No. 4

McDonnell-Douglas DC-8-61, C-GMXQ, accident at King Abdulaziz International Airport, Jeddah, Saudi Arabia, on 11 July 1991. Report released by the Presidency of Civil Aviation, Kingdom of Saudi Arabia.

SYNOPSIS

A Canadian registered DC-8 Aircraft, C-GMXQ, owned and operated by Nationair, took-off from runway 34L at King Abdulaziz International Airport, Jeddah, Kingdom of Saudi Arabia. It was chartered to convey pilgrims from Saudi Arabia to Nigeria; on board were 247 passengers and 14 crew members.

During the take-off roll, tyres and wheels failed on the left main undercarriage and a piece of a wheel rim damaged the airframe. Remnants of tyres on the bogie were burning when the gear was retracted after take-off.

A fire developed within the main wheel wells causing loss of pressurisation, loss of hydraulics, structural damage and finally, loss of control.

During the final stages of the approach to runway 34C, witnesses reported a significant increase of fire and smoke and the aircraft dived and rolled to crash some 2,875 metres short of the threshold.

There were no survivors.

1 FACTUAL INFORMATION

1.1 History of the Flight

1.1.1 Purpose of the Flight

Nationair DC-8, registration C-GMXQ was under charter to transport pilgrims from Jeddah to destinations in west Africa. This particular flight was intended to operate from Jeddah to Sokoto, Nigeria, operating as Nigerian Airways Flight 2120.

1.1.2 Pre-Flight Activities

The aircraft arrived at Jeddah at 1400 hours[1] on Wednesday 10 July 1991 and was originally scheduled to depart later that same day. As there were some difficulties in the processing of passengers, the flight was delayed until 11 July.

Immediately after arrival, the operating crew went to the hotel; mechanics, who were travelling on the aircraft, remained at the aircraft to perform maintenance functions. A witness reported that he understood a wheel change would be made but there is no evidence of a wheel change. The maintenance activities were completed within three hours of arrival and the mechanics went to the hotel.

A co-ordinator[2] at the airport was in continuous contact with Nationair personnel at the hotel and he passed an estimate of the time at which passenger processing would be completed. As a result, the crew were called at 0300 hours and departed from the hotel shortly after 0400 hours.

The crew arrived at the airport at about 0500 hours and, after routine airport administrative procedures, went to the aircraft. Witnesses stated that baggage loading was already underway when the crew arrived. The flight engineer supervised the refuelling of the aircraft and, it is reported, instructed the handling agent to limit loading of checked-in baggage to four tons.

The co-ordinator stated that at about the time that all passengers had been loaded, shortly before 0800 hours, the mechanic told him that he needed nitrogen to inflate a tyre. The co-ordinator further stated that he observed the rear inboard tyre on the left main gear bogie to be under-inflated. A ramp supervisor stated that he drove the mechanic to a support facility which serviced other airlines under contract. They asked for nitrogen but were told that the bottles were empty. The only other source of nitrogen would have been Saudi Arabian Airlines' line maintenance facility and, according to witnesses, the inevitable delay in obtaining nitrogen from this source was unacceptable to the project manager. The co-ordinator stated that the project manager said: "Forget it."

1.1.3 Start-up and Taxi

Doors were closed and the engines were started. The captain called for the after-start checklist which, according to the Nationair flight handbook, is "challenged by the flight

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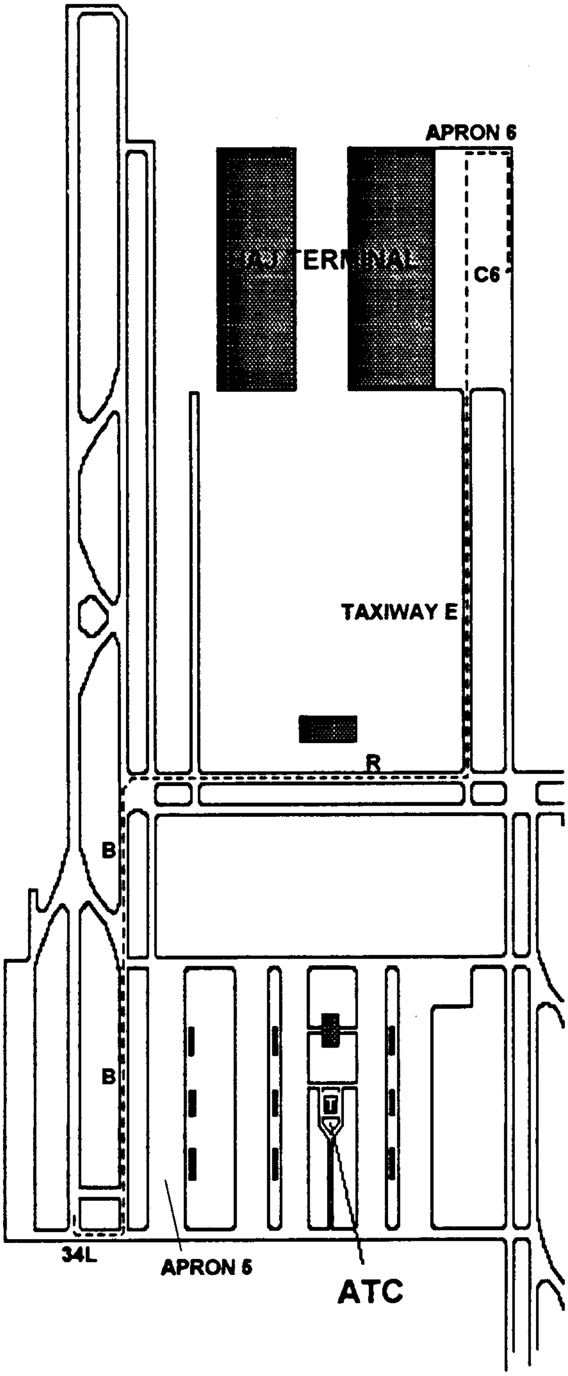
[1] All times in the report are based on Jeddah LOCAL time which is GMT +3

[2] See 1.17.8.2.

engineer." The cockpit voice recorder (CVR) indicates that the Nationair Quick Reference Checklist was followed. The aircraft was pushed back at about 0810 hours. After a short pause, the aircraft began to taxi from the apron towards the threshold of runway 34L, a total distance of some 5,200 metres. It took 11 minutes to taxi that distance.

1.1.3.1 Taxi Route

The taxi pattern following push-back was in accordance with the published procedures for the Haj Terminal and is shown by the dotted line. The diagram is reasonably to scale in the major axes. Buildings and widths of paved surfaces are not to scale.



The aircraft taxied in a northerly direction to the end of the apron and then followed a track leading to taxiways "E," "R" and "B" which were followed to the runway.

Once the aircraft had begun to taxi under its own power, two 90 degree left turns were performed on the ramp. These turns took 13 seconds and 17 seconds respectively. Thereafter, the taxi route consisted of a straight track averaging 11 knots ground speed, a 90 degree right turn which took 16 seconds, a straight track averaging 20 knots ground speed, a 90 degree left turn which took 16 seconds, a straight track averaging 17 knots, a 90 degree right turn which took 16 seconds, a 13 second hold and the line-up on the runway which took 31 seconds to change direction by 90 degrees.

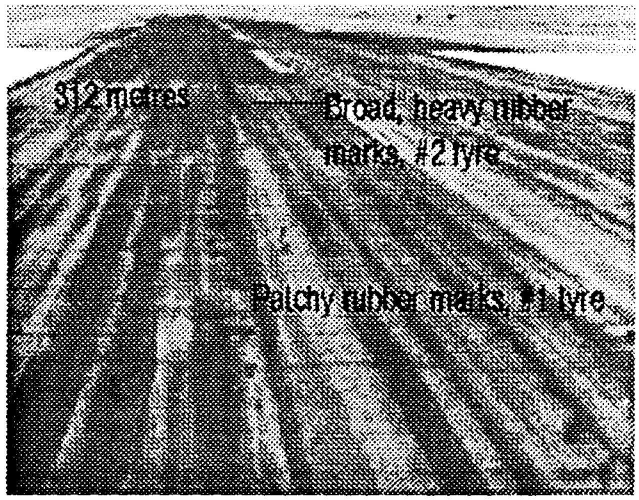
Other points covered elsewhere in the report include:

- The ATC tower is 1,000 metres and 830 metres from taxiways "R" and "B" at the closest points.
- A number of witnesses watched the take-off from apron 5.

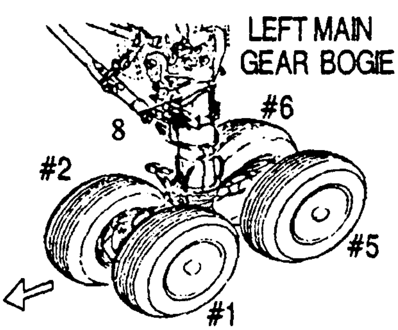
1.1.4 Take-Off

Take-off clearance was given and the aircraft lined up on the runway. The V_1, V_R, and V_2 speeds were 141, 156 and 167 knots. The clearance was to climb on heading 304° to

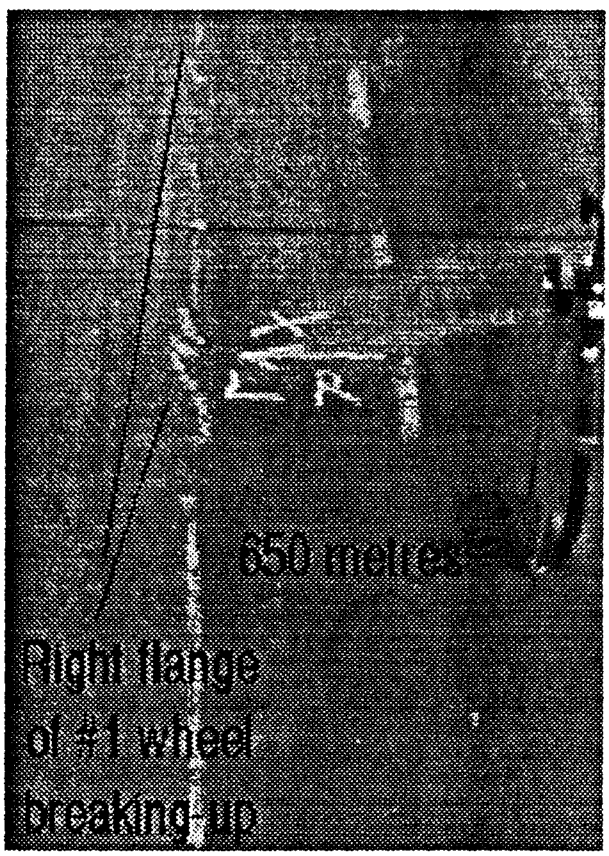
4000 feet on a "Dungu Two Charlie" Standard Instrument Departure. Control was given to the first officer who released the brakes; take-off power was established and the take-off roll began.



160 metres from the threshold, #1 tyre began to deposit "patchy" rubber marks on the runway. By 185 metres (from the threshold) #1 tyre was depositing dense, broad patchy rubber marks. At a distance of 290 metres from the threshold, #1 tyre had ceased depositing tread marks and the #1 wheel rim began to contact the runway surface. At the same time, #2 tyre began to deposit dense broad patchy rubber marks on the runway. To allow for the turning radius of the aircraft while lining up on the centre line, the measured distances along the runway should be reduced by 30 to 60 metres to tie in with the aircraft take-off roll.



Some 15 seconds after brake release, at a speed of about 50 knots, an oscillating sound was heard in the cockpit; within 2 seconds, the flight engineer said: "What's that?"



The first officer said: "We gotta flat tyre, you figure?" Two seconds later, an oscillating sound was again recorded. The captain said: "You're not leaning on the brakes, eh?" The first officer responded: "No I'm not, I got my feet on the bottom of the rudder;" the aircraft had now accelerated to about 80 knots.

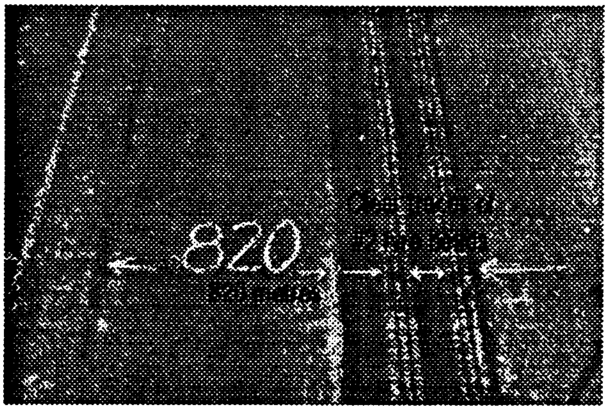
Marks on the runway showed that the #1 wheel started to break up at about this time. In addition, the left and right flanges of #2 wheel began to trace on the runway; rubber deposit from #2 tyre continued which appeared to be from a deflated tyre between the flanges.

The captain said: "OK."

By now, marks on the runway showed continuous metal to surface contact of the left flange of wheel #1, both flanges of wheel #2 and tyre beads of tyre #2. Rubber deposits ceased.

28 seconds after brake release, a speed of 90 knots was called by the captain and confirmed by the first officer.

Marks on the runway showed continuous contact by the right side of the base of the tyre-well of #1 wheel; #2 wheel had stopped rotating and both flanges and the tyre beads of #2 wheel were being ground away.



45 seconds from brake release, the captain called: "V one." Two seconds later, the first officer observed: "Sort of a shimmy like if you're riding on one of those ah thingamajigs."

Marks on the runway showed that #2 wheel was not rotating and that the full width of the wheel assembly was being ground away and had progressed beyond a wheel tie bolt. #1 wheel continued to trace.

51 seconds after brake release, the captain called: "Rotate." Nine seconds later, he reported: "Positive rate."

The last trace on the runway was 2,375 metres from the threshold, 1,315 metres from the upwind end of the runway.

The gear was raised and the aircraft climbed away.

Witnesses on the ground reported that the take-off seemed normal except that sparks and flame were seen in the area of the left main landing gear. The flames remained visible until the landing gear was retracted shortly after take-off; the consensus was that once the gear was retracted, there were no abnormal signs. One witness who was abeam the lift-off point stated that he heard an explosion, as if a tyre had burst, just as the aircraft became airborne. A witness below the initial climb flight path reported no abnormal signs as he watched the aircraft continue its climbing turn on to a westerly heading. The tower controller stated that he observed no abnormality during the take off.

1.1.5 Remainder of the Flight

Two minutes and 16 seconds after brake release, during a climbing turn to the left (climbing through 1,600 feet, turning through west) the flight engineer reported: "... four low pressure lights," followed 12 seconds later by: "... losing pressurisation." During the following three minutes, several indications of system anomalies occurred which included: a spoiler light; a gear unsafe light; a loss of hydraulics and a flap-slot light.

Two minutes and 37 seconds after brake release, the captain called air traffic control to request a level off at 2,000 feet because of a pressurisation problem. In this transmission the captain used the callsign "Nationair Two One Two Zero" instead of "Nigerian Two One Two Zero." Air traffic responded by asking for the callsign. This was not given. The controller mistook the transmission to be from a Saudia flight which was returning to Jeddah, from the north, with a pressurisation problem; he gave clearance to descend to 3,000 feet. The captain of C-GMXQ acknowledged, without a callsign, saying: "... understand you want us up to 3,000 feet."

During the next three minutes, no callsign was transmitted by the captain of C-GMXQ (although the controller used the callsign of the Saudia aircraft on two occasions). As a result, the air traffic controller assumed, until six minutes after brake release when C-GMXQ was some 11 nautical miles south south-west of the airport, that all calls from C-GMXQ were from the Saudia aircraft; the controller's responses were directed towards the Saudia aircraft but usually acknowledged by C-GMXQ.

As the aircraft approached a position abeam the departure end of runway 34L, the captain (without using his callsign) informed air traffic control that they were losing hydraulics and would need to return to Jeddah. At about this time a witness in a fishing boat saw that the aircraft was leaving a trail of smoke which he took to be fuel being jettisoned. Another witness (on the airport who had seen flames during the take-off) reported that as the aircraft was abeam the threshold of 34L, he observed smoke begin to trail behind the aircraft.

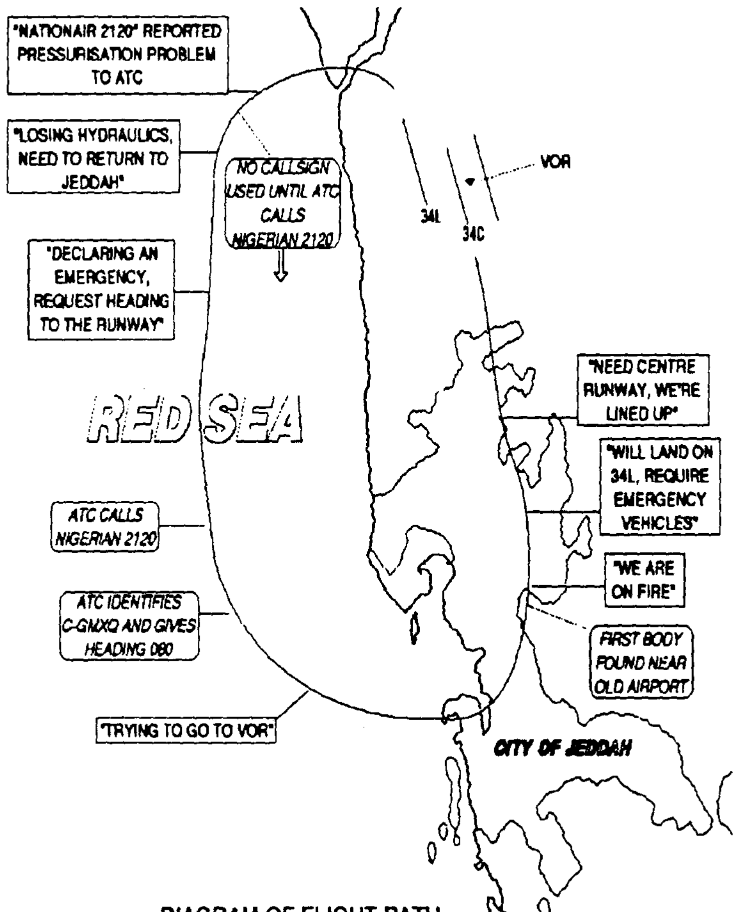


DIAGRAM OF FLIGHT PATH

Four minutes after brake release, the captain called Air Traffic Control and reported: "OK levelling at three thousand feet and ah, if you could give us a heading back towards ah... (the first officer interjected '***[3] declaring an emergency') ...the runway, we'll advise you of the problem. We're declaring an emergency at this time. We believe we have ah, blown tyres... ah sir, over." Still believing he was addressing the Saudia

[3] *** represents questionable or unintelligible words.

aircraft, the air traffic controller offered runway 16 but this was refused by the captain; "... thirty four would be better, we're going to need some time to get ready for the landing."

The aircraft continued on a downwind heading. Five minutes after brake release, the cabin in-flight director came to the cockpit and reported: "*** smoke in the back...real bad." The captain acknowledged: "Yeah, we're going back, we've got blown tyres... and we got a hydraulic problem Kay... [the in-flight director said something, not determined, to the captain] yeah, just tell them we'll be returning to ah Jeddah ***."

When the aircraft was some 11 nautical miles south-south-west of the airport, the air traffic controller, whose attention had been focused on the Saudia aircraft, noticed that C-GMXQ was not following the departure clearance. He called twice to instruct: "Nigeria Two One Two Zero, climb 150, intercept radial 227, call Jeddah 119.1." Just after the second call, the first officer reported: "I've got no ailerons," and the captain responded: "OK, hang on, I've got it." This was the last record on the cockpit voice recorder.

In response to a further call from air traffic control, the captain responded: "Nigerian Two One Two Zero, yes sir, go ahead." The controller repeated his instructions and the captain responded: "OK sir I cannot climb, I cannot climb. We are at two thousand feet now declaring an emergency, we have flight control problems." Only then did the controller realise that it was in fact C-GMXQ which was in an emergency situation. The controller gave a heading to intercept the final approach and thereafter continued to give heading information.

At about 11 miles from the airport on final approach, which would be a reasonable position for extending the landing gear, the first of a number of casualties fell from the aircraft which was at about 2,200 feet.

The captain, who was apparently both flying the aircraft and operating the radio, reported control difficulties on a number of occasions. He requested vectors to the runway and informed that they were trying to return to the VOR. The controller then tried to call the aircraft three times without response; at eight and a half minutes after brake release, 10 miles from the runway, the captain declared an emergency (for the third time) reporting: "Nigeria Two One Two Zero declaring an emergency, we are on fire, we are on fire, we are returning to base immediately." The controller cleared the aircraft to land on runway 34L. The flight data recorder ceased to function at this time, about one and a half minutes before impact.

About one minute before impact, the captain called: "OK sir, we are ah.. coming straight in for runway three four, we'll land on the ah.. on the ah.. left. Require emergency vehicles immediately, we have a fire. We will be ground evacuating." The controller gave clearance to land on 34L. The last transmissions from the aircraft, about 40 seconds before impact, was: "OK three four left, we need the right, sorry the centre, we're lined up." The controller cleared them to land on any runway. During the final approach, witnesses reported seeing flames and smoke coming from the underside of the aircraft in the wheel-well area or landing gear. An airborne witness who saw the aircraft briefly when it was about five miles from the threshold, thought that the nose landing gear was down but was unsure of the position of the main gear. Pieces of the aircraft and a number of bodies fell from the aircraft during the approach. Witnesses who gave specific details of the final seconds of flight, variously reported that:

A: "... and saw an aircraft approaching the 34C and all of sudden came down head first in about 70 degree crashed and exploded into a large flame. ..."

B: "... suddenly and over the site on which it fell the A/C exploded. It rapidly went down to the ground, before reaching the ground it turned half a circle from the right wing side whereas its roof turned towards the ground and fell on the ground ..."

C: "The plane was approaching the runway, it was about to land, the smoke was entirely covering its tail. We saw the plane exploding near to runway 34C. Within minutes it fell to the ground on its nose."

D: [1,250 metres from the impact area] "... on duty at Guardhouse-13, I saw first the plane in the sky, smoking black in colour coming from the engine of the said plane. After that, I came outside the guardhouse and saw some parts of the engine falling down, and I have seen fire from the plane. Afterwards I have seen also the aircraft being cut-off into two pieces. The rear side of the plane or the back tail piece was the first fell down and the front side body got fired and fell down."

E: [Located on apron 5, 5 kilometres north west of the crash site, view of the site obstructed by buildings.] "... Before it could reach the runway, an explosion of heavy smoke occurred. The aircraft was getting much closer and height was about 200 metres or so. After the explosion of smoke, only the front portion was visible. The aircraft made a small tilt toward the left-hand side. [aircraft heading towards the witness] After tilting left, it crashed in not more than 5 seconds. Within that five seconds an explosion and fireball appeared."

The aircraft crashed 2,875 metres short of the runway and was destroyed. There were no survivors.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	14	247	-
Serious	-	-	-
Minor/None	-	-	

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

Nil

1.5 Personnel Information

1.5.1 Cockpit Crew

No flight crew logbooks were recovered. Flight times are based on company records, journey logs and Transport Canada records.

	Captain	First Officer	Flight Engineer
Total Flying:	10,700	8,000	7,500
On Type:	1,000	550	1,000
Last 90 days:	140	185	91
Licence:	ATPL	ATPL	F/E & AME[4]
Medical	Valid	Valid	Valid

1.5.2 Captain

Captain 47 years old, was qualified and certified for the flight. He had completed a pilot proficiency check, in a simulator, on 10 April 1991 and held a Class 1 Group 1 instrument rating. His Licence Validation Certificate was valid with a requirement to have glasses available. At the time of the accident he had been on duty for 3½ hours and had previously been off duty for 40 hours.

The captain had been a pilot in the Canadian Military for 21 years. He flew jet aircraft during training (the Tutor) and then flew DC-3 Dakota, DHC-3 Single Otter and C-130 Hercules aircraft. Leaving the military in 1989, he joined Wardair as a first officer on the Airbus A310. He joined Nationair on 26 April 1989 and was employed as a first officer on the DC-8. He qualified as DC-8 captain in May 1990. His Nationair records show a normal progression through training and satisfactory flight checks.

1.5.3 First Officer

First Officer 36 years old, was qualified and certified for the flight. He had completed a pilot proficiency check, in a simulator, on 20 April 1991 and held a Class 1 Group 1 instrument rating. His Licence Validation Certificate was valid with a requirement to wear glasses. At the time of the accident he had been on duty for 3½ hours and had previously been off duty for 40 hours.

Prior to joining Nationair, the first officer had accumulated about 5,000 hours on DC-3 Dakota, DHC-6 Twin Otter and DHC-8 Dash 8; 1,200 hours on Airbus A310-300. His Nationair records show satisfactory performance.

1.5.4 Flight Engineer

Flight Engineer 46 years old, was qualified and certified for the flight. He had completed a flight engineer simulator check on 20 October 1990. His Licence Validation Certificate was valid with no restrictions. At the time of the accident he had been on duty for 3½ hours and had previously been off duty for 40 hours.

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4 (Licensed) Aircraft Maintenance Engineer.

ICAO Note.— Names of personnel were deleted.

The flight engineer served in the military for 24 years, the last 14 years as a flight engineer. His flying experience was mainly on the C-130 Hercules. His Nationair records show satisfactory performance.

1.5.5 In-Flight Director

Miss 37 years old, had been flying as a flight attendant for 2½ years. Her crew status was that of in-flight director. She was current and qualified to operate the flight.

1.5.6 Purser

Mr. 32 years old, had been flying as a flight attendant for 4 years, the last 1½ years as purser. He was current and qualified to operate the flight.

1.5.7 Cabin Attendants

Mrs. 23 years old, a flight attendant for three years; had been flying with Nationair for 1 year and 2 months. She was current and qualified to operate the flight.

Miss 24 years old, had been flying as a flight attendant with Nationair for 2 years. She was current and qualified to operate the flight.

Miss 29 years old, had been flying as a flight attendant with Nationair for 4 years. She was current and qualified to operate the flight.

Miss 26 years old, had been flying as a flight attendant with Nationair for 1 year. She was current and qualified to operate the flight.

Miss 26 years old, had been flying as a flight attendant with Nationair for 2 years. She was current and qualified to operate the flight.

Miss 21 years old, had been flying as a flight attendant with Nationair for 1½ years. She was current and qualified to operate the flight.

Miss 24 years old, had been flying as a flight attendant with Nationair for 1½ years. She was current and qualified to operate the flight.

1.5.8 Project Manager

Mr. 41 years old, was not certified as a crew member. He had only recently been hired by the Nationair Planning department; he had worked under contract to Nationair for a short period earlier during the course of 1991. His previous employment had been as a passenger services supervisor for Canadian Airlines International. He had worked in the airline industry for 20 years.

