FINAL REPORT

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In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Accidents, on 14 June 2004, appointed Mr Graham Liddy, as the Investigator-in-Charge to carry out a Field Investigation into this accident and prepare a Synoptic Report.

Aircraft Type and Registration:	Bell 206B, EI-BYJ
No. and Type of Engines:	1 x Allison 250
Aircraft Serial Number:	1897
Year of Manufacture:	1976
Date and Time (UTC):	13 June 2004 @ 18.15 hrs (19.15 hrs Local)
Location:	Inniskeen, Co. Monaghan
Type of Flight:	Public Transport
Persons on Board:	Crew - 1 Passengers – 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	Tail boom damage following autorotation.
Commander's Licence:	Airline Transport Pilot's Licence (Aeroplanes) & Commercial Pilot's Licence (Helicopters)
Commander's Details:	Male, aged 45 years
Commander's Flying Experience:	8,830 hours, of which 263 were on type
Information Source:	Station Manager, ATC Dublin. AAIU Field Investigation

SYNOPSIS

The helicopter was carrying out routine commercial pleasure flights in the Carrickmacross area of Co. Monaghan. On the final flight the pilot reported that a "FUEL PUMP" warning light illuminated and the engine failed seconds later. He carried out an autorotation approach and landed in a cornfield. All on board exited the helicopter safely and without injury. There was no fire. The helicopter suffered significant damage in the landing. The Investigation found that the engine stoppage was due to insufficient fuel in the helicopter's fuel tank. This report makes four Safety Recommendations.

FINAL REPORT

1. FACTUAL INFORMATION

1.1 History of the Flight

On Sunday 13 June 2004 the Operator, Celtic Helicopters Ltd., operated a pleasure flight service at Kilanny Sports Day, Kilanny, Co. Monaghan. It was a fine summer day, with a light wind of 330/10 kt and the operation was conducted in accordance with Visual Flight Rules (VFR). Operations started at 14.00 hrs local time. Initially, the service was operated by another company helicopter, EI-BIJ. The service consisted of short flights in the local area, typically of 5 minutes duration. After landing, the engine and rotors continued to run at idle speed while the previous passengers disembarked and the new passengers were boarded. During boarding, passengers were escorted by two Celtic staff members, who secured and fastened their safety-belts.

At this time, EI-BYJ was tasked on a separate company mission from the base at Knocksedan, near Dublin Airport, to Glandore, Co. Cork and back to base. Take-off was at 11.45 hrs with a return refuelling stop at Cork Airport. On arrival back at base, the pilot received a phone call from his on-site colleagues in Co. Monaghan requesting his assistance with EI-BYJ, as they were "*snowed under*" with requests for pleasure trips. He agreed to this request and, after a very short time on the ground at base, he routed to Co. Monaghan to join the ongoing operations there.

EI-BYJ arrived at Kilanny at 16.40 hrs and immediately commenced operations. Subsequently, the Operator's ground staff carried out a hot refuelling of the helicopter. This entailed landing beside the Operator's mobile refueller, with the engine and rotors running at idle RPM, while the qualified refueller person carried out the refuelling. 33 U.S. gallons[1] (123 litres) of aviation fuel (AVTUR) were uplifted. During this operation the pilot was seated at the controls of the helicopter, monitoring the fuel gauge and determining the amount of fuel to be uplifted. The pilot recalled landing with 20 U.S. gallons in Kilanny and that the total of 50 to 53 U.S. gallons was his requirement for his intended flights. He carried out between 12 and 14 trips, as he recalled, of 5-6 minutes duration each, which was normal in such operations. At some time around 19.00 hrs, the refueller operator asked the pilot, during a passenger pick-up stop, how he was for fuel. The pilot declined to take on fuel at that stage. The helicopter then took off and the engine stopped 2 to 4 minutes later at approximately 19.15 hrs. The pilot performed an autorotation but had to turn through 180° and land downwind due to terrain restrictions. The helicopter landed somewhat heavily with some forward speed, in a corn field.

1.2 The Pilot

On the day of the accident, the pilot of EI-BYJ was an Airline Captain who occasionally flew helicopters on his days off or during annual leave. He renewed his helicopter licence in January 2004 and commenced part-time commercial flying with the operator in February 2004. On 13 June 2004, which was rostered as an "OFF" day by the Airline, the pilot was scheduled, by the helicopter operator, to fly from Dublin to collect a client in Co. Kildare and then route to Glandore in West Cork, back to Cork Airport to refuel and thence back to base in Dublin. He had expected to have been stood down in the middle of the afternoon at Dublin at the end of this flight and thereafter to drive to his home.

