----- AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT -------

1. ACCIDENT:

Location:	Las Vegas, Nevada
Date:	September 8th, 2015
Time:	About 1627 PDT
Aircraft:	Boeing 777-200
Serial Number:	29320
Registration:	G-VIIO

2. SYSTEMS GROUP:

Chairman: Michael Bauer
National Transportation Safety Board
Washington, D.C.

Member: Joseph Panagiotou
National Transportation Safety Board
Washington, D.C.

Member: Michael Levine
Federal Aviation Administration
Washington, D.C.

Member: Justin Doxey
Air Accidents Investigation Branch (AAIB)
Aldershot, United Kingdom

Member: Judd Mathiason
The Boeing Company
Seattle, WA

Member: Mike Madden
The Boeing Company
Seattle, WA

Member: Richard Rachowiecki
British Airways
London, United Kingdom

3. SUMMARY

3.1 Event Summary

On September 8, 2015, at about 1613 Pacific daylight time (PDT), a British Airways flight 2276, a Boeing 777-236ER, registration number G-VIIO, powered by two General Electric GE90-85BG11 turbofan engines experienced a No. 1 engine (left) uncontained failure and subsequent fire during the takeoff ground roll on runway 07L at McCarran International Airport (LAS), Las Vegas, Nevada. The flightcrew aborted the takeoff, stopped the aircraft on runway 07L, and evacuated the airplane. The No. 1 engine, the inboard left wing, and a portion of the left and right fuselage experienced fire damage. The fire was extinguished by airport rescue and firefighting (ARFF) after the evacuation started. The 157 passengers, including 1 lap child, and 13 crew members evacuated via emergency slides on the runway. There were 19 minor injuries and 1 serious injury reported. The airplane was substantially damaged. The flight was operating under the provisions of 14 Code of Federal Regulations (CFR) Part 129 flight from LAS to London-Gatwick International Airport (LGW) Horley, England.

3.2 Airworthiness Group Summary

The Airworthiness group was formed during the on scene phase of the investigation. The work performed by the group occurred mainly on the ramp on the aircraft at the cargo facilities at McCarran International Airport, Las Vegas, Nevada. Prior to arrival of the NTSB, the aircraft was repositioned from RWY 7L to the cargo facilities.

3.3 Acronyms

AC	Alternating Current	LGW	London-Gatwick Airport
APU	Auxiliary Power Unit	LH	Left Hand
ARINC	Aeronautical Radio Incorporated	LHS	Left Hand Side
ASCS	Air Supply Control System	MID	Middle
BBL	Body Buttock Line	MLG	Main Landing Gear
BTMS	Brake Temperature Monitoring System	N/A	Not Applicable
C	Celsius	N1	Low-pressure compressor speed (fan speed)
CFR	Code of Federal Regulations	N2	High-pressure compressor speed (core speed)
DISCH	Discharge	NTSB	National Transportation Safety Board
EEC	Electronic Engine Control	OPAS	Overhead Panel ARINC System
EICAS	Engine Indicating and Crew Alerting System	OUTBD	Outboard
ELMS	Electrical Load Management System	P/N	Part Number
ENG	Engine	PDT	Pacific Daylight Time
EPAS	Emergency Power Assist System	PED	Passenger Entry Door
F	Fahrenheit	PSI	Pounds per Square Inch
FDR	Flight Data Recorder	PSIG	Pounds per Square Inch-Gage
FQIS	Fuel Quantity Indication System	PSU	Passenger Service Unit
FS	Frame Station	QAR	Quick Access Recorder
Ft	feet	R	Right
FWD	Forward	RBBL	Right Body Buttock Line
Gal	Gallon	RH	Right Hand
GPS	Global Positioning System	RHS	Right Hand Side
HPSOV	High Pressure Shutoff Valve	RWY	Runway
IFE	Inflight Entertainment	S/N	Serial Number
INDB	Inboard	TLA	Throttle Lever Angle
Kg	Kilogram	TPIS	Tire Pressure Indication System
L	Left	V1	Takeoff Decision Speed
L	Liter	VDC	Volts Direct Current
LAS	McCarran International Airport, Las Vegas Nevada	WBL	Wing Buttock Line
Lb	Pound(s)	WS	Wing Station
LBBL	Left Body Buttock Line		

4. DETAILS OF THE INVESTIGATION:

4.1 Recovery Operation

The following information was provided by Nevada Airlines Services who was contracted by British Airways to provided operational support at LAS. The NTSB authorized the removal of the aircraft from the runway prior to the arrival of NTSB personnel.

The aircraft was moved from the runway after the evacuation slides were removed. Based on advice from the fire department the aircraft was towed with the doors involved with the evacuation open. The aircraft was relocated to the cargo operations area at LAS and chocked.

Under guidance from the NTSB and assisted by the FAA the flight data recorder (FDR), cockpit voice recorder (CVR) and quick access recorder (QAR) were removed from the aircraft. The FDR, CVR and QAR were then shipped by the FAA to NTSB headquarters for further examination and downloading. The doors were closed and the aircraft secured until the arrival of the NTSB.

4.2 Sequence of Events for Incident Flight

The flight data recorder (FDR), the Quick Access Recorder (QAR)[1] and the electronic engine control (EEC) were downloaded and tabular data along with various plots were created. A sequence of events timeline was created based on data from the FDR and QAR and is provided in Table 1. It should be noted that the parameters are sampled at different rates based on the need for the fidelity of that data and are recorded at different times. For example, on the FDR the groundspeed, fan and low rotor speed (N1), engine fail warning, HPSOV position, fuel spar valve, TLA, and mastering warning are all sampled every second; engine fire warning, engine fuel lever cutoff, and high rotor speed (N2) are sampled every 2 seconds; the fire suppression bottle pressure (normal/low) and GPS data points are sampled every 4 seconds; longitudinal acceleration is sampled 4 times a second. On the QAR N2 is sampled every second. Also, each second is partitioned into multiple fractions of a second so that even if two parameters are recorded in that same whole second, the order that the parameters were recorded may be chronologically different. Due to variations in sample rates and recording times, it was not possible to align all the parameters perfectly on a common time, instead the information is provided in chronological order and represents the best estimate of the occurrence.[2]

[1] Quick Access Recorder data is a copy of the FDR and thus records the same data. It allows a quick and easy recovery of the raw data recorded in FDR. Only raw data is used for the event analysis.
[2] Further information and additional data from the FDR and QAR can be found in the Flight Data Recorder Group Factual Report.

Table 1 - FDR/QAR Sequence of Events

ESTIMATED ELAPSED TIME[1] (MINUTES:SECONDS)	EVENT DESCRIPTION
T = -00:22	Both thrust levers (TLA) advanced for takeoff
T = -00:21	Engine 1 & 2 N2 starts to increase
T = -00:21	Engine 1 & 2 N1 starts to increase
T = -00:21	Airplane takeoff roll starts
T = -00:20	Airplane takeoff groundspeed comes alive
T = -00:12	Engine 2 N2 reached value for takeoff
T = -00:11	Engine 2 TLA reaches takeoff setting (maximum value)
T = -00:11	Engine 1 N2 reached value for takeoff
T = -00:11	Engine 1 TLA reaches takeoff setting (maximum value)
T = -00:10	Engine 1 N1 reached value for takeoff
T = -00:09	Engine 2 N1 reached value for takeoff
T = -00:06	Engine 1 failure event
T = -00:05	Engine 1 fuel cutoff valve - **CLOSED**
T = -00:05	Engine 1 fail warning - **ON**
T = -00:05	Burner pressure drops dramatically
T = -00.05	Engine 1 TLA to idle
T = -00:04	Master warning - **ON**
T = -00:04	Maximum groundspeed
T = -00:04	Engine 2 TLA to idle
T = -00:04	Airplane starts to decelerate
T = -00.03	Brake pressure increases followed by groundspeed decrease
T = 00:00	**Engine 1 fire warning - ON**
T = +00:03	Master warning - **OFF**
T = +00:09	Engine 1 overheat caution - **ON**
T = +00:09	Airplane stopped
T = +00:09	Parking brake set
T = +00:19	Auto throttle - **DISENGAGED**
T = +00:22	Engine 1 fuel cutoff lever – **IN CUTOFF**
T = +00:22	Engine 1 fuel spar valve - **CLOSED**
T = +00:22	Engine 1 fail warning - **OFF**
T = +00:25	**Air supply control system** (ASCS) HPSOV - **CLOSED***
T = +00:30	Engine fire bottle 1 discharge pressure - **LOW**
T = +00:42	Engine 1 fire warning - **OFF**
T = +00:45	Engine fire bottle 2 discharge pressure - **LOW**
T = +01:15	APU speed begins to increase
T = +01:34	All entry doors – **NOT CLOSED, LATCHED AND LOCKED**
T = +01:52	APU running discrete is set (APU RPM ~ 100%)
T = +02:09	Forward Cargo Smoke Warning - **ON**
T = +02:08	Engine 2 fuel cutoff lever - **IN CUTOFF**
T = +02:10	Engine 2 fuel spar valve - **CLOSED**
T = +02:11	Engine 2 fuel cutoff valve - **CLOSED**
T = +02:12	Forward cargo smoke warning - **OFF**
T = +02:19	Last APU speed signal (APU ~ 100%)

Notes:
1 – Estimated elapsed time is referenced from the event “Engine 1 Fire Warning-ON”

4.3 Initial Aircraft Examination

The aircraft came to rest on RWY 7L where the passengers and crew evacuated the aircraft. Five (1L, 4L, 1R, 3R, 4R) of the eight entry doors were opened during the evacuation with slides deployed. Door 2R was opened following the evacuation and the slide was deployed. Figure 1, Figure 2 and Figure 3 show the doors after the evacuation was complete and prior to the aircraft being relocated.