1.5.9 Lead Mechanic

Mr. 38 years old, was trained in France and held "un brevet de mécanicien" qualification, endorsed for several aircraft including the DC-8, and a United States FAA Licence; however, he had not yet obtained a Canadian Aircraft Maintenance Engineer Licence, nor had he received any Technair sponsored aircraft courses. He was first hired, as a senior mechanic, in 1989. He resigned fourteen days later. During this 14 days, he was assessed as a capable mechanic but it was noted that he was not very familiar with the DC-8. The lead mechanic was re-hired, as a foreman in training, in February 1991.

When re-hired, he was first employed at the Mirabel facilities doing "hands-on" servicing and repair tasks. He was then paired with a supervisor in the Technair Maintenance Control Center for a period of two months. Shortly after he was re-hired, he applied for a supervisor position in the Technair Maintenance Control Center, but he was turned down because his ability to communicate in the English language was as yet inadequate. He was however invited to apply for any future supervisory positions that became available.

His personnel records at Technair contained a copy of his resume, employment application, his intellectual ability and aptitude test, and his initial personal evaluation report. Out of twenty-two factors assessed on this report, he had four "A" (Superior) ratings, two "C" (Adequate) ratings, and all others were "B" (Satisfactory) ratings. The "A" ratings were for leadership ability, maturity and responsibility, positive personal presentation and punctuality. For his ability to do the work with cleanliness, precision and according to exact company procedures, as well as his ability to work with minimal supervision, he was allotted the lower "C" rating. The tendency factors all indicated "A" (Improvement Noted). Also, his supervisor reported that he tended to report directly to the Technair General Manager and had to be reminded to follow the chain of command.

As lead mechanic for the deployment, he was responsible directly to the Director of Production in Mirabel, and his responsibilities included the following:

- Supplementing the Fly-Away-Kit;
- Scheduling the mechanics' work tables;
- Sending maintenance activity records and copies of the aircraft journey log to Technair Maintenance Control Center;
- Reporting maintenance activities to Technair supervisors;
- Evaluating maintenance facilities and resources and planning maintenance accordingly;
- Liaison with Technair Maintenance Control Center for technical information, parts procurement; and co-ordinating delivery.
- Arranging with the flight engineers on the deployment to have completed maintenance work certified.

His planning and preparation for the deployment impressed his superiors, in particular all the phone contacts he made to various African destination airports to arrange for eventual maintenance, and his efforts to build up a comprehensive Fly-Away-Kit.

During the deployment, he made daily phone calls to the Director of Production; he also phoned the General Manager. He never reported any problems and, on each call, re-affirmed that the aircraft and the operation were perfect.

1.5.10 Mechanic

Mr. the airframe & power plant mechanic joined Technair in November 1987 and had been a senior mechanic since March 1989. He held an United States FAA Airframe and Power plant licence with a DC-8 rating.

His responsibilities during the deployment were primarily for the maintenance of the aircraft structures and power plants; he was expected to contribute in other technical areas if the occasion demanded.

He had worked as a mechanic on other Nationair deployments.

1.5.11 Avionics Specialist

Mr. the avionics specialist first started with Technair as a summer student from an aviation college. He was given a permanent job when he graduated from the electronic course in May 1989. In accordance with Technair's policy, he was given on-job-training on airframe and Powerplants prior to being assigned to specialised electronics-related duties.

He had worked as a specialist on several other deployment contracts with Nationair.

In preparation for this contract, he prepared the electronic equipment needed for the Fly-Away-Kit. His prime responsibility was to maintain the aircraft electronic systems; he was also to assist the other mechanics on the deployment.

1.5.12 Additional Flight Engineer

As with other previous Nationair/Technair short-duration contracts, none of the mechanics or specialists on the deployment had Canadian aircraft maintenance engineer licences nor company authority for certification. The flight engineers on the deployment, who had these qualifications, were required to certify any maintenance work carried out. The fourth flight engineer on the deployment, Mr. was expected to augment the technical team when he was not assigned to flying duties. During interview, Mr. indicated that he performed no maintenance. He was unable to provide any information about tyre pressures.

1.5.13 Operations Officer

Captain an experienced captain, was assigned as operations officer to assist with operational decisions as well as act as a spare pilot, although this was never required.

1.6 Aircraft Information

1.6.1 Registration and Maintenance Records

DC-8-61 serial #45982, registration C-GMXQ was manufactured by McDonnell Douglas Corporation in 1968. The aircraft was imported into Canada in 1984 and was registered under the ownership of Nolisair International Inc. Records show that in 1988, Nolisair International sold the aircraft to National Express Aviation who then leased the aircraft to Nolisair. The duration of the lease was until June 1993.

Technical records showed that all applicable Airworthiness Directives had been complied with, all applicable Service Bulletins appeared to have been complied with and that all requirements of the approved maintenance programme were completed on time or within the approved tolerances. However, during this operation, documentation showed that maintenance personnel were performing A-Checks in segments without authorisation. (i.e. when convenient, parts of the check would be done.)

At the time of dispatch on the morning of 11 July 1991, the aircraft had accumulated a total time of 49,318 hours in 30,173 cycles.

1.6.2 Maintenance Checklists

Checklists used during the deployment were:

1.6.2.1 Transit Check Checklist

The Transit Check checklist is used for stops of less than four hours duration. This checklist requires that only a visual check of the landing gear components be made. Some mechanics interviewed stated that they use a gauge to take tyre pressures during transit checks most of the time but this is not a company wide procedure. Using a gauge to check tyre pressures was not a routine practice during the deployment, and no evidence was found to indicate that tyre pressures were taken at any time after the July 8 flight from Accra to Jeddah.

1.6.2.2 Pre-Flight Check Checklist

The Pre-Flight Check checklist applies to an aircraft inspection that is to be done before the first flight of the day and for stops of greater than four hours. This checklist specifies tyre pressures for the DC-8 Series 61, 62, and 63. For the '61, it calls for 180 psi with no tolerance. It further states that the tyre is to be inflated if required. The form also reminds the mechanic of the requirement to replace a wheel/tyre assembly if the tyre pressure is found below 146 psi and to replace the other wheel on the same axle if one tyre has been flat while the aircraft was taxiing. These figures differ from the manufacturers data.

The Pre-Flight Check checklist provides a block for each of the three aspects of the tyre condition check: the first block being the wheel condition, the second block being the tyre condition, and the third block being the tyre pressure and a requirement for a mechanic to wait a minimum of two hours after arrival prior to taking tyre pressures. These blocks are to be initialed by the person attesting to the proper condition of the checked item. According to the mechanics involved in the contract, tyre pressures should have been checked using a gauge on all pre-flight checks during the deployment. However, no evidence was found to indicate that tyre pressures were taken at any time after the July 8 flight from Accra to Jeddah.

1.6.2.3 A-Check Checklist

The A-Check is due every 125 flight hours. The part of this checklist relating to tyre pressures is similar to the pre-flight checklist, except that to the left and adjacent to the initials' block, there is a series of blocks matching the wheel identification: nose wheel right and left, and numbers 1 to 8 for the main wheels.

1.6.2.4 Maintenance During the Deployment

Several maintenance repair actions took place during the deployment. All maintenance tasks were reported to have been done by the two mechanics and the specialist with little involvement on the part of the flight engineers. An examination of the aircraft times during the deployment indicated that, excluding the maintenance delay in Accra waiting for the radar parts, the average aircraft stop-over duration on the ground at the African airports was just over two hours, and at Jeddah Airport, nine hours. The summary of non-routine maintenance activities is tabulated below:

Date	Station	Non-routine Maintenance
3 July	Athens	None recorded
4 July	Jeddah	None recorded
4 July	Kano	None recorded
4 July	Conakry	Audio & Freon
5 July	Jeddah	Water system drain
5 July	Kano	None recorded
5 July	Conakry	#1 engine oil leak; Wing slot indicator
6 July	Jeddah	Audio box; No repair to reported weather radar failure in flight
6 July	Kano	None recorded
6 July	Conakry	Deferred cargo door light
6 July to 8 July	Accra	Wx. radar replaced and some A-Check items done; Recorded low tyre pressures in #2 & #4.
8 July	Jeddah	L/H freon deferred
8 July	Kano	None recorded
9 July	Accra	None recorded
9 July	Jeddah	None recorded
9 July	Kano	None recorded
10 July	Accra	Work started to change tyres but not completed.
10 July	Jeddah	None recorded but: lubricating of engine reversers; cargo door light inoperative; L/H freon inoperative reported to Technair.

The following paragraphs amplify some of the maintenance work that was carried out:

1.6.2.4.1 6 July: Weather Radar Failure

A radar malfunction occurred in flight and, because there was significant weather build-up along the route of the flight, the aircraft returned to Accra, Ghana. The required parts were ordered through Technair Maintenance Control Center, and the radar repair was completed on 8 July 1991. The aircraft was on the ground for nearly 34 hours.

1.6.2.4.2 7 July: A-Check

During down-time for the weather-radar problem in Accra, an A-Check was started by the avionics specialist, even though it was not required for another 32.5 flight hours. Portions of the A-Check checklist were completed on the days following the aircraft's return to Jeddah on 8 July 1992. Pages 1 through 19 of the 20-page checklist were recovered from the wreckage; except for section 25, Standard Equipment (Ref Card serial number 061), all the checklist items had been signed as being completed. The missing Page 20 would be the location of the final administrative sign-off sections of the A-Check; these sections are required to be signed prior to the flight following the A-Check.

According to the maintenance personnel the A-Check was not completed; the A-Check block on the journey log sheet was not checked off — a requirement when the A-Check is completed. Prior to departure of the flight from Jeddah on the morning of the accident, only 8.2 hours remained on the 125 hour validity period of the previous A-Check. If the last page was to be signed just prior to the aircraft flight time reaching the 125 hour limit of the previous A-Check, the aircraft would have accumulated about 35 hours from the time that the A-Check was started.

The "Tyre Pressure Check" of this A-Check was performed by the avionics specialist. During initial interview, he recalled that the pressures for tyres #2 and #4 were on the low side, that he recorded the low tyre pressures on the checklist sheet and that he discussed the situation with at least one flight engineer in Accra on 7 July 1991. He also stated that he advised the lead mechanic and the other mechanic about his progress on the A-Check and the low pressures on tyres #2 and #4. During a later interview on 8 April 1992, he could remember neither pressures nor wheel stations.

The avionics specialist and the mechanic acknowledged their initials in the "Tyre Pressure Check" section.

The specialist "CA," who recorded initial tyre-pressure readings in blue ink on the sheet for all tyres that he checked, used dash marks to indicate wheels that he had not done (nose wheels) or wheels he had found to be not in accordance with the figures given on the A-check form. For those tyres (#2 and #4) that were found below the prescribed pressures, he had not initialed the form.

During interviews, mechanic "J" stated that he had initialed the tyre-pressure section of the A-Check sheet, identifying his initials as those on the form in black ink, and those of specialist "CA" being in blue ink. He could not recall when or under what conditions he initialed the sheet, or what changes if any were made to the tyre pressures.

Because it was difficult to read figures which had apparently been changed, the checklist page was sent for forensic examination. The following is a summary of the findings of the forensic examination:

Findings of forensic examination:

TYRE	VISIBLE FIGURES	MECH INITS	INVESTIGATOR'S COMMENTS
NOSE L	(150)	"CA"	There was a dash mark on the outside edge of the form
NOSE R	(150)	"CA"	There was a second initial, a "J" in the MECH block, and a dash mark on the outside edge of the form
MAIN #1	18	"CA"	On the right side of the visible figures "18" the forensic examination of the form determined that there was another figure "5" in this block.

TYRE	VISIBLE FIGURES	MECH INITS	INVESTIGATOR'S COMMENTS
MAIN #2	180	"J"	There was a dash mark on the outside edge of the form and based on forensic evidence, a previous figure of 160 had been recorded in the tyre-pressure block probably in blue ink, but it had been over-written in black ink to indicate 180.
MAIN #3	?	"CA"	The forensic examination of the form determined that this tyre pressure was recorded as 179.
MAIN #4	?	"J"	There was a dash mark on the outside edge of the form; forensic evidence confirmed that the outside numbers were "1" and "5" and suggested that the middle number could have been a "5" which had been over-written in black ink to a "6" or an "8."
MAIN #5	?	"CA"	The recorded tyre pressure was 180.
MAIN #6	?	"CA"	The recorded tyre pressure was 185.
MAIN #7	8	"CA"	The recorded tyre pressure was 185.
MAIN #8	185	"CA"	

Canadian Air Regulation 828 states, in part, that no person shall alter an entry made in an aircraft log. Airworthiness Manual Section 575.3 states, in part, that the aircraft maintenance record includes inspection check sheets.

1.6.2.4.3 10 July: Aborted Tyre Change

A four hour maintenance stop was planned in Accra to change some tyres, following the series of flights on 9 July. Two mechanics stayed in Accra on 8 July, after the second scheduled arrival, to make arrangements for the tyre change. They were joined by the specialist and additional flight engineer who were on board the aircraft when it arrived in Accra, from Kano, at 0450 hours on 10 July.

This site was chosen to avoid the formalities of accessing the highly secure ramp in Jeddah and because all the maintenance team would be at Accra on that date. On a previous flight on 6 July, the spare wheel/tyres and some equipment had been left in the care of a local aviation company.

According to the mechanics and flight engineers involved, the wheel/tyres on the aircraft did not require immediate changing because the tyres were not yet worn to the first fabric layer. However, the lead mechanic decided to change the wheel/tyres early to minimise the risk of subsequent delays. The plan was to change the nose wheels, and main wheels #1, #2 and #4.

About one and one-half hours prior to the arrival of the aircraft, the two mechanics proceeded to the Accra airport and started preparations for the tyre change. No attempt to retrieve the spare wheels/tyres was made until after the arrival of the aircraft and the work on the aircraft was started. Subsequently, the work was stopped because the maintenance crew was having difficulty getting access to the spare wheels and some additional maintenance equipment in locked storage. The wheel/tyres were finally retrieved but by then, a facsimile from the project manager, in Jeddah, requested that the aircraft return immediately to Jeddah to avoid the loss of future charter flights. The text of the message was:

> "RE: FLT TO SOKOTO TOP URGENT Pls do all possible to get back the A/C to Jed by 0800 GMT or 1100 LT Jed or we stand to loose [sic] a lot. Situation with Nigerian Airways critical they are giving our pax away due delay. Do not let maint change wheels in Acc. If you have a chance call me ASAP."

In consequence of this message, a decision to abandon the wheel/tyres change was taken after consultations between the maintenance team, the operations officer, flight engineers, and air crew. Witnesses stated that all parties agreed that the tyre change was not necessary at that time. Because this would be the last planned flight through Accra, all the replacement wheels were loaded on the aircraft. It was reported that the lead mechanic planned to explore the possibility of doing the wheel/tyre changes at a later date in Sokoto, Nigeria, where he anticipated there would be the required maintenance equipment. All maintenance action was stopped, and the flight departed for Jeddah at 0730 hours. According to the mechanics involved, when the wheel/tyre change was stopped, it had only progressed on wheel #1 up to but excluding the removal of the axle nut; the tyre pressure had not yet been reduced[5]. Because of their involvement with trying to retrieve the stored wheel/tyres, none of the deployment mechanics or other crew members was present at the aircraft throughout the period from the start of the preparatory work on wheel #1 up to the point that the wheel assembly was made ready for the flight to Jeddah. Although one witness believes that a tyre had been removed and stated, during interview, that he saw the wheel resting against the inboard side of the left main gear bogie, no other evidence was found to support this statement. In particular, all the mechanics and flight engineers involved testified that the wheel was never removed and that no nitrogen was added to any of the aircraft tyres. The aircraft journey log did not contain an entry for wheel/tyre related maintenance action. After the crash, the identification of the wheels confirmed that wheels were not changed in Accra.

1.6.2.4.4 10 July: Post-Flight Maintenance

Following the aircraft's return to Jeddah on 10 July, the three maintenance personnel stayed with the aircraft and the following maintenance actions reportedly took place:

- A thrust reverser track was lubricated and checked using an air start cart.
- A hydraulic engine driven pump fault was corrected by fixing a defect in a canon plug; and
- A communications audio box problem was also fixed.

None of these maintenance actions was recorded in the aircraft journey log. During this time at the airport, it was decided that the lead mechanic would be the only maintenance team member who would fly on the next flight. During his last interview, on 8 April 1992,

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[5] Although not a maintenance manual procedure, the mechanic stated he would partially deflate a tyre prior to removal.

the airframe & power plant mechanic stated that he reminded the lead mechanic that the tyre pressures would have to be checked prior to the next flight and that the reminder was acknowledged.

1.6.2.4.5 11 July: Pre-Flight Check

The lead mechanic arrived at the airport with the flight crew around 0500 hours on the morning of the accident. One of his tasks was to carry out a pre-flight check, which, in addition to other tasks, includes a check of the tyre pressures using a gauge. According to times recorded on the fuel invoice, (more) fuel was ordered at 0525, arrived at 0535 and the refuelling of the aircraft was completed at approximately 0615 hours.

At approximately 0755 hours, 20 minutes before take-off and after the passengers had boarded the plane, the lead mechanic made a request to the ramp co-ordinator for nitrogen stating that it was required to inflate a low tyre. The co-ordinator passed the request to a ramp supervisor who stated that he drove the lead mechanic to the Saudia Tourist Travel Bureau maintenance facility. The ramp supervisor further stated that they were told the nitrogen bottles were empty and that he informed the lead mechanic that it would have to be requested from Saudia. They drove back to the aircraft and the lead mechanic spoke to a member[6] of the crew, then came to him and said: "it's OK." The ramp co-ordinator stated that the lead mechanic told the Nationair project manager that nitrogen was not immediately available through the Saudia Tourist Travel Bureau maintenance organisation and it would have to be requested from Saudia; obtaining nitrogen from Saudia would take time and would probably delay the aircraft departure. The ramp co-ordinator stated that the project manager, without conferring with anybody, said: "Forget it." The ramp co-ordinator also mentioned that the tyre #6 was visibly low. He further stated that he did not know if the flight crew were made aware of the low-tyre situation, but he had seen the flight engineer under the belly of the aircraft doing his external inspection. (The ramp supervisor also stated that he had seen the lead mechanic checking the tyres but he did not notice if he was using a tyre pressure gauge.)

There are no indications that the lead mechanic objected to the project manager's actions. Aircraft journey log sheet serial number 17885 for the accident flight contained the lead mechanic's initials for the inspection of the engines, constant speed drive, and hydraulics; the fluid added to these components was also recorded. On the same sheet, at 0540 hours, the flight engineer had signed for the maintenance release of the aircraft; the letters "TC" for a Transit Check and "PF" for a Pre-Flight Check were also circled. Log sheet serial number 17886 contained the flight engineer's signature for the walk-around having been completed; there is no provision on the form to indicate the walk-around completion time.

None of the witnesses recalled seeing a nitrogen cart near the aircraft during the deployment; the is no evidence of any of the maintenance team adding nitrogen to the aircraft tyres during the deployment. No documentation could be found in Accra or Jeddah to show that nitrogen had been acquired and paid for by the deployment team. The CVR tape contained no mention of an under-inflated tyre.

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6 The project manager wore a captain's uniform.

1.6.3 Weight and Balance

The aircraft Weight and Balance Configuration Record, valid for five years, is dated 17 September 1990 and gives the Operating Empty Weight as 165,633 pounds.

The Company's records include the following:

Basic Operating Empty Weight:	165,688 lbs.
Maximum Zero Fuel Weight:	224,000 lbs.
Maximum Taxi Weight:	328,000 lbs.
Maximum Take-Off Weight:	325,000 lbs.
Maximum Landing Weight:	240,000 lbs.

A copy of a Nationair Weight and Balance Form, completed by the first officer, was left with the ground handler prior to departure. The recorded take-off weight was 313,493 lbs. The many alterations and irreconcilable figures on the form, preclude determination of the accurate take-off weight. It was not possible to determine which of the many figures were used, by the first officer, to arrive at the recorded take-off weight.

The handling agents recorded the weights (and pieces) of checked-in baggage of passengers; that checked-in baggage averaged about 40 kilograms or 88 pounds weight per passenger. The ground handlers stated that, as instructed by the operating crew, only four tons of checked-in baggage was loaded. The remaining six tons of checked-in baggage was never accounted for. Various reports indicated that it was taken to Nigeria in a DC-10 aircraft at a later date but neither flight nor manifest details could be produced.

Traditionally, pilgrims' carry-on baggage includes household goods, containers of water and other souvenirs; because of this, ground handlers waited at the aircraft and insisted that much of the carry-on baggage was loaded in the cargo compartments. The weight of carry-on baggage could not be established.

Evidence of aircraft weight is provided by the ground contact marks left on the runway at departure. Theoretical take-off performance was compared to the actual performance of the aircraft. Actual take-off, based on runway marks and the flight data recorder, took two seconds longer and 550 feet greater distance than theoretical.

1.6.4 Powerplants

The aircraft was powered by four Pratt & Whitney JT3D-3B engines.

Engine:	#1	#2	#3	#4
Serial #	644626	P66930DAB	669293	P644404
Hours:	54143	40896	50030	50400
Cycles:	26885	13380	19148	15067

Airworthiness Directives had been complied with.

1.6.5 Hydraulic System

The DC-8-61 has three separate hydraulic systems: a general system, a spoiler system and a standby rudder system.

The general system is pressurised to approximately 3,000 psi by two engine driven pumps on the inboard engines, and is divided by a priority valve into "priority" and "non-priority" distribution systems. Priority subsystems include ailerons, rudder and horizontal stabiliser. If system pressure reduces below 1,700 psi, the priority valve directs all available pressure to the primary flight controls.

A 13 gallon capacity main reservoir, located in the left wing root, provides the only source of fluid for the engine driven pumps. In the event of engine driven pump failure, an electrically driven auxiliary pump utilises the same hydraulic supply to provide normal hydraulic power for operation of the general system.

A two gallon capacity auxiliary reservoir, also located in the left wing root, is available to the auxiliary pump for wing flaps and main gear down-lock operation only.

A spoiler hydraulic reservoir, located in the right main wheel well aft inboard corner, contains 1.2 gallons of fluid.

The reservoir for the standby rudder system is located in the left main wheel well.

1.6.6 Flight Controls

The primary controls are the ailerons, rudder, elevators and horizontal stabiliser. The ailerons and rudder are normally operated by hydraulic power, the elevators are controlled manually and the horizontal stabiliser is normally adjusted by hydraulic power but may be operated electrically.

1.6.6.1 Ailerons

The ailerons are actuated by hydraulic pressure from the main or auxiliary systems. When hydraulic pressure is not available, the ailerons are operated by mechanically controlled tabs.

1.6.6.2 Elevators and Horizontal Stabiliser

Each elevator has two tabs, a control tab and a geared tab. Movement of the pilot's control column is transmitted mechanically to the control tabs. Aerodynamic loads generated by the displaced control tabs drive the elevators; as the elevators move, the geared tabs move, in the same direction as the control tabs, to reduce the control input loads.

The incidence of the horizontal stabiliser is changed, in response to a trim demand, by jackscrews which are powered by either the main hydraulic system or an electrical servo motor.

1.6.6.3 Rudder

The rudder is normally operated by hydraulic pressure from the general system. If hydraulic pressure is not available from the general system, an electrically powered standby rudder hydraulic pump may be used. During hydraulic operation, the rudder tab is locked; during manual operation, the tab is unlocked and the rudder pedals move the tab directly.

1.6.6.4 Spoilers

An electric pump provides hydraulic pressure for spoiler operation.

1.6.6.5 Wheel Brakes

When the landing gear is retracted, hydraulic return pressure is taken from the gear retraction return lines to brake the wheels. Components mounted on the main gear struts limit the loss of hydraulic fluid should either a brake unit or a flexi-hose leak. In the event of a leak from a hydraulic component or pipe assembly upstream of the fluid quantity limiting devices on the gear struts, or a leak from hydraulic components or pipe assemblies in the landing gear rear retract system, general system hydraulic fluid can be depleted.

1.6.7 Hydraulic System Indicators and Warnings

1.6.7.1 Indicators

- The fluid quantity in the main hydraulic reservoir is indicated on a gauge at the flight engineer's station.
- The temperature of the fluid in the main hydraulic reservoir is indicated on a gauge at the flight engineer's station.
- The hydraulic system pressure is indicated on a gauge at the flight engineer's station. This gauge will indicate zero if the priority valve closes.
- The hydraulic pressure available to the spoilers is indicated on a gauge at the flight engineer's station.

1.6.7.2 Warning Lights

- Hydraulic Temperature Warning Light located on the flight engineer's panel illuminates when the fluid in the main reservoir overheats.
- Hydraulic Reservoir Low Level Warning light located on the captain's glare shield illuminates when the reservoir is less than half full.
- Emergency Hydraulic Level Light located on the flight engineer's control panel illuminates when the reservoir is half full.
- Reservoir Air Low Pressure Warning Light located on the flight engineer's panel illuminates when reservoir air pressure drops to 25 ± 2 psi.
- Rudder Control Manual Light located on the first officer's instrument panel illuminates when the rudder reverts to manual control.
- Aileron Control Manual Light located (with the Rudder Control Manual Light) on the first officer's instrument panel illuminates when the ailerons revert to manual control.
- The only four pressure warning lights grouped together on the pilots' instrument panel are those for engine oil pressure. The electrical circuits which carry the signals are located in the leading edges of the wings the only common routing well forward of the wheel bay.

- The flight engineer's fuel panel has four low pressure lights which illuminate when the main fuel tank pump switches are in the OFF position or whenever the corresponding feed pump is not operating properly. The lights go out when the switches are selected to BOOST & FEED or FEED ONLY and adequate pressure is obtained. The switches would have been off for take-off, according to the check list in the flight handbook. The CVR does not record a check of the switches.

1.6.8 Landing Gear Indicators

The position of the landing gear is indicated by lights located below the landing gear control lever. Brake hydraulic pressure is indicated on a gauge on the first officer's instrument panel. There are no indicators to show brake temperature or tyre pressures. There is no warning system to show fire or high temperature in the wheel wells.

1.6.9 Fire Detection and Protection Systems

Aircraft fire protection is provided by:

- Engine fire detection and extinguishers;
- Portable fire extinguishers in the cockpit and cabin.

There are no fire detection or extinguishing systems in the cargo compartments because they are Class D; fires should self-extinguish because of lack of ventilation. There are no other fire detection or protection systems fitted in the aircraft.

