Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION OCCURRENCE REPORT

DECLARED EMERGENCY/WHEEL FAILURE

ADVANCE AIR CHARTERS
MCDONNELL DOUGLAS DC-8-62F C-FHAA
CALGARY INTERNATIONAL AIRPORT, ALBERTA
08 MARCH 1994

REPORT NUMBER A94W0026

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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Synopsis

While the Advance Air Charter aircraft was taxiing out for take-off on a charter flight from Calgary, Alberta, to Murmansk, Russia, two diagonally-opposite main wheel tires on the left side failed. The flight crew were not aware of the failure and proceeded to take off. During the take-off, the flight engineer reported low power on the No. 1 engine. After the aircraft became airborne, air traffic control advised the crew that rubber was found on the runway. Fuel was dumped, and the flight returned for a successful emergency landing. There were no injuries to the crew or passengers.

The Board determined that the No. 2 tire deflated while the aircraft was taxiing as a result of a wheel rim separation caused by an undetected fatigue crack. The No. 5 tire was punctured by a broken section of the No. 2 wheel rim. As a result of ineffective communications, the crew continued the take-off in an aircraft with two failed tires on the left side. Contributing to the ineffective crew communications was the lack of crew resource management training provided by the operator.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

On 08 March 1994, at 0625 mountain standard time (MST)[1], Advance Air Charter flight ADV200, a Douglas DC-8-62F combination passenger/freight aircraft, prepared to depart from Calgary International Airport, Alberta, on a charter flight to Murmansk, Russia.

The aircraft carried 8 crew and 75 passengers, and the forward cargo bay (located between the flight deck and the passenger cabin) was loaded with 5 pallets of freight. On push-back from gate 24, the aircraft was positioned on the ramp so that a sharp, 180-degree turn to the right was necessary to enter taxiway Charlie. While taxiing south on Charlie at the intersection of runway 07/25, the captain placed the two inboard engines in idle reverse.

After crossing the intersection of runway 07/25, the flight crew heard a thump which they concluded was an oleo bottoming. The occupants of the passenger cabin, including the flight attendants and a company loadmaster, heard a bang. The purser, sitting in the rear of the cabin, discussed the unusual sound with a second flight attendant, then called the flight deck on the interphone and asked the flight engineer (FE)[2] what the noise was. The FE gave a humorous response, but did not discuss the call with the other flight crew members. None of the passengers advised the flight attendants of their concerns about the noise before take-off.

On the ground, the vice-president (VP) of maintenance and two other company personnel heard two loud, almost simultaneous booms as the aircraft was taxiing south on Charlie. They initially thought that an engine was compressor stalling, and they began assembling a crew to drive out to the holding bay for runway 34 to check the engines of the DC-8, if required. After the aircraft departed, the contract flight plan company was asked to contact the crew by radio to check for any abnormalities, particularly with the engines.

The aircraft stopped on the button of runway 34 until the crew received their take-off clearance. The captain then advanced the power levers, and the FE observed that the No. 1 engine pressure ratio (EPR) indication was slow to increase. The captain released the brakes and, as the aircraft accelerated, a vibration was felt by the flight crew that they concluded to be nose wheel shimmy. The FE then advanced the power levers and attempted to adjust the EPRs to the calculated take-off setting of 1.98. The No. 1 engine (Pratt & Whitney JT3D-3B) was indicating about 1.80 EPR, which was lower than the other three engines, and the No. 1 engine power lever knob was forward of the other three levers by one-and-a-half knobs.

At the 80-knot call, the FE advised the captain of low EPR on the No. 1 engine. The captain advised the FE that he would fly by reference to the engine high pressure compressor rpm (N_2) and continued the take-off. At about 100 knots, the FE observed the No. 1 engine low pressure compressor rpm (N_1) decay from 103 to 98 per cent and called out, "low power number one." The captain was observed to

1 All times are MST (Coordinated Universal Time [UTC] minus seven hours) unless otherwise stated.

2 See Glossary at Appendix B for all abbreviations and acronyms.

place his hand on the power levers, but as the speed approached about 130 knots the first officer (FO) advised against rejecting the take-off. The aircraft accelerated through the take-off decision speed (V_1) of 147 knots and rotated at the calculated rotation speed (V_R) of 162 knots. The captain observed that the take-off run was slightly longer than normal, but there was no unusual yaw or other indications of power reduction. The cabin occupants felt a noticeable vibration on the take-off roll prior to lift-off. On climb-out, the landing gear retracted normally and the No. 1 engine EPR reading gradually realigned with the other three engine power indicators.