[1] The fuel gauges and the Flight manual of the Bell 206 helicopter use US gallons as a measurement of fuel. For consistency, this reports uses US gallons in certain areas. 1 US Gallon equals 3.785 litres

He was scheduled by the Airline to report for duty in Shannon at 06.15 hrs the next day. However, the stand-down at Dublin did not occur, and, after a very brief stop there, the pilot flew on to Kilanny, as requested by the Operator's on-site pilot.

The Pilot stated that he had renewed his helicopter pilot's licence earlier in the year, after a break of several years. The day of the accident was his first time to operate such pleasure fights in more than 10 years.

1.3 Pilot's Recollection

The pilot stated that there were 20 US gallons in the helicopter when he initially arrived at Kilanny. He further stated that he refuelled on arrival, taking on 33 US gallons, bringing the total to 53 US gallons. He said the standard practice for this kind of operation was to fill the helicopter to about 50 US gallons (2/3's of capacity), in order to keep the helicopter reasonably light. The pilot stated he had a discussion with the refueller operator immediately before the last (accident) flight, saying he had enough fuel for this flight and would refuel after it. The pilot subsequently stated that prior to take-off on the last flight, he recalled seeing in excess of 10 U.S. gallons indicated on the fuel gauge. He recalled that, on the way back to the landing zone, at about 1,000 ft with the trip almost completed, the "FUEL PUMP" Warning light illuminated and about 5 or 6 seconds later the engine failed. He recalled that his front seat passenger had also pointed out this light illumination to him but that he had to react swiftly to events by entering into full autorotative flight and by quickly finding somewhere safe to land. As the local terrain was hilly with drumlins he had to execute a 180˚ turn during the descent and land downwind in a corn field, with a slight forward speed on touchdown. The pilot recalled that the descent was difficult, with the engine failure warning horn continuously sounding, and the passengers were audibly upset at the turn of events. On the ground, once the rotors stopped turning, the pilot's main preoccupation was the safety and evacuation of his passengers. This was achieved, and there were no injuries to the pilot or his passengers. There was damage to the helicopter. The pilot advised his local ground operations of what had occurred, while the passengers, who were from the locality, were collected by some friends.

The pilot was unable to tell the Investigation exactly how many of these pleasure trips he had completed that afternoon at Kilanny, but he believed that it was 12 or 14. No log was maintained of the individual trips completed.

In his debrief to the Investigation he said that he relied on his fuel gauge and time flown to estimate the flying time remaining. He stated that, immediately prior to the final flight, he noted that the fuel gauge was at or slightly above 10 US gallons which, he felt, was adequate to complete this trip. He was of the view that 10 US gallons would give him in excess of fifteen minutes flying time.

The pilot subsequently said that the event had occurred at the end of a long day's flying, and that he felt sure he had adequate fuel on board to complete the last trip as planned. He was also conscious of the fact that he still had to refuel the helicopter and then fly back to base. Even then, his day was not yet finished as he still had a lengthy drive to his home.

In response to the Draft Report of this event, the pilot subsequently stated "that after the helicopter was landed, he assisted the passengers to evacuate when it was safe to do so, i.e., when the rotor blades had come to a complete stop, he escorted them away from the aircraft."

1.4 Passengers' Recollection

The passengers on the subject flight were a husband and wife and their two young boys. Confirming that it was a busy afternoon for the Operator, the husband recalled that they queued for almost two hours, awaiting their turn for a flight. As he had flown in a helicopter the previous year, his wife sat into the front seat alongside the pilot, while he sat in the rear seat on the left side of the helicopter. His younger son was in the centre and the elder son was in the right end of the bench seat. He asked the pilot to route towards Inniskeen, where his home was located, rather than Carrickmacross, and pointed out the direction. Immediately after take-off, the wife recalled, she saw a red light on with, as she thought, the letters ENG and some three other letters which she could not recall. She pointed out this light to the pilot who seemed to acknowledge it also, but carried on with the trip. The wife felt that the flight may have lasted some 3 or 4 minutes after this red light came on and when the engine stopped she noticed that all lights (on the panel) came on. Her husband subsequently stated that the helicopter was still heading towards their home (i.e. outbound), at this point, with approximately 30 seconds to run before it would have been overhead their home. She recalled hearing two very loud sirens as the engine went quiet, the helicopter started wobbling and the children became upset, crying and screaming. However, the pilot got the helicopter down into a big green field and it tilted forward and backwards a few times on the ground before it came to a complete stop. The pilot jumped out and moved/ran some 20 yards away, as the wife unbuckled her seat belt with difficulty. She then alighted from the helicopter and assisted her husband by opening the rear doors from the outside, as he had experienced difficulty in locating the opening handle on the inside. Her action released him and their children into the field. The pilot came back and, having ascertained that all was well with his passengers, he apologised for what had happened, and offered them a flight back in the other helicopter. This was "refused point blank" .

