

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 747-8R7F, LX-VCF	
No & Type of Engines:	4 x GEnx-2B67 turbofan engines	
Year of Manufacture:	2012	
Date & Time (UTC):	30 March 2017 at 1216 hrs	
Location:	En route from Houston to Prestwick	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew - 3	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Extensive fuel contamination of aircraft interior and wiring	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	12,900 hours (of which 9,200 were on type) Last 90 days - 164 hours Last 28 days - 47 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Following an uneventful scheduled cargo flight, it became apparent after landing that a large quantity of fuel had leaked from a Bell 412EP helicopter which was being shipped as cargo on the main deck of the freighter aircraft. The escaped fuel then made its way through the lower deck and spilled onto the airport apron. Airport Rescue and Fire Fighting Services (RFFS) attended the aircraft to contain the fuel spill and manage the associated risk of fire and explosion.

The investigation determined that the helicopter, which was disassembled and prepared for transportation some months prior to the incident, had not been shipped in accordance with the required provisions for transportation of such vehicles by air. In particular, the helicopter had not been drained of fuel prior to transportation. Approximately 322 litres of fuel escaped from the helicopter during the flight.

One Safety Recommendation is made concerning procedures for the preparation of helicopters for air transportation.

History of the flight

On 30 March 2017, LX-VCF was operating scheduled cargo flight CV7754 from Houston, Texas to Luxembourg with an intermediate stop at Prestwick International Airport, UK. Following an uneventful flight, the aircraft arrived at Prestwick and parked on stand. As the

flight crew were shutting down the engines they smelled fuel. When the ground operations agent entered the aircraft via the main deck door to commence unloading operations, he too detected a strong smell of aviation fuel and heard the sound of running liquid. He identified the source as a Bell 412EP helicopter, which was being shipped as cargo on the main deck of the aircraft and noted that fuel appeared to be leaking from a vent on the forward right-hand side of the helicopter. The ground operations agent reported the situation to the flight crew. The Airport Authority and RFFS were notified and the airport emergency response plan was activated. The flight crew shut down the aircraft and opened the escape hatch and upper deck service door to ventilate the aircraft. Upon arrival at the aircraft the RFFS noted that fuel was coming out of the bottom of LX-VCF's fuselage, close to the left body landing gear, having leaked through the main deck, lower deck and avionics bay and was pooling on the apron beneath the aircraft (Figure 1). The aircraft was evacuated, electrically isolated and quarantined by the RFFS. The RFFS subsequently stated that the measured fuel vapour levels indicated a high risk of explosion and that the fuel flammability limits were potentially in range. After the aircraft had been made safe, all cargo, including the helicopter, was offloaded manually.



Figure 1

Fuel exiting lower fuselage of LX-VCF

Examination of the aircraft and helicopter

The aircraft and helicopter were examined on 4 April 2017 by representatives from the aircraft operator, the UK Civil Aviation Authority (CAA), the airport authority, the helicopter owner and the owner's insurer. Based on the initial information available, the AAIB had initiated a Correspondence Investigation and did not attend this examination. However, those who participated in the examination provided information to the investigation and the AAIB subsequently upgraded the investigation to a Field Investigation.

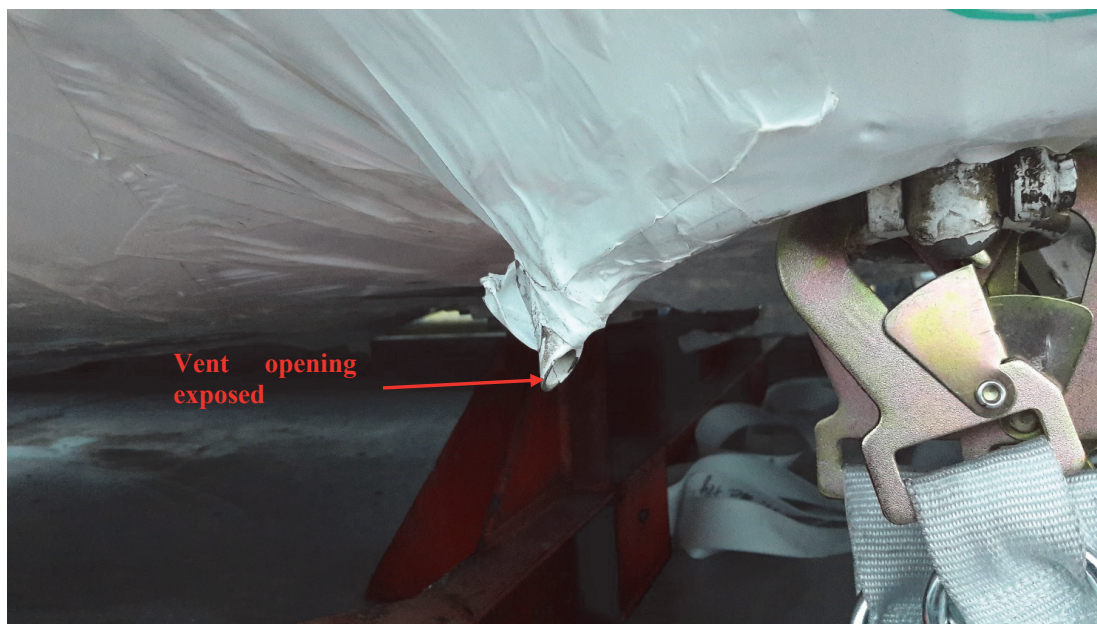
The helicopter was encased in strong white plastic shrink-wrap and had been secured to a cargo pallet for the flight, which occupied three loading positions on the right side of the aircraft's main cargo deck (Figure 2). During the aircraft examination, some fuel was present in the wells of the pallet and the securing straps were soaked with fuel.



