This occurrence was investigated initially by the Aviation Safety Bureau of Transport Canada. The continued investigation and review were conducted by the Canadian Aviation Safety Board. The purpose of the investigation is to advance aviation safety, not to determine or apportion any blame or liability.

AVIATION OCCURRENCE REPORT

PACIFIC WESTERN AIRLINES LTD.
BOEING 737-200 C-GQPW
CALGARY INTERNATIONAL AIRPORT
CALGARY, ALBERTA
22 MARCH 1984

REPORT NUMBER 84-H40003

SYNOPSIS

During the take-off roll, the flight crew heard a loud bang which was accompanied by a slight veer to the left. The take-off was rejected, and all 119 persons successfully evacuated the aircraft when a severe fuel-fed fire developed.

The Canadian Aviation Safety Board (CASB) determined that an uncontained failure of the left engine thirteenth stage compressor disc had occurred. Debris from the engine punctured a fuel cell, resulting in the fire. The disc failure was the result of fatigue cracking.

Ce rapport est également disponible en français.

24 February 1987

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1.0 FACTUAL INFORMATION

1.1 History of the Flight

Pacific Western Airlines (PWA)* Flight 501, a Boeing 737-200, C-GQPW, was to depart Calgary, Alberta at 0730 mountain standard time (MST)** on 22 March 1984, on a scheduled flight to Edmonton, Alberta. On board were 114 passengers and a crew of 5. Following a ramp delay, push-back and engine-start were accomplished at 0735, and at 0736 the flight taxied for departure on runway 34.

Take-off was begun at 0742 from the intersection of runway 34 and taxiway C-1 (See Appendix A). About 20 seconds into the take-off roll, at an airspeed of approximately 70 knots***, the flight crew heard a loud bang which was accompanied by a slight veer to the left. The captain immediately rejected the take-off using brakes and reverse thrust. Both the captain and first officer assumed the noise and slight veer were the result of a blown tire on the left main landing gear.

The aircraft was quickly brought to taxiing speed. As the speed reduced, the captain decided to taxi clear of the runway at taxiway C-4. Approaching taxiway C-4, both pilots noted that the left engine low pressure unit rpm was indicating 0 per cent. The illumination of annunciator panel lights associated with the loss of electrical power produced by the left engine was also noted. While both pilots were analysing this new information, the captain continued to taxi and cleared the runway at C-4.

Twenty-three seconds after the initiation of the rejected take-off, the first officer called clear of the runway on tower frequency. The captain then continued to taxi slowly up C-4 while both pilots continued to question the source of their problem. Forty-five seconds after the initiation of the rejected take-off, the cockpit door was unlocked in response to the knocks of the purser. Upon entering the cockpit, she asked if they had blown a tire. She then stated that there was some fire at the rear of the aircraft. A verbal exchange lasting five seconds ensued in which the captain queried the existence of fire, and the purser elaborated that the fire was "on the back of the wing", "fire on the left wing." During this exchange, there was a brief sounding of the fire bell, and the flight attendant cockpit call chime began to sound repeatedly.

At the end of this verbal exchange between the purser and captain, the first officer requested confirmation of the fire from the tower. One minute and two seconds after the initiation of the rejected take-off, the tower controller stated that there was "considerable amount off the back - on the left side engine,

* See glossary for all abbreviations and acronyms.

** All times are MST (Greenwich mean time (GMT) minus seven hours) unless otherwise stated.

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

and it's starting to diminish there. There's a fire going on the left side." Immediately after this the purser further stated that "the whole left-hand side, the whole back side of it is burning", following which, at an elapsed time of 1 minute 11 seconds, the captain advised the purser to prepare for evacuation. About this time, the captain also discharged a fire bottle into the left engine, and the first officer requested tower to dispatch the emergency equipment. He also advised the tower that they had no fire warning. The tower controller advised that the trucks were on the way and then suggested that the crew continue taxiing to taxiway Juliett to meet the fire vehicles. The captain advised the first officer that he was "going to Juliett", and the first officer so advised the tower. The tower controller then advised that it would probably be best for the crew to stop the aircraft in its present location. At an elapsed time of 1 minute 33 seconds, the tower controller further advised that flames were coming out the left-hand side of the aircraft.

Immediately following this transmission, at an elapsed time of 1 minute 36 seconds, the cockpit fire warning bell activated and continued to ring. Simultaneously, the purser re-entered the cockpit and reported that it was getting bad at the back. At an elapsed time of 1 minute 40 seconds, the first officer reported to the tower controller that they now had a fire warning. At the same time, the captain activated the second fire bottle and again directed the purser to prepare for an emergency evacuation. He then stopped the aircraft and, along with the first officer, carried out the procedures for an emergency evacuation.

At an elapsed time of 1 minute 55 seconds, the flight attendants initiated an emergency evacuation of the passengers, following which the flight attendants and flight crew evacuated the aircraft. Fire consumed substantial portions of the aircraft before being extinguished by airport Crash Firefighting and Rescue (CFR) services.

The accident occurred at lat 51°07'N, long 114°01'W at 0742 during the hours of daylight.

1.2 <u>Injuries to Persons</u>

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	4	-	4
Minor/None	5	110	-	115
Total	5	114	-	119

1.3 <u>Damage to Aircraft</u>

The aircraft was substantially damaged by a fuel-fed fire.

1.4 <u>Other Damage</u>

- Not applicable -

1.5 Personnel Information

1.5.1 Flight Crew

	Captain	First Officer
Age	43	39
Pilot Licence	Airline Transport	Airline Transport
Medical Expiry Date	01 May 1984	01 June 1984
Total Flying Time	10,000 hr	6,800 hr
Total on Type	6,000 hr	2,100 hr
Total Last 90 Days	120 hr	150 hr
Total on Type Last 90 Days	120 hr	150 hr
Hours on Duty Prior to Occurrence	1.2 hr	1.2 hr
Hours off Duty Prior to Work Period	12 hr	12 hr

The flight crew was medically fit and qualified to fly the B737 aircraft. Route and instrument checks, simulator training, and emergency procedures training had been satisfactorily completed. There was no evidence of personal, family or business pressure which would have placed either under undue stress. Both had received the off-duty time prescribed by regulations. The captain occupied the left seat and was at the controls.

1.5.2 Cabin Crew

	Purser	Flt. Att. #2	Flt. Att. #3
Age	28	29	34
Last Recurrent Training	Oct. 1983	Nov. 1983	Aug. 1983

The cabin crew was medically fit and qualified for their duties. All had received the off-duty times prescribed by regulations.

1.6 Aircraft Information

Manufacturer	Boeing Aircraft Company
Type	737-200
Year of Manufacture	1981
Serial Number	22265
Certificate of Airworthiness	Valid
Total Airframe Time	7447.6 hr
Engine Type (2)	Pratt & Whitney JT8D-9A
Maximum Allowable Take-off Weight	117,000 lb
Recommended Fuel Type	JET A-1

Records indicate that the aircraft was maintained in accordance with procedures adopted by the company and approved by Transport Canada. The aircraft was serviceable prior to the accident, and the aircraft was within the allowable weight and centre of gravity limits.

1.6.1 Left Engine History

A Pratt & Whitney JT8D-9A engine (See Appendix B), serial number P687739, was installed in the number one (left) position of the aircraft. At the time of the accident, it had accumulated 17,151 hours and 24,300 cycles in service.

In March of 1982, the engine underwent a fuel saving modification, which involved work on the high pressure compressor section of the engine. It was during this procedure that a replacement thirteenth stage compressor disc was installed. This thirteenth stage disc was originally shipped from Pratt & Whitney in engine serial number P707313, in May 1980. That engine sustained severe damage as the result of a bird ingestion, after 332 hours and 350 cycles in service. Damage to the thirteenth stage assembly required the replacement of all 74 compressor blades. The disc was inspected in accordance with requirements specified by Pratt & Whitney but, because of a failure to meet specified clearances on the thirteenth stage rear knife edge seals, was not installed when the engine P707313 was rebuilt. Instead, the disc was held as a spare and eventually installed in engine P687739 after a procedure for reworking of the thirteenth stage airseal and disc was introduced. At the time of the accident, the disc had accumulated a total of 4,937.6 hours and 6,498 cycles.

The thirteenth stage stator was installed new in engine serial number P674584. In February 1980, at 2,244 hours and 3,960 cycles in service, the stator was removed and overhauled. The stator was subsequently installed in another engine and removed again in May 1981 when it underwent another overhaul. The overhauled stator was installed on engine serial number P687739 where it remained until the accident, at which time it had accumulated 8,491 hours and 12,983 cycles since new, or 4,606 hours and 6,148 cycles since overhaul.

On 08 November 1983, at 3,960 hours and 5,188 cycles in service, the engine experienced a severe compressor stall while at climb power. This stall was determined to be the result of the separation and ingestion of vibration damping rubber from the first stage stator. A boroscope inspection of the internal engine parts including the thirteenth stage compressor blades and stator vanes was completed in accordance with procedures developed by PWA. No evidence of mechanical damage was observed, and the engine was released for service.

1.6.2 Previous Disc Failure History

High-cycle fatigue fractures of the JT8D thirteenth stage compressor disc were experienced in 1967, both in engines in service and in new engines at Pratt & Whitney during engine testing. An investigation by the company at that time revealed that the disc fractures were confined to engines which incorporated engineering changes that loosened the radial fit between the twelfth and thirteenth stage stator outer snap diameter and a thirteenth stage inner airseal axial respacing.

Extensive engine testing and engineering laboratory investigation by Pratt & Whitney at that time revealed the cause of the disc fractures to be high-cycle fatigue produced by a vibration in the high power range of the engine which was induced by the thirteenth stage assembly and was the result of coincidence between the disc and stator. It was verified by engine testing that the excessive disc vibratory stress occurred only with the loose radial snap fit between the twelfth and thirteenth stator. This loose fit resulted in the loss of mechanical damping which controlled the vibration amplitude of the stator and, therefore, the stress level of the disc.

The engineering change which had loosened the twelfth/thirteenth stator fit was cancelled, and all engine hardware was returned to the pre-change dimensions.

A subsequent redesign of the thirteenth stage disc eliminated the coincidence at high power setting by moving this condition above engine redline speed. However, another coincidence of relatively low energy level was introduced into the low power range.

1.7 Meteorological Information

Weather conditions were not a factor in this accident. The Calgary surface observation taken at 0645 was as follows:

> ceiling estimated 5,000 ft broken, visibility 40 mi, temperature 3°C, dew point -1°C, wind 300° T at 5 kt.

1.8 Aids to Navigation

- Not applicable -

1.9 Communications

Communication services were normal in all respects. At the time of the accident, Flight 501 was transmitting and receiving on the Calgary tower frequency.

The airport controller heard and saw the left engine explode into flames during the take-off roll. Almost immediately, Flight 501 transmitted that they were rejecting the take-off. The airport controller acknowledged this transmission but did not relay his observations regarding the presence of a fire. When the flight crew called clear of the runway, the controller advised that the emergency vehicles were on the way.

About one minute after the explosion, the flight crew requested the controller to confirm the existence of fire. The controller responded that there was, in fact, considerable amount of fire on the left side of the aircraft but that it was starting to diminish. This was the first communication between air traffic control personnel and Flight 501 regarding the existence of fire (See Appendix C).

The Transport Canada Air Traffic Control Manual of Operations (MANOPS) provides general guidance to controllers regarding the need to ensure that aircrew are apprised of conditions that may affect the safety of flight. However, specific direction to immediately advise of an observed fire is not given.

1.10 Aerodrome Information

Calgary International Airport is owned and operated by Transport Canada. Runway 34 is 12,675 feet long. From the intersection of taxiway C-1, the runway length remaining is 6,580 feet. At the time of the accident, the surface was bare and dry.

The emergency procedures for the airport are published under the authority of the Airport General Manager. Published procedures include the response to an aircraft crash on the airfield as well as various other emergency procedures. At the time of the accident, there were no specific procedures or contingencies which addressed the control of a large number of passengers, following an emergency evacuation of an aircraft.