Friends of the passengers came from their nearby house and took them back to their departure field to collect their car. The husband came back later that evening and spoke to the pilot about the red light illumination, as seen by his wife. The pilot acknowledged that the red light did come on, but only seconds before the actual engine failure, in his recall of events. The wife was adamant that it had come on some minutes earlier, on take-off from the field. She only advised her husband of her recollection of the red light event after the landing.

1.5 Refueller's Recollection

The refueller operator subsequently stated EI-BYJ was not refuelled when it initially arrived at Kilanny but at some time later. He did confirm that 123 litres (33 US Gallons) of fuel were pumped into the helicopter during this refuelling. This is confirmed by the Operator's refuelling log. At the time of the accident, it was not company procedure to record the time of refuelling in the log. The procedure was subsequently changed to include time of refuelling. He also stated that, around 19.00 hrs, he made a routine check with the pilot, during a passenger pick-up stop, regarding the fuel situation. Because of the high ambient noise level, this conversation was conducted by radio. The pilot replied that he was O.K. for this and two more trips, i.e. 3 trips in all, after which he would refuel and then return to base at Knocksedan. The refueller operator believed that the engine stoppage occurred either on the next flight or the subsequent one.

1.6 Damage to the Helicopter

The tailboom struck the ground during the landing, causing a crease in the structural skin of the boom. The main gearbox rocked on its mounting during the landing, resulting in further significant damage.

1.7 Description of Fuel System

A schematic for the Bell 206 fuel system is shown in **APPENDIX A**. The helicopter is fitted with a single fuel tank, as shown on **APPENDIX B**. The tank is in the shape of an L, with the foot of the L facing forward. The fuel contents are measured by two float sensor units, which are wired in series. The upper section float sensor measures the contents in the vertical section of the L while the lower section float sensor measures the fuel in the bottom section of the tank. The fuel contents gauge registers the sum of these two sensors. As the tank contents reduce, the sensor from the upper section hits a bottom stop at a point where the fuel quantity is level with the top of the lower section. At this point the fuel quantity in the tank is approximately 15 US gallons. As the fuel is further exhausted, the contents are measured solely by the sensor in the lower section.

Because the two sensors are longitudinally displaced, the fuel quantity reading when the upper sensor hits the bottom stop can be slightly in error. This is caused by variation in the flight pitch angle of the helicopter. This means that in normal forward flight, with a nose pitch down angle, the fuel gauge indication remains at or about the 15 US gallon point for a short period.

Fuel is pumped to the engines by two electric pumps fitted in the bottom of the tanks. These pumps are connected in parallel, and pump fuel from the tank up to the engine. If either pump fails, or if the intake is uncovered (so that the pump draws in air), the loss of fuel pressure is detected by a pressure sensor on the pump outlet which turns on a warning light on the caution panel of the cockpit instrument panel. The sensor on either pump feeds into the single warning light. This warning light is red and contains yellow script "FUEL PUMP".

Each pump is fitted with a non-return valve (NRV), so that in the event of pump failure, or the pump inlet uncovering, the fuel provided by the remaining serviceable pump is not lost by escaping back into the tank through the unserviceable pump.

The unusable fuel of the Bell 206 is approximately 2.4 US gallons. This relatively high figure is, in part, due to the relative large area of the tank bottom. The figure for the unusable fuel is somewhat approximate, due to the effects of longitudinal pitch changes. Because the two pumps are longitudinally displaced along the helicopters fore-aft axis, the rear pump will usually uncover first, as the fuel level reduces, when the helicopter is in the nose down altitude associated with forward flight. The fuel available from the time the first pump uncovers, and activates the warning light, until the engine stops due to the second pump inlet uncovering is not constant. It varies according to the nose down pitch angle, which changes considerably throughout the flight operating envelope.

If one or both of the booster pumps fail, the red "FUEL PUMP" warning light will illuminate, but the engine will continue to run as fuel will be sucked through the inoperative booster pump(s) by the engine driven pump, thereby maintaining the fuel supply to the engine.

If the inlet of one booster pump uncovers, its NRV will be closed by the pressure from the second booster pump and the fuel supply to the engine will continue, albeit with the red "FUEL PUMP" warning light illuminated. However, if the inlets to both booster pumps are simultaneously uncovered, the engine driven pump will suck in air through the uncovered inlets and the engine will stop due to fuel starvation.