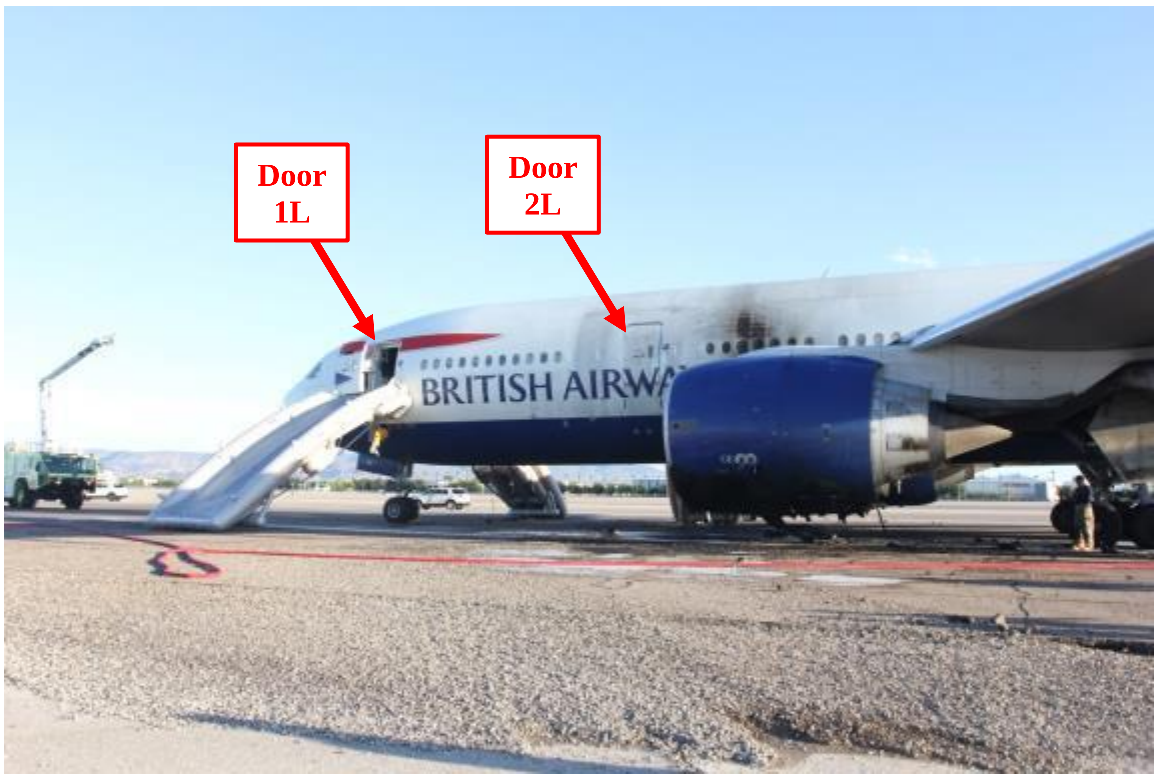


Figure 1 - View of FWD LHS of the aircraft on RWY 7L, doors 1L and 2L shown

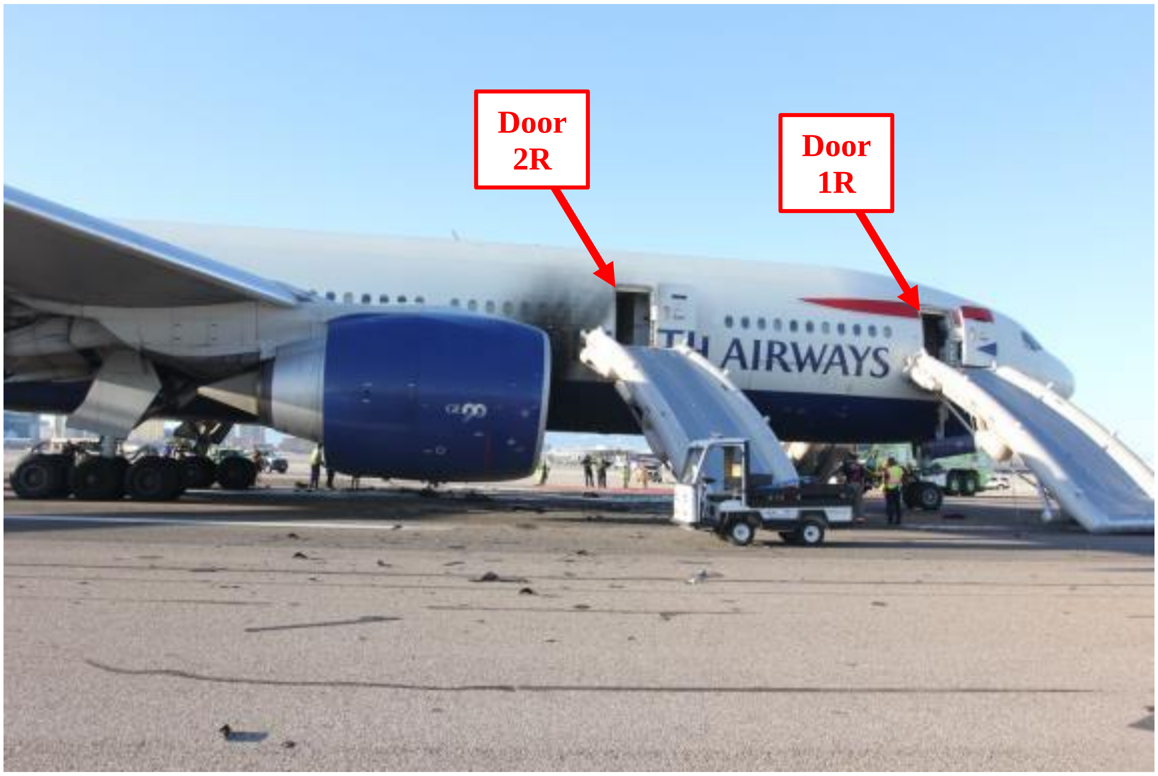


Figure 2 - View of FWD RHS of the aircraft on RWY 7L, doors 1R and 2R shown

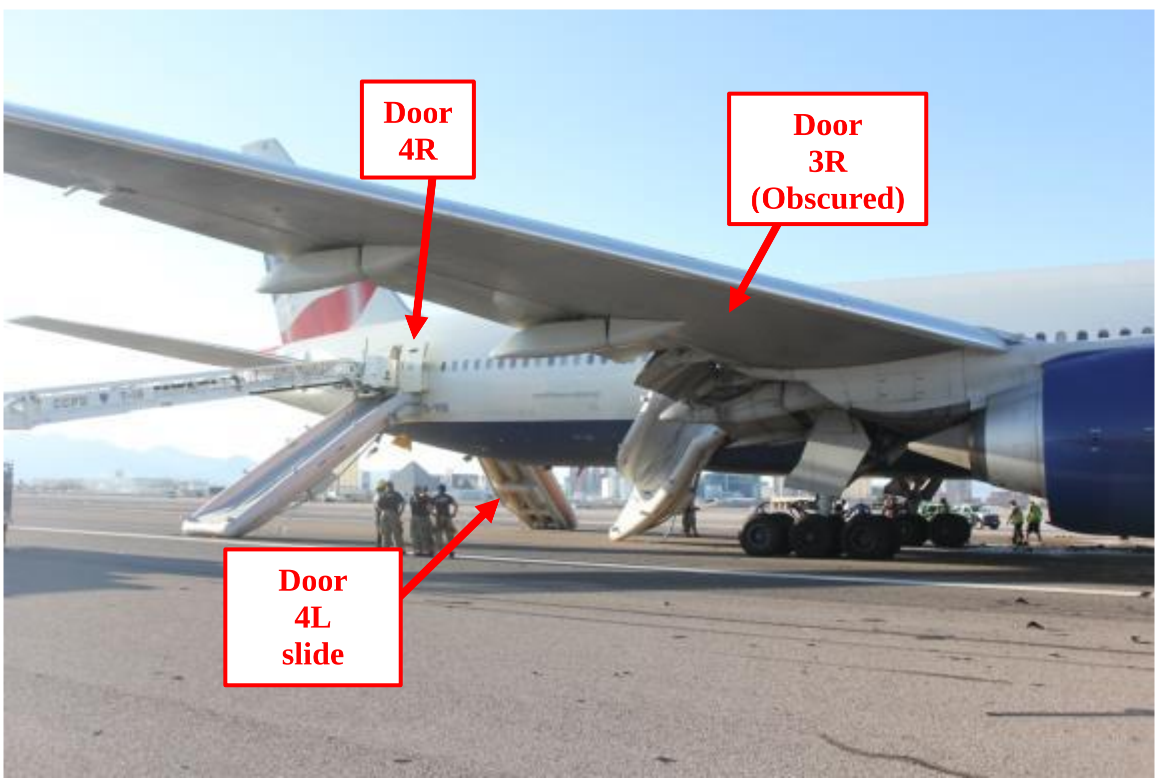


Figure 3 - View of aft RHS of the aircraft on RWY 7L, doors 3R and 4L obscured and 4R shown.

Skid marks were visible, see Figure 4, on the runway surface from both of the main landing gear assemblies and extended approximately 700 ft. from the aircraft's final resting place.

Figure 4 - MLG skid marks on RWY 7L

The aft-most tire on the outboard left hand main gear, referred to as tire 9, was found deflated, see Figure 5.[3]

[3] Tire numbering is based on the Boeing Aircraft Maintenance Manual number system. Tire number 1 is the forward-most tire on the left hand main gear. The tire number increments by one from left to right when looking down on the aircraft. There are twelve main gear tires and two nose wheel tires.

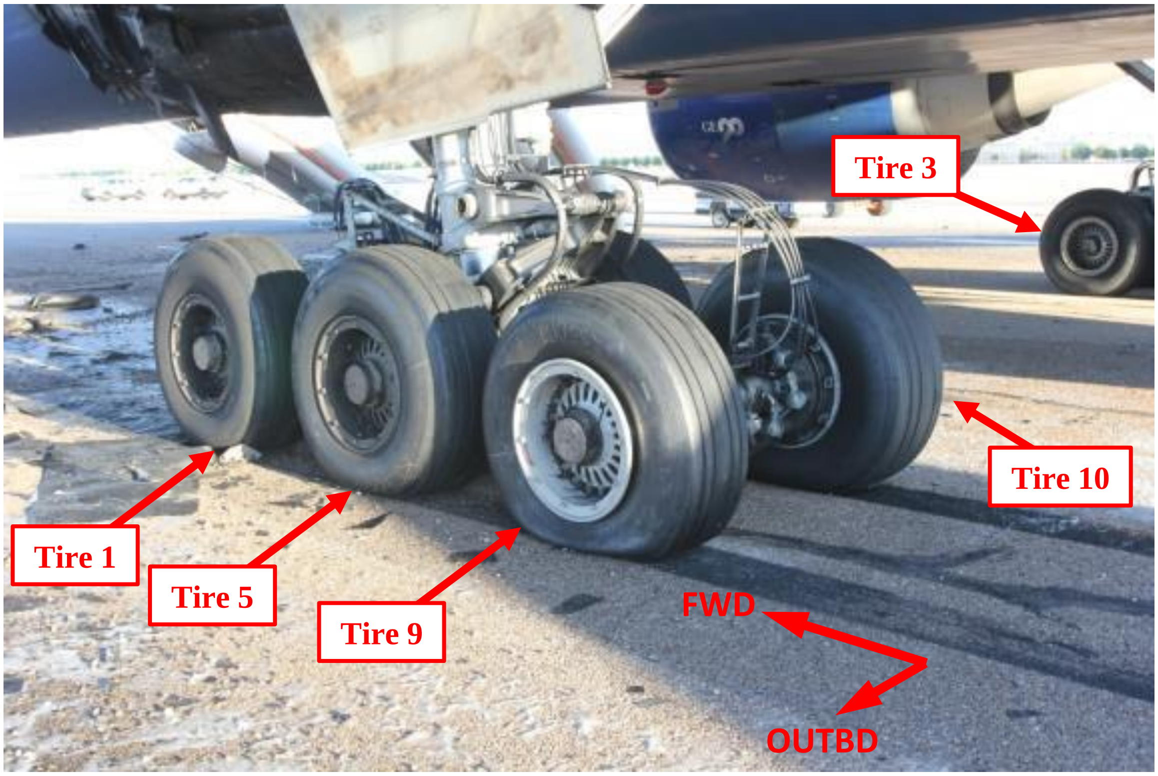


Figure 5 - LH main gear as found after aircraft stopped, tire 9 is deflated

4.4 Flight Deck

4.4.1 On-Scene Examination

Members of the group inspected the cockpit after the aircraft was parked in the cargo area. The cockpit was photographed and relevant panels were inspected. Due to the damage to the aircraft wiring in the area near the fire, power was not applied to the aircraft.

Unless otherwise noted, switches were in their nominal takeoff configuration.

The following lists the condition of relevant handle and switch positions located on the center pedestal, see Figure 6:

- The parking brake was not set.
- The Flap handle was in the 5 position.
- L and R TLA's were in the idle position and the thrust reverser piggybacks stowed.
- L and R FUEL CONTROL switches were in the CUTOFF position.
- L ENG FIRE handle was in the pulled position and rotated towards the number 2 fire bottle position; Figure 7 and Figure 8.

- R ENG FIRE handle was in the not pulled position and was not rotated towards either the number 1 or number 2 fire bottle positions; Figure 7 and Figure 8.
- The guard on the evacuation command switch was raised and the "Command" switch was in the ON position, Figure 9.

Figure 6 - Center Pedestal

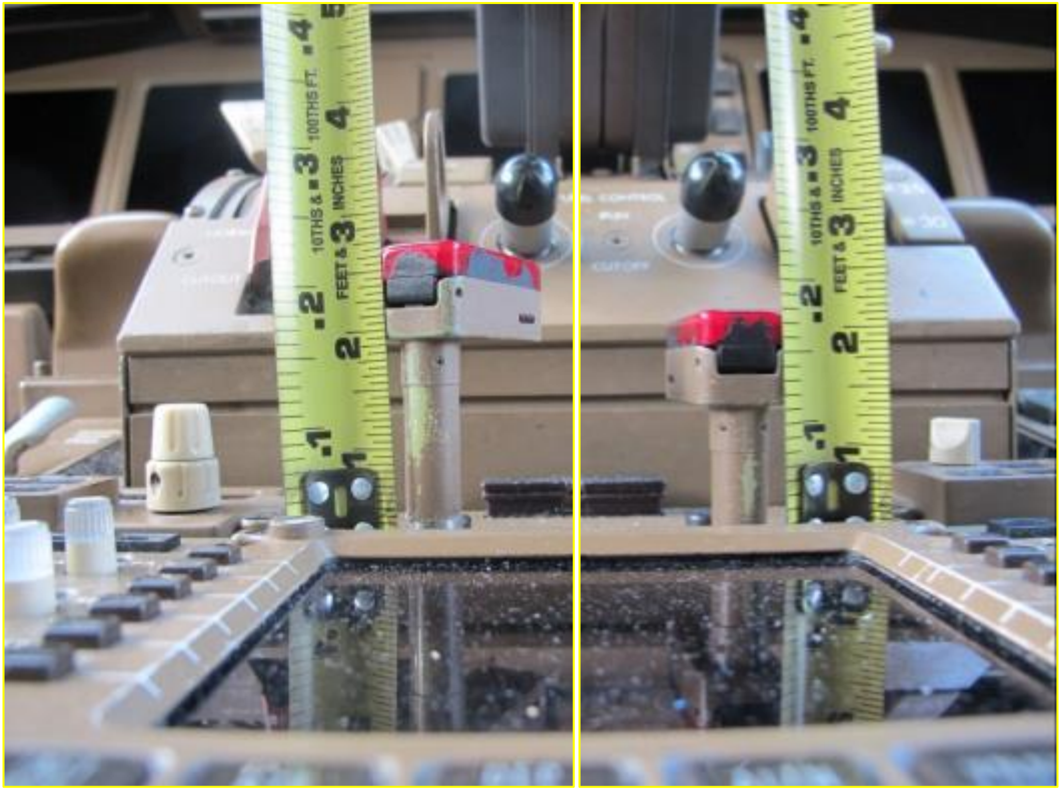


Figure 7 - Left and Right Fire Handles - Side View looking forward

Figure 8 - Fuel control and fire handles – View looking down

Figure 9 - Evacuation Panel

The following lists the condition of relevant handle and switch positions located on the overhead panel:

- APU/Cargo Panel - The FWD cargo bay arm switch was armed and depressed, Figure 10.
- APU/Cargo Panel - The AFT cargo bay arm switch was not armed and not depressed, Figure 10.
- APU/Cargo Panel - The APU fire handle was extended 2.75 inches and not rotated, Figure 10.
- Pressurization Panel - Both outflow valves (FWD and AFT) were in the MANUAL position, Figure 11.
- Fuel Panel - Both L and R center fuel pumps were ON, Figure 12.
- Fuel Panel - Both FWD and AFT, L and R fuel pumps were ON, Figure 12.

Figure 10 - APU and Cargo Fire Panel

Figure 11 - Pressurization Panel

Figure 12 - Fuel Overhead Panel

An inspection of the overhead circuit breaker panels showed that all circuit breakers remained closed.

4.5 Structure

4.5.1 Description and Operation

4.5.1.1 Aircraft Structure

The 777-200 fuselage shell is a semi-monocoque structure with skin, longitudinal stringers and circumferential frames and bulkheads. The fuselage is a complete torque box throughout its length. Cutouts for doors, windows, escape hatches, and other fuselage openings are reinforced by a local framework of frames, sills, and doublers.

