoken in the KLM cockpit:

Time	Source	Content
1706:32.43	C3	Is he not clear, then?
1706:34.10	C1	What do you say?
1706:34.15	PA	Yup
1706:34.70	C3	Is he not clear that Pan American?
1706:35.70	C1	Oh, yes. (emphatic)

At 1706:43.49, the co-pilot intoned the V_1 and subsequently on the DFDR recording the following were observed: a pulling of the control column, with the aeroplane nose pointing up, 16 per cent of the way back from a 44 per cent forward position and from Pitch 2, aeroplane nose pointing up.

At 1706:46.04, *i.e.*, 2.99 seconds before impact, increased direction toward the right is observed in the HEAD; 0.46 seconds later, a curving of the aeroplane to the left is seen in the Roll parameter (ROLL) and, 1.54 seconds before impact, a roll to the right is observed in the Roll Control Wheel Position parameter (RCW).

At 1706:47.44, the captain utters an exclamation, while the impact takes place shortly afterwards.

On listening to the PAA CFR, it may be deduced that its crew saw the KLM aeroplane 9.5 seconds before the impact.

From the actions of the Tenerife Control Tower, it may be inferred that their ordering the KLM aeroplane to leave the runway by the third taxiway was so that they should leave the main runway as soon as possible and proceed along the parallel taxiway. This third taxiway was the first by which it was possible to take the aeroplane off the main runway because access to the parallel taxiway by C-1 and C-2 was not possible on account of the aircraft congestion on the parking apron.

Later, in order to make the manoeuvre easier, the controller chose to order this aeroplane to continue down the right side of the main runway and at the end of same make an 180 degree turn.

Likewise, he indicated to the PAA crew that they should leave by the third taxiway. At first there was some confusion regarding the words "first" and "third". But this was finally dispelled because the controller made the following clarification: "The third one, sir, one, two, three, third one."

The situation deteriorated further when low-lying clouds reduced visibility to the point at which neither aeroplanes taxiing on the main runway, nor some of those located in the parking area, were visible from the tower.

It transpires from careful listening to the KLM CVR that although cockpit operation was correct and the check-lists were adequately kept, there was some feeling of anxiety regarding a series of factors, which were: the time margin remaining to them, to the point of straining the allowable limit of their duty time; the poor and changing visibility which, especially as the runway centre lights were not operative, might prevent the possibility of take-off within the weather limits required by the company; the inconvenience for the passengers, etc. It is also observed that, as the time for take-off approached, the captain - perhaps on account of all these worries - seemed a little absent from all that was heard in the cockpit. He enquired several times, and after the co-pilot confirmed the order to backtrack, he asked the tower if he should leave the runway by C-1, and subsequently asked his co-pilot if he should do so by C-4. On arriving at the end of the runway and making an 180 degree turn in order to place himself in take-off position, he was advised by the co-pilot that he should wait as they still did not have an ATC clearance. The captain asked him to request it, which he did, but while the co-pilot was still repeating the clearance, the captain opened the throttle and started to take off. Then the co-pilot, instead of requesting take-off clearance or advising that they did not yet have it, added to his read-back, "We are now at take-off." The tower, which was not expecting the aircraft to take off as it had not given clearance, interpreted the sentence as, "We are now at take-off position"[1] and the controller replied: "O.K., ... stand by for take-off ... I will call you." Nor did the Pan Am crew, on hearing the "We are now at take-off", interpret it as an unequivocal indication of take-off. However, in order to make their own position clear, they said, "We are still taxiing down the runway." This transmission coincided with the "Stand by for take-off ... I will call you", causing a whistling sound in the tower transmission and making its reception in the KLM cockpit not as clear as it should have been, even though it did not thereby become unintelligible.

The communication from the tower to the PAA aeroplane requested the latter to report when it left the runway clear. In the cockpit of the KLM aeroplane which was taking off, nobody at first confirmed receiving these communications (Appendix 5) until the Pan Am aeroplane responded to the tower's request that it should report leaving the runway with an "O.K., we'll report when we're clear." On hearing this, the KLM flight engineer asked: "Is he not clear then?" The captain didn't understand him and he repeated: "Is he not clear that Pan American?" The captain replied with an emphatic "Yes" and, perhaps influenced by his great prestige, making it difficult to imagine an error of this magnitude on the part of such an expert pilot, both the co-pilot and the flight engineer made no further objections. The impact took place about thirteen seconds later.

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[1] When the Spanish, American and Dutch investigating teams heard the tower recording together for the first time, no one, or hardly anyone, understood that this transmission meant that they were taking off.

From that moment until the next call to the aeroplanes, the tower took care of Flights IB-185 and the BX-387 and awaited the communication from Pan Am Flight 1736 reporting the "runway clear". It also received information coming from two aeroplanes located in the parking area that there was a fire in an undetermined place on the field, sounded the alarm, informed the Fire Fighting and Health Services, and broadcasted the news of the emergency situation; it then called the two aeroplanes on the runway, without receiving any reply.

The conversations which took place in the Pan Am cockpit and between the aeroplanes and the control tower from 1701:57.0 were as follows. The times were taken from the PAA CVR.

Time	Source	Content
1701:57.0	CL1736	Tenerife the Clipper one seven three six. (1702:00.2)
1702:01.8	APP	Clipper one seven three six Tenerife.
1702:03.6	RDO-2	Ah- We were instructed to contact you and also to taxi down the runway, is that correct? (1702:07.4)
1702:08.4	APP	Affirmative, taxi into the runway and -ah- leave the runway third, third to your left, (background conversation in the tower).
1702:16.4	RDO-2	Third to the left, O.K. (17:02.18.3)
1702:18.4	CAM-3	Third he said.
	CAM-?	Three.
1702:20.6	APP	-ird one to your left.
1702:21.9	CAM-1	I think he said first.
1702:26.4	CAM-2	I'll ask him again.
	CAM-?	**
1702:32.2	CAM-2	Left turn.
1702:33.1	CAM-1	I don't think they have take-off minimums anywhere right now.
1702:39.2	CAM-1	What really happened over there today?
1702:41.6	CAM-4	They put a bomb (in) the terminal, Sir, right where the check-in counters are.