Airport CFR services are provided under contract by the City of Calgary Fire Department. Two fire halls are maintained on the airport; one is adjacent to the main terminal ramp, the other is at the southern extremity of the airport.

The primary objective of CFR, as established by Transport Canada, is to save lives in the event of an aircraft accident, incident or fire at an airport. This objective is accomplished by providing a fire-free escape route for the safe evacuation or rescue of passengers and crew. A secondary objective is to preserve the property involved by containing or extinguishing, where practical, any fire resulting from an aircraft accident or incident.

In accordance with CFR services standards established by Transport Canada, Calgary Airport is identified as a Category 8 airport. Categorization is related to the overall length of the longest aircraft normally using the airport. Levels of fire protection, which include specific vehicle and staffing requirements, are also established in the Transport Canada CFR service standards. In accordance with these standards six fire-fighters were required to be on duty; 11 fire-fighters were on duty at the time of the accident. The following equipment was available for response: two foam trucks, one dry chemical truck, one water pumper, and one water tanker.

1.11 Flight Recorders

The aircraft was equipped with a cockpit voice recorder (CVR) and a digital flight data recorder (DFDR) located in the tail of the aircraft. Both were recovered and provided useful data.

The recorders had sustained external fire damage; however, the tapes were undamaged.

The voice recording was of good quality. A transcript was prepared with the assistance of the crew. Pertinent information from the recording is included in this report.

The data recording was used to confirm the time sequence of certain events. There was no indication of any engine abnormality prior to the engine failure.

1.12 Wreckage and Impact Information

The aircraft came to rest on taxiway C-4 about 119 feet from the intersection of C-4 and taxiway C. The main section of the aircraft, composed of its wings and fuselage forward of the wings, was resting on the nose landing gear, right landing gear, and the left engine. Some of the support structure of the left landing gear had melted away, allowing the left side of the aircraft to settle until the left engine rested on the taxiway. The tail section of the aircraft had burned through at the crown, and the aft fuselage had descended until the tail rested on the ground. It was still attached to the main structure at the bottom.

The left side of the fuselage sustained smoke and heat damage extending from fuselage station 450 to station 1064 (See Appendix D). The fuselage had fractured at station 747 and a large section above the window line between stations 747 and 890 was burned away. The right side of the fuselage sustained smoke and heat damage of a lesser nature between stations 480 and 1010.

The nose area of the aircraft was undamaged, as was the empennage.

The left front emergency slide was deployed but had deflated because of fire damage. The right front emergency slide was deployed and remained inflated. The right rear emergency slide was deployed and was destroyed by fire. The right over-wing emergency exit window had been removed and was lying on the right wing.

The right wing sustained heat and fire damage of a minor nature, except for portions of the leading edge devices, spoilers, flaps, and wing undersurface which sustained severe damage. The left wing was extensively damaged from the fuselage out to the wing tip. The leading edge devices and leading edge were almost burned away. All but the leading edge of the aileron was burned away as well. The trailing edge inboard flap and spoilers were burned away, and there were numerous protruding surface splits in the upper surface of the wing.

The left engine was extensively fire damaged. There was debris in both the intake and tail pipe areas, but no foreign object damage was noted. The engine case and nacelle were perforated at approximately the one o'clock position when viewed from the rear. The perforation, which was located about nacelle station 150, opposite the thirteenth stage of the high pressure compressor, had been made from the inside out.

A second perforation was found on the lower surface of the left wing, just inboard and in line with the perforation in the engine nacelle. This hole was located seven inches inboard of the engine pylon and five inches aft of the front edge of the centre wing skin plank. The wing skin was penetrated, and the fuel cell was broken. The hole measured three inches in length by approximately one-half inch in width, with its longitudinal axis in line with the hole in the nacelle and parallel with the joint on the lower wing surface. Other marks were present on the lower wing surface, apparently caused by expelled engine parts, but the engine parts did not penetrate the fuel tank.

Various pieces of aircraft structure and components were found on the runway and taxiway surface. Two large pieces of the left engine thirteenth stage compressor disc were found about 1,300 feet from the beginning of the take-off roll (See Appendix D). Impact marks in the runway surface made by the compressor disc pieces were found 1,295 feet from the start of the take-off roll. Pieces of compressor blades, engine casing, engine duct, and engine cowling were located between 1,300 feet and 2,000 feet from the starting point of the take-off roll.

A trail of raw and/or burnt fuel residues started approximately 2,200 feet from the starting point of the take-off roll. At about the intersection of runway 34 and runway 28, globules of melted aluminum were found on the runway surface. The fuel trail and globules of aluminum continued to the final resting position of the aircraft. In some places, large sheets of fire-damaged aluminum skin and honeycomb material had fallen from the left wing of the aircraft.

Inside the aircraft, heat and smoke damage was evident on the left side windows aft of seat row three. Aft of seat row eight, flame damage had occurred to the interior of the passenger cabin. Windows had melted or burned away, and the fuselage liners and seat upholstery were heavily damaged by fire entering through the window openings. From the break in the fuselage aft to the rear pressure bulkhead, the aircraft interior had been completely gutted by fire.

1.12.1 Left Engine Examination

The left engine was removed from the aircraft and taken to the Canadian Pacific Airlines (CP Air) maintenance facility in Vancouver for disassembly and detailed examination. The work was conducted under the supervision and the direction of members of the Aviation Safety Bureau. Representatives of the aircraft and engine manufacturers, Pacific Western Airlines, CP Air, the United States National Transportation Safety Board, the United States Federal Aviation Administration, and Transport Canada Airworthiness Branch were in attendance.

The gear box assembly and all externally mounted components were removed, and the engine was then separated into modules. External examination of the low pressure compressor did not reveal any discrepancies.

The high pressure compressor was completely disassembled. An area measuring about three inches by seventeen inches was missing from the thirteenth stage compressor disc. The disc pieces which were found on the runway were matched with the main section of the disc, and all major portions were accounted for. No other discrepancies or unserviceabilities were found beyond those attributable to the disc failure and subsequent fire.

1.13 Medical Information

There was no evidence that incapacitation, physiological or psychological factors affected the crew's performance.

1.14 Fire

Fire broke out coincidently with the explosion-type sound heard by people both inside and outside the aircraft. As the aircraft decelerated and proceeded down the runway onto the taxiway, it was trailing flame from the left wing area.

Airport fire crews were immediately notified of the fire by the control tower. Fire vehicles from the north fire hall arrived at the aircraft about two minutes after notification; vehicles from the south hall arrived about two minutes later. Fire was concentrated in the left wing area between the engine nacelle and fuselage. Dry chemical and foam were expelled into the fire area to control the fire and provide a fire-free escape route for evacuation. The initial positioning of the fire vehicles behind the aircraft and near the left wing tip prevented unrestricted access to the fire, and, as a result, initial attempts to extinguish the fire were not successful. Efforts to combat the fire were complicated by the nature of the fire involved. Fires of this nature are known as "three-dimensional fires" and consist of an elevated fuel source, a running (falling) fire, and a ground pooling fire. Although the fire was substantially knocked down and evacuation routes kept open, the engine nacelle and the wing blocked access from the foam cannons, located on the top of the fire vehicles, to the source of the fire, which was under the left wing, inboard of the engine.

Fire control attempts were further impeded when one foam truck became mired in the soft ground adjacent to the taxiway, while attempting to move to a more effective position. As a result, time was lost, and the fire-extinguishing agent continued to be applied in a less than ideal fashion. Both foam vehicles ran out of extinguishing agent before the fire could be extinguished.

Other vehicles continued to apply cooling water, while the foam trucks returned to the fire halls to replenish their water and foam agent supplies. During their absence, the fire significantly increased when the fuel cell vented through the upper surface of the wing. The fire was eventually extinguished by the foam trucks using hand lines when they returned following replenishment.

1.15 Survival Aspects

Passengers who were on the left side of the aircraft near the wing were almost immediately aware of the existence of fire. As the aircraft slowed, several passengers left their seats, and, as more became aware of the fire, a general level of agitation developed. The number two flight attendant seated in the rear of the aircraft heard a passenger yell "fire" within ten seconds of the occurrence; the purser and number three flight attendant

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both seated at the front of the aircraft, were aware of the fire within twenty-five seconds of its occurrence.

In accordance with published procedures for a rejected take-off, the three flight attendants remained in their seats awaiting instruction from the captain. All assumed that, because the aircraft continued to taxi, the captain was aware of the situation and that it was under control. As the fire continued to increase in size, the flight attendants attempted to contact the flight crew. The number two flight attendant, seated in the rear of the aircraft, attempted to notify the flight deck of the fire by using the aircraft interphone system. Although the signal tone was heard on the flight deck, it went unanswered because the first officer mistook the tone for that associated with the passenger flight attendant call button. The number two flight attendant continued in his attempts to contact the flight deck and also began to call the front cabin flight attendant station. The purser attempted to enter the flight deck but was unable to do so because the door was locked in accordance with standard company procedures. The door was unlocked in response to her knocks, and, about 45 seconds after the take-off was rejected, she entered the flight deck and, after first asking if they had blown a tire, informed the captain of a fire at the back. In the meantime, the number three flight attendant made a brief public address (PA) announcement for the passengers to remain seated and calm. After having been informed by the captain to prepare for an evacuation, the purser then returned to the cabin. Upon returning, she answered the interphone and was informed by the number two flight attendant that there was a fire at the back and that the aircraft should be stopped. Throughout this period, the aircraft continued to taxi slowly up C-4.

The purser then returned to the flight deck, advised the captain of the deteriorating situation, and was again directed to prepare for evacuation. The purser then left the flight deck and directed the two flight attendants to prepare for evacuation. When the aircraft stopped, the three flight attendants initiated an evacuation by opening their doors and inflating the escape slides.

There was no general announcement of the evacuation made by either the captain or the flight attendants. Evacuation commands were given to passengers as they exited the aircraft. The passengers' decisions to leave their seats and evacuate were based on their perceptions of the emergency situation and their observations of the flight attendants opening the exits. Passengers were at the doors awaiting the inflation of the escape slides.

Four exits were used during the evacuation; these were as follows: main entrance door (left front); galley service door (right front); right over-wing exit; and right rear service door. The main entrance door was opened by the number three flight attendant and the galley service door by the purser. The right over-wing exit was opened by the passenger seated next to it at the urging of several passengers seated nearby. The first few passengers out this exit reported that the escape slide at the galley service door had not yet deployed when they exited the aircraft. The right rear service door was opened by the number two flight attendant.

Shortly after the evacuation commenced, fire melted windows along the left side of the aircraft. When the windows melted through, heat and smoke entered the aircraft, and the cabin environment quickly deteriorated. Substantial quantities of smoke also entered through the right over-wing exit and right rear service door.

Conditions within the aircraft cabin were significantly worse in the aft section. Heat was felt as the windows melted through. Those passengers who had been seated beside the windows nearest the fire experienced some singeing of hair and clothing. Smoke obscured visibility almost totally during the latter stages of the evacuation.

Passenger perceptions in the forward part of the cabin differed markedly from those in the aft. It took much longer for them to be aware of the existence of fire, and, even then, some did not perceive the seriousness of the situation.

Most passengers chose the closest exit for evacuation. Many stopped to retrieve handbaggage before they left. Those passengers who exited through the main entrance door and galley service door were seated primarily in rows one through seven. Most initially chose to use the main entrance door until the number three flight attendant began directing alternate passengers to the galley service door. The passengers who exited through the right over-wing exit were almost all seated in rows 8 through 16. With only a few exceptions, the rear exit was used by all passengers seated aft of row 16.

The evacuation was without panic; however, a sense of urgency prevailed. There was some pushing, and several people went over seat backs to get to the exit ahead of others already in the aisle. There was no noticeable yelling or screaming.

