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96-421

MINISTÉRIO DA AERONÁUTICA ESTADO-MAIOR DA AERONÁUTICA

CENIPA 04

Aeronautical Accident investigation
and Prevention System

FINAL REPORT

	Model: FOKKER - 100	OPERATOR: TAM
ACCIDENT	Date/time: 31/OCT/96 - 10:27 UTC Location: Congonhas Airport State: São Paulo	TYPE: Loss of control in flight

"The only objective of accident investigation is the prevention of future accidents or incidents. The purpose of such activity is not to determine guilt or responsibility, a principle contained in art. 3.1 of Appendix 13 of the International Civil Aviation Organization - ICAO, of which Brazil is a signatory country.

It is recommended that its use is for exclusive purposes of preventing aeronautical accidents."

I. BACKGROUND OF THE ACCIDENT.

The aircraft was performing a regular passenger transportation flight, TAM 402, departing from São Paulo (Congonhas - SBSP) with destination to Rio de Janeiro (Santos Dumont - SBRJ).

Around 08:26P, during the take-off and right after leaving the ground, the crew was taken by the surprise of an abnormal circumstance at this phase of the flight, which they interpreted as being the continuation of an indication of failure in the auto-throttle system, and immediately tried to execute a corrective action.

It was seen by witnesses that the right hand engine reverser opened and closed some times, whereby the noise corresponding to such situation has been heard.

During the next total twenty four seconds of flight, the aircraft drifted towards the right, maintaining itself at low height and speed, reaching an attitude of pronounced tilting to the right, and eventually colliding with buildings, projecting itself to the ground and next catching fire, suffering a total loss.

All eighty nine passengers and the six crew members died in the accident, in addition to four other fatalities of third parties.

II. INJURIES AND DAMAGES CAUSED

1. Personal Injuries

Injuries	Passengers	Crew	Third Parties
Total	89	06	04
Serious	--	--	--
Light	--	--	--
Uninjured	--	--	--

2. Materials Damages

a. To the aircraft

The aircraft has suffered damages beyond any recovery.

b. To third parties

Because the accident has occurred in a residential area, several building of street Luís Orsini de Castro, in Jabaquara district, have been hit.

III. INVESTIGATION ELEMENTS

1. Information about the personal involved

a. Flight hours	PILOT	COPILOT
Total.....	6.433:00	3.000:00
Total in the last 30 days.....	60:25	75:51
Total in the last 24 hours.....	01:43	01:43
In this type of aircraft.....	2.392:05	230:41
In this type in the last 30 days.....	60:25	75:51
In this type in the last 24 hours.....	01:43	01:43

b. Graduation

The pilot graduated from Mogi-Mirim Airclub, in the State of São Paulo, since 1978.

The copilot graduated from Rio Claro Airclub, in the State of São Paulo, since 1988.

c. Validity and category of the permits and certificates

The pilot had a valid Airline Pilot (ATP) category permit and IFR Certificate.

The copilot had a valid Airline Pilot category permit and IFR Certificate.

d. Flight qualification and experience for the type of mission performed

(1) Pilot

Was an eligible and qualified instructor in aircraft FK100, having been considered experienced with the equipment.

(2) Copilot

Was eligible, having little experience with this type of aircraft, having been checked as for such qualification the week before.

e. Validity of the health inspection

Both pilots had valid Physical Fitness Certificates (CCF).

2. Information about the aircraft

Model F28MK0100, nationality and registration markings PT-MRK, has been manufactured by FOKKER AIRCRAFT B.V. on 07/FEB/93, under serial number 11440,

being registered with the Brazilian Aeronautical Registry (RAB) as being the property of BBV Leasing Funds GMBH CO MY KG, and having as operator TAM Transportes Aéreos Regionais S/A.

At the time of the accident, it had a total of 8,171 cell hours. The revision and maintenance services have been considered periodic and adequate, and its Airworthiness and Enrollment Certificates were valid.

3. Examinations, tests and researches

a. Engines

The aircraft was equipped with two ROLLS ROYCE ENGINES, MODEL TAY 650-15, identified with S/N 17336 on the left side, and N/S 17367 on the right side, as provided for in the TYPE CERTIFICATE (TC) for such aircraft.

The left hand engine had a total of 11,170 cycles, and the right hand engine 9,523 cycles.

Both engines have been carried to the ROLLS ROYCE Engine Maintenance Shop (MRR), homologated by DAC/STE, located in São Bernardo do Campo, in great São Paulo.

With the support of MRR's infrastructure, engineering, technical personnel, publications, comparison standards, machines and tooling, specific for the engines in question, both engines have been disassembled, analyzed and investigated by INSTITUTO DE FOMENTO E COORDENAÇÃO INDUSTRIAL (IFI - Industrial Furtherance and Coordination Institute) of CENTRO TÉCNICO AEROESPACIAL (CTA - Aerospacial Technical Center), of the Ministry of Aeronautics.

After the end of such investigations, CTA concluded that both moto-propulsion sets were fully operational and developing power at the moment of the impact.

b. Engine Reversion System

(1) Electric System

Evidences indicate this system is one of the factors contributing to the opening of the reverser in flight. However, considering its constructive and operational complexity, its interconnection with practically all other systems of the highly computerized aircraft, and also due to the required quantity of agencies, companies, engineers and technicians involved in this matter, the investigation of this system will not be exhausted in one single item of the report, but to the contrary, shall be analyzed, discussed and presented in the course of this report as a whole.

(2) Hydraulic System

The reverser's hydraulic system is simple, having basically two vital components, to wit: a THRUST SELECTOR VALVE, that actuates hydraulically on the system and is activated electrically; and the THRUST RVSR ACTUATOR, that actuates mechanically on the system and is activated hydraulically. Both are fed hydraulically by the MAIN HYDRAULIC SYSTEM, which was operating normally.

- THRUST REVERSER SELECTOR VALVE

The aircraft was equipped, according to its TC (Type Certificate) with two Model 114168001 valves manufactured by DOWTY AEROSPACE HYDRAULICS. Such

valves have been tested and inspected at the Manufacturer, in ONCHAN - ISLE OF MAN - UK, and the inspection has been attended by an engineer of CTA and representatives of DOWTY, FOKKER SERVICES, AAIB, NASB and TAM.

The conclusion of the tests and of the subsequent inspection was that none of the two valves presented any type of operational anomaly, and therefore they do not amount to factors contributing to the opening of the reverser.

According to EW/B96/10/2, dated 07/Jan/97, issued by AAIB's representative who was present at the tests, the hydraulic pressure required to operate the SPOOL of the tested valves was low in relation to the pressure of the hydraulic system. The valve for thrust reverser # 2 operated from 48 to 52 PSIG (STOW - DEPLOY) and from 48 to 49 PSIG (DEPLOY - STOW). While such values were normal and well within the limits of FOKKER's and DOWTY's requirements, it has been noticed they were 2% below the system's available pressure: 3,000 PSIG. It has been considered that such characteristic might render the SELECTOR VALVE unnecessarily susceptible to abnormalities, such as the effects of small debris (filings). However, no evidence has been found that might indicate that such fact has had importance at the accident.

- THRUST REVERSER ACTUATOR

The aircraft was equipped, according to its TC, with two hydraulic actuators, model A62H200-7 (LH - S/N S00364 and RH - S/N S00358), manufactured by NORTHROP-GRUMMAN CORP - USA. Such actuators have subsequently been tested and inspected at S&L METAL PRODUCTS CORP. MASPETH-NY-USA, on 30/JAN/97.

The inspection has been attended by an engineer of CTA and by representatives of NORTHROP-GRUMMAN, S&L METAL, FOKKER SERVICES, TAM, FAA, NTSB, NASB and AAIB.

The conclusion of the tests and of the subsequent inspection was that the actuators were fully operational.

c. Other Reports issued

(1) Hypothesis for cycling the reverse open-close (DEPLOY-STOW)

Prepared by a technician of FOKKER SERVICES, in CTA's premises, on 11/NOV/96, where it shows a high resistance at SWITCH S1 of SEC LOCK ACTUATOR, which would possibly have reduced the performance of the STOW LIMIT RELAY, sending spurious signals to the SELECTOR VALVE's STOW SOLENOID.

It also showed a fault in the energized position of the SEC LOCK RLY1 ENG2, whereby such simple fault would not command the opening of the reverser, but would inhibit the warning at the cockpit, should the opening occur.

There is still the hypothesis of the two previous faults occurring jointly, considering a voltage drop on the electric system or due to 'G' loads at the moment of the lift-off. The double fault, under the above conditions, might cause the cycling of the reversers.

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(2) JOINT OBSERVATIONS ON WRECKAGE EXAMINATION

Prepared at CTA with the attendance of engineers and technicians of that Center and of investigation board, by FOKKER SERVICES and by AAIB's representative, on 18/NOV/96, by way of preliminary information as for the assessments carried out on several components of the reversers of engines 1(LH) and 2(RH):

(a) N.º 2 SECONDARY LOCK ACTUATOR (RH)

The operations of S1 and S2 were checked by measuring their electric resistances, while it was manually commanded from the totally extended position (DEPLOYED) to the totally retracted position (STOW). As initial result, electric resistance values of up to 357 OHMS have been found on S1, considered extremely high, because the normal would be resistance values not exceeding 0.7 OHMS; and

(b) No. 1 SECONDARY LOCK ACTUATOR (LH)

Measurements similar to those of No. 2 have been carried out, and values of a maximum of 0.5 OHMS have been found.

REMARK: After the above analyses and with the result of the X-Ray examinations by CTA, it has been decided to send the parts to the manufacturer, along with a team of CIAA, for a more comprehensive analysis.

(3) PERFORMANCE ASSESSMENT ON A FOKKER 100 SIMULATOR

It is an analysis report, with the objective of assessing the performance of the FOKKER 100 aircraft under the accident conditions. It has been prepared by CTA officers on 05/DEC/96. Amongst the several topics that have been addressed, such report contains:

(a) RELEVANT CONDITIONS

The drag introduced by the opening of the shells is a function of the opening angle, the aerodynamic speed and the thrust itself of the reverse jet;

(b) ANALYSIS OF THE SSFDR DATA

The analysis of the SSFDR's information indicated that the maximum power has been attained with the Thrust Reverser open. The analysis of the mechanism revealed that this could have occurred only after the separation of the Feedback system; and

(c) ANALYSIS OF THE CREW PROCEDURES

The AIRPLANE OPERATION MANUAL describes the procedure in case of REVERSER UNLOCKED. In the described procedure, the crew would have the failure information through the MASTER CAUTION light and the warning at the MFDS (REVERSER ENG.2), which, which according to the CVR's data has not been informed to the crew. The THRUST REVERSER UNLOCKED information was available on the SSFDR, and was not available to the crew.

(4) ELECTRICAL ANALYSIS OF THE FOKKER 100'S REVERSER

Analysis report issued by an engineer of CIA, dated 20/DEC/96. Among other data, such document contains:

(a) DESCRIPTION OF THE REVERSE SYSTEM

-Pre-Mod (pre-modification - before the modification)

When the aircraft has been certified in Brazil, in 1990, the electric system had a set-up in which the STOW solenoid of the THRUST RVSR SELECTOR VALVE remained energized always, maintaining the THRUST RVSR ACTUATOR pressurized to the effect of closing the shells, except when the opening of the reverse was commanded, on landing. Such condition ensured greater reliability as for an inadvertent opening of the reversers, but the feeding was provided by the ESSENTIAL DC BUS, which did not permit the use of the reverse, on landing, should there be a condition of 'loss' of such bus; and

-Post-Mod (post-modification - after modification)

To correct the above condition, FOKKER issued SERVICE BULLETIN F100-78-004, which changed the feeding to the BATTERY BUS (emergency bus), but it has been necessary, to meet the strict operation time requirements of the aircraft in the electric emergency condition, to save electric power. Such saving has been attained by de-energizing the STOW solenoid with the introduction of a STOW LIMIT RELAY, which energized the STOW solenoid only when there was a positive command to such effect. However, such condition, during the flight phases in which the reverser is not utilized, keeps the THRUST RVSR ACTUATOR non-pressurized.- PRÉ-MOD

(b) FAULT TREE - PRE-MOD

The reverser fault tree report, issued by the manufacturer for the homologation process, did not present all possible conditions of INADVERTENT POSITIVE, and did not consider the possibility of a dormant fail, whereby the fault probability has been calculated as of the order of 10^{-11} , which met JAR/FAR 25.1309 at the level of 'extremely unlikely' fault.

REMARKS: (1). FAR 25.1309 determines, in brief, that that aircraft equipment items, systems and installations, whether considered severally or in relation to other systems, are to be defined so that on the occurrence of any fault that might prevent the continuation of a safe flight and the landing of the aircraft, the fault is to be classified as 'extremely unlikely';

(2). A ADVISORY CIRCULAR N.º 25.1309-1A determines, in brief, that for a fault to be considered 'extremely unlikely', the probability of the fault occurring should be of the order of 10^{-9} or less, and

(3). A FAR 25.1309, letter (c), determines, in brief, that information and warnings should warn the crew about unsafe operational conditions, enabling appropriate corrective actions to be performed. The warning systems are to be designed to minimize crew errors, which might create additional risks. letra

(c) FAULT TREE - POS-MOD

The manufacturer has not considered the possibility of the contacts of SECONDARY LOCK RLY 1 becoming stuck, the case has not been analyzed in REPORT No. UK-28-313 SAFETY ASSESSMENT OF THE THRUST REVERSER CONTROL SYSTEM and its appendixes, and furthermore, it would be a dormant fail (a fault that may install itself, however without being perceived).