While the aircraft was climbing through about 8,000 feet above sea level (asl), air traffic control (ATC) advised ADV200 that rubber debris was found on the departure runway. The flight crew discussed the possibility of a failed nose-wheel tire.

An attempt by the FE to tell the purser about the rubber found on the runway, over the interphone, was unsuccessful due to static interference. The purser walked up to the flight deck and, after being advised that rubber debris had been reported on the runway, returned to the cabin to brief the flight attendants.

The company loadmaster, who had been seated in the cabin over the wing, came up to the flight deck after the seat-belt sign was turned off, and advised the flight crew that he believed main wheel tires had failed on the left side. It was reported that he received limited response from the flight crew.

The flight crew received a message from their company advising that the rubber had been identified as tire material. Following a discussion of options, the captain elected to dump 112,000 pounds of fuel to reduce the aircraft weight to the landing maximum, and conduct an emergency landing at Calgary International Airport.

The captain called the purser to the flight deck and told her to prepare the passengers for an emergency landing. The captain advised the passengers of the tire failure, and indicated that an emergency landing would be conducted at Calgary.

Later, the purser was recalled to the flight deck and was advised by the captain that emergency response service (ERS) vehicles would be attending, and to prepare for the possibility of a fire on landing. The purser was asked to advise the flight deck if any abnormalities were observed on the landing roll; the purser would be notified if the aircraft had to be evacuated. The purser and the flight attendants briefed the passengers, and ensured that the emergency exits were properly manned. The atmosphere in the cabin was generally calm, and some passengers were trying to sleep. The flight attendants did not utilize the emergency checklists in their flight attendant manuals, nor did they brief the passengers on the brace position. On approach, the FE advised the purser that the landing would be normal.

When the aircraft landing gear was extended and the cabin was depressurized, the flight mechanic, riding in the jump seat, viewed the nose gear through the eyebrow port, and reported to the flight crew that both nose wheel tires appeared to be intact.

The aircraft touched down smoothly on runway 16. The captain applied reverse thrust, deployed the spoilers, and used wheel braking after the speed decreased. The captain taxied slowly off the runway and into the holding bay, where he stopped and shut down all but the No. 4 engine. Full ERS support was in attendance. The passengers were held in the aircraft for about 40 minutes, to ensure that the remaining tires on the left side had not been heat damaged. The passengers were then deplaned and taken by bus to a private passenger facility. The aircraft was examined and towed to the company ramp area.

3 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

The incident occurred at 0638 MST during the hours of twilight, at latitude 51°06'N, longitude 114°01'W, at an elevation of 3,542 feet asl.[3]

1.2 *Injuries to Persons*

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	8	75	-	83
Total	8	75	-	83

1.3 *Damage to Aircraft*

As the aircraft was taxiing down Charlie, the inboard rim on the No. 2 wheel separated violently, and a jagged section of the rim struck the No. 5 tire, causing a puncture. The No. 2 and 5 tires were shredded during the take-off and landing. The flailing tire cords damaged the forward anti-skid wiring harness during the landing. There was minor damage to the undersurface of the left flap, landing gear door, and lower wing skin from thrown debris. There was also abrasion and impact damage to the No. 1 and 2 brake packs.

Douglas Aircraft numbers the tires/wheels as follows.

NOSE GEAR

Left Right

LEFT MAIN		RIGHT MAIN	
#1	#2	#3	#4
#5	#6	#7	#8

1.4 *Other Damage*

There was no other damage.

1.5 *Personnel Information*

	Captain	First Officer
Age	45	55
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01 May 94	01 July 94
Total Flying Hours	10,000	11,000
Hours on Type	3,000	2,500
Hours Last 90 Days	66	76
Hours on Type Last 90 Days	66	76
Hours on Duty Prior to Occurrence	3	3
Hours off Duty Prior to Work Period	24	72

1.5.1 *Captain*

The captain had been flying for the operator for 10 months. He held a valid airline transport pilot licence (ATPL) with an endorsement on DC-8 aircraft, and a Class 1, Group 1, instrument rating. He had completed his last pilot proficiency check (PPC) ride on 03 August 1993, and had completed the required recurrent simulator training. He had worked as an aircraft maintenance engineer (AME) and FE, prior to flying commercially, with a series of related American freight/passenger companies. He had not experienced a tire failure while taxiing before.

1.5.2 *First Officer*

The FO had been flying for the operator for 10 months. He held a valid ATPL endorsed for the DC-8 aircraft and a Class 1, Group 1, instrument rating. He had completed his last PPC ride on 01 August 1993, and had completed the required recurrent simulator training. He held captain's status with the operator. After completing 27 years in the Canadian Armed Forces as a navigator and pilot, he flew for a DC-8 operator as a pilot. He had not experienced a tire failure while taxiing before.