As the evacuation progressed, smoke began to thicken and obscure vision. Smoke conditions were worse in the aft section of the cabin. Passengers who exited via the rear exit reported that they were unable to see the exit and were required to follow the person ahead to locate it. By the time most had reached this exit, the smoke had lowered to about knee height. The bottom portion of the door and the slide were all that was visible. The passenger who was the last one to exit via the over-wing exit reported he had to drop to his knees to breathe fresh air before he was able to reach the exit. Only when he neared the exit, did it become visible through the smoke.

All passengers who exited via the over-wing exit jumped off the leading edge of the wing. The vertical drop from the wing to the ground is in excess of six feet, and this distance increases as one moves outward from the wing root. Smoke and flames near the trailing edge influenced the passengers to go forward after they had left the aircraft. Most jumped down from the wing inboard of the engine, although several proceeded out the wing before dropping to the ground.

The rear slide was observed to deflate, because of fire damage, immediately after the number two flight attendant exited the aircraft.

A precise determination of the time taken to evacuate the aircraft could not be made; however, it is estimated that the evacuation took between two and three minutes.

Four passengers sustained serious injuries during the evacuation. All four exited the aircraft via the right over-wing exit. Three of these passengers sustained bone fractures of varying severity when they jumped to the ground from the leading edge of the wing. The fourth passenger, who was apparently the last person to exit the aircraft, sustained pelvis and rib fractures when he fell to the ground, after slipping on foam on the wing.

Numerous other passengers sustained minor bruises, cuts, abrasions, and sprains during the evacuation. Some singeing of hair and mild blushing of the skin from heat were also reported. Blood samples were taken from the 29 passengers who reported to hospital. Carbon monoxide levels were minimal when measured, and there were no reports of other toxic substances.

Following the evacuation, the passengers and crew gathered in groups a short distance from the aircraft and observed the fire-fighting activities. Those passengers who required assistance were helped away from the aircraft by other passengers and cabin crew. Some passengers had to be told to move away from the aircraft and fire. A head count was attempted by the cabin crew, but it was not started until after some passengers had begun to wander away from the scene. After a while, a few passengers began to disperse and make their own way back to the terminal. Later, taxi cabs were dispatched to transport the remaining passengers back to the terminal building.

1.16 Tests and Research

1.16.1 Left Engine

Field examination of the left engine indicated that an uncontained failure of the thirteenth stage high pressure compressor disc had occurred. Examination of the failed disc disclosed areas of fatigue cracking. As a result of these observations, extensive tests and research were undertaken to identify the cause of the fatigue cracking. The tests and research were conducted over a period of many months at the CASB Engineering Laboratory in Ottawa, the National Research Council facilities in Ottawa, and at Pratt & Whitney in East Hartford, Connecticut, U.S.A.

Initial examination of the failed disc at the CASB Engineering Laboratory determined that the disc failure had occurred through the release of a 20-blade segment of the rim outboard of the rear snap between tie-bolt holes 7 and 10 (See Appendix E, Figures 1 and 2). The snap is commonly referred to by the manufacturer as the machined surface which forms the mating point between the disc and adjacent engine components. Continuity of scrape and other markings across the two fragments indicated that the sections had separated in a single piece and had broken in two during penetration through the engine containment. Examination determined the presence of half-moon-shaped fatigue cracks (See Appendix F, Figures 3 and 4, Appendix G, Figures 5 and 6) emanating from the snap radius on the rear face of the disc which were approximately equal in size and were characterized by well-defined crack progression markings typical of a fatigue mode of formation. Further laboratory examination of the remainder of the rear snap disclosed another circumferential fatigue crack (See Appendix H, Figure 7) which was exposed and found to exhibit a similar failure mode to the crack surfaces of the released rim. Fatigue cracking was also identified at 6 of the 12 tie-bolt holes.

Extensive scanning electron microscope (SEM) examinations were conducted on all fracture surfaces. The examination revealed micro-striations consistent with a fatigue mode of failure in all regions of the cracks. The spacings and appearance of the striations were found to vary widely with location. Two populations of striations could be identified for the initial stages of cracking, consisting of a background structure of fine striations with a superimposed pattern of coarser striations.

The fracture surfaces were also subjected to transmission electron microscope (TEM) examination at the National Aeronautical Establishment of the National Research Council. The TEM examination confirmed the same discontinuous nature and distribution of the fatigue striations.

The fatigue cracks were examined extensively for possible causes of initiation. Examination of the region of origin in the rear snap disclosed the existence of a feedline, resulting from the failure of the radius to blend smoothly with the rear face of the disc. The location of this feedline was coincident with the position of crack initiation. Further examination determined that the feedline resulted in a snap radius dimension that did not fully conform to blueprint requirements.

Metallographic examination of sections through the disc at the rear snap revealed no evidence of microstructural deficiencies or abnormalities other than the feedline.

Metallographic examination of the disc sections and energy dispersive x-ray analysis revealed the material was in a condition consistent with Pratt & Whitney specifications. A review of Pratt & Whitney data indicated that the disc conformed to specifications with respect to tensile strength, yield strength, elongation, and reduction of area requirements.

As a result of this detailed examination of the failed disc, investigators concluded that the failure was the result of high-cycle fatigue crack initiation and propagation in the snap, with a superimposed low-cycle event, which was responsible for the observed coarse striations. The driving force was considered to be an unidentified engine resonance condition.

Following the examination at the CASB Engineering Laboratory, the disc and engine were shipped to Pratt & Whitney in East Hartford, Connecticut, where further tests and examinations were conducted under the control of the CASB.

During their examination, Pratt & Whitney noted the following conditions:

a) an absence of hard face material on the twelfth and thirteenth stage stator snaps;
b) the thirteenth stage stator inner shroud mounting flange was .021 to .027 inches under minimum thickness;
c) the presence of similar characteristic fatigue cracks in the thirteenth stage disc and thirteenth stage stator; and
d) the front lip was missing from the thirteenth stage stator inner shroud.

It was their conclusion that these conditions represented fit and clearance deficiencies between the rotating and stationary components of the thirteenth stage, sufficient to result in the transmission of vibratory stress to the thirteenth stage disc because of rotor-stator coincidence.

Pratt & Whitney also noted cracking in other engine components, including the seventh to twelfth stage stators and the diffuser case. These cracks were considered to be secondary and not associated with the vibratory stress.

The disc failure was considered by Pratt & Whitney to be related to the earlier disc cracking problems experienced in 1967. They concluded that the observed conditions noted above had created vibratory conditions which Pratt & Whitney had previously rectified by the changes in engine-build specifications and redesign of the disc. In this case, the specific vibration identified was, according to Pratt & Whitney, the one occurring at low power settings.

Conditions that induced the vibration were, in Pratt & Whitney's opinion, introduced by incorrect rework procedures during engine overhaul.

Following the examinations conducted at Pratt & Whitney, the engine and failed disc were returned to the CASB Engineering Laboratory in Ottawa, where further examinations were conducted to evaluate the Pratt & Whitney observations and conclusions.

Board investigators confirmed the hardware deficiencies noted by Pratt & Whitney. Also observed during this investigation was evidence of high-cycle fatigue cracking in the diffuser case similar to that found in the thirteenth stator and disc.

Investigators determined that the absence of hard face material on the twelfth stage stator was the result of incorrect processing at the last stator overhaul. By reviewing overhaul records, it was determined that up to 50 other stators had been similarly processed. With respect to the absence of hard face on the thirteenth stage stator, investigators were unable to trace the overhaul history completely. The deficiencies in the thirteenth stage inner shroud were attributed to non-prescribed repair procedures and dimensional changes, which originated during the last overhaul.

Additional examinations of the left engine were conducted by representatives of PWA following completion of the final examination by the CASB Engineering Laboratory in Ottawa. Particular attention was directed towards explaining the involvement of the diffuser case which was of a configuration not commonly found in a JT8D engine. PWA hypothesised that case cracking from defective welds on the doubler strengthening elements of the original thin wall case brought about a change in the vibration characteristics of the case, allowing a contribution to the thirteenth stage rotor-stator coincidence. PWA further hypothesised that the coincidence which caused the disc cracking occurred during an engine transient in the high power range, but was itself transitory, and ceased to function as further cracking of the diffuser case occurred. The latter was used to explain the apparent change in fracture mode from high- to low-cycle fatigue in the disc cracks.

1.17 Additional Information

1.17.1 Flight Crew Emergency and Abnormal Procedures

Section Two of the Pacific Western Airlines Boeing 737 Operations Manual contains procedures to be followed in the event of an emergency or abnormality. Published procedures include rejected take-off and engine-fire-on-the-ground (See Appendix I).

The rejected take-off procedure is used when an engine failure, fire or take-off warning is recognized before take-off decision speed is reached. The final action of this procedure is to stop the aircraft and evaluate the problem. If conditions permit, the aircraft may be taxied clear of the runway.

The engine-fire-on-the-ground procedure is to be performed simultaneously by the captain and the first officer from memory. The initial action of this procedure is to close the thrust levers, followed by setting the parking brake. The procedure ends in an evacuation of the aircraft.

1.17.2 Passenger Profile

Flight 501 was a PWA "Airbus" flight operating between Calgary and Edmonton Municipal Airport. PWA operates a daily series of Airbus flights on a high frequency basis between the two cities. The flights cater to a large extent to business travellers and offer time-saving features such as a "quick-ticket" system.

During the course of the investigation, over 75 passengers from the flight were interviewed by investigation team members. Almost all stated that they were travelling for business purposes and were regular travellers on the B737 aircraft. There were no young children or elderly persons aboard this flight. With the exception of one woman who required crutches, none of the passengers reported physical handicaps.

1.17.3 PWA Ticketing Procedures

Some passengers on this flight had utilized PWA's quick-ticket system, whereby they write their own ticket and a reservation is not recorded in the computer. The only record for manifest purposes is the ticket coupon which is handed in to the passenger agent when boarding. When these tickets were returned to the passengers following the accident, there was no longer any record of their presence on the flight. Because of this, PWA encountered great difficulty in providing a complete passenger manifest for the flight. An initial list included only 92 of the 114 passengers on board. This list was later updated to include 96 passengers. It was several weeks before PWA was able to provide a complete passenger list. This list was based on baggage claims and other claims for loss of personal effects.

1.17.4 Runway Sweeping

Shortly after the accident, air traffic control closed the airport to aircraft traffic because of the large number of ground vehicles operating on airport surfaces in response to the emergency. A blanket clearance was issued to all ground vehicles to operate anywhere on the airport. This blanket clearance was inadvertently interpreted by some airport personnel as permission to allow airport maintenance vehicles (sweepers) to clean debris from runway 34. Before action was taken to suspend the sweeping, the centre 100 feet of the runway had been cleared of debris without the authorization of safety investigators.

Air regulations in effect at the time prohibited interfering with or disturbing such debris, without the authorization of a safety investigator.

1.17.5 Other Uncontained Engine Failures

There have been a number of uncontained engine failures that have resulted in serious aviation occurrences. Some examples follow. On 30 August 1984, a Cameroon Airlines, Boeing 737, experienced an uncontained engine failure while taxiing for take-off at Douala, Cameroon. In this case, portions of the seventh stage compressor disc of the right engine separated and penetrated the number two fuel tank inboard of the engine. A serious fire ensued which destroyed the aircraft and resulted in fatalities to passengers.

On 22 August 1985, a British Airtours, Boeing 737, experienced an uncontained engine failure during take-off at Manchester, United Kingdom. In this case, a portion of the combustion chamber was ejected from the left engine and penetrated a number one fuel tank access door outboard of the engine. A serious fire ensued, which destroyed the aircraft and resulted in 55 fatalities.

On 15 September 1979, an Iberia International Airlines, Douglas DC-9 experienced an uncontained failure of the right engine at 20,000 feet, during climb-out from Madrid, Spain. Debris from the engine compressor section penetrated the rear fuselage, depressurizing the cabin and severing a fuel line and wiring bundle, damaging components of the flight control system. An uncontrolled descent resulted from which the pilot recovered at 14,000 feet. The flight returned successfully to Madrid.

2.0 ANALYSIS

The investigation was principally concerned with establishing the cause of the engine failure. Other areas examined were the rapid propagation of fire and the emergency response of the flight crew, cabin crew, and airport personnel.