The 777-200 wing is a cantilever, semi-monocoque, cellular structure tapering both in planform and depth. Splices at the side-of-body (Body Buttock Line (BBL) 122.45) join the outboard wing sections to the wing center section. The outboard wing is comprised of leading edge structure, inspar wing box, and trailing edge structure. The wing box structure consists of the upper and lower skin panels and the front and rear spars with ribs located perpendicular to the rear spar. Major fittings that interface with the outboard wing box include the nacelle support structure, flap support structure and the main landing gear support structure. The nacelle strut, centered at approximately Wing Buttock Line (WBL) 381, is attached to the inspar wing box via a redundant six point support configuration. The supports consist of the front spar pitch load ("overwing") fitting assembly (R1), the inboard and outboard side load fitting assemblies (R4 and R3 respectively), a two point lower panel fail-safe link fitting (R7 and R8), and the lower panel thrust link fitting assembly (R2).

The main landing gear of the 777-200 is supported by the main landing gear beam, and the wing rear spar. The gear attaches to the wing rear spar via a drag brace, near the side of body, and a forward trunnion attachment, at approximately Wing Station (WS) 387. The main landing gear beam, which supports the main landing gear aft trunnion and side brace, is attached to the wing rear spar at approximately WS 490, via the mini-cantilever fitting, and the fuselage at BS 1371, via the hanger link.

The wing center section box runs through the fuselage from Left Body Buttock Line (LBBL) 122.45 to Right Body Buttock Line (RBBL) 122.45 and consists of upper and lower skin panels, front and rear spars, spanwise beams, overwing beams and internal lower beams. The keel beam is attached to the lower panel of the wing center section through fasteners, common to the keel beam upper chord and tension fittings, which are located at the spanwise beam locations.

On the 777-200, the wing box structure acts an integral fuel cell and carries the entire mission fuel for the airplane. The incident airplane featured three (3) individual fuel tanks; one in each outboard wing, between Rib 8 (WS 387.0) and Rib 32 (WS 1021.5) and a center fuel tank, located between right-hand and left-hand Rib 8 (including the wing center section, within the fuselage contour). The tanks are isolated from one another via structural fuel barriers (tank end ribs), with cross-tank communication provided by the airplane fuel system.

4.5.1.2 Main Cabin Doors

The fuselage has four passenger entry doors (PED) on each side of the fuselage, three lower lobe cargo doors on the right side of the fuselage, see Figure 13. The entry doors are inward-outward opening plug type doors. Each door was equipped with an emergency power assist system (EPAS) and an escape slide/raft.

Each door contains handles to unlock and unlatch or latch and lock the door from either the inside or the outside of the aircraft. The door mode select lever on each door controls the arming and disarming of the EPAS and slide/raft. Prior to departure the door mode select lever is set to the automatic position arming the EPAS and slide/raft for automatic deployment.

In the event of an emergency egress, if the internal door handle is moved to the open position while in the automatic mode, the door is powered open by the EPAS. The escape slide/raft will deploy from the door and automatically inflate for operation.

Access ports are provided to allow for visual verification of pressure levels for the EPAS and escape raft/slide pneumatic pressure bottles.

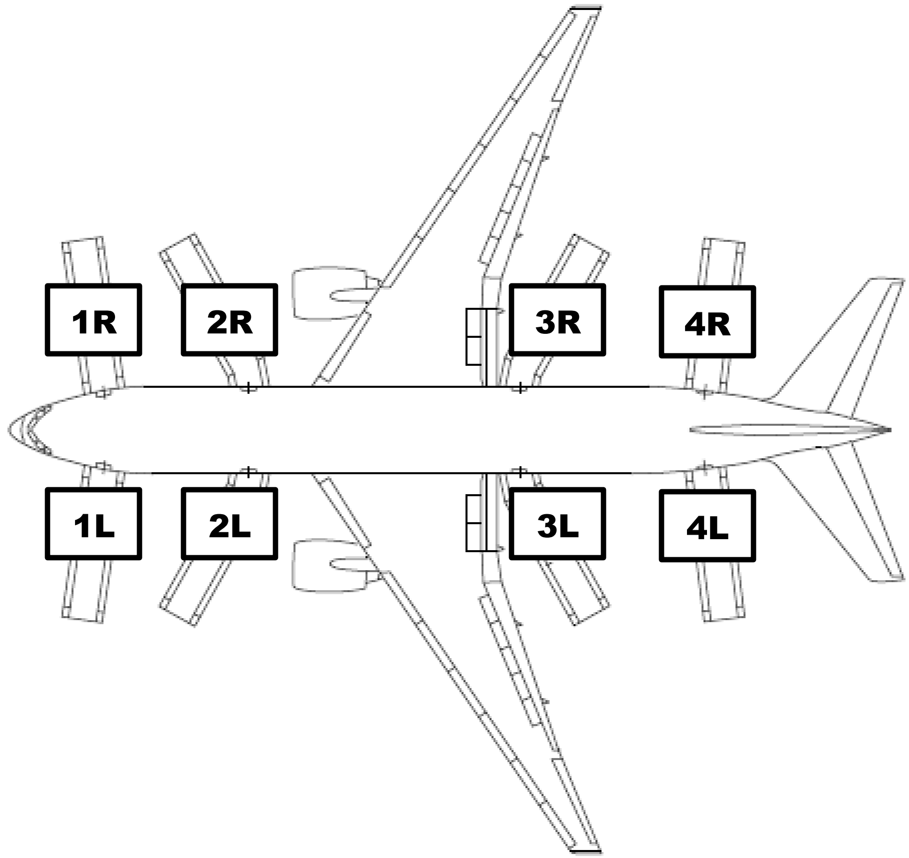


Figure 13 - Boeing 777-200 Door/Slide Identification

4.5.2 On-Scene Examination

4.5.2.1 Exterior Structure

The thermal damage on the exterior of the aircraft was concentrated along the midsection of the aircraft, extending from the left engine all the way to the right side of the fuselage.

4.5.2.1.1 Left Engine

On the left engine the cowling was thermally damaged from the 4 o'clock position (just below the pressure relief port) to the 12 o'clock position (engine mounting strut) as viewed from the front. The degree of this thermal damage was more extensive in between the 6 and 12 o'clock positions (inboard side of the engine) causing the composite cowling to delaminate, see Figure 14. The aluminum leading edge of the cowling was partially melted along the 7 – 8 o'clock position. Once the cowling was removed it was evident that the interior of the engine was not nearly as thermally damaged as the exterior and primarily had sooting on some surfaces but no significant thermal degradation to the components. It was discovered that the main fuel supply line had been severed at the engine.

Figure 14 - Inboard side of left engine.

4.5.2.1.2 Left Wing

The left wing sustained thermal damage in the area between the left engine and the fuselage. There was no evidence of engine debris impacting or penetrating the left wing structure. The aluminum slat in this area was melted on the inboard and outboard ends but remained intact in the middle section, see Figure 15. The aluminum Krueger flap adjacent to the strut was charred and damaged. The aluminum strakelet exhibited areas of buckling, cracking and portions of missing material, see Figure 16. The composite lower fixed leading edge panels were thermally damaged and exhibited delamination of the external plies, see Figure 17. Their cores were still in place but had suffered thermal degradation. The composite flap track fairing exhibited charred and blistered paint along its lower portion. The aluminum/composite fuel tank access doors on the inboard portion of the wing (inboard of the engine) were weeping gasket grease from beneath the clamp ring, see Figure 18. There was no evidence of fuel leakage from the wing tank. The interior side of the composite lower fixed leading edge panels exhibited thermal degradation in the areas near the slat. The thermal degradation diminished towards the front spar. The composite upper fixed leading edge was charred all the way out to the strut, see Figure 19. The wing surfaces outboard of the strut, both the top and bottom, did not exhibit any damage from the fire. Examination of the aluminum front spar did not reveal any adverse thermal effects. The composite panel mounted to the shock strut of the left main landing gear exhibited blistering of the paint and some delamination of the outer plies.

Figure 15 - Thermal damage to slat and top surface of fixed leading edge of the left wing.

Figure 16 - Close-up view of thermal damage to strakelet.

Figure 17 - View of bottom surface of left wing fixed leading edge.

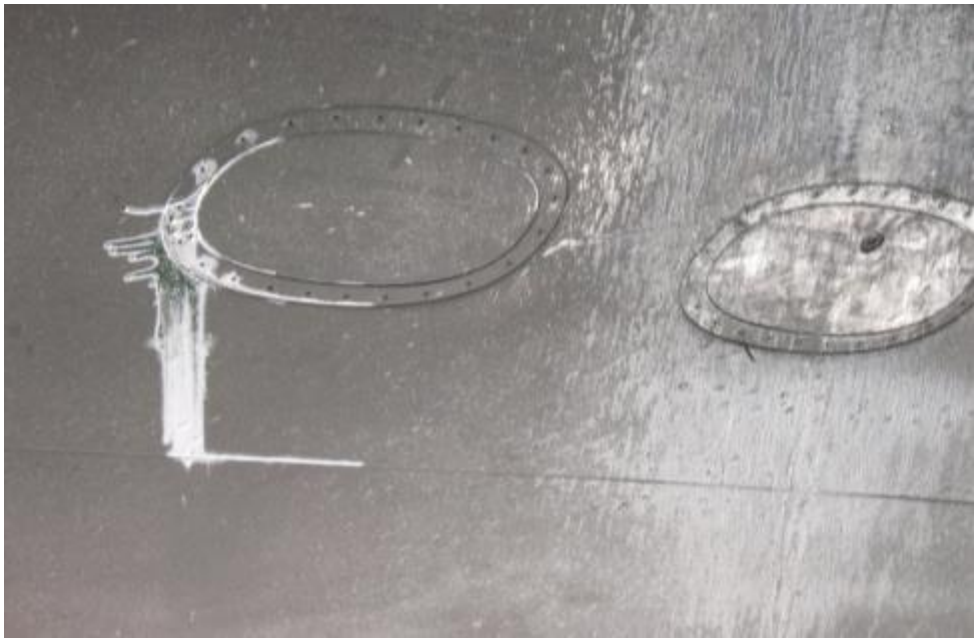


Figure 18 - Fuel tank access door on the inboard (of the engine) portion of the wing.

Figure 19 - Left wing upper surface of fixed leading edge.

4.5.2.1.3 Fuselage (left side)

The fuselage skin exhibited thermal damage in the form of missing and charred paint from frame station (FS) 867 to FS 993 and stringer 15 to 30. The center of this thermally damaged region exhibited buckling and some cracks in the skin, the longest being approximately 12 inches long, see Figure 20 and Figure 21. These cracks in the skin coincided with the area of most severe thermal damage to the wall panels in the interior of the aircraft. There were 13 thermally crazed windows on the fuselage extending from the L2 door back to FS 1119. There was no evidence of engine debris impacting or penetrating the left side of the fuselage structure.

Figure 20 - Thermally damaged fuselage skin exhibiting cracks.

Figure 21 - Thermally damaged fuselage skin and thermally crazed windows.

4.5.2.1.4 Wing to Body Fairings and Belly

Both the left and right side air inlets for the air-conditioning packs were charred on the inside surface for as far as could be seen looking in from the open forward ends. From within the air-conditioning compartment the ducts felt soft and compliant for nearly their full length from the open ends towards the rear. This damage appeared to be similar on both sides of the aircraft. The wing to body fairings exhibited widespread delamination and blistering, see Figure 22. The cores of the composite fairings appeared to be intact and felt solid. There was complete skin delamination of the composite fairing forward of FS 1063 and loosening of the lamination bond aft of FS 1063, with blistering aft of FS 1063 common to the underwing and over wing fairings. The composite panels on the belly of the aircraft in the area of the wing to body junction were thermally damaged and exhibited delamination of the panels, see Figure 23. The inside of the fairings did not exhibit thermal damage. The wing to body fairing panels on the right side of the aircraft also sustained thermal damage and exhibited delamination but to a lesser degree than those on the left side, see Figure 24. There was no evidence of engine debris impacting or penetrating the wing to body and belly fairing.

Figure 22 - Left side wing to body fairing exhibiting thermal damage and delamination.

Figure 23 - Thermally damaged composite panels on the belly of the aircraft in the area of the wing to body junction. Photo taken looking aft.

Figure 24 - Thermal damage on the right side wing to body fairing.

4.5.2.1.5 Fuselage (right side)

On the right side of the aircraft above the wing to body fairing the fuselage was sooted. Buckling that created a tactile waviness to the aluminum skin was found in the area from FS 867 to FS 909 in between stringers 27 – 30, see Figure 25. Two of the windows above this area exhibited thermal crazing.

Figure 25 - Sooting and thermal damage to right side fuselage.

4.5.2.2 Main Cabin Doors

The main cabin doors were inspected by members of the airworthiness group. During the accident, all doors except 2R, 2L and 3L were opened during the evacuation sequence. Door 2R was opened and the 2R escape slide deployed after the evacuation and before the airplane was towed. The doors were inspected after the aircraft had been towed to the cargo area.

All main cabin doors, except door 2L, had no signs of interior or exterior damage. The exterior of the door 2L was covered in black soot and the window was crazed. The interior surface of the door had no signs of visible damage. All doors were manually operated and could be opened and closed without difficulty.

The escape slide/rafts were removed after the event to permit relocation of the aircraft from all of the doors except for doors 2L and 3L. Door 1R was the main point of entry for the investigation team and was opened and closed multiple times during the on-scene work by the group. EPAS and slide pressures, where applicable, were documented and the results are contained in Table 2.