Figure 2

Bell 412-EP fuselage, wrapped in shrink-wrap, on main deck of LX-VCF prior to being offloaded at Prestwick

In the area of the helicopter's forward right-hand fuel vent, from which fuel was reported to have leaked, the shrink-wrap had been applied so that the opening of the vent was exposed (Figure 3). White tape had been applied on top of the shrink-wrap in the vicinity of the vent.

**Fig 3**

Forward right-hand fuel vent on Bell 412-EP helicopter

By comparison, the forward left-hand fuel vent on the opposite side of the helicopter was completely covered in shrink-wrap, so that the vent opening was sealed. White tape had also been applied in this area, but there was no evidence of fuel having leaked from this vent.

The shrink-wrap was removed from the helicopter. No standing fuel was observed inside the shrink-wrap but some oil staining was evident on the inner surface of the wrapping. Some absorbent pads were also found inside the shrink-wrap.

Upon opening the helicopter cabin, it was noted that the helicopter's main battery (which displayed a 'Class 8 (corrosive) hazard' label) was installed in its normal stowage, but was disconnected. A fire extinguisher was secured to a stowage on the cabin floor. A number of cardboard packages containing various items were also found inside the helicopter cabin.

During the examination the helicopter, including all wrapping and the internal packages, was weighed on the pallet and the total pallet weight was noted as 4,200 kg.

The fuel filler cap was removed, allowing access to visually inspect the right upper fuel cell; fuel was present and the level was observed to be approximately half-way up the cell. There was no means to visually inspect the remaining cells.

The helicopter was powered-up and the cockpit fuel quantity indicator indicated a total quantity of fuel on board of 1,440 lb. The helicopter was subsequently refuelled to full, after which the total fuel quantity indicated was 2,160 lb. The fuel bowser meter registered 467 litres. Following refuelling, the helicopter was observed by the onsite team for a period of two hours and the RFFS continued to observe the helicopter overnight. No fuel leaks

were observed. The helicopter was subsequently defuelled and shipped to the owner, after which it underwent a '5-year' maintenance inspection. The owner advised that no defects were noted on the fuel system during this inspection which could have accounted for the fuel leak.

Aircraft damage

The interior of LX-VCF had suffered extensive fuel contamination. After the fuel vapours had dispersed, internal floor panels, ceiling panels and sidewall liners in the aircraft were lifted and contaminated insulation blankets were removed. Additionally, all aircraft system electronics, avionics wire looms and harnesses required decontamination.

The aircraft undertook a ferry flight to its home base on 11 April 2017, after which a number of additional actions were required to return it to a fully airworthy condition, including extensive inspections, cleaning and application of corrosion-inhibiting fluid. All insulation blankets and lower deck ceiling liner panels and some elements of the cargo loading system required replacement.

Background information

In December 2016, the helicopter, a Bell 412EP serial number (S/N) 36414 had been sold by Bristow US LLC based in Louisiana, United States (the seller) to Agrarflug Helilift GmbH and Co in Germany (the buyer).

Several agencies and individuals were involved in various aspects of the sale, preparation and transport of the helicopter. In addition to the seller and buyer, these included a sales agent acting as the buyer's representative in the United States (US) and his assistants. Freight forwarding¹ work was carried out by three organisations. A routing agent based in New Zealand was appointed to oversee the export requirements and transportation of the helicopter to Germany. It subsequently sub-contracted this work to a US-based cargo logistics company to act on their behalf in the US, which in turn appointed a US-based shipping agent to prepare the Air Waybill² and report on progress.

The helicopter was disassembled and prepared for transportation by the seller's staff at their facility and loose items were loaded into crates. To protect it during transport, the helicopter fuselage was shrink-wrapped by a specialist company contracted by the sales agent. A road transport company then collected the shipment from the seller's facility in Louisiana on 23 January 2017 and transported it by road to Houston Airport.

It was intended that the buyer's sales agent would oversee the disassembly and preparation of the helicopter for transport; however, he was unable to attend and instead sent two assistants to oversee the preparations on his behalf and to ensure that no

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¹ A freight forwarder, or forwarding agent, is a person or organisation that organises shipments of goods, often contracting with multiple carriers to move the goods. Freight forwarders who handle international shipments typically have additional expertise in preparing and processing customs and other shipping documentation.

² The Air Waybill is a document issued by, or on behalf of, the shipper for the air transportation of cargo. It acts as a contract of carriage between the shipper and the carrier(s).

damage occurred to the helicopter. One assistant was present at the seller's facility when the helicopter was shrink-wrapped; however, it had already been disassembled prior to his arrival. A second assistant was present to observe the helicopter shipment being loaded onto the delivery trucks.