The Investigation took a sample of fuel from the tank after the incident. Laboratory analysis of this sample showed that the fuel conformed to the specification of AVTUR and was free of contamination.

A separate "FUEL LOW" warning light modification, whereby a warning light comes on when fuel contents reduce to 20 US gallons, is available for the Bell 206 as an optional modification. The Flight Manual contains an instruction to land as soon as practical when such a light illuminates. This modification was not fitted to EI-BYJ.

The fuel gauge is shown at approximately full size in **APPENDIX C.** It is noteworthy that the graduations are small and that there is relatively little needle movement between 10 Gallons and zero. As the pilot is not seated directly in front of the gauge, the effects of parallax can lead to reading errors.

1.8 Fuel Management

Because of the problem of sloshing in the relatively large area in the bottom of the tank, the Flight Manual contains a warning :

"*Operation with both fuel boost pumps inoperative is not authorized. Due to possible fuel sloshing in unusual attitudes or out of trim conditions and one or both fuel boost pumps inoperative, the unusable fuel is ten gallons*".

Apart from this the manufacturer's Flight Manual does not make recommendations regarding minimum operating fuel quantities.

At the time of this accident the relevant Statutory Instrument (SI) of the Irish Aviation Authority (IAA) was S.I. No. 437 of 2002 IRISH AVIATION AUTHORITY (OPERATIONS) ORDER, 2002. Regulation 34 (4) (a) of this SI lays down the minimum fuel requirements for all helicopter operations:

> *(4) (a) In the case of a helicopter operating under visual flight rules (VFR) conditions* (EI-BYJ was operating under these conditions at the time of the accident) *the fuel and oil carried shall be at least the amount sufficient to enable the helicopter -*
>
> *(i) to fly to the heliport to which the flight is planned,*
> *(ii) to fly thereafter for a period of 20 minutes at best range speed plus 10 per cent of the planned flight time, and*
> *(iii) to have an additional amount of fuel, sufficient to provide for the increased consumption on the occurrence of any potential contingencies for the flight concerned.*

The USA, the State of Manufacture for the Bell 206, lays down in FAA CFR 91.15 1: *"no person may begin a flight in a rotorcraft under VFR conditions unless there is enough fuel to fly to first point of intended landing and, assuming normal cruising speed, fly after that for at least 20 minutes"* (20 minutes flying is approximately about 8.7 US gallons in the 206 B helicopter).

The Operator's own Operations Manual (OM) also addresses the issue of fuel states and in Para 7.2.5 of the OM is the heading "MINIMUM IN FLIGHT FUEL" which states that " *the minimum fuel to be left in the tank(s) before a landing must be made AS SOON AS POSSIBLE is: Bell 206/12 US GAL"*.

The normal fuel consumption of the Bell 206 is approximately 26 US gallons per flying hour. While on the ground, with the engine at idle, the fuel consumption is about 6 US Gallons per hour. With regards to the type of flying being performed by EI-BYJ at the time of the accident, the Operator's Chief Pilot reckoned that, given the normal ratio of flying time and idling time on the ground, the fuel consumption in one hour of such operations (including ground time) is 20 US gallons.

1.9 Fuel Calculations

While there is varying evidence as to when EI-BYJ was refuelled at Kilanny, the available data is that the helicopter arrived there at 16.40 hrs, with 20 US gallons on board and immediately commenced continuous operations. At some stage a further 33 US gallons was added. The engine stoppage occurred at 19.15 hrs. Thus the helicopter operated for a total of 2 hrs 35 min (=2.583 hrs), including ground idle time. Using the Chief Pilot's estimate of 20 US gallons per hour of such operations, the helicopter would have consumed 51.7 US gallons during this period. When this is added to the approximately 2.4 US gallons of unusable fuel, the total required is 54.1 US gallons. This corresponds closely to the total of 53 US gallons known to have been in the helicopter. Thus if the pilot kept track of his fuel consumption using this simple calculation, he would have been aware that the fuel situation was critical before the final take-off.

1.10 Rear Door Mechanism

The cabin has a door on either side of the helicopter. These doors are hinged on their leading edges and open outwards. The door locking/opening mechanism consists of a rotating handle as shown in **APPENDIX D**, **Photo 1** . The handle is rotated clockwise to open the door and anticlockwise to lock it. The handle is located somewhat low and towards the rear on the door. The Investigation noted that a person seated beside either rear door does not have a clear view of the door operating handle, as it is obscured by their own leg, as shown in **APPENDIX D**, **Photo 2**. Furthermore their view of the operating handle on the opposite door would be obscured by the person sitting next to that door. The door can also be opened and locked from the outside by a corresponding rotating handle on the door's external surface.