1.5.3 *Flight Engineer*

The FE had been with the operator for 10 months. He held valid FE and AME licences endorsed on the DC-8. He had successfully completed simulator recurrent training on 27 November 1993. His previous aviation experience was with the military and two DC-8 operators. He had not experienced a tire failure while taxiing before.

1.5.4 *Flight Mechanic*

The flight mechanic held a valid AME licence with a DC-8 endorsement, and had been working for the operator for about seven months. His duties on this flight included assisting the loadmaster. He had previously worked for a DC-8 operator and a Canadian aircraft manufacturer. He was sitting in the cockpit jump seat for the duration of the incident. He had not experienced a tire failure while taxiing before.

1.5.5 *Loadmaster*

The loadmaster, or logistics manager, was not subject to Transport Canada (TC) licensing. He had been working in this specialty for numerous large operators before joining this company. He was sitting in the passenger cabin, over the wing, during the incident. During his past service, he had experienced several tire failures and was familiar with the sounds and vibration. He later indicated that he did not call the flight attendant when he heard the tires fail.

1.5.6 *Purser*

The purser was not subject to TC licensing. She had worked as a flight attendant for about two years for two large operators before joining the operator as a purser. She was sitting in the rear flight attendant seat when she heard the bang. She had not experienced a tire failure while taxiing before.

1.5.7 *Flight Attendants*

One flight attendant was sitting in the forward flight attendant jump seat while the second flight attendant was sitting in the rear jump seat. One attendant had nine months experience while the second had two years experience. They both heard the bang during taxi. One attendant was sitting next to the purser and encouraged her to call the flight deck about the noise. Neither attendant had experienced a tire failure while taxiing before.

1.6 *Aircraft Information*

Manufacturer	McDonnell Douglas

Type and Model	DC-8-62F (Combi)
Year of Manufacture	1968
Serial Number	45961
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	56,453 hr
Engine Type (number of)	Pratt & Whitney JT3D-3B (4)
Propeller/Rotor Type (number of)	N/A
Maximum Allowable Take-off Weight	350,000 lb
Recommended Fuel Type(s)	Jet B
Fuel Type Used	Jet B

The flight deck is located 80 feet forward of the main landing gear.

1.6.1 *Aircraft Weight and Balance*

The aircraft had been loaded to its maximum allowable gross weight of 350,000 pounds. Following the incident, the operator unloaded and reweighed all cargo, and found the actual weights were 800 pounds lower than calculated. The aircraft centre of gravity (C of G) calculations were found to be within limits.

1.6.2 *Tire Pressure Gauge*

Following the incident, the contract maintenance company sent their tire gauge out for a calibration check; there was no abnormal calibration error.

1.6.3 *Aircraft Maintenance*

A review of the maintenance logs indicated that the aircraft had experienced a series of unrelated, repetitive unserviceabilities involving compressor stall (surge), a low EPR indication on the No. 1 engine, and malfunctioning spoilers.

The problems with the No. 1 engine low EPR first showed up on the previous flight, a departure from Russia. The FE's write-up of the unserviceability indicates almost exactly the same EPR drop on take-off followed by recovery to normal values during climb-out as on the occurrence flight. The log entry included a detailed description of the FE's in-flight trouble-shooting of the pneumatic system which indicated excessive air leakage during the manifold decay check. On arrival in Canada, the rectification indicated was replacement of the No. 1 engine pneumatic relief valve due to sticking. The entry indicates that a ground run was carried out, and that all parameters were found normal. However, this maintenance action did not prove to be effective in rectifying the intermittent low EPR problem.

Following the occurrence flight, the No. 1 engine surge bleed valve was replaced for intermittent operation, a loose airstart pneumatic line in the nose wheel well was tightened, and a leaking peri seal was replaced. A ground test indicated that the manifold decay check was now within normal limits. The aircraft was reported to operate normally following this action.

1.6.4 *Take-off Power Settings*

The operator's weight and balance form contains a take-off performance chart that is completed prior to departure. The take-off chart for the occurrence flight indicated that the full thrust take-off EPR should be 1.98, the flight take-off EPR 1.94, and the climb EPR 1.78. The chart indicated that the calculations were based on a field temperature of minus five degrees Celsius. The company operations manual indicates that the minimum N_1 rpm for an EPR setting of 1.98 should be 103 per cent, and that if the minimum N_1 is not achieved between 60 and 80 knots on take-off, the take-off should be rejected.

1.6.5 *Power Lever (Throttle) Stagger*

The FE reported that the No. 1 power lever was advanced one and one-half knobs beyond the other three power levers during take-off.

The company operations manual indicates that throttles may be out of alignment, at any power setting, a maximum of one throttle-knob diameter.

