

3 - CONCLUSION

3.1 Findings

- The aircraft possessed a valid certificate of airworthiness.
- The Captain and the Flight Engineer possessed the requisite qualifications and certificates to undertake the flight. In application of a clause in the FCL 1 regulations on the length of validity of medical certificates, subsequently modified, the First Officer's licence was not valid after 18 July 2000.
- The spacer on the left main landing gear bogie had not been re-installed during replacement of the bogie on 17 and 18 July 2000. This omission did not contribute to the accident.
- The aircraft was not subject to acceptable deferred defect limitations on departure from the stand. The electrical system for rudder control had switched to Green during taxiing; departure under these conditions was in accordance with the minimum equipment list.
- Repeating the calculations for the flight preparation showed that the estimated weight of the aircraft on departure was in accordance with operational limits.
- Taking into account the fuel not consumed during taxiing, the aircraft's takeoff weight in fact exceeded the maximum weight by about one ton. Any effect on takeoff performance from this excess weight was negligible.
- During takeoff, after V1, the tyre on wheel No 2 was cut by a metallic strip present on the runway.
- The metallic strip came from the thrust reverser cowl door of engine 3 on a DC 10 that had taken off five minutes before the Concorde.
- This metallic strip had been replaced in Tel Aviv in June 2000 during the aircraft's "C" check, then again in Houston on 9 July.
- The strip installed in Houston had neither been manufactured nor installed in accordance with the procedures as defined by the manufacturer.
- A piece of the tyre from wheel No 2 weighing 4.5 kg was found on the runway, near the metallic strip. Other pieces of this tyre and a few light pieces from the aircraft were also found.
- Rubber marks from the damaged tyre on wheel No 2 then appeared.
- A large part of the underside of tank 5 was found on the runway. It bore no signs of impact and had been ripped away from the inside towards the outside.
- Another part of the underside of tank 5 was found at the accident site. It had a puncture ten millimetres wide and forty millimetres long.

- Research showed that a projectile penetrating tank 5 could have generated a hydrodynamic pressure surge but that this could not have caused the ripping out of the piece of the tank found on the runway.
- A large kerosene mark was found on the runway, immediately after the piece of the tank.
- The fuel that was leaking was ignited; a flame and large quantities of smoke appeared behind and to the left of the aircraft.
- Around ten metres after the unburned kerosene mark, some soot marks on the runway and then some traces of burnt grass on the left edge of the runway were noted over a distance of 1,300 metres.
- After the aircraft's passage over the metallic strip, the rupture of tank 5 and the ignition of the leak, engines 1 and 2 suffered simultaneous surges leading to slight loss of thrust on engine 1 and a severe loss on engine 2.
- The surge on engine 1 was most likely caused by ingestion of hot gases or solid debris, probably pieces of tyre, that on engine 2 resulting from ingestion of hot gases due to the fire.
- The crew began aircraft rotation at the same time, at a speed of 183 kt, 15 kt before VR.
- The marks on the runway show the aircraft deviating to the left of in relation to the runway centreline.
- The crew were advised by the ATC that there were large flames behind them.
- Engine 1 regained almost nominal thrust before suffering, at the moment of takeoff, a second surge leading to a severe loss of thrust; engine 2, in a slight recovery phase, also surged for the second time at that moment.
- The second surge on engine 1 was caused by ingestion of hot gases and/or kerosene, that on engine 2 by ingestion of hot gases through the auxiliary air intake which was beginning to re-open.
- Engine 2's fire alarm was activated.
- The Flight Engineer announced "shut down engine 2" and the Captain called for the engine fire procedure.
- Engine 2's thrust lever was then positioned at idle, the fire handle was subsequently pulled by the Flight Engineer.
- Because of incomplete opening of the left main landing gear door or the absence of detection of opening of these doors, the crew were unable to retract the landing gear.
- Because of the lack of thrust and the impossibility of retracting the landing gear, the aircraft was in a flight configuration which made it impossible to climb or to gain speed.

- Following the third surge due to ingestion of pieces of the aircraft structure, of hot gases and/or of kerosene, engine 1 suffered a final loss of thrust.
- The aircraft then adopted a very pronounced angle of attack and roll attitude.
- The loss of thrust on engines 3 and 4 was caused by a combination of deliberate selection of idle and by a surge due to excessive airflow distortion. This allowed aircraft bank to be reduced.
- The aircraft crashed practically flat, destroying a building and was immediately consumed by a violent fire.
- Many pieces of the aircraft found along the track indicate that severe damage to the aircraft's structure was caused in flight by the fire.
- Even with the engines operating normally, the significant damage caused to the aircraft's structure would have led to the loss of the aircraft.

3.2 Probable Causes

The accident was due to the following causes:

- High-speed passage of a tyre over a part lost by an aircraft that had taken off five minutes earlier and the destruction of the tyre.
- The ripping out of a large piece of tank in a complex process of transmission of the energy produced by the impact of a piece of tyre at another point on the tank, this transmission associating deformation of the tank skin and the movement of the fuel, with perhaps the contributory effect of other more minor shocks and /or a hydrodynamic pressure surge.
- Ignition of the leaking fuel by an electric arc in the landing gear bay or through contact with the hot parts of the engine with forward propagation of the flame causing a very large fire under the aircraft's wing and severe loss of thrust on engine 2 then engine 1.

In addition, the impossibility of retracting the landing gear probably contributed to the retention and stabilisation of the flame throughout the flight.