Shipping of the helicopter

The shipping agent booked the shipment with the operator's sales department on 23 January 2017, having previously obtained a quotation for shipment from the operator in August 2016. During the quotation and booking process, the shipping agent explicitly indicated in writing that all fuels and batteries had been removed from the helicopter and that the shipment was non-hazardous. The shipping agent issued an Air Waybill for the shipment on 24 January 2017. The final destination for the shipment was Germany, and it was planned to travel by air via Luxembourg to Brussels and then onward by road to Germany.

The shipment, comprising nine loose crates and the helicopter secured to a 20 ft pallet, was delivered to the operator's facility at Houston Airport on 26 January 2017. After checking the documentation and conducting a visual inspection of the exterior of the wrapped helicopter, it was accepted for travel by the Dangerous Goods Manager from the operator's contracted Ground Handling Agent (GHA). The loose crates were built-up on two pallets.

The shipment was subsequently placed on hold by both the US Department of Commerce and US Customs, and was not released for export until 21 March 2017. It remained in the operator's cargo warehouse during this time.

The shipment was booked to travel on flight CV8617 on 24 March 2017; however, the operator was unable to produce a lashing scheme to secure the helicopter due to a software problem and only the nine loose crates travelled on this flight. The helicopter was re-booked to travel on flight CV8617, on 27 March 2017. However, after having been loaded onto flight CV8617 the operator's loading supervisor noticed a small fuel leak from the helicopter. The leak was described as a *'patch/stain of fluid on the ULD under the centre of the helicopter, approximately 6 to 10 inches in diameter'* and was reported to smell like jet fuel. The helicopter was offloaded and returned to the cargo warehouse. The operator's sales department informed the shipping agent and asked it to arrange for an inspection of the helicopter.

On 28 March 2017, a mechanic³ inspected the helicopter at the operator's cargo facility. Also present was a representative from the shipping agent⁴ and one from the operator's sales department. The mechanic, again accompanied by the shipping agent, returned later the same day to re-inspect the helicopter and perform additional work. They were escorted by a GHA agent. Review of CCTV footage from the cargo facility showed that

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³ Who was also one of the sales agent's assistants and had witnessed the helicopter being loaded onto the road transportation at the seller's facility.

⁴ Who had prepared the Air Waybill.

this inspection lasted approximately 30 minutes. No walkaround was conducted and the mechanic appeared to focus his attention on the lower surface of the helicopter. He did not use any tools or remove the shrink-wrap to facilitate inspection of the helicopter. He used a cleaning spray to clean parts of the exterior surface, inserted absorbent pads between the shrink-wrap and the helicopter skin and applied some white tape over the shrink-wrap. The mechanic and shipping agent informed the cargo operator, and the other agencies involved in the transportation including the cargo logistics company, that the fuel leak had originated from residual fuel in the fuel lines and had been capped off.

On 29 March 2017, the shipping agent provided the cargo operator with a revised Air Waybill and Air Cargo Manifest, together with a Purge Certificate indicating that the helicopter was free from fuel.

The cargo operator accepted the shipment for travel and it was loaded on flight CV7754, which departed Houston on 30 March 2017. The loading supervisor responsible for this flight checked the helicopter several times prior to, during, and after loading and there was no evidence of a fuel leak or spill.

Documentation

The aircraft sales agreement for purchase of the helicopter was signed on 30 December 2016. The supporting documentation which formed part of the sales agreement stated that the helicopter was sold on an 'As is – where is' basis; that the helicopter was in a non-flyable condition at the time of sale; that the helicopter would be 'delivered' (handed over) at the seller's (Bristow US LLC) facility for shipment at the buyer's (Agrarflug's) expense; that the seller would assist the buyer in disassembly and packaging of the aircraft at the seller's facility, using reasonable packing practices; and, that the buyer's representatives would be on hand to supervise and accept the packaging.

A US Department of Commerce Shipper's Export Declaration prepared by the cargo logistics company, stated that no hazardous materials were being exported. This document was signed by a Bristow US LLC employee on 23 January 2017, authorising the cargo logistics company to act as a forwarding agent for export control and customs purposes for the export of the helicopter.

The original Air Waybill, issued by the shipping agent on 24 January 2017, described the helicopter as '*Civil Model B412EP Helicopter (Helicopter main cabin)*' and declared the shipment as: '*Consolidated cargo⁵ as per attached manifest*', which was also reflected on the original Air Cargo Manifest issued on 29 January 2017. Both the Air Waybill and the Air Cargo Manifest listed the cargo logistics company as the shipper. An Air Waybill requires two signatures, one from the '*Shipper or his agent*' and one from the '*Issuing carrier or its agent*'. The original Air Waybill had a single signature across both fields.

Footnote

⁵ Consolidated cargo refers to a consignment comprising of multiple packages, originating from more than one person, and shipped under one Air Waybill.

Following inspection of the helicopter in Houston, a new Air Waybill and Air Cargo Manifest were issued by the shipping agent with the following statement added: *'Not restricted as per special provisions A70.'* The revised Air Waybill was not signed. Additionally, a Purge Certificate dated 29 March 2017, produced by Agrarflug and signed by its Director of Maintenance, was provided to the cargo operator. This stated that the helicopter had been:

'flushed, purged of all fluids and is clean and dry. Inhibiting fluid in accordance with (IATA) International Air Transportation Associated [sic] and is NOT considered as DANGEROUS GOODS.'