1.7 *Meteorological Information*

The 0600 MST weather, as reported by the Calgary Atmospheric Environment Service, was as follows: sky condition clear, temperature minus 9 degrees Celsius, dew point minus 14 degrees Celsius, wind 320 degrees Magnetic at 4 knots, altimeter setting 30.11, and visibility 15 miles.

1.8 *Aids to Navigation*

All navigation aids were serviceable.

1.9 *Communications*

1.9.1 *ATC Communications*

All pertinent ATC tapes were secured and reviewed.

1.9.2 *Aircraft Service Interphone System*

The aircraft was fitted with a service interphone system that provides a handset at the FE's station, but was not wired so that other crew members on the flight deck could hear any communications from the flight attendants. The system does not signal other flight attendant stations that there is communication under way between the flight deck and a flight attendant station.

1.10 *Aerodrome Information*

Calgary International Airport is a certified aerodrome operated by the Calgary Airport Authority. The reference elevation is 3,557 feet asl, and the airport is equipped with all required communication, lighting, and navigational services. TC provides all ATC services, including terminal radar. Runway 34, which was used for take-off, has a 12,675-by-200 foot asphalt surface. The transition at the intersection of the concrete taxiway Charlie and the asphalt runway 07/25 was smooth, and no irregularities were observed.

1.11 *Flight Recorders*

1.11.1 *Flight Data Recorder (FDR)*

The aircraft was equipped with a 17-channel recording system Sundstrand F800 universal flight data recorder (UFDR). The Sundstrand UFDR was subject to a temporary waiver from TC, allowing 12 recorded channels. The TSB Engineering Branch laboratory prepared a printout of the take-off sequence and correlated it with the Calgary ground radar tape data from ATC. It was determined that the No. 2 engine EPR sensor was faulty. The longitudinal acceleration and engine EPR data indicated the start of the take-off roll with EPR values stabilizing through about 50 knots ground speed. The No. 1 engine EPR, however, stabilized at approximately 1.9, compared to 2.0 for engines three and four. Approximately 38 seconds after brake release, No. 1 engine EPR decreased to about 1.71 for about 7 seconds, after which a slight increase to 1.79 occurred. Engines three and four remained at about 1.98 to 1.99 during this time. The aircraft had reached a ground speed of about 111 knots, and was about 3,800 feet from the start of the take-off run at the time of the No. 1 engine EPR drop. No. 1 engine EPR values subsequently increased to match those of engines three and four which had decreased to about 1.8 as the aircraft climbed through approximately 5,200-feet-pressure altitude.

The FDR data indicated that the actual take-off distances at V_1, V_R and V_2 (take-off safety speed) were less than the aircraft manufacturer's performance calculations.

1.11.2 Cockpit Voice Recorder

The Collins 642 cockpit voice recorder (CVR) was capable of recording 30 minutes of information. The CVR continued to operate while preparations were being made for the emergency landing, and all information relative to the occurrence was overwritten.

1.12 Wreckage and Impact Information

1.12.1 General

Airport personnel located broken sections of the No. 2 wheel rim and the wheel cover from the No. 2 wheel on Charlie taxiway, south of the intersection of runway 07/25. A semi-circular, silver-coloured paint smear was observed on the concrete taxiway surface near the same location where the wheel section was found. Several small sections of rubber tire material were found on Charlie taxiway south of this location, and larger rubber sections were found scattered over the length of runway 34. Examination of the ramp area, where the aircraft had begun taxiing, indicated rubber transfer marks on the concrete surface resulting from a sharp turn. The DC-8, which does not incorporate swivel bogies in the main gear, will scrub or roll the tires over the rims during a sharp radius turn. This scrubbing action results in increased stress to the wheel rim.

1.12.2 Wheels and Tires

The No. 2 and 5 wheels and tires were examined by the TSB Engineering Branch laboratory.

It was determined that the failure of the No. 2 inboard wheel half was a result of a fatigue-generated crack that initiated in the bead seat area of the tube well and then fractured in overload extension; the tire then deflated. The cause of the fatigue crack initiation was not determined. The No. 2 wheel met the manufacturer's specification for material composition, hardness, and cross-sectional thickness in critical areas. The wheel manufacturer (Bendix) indicated that the fracture appeared typical of high-cycle wheel failures. The 2.7-inch crack lay in a single plane of propagation, indicating that the wheel had been used on the same side of the landing bogie since the crack had initiated. The absence of an obvious stress riser has been noted by the wheel manufacturer in previous failures, and may be related to the accumulative effects of long term damage on the microscopic level, giving rise to the necessary fatigue crack initiation. The location of the crack directly under the tire bead probably would not result in a loss of tire pressure prior to failure.

