CENIPA Final Report from the accident of Fokker-100 PT-MRK

TAM flight 402, 31 October 1996

Excerpt containing Accident Board Findings (Text extracted from the printed English translation.)

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 Sao 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 (Iiftoff);

I. 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: TRANSITI O N - 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 b u s , a n d with this configuration it would not be possible to apply the reverser i n case of a failure of such bus. To correct such problem S B F 1 00-31 -008 and 7 8-004 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 REPO RT No. U K-28-31 3 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 (SIN 874 and SIN 870) that equipped the aircraft that suffered the accident, on the operational tests proposed and carried out, presented a performance below the minimum acceptable (0 assure the safety and reliability of the system, and as concluded at the end of the work, specifically in the case of SIN 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 1 266A, characterized by the 'melting' of any of contacts A1 /A2, B 1 /B2 or D 1 1D2 (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) Organizational 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 nonoccurrence 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 autothrottle failure (illusion).

b. Material Factor

(1). Design 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 reverser’s 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 25.933(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, ie., 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 b e 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.