The load sheet for flight CV7754/30 March 2017 on which the helicopter travelled stated that the weight of the helicopter pallet was 4,455 kg. The Notification to Captain (NOTOC⁶) document for flight CV7754/230 March 2017 did not include any reference to the helicopter shipment.

Additional information

Bristow US LLC advised that, under the terms of the sales agreement, the buyer had complete responsibility for inspecting and transporting the helicopter.

Agrarflug advised that it understood that the seller was responsible for preparing the helicopter for transport. It provided an email from the seller written in December 2016 which stated that *'the aircraft will be prepared for shipping on 09 Jan.'* Other email correspondence from the buyer indicated that its representatives would oversee preparations of the helicopter for movement to Germany.

The buyer's sales agent confirmed that neither he nor his assistants had performed any work to disassemble, clean, drain, or package the helicopter and were not present when it was disassembled for transport. Additionally, he stated that he had no reason to suspect that the helicopter was fuelled as the Shipper's Export Declaration provided to him by the seller indicated that no hazardous materials were being exported. Furthermore, based on his previous experience, he was aware that Bristow US LLC usually drained all fuel from helicopters it sold.

A representative from the company who shrink-wrapped the helicopter advised that an open-flame torch was used to shrink the plastic wrap and stated that they would not have wrapped the helicopter if they had known it was fuelled.

Representatives from both the cargo logistics company and the shipping agent reported that they were not aware that there was fuel or other dangerous good onboard the helicopter, when making arrangements for its transport or producing the Air Waybill. They based this understanding on the Shipper's Export Declaration which indicated that no hazardous materials were being exported.

Footnote

⁶ The NOTOC is a form which is used to notify the commander of an aircraft when dangerous goods are to be loaded on the aircraft board their flights. The NOTOC describes the nature, quantity of the dangerous goods and the location where it is loaded on the aircraft.

The mechanic who inspected the helicopter in the cargo warehouse in Houston informed the investigation that he had not seen any active dripping of fuel, just fuel residue. He concluded that escape of fuel was due to residual fuel in a fuel line that had been released when the helicopter was moved. He stated that the drip appeared to have come from the right side of the helicopter in the area of the fuel booster pump.

In email correspondence relating to the fuel leak and subsequent inspection of the helicopter in Houston, the cargo logistics company indicated that if the mechanic could remove all the residual fuel, it might still be possible to ship the helicopter as non-hazardous cargo, but that a purge letter would be required from the shipper on company letterhead to verify this. The routing agent indicated that he did not believe the seller would provide this and instead asked Agrarflug to provide this.

An email sent by the mechanic on 28 March 2017 following his inspection of the helicopter stated that *'there was a minimal amount of residual fuel which had collected in the left-hand sump area and was seeping out of the drain'*. He also indicated in the email that he had cleaned up the escaped fuel and placed approximately 50 absorbent pads between the fuselage and the shrink-wrap to absorb any additional fuel which might move to the sump area when the aircraft was moved.

The buyer's Director of Maintenance informed the investigation that he had issued the Purge Certificate stating that the helicopter had been flushed and purged of all fluids, following confirmation from the mechanic that the fuel leak in Houston was caused by residual fuel in the fuel lines.

Shipping of dangerous goods by air

The International Air Transport Association (IATA) Dangerous Goods Regulations (DGR) describe the regulations governing the preparation, documentation and transportation by air of dangerous goods. The 58th edition of the DGR, effective 1 January 2017, was valid at the time the helicopter was packaged and transported. Air transportation of a vehicle, such as the helicopter, falls into the category of *'UN3166 Vehicle, flammable - liquid powered'* and is considered as Class 9 Dangerous Goods. Shipment by air would require compliance with stringent requirements for preparation, packaging and labelling of the helicopter to identify it as dangerous goods. However, the DGR contained Special Provision A70 relating to the transport of engines and vehicles, which states:

'A70 Internal combustion or fuel cell engines of machinery, being shipped either separately or incorporated into a vehicle, machine or other apparatus, without batteries or other dangerous goods, are not subject to these Regulations when carried as cargo, provided that:

(a) For flammable liquid powered engines:

- 1. The engine is powered by a fuel that does not meet the classification criteria for any class or division; or*

2. *The fuel tank of the vehicle, machine or other apparatus has never contained any fuel, or the fuel tank has been flushed and purged of vapours and adequate measures taken to nullify the hazard; and*
3. *The entire fuel system of the engine has no free liquid and all fuel lines are sealed or capped or securely connected to the engine and vehicle, machinery or apparatus.*

.....

When this special provision is used, the words "Not Restricted" and the Special provision number must be included in the description of the substance on the Air Waybill as required by 8.2.6., when an Air Waybill is issued.'

The DGR defines the shipper's responsibilities when offering a consignment of dangerous goods for air transportation. Section 1.3.2 'Specific Responsibilities' states:

'

- (b) *the shipper must ensure that the articles or substances are not prohibited for transport by air*
- (c) *the articles or substances must be properly identified, classified, packed, marked, labelled, documented and be in the condition for transport in accordance with these Regulations.'*

Helicopter transportation guidance

Bell Helicopter publish transportation guidance for the 412-series helicopter in a document entitled '*M412 Transportation Guide*'. It describes the actions taken by Bell when a helicopter is prepared for shipping from its manufacturing facility. In the list of components removed for shipping, it recommends that fuel is drained from the helicopter. Agrarflug indicated that it believed the helicopter had been prepared for transportation in accordance with this guidance.