The No. 5 tire deflated when it was punctured by the separated section of rim flange from the No. 2 wheel.

1.13 Wheel Inspection and Failure

1.13.1 General

The failed wheel had last been inspected by an American operator prior to the aircraft being imported into Canada. The bilateral airworthiness agreement between Canada and the USA accepts component certification based on Federal Aviation Administration (FAA) requirements. Although the American operator's overhaul records did not specify what non-destructive testing (NDT) methods were used to check for cracks on the failed wheel, it was determined that an eddy current inspection was conducted after every fifth tire change. The wheel manufacturer's overhaul manual permits the inspection of critical bead seat areas using dye penetrant methods, but recommends the use of more advanced eddy current inspection after every tire change. Dye penetrant does not provide the level of assurance of detection of small cracks that a modern eddy current method can.

Major air carriers in Canada are presently inspecting aircraft wheels at each tire change using modern eddy current inspection methods. Wheel rim failures in their aircraft fleets have been virtually eliminated.

1.13.2 Manufacturer's All Operator Letters (AOL)

Two AOLs published by the manufacturer as recommendations were pertinent to this occurrence.

A) AOL 8-68, *Main Landing Gear Wheel Failure*, issued 30 March 1966 - This AOL recommended recording the individual tire pressures found during the pre-flight inspection in order to detect a wheel that is slowly leaking through a small crack.

Although this practice was not being followed by the contract maintenance organization, their Inspection Program Approval included a requirement to remove a tire from service if leakage exceeded 25 per cent of normal tire pressure.

B) AOL 8-003, *Reiteration of Procedures and Techniques Regarding Wheels, Tires, and Brakes*, issued 19 August 1991 - This AOL suggests that, at speeds over V_1 minus 20 knots, the captain may want to limit his reject option to engine failure only.

This subject had apparently been discussed during previous company training; however, the captain could not recall briefing his crew on this subject. The company operations manual did not contain a specific reference to this procedure, nor is it required.

A rejected take-off, especially on an aircraft operating at maximum take-off weight, is considered an emergency procedure, and, if not actioned promptly and at low enough airspeed, could possibly result in tire failures, fire, and landing gear damage.

1.14 The Company

1.14.1 General

Advance Air Charters (AAC) commenced operations in July 1993, operating two DC-8 aircraft. The company has carried passengers and cargo to remote international locations including northern Russia, the Middle East, Southeast Asia, and South America.

1.14.2 Flight Operations

The operator employs contract operations personnel, including pilots, FEs, and flight attendants, who live in centres across Canada and commute to fulfil scheduled flight duty. The typical contract would include a minimum of 40 hours of flying per month. The chief pilot, who lives in Victoria, felt that crew resource management (CRM) was used by his ex-military pilots. The VP of operations maintained DC-8 captain status by flying as a line pilot, and had been heavily tasked with marketing responsibilities to the exclusion of his normal duties. The VP of operations indicated that company executives had spent considerable time developing a safety philosophy or "culture" (the set of beliefs, norms, attitudes, roles, and social and technical programmes within an organization).

Although a flight safety committee met regularly, there were no line pilots included on the committee.

Recent decreased market activity has resulted in less flying time for pilots. As a result, two pilots of captain status fly together. Obviously, one will have to perform the duties of the FO and defer to the other on issues of command. The roles could be reversed on the next leg.

1.14.3 Maintenance Organization

The operator contracts aircraft maintenance to Canadian Commercial Aircraft Overhaul (CCAO or CanCom). This contractor is a TC-approved aircraft maintenance organization (AMO) authorized to perform limited maintenance on the operator's aircraft in accordance with an approved maintenance control manual (MCM). The President of CanCom is also listed as the VP in charge of maintenance for the operator.

1.14.4 Company Safety Culture

The corporate culture of this company is consistent with that of other new, small, limited budget/revenue charter operations. It is apparent that the company did not fully appreciate the impact of trying to organize and manage a "part-time" workforce within an organizational structure designed for a "full-time" operation.

The VP of operations indicated that he was very busy with many aspects of company business, and that he had not had sufficient time to dedicate to the operational and safety aspects of the company. In particular, he was aware that the safety committee was not as effective as it could be, and planned to incorporate improvements in the future.

The chief pilot has the responsibility to merge or blend the safety culture of all the pilots flying under him who have come from other operators. This could take the form of standard operating procedures (SOPs), and should be reinforced during recurrent training. The chief pilot felt that CRM was practised by his pilots, especially those with a military background, when in reality no evidence of this was found.

