AVIATION OCCURRENCE REPORT

ENGINE FIRE AND EVACUATION

AIR CANADA
MCDONNELL DOUGLAS DC-9-32 C-FTMD
VANCOUVER INTERNATIONAL AIRPORT, BRITISH COLUMBIA
27 JUNE 1995

REPORT NUMBER A95P0138

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

AVIATION OCCURRENCE REPORT

ENGINE FIRE AND EVACUATION

AIR CANADA
MCDONNELL DOUGLAS DC-9-32 C-FTMD

VANCOUVER INTERNATIONAL AIRPORT, BRITISH COLUMBIA

27 JUNE 1995

REPORT NUMBER A95P0138

Summary

The Air Canada DC-9-32 (ACA216), with 5 crew members and 72 passengers on board, was being pushed back from Gate 1 at the Vancouver International Airport in preparation for departure to Calgary, Alberta. In accordance with standard company procedures, the captain initiated the starting sequence for the No. 2 (right side) engine during the push-back. The start was unremarkable and, while the first officer completed the required after-start engine and electrical checks, the captain initiated the starting sequence for the No. 1 (left side) engine. The engine did not start, however, and the captain informed the first officer that they had a wet start, discontinued the start, and began the Wet Start and Unsatisfactory Start procedures.

While the pilots were completing the engine shut-down procedures, they were informed by ground personnel and the crew of a passing aircraft that black smoke and flames were visible in the vicinity of the left engine. There were no cockpit indications of fire, but, based on these external reports, the captain activated the engine fire extinguisher bottle No. 1, and informed the flight-attendant-in-charge. A short time later, the pilots received a second report of fire from personnel working near the aircraft. The captain immediately activated the engine fire extinguisher bottle No. 2, and, because the aircraft had already been pushed back from the terminal gate, he ordered an emergency evacuation through the two forward doors. The flight attendants deployed the two forward escape slides and began the emergency evacuation. During the evacuation, the right-side escape slide partially deflated, but it remained sufficiently firm for the evacuation. There were four minor injuries during the evacuation, and the aircraft was not damaged.

Other Factual Information

This Douglas DC-9 has two JT8D-7B turbo-fan engines mounted on the rear fuselage, each containing two igniter plugs to provide initial ignition of the fuel/air mixture during start; the plugs are identified as "A" and "B" systems. By design, an igniter plug is a consumable component, requiring replacement from time to time throughout the service life of an engine. The two igniter plugs installed on this engine at the time of the incident were made by different manufacturers, Champion (part number AA725) and Auburn (part number JB3).

The normal engine starting procedures in the Air Canada DC-9 Operating Manual prescribe the specific phraseology that pilots must use during the critical elements of the starting cycle. The starting checklist and the required pilots' verbal calls, for either engine, are summarized, in part, as follows for the right engine:

Item	Action	Pilot Phraseology
Start switch	On	"Starting Right"
Start valve	'Open light' ON	"Valve Open"
N2 RPM	Rising	"N2"
Oil pressure	Rising	"Oil Pressure"
N1 RPM	At 20% N2, confirm N1 rotation	"N1"
Fuel control lever	Lever to ON	"Fuel On"
Fuel flow	Check at 800 pph	none
EGT gauge	Rising within 10 seconds	"Light on Right"
Start switch	Release at 35% N2	none
Start valve	'Open light' OUT	"Valve Closed"
Engine parameters	Check for normal indications	"Right engine normal"
Electrical systems	Check for normal indications	"Right electrics normal"

Figure 1 - Engine Starting Procedure Summary (right engine)

The engine starting procedures require the captain to confirm that the exhaust gas temperature (EGT) begins to rise within 10 seconds of moving the fuel control lever to ON. If the EGT does not rise, the captain discontinues the start, and proceeds with both the Wet Start and the Unsatisfactory Start procedures as follows:

"NO EGT RISE DURING START (WET START)"

IF NO EGT RISE WITHIN 10 SECONDS OF FUEL ON:

DISCONTINUE START AND PROCEED WITH UNSATISFACTORY START PROCEDURE (QRH 1.25)

CAUTION: DO NOT SWITCH IGNITION SYSTEMS DURING ENGINE ROTATION

IGNITION C/B (K24 OR L24). . . CHECK SET

WHEN ROTATION STOPPED, SELECT OTHER IGNITION SYSTEM AND ATTEMPT RESTART.