1.7 Meteorological Information

No formal record was made of weather observations at the time of the accident because of a breakdown in communications. Routine records for the period covering the time of the accident were provided. The record of observations included:

0800: No cloud; visibility more than 10 kilometres; temperature +29°C; wind velocity 350° at 10 knots; pressure 1002 millibars.

0900: No cloud; visibility more than 10 kilometres; temperature +31°C; wind velocity 360° at 12 knots; pressure 1002 millibars.

Weather was not a factor.

1.8 Aids to Navigation

All runways have ILS with DME co-located with the Glide Path. More than one ILS operate simultaneously. DVORTAC is located midway between runways 34C and 34R approximately mid distance along those runways. Air traffic within the Jeddah circuit pattern is under radar control. Normally right-hand traffic patterns are flown for runways 34. All navigation aids were serviceable. The primary visual aid is the Haj Terminal, at the northern end of the airport, because of its colour and shape. In conditions of dust and heat haze, it is sometimes difficult to visually acquire the runways until within some 4 to 6 nautical miles from touchdown.

1.9 Communications

All ground communications equipment was serviceable. The cockpit voice recorder recorded air traffic transmissions which were not always acknowledged by the crew but there was considerable voice traffic within the cockpit as the symptoms of failure occurred. The crew used the wrong callsign to request "... level off at 2,000 feet ... because of pressurisation problems." The next eight radio calls from the crew, including the declaration of an emergency by the captain (prompted by the first officer), were not identified by callsign. During this three minutes, the controller responded without using the aircraft callsign. The first time the crew used their proper callsign during the handling of the emergency was three minutes after using Nationair 2120, in response to repeated calls from the controller. Even then, although the captain responded: "Nigerian 2120 yes sir go ahead," his second declaration of emergency was prefixed by neither callsign nor internationally recognised standard emergency code words. The aircraft was now approaching the end of the downwind leg. It was only at this time that the controller realised that he had wrongly assumed that the radio calls to which he had been responding, were actually from C-GMXQ and not Saudia 738.

During this period of mistaken identity, the crew recognised a need to level off at low altitude and return to Jeddah; the controller was conscious of high ground to the east of the airport and was reluctant to clear what he thought was the Saudia flight down to 2,000 feet; the Saudia captain, using his callsign, acknowledged clearance to descend to 3,000 feet. (The controller used the Saudia callsign during two of the three exchanges with the Saudia aircraft.)

The mistaken identity did not effect the conduct of the flight because the instructions passed by the controller, to what he thought was SV738, happened to fit the desired flight path of the captain of C-GMXQ.

The final issue relating to communications is that of language and accent. The Kingdom of Saudi Arabia uses English as the language of aviation. All personnel involved in aviation have to pass formal tests in English before they may exercise the privileges of their licences. However, a newcomer to the radio environment may have difficulty in identifying all terms used because of accent; similarly, natural Arabic speakers may have difficulty understanding unfamiliar accents of foreign crews. The lead mechanic's command of English was inadequate[7,8] and his French was described as "Parisian" by one of the deployed personnel. However, there was no evidence that language had any bearing on the accident.

1.9.1 Air Traffic Services

All communications were recorded on two tape recorders. The official record of transmissions is that provided by a 32 channel recorder. The tapes on both machines were

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[7] See 1.5.9.

[8] UTA (Union de Transports Aeriens) DC-8 technical documents, written in French, were recovered from the crash site.

removed and impounded by the Chief of Air Traffic Services. The tapes were identified as follows:

- 32 channel tape, APP #11, 11 July 91 (start 00 00 00 Z stop 0615 Z,),
- 64 channel tape, RACAL #11, 11 July 91 64 CH (start 0000Z stop 0705Z)

As the 64 channel RACAL tape recorder is technically superior, the 32 channel tape was sealed as the official original and the RACAL tape was selected for the transcript. The quality of the recording was found to be good and by the end of two days, most of the transmissions to and from flight 2120 had been re-recorded and verified. Although most of the radio transmissions were in English, occasional Arabic words and phrases were inserted. These were translated and verified by the Arabic speaking Chief of the Jeddah ATS Facility. Background co-ordination in Arabic was also translated into English.

A radar plot of flight '2120 was produced from data from the Jeddah Terminal Area Secondary Surveillance Radar (SSR). The SSR data is presented on the radar screens in the control room and recorded by computer. There is no facility for recording primary radar returns. To eliminate "ground clutter" this radar has a floor of 400 feet above ground level below which no data is displayed or recorded. It was determined that the flight had not been tracked by a another radar site located some 80 nautical miles away. The radar plot was transferred onto a large scale map which was used for flight path analysis and for helicopter and hover craft search under over the flight path.

The Chief of ATS also provided the flight plan and general declaration, the ATC progress strips, appropriate pages of the unit (sign-in) logs, Tower and Approach controller-on-duty statements, operating logs, shift schedules and attendance and any other related documents and correspondence concerning the flight of Nigerian 2120.

1.9.2 Use of Communications and Radar Data

A transcript of the air traffic tapes was completed and integrated with the radar plot which included the profile of Saudia flight 738. (The radar plot with the radio communications was subsequently correlated with the cockpit voice recorder and the flight data recorder.) There were no flight profile recording anomalies other than very slight time synchronisation discrepancies. The combination of all records enabled reconstruction of the flight path until the aircraft descended through 400 feet.

The following is a summary of significant events extracted from the air traffic tapes with comment. The times are those recorded on the air traffic tapes, converted to local time. Position data is derived from the radar plot. Where a callsign is listed, it indicates the use of that callsign; where *C-GMXQ* (in italics) is listed, it indicates that no callsign was used.

10 July 1991

1352 DC-8 C-GMXQ operating as Ghana Airway, Flight 404, landed on runway 34C at Jeddah KAIA and was directed to Apron 6 (Haj Terminal East) Stand C6.

11 July 1991

0703 A flight plan from Jeddah to Sokoto Nigeria was filed for DC-8 C-GMXQ, to be operated as Nigeria Airways flight 2120.

0754:01 Nigerian 2120, made first radio contact with Jeddah Ground Control.

0803:47 Nigerian 2120, requested and received clearance to start engines.

0809:57 Nigerian 2120 received clearance for push back.

0815:15 Nigerian 2120 was cleared to taxi from Apron 6 to runway 34L.

0816:54 Saudia Flight 738, approximately 70 nautical miles north of Jeddah a B-737 en route from Jeddah to Hail, declared a "pressurisation problem" and requested clearance to return to Jeddah. SV738 was cleared to Jeddah and cleared to descend to 5000 feet. SV738 specified that no ground assistance was required.

0824:07 Nigerian 2120 cleared by ATC to destination and given Standard Instrument Departure (SID) instructions.

0826:25 Nigeria 2120 received take off clearance.

0827:45 Saudia 738 requested clearance for further ...

0829:07 ... descent, fuel and passenger information was requested by ATC; SV738 stated that they were not declaring an emergency.

0829:40 Nigeria 2120 initiated radio contact with Jeddah Approach Control "lower sector" after take off and was cleared to climb to Flight Level 150 on a heading of 190° magnetic thus cancelling the SID.

0830:35 The aircraft, using callsign Nationair 2120, requested to level at 2000 feet declaring "a slight pressurisation problem."

0830:42 ATC requested confirmation of call sign. There was no response.

0830:44 *C-GMXQ* repeated the request to level at 2000 feet and restated "a slight pressurisation problem." No call sign was used.

0830:52 ATC cleared *C-GMXQ*, the aircraft he thought was SV738, to descend to 3000 feet on heading 160°.

0831:08 *C-GMXQ* declared loss of hydraulics and "need to come back to Jeddah to land."

0831:54 *C-GMXQ* requested a heading back towards the runway, declared an emergency and stated that they believe they have blown tyres.

0832:07 ATC offered runway 16. At this time C-GMXQ was approximately 12 nm. south west of the Jeddah airport. SV738 was approximately 15 nm. North of the airport and close to the extended centreline of runway 16C.

0832:12 *C-GMXQ* declined runway 16 stating they would need "time to get ready for the landing." *[Nationair DC-8 Aircraft Operating Manual Page 5-11(1) advises to "Delay turning base leg to insure a long straight final approach" for Zero/Partial Flap Landing.]*

0832:53 SV738 called requesting descent from 5000 feet. ATC cleared SV738 to 3000 feet and directed to fly a heading of 140°.

0833:15 ATC directed Nigeria 2120 to intercept VOR radial 227. No response

0833:25 ATC directed Nigerian 2120 to climb to 150, intercept radial 227 and call Jeddah on 119.1 (MHz).

0833:39 ATC called Nigerian 2120.

0833:42 Nigerian 2120 responded: "... yes sir go ahead."

0833:45 ATC instructed: "Proceed direct to radial two two seven, climb to one five zero."

0833:50 *C-GMXQ* declared an emergency and reported flight control problems.

0833:57 ATC realised aircraft with emergency was Nigerian 2120 not SV738 and directed Nigerian 2120 to turn left towards runway 34L.

0834:08 *C-GMXQ* reported turning left and having flight control problems.

0834:21 ATC asked for persons on board and fuel.

0834:24 *C-GMXQ* reported nine hours fuel.

0834:54 *C-GMXQ* reported having trouble turning and flight control problems.

0835:06 ATC acknowledged and gave heading information.

0835:31 Saudia 738 requested visual approach to runway 34C.

0835:39 ATC requested Saudia 738 to confirm other traffic in sight.

0835:41 Saudia 738 reported traffic in sight.

0835:44 ATC instructed the Saudia flight that he was number two and to contact tower frequency.

0835:58 ATC instructed Nigerian 2120 to fly heading 010° and cleared for an ILS approach on runway 34L.

0835:07 ATC instructed Nigerian 2120 to fly heading 010° and cleared for an ILS approach on runway 34L.

0836:17 ATC instructed Nigerian 2120 to fly heading 010° and cleared for an ILS approach on runway 34L.

0836:35 Nigeria 2120 declared an emergency stating they were on fire and returning immediately.

0836:42 ATC cleared Nigeria 2120 to land on runway 34L and change to tower frequency.

0836:59 *C-GMXQ* indicated coming straight in for runway 34L, needed emergency vehicles, fire, and would be ground evacuating.

0837:16 ATC[9] cleared '2120 to land on runway 34L.

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[9] C-GMXQ did not change frequency and all further communication was still with Approach Control.

0837:20 *C-GMXQ* called indicating they needed 34R, corrected to 34C, and that they were lined up.

0837:51 ATC cleared '2120 to land on any runway, 34L, 34C or 34R.

0838:03 Saudia 738 called ATC.

0838:07 ATC instructed Saudia 738 to climb to 3,000 feet because of another emergency.

0838:12 The Saudia flight reported that he had to discontinue the visual approach because of the other aircraft...

0838:19 ATC informed the Saudia flight that the other aircraft was now coming for 34C and had fire on board.

0838:31 The Saudia flight reported climbing to 3,000 feet and requested a heading.

0838:33 ATC gave a heading.

0838:37 The Saudia flight repeated the heading.

0838:38 ATC said: "Affirmative."

0838:41 Saudia 738 reported turning right to heading 230; in the background voices could be heard, in Arabic, saying Nigerian 2120 has just crashed short of runway 34C.

1.10 Aerodrome Information

King Abdulaziz International Airport is located 13 nautical miles (24 kilometres) north of Jeddah Islamic Harbour. Airport elevation is 48 feet. The reference point is 21°40'52" North, 039°09'18.5" East, which is 920 metres on a bearing of 063° from the Control Tower.

There are three runways:

Runway	Length	Elevation	Slope
16L	3,690 metres	29.7 feet	0.17% up
34R	3,690 metres	47.5 feet	0.17% down
16C/34C	3,300 metres	26 feet	No slope
16R/34L	3,800 metres	13 feet	No slope

Because of the airport layout, runway 34L is the preferred runway for departure and 34C is the preferred runway for arrival. Both runways have precision approach lighting, Category Two, variable intensity.

The taxi distance from the apron to the runway was 5,200 metres.

1.10.1 The Air Traffic Control Tower

The Control Tower, listed as 60 metres high, is located some 1,100 metres north-east of the threshold of runway 34L. The height of the ground and tower controllers' positions is approximately 150 feet above the threshold. The controllers have an unrestricted view of the runway and the taxiways leading to the runway. The distances between the tower and two of the taxiways used are 1,000 metres and 830 metres at the closest points.

Observation of aircraft ground movements from the control tower showed that, while taxiing down the taxiway used and abeam the tower, the left wing of most aircraft types obscured the left landing gear. At the holding point and during the take off roll, the left landing gear was obscured by the fuselage until after lift off. Even if the controller had an unobstructed line of sight to the landing gear, the viewing distance would prevent identification of a flat tyre.

The ground controller's responsibilities are to provide current information regarding the active runway, surface wind, altimeter setting, and correct time; he will issue taxi clearance by a specific route to the holding point of the active runway; he will monitor the progress of ground aircraft traffic to ensure they are maintaining the assigned routes. He will not make a close visual inspection of any aircraft unless something out of the ordinary is drawn to his attention.

The tower controller co-ordinates air traffic movements with the approach controllers and visually monitors aircraft during arrival, departure and in the circuit. His position precludes close scrutiny of aircraft and he is not required to do so.

1.11 Flight Recorders

Flight recorders were processed by the Transportation Safety Board of Canada.

1.11.1 Cockpit Voice Recorder

The cockpit voice recorder was a "Sundstrand (United Data Control) V557 model, serial #1081." There was impact damage to the outer casing and the tape, although in good condition, had several "kinks" due to impact loads on tape within a "random storage bin." A transcript (included in Appendix A) of the entire 30 minute endless loop was made. It began just prior to push-back and ended five and a half minutes after brake release, when recording ceased simultaneously on all tracks.

1.11.2 Flight Data Recorder

The Flight Data Recorder was a "Davall digital wire recorder, type 1190, serial #199." There was external impact damage and the (internal) wire recording medium was found to be broken in several places. A total of 35 parameters were recorded and relevant data were used to reconstruct the flight profile and performance.

1.12 Wreckage and Impact Information

1.12.1 Take-Off Runway

Immediately after the accident, runway 34L was inspected by airport operations staff. Pieces of tyres and wheels were collected from the runway surface but the location of the material was not plotted, as the primary purpose was to clear the runway and return it to use. The pieces of tyres and wheels were later examined to identify the origin.

A full survey of the runway, the basic strip and the area under the initial climb-out track, as far as the airfield boundary, was carried out subsequently. The threshold of runway 34L was used as the origin for measured longitudinal distances. The lateral distances of the wheel traces showed that the nose wheel was always to the right of the runway centreline and that the minimum distance, between the left main gear inner wheels and the centreline, was 0.85 metres—at about the time that the first officer queried the possibility of a flat tyre. The following table lists the distances of some of the significant marks and material. Because it was not possible to identify whether it was the front or rear tyre or wheel of a tandem arrangement which left the witness marks, the table is listed under the probable identification with the other tyre or wheel in parentheses. Subsequent evidence showed that the traces and marks were from #1 and #2 wheels and tyres although there were also signs that #6 tyre was distressed during the latter part of the take-off roll. In the following table, "TRACES" indicate metal to concrete contact and "MARKS" indicate rubber to concrete contact.

DIST Metres	OUTER LEFT BOGIE WHEEL 1 (or 5)	INNER LEFT BOGIE WHEEL 2 (or 6)
158	First patchy rubber tyre marks	
185	Dense broad patchy rubber tyre marks	No marks
233	Dense broad patchy rubber tyre marks	No marks
253	Dense broad patchy rubber tyre marks	No marks
290	Less dense patchy rubber tyre marks	First incidence of patchy rubber tyre marks
292	Left flange: first trace.	Dense patchy rubber tyre marks
312	Left flange: intermittent trace	Broad and heavy rubber tyre marks
318	Left flange: intermittent trace	Left flange & right flange traces begin: Heavy broad rubber tyre "drag" mark
351	Left flange continuous trace; Right flange start of heavy trace.	Left flange & right flange traces. Heavy broad rubber with pattern between.
483	Left flange continuous trace. Right flange continuous trace	Left flange broad trace: Right flange broad trace: Rubber marks continuous.
650	Left flange light trace; Right flange trace shows break up of flange.	Left flange trace heavy & broad: Broad tyre marks continue
658	Left flange light trace; Right flange trace shows break-up of flange.	Same as above + heavy and broad trace of right flange
670	Left flange fat tracing: Right flange not tracing	Left & right flanges tracing; Broad rubber tyre marking with pattern in the centre
714	One continuous fat trace full width of wheel	Left & right traces: Clear central tracing in tyre mark
717	One continuous fat trace: A nick in concrete slab joint on right side of fat trace	As above + flat scraping trace of about 40 cm. width with some variation. 5 individual traces within main trace.
820	One continuous fat trace	As above with clear 6 trace marks in two pairs of 3 each - tyre beads?

DIST Metres	OUTER LEFT BOGIE WHEEL 1 (or 5)	INNER LEFT BOGIE WHEEL 2 (or 6)
920	One continuous fat trace	As above with right flange trace now very heavy
926	Left flange fat trace starts to lighten: Start of right flange fat trace	As above.
927	Right flange continuous fat trace; Piece of wheel rim metal	As above
1109	Right flange fat trace	Continuous trace 0.44 metres wide.
1116	Right flange fat trace	As above & ground-down bolt within trace.
1729	Right flange fat trace	Traces intermittent
2247	Right flange fat trace	Probably bead marks
2375	Trace ends	No traces
4935	Piece of a tyre on the extended centre line of the runway, beyond the end.	

Note: The pattern noted within the marks and traces of the right wheel was subsequently identified as being produced by the tyre beads.

1.12.2 Under the Aircraft's Flight Path

The land area under the climb and departure tracks was searched both from the air and on foot. The shore zones, reefs and islets under the flight path of the aircraft as it crossed the coastline, outbound and inbound, with allowances for wind and tide, were searched by hover craft. Nothing was found. The aircraft crossed the coastline, inbound, over the city of Jeddah.

Bodies of aircraft passengers were recovered from under the aircraft's flight path. The first was about 11 miles south; six more were between that point and the airport boundary. Fire-damaged pieces of cabin equipment were also found including pieces of passenger seats that had been spattered with molten aluminium.

Within the airport boundary a trail of debris, included a double seat about 500 metres short of the main impact followed by four more double seats and one triple seat, led up to the impact point. All had been spattered with molten aluminium. Bodies were also located in this area.

1.12.3 Crash Site

The initial impact was 2,875 metres short of runway 34C and about 55 metres to the right of the extended centreline. Two relatively shallow (about one metre) impact craters contained engine parts plus wing fragments and pieces of main landing gear wheels. The wreckage was mainly confined to an area of about 400 metres long by 200 metres wide although some items, including tyres and engine components, had carried up to 1,100 metres from the initial impact.

The left horizontal stabiliser was located short of and to the right of the main impact point; the right horizontal stabiliser was past and to the left of the main impact point. The cockpit area was located forward and to the right side. The outboard portion of the left wing was located forward and well to the right while the outer section and tip of the right wing was to the rear and to the left of the wreckage. A large portion of the left main landing gear was located forward and to the right; portions of the right main landing gear were to the rear and left.

The effect of the post crash fire varied considerably; some parts of the wreckage were hardly burned while other parts were totally consumed leaving only a basic outline on the sand.

The majority of the bodies were recovered from an area forward and left in the wreckage area.

1.12.4 Engines

Most engine parts, including all engine cores, were located in the forward right quadrant of the site; engines #3 and #4 were almost in the centre of the site and #1 and #2 were forward and to the right. There was a trail of small engine parts from the initial impact to the location of the major components. All engine parts were damaged by the impact. Fan blades were missing or broken at the blade roots; low pressure and high pressure compressor blades were either severely bent and flattened or missing; high pressure and low pressure turbine blades were mainly missing but some blades were bent opposite to the direction of rotation. There were marks throughout the rotational parts of the engines indicating rotation at the time of impact.

Parts of the thrust reversers, exhaust nozzle, gear box and hush-kits had disintegrated and flattened; these parts were distributed throughout the wreckage path. Some engine accessories, including one fuel control unit, some booster pumps and one fuel/oil cooler were located and identified. All were severely damaged and were not in a condition which would allow functional tests. None of the accessories could be used to determine an engine power setting; no oil or fuel samples could be taken.

There was no evidence of an engine abnormality prior to impact.

1.12.5 Fuselage

The break-up was extensive with the structure broken into pieces and distributed over the wreckage area. In general, impact and fire damage was such that precise identification was extremely difficult and often impossible. Several large, identifiable sections of the fuselage structure were located at the forward end of the area. Many of the fuselage pieces were within the fuel burn area and were extensively damaged by the post crash fire. Some pieces that were beyond the primary ground fire area had been sprayed with fuel and severely burnt.

Except for the forward left passenger door, all doors and overwing exits were located in the wreckage. The characteristics of some of the exits preclude determination of left or right side location. The forward and aft overwing exits have identifiable differences and one of the aft overwing exits had been severely burned, from the inside, prior to impact;

the window had been burned and melted and there was some burn damage on the exterior. This exit was found outside the post-crash fire area. There was no evidence that overwing exits had been removed and placed within the cabin prior to impact. McDonnell Douglas calculations indicate a considerable aerodynamic force (up to 400 pounds) on the overwing exits, acting to keep the exits closed.

Three of the cabin doors were found with the handles in the "unlocked" position. Two of them could be readily explained by impact damage. The third door, detached from the frame, was relatively intact. This door was identified as the rear left passenger door. It would have been possible to unlock the door prior to impact but air loads would have prevented opening to the extent to permit egress in flight. The hinges had broken and both internal and external operating handles coincided in the unlocked position. The door was near to a door frame within a section of the fuselage that was positively identified as being the source of the door; the fractures in the hinges were a perfect match. The condition of the door frame was excellent and indicated that the door had been fully closed on impact and had separated from its support structure into the remains of the cabin.

1.12.6 Wings

Both wings were broken up into relatively small sections of upper and lower plank structure. A major section consisting of the upper skin of the centre wing immediately forward of the rear spar together with adjacent upper wing planking was found at the forward end of the site. Nearby, were two triangular shaped box structures which provide the mounting points for the main landing gear struts. The upper cylinder portion of the left main gear shock strut cylinder was attached to the wing fitting; the right gear had broken completely away at the fitting.

1.12.7 Flaps

Most of the wing flaps had been involved in the ground fire. A number of sections were extensively burned with major portions missing. The left inboard flap was found to have a piece of a main landing gear wheel assembly lodged in its damaged leading edge. The location of the damage was directly aft of the left main landing gear when extended and the piece was identified as being part of the rim of #1 wheel.

Rim Piece

1.12.8 Rudder

The vertical stabiliser was fairly intact and had molten aluminium deposits along the lower leading edge. Several samples of deposits were scraped from various components and subjected to laboratory analysis. Although various metals were identified, it was not possible to determine the source of the molten metal. The rudder had separated from the vertical stabiliser at the hinge points and was broken into three parts. All parts were found to the left and forward of the main impact crater, outside the area of the ground fire. There was some light sooting but none of these parts showed evidence of fire damage.

1.12.9 Elevators

The two halves of the horizontal stabiliser were relatively intact. The right horizontal stabiliser had molten aluminium deposits on the leading edge. Samples from the surface of the left horizontal stabiliser proved, under laboratory analysis, to be primarily composed of stony particles representative of the soil at the crash site. Three pieces of the left elevator were found, amounting to about 80% of its surface. The remainder of the elevators could not be identified.

1.12.10 Ailerons

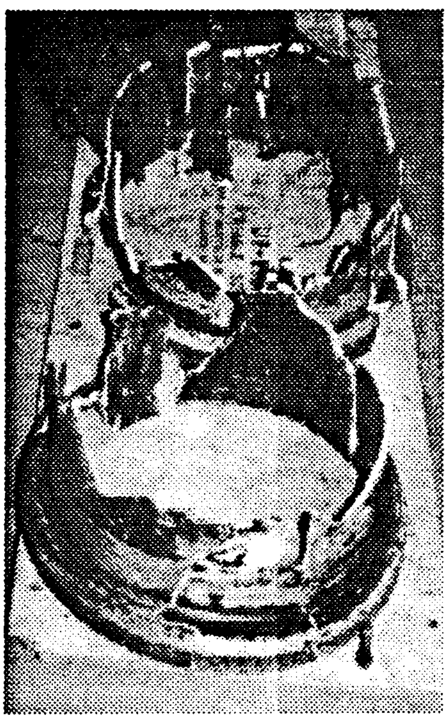
Major portions of both inboard panels of the ailerons were found. The outboard panels were torn into relatively small parts and no specific identification could be made.

1.12.11 Landing Gear

With the exception of the left main landing gear shock strut cylinder, the landing gear had separated from the attachment fittings as a result of massive overload. The failure pattern and the distribution of parts through the wreckage were consistent with the landing gear being down at the time of impact.

1.12.12 Wheel and Brake Examination

The examination of the runway used for take-off showed wheel flange marks of wheels #1 and #2 extending beyond tyre failure points. Wheel pieces recovered from the runway were identified by serial number and physical matching as being from the #1 wheel assembly. Wheels #1 and #2 were the only wheels to show signs of running on the rims. Examination further indicated that the damage to the wheels was secondary to the failures of the tyres and that the wheels did not contribute to the initial tyre failure; the wheels were intact for some time after the tyre failures.



#1 Wheel Pieces

1.12.12.1 Wheel #1

The central hub and spoke section was recovered from the accident site, as was a portion of rim section which was found lodged in the leading edge of the inboard left wing flap panel. Reconstruction of recovered parts accounted for almost all of the wheel assembly; two small rim sections three and a half and four inches of the outer circumference were missing. The edges of fractures on adjacent parts were clean and sharp. The outer diameters of both rims were roughened in an even pattern over the full circumference.

1.12.12.2 Wheel #2

This wheel was recovered from the accident site. The wheel was largely intact with the exception of a segment comprising 18% of the circumference which had been ground away. In addition, a section of rim was missing which broke off before the wheel stopped rotating. This piece was not found on the runway. The outboard wheel half was deformed as if subjected to high temperature while under load. The outer circumference of both rims were scarred and gouged but were not roughened to the same extent as #1 wheel.

1.12.12.3 Wheels #5 and #6

Wheels #5 and #6 were recovered from the accident site. Wheel #6 was incorrectly recorded in the aircraft records as wheel #4, possibly because a mechanic was confused over the numbering system. There were no indications of either wheel having rims in rolling contact with the runway.

1.12.12.4 Laboratory Analysis

All recovered parts of #1 wheel were examined by the Engineering Branch Physical Analysis Division of the Canadian Transportation Safety Board. Laboratory fracture analysis determined that all breaks were a result of overload with no indication of pre-cracking or progressive failure.

1.12.12.5 Brakes

Because of the extent of damage to the #1 and #2 brake assemblies it could not be established whether or not a dragging brake occurred.