Operator's procedures

The operator's Ground Operations Manual states the following with respect to accepting shipments:

'Reasonable measures (e.g. physical check of documentation and/or packages) shall be taken to avoid the transportation of hidden dangerous goods; confirmation shall be obtained from the shipper/forwarder about the contents of any consignment whenever there is any suspicion that it may contain dangerous goods.'

It also states:

'Vehicles including cars, motorcycles, helicopters etc. shall be booked as dangerous goods, unless they are shipped under Special provision A70 and do not contain any hazardous equipment such as a battery, fire extinguisher, tire-inflation canister, safety device, etc. and completely empty of residual fuel. This means that they must be completely drained, sufficiently cleared of residue and purged of vapors [sic] to remove/nullify potential hazard.'

The operator's procedures included a Helicopter Acceptance Checklist to be used when an unpackaged helicopter was booked as dangerous goods however, it was not required to be used if a helicopter was shipped under Special Provision A70.

Operator's safety investigation

The cargo operator's safety department conducted an internal safety investigation. It identified a number of issues relating to recurrent training of its staff; however, both the loading supervisors and the GHA DG Manager involved in the shipping of the helicopter held valid dangerous goods licenses.

The operator also identified some issues with adherence to its internal emergency notification and response procedures, and the reporting of occurrences pertaining to damaged or leaking dangerous goods to its safety department.

Following this event, the operator made a number of revisions to its procedures and made safety recommendations to various areas of its business. This including recommending that its contracted GHA take steps to raise awareness among its staff about the possibility of dangerous goods in general cargo and to improve methods for detecting of undeclared dangerous goods.

Bell 412EP fuel system description

General

The Bell 412EP helicopter is fuelled by Jet A1 fuel and, in its standard configuration, has a total fuel capacity of 337.5 US Gallons (USG)/1,277.58 litres. Fuel is stored in ten interconnected lightweight cells made from a laminated fabric and rubber construction. There are six cells below the cabin floor; three on each side, and four cells located below the engine compartments aft of the cabin and pylon (Figure 4). The helicopter is fuelled through a filler cap in the upper right cell, located on the right side of the aft fuselage. Fuel gravity-feeds from the upper cells into lower cells through interconnecting fuel lines.

The helicopter being transported in LX-VCF had been modified to add a single rigid auxiliary fuel tank on the left side of the aft cabin, which had a capacity of 81.7 USG (309 litres), giving a total fuel capacity of 419.2 USG (1,587 litres). The auxiliary tank was installed by Bristow US LLC, in accordance with Bell Helicopter's Service Instruction BHT-412-SI-4 '*Bell Model 412 Service Instruction for Auxiliary Fuel Kit*'.

The fuel system includes a number of fuel transfer, boost and ejector pumps located in the lower fuel cells. Each of the six lower cells has a spring-loaded, poppet-type sump drain valve; those in the lower main cells can be opened by either electrical or manual actuation, while those in other lower cells are manually operated, push-to-drain valves. Defuelling valves located in the sump areas of the lower main cells require removal of a plug and insertion of a standard fitting to open the spring-loaded poppet and operate the valve.

To enable fuel transfer, an interconnect system, shown by the pink lines in Figure 4, joins the lower cells together. Each lower forward and lower middle cell is permanently connected to its opposite side cell via the interconnect lines and fuel can pass freely from the left to right side and vice versa. The combined capacity of the two lower forward cells is approximately 48.5 USG (183.6 litres) and the combined capacity of the two lower middle cells is approximately 32 USG (121.1 litres).

At fuel loads above approximately 1,663 lb, all six lower cells would be full.

Fuel vent system

The fuel vent system is shown by blue lines in Figure 4. A collective vent on top of upper aft centre cell connects the four upper cell vent spaces with two vertical lines which vent overboard beneath the fuselage. Each lower main cell vents through a line connecting into the upper forward centre cell.

A forward vent line on each side of the fuselage connects with the respective lower forward and lower middle cells. These lines rise through the helicopter doorposts to a waterline above the upper cells and then double back downward to vent overboard beneath the fuselage.

AAIB investigation

The US Federal Aviation Administration (FAA) Hazardous Materials Safety Division were notified of this event and initiated its own separate investigation to explore the issues relating to undeclared and leaking dangerous goods. The FAA interviewed many of the individuals and organisations involved in preparing the helicopter for transportation and issuing the associated shipping documentation. Details from these interviews were shared with the AAIB; however, not all the individuals and organisations engaged directly with the AAIB safety investigation. The AAIB was therefore limited in its ability to explore more fully some of the issues relating to this event.

Discussion

General

The escape of fuel from the helicopter represented a substantial hazard to the safety of the aircraft, the flight crew and those on the ground at Prestwick Airport. The airport RFFS advised that the measured fuel vapour levels within the aircraft indicated a high risk of explosion and that the fuel flammability limits were potentially in range. Additionally, photographs show that fuel was exiting the aircraft close to the left body landing gear and pooling beneath the aircraft. The presence of fuel in proximity to potentially hot wheel brakes created a substantial risk of fire.