1.11 Survival

The Investigation noted that the helicopter operator's safety brief to passengers during such pleasure trip operations was by means of a safety card ("Passenger Briefing Card" - see **APPENDIX E**) displayed in the booking area.

This safety card did not contain any information on how to open the safety belts, in particular the 4-point harness fitted to both front seats. This harness fastens and releases in a totally different manner to normal passenger lap straps (such as those fitted to the rear seats). Neither did the leaflet indicate the location of the internal door opening lever on the rear cabin doors.

The Investigation found that there was no safety card in the helicopter.

The operator's Operations Manual, in para 8.3.16 states: " *The commander is responsible for ensuring that all passengers are given the appropriate briefing, or safety equipment demonstration for the various stages of the flight, as outlined in the following paragraphs".* In the subsequent paragraphs, section 8.3.16.2 (c) includes *"location and use of emergency exits"* and section 8.3.16.3(a) includes *"the use, fastening and unfastening of safety belts/harnesses".* These responsibilities are repeated in section 1.4.3(f) of the same manual. Such responsibilities are consistent with the appropriate JAR-OPS regulations.

1.12 Tests on Helicopter

After the helicopter was returned to the Operator's base by road, the Investigation examined the helicopter. Due to the extent of the damage, it was not possible to run the engine at this stage. The helicopter was inspected for any indications of fuel leaks. None were found.

A series of tests were then conducted on the fuel system. The fuel gauge was showing approximately 2 US gallons at this time. The tank was then drained completely and the contents was found to be 9 litres (2.4 US gallons). The tank was then filled progressively in 10 litre (2.6 US gallons) increments, to 60 litres (15.8 US gallons), and the gauge reading was noted at each addition. This test showed that the fuel gauge was accurate to within 10% over this range. This test was conducted with the helicopter in the level (approximately hovering) attitude.

The operation of both booster pumps was also checked, running both separately and together. This test showed that both pumps were operating satisfactorily. The pumps were then allowed to run until the reducing fuel in the tank caused one of the booster pump intakes to uncover, thereby drawing in air. This in turn activated the pressure sensor and caused the warning light to illuminate. This occurred when the fuel gauge was reading 5 US gallons. **APPENDIX F** shows the instrument panel when the booster pump warning light is illuminated. This is the same configuration of the warning panel that was seen on EI-BJY after the first booster pump uncovered but before the second pump uncovered and the engine failed.

After the helicopter was repaired, similar tests were conducted with the engine running and the rotor rotating. For safety reasons[2] it was not feasible to run the engine above idle power. In these tests the fuel pump warning light came on when the gauge was reading 2.5 US gallons. The engine then cut out when the gauge was reading just under 2 US gallons. These tests were conducted with the helicopter resting on the main undercarriage.

[2] If the helicopter suffered ground resonance, it would not be safe to follow the normal recovery action of lifting the helicopter off the ground. This is because the helicopter was running with minimal fuel in the tank. Therefore, engine fuel starvation, and consequent engine shut-down, was a real possibility.

1.13 Other information

The Investigation examined the pilot's log book and his annual flight time record as maintained by his principle employer. These records showed that in the 12 month period, from 1 April 2003 to 31 March 2004, he had flown 890 hrs on medium weight turbo-jet public transport aircraft and 9 hrs on helicopters, giving a total for the year of 899 which was just within the laid down limit of 900 hours. The Investigation also found that the pilot's principle employer, the Airline, had issued, in February 2003 a Flight Crew Instruction (FCI) which required all Flight Crew members to provide details of all flight times flown on aircraft other than those of the Airline. The Chief Pilot of the Airline informed the Investigation that he had not been informed by the pilot of the accident helicopter that he was flying aircraft for other operators. The pilot also confirmed to the Investigation that he had not informed the Airline of his helicopter flying.

2. ANALYSIS

2.1 The pilot's statement said there was a gauge indication of "over 10 US gallons" at take-off. However, given the amount of fuel found in the helicopter tank after the event (2.4 US gallons) and the fuel consumed in the flight of approximately 6 minutes duration before the engine failed (2.6 US gallons), and the absence of any indications of fuel leaks, the Investigation estimates that there was approximately 5 US gallons in the helicopter when it took off on the final flight. This is less than the 12 US gallons required by the operator's Operations Manual. As this Manual was part of the requirements of the JAR FCL under which this operation was taking place, the pilot was required to conform to the stipulations of this Manual. The fuel contents at take-off were also below the requirements stated in the IAA regulations.