1.15 Transport Canada

The responsibility for surveillance of the operator has been divided between the regional TC Airworthiness office monitoring maintenance and the 7th Region (Ottawa-based) office that is responsible for operations. At the time of the occurrence, no TC operations or maintenance audits had been conducted on the operator in the 10 months it had been in operation.

It was determined that the regional TC Airworthiness library did not contain a complete set of updated DC-8 technical manuals that the airworthiness inspectors would normally require as references for their regular audit function.

It was also determined that technical training on the DC-8 had not been provided to the regional air carrier airworthiness inspectors responsible for this operator.

The TC principal maintenance inspector assigned to this operator was based in the Calgary sub-office, and had assisted in the development of the maintenance program, the import of a second aircraft, and attempts to solve the recurring compressor stall problems.

1.16 Operations from Runways in Russia

Crew members indicated that the expansion joints on concrete runways in Russia were extremely rough, and that they were used to hearing loud banging noises from the landing gear. The operator suggested that this might have some relationship to the wheel fatigue cracking. An FDR data readout was obtained from a later flight to Russia. Examination of the vertical acceleration traces by the TSB Engineering Branch Laboratory determined that the take-offs and landings at Murmansk exhibited the highest vibration levels, indicating a much rougher surface than encountered during operations out of Calgary (approximately 100 per cent increase in average peak-to-peak amplitude). It was noted that one take-off or landing at Murmansk might subject the aircraft to vertical G loads equivalent to that of several normal landings at a typical North American airport such as Calgary.

1.17 Crew Resource Management

The definition of CRM is generally accepted as the effective use of all resources available to the flight crew, including equipment, technical procedural skills, and the contributions of flight crew and others. CRM concepts include how flight crew members communicate with one another, how they make decisions as a crew, how leadership is exercised, how problems are assessed and dealt with, along with other crew-centred factors.

The operator's training program did not include CRM, although senior operations personnel agreed with its principles. TC encourages air carriers to use CRM, but has not made it mandatory.

2.0 Analysis

2.1 Introduction

The analysis will look at the decisions and action of the crew when the wheel failed during taxi, and the subsequent low power indication on take-off.

2.2 Wheel Failure

There was no indication that the No. 2 wheel was damaged during the sharp radius turn at the terminal. There was no evidence found that differential braking or asymmetric power was used to augment the turn.

The NDT inspection method last used on the No. 2 wheel by the previous American owner was an eddy current inspection after the fifth tire change, although the wheel manufacturer recommends an eddy current inspection after every tire change.

The FDR data gathered on Russian operations indicates that the operations on the rough runways may impart an increase in wheel stress which may require increased inspection.

2.3 Crew Reactions to the Sounds of Tires Failing

The bangs made while the aircraft was taxiing were heard by all of the crew on the flight deck, passengers, flight attendants, maintenance personnel at the company ramp area, and the loadmaster sitting in the cabin. The loadmaster was the only person who believed that the bangs were made by exploding tires.

The aircraft, which was loaded to its maximum gross weight, had just taxied over the intersection of runway 07/25. The flight crew had discussed the sound and concluded that they were hearing an oleo bottom out. The flight crew had experienced rough runways in Russia, and may have been conditioned to the sound of banging oleos. The two inboard engines had been placed in idle reverse to avoid brake use on the slight decline, which resulted in higher noise levels on the flight deck. The cockpit crew, none of whom had experienced a tire failure on taxi before, were also wearing headsets which would attenuate external sounds.

The bang would be louder for the occupants of the passenger cabin than for the flight crew since the main gear is located under the wing outboard of the cabin, 80 feet aft of the cockpit. The cockpit was also isolated from the passenger cabin by the bulkheads of the forward cargo hold, and the five pallets of crated cargo which probably muffled the sound.

When the purser called the flight deck, she asked what the noise was, rather than describing what she and the flight attendant heard and felt. The response from the FE, which was given in a humorous manner, was interpreted to mean that everything was under control. This interchange between these two crew members was not effective in communicating the serious nature of what was heard. The physical limitations of the service interphone system in the aircraft allow only the purser to speak to the FE. If the captain or FO had been able to hear the call from the purser, they might have been cued to think about tires instead of oleos.

The loadmaster, who had experienced a tire failure before, was reluctant to call a flight attendant or alert the flight crew before take-off, when he heard the tires fail. When the loadmaster finally went to the flight deck, after take-off, and told the flight crew of his suspicions, they were already aware of the rubber on the runway and paid little attention to his comments.