Time	Source	Content
1702:46.6	CAM-1	Well we asked them if we could hold and -uh- I guess you got the word, we landed here * *
	CAM-X	* * *
1702:49.8	APP	KLM four eight zero five how many taxiway -ah- did you pass?
1702:55.6	KLM	I think we just passed charlie four now.
1702:59.9	APP	O.K. ... at the end of the runway make one eighty and report -ah- ready -ah- for ATC clearance (background conversation in the tower).
1703:09.3	CAM-2	The first one is a ninety degree turn.
1703:11.0	CAM-1	Yeah, O.K.
1703:12.1	CAM-2	Must be the third ... I'll ask him again.
1703:14.2	CAM-1	O.K.
1703:16.6	CAM-1	We could probably go in it's ah ...
1703:19.1	CAM-2	You gotta make a ninety degree turn.
1703:21.6	CAM-1	Yeah, uh.
1703:21.6	CAM-2	Ninety degree turn to get around this ... this one down here it's a forty five.
1703:29.3	RDO-2	Would you confirm that you want the clipper one seven three six to turn left at the third intersection? (1703:35.4). (PAA: "third" drawn out and emphasized).
1703:35.1	CAM-1	One, two.
1703:36.4	APP	The third one, sir, one, two, three, third, third one (1703:38.3).
1703:38.3	CAM-?	One two (four).
1703:39.0	CAM-1	Good .
1703:39.2	RDO-2	Very good, thank you (1703:40.4).
1703:40.1	CAM-1	That's what we need right, the third one.

Time	Source	Content
1703:42.9	CAM-3	Uno, dos, tres.
1703:44.0	CAM-1	Uno, dos, tres.
1703:44.9	CAM-3	Tres - uh - si.
1703:46.5	CAM-1	Right.
1703:47.6	CAM-3	We'll make it yet.
1703:47.6	APP	...er seven one three six report leaving the runway.
1703:49.1	CAM-2	Wing flaps?
1703:50.2	CAM-1	Ten, indicate ten, leading edge lights are green.
1703:54.1	CAM-?	Get that.
1703:55.0	RDO-2	Clipper one seven three six (1703:56.4)
1703:56.5	CAM-2	Yaw damp and instrument?
1703:58.6	CAM-1	Ah- Bob we'll get a left one *.
1703:59.3	CAM-2	I got a left.
1704:00.6	CAM-1	Did you?
1704.00.9	CAM-2	And -ah- need a right.
1704:02.6	CAM-1	I'll give you a little *
1704:03.8	CAM-2	Put a little aileron in this thing.
1704:05.0	CAM-1	O.K., here's a left and I'll give you a right one right here.
1704:09.7	CAM-1	O.K. right turn right and left yaw.
1704:11.4	CAM-2	Left yaw checks.
1704:12.4	CAM-1	O.K., here's the rudders.
1704:13.6	CAM-1	Here's two left, centre, two right centre.
1704:17.8	CAM-2	Checks.
1704:19.2	CAM-2	Controls.

Time	Source	Content
1704:19.6	CAM-1	Haven't seen any yet!
1704:20.3	CAM-2	I haven't either.
1704:21.7	CAM-1	They're free, the indicators are checked.
1704:24.6	CAM-2	There's one.
1704:25.8	CAM-1	There's one.
1704:26.4	CAM-1	That's the ninety degree.
1704:28.5	CAM-?	O.K.
1704:34.5	CAM-?	* * *
	CAM-2	Weight and balance finals?
1704:37.7	CAM	(Sounds similar to stabilizer trim). (1704:44.8)
1704:37.2	CAM-1	We were gonna put that on four and a half
1704:39.8	CAM-3	We got four and a half and we weigh five thirty four (sound of stabilizer trim).
1704:44.6	CAM-2	Four and a half on the right.
1704:46.8	CAM-2	Engineer's taxi check.
1704:48.4	CAM-3	Taxi check is complete.
1704:50.5	CAM-2	Take-off and departure briefing?
1704:52.1	CAM-1	O.K., it'll be standard, we gonna go straight out there till we get thirty-five hundred feet then we're gonna make that reversal and go back out to * fourteen.
1704:58.2	APP	-m eight seven zero five and clipper one seven ... three six, for your information, the centre line lighting is out of service. (APP: transmission is readable but slightly broken.)
1705:05.8	KLM	I copied that.
1705:07.7	RDO-2	Clipper one seven three six.

Time	Source	Content
1705:09.6	CAM-1	We got centre line markings (* only) (could be "don't we) they count the same thing as ... we need eight hundred metres if you don't have that centre line... I read that on the back (of this) just a while ago.
1705:22.0	CAM-1	That's two.
1705:23.5	CAM-3	Yeh, that's forty-five there.
1705:25.7	CAM-1	Yeh.
1705:26.5	CAM-2	That's this one right here.
1705:27.2	CAM-1	(Yeh) I know.
1705:28.1	CAM-3	O.K.
1705:28.5	CAM-3	Next one is almost a forty-five, huh yeh.
1705:30.6	CAM-1	But it goes...
1705:32.4	CAM-1	Yeh, but it goes ... ahead, I think (it's) gonna put us on (the) taxiway.
1705:35.9	CAM-3	Yeah, just a little bit yeh.
1705:39.8	CAM-?	O.K., for sure.
1705:40.0	CAM-2	Maybe he, maybe he counts these (are) three.
	CAM-?	Huh.
1705:44.8	CAM-?	I like this.
1705:44.8	KLM	Uh, the KLM ... four eight zero five is now ready for take-off ... uh and we're waiting for our ATC clearance.
1705:53.4	APP	KLM eight seven * zero five uh you are cleared to the Papa Beacon climb to and maintain flight level nine zero ... right turn after take-off proceed with heading zero four zero until intercepting the three two five radial from Las Palmas VOR. (1706:08.2).