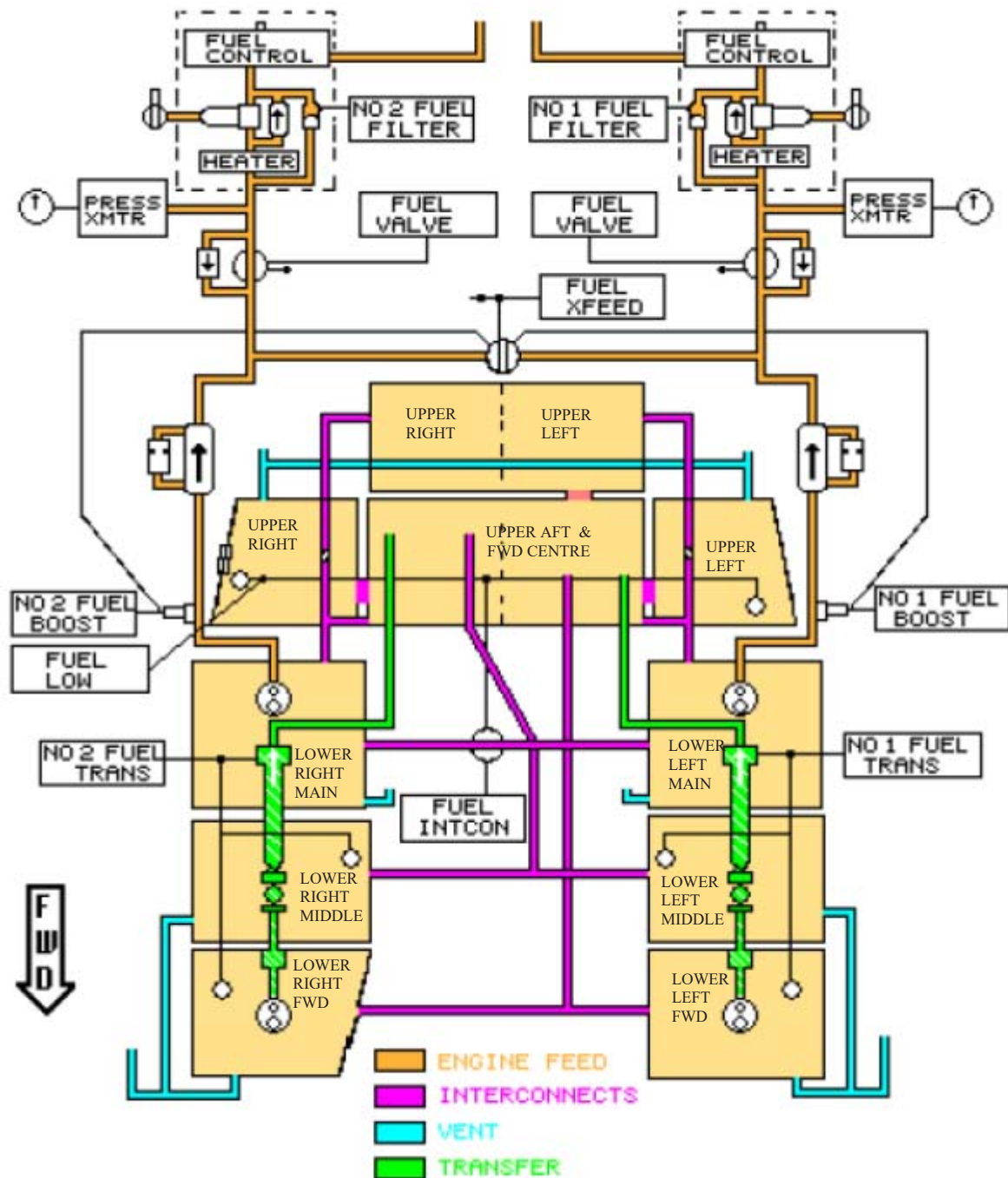


Figure 4

Bell 412EP Simplified fuel system schematic (Note: auxiliary tank not shown)

Preparation and packaging of the helicopter for transport

Correspondence and documentation relating to the sale of the helicopter indicated that the seller would assist the buyer in disassembly and preparation of the helicopter for transportation, under the supervision of the buyer's representatives. The buyer believed that these preparations would include defuelling of the helicopter. The seller considered

that all transportation matters were the responsibility of the buyer, but was aware of the intention for the helicopter to be transported as air cargo.

Notwithstanding the issue of where the contractual commitment for preparation and defuelling of the helicopter lay, the disassembly of the helicopter and preparations for its transport took place at the seller's facility and were conducted by its staff, despite a substantial amount of fuel remaining on the helicopter. The buyer assumed that the helicopter would be prepared in accordance with guidance published by the helicopter manufacturer, which recommends defuelling as part of the preparations for transportation. The preparations also included packaging of the helicopter using an open flame, which would have represented a significant health and safety risk to those involved. Neither the seller's staff undertaking the disassembly, nor the buyer's representatives who were subsequently in attendance, identified the fact that a substantial amount of fuel remained onboard the helicopter prior to it being packaged and transported.

The following Safety Recommendation is therefore made:

Safety Recommendation 2018-011

It is recommended that Bristow US LLC review their procedures relating to the preparation of helicopters for air transportation to ensure that they are defuelled.

Shipping and shipping documentation

The Shipper's Export Declaration for the helicopter indicated that no hazardous materials were being exported. This document formed the basis upon which other transportation documentation was raised. However, it did not accurately reflect the presence of fuel on board the helicopter, nor the battery and fire extinguisher within the helicopter cabin, which also required identification as dangerous goods.