2.1 Engine Failure

Field examination of the engine established that an uncontained failure of the thirteenth stage high pressure compressor disc initiated the engine failure and subsequent fire. Examination of the failed disc showed the presence of extensive fatigue cracking emanating from the snap radius on the rear face of the disc. Fatigue cracking was also present at the tie-bolt holes of the disc. These cracks had progressed significantly, resulting in release of a segment of the disc during the take-off roll. The released segment penetrated the engine casing and ruptured the wing inboard fuel cell adjacent to the engine.

2.1.1 Fatigue Crack Initiation

Examination of the fractures indicated that crack initiation and early propagation was the result of high-cycle fatigue. The observed superimposed pattern of coarser striations is indicative of concurrent occurrence of lower cycle fatigue.

This conjoint action of high-cycle and low-cycle fatigue continued over approximately 70 to 80 per cent of the pre-crack depth, at which time an abrupt transition to a wholly low-cycle fatigue mode occurred, which persisted to the point of instantaneous overload.

Release of the segment of the disc occurred through the overload extension of the pre-crack at the number eight tie-bolt hole and subsequent linking with the two largest cracks in the snap diameter.

Consideration was given to the possibility that fatigue cracking was initiated by the presence of a geometrical stress concentration caused by the feedline. Although it was determined that the geometry of the feedline did not fully conform with blueprint requirements, it could not be considered the initiator of the disc fracture. The apparently concurrent initiation of fatigue at the snap and tie-bolt holes counters any theory of fatigue crack initiation based solely on such a stress concentration. In addition, stress analyses provided by Pratt & Whitney showed that such a feedline could be accommodated without compromise of a low-cycle fatigue service life in excess of 20,000 cycles. Similar feedlines have been identified in discs of the same manufacture with varying service lifes, including time-expired discs. None have displayed any signs of fatigue cracking. The feedline would, however, be expected to serve as a stress raiser and site for fatigue propagation in the presence of conditions necessary to initiate fatigue.

Investigators also considered the possibility that previous engine events such as the bird strike or compressor stall were fatigue precursors. However, examination revealed no evidence of microstructural deficiencies or fracture surface anomalies which pre-dated the fatigue.

The nature of the fatigue crack initiation at the tie-bolt holes could not be clearly established. It was noted that the fatigue was associated with regions of light fretting on the surface of the disc at the tie-bolt holes. This fretting could be induced by vibration between the disc and the number four hub shaft front flange.

It proved impossible to correlate the various types of fatigue striations on the fractured surfaces with the various cyclic stress conditions that may have led to the fatigue failure of the disc. As a result, it was not possible to determine precisely at what point in the disc life fatigue cracking originated. However, analysis showed that fatigue initiation was an event of comparatively recent origin in the life of the disc. It was concluded that high-cycle fatigue originated from a particular engine condition, which developed progressively in the life of the engine.

The Board is in general agreement with Pratt & Whitney's contention that an engine vibration was responsible for the initiation and propagation of high-cycle fatigue in the disc. Further, the Board also supports Pratt & Whitney's contention that deficiencies introduced at the last overhaul were contributory. However, it does not consider the evidence conclusive with respect to the precise mechanism of the failure and considers that all contributing factors have not been identified. Pratt & Whitney attributed the vibratory stress to rotor-stator coincidence caused by deficiencies in fit and clearances between rotating and stationary components of the thirteenth stage. Parallels were drawn between this coincidence and that experienced in JT8D engines in 1967. It is the opinion of the Board that the deficiencies in fit and clearances identified by Pratt & Whitney are not unique to this engine and may be more common than envisaged by Pratt & Whitney. Specifically, it was determined that the observed absence of hard face material on the twelfth and thirteenth stage stators is a condition common to a number of other engines. As a result, the Board does not consider that this condition is sufficient to explain the failure. Furthermore, the presence of fatigue cracking of the diffuser case, similar to that found in the disc and stator, would indicate a diffuser case involvement in the vibratory stresses of the rotating and stationary hardware of the engine, which was not addressed in the Pratt & Whitney analysis and conclusion.

The specific role played by the diffuser case could not be identified. Although PWA developed one particular hypothesis, it is the opinion of the Board that this hypothesis is not supported by sufficient evidence to be considered conclusive.

As a result, and in spite of the extensive examinations and analysis, the Board can only conclude that the fatigue cracking of the disc occurred from an unidentified combination of factors which developed progressively over an unknown period of time, following the last major overhaul, and which may have been unique to this engine.

2.2 Engine Containment

The Board recognizes that present aircraft certification requirements for turbine engines do not demand that failed discs be prevented from penetrating the engine walls. However, as evidenced by the circumstances of this occurrence and the other occurrences noted, failed components that exit the engine can present a serious hazard to aircraft structure. In Boeing 737 aircraft and others with wing-mounted engines, the proximity of the engines to the wing fuel tanks presents the potential for a serious fire in the event of an uncontained engine failure. As evidenced by the Iberia DC-9 occurrence, the hazards associated with uncontained engine failure are not unique to aircraft with wing-mounted engines or solely associated with the occurrence of fire.

2.3 Fire Initiation and Propagation

Analysis of the exact progression of the fire involved in this accident was difficult due to the extent of fire damage that occurred after the aircraft had been stopped and evacuated. The intensity and extent of the pre-evacuation fire were largely assessed using eye-witness statements.

The only source of fuel that was initially available for the fire was the fuel that was escaping from the hole in the inboard lower surface of the left wing, caused by the penetration of a piece of thirteenth stage compressor disc. No other fuel or hydraulic lines were found to have been ruptured by the engine failure. Witness statements show that ignition of the leaking fuel was instantaneous. It is likely that the fuel was ignited by sparks from the still rotating high pressure compressor. The burning fuel would have resulted in flames trailing back and impinging upon the inboard flaps. The fuselage was not penetrated by flame until about the time the evacuation commenced. The escaping fuel poured onto the taxiway and pooled under the wing centre section and fuselage just aft of the wing. The result was an intense fire which penetrated the cabin.

Fire-fighters were unable to extinguish the fire, because of the location of the hole in the lower wing skin. The foam cannons used were mounted on the top of the foam trucks, making it impossible to get low enough to hit the main source of the fuel and knock down the flames at that point. The fire therefore continued until the left wing fuel cells were almost completely empty.

2.4 Crew Response

2.4.1 Flight Crew

The flight crew responded promptly to the abnormality during the take-off. A rejected take-off was initiated within one second of the crew's hearing the bang which accompanied the failure of the compressor disc. The aircraft was brought to taxiing speed within ten seconds of the initiation of the rejected take-off. After reducing speed, the captain continued to taxi while he and the first officer assessed the situation. Other members of the crew also tried to assess the nature of the emergency and communicate with the flight crew.

The first cockpit indication of an emergency was a fire warning bell which rang very briefly (less than one second) 51 seconds after the failure of the thirteenth stage disc. This warning occurred simultaneously with the sounding of the cabin call chime and during an exchange between the captain and the purser. The purser, after getting the flight crew to unlock the flight deck door, had entered the flight deck three seconds earlier to inform the captain that there was a fire "on the back of the wing." Before giving this critical message, the purser asked if they had blown a tire.

Fifty-six seconds after the disc failure, Flight 501 requested the tower to confirm the existence of a fire. The tower then confirmed that there was "considerable amount off the back - on the left side engine, and it's starting to diminish there. There's a fire going on the left side." Twenty-five seconds after first being informed of the fire, the crew advised that they were stopping the aircraft. Twenty seconds later, 1 minute 55 seconds after rejecting the take-off, the aircraft was stopped, and the evacuation commenced.

The rejected take-off procedure specified in the B737 Operations Manual requires that the aircraft be brought to a full stop when a take-off is rejected.

It is recognized that there is a need to assess a situation before deciding an emergency action. However, in this case, the time taken to stop the aircraft was excessive given the knowledge that fire existed. This delay in stopping the aircraft and initiating the evacuation could have jeopardized its success.

Investigation of previous aircraft fires on the ground had reaffirmed the importance of stopping a fire-stricken aircraft and evacuating the passengers and crew as soon as possible.

2.4.2 Communications

The captain's decision to continue taxiing and the delay in initiating evacuation procedures were due to a lack of awareness of the seriousness of the fire. One minute elapsed before the flight crew was fully aware of the fire. Without directly observing the fire and because of the initial absence of observed cockpit indications, the flight crew relied on the cabin crew and the air traffic controller for information about the fire. The tower controller who observed the fire did not report it to the crew until he was asked for confirmation.

A flight attendant at the rear of the aircraft was aware of the fire approximately 40 seconds before the flight crew. Two flight attendants at the front of the aircraft were aware of the fire 25 seconds before the flight crew.

As required by published procedures for a rejected take-off, the three flight attendants remained in their seats awaiting instructions from the captain. Further, because the aircraft continued to taxi, all initially assumed that the captain was aware of the situation and that it was under control. When the flight attendants observed the fire increasing in magnitude while the aircraft continued to taxi, they attempted to contact the flight crew. However, these attempts were delayed by the locked flight deck door and the crew's not answering the service interphone. In all, 48 seconds elapsed from the time of the disc failure until the purser was able to relay the first information about the fire to the captain.

The 48-second delay in the receipt of information on the fire's existence is indicative of inadequate communication procedures and coordination between the cabin and flight deck. Further, Transport Canada procedures in effect at the time of the occurrence did not require air traffic controllers to advise aircraft of an observed fire.

2.4.3 Published Emergency Procedures and Training

In their efforts to assess the emergency, the flight crew relied heavily on cockpit indications of a fire. Positive action in response to the fire did not take place until after the fire warning activated. This can, in part, be traced to published emergency procedures and training. The emergency procedures to be followed in the event of a fire published in the B737 airplane flight manual and the Pacific Western Airlines B737 Operations Manual, approved by Transport Canada, are predicated exclusively on the activation of fire warning systems and resulting cockpit indications. Similarly, recurrent simulator training uses cockpit indications when simulating emergency situations with respect to fire. Neither published procedures, nor simulator training give consideration to those fires which do not immediately activate the engine, auxiliary power unit, cargo compartment, or wheel well fire warning systems. There is no published general fire procedure, nor is this condition simulated during recurrent training by alerting the crew to fire through means other than the various fire detection systems. Given the circumstances of this accident, it is concluded that published emergency procedures and training provide inadequate guidance for response to general aircraft fires.

2.5 Passenger Evacuation

One hundred fourteen passengers and five crew members successfully evacuated the aircraft. Despite the severity of the fire, there was no loss of life. By all accounts, once begun, the evacuation progressed without significant problems.

The PA system was not used for a general announcement of evacuation, although it had been used earlier by the number three flight attendant to direct the passengers to stay seated and remain calm. When the aircraft stopped, the three flight attendants initiated evacuation by opening their doors and inflating the escape slides. In addition, evacuation commands were given to passengers as they exited the aircraft. In addition to the three doors opened by the flight attendants, the right over-wing exit was opened by a passenger seated next to it at the urging of several passengers seated nearby.

Passengers, observing the fire and the flight attendants opening the doors, began to move towards the exits. Some of the first passengers to arrive at the doors had to await inflation of the escape slides. Hence, the lack of a specific general command on the PA to evacuate the aircraft did not delay evacuation, but such a command would have provided clear direction to all.

Almost all the passengers were frequent air travellers familiar with the Boeing 737. This contributed to the success of the evacuation. Although not directly related to this occurrence, other safety considerations merit discussion in this analysis. Had there been a different mix of passengers, it is probable that the evacuation would not have progressed as smoothly as it did and would have resulted in a significant extension of the time taken to evacuate the aircraft. Studies indicate that in the absence of command, some passengers will remain seated and await orders. Had a number of young children, physically handicapped or elderly passengers been on board, it is likely that the evacuation time would have been further extended. It is also possible to assume that other, less familiar passengers would not have opened the over-wing exit without supervision or command of a flight attendant. It is estimated that about 40 passengers exited via the over-wing exit. Had this exit not been available for use or not been available until later in the evacuation sequence, the evacuation time would have been significantly increased.