Time	Source	Content
1706:09.6	KLM	Ah roger, sir, we're cleared to the Papa Beacon flight level nine zero, right turn out zero four zero until intercepting the three two five and we're now (at take-off). (1706:17.9).

From the foregoing it may be inferred that the Pan Am crew at first had difficulty in understanding "third", thinking that it was "first". In any case, the co-pilot asked again and this doubt was dispelled at 1703:36.4 as the tower controller told him: "The third, sir, one, two, three, the third, third", and the co-pilot confirmed this at 1703:39.2.

As a result of the poor visibility, the crew had difficulty in localizing the exits from the runway whose position they were following on the little map that they had with them. Nevertheless, at 1704:26.4 the captain identified C-1 (which is the 90 degree exit). At 1705:22.0, they also identified C-2. Then, perhaps through error, or thinking that C-4 was an easier exit than C-3, they overshot the exit ordered by the Tower.

From Appendix 5, which gives the time correlation between the conversations taking place with the tower and inside the KLM 4805 and Clipper 1736 cockpits, as well as the data obtained from the KLM 4805 DFDR during the last 88 seconds before impact, the following may be ascertained.

When, at 1706:17.9, KLM 4805 finished reading back the ATC clearance given by the control tower and added, "We are now (at take-off)" and before the controller finished the sentence "O.K.... stand by for take-off, I will call you.", only "...k" is heard in the Pan Am cockpit. The pilot says: "No uh ..." and the co-pilot says "And we're still taxiing down the runway, the Clipper one seven three six..." (1706:23.6). These communications caused a shrill noise in the KLM cockpit, which lasted approximately 3.74 seconds.

During this time the KLM take-off EPR was reached and stabilized (1.39 to 1.42).

At 1706:25.6, the tower controller gave the Pan Am crew confirmation in the following manner: "Roger alpha one seven three six report the runway clear" - to which the Pan Am crew replied at 1706:29.6, "O.K., we'll report when we're clear." The tower replied, "Thank you", but the KLM aircraft had already started its take-off run. The Pan Am crew saw the KLM aeroplane approximately 8.50 seconds before the impact. Amidst logical exclamations of alarm they accelerated in order to try to get off the runway, but the collision was already inevitable.

2.2 Conclusions

From all of this it may be ascertained that the KLM 4805 captain, as soon as he heard the ATC clearance, decided to take off.

The fundamental cause of this accident was the fact that the KLM captain:

1. Took off without clearance.

2. Did not obey the "stand by for take-off" from the tower.

3. Did not interrupt take-off when Pan Am reported that they were still on the runway.

4. In reply to the flight engineer's query as to whether the Pan Am aeroplane had already left the runway, replied emphatically in the affirmative.

Now, how is it possible that a pilot with the technical capacity and experience of the captain, whose state of mind during the stopover at Tenerife seemed perfectly normal and correct, was able, a few minutes later, to commit a basic error in spite of all the warnings repeatedly addressed to him?

An explanation may be found in a series of factors which possibly contributed to the occurrence of the accident.

1. A growing feeling of tension as the problems for the captain continued to accumulate. He knew that, on account of the strictness in the Netherlands regarding the application of rules on the limitation of duty time, if he did not take off within a relatively short space of time he might have to interrupt the flight - with the consequent upset for his company and inconvenience for the passengers. Moreover, the weather conditions in the airport were getting rapidly worse, which meant that he would either have to take off under his minima or else wait for better conditions and run the risk of exceeding the aforementioned duty-time limit.

2. The special weather conditions in Tenerife must also be considered a factor in themselves. What frequently makes visibility difficult is not actually fog, whose density and therefore the visibility which it allows can be fairly accurately measured, but rather layers of low-lying clouds which are blown by the wind and therefore cause sudden and radical changes in visibility. The latter can be 0 m at certain moments and change to 500 m or 1 km in a short space of time, only to revert to practically zero a few moments later. These conditions undoubtedly make a pilot's decisions regarding take-off and landing operations much more difficult.

3. The fact that two transmissions took place at the same time. The "stand by for take-off ... I will call you" from the tower coincided with Pan Am's "we are still taxiing down the runway", which meant that the transmission was not received with all the clarity that might have been desired. The whistling sound which interfered with the communication lasted for about three seconds.

The following must also be considered factors which contributed to the accident:

1. Inadequate language. When the KLM co-pilot repeated the ATC clearance, he ended with the words, "we are now at take-off". The controller, who had not been asked for take-off clearance, and who consequently had not granted it, did not understand that they were taking off. The "O.K." from the tower, which preceded the "stand by for take-off" was likewise incorrect - although irrelevant in this case because take-off had already started about six and a half seconds before.

2. The fact that the Pan Am aeroplane had not left the runway at the third intersection. This aeroplane should, in fact, have consulted with the tower to find out whether the third intersection referred to was C-3 or C-4, if it had any doubts, and this it did not do. However, this was not very relevant either since the Pan Am aeroplane never reported the runway clear but, on the contrary, twice advised that it was taxiing on it.

3. Unusual traffic congestion which obliged the tower to carry out taxiing manoeuvres which, although statutory, as in the case of having aeroplanes taxi on an active runway, are not standard and can be potentially dangerous.

Although contributing to the accident, the following occurrences must not be considered direct factors in it: the bomb incident in Las Palmas; the KLM refuelling; the latter's take-off at reduced power; etc.