2.2 In his debrief to the Investigation the pilot said that he relied on his fuel gauge and time flown to estimate the flying time remaining. Hence, on the final trip, he noted that the fuel gauge was at or slightly above 10 US gallons which, he felt, was adequate to complete this trip. He was of the view that 10 US gallons would give him in excess of fifteen minutes flying time. However this belief made no allowance for the sloshing problem. It also indicated that the pilot was depending totally on his fuel gauge for information on his fuel situation. The fact that the pilot was not aware of the exact number of trips completed further indicates that he was not using time flown as a cross check on his fuel status. Total reliance on gauges for fuel contents information in small helicopters is generally recognised as inadvisable. Furthermore there is the possibility of misreading the gauge as discussed in para 2.12 below.

2.3 The Investigation has not been able to reconcile the statement of the pilot that this was the last trip before refuelling, with that of the refueller operator who stated that the pilot informed him that he intended to perform further additional flights before refuelling.

2.4 In the event, the pilot never completed further trips because of the engine stoppage. The evidence that no useable fuel was found in the helicopter fuel tank after the event clearly indicates that the engine shut-down was caused by a lack of fuel supply to the engine.

2.5 The tests on the fuel pumps and the warning system indicate that there was no mal-function in the system.

2.6 It can not be precisely stated what fuel levels will cause the first (uppermost) booster pump to uncover. Neither is it possible to state precisely at what level the lower booster pump will uncover and cause the fuel supply to the engine to cease. This is because the attitude of the helicopter varies significantly, in pitch and roll throughout the operating envelope. Furthermore, transient manoeuvres, such as accelerating, turning, banking etc., will produce movement, or sloshing, of fuel in the tank. This causes a build up of fuel in one side of the tank, and can lead to uncovering of a pump inlet. If both pumps' inlets uncover simultaneously, then the fuel supply to the engine will cease and the engine will fail.

2.7 Unfortunately, even if the fuel levels out again, and a pump inlet is again covered by fuel and the fuel supply to the engine is restored, the gas turbine engine will not restart automatically. This is because the temperature falls rapidly in the combustion chamber, to such an extent that the fresh fuel will not ignite. Consequently engine power is not restored. Auto-ignition is available as an optional modification. This system senses the loss of combustion in an engine and powers up the electronic igniters, which are normally only used during initial engine start-up. This modification would, to some measure, assist in the restoration of engine power in such a situation. However, EI-BYJ was not equipped with this modification.

2.8 The ground tests demonstrated that there was a reduction of fuel of approximately 3 US gallons between the first and the second booster pump uncovering. This would equate to approximately 7 minutes flying. This would appear to co-relate well with the front passenger's statement that the warning light came on shortly after take off. However the effects of pitch changes and fuel sloshing must also be considered in this regard. Unfortunately, this effect is impossible to quantify.

2.9 There is a significant difference between the statements of the pilot and the front seat passenger with regard to what point in the flight the booster pump warning light illuminated. Because of the effects of pitch change and sloshing, the Investigation can not make a definite determination as to precisely when the warning light came on. However it is probable, based on the tests conducted in the course of this Investigation, that the light did come on more than 5 or 6 seconds before the engine shut down.

2.10 As the pilot himself stated, the event had occurred at the end of a long day's flying. He felt sure that he had adequate fuel on board to complete the last trips as planned. He was also conscious of the fact that he still had to refuel the helicopter and then fly back to base. Even then, his day was not yet finished as he then to complete significant drive to his home. This amounted to insidious pressure, knowingly or unknowingly, on the pilot. He accepted that the day had not turned out as he planned, in any respect, and that, with hindsight, accumulative fatigue may have impaired his judgement in operating EI-BYJ for the last trips.

2.11 The fact that the pilot had not flown such short duration pleasure flight operations for 10 years may have dulled his awareness of the pitfalls associated with this type of operation.

2.12 It is possible that the pilot, at the end of a long and tiring day, misread a fuel gauge reading of 5 US gallons (or slightly above) for a perceived reading of 10 (or slightly above) US gallons. The Investigation concludes that there was probably 5 US gallons in the tank at the time of the final take-off.

While this possibility can not be proven, it is consistent with the facts. Examination of **APPENDIX C** indicates the possibility of such a misreading.

2.13 The Pilot's belief that an indication of 10 US gallons would provide 15 minutes flying is accurate in that, at a consumption rate of 26 US gallons per hour, the remaining usable fuel of 7.6 gallons would theoretically provide 17 minutes of flying. However, this belief made no allowance for the possibility of the inlets of both pumps becoming simultaneously uncovered due to a combination of low fuel level and fuel sloshing. In this regard it should be noted that the effects of fuel sloshing become more pronounced when the fuel level reduces to the point where there is only fuel in the broad bottom section of the tank, i.e. less than 15 US gallons.