The evacuation was completed with little time to spare. Passengers stated that the cabin environment deteriorated rapidly after the doors and over-wing exit were opened. Those passengers who were among the last to exit stated that the thick smoke made visual identification of exit locations extremely difficult. Had any further delays in the evacuation occurred, increasing quantities of smoke and toxic gases would have made evacuation procedures more difficult to execute and complete. These difficulties would have significantly limited the success of the evacuation. Based on passenger descriptions of the cabin conditions and the steady progress of the fire, it is evident that the cabin environment was rapidly becoming non-survivable.

Delays in the evacuation could also have limited the number of exits available. The rear slide deflated almost immediately after the number two flight attendant left the aircraft. Had passengers still been aboard the aircraft when the slide deflated, it would have been necessary for them to move forward either to the over-wing exit or to the exits at the front of the cabin. This would have resulted in confusion and further delay and would likely have jeopardized the safe evacuation of the passengers.

2.6 Airport Response

CFR services responded immediately and began arriving at the accident scene about two minutes after notification.

In accordance with their primary objective, fire-fighters attempted to control the fire and provide fire-free escape routes for evacuees. Because the initial position of the fire vehicles did not provide unrestricted access to the source of the fire, initial attempts to extinguish the fire were ineffective. Fire control attempts were further impeded when a fire vehicle became mired in the soft ground. As a result, time and fire extinguishing agent were lost, and it proved impossible to extinguish the fire before the foam trucks had expended all their agent. Had the mobility problem not occurred, the fire crews reported that it is likely the fire would have been extinguished before truck replenishment was required, and the damage to the aircraft would have been significantly reduced. Despite the difficulties and delays encountered in extinguishing the fire, the primary objective was accomplished. Initial control of the fire was sufficient to keep the emergency exits and escape routes clear of the fire, thus assisting in a successful evacuation.

The difficulty experienced by the CFR vehicles traversing the soft, wet terrain does illustrate a potential problem area. Had the circumstances of this accident been different and had the aircraft not come to rest on a paved surface of the airport, the capability of the CFR services to accomplish their primary objective could have been severely hampered. Previous accidents (e.g., Cranbrook, British Columbia, 11 February 1978) have highlighted the problems of CFR vehicle mobility in various terrain and climatic conditions.

Although inadvertent, the sweeping of the runway following the occurrence was not in accordance with regulations in force at the time. In this case, the disturbance of the wreckage did not have any adverse effect on the investigation. However, it is indicative of a breakdown in coordination and communication amongst various airport personnel and, under different circumstances, could have serious ramifications for an investigation.

The lack of airport response procedures dealing with emergency evacuations resulted in insufficient control being exercised over the passengers who had evacuated the aircraft. This lack of control enabled passengers to make their own way back to various areas of the terminal across the active surfaces of the airport, thus creating a potential hazard between pedestrians, vehicles, and other aircraft. The departure of passengers also prevented the taking of an accurate head count, and it was not known if all passengers had evacuated the aircraft until a final search of the aircraft was conducted after the fire had been extinguished.

3.0 FINDINGS

3.1 Cause-Related Findings

1. An uncontained rupture of the left engine thirteenth stage compressor disc occurred approximately 1,300 feet into the take-off roll.

2. Failure of the disc was the result of fatigue cracking at three main locations in the rear snap and adjacent to 6 of the 12 tie-bolt holes.

3. Fatigue cracking initiated as a result of an unidentified combination of factors which developed progressively over an undefined period of time, following the last major overhaul in May 1981.

4. Some stator repair procedures carried out at the last major overhaul were not in accordance with the provisions of the Pratt & Whitney JT8D engine overhaul manual; as a result, deficiencies in the thirteenth stage stator assembly occurred.

5. The ruptured piece of the compressor disc exited the engine and penetrated the left lower inboard wing skin, puncturing a fuel cell.

6. Fuel leaking from the punctured fuel cell was ignited instantaneously.

7. The fuel-fed fire increased in size and engulfed the left wing and aft section of the aircraft.

3.2 Other Findings

1. The flight crew reacted promptly to the abnormality in the take-off run by initiating a rejected take-off.

2. The aircraft was not brought to a stop in accordance with the published rejected take-off procedure.

3. Communication and coordination between the cabin and the flight deck did not result in an early appreciation of the problem and resulted in a significant delay before the flight crew was aware of the existence and seriousness of the fire.

4. Air traffic services personnel were immediately aware of the fire but did not immediately inform the flight crew.

5. The flight crew relied excessively on the cockpit fire warning indicators to confirm the existence of fire.

6. Published emergency procedures and training did not provide adequate guidance in the event of a general aircraft fire.

7. Once aware of the fire, the flight crew did not immediately take appropriate emergency action.

8. All 114 passengers and 5 crew members successfully evacuated the aircraft.

9. No specific command to evacuate the aircraft was given.

10. Some passengers initiated an evacuation through the right over-wing exit.

11. Most passengers were regular travellers, familiar with the Boeing 737; this contributed to the success of the evacuation.

12. The last passengers to evacuate the aircraft evacuated at about the last possible moment.

13. The aircraft was not brought to a stop on the runway, thereby limiting the paved manoeuvring space available for the Crash Firefighting and Rescue vehicles.

14. Crash Firefighting and Rescue services were hampered by the difficulty encountered by a vehicle traversing the soft, wet terrain.

15. Calgary International Airport Emergency Procedures did not contain procedures for the exercise of control over passengers being evacuated onto the airport infield.

16. Debris from the accident aircraft was cleared from the runway by airport personnel without the required authorization from safety investigators.

17. The aircraft crew was certified and qualified for the flight in accordance with existing regulations.

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

19. The aircraft's weight and centre of gravity were within the prescribed limits.

4.0 SAFETY ACTION

4.1 Action Taken

The Canadian Aviation Safety Board (CASB) notes that as a result of this occurrence, the air carrier has taken the following corrective action with respect to its Boeing 737 emergency and standard operating procedures:

a) Pacific Western Airlines has instituted combined recurrent emergency procedures training for flight and cabin crews in order to improve total crew coordination during emergencies;

b) Modifications to the service interphone system and cabin to cockpit call lights are underway to allow direct and immediate communication between the flight and cabin crew; and

c) Emergency procedures training now emphasizes the need to stop the aircraft immediately and determine the cause of the rejected take-off. For fires-on-the-ground, training puts greater emphasis on visual inspection by opening the cockpit window and by soliciting information from any and all sources.

4.2 Action Required

4.2.1 Quality Control of Engine Overhaul Procedures

The CASB notes the manufacturer's findings that a higher than normal vibratory stress in the accident engine was produced by coincidence between the thirteenth stage compressor rotor and stator. The excessive stress can be partly attributed to the loss of damping caused by a loose outer snap fit between the twelfth and thirteenth stators.

The undersized mounting flange on the thirteenth stage inner shroud and the reduction in height of the front lip of the inner shroud were also found to be contributory to the condition. A combination of these and other unidentified factors resulted in the formation of the high-cycle fatigue cracks which propagated until the eventual failure of the thirteenth stage compressor disc.

The CASB is aware that the failure of the thirteenth stage compressor disc in the accident engine is the first such occurrence since the disc design was modified in 1968 to correct previously identified vibratory stress problems. Furthermore, the CASB recognizes that the circumstances that led to this occurrence may well have been unique to the accident engine.

Nevertheless, the CASB believes that deficiencies in quality control during engine overhaul allowed critical engine components that did not meet the manufacturer's specifications to be re-entered into service. Therefore, the CASB recommends that:

> The Department of Transport take the necessary steps to ensure that critical Pratt & Whitney JT8D engine components fully comply with manufacturer's specifications during reassembly at any overhaul facility.
>
> CASB 87-01

4.2.2 Response to Emergencies

The Board believes that reaction to critical emergencies which require an immediate response, during the take-off phase of flight for example, should seldom be dependent upon judgement. Airlines have long recognized that emergency procedures based upon standard and pre-conditioned responses ensure the greatest probability of correct reaction to a specific emergency.

This occurrence highlights the need for immediate and aggressive action to ensure that the aircraft is stopped and passengers and crew are evacuated as quickly as possible during an aircraft-on-the-ground fire. Effective coordination and exchange of information between the cockpit and cabin crew, air traffic services personnel, and the CFR service is necessary to ensure that lives and property are exposed to minimal risk.

The CASB wishes to underline the requirement for all cockpit and cabin crew, air traffic services, and airport personnel to be trained to the point where they respond promptly to an emergency, such as an aircraft fire, in accordance with pre-established and practised procedures.

4.2.2.1 Air Traffic Services Response During an Emergency

The Air Traffic Control Manual of Operations (MANOPS) does not specifically require air traffic services personnel to advise flight crew as soon as an aircraft fire is observed. Nor is there reference made in air traffic services plans and procedures to the fact that notification of flight crews by air traffic services personnel may save valuable seconds in stopping burning aircraft on the ground as quickly as possible. MANOPS provides general guidance to controllers regarding the need to ensure that flight crews are apprised of conditions that may affect the safety of flight; however, specific direction is not given as to the critical nature of emergencies during the take-off phase of flight. Consequently, the CASB recommends that:

> The Department of Transport revise its training syllabus, procedures, and Air Traffic Control Manual of Operations (MANOPS) to require that air traffic services personnel take immediate action to inform the pilots of an aircraft of any observed condition that may adversely affect that aircraft's safety, such as a fire.
>
> CASB 87-02

4.2.2.2 Cockpit/Cabin Crew Response to an Emergency

The flight crew of Pacific Western Airlines, Flight 501, rejected the take-off immediately upon hearing the loud bang emanating from the left side of the aircraft. Having observed no indications to the contrary, they proceeded in the incorrect belief that a blown tire was the source of the loud bang. The flight crew reacted immediately and correctly to the emergency during the take-off roll by rejecting the take-off; however, after decelerating to taxiing speed, the flight crew did not stop the aircraft and determine the cause of the loud bang.

Air traffic services personnel did not immediately advise Flight 501 of the fire's existence, as it was assumed that the flight crew were aware of the fire. The cabin crew were not able to immediately contact the flight crew, either directly or via the service interphone, and advise that a fire was under the left wing. When the flight crew were apprised of the existence of the fire, the information conflicted with their initial assumption that a tire had blown. The resolution of this conflict resulted in further delay in stopping the aircraft and commencing an evacuation.

The CASB believes that this occurrence highlights deficiencies in cockpit crew response to an aircraft-on-the-ground emergency; cockpit crew/cabin crew coordination during an emergency; cockpit crew/air traffic services coordination; and the service interphone system. The deficiencies in cockpit crew, cabin crew, and air traffic services coordination may be attributable in part to a lack of consultation between these three groups during the development of emergency procedures. As a consequence, the CASB recommends that:

> The Department of Transport require that aircraft-on-the-ground emergency procedures and training emphasize the need to stop an aircraft immediately and determine the nature of the emergency;
>
> CASB 87-03

The Department of Transport require that emergency procedures and training incorporate coordinated responses by the total crew complement; and

CASB 87-04

The Department of Transport require that transport category aircraft have a means for the cabin crew to alert the cockpit crew directly and immediately of any critical on-board emergency.

CASB 87-05

4.2.2.3 Emergency Fire Procedure

The flight crew's inability to quickly assess the true nature of the emergency and the consequent need to stop and evacuate the aircraft can be partly attributed to the fact that the flight crew was unable to recognize that the aircraft was on fire. Without the engine, auxiliary power unit (APU), or cargo passenger compartment fire or smoke alarms being activated, the cockpit crew had difficulty accepting the delayed information provided by the purser and air traffic services personnel that a fire was underway. Existing emergency procedures, reinforced through simulator and recurrent training, are based on the premise that aircraft sensors will first signal a fire warning. Clearly, critical fires can occur which will not be promptly detected by on-board sensors. In the accident aircraft, a fuel-fed wing fire was not apparent to the flight crew until the fire was well underway. Therefore, the CASB recommends that:

The Department of Transport require that emergency procedures be implemented for those fires which do not immediately activate on-board fire or smoke detection systems.