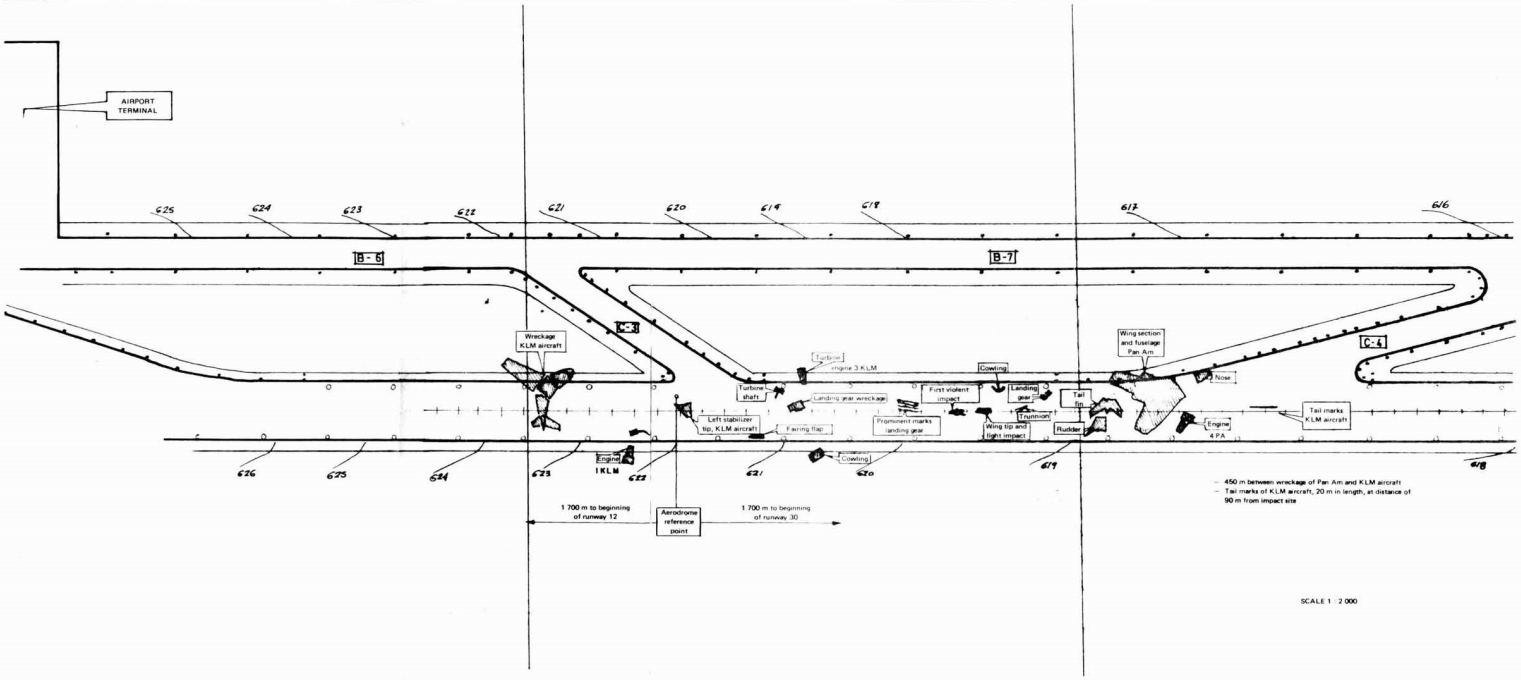
3.- RECOMMENDATIONS

3.1 Placing of great emphasis on the importance of exact compliance with instructions and clearances.

3.2 Use of standard, concise and unequivocal aeronautical language.

3.3 Avoidance of the word "TAKE-OFF" in the ATC clearance and adequate time separation between the ATC clearance and the TAKE-OFF clearance.

ICAO Note: Only Appendix 5 to the report is reproduced.
ICAO Ref.: AIG/056/77.


AIRPORT TERMINAL
625
624
623
622
621
620
619
618
617
616
B-6
B-7
C-3
C-4
Wreckage KLM aircraft
Turbine engine 3 KLM
Turbine shaft
Landing gear wreckage
First violent impact
Cowling
Landing gear
Tail fin
Fuselage
Wing section and fuselage Pan Am
Nose
Engine 4 PA
Tail marks KLM aircraft
Left stabilizer tip, KLM aircraft
Fairing flap
Prominent marks landing gear
Wing tip and light impact
Rudder
Engine 1 KLM
Cowling
626
625
624
623
622
621
620
619
618
1 700 m to beginning of runway 12
Aerodrome reference point
1 700 m to beginning of runway 30
– 450 m between wreckage of Pan Am and KLM aircraft
– Tail marks of KLM aircraft, 20 m in length, at distance of 90 m from impact site
SCALE 1 : 2 000

COMMENTS OF THE STATE OF REGISTRY (KINGDOM OF THE NETHERLANDS)

The following comments have been made by the authorities of the Kingdom of the Netherlands, being the State of Registry of one of the aircraft involved, on the causes of the accident as set out in the Spanish report.

In accordance with paragraphs 5.20 and 5.26 of Annex 13 to the Convention of Chicago, an accredited representative of the Kingdom of the Netherlands and qualified technical advisers to assist him, participated actively in the investigation with a view to contributing to the real causes of the accident. The results of their investigation have been presented to the Spanish accident investigation commission.

There is no disagreement on the facts and evidence established in the joint investigation. With regard to the interpretation of the facts and evidence, however, the views of the Netherlands investigation authorities differ substantially.

The considerations concerning the cause of the accident as mentioned in the Spanish report do not answer the question which factors explain the action or inaction of the KLM crew. In order to reach this conclusion the Spanish report over-emphasizes the influence of human factors on the KLM crew only and bases its view on assumptions and suppositions, the correctness of which cannot be found in the available evidence and, on certain points, is in contradiction with it. The inevitable consequence is that the essential lessons, which must be derived from this accident are missing in this report.