The diagram of the reverser's fault tree carried out recently by the manufacturer, considering the POST-MOD version, even without taking into account a dormant fail, indicates that the probability of an inadvertent opening of the reversers is of the order of 10^{-6} . Therefore, the POST-MOD version does not meet the airworthiness requirements of FAR/RBHA 25.1309.

(5) ELECTRONIC RELATIONSHIP BETWEEN THE ATS AND THE THRUST

The AUTO-THROTTLE SYSTEM (ATS), before engaging, checks the conditions of several other systems. Under the T/R NOT STOWED condition, SWITCH S1 of SEC LOCK ACTUATOR sends a signal to the FCC computer, not permitting the ATS to engage, and sends another signal to the pilot warning system (FWS), which in turn generates an A/T FAIL warning.

(6) AOPENING AND CLOSING OF THE "T/R" AS COMPARED TO THE "TLA"

Report issued on 23/JAN/97, of this CIAA, with the objective of documenting the tests carried out on two FOKKER 100 aircrafts, where the relationship between the reversers' shell opening angle and the position of the thrust lever (TLA) is verified.

- (a) The total opening of the shells produces an angle of 62° ;
- (b) The thrust lever starts its backward stroke only when the shells are already with an opening of approximately 24° (38.6% of the total opening, in average); and
- (c) From the position in which the shells are totally open, taking them towards the position in which they will be totally closed, the thrust lever is released to be accelerated, when the shells have an opening of approximately 21° (33.4% of the total opening, in average).

It has been concluded that in two phases of the complete cycle of the reversers, at the start of the opening and at the end of the closing of the shells, it is possible to apply power higher than IDLE, with the shells partially open, which does not meet RBHA/FAR 25.933.

(7) Report of AMR/IAE/CTA

(a) All mechanical components that have been examined, except the right hand engine's FEEDBACK CABLE, have fractured due to overload, probably at the moment of the aircraft impact, and showed no evidence of prior cracks.

(b) The examinations carried out on the bulb filaments of ATS key of the GLARESHIELD board and on the bulb filaments of ATS, YD, STAB TRIM and RUDD LIM keys have not identified the presence of 'stretchings', indicating that they were off at the time of the aircraft impact;

(c) The examination of the FEEDBACK CABLES that were installed on the aircraft that suffered the accident showed results different among themselves, in relation to the final measures of the internal opening and of the external wall of the 'housing' of the 'connection pin' (the interconnection point between the rear and front portions of the cable):

LH ENGINE - OPENING = 2.21 mm - WALL = 4.14 mm

Q.A.

RH ENGINE - OPENING = 2.89 mm - WALL = 4.49 mm

(d) By comparing the cable that was installed on the right hand engine with a new cable, that has been used in the tensile rupture test, one may verify that the final measurements of the internal opening and the external wall are quite similar:

RH ENGINE - OPENING = 2.89 mm - WALL = 4.49 mm

NEW CABLE - OPENING = 2.92 mm - WALL = 4.46 mm

(e) The tensile test carried out on the new cable indicated that the physical separation (RELEASE) of the 'connection pin' from its 'housing' has started when the load reached 240 Kgf.

(8) REPORT ON THE SECONDARY LOCK ACTUATORS

Issued by CTA/IFI, on 03/FEB/97, it shows the tests carried out on the SECONDARY LOCK SOLENOIDS, at COMMUNICATIONS INSTRUMENTS INC (C.I.I.), in the USA. The tests have been attended by an engineer of CTA and representatives of C.I.I., NORTHROP GRUMMAN, FOKKER, NASB, AAIB, NTSB, FAA and TAM.

The report concluded that 'The tests carried out on the two solenoids of the Secondary Lock Actuator (C.I.I. P/N A-1355, S/NM 874 - of the left hand reverser and S/N 870 - of the right hand reverser), that actuate the secondary lock of the doors of the turbine thrust reversers, showed inconsistency in their responses, and the consequent lack of reliability they showed.

The components, that should present an aeronautical quality standard, when placed in operation, undergo an abnormal deterioration, not explained by the manufacturers themselves, that have since some time been researching ways for optimization.

Even so, it became clear that the units go on being assembled and supplied to the customers with the deficiencies that apparently were not known by FAA only - because the Manufacturer demonstrated that he knew them already, and that body's Accredited Representative showed surprise with what he saw.

In brief, the units (S/N 874 and S/N 870) that equipped the aircraft that suffered the accident, in the operational tests proposed and carried out, showed a performance much below the minimum acceptable to assure the system's safety and reliability, and, as has been concluded at the end of the work, specifically S/N 870 (of the right hand reverser), had a share of contribution in the sequence of events that led to the non-commanded opening of the thrust reverser doors of turbine no. 2 during the aircraft take-off phase.

The REPORT OF MICROSWITCH HONEYWELL INC shows the assessment of MICRO S1, used as a component part of SECONDARY LOCK ACTUATOR, GRUMMAN P/N 1159SCP408-1 S/N 870, that was installed on the right hand engine of PT-MRK. Such report has shown, as relevant, the following data:

a) Upon the removal of the protection cap, it was noticed it became separated more easily than expected, which has been attributed to the suspicion of a long exposure to heating.

b) The surfaces of both contacts show contamination by silica, deriving from the degradation of organic silicone.

c) That organic silicone is not utilized in the component manufacture, and therefore the source of such contamination is unknown

(9) T/R HIDRAULIC STOW CONDITIONS

On 08/APR/97, DIPAA/DAC has requested FOKKER to carry out a test to clarify the situation of the ENGINE VERSUS HYDRAULIC POWER.

A document issued by FOKKER SERVICES on 17/APR/97, in reply to DIPAA, informs, among other data, that:

'(a) With the engine developing maximum power (LEVER FORWARD) and the reverser shells fully open (FULLY DEPLOYED), the hydraulic pressure (3000 PSIG) is not sufficient to close the shells, i.e., under such conditions the reverser will remain totally open; and

(b) The engine power may have been, and maintained, high enough to prevent the T/R from closing again, interrupting the cycling and keeping the T/R totally open. This might occur only if the thrust lever were forcibly maintained forward while the T/R was shifting towards opening.'

(10) ANALYSIS OF THE REDUCTION OF SSFDR'S DATA

On analyzing the section recorded on the SSFDR between the moment of the lift-off and the first impact, it may be verified, among several important information, that the EPR 2 (Right Hand Engine Power) curve shows three power reduction and application cycles, and the position curve of T/R - E2 (Right Hand Reverser Shell) shows one single movement from TRNS (TRANSIT Position) to DPLD (DEPLOYED Position).

On analyzing the information of Document TS96.67993, issued by FOKKER SERVICES, one may verify that the EPRE2 (Right Hand Engine Power) chart indicates there have been three power reduction and application cycles, and chart DDPLA2 (Angle of the Right Hand Engine Thrust lever) indicates that there have been three reduction and advance cycles of said lever.

By comparing the information rendered by the aircraft maintenance mechanic that has witnessed the cycling of the right hand engine reverser, with the charts described above (T/R - E2 and EPRE2), one may verify that, although at least three full opening and closing cycles of the shells of the right hand engine reverser have occurred, the SSFDR has recorded only the moment when such reverser physically and electrically reached the FULLY DEPLOYED position and remained a 'certain time' in such position.

(11) "FOURTH" CYCLE OF THE REVERSER

On analyzing the last ten (10) seconds of the reduction of the SSFDR data, particularly the THRUST REVERSER # 2 (T/REV - E2) and ENGINE POWER RATIO # 2 (EPR 2) curves, and considering:

(a) The existing 'plays' for actuating the thrust lever, of approximately 21° towards the closing of the shell, and 24° towards the opening of the reverser shells;

(b) That everything indicates that one of the pilots insisted on pushing the lever to maximum thrust:

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(c) That it is possible, due to the previously described 'plays', that there has been the possibility of one of the pilots having 'maintained' the thrust lever full forward, and as a function of the three previous returns, be 'holding' it, which would favor the 'extended arm' position and its body totally supported on the back of his chair;

(d) From the drawing and structural assembly of the FEEDBACK CABLE, one may evaluate the introduction of 'significant friction forces' in the cable assembly, by reason of what has been described above;

(e) The lever arm existing by reason of the length of the thrust lever;

(f) That the maximum force of static tension the FEEDBACK CABLE withstands during the lever's 'full forward' position, while the shells are totally open, is 632 LBS; and

(g) That the acceleration delay (SLAM ACCEL) of this engine is approximately 2 seconds.

Taking the real and existing situations, and understanding the other considerations described above as possible, one may accept as correct the assessment that 'rebounding after the elimination of the existing plays', produced by the opening of the shells with the lever held full forward, gathered together all the conditions to have exceeded the strength limits of the FEEDBACK CABLE, having as consequence its severance.

(12) SELECTRIC CONTROL SYSTEM FOR ACTUATION OF THE REVERSER - F100

This report, issued by an engineer who is a member of CIAA, dated 16/APR/97, analyzes and tests the contingent possibility of the T/R SECONDARY LOCK RELAY 1 (K1266A), P/N FOKKER FON9-6105D4L, presenting an internal fault, the consequence of which would be to inadvertently bring (or maintain) at least two of its contacts (out of a total of four) to the 'energized' position.

The report assesses, based on the F100 TROUBLESHOOTING SCHEMATIC MANUAL, that such relay has not failed due to an inadvertent feeding of its control wire, but instead due to an internal fault, because this wire is also connected directly to relay K 2096A (T/R SEC. LCK. RLY 2), which it is assumed, for the same hypothesis, remained de-energized.

It informs that inductive loads, such as those of SEC. LCK. ACTUATOR, are detrimental to the contacts that control them, particularly on de-energization, in case there is no protective diode, which is apparently the case of SEC. LCK. ACTUATOR.

It also assesses the possibility of the existence of 'quick cycles' of reversion during maintenance services, in which the closing of the shells is commanded before its opening has been completed, and in this case the turning off of both solenoids (SEC. LCK. ACTUATOR and DEPLOY SOLENOID) will be carried out by relay K 1266A. The simultaneous interruption of both solenoids together might compromise the contacts of this relay.

The report concludes that one may accept that there is the possibility that a simple failure of relay K 1266A, characterized by the 'melting' of any of contacts A1/A2, B1/B2 or D1/D2 (particularly A1/A2), causes the continuous command of the

DEPLOY coil (through the feeding of SEC. LCK. ACTUATOR) and at the same time causes the inhibition of the alarms, because the latter depend on the closing of contacts C2/C3, a closing that does not occur. Such fault may be caused by excessive load on one of those three contacts.

(13) EXAMINATION AT LEACH INT FRANCE

Report issued by NASB's representative on 25/APR/97, under no. 520197/96-78/A-17/56, summarizing the examinations carried out at LEACH INT on 20/MAR/97, on six relays similar to component FOKKER P/N FON96105D4L. Such document has been accepted by LEACH, pursuant to TELEFAX No. 1285, of 05/JUN/97, as being the final report regarding the researches carried out at that manufacturer.

In the report, LEACH informs that the overheating of relay contacts may result from sparking, if there are bounces during the relay operation, even if the electric current on the contacts is not excessive. The sequence of bounces on the contacts is usually not a problem when the relay energizes, but it may occur on de-energization, due to the power stored in the relay coil. LEACH considers that adequate for protection against such power stored in the relay coil is the utilization of a ZENER type diode, plus one more diode to minimize the bouncing effect. An inadequate protection against such effect may cause the occurrence of 8 to 10 bounces on the contacts, in a period of the order of milliseconds.

Another possibility described by LEACH is that the overheating of the relay contacts may also have originated in a relay cycling process, causing a mechanical switching that is normally frequent (with normal load values around 5 A), in the circuit of the relay coil, due to some characteristic in such circuit, producing a bouncing effect of long duration.

(14) TESTS ON THE FEEDBACK CABLE

1 - TS97.52804 - T/R FEEDBACK CABLE INFO

On 11/MAR/97, through document TS97.52804, FOKKER SERVICES informed it was concluding some tests on the FEEDBACK CABLE, and among other data, such document informs that:

a) The reference to document UK-28-292 defines as 632 lb. the static stress when the pilot is exercising maximum force during the acceleration movement, while the reverser is open. This is equal to approximately 100 lb. of maximum force on the thrust lever. And this load level, 'for which there seems to exist no specific airworthiness requirement,' is aligned with values used by other manufacturers for loads imposed on the engine power controls.

b) According to the certificate, a failure or disconnection of the FEEDBACK SYSTEM should not occur until 632 lb. (2815 N).

c) Considering the situation in which the lever is forced forward, while the reverser is in the open (deployed) position, the friction on the cable may twist the external front portion of the cable (the MORSE portion) at a load level quite higher than the 100 lb. (450 N), without subjecting the (FEMALE/MALE) connection and the rear portion of the cable to a maximum load level, i.e., the friction on the front portion of the cable will tend to 'protect' such portions.

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d) On considering the situation in which the lever is forcibly held forward while the reverser is opening (deploying), the maximum loads on the rear portion of the cable and on the connection may be exercised by a load on the lever below 100 lb. (450 N), because the rear portion of the cable might have reacted abruptly, by friction, on the front portion, i.e., such friction force has left the coupling of such portions 'exposed' as a function of the stretching of the cable.

e) Using increments of 500 N, when the test load reached 3500 N (786 lb.), the cable disconnected, and it was verified that there had been a displacement of the connection of approximately 36.0 mm (20.5 mm of stretching and 15.5 mm of displacement of the assembly). It was also verified that the (FEMALE/MALE) connection opened without a crack, when it reached the inner rim of the TURNBUCKLE.