Table 2- Main cabin door inspection results

Door	EPAS Pressure Reading[1]	Slide Pressure Reading[1]	Manual/Auto Handle Position[2]
1L	Red (0 PSI)	N/A	Automatic
1R	Red (0 PSI)	N/A	Manual
2L	Green	Green	Manual
2R	Red (0 PSI)	N/A	Manual
3L	Green	Green	Manual
3R	Red (0 PSI)	N/A	Manual
4L	Red (0 PSI)	N/A	Manual
4R	Red (0 PSI)	N/A	Manual

[1] – Pressure indications are based on the gages color band, Red for No-Go, Green for Go
[2] – Handle position was at the time of the inspection of the door, not immediately following the event

4.5.2.3 Escape Slide/Rafts

Five slides were deployed during the evacuation, and one was deployed following the evacuation.[4]. Prior to the group arriving, the slides were removed to allow repositioning of the aircraft. The slides were inspected by the members of the airworthiness group on Sep 10th, 2015.

All of the slides were visually inspected and the results are summarized in Table 3. None of the slides showed signs of heat damage. The slides were manually deflated and then packed onto wood pallets and placed in the rear cargo bay of the accident aircraft.

Table 3- Escape slide/raft inspection results

Door	Slide P/N (S/N)	Chamber		Slide Condition (toe end is closest to tarmac)
		Upper	Lower	
1L	62771-117 (446)	Inflated	Partially Inflated	Light scuffing on toe end
1R	62771-120 (740)	Inflated	Partially Inflated	No scuffing on toe end
2L	Not Recorded	Slide Not Deployed		N/A
2R	62771-216 (758)	Inflated	Inflated	Light scuffing and minor soot spots on toe end
3L	Not Recorded	Slide Not Deployed		N/A
3R	62771-304 (122)	Inflated	Partially Inflated	Light scuffing on toe end

[4] As mentioned in the previous section, the door 2R slide/raft was deployed after the evacuation was complete but prior to aircraft relocation.

Door	Slide P/N (S/N)	Chamber		Slide Condition (toe end is closest to tarmac)
		Upper	Lower	
4L	62771-415 (667)	Inflated	Inflated	Light scuffing on toe end
4R	62771-416 (541)	Inflated	Inflated	Light scuffing on toe end

4.5.2.4 Interior Cabin

The thermal damage to the interior cabin was confined to the wall panels at the location of seat 11A, see Figure 26. The thermal damage consisted of blistering and charring of the decorative face sheet on the wall panels. There was no soot on any surfaces adjacent to the thermally damaged areas. The damage was consistent with thermal decomposition and charring and not flaming combustion on the inboard surfaces of the damaged panels. The seat adjacent to the charred wall panel did not sustain any thermal damage. The majority of the charring to the panels was concentrated in between frame 909 and frame 951. The most severe damage was in between frame 909 and frame 930 where charring was observed from the vent grill at the floor and extended up to just below the passenger service unit (PSU). In between frame 930 and frame 951 the charring extended from the vent grill at the floor to just below the window, see Figure 27.

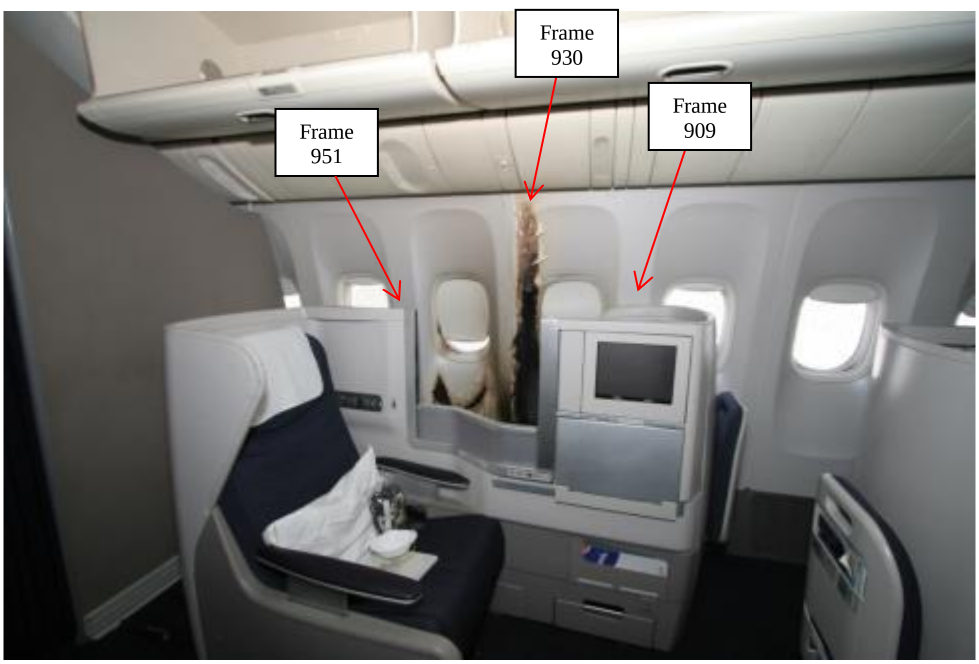


Figure 26 - Cabin interior at the location of seating row 11

Figure 27 - Interior wall panel at seat 11A.

The wall panels were removed to document the damage to the inboard side of the insulation behind them. This exposed the thermal acoustic insulation from the floor level up to the PSU, see Figure 28 and Figure 29

In between frame 888 and frame 909 the damage to the insulation was located at floor level and extended up the insulation covering frame 909 to the height of the top of the window. The damage consisted of melted and missing insulation vapor barrier film.

In between frame 909 and frame 930 the damage extended from the floor level up to the PSU and filled the width of the bay. This damage consisted of missing insulation film and blackened glass batting.

In between frame 930 and frame 951 the damage to the insulation extended from floor level up to the bottom of the window and covered the width of the bay. The damage consisted of missing insulation film and charred glass batting. Above the damaged portion, the insulation had some soot on the film mostly on the side nearest frame 951.

In between frame 951 and frame 972 the damage to the insulation extended from the floor level and up about 12 inches. The damage consisted of missing insulation film and some charring near frame 951.

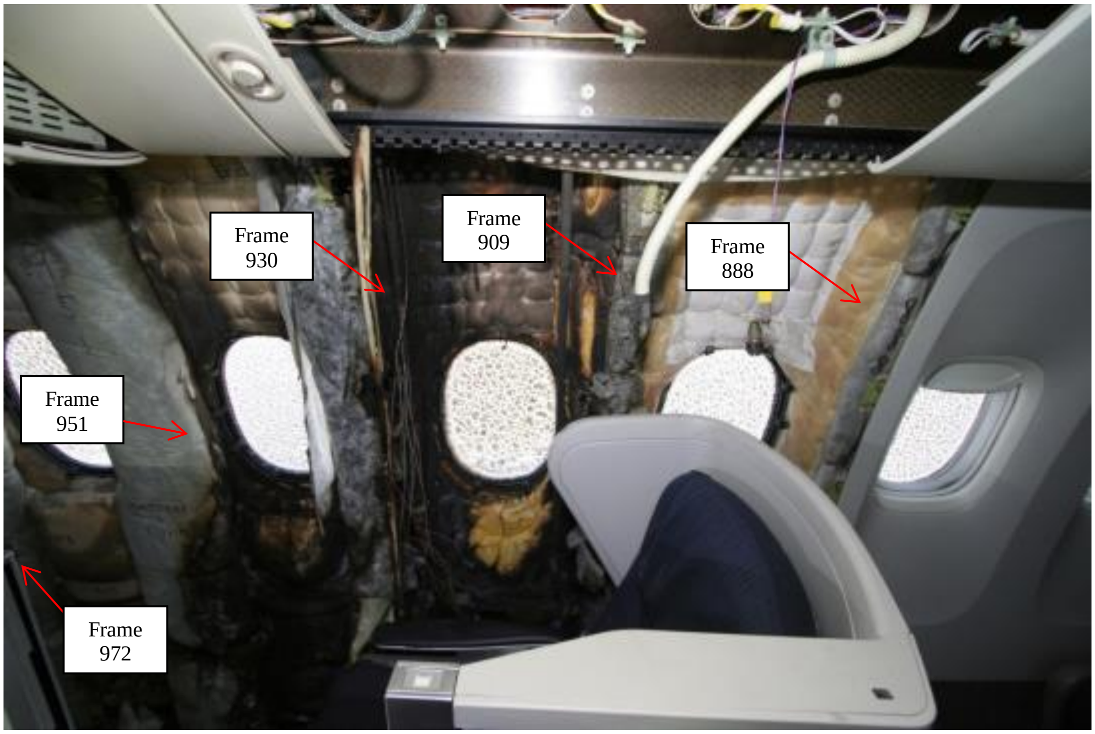


Figure 28 - Insulation exposed between frame 888 and frame 972

Figure 29 - Insulation exposed between frame 909 and frame 972

Panels were removed above the baggage bins to see how far up the damage to the insulation extended. In this area the damage was confined to the bay between frame 909 and frame 930. This damage consisted primarily of discolored insulation film and small areas of missing film, see Figure 30 and Figure 31

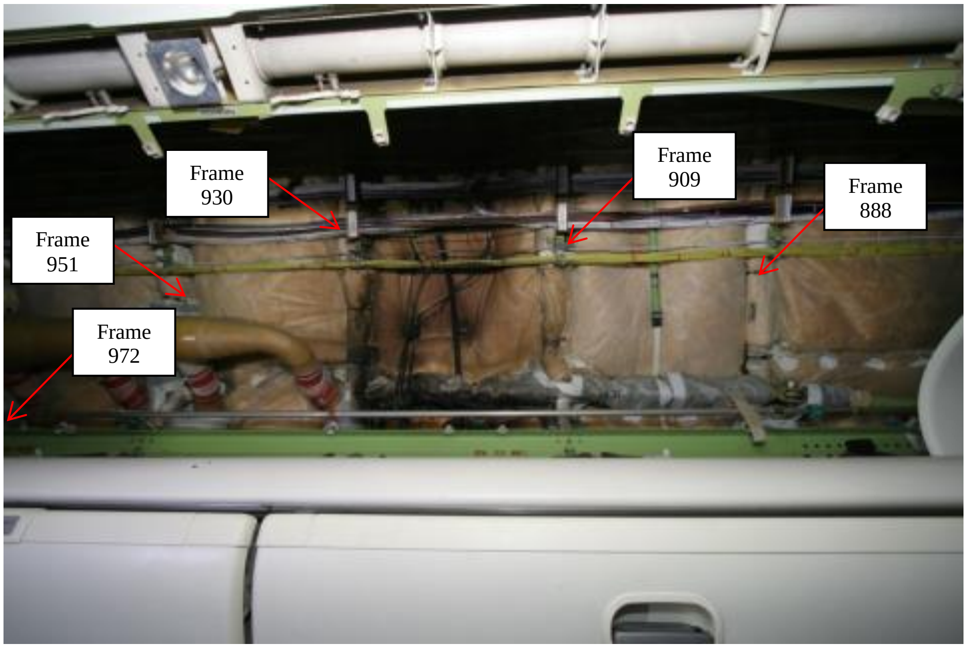


Figure 30 - Insulation exposed above baggage bins between FS 888 and FS 972

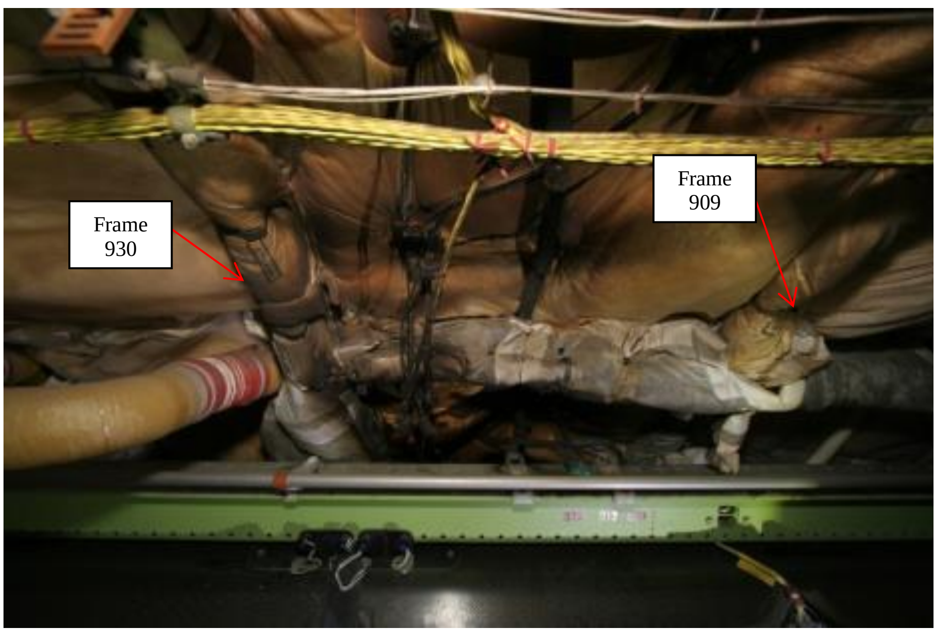


Figure 31 - Insulation above the baggage bin between frame 909 and 930 (view angled downward)

The insulation was peeled back to examine the damage to its outboard side and expose the interior side of the fuselage skin.

In between frame 888 and frame 909 the thermal damage to the insulation was more severe on the outboard side than on the inboard side. The primer on the fuselage skin was charred behind the insulation, see Figure 32.