1.12.13 Tyres

There were 10 tyres mounted on the aircraft and one complete set of spares stored in the cargo area.

1.12.13.1 Tyre Identification

1.12.13.1.1 Spare Tyres

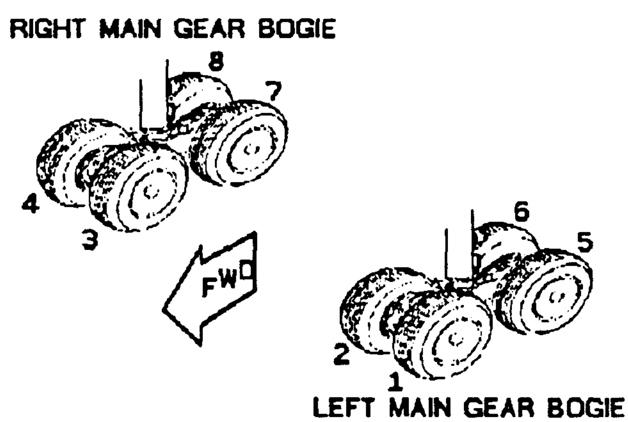
The spare tyres were identified by their full tread, about 3/8 inch.

1.12.13.1.2 Tyre #1 and #2

Tyres #1 and #2 were identified by tyre serial numbers that were on pieces found on and about the runway.

1.12.13.1.3 Other Tyres

The other tyre identification marks were destroyed by fire.



1.12.13.2 Left Main Gear Tyres

Tyre #5 was not on the wheel and was not positively identified. A relatively intact tyre was assumed to be #5 because of its condition: the tread surface was cut and scarred around the full circumference consistent with "running over" metallic debris presumed to be from #1 wheel; the wires of the bead bundle on one side of the tyre had well defined kinks which were consistent with the separation of part of the #5 wheel rim which broke off during the crash. The tyre had been severely burned over part of the surface and the pattern suggested a localised flame playing on the tyre.

Tyre #6 was still mounted on the wheel—which was identified, but was deflated. The tyre was essentially intact but the entire surface had been burned to the extent that much of the rubber had been burned away down to the carcass cords. The inboard sidewall was ruptured circumferentially through approximately 270°. Near the mid point of this split, an area of burst damage involved most of the cord body plies. A flap of cord body had been pushed out through the split. The liner, which was not damaged by fire, showed no indications of running while deflated. Black deposits on the runway beyond 800 metres from the start of the take-off roll were consistent with the condition of the tyre and indicate that the tyre was heavily loaded but intact until after take-off.

1.12.13.3 Right Main Gear Tyres

Tyres #3, #4, #7 and #8 could not be identified. One of the unidentified tyres showed evidence of bursting under pressure prior to impact. One of the witnesses reported hearing a "bang" at about the time the aircraft became airborne.

1.12.13.4 Examination on Site

None of the tyres which were identified as having been mounted on the aircraft main landing gear showed evidence of long term under-inflation. Tread groove depth readings indicated greatest groove depths at the outside of the tyres indicating generally adequate inflation pressure. No evidence was found of cuts or other defects caused by foreign objects on remnants of #1 and #2 tyres.

Tyre material, recovered from the runway, showed indications of high temperature but no obvious signs of burning. Post-crash investigation of wheels, tyres and marks on the runway indicated that tyre #1 failed early in the take-off run and tyre #2 failed approximately 130 metres beyond that point.

1.12.13.5 Laboratory Examination (1)

The remnants of tyres found on the runway, as well as the left bogie tyres, were transported to the Engineering Laboratory of the Transportation Safety Board of Canada further examination. They were examined by Transportation Safety Board officials as well as experts from the tyre manufacturer and industry. The visual examination determined the mode of failure and defined further laboratory examination requirements.

Analysis showed that tyre #1 failed when the bead sections separated from the tyre sidewall at the point where the bead transitions into the sidewall. Examination of the sidewall remnants of tyre #2 showed similar evidence of the effect of over-temperature on the nylon cord at the sidewall mid point. Both the tyres were found to have failed due to overheating of the sidewall area, partially melting and weakening the nylon cord body until rupture occurred. The conclusions were that tyre #1 failed when over-deflection and overloading, resulting from the under-inflation of tyre #2, caused excessive heat build up in the sidewall until cord-body melting reduced the tyre strength and rupture occurred. Tyre #2 failed for essentially the same reason following load transfer after the first failure. A further conclusion was that as a certain amount of operating time is required for the tyre temperature to build to the point where it fails, it is probable that the #2 tyre was under-inflated when the aircraft left the parking area to begin this flight.

Details of #1 and #2 tyres are as follows:

1.12.13.5.1 Tyre #1

This tyre, serial #82600262, manufactured by Goodyear, was last retreaded by the Thompson Aircraft Tire Company to R3 in July 1990.

Two bead sections, found on the runway, were determined to be from the tyre on #1 wheel, since this was the only wheel which had both rim sections broken away thus allowing the bead sections to come off the wheel. These bead sections had separated from the sidewall and were abraded on the outside diameter. Two large pieces made up most of the remaining carcass. During examination, a large number of smaller pieces were matched to show that the full circumference of the tyre was recovered accounting for nearly the complete tyre structure.

Major portion of #1 Tyre Carcass

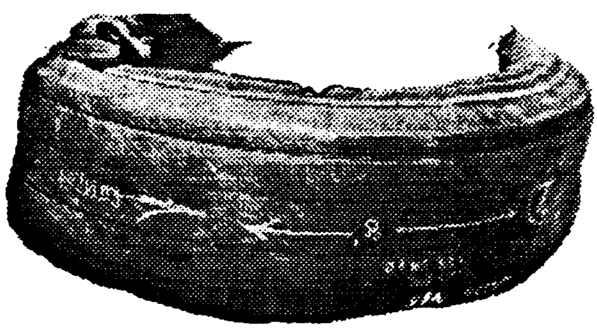
The tread was worn evenly and there was no indication of failure that could be related to foreign object damage. The tread groove depths showed slightly more wear at the centre than at the shoulders. The wear was near the point where removal would be required if the carcass was to remain suitable for retreading.

The tyre ruptured in the mid-to-lower sidewall between the tread and the bead. At this point the nylon reinforcing cords were hardened and partially melted. At other tear locations the cords were more pliable. There was no evidence of heat generated from outside the tyre structure.

1.12.13.5.2 Tyre #2

This tyre, serial #81120176, manufactured by Goodyear, was last retreaded by the Thompson Aircraft Tyre Company to R3 in June, 1990.

The bead sections of this tyre were recovered from the main crash site. Both were ground down in a pattern which matched that of wheel #2. The bead pieces were burned and charred but remained intact. The carcass of this tyre was broken into one large piece and a number of small pieces. Enough pieces of tread surface were recovered from the runway (when matched) to



Part of #2 Tyre Carcass

complete the full (tread) circumference. There was still a significant amount of missing tyre. The large number of small fragments that could not be directly matched to either the #1 or #2 tyre would not have accounted for all the missing material.

The tread was worn at or near the limit for removal for retreading. The centre grooves were slightly shallower than those at the shoulders. There was no indication of foreign object damage that could have resulted in a rupture.

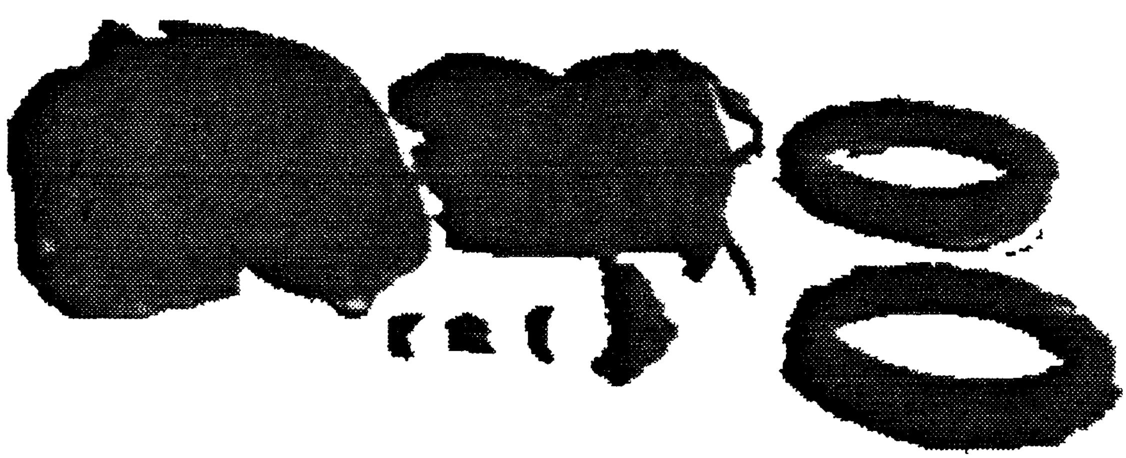
The sidewall remnants, found on the runway, showed similar evidence of the effect of over-temperature on the nylon cord at the sidewall mid point as was seen in the #1 tyre. The nylon reinforcing cords were hardened and partially melted. There was no evidence of heat generated external to the tyre remnants.

1.12.13.6 Laboratory Examination (2)

The recovered parts of #1 and #2 tyres were then sent to the Canadian Department of National Defense Quality Engineering Test Establishment. The purpose was to determine the mode and cause of failure of the tyres from laboratory analysis. Visual, microscopic and x-ray examinations were performed. The total weight of the available tyre remnants was calculated to determine the amount, if any, of missing material. The cord and rubber materials were identified by chemical analysis. The findings of the examination were:

1.12.13.6.1 Tyre #1

The identifiable remains of tyre #1 consisted of:



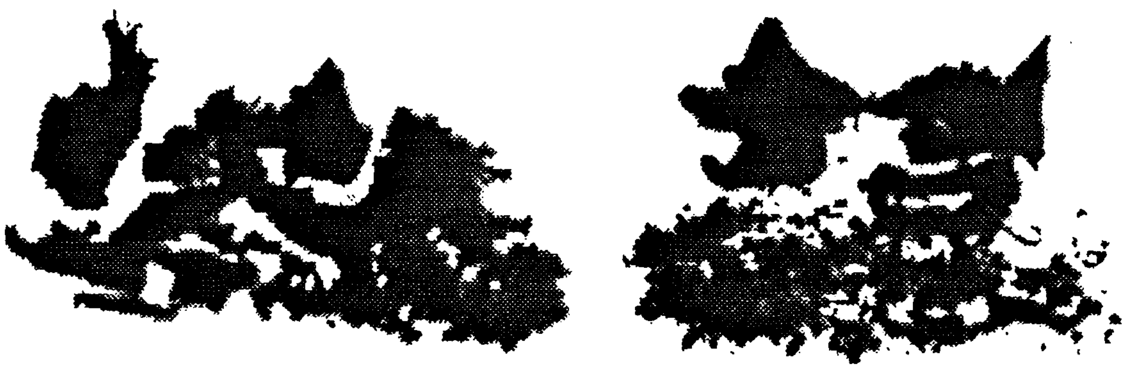
- a tread/sidewall section measuring approximately 1.96 metres (77 ins.) circumferentially and 60 centimetres (24 ins.) laterally;
- a tread/sidewall section measuring approximately 2.34 metres (92 ins.) circumferentially and 70 centimetres (28 ins.) laterally;
- four sidewall fragments varying from approximately 15 centimetres (6 ins.) to 46 centimetres (18 ins.) circumferentially, and from approximately 5 centimetres (2 ins.) to 15 centimetres (6 ins.) laterally;
- two bead sections.

1.12.13.6.2 Tyre #2

The identifiable remains of tyre #2 consisted of:

- a tread/sidewall section measuring approximately 2.54 metres (100 ins.) circumferentially and 68 centimetres (27 ins.) laterally;
- six tread/sidewall fragments varying from approximately 23 centimetres (9 ins.) to 43 centimetres (17 ins.) circumferentially, and from approximately 10 centimetres (4 ins.) to 35 centimetres (14 ins.) laterally;
- three sidewall fragments varying from approximately 15 centimetres (6 ins.) to 43 centimetres (17 ins.) circumferentially, and from approximately 8 centimetres (3 ins.) to 15 centimetres (6 ins.) laterally;
- two bead sections.

Submitted tyre remnants also included numerous unidentifiable items, ranging from large carcass ply sections to small, congealed cord/rubber fragments.



1.12.13.6.3 Visual and Microscopic Examinations

Visual examinations of the remains of the two tyres indicated that the sequence of failure to both was complete circumferential rupturing in the mid-to-lower sidewall regions, followed by tread and sidewall break-up and extensive internal casing ply delamination and fragmentation. The nature and location of the circumferential sidewall ruptures is consistent with operating a tyre in an under-inflated and/or overloaded condition, resulting in sidewall over-flexing which, in turn, causes extreme localised heat generation. Such heat generation is symptomised by congealed ply cords and reverted rubber, both of which were detected by microscopic examinations along the circumferential rupture lines in the sidewalls of both tyres. The magnitude of the heat generation may be estimated by the fact that the tyre cord materials were composed of nylon 6/6 which has a melting point of 265-270°C (509-518°F).

While the bead sections from tyre #1 were structurally intact, the bead sections from tyre #2 were severely abraded through approximately 18 centimetres (7 ins.) of their total inside circumference and portions of the wire bundles were exposed due to fire damage to the covering rubber/ply structure. There was no evidence of fire damage to the tread or sidewall remnants of either tyre, indicating that such damage occurred after the tread and sidewall components had broken away from the bead section.

The severe abrasion exhibited by the bead sections from tyre #2 indicates that the #2 wheel had stopped rotating at some point during the take-off roll. The fact that there was no evidence of abrasion damage to the tread and sidewall remnants of the tyre indicates that these components had already broken away from the bead section when wheel rotation stopped. While these findings indicate that the apparent lock-up of the #2 wheel was not a contributing or cause factor to the tyre failure, they do not discount the possibility that remnants of either or both of the failed tyres, mounted side-by-side, caused the rotational lock-up by jamming in the undercarriage structure. There was however, no visible evidence of such an occurrence on any of the tyre remnants.

It was noted during the course of the visual examinations that both tyres had reached, but not surpassed, the normal tread wear limit; the tread surfaces were worn to the bottom of the centre grooves and were therefore due to be removed from the aircraft. There was, however, no evidence to suggest that this was a factor in the failure occurrence. The thickness of the remaining tread rubber on each tyre was measured and the minimum was found to be approximately 5 millimetres (0.20 ins.) to the first outer reinforcing ply level and 8 millimetres (0.32 ins.) to the first outer carcass ply level, representing a substantial margin before tread wear would have become a critical safety factor.

There was no evidence to suggest that the fact that both tyres had been retreaded 3 times was a factor in the failure occurrence. This type of aircraft tyre (Type VII) is routinely retreaded 6 times or more before being taken out of service. The criteria for final rejection for retreading, except for severe cuts or impact damage, is advanced carcass structural deterioration. Such structural deterioration, symptomised by propagating interply separation, should be evaluated at each retread level, by the retreader, using non-destructive testing methods such as Air Needle and/or Holography techniques. Detailed visual examinations of the delaminated ply surfaces on the tyre remnants revealed no evidence of previous internal separations. There were also no indications of ply separation at the old and new tread interface on either tyre.

Visual and microscopic examinations revealed no evidence of an inherent material or manufacturing defect or irregularity in the remnants of either tyre which could be considered a contributing or cause factor to the failures. There was also no evidence of pre-failure damage such as cuts, punctures or impact ruptures in the tyre walls. It should be noted however, that such damage may have been obliterated by the more extensive post-failure damage.

1.12.13.6.4 X-Ray Examination

X-ray examinations of the tread remnants and bead sections revealed no significant internal defect or irregularity which could be considered a contributing or cause factor to the failure of either tyre.

1.12.13.6.5 Weight of Tyre Remnants

The total weight of the available tyre remnants was calculated and found to be approximately 102 kilograms (225 lb.). The combined weight of the two tyres prior to failure should have been approximately 150 kg (330 lb.[10]), indicating that approximately 32% of the total tyre mass is missing.

1.12.13.6.6 Chemical Analysis

The base polymer of the tread rubber from each tyre was identified by Pyrolysis Gas Chromatography and Thermogravimetric analysis as a composition of 73±5% polyisoprene (natural rubber) and 27±5% butadiene. Chemical analysis revealed no defects or irregularities in materials or composition in the components of either tyre.

1.12.13.7 Summary of Tyre Information

Examination of the recovered parts of tyres #1 and #2 determined that the tread was worn fairly evenly and that there was no indication of a failure which could be related to a cut or any form of foreign object damage. The tread groove depths were reasonably uniform and the extent of wear was judged to be at, or near the point, where removal would be warranted to ensure the carcass remained suitable for the retread process.

- The failure sequence of both tyres was rupture of the circumference in the mid to lower sidewall area.
- There was tread and sidewall break-up and extensive internal casing ply delamination and disintegration.
- Fused ply cords and rubber reversion was evident along the circumferential rupture lines of both tyres.
- The nature and location of the circumferential sidewall ruptures is consistent with over-flexing resulting in localised heat build-up.

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[10] Thompson Aircraft Tire Company indicate that a tyre of this size, when received for retreading, weighs approximately 165 pounds.

- The bead component of tyre #1 was structurally intact.
- The bead component of tyre #2 was severely abraded through approximately 18 cm of its total circumference and portions of the wire bundles were exposed due to fire damage to the covering rubber/ply structure.
- There was no evidence of fire damage to the tread or sidewall remnants of tyre #1 or #2.

1.12.13.8 Gas Analysis

Gas samples were taken from two still inflated spare tyres removed from the wreckage. These samples were analysed by the Air Accident Investigation Branch, Farnborough, Great Britain. The analysis of the samples showed the gas ratios, by volume, to be:

(1) 96% Nitrogen, 3% Oxygen

(2) 90% Nitrogen, 9% Oxygen .

(Air contains 78% Nitrogen, 21% Oxygen, 1% other gases.]

1.13 Medical and Pathological Information

1.13.1 Crash Site

Because of the high ambient temperature, recovery of human remains was begun without delay and the distribution was not plotted. The remains were transported in refrigerator trucks to three hospitals.

Observations at the crash scene showed a severely disrupted airframe, with very little of the fuselage recognisable. Many of the triple seat assemblies were burned, including several showing molten aluminium alloy deposited along the forward facing edge. The seat cover material was, in most cases, completely burned away, leaving only the fire block layer. In some cases this layer had been penetrated by fire, exposing the foam. All the seat assemblies showed severe impact damage, with broken legs, backrests torn off, and track attachment points broken off, bent and twisted. The seatbelts (that were recoverable) showed failure in tension, usually a failure in the loop or ring that is welded to the seat; however several showed disruption of the belt fabric (tearing). Some of the seatbelts at the crash site were still buckled, but broken at some other point, or completely detached from the seat.

1.13.2 Identification

Nine members of the crew were identified. No attempt was made to identify the passengers.

1.13.3 Injury Patterns

The bodies found outside the crash site showed charring and severe impact injuries. Also found near the first body was a yellow life vest which was charred all along one edge, consistent with being folded underneath the seat and being charred in situ. This indicates that there was a severe fire in the cabin of the aircraft at least 11 miles from the runway. At that point the fire had caused severe burns to the first casualty and had burned the edge of the life vest stored underneath the seat (including the depositing of molten metal on the life vest). Bodies recovered from the wreckage showed burns consistent with the flash fire that took place post-impact; one third of the bodies recovered showed signs of severe burns sustained prior to impact. The occupants of the cockpit suffered little or no burns either pre or post impact.

The physical injuries to the passengers were consistent with a high-speed impact, with severe cabin break-up. An estimate of the "G" forces necessary to accomplish this level of impact injury is difficult, if not impossible (the seats are only stressed to 10G, and the seatbelts are only stressed to approx. 25G-10,000 lbs breaking strength with a 167 lb. subject). The massive destruction of the seats and belts indicates that the impact was very much in excess of these design limits. The injury pattern is consistent with following impact scenario: aircraft nose down, with the main cabin pitching over the nose, placing the major deceleration force in the vertical plane causing initial head injuries by contact with the cabin roof.

1.13.4 Post Mortem Examination

Post Mortem examination of the crew was limited to that required for identification. Toxicological testing of tissue samples from the flight crew proved negative.

Post Mortem examination of the passengers was not required nor practical in the time available prior to burial.

1.13.5 Personnel Medical Information

The flight crew's medical histories were reviewed. There were no indications in the medical files of uncorrected visual faults, hearing impairments, or any conditions which could have impaired mental processing, musculoskeletal function or the maintenance of an alert and vigilant status.

The cabin crew company medical files were reviewed. The cabin crew were all considered fit for duty. Further, there was no evidence to indicate that any of the cabin crew were suffering illness at the time of the accident.

1.13.6 Crew Rest

The crew had arrived in Jeddah, from Accra, at midday on 9 July and was off duty until the morning of the accident. The evening of 10 July was the first time since the beginning of the deployment that all of the crews were together. That evening, several of the various crews went shopping, including the first officer and flight engineer. The captain did not join the others, but remained in the hotel, apparently in his room. The cabin crew returned and were reported to have retired to their rooms by about 2300 hours. The first officer and flight engineer returned sometime between 2300 and 2400 and retired, reportedly in good spirits. Following a wake-up call at 0300 hours, the crew breakfasted together in the hotel. They departed for the airport shortly after 0400, having been off duty for about 40 hours.

Evidence indicates that Captain was adequately rested and had not voiced any complaints, physical or emotional, to any of the other deployment personnel; he was in good spirits and was looking forward to getting back home.

First Officer was reported to have complained of a "mild cold" the day before but stated "that he was fine." There is no evidence to indicate that he was suffering from any emotional problems on the day of the accident.

Flight Engineer had not voiced any complaints, physical or mental, to any of the deployment personnel interviewed. In fact, he declined the opportunity to turn this flight over to the "spare" flight engineer on the morning of the accident.

In-Flight Director had not voiced any complaints, physical or mental, to any of the survivors interviewed. Witnesses reported that she retired to bed some three to four hours prior to the wake-up call.

1.13.7 Crew Profiles

Crew profiles were developed from information gathered during review of military and company records and during interviews with next-of-kin, friends, colleagues, and supervisors.

1.13.7.1 The Captain

The captain was described as a jovial, robust individual who generally got along well with most people. He had a strong personality and was very forthright in expressing his opinions. The captain and his wife were divorced in 1987. At the time of the accident, he was described as being in better spirits than he had been in a long time and that he had seemed finally happy. He was in good health, and there were no apparent outside stressors that would have affected his performance.

During his upgrade to captain at Nationair and his subsequent recurrent training, his performance reflected a disciplined, capable individual. During simulator sessions or line checks, he exhibited a professional attitude in the cockpit. His management style, which was for the most part rated as to how well the crew performed during emergencies using appropriate standard operating procedures, was rated normal. He was considered a capable, professional pilot who demanded an exacting and professional calibre of performance from others. He went by the book, and was described as an individual who could not be easily pressured into doing something which he felt was unsafe. The captain was technically minded and prided himself on knowing the aircraft systems. He was pleased to be flying with Nationair and was described as a good company man.

When questioned about the captain's ability to interact with other flight crew on the flight deck, flight crew members from Nationair and from the military who had flown with him gave several opinions. He was said to be very confident in his own ability but, at times, lacked confidence in other's abilities, depending on their background. He was described as a dogmatic individual whose management style could inhibit others. He did not delegate duties well and had a tendency to micro manage, particularly with first officers.

Prior to the accident, a review of claims that the captain was difficult and hard on crews was undertaken by the DC-8 chief pilot at Nationair. After discussing the situation with some of the first officers, the chief pilot decided that the rumours were unsubstantiated and thus did not believe it necessary to discuss the situation with the captain. However, he scheduled a check flight to assess the captain; the results of the flight were positive and the matter was considered settled. During preparations for the Jeddah deployment, some of the flight crew and some of the cabin crew voiced concerns about being paired with the captain.

The captain had many hobbies and was described as meticulous and thorough in his work.

1.13.7.2 The First Officer

People enjoyed associating with the first officer who was described as a well-liked, good humoured outgoing individual who extended his help generously. He had a forceful personality and was outspoken. The first officer was not married. He was in good health. The first officer was described as a very professional pilot. He was conscientious and eager to learn. He was knowledgeable about the aircraft and was confident in his abilities. He was described as a keen, dedicated individual who knew his job well and who was always thinking ahead. The first officer was an avid flyer and liked flying the DC-8. Although he had flown in Africa before, he had not flown in the area of this operation and was excited about the Jeddah deployment.

During training on the B757, it was noted that he did not receive criticism well. This particular attitude led to his being evaluated on two occasions by another Nationair captain with respect to flying abilities and interactions with others. This captain found that there were no problems with the first officer's handling or knowledge of the aircraft, but that his difficulty stemmed from his tendency to interrupt with explanations when he was being debriefed.

1.13.7.3 The Flight Engineer

The flight engineer was well thought of by both his peers and his superiors. He was described as a quiet, easy-going person who got along well with everyone. He was married with two children and was a devoted family man. He was in good health and there were no apparent outside stressors that would have affected his performance.

The flight engineer was described as a consummate professional. He was an experienced engineer who was co-operative and provided good support to his flight crews. He was conscientious and level-headed in his approach and was considered to be knowledgeable about the aircraft systems and very adept at analysing discrepancies in those systems. It was believed that, if he thought something was wrong, he would speak out.

1.13.7.4 The In-Flight Director

The in-flight director was described as a cheerful person who was well liked by both supervisory and subordinate personnel. She enjoyed her job, was keen on overseas deployments, had recently returned from a deployment to Indonesia and was looking forward to returning to that part of the world. She was in good health, and there were no apparent outside stressors that would have affected her performance.

The in-flight director was said to be a responsible, professional individual who performed her duties in a conscientious manner, expecting strict adherence to company procedures from her crews. Crews under her supervision worked effectively, and her leadership qualities were such that she was assessed as a good in-flight director with the potential to become a quality manager within the company.

1.13.8 Crew Interaction

According to one of the other captains on the deployment, First Officer had told him that he had asked one of the other first officers to exchange pairings because he ( ) was having problems "getting along" with Captain reportedly told this other captain that Captain was always criticising ana that they had had an argument on one flight.

Another witness reported that he had overheard a conversation between and the other first officer, during which discussed problems he was having with Captain The witness stated that he heard the other first officer offer to exchange pairings but refused.

The "other first officer," when interviewed, stated that had not asked him to "switch" crews; rather he, the other first officer, had offered to exchange pairings but declined, saying he could "handle it;" had also indicated that both he and the flight engineer were disinclined to voice their ideas or concerns, "... it's to the point where we just let him do his own thing."