2 - COMPONENT MAINTENANCE MANUAL -78-34-10

Manual 78-334—10, concerning the FEEDBACK CABLE, shows in its page 21 - SEP 01/93, the figure of the TURNBUCKLE (extending part) as being ITEM No. 440 of FIG 1, where it is numbered as P/N 59487-1 and its nomenclature is ADJUSTER ASSY (adjuster assembly).

The TURNBUCKLE is manufactured by TELEFLEX INC. - AEROSPACE DIV. of NORTH WALES -PA - USA.

As can be verified, the component is mounted immediately next to the CLAMP ASSY (clamp), which is the part where the connection between the cable's front (MORSE - FEMALE portion) and rear (GRUMMAN - MALE portion) portions takes place, whereby the TURNBUCKLE is installed on the side towards which the connection moves when the reverser is commanded to open. I.e., the same side towards which the connection moves when the situation occurs in which the lever is forcibly held forward while the reverser is opening (deploying).

3 - PAGE 11/24 DO REPORT P-100-3018

Page 11 of report P-100-3018, of MAR/97, issued by FOKKER SERVICES, schematically represents (attached hereto) the 'movement' of the assembled connection (MORSE CABLE - FEMALE portion coupled to the GRUMMAN CABLE - MALE portion):

FIGURE 1

Shows the connection while the reverser is in the STOWED position and there is no load (ZERO N) on the actuator. One notices that the connection is inside the QUICK FIT COUPLING.

FIGURE 2

Shows the connection while the reverser is in the STOWED position and there is a load of 3500 N (778 lb.) on the actuator. One notices that the connection has moved to the inside of the TURNBUCKLE. In this position, the female portion of the connection is radically compressed by its narrow fit inside the TURNBUCKLE, tending to protect the connection against a possible separation under the effects of a radial load.

FIGURE 3

Shows the connection in the position in which the separation occurred, and there is a load of 3500 ON on the actuator. One notices there is an **internal space** in the TURNBUCKLE, where friction no longer exists because the connection becomes exposed, and the female of the connector is **no longer compressed radically**.

FIGURE 4

Shows the connection while the reverser is in the FULL DEPLOYED position and there is a load of 3500 N on the actuator. This would be the position in case the separation of the connection had not occurred.

(15) ASSESSMENT AND TESTS CARRIED OUT ON THE FEEDBACK CABLE

The report, prepared on 31/JUL/97 by an engineer that is a member of CIAA, shows a summary of the observations collected while the FEEDBACK CABLE tests were carried out at FOKKER's plant on 05 and 06/JUN/97.

1 - INTRODUCTION

The objective of the test was to represent the condition of the accident in relation to such protection device. The condition chosen by CIAA was that, by **hypothesis**, during the last opening cycle of the reverser shells, the lever has been forcibly held forward, with one of the pilots exercising an **opposite force**, while the shells opened.

2 - TEST ON THE 5TH DAY OF JUN/97

During the load application stage to 3000 N, there has been the separation of the FEEDBACK CABLE connection when the value of the load on the reverser side reached **2625 N**, while the value of the load on the lever side reached **1835 N**, with the lever side being kept stationary (the pilot holding the lever forward). No deformation or undulation has been observed anywhere on the cable.

3 - TEST ON THE 6TH DAY OF JUN/97

Under the same condition as that one of the previous day, there has been the separation of the connection before there was a displacement of the cable, when the load on the reverser side was **2500 N**, while the load on the lever side was **1732 N**. This time, however, deformations/undulations have been ascertained on the MORSE cable, without the GRUMMAN cable showing any deformation.

4 - ASSESSMENT OF THE RESULTS

From what has been researched, the manufacturer met the requirement of FAR 25.933(a)(1), as for the aspect that a reverse system to be used on the ground only, (the engine) would produce slow running pull only, in case the shells would open in flight.

FOKKER has considered the loads induced by the pilot and by the opening shells on specifying the FEEDBACK system, and followed values prescribed by

most aeronautical manufacturers. Furthermore, the FOKKER Design Requirements stipulated a limit-value of **2812 N**, considering the shell open and the pilot exercising maximum effort on bringing the lever forward. However, it did not consider the case of the pilot resisting the lever's trend to reduce under the action of the shells opening, and that presented the result recorded in the tests, with values below the values stipulated by FOKKER itself in the Design Requirements. I.e., **1732 N** and **2500 N** are values lower than **2812 N**, if measured next to the reverser shells, but possibly equal or higher for the connection point called QUICK DISCONNECT.

The above inaccuracy was due to the fact that the MORSE cable, on being forced during the test, has shown a high degree of internal friction, rendered evident by the deformation/undulation that occurred on this portion of the cable, thus 'masking' the actual loads to which the cable as a whole was being subjected. Such behavior of the cable was unknown to the aircraft's manufacturer.

The tests have been positive in pointing to the place where the separation of the FEEDBACK CABLE occurred, which has been inside the TURNBUCKLE, the inside diameter of which is larger than the diameter of the cable's outside cover, which permitted an 'expansion' of the female connection to occur with the exiting of the male pin during the tensioning, and which resulted in damages to such parts, in a way similar to the damages that occurred to the parts belonging to the right hand engine of the PT-MRK, the assessment of which is set forth in report no. 02-AMR-E/97.

Therefore, the tests complement and corroborate the examinations carried out at CTA on the parts of the PT-MRK, being an indication that there has been the separation of the FEEDBACK CABLE in flight, at the final instants preceding the aircraft crash.

Finally, still according to the applicable requirements, FAR 25.933(a)(3) determines that each [reverse] system is to be provided with means to prevent the engine from producing more power than slow running power upon a failure in the reverse system [not stipulating the type of failure]. Such requirement has not been met, both in relation to the control system, which permitted the shells to open in flight, and in relation to protection, which became non-existent on the occurrence of the disengagement of the FEEDBACK CABLE due to the pilot's unpredicted action on the lever, with the intention of resuming the affected engine's power.

(16) SIMULATION OF THE REVERSER CYCLING (TAM'S HANGAR)

TAM's engineering, exchanging information with CTA's engineers and the foreign technicians, has carried out an analysis of the electric diagrams, simulating the cycling of the reversers. Between the 5th and the 7th days of NOV/96, simulations of the reverser cycling have been carried out on an aircraft of the Brazilian operator.

Admitting the possibility of a failure associated to a dormant fail, and after activating the SWITCH REVERSER SECONDARY LOCK RELAY 1 ENG 2, such failure, along with the contact resistance on SWITCH S1 of the SECONDARY LOCK ACTUATOR, produced the cycling of the reverser, normally 3 to 8 times, this with the ambient temperature below 20°C. With temperatures higher than 25°C, the reverser would not cycle.

Still according to such tests, carried out by TAM and attended by members of the Committee, this also explained the lack of the REVERSER ENG2 message at the cockpit.

4. Meteorological information

The conditions reported at the time of the accident were:

Wind from 060, of 06 Kt, visibility better than 10 Km, CAVOK and temperature of 22°C.

The meteorological conditions of Congonhas Airport (SBSP) were satisfactory for the flight.

5. Navigation

All navigation/communication aids of SBSP airport provided for the traffic authorization, taxiing and take-off phases have been utilized.

6. Communication

The aircraft-Congonhas Tower (TWR SP) communications established with a bilateral nature have been clear and satisfactory, during the whole time the aircraft remained on the ground.

The emergencies that took place on board have not been transmitted to ATC. There has been no contact of the aircraft with the control bodies after the take-off.

ATC has been informed about the accident through INFRAERO.

TWR-SP has not seen the accident occurring.

7. Information about the airport

Congonhas Airport (SBSP) is homologated for visual (VFR) and instrument (IFR) operations, day and night. Runway 17R, utilized for the take-off, is 1940 m long by 49 m wide, and is asphalt-paved.

8. Information about the crash and the wreckage

The place where the aircraft suffered the accident is densely populated. The first impact of the airplane was with the tip of the right hand wing against the roof of a two stories high building.

The airplane, at the moment of the first impact, had a quite pronounced tilting angle to the right, reaching 108.46 degrees upon the final impact.

There has been a sudden deceleration, i.e., the reduction from 129 Kt (239 Km/h) in a space of 140 m. The wreck debris have become scattered in a linear way and aligned in the direction of the movement. Due to the high degree of destruction of the aircraft, it has not been possible to determine the precise position in which the aircraft remained after the crash.

9. Data on fire

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Due to the linear dispersion of the wreck debris, and in view of the scattering of the fuel, a large portion of the aircraft and its components caught fire, in a disorderly and immediate way. Despite the Fire Fighting Service having been quite efficient, fighting the fire quickly, there were no conditions to attenuate this accident's high degree of destruction.

Due to the large quantity of fuel (the total required for the Congonhas - S. Dumont leg - 4400 Kg.), which has scattered in the surroundings after the collision with the buildings and the ground, a large portion of the aircraft has been consumed, rendering it extremely difficult to locate and preserve the several components.

10. Aspects on survival and/or aircraft abandonment

This accident has permitted no survival conditions to the occupants, due to the high degree of destruction suffered by the aircraft.

11. Flight Recorders

a. COCKPIT VOICE RECORDER

The aircraft was equipped with a cockpit voice recorder (CVR) manufactured by 'Allied Signal', model AV 557C, Serial Number 11976, Part Number 980-6005-076, located in the AFT Cargo Compartment Hatch.

It has been found practically intact, and has been examined initially by a representative in the city of São Paulo.

Due to the auto-reverse feature of this recorder, it has not possible to carry out its reading, because the representative did not have the adequate equipment.

As a consequence, it was necessary to send it for analysis at the Flight Recorders Laboratory of the 'National Transportation Safety Board - NTSB', in the city of Washington -DC, USA.

The recording, with a total of thirty five (35) minutes recorded, has its start coinciding with the moment of the final approach of the flight preceding the accident.

(b) SOLID STATE FLIGHT DATA RECORDER -SSFDR

The equipment is manufactured by 'Allied Signal' (SEATTLE - USA), PN 980-4700-003, NS 1399, and was located in the AFT Baggage Compartment.

Due to the conditions in which it was, and with the primary purpose of preserving the information contained therein, it was decided to send it to the manufacturing company, in coordination with the National Transportation Safety Board - NTSB, because it was the first time a SSFDR of this model was opened.

The transcriptions of the CVR and of the SSFDR (set forth in operational procedures, in the analysis), have facilitated the clarifications of what happened.

12. Operational aspects

a. Aircraft's Performance

The flight simulation to assess the conditions of the accident have considered the parameters existing at Congonhas airport at the moment of the accident. Temperature

23°C, wind 060/06, field elevation 2,510 feet, weight 37,970 Kgf, V₁V₁V₂ - 127/127/132 Kt, flaps 8, EPR1 - 1.71 (left hand engine).

The following climb ratios in feet/min have been obtained in the simulator:

- with the reverser open and landing gear retracted - **390 feet/min.**
- with the reverser open and landing gear lowered - **120 feet/min.**

Remark: Other configurations and clarifications are contained in figure 1 (pg. 31 *[of the original in Portuguese]*).

The pilot has passed the Flight Operational Dispatch (DOV), has carried out the briefings with the copilot and the stewards. The crew had a relatively long solo time, around 35 minutes. The previous flight had landed in time.

From the recordings of the Cockpit Voice Recorder - CVR, it has been ascertained that despite the several interferences existing in the recording, the pilot has carried out the take-off briefing. It was not possible to check its contents.

As has been observed, it should be pointed out that the checklist procedure 'Before Starting Check' has not been carried out by the crew in the standard way, whereby it has been carried out by the copilot only. Such situation, although it has not contributed to the accident in question, amounted to a doctrine fault as for the fulfillment of the respective flight standard.

After the landing in São Paulo (the flight preceding the accident), the reverse of engine no. 2 has remained in the 'in transit' position, according to the data of the Flight Data Recorder (FDR).

In relation to a possible indication of such position, the crew that made the preceding flight has reported nothing about it. Furthermore, on reading the CVR no comment is identified on the part of both crews, in relation to such abnormality.

In the recordings of SS FDR, the reverse of engine no. 2 has presented the 'in transit' indication since the preceding landing.

Considering that both crews (of the preceding flight and of that one of the accident) have reported nothing in relation to such system, this amounts to a lack of indication of the actual condition of the reverse in the instrument board.

It should be pointed out that such indication system is inhibited at a speed higher than 80b Kt and up to a height of 1000 feet, exactly at an instant when the pilots would need this information most.

The pilot was quite experienced, with 2,932:00 flight hours on F-100 aircraft. The copilot had a total of 230:00 hours on this aircraft model.

It is in the record that the copilot had been checked for this function the previous week.

While taxiing to end 17 of the runway, a level two (2) warning has occurred, that has not been identified by the crew members, because such warning has disappeared right away.

During the take-off run, under 80 Kt, there was the failure of one (01) auto-throttle channel, and right away of the other one, this being a 'GO' condition.

During the take-off run, the pilot informed, in three distinct situations, that the auto-throttle system was inoperative.

The abnormality has arisen on the precise moment of the lift-off, with a quick reduction of the lever of the right hand engine (1st second of flight).

According to the recording of the Cockpit Voice Recording (CVR), after an exclamation of surprise, the copilot informed the lever was locked (approximately on the 5th second of flight).

The thrust lever of the right hand engine was taken from the 'IDLE' position to the take-off thrust.