2.14 This aircraft was not fitted with the optional modification of an independent low level fuel warning light. Apart from the obvious advantage of a back up for the gauging system, which can be inaccurate on smaller aircraft and helicopters, it is possible that the illumination of such a light may have made the pilot aware, at an earlier point, of his critically low fuel situation. Because of the difficulties of performing successful autorotations at the typical low level of such helicopter operations, the Investigation sees merit in the fitting of such warning systems to helicopters engaged in commercial operations.

2.15 In this type of short duration, high frequency pleasure flights, the passengers board the helicopter with the engine running at idle and the rotors rotating. This noisy environment precludes any effective safety briefing of the passengers by either the pilot or the ground handling staff. While it is the commander's responsibility to ensure an adequate safety briefing of passengers, it is not feasible for him to effect such a briefing in this type of operation, due to the following factors:

- There are no other crew members with him in the helicopter
- The high ambient noise levels due to the engine and spinning rotors
- The physical divide of the bulkhead between the pilot and the passengers in the rear seats in the Bell 206

The Investigation is concerned that it is not feasible for the pilot of such operations to effectively ensure that the passengers are properly briefed.

2.16 The time pressure of this type of operation also mitigates against effective briefing. As a result, the front LH seat passenger was not aware how to open the 4-point harness fitted to her seat. It is also noted that the operation of this somewhat unusual harness release is not covered in the safety card. For the foregoing reasons, her difficulty in opening it is understandable.

2.17 In the case of this particular accident, the father was seated by the left rear door. Hence his view of the door opening handle was obscured by his left leg and he was unable to locate it. His view of the operating handle on the right door was obscured by the two children. The Investigation noted that there were no instructions in the Safety Leaflet covering the location or operation of the handle, or on opening the door, particularly from inside the helicopter.

2.18 The Investigation has not been able to reconcile the pilot's account of events after the landing with those of the passengers. The difficulties of the passengers in opening the front seat harness and the rear door would indicate that the pilot was not in the immediate proximity during these difficulties.

2.19 The pilot had undertaken to complete a task of commercial flying for the helicopter operator on his day off from his airline flying. The original plan was for a somewhat less strenuous day's flying. He then became involved in on-going flying and a long day of activity. The final type of operation - short duration, high frequency pleasure flights - is particularly unrelenting. The Investigation is of the opinion that fatigue may well have blurred the pilot's judgement and airmanship towards the end of the day. The Investigation also notes that the pilot's annual flying activity in the previous period was just short of the 900 hour annual flying limit laid down by the IAA. The wisdom of getting involved with further commercial operations is therefore dubious, particularly when this was done without notifying his prime employer.

3. CONCLUSIONS

(a) Findings

1. The pilot was qualified to carry out the Operation in accordance with JAR regulations
2. The helicopter was serviceable when the engine stopped.
3. The fuel was of the correct type and free of contamination.
4. The engine stoppage was caused by fuel starvation due to insufficient fuel in the helicopter's fuel tank.
5. At the start of the final flight the fuel quantities did not meet the minimum requirement of the IAA or the approved Operations Manual. In fact, there was insufficient fuel in the helicopter to actually complete this flight, as subsequent events demonstrated.
6. By deciding to undertake the final trip the pilot displayed unsound judgement that was contrary to the Operator's Operations Manual, the prescribed fuel minimum requirements and good airmanship.
7. The passenger briefing was inadequate.
8. In the circumstances, the pilot carried out a successful engine-off autorotation into the corn field, from which all persons on board exited the helicopter safely.

(b) Causal Factors

1. This accident was caused by insufficient fuel in the helicopter, leading to fuel starvation and engine shutdown
2. Contributory factors include the pilot's failure to adequately monitor the available fuel, non-adherence to the Operator's SOP's and possible cumulative fatigue.