END OF CHECKLIST

Figure 2 - Wet Start Checklist

"UNSATISFACTORY START PROCEDURE"

FUEL CONTROL LEVER . . . . . OFF

IF START SWITCH IS STILL ENGAGED, CONTINUE MOTORING ENGINE FOR 15 SECONDS TO CLEAR UNBURNT FUEL.

START SWITCH . . . . . OFF
IGNITION SWITCH. . . . . OFF

IF START SWITCH DID NOT REMAIN OPERATING FOR AT LEAST 10 SECONDS AFTER FUEL CONTROL LEVER WAS MOVED TO OFF, ALLOW 30 SECOND FUEL DRAINING PERIOD PRIOR TO NEXT START ATTEMPT.

END OF CHECKLIST

Figure 3 - Unsatisfactory Start Checklist

The aircraft had both flight data recorder (FDR) and cockpit voice recorder (CVR) units installed, and both had recorded information relevant to the occurrence. The following graph is derived from the flight recorder Engineering Report.

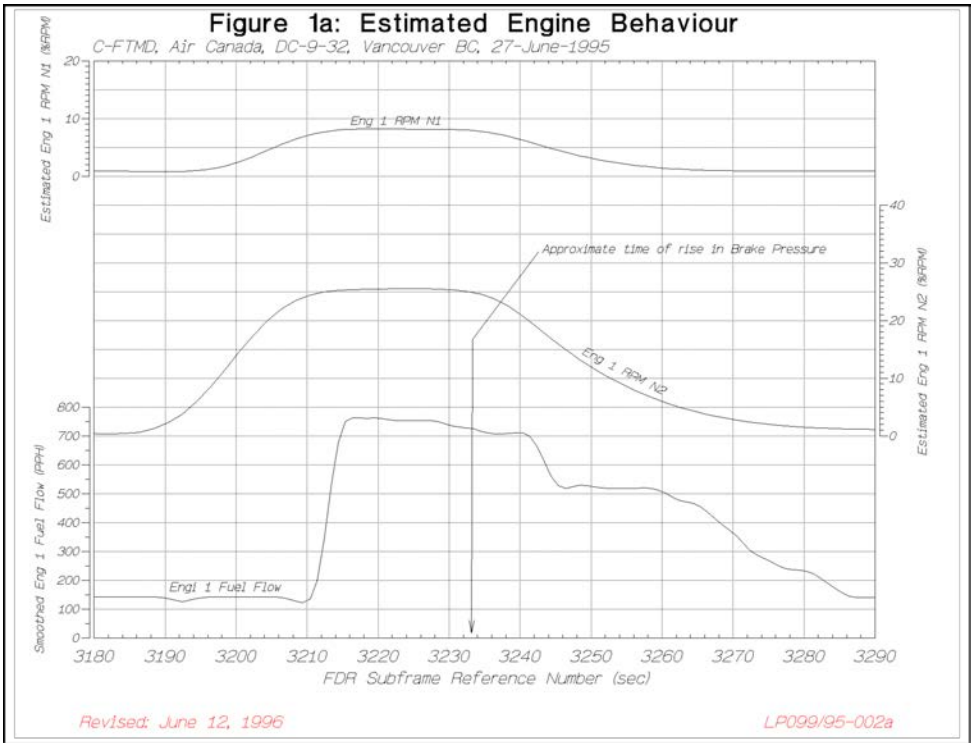

Figure 4 - FDR Data of the Left Engine Start

The following table summarizes the FDR data pertaining to the unsuccessful start of the left engine:

Ref	FDR time	Event
1	3915	N2 rises from zero [Starter engaged on left engine]
2	3204	N2 reaches 25% / N1 reaches 8%
3	3213	Fuel flow rises from static [Fuel control lever 'ON']
4	3224	N2 maintained at 25% / No ignition Ground crew requests brakes
5	3232	N2 maintained at 25% Brake pressure rises [Captain applies brakes]
6	3235	N2 and Fuel flow begin to drop [Start discontinued]
7	3236	Brake pressure constant [Parking brake applied]
8	3260	Ground tells captain of engine fire
9	3264	N1 reaches zero
10	3286	Fuel flow reaches static / N2 reaches zero