The act of suddenly moving the lever from the minimum power (idle) position to maximum power (45° - Full Power) in about 1 second has caused a slight forward movement of the lever of the left hand engine, giving rise to a slight increase of EPR - power (with the EPR increasing from 1.68 to 1.71).

On the 6th second of flight, the two levers started a (backward) movement from 'Full Power' to 'Idle', whereby the lever of the left hand engine has stopped at (+/- 20°) half stroke (EPR = 1.3) and that one of the right hand engine close to the 'Idle' +/- 5° position (EPR 2 = 1.1). Two seconds later, the pilot made the following request:

- 'turn it off up there - auto-throttle - pull here'.

During this period of the flight, the following actions to face the abnormality are observed:

- The first one occurs with one of the crew members pushing the lever of engine 2 (increase of power on the right hand engine).

- The second when the crew member who brought the lever of engine # 2 (right hand) to the 'Full Power' position also brought the lever of engine 1, keeping both levers held forward. Such fact has determined that in the second reduction of the right hand lever, under the force of the shell-like movement of the crew member's fingers, both levers were reduced simultaneously. On perceiving what had occurred, the pilot probably released the levers. The right hand lever continued reducing to 'Idle', with the left hand one remaining at half-stroke (EPR 1.3). Such reduction of both levers has caused a degradation in the aircraft's performance.

Next, releasing the lever of engine 2, the system permitted that one of the pilots brought the right hand lever forward, which caused the left hand lever, which was at half-stroke, to be advanced also, but to a position (EPR = 1.67) below take-off power (1.71).

The time interval (4 seconds) during which both levers stayed below take-off power, plus the 4 seconds during which the lever of engine 1 stayed below take-off power, have compromised the aircraft's performance.

In parallel, it has been ascertained that the landing gear has not been retracted, according to the data of the SSFDR. Three hypotheses present themselves to explain such non-execution of a checklist item.

The first one would be the deviation of the crew members' attention and concentration to the abnormality that presented itself at the first instant of flight, and that with this has changed the sequence of the checks that should be followed, in this case the 'Gear Up' request.

The second possibility would be the non-identification of the positive indication of climb ratio, which would not have happened, or, in case it has happened, has not

been verified by the crew, because the pilots had concentrated their attention already on the failure that had arisen.

The third situation could have arisen as a function of the little height gained after take-off, which would explain the fact that the pilot has not requested the retraction of the landing gear, in view of the possibility of returning to the ground. Such attitude (Gear Down) would agree with what the forced landing procedure prescribes (unlikely).

The retraction of the landing gear, as verified during the tests carried out on the simulator, would enable an improvement of at least 150 feet/min in the aircraft's climb ratio.

Doctrinally, any action by a crew, in face of any abnormality, in the cockpit environment, below 400 Ft, is **NOT RECOMMENDED**.

Statistically, making decisions below such height does, as a rule, aggravate the circumstances of the danger situation, increasing the risk.

However, in the case in question, the simple assertion that the crew of this flight would have witlessly failed to comply with such axiom is not patent, having in mind the circumstances and the small period of time during which all elements of the sequence of events broke out and presented themselves, not demonstrating clearly the actual situation of the failure of the aircraft's reversers system, during the take-off run, at the precise moment of the lift-off.

At no moment, during this short period of time - 24 seconds - has there been a consistent information for the crew that there was a failure in the aircraft's reverse system. There were - yes - several induced information that led the crew members, during all this time, to manage that 'emergency' as a failure of the **auto-throttle system (single & double chime and warning lights)**.

The failure was unusual, and was not predicted in the emergency procedures, occurring at the most critical phase of the flight performance: **TRANSITION - take-off run/climb** - and further, subject to induced interpretations, corroborated by previous information, aggravated by the audible and light warnings, and further by the intermittence of the lock/unlock of the right hand engine's lever - **reverser cycling**.

RBHA 121.557 - Emergencies. Domestic and Flag Airline Companies - in its item (a) states that 'In an emergency situation requiring immediate decision and action, the pilot is to act as he may deem necessary in face of the circumstances. In such cases, in the interest of safety, he may depart from established operational procedures, from the minimum meteorological factors applicable and from the rules of this regulation, as much as necessary.'

After the analysis of the SSFDR and from the investigation of the Material Factor, it has been ascertained that in this accident a 'reverser unlocked' failure has occurred.

The only indication presented to the crew members in relation to this problem was the quick reduction of the thrust lever of engine no. 2, immediately after the lift-off. However, the failure was disguised for the pilots, because the lever of engine no. 2 has been released right away, enabling it to be moved to maximum power. And further, the reduction of both levers, the right hand one as a consequence of the opening of the reverser, and that one on the left inadvertently brought by the hand of one of the pilots,

induced the crew members, of at least the pilot, to reason based on auto-throttle failure.

The 'reverser unlocked' procedure during take-off has not been trained on the flight simulator by the company's crew members by virtue of a letter from the aircraft's Manufacturer addressed to the operator, after the latter's prior consultation, dated 28 June 1995, in which the matter 'Reverser Unlocked Procedure' has been dealt with.

In said letter, it has been informed that an opening of the reverse in flight through its actuation would not be possible, due to the Ground/Flight Switch protection of the selected system. This way, the opening of the reverse as a function of a fault in the mechanical lock, right after take-off, should not occur if the speed were below 200 Kt.

The lever locking time was insufficient for the pilots to be able to ascertain the 'reverser unlocked' symptom, as the checklist provides for, which states: 'If thrust reverser blocked', i.e., the pilot would have to check the locking manually, in order to characterize said problem.

The pilot had taken the Cockpit Resource Management Course 'CRM' in 1993, having revalidated such Course on the following year.

The copilot had not taken such Course.

It has also been observed that both the pilot and the copilot had taken Loft flight training. The scenery was Rio de Janeiro.

It should be pointed out that with the Secondary Lock unlocked, there is no possibility of perceiving such condition through an external inspection by the crew/maintenance.

13. Human aspects

a. Physiological Aspect

The crew members had their Physical Fitness Certificates valid, and were healthy.

According to the data analyzed, there is no evidence of participation of the physiological aspect in the accident in question.

b. Psychological Aspect

The Pilot and the Copilot were rested and within the normal performance standards (according to Law no. 7183/84). No significant change has been noticed, either in the behavioral or the emotional spheres. No family conflicts have been identified, nor clashes at organizational or group level. They were well accepted as professionals and as persons.

Both were classified as individuals who had a mean-superior intellectual and potential level, in the psychological assessments made by the Aeronautics Hospital of São Paulo, during the routine medical expert examinations and by the operator in the selection process.

The Pilot was quite experienced, with about two thousand four hundred hours on the equipment, and took a CRM course (Cockpit Resource Management). The

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Copilot had little experience with the airplane, and it is not stated that he has taken CRM instruction.

The take-off briefing has been carried out, although the checklist has not been carried out the standard way. The transit and external inspections have been carried out. In such stage, the time on the ground was sufficient for the necessary checks to be taken care of and completed.

At the beginning of the take-off there was a failure of one and then both auto-throttles, which actually called the attention of both pilots ('... it's out.'). Such failure was considered simple, and showed up with a certain frequency, due to other motives.

Some pilots that have been interviewed informed a natural trend to minimize this automated information, not only due to the quantity of times it showed up, but also due to the 'GO' classification.

The aircraft, by design, was actually with the 'reverse unlocked' warning devices inhibited (in this phase of the flight), to 'inform' the pilot, or just to 'warn'. Audible and light signs communicate to the pilot that there is a situation that may become an emergency, in case he permits the situation to continue. It requires adequate attention, but not necessarily immediate action.

A factor contributing to the accident, of domain of the organizational culture, may be present here. A warning, that has its real importance, becomes ignored due to its constant repetition without visible effects, or measures taken and not divulged. The information were not even noted down, and sometimes reported (lack of documents).

The operation philosophy in the world for commercial jets is that no procedure or action below safety height should be adopted, except to 'fly the plane'. The reasons for this are in the temporal aspect that exists between perceiving and acting safely, in order not to feed back information rendered false by perception itself, which may become saturated by an excess of information, that may demand actions to be timely unleashed.

The opening and cycling of the reverse in flight has been an unprecedented failure in F-100 aircrafts, and some perceptive factors of the crew have contributed to disguise the emergency, within the organizational context mentioned already. The training on the simulator is provided for open reverser; thus, the treatment of the information would be to identify the open reverser condition. The only constant of the manuals is: 'lever back and locked'. The yielding by the thrust lever, permitted by the reverser cycling, caused the basic and identifying condition of open reverser to disappear.

The pilot's attention was deviated to the abnormality they faced. Such deviation inhibited the identification of a positive indication of climb ratio, 'consuming' the focus of the attention, interrupting the sequence of the subsequent action, which would be the retraction of the landing gear.

From the reading of the SSFDR, synchronized with the recording of the CVR, that may be seen in the tridimensional representation of the accident, it has been possible to infer that the crew's actions were to the effect of coordinating immediate aircraft control actions. In the flight phase they were, they have been taken unaware by the situation lived through in the lapse of only 24 seconds, with reactions opposite to or out of what would be expected, such as: to wish to accelerate the engine and the lever having been locked, in the next instant the lever could already be brought

forward; at the time the aircraft was rolling, it had to be strongly opposed, requiring actuation on the roll commands, deviating the attention, for example, to the actuation on the commands to make the aircraft climb, etc.

The pilot's correct decision and its timely execution makes the difference between success or failure, but it depends always on the possibility of there being time to get cognizance and/or perceive. It is the study field of Human Engineering, a sub-specialty of Psychology, that sustains the principle that man 'has to be ahead of the machine'. Such principle, of human behavior science, sustains that no structural design, available technology or performance may violate human limitations, whether physical, mental, operative or functional.

The interaction between safety systems and pilot warning systems is fundamental. Although sophisticated, the most advanced systems are not infallible, and demand the intervention of human being, who in turn needs inputs (information) and time to carry it out. It is a permanent systemic exchange of information, where the automated aid may not be a complicating factor, but rather a facilitating support to flight management.

An information system that becomes dubious or discredited, which in the course of a critical event is not sufficiently clear to warn the pilot, should be revised in any design. The inhibition of warning signs, in order not to saturate the piloting with information in given phases of the flight, may not be ahead of the pilot, in the conduction of the flight.

The human factor, in the psychological aspect, in the neuro-psychological area, has been present in the accident, for its limitations of a perceptive nature, with few possibilities of emitting responses to situations of dubious interpretation or unknown, and for not having adequate conditions to act in a coordinate way, in a badly perceived action. Such limitations, inherent to the human being, exhibit their fragility as a system, when there is no perfect interaction with the machine. The aircraft knew, through a system, that it was in an out of normal situation, and through another system, it has not been capable of informing the situation to the pilot, for his adequate and expected intervention, would also be an inter-system limitation (machine-machine), also studied by the Operational and/or Material Factor.

14. Ergonomic aspects

Nothing to report.

15. Additional information

a. The investigations had their degree of difficulty very expanded and its time of execution and costs increased due to the difficulties imposed to the work of the members of the Investigation Committee during the initial action, particularly on the afternoon and night of the 31st day of October, 1996. The main difficulties were:

(1). The local organizations (Civil and Military Polices, Civil Defense, Fire Department, District Administration and Press) have prioritized excessively their respective activities, even to the total detriment of the preservation of evidences sought by the Committee's experts, thus contributing decisively to impair the subsequent progress of the investigations.

(2). The police responsible for the isolation of the area did not carry it out effectively, whereby in the evening they released most of their manpower, permitting

the invasion of the site by onlookers, profiteers and some press representatives who were little prepared or not at all.

(3). Even after the fire fighters had carried out their fire fighting work, in the search for possible survivors and the removal of all bodies, priority has not been given to the Committee to work on the wreckage (initial action). Some fire fighters, that were engaged in the 'quenching', ignored the several requests of the OSVs present at the site. Under the allegation that they had to release the wreckage site on the following morning already, for Eletropaulo [*Translator's remark: the local power utility*] to reconnect the electric power, such fire fighters started breaking slabs of the houses disorderly, moving the debris to other locations with power shovels, throwing them on top of the aircraft wreckage, mixing them with the latter, thus greatly impairing the accident investigation work (evidence preservation).

(4). Lack of a CECOMSAER member or of someone designated by it to coordinate the work of the press reporters at the accident site.

IV. ANALYSIS

1. Human Factor

a. Physiological Aspect

The crew members' Physical Fitness (CCF) and Technical Eligibility Certificates were valid. No evidence or facts have been verified that could contribute to the reduction of their performance in flight. It was the first take-off of the day, and they were rested.

b. Psychological Aspect

Organizational aspect

The crew members have had no information, nor written instructions or training, for such specific emergency of the opening of the reverse at the take-off phase. Such lack of information and training has contributed to the difficulties of recognition during the entire phase during which the abnormality has evolved.

Individual aspect

The quick reduction of the lever at the precise moment of the rotation has distracted the crew members' attention. In addition to his surprise, the Pilot had to apply his capabilities to neutralize the asymmetric power condition. The copilot had his attention (concentration) turned to the abnormality.

The occurrence of the auto-throttle failure during the take-off run and the absence of other warnings, that were anticipated to occur in case of 'unlocked reverse', strengthen the initiatives, on the part of one of the crew members, to advance the lever of the affected engine before reaching safety height. The actions and reactions deriving from such initiative have distracted the attention and have generated other focuses, which have compromised even more the identification of the unusual abnormality.