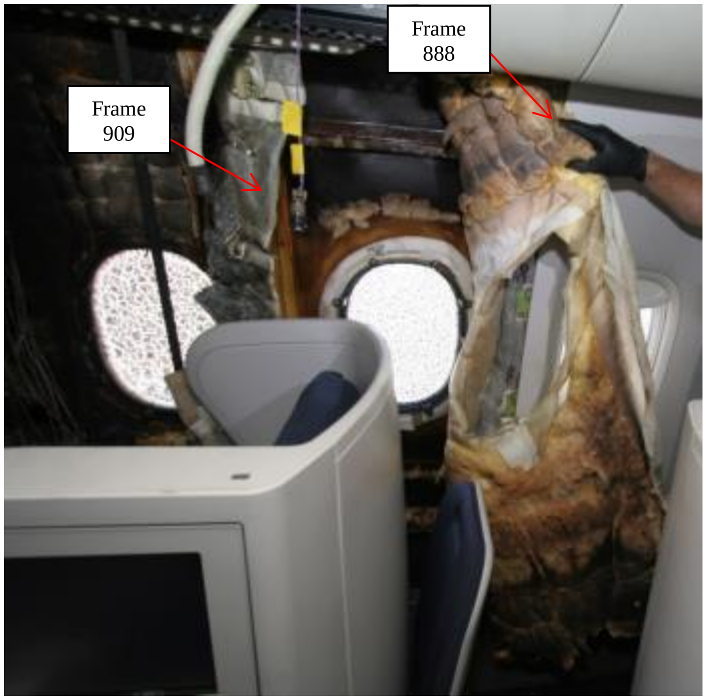


Figure 32 - outboard side of insulation between frames 888 and 909.

In between frame 909 and frame 930 the thermal damage to the insulation along the lower portion up to the window was similarly damaged on both the outboard side and the inboard side, see Figure 33. From the window and up, the thermal damage to the insulation was more severe on the inboard side. In this frame bay there was a bundle of wires extending vertically along the side of frame 930 and the thermal damage seemed to coincide with this wire chase. The primer on the fuselage skin was charred behind the insulation in the entire frame bay. There was a split in the fuselage skin visible at floor level and included some buckled stringers just above the floor, Figure 34. From the outboard side, the visible edges of the split were bright and soot was not present, see Figure 35.

In between frames 930 and frame 951 the outboard side of the insulation above the window level was not severely damaged and exhibited some discoloration. In this frame bay two ducts were oriented vertically, one adjacent to frame 930 and one adjacent to 951. These ducts were charred and friable below the window level, Figure 36. The insulation below the window level was also charred on the outboard side. The primer on the fuselage skin in this frame bay was charred.

Figure 33 - Outboard side of the insulation in frame bay 909 to 930

Figure 34 - Split in the fuselage skin near floor level between 909 and 930

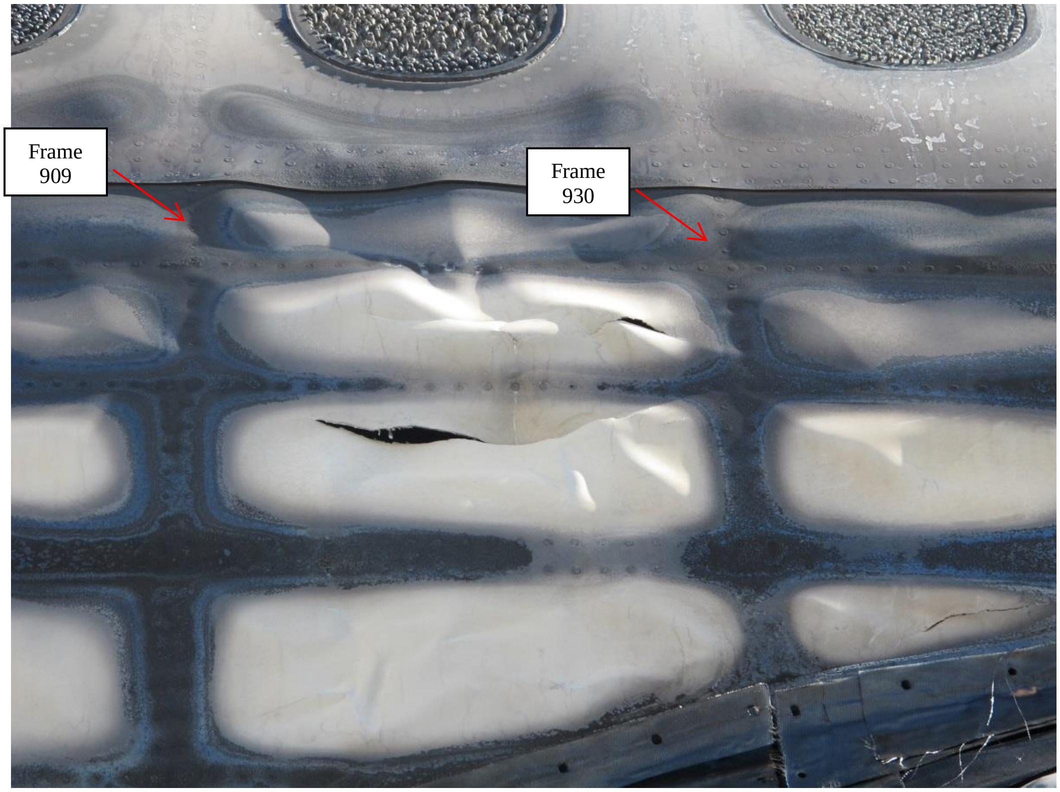


Figure 35 - Outboard side of skin split between frames 909 and 930.

Figure 36 - Insulation and duct between frame 930 and frame 951

4.5.2.5 Forward Cargo Bay

The cargo compartment and liners looked normal, no soot or thermal damage was evident. The ceiling liners did have spray pattern stains locally around the Halon discharge nozzles which is not unusual after a discharge.

The cargo liners were opened between frames 888 and 940 to reveal the area inboard of the external fire damaged area see Figure 37 through Figure 40. The following observations were made:

- Between frames 867 and 888 the insulation just below the floor (~6") was discolored and a small area of the film was melted.
- Between frames 888 and 909 the insulation just below the floor (~8") was charred and the film shrank back.
- Between frames 909-930 there were small areas on the lower section of the blanket with burned film due to drips. The insulation blanket just below the floor (~8") was charred.
- Between frames 930 and 951 the insulation blanket was charred (6") just below the floor, and approximately 12" of the film shrank back.

Figure 37 - Forward cargo compartment left hand sidewall frames 888-930 (cargo liner pulled back)

Figure 38 - Looking up and outboard at station 890-909 (just below main deck floor)

Figure 39 - Looking up and outboard at station 920-930 (just below main deck floor)

Figure 40 - Looking up and outboard at station 940-951 (just below main deck floor)

4.6 Forward Cargo Bay Smoke Detection and Fire Suppression

4.6.1 Description and Operation

The FWD and aft cargo compartments each contain one smoke detector. The smoke detector monitors the cargo compartment air for smoke and the operation is automatic and does not need crew action. Air is drawn from multiple locations in the cargo compartment by a fan downstream of the smoke detectors. The sampled air travels through the detection circuits and if smoke is sensed an alarm is triggered in the cockpit.

The following indications occur in the cockpit for a FWD cargo compartment smoke detection event:

- A “FIRE CARGO FWD” EICAS message is displayed
- The master warning light comes on
- The fire warning aural sounds

- The FWD cargo fire warning light on the overhead panel comes on, Figure 41

If the smoke is detected during take-off, the master warning lights and fire bell alerts may be inhibited.[5]

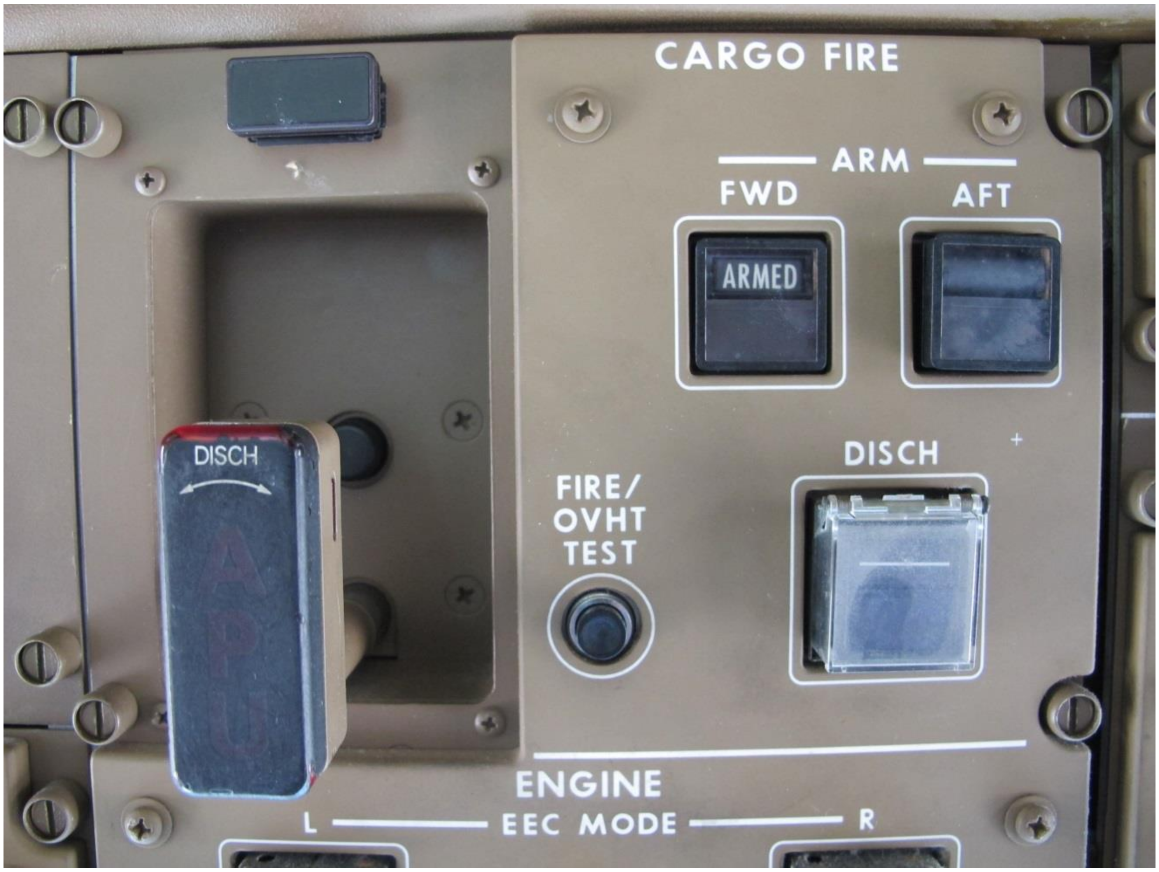


Figure 41 - Cargo Fire/Engine control panel from accident aircraft as found

The lower cargo fire extinguishing system, extinguishes fires in the forward or aft lower cargo compartments. The system consists of two fire extinguishing dump bottles, three fire extinguishing metered bottles, eight discharge nozzles (four in the FWD and four in the aft compartment), in-line pressure switches and additional system tubing and components. The fire extinguishing bottles contain halon 1301 fire extinguishing agent pressurized with nitrogen. Flow valves will send the halon to the forward or aft cargo compartments depending on crew selection.

The two dump bottles (1A and 1B) and the three metered bottles (2A, 2B, and 2C) are mounted along the right hand side of the aircraft, below the main cabin floor, adjacent to the forward cargo compartment, see Figure 42.

5 Alerts are inhibited when they are operationally unnecessary or inappropriate. The Master Warning and Fire Bell alerts are inhibited if they occur after V1 or rotation (whichever occurs first) to prevent distracting the crew. The inhibit ends at 400 feet radio altitude or 25 seconds after the inhibit started (whichever occurs first).