The operations officer stated that he was not aware of any crew problems on the deployment and there is no evidence that the flight engineer or the captain had spoken to anyone about the atmosphere in the cockpit.

During the taxi to position for take-off on the morning of the accident, the crew exchanged only information necessary for flight preparation. This level of conversation was in keeping with Nationair take-off procedures which indicate that crews respect the sterile cockpit concept below 10,000 feet; this includes the time during taxi after all required checks have been completed and before the final four-items check. During this period, crews restrict their communications to operational matters.

1.14 Fire

1.14.1 Fire on the Runway

Witnesses reported sparks and flame from the left main landing gear before the aircraft became airborne. The #2 tyre failed (after #1) early in the take-off roll and the wheel stopped rotating. A bolt which had been ground down to one third of its original diameter was 1,109 metres from the threshold. It was identified as a tube-well bolt from #2 wheel. The appearance of this bolt indicated that it had reached a temperature of at least 485°C. The ignition temperature of rubber is about 260°C.

Although #1 wheel break-up resulted in damage to a flap section[11], damage to fuel or hydraulic components within the wheel well or airframe could not be established.

Damage to hydraulic lines to the brakes, landing gear bogie trim actuator and the bogie swivel unlock cylinder, during the tyre and wheel break-up, could not be established. Hydraulic fluid, although fire resistant, will burn if provided with sufficient heat and an ignition source.

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[11] See 1.12.12.1

1.14.2 Fire in Flight

The first indication to the cockpit crew of fire in flight was the reporting of smoke in the cabin five minutes after brake release. The cockpit voice recorder failed about one minute later. The first indication to air traffic control of a fire was three and a half minutes after the report of smoke in the cabin, when the captain declared an emergency for the third time, also reporting "... we are on fire, we are on fire ..."

Witnesses on the ground reported symptoms increasing progressively from a smoke trail to a fierce fire in the right wing root area. The departure of passengers and debris from the cabin interior, along the approach path, indicate a loss of part of the aircraft fuselage structure.

1.14.3 Fire at Impact

Some witnesses reported that there was a brief fireball prior to impact; others that there was a brief fireball after impact. Marks on the ground showed that the fuel was spread over a wide area in a tear-drop pattern. An intense fire consumed most of the airframe; heavy sooting on remaining structure indicated a fuel rich fire.

1.14.4 Fire Damage to Structure

Aircraft structure forward of the wheel well area showed little or no exposure to prolonged heat or extensive smoke. The forward overwing exits showed little or no evidence of a sustained cabin fire. The aft overwing exits, about seven feet behind and located above the wheel well area, were extensively damaged by what appears to have been a sustained fierce fire.

The DC-8 main landing gear is attached to the wing structure in the area of the rear spar and swings inward on retraction. Each side has four wheel assemblies mounted in pairs on tandem axles. These assemblies stow in wells on either side of the fuselage centreline. The left and right main gear wheel wells are separated by a dividing wall; the centre fuel tank is immediately forward of the wheel wells; above the wheel wells is the cabin floor. The gear struts are faired into the wing, when retracted, by leg mounted doors. The wheel doors are attached by piano type hinges to the fuselage keel structure between the wells and are opened and closed by hydraulic actuators.

A partial reconstruction comprising the fuselage and wing structure in the immediate area of the main landing gear wheel wells was conducted to gain a clearer picture of the path of the fire through the aircraft.

With the exception of a portion of the forward structure and the outboard areas with the landing gear attachment fittings, much of the structure which formed the twin boxes of the wheel wells, including the dividing wall, was missing. A small section of the upper portion at the forward end remained attached to the wall. Examination showed that the fire had perforated the forward pressure panel near the outboard ends providing entry to the lightweight structure of the passenger cabin floor. The rear wall or pressure panel from the wheel well ceiling down to the lower structure of the aft cargo compartment was missing with evidence of it having burned away although there was no appreciable fire damage to the compartment lower structure. Structure forming the forward top of the left and right wheel wells was bent downwards due to impact; holes in both left and right structures, larger than 15 centimetres square, had been burned through from below during flight.

The spoiler reserve hydraulic reservoir and spoiler pump, which are normally mounted in the aft inboard corner of the right wheel well, were found to be heavily coated with molten aluminium deposits on the forward face. The spoiler reserve hydraulic reservoir case had fractured and the inside was also slightly spattered with aluminium. The hydraulic actuator for the right main gear door was also heavily coated with deposit. The left door actuator had only traces of such material but this item also showed evidence of more severe ground fire exposure.

The longerons and other structural parts of the fuselage and mating portions of inboard wing structure adjacent to the outboard rear corners of the wheel wells were burned in a pattern which indicated propagation of an intense fire from each wheel well upward and aft into the passenger cabin. Aluminium cable guides within the wheel wells were melted from below. Heat distortion had occurred but there was no soot. (Soot does not deposit on surfaces hotter than about 375°C.) Very little of the fuselage skin and structure from the immediate area of this severely burned location were identified in the examination of wreckage at the site. The heavier structural members had breaks exhibiting the "broomstraw" appearance which results from fracture at high temperature. Although somewhat similar damage was found on both sides of the aircraft the most material was lost from the aircraft right side.

1.14.5 Hydraulic Fluid and Fuel Burning

Phosphate Ester based hydraulic fluid does not burn easily without the presence of continuous ignition. Even when ignited, hydraulic fluid produces a smaller and less intense fire than the burning of the same quantity of jet fuel. The trail of debris short of the crash site and the components from the passenger cabin all indicate a rapid penetration of the cabin and an intense fire.

1.15 Survival Aspects

The accident was not survivable.

1.15.1 Fire Rescue Services

King Abdulaziz International Airport is equipped to ICAO Category nine standard with considerable reserves of equipment. More than 200% reserves of extinguishing agent are maintained. The main Fire Rescue Services station is located near the control tower in the centre of the airport. Substations are located at:

Station 2:	Threshold of runway 16R;
Station 3:	Threshold of runway 34C;
Station 4:	Southwest of main terminal building, groundside;
Station 5:	Haj Terminal;
Station 6:	East of runway 16L/34R;

FRS stations and vehicles are equipped with communications equipment as follows:

387.15MHz:	FRS Operational communications;
133.50MHz:	FRS Operational communications;
121.60Mhz:	Air Traffic Ground Control;

In addition, The Fire Communications Centre is provided with direct telephone links with Air Traffic Control and all fire stations; radio paging; telephone trunk lines; message taping of the complete communications network; aircraft arrival and departure details on a display monitor; Tower and Radar frequencies; Direct telephone links to Civil Defence, Royal Saudi Air Force and other support agencies.

The sequence of alerts was as follows:

- Alert 1 was declared at 0832 hours for Saudia B737 returning with a pressurisation problem;
- Alert 2 was declared at 0836 hours with the runway designated as 34L;
- Alert 3 was declared at 0839;

At Alert 1, all FRS units were notified and adopted alert status at the stations.

At Alert 2, Main and station 2 responded and assumed the predetermined crash standby locations at runway 34L.

At Alert 3, All FRS units responded to the site. The first vehicle arrived at the site at 0843:41. The following vehicles attended:

5 Major foam vehicles;	2 Medium foam vehicles;	2 Pumper vehicles.
1 Water tanker;	1 Rosenbauer;	1 Rescue truck.
3 Rapid Intervention vehicles;	4 Ambulances;	1 Medical Truck.
3 Command post vehicles;	3 Utility vehicles.	

Eight vehicles remained at stations; Three vehicles were undergoing maintenance.

Pre-positioned vehicles drove from runway 34L east past the control tower and then south, along a taxiway and roads, through a crash exit, direct to the site. All air-side stations responded by the most direct routes. Ground-side responded through a controlled gate to airside and then through a crash gate to the site. All vehicles travelled on paved surfaces except for the last 1,000 metres or so to the site. One paramedic vehicle became bogged and the crew and supplies were transferred to another vehicle.

The fireball had subsided by the time FRS units arrived at the scene. Residual fires were extinguished by 0846 hours and a search for survivors was conducted. Water was sprayed on scorched areas to facilitate the search. There were no survivors. The area was cordoned off and recovery of bodies initiated.

Additional response included Royal Saudi Air Force and Civil Defence units.

1.15.2 Cabin Fire Extinguishers

It was not possible to determine if cabin fire extinguishers had been used.

1.16 Tests and Research

1.16.1 Aircraft Manufacturer's Recommended Practices

The aircraft manufacturer provides information and recommendations in respect to tyre maintenance and use; the following extract is taken from ***"Aircraft Tire Inflation And Maintenance,"*** *F. W. Moore - Hydro-Mechanical Systems, McDonnell Douglas. (Douglas Service Second Quarter 1986)*

One possible effect of over-inflation is an increase of the tire's load-carrying capability. This capability far outweighs the negative aspects of over-inflation, because an over-inflated tire can better withstand the overload created if the mate tire on the same axle were to fail.

The tensile strength of nylon cord decreases approximately 25% when the tire temperature reaches 200°F resulting in a decreased load-carrying ability. Once the tensile strength loss has occurred, the risk of tire failure remains increased even if the tire is re-inflated to recommended limits.

... The following are recommended limits for tires at or above ambient temperature:

Tires at Ambient Temperature:

If the differential pressure of paired tires on an axle is greater than 10 psi and the lower inflation pressure is equal to or greater than the minimum inflation pressure suggested in the maintenance manual, the lower tire may be re-inflated to the pressure of the adjacent tire if desired. If the inflation pressure of the low tire is less than the suggested minimum inflation pressure by no more than 14 psi, the low tire must be re-inflated to the pressure of the adjacent tire, provided that the adjacent tire is properly inflated. In the event that both tires on an axle are under-inflated by no more than 14 psi both should be inflated above the minimum acceptable pressure. It is recommended that a record be kept, for all inflated tires, to include the pressure and date of re-inflation. This may be done by marking directly on the tire.

Tires Above Ambient Temperature:

If tire pressures are above the minimum recommended for the operating gross weight, re-inflation solely to match tire pressure is not necessary. If either tire is below the minimum recommended pressure for the operating gross weight by no more than 14 psi, that tire must be re-inflated to comply with maintenance manual recommendations. In this situation, the low tire should be re-inflated to the maximum allowable tire pressure for the operating weight or to the pressure of the adjacent tire on that axle, whichever is less.

Regardless of tire temperature, if any tire is inflated 15 to 29 psi below the minimum value specified for that particular operating gross weight, that tire should be replaced. If the pressure of any tire is under-inflated by 30 psi or more, both tires on that axle should be replaced. The intent of these recommendations is to prevent tire deflection beyond the design capability of that tire.

... Since tires can lose up to 5% of their inflation pressure each day, inflation pressure should be checked with a calibrated gage prior to each flight or at least daily.

In DC Fight Approach, #25, January 1976, an article entitled "Tire Conservation" dealt in detail with the hazards associated with under-inflated tyres. It concluded with the following:

In short, McDonnell Douglas recommends (There were eight other recommendations in addition to the following two):

Inflate tires with dry nitrogen to the pressure required for aircraft take-off gross weight. Check and record tire pressure daily or prior to first flight of the day and require a sign-off on tire checks.

... Establishment and adherence to rules and guidelines for removing or re-inflating a tire when it is found to be under-inflated.

The Goodyear "What you should know about Aircraft Tires" Manual:

The following are extracts from the document:

Keeping aircraft tires at their correct inflation pressures is the most important job in any preventive maintenance program. The problems caused by under-inflation can be particularly severe. Under-inflation produces uneven tread wear, shortens tire life because of excessive flex heating and allows tube-type tires to slip around the rim and shear off valve stems. Over-inflation causes uneven tread wear, reduces traction, increases tire growth, and makes treads more susceptible to cutting.

Tire pressures should be checked with an accurate gauge on a daily basis. Ideally, pressures on high performance aircraft should be checked before each flight. ...

ADJUSTING FOR TEMPERATURE:

When tires will be subjected to ground temperature changes in excess of 50°F (27.5°C) because of flight to a different climate, inflation pressures should be adjusted for the worst case prior to take-off. The minimum required inflation must be maintained at the cooler climate; pressure can be adjusted in the warmer climate. An allowance must be made for the inflation drop in the cooler climate. An ambient temperature change of 5°F (2.75°C) produces approximately one percent pressure change.

If tire pressure is checked and found to be less than the minimum pressure, the following table should be consulted.

Tire Pressure	Recommended Action
100-85% of service pressure	Re-inflate to specified pressure.
85-70% of service pressure	Remove tire from aircraft
70% or less	Remove tire & axle mate
Blown fuse plug	Scrap tire. In service remove axle mate.

/NOTE

NOTE: Any tire removed because of low inflation pressure must be inspected to verify that the carcass has not sustained internal carcass degradation. If it has, the tire must be scrapped.

1.16.2 DC-8 Tyre Inflation

DC-8-61 tyre pressure specifications are shown on a tyre pressure chart in the Aircraft Maintenance Manual provided by McDonnell Douglas. The chart also provides figures for all aircraft weights, and states that the pressure tolerances for DC-8 main landing gear tyres are plus five and minus zero psi. For the maximum gross design weight of 325,000 pounds, the tyre pressure should be 185 psi. The manufacturer also allows for inflating the tyres to the maximum gross weight figure even when operating at lower weights. For the weight and balance sheet figure of 313,933 lbs, the tyre pressure should have been 183 psi.

The manufacturer also specifies that if a tyre is found to be 15 psi or more below the rated pressure, the tyre must be replaced. If the pressure of a tyre is found to be 30 psi or more below the rated pressure, both the tyre and its pair on the axle must be replaced. According to the tyre manufacturer, a daily, pressure leak-rate of 5% should be expected on its tyres. Technair personnel who were interviewed, all stated that such a leak rate is seldom encountered on its DC-8 tyres.

1.16.3 Tyre Under-Inflation

During the course of the investigation, interviews with a cross section of airline personnel revealed a general lack of awareness of some of the consequences associated with improperly inflated tyres. Other than for a grossly under-inflated condition, most people thought that the most significant consequences of under-inflation were abnormal wear patterns and reduced tyre life. A review of popular posters and training manuals shows that they tend to stress the loss of tyre longevity due to improper inflation, and this focus is emphasised in the photographs supporting the articles.

Manufacturers' pamphlets and letters state that improper inflation will result in loss of tyre carcass strength and potential tyre failure and attribute the failure potential to a heat rise in the tyre resulting from high taxi speeds. However, some manufacturers' data, based on research done on the DC-10 which uses paired tandem-bogie wheels similar to the DC-8, do indicate that a tyre-overload condition, sufficient to precipitate a critical temperature rise in a tyre, can occur if a paired tyre is under-inflated by as little as 15%. Although ambient temperatures do not contribute significantly to the heat rise, they may precipitate an earlier tyre failure because of the higher threshold temperature of the tyre.

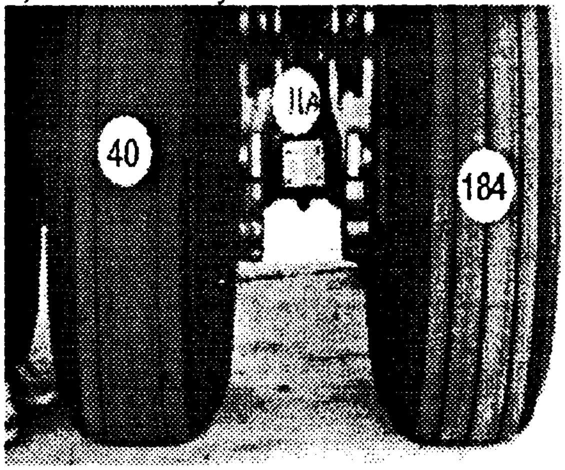
Fuse plugs are installed on aircraft wheels to bleed off excessive tyre pressure that may occur as the result of overheating brakes heating the aircraft wheels and the nitrogen inside the tyres. However, in the case of tyres overheating as a result of overload or under-inflation, the heat generated in the tyre plies does not conduct easily through the rubber to the wheel core. Consequently, a tyre heat rise sufficient to cause the tyre to fail will occur well before the fuse plug in the wheel core will melt.

1.16.4 Identification of Low Tyre Pressure

To assess the effectiveness of a visual inspection to detect an under-inflated tyre, several people in the aviation industry were canvassed on the issue. Most felt that when there is a low tyre on a paired axle, the low tyre could be readily spotted because the low tyre would bulge when under-inflated. Conversations with Technair maintenance leaders, technicians, mechanics, industry consultants, and flight engineers showed this belief was prevalent in the aviation community.

This opinion was not shared by the Goodyear Tire or Thompson Aircraft Tire representatives. They said that the paired, correctly inflated tyres would flex and, in supporting the under-inflated tyre, they would bulge evenly with the under-inflated tyre.

Investigators, with the co-operation of Technair, conducted a tyre deflation exercise. The #2 tyre of a DC-8 was deflated in increments of 10 psi, first from 179 to 120 psi and then in 20 psi increments down to 40 psi; the #1 tyre remained at 181-184 psi. A photographic record was made and a review of the photographs shows no discernible differences between the paired, or other tyres on the bogie, at the 150/160 psi range - which is in the 15% range when under-inflation gets critical. Even at the lowest pressure of 40 psi, except for a slightly longer tread print on the ground and a somewhat increased squareness between the tyre wall and the tread at the upper portion of the deflated tyre, there was no clear visual evidence of the under-inflation.



1.16.5 Wear Characteristics of Aviation Tyres

Aircraft tyres are designed to sustain several retreads. Retreaded tyres have a better wear resistance than new ones and can endure about 10% more landings. During initial use, the carcass of a new tyre stretches, resulting in some stress on its tread. However, by the time a tyre is retreaded, the carcass has stopped expanding and the new tread is subjected to less tension and thereby offers more resistance to abrasion.

The tyres used on DC-8s have a tread portion that contains three fabric re-enforcing layers. These layers protect the tyre carcass to some extent against foreign object damage. A tyre tread, however, does not contribute to the carcass integrity; even when a tyre is worn to the third fabric layer, the normal change point, it does not lose any structural integrity. The mandatory change point for a tyre is when it is worn to the carcass layer; however, at this point, the tyre could not undergo a retread.

A worn tyre is subject to less centrifugal force because of the reduced weight of the tread This reduces the inner tension within the tyre and associated heat build-up. Being thinner, a worn tyre offers slightly better heat dissipation.

1.16.6 Tyre Failure

1.16.6.1 Tyre Rolling Limitations.

Specifications for aviation tyres call for the capability of bearing weights exceeding 40,000 pounds, while at the same time being as small and as light as possible. The tyres are designed to flex by up to and beyond 35% when loaded. When a loaded tyre rotates, the sections of the tyre walls flex continually - maximum distortion occurring at the portion of the tyre that is in contact with the ground. Additional flexing occurs when, immediately past the footprint, the tyre tread extends, stretches beyond its normal radius, and then returns to its normal position again. This latter flexing cycle is referred to as a traction wave. It can take several cycles before the wave dampens completely. Under-inflation will worsen the traction wave phenomenon.

Flexing causes a significant heat rise within the tyre walls; the heat will continue to rise to the point where tyre failure occurs. This characteristic is recognised by imposing a ground-roll limitation (typically 35,000 feet at taxi speed) when the tyre is certificated.

Studies published by the tyre manufacturer showed that because of carcass fatigue resulting from under-inflation or overload, the endurance of a tyre under-inflated or overloaded by 10%, was 90% below the endurance of a properly inflated tyre.

Other tests by the manufacturer using a dynamometer on tyres at taxiing speed, showed that when a normally inflated tyre was paired with one deflated by 38%, the correctly inflated tyre picked up 63% of the load and failed after continuous roll of 29,773 feet (9,075 metres). There was a slight variation from one test to another but, in all cases, under-inflation resulted in the early failure of the overloaded tyre.

The manufacturer also assessed that there would be long-term, adverse effects on a tyre's durability each time that the tyre carcass experienced significant heat rise in the tyre walls as the result of under-inflation or overloading. A substantial heat rise within the tyre causes some loss of adhesion between plies and stretching of the nylon cords. Loss of adhesion will result in an incipient delamination of the plies which will cause additional friction when the tyre is flexed and in a more rapid onset of the heat rise. In addition, stretching of the nylon cords can subject them to knotting which decreases their strength. The manufacturer's overall assessment is that, following an exposure to overheating in the sidewalls, a tyre during subsequent operations would be more susceptible to heat build-up; after each heat-rise event, the tyre's overall strength would be reduced. These combined adverse conditions could limit the life of an overloaded or under-inflated tyre to just a few take-offs and landings.

At many international airports, tyre ground roll from the terminal to the take-off point is often within the figure of 4,500 metres, 15,000 feet. In high ambient temperatures, tyre roll distance combined with the inevitable internal tyre temperature rise, could be critical.

1.16.6.2 Tyre Failure Characteristics

When a tyre carcass fails, the forces which cause the tyre failure leave unique failure characteristics which can be recognised:

1.16.6.2.1 Fracture Surface

If a tyre hits an object and ruptures, the nylon cords of the ruptured edges of the tyre will have a smooth paint-brush texture. Whereas, when a tyre overheats to the point where the nylon cords within the carcass plies lose their strength and rupture, the fracture edges of the tyre have a rough, steel-brush-like texture. This fracture characteristic is caused by the melting and re-hardening of the nylon chords at the fracture point.

1.16.6.2.2 Fracture Location

When a tyre ruptures as the result of hitting an object, one failure characteristic is that the tyre side wall will stay attached to the tyre bead.

When a tyre is completely deflated, the accentuated bending between the tyre wall and the tread portion will cause a heat rise and ultimately rupture at a point separating the side wall from the tread. Because a flat tyre carries very little load, the heat rise will be slow, and it will take several take-off and landings cycles for this type of failure to fully develop.

When a tyre is overloaded, as is the case when a paired tyre is under-inflated, the heat rise and failure will occur just above the tyre bead. A major factor that affects the critical heat rise is that all the plies are wrapped around the bead and joined to other plies in this area. Effectively, all the load carried by the tyre, which is transmitted through the plies, is concentrated at this ply junction and accentuates the heat build up in this area. Because this area is the thickest part of the tyre wall, it offers the slowest heat dissipation.

1.17 Other Information

1.17.1 Nationair and Technair Organisation

Under Canadian Regulations, an air carrier has the choice to set up its own maintenance organisation or to contract it to another approved company. Nationair decided to have its maintenance done under a separate entity and Technair was formed. The President of Nationair is also the President of Technair. Nationair, as required by Canadian Regulations, appointed a Director of Maintenance separate from its Technair organisation. However, in practice, the General Manager of Technair functions as the Director of Maintenance for Nationair.

Technair is certified under Canadian Regulations as an independent Approved Maintenance Organisation.

1.17.2 Nationair and Technair Maintenance - General

The Technair Approved Maintenance Organisation Certificate of Approval is valid for a large spectrum of maintenance work applicable to the aircraft types that it maintains. Technair is authorised to maintain DC-8, B747 and B757 but the scope of permitted maintenance varies according to the type. Technair is required to produce a Maintenance Control Manual which details how the company will do its work to fulfil the requirements of its certification. Both Nationair and Technair Maintenance Control Manuals were carried on board the aircraft.

Tasking and control of work carried out in Technair are accomplished using a standard work-order system. Certification of completed maintenance work is normally done by the

Production Department inspectors but, depending on the scope of the work, certifications may be done by Quality Assurance Department inspectors.

Technair operates a 24 hour Maintenance Control Centre to support operations. The Technair Maintenance Control Center co-ordinates maintenance requirements of deployed aircraft and channels technical problems to appropriate departments.

1.17.3 Personnel Recruiting

Nationair and Technair use a common department for recruitment. In addition to intellectual and aptitude testing, managers interview candidates to assess technical ability and suitability.

1.17.3.1 Technicians, Mechanics and Specialists

Technair recruits aircraft maintenance engineers, mechanics and specialists with aviation maintenance experience or who are graduates from technical aviation colleges.

1.17.3.2 Flight Engineers

Nationair recruits flight engineers who have previous experience, are licensed aircraft maintenance engineers, and who are type-rated. However, the company has trained Technair licensed technicians. Many flight engineers, including the one on board the accident flight, were formerly Canadian Forces flight engineers. These would have had several years of aircraft maintenance experience as a prerequisite for selection and training as military flight engineers.

1.17.4 Training

Nationair and Technair provide new employees with courses to familiarise them with the company procedures. Although credentials of personnel hired are not normally challenged, ability to meet the company criteria is verified during a probation period. An evaluation is then made to decide if the individual is to be retained. Thereafter individuals are subject to an annual evaluation.

1.17.4.1 Nationair Training

1.17.4.1.1 Operations in High Ambient Temperature

Policies and procedures for coping with the possibility of hot tyres and brakes due to the high ambient temperatures, long taxi distances and high taxi speeds were not provided. There were no specific procedures provided by the Company to minimise the heat build-up in tyre/wheel/brake assemblies during prolonged hot-weather taxis. Interviews after the accident showed that captains use a range of techniques for mitigating the effects of high temperatures. These include taxiing with one or more thrust reversers extended and increased engine speed for improved air conditioning; leaving the gear down after take-off to dissipate heat build-up.

1.17.4.1.2 Rejected Take-Off

Nationair rejected take-off procedure is based on any of the flight crew identifying a problem and informing the captain. The captain then decides whether or not to continue the take-off. The procedure is practised as a normal part of simulator training. Crews are trained to reject for engine failure, engine fire, and total electrical failure. Training for rejected take-offs because of tyre/wheel failure is not done nor is it a Transport Canada requirement. Because crew co-ordination is extremely important, as the identification, communication and decision processes often must be accomplished in a few seconds, some other operators employ a system where any qualified flight crew member can call for a reject and the pilot flying the aircraft executes.

Interviews with Nationair Pilots, after the accident, reflected differences of opinion on the subject of rejecting take-off for other than mandatory items: some captains stated that if the aircraft was at a low speed (undefined, but assumed to be well below V_1) they would reject rather than take the problem into the air; some captains stated that, other than for mandatory reject items, they would continue the take-off.

1.17.4.1.3 Tyre and Wheel Failures

It is not possible to simulate such failures in the simulators used for DC-8 training. Interviews suggest that pilots' knowledge of tyre performance is limited; attitudes to tyre/wheel failure and the consequences showed marked differences. Comments regarding raising the gear after a suspected failure, both for and against, were apparently based on Douglas information and Nationair experience—the company has had tyre failures on take-off and landing in DC-8s.

1.17.4.1.4 Multiple Unrelated Failure

Nationair does not include training in multiple unrelated failures, nor is it a Transport Canada requirement.

1.17.4.1.5 Flight Simulators

From 1988, nearly all of the initial and recurrent training for Nationair crews was conducted at the Worldways Canada DC-8 simulator in Toronto, Ontario. This simulator is certified as a "visual simulator" and cannot accurately reproduce the aircraft's handling characteristics below ground effect altitude. It is not certified for taxi, take-off or landing.