2. Material Factor

The facts and the circumstances of this occurrence, when compared to the results achieved in the investigations, lead to two types of failures of the material

factor, involving the design aspect. One involves the electric components of the reverse system, and the other involves an electric and mechanical failure in the disconnection of the reverse safety cable.

Placed in a logical sequence, the following has been verified:

a. As soon as the possible debris have been gathered (after the predatory actuation in the rescue), thorough examinations have been carried out on the fractured and non-fractured parts, leading to the hypothesis of the following sequence of failures:

- existence of high resistance on switch S1 of the Sec Lock Actuator;
- possibly reducing the performance of the Stow Limit Relay; which sent spurious signals to the stow solenoid of the selector valve); and
- failure in the energized position of SEC LOCK RLY1 of engine 2, inhibiting the warnings in the cockpit, in case of occurrence of the opening of the reverse in flight.

b. Examinations and tests on switch S1.

In the operational tests of the reverse opening and closing, it has been verified that the electric resistance values of microswitch S1 of the right hand actuator (No. 2 SECONDARY LOCK ACTUATOR) were extremely high, reaching 357 ohms, while the normal would be not to exceed 0.7 ohms. On the other switches, the maximum value found was 0.5 ohms.

Upon the assessment examinations of S1, evidence has been ascertained of long exposure to heating; the surfaces of both contacts presented contamination by silica, originating from the degradation of organic silicone; and it has been ascertained silicone does not exist in the manufacture of S1.

c. Examinations, tests and analyses of the STOW LIMIT RELAY.

During the researches about the electric system of the reverse it has been verified there are two versions thereof, one (Pre-Mod) prior to service bulletin F-100-78-004, and the other (Post-Mod) subsequent to the modification.

In the 'Pre-Mod' version, the reverse closing solenoid (STOW solenoid of the THRUST RVSR SELECTOR VALVE), except when commanded to open right after landing, remained energized always, keeping the THRUST RVSR ACTUATOR pressurized to the effect of closing. Such condition of great reliability against the opening of the reverser in flight was provided by the direct current bus (ESSENTIAL DC BUS), which would render the use of the reverse impossible on landing, should the 'loss' of such bar occur.

Post-Mod Version

In order to correct the above situation, FOKKER issued SERVICE BULLETIN F-100-78-004, which changed the feeding to the BATTERY BUS (emergency bus), but in order to meet the strict operation time requirements of the aircraft under the electric emergency condition, it was necessary to save power. Such saving has been achieved by de-energizing the STOW solenoid with the introduction of a STOW LIMIT RELAY, which energized the STOW solenoid only when there was a positive command to such effect. However, during the flight phases in which the

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reverser is not utilized, such condition keeps the THRUST RVSR ACTUATOR non-pressurized.

(1). Consideration about the fault tree of the Pre-Mod.

The reverse fault tree report issued by the manufacturer for the homologation process did not present all possible conditions of INADVERTENT POSITIVE, and did not consider the possibility of a dormant fail, the probability of failure being calculated as of the order of 10^{-11} , which met JAR/FAR/RBHA 25.1309 at the level of 'extremely unlikely' failure.

(a) - FAR 25.1309 determines, in brief, that aircraft equipment items, systems and installations, considered severally or in relation to other systems, are to be defined so that on the occurrence of any failure that may prevent the continuation of a safe flight and the landing of the aircraft, the failure is to be classified as 'extremely unlikely';

(b) - ADVISORY CIRCULAR No. 25.1309-1A determines, in brief, that for a failure to be considered 'extremely unlikely', the probability of the failure occurring should be of the order of 10^{-9} or less; and

(c) - FAR 25.1209, letter (c), determines, in brief, that information and warnings should warn the crew about unsafe operation conditions, enabling the adoption of appropriate corrective actions. The warning systems are to be designed to minimize crew errors that might create additional risks.

(2) Conclusions reached in the analysis of Pre-Mod failure.

The manufacturer has not considered the possibility of the contacts of SECONDARY LOCK RLY 1 becoming stuck, the case has not been analyzed in REPORT No. UK-28-313 SAFETY ASSESSMENT OF THE THRUST REVERSER CONTROL SYSTEM and its appendixes, and furthermore it would be a dormant fail.

The diagram of the reverser fault tree, made recently by the manufacturer considering the Post-Mod version, even not taking a dormant fail into account, indicates that the probability of an inadvertent opening of the reversers is of the order of 10^{-6} . Therefore, the Post-Mod version does not meet the airworthiness requirements of FAR/RBHA 25.1309.

(d) Examinations and tests on the SECONDARY LOCK ACTUATORS

The tests carried out on the two solenoids of the SECONDARY LOCK ACTUATOR (C.I.I. P/N A-1355, S/N 874 - of the left hand reverser, and S/N 870 - of the right hand reverser) for actuation of the secondary lock of the doors of the turbine thrust reversers showed inconsistency in their responses and the consequent lack of reliability they presented. They had a performance much below the minimum acceptable to assure the system's safety and reliability, whereby unit S/N 870 (of the right hand reverser) has presented a share of contribution in the sequence of events that led to the non-commanded opening of the doors of the thrust reverser of turbine no. 2, during the take-off phase.

(e) Ratio between the Thrust Lever Angle (TLA) and the reverser (T/R).

Tests carried out in two FOKKER 100 aircrafts have permitted to ascertain the following values in relation to the opening of the shells:

- 1) The shell's total opening produces an angle of 62° ;

2.1

- 2) The thrust lever starts its backward stroke only when the shells are approximately 24° open already (38.6% of the total opening, in average); and
- 3) From the position in which the shells are totally open, bringing them towards the position in which they will be totally closed, the thrust lever is released to be accelerated when the shells are approximately 21° open (33.4% of the total opening, in average).

It has been concluded that in both phases of the reversers' complete cycle, at the start of the opening and at the end of the closing, it is possible to apply thrust higher than IDLE with the shells partially open. Which does not meet RBHA/FAR 25.933.

(f) Possibility of failure of relay 1 of the secondary lock (T/R Secondary Lock RELAY 1 (K 1266A).

Based on F100 Troubleshooting Schematic Manual, the report assesses that it is possible that such relay has failed due to an internal fault, since such wire is also connected directly to relay K 2096A (T/R SEC. LCK. RLY 2), which is presumed, in the same hypothesis, that it remained de-energized.

It informs that inductive loads, such as those of SEC. LCK. ACTUATOR, are detrimental to the contacts that command them, particularly on de-energization, in case there is no protection diode, which is apparently the case of SEC. LCK. ACTUATOR.

It also assesses the possibility of existence of 'quick reverse cycles' during maintenance services in which the closing of the shells is commanded before its opening has been completed, and in this case the turning-off of both solenoids (SEC. LCK. ACTUATOR and DEPLOY SOLENOID) will be carried out by relay K 1266A. The simultaneous interruption of both solenoids together might compromise the contacts of such relay.

The report concludes that it may be accepted that there is the possibility of a simple fault on relay K 1266A, amounting to the 'melting' of any one of the contacts A1/A2, B1/B2 or D1/D2 (particularly A1/A2), causing the continuous command of the DEPLOY coil (through the feeding of SEC. LCK. ACTUATOR), and at the same time causing the inhibition of the alarms, because these depend on the closing of contacts C2/C3, a closing that does not occur. Such fault may be caused by an excessive load on one of those three contacts.

(g) Simulation of the engine cycling.

Admitting the possibility of a fault associated to a dormant fail, and after activating the SWITCH REVERSER SECONDARY LOCK RELAY 1 ENG 2, such fault along with the contact resistance on SWITCH S1 of the SECONDARY LOCK ACTUATOR, has produced the cycling of the reverser, normally from 3 to 8 times, and this with the environment temperature below 20°C. With temperatures higher than 25°C, the reverser did not cycle.

From the study of the electric diagrams involving the reverse system of FOKKER F-100, simulations of the reverser cycling have been carried out.

Still according to such tests, carried out by a technical team of TAM and attended by members of CIAA, this would also explain the lack of the REVERSER ENG2 message at the cockpit.

(h) Study of the cable failure.

Report of examinations and tests on several fractured and non-fractured components, issued by AMR of the Aeronautics and Space Institute - IAE - of CTA.

- a) Except for the safety reduction cable of the thrust lever (Feedback Cable) of the right hand engine, all mechanical components (parts) that have been examined have suffered fracture due to overload, probably caused by the impact of the aircraft with the obstacles, and presented no evidences of prior cracks.
- b) The examinations carried out on the bulb filaments of the ATS key of the GLARESHIELD board and the bulb filaments of keys ATS, YD, STAB TRIM and RUDD LIM did not identify the presence of 'stretching', indicating that they were off at the moment of the aircraft crash.
- c) The examination of the FEEDBACK CABLES that were installed on the aircraft that suffered the accident have presented results different from one another, in relation to the final measurements of the internal opening and of the external wall of the 'housing' of the 'connection pin' (point of interconnection between the rear and front portions of the cable):
- LH ENGINE - OPENING = 2.21 mm - WALL = 4.14 mm
- RH ENGINE - OPENING = 2.89 mm - WALL = 4.49 mm
- d) On comparing the cable that was installed on the right hand engine with a new cable that has been used in the tensile rupture test, one may verify that the final measurements of the internal opening and of the external wall are quite similar:
- RH ENGINE - OPENING = 2.89 mm - WALL = 4.49 mm
- NEW CABLE - OPENING = 2.92 mm - WALL = 4.46 mm
- e) The tensile test carried out on the new cable has indicated that the physical separation (DISENGAGEMENT) of the 'connection pin' from its 'housing' has begun when the load reached 240 Kgf.

From what has been researched, the manufacturer has met the requirement of FAR 25.933(a)(1) in the aspect that for a reverse system to be utilized on the ground only, (the engine) would produce slow running pull only, in case there would be the opening of the shells in flight.

FOKKER has considered the loads induced by the pilot and by the shells opening, on specifying the FEEDBACK system, and followed values prescribed by most aeronautical manufacturers. Furthermore, FOKKER's Design Requirements stipulated a limit value of 2812 N, considering the shell open and the pilot exercising maximum effort on bringing the lever forward. However, it has not considered the case of the pilot resisting the lever's trend to reduce under the action of the shells opening, and that presented the result obtained in the tests, with values lower than the values stipulated by FOKKER itself in the Design Requirements. I.e., 1732 N and 2500 N are values lower than 2812 N, if measured next to the reverse shells, but possibly equal or higher for the point of the connection named 'QUICK DISCONNECT'.

The above inaccuracy was due to the fact that the MORSE cable, on being forced during the test, has shown a high degree of internal friction, rendered evident by the deformation/undulation that occurred in this portion of the cable, thus 'disguising' the actual loads to which the cable as a whole would have been submitted. This behavior of the cable was unknown to the aircraft's manufacturer.

The tests have been positive in indicating the location where the disengagement of the FEEDBACK CABLE has occurred, internally in the TURNBUCKLE, the inside diameter of which is larger than the diameter of the external cap of the cable, enabling an 'expansion' of the female connection with the exiting of the male pin during the tensioning, and that resulted in damages to such parts in a way similar to the damages that occurred to the parts belonging to the right hand engine of the PT-MRK, the assessment of which is set forth in report No. 02-AMR-E-97.

Therefore, the tests complement and corroborate the examinations carried out at CTA on the parts of the PT-MRK, being an indication that there has been the separation of the FEEDBACK CABLE in flight, at the final instants preceding the aircraft crash.

Finally, still according to the applicable requirements, FAR 25.933(a)(3) determines that each [reverse] system is to be provided with means to prevent the engine from producing more power than slow running power upon a failure in the reverse system [not stipulating the type of failure]. Such requirement has not been met, both in relation to the control system, which permitted the shells to open in flight, and in relation to protection, which became non-existent on the occurrence of the disengagement of the FEEDBACK CABLE due to the pilot's unpredicted action on the lever, with the intention of resuming the affected engine's power.

3. Operational factor

a. Meteorology

The meteorological conditions at the time of the take-off (08:26P) were favorable to visual flight, the wind was 060 Kt, CAVOK conditions, temperature of 22°C. There has been no contribution of this aspect to the accident.

b. Infrastructure

The take-off runway of Congonhas Airport - São Paulo, asphalt-paved, with dimensions of 1,940 x 49 m and elevation of 2,600 feet, is adequate for operation of the F-100 with its maximum weight. There has been no contribution of this aspect to the accident.

c. Planning

The aircraft weight was 37,973 Kg, and its trim conditions were 23.4, within the limits provided for.

d. Crew Members' Conditions

Both crew members had their licenses valid and were fit for the flight.

- 1) The pilot had an overall total of 6,433:00 flight hours, of which 2,392:05 h on the FOKKER F-100 model, being an instructor on such aircraft.
- 2) The copilot had 3,000.00 h total flight hours. Despite such experience, he was little experienced on the FOKKER F-100 model, this aircraft being the

first one he flew that had a 'glass cockpit' conception, totally automated, and with an automatic acceleration lever control system (auto-throttle system - ATS). He had 230:41 h of flight on the F100, having been checked and approved a few days before the accident.

e. Instruction

The operator has a complete training sector that meets the specifications prescribed in RBHA-121.

The manufacturer's instructions comment sufficiently the ATS and reverse systems of the F-100 aircraft, covering the crew members' operational needs.