CASB 87-06

4.2.3 Hazard of Failed Engine Components to Aircraft Structure

The CASB recognizes that, under present certification requirements, turbine engines are not required to contain failed discs. Nevertheless, failed engine components that exit an engine constitute an extreme hazard to the aircraft structure. In the Boeing 737 and other aircraft with wing-mounted engines, the proximity of the engines to the wing fuel tanks presents a critical situation during uncontained engine failure, as witnessed by this and other occurrences. In addition, the Iberia International Airlines, Douglas DC-9 occurrence at Madrid, Spain on 15 September 1979 shows that the hazards associated with uncontained engine failures are not unique to aircraft with wing-mounted engines or solely associated with the presence of fire. As a result, the CASB recommends that:

> The Department of Transport review current aircraft design criteria with the long-term objective of reducing or eliminating the hazard of uncontained engine components compromising the airworthiness of the aircraft.
>
> CASB 87-07

4.2.4 Calgary International Airport Disaster Plan

Although the Calgary International Airport Disaster Response Plan was developed in accordance with the Department of Transport's Standards for Plans and Procedures for Airport Emergencies, the possibility of a large number of survivors of an on-the-field aircraft accident was not foreseen. The lack of coordination, control, and transport of the survivors not requiring medical attention resulted in passengers departing the airport terminal prior to a complete survivor list being compiled.

In order to minimize the possibility of a recurrence, the CASB recommends that:

> The Department of Transport revise its Standards for Plans and Procedures for Airport Emergencies to ensure that the control of survivors of on-the-field aircraft accidents is sufficient and enables the timely and accurate compilation of survivor lists and details as to where survivors can be located.
>
> CASB 87-08

Furthermore, debris from the accident aircraft was cleared from the runway by airport authorities without the consent of the investigator-in-charge. The CASB recognizes the need to return runways to operational service in as timely a manner as possible, in order to minimize the impact upon air traffic. However, from an accident investigator's perspective, it is essential that aircraft wreckage remain undisturbed to allow the gathering of the maximum possible evidence about the contributing factors and causes of the accident. Therefore, the CASB recommends that:

> The Department of Transport revise its Standards for Plans and Procedures for Airport Emergencies to take into account section 7 of the CASB Regulations and require authorization by the CASB investigator-in-charge prior to the accident runway being cleared and returned to operational service.
>
> CASB 87-09

4.3 Other Safety Concerns

4.3.1 Crash Firefighting and Rescue Vehicles Suitable for Canadian Environmental Conditions

Conventionally wheeled CFR vehicles are constrained in their ability to manoeuvre on soft or unprepared terrain. The CASB notes that the Department of Transport received Treasury Board approval in September 1983 to acquire six all-terrain CFR vehicles (for use at Edmonton, Calgary, Winnipeg, Dorval, Halifax, and Gander) in addition to the three presently in use at the Toronto/Lester B. Pearson, Mirabel, and Vancouver International Airports. It is understood that the first of the six all-terrain CFR vehicles will be available for service by mid 1987. Treasury Board approval has also been received for the acquisition of 68 rapid intervention all-terrain CFR vehicles for use at airports across Canada.

The CASB supports this improvement in all-terrain CFR capability. Since Canada is a world leader in the development of large all-terrain vehicles, the CASB encourages further efforts by the Department of Transport to develop even better all-terrain vehicles to meet Canadian environmental conditions - particularly with respect to load-carrying capability and manoeuvrability.

4.3.2 Cabin Safety

Fires that occur in transport category aircraft continue to provide graphic proof of their swift and catastrophic effect on passengers and crews. The CASB notes that much effort has been expended over the years to improve cabin safety in transport category aircraft, particularly, the recent revisions to Air Navigation Orders (ANO) Series II, Nos. 28, 29, and 30, requiring the installation of fire-blocking materials, floor proximity emergency escape path marking and HALON fire extinguishers in passenger compartments of transport category aircraft. These revisions to the ANOs were signed by the Minister of Transport on 06 June 1986, and compliance is required by 31 December 1988.

While the CASB commends these much-needed advances, fire-related occurrences such as this one confirm the need for further effort. Toxic gases generated by synthetic materials used in aircraft cabins quickly create a lethal environment for passengers and crew of a burning aircraft. Additionally, dense smoke in the cabin reduces visibility and limits survivors' ability to quickly select the best escape route.

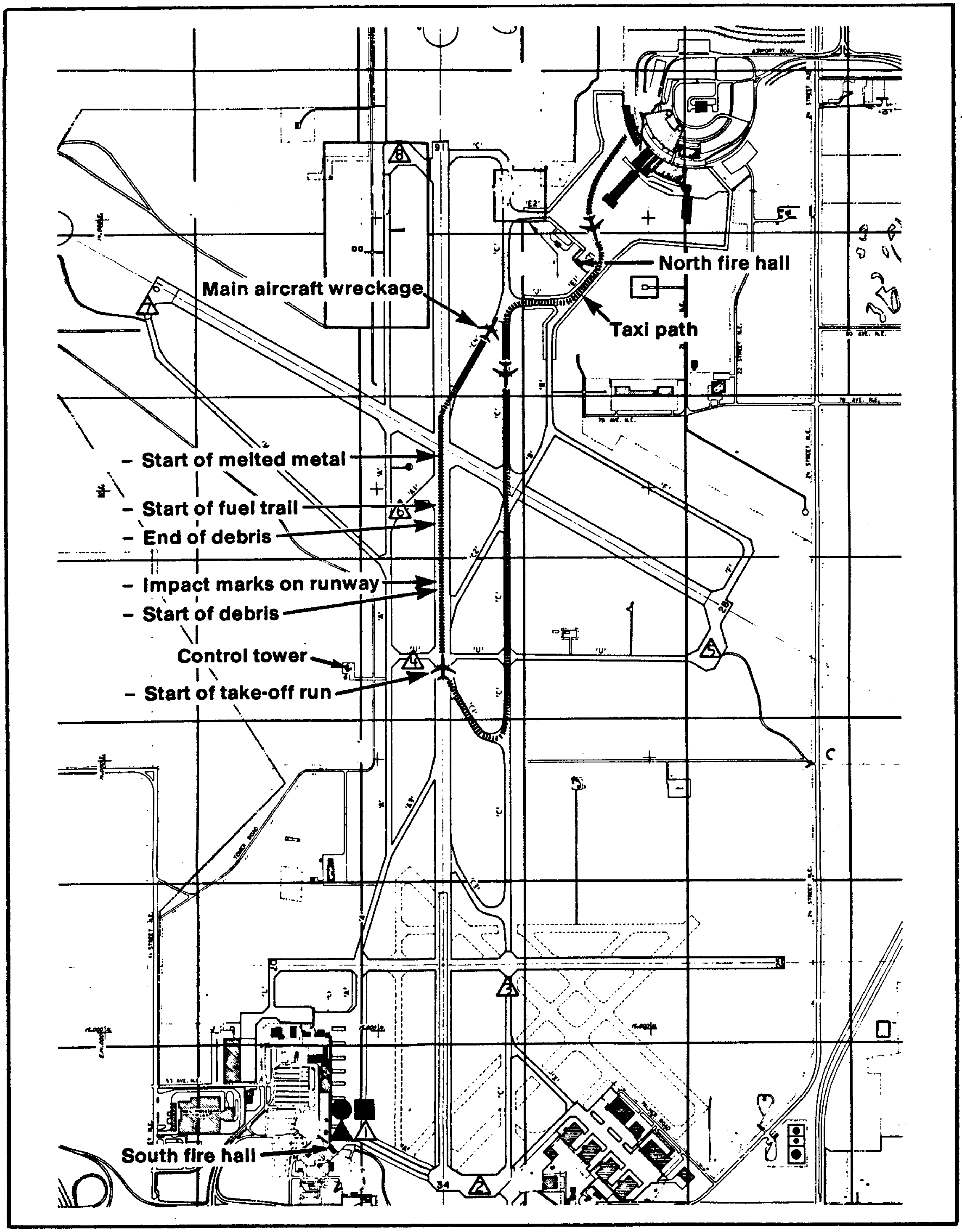
A number of the recommendations put forth as a result of this occurrence seek to improve the emergency procedures used to evacuate survivors and thereby reduce the time passengers and crews are exposed to risk in a burning aircraft. The CASB will carefully monitor such on-going efforts to improve cabin safety, such as passenger smoke hoods, and will consider further safety action to reduce the lethal nature of fires in transport category aircraft.

This report and the safety action therein has been adopted by the Chairman, Bernard M.-Deschênes, Q.C. and Board Members:

Norman Bobbitt
Leslie Filotas......abstained due to absence during the review of interested party comments.
Roger Lacroix
William MacEachern
David Mussallem.....abstained due to absence during the review of interested party comments.
Arthur Portelance
Bruce Pultz.........abstained due to absence during the review of interested party comments.
Ross Stevenson
Frank Thurston
and Ron Baker (former member of Aircraft Accident Review Board)

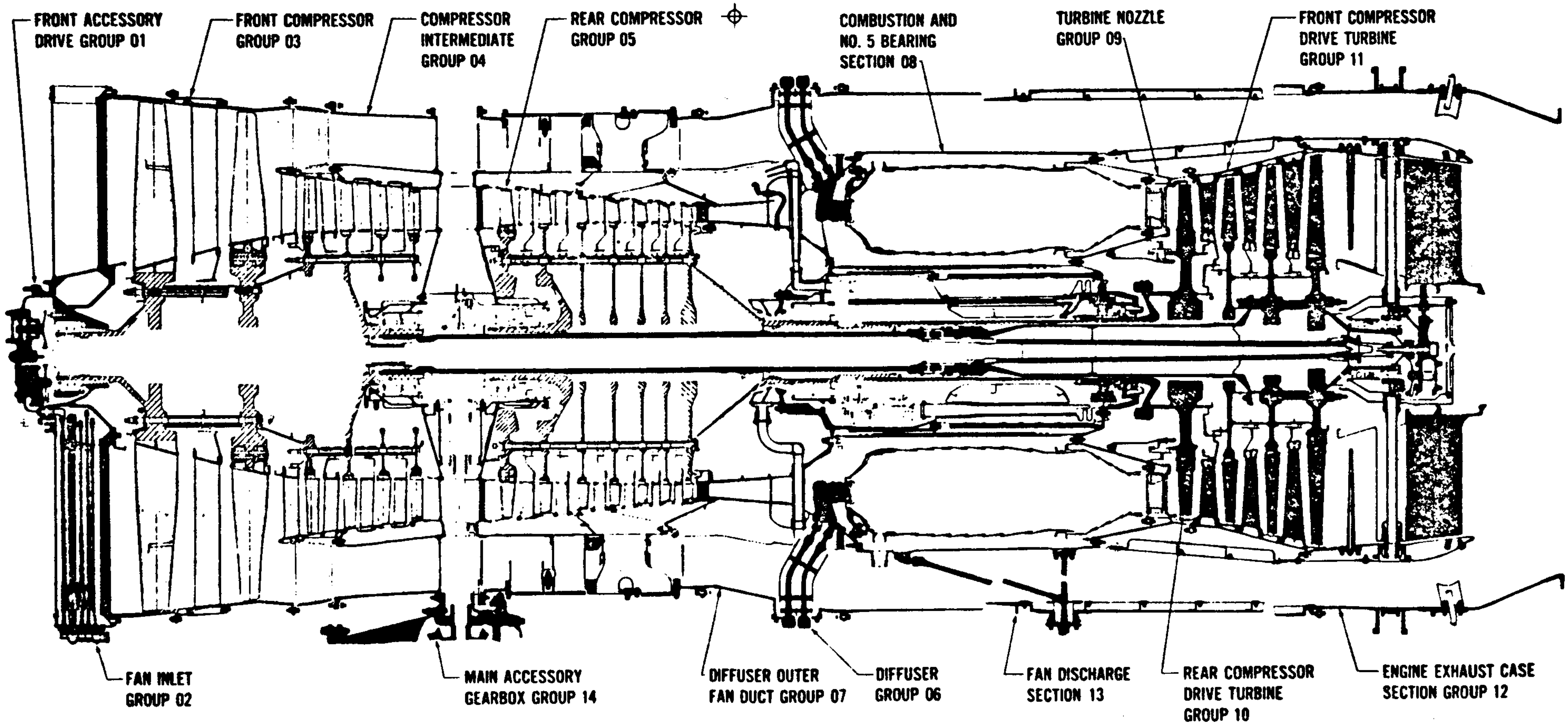
LEFT VIEW OF AIRCRAFT

RIGHT VIEW OF AIRCRAFT



AIRPORT DIAGRAM – CALGARY INTERNATIONAL AIRPORT

JT8D ENGINE SCHEMATIC



Items shown in black are installed when two or more build groups are assembled together.