1.17.4.1.6 Crew Resource Management

Crew resource management (CRM) is the effective use of all available resources to achieve a safe and efficient flight. Specific issues such as leadership, assertiveness, decision-making, work organisation, delegation and acceptance of responsibility, as well as crew interaction and communication all constitute the basic elements of CRM. The principles and their practice dispel the notion that proficiency on the aircraft alone is sufficient for effective flight deck management. Total CRM actively includes flight attendants with flight crew in crew co-ordination exercises.

One of the prime objectives of CRM training is to produce an atmosphere of sound leadership by the pilot-in-command. Good leadership not only clearly establishes who is in command, it also fosters participation by subordinates by encouraging captains to be receptive to their inputs. Hand-in-hand with that objective is the need to encourage assertiveness in subordinate crew when they are expressing their concerns. Implicit in these roles of effective leader and effective follower are good interpersonal communication skills. Intrinsic in the training is the recognition of personality types and their effects on interpersonal relationships and flight deck management. CRM training does not attempt to change personality, but stresses appropriate changes in attitudes and behaviour that would allow for more effective operations.

Crew resource management training has been re-evaluated since its inception. Concerns have been expressed about the "honeymoon phenomenon"; that is, the level of adherence to CRM techniques is inversely proportional to the amount of time since the last course or update. In 1989, the United States Federal Aviation Administration issued an advisory circular, AC No. 120-51, that addresses this phenomenon.

In February 1989, Transport Canada issued Policy Letter No. 19 in which the need for joint crew training was reinforced. The Policy Letter emphasised that training programs for flight crews and flight attendants, for the same operator, must include representation by flight operations and cabin crews in the presentation and discussion of co-ordinated emergency procedures, both in the air and on the ground.

Although not formally included as a syllabus subject, crew resource management practices and procedures were reinforced and evaluated as an integral part of simulator training, at Nationair, at the time of the accident. CRM training is not required by Transport Canada.

1.17.4.1.7 Flight Attendant Training

Nationair training of flight crew and flight attendants, including emergencies training, is carried out separately. The requirement for and content of flight attendant training is contained in "Air Navigation Order Series VII, N^{O}. 2, Standards and Procedures for Air Carriers using Larger Aeroplanes." The Air Transportation Association of Canada Cabin Attendant Training Syllabus specifies some minimum requirements on what cabin crews must know about flight crew roles and responsibilities. These requirements include knowledge of the authority of the captain, chain of command, means of communication with the flight deck, procedures in the event of pilot incapacitation, security measures in the event of bomb threat or hijacking, as well as crew duties during emergency evacuation.

Flight attendants are expected to know safety procedures associated with propellers, jet intakes, aircraft surface contamination; rejected take-off, missed approach, decompression, runaway propeller, electrical and cabin fire, engine fire and torching. However this requirement comprises only their own actions in these circumstances. Training which has particular relevance to this accident is amplified as follows:

1.17.4.1.7.1 Taxiing, Take-Off, and Initial Climb Incidents

Flight attendants are trained that should they discover an anomaly or if an incident occurs during taxiing, they should notify the in-flight director, who will inform the flight crew. The Flight Attendant Manual (issued April 1987, last revision date 01 Jan 91) includes, in various sections:

- "In all cases, the In Charge [sic] will serve as liaison between the Captain and the Flight Attendants."
- "if an incident occurs during taxiing, liaison with the flight deck ....."
- "Avoid using the interphone during taxi, actual take-off roll/climb or during final approach unless the call is of most importance."

It does not instruct the flight attendants how to handle emergencies during the take-off roll. The reasonable interpretation is that flight attendants should remain seated and wait until after take-off, before advising the flight crew. This same "lack of action" is expected of the flight attendants during initial climb-out until the "seatbelt" or "no smoking" lights are extinguished, when the captain should be informed "... as soon as practicable."

1.17.4.1.7.2 Fire-Fighting Procedures

Flight attendants are trained to fight fires. The actions prescribed by the Flight Attendant Manual, for any type of fire, are to "Locate source of fire; call for assistance; advise captain immediately; bring additional extinguishers." It then details the methods to fight individual types, electrical, garbage etc..

The Flight Attendant Manual has no standard phraseology for reporting the degree of severity, location, or type of fire. The B-747 section of the manual contains **smoke removal procedures** (not relevant to the DC-8) which, among other things, require flight attendants to notify the captain of the zone or section of the cabin where the smoke source is located, the extent of the smoke condition, and whether or not it is at a tolerable level. This requirement is not reflected elsewhere in the Flight Attendant Manual.

1.17.4.2 Technair Training

1.17.4.2.1 Technicians, Mechanics and Specialists

Technair provides technical training for its technicians, mechanics, and specialists on the aircraft types that they will maintain. Non-licensed company mechanics are encouraged to obtain aircraft maintenance engineer licences and some company tutoring is available.

1.17.4.2.2 Flight Engineers

When hired, those flight engineers who are not already type-rated are given a maintenance course on the aircraft on which they will fly. Once trained and on active flying duty, there is no requirement for technical recurrent training or further hands-on maintenance at the main base. When abroad, flight engineers are required to co-ordinate aircraft repairs and to certify the aircraft as airworthy.

1.17.5 Authorisation to Certify Aircraft

The holding of a Canadian aircraft maintenance engineer licence with a type rating does not automatically entitle Technair employees to exercise the privilege of aircraft certification within the company. The company limits the number of holders of this privilege for two reasons: having signing authority entitles an individual to extra pay; limiting the number of persons facilitates the maintenance of standards. Type-rated flight engineers are granted Technair signing privileges.

1.17.6 Certification of Work Carried Out

At a Technair maintenance base, work carried out on the aircraft is certified by those Technair aircraft maintenance engineers designated in the Technair Maintenance Control Manual; away from a Technair base when a Technair aircraft maintenance engineer is not available, the flight engineer has the responsibility.

The aircraft maintenance engineer licence qualification recognises that the person has the knowledge and judgement to assess that a job has been correctly done. It is not a requirement for Nationair flight engineers, as aircraft maintenance engineers, to carry out the maintenance work. However, it is the flight engineer's responsibility, as a licensed aircraft maintenance engineer, to fully acquaint himself with the particulars of the work carried out. He has full latitude in deciding what portion of the repairs that he has to monitor in order to meet the certification specifications.

Flight engineers have access to the manuals on board the aircraft and, if required, to the resources of the Technair Maintenance Control Center. To enable Technair to monitor all maintenance activities, the flight engineer is required to advise Technair Maintenance Control Center of all maintenance issues.

1.17.7 Wheel and Tyre Maintenance

According to Technair's and the manufacturer's procedures, aircraft tyre pressures must be checked with a tyre pressure gauge. Technair provides guidance on tyre pressure checking to its mechanics in the form of check lists. The Nationair Maintenance Control Manual specifies that tyre pressures should not be taken until two hours after the aircraft's arrival, and if not done at that time, an annotation must be made to ensure that the tyre pressure is taken prior to departure. This two-hour requirement is also emphasised on the checklist sheets. Neither Nationair's nor Technair's Maintenance Control Manuals contain procedures to follow when a tyre is found low or when to fill out the checklist forms.

There was some reported inconsistency as to how the tyre pressure is recorded on the A-Check form. All interviewees agreed that acceptable tyre pressures are recorded on the line for the specific tyre and the checker's signature is put in the "Mechanics" block; however, for tyre pressures below the acceptable range, some mechanics indicated that the abnormal tyre pressure would be first recorded then, after the tyre is inflated, the tyre pressure would be changed to reflect the new value—at which time the signature block would be initialed. A second method used is that the abnormal pressure would **not** be recorded, and nothing would be entered until the tyre pressure was adjusted to the acceptable range.

1.17.8 Nationair Deployment

1.17.8.1 Contract

Nationair contracted the aircraft to an organisation in Saudi Arabia (Al Rajhi International Trading Company). The contract was to transport pilgrims from Jeddah to their homes in Guinea and Nigeria after they had completed the purpose of their visit. The contractual arrangements between the major parties concerned is summarised below:

- The Nigerian Pilgrim Board contracted a Nigerian corporation, "Hold Trade," to convey pilgrims for the 1991 Haj pilgrimage.
- Hold Trade had a contract with Al Rahji whereby Al Rahji would provide aircraft. One of the terms was "That flights will be operated under the auspices of Nigerian Airways."

- Hold Trade had a contract with Nigerian Airways whereby Nigerian Airways provided ground support and over-flight support.
- Nigerian Airways has a contract with Areen Travel whereby Areen Travel is the Ground Servicing Agent for Nigerian Airways' ground handling at Jeddah. An annex to the agreement, valid for the 1991 Haj, detailed additional duties which Areen would perform during that pilgrimage season.
- Al Rahji chartered the aircraft from Nolisair International Inc., the parent company of Nationair, through a brokerage company "AGOS." The contract between Al Rahji and Nolisair was not exclusively for operations to Nigeria.

1.17.8.2 Ground Support

The provision of ground support in Jeddah was through a handling agent. During three passenger flights to Conakry and two to Accra, the flights were operating as Ghana Airways and were being supported on the ground by the normal Ghana Airways handling agent, Attar Travel. As the flight to Sokoto was to be for Nigerian Airways the handling agent changed to Areen Travel.

The handling agents fill the role of passenger agent and dispatcher. They provide passenger and cargo loading services, load sheets, weather information, NOTAM information, passenger and load manifests, overflight permission, general declarations and any other pre-flight documentation.

A broker involved with arranging the leasing of the aircraft provided further ground support in the form of a "co-ordinator." This man was multilingual, operated on the King Abdulaziz International Airport normally, and knew what was required to assist the operation that would be outside the handling agent's area of responsibility. The co-ordinator would be present for all aircraft movements to assist the crew through immigration by handling their passports and communicating with the handling agent representatives who were mainly Arabic speaking.

1.17.8.3 Management and Supervision

There was no written reporting structure with assigned responsibility.

There were three persons in the Jeddah operation who had management or supervisory functions; the project manager, the operations officer and the lead mechanic. These people were from different areas of responsibility in the Nationair and Technair organisations.

The project manager was assigned from Nationair's planning department. He flew with the crews, alternating with the operations officer, and was considered by the Nationair personnel to be in a supervisory position. He influenced decisions that affected maintenance and operational matters. If there was consultation in respect to these decisions it was not obvious from the evidence. His reporting line was direct to Nationair planning department.

The operations officer was an experienced captain who was assigned to assist with operation decisions, as well as to act as a spare pilot, although this was never required. His reporting line was to the Nationair operations department.

The lead mechanic for the Jeddah operation was responsible for the aircraft maintenance and for the work of two other unlicensed maintenance personnel. He was responsible for the co-ordination of maintenance activities and reporting to the Technair Maintenance Control Center.

1.17.8.4 Flight Schedule

The aircraft, operating as Ghana Airways Flight 395, departed the Nationair base, Montreal Canada on 2 July with three complete flight and cabin crews. There was an additional flight engineer and an additional senior captain who was providing operational support. Also on board were three mechanics and the project manager, for a total number of persons on board of forty-two.

The aircraft completed a nine hour flight to Athens, where a technical stop was made for refuelling. A Transit Check was completed and the aircraft departed for Jeddah in less than one hour. The aircraft arrived in Jeddah at about 0840 hours on 3 July.

The first flight carrying passengers, operating as Ghana Airways Flight 395, departed Jeddah at 0450 hours on 4 July. The destination was Conakry, Guinea. As fuel on board was limited by the weight of passengers and baggage, it was necessary to stop for fuel at Kano, Nigeria, a flight time of about 4:30 hours. The aircraft departed Kano after about 1:40 hours and landed in Conakry about 3:15 hours later. After refuelling the aircraft was flown non-stop back to Jeddah, arriving at about 0122 hours the following day. Two more flights were completed to Conakry, Guinea with technical stops in Kano and rotation of flight crews.

When the Conakry flights were completed on 6 July, the aircraft was flown to Accra, arriving at about 1945 hours, to preposition a flight crew for the forthcoming Accra flights. On 6 July the aircraft departed Accra for Jeddah but had to return because of malfunctioning radar, landing, back at Accra, at 0005 hours on 7 July. 34 hours later, after the radar was repaired, the aircraft departed Accra at 0940 hours on 8 July, arriving at Jeddah at 1615 hours.

At 1930 hours on 8 July, the first flight with passengers for Accra departed Jeddah. As with the Conakry flights these flights to Accra were routed through Kano for a refuelling stop. The second (and last) flight to Accra arrived in Accra at about 0450 hours on 10 July. As the return flight to Jeddah on 10 July was to be the last flight out of Accra and it was to be a four hour stop, it was intended to change main wheel tyres. This was not done. The spare tyres were loaded into the cargo compartment and the aircraft departed early at about 0730 hours to arrive at Jeddah at about 1400 hours on 10 July.

1.17.9 Technair Deployment

1.17.9.1 Deployment Planning

Technair responds to Nationair contracts according to the requirement of the operation. Planning considerations include contract duration, hours/cycles to be flown, types of aircraft inspections required, availability of contract maintenance services, consequences of repair delays and the area of operations for the contract. For short-duration operations a maintenance lead mechanic is appointed. He liaises with the Production Manager to determine maintenance requirements and to select appropriately qualified mechanics and specialists to make up the rest of the maintenance team. This team then prepares the Fly-Away-Kit to meet the anticipated needs of the operation.

Because Canadian regulations require that aircraft maintenance be under the supervision and responsibility of a licensed aircraft maintenance engineer, all maintenance releases for the deployment aircraft had to be signed by one of the flight engineers, all of whom were licensed aircraft maintenance engineers. However, because of the flight duties the effect was that flight engineer's did not participate in aircraft maintenance activities except for signing documents to fulfil the legal requirement. The lead mechanic, the other two mechanics and the extra flight engineer were divided into pairs that would usually accompany the aircraft crews for maintenance purposes.

Technair managers were given four days notice of the operation which they considered to be sufficient.

1.17.9.2 Other Technical Preparation

To enhance its ability to service and repair the deployed aircraft, Technair established an arrangement with a Jeddah based Saudia employee who is a principal of an independent company: "Avions International." This individual, whose company supports Nationair under contract in other areas of the world, was expected to provide technical assistance to the deployed maintenance team if and when required.

General information was passed to the maintenance team and Technair was confident that the lead mechanic's previous African experience and his knowledge of the climatic, cultural, and other conditions specific to this operation would be adequate to meet any anticipated contingency.

The lead mechanic decided to split the maintenance team into two crews to provide better maintenance coverage. The lead mechanic and the airframe & power plant mechanic would normally work together, while the electronic specialist teamed up with the fourth flight engineer. The crews would fly with the deployed aircraft on alternate flights from Jeddah, so as to provide the necessary maintenance capability at the other stop-over points during the operation.

1.17.9.3 Maintenance at Jeddah

Upon arrival at Jeddah, the lead mechanic met the maintenance support person from "Avions International" who showed him the airport facilities and explained the procedures governing aircraft maintenance and security. The lead mechanic informed him that Nationair would do most of its maintenance at the African airports (the lead mechanic had made many phone calls to these airports to make maintenance arrangements).

The lead mechanic believed that access to the Jeddah ramp area was difficult, unless you were part of the crew departing on a flight. This opinion about ramp accessibility was contradicted by one of the maintenance team, who stated that he had been informed by "Avions" that the airport was in fact accessible with some pre-planning. In the case of major maintenance, the aircraft could be moved over to a maintenance area away from the terminal building.

1.17.9.4 Maintenance Control During the Deployment

To fulfil the Airworthiness Manual requirement for the company to maintain complete and current maintenance records for its aircraft, the company's Maintenance Control Manual stipulated that Technair Maintenance Control Center was to be kept informed of the deployed aircraft status and hours flown, and that the maintenance records for aircraft were to be sent back to Technair Maintenance Control Center on a daily basis by mail or facsimile. Routine data which should have been submitted daily were to include the two pages of the aircraft journey log, the Pre-Flight-Check and Transit-Check sheets, fuel slips, and any other documentation on contracted maintenance done. In addition, the lead mechanic was requested to keep his manager informed about the maintenance issues associated with the deployment.

According to Technair managers, the lead mechanic did keep in touch on a regular basis by phone, not only with his immediate superior, but also with the General Manager; his reports consistently indicated that all was going well and that there were no problems encountered. The only maintenance irregularity reported to the Mirabel base was the weather radar snag, which required Technair support to secure a replacement part.

Not all of the required records covering the deployment could be found during the investigation. Photocopies of some documentation that was sent by facsimile to Technair Maintenance Control Center were found.

- Although journey log sheets were found for each day of the deployment, including the accident flight, not all the pages of the journey logs could be found at Technair. Apparently, none of the Pre-Flight Checks, Transit-Checks, or fuel sheets was sent to the Technair Maintenance Control Center by the lead mechanic;
- The Transit-Check and Pre-Flight-Check sheets that were found did not record the aircraft and flight specifics called for in the header of the sheets; the applicable portion of the journey log sheets did not consistently report whether the Pre-Flight and Transit checks were done;
- Evidence indicates that the Transit-Check and Pre-Flight check sheets were not normally filled out at the time the check was completed and before the next flight; instead, they were normally completed at the end of a flight cycle by the maintenance team following consultations between the lead mechanic, the mechanic and the specialist.
- The flight engineers routinely accepted the aircraft for the next flight without confirming that the Pre-Flight or Transit checks had been completed; they assumed that the presence of maintenance personnel assured that checks were being properly completed.
- Not all the maintenance defects encountered and the resulting maintenance actions taken, during the deployment, were recorded on the aircraft journey logs.

1.17.10 Surveillance

Transport Canada does not approve or monitor charter agreements made by Canadian carriers unless they exceed 21 days; this agreement was for 20 days. If it is over 21 days the carrier must have approval through amendment to their operations certificate. To obtain the amendment they must provide documentation. In such an event Transport Canada would have the opportunity to perform surveillance and inspection. Transport Canada was not advised of the operation nor was it a requirement.

2 ANALYSIS

2.1 Management and Supervision

The aircraft was to operate under different conditions from the Canadian environment. However, Nationair operated charter flights throughout the world and should have had the experience and personnel to support a safe operation.

2.1.1 Selection of Deployment Personnel

The project manager for the Haj operation worked for Vice President Planning. During interview, Vice President Planning stated that he recognised that the individual did not have the experience necessary to deal with operational matters and that he and the Vice President Operations agreed to send an operations officer who would be better able to evaluate operational issues. The operations officer and the project manager accompanied the flights on a rotational basis to comply with the 72-hour visa requirements imposed on them and to guarantee that one or the other accompanied all flights. The project manager's role was to ensure that contractual responsibilities concerning payload, fuel payment, timeliness of the operation from a support role, etc. were being met. He reported directly to Head Office, Mirabel.

The operations officer was a representative of the Nationair Director of Flight Operations and was to act as facilitator. He had experience in charter operations and was appointed to assist the project manager with operational issues and to co-ordinate and monitor the crew and flight scheduling during the deployment; he was not given any additional authority, including supervisory responsibilities, for the deployment. He was also to serve as a fourth captain in the event one of the other three was unable to fly.

The lead mechanic was chosen to head the deployment maintenance team because of his previous work experience and contacts in the African countries in which the aircraft would be operating, and because of his previous experience on the DC-8-61 aircraft. When informed that he would be team leader of the maintenance crew for the operation, he assured the general manager that this operation would be the smoothest one Technair would ever encounter. For the deployment, he was given latitude in choosing the number of maintenance personnel, their expertise, and the individuals that he felt would best meet the needs of the operation.

2.1.2 Deployment

The lack of written terms of reference precludes a detailed analysis of the supervisory structure of the deployment. However, it is clear that supervision at deployment level was fragmented; it was split between a contract element, an operations element and a maintenance element with, apparently, no deployment head other than the project manager. The fact that an improperly maintained, un-airworthy aircraft having at least two main wheel tyres with pressures less than the minimum required was dispatched, testifies to the inadequacy of the level of supervision exercised at deployment level.

2.1.2.1 Project Management

The project management appears to have been successful up to the time of the accident in that the aircraft, when serviceable, performed contract flights. However, evidence suggests that aircraft availability for contract flights over-rode the interests of proper servicing and safety. The project manager, a totally unqualified person in terms of aircraft safety, was allowed to make decisions on operational and technical matters.

2.1.2.2 Operations

Operational supervision involved the schedules of crews and the completion of the various formalities involved with an operation of this nature. As the constitution of the crews was predetermined, there would be little call for crew planning other than geographical disposition and legality.

2.1.2.3 Maintenance

Maintenance supervision at deployment level was fragmented. It was split between the lead mechanic for practical activities and the flight engineers for aircraft certification. The role of the flight engineers in the Jeddah operation was twofold: they were members of the flight crew with all the attendant duties and they were aircraft maintenance engineers, responsible for signing aircraft maintenance releases; however, they were not involved in maintenance work or maintenance decisions. The extra flight engineer assigned to the operation teamed up with one of the mechanics, but his role was similar to the other flight engineers. As members of the flight crew, the flight engineers travelled and operated with the pilots for duty day purposes and therefore did not participate in maintenance procedures.

The evidence indicates that the maintenance release of the aircraft, prior to flight, was improper on several occasions. It is clear that the aircraft operated a series of flights in an un-airworthy condition; it is probable that at least some flight engineers knew this. Maintenance supervision was inadequate.

2.2 Maintenance of the Aircraft

In general terms, the maintenance personnel worked to enable the aircraft to meet contract requirements. There is evidence of "carrying" maintenance defects to more convenient locations for repair. Some maintenance work was performed prior to actual requirement, again for convenience. Except for the neglect of the tyres and ineffective action indicated by repeated defects, the aircraft was maintained in a reasonable condition. The conduct of the A-Check, on a progressive basis—not authorised by the regulator, together with the response to the discovery of tyre pressures below limits, indicates that the lead mechanic was prepared to condone, if not encourage, deviations from required procedures and standards. His technical knowledge was insufficient to prevent the project manager from initiating the departure of the aircraft in an un-airworthy condition.

These practices, not only improper, hardly reflect credit on the selection of this individual to manage the maintenance of the aircraft on deployment.

2.2.1 Maintenance Recording

To satisfy the Airworthiness Manual requirement for the company to maintain complete and current maintenance records for its aircraft, the lead mechanic was to send, by mail or fax, daily records of the aircraft status, hours flown, journey logs, pre-flight and transit checks, fuel slips and other documentation of contracted maintenance.

Although the lead mechanic reported by telephone on a regular basis, a review of documentation at the Technair facility indicated that the lead mechanic failed to send all of the required documents.

Evidence shows that maintenance defects, transit checks and pre-flight inspections were not properly recorded.

2.2.2 Alteration of a Document

During part of the A-Check performed in Accra on 7 July, the avionics specialist found that two tyres were under-inflated. Forensic examination showed that he entered the pressure of tyres #2 and #4 as 160 and 155 psi respectively. He also annotated the margin presumably to check with the mechanic. Forensic examination showed that the mechanic subsequently changed these figures to 180 and 185 psi. There is no evidence to show that nitrogen was added to any tyre at any time during the deployment.

Neither the avionics specialist nor the mechanic have been able to remember significant numbers. The avionics specialist, during initial interview on 12 July 1991, acknowledged his initials on the A-Check form; on 8 April 1992, during an interview conducted in Canada, he confirmed that he had checked the tyre pressures with a gauge but could not remember the figures or the wheel stations. The mechanic was not in Accra when the low tyre pressure were recorded; he must have changed them later, probably when the aircraft returned to Jeddah. His recall, during a further interview on 8 April 1992, was inadequate in terms of when, why, how or if he altered the figures. His overall reaction was one of acknowledging the facts but being unable to rationalise the circumstances surrounding the alterations.

The motivation for altering the A-Check records instead of rectifying the tyre inflation problem has not been established. A reasonable presumption would be that the significance of low tyre pressures was just not known. Furthermore, with a planned tyre change in the near future, the tyres were probably considered to be in an adequate state to perform as normal. Another consideration may have been that, contrary to authorised practice, the progressive completion of the A-Check was intended to be signed immediately prior to its requirement and, by that time, the deficiencies would have been rectified. Since there was no signature in the journey log to indicate that the A-Check had been completed, the A-Check cannot be considered to have been completed.

2.2.3 Aircraft Maintenance Release

The mechanics were not authorised to certify the aircraft as fit for flight. There is enough evidence to suggest that at least some of the flight engineers, who had this responsibility, undertook this duty too lightly. The avionics specialist stated that he told a flight engineer of the low tyre pressures on 7 July, when he entered the tyre pressures on the A-Check form. From the time that low tyre pressures were first identified, the aircraft continued to be certified as being airworthy when in fact it was not.

2.2.4 Pre-Flight Inspection

On the morning of the accident, the still under-inflated tyre was not identified as needing attention until after all the passengers had boarded the aircraft. The crew had been at the aircraft for at least one hour prior to departure but action was not taken to correct this deficiency until minutes before the scheduled departure. The evidence indicates that the lead mechanic had previous knowledge of the low tyre pressures.

Considering his experience, the lead mechanic should have been aware of his responsibility in respect to aircraft airworthiness. His attempt to obtain nitrogen indicated his concern for the under-inflated tyre. Nevertheless, he boarded the aircraft apparently with the belief that the aircraft was safe for flight, when one or more of the tyres were under-inflated, because of lack of knowledge of the potential hazards and the fact that the aircraft had operated previous flights in the same condition.

2.2.5 Acceptance of the Aircraft

It cannot be confirmed whether or not captains were aware of the low tyre pressures. As there were a number of deferred items in the aircraft technical log, it is presumed that captains would review the technical log prior to aircraft acceptance; it is also reasonable to presume that captains would briefly discuss the state of the aircraft with the flight engineers. As the captain has the final word on whether or not to accept the aircraft, it would be reasonable to assume that he would be given all the facts, including deficiencies carried by word of mouth. It seems unlikely that subordinates would bear the onus of responsibility when they could simply tell the captains and let them decide. However, on the morning of the final departure, the evidence indicates that the decision to depart was taken at a very late stage and time for any possible discussion with the captain was very short; the aircraft departed the gate very soon after the project manager, when he learned that obtaining the nitrogen requested by the lead mechanic would result in a delay, reportedly said: “Forget it.”

The Cockpit Voice Recorder had no record of anyone informing the captain, or any other flight crew members, that a tyre was under-inflated.

2.3 Low Tyre Pressures

Nationair standard practice was to inflate the main wheel tyres to 180 psi regardless of aircraft weight. This is reflected in the Nationair A-Check document. This practice is contrary to the procedure given in the McDonnell Douglas Aircraft Maintenance Manual which established inflation pressures based on aircraft weight.