As for the ATS, one verifies it is an auxiliary device that provides conditions to maximize the operational efficiency, responding to the aircraft performance management system when coupled. It also answers for the reduction of the crew members' work load, accelerating or decelerating the engines automatically. The movements of the levers may be opposed with little effort by the crew member(s) directly on them. A failure in such system may be due to several origins. When either one of the levers presents abnormal operation, the system uncouples. In every case, without exception, the levers become static, without automatic movement, but free for manual handling, as it occurs in older aircrafts. A failure on the ATS (auto-throttle) is not significant for the operation.

The actuation of the protection system of the reverse actuation in flight.

Years ago, the engine power reverse system has actuated in flight already, causing the loss of control of a big cargo jet. Since then the certification of such aircrafts requires that a protection system against an inadvertent opening of the reverse in flight is operational. On the F-100, the engine power lever is a slave of the respective reverse. In case an inadvertent opening of the reverser occurs in flight, the engine is simultaneously reduced to idle (slow running). The enslavement takes place on the thrust lever, which is quickly reduced to the slow-running detent (idle position), and is to be locked at such position. The speed of the lever reduction movement is significantly faster (about eight times more) than the movement carried out by the auto-throttle.

Aircraft's Performance

Considering the data concerning the conditions of Congonhas Airport - São Paulo - at the moment of the accident as parameters for the test on a simulator, and comparing the results obtained in the test flight with the aircraft's performance charts, among other ones, the following results have been reached:

Table 1 - Climb Ratio (Feet/Min) - Simulator

Set-up	Position of the RH Engine Reverser			
	Closedo	Cycling	Open	Open
Gear Retracted	670 (2) (3)	560 (1)	390 (1)	-
Gear Down	480 (2)	410 (1)	120 (1)	480 (2)

(1) Right Hand Engine idle"

(2) Right Hand Engine off

(3) Climb ratio of the AFM = 736 Ft/min

The table above permits to consider:

- a) The effect of the reverser cycling, with the motor idle, degrades the climb ratio by 110 Ft/min.
- b) The effect of the reverser open, with the motor idle, degrades the climb ratio by 280 Ft/min.
- c) When the landing gear is down, with the engine cut, the effect of the open or closed reverser is negligible as for the aircraft's climb performance.
- d) The retraction of the landing gear increases the climb ratio by more than 150 Ft/min.
- e) The performance attained on the simulator, in terms of climb ratio, is similar to the values set forth in the **Flight Manual (AFM)** under the condition of landing gear and reverser closed.

Climb ratio of the AFM = 736 feet/min. Altitude: 3,000 feet to 4,500 feet.

Climb ratio on the simulator = 670 feet/min. Altitude: 2,160 feet to 5,080 feet.

- 1) The climb ratio on the simulator, with the set-up of right hand engine cut, landing gear retracted and flap 8 is similar to the climb ratio provided for in the AFM.
- 2) The climb ratio values on the simulator with the reverse cycling or open should not be considered in a final way, because the model has not been validated.
- 3) Based on the simulator data, if the landing gear had been retracted, the aircraft would have a positive climb ratio of 390 Ft/min with the reverser open, and 560 Ft/min with the reverser cycling.
- 4) Based on the FDR data, if the left hand engine had not been reduced after the take-off, the aircraft would have had a positive residual climb ratio.
- 5) The opening of the T/R, associated to the use of maximum thrust, does not cause a loss of sideways-directional controllability, however it causes performance deterioration (rendering the flight unfeasible in this phase).
- 6) Based on the CVR data, the crew had no information on the MFDS about the malfunctioning of the T/R, which has, however, been recorded on the FDR.
- 7) Based on the CVR data, the information about the auto-throttle being out at the take-off run may have induced the crew to associate the reduction of the right hand lever, after the take-off, with the auto-throttle failure.
- 8) The reduction of the right hand lever may have distracted the crew's attention and contributed to their forgetting to retract the landing gear. Consequently, the climb performance has been degraded.
- 9) The crew did not follow the prescribed check procedure after take-off, the landing gear has not been retracted after the positive climb.

Such results indicate that the aircraft had no flight conditions only with one reverser open associated to maximum thrust due to the loss of performance. In the case of this accident, to be added to the conditions commented upon above is the performance deterioration resulting from the reduction of the left hand engine for four seconds, and the delay, for another four, in resuming the take-off thrust. The resulting roll during the last seconds of flight is consistent with stall conditions, as corroborated by the sinking and actuation of the stick shaker.

Operational Procedures

Operational procedures (Flight Standards) correspond to actions and actuations performed by the several members involved in carrying out the tasks that enable a safe flight. They follow what is contained in the Brazilian Aeronautical Homologation Regulation (RBHA), in the manufacturer's manual, and usually are set forth in the company's operational routine. In time, the experience of the pilots group brings on some adaptations, which as a rule improve the flight performance and constitute the operational doctrine of that group.

Aeronautical accidents that occurred in the past and have been extensively investigated led to some recommendations that improved flight safety. One of them, contained in the Manufacturer's Manual and has been adopted in the company's operational routine, 'recommends' that safety actions are to be adopted above the height of 1000 feet, when it is not the case of fire or engine superheating, in which case it is lowered to 400 feet.

As verified in the transcription of the recording on the Cockpit Voice Recorder - CVR, the procedures carried out as of 08:12P (local time), including the push back, engine start, taxiing and check reading, have gone on within tranquil normality.

During the reading of the before-take-off checklist, the copilot asked: 'Briefing?', and the Pilot (Cmt) answered 'It has been done already' [*Translator's Remark: In the original this last passage was in Portuguese, but also translated into English as 'Have done it before'*].

Briefing is a clarification of the procedures to be carried out during the take-off, the climb and on leaving the Terminal. Further included therein are the alternative procedures to be carried out in case of abnormalities and/or emergencies. Having been carried out previously, as asserted by the Pilot and confirmed by the copilot, the item has been considered carried out. It was not possible to determine the contents of the briefing.

A double beep signal sounded in the cockpit at 08:17:53, without causing any apprehension or concern to the crew members. The warning was of minor importance, and disappeared right after.

'The opening of the reverser in flight is not considered an emergency during take-off, but rather an abnormality. As verified during the test carried out on the simulator, the other engine at take-off power would overcome such adversity even with the landing gear not retracted.'

The behavior of the aircraft, obtained at the test on the simulator, corresponds to that one provided for in the charts of the Flight Manual (AFM).

The Manufacturer anticipated that an opening of the reverser during take-off was at 'extremely remote' level (probability 10^{-11} , i.e., 1 to 100 billion); and informed it is

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not necessary to train such failure during take-off, but rather at speeds exceeding 200 Kt.

Actuation of the crew members according to the CVR recording and the SSFDR data.

The crew assumed the flight without abnormalities. The procedures carried out were according to the company's operational routine, except for the 'before start check list', which has been carried out by the copilot without the presence of the pilot in the cockpit. Such fact has represented no contribution to the accident.

Between 08:18P and 08:25P, the PT-MRK has been in position two (waiting position) awaiting for the authorization to take off, there having been no abnormality in such period of time, except the interference of a pirate radio station for a few moments.

At 08:25:54, TAM 402 received authorization to take off, wind from 060 degrees, of 06 knots, and after the take-off, to call 119.8 (APP SP).

At 08:26:00, the copilot informed: '-starting'.

(from this point on only the minutes and seconds shall be referred to).

The initial engine acceleration is heard on the recording. The Pilot announced the actuation of the 'Take Off Go Around' - 'TOGA' switch. The copilot confirmed the normal condition: '-Take off, take off green.' In the cockpit everything was normal. On the SSFDR (flight data recorder), engine two presented 'transit' situation for the reverser of engine 2, which was not retransmitted to the cockpit.

At 26:04 the beep level 1 signal sounded. Such simple signal does not require any action from the crew. The Pilot informed: - 'Hey, this is what.... it's out, see?' And the copilot confirmed: - 'Manual'.

One of the two auto-throttle channels had been set off (disconnected from the system), such abnormality requiring no correction. The Pilot repeated: - 'The auto-throttle is out.'

At 26:10, beep level 2 signal (double beep) sounded. On the SSFDR, the recording of a momentary Caution signal arises, with a duration between one and two seconds.

At 26:15, the Pilot repeated: - 'The auto-throttle is out.' He was probably warning the copilot for him to adjust the thrust manually, because the auto-throttle was inert. At 26:30, the copilot informed: - 'Thrust check.' With this information, he confirmed that the take-off thrust had been adjusted and checked.

At 26:19, the SSFDR recorded the crossing of the speed 80 knots.

At 26:32, the copilot informed: - 'V-one.' On the flight data (SSFDR), the speed of 127 knots was recorded.

At 26:34, the copilot informed: - 'Rotate.' The speed was 131 Kt. The pitch angle leaves zero, growing in positive values. At 26:36, the speed was about 136 Kt, accelerating, the pitch angle crossed 10°, and the air/ground switch transited from 'ground' to 'air position', indicating the moment of the take-off. The knocks heard on the CVR, not entirely identified, may have resulted either from the clash of the reverser shells or from the noise of the landing gear shock absorbers extending during the take-off. According to the SSFDR, at the same moment (26:36), the EPR of engine 2 (EPR2) starts dropping from 1.69 to 1.34, indicating loss of thrust.

At 26:38, the copilot utters an exclamation, thus registering the observation of the occurrence of some abnormality.

During this time interval, between 26:36 and 26:40, the roll angle to the right (positive) grows from almost zero to 11.2° , at an approximate rate of 3° per second, while the heading varies, to the right, from 163.51° up to 173.8° , also at a rate of about 3° per second. Next, both movements have almost been stabilized, with the aircraft being tilted (roll angle) between 5° and 8° to the right, keeping the heading of 172° . Such movement is consistent with the loss of power of the right hand engine. In order to oppose such trends, the Pilot applied pressure on the left pedal until reaching 16.3° units, and stick left up to 9.8° of aileron. With such efforts, he dominated satisfactorily the lateral trends, and pulled up to 14° to keep flight conditions. The SSFDR did not record the reverse opening movement. Such fact, however, has been seen by one witness, who confirmed having seen at least two complete cycles and heard two knocks resulting from the clashes of the shells at the end of the opening.

At 26:40, the copilot commented: '-it locked.' It is very likely that he were referring to the impossibility of bringing the lever from the slow running (idle) position forward. According to the FDR, a slight drop of speed begins, while the pull-up angle is increased to 16° , at 26:44. The height gain, of 120 feet, is consistent with the speed reduction, by 4 knots per second, during the two next seconds. Between 26:40 and 26:45, the climb ratio has been $\pm 2,100$ feet/min.

At 26:41, EPR2 starts raising to 1.240, and EPR1 is increased to 1.719. According to the lever angle chart (DPPLA), both are brought to the forward detent (45°), where they stay for about one second. Both have been reduced almost immediately. The lever of engine 1 has been reduced to 1.328 EPR, and that one of engine 2 reaches 1.133 (TLA = 5°), where it stays for one second.

The above event leads to the interpretation that the lever has been reduced and became restricted at idle. Since the lever reduction has not been accompanied by the corresponding audible and light warnings, at least for one of the crew members the opening of the reverser in flight has not become characterized. One of the crew members, probably the copilot, forced the lever of engine 2 forward (normal action). Coincidentally the lever has been released (probably by the passage of the shells by the 21° angle). The lever was advanced to the forward detent (45°), with the lever of engine 1 being moved along. The cycle repeated itself and the shells opened, the lever has been reduced, overcoming the force by the crew member, who inadvertently brought back both levers.

The reactions resulting from the engine power variations continued to demand several command corrections, distracting the pilot's attention.

At 26:44, he requested: '-Turn it off up there, auto-throttle, pull here.' Such request confirms the difficulties he felt with the controls, and the confusion between the actually existing failure and the one that was similar to it.

At 26:45, EPR2 starts to raise again. The lever of engine two was brought to almost 39° , and of engine 1 to the angle of 42° , net reaching the take-off EPR. The lever of engine 2 is once more reduced abruptly, reaching zero degrees (idle detent), where it stays for almost two seconds.

At the same instant (26:45), the elevator reaches 1.55° , nose down, and the application of the rudder reaches 11.0 degrees.

At 26:47, the speed drops to 126 Kt (one knot below V2). To this moment, the SSFDR has not picked up any cycling of the reverse, probably due to the extremely short time during which the shells stayed open.

At 26:48, the copilot informs: '-It's off.' Probably confirming that the auto-throttle system was off.

Close to 26:49, the lever of engine 2 was abruptly positioned full forward (45° detent) along with the lever of engine 1. Most probably the shells of the reverser of engine 2 have cycled (opened) again, causing another jolt on the lever cable. The force applied against the lever prevented it from being reduced, and caused the disconnection of the cable at the quick disconnect point. Released from the cable, the lever remained at the 45° position (full thrust).

The effort against the lever was necessarily great. It may have been applied by the pilot, by the copilot or even by both. It was not possible to verify.

At 26:51, a knock is heard on the CVR. It was not possible to determine its origin accurately. Perhaps it was the lever hitting the 45° detent.

With the reverser of engine 2 open, at 26:54 both engines exceeded 1,724 of EPR, which was maintained until the crash.

At 26:52, the pilot repeated: '-Turn off up there, here also.' He again referred to the auto-throttle (on/off) control switch, located on the upper board and the other one existing on the lever itself. Such assertion may be an evidence that probably he had his hands busy with the lever, whereby he himself could not try to turn off said switches.

At 26:53, the pitch angle was 12.7°, while the FDR recorded the opening of reverser 2. The speed starts deteriorating.

At 26:55, with the speed deteriorating about 2 Kt/s, the stall warning (stick shaker) is actuated, sounding until the end of the recording.