The comments contain in Part One the interpretation by the Netherlands investigation authorities of the facts and evidence established in the joint investigation, and in Part Two the considerations and conclusions as done by the Netherlands Aircraft Accident Inquiry Board in its verdict.

It should be noted that the Netherlands Aircraft Accident Inquiry Board, in its public session on 28 and 29 May 1979, has limited itself to the lessons to be drawn from the accident. The analysis and interpretation contained in Part One should be seen totally separate from the verdict of the Board.

PART ONE

Comments of the Netherlands Department of Civil Aviation

Analysis

Based on the total available evidence this analysis discusses the following items:

a) Human factors of the KLM crew, Pan Am crew and air traffic controller, which could have been of influence on the course of events.

b) The radio-communications, which can be shown to have caused a mutual misunderstanding between the KLM crew and the air traffic controller, which misunderstanding has arisen from normal, but ambiguous terminology.

c) The coincidence of a number of circumstances, which coincidence directly influenced the course of events and ultimately resulted in the collision.

a) Human factors

KLM

- The voice recorder of the KLM cockpit shows an almost relaxed atmosphere and an orderly progress of the preparations for take-off and taxiing. The weather deteriorations have been highly variable in intensity, due to drifting layers of low clouds. The crew of the American aircraft saw the landing lights of the KLM aircraft 9.5 seconds before the collision.

  From the DFDR-data it has been established that the relative distance was then 700 m, which illustrates that the visibility at that moment far exceeded the KLM limit of 300 m. Nor does the Spanish report mention any doubt about a visibility-value of more than 300 m.

  The actual visibility left the KLM captain with no doubt about the legal and practical aspects to perform the take-off. An unacceptable factor of human stress cannot be demonstrated here.

- When the cockpit check-list had been completed, the captain, keeping the aircraft on the brakes, applied standard engine power, i.e. 1.10 EPR, this value being slightly higher than idle power. This is done to check the so-called spin up of the engines prior to take-off; it is normal practice and does not imply an indication of haste.

- From the voice recorder of the KLM cockpit it is evident that the captain was aware that the ATC clearance was not yet received and he allowed himself normal time for it.

- It is an essential part of the take-off procedure that no take-off will be started without a take-off clearance, which is demonstrated by the fact that the first officer also requests for take-off clearance. This item will be further explained under paragraph b).

- After the tower had issued the clearance, the captain started the take-off run while the first officer was reading back the clearance. It is considered a normal human way of thinking of the captain that, where the entire preparation of the take-off was finished and the captain on the basis of the radio-communication was convinced to have a take-off clearance, he no longer wanted to lose time where the conditions of visibility at that moment allowed a safe take-off. Also taking into account the preceding calmness and discipline in the cockpit, this operational deviation of 6 seconds is not considered a factor which indicates an already pre-existing general picture of hurry, nor does it imply a serious operational error. It has also no direct connexion with the misunderstanding that had already arisen from the radio-communication.

- The cockpit conversation clearly indicates that the captain had the intention strictly to adhere to the official work and rest-time regulations. No factual information shows that compliance with these regulations has subjected him to a higher than normal stress. Nor does any factual information suggest that he made haste to comply with the work- and rest-time regulations.

- During taxiing out the captain several times asked the first officer information which was already supplied. This might indicate some form of absent-mindedness. However, it must be taken into account that he was occupied with the performance of the cockpit check-list.

  When the first officer remarked that they had not yet received an ATC clearance, the captain replies" "Nee, dat week ik, vraag maar" (No, I know, ask for it). It cannot be construed that he had forgotten it.

  The request for take-off clearance is part of the standard procedure and such request was made some moments later in the message of the first officer.

- The fact that the captain, being the chief instructor on this type of aircraft, had a certain prestige in relation to the first officer, is in practice a normally occurring situation in a cockpit.

  If a condition like this is not accepted as a perfectly normal situation in flight operations, the composition of a cockpit crew might in numerous cases be practically impossible.

  Considering the large flying experience of the first officer, there certainly existed no such relationship of authority between the captain and the first officer, that it would have withheld the latter from taking the correct action in case of essential shortcomings of the captain. This is already shown by the fact that the first officer drew the captain's attention to having not yet received an ATC clearance.

- Influences on human activities due to cockpit noise have been recognized over the years as an additional factor; nevertheless, it can certainly be overcome. The noise level in a B-747 cockpit during the take-off cannot be considered a factor of serious disturbance.

  The following can be concluded:

  On the basis of the available evidence it cannot be demonstrated that the cockpit crew of the KLM aircraft performed its duties in haste or was under greater stress than can be considered normal in the light of the prevailing circumstances of the delay and the weather changes. The evidence also shows no excessive fatigue either.

  The influence of human factors as applicable to all types of human activities will certainly have applied to the activities of the crew of the KLM aircraft. Yet the causal influence of the human factors on the premature take-off has not been shown in the findings of the Spanish or Netherlands investigation. Assumptions to that effect are not supported by the established facts.

PAN AM

- From the cockpit voice recorder of the Pan Am cockpit it shows that during the taxiing on the runway, the Pan Am crew was highly irritated by the extra delay caused by the refuelling of the KLM aircraft. The departure of the Pan Am aircraft was indeed delayed.

  However, the possibility that this irritation caused them to taxi past the intersection which they were instructed by the tower to use, is not evident from the facts.

The explanation of the missing of the intersection in question may be found with greater probability in the facts established by the investigation, such as: the fog that made a complete view of all intersections impossible, the absence of markers alongside the runway; the small size of the map which was used as a reference to the correct intersection, and the circumstance that during the passing of the intersections C2 and C3 the crew was performing the check-list. Also here, factors such as the rapidly varying visibility, which was far below the take-off limits applicable to Pan Am might have had an influence.

- All these human factors, however, are inherent in the normal aspects of flight operation.

  The unacceptability of these factors has never been shown in practice.

  The tower controller

- The investigation has shown that the tower controller was on duty the whole day already and had to handle an unusually high traffic load.