The figure of 180 psi was presumably determined by a person who believed the figure to be adequate for all operations. As a result, there can be no doubt that, even after servicing to this pressure, aircraft have operated with under-inflated tyres.

2.3.1 First Indication of Low Tyre Pressure

According to witnesses, the first time that anyone became aware of low pressures in tyres was during the ground time at Accra on 7 July. This was as a result of the avionics specialist performing parts of the next A-check which would become due in the near future.

It is not known if this A-Check was ever signed as being completed. What is known is that the avionics specialist recorded low pressures for #2 and #4 tyres. During interviews, both the avionics specialist and the mechanic acknowledged signatures, in different coloured inks, on the part of the A-Check form recording tyre pressures. As neither of them could recall the actual pressures first recorded, it was necessary to resort to forensic examination to determine:

- #2 tyre was initially recorded as 160 psi, and
- #4 tyre was, beyond reasonable doubt, initially recorded as 155 psi.

2.3.2 Notification of Low Tyre Pressures

The avionics specialist stated that he informed the additional flight engineer of the discrepancy. It is considered extremely unlikely that the avionics specialist would measure and record tyre pressures below limits and then neglect to inform the person who would sign the aircraft technical log. Similarly, the lead mechanic was informed. Subsequently, the figures were changed, by the mechanic, to:

- #2 tyre: 180 psi, and
- #4 tyre: either 165 or 185 psi. As it is improbable that the mechanic would record another figure below limits, the reasonable assumption is that he wrote 185 psi.

It could not be determined whether or not the information about the low tyre pressures was communicated to all flight crew members of the deployment. However, it is considered most unlikely that this information would not be relayed to at least some of the other cockpit crews; this was a small detachment and crews tend to talk to each other - particularly when what are considered to be minor technical discrepancies may well be carried verbally rather than recorded in the aircraft technical log. If the significance of low tyre pressure was not well understood, flight crews could be relying on the advice and opinion of technical personnel and accepting the aircraft with what was thought to be a minor discrepancy. There is certainly irrefutable evidence that maintenance activities were not always recorded. It is a reasonable presumption that the project manager was also informed; he was certainly aware of a later planned (but aborted) tyre change.

Both the avionics specialist and the mechanic stated that the lead mechanic knew of the low tyre pressures prior to the departure of the last flight.

2.3.3 Response

The response to the reported low pressures was, apparently, on the morning before the final departure, when the lead mechanic tried to obtain nitrogen to re-inflate the tyres. Between the departure from Accra on 8 July to the arrival at Jeddah on 10 July, the maximum ground time between the series of flights was more than 6 hours on 9 July, at

Jeddah. The lead mechanic may have previously thought that the plan to change tyres, which included #2 and #4, at Accra on 9 July would avoid the need to "top-up" the low tyres; the cancellation of this plan resulted in the prospective departure of a fully laden aircraft with low tyre pressures. However, leaving the re-inflation to the last few minutes of an 18 hour stopover seems to lack planning.

It may be that the decision to re-inflate was only taken when he *saw* that the tyre was under-inflated. (The ramp co-ordinator, in evidence given on 8 December 1991, identified a visibly low tyre as #6; no other evidence was found to support this identification. Evidence indicates that #6 tyre was intact until after take-off, even though it had been heavily loaded during the take-off roll.) Empirical tests have shown that it is not possible to visually identify a partially deflated tyre, when one of a pair, until the pressure in that tyre is less than 40 psi. However, if any tyre *was* visibly "low," the pressure must have been significantly less than the correct figure.

The lead mechanic's eventual acceptance of an aircraft unserviceability may have been influenced by the project manager but it certainly indicated a lack of professional standards with respect to maintenance and airworthiness.

2.3.4 Awareness of Tyre Performance

Research by tyre manufacturers has shown the critical relationship between maintenance and performance. Despite the many publications and advisory notices from tyre and aircraft manufacturers, there appears to be a very poor grasp of tyre performance characteristics within the industry generally and this company specifically.

2.4 Tyre Failure

Tyre design deflection profile under load is about a one-third reduction in tyre section radius. If the tyre is overloaded, over-deflection will occur. Over-deflection results in a larger heat increase than would be expected from under-inflation. If one of a pair of tyres on the same axle is under-inflated, the other tyre may be overloaded.

There is evidence of under-inflation of one or more tyres from witness statements, the uncompleted A-Check and the unsuccessful attempt to obtain nitrogen. It is likely that there were multiple low (pressured) tyres on the day of the accident.

As #2 tyre was under-inflated, the resulting transfer of load to #1 tyre caused over-deflection. The over-deflection resulted in the failure of #1 tyre. The transfer of load to the under-inflated #2 tyre caused a very rapid failure.

The partially melted nylon cord in the remnants of #1 and #2 tyres, found on the runway, confirmed temperature generation of about 250°C (480°F).

As tyre heat damage is cumulative, any previous under-inflation and/or overloading could have caused tyre damage. However, in this case, examination of the tyre remains showed no evidence of long term operation while under-inflated.

Recorded (original) tyre pressures noted on the A-Check form confirm the use of a tyre pressure gauge at that time. However, no evidence could be found to confirm that the tyres had been checked with a pressure gauge after 7 July.

2.4.1 Runway Evidence

The first rubber marks on the runway at a measured distance of 158 metres from the start of the takeoff were made by the #1 tyre. These and the following rubber deposits indicate that the tyre failed. At 290 metres the runways marks indicated the #2 tyre began to leave a wide and abundant rubber deposit indicating a tyre failure. At about this same point the last rubber deposits from #1 were found. From the condition of the deposited rubber it appears that #2 wheel ceased rotating near this point. There was no evidence of a brake failure. It may be that part of the tyre caught in the bogie structure and jammed the wheel but the exact cause could not be determined.

The examination of the tyre fragments found on the runway show that the failures in both #1 and #2 tyres were similar. They both failed in a circumferential manner in the sidewall area. The fused ply cords and the rubber reversion along the rupture lines of both tyres is consistent with over-deflection and over-heating.

2.4.2 Plot Of Take-Off Features

Flight data records of heading, IAS, rudder and elevator position during the first 54 seconds, from brake release, tabulated at Appendix B, were used to provide a graphical presentation of take-off features.

The IAS record was used to calculate still-air distance travelled during the ground roll. The inaccuracy of the IAS record at low speed is recognised; in addition, figures have been rounded to the nearest whole number.

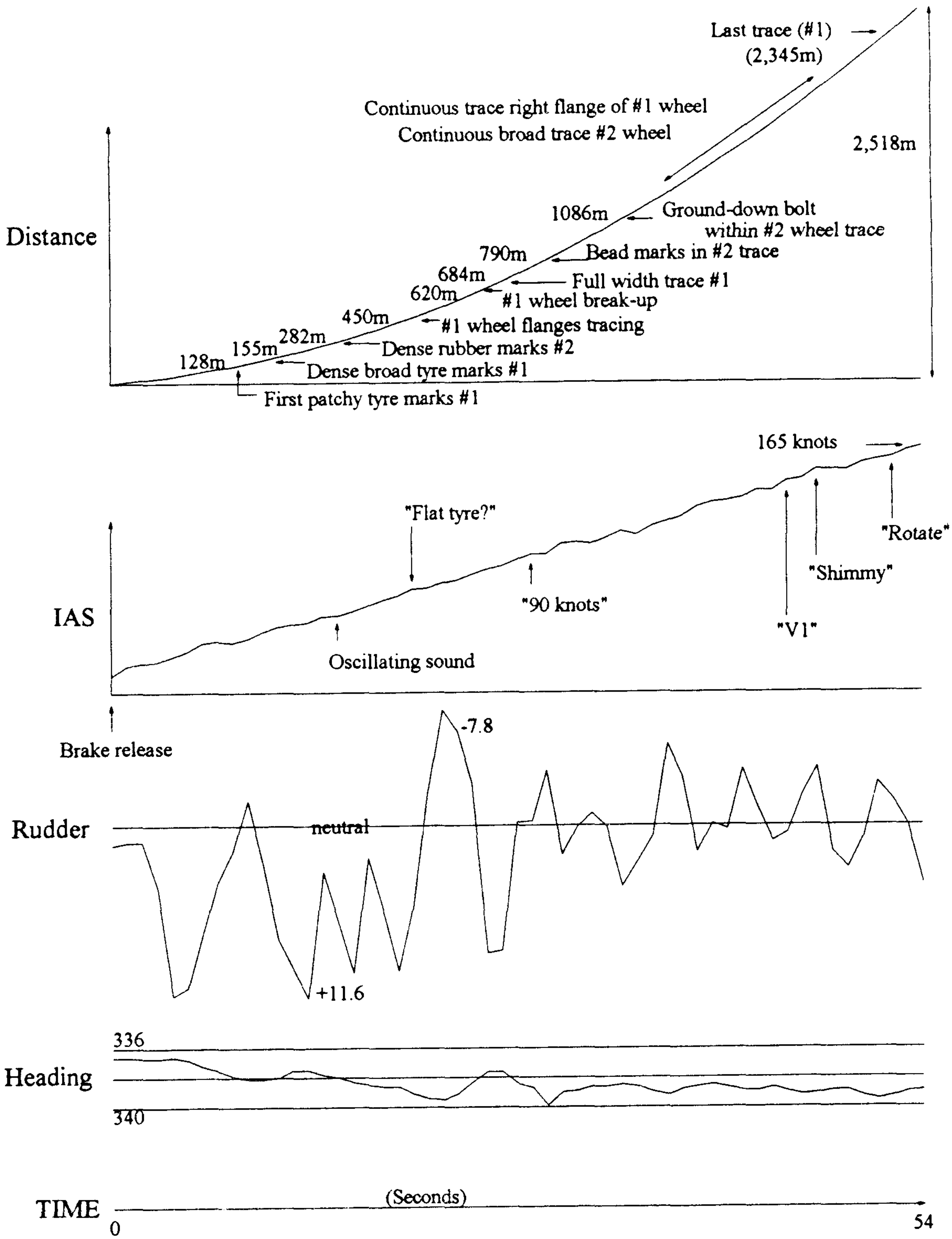
The heading, rudder and elevator records are included for reference.

Extracts from the cockpit voice recorder were added in the last column.

Plots were then made of the derived data, with the exception of the elevator.

- The distance plot includes annotations derived from the runway survey (See 1.12.1) with the measured distances from the runway threshold reduced by an arbitrary 30 metres.
- The IAS stagnation points, recorded in the table and plotted, may be significant; they may be data recording errors. The annotations on the IAS plot are abbreviated extracts from the CVR.
- The rudder plot shows control activity and may indicate the directional effect of the tyre and wheel failures.
- The heading plot is fairly consistent with the traces and marks noted during the survey of the runway.

The elevator position was not plotted because no anomalies were apparent.



Take-off Features.

2.4.3 Events after Take-Off

A witness who was located abeam the position at which the aircraft became airborne, reported a noise "as if a tyre had burst." Examination of tyres recovered from the crash site revealed that one of the unidentified but mounted tyres had burst while within the wheel well. What damage this caused could not be determined. Any release of nitrogen would tend to suppress fire but evidence also indicates that the temperature of self-sustaining burning rubber had already been exceeded. The presence within the wheel well of numerous hydraulic components and hydraulic lines provides an additional source of fuel in the event of damage from tyre or wheel debris.

2.5 Aircraft Structure

2.5.1 Wheel Wells Area

In the event of a fire within either of the left or right wheel wells, vulnerable items initially include the tyres and the hydraulic components. An intense fire increases the vulnerability because of the potential for providing pressurised hydraulic fluid to feed the fire. A burning pressurised mist of hydraulic fluid has the potential to "blow torch" through metal structure. Although the supply of hydraulic fluid is limited in quantity, if the rear face of the centre fuel tank is burned through, the release of aviation fuel will rapidly increase the intensity of fire. Magnesium alloy aileron pulley brackets in the wheel well, if ignited, would have significantly increased the temperature of the fire and increased the potential for involvement of the fuel stored in the centre wing tank.

Depending on the fire pattern and the degree of penetration into the fuel tank, the result could be either an explosion or severe structural damage. In the case of a contained fire within the wheel well, fed by fuel through a restricted orifice, the development of the fire would be up and aft. The development of a severe fire at the centre section of the fuselage would rapidly lead to a loss of structural integrity, preceded by inevitable control degradation due to the loss of hydraulic power and damage to control runs.

As the cabin floor is of a fairly light structure, penetration of the floor could be expected as an early development. Once the cabin floor was penetrated, the conditions of heat, smoke and fire within the cabin would preclude survival for occupants in the immediate location and aft of the breach.

2.5.2 Fire Development

Information derived from the CVR and the FDR may give a possible sequence of fire development:

- Four parameters of the FDR ceased to record at the same time. These were: rudder pedal position; control column position; control wheel position; vertical "G." All inputs share the same circuit breaker; the power lead to the accelerometer enters the left wheel well at the aft outboard upper corner, routes across to the inboard corner output and then down and forward to the accelerometer which is mounted on the keel beam at the mid point of the well. Mechanical or fire damage exposing the conductor would cause the circuit breaker to trip.

- The wiring for the left spoiler warning enters the left wheel well at the upper outboard forward corner and exits to the wing at the leg cut-out. Mechanical or Fire damage could cause the light to illuminate.
- The wiring for the gear unsafe light enters the wheel well at the same location as the spoiler. When the gear handle is selected up, a relay "powers" the circuit to the switch for ground. "Shorting" the wire would cause the light to illuminate.
- The emergency brake control in the cockpit is connected mechanically to operate the air valve. The air valve is located in the upper forward inboard corner of the left wheel well. Fire damage to a cable-drum assembly or pushrod could result in the cockpit control handle being free to drop.
- Wiring for the flap-slot light is in the right wheel well. Discontinuity causes the light to illuminate.
- The CVR wiring is in two conduits between the top of the wheel wells and the cabin floor.

The foregoing suggests that the first area to be affected was the inboard aft wall of the left wheel well which would be close to a burning aft left main wheel tyre. The fire then progressed across the front of the well, penetrated the web between wells and crossed into the right well. At the same time, it probably burned through the roof of the wells and attacked the cabin floor. As the fire progressed, hydraulic systems, electrical systems, control systems and structure were severely damaged; the burned seats and victims indicate the extent of the fire prior to the crash. The fuel for the propagation, initially burning rubber and then hydraulic fluid from one of the many components within the wheel wells, was probably augmented by fuel at some stage.[12]

2.5.3 Aerodynamic Forces on a Weakened Structure

Because the centre of gravity of transport aircraft is usually forward of the centre of pressure of the wings, aerodynamic forces on the airframe include a down-load on the *horizontal stabiliser. Once the fuselage has weakened significantly, aft of the wheel well,* provided the aircraft is in a relatively normal attitude, one would expect the fuselage to fold with the nose and tail sections both moving down relative to the centre section.

As one witness reported that the landing gear was retracted as the aircraft passed his location, some four nautical miles short of the impact, the possibility of the final event being the outcome of lowering the gear, at less than two miles short of the runway, was considered. If the gear was extended shortly before loss of control, the opening of the gear doors would increase the airflow in the area of the fire and cause a significant increase in the intensity of the fire. However, evidence of another witness in an aircraft, plus the finding of a body 11 miles from the airport, support the view that the landing gear was extended at 11 miles.

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[12] See 1.14.4, Fire Damage to Structure

2.6 Aircraft Performance

2.6.1 Weight and Balance

2.6.1.1 The Weight and Balance Form

Figures recorded on what is believed to be a copy of the final Weight & Balance are shown (in lbs) as follows:

Basic weight:	164,241
Forward Cargo Compartment 1:	3,750
Forward Cargo Compartment 2:	5,750 or 3,750
Aft Cargo Compartment 3:	5,750
Aft Cargo Compartment 4:	2,452
Total Passengers and weight:	47,500
Zero Fuel Weight:	229,443 or 227,443

The above figures produce zero fuel weights which exceed the Maximum Design Zero Fuel Weight of 224,400. Adding the flight fuel would result in the following:

Zero Fuel Weight:	229,443 or 227,443
Adding the Flight Fuel:	93,600
Take-Off Weight:	323,043 or 321,043

The Take-Off Weights shown above exceed the Maximum Operational Take-Off Weight (the sum of the Maximum Landing Weight plus the calculated weight of fuel used during the flight) of 313,493 lbs, entered on the Weight and Balance Form. This would be obvious to the first officer, who performed the calculations. There was an additional figure of 8,152 written between the "Forward Cargo" and "Aft Cargo" block designators. The Weight and Balance Form appears to have been used as a "scratch pad" by the first officer. His derived take-off weight of 313,493 appears to have been achieved by adding:

Basic Weight:	164,241
Cargo Compartments:	8,152
Passenger Weight:	47,500
Fuel Weight:	93,600
Take-Off Weight:	313,493

The captain signed the Weight and Balance Form.

2.6.1.2 Passenger Weights

The passenger weight figure is difficult to explain because it neither conforms to Canadian standards nor recognises the contract allowance of 88 lbs. (40 kg) of free baggage entitlement. It suggests a guess of the average body weight of 140 plus an assumed baggage weight 50 lbs. for 250 passengers. The passenger manifest lists the sex of all except 15 passengers. Those passengers are assumed to be males. Using figures of Males + Carry-on of 180 lbs; females + Carry-on of 135 lbs, the passenger weights *excluding* checked-in baggage add up to: 42,165.

2.6.1.3 Checked-in Baggage

The passenger manifest prepared by the handling agent included the weights of checked-in baggage. The average weight per passenger was very close to the free allowance of 88 lbs. Evidence shows that the crew recognised that the aircraft was weight limited and instructed the handling agent to restrict cargo weight to 4 tons. The loading restriction was applied by the handling agents using experience of the capacity of baggage carts and loading only a proportion of the checked-in baggage. This is assumed to have been 8,800 lbs.

2.6.1.4 Excess Carry-on Baggage

The crew and the handling agents were aware of the tendency of passengers to try to carry-on excess hand baggage. To prevent this, passengers were inspected at the aircraft and excess baggage was taken from the passengers and loaded in the cargo compartments. It is assumed that significant excess carry-on weighed 20 lbs per passenger. This is equivalent to the weight of one standard water container, filled with spring water, per passenger. This excess amounts to a total of approximately 5,000 lbs.

2.6.1.5 Another Estimate of the Take-Off Weight

This estimate is based on two reasonably accurate figure and three assumptions:

Basic Weight:	164,241
Fuel Weight:	93,600
Passengers + Carry-on:	42,165
Excess Carry-on	5,000
Checked-in Baggage:	8,800
Minus fuel burn for taxi:	1,000
Estimated Take-Off Weight:	312,806

The witness marks on the runway do not support the probability of an overloaded aircraft. The total length of the marks, when performance degradation caused by the failures of the tyres and wheels is considered, strongly suggest a "light" aircraft. (See 2.6.2)

2.6.1.6 Reasonable Conclusions

- Maximum Design Zero Fuel Weight was not exceeded.
- Maximum Operational Take-Off Weight was not exceeded.
- %MAC was between 27.5 & 27.9
- The aircraft was not overloaded and the centre of gravity was within limits.

2.6.2 Take-Off

Theoretical take-off performance was compared to the actual performance of the aircraft. Actual take-off took two seconds longer and 550 feet greater distance than theoretical. The length of the runway trace indicates that, allowing for performance degradation due to tyre and wheel damage, the aircraft was not over weight.

2.6.3 The Circuit

Despite the progressive and cumulative loss of systems, the aircraft was successfully flown around a circuit pattern to just short of runway 34C.

2.6.4 System Failures

The almost complete destruction of the aircraft made it impossible to identify and reconstruct systems. The evidence indicates that the hydraulic system ceased to function very soon after take-off because of fire damage and loss of hydraulic fluid. The manual control system appeared to function although the first officer's report of "... no ailerons ..." could be taken to indicate either very heavy manual forces or severe degradation of roll control. It may be that the captain, who apparently flew[13] the latter stages of the circuit, was using the secondary effects of rudder for roll control. Apart from damage to parts of the electrical system, there was no evidence to indicate failure of other aircraft systems.

2.6.5 Final Approach

As the aircraft began the final approach, there was enough structural damage to permit the first body and some cabin equipment to fall to ground. The scenario which best explains these circumstances is that during the downwind and base legs, the fire had consumed the cabin floor above the wheel wells, permitting cabin furnishing to sag into the wheel wells. When the gear was probably extended at 11 miles on the final approach, the first body fell out because fire had burned through the seat harness. Subsequently, with the gear down and a forceful air supply through the open gear doors, rapid destruction of more floor structure permitted the loss of more bodies and seat assemblies. Despite the considerable destruction to the airframe, the aircraft appeared to have been controllable until just before the crash.

2.6.6 The Crash

The crash was the result of loss of control probably as a result of the cumulative effects of the fire on the structure. It may have been the result of loss of aerodynamic controls with the aircraft out of trim but witness statements tend to support an in-flight break-up which occurred shortly before ground impact.

The evidence of witness statements, the impact marks and the distribution of wreckage indicate that the major portion of the aircraft struck the ground in a nose-low, right banked attitude. The rear fuselage and tail assembly separated at or near the trailing edge of the wing, either on or prior to initial impact, striking the ground independently, tail first. The major portions of the tail assembly remained close to their initial impact point. The nose section and forward fuselage slewed to the right and either rolled inverted or tipped over the nose to the inverted position. The right wing broke into pieces and the right engines were deposited forward along the wreckage path. As the left wing swung to the right, it broke up and the left engines were thrown forward and to the right. Major portions of the cabin sections travelled forward and came to rest to the left.

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[13] Appendix A, CVR transcript, time 0833:32.

2.7 Crew Performance

2.7.1 Taxi to the Runway.

The CVR contained no information relating to taxi technique; it did contain evidence of various checks and procedures. The Flight Data Recorder data could only be used to provide a very general idea of the directional control, speed and turning performance. However, because of the known adverse effects of high taxi speeds on tyre performance, the crew performance in this respect has to be addressed. Because the FDR does not record low speeds, the assessment has to rely on recorded headings, times and power settings related to the known physical characteristics of the taxi route.

Once the aircraft had begun to taxi under its own power, two 90 degree left turns were performed on the ramp. These turns took 13 seconds and 17 seconds respectively. Thereafter, the taxi route consisted of a straight track averaging 11 knots ground speed, a 90 degree right turn which took 16 seconds, a straight track averaging 20 knots ground speed, a 90 degree left turn which took 16 seconds, a straight track averaging 17 knots, a 90 degree right turn which took 16 seconds, a 13 second hold and the line-up on the runway which took 31 seconds to change direction by 90 degrees. The indications are that nose wheel steering was used for directional control and that asymmetric braking was not used; the rudder pedals were moved during the flight control check; engine power was increased slightly during the latter part of and after turns.

There is no evidence of excessive taxi speeds.

2.7.2 Take-Off

The crew would not notice the minimal degradation of aircraft performance. Other indications which were apparent to the crew during the take-off roll, appeared to have been regarded as insignificant.

At about the time that #1 tyre failed, the Flight Data Recorder shows right rudder deflection. This may have been applied to correct a yaw to the left. (Traces of the left main gear on the runway show that the nose wheels were to the right of the centreline and never crossed it.) About 500 metres from the threshold, the inner wheels of the left main gear bogie had closed from about 2½ metres to about one metre to the left of the centreline; this may have been because of over-correction for a tendency to yaw to the left or weather-cocking because of the surface wind. Whatever the reason, the actual deviation would probably have been considered insignificant to the cockpit crew. The sequence of aural and other sensations caused comment within the cockpit; the captain, who had the sole authority and responsibility for initiating a rejected take-off, queried the possibility of the first officer's inadvertent use of brakes when the first officer queried the possibility of a flat tyre.

The first officer and flight engineer were certainly aware of anomalies; the only suggestion of awareness by the captain was his late call of: "80 knots," if it was the result of partial preoccupation with an analysis of the available symptoms.

The cues available were insufficiently demanding to make the captain believe that a reject was essential. Conditioning factors may have included the captain's training regarding take-off decision speed and a lack of adequate knowledge of the tyre conditions or the consequences of operating an under-inflated tyre.

2.7.2.1 Take-Off Decision Speed

Take-Off Decision Speed (V_1) is variously defined but differences are quite small. The rules can be stated simply as:

- If an engine fails before V_1, reject;
- If an engine fails at or after V_1, continue the take-off.

In other words, the crucial factor is said to be engine rather than aircraft serviceability and the certification standards are predicated on the engine failure as the worst case.

When the decision speed is calculated, the ability to accelerate and climb, the remaining runway length and the inherent braking performance are all considerations. In considering the braking performance, the use of wheel brakes only is assumed. Performance may be summarised as follows:

- If the reject is initiated before V_1, the aircraft can be brought to rest on the remaining runway.
- If an engine fails at or after V_1, the take-off may be continued safely with the remaining engines.

There is a general view that other system failures may be more safely handled by continuing the take-off and then returning to land. There is merit in this philosophy because considerable redundancy is designed into aircraft systems. Furthermore, in the event of tyre or brake defects, it can be argued that the reduced braking efficiency may cause the aircraft to over-run the paved surface should the reject be initiated immediately prior to V_1. This neglects consideration of the use of reverse thrust and aerodynamic drag devices which are effective at high airspeeds. The net result is that V_1 is almost exclusively treated as engine failure recognition speed rather than, more appropriately, GO/NO GO speed.

All discussions and viewpoints seem to revolve about the decision to reject or take off *being made* at V_1. In particular, captains of aircraft canvassed, usually stated that their major concern was "... a reject at decision speed, for a tyre failure, would invariably result in greater damage than if the take-off was continued, because of degradation of braking performance and control on the ground." The slight inference that a reject decision may be deferred until just before V_1 is unfortunately present, without actually being stated, in the later case.

In 1989-1990, the U.S. Air Transport Association and Aerospace Industries Association formed a group to study the rejected take-off over-run problem. The group was called the RTO Safety Task Force and consisted of airlines, pilot associations, government and regulatory agencies and airframe manufacturers. The task force concluded that the most significant opportunities for improvement were in the areas of training practices and operating procedures.

The Boeing Company agreed to lead an industry/government working group to develop a training aid. The working group consisted of 35 airlines, 10 manufacturers, 7 government agencies, 5 industry associations and 3 pilot associations. The outcome is a training aid which presents a wealth of information which can enhance the decision-making process of cockpit crews.

The following extracts appear to be particularly relevant to this accident—which occurred before announcement of the availability of the training aid.