Figure 5 - Flight Recorder Partial Summary

The CVR had recorded cockpit communication apparently without error. The FDR unit had recorded data on only 3 of the 7 available tracks, reducing the available recording time from 25 hours to 11 hours; the quality of the FDR data was not affected. The FDR data captured for the engines' N1 and N2 rpm (expressed in terms of percentage rpm)

contained anomalies during the start-up and shut-down phases; these anomalies were also evident for previous flights. The anomalies revealed sensor characteristics that resulted in some invalid or sporadic high values for the N1 and N2, when the N2 values were below 20 per cent. Thus, in the TSB FDR report, some engine N1 rpm values and N2 rpm values below 20 per cent were estimated. The EGT is not recorded by the FDR.

Concurrent with the events in the cockpit, the aircraft was being pushed back from the gate. FDR data revealed that the initial segment of the left engine starting cycle was normal. The captain did not use standard phraseology (see Figure 1) during either start; however, he did discuss passenger loading.

After the captain engaged the starter, the N2 increased and stabilized at about 25 per cent; the fuel flow then increased to about 750 pounds per hour (pph) in about a second, and stabilized at that value. FDR data recorded before this incident showed that the fuel flow on start normally rises to about 750 pph in 1 to 2 seconds. There was no further change in the N2 rpm or fuel flow. About 11 seconds after the captain moved the fuel control lever to ON, he informed the first officer that there was no ignition and continued to motor the engine. Both pilots later reported that the captain moved the fuel control lever to OFF at this time. Moving the fuel control lever to OFF cuts off the fuel supply to the engine and inhibits the ignition system. By design, the FDR does not record the movement of the fuel control lever; the sound of the fuel lever being moved may have been recorded on the CVR. Spectral analyses of certain recorded sounds were conducted by the National Research Council and the TSB Engineering Branch; they assessed that the sounds were dissimilar to the fuel control lever being shut off and locked in position.

At the same time that the captain informed the first officer that there was no ignition on the left engine (FDR ref. 3224), the ground crewman advised the cockpit on the intercom system that push-back was complete and requested the brakes be set. Eight seconds later, the captain replied that the brakes had been set. FDR data (3232) showed that the brake pressure rose to about 1,300 psi, and that pressure was maintained for the duration of the recorded data. Analysis of the FDR data showed that the N2 rpm began to drop immediately before the brakes were set.

After peaking at about 750 pph, the fuel flow dropped slowly to 700 pph over 26 seconds. The fuel flow then dropped markedly to maintain about 525 pph, before gradually decreasing to the original static value. Concomitant with this latter decrease in fuel flow, the N2 rpm also decreased. FDR data also revealed that on each previous engine shutdown from an N2 of about 56 per cent, the recorded fuel flow values characteristically decreased from a steady 800 pph to the original static value within about 7 seconds of the fuel control lever being moved to OFF. As well, the N2 rpm reduced to 20 per cent in about 15 seconds, and to zero in another 45 seconds.

None of the fire warning systems activated during the incident, and there were no cockpit indications of fire, nor of any other abnormal situation. The pilots assessed that the engine had experienced a minor malfunction during the starting cycle, and all cockpit indications supported this assessment.

The normal procedures of starting an engine require, in part, that the captain (in the left seat) move the fuel control lever, located in the control pedestal, with his right hand. At the same time, the captain's left hand operates the starter switch located in the forward overhead panel. The parking brake control is mounted on the nose-wheel steering wheel near the captain's left knee, and is also operated by the captain's left hand. During the initial part of the starting sequence, because the start switch is spring-loaded OFF, the captain has to maintain pressure on the switch to continue turning the engine. The switch is normally released after the engine has ignited and reached self-sustaining rpm, that is, by 35 per cent N2 rpm; if the switch is released before the engine has ignited satisfactorily, the engine rpm will decrease and coast down to zero in about 45 seconds.