  In the transmissions of the tower, background noises are audible which suggest a football match, which could imply a distraction. This will be discussed later.

- During taxiing on the runway the tower controller asked KLM to report when they were ready to copy the ATC clearance. Since at that moment the KLM crew was performing the check-list, copying of this clearance was postponed until the moment that the aircraft was lined up in take-off direction. This had as a result that the requests for take-off clearance and for ATC clearance were made simultaneously.

  This procedure is not considered abnormal. A disturbing influence of a human factor in this procedure cannot be evidenced.

- The tower controller intended the Pan Am aircraft to leave the runway at the third intersection. Due to the sharp angle this intersection was more difficult than the next intersection. The controller had relatively little experience with B-747 aircraft. His instruction to use the C3 intersection might have been the consequence of a limited appreciation of the manoeuvrability of a B-747.

  From tests with a B-747 at Schiphol Airport, carried out as a part of the Netherlands investigation, it is evident that this manoeuvre could reasonably be performed.

- In the radio-communication the tower controller has been clearly audible. Nothing but usual, if not formally prescribed terminology, was found to have been used. The misunderstanding that arose from the terminology in the radio-communication is certainly not the result of errors in it. The misunderstanding will be further discussed in paragraph b). There are no human factors to be indicated as evidently disturbing influences. Only usual terminologies are employed in the communication. Even the word "O.K.", used by the controller and meaningless as it is, is often used in aviation communication. Due to coincidences it has had a confirmative effect which was not intended.

- Due to the fog there existed no visual clues for information. A picture of the situation could only be obtained by means of the radio-communication.

  Two aircraft were taxiing simultaneously on the active runway. After the tower controller had given his instruction to the KLM aircraft to hold with the words "Stand by for take-off, I will call you", it would have been more careful if he had asked the KLM for a confirmation of his instruction.

  If a confirmation had been asked for it would, in all probability, have been a timely warning to abort the take-off.

  However, it is to be considered that from none of the preceding messages the controller had received the impression that the KLM aircraft was not stationary. His statement that he thought to have heard: "We are at take-off position", also indicates this.

  From the tower tape and from the cockpit voice recorders of both KLM and Pan Am, however, it is evident that the word "position" was not used by KLM.

  Even when considering the factor as is just discussed, the tower controller has applied usual terminologies and procedures. He could not know that due to a coincidence, a squeal made his message unreadable and so he was in no way alarmed.

  It is thought that no more importance should be given to this circumstance than to all other normally occurring circumstances, which were, as shows from the investigation, applicable to all involved. Those circumstances can, however, be considered as indicative of a non-optimal functioning.

- The background noises in the tower transmissions, which suggest a football match, were not analysed in the Spanish investigation. These background noises are also audible on the cockpit voice recorder of the KLM aircraft.

  This indicates that they were really present in the tower, could be heard by the controller and were transmitted together with the communication. Listening to or looking at a football match on radio or television would imply a serious distraction. Nevertheless, the real indications that they actually caused distraction are considered not sufficiently strong to warrant any conclusions as to the human actions of the controllers.

b) The radio-communications

Due to the fact that during taxiing the KLM crew had not accepted the offer of the tower to copy the ATC clearance, both the take-off clearance and the ATC clearance had to be requested at the moment that the aircraft was lined up, ready for take-off and the check-list had been completed.

The first officer remarked to the captain that they had not yet received the ATC clearance, whereupon the captain replies: "Nee, dat weet ik, vraag maar" (No, I know, ask for it). The subsequent message of the first officer was made with the words: "We are now ready for take-off and we are waiting for our ATC clearance."

The use and meaning of the phrase "We are ready for take-off" has been extensively examined and illustrated in the Netherlands investigation report, for the purpose of which a world-wide review about its habitual meaning was made. From this part of the investigation it has been clearly established that in this phrase, two requests are made: the request for take-off clearance as well as the request for ATC clearance.

With regard to the reply to this question the following applies. The reply of the tower was: "You are cleared to the Papa beacon etc.", on which the first officer, with an increasing rate of speech, reads back the clearance and at the end adds: "We are now at take-off" or "We are now taking off".

From the CVR and the DFDR of the KLM aircraft it is evident that during the readback of this clearance, engine thrust was increased to take-off thrust, that 5 1/2 sec before the end of the readback, i.e. halfway the message, which lasts 8 seconds, the captain says: "We gaan - check thrust" (We go - check thrust), that the brakes were released and that the take-off run was started.

From these factual events it shows that the KLM crew has understood from the clearance issued by the tower, to have been cleared for take-off as well.

From the fact that the take-off run was started and from the course of events during the take-off, it is evident that the KLM crew had the absolute conviction that they were cleared for it. Considering the fog, this conviction can only be obtained through the radio-communication.

With regard to the misunderstanding which evidently resulted from the radio-communication, the following can be considered. With his message: "You are cleared to the Papa beacon etc.", the tower controller only replies to the second request, which concerned the ATC clearance. He replies on the first request, concerning the take-off clearance, only after the readback. In view of the two requests, the wording in which the clearance was given holds the possibility for the misinterpretation that on that moment clearance was given to depart actually via the indicated route.

In the context of the two requests, it is this wording from which with almost certainty, the misunderstanding of the KLM crew has arisen.

After the readback the tower controller reacts with the message: "O.K." - approx. 2 seconds pause - "stand by for take-off, I will call you."

This O.K. from the tower can only have promoted the misunderstanding, it contains a confirmation of which was just previously reported by the first officer, i.e. that they were - at take-off - or - eh, taking-off.

The tower controller stated during the joint hearing by the investigation commission, to have understood that the KLM aircraft had reported to be "at take-off position". This indicates the stationary condition of the aircraft, so that he was not alarmed by it.

It is evident that, emanating from the radio-communication, a mutual misunderstanding has arisen.