> Any Go/No Go decision can be considered "successful" if it does not result in injury or airplane damage.
>
> Available data indicates that over 75% of all RTO's are initiated at speeds of 80 knots or less.
>
> ... the infrequency of RTO events may lead to complacency about maintaining sharp decision-making skills and procedural effectiveness. In spite of the equipment reliability, every pilot must be prepared to make the correct Go/No Go decision on every takeoff - just in case.
>
> ... the crew must always be prepared to make the Go/No Go decision prior to the airplane reaching V_1 speed ... as speed approaches V_1, the successful completion of an RTO becomes increasingly more difficult.
>
> ... V_1 is not the point to begin making the operational Go/No Go decision.
>
> The Takeoff Briefing:
>
> Crew members must know what is expected of them and from others. For optimum crew effectiveness, they should share a common perception -- a mental image -- of what is happening and what is planned. This common perception involves a number of CRM areas: communications, situational awareness, workload distribution, cross checking and monitoring. ... A takeoff briefing is another means of improving the crew's awareness, knowledge and team effectiveness ... A review of actions for a blown tire ... appropriate for before takeoff ... review
>
> ... The crewmember noting a problem should communicate clearly and precisely ... The pilot tasked to make the RTO decision should clearly announce his decision, whether it be continue or reject. It's important to understand that all crewmembers on the flight deck play an important role in the Go/No Go decision and RTO maneuver. Company policies shape these roles, however, how the team is organized for each takeoff can make a difference in team performance.

A Draft Advisory Circular 120-XX dated August 3, 1992 was released by the United States Federal Aviation Administration. The circular announced the availability of a joint industry/Federal Aviation Administration Takeoff Safety Training Aid and recommended early consideration of the information contained in the aid and use of the aid for training purposes. The title of the training package is the "Takeoff Safety Training Aid."

2.7.2.2 Knowledge of Tyre Conditions

The flight was attempted with under-inflated tyres. There is no evidence to prove that this captain, or any of his flight crew, were aware of the deficiency; if the captain was aware, he may have thought the state of the tyre was acceptable for flight. The project manager and the lead mechanic were certainly aware. Within the first one minute of the CVR recording, for brief periods several voices spoke at the same time; these voices were unintelligible. Then, just after the captain called for the start check, the flight attendant said: "OK, you're not going down." Although there may be many interpretations of this question, the possibility exists that the query centred around an anticipation that the captain would go and have a look at "the tyre." What is difficult to accept is the idea that a maintenance person and a marketing person, would be bold enough to conceal a significant defect from the crew; why would they make a decision when they could easily pass the responsibility to another person?

It may be argued that the captain, if aware of the pre-existing tyre condition, would be predisposed to reject the take-off if he recognised a failure. The counter argument is simply that if he suspected that the tyre had failed, he also believed that a burst tyre could be carried to destination and the wheel could be changed from the stock on board the aircraft.

The recorded evidence makes a strong case for at least the first officer suspecting a tyre burst on the runway ("We gotta flat tyre, you figure?"), during the take-off roll. The captain's question: "You're not leaning on the brakes, eh?" is difficult to rationalise. If "leaning on the brakes" had burst a tyre, the take-off should have been rejected; if the question was a prompt to ensure that inadvertent braking was to be avoided from then on, it could mean either:

- the captain also suspected a tyre burst and believing the condition was safe to continue the take-off, wanted to avoid another, or
- the captain was aware of the pre-departure state of a particular tyre, was not completely taken by surprise and believed that the remaining three tyres were sufficient to continue the take-off safely, or
- the captain believed that "leaning on the brakes" could cause unusual or symptoms of a tyre burst without actually causing one.

Prior to V_1, the captain missed a speed check by 10 knots. This could have been due to preoccupation with analysis of symptoms; it could have been preoccupation with the process of decision making; it could have been a momentary aberration. After V_1, noises and further conversation recorded on the CVR make it very difficult to believe that the captain could not have suspected a tyre burst on the runway.

As soon as the aircraft became airborne with a positive rate of climb, the first officer called "Gear up" and the captain raised the gear. There was no suggestion, by any crew member, that the gear should be left down for any reason.

2.7.3 The Circuit

Once the aircraft had become airborne, a sequence of failures necessitated a return to Jeddah. The captain acknowledged the reporting of the initial failure indications by calling for a level off, transmitting "Ah... Nationair two one two zero, we'd like to just level off at two thousand feet ah... if that's OK, we're having a slight pressurisation problem."

Following a further sequence of system failures, the captain demonstrated an appreciation of the gravity of the situation and declared an emergency, without using his callsign or emergency prefix, three minutes after take-off, stating: "... we believe we have blown tyres ..." In the interim, the first officer had called for "flaps 10" twice and referred to "flaps" on two more occasions. The flight engineer was very positive when he spoke very loudly, "Level off right now, level off right now." At the time, the aircraft was about 300 feet above its assigned altitude and the cockpit indications were of multiple failures.

When the in-flight director reported smoke in the back, the captain did not ask for details; very soon afterwards he said; "OK, let's get squared away and see what we've got here please." There were more reports of failures and the captain apparently took the controls, saying: "OK, hang on, I've got it." when the first officer reported: "I've got no ailerons." The CVR ceased to function one second later. Throughout the recorded sequence, there was little evidence of crew resource management or the use of emergency checklists except, just after the first officer had reported loss of hydraulics, he said: "Autopilot, yaw damper's off." The flight engineer responded: "Off." to what could have been the first line of the hydraulic failure check list.

2.7.4 Procedures

The captain's radio procedures were poor; he confused his callsign and then neglected to use a callsign; he failed to use an internationally recognised standard emergency prefix to declare his emergency. The failure to use a callsign, although probably having no effect on the final outcome, delayed identification and possibly increased crew stress when the ATC controller tried to get them to depart on flight plan. The failure to use an emergency prefix is internationally common in civil aviation; many civil pilots appear to believe that the use of an appropriate prefix has adverse connotations. It should be recognised that even with only two prefixes to choose from, some degree of priority can be assigned by Air Traffic Controllers but, more importantly, every station monitoring the frequency is immediately aware that the situation is serious and non-essential radio communications should cease.

2.8 Air Traffic Control

The mis-identification of the source of the radio calls from C-GMXQ resulted from four factors:

- The failure of the captain of C-GMXQ to identify his aircraft.
- The returning Saudia aircraft with a pressurisation problem led the controller to assume that unidentified "pressurisation calls" were from that aircraft.
- The failure of the Saudia aircraft to use its callsign in some transmissions.
- The failure of the controller to use aircraft callsigns in some transmissions.

Once the Air Traffic Controller was aware that C-GMXQ was in an emergency situation, he did everything he could to assist the captain by offering him options and finally clearing him to land on any runway.

2.9 Ergonomics

2.9.1 Cockpit Environment

Although the DC-8-61 is a relatively old aircraft, the warning systems and cockpit ergonomics (i.e. seat position, instrument locations, warning lights and tones etc.) all met the minimum certification requirements at the time it was designed, and in fact may have been "state of the art" at the time.

Because there are no tyre pressure sensors, no temperature sensors or fire detectors in the wheel-wells and because the tyres are not visible from anywhere in the aircraft, the flight crew did not have enough information to evaluate the situation and make appropriate and timely decisions during the taxi, take-off, and while airborne. The crew was forced to use their experience of normal vibration, noise and performance for reference. Reliance on secondary indicators is fraught with difficulties, particularly non-identification or mis-identification of a problem, and more importantly, in this case, a denial that the noise and vibration is a problem at all. The reliance on secondary indicators is problematic at the best of times, but is more so during critical phases of flight, when the additional time required for identification and evaluation of the problem, is not available.

Interview evidence indicates that the majority of flight crews felt that the detection of a tyre/wheel failure on the DC-8-61 would be unlikely, citing the noisy environment and the location of the landing gear as reasons. The majority of those interviewed who had experienced a tyre or wheel failure on take-off or landing, stated that they were unaware of anything untoward, in fact some stated that it wasn't until ATC notified them of debris on the runway were they aware of a problem.

The CVR cockpit area microphone recorded that the cockpit loudspeaker was on during the entire flight. It is not known if the flight crew were wearing headsets and what attenuation of the "flapping" sound, recorded on the CVR during the take-off roll, may have existed.

2.9.2 Cabin Environment

The cabin of the accident aircraft was configured as a long and entirely open space, divided into three sections -forward, mid, and aft, with 47 rows of seats. There were eight designated flight attendant jumpseats and one passenger seat designated for use by a flight attendant. The in-flight director normally sat next to the flight deck door. The purser normally sat at the rear with a clear view of the full length of the cabin. A passenger seat at 21D was designated for a flight attendant. If flight attendants seated at 12C and 39C, in the middle cabin, noticed anything reportable during the take-off roll, the only method of communicating with the in-flight director was through the Public Address system. It is unlikely that they would use the public address to broadcast their concerns to all of the passengers as well as the in-flight director. For the flight attendant in seat 21D, there was no direct means of communication with any other crew members.

Although described as a noisy, rough aircraft on take-off and landing by cabin and flight crews alike, in at least one incident at Nationair, a blown tyre on take-off was heard in the cabin. It is likely that flight attendants, especially those stationed in the centre of the aircraft cabin, felt the vibration and/or heard the flapping noise. However, even if perceived, it is possible that the significance of such indications was not recognised because flight attendants are not trained to identify abnormal system or operating situations. The cabin crew might also have assumed that the flight crew was aware of the situation.

The effectiveness of the cabin crew's role in augmenting flight crew situational awareness is impaired by the lack of guidance about when, what and how to report an anomaly noticed on take-off. Flight attendants are trained to remain seated during the take-off roll and initial climb to prevent injury in the event of abrupt aircraft movements and to prevent distraction of the flight crew during critical phases of flight. There are no procedures for cabin crew to follow in the event that an anomaly is noticed during the take-off roll. Except for opening the cockpit door during the take-off, the in-flight director has only the interphone system to communicate directly with the cockpit. However, because the chime that sounds in the cockpit is nearly inaudible and because the flight crew would be disinclined to respond to it anyway during this critical phase of flight, the interphone system is not an effective tool in the event of an emergency during take-off. Essentially, if an in-flight director or other flight attendant does not take the initiative and enter the cockpit to report an anomaly, the flight crew may not be informed of the situation.

The in-flight director entered the cockpit and reported smoke in the cabin approximately one minute after the aircraft had begun to level off at 3,000 feet, and five minutes after brake release; her report of: "(***) smoke in the back ... real bad." gave the flight crew their first indication that the anomalies indicated in the cockpit were due to an in-flight fire. There is no standardised phraseology for reporting fire in the cabin in the Flight Attendant Manual.

2.9.3 Communications Systems

On the DC-8-61, there are two flight attendant panels, one forward above the in-flight director's seat, and one aft above the purser's seat. The system consists of two communications components, interphone and public address. The interphone has two call buttons, one to the pilot and one to the other flight attendant panel. Pressing the designated button sounds a chime at the station or in the cockpit, and illuminates a pink light in the master call light panels located in the ceiling at both extremes of the cabin. For the flight attendants in 12C, 39C, and the aft starboard jumpseats, the only means of communicating is the public address microphone, necessitating a general public announcement. The flight attendant in 21D has no means of communicating, other than waving arms to attract the attention of the in-flight director, and using hand signals. The cabin can be called from the cockpit.

2.10 Crew Co-ordination

2.10.1 Crew Pairing

Crew pairings for the Jeddah operation were completed by the designated operations officer, and by the chief flight engineer, DC-8. Flight crew were contacted and given the opportunity to volunteer. Some amongst the flight crew indicated their preferences for a particular crew pairing, and for those that expressed a preference, or were able to, these preferences were apparently satisfied. The captain and first officer were paired as a reflection of their respective experience. Prior to the Jeddah deployment, the captain and first officer had not flown together. During the deployment, they flew four flights together before the accident flight.

2.10.2 Cockpit Co-ordination

The captain and the first officer had vastly different backgrounds and experience to call upon. The captain's military background, with its inherent command structure, was different to that of the first officer, who had progressed through smaller aircraft where command and control had been his responsibility and he was reportedly uncomfortable with the captain's "commanding" cockpit management style.

A strained relationship may cause a communications breakdown resulting in a loss or degradation of cockpit co-ordination. Effects could be a reluctance of other crew members to offer advice or make relevant observations to the captain, together with a reluctance of the captain to accept advice. Even if advice were to be offered, it could be phrased in such a way that anticipated confrontation would be avoided. Rather than a co-ordinated cockpit, a situation could exist whereby important inputs from other crew members would be diluted and the captain would inevitable act as the sole reactive analyst of information available to all of the cockpit crew.

Throughout the sequence of system failures, the crew maintained control of the aircraft; however, the first positive indication that the captain was preparing to analyse the situation was the captain's statement "OK let's ah get squared away and see what we've got here please." Even then, he sought no details of cabin conditions. The CVR ends shortly thereafter and it is not known what further action the crew may have taken. There was an indication of crew co-ordination between the first officer and flight engineer when, apparently, the first item of the hydraulic failure checklist was called and acknowledged, shortly after take-off.

2.10.3 Cabin Crew Co-ordination

Each designated flight attendant seat position has various duties attached to that position. According to the Flight Attendant Manual, flight attendants are obliged to inform the in-flight director of any circumstances or malfunction of equipment which may affect the safety of the flight. In all cases, the in-flight director will serve as liaison between the captain and the flight attendants. Flight attendants are trained to communicate with the cockpit if they deem the situation critical; however, they would usually consult with the in-flight director first.

2.10.4 Communications

2.10.4.1 Cockpit Crew Communications

For critical information or concerns to be communicated effectively, they should be expressed in an assertive manner. Concerns expressed in the form of questions or statements hedged with qualifications such as "you figure?" tend to mitigate the message. In the cockpit, such messages are less likely to be followed up by other crew members or accepted by the captain. The requirement to relay crucial information effectively is essential in the cockpit during critical phases of flight such as the take-off when time is critical.

The CVR indicates that the level, tone and content of the conversation was entirely consistent with the company policy of a "sterile cockpit" below 10,000 feet. In addition to trying to react to the failure indications, the captain was also transmitting and monitoring radio transmissions. He made 10 radio calls, and received or monitored 14.

The indications of strained interpersonal relationships within the flight crew, particularly between the captain that the first officer, suggest a reduction in effective crew co-ordination and communication. For a crew to become noncommittal in any aircraft—in particular one that is governed by the captain-only reject procedure, is to deprive the captain of information that could be crucial for correct diagnosis of the situation.

Training crews to be effective leaders and effective followers results in better co-ordination, more effective communication, greater situational awareness, and appropriate decision-making. FAA AC No. 120-51 reflects on the importance of CRM training, encouraging its incorporation into a company's culture. The flight crew of the accident flight had not received a CRM course, nor is it required by Transport Canada.

2.10.4.2 Cabin to Cockpit Communications

The Flight Attendant Manual indicates that cabin staff should avoid using the interphone during taxi, take-off roll, climb, or during final approach unless the call is of utmost importance; furthermore, the interphone should be used at all times when communicating with the flight deck, thus avoiding unnecessary entry.

Interviewed flight crew members stated that, during the take-off roll and initial climb, ambient noise in the cockpit would make the interphone chime in the cockpit difficult to hear; most of those flight crew indicated that they would probably ignore it during take-off and initial climb-out anyway. In general, opinion was that cabin staff do not hesitate to inform the flight crew of any anomalies, however; guidelines as to how to inform the flight crew of specific anomalies in the DC-8 are vague.

2.10.4.3 Inter-Departmental Communications

Both the project manager and the lead mechanic were new employees. This deployment was an opportunity to establish their ability to perform their duties successfully. However, the reporting structure under which the deployment team was operating may have restricted the flow of information to the flight crew.

The decision to employ the lead mechanic as the head of the maintenance crew on this deployment was based on his previous managerial experience in Western Africa, not on any supervisory experience at Nationair. Both his hands-on experience and his knowledge of Nationair maintenance procedures were limited. During the deployment, the lead mechanic allowed the aircraft to depart on more than one occasion with an under-inflated tyre. His performance may have been influenced by his desire to prove his supervisory ability based on the achieved aircraft schedule, or by pressure the project manager was effecting. The sense of urgency conveyed by the project manager in his facsimile to the operations officer in Accra and the quick response to it might have left the impression that delays were a serious threat to the contract. The lead mechanic was probably not familiar with the terms of the contract. On the morning of the accident, the project manager, unaware of the significance of under-inflated tyres, when told that obtaining nitrogen would take time, reportedly did not communicate the information to the operating crew and said: "forget it." Although the lead mechanic was responsible for maintenance, he wanted to avoid aircraft delays due to maintenance, he was not actually responsible for signing the maintenance release and he did not understand the operational implications of taxiing, taking off, and landing with under-inflated tyres. Nevertheless, he should have informed the flight engineer who had to sign the maintenance release.

2.10.4.4 Man-Machine Interface

It is likely that the captain did not consider the significance of the observations more conclusively because there were insufficient stimuli to persuade him to do otherwise; the manner in which the observations were communicated de-emphasised their message. Had there been clearer indications of a problem, a rejected take-off at low speed would probably have been executed. The only other source of effective communication, if fitted, would have been indicators and warning systems requiring no interpretation.

2.11 Decision Making

In a multiple-member cockpit, there can be varying levels of situational awareness. Effective decisions rely on an accurate and complete picture of what is happening. If there is an absence of effective communication in the cockpit about a developing situation, then the decisions being made are based solely on the situational awareness of the decision-maker. That in itself is not unsafe if the decision-maker, the captain, is aware of the real situation. If, however, his assessment is incorrect and if he is not apprised of the real situation by the other crew members, then his decisions are potentially unsafe.

On take-off, flight crews are in a "go mode," and, unless given clear information to do otherwise, the take-off will continue. Analysis of the CVR of the accident flight revealed that all three flight crew members made observations about an anomaly during the take-off roll. The observations either took the form of a question or suggestion; however, the comments and sensations led to no immediate follow-up to the first officer's suspicions of a "flat tyre."

The captain's continuance of the take-off was based on his perception of the circumstances and his mental model of the outside world. The creation of a mental model is based not only on the information provided by one's sensory systems but also on one's training and experience (or lack thereof) and expectations. The decisions and responses that result are a reflection of that perception and mental model.

The captain's training on the DC-8, as well as that of the other flight crew members, did not include rejecting for tyre or wheel failures, nor was there any such requirement. At Nationair, flight crews are trained to reject for engine fire, engine failure and complete electrical failure, prior to V_1. Given this training, the captain's continuance of the take-off was entirely consistent with his training. He had no rules or ingrained procedures to aid in his decision-making when he was presented with a suspected tyre/wheel problem. When there are no rules, people resort to experience, knowledge, and expectations. It is possible that the captain's experience, knowledge and expectations reflected those of other pilots interviewed, and that he may have known of Nationair's past history of tyre/wheel failures on take-off and landing. If so, he may have understood that operating with damaged tyres on take-off to be of little consequence. This understanding would be entirely in keeping with the attitudes of those company pilots interviewed, Nationair's experience and supported by the company training and SOPs.

Simulator training is a critical component of flight crew training at Nationair. During actual emergencies, the flight crew's actions are predicated upon procedures practised in the simulator. If there is no training and there are no SOPs, flight crews must rely on their experience. Because the DC-8 simulators used by Nationair were not equipped or certified to simulate tyre/wheel failure and the problem is not addressed in the Company SOPs, the captain's decision-making was based entirely upon his knowledge, experience and expectations.

Therefore, the decision to raise the landing gear immediately after take-off was in accordance with company procedures and followed the checklist. Any decision to leave the gear down would have been an individual airmanship decision of the captain.

Flight crews are not specifically trained for multiple, unrelated failures, nor are they required to be. Because the failures appeared unrelated, the crew did not have a stable set of clues to diagnose. Even when failures occur in an expected sequence, problem diagnosis often takes longer than the problem solving. When clues indicating a problem are confusing, it is difficult to diagnose the source of the problem. During this flight, the crew was presented with an increasing work load and did not have the capacity to diagnose a probable root of their problems.

The training items that would have been useful to the crew during this occurrence were not covered in the Company training. For this accident, training issues include; rejecting take-off for suspected tyre/wheel failure and dealing with known or suspected landing gear damage, after becoming airborne. Leaving such issues to airmanship presupposes a level of knowledge and experience that was not apparent in the actions of the flight crew.

2.12 Indicators and Protection Systems

Regardless of any possible knowledge of the tyre condition prior to take-off, the symptoms presented while still on the runway were insufficiently demanding to cause this particular captain to reject the take-off. It is likely that this particular captain was representative of a large group of captains currently operating. It is probable that had clearer indications been available to the captain, the take-off would have been rejected and the accident would not have occurred.

Indicators and protection systems available on other aircraft include:

- wheel well over-heat indicators;
- wheel well fire warning;
- wheel well fire extinguishers;
- brake temperature indications;
- tyre pressure indications.

A trial of wide angle close circuit television systems, giving cockpit crew a view of the airframe, is being conducted by one operator.

3 CONCLUSIONS

3.1 Findings Not Related To Cause

3.1.1 The flight crew were properly licensed and qualified to undertake the flight.

3.1.2 The flight crew took a keen interest in load control to keep take-off weight within limits, but the load sheet was improperly prepared.

3.1.3 The available information indicated that the aircraft was not overloaded.

3.1.4 No pre-existing defects in the wheels or brake units, which could have caused tyre failures, were identified .

3.1.5 The damage to the wheels and brakes on the left bogie was as a result of the failure of #1 and #2 tyres.

3.1.6 All ground agencies involved in the handling of the emergency and the subsequent operations performed adequately.

3.2 Findings Related To Cause

3.2.1 The organisational structure for the deployment team was ill-defined and fragmented.

3.2.2 Deployment maintenance personnel were not qualified or authorised to perform the function of releasing the aircraft as being fit to fly.

3.2.3 The release of the aircraft as being fit to fly was delegated to non-practising Aircraft Maintenance Engineers whose primary function was to operate the aircraft as flight crew members.

3.2.4 The aircraft was signed-off as fit for flight, in an unairworthy condition, by the operating flight engineer who had no involvement in the aircraft servicing.

3.2.5 The #2 and #4 tyre pressures were below the minimum for flight dispatch. Other tyres may also have been below minimum pressures.

3.2.6 Maintenance personnel were aware of the low tyre pressures but failed to rectify the faults.

3.2.7 The mechanic altered the only record of the actual low pressures, measured by the avionics specialist on 7 July, four days before the accident.

3.2.8 There was no evidence that the tyre pressures had been checked, using a tyre pressure gauge, after 7 July.

3.2.9 The lead mechanic was aware of the low tyre pressures.

3.2.10 The persons who were aware of the low pressures had insufficient knowledge of the hazards of operating at low tyre pressures.

3.2.11 The project manager was aware of a low tyre pressure but was not qualified to assess its importance.

3.2.12 The project manager was responsible for the aircraft schedule and directed that the aircraft depart without servicing the tyre.

3.2.13 The lead mechanic who was aware of the requirement for, and had requested nitrogen for tyre servicing, did not countermand the decision of the project manager.

3.2.14 There was no evidence to indicate that this flight crew were ever informed of the low tyre pressures.

3.2.15 The aircraft departed the ramp in an unairworthy condition.

3.2.16 During the taxi from the ramp to the runway, the transfer of the load from the under-inflated #2 tyre to #1 tyre on the same axle, resulted in over-deflection, over-heating and structural weakening of the #1 tyre.

3.2.17 The #1 tyre failed very early on the take-off roll due to degeneration of the structure, caused by over-deflection.

3.2.18 The #2 tyre failed almost immediately after #1 due to over-deflection and rapid over-heating when the load was transferred from the #1 tyre.

3.2.19 The #2 wheel stopped rotating for reasons not established. Friction between the wheel/brake assembly and the runway generated sufficient heat to raise the temperature of tyre remnants above that required for a tyre fire to be self-sustaining. Rubber remnants ignited during the take-off roll.

3.2.20 Numbers 1 and 2 wheels were severely damaged and at least one piece of #1 wheel rim struck the airframe, becoming embedded in the left flap.

3.2.21 The crew were aware of unusual symptoms early and throughout the take-off roll; the captain continued the take-off.

3.2.22 The aircraft was not equipped with warning systems which would have provided the flight crew with adequate information on which to make a decision to reject the take-off after tyre(s) failure.

3.2.23 The captain did not receive sufficient cues to convince him that a rejected take-off was warranted.

3.2.24 The crew retracted the gear, consistent with company procedures, and burning rubber was brought into close proximity with hydraulic and electrical system components.

3.2.25 The evidence indicates that the wheel well fire involved tyres, hydraulic fluid, magnesium alloy and fuel. The fuel was probably introduced as a result of "burn through" of the centre fuel tank.

3.2.26 Fire within the wheel wells spread and intensified until the cabin floor was breached and control systems were disabled.

3.2.27 The fuel increased the intensity of the fire until, shortly before impact, airframe structural integrity was lost.

3.2.28 Tyre characteristics and performance are not adequately addressed during training and licensing of both flight crews and technical personnel.

3.2.29 The aircraft operator's tyre inflation pressures did not accurately reflect what was contained in the aircraft manufacturer's maintenance manual.

3.2.30 The operator's maintenance and operating documentation for the DC-8 does not contain adequate information for the proper maintenance and operation of aircraft tyres.

4 RECOMMENDATIONS

4.1 It is recommended that all public transport aircraft be equipped with wheel well over-heat and fire detectors, wheel well fire protection, brake temperature sensors, tyre pressure sensors and corresponding indicators in the cockpit.

4.2 It is recommended that aviation regulatory authorities monitor and ensure the use of proper radio telephony procedures and code words.

4.3 It is recommended that aviation regulatory authorities monitor and ensure:

a) the use of operating manuals and procedures that are complete, current and accurate and which include actions for dealing with tyre failures during and after take-off;;

b) the training of flight crews to include adequate information on tyre performance and vulnerability to ensure safe operation and the formal inclusion of crew resource management in initial and recurrent training.

4.4 It is recommended that aviation regulatory authorities monitor and ensure:

a) the use of maintenance manuals and procedures which are complete, current and accurate and which reflect the current knowledge of aircraft tyre vulnerability;

b) proper maintenance practices and documentation and a requirement for personnel involved in decisions affecting airworthiness matters to be qualified;

c) the training of maintenance personnel to include adequate information on tyre servicing and vulnerability to ensure safe operation;

d) quality assurance programmes for all maintenance work completed by all aircraft maintenance engineers, mechanics and other technicians and specialists.

4.5 It is recommended that International Civil Aviation Organization disseminate the information contained within U.S. Department of Transportation Federal Aviation Administration Draft Advisory Circular 120-XX, subject "Takeoff Safety Training Aid," dated August 3, 1992 and endorse the use of the training aid by all operators, world-wide.

ICAO Note.— Names of personnel were deleted. Appendices A and B were not reproduced.
ICAO Ref. 0272/91.