Shortly after the captain received the first verbal report of fire near the left engine, he discharged the No. 1 fire bottle into the left engine. Following this initial response, the captain received conflicting information on the status of the fire. He was subsequently given a second verbal notification that flames were present near the left engine. Based on that information, it appeared to him that the fire had not yet been extinguished by the first fire bottle; the captain then discharged the No. 2 fire bottle and ordered an emergency evacuation using the forward slides.

Once the captain had ordered the emergency evacuation, the first officer performed a "Severe Aircraft Damage" check and informed Air Traffic Control of the emergency situation. The emergency rescue services (ERS) responded without delay and applied foam to the left engine. The evacuation was reportedly completed in a timely and orderly fashion, and was supported by the RCMP, ERS crews, ramp attendants, and Air Canada ground personnel. Although the right-hand escape slide partially deflated, it did not hamper the evacuation process, and of the four minor injuries, only one involved the right-hand slide.

Once the aircraft was taken to the Air Canada hangar, maintenance personnel checked the engine controls for security, the HP cock, the throttles for travel and movement, and binding of engine controls. They were satisfied that there was no restriction, malfunction, or abnormal behaviour of any of the engine controls.

Air Canada Maintenance then washed out the engine because it had been foamed. They successfully started the engine twice, on both A and B ignition systems. No abnormalities were noted. They checked all the engine controls again and no abnormalities were found.

The left engine was removed from the aircraft and taken to an approved maintenance facility for examination and testing. Before the engine test run began, a static examination of the engine revealed that the ceramic portion of the Auburn igniter plug "B" had cracked; such damage would have rendered it intermittent and unserviceable. The igniter plug "A" was unremarkable. A bench test of both igniter plugs revealed that the Auburn plug was firing from the crack in the ceramic and not the tip, while the Champion plug fired normally.

With the engine in the same configuration as it had been when installed in the aircraft, technicians made four attempts to start it. The first attempt was conducted using ignition system "A"; the start was normal and the engine performed in accordance with the manufacturer's specifications. The second and third starts were conducted using ignition system "B", which included the defective igniter plug. On each occasion, the engine did not start within the specified time limit, and the start sequence was intentionally aborted. During both of these unsuccessful start attempts, the technicians observed a steady stream of unburnt fuel issuing from the exhaust pipe. A fourth start attempt was conducted using ignition system "B" again, but with a serviceable igniter plug installed. The engine then started and performed in accordance with the manufacturer's specifications.

Bench-testing of the fuel control unit (FCU) on this engine revealed that the fuel shut-off lever indexing was correct, that moving the shut-off lever OFF immediately stopped the fuel to the FCU, and that the shut-off valve did not leak when closed. By design, the fuel control lever has no intermediate positions, that is, the valve was either open or closed; a part-way position was, therefore, improbable in the incident circumstances.

The defective escape slide from the right-hand galley door was removed for examination and testing at an approved maintenance and overhaul facility. Examination of the slide revealed that the slide fabric had been punctured in several locations by a metal guard (part number 30279) that is designed to protect the pressure gauge of the inflation bottle. Air Canada had recently modified their escape slide packing procedures, and, during the last repacking process on this slide, a protective pad for the pressure gauge guard had unintentionally been omitted. Although the slide unit was covered and protected by the galley door cover, with the internal protective pad missing from around the gauge guard, the slide fabric was punctured as a result of repeated impacts. The most likely source of the impacts was the food service carts that were regularly loaded and unloaded through the right-hand galley door.

Analysis

The engine wet start was caused by a defective igniter plug which had malfunctioned during the engine starting sequence. As a result, proper ignition did not occur and unburnt fuel pooled within the combustion chamber section. The igniter fired through the crack in the ceramic shield outside the combustion chamber itself, and ignited the pooled fuel, causing an internal engine fire. The engine fire was short-lived and was contained within the combustion, turbine, and tail-pipe sections of the engine, and it did not pose a significant threat to the aircraft or its occupants. There were no direct cockpit indications of engine fire because the fire was isolated from the fire sensor system.

It was not determined why the captain did not follow the standard phraseology during the engine start sequence; the initial discussion about passenger seating in the cabin seemed to take priority and replaced the standard engine starting phraseology.