4. SAFETY RECOMMENDATIONS

1. The Operator should revise the Safety Card used on its helicopters to cover the opening of all types of seat harnesses fitted to its aircraft and to give instructions on how the doors should be opened from inside the helicopter. The Safety Cards should be always available, in the helicopter, particularly in the rear seat area. Consideration should be given to permanently fixing such Safety Cards to the rear of the bulkhead immediately in front of the rear seats. **(SR 15 of 2006)**

2. The IAA should review the operation of high frequency, high turnaround commercial helicopter operations with the objective of devising an operations procedure that would ensure that passengers are effectively briefed on safety matters. **(SR 16 of 2006)**

3. The European Aviation Safety Agency (EASA) should review the certification for helicopters engaged in commercial operations, with the objective of requiring such helicopters to be fitted with an independent low fuel contents warning light. **(SR 17 of 2006)**

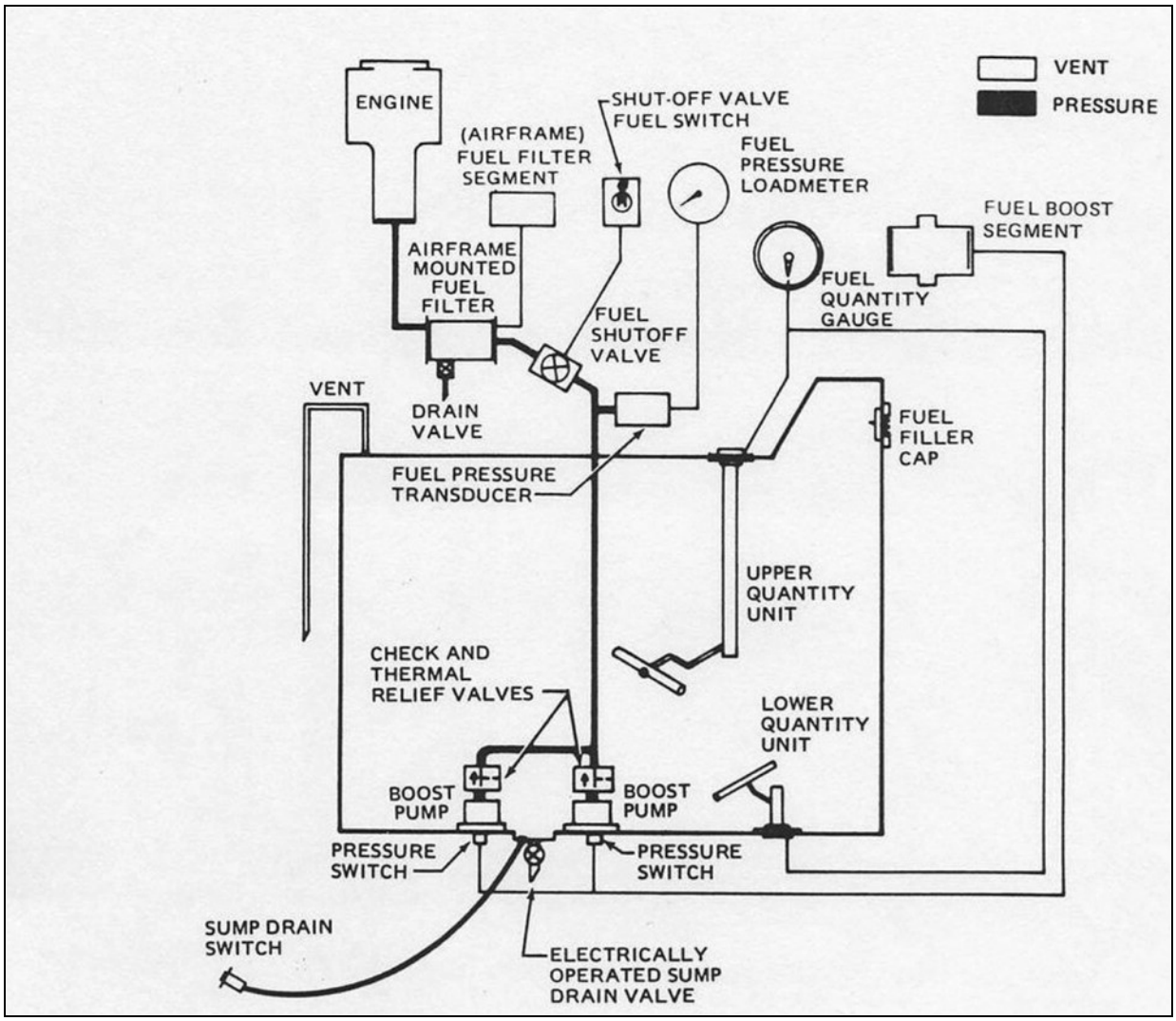
4. In recognition of the reality that pilots may exercise the privilege of their licence in more than one form of flying, the IAA should issue a notice to pilot licence holders bringing to their attention:

   - Their responsibilities to regulate their flying activities in accordance with their employers FTL schemes.
   - Their responsibilities to use duty /days off so as to ensure that they are adequately rested and in a manner acceptable to the Authority. **(SR 18 of 2006)**

FINAL REPORT

APPENDIX A