For the KLM crew this resulted in the conviction that they were cleared for take-off; for the tower controller it gave the conviction that the aircraft remained stationary.

A confirmation of the possibility that a misunderstanding could arise from the way in which the radio-communication was carried out, is found in the prompt reaction of the captain and the first officer of the Pan Am aircraft. On hearing the radio conversation up to and including the word O.K., this crew feared that the issued

clearance could possibly be understood as a take-off clearance as well. A tape recording, made shortly after the accident, on which the Pan Am captain gives his first impression, as well as the combined statement of the Pan Am crew members as contained in the NTSB contribution to the Spanish investigation, clearly substantiates this.

Their fear of a misunderstanding was so urgent that immediately after the O.K. from the tower, they reported to the KLM aircraft that they were still taxiing on the runway. The pause of approximately 2 seconds which the tower allowed between "O.K." and "Stand by for take-off, I will call you", gave the Pan Am crew the impression that the message was ended with the "O.K.", on which they immediately transmitted their warning message.

The coincidence of the message of the tower and the warning of Pan Am: "No - eh - and we are still taxiing down the runway -" caused, exclusively in the KLM cockpit, a squeal, which seriously mutilated both messages and prevented them from being received by those for whom the messages were meant.

The continuation of the take-off indicates that this message has not been intelligibly audible to both pilots.

It is noted in the Spanish report that during the investigation the sounds on the KLM CVR tape were filtered in order to improve the quality of the audibility of the tape.

In this stage of the take-off the crew was fully concentrated on the take-off run. It is not surprising that these messages, strongly disturbed by the squeal, could not be effective.

Two remarks should be made here:

- The tower controller, in no way alarmed, has in his routine, not requested a confirmation of his order to KLM: "Stand by for take-off".

- Neither the Pan Am crew nor the tower could hear the squeal, so they were not aware of this or its effect.

The messages exchanged shortly thereafter between tower and Pan Am aircraft, containing the order and the confirmation of the Pan Am aircraft to report when clear of the runway, were heard by the flight engineer of the KLM aircraft. These messages came after the squeal had stopped and on the KLM CVR they are clearly audible.

On the question of the flight engineer: "Is hij er niet af dan?" (Did he not clear the runway then?), repeated with: "Is hij er niet af, die Pan American?" (Did he not clear the runway, that Pan American?), both pilots reply with: "Jawel" (Yes, he did).

This again shows that they were absolutely convinced that the runway was clear and that take-off clearance had been given. The fact that the flight engineer puts this question shows that he, too, had the same conviction. The way in which he puts this question shows that this last received message was not consistent with the mental picture of the situation he had so far. If from this last message the flight engineer would have been convinced that the runway was not clear, he would, to all reasonability, have taken action to abort the take-off, such as a.o. an exclamation to that effect.

Also the fact that he did not interfere in the take-off, for instance by closing the throttles, for which action he would have been fully authorized in case of real doubt, indicates that the preceding communication has caused a wrong conviction.

It should be remarked that from the DFDR data can be derived that at the moment of the word "Jawel" (Yes, he did) an abort of the take-off could still be carried out successfully.

It is evident that the message heard by the flight engineer was not heard by the pilots, causing that they also did not understand the reason of his question. Seen from a point of view of operational practice, it is understandable that in this phase of the take-off, an exchange of communication, - which did not contain the call-sign of the KLM aircraft - was not registered in the minds of the unsuspecting pilots.

Summarizing, it can be stated:

- The radio-communication has not at all been exceptional in nature or contents and can be considered the usual practice.

- It is considered evident that from the radio-communication a mutual misunderstanding has arisen. This applied to both the KLM crew and the tower controller.

  From this conversation the KLM crew obtained the conviction that they were cleared for take-off; the tower controller obtained the conviction that the aircraft remained stationary. The Pan Am crew recognized and feared the possibility that the KLM could understand the clearance as a take-off clearance as well and got alarmed by it.

- Due to the generation of the squeal the audibility of essential messages of the tower and of Pan Am, were strongly disturbed in the KLM cockpit and the meaning of these messages did not reach the crew.

- The convinced reply of both pilots to the question of the flight engineer can be explained from the fact that, as no KLM call sign was used, the conversation between Pan Am and tower, from which the flight engineer derived his doubt, was not intelligibly registered in the minds of the pilots; such took place in a phase of the flight in which they were fully concentrated in performing the take-off.

- The misunderstanding did arise exclusively from the radio-communication, without other interfering circumstances. It can be stated that even without the fog, the misunderstanding could have arisen from the radio-communication.

- The procedures which in the course of events have been followed for the request and issue of the clearances, do not contain circumstances which can be considered unusual or abnormal, be it that in practice only incidentally, take-off clearance and ATC clearance are handled simultaneously.

  Possibly this explains the fact that the tower controller handles the two requests in a reversed order than in which they were made, with all consequences thereof.

- In the radio-communication terminologies were used which, though generally accepted in practice, do not express their meaning unambiguously.

  Standard procedures and terminologies for radio-communication are contained in ICAO Doc 4444, Procedures for Air Navigation Services - Rules of the Air and Air Traffic Services (PANS-RAC) and ICAO Annex 10. However, standard terminologies for the communication of aircraft with regard to requesting take-off clearance or ATC clearance are not given.

  Therefore, there can be no discussion about a standard terminology which the KLM crew should have used in requesting their clearances.

  In cases where no standard terminology is prescribed, in practice a phraseology is applied which, due to its uniform unambiguity, is considered usual and as such can be indicated as standard.

  In the relevant case "We request ....." could have been used instead of "We are ready for .....".

  In a world-wide examination, carried out as part of the Netherlands investigation concerning usual phraseology, it has positively been established that the latter terminology is in common international use as well.