Special Provision A70 of the IATA Dangerous Goods Regulations allows vehicles such as the helicopter to be transported by air without being declared as dangerous goods, providing batteries or other dangerous goods are removed, that the fuel tank and fuel system has been flushed and purged of all fuel and fuel vapours and that the statement '*Not restricted as per special provision A70*' is included on the Air Waybill. When using this provision, it is the shipper's responsibility to ensure that the shipment complies with these requirements.

Email correspondence between the shipping agent and the cargo operator during the booking process specifically stated that all fuels and batteries had been removed and that the shipment was non-hazardous. However, although the paperwork generated for transportation and export of the helicopter indicated that the shipment was non-hazardous consolidated cargo, there were a number of anomalies with the shipping documentation. The original Air Waybill neither declared the shipment as dangerous goods, nor referenced the exemptions of Special Provision A70, and was therefore not in compliance with either the DGR or the operator's own acceptance procedures. Additionally, neither the original nor the revised Air Waybill contained the required signatures. The operator's GHA acceptance staff

indicated that the decision to accept the shipment was influenced in part by the description of the helicopter as '*Civil Model B412EP Helicopter Main Cabin*' on the Air Cargo Manifest and the assumption that only the frame of the helicopter was being shipped.

Although the revised shipping documentation subsequently indicated the helicopter was being shipped as unrestricted cargo under the provisions of Special Provision A70, it did not reflect the actual condition of the helicopter and the shipment was not in compliance with the requirements of the Special Provision. As such, the helicopter was shipped as non-declared dangerous goods and this hazard was not identified to the operator, nor the flight crew of flight CV7754.

Proper declaration and documentation of dangerous goods by a shipper ensures that all parties involved in the transportation chain know what type of goods they are transporting, how to load and handle them and what steps to take in the event of an incident such as a leakage. Three entities were involved in organising the shipping logistics and documentation for the helicopter. The routing agent took a coordinating role, having sub-contracted responsibility for the export and transportation of the helicopter to the cargo logistics company. As the designated shipper named on the Air Waybill, the legal contract of carriage by air was between the cargo logistics company and the operator. The DGR identify that it is the shipper's responsibility to ensure articles are properly identified, classified, packed, marked, labelled and documented. However, the cargo logistics company further delegated responsibility for production of the shipping documentation to the shipping agent and the documentation did not fully comply with the DGR, nor did it reflect the actual state of the helicopter. The dilution of responsibility among the various individuals and organisations involved in the shipping of the helicopter meant that no single organisation or individual was able to assure that the shipping documentation reflected the actual condition of the helicopter.

The investigation did not determine whether this was indicative of a wider issue within the air freight industry, however the cargo operator indicated its belief that it was. Due to the limitations of the AAIB investigation there was not considered to be sufficient evidence to make a formal Safety Recommendation on this subject. However, this report has been shared with the IATA Dangerous Goods Board⁷ for its consideration.

Opportunity to detect the presence of Dangerous Goods in Houston

A small fuel leak observed while the helicopter was being loaded onto an aircraft for planned travel on 27 March 2017 resulted in the shipment being offloaded and returned to the cargo warehouse. This fuel leak, and the subsequent inspection of the helicopter by a mechanic and shipping agent, presented an opportunity to detect that the helicopter had not been defueled prior to transport. However, CCTV footage of the inspection shows that while the mechanic cleaned fuel residue from the shrink-wrap coating and inserted absorbent pads, he took no steps to determine the actual fuel state of the helicopter during the inspection.

Footnote

⁷ The IATA Dangerous Goods Board reviews and determines standards and procedures necessary for the safe carriage of dangerous goods by air, and promotes the worldwide recognition, adoption of and adherence to those standards and procedures.

Despite this, the mechanic subsequently confirmed that the source of leak was residual fuel in the fuel lines and this information was communicated to the cargo operator and to the other agencies involved in the transportation of the helicopter. Based on this information, and at the request of the routing agent, Agrarflug issued a Purge Certificate, expressly stating that the helicopter had been purged of all fluids and was not considered as dangerous goods, despite not having been able to verify the actual condition of the helicopter. The Air Waybill and Air Cargo Manifest were updated accordingly and these three documents were presented to the operator. The operator did not question the fact that the Purge Certificate had been issued by the buyer in Germany, as it is not a mandatory document for items shipped under Special Provision A70. With no expectation that dangerous goods were a factor in the transportation of the helicopter, and having taken steps to address the source of the fuel leak from the helicopter, the operator accepted the helicopter for transport on its aircraft.

Escape of fuel during the flight

During the post-incident inspection at Prestwick, the helicopter battery was observed to be disconnected; therefore, none of the helicopter fuel pumps could have operated during the incident flight. The investigation considered that possible routes for fuel to escape from the helicopter could have included: via the sump drain valves, defuelling valves, the fuel vent lines or a loose connection in a fuel system interconnect line.

With the exception of the small fuel leak noticed on 27 March 2017, no fuel was observed to escape from the helicopter during the two-month period it was stored in the cargo warehouse in Houston. Nor did any fuel escape from the helicopter after refuelling in Prestwick following the incident. Furthermore, a subsequent maintenance inspection at the new owner's facility, did not reveal any defects with the fuel system which could have accounted for the fuel leak. It was therefore considered unlikely that a loose connection in a fuel line or a partially-open or stuck sump drain/defuelling valve could have contributed to the fuel escape during the flight.