At 26:56, with the controls on the detents, the pilot exclaims: '-Oh my God.' From 26:57 onwards, the aircraft has turned without control, passing 39° of tilting towards the right at 26:58 and 87° at 26:59, while the ground proximity warning signal (GPSW) announces no to sink: '-Don't Sink.'

The loss of flight control is characterized, with the crash on the ground and the end of the recording ending at 08:27:01P.

The insufficiency of the above data render impossible a precise definition of several items that might clarify the occurrence with the accurateness an investigation of this scope requires. To reach a conclusion on a level with the work carried out and that achieves recommendations of great value for prevention, it is necessary to formulate at least one hypothesis.

Hypothesis

During the take-off run close to the speed of 80 Kt, two auto-throttle channel failures have occurred, with their respective warnings. The warnings have been cancelled, and the take-off has been continued properly. The lack of auto-throttle does not involve a risk to the operation, but the handling of the levers becomes manual.

The pilot informed, at three distinct moments, the auto-throttle failure, probably warning the copilot as for the adjustment of the levers or another similar measure.

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During the run, at the moment the lift-off took place, the reverser of engine 2 opened. In the cockpit, the only signal of such abnormality was the quick reduction of the lever of engine 2. The visual (Master Caution and Reverse Unlocked) and sound signals did not show up.

The lack of prior information, instructions and training for such type of abnormality, the manual operation of the levers and the absence of other warnings, have not retained, and to the contrary, they have encouraged, the impulse (precipitation) on the part of one of the crew members, of trying to push the lever forward. Coincidentally, the lever has been released from the slow running detent (new cycling) and the crew member felt himself forced [*Translator's remark: in the original in Portuguese 'reinforced'*] to recover the power of engine 2.

Due to the effort in advancing the lever, that one of engine 1 has advanced also. At this moment, a new cycling of the reverser caused another quick reduction of the lever, bringing the crew member's hand along. Inadvertently, the lever of engine 1 has also been reduced to 1.3 EPR.

Other measures, in addition to surprise, caused a 4 seconds delay with the two engines with very low power, deteriorating the aircraft's performance.

At the end of the 4th second, one of the crew members has achieved to advance both levers. Engine 1 stayed below take-off power, and the lever of engine 2 was reduced immediately.

In a third release, the lever has been brought, and maintained, along with the lever of engine 1, to the full thrust position. The efforts have caused the disconnection of the cable, releasing the lever in acceleration, while the reverser remained open.

Without any abnormality warning signal, with the levers forward and the engines accelerated, it was humanly impossible for the crew members to identify the motive of the sudden performance deterioration and loss of control that followed.

V. CONCLUSION

1. Facts

- a. The crew members had their Physical Fitness (CCF) and Technical Eligibility (CHT) Certificates valid;
- b. They were rested, and this was the first take-off of the day;
- c. The pilot was experienced, with 2,392:00 h on F-100 aircrafts. The copilot was newly graduated, having a total of 230:00 h on such model of aircraft.
- d. The aircraft had its revisions and inspections in order and updated, and the Airworthiness and Enrollment Certificates were valid;
- e. After the landing in São Paulo (previous flight), according to the data of the flight data recorder (SSFDR), the reverser of engine 2 remained 'in transit';
- f. The two crews (of the previous flight and of the accident) have reported nothing in relation to such system, facts that characterize the lack of indication of the actual condition of the reverse on the instrument board;
- g. The indication system is inhibited during the take-off phase, from the speed of 80 Kt on and up to the height of 1,000 feet;

- h. During the take-off run, under 80 Kt, there was a failure of one auto-throttle, followed by the failure of the other one, this being a condition of proceeding with the flight (GO condition);
- i. The Pilot has warned the copilot to the inoperative auto-throttle condition, on three distinct occasions;
- j. The abnormality arose on the exact instant of the lift-off, with the quick reduction of the lever of the right hand engine (first second of flight);
- k. The investigation has ascertained an inadvertent opening of reverse ('reverse unlocked') of the right hand engine has occurred when the aircraft left the runway (lift-off);A
- l. No occurrences of abnormality sound (chime) and light (master caution and RVSR Unlk) signals have been verified in the cockpit (CVR and SSFDR) along with the lever reduction;
- m. According to the CVR, the copilot has demonstrated having observed the quick lever reduction (08:26:38) two seconds after the lift-off;
The copilot ASSERTED: -'It locked' at 26:40, demonstrating he verified the lever locked at the idle detent;
- o. The reverse has reverted the cycle (it cycled the reverse shells) for three times in 10 seconds;
- p. The lever of engine 2 had its lock released, permitting it to be moved forward;
- q. On the first recycling, the reduction of the lever of engine 2 has caused the (involuntary) reduction of the lever of engine 1;
- r. For 4 seconds the aircraft has been with very low power (EPR1 - 1,328 and EPR2 - 1,113), deteriorating its performance;
- s. The lever of engine 2 was advanced again along with the lever of engine 1, which was positioned below take-off thrust;
- t. At 26:44, the Pilot gave instructions to the copilot to turn off the auto-throttle, repeating such instruction at 26:52. On both occasions the copilot confirmed they were turned off;
- u. On the third advance of the acceleration lever of engine 2 the safety cable (feedback cable) disconnected, releasing the acceleration lever while the reverse shells of engine 2 remained closed;
- v. Without any warning in the cockpit about the abnormality in reverser 2, the levers remained in the MAXIMUM EPR position;
- w. With the reverse open, the aircraft suffered a fast loss of performance, whereby the pilot lost control;
- x. Doctrinally, any action of a crew facing an abnormality in the environment of the cockpit below 400 Ft is NOT RECOMMENDABLE;
- y. Statistically, as a rule the making of decisions below such height aggravate the circumstances of the danger situation, increasing the risk;
- z. The failure was unusual and was not provided for in the emergency procedures, occurring during the most critical flight performance phase: TRANSITION - take-off run/climb - and more, subjected to induced interpretations, as corroborated by the

previous information, aggravated by the sound and light warnings and further by the intermittence of the locking/unlocking of the lever of the right hand engine - cycling of the reverser.

- aa. The 'reverser unlocked' on take-off procedure has not been trained on the flight simulator by the company's crew members, due to a letter from the aircraft's Manufacturer addressed to the operator, after the latter's prior inquiry, dated 28 June 1995;
- bb. In said letter, it was informed that an opening of the reverse in flight through its actuation would not be possible, due to the protection of the selected system's 'Ground/Flight Switch'. This way, an opening of the reverse as a function of a failure of the mechanical lock, right after take-off, should not occur if the speed were under 200 Kt;
- cc. Upon the homologation of the aircraft, the electric system kept the STOW solenoid always energized, keeping the T/R ACTUATOR pressurized to the effect of closing the shells. However, the electric supply was provided by the essential bus, and with this configuration it would not be possible to apply the reverser in case of a failure of such bus. To correct such problem SB F100-31-008 and 78-004 have been incorporated, qualified as non-mandatory, approved by the RLD and incorporated by the manufacturer in the production line, as provided for in the bulletins themselves;
- dd. On the aircraft, in the Post-Mod version, the possibility of the contacts of SECONDARY LOCK RLY 1 getting stuck has not been considered by the Manufacturer, the case has not been analyzed in REPORT No. UK-28-313 SAFETY ASSESSMENT OF THE THRUST REVERSER CONTROL SYSTEM and its Appendixes, and furthermore it will be a dormant fail;
- ee. The reverser fault tree diagram, made recently by the manufacturer considering the Post-Mod version, even not taking into account a dormant fail, indicates that the probability of an inadvertent opening of the reversers is of the order of 10^{-6} . Therefore, the Post-Mod version does not meet the airworthiness requirements of FAR-RBHA 25.1309;
- ff. On two phases of the complete reversers cycle, at the beginning of the opening and at the end of the shell closing, it is possible to apply power higher than IDLE, with the shells partially open, which does not meet RBHA/FAR 25.933;
- gg. The SECONDARY LOCK ACTUATORS (S/N 874 and S/N 870) that equipped the aircraft that suffered the accident, on the operational tests proposed and carried out, presented a performance below the minimum acceptable to assure the safety and reliability of the system, and as concluded at the end of the work, specifically in the case of S/N 870, it had a share of contribution in the sequence of events that led to the non-commanded opening of the thrust reverser doors of turbine no. 2 during the aircraft take-off phase;
- hh. It may be accepted that there is the possibility that a simple failure of relay K 1266A, characterized by the 'melting' of any of contacts A1/A2, B1/B2 or D1/D2 (particularly A1/A2), causing the continuous command of the DEPLOY coil (through the feeding of SEC. LCK. ACTUATOR), and at the same time brings on the inhibition of the alarms, because the latter depend on the closing of contacts C2/C3, a closing that does not occur. Such failure may be caused by overload on one of those three contacts.
- ii. With the thrust lever having been held full forward, a high resistive force has developed, which added to the friction forces on the cable assembly, also added to the force of the

'ricochet' on the FEEDBACK CABLE, produced by the opening of the shells, had as consequence a resulting tensile force that exceeded the strength established for said cable; and

- jj. The holding of the thrust lever full forward, with the forces produced by the opening of the reverse shells, has exceeded the strength established for said cable.

2. Fatores contribuintes

a. Contributing Factors

Psychological Aspect - Contributed

a) Oorganizational aspect

The lack of information, instructions in writing and practice, contributed to the non-recognition of the abnormality during its unfolding.

b) Individual aspect

The unusual occurrence of the quick reduction of the lever, on a particularly difficult phase of the operation (transition from take-off run to flight); the non-occurrence of failure discriminating (sound and visual) warnings, and the lack of cognizance and specific training for such abnormality bring on surprise and distraction of the crew members' attention.

- The release of the restriction of the lever of engine 2 at the idle detent without the occurrence of the abnormality warnings strengthened the tendency (in at least one of the crew members) to try to recover the power on the engine.

- The lack of warnings and the difficulties that are characteristic of such abnormality have diverted the crew members' concentration from the procedures provided for, to concentrate it on the solution of the abnormality, initially imagined as being an auto-throttle failure, and later the recovery of thrust.

- The occurrence of auto-throttle failure warnings (before the 80 Kt) and the lack of specific reverse opening warnings (Master Caution and RSVS UNLK) have strengthened, in the crew members, the belief that they were experiencing an auto-throttle failure (illusion).

b. Material Factor

(1). Desing Deficiency - Contributed

The reverser fault tree chart made recently by the manufacturer considering the Post-Mod version, even not taking into account a dormant fail, has indicated that the probability of an inadvertent opening of the reversers is of the order of 10^{-6} . The Post-Mod version does not meet the airworthiness requirements of FAR/RBHA 25.1309.

On two phases of the complete reversers cycle, at the beginning of the opening and at the end of the shell closing, it is possible to apply power higher than IDLE with the shells partially open, which does not meet RBHA/FAR 25.933.

The reverser unlocked indication system is inhibited at speeds higher than 80 Kt and up to the height of 1000 feet, exactly at an instant when the pilots would need such information most.

The SECONDARY LOCK ACTUATORS (S/N 874 and S/N 870) that equipped the aircraft that suffered the accident, on the operational tests proposed and carried

out, presented a performance much below the minimum acceptable to assure the safety and reliability of the system.

The applicable FAR 25.993(a)(3) requirements determine that each [reverse] system is to be provided with means to prevent the engine from producing power higher than idle power upon a failure on the reverse system [not stipulating the type of failure]. Such requirement has not been complied with, both in relation to the control system, which permitted the shells to open in flight, and in relation to protection, which became non-existent when the separation of the FEEDBACK CABLE occurred due to the unpredicted pilot's action on the lever, with the intention of recovering the power of the affected engine.

The TURNBUCKLE is installed on the side to which the connection moves when the reverser is commanded to open, i.e., the same side towards which the connection moves when the situation occurs in which the lever is forcibly held forward while the reverser is opening (deploying).

The THRUST SELECTOR VALVE may be moved with less than 2% of the normal functioning pressure, when the selector valve is de-energized, which was the condition at the time of the accident.

The inductive loads as those of SEC. LCK. ACTUATOR are detrimental to the contacts that command them, particularly on de-energization, in case there is no protection diode, which is apparently the case of SEC. LCK. ACTUATOR.

The THRUST REVERSER ACTUATOR, in the Post-Mod configuration, incorporated to the assembly line by the manufacturer, remains de-energized during the periods in which there is no commanding by the pilot, and this way it stays in an unstable and dangerous situation.

Design faults, an insufficient assessment of the fault tree diagram as compared to FAR 25.1309 and 25.933, and in the guidance to the operator not to train the abnormality that occurred on that phase, have indirectly contributed to the sequence of events that led to place the crew facing an unprecedented situation, without possibilities of recognizing and responding properly to avoid the loss of control.

c. Operational Factor

(1). Little experience on the aircraft - indeterminate

limitation of information and aids to the pilot. He had 230:00 total flight hours on this aircraft model, however the condition under which the unusual abnormality presented itself renders indeterminate the degree of experience that may be expected from a crew member to face such condition.

(2). Deficient Application of Control - Indeterminate.

For three times, the thrust lever of engine 2 has been reduced and advanced. Such interventions on that lever have brought on the reduction of the thrust lever of the left hand engine, impairing the aircraft's performance. The non-return of the left hand lever to take-off thrust immediately, and the another four seconds delay in attaining such thrust, have contributed to deteriorate even more the aircraft's climbing capability.

The condition under which the unusual abnormality presented itself to the crew, and the lack of warning signals, has rendered the intentionality of the action

indeterminate, and furthermore it was not possible to determine which of the two crew members has actuated the levers.