As the captain stopped on the button of runway 34 in preparation for take-off, he was not aware that tires had failed. Although there was communication between some crew members and some persons were concerned, these concerns were not communicated to the captain. Had the concerns been brought to the captain's attention and analyzed collectively, it is possible that he would have responded differently. As it happened, each individual's concern was either intercepted or dismissed on its own. With a mind-set to go, it often takes strong evidence or a significant defect, readily apparent and unambiguous, to evoke a correct response. It is natural and human to seek to mitigate or rationalize against those stimuli which do not support the planned course of action.

2.4 Take-off

When the power levers were advanced, the FE noticed that the No. 1 engine EPR was slow to increase. He had experienced exactly the same problem on the previous flight, and he advised the captain of the low EPR condition. Because of the low No. 1 EPR, the normal take-off challenge and response sequence was interrupted. When the N_1 decayed from 103 per cent to 98 per cent, the FE expected the captain to reject the take-off, but the captain elected to continue, indicating he would "fly N_2." The sudden drop in No. 1 engine EPR recorded on the FDR at 111 knots ground speed likely corresponds to the N_1 decay and enters the threshold of the high energy regime. The captain later indicated that there was no unusual yaw or sensation of power loss which would indicate low power, and that he therefore decided to continue the take-off. One strong cue available to the captain was the one and one-half knob throttle stagger that he would have felt when he placed his hand on the power levers.

The manufacturer's AOL addresses rejected take-offs by stating, "...at speeds over V_1 minus 20 knots, the captain may want to limit his reject option to engine failure only."

The aircraft vibrated as it accelerated, and the flight crew were of the opinion that it was nose wheel shimmy; in reality, the vibration was caused by the two flat and disintegrating tires. The vibration was more pronounced in the cabin, but the purser did not consider it adverse enough to call the flight deck since she had not experienced a tire failure before.

2.5 Preparation for Emergency Landing

Due to static interference in the interphone system when airborne, the purser had to walk up to the flight deck to receive instructions directly from the captain. The purser was advised twice that there would be an emergency landing and that there might be a fire on touchdown. The captain was of the opinion that the purser would carry out the required emergency procedures as outlined in her manual, and was not aware that this did not happen. The cabin crew's decision to not use the emergency checklist appears to have been made predominantly on the assumption that everything was going well to this point, and they did not want to alarm the passengers. The FE advised the purser on approach that the landing would be normal, when in reality an emergency landing was under way with potential for the worst possible outcome.

2.6 Maintenance

The maintenance conducted on the No. 1 engine by the maintenance contractor prior to the occurrence was not effective in eliminating an intermittent low EPR discrepancy.

3.0 Conclusions

3.1 Findings

1. The flight crew were certified and qualified for the flight in accordance with existing regulations.

2. The aircraft was certified in accordance with existing regulations and approved procedures.

3. The aircraft weight and C of G were within prescribed limits.

4. The No. 2 wheel rim failed while the aircraft was taxiing as a result of an undetected fatigue crack, allowing the tire to deflate explosively.

5. The No. 5 tire was punctured by a broken section of the No. 2 wheel rim.

6. The flight crew, none of whom had experienced a tire failure while taxiing, mistook the bangs for a bottoming oleo.

7. Communications between the purser and the flight deck were ineffective due to the design of the interphone system.

8. The purser's call to the FE on the interphone to inquire about the bang was not effective in providing the flight crew with information about what was heard and felt in the cabin.

9. The FE's humorous response to the purser's inquiry was interpreted to mean that everything was under control.

10. The loadmaster, who was sitting in the cabin and who had previously experienced tire failures, did not advise the crew of his concerns until after the aircraft was airborne.

11. The vibrations from the flailing main wheel tires were felt on the flight deck during take-off, but were misidentified as nose wheel shimmy.

12. The vibration was more pronounced in the cabin, but the purser did not consider it adverse enough to call the flight deck during the take-off roll.

13. On the take-off roll, the FE twice advised the captain that the No. 1 engine power indication was low.

14. The captain elected to continue the take-off, while aware of a low No. 1 engine EPR, low N_1, and a pronounced power lever stagger.

15. The purser did not ensure that the flight attendants used the emergency checklists or briefed the passengers on the brace position, despite being advised by the captain to prepare for an emergency landing that might result in fire during touchdown.

16. On approach, the FE advised the purser that the landing would be normal.

17. At the time of the occurrence, the operator had never received

maintenance or operations audits by TC.

18. The flight crew may have become conditioned to bottoming oleos while operating on rough runways in Russia.

19. The maintenance carried out on the No. 1 engine following the previous flight was not effective in eliminating the intermittent low EPR condition.