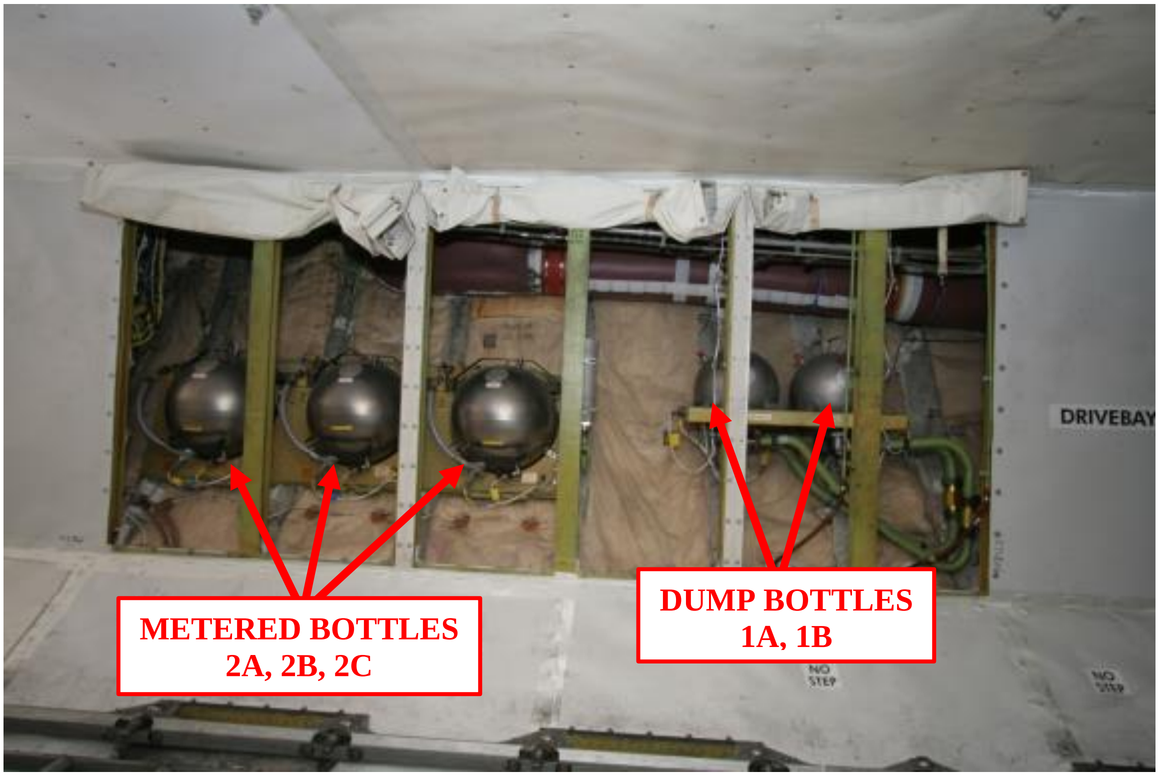


Figure 42 - Cargo fire extinguishing system bottles

The fire extinguishing system is operated by cargo fire/engine control panel in the cockpit, Figure 41. The crew first arms the appropriate cargo compartment by depressing the forward or aft arm pushbutton. The pushbutton will display "ARMED" for the selected compartment. When the forward system is armed, the environmental control system will perform the following actions:

- The lower recirculation fans, IFE cooling fan and gallery chiller fan are turned off
- The air condition packs flow schedule is changed
- The forward and aft outflow valves are positioned to 50%
- The equipment cooling system is placed in override mode
- The equipment cooling vent valve is closed

To discharge fire bottles, the crew will depress the guarded discharge pushbutton (labeled "DISCH"). A pressure switch in the tubing will turn on the "DISCH" indication to show that the discharge sequence has started.

Selecting discharge will fire an explosive squib which will release the halon and will immediately discharge the contents of both of the dump bottles into the selected cargo compartment. After a pre-set time delay the explosive squib on the metered bottles will fire and discharge the metered bottle contents at a slow controlled rate to keep the fire extinguished for 195 minutes. In the event the cargo bay discharge occurs while the aircraft is on the ground, after twenty minutes from when the initial discharge is selected, only one of the metered bottles will be emptied into the cargo compartment. Once any of the bottles have been activated they will discharge until they are empty. Each bottle contains a pressure switch to indicate a low bottle pressure.

4.6.2 On-Scene Examination

The Cargo Fire/Engine control panel was documented by the group during the cockpit examination, see Figure 41. The forward cargo compartment arm pushbutton was found armed and depressed. The forward pushbutton displayed “ARMED”. The aft cargo compartment arm pushbutton was found not armed and not depressed. The “DISCH” pushbutton guard was in the guarded position.

As stated previously in 4.5.2.5, the cargo compartment and liners looked normal, no soot or thermal damage was evident. The cargo liners on the right hand side of the aircraft were opened between frames 655 and 772 to reveal the cargo fire bottles, see Figure 42.

The four halon discharge ports in the ceiling liners did have spray pattern stains locally around the Halon discharge nozzles, see Figure 43.

Figure 43 - Forward cargo compartment halon discharge ports

The cargo fire extinguisher bottles were visually inspected and using a digital multi-meter a verification of the position of the bottles pressure switch was accomplished. The connector on each fire bottle pressure switch was removed and continuity was checked. Based on information from the Boeing 777 Aircraft Maintenance Manuals, if the bottle pressure is greater than 100 PSI, the switch continuity should be open, otherwise the signal would read closed (continuous). The following table outlines the results of the visual inspection and the pressure switch checks.

Table 4- Cargo fire bottle inspection and continuity test results

Bottle	P/N	S/N	Inspection Date	Listed Full Weight (lbs)	Switch Continuity Test Result
1A	S218W601-1	1435 AY	03/10	62.50	Closed
1B	S218W601-1	54672 EL	5/10	62.46	Closed
2A	S218W601-2	18699 EL	2/11	83.88	Closed
2B	S218W601-2	55623 EL	11/10	84.15	Open
2C	S218W601-2	55725 EL	11/10	84.12	Open

The cargo fire bottles were not removed from the aircraft.

4.7 Fuel System

4.7.1 Description and Operation

The following description relates only to the portion of the fuel system relevant to this investigation.

4.7.1.1 Engine Fuel Feed System

The engine fuel feed system controls and supplies fuel to the engines. The system takes inputs from the fuel panel, fuel control switches, the engine fire switches and the electrical load management system (ELMS). The engine fuel feed system uses fuel pumps, fuel pump pressure switches, cross-feed valves and spar valves to supply fuel to the engines, see Figure 44.

The main tanks are each equipped with two AC-powered centrifugal boost pumps, either of which can supply the fuel flow and pressure requirements of a single engine. Also provided is a suction feed bypass inlet in each main tank. The pump and suction feed inlets are positioned in the lowest portion of the tank for most ground and flight conditions, to maximize the usable fuel quantities throughout operation.

The center tank is equipped with two AC-powered centrifugal override/jettison pumps that provide a higher output pressure than the main tank boost pumps. When the override/jettison pumps and boost pumps are both operating, the higher output pressure of the override/jettison pump ensures fuel from the center tank is burned first, with a seamless transition to main tank when the center tank is exhausted without any pilot action.

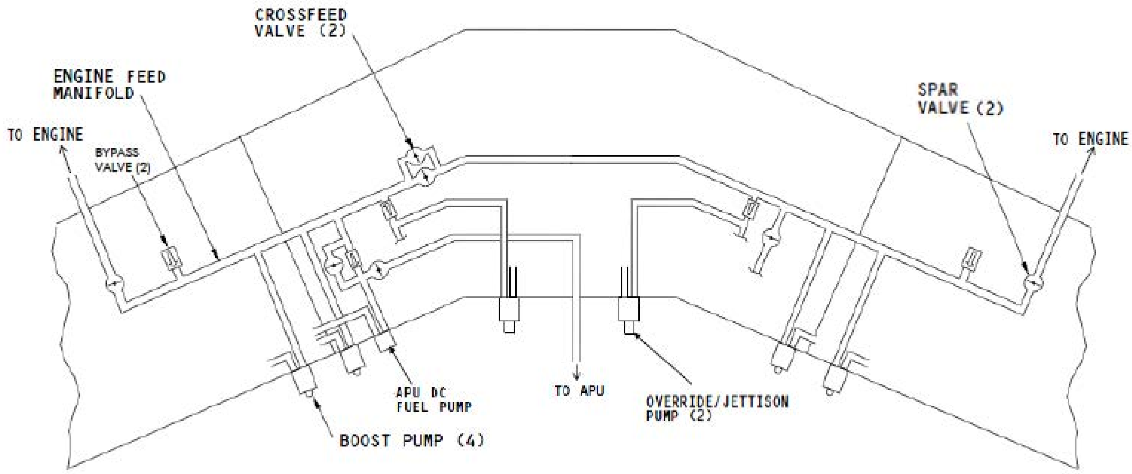


Figure 44 - Simplified Engine Fuel Feed System for incident aircraft (source: Boeing)

The cross-feed manifold contains two parallel shutoff valves connecting the two sides of the system, allowing one main tank to feed both engines even in the unlikely event that one cross-feed valve or valve actuator fails closed. Each engine fuel feed line is equipped with a rear spar-mounted shutoff valve, also called the spar valve, to terminate fuel flow to that engine at normal engine shutdown or in the event of an emergency that would require engine shutdown. A similar valve is installed in the APU fuel feed line.

The shutoff valve, also called the spar valve, is a butterfly type design of similar diameter to the line in which it is mounted. The valves are mounted in the feed line and are electrically driven by actuators mounted on the aft side of the rear spar near their respective valves. Each shutoff valve actuator has two sets of redundant control wiring running in separated bundles. This protects valves and wiring from the effects of powerplant or engine-mount structural failure. With a nominal 28 VDC supply voltage the normal actuation time is three to five seconds. Between the actuator and the valve there is an adapter shaft which incorporates universal joints on each end to accommodate installation geometry and tolerances.

The fuel pumps are selected on through switches on the overhead panel in the cockpit, see Figure 12. If fuel pressure is low, the pump pressure switches send a signal to the ELMS which then sends the low pressure signal through the overhead panel ARINC 629 system (OPAS) to turn on the appropriate low pressure lights on the pump switches. The cross-feed valve allows the fuel pumps to draw fuel from the opposite fuel tank.

4.7.1.2 Fuel Storage and Quantity Indication

The fuel storage system holds the fuel necessary for engine and APU operations. The 777-200 contains three fuel tanks, the left main, right main and center tank. Surge tanks collect fuel overflow and drain into the main tank. The left and right main tank are located in the wing box of their respective side, with the surge tanks located outboard each main tank. The center tank is in the center wing section and in the inboard wing box of both the left and right wings. The approximate capacity of each tank is listed in Table 5.

Table 5 - Approximate Tank Quantities for 777-200 G-VIIO

Tank	Gals	Liters	Lb[1]	Kg[1]
Left Main	9,560	36,200	64,626	29,322
Right Main	9,560	36,200	64,626	29,322
Center	26,100	98,800	176,436	80,028
Total	45,220	171,200	305,688	138,672

[1] - Density = 6.76 lb/gal (0.81 kg/L)

The fuel quantity indication system (FQIS) measures the fuel quantity in the individual tanks. The primary display system and integrated refuel panel show the fuel quantity.

If necessary, fuel measuring sticks permit manual measurement of the fuel quantity in each tank. Six measuring sticks are installed in each main tank and four in the center tank, see Figure 45. When measuring the fuel quantity using the measuring sticks, the aircrafts attitude in pitch and roll is recorded using inclinometers in the nose wheel well and a plumb bob that is attached in the right main wheel well. The readings from the measuring sticks, the fuel density and aircraft attitude are then compared to conversion tables provided by the aircraft manufacturer to determine the fuel quantity.

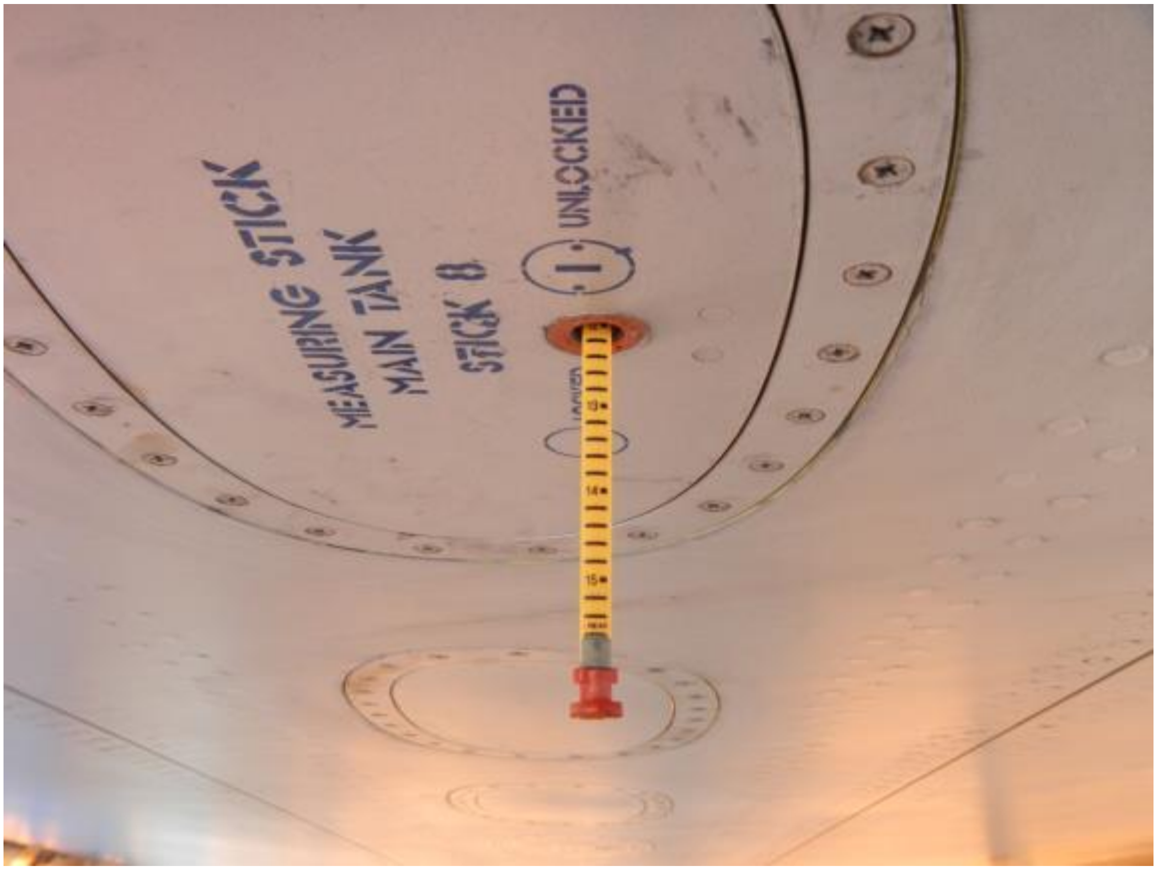


Figure 45 - Fuel Quantity Measuring Stick

4.7.2 On-Scene Examination

4.7.2.1 Engine Fuel Feed System

Section 4.4.1 described the condition of the overhead fuel panel and the selection of the fuel pumps and valves. Both fuel control switches were in their “CUTOFF” position.