When the aircraft arrived in Prestwick, the ground operations agent who first entered the aircraft observed that fuel appeared to be escaping via a vent tube on the forward right-hand side of the helicopter. Subsequent inspection of the helicopter identified that the shrink-wrap in which the helicopter had been encased had been applied such that the opening in the forward right-hand fuel vent tube was exposed, while that on the forward left-hand vent was completely sealed.

The forward vent lines serve the lower forward and lower middle cells on each side of the helicopter. Although the left and right side vent lines are not connected, each lower forward and lower middle cell is permanently connected to its opposite side cell via the interconnect lines and fuel can pass freely from the left to right side and vice versa. The manner in which the helicopter was shrink-wrapped created a seal over the forward left vent tube; this may have prevented the pressure within the four forward fuel cells from equalising in response to aircraft cabin pressure changes during the descent into Prestwick. In the absence of any other defects which could account for the escape of fuel, the investigation considered that this wrapping of the vents may have induced a siphon-like effect, or caused the flexible fuel cells to temporarily deform, as the aircraft's cabin pressure equalised during the descent to land at Prestwick, causing fuel to be ejected via the forward right-hand vent tube.

The aircraft operator reviewed the aircraft's pressurisation profile for the incident flight and compared it with a number of flights by the same aircraft on the same route. There was nothing unusual about the pressurisation profile on the incident flight.

The helicopter manufacturer checked its occurrence database and did not find any reports of customers reporting fuel exiting out of the forward fuel vent tubes. The manufacturer commented that there is a fuel/air separator within the forward fuel vent system which is intended to allow fuel vapours to escape to the overboard vent, while any liquid fuel should drain back into the relevant fuel cell by gravity. However, the circumstances of this fuel leak are somewhat unique, and it is highly unlikely that the behaviour of the helicopter fuel system in such circumstances would have been previously considered or predicted.

The precise fuel state of the helicopter prior to its shipment by air is not known however, the post-incident weight of the helicopter pallet was some 255 kg lighter than that noted on the label attached to the pallet and the load sheet for flight CV7754. The scales used to weigh the pallet in Houston and Prestwick were both within calibration requirements. It is therefore concluded that approximately 255 kg of fuel had escaped from the helicopter during the flight, which equates to approximately 322 litres⁸ of fuel.

Only the upper right fuel cell can be visually inspected on the Bell 412EP and during the post-incident inspection in Prestwick this cell was observed to be approximately half full. The fuel distribution within the remaining cells was not determined. The total indicated fuel quantity was noted as 1,440 lb, symmetrically distributed between the left and right cells. When the helicopter was refuelled, 467 litres were required to reach the fully fuelled condition. Given the helicopter's total fuel capacity of 1,587 litres, the post-incident volume of fuel was determined to have been 1,120 litres. Taking into account the approximate 322 litres which escaped, the fuel state prior to transportation of the helicopter was calculated to have been approximately 1,442 litres. At this fuel state, all the lower fuel cells would have been full.

The combined capacity of the lower forward and lower middle tanks, served by the forward vent lines, is approximately 304.7 litres, which is broadly equivalent to the quantity of fuel calculated to have escaped during the flight.

Conclusions

Regardless of the exact mechanism by which the fuel escaped from the helicopter, the IATA Dangerous Goods Regulations exist to prevent the transportation of hazardous cargo representing a hazard to the safety of an aircraft. Adequate steps were not taken to correctly prepare the helicopter for transport and this situation was not identified prior to it being offered for transportation by air. The investigation identified that the dilution of responsibility among the various individuals and agencies involved meant that no one

Footnote

⁸ Converting a weight of fuel to a volume of fuel requires the specific gravity of the fuel to be known. The specific gravity of fuel varies with temperature and can be influenced by a number of other factors. The specific gravity of Jet A1 fuel is typically 0.79 at 15°C, but can range from 0.77 to 0.83. The specific gravity of the fuel on the helicopter is not known however a specific gravity of 0.79 has been used for illustrative purposes.

agency or individual could assure that the shipping documentation reflected the actual condition of the helicopter and was in compliance with the DGR. An inspection of the helicopter prior to travel was superficial in nature and, although no attempt was made to verify the actual fuel state of the helicopter, incorrectly concluded that the helicopter had been defuelled.

This resulted in the helicopter shipment being identified as unrestricted cargo, despite containing non-declared dangerous goods. The fuel hazard was not identified to the operator or the commander of the flight on which the helicopter travelled, and they were therefore unaware of the risk it posed. The escape of fuel from the helicopter during the flight represented a substantial hazard to the safety of the aircraft, the flight crew and those on the ground at Prestwick Airport. The containment actions taken by the RFFS at Prestwick Airport substantially reduced the possibility of a more adverse outcome.

One Safety Recommendation is made concerning procedures for the preparation of helicopters for air transportation.

In addition, the operator has made a number of revisions to its procedures. It has also recommended that its contracted GHA take steps to raise awareness among its staff about the possibility of dangerous goods in general cargo and to improve methods for detecting of undeclared dangerous goods.