20. The flight crew and cabin crew are trained separately in emergency procedures.

21. The operator does not provide CRM training to its operational personnel, nor is it required by regulations.

3.2 Causes

The No. 2 tire deflated while the aircraft was taxiing as a result of a wheel rim separation caused by an undetected fatigue crack. The No. 5 tire was punctured by a broken section of the No. 2 wheel rim. As a result of ineffective communications, the crew continued the take-off in an aircraft with two failed tires on the left side. Contributing to the ineffective crew communications was the lack of crew resource management training provided by the operator.

4.0 *Safety Action*

4.1 *Action Taken*

4.1.1 *Operator Actions*

Following the occurrence, the operator's maintenance facility revised the pre-flight inspection form so that tire pressure leakage can be monitored. Safety memoranda concerning effective crew communication were also issued to flight crew. To increase the awareness of N1 and the procedure to reject the take-off at 80 knots in the event of low N1, the operator is now recording minimum N1 on their take-off data card for all take-offs.

In addition, the operator indicated that other actions would be taken to enhance safety, including use of eddy current methods to inspect wheels at time of tire changes, measures to reduce strain on landing gear, establishment of a communications base station, modification of the aircraft interphone, appointment of a pilot to the company safety committee, joint cockpit/cabin crew emergency training, and re-allocation of duties which had been assigned to the VP Operations.

4.1.2 *Transport Canada*

After the incident, Transport Canada (TC) carried out a cabin safety base inspection and coordinated in-flight inspections. This was followed by a base inspection which included flight operations and cabin safety and then an operations audit. TC requested and received amendments to the air carrier's operating manual, flight attendant manual, and crew training programs.

The draft Canadian Aviation Regulations (CARs) will contain provisions to require air carriers to implement crew resource management (CRM) training and to conduct joint crew training with pilots and flight attendants.

4.1.3 *Audits*

At the time of the occurrence, the operator had never received maintenance or operations audits by TC. The *Manual of Regulatory Audits* (MRA) calls for all companies to be audited six months after initial certification.

In conjunction with information gathered from other occurrences over the past 10 years, the TSB identified shortcomings in the regulatory audit process of air carriers. In particular, it was found that TC audits lacked scope and depth, and that TC's verification of corrective action following the audits was inadequate. Therefore, the Board has recommended that:

> The Department of Transport amend the *Manual of Regulatory Audits* to provide for more in-depth audits of those air carriers demonstrating an adverse trend in its risk management indicators;
> (A94-23, issued December 1994)

> The Department of Transport ensure that its inspectors involved in the audit process are able to apply risk management methods in identifying carriers warranting increased audit attention;
> (A94-24, issued December 1994)

> The Department of Transport develop, as a priority, a system to track audit follow-up actions;
> (A94-25, issued December 1994)

> The Department of Transport implement both short and long term actions to place greater emphasis on verification of required audit follow-up action and on enforcement action in cases of non-compliance.
> (A94-26, issued December 1994)

In response to these recommendations, TC has indicated that both recommendations A94-23 and A94-24 will be taken into consideration during amendments to the MRA. Also, TC will ensure that the Audit Procedures training program for inspectors takes into account recommendation A94-24 so that risk management methods are clearly understood and applied.

With respect to recommendations A94-25 and A94-26, TC replied that the MRA will be reviewed to ensure clear policy direction is given to ensure effective audit follow-up systems are in place. Furthermore, an enhanced National Aviation Company Information System (NACIS) should be operational by September 1995 to track audit follow-up on a national basis. In the interim, a policy directive will be issued to regions to require a review of respective regional follow-up systems.

4.1.4 *Crew Resource Management*

Ineffective crew communications contributed to this occurrence. Improving crew communication skills is an integral part of CRM training. Although CRM is currently not mandatory, Transport Canada's *Standards of Training* (to be enabled by the Canadian Aviation Regulations) includes a requirement that airline operators provide flight crew members with joint on-going CRM training.

As a result of numerous occurrences in which inappropriate CRM and pilot decision making (PDM) were identified as contributing factors, the Board recently recommended that:

> The Department of Transport establish guidelines for crew resource management (CRM) and decision-making training for all operators and aircrew involved in commercial aviation; and
> (A95-11, issued May 1995)

> The Department of Transport establish procedures for evaluating crew resource management (CRM) and pilot decision-making (PDM) skills on a recurrent basis for all aircrew involved in commercial aviation.
> (A95-12, issued May 1995)

In response to recommendation A95-11, TC has indicated that CRM and PDM training will be mandated for all air operators who are required to adhere to the Airline Operations regulations. In response to recommendation A95-12, TC has indicated that evaluation of CRM skills will be accomplished by way of a debriefing session following joint pilot/cabin crew recurrent training. Transport Canada is currently developing three human factors handbooks. The handbooks will include tools to evaluate attitudes, knowledge and skills for PDM, and will also include CRM measurement tools.

APPENDICES

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