The position of the left main spar valve was verified by a visual inspection of the valve’s position indicator on the rear spar of the wing. The left main spar valve was in the closed position. Fuel was not found leaking from the severed main fuel feed line. Information regarding the severed main fuel feed line can be found in the Powerplants Group Chairman’s Factual Report.

Figure 46 - Left Engine Fuel Spar Valve in Closed Position

4.7.2.2 Fuel Storage and Quantity Indication

The visual inspection of the left wing showed no evidence of a fuel leak from either the left main tank or the center tank, as previously discussed in section 4.5.2.1.2. A visual inspection of the right wing also showed no evidence of a fuel leak from the right main tank.

The total aircraft fuel prior to departure per the fuel load sheet was 63,300 kg. The load sheet listed the specific gravity at 0.802 the fuel as “JET” and a temperature of 40° C.

Due to the thermal damage, power was not reapplied to the aircraft after the incident. The aircraft fuel quantity was measured on September 11th, 2015 using the manual fuel measuring sticks. The stick readings calculated the fuel load on the aircraft to be 64,168 kg. The calculation sheet is provided in Appendix A.

4.7.3 Spilled Fuel Quantity

During the investigation, the group requested that Boeing perform an analysis to approximate the amount of fuel spilt on the tarmac after the main engine fuel feed line separated from the engine.

The analysis assumed the following:

- The engine feed line was completely severed and open to the atmosphere
- Both main tank boost pumps and the center tank override/jettison pumps were on
- Pump performance for the aircraft pumps match sea level pump qualification data
- Fuel density is the same for each tank
- The number of bends in the flow line was reduced by 50% to reduce the analysis complexity

Based on the time between the start of the engine failure and the spar valve closure of 27.9 seconds from the FDR data, the estimated amount of fuel spilt was approximately 97 gallons.

Further information on the analysis can be found in Appendix B.

4.8 Main Landing Gear and Brakes

4.8.1 Description and Operation

Each main landing gear consists of a six-wheeled truck. Each wheel and tire assembly has a tire pressure indication system (TPIS) on the aircraft. Tire pressure data can be displayed on the landing gear synoptic display and a maintenance page. An over-pressure relief valve is installed on each wheel and tire and will relieve pressure if it exceeds 375-450 psig. The maximum nominal MLG tire pressure for a cold, loaded tire is 215 psig. Tire pressure data was recorded by the aircraft's quick access recorder (QAR).

Each wheel and tire assembly contains a brake assembly. The brake system hydro-mechanical control system controls hydraulic pressure to the brakes. The antiskid system will automatically decrease brake pressure to prevent tire skid conditions during braking application. The parking brake system latches the brake pedals in the brake applied position. A brake temperature monitoring system (BTMS) monitors brake temperatures and provides information to the crew via the landing gear synoptic pages. Each wheel and tire assembly contains three or four thermal fuse plugs which prevent tire explosions caused by hot brakes. The fuse plugs will melt and release tire pressure when temperatures exceed approximately 361°F (183 °C).

4.8.2 On-Scene Examination

The left and right hand main landing gear were inspected by the group. The aircraft was towed from the runway to the cargo ramp and the aircraft was parked with the parking brake not set.

The shock strut mounted panel on the LH main gear had paint blisters and large delaminated areas.

Figure 47 - LH Main gear shock strut mounted panels

The outer braid of multiple landing gear hydraulic hoses was melted on the outboard facing side only. Areas shielded by the tires and strut-mounted panel showed no signs of heat damage including the forward or inboard areas of the gear or gear systems.

Figure 48 - Area of melted outer hose braid on LH main landing gear

Figure 49 – LH MLG Outboard Tires (From Left, 1-5-9)

Figure 50 - LH MLG Inboard Tires (From Left, 10-6-2)

Figure 51 - RH MLG Inboard Tires (From Left, 3-7-11)

Figure 52 - RH MLG Outboard Tires (From Left, 12-8-4)

A visual inspection at the cargo ramp of the visible sections of all tires of the main landing gear showed no signs of flat spotting on the tread area of the tire.

The sidewalls of the main landing gear tires were inspected and a side wall cut was also found in the outboard sidewall of tire 5, see Figure 53. The total length of the cut was approximately 1.25 inches.

Figure 53 - Cut found in the outboard side of tire 5

On tire 9, a “vee” shaped cut was seen on the sidewall of the outboard side of the tire. One arm of the “vee” was measured at approximately 0.75 inches and the other arm of the “vee” was measured at approximately 0.375 inches, Figure 54.

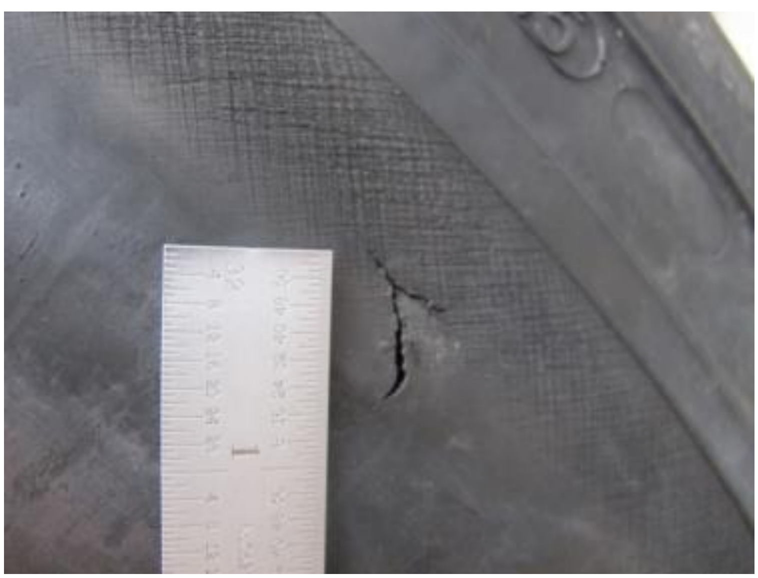


Figure 54 - "Vee" shaped cut in sidewall of tire 9

Tire 9 was removed to allow for inspection of the thermal fuse plugs. Four thermal plugs were installed on the inner portion of the wheel hub. The four fuse plugs were removed and visually inspected and did not appear to be fused open, see Figure 55. During the removal of one of the fuse plugs, the fuse plug broke in the wheel rim, but the fuse plug showed no signs of activation.

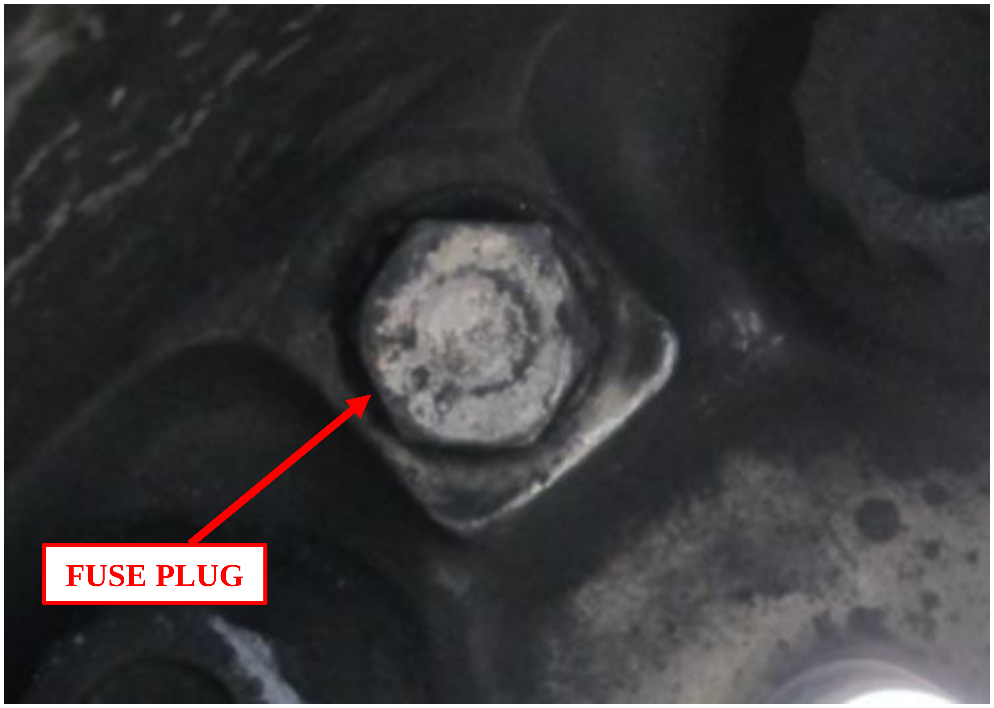


Figure 55 – Typical fuse plug condition

The overpressure relief valve was removed from tire 9 and visually inspected. Air was also applied to the valve and indicated that the overpressure relief valve was not activated.

The tire pressures of the main and nose landing gear was measured. Table 6 and Table 7 contain the nose and main gear tire pressure readings.

Table 6 - Measured nose gear tire pressures

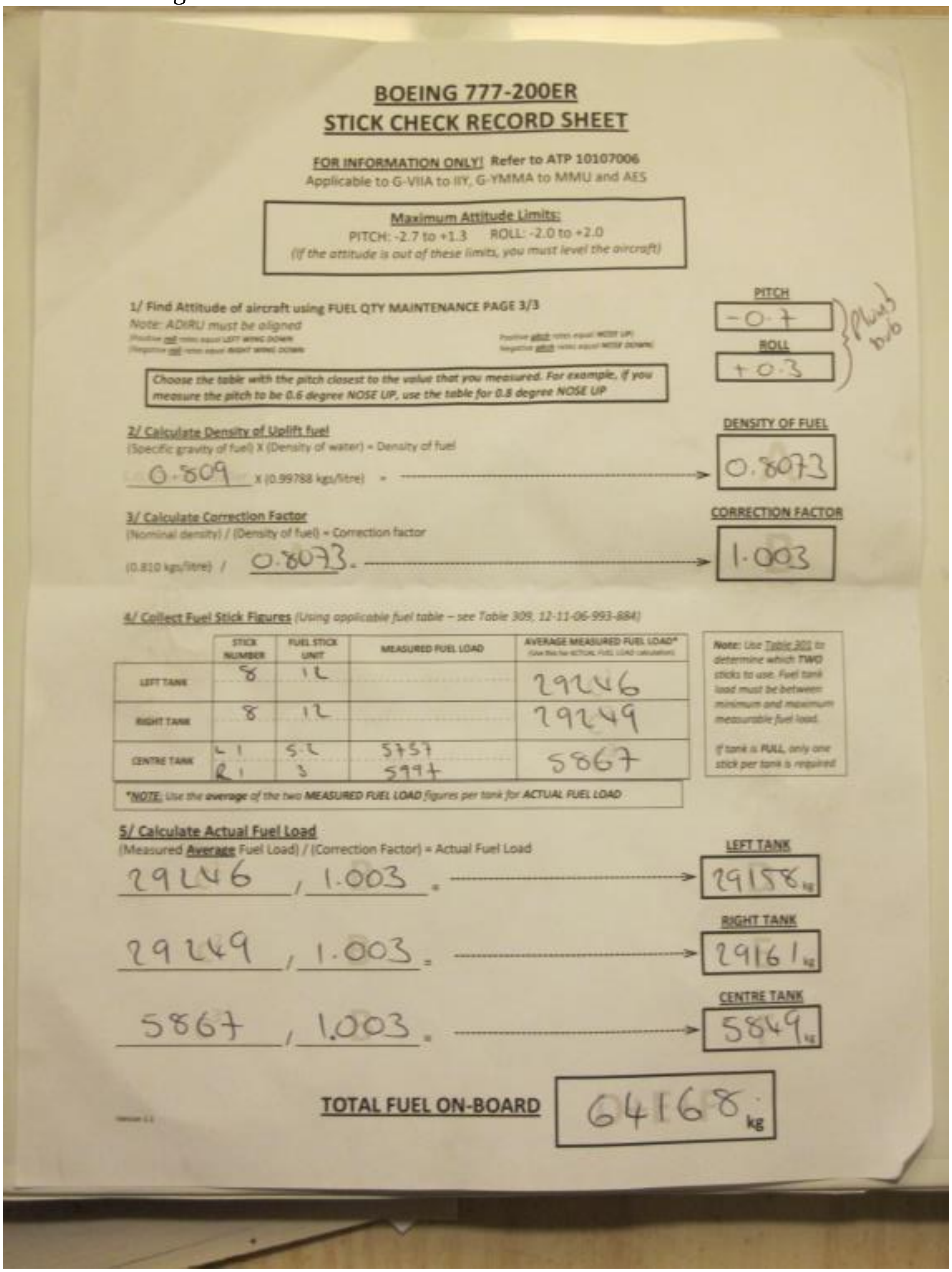
Tire 13 (LH)	Tire 14 (RH)
207	210

Table 7 - Measured main gear tire pressures

LH MLG FWD OUTBD - 1	LH MLG FWD INBD - 2	RH MLG FWD INBD - 3	RH MLG FWD OUTBD - 4
213	220	213	228
LH MLG MID OUTBD - 5	LH MLG MID INBD - 6	RH MLG MID INBD - 7	RH MLG MID OUTBD - 8
220	222	220	222
LH MLG AFT OUTBD - 9	LH MLG AFT INBD - 10	RH MLG AFT INBD - 11	RH MLG AFT OUTBD - 12
---	228	218	225

A APPENDIX A

G-VIIO - Boeing 777-200 ER Stick Check Record Sheet



BOEING 777-200ER
STICK CHECK RECORD SHEET

FOR INFORMATION ONLY! Refer to ATP 10107006
Applicable to G-VIIA to IIY, G-YMMA to MMU and AES

Maximum Attitude Limits:
PITCH: -2.7 to +1.3 ROLL: -2.0 to +2.0
(If the attitude is out of these limits, you must level the aircraft)

1/ Find Attitude of aircraft using FUEL QTY MAINTENANCE PAGE 3/3
Note: ADIRU must be aligned

PITCH: -0.7
ROLL: +0.3
(Plus) b/o

Choose the table with the pitch closest to the value that you measured. For example, if you measure the pitch to be 0.6 degree NOSE UP, use the table for 0.8 degree NOSE UP

2/ Calculate Density of Uplift fuel
(Specific gravity of fuel) X (Density of water) = Density of fuel
0.809 X (0.99788 kgs/litre) = → DENSITY OF FUEL: 0.8073

3/ Calculate Correction Factor
(Nominal density) / (Density of fuel) = Correction factor
(0.810 kgs/litre) / 0.8073 = → CORRECTION FACTOR: 1.003

4/ Collect Fuel Stick Figures *(Using applicable fuel table – see Table 309, 12-11-06-993-884)*

	STICK NUMBER	FUEL STICK UNIT	MEASURED FUEL LOAD	AVERAGE MEASURED FUEL LOAD*
LEFT TANK	8	12		29246
RIGHT TANK	8	12		29249
CENTRE TANK	L 1 R 1	5.2 3	5757 5997	5867

*NOTE: Use the **average** of the two **MEASURED FUEL LOAD** figures per tank for **ACTUAL FUEL LOAD***

Note: Use Table 301 to determine which TWO sticks to use. Fuel tank load must be between minimum and maximum measurable fuel load.