Historical FDR data shows that the engine typically coasts down from 20 per cent N2 in about 45 seconds, and since engine stop was recorded

at about FDR 3286, the starter was disengaged at or before FDR 3240. The drop in N2 rpm at about FDR 3235, however, indicated starter release, and was immediately followed by the parking brake being set at FDR 3236.

Because the recorded FDR data did not show the characteristic and rapid decrease in fuel flow to the left engine normally seen when the fuel control lever was selected OFF, it is concluded that the fuel lever was not moved to the OFF position during the starting sequence.

It was not determined why the captain did not return the fuel control lever to OFF at the appropriate time; it is likely, however, that his sequence of vital actions was momentarily interrupted by the request from the ground crew to set the brakes. Fuel continued to flow to the engine at a point in the shut-down sequence where continued motoring of the engine would normally have been effective in dispersing any pooled fuel and minimizing the possibility of engine fire. The continued motoring of the engine by the captain with the fuel control lever ON augmented the volume of fuel pooling in the engine and would have exacerbated any fire. Further, after the starter was released, fuel continued to flow into the engine as the engine rpm gradually decreased.

There was a time delay between the first and the second reports of the engine fire, and it is likely that the second report was not based on current or accurate information; however, from the captain's perspective, it would have appeared that the reported engine fire had persisted, despite his activating the No. 1 fire extinguisher bottle. Faced with uncertainty regarding the safety of his aircraft, crew, and passengers, the captain responded by activating the second fire extinguisher bottle and by ordering an emergency evacuation of the aircraft.

The following Engineering Branch report was completed:
LP 099/95 - FDR/CVR Analysis.

Findings

1. The abnormal engine start was caused by a defective igniter plug.

2. The engine tail-pipe fire was caused by the ignition of fuel that had pooled in the combustion chambers during the starting sequence.

3. There were no direct cockpit indications of engine fire because the fire was contained within the combustion section of the engine, and was isolated from the fire sensor system.

4. The captain did not return the fuel control lever to the OFF position when he identified a wet start situation.

5. The amount of unburnt fuel introduced into the engine during the start was augmented as a result of the fuel control lever still being ON.

6. The captain's decision to evacuate the aircraft was appropriate, given the untimely and inaccurate reports he received of an uncontained fire in the left engine.

7. During the aircraft evacuation, the escape slide on the right-hand galley door partially deflated, but it remained sufficiently firm for the evacuation.

8. The galley door escape slide had unknowingly been punctured prior to the incident as a result of incomplete slide packing procedures and by impact damage to the slide pack assembly.

9. An intensive, fleet-wide inspection of all DC-9 escape slides did not reveal a systemic deficiency in the Air Canada slide maintenance process.

10. The captain did not use standard phraseology during the engine starting sequences, nor did he completely follow the standard procedures for the wet start event.

Causes and Contributing Factors

The abnormal start and subsequent tail-pipe fire were caused by a defective engine igniter plug. Exacerbating the fire were the captain's incomplete Unsatisfactory Start procedures. Contributing to the incident were the inaccurate and untimely reports of a continuing and uncontained fire in the left engine.

Safety Action Taken

As a result of discovering the incorrect packing process, Air Canada thoroughly reviewed and amended their escape slide repacking procedures. Additionally, an inspection campaign was immediately carried out to verify the serviceability of all escape slides in the Air Canada DC-9 fleet. This campaign required that all escape slides be opened, examined for punctures, and re-closed. During this fleet-wide campaign, only two slides were found to be similarly punctured and the problem, therefore, was not considered to be widespread.

After the most probable cause for the escape slide damage was identified, Air Canada issued an internal bulletin to all cabin crew and cabin servicing personnel, highlighting the potential for damage to the slides during ground servicing operations. Transport Canada is satisfied that the Air Canada maintenance programme for escape slides meets the requirements of the Airworthiness Manual.

Monitoring by Air Canada of the Auburn igniter plugs revealed instances of similar ceramic cracking. The maintenance history of this plug showed that it had not exhibited the longevity that Air Canada had expected, and, shortly after this incident, Air Canada discontinued using it in their engines; no similar occurrences have been reported since. Transport Canada is satisfied that the Air Canada maintenance programme for the ignition system meets the requirements of the Airworthiness Manual.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice

Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 05 March 1997.