AIR TRAFFIC CONTROL TRANSCRIPT
CALGARY TOWER FREQUENCY

AGENCY ABBREVIATIONS

PW 501 - PWA FLIGHT 501

TOWER - CALGARY TOWER CONTROLLER

MO 225 - OTHER AIRCRAFT

WD 274 - OTHER AIRCRAFT

DEPARTURE - CALGARY DEPARTURE CONTROLLER

TIME	AGENCY	COMMUNICATIONS
1441:20	TOWER	P DUB 501'S CLEARED FOR TAKE-OFF. DEPARTURE'S ONE NINETEEN EIGHT. GOOD MORNING.
1441:24	PW 501	501 CLEARED TO GO.
1441:28	MO 225	TOWER MOBIL 225 READY IN SEQUENCE.
1441:30	TOWER	MOBIL 225 TO POSITION.
1441:32	MO 225	MOBIL 225.
1441:37	TOWER	PW 501 BE AWAY AT 41.
1441:40	DEPARTURE	OKAY.
1442:26	PW 501	501 REJECT THE TAKE-OFF HERE.
1442:29	TOWER	OKAY, ALPHA 1 THERE - EH CHARLIE 4 RATHER.
1442:33	TOWER	MOBIL 225 IT'LL BE A WHILE.
1442:35	MO 225	YEH, WE SEE THAT - WE'LL GO FOR 28 IF HE'S GOING TO BE TIED UP THERE.
1442:40	TOWER	OKAY HOW ABOUT 25 - YOU CAN TURN RIGHT ON 25.
1442:41	MO 225	OKAY.
1442:44	PW 501	501 CLEAR HERE ON CHARLIE 4.
1442:45	TOWER	RIGHT ON.

1442:47	MO 225	LOOKS LIKE HE'S GOT SOMETHING GOING THERE.
1442:49	TOWER	YEH HE DOES.
1442:55	TOWER	501 TRUCKS ARE ON THE WAY.
1442:58	DEPARTURE	DID YOU SAY 501 WAS UP?
1442:59	TOWER	HE REJECTED TAKE-OFF THERE, HE'S GOT A FIRE (---).
1443:03	WD 274	CALGARY TOWER, GOOD MORNING, IT WARDAIR'S 274 HEAVY WITH YOU ON A RIGHT HAND FOR 34.
1443:06	TOWER	WD 274 HEAVY - JUST STAY MY FREQUENCY, MAINTAIN SIX.
1443:12	WD 274	MAINTAIN SIX.
1443:15	PW 501	AND TOWER 501.
1443:17	TOWER	GO AHEAD.
1443:19	PW 501	THEY'RE SAYING THERE'S SOME FIRE THERE. CAN YOU SEE ANY FIRE AROUND THERE?
1443:22	TOWER	CONSIDERABLE AMOUNT OFF THE BACK - ON THE LEFT SIDE ENGINE THERE - AND - EH - IT'S STARTING TO DIMINISH THERE. EH - THERE'S A FIRE GOING ON THE LEFT SIDE.
1443:30	PW 501	OKAY WE HAVE NO, EH, FIRE - EH COULD YOU GET THE EMERGENCY EQUIPMENT AFTER US HERE PLEASE.
1443:33	TOWER	OKAY THE TRUCKS ARE ON THEIR WAY 501 - AND IF YOU CAN MAKE JULIETT THEY'RE COMING OUT THE NORTH HALL THERE - THEY'LL BE THE QUICKEST THAT WAY.
1443:42	PW 501	OKAY. WE'LL TRY JULIETT HERE.
1443:45	TOWER	501 ACTUALLY THAT'S PROBABLY THE BEST BET - JUST WHERE YOU'RE AT THERE AND THEY'RE ON THEIR WAY. DO YOU SEE THEM THERE.
1443:49	PW 501	OKAY WE'RE STOPPING HERE - YEAH WE (--) THE TRUCKS ON THEIR WAY.
1443:52	TOWER	OKAY --- 501 EH YOU HAVE A BIT OF FLAME COMING OUT THE LEFT SIDE NOW STILL.

1443:58	PW 501	OKAY - WE'VE GOT THE FIRE SWITCH NOW. (background alarm bell)
1444:06	TOWER	WD 274, 34, AND 28 ARE BOTH CLOSED. JUST MAINTAIN SIX AND WHAT WOULD YOU LIKE TO DO - GO TO EDMONTON?
1444:16	WD 274	OKAY - JUST STANDBY.
1444:18	TOWER	OKAY.
1444:19	TOWER	501 - YOU GOT A REAL GOOD FIRE GOING THERE ON THE LEFT SIDE NOW.
1444:23	PW 501	OKAY. (background alarm)
1444:24	TOWER	AND IT'S STARTING TO CLIMB UP THE LEFT-HAND SIDE OF THE FUSELAGE -- BOTH SIDES.

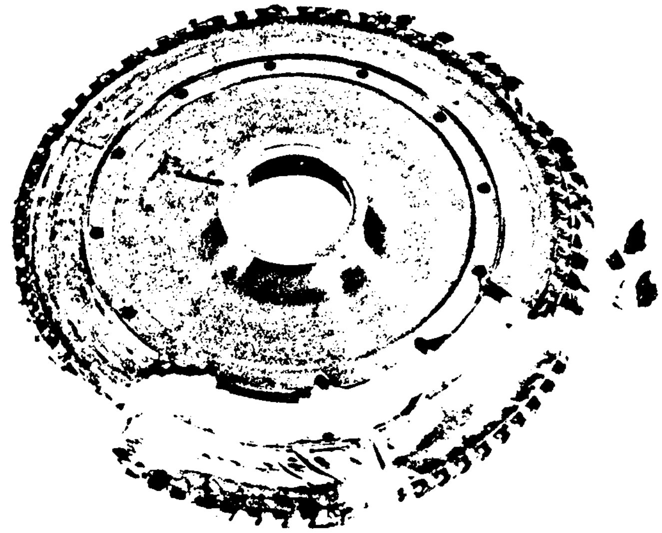


Figure 1 – 13th stage compressor disc, p/n 717313H, s/n J60916, as received, front face.

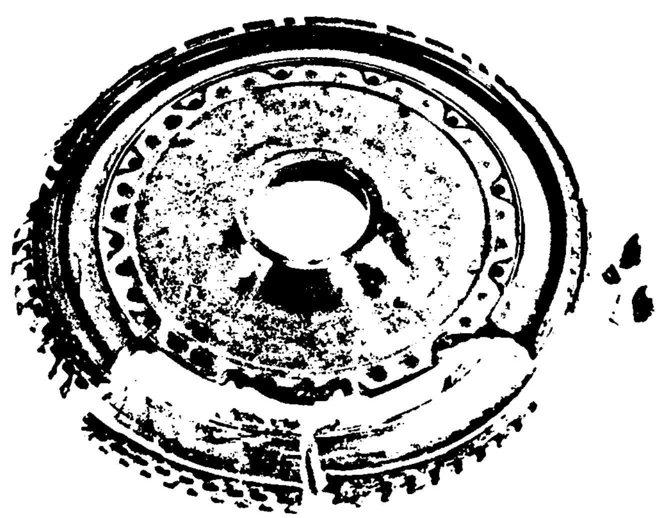


Figure 2 – 13th stage compressor disc, p/n 717313H, s/n J60616, as received, rear face.

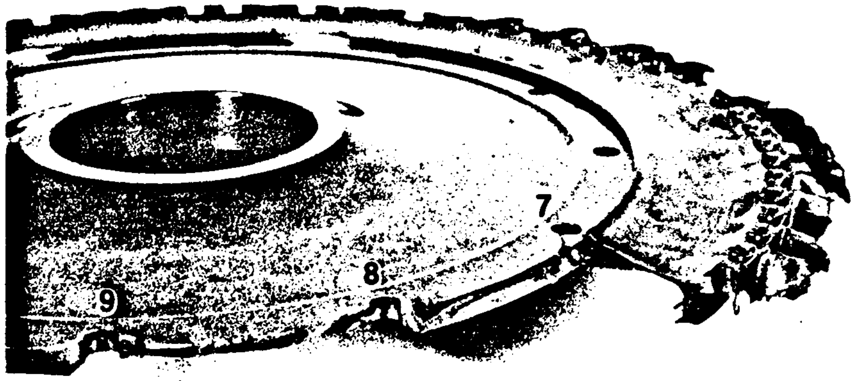


Figure 3 – 13th stage compressor disc, crack A, fatigue crack between tie bolt holes No. 7 and No. 8.

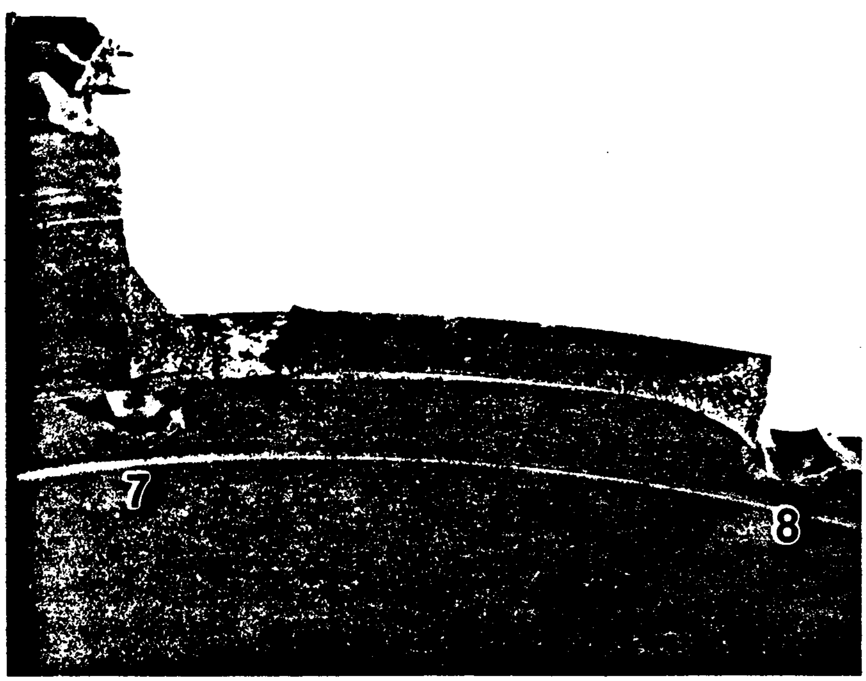


Figure 4 – 13th stage compressor disc, showing location of crack A.