  The word "O.K.", which implies a confirmation, is non-standard. The ICAO standard term for a confirmation is: Roger, that is correct, wilco or affirmative. However, the word "O.K." is also often used.

c. Coincidences

- From the facts which were established in the investigation it is evident that the coincidence of a number of circumstances had a direct influence on the occurrences related to the take-off. A chain of coinciding circumstances made the accident almost inevitable. If any of these circumstances had not been there, it is almost certain that the accident would not have occurred.

  The following circumstances are considered coinciding:

1. The fog, due to which the radio was the only means of communication and the three parties involved were not visible to each other.

2. The congestion on the airport, due to which the two aircraft were taxiing simultaneously on the only available and active runway.

3. The fact that the KLM crew initially did not accept the offer by the tower to deliver the ATC clearance. As a result of this, the request for the ATC clearance coincided with the request for take-off clearance, at such a moment that the KLM aircraft stood lined up in take-off direction.

4. The misunderstanding between KLM and tower, arisen from the radio-communication and from which erroneously the respective convictions resulted; for the KLM that they were cleared for take-off and for the tower, that the aircraft remained stationary.

5. The coincidental misleading effect of the word "O.K." of the tower, after the KLM had reported "We are at take-off" or "We are -eh-, taking off". Only the word "O.K." has been clearly audible in the KLM cockpit, which could be taken as a confirmation for the correctness of the message transmitted by KLM.

6. The pause of about two seconds after the word "O.K.", from which the Pan Am crew concluded that the message of the tower had been ended and on which moment they jumped in to warn the KLM crew.

   This pause had as a result that due to the unintentional transmission of two essential messages, i.e. the message of the tower: "Stand by for take-off, I will call you" and of the Pan Am: "And we are still taxiing down the runway", a squeal was generated, by which noise both messages were lost. This pause, as an ultimate of coincidence, has proven fatal.

7. The squeal, primarily caused by the fear of the Pan Am crew that from the terminology of the clearance a misinterpretation of the KLM crew could arise.

8. The KLM crew apparently did not follow the communication between Pan Am and tower.

9. The predominant coincidence, ultimately resulting in the collision, consists of the premature take-off of the KLM aircraft coinciding with the taxiing too far of the Pan Am aircraft.

   Performance calculations and taxi tests with a B-747 turning off on an intersection comparable to the C3 at Tenerife, as part of the Netherlands investigation, indicate that in all probability no collision, and almost certainly no fatal collision would have occurred if the Pan Am aircraft had not taxied farther than the third intersection, which was emphatically instructed by the tower controller.

   Although the Pan Am aircraft, which unintentionally taxied too far, has clearly reported that it was still on the runway, this operational deviation coincided with the early take-off of the KLM aircraft; it has been a causal coincidence to the ultimate fatal collision.

General Summary

From the investigation it can be established that the accident was not due to a single cause.

The misunderstanding arose from generally used procedures, terminologies and habit-patterns.

The unfortunate coincidence of the misunderstanding with a number of other factors has nevertheless resulted in a fatal accident. Neither in the operation of the KLM crew, nor in those of the tower controller or the Pan Am crew, actions can be indicated which should be considered as serious errors. However, in varying degrees, a non-optimal functioning can be recognized with all parties.

Cause

The KLM aircraft has taken off without take-off clearance, in the absolute conviction that this clearance had been obtained, which was the result of a misunderstanding between the tower and the KLM aircraft.

This misunderstanding has arisen from the mutual use of usual terminology which, however, gave rise to misinterpretation. In combination with a number of other coinciding circumstances, the premature take-off of the KLM aircraft resulted in a collision with the Pan Am aircraft, because the latter was still on the runway since it had missed the correct intersection.

PART TWO

Considerations and conclusions of the Netherlands Aircraft Accident Inquiry Board

No evidence was found that any air traffic controller or any crew member of the aircraft in question was not or to a lesser degree capable for the execution of his function. Neither was it found that with any of them a particular state of mind has played a significant role.

Considering the stresses to which members of an aircraft in their work situation are subject on the one hand and, on the other, taking into account the experience of these crew members, the Board does not find it plausible that the stresses on the crew members, emanating from the work situation, were too heavy for any one of them.

As far as can be verified, the technical condition of each aircraft has not contributed to the accident.

From the investigation - especially considering the aforementioned sequence of events leading to the accident, particularly the presented coincidence of occurrences, and the statements of the experts given during the session, everything as seen in their mutual connexion and relation - the Board found that, in order to prevent such an occurrence in the future:

I. It is desirable that regulations are issued, according to which:

   A. A pilot (if circumstances permit) does not request a taxi clearance until after he has requested, received and confirmed by read-back, a departure instruction and/or an en-route clearance.

   B. A pilot never combines the request for a take-off clearance with any other message.

   C. If practicable, a departure instruction and/or an en-route clearance and a take-off clearance are issued on different radio frequencies.

   D. The phrase "take-off" is used exclusively in the request, the issue and confirmation of a take-off clearance.

E. The safety of traffic (aircraft taxiing, taking-off and landing, as well as other traffic which is simultaneously on a take-off and/or landing runway) is guaranteed, especially when the air traffic controller only has radio-communication at his disposal and is unable to observe that take-off and/or landing runway continuously.

F. Exits of a take-off and landing runway are provided with clearly distinguishable markings, whereby every marking corresponds with the relevant marking on the lay-outs which are used for taxiing.

G. In the radio-communication between the crew of an aircraft and air traffic control, additional use of standard terminology is regulated for crews, and which is in conformity with the regulated standard terminology, which is used by air traffic control.

II. It is recommendable that:

A. Air traffic control has, besides radio-communication, other systems at its disposal such as: ground radar, block safety systems, visual confirmation by means of lights and the so-called data-link, in order to control by such means more effectively the traffic on take-off and landing runways and when necessary on taxiways, during conditions of bad visibility.

B. In the cockpit voice recorder of an aircraft a signal is incorporated appearing at regular intervals, for synchronization with the flight data recorder in the aircraft.

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