(3). Deficient Judgement - Indeterminate

The lack of cognizance, on the part of the crew members, for insufficiency of warning signals and information about the abnormality, has been a determinant for them to abandon the normal sequence of procedures, such as retracting the landing gear and actuating the Auto-Pilot, in order to take the initiatives of prioritizing the solution of an unusual situation installed in the cockpit, below safety height and that eventually brought on the loss of control of the aircraft, whereby it has also not been possible to determine which one of them took the initiative. Such facts render such aspect indeterminate.

d. Other Aspects

(1). External Inspection - Contributor

There is no condition of seeing the 'Secondary Lock' open, during the external inspection.

(2). Performing Action Below 400 feet - Contributor.

Doctrinally, any action by a crew facing any abnormality in the cockpit environment below 400 feet is **NOT RECOMMENDABLE**.

The crew tried to manage the 'abnormality' concurrently with the control of the aircraft below 400 feet. Under such risk condition, a power reduction occurred on the other engine, compromising the aircraft's performance. As a consequence, the crew was obligated to prioritize the thrust needs to the detriment of other procedures.

(3). Inadequate Action In Face of an Unpredicted Failure - Contributor.

Based on the data collected on the SSFDR about the FUEL FLOW and EPR parameters, the lever of engine no. 2 was brought to the maximum power position, after the locking of said lever at the IDLE position.

Such locking occurred immediately after the lift-off, when the lever was reduced by itself to the 'IDLE' position, staying locked for about three (3) seconds. However, the system itself released the lever, inducing the copilot to bring it to the full power position, even after having informed the pilot about its locking.

It should be pointed out that the pilot has not requested such action after having been informed about the locking, as well as that the copilot has not asked whether such action should be done or not.

The airplane has not provided means for both pilots to be able to imagine how untimely such attitude would become at that extremely critical moment of the flight.

In case the action has not been performed by the copilot, the suspicion falls upon the pilot, induced by the same reasons presented before.

VI. RECOMMENDATIONS

1. Primary Homologation Bodies

- a. They are to improve the quality of the analyses of all bulletins, even if considered MINOR CHANGES, regardless of their classification, and are to determine that it is mandatory, for the manufacturers, to remake the FAULT TREE ANALYSIS for every and any proposition of modification in any of the systems, that may in some way interfere with the aircraft's airworthiness.
- b. They are to issue a Rule Proposition Notice (NPR), suggesting a modification of FAR 25.933, particularly as for the provision of automatic reduction of the thrust lever, because there is no specific requirement defining the effort levels such device should withstand.
- c. They are to revise the data sampling rates of the SSFDRs they homologate, with the objective that same may reflect in their recordings, in the way closest to reality, the data regarding the several positions of the thrust reverser shells installed on aircrafts' engines, as well as to revise the sampling rates about other parameters that may have a recording behavior similar to the SSFDR.
- d. They are to revise the requirements of the SSFDRs they homologate, with the objective that: the THRUST LEVER ANGLE (TLA) data are included among the data to be recorded mandatorily.

2. To the Homologation Division of IFI/CTA

- a. To study and issue a Rule Proposition Notice (NPR) with the purpose of analyzing and implementing a Cockpit Video and Voice Recorder system, initially with the intent of aiding in the field of Aeronautical Accident Investigation, and in the future, once the possible obstacles of a legal nature have been removed, to aid in Prevention also.

3. RLD

- a. To revise the fault trees of the several systems of the FOKKER 100, for them to really meet the items of FAR 25.1309 and FAR 25.933.
- b. To revise the homologation requirements of the FOKKER 100 so that by design a simple failure may not inhibit a warning, if the information is available to another system of the aircraft.
- c. To develop an airworthiness directive (BLA):

-For the reversers system of aircraft FOKKER 100, that determines the possibility of visual and external verification, during the pre- and post-flight inspections, of the position of the mechanical locking system of the SECONDARY LOCK. To include such visual check in the aircraft's maintenance plan and in the external inspection prior to each flight.

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- Modifying the FLIGHT WARNING COMPUTER (FWC) so that the REVERSER ENGINE 1/2 warning is classified as LEVEL 3, informing the crew through the MASTER WARNING.
- Modifying the FWC so that the REVERSER ENGINE 1/2 warning is not inhibited, and is informed to the crew during any phase of the flight.
- That it eliminates the STOW LIMIT RELAY, this way keeping the STOW side of the selector valve energized always, except when there is an actual command of the reverser.
- That it modifies the electric wiring of the alarm system, so that the signal indicating that the reverser shell is not locked (THRUST REV NOT STOWED), that passes by the contacts of the T/R SEC LOCK RELAY 1 ENG 1/2 is sent directly to the alarm system (FWS), not permitting that in case of a failure of such relay the alarm in the cockpit may be inhibited.
- That it introduces a protection against sparking of terminals A1/A2 upon the turning off of the inductive load of the SECONDARY LOCK ACTUATOR.
- That it introduces a modification in the T/R SELECTOR VALVES, avoiding that any unstable balance may result in easier opening of the shells, in case of a lock failure of the SECONDARY LOCK ACTUATOR in the UNLOCKED position, associated or not to an hydraulic leak problem on the STOW line.

4. FOKKER

- a. To modify the electric system of the reverse system so as to meet the airworthiness requirements, particularly FAR 25.1309 and 25.933, according to the contemporaneous philosophy of their interpretation.
- b. The present FEEDBACK CABLE SYSTEM connected to the lever has been associated to an ATS failure. FOKKER is to evaluate a system connected directly to the FUEL CONTROL UNIT, regardless of the lever position, and that meets fully the airworthiness requirements of FAR 25.933(a)(1) and FAR 25.933(a)(3), which determine that on the opening the reverser in flight the engine produces no power exceeding IDLE.
- c. To review the FEEDBACK CABLE SYSTEM to meet the requirement of FAR 25.933(a)(1) entirely, because there are time intervals in the opening and closing of the shells as compared to the position of the thrust lever, during which the reverser is open in flight and there is the condition for the engine to be producing power higher than IDLE.

5. CENIPA/CECOMSAER

- a. They are to render feasible, under the coordination of CECOMSAER, clarification and integration activities of the Panel, Seminar, Lecture and Symposium types, about Flight Safety, to the professionals of the media

- b. For aeronautical accidents with a great public repercussion, they are to define a physical location (auditorium) where daily collective divulgences shall be made, in order to clarify all communications means (TV, Radio, Newspapers, etc.), and consequently the public opinion, avoiding conflicts and facilitating information.
- c. They are to render feasible, under the coordination of the Regional Air Commands, the carrying out of Lectures and Seminars on Initial Action in case of mass aeronautical accidents, to the Organizations subordinated to the Public Security State Secretariats (Civil Police, Military Police, Fire Department, Civil Defense, etc.).
- d. They are to include, in the CIAA of the accidents with a great public repercussion, one Public Relations Officer and one Information Officer at the site of the accident, and another Public Relations Officer at the place where the collective Press interviews are to take place.

6. GRUMMAN / FOKKER / FAA / RLD

- a. The reversers' SECONDARY LOCK ACTUATORS are to be re-analyzed and have their reliability increased, including final tests of impedance and electric resistance, prior to delivery and post-assembly on the aircraft.
- b. To define a primary maintenance process determining the failure mode of the SEC. LOCK ACTUATOR, aiming to avoid the dormant fail of such component.
- c. To determine an analyses and tests program for the SEC. LCK. ACTUATOR, with the objective of explaining the causes of the contamination of the internal switches of such actuator, providing an effective way to avoid it.
- d. To re-design the FEEDBACK CABLE so that on its moving due to the DEPLOY command, the (MORSE/GRUMMAN) connection finds no 'free' space as that one existing inside the TURNBUCKLE, where an inadvertent separation may occur. Or further, within the same philosophy, to modify the coupling process between the rear and front portions of the FEEDBACK CABLE, preventing said separation.

7. FOKKER / RLD

- a. To analyze the present application of RELAY P/N FOKKER FON9-6105D4L, manufactured by LRE FRANCE under P/N M400-D4L003, and by other manufacturers, utilized on FOKKER 100's THRUST REVERSER SYSTEM, carrying out a study jointly with LEACH and the other manufacturers of the same type of relay, with the purpose of establishing the actual reliability of such relay.
- b. To define a primary maintenance process determining the failure mode of T/R SEC. LCK. RELAY, aiming to avoid the dormant fail of such component.

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- c. To analyze the incorporation of a component or circuit for protection against sparking of the contacts of T/R SEC. LCK. RLY.1 ENG 1/2, produced by the inductive loads of the solenoids that are placed in the same electric circuit.
- d. They are to emphasize, to the crews, that a failure in the ATS system causing a lever delay will normally affect both levers. It should be emphasized also that in case of non-intentional delay of a lever during take-off or the initial climb, the crew is not to try to reopen the lever - it should handle the situation as if it were an engine failure.

8. FOKKER / DOWTY AEROSPACE HYDRAULICS / RLD / CAA

To introduce a modification in the THRUST REVERSER SELECTOR VALVES P/N 114168001, avoiding that any unstable balance may result in easier shell opening, in case of a failure of the lock of the SECONDARY LOCK ACTUATOR at the UNLOCKED position, associated or not to an hydraulic leak problem on the STOW line.

9. TAM

- a. To amend the aircraft log, with the objective of improving the failure entries so that each sheet is detached at every transit, with a copy remaining at the base that has carried out the aircraft return to the flight. The original is to be sent for processing on the TROUBLE SHOOTING, and the other copy is to remain in the log, within the aircraft, for reference by the crew, while there is an item pending.
- b. SIPAA and the company's Engineering shall develop a program, jointly with the manufacturer, with the objective of listing all situations of basic failures that accept RESET, analyzing each case in depth, and preparing a training program for the flight group, particularly the technical crew members, with the purpose of changing the organizational environment formed, as a function of the operation of extremely computerized aircrafts, where failures that accept RESET do not need to be entered in the aircraft log.
- c. It is to give more emphasis to the training sessions carried out on flight simulators in relation to the opening of the reverse in the several phases of the flight.
- d. In the initial and revalidation training sessions it is to emphasize to the importance of not performing actions below 400 feet.
- e. To be included in the theoretical and in the simulator training is a procedure for the case of non-commanded delay of one of the thrust levers during the take-off and climbing phases.

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- f. It is to increment CRM (COCKPIT RESOURCE MANAGEMENT) training to all the company's crew members. Circular 227-AN-136 of OACI, Human Factors Digest no. 3, is to be observed.
- g. Although it has had no influence to the occurrence of the accident, it has been verified that sometimes the crew members flight schedule came out with daily working hours exceeding those permitted. The Company is to prepare flight schedules for all crew members complying with what is provided for in Law 7183, of 05 April 1984.
- h. The Operations Officer of said Company is to emphasize to the flight group personnel (pilots and copilots) the obligatoriness of reading the checklist, as provided for in the Operations Manual.

10. IFI

To study and propose to DAC [*Translator's Remark: Civil Aviation Directorate of the Ministry of Aeronautics*] the implementation of a recommendation of a procedure restricting the manipulation of the engine's thrust levers by copilots, at critical flight phases, below safety height, to the effect of avoiding precipitated initiatives and without the due supervision and coordination of the Pilots, for crews operating under RBHA 121.

11. DAC

- a. Based on the chain of events verified in this accident, to strengthen the safety instructions to be observed in case of unprecedented situations arising during critical operation phases (such as: acceleration on take-off and stabilization during the final approach for landing, etc.), to the effect that actions are performed orderly, without precipitations that might occasion fatally improper initiatives or conflict in the cockpit.
- b. To determine to the operators of big cargo aircrafts to guide the pilots group to respect, particularly for aircrafts with a high degree of automatism sophistication, the limits of actuation of the flight controls management systems, like in the case of the levers (auto-throttle), avoiding any precipitation in their use.

12. DAC/STE

- a. Considering that in the antecedent occurrences occasioned by failures of the reverse in flight the crews have had difficulties in recognizing the failure or its seriousness, STE is to give more emphasis to the requirements of flight simulator training sessions, both for companies that are authorized to operate already and those for which operation authorization will be granted in the future.

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- b. To study the feasibility of establishing, through RBHA or IAC, for the companies that operate according to RBHA 121, a procedure for utilization of the FDR in a PREVENTIVE way, turned to flight safety.

13. DAC/CENIPA

- a. They are to carry out a study in order to provide, as soon as possible, DAC's DIPAA with an Emergency Fund for use by the CIAAs, with the purpose of covering costs (daily wages, tickets, lodging, etc.) of the personnel involved in the Investigation that do not belong to the Ministry of Aeronautics, complying with what is provided for in NSMA 3-6.
- b. To develop a program for divulgence and implementation of rescue techniques in cases of mass aeronautical accidents, with the purpose of implementing communication, control and coordina-tion among the agencies involved and the CIAA, with the objective of preserving the evidences essential to the investigation of the aeronautical accident.

On 11 December '97.

DOUGLAS FERREIRA MACHADO - Air Force Colonel
Head of CENIPA

APPROVE THE COMPLIANCE WITH THE SAFETY
RECOMMENDATIONS:

RONALD EDUARDO JAECKEL, Air Force Lieutenant Brigadier
Head of EMAer (Air Force General Staff)

DFMJRSB

This document is totally in accordance with its original in portuguese.

Brasília - DF, 10/30/1998


PAULO ALBANO DE GODOY PENTEADO - Air Force Colonel
Head of CENIPA