If tank is FULL, only one stick per tank is required

5/ Calculate Actual Fuel Load
(Measured **Average** Fuel Load) / (Correction Factor) = Actual Fuel Load

29246 / 1.003 = → LEFT TANK: 29158 kg

29249 / 1.003 = → RIGHT TANK: 29161 kg

5867 / 1.003 = → CENTRE TANK: 5849 kg

TOTAL FUEL ON-BOARD 64168 kg

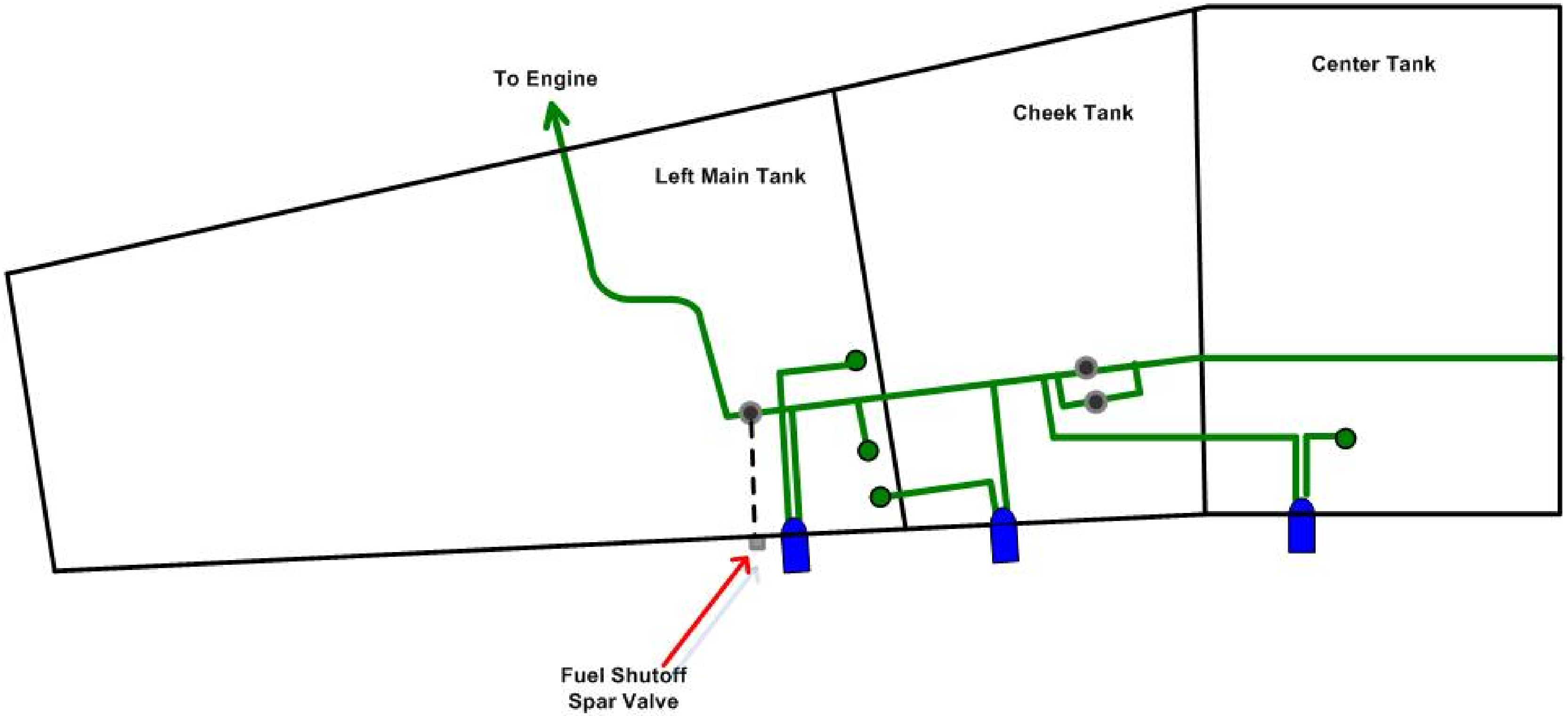
B APPENDIX B

Boeing Fuel Spill Assessment

Boeing Fuel Spill Assessment

2/10/2016

777 G-VIIO Fuel System Diagram



Analysis Summary

Boeing analyzed the scenario observed following a left engine failure event on September 8, 2015 at McCarran International Airport in Las Vegas in which the Engine Fuel Feed Line was completely severed from the Engine Driven Pump. The purpose of the analysis was to identify the amount of fuel that spilled between the time the engine feed line was severed and the fuel shutoff spar valve closed.

During the analysis the following assumptions were made:

1. The engine feed line was completely severed and open to atmosphere allowing fuel to flow freely without any back pressure from engine components.
2. Both main tank boost pumps and the center tank override/jettison pumps were ON.
3. The performance of the pumps on the airplane matches the sea level pump qualification data.
4. The fuel density was assumed to be the same in all tanks. Though the recorded airplane data indicated the density of the center tank fuel was slightly lower than the main tank fuel (780 kg/m^3 vs. 790 kg/m^3) this delta is considered to be negligible.
5. To reduce analysis complexity the number of bends downstream of the spar valve was reduced by 50%. This is assumption is considered negligible.

The following items were taken from the recorded data for use in the analysis:

1. At the time of the event the airplane was loaded with 28,700 kilograms (63,273 lbs) of fuel in each main tank and 5,400 kilograms (11,905 lbs) of fuel in the center tank.
2. There was a period of 27.9 seconds (within the accuracy permitted by the recorded data sample rate) from the point when the fuel line was assumed to be severed (as indicated by a change in the rate of longitudinal acceleration), to when the fuel shutoff spar valve was recorded closed.

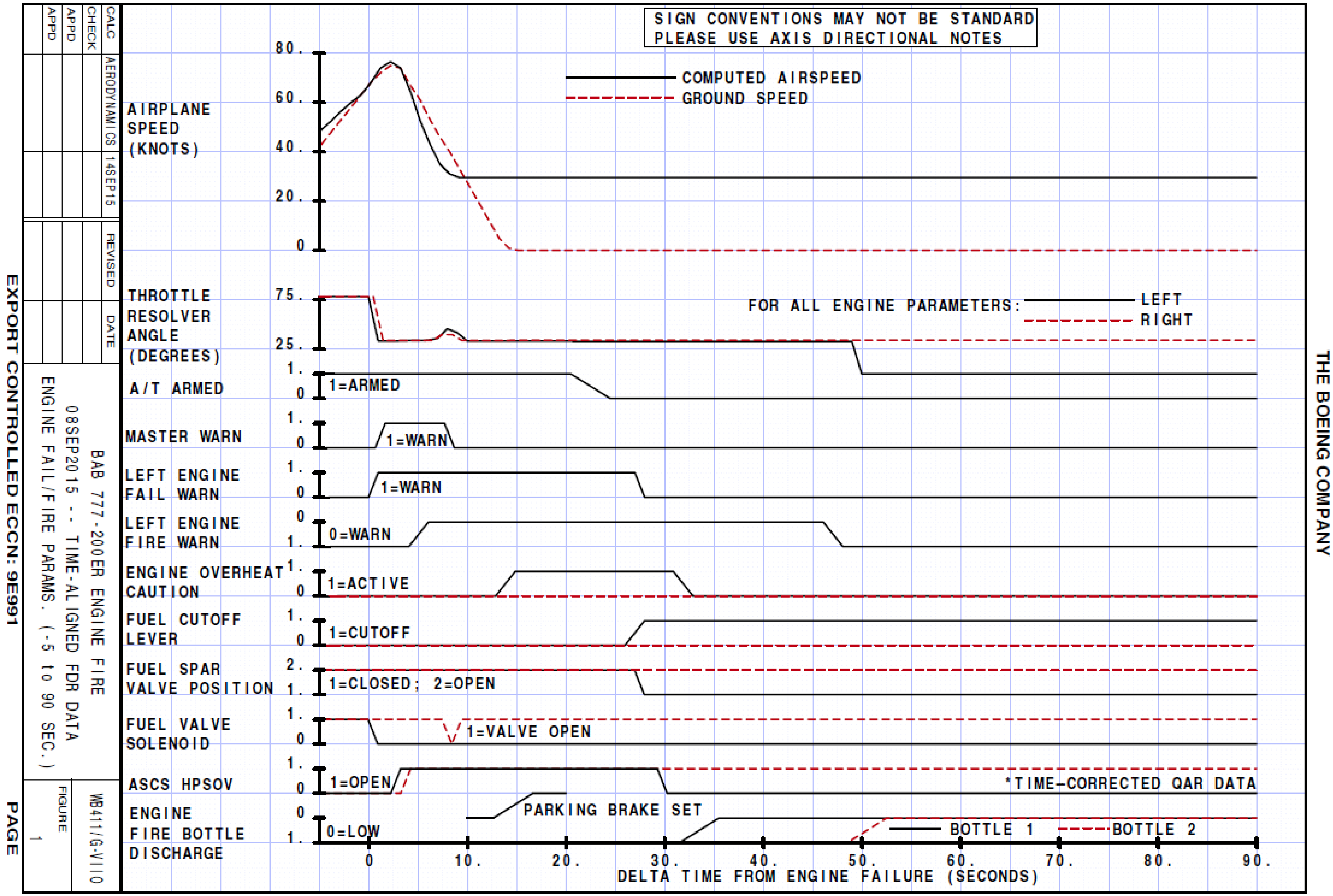
Analysis Summary

To perform this analysis an existing proprietary 777 fuel feed system computer model was modified to match the airplane configuration. The engine fuel feed system computer model is represented by the fuel tubing and associated components, fuel pumps, fuel valves, and fuel tanks. Prior to this analysis the geometry in the model ended at the fuel shutoff spar valve. For this analysis an additional 305.4 inches of tubing with an internal diameter of 1.92 inches and a height drop of 111.7 inches was added downstream of the spar valve with a routing that is representative of the airplane installation (see assumption 5 above).

The analysis results indicates there would be shared flow from the center tank override/jettison pump and main tank boost pumps though the majority of fuel would come from the center tank. This results in a combined fuel flow rate of 208.5 gallons per minute. This flow rate would result in 97 gallons (289.8 kilograms or 638.9 lbs) of fuel flow through the feed line over a period of 27.9 seconds.

This is consistent with the recorded airplane Fuel Quantity Indication System (FQIS) data which indicates a total fuel quantity change of 300 kilograms from when the event occurred until 2 minutes later. The 777 FQIS includes filters that limit the amount of change in indication over a short period of time. A loss of 97 gallons over 27.9 seconds would result in a short indication delay before the entire change in quantity would be displayed. Therefore comparing the analysis results to a change in indication over a two minute timeframe is appropriate.

FDR Data



SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
AIRPLANE SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
THROTTLE RESOLVER ANGLE (DEGREES)
FOR ALL ENGINE PARAMETERS: LEFT RIGHT
A/T ARMED
1=ARMED
MASTER WARN
1=WARN
LEFT ENGINE FAIL WARN
1=WARN
LEFT ENGINE FIRE WARN
0=WARN
ENGINE OVERHEAT CAUTION
1=ACTIVE
FUEL CUTOFF LEVER
1=CUTOFF
FUEL SPAR VALVE POSITION
1=CLOSED; 2=OPEN
FUEL VALVE SOLENOID
1=VALVE OPEN
ASCS HPSOV
1=OPEN
*TIME-CORRECTED QAR DATA
ENGINE FIRE BOTTLE DISCHARGE
0=LOW
PARKING BRAKE SET
BOTTLE 1
BOTTLE 2
DELTA TIME FROM ENGINE FAILURE (SECONDS)
CALC
CHECK
APPD
APPD
AERODYNAMICS
14SEP15
REVISED
DATE
BAB 777-200ER ENGINE FIRE
08SEP2015 -- TIME-ALIGNED FDR DATA
ENGINE FAIL/FIRE PARAMS. (-5 to 90 SEC.)
FIGURE 1
WB411/G-VIIO
PAGE
EXPORT CONTROLLED ECCN: 9E991
THE BOEING COMPANY