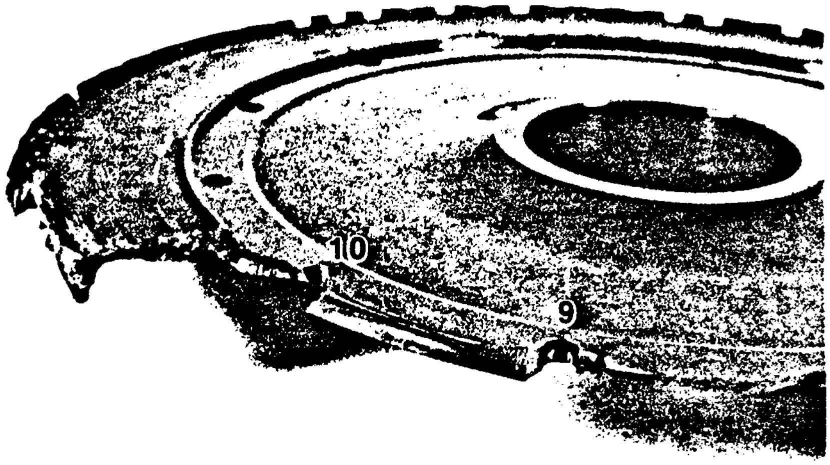


Figure 5 – 13th stage compressor disc, crack B, fatigue crack between tie bolt holes No. 9 and No. 10.

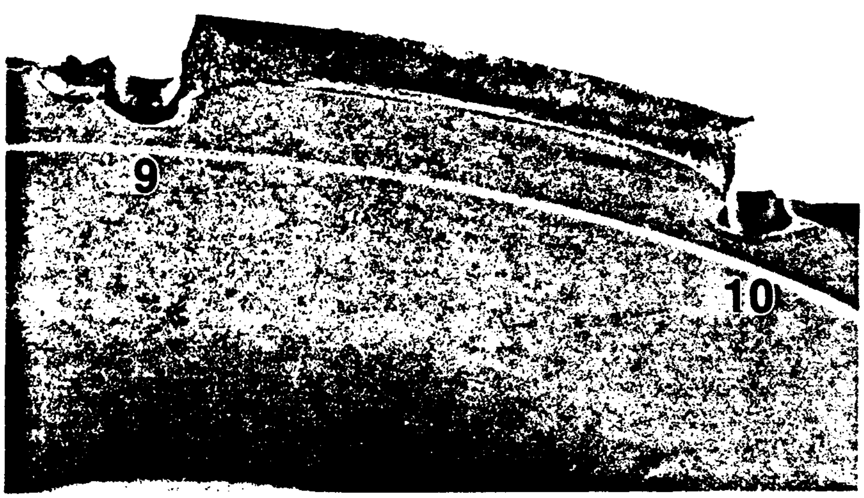


Figure 6 – 13th stage compressor disc, showing location of crack B.

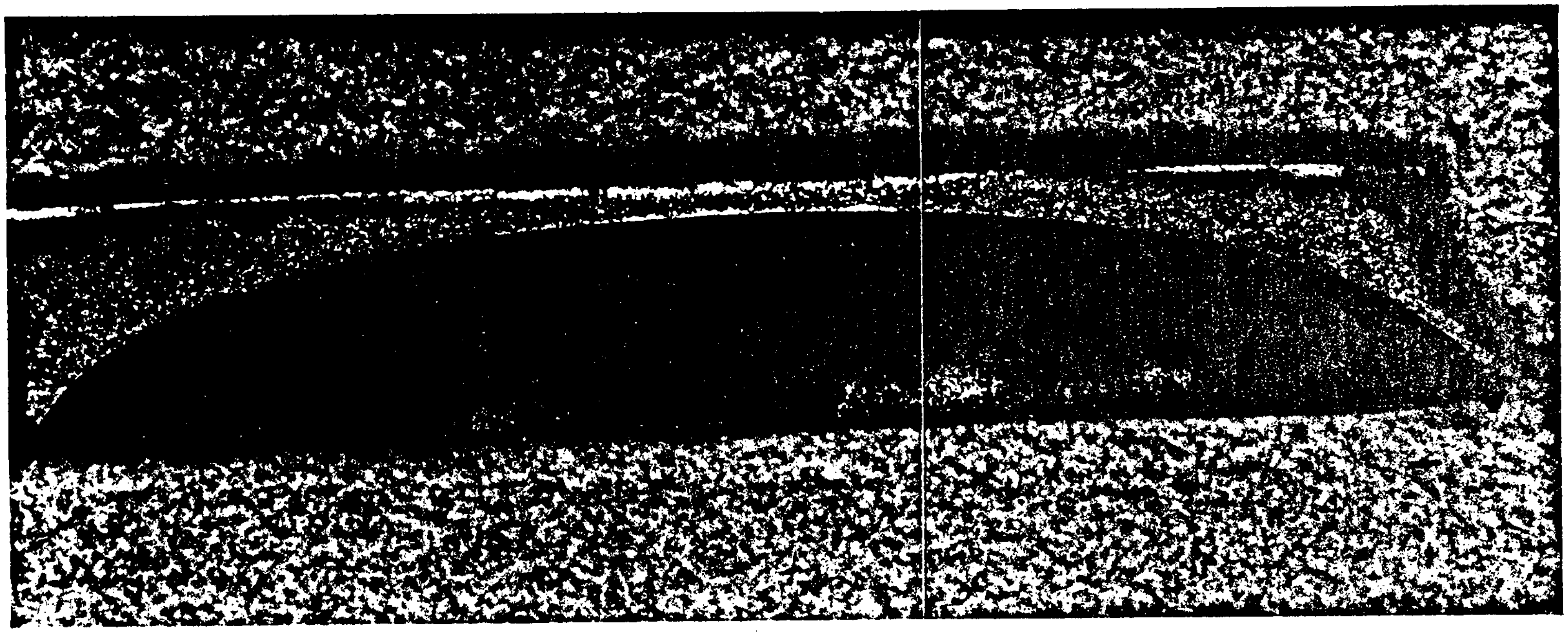


Figure 7 – Laboratory exposed fatigue crack C, located in rear snap between tie bolt holes No. 11 and No. 12. Magnification 3.75X.

PACIFIC WESTERN AIRLINES

EMERGENCY AND ABNORMAL PROCEDURES
FLIGHT PATTERNS

REJECTED TAKEOFF PROCEDURE

Rejected takeoff is required when engine failure, fire or takeoff warning is recognized before V_1.

Upon recognition of failure or warning either pilot will call out "engine failure," "engine fire" or "takeoff warning."

Rejecting the takeoff solely for the amber Master Caution light, above 80 knots and takeoff roll has been established, is not recommended.

CAPTAIN	FIRST OFFICER
Simultaneously: Thrust Levers – IDLE Brakes – APPLY MAXIMUM WHEEL BRAKES	
Speed Brake – FULL UP	Check Speed Brake FULL UP.
Apply reverse thrust rapidly as required.	Engine Instruments – MONITOR Advise Captain of any engine limit or abnormality.
Stop airplane and evaluate the problem. If conditions permit, taxi clear of the runway.	

NOTE

Insure the brakes are cool prior to next takeoff.

ENGINE FAILURE AFTER V_1

CAPTAIN	FIRST OFFICER
Maintain directional control, rotate to takeoff attitude at V_R. · Fly the airplane!	Call rotate at V_R.
When positive rate of climb indicated, call gear up.	Check positive rate of climb. Position landing gear lever to up.
(1) Climb at V_2, limit bank angle to 15^o.	Monitor engine and flight instruments.
At flap retraction altitude, retract flaps on flap/speed schedule in slight climb at 100-200 FPM.	Retract flaps on command. Monitor flap indications and leading edge lights.
After flaps retracted, call for maximum continuous thrust, climb at 210 kts (220 kts above 117,000 pounds (53,070 kgs), call for Engine Failure and Shutdown checklist and After Takeoff checklist.	Set maximum continuous thrust. Complete Engine Failure and Shutdown checklist on command. Complete After Takeoff Procedure and checklist.
Determine next course of action.	Advise ATC of Captain's intentions.

(1) If an engine failure occurs prior to V_2, maintain V_2 up to height required for obstacle clearance. If an engine failure occurs after V_2 but less than V_2 + 25 knots, maintain speed reached at time of the engine failure. If an engine failure occurs at V_2 + 25 knots, maintain speed V_2 + 25 knots. If an engine failure occurs at a speed higher than V_2 + 25 knots with flaps at takeoff setting, increase pitch attitude to reduce speed to and maintain V_2 + 25 knots until clear of obstacles.

PWA FLIGHT #501
22 MARCH 1984

SEQUENCE OF EVENTS
(Determined from CVR recording, ATC recording, and witness interviews.)

GMT	ELAPSED TIME	EVENTS
1441:20		Flight 501 cleared for take-off.
1441:24		Take-off clearance acknowledged.
1442:01		Engine spool up.
1442:19	00:00	Compressor disc fails. Loud bang heard in cabin and cockpit. Fire immediately evident to some passengers and tower personnel.
1442:20	00:01	Reject initiated.
1442:26	00:07	501 informs control tower that they are rejecting the take-off.
1442:27	00:08	Firehall No. 13 advised of fire and responds.
1442:40	00:21	Captain and first officer query left engine. N1 on No. 1 engine is zero.
1442:43	00:24	Firehall No. 27 advised of fire and responds.
1442:44	00:25	501 advises control tower that they are clear of the runway and on taxiway Charlie 4.
1442:55	00:36	Tower advises 501 "...trucks are on the way..."
1443:07	00:48	Purser enters cockpit, asks if they have blown a tire then advised fire at rear, "on the back of the wing."
1443:10	00:51	Cabin call chime rings in cockpit. (Chime continues intermittently). Fire bell sounds for less than one second.
1443:10	00:51	Public address announcement to remain seated and calm by Flight Attendant No. 3.
1443:15	00:56	501 requests tower to confirm existence of fire.
1443:22	01:03	Tower confirms "...considerable amount off the back - on the left side engine....starting to diminish..."

1443:25	01:06	Purser returns to cockpit confirms fire "...the whole left-hand side, the whole back side of it is burning..."
1443:30	01:11	Captain advises "...prepare for evacuation..."
1443:30	01:11	501 requests emergency equipment, first officer advises tower that they do not have a fire warning indication.
1443:33	01:14	Tower advises "...trucks are on the way..." and suggests 501 continue to taxiway Juliett.
1443:42	01:23	501 acknowledges it will try for Juliett.
1443:43	01:24	Last chime sounds. (Purser picks up interphone, Flight Attendant No. 2 advises of fire).
1443:45	01:26	Tower suggests to 501 "...that's probably the best bet - just where you're at there..." and asks if 501 can see the emergency vehicles.
1443:49	01:30	501 responds "...okay, we're stopping here, yeah we (--) the trucks on the way..."
1443:52	01:33	Tower advises flames are visible on the left side of the aircraft.
1443:55	01:36	Fire bell begins to ring in cockpit and continues to ring until the end of CVR recording.
1443:56	01:37	Purser returns to cockpit and says "...it's really quite bad in the back..."
1443:57	01:38	Captain responds "...it is, is it?..."
1443:58	01:39	First officer informs control tower that they have fire bells now.
1444:03	01:44	Captain states "...prepare for emergency evacuation..."
1444:09	01:50	Flight crew begins shutdown procedure. Aircraft stopped.
1444:10	01:51	AC power lost (CVR and FDR de-energize).
1444:14	01:55	Evacuation commences.

LIST OF LABORATORY REPORTS

The following laboratory reports were completed:

LP 120/84 - High Pressure Compressor Disc
LP 132/84 - Magnetic Plug Debris Analysis
LP 153/84 - Thirteenth Stage Bleed Valves
LP 156/84 - JT8D-9A Engine Component Examination
LP 185/84 - Video Documentation

These reports are available on request from the Canadian Aviation Safety Board.

GLOSSARY

C	Celsius
CASB	Canadian Aviation Safety Board
CFR	Crash Firefighting and Rescue
cm	centimetre (s)
CP	Canadian Pacific
CVR	cockpit voice recorder
DFDR	digital flight data recorder
ft	feet
GMT	Greenwich mean time
hr	hour (s)
kt	knot (s)
lat	latitude
lb	pound (s)
long	longitude
MANOPS	Manual of Air Traffic Control Operations
mi	mile (s)
MST	mountain standard time
N	north
N1	low pressure unit rpm
PA	public address
PWA	Pacific Western Airlines
SEM	scanning electron microscope
TEM	transmission electron microscope
T	true
W	west
o	degree (s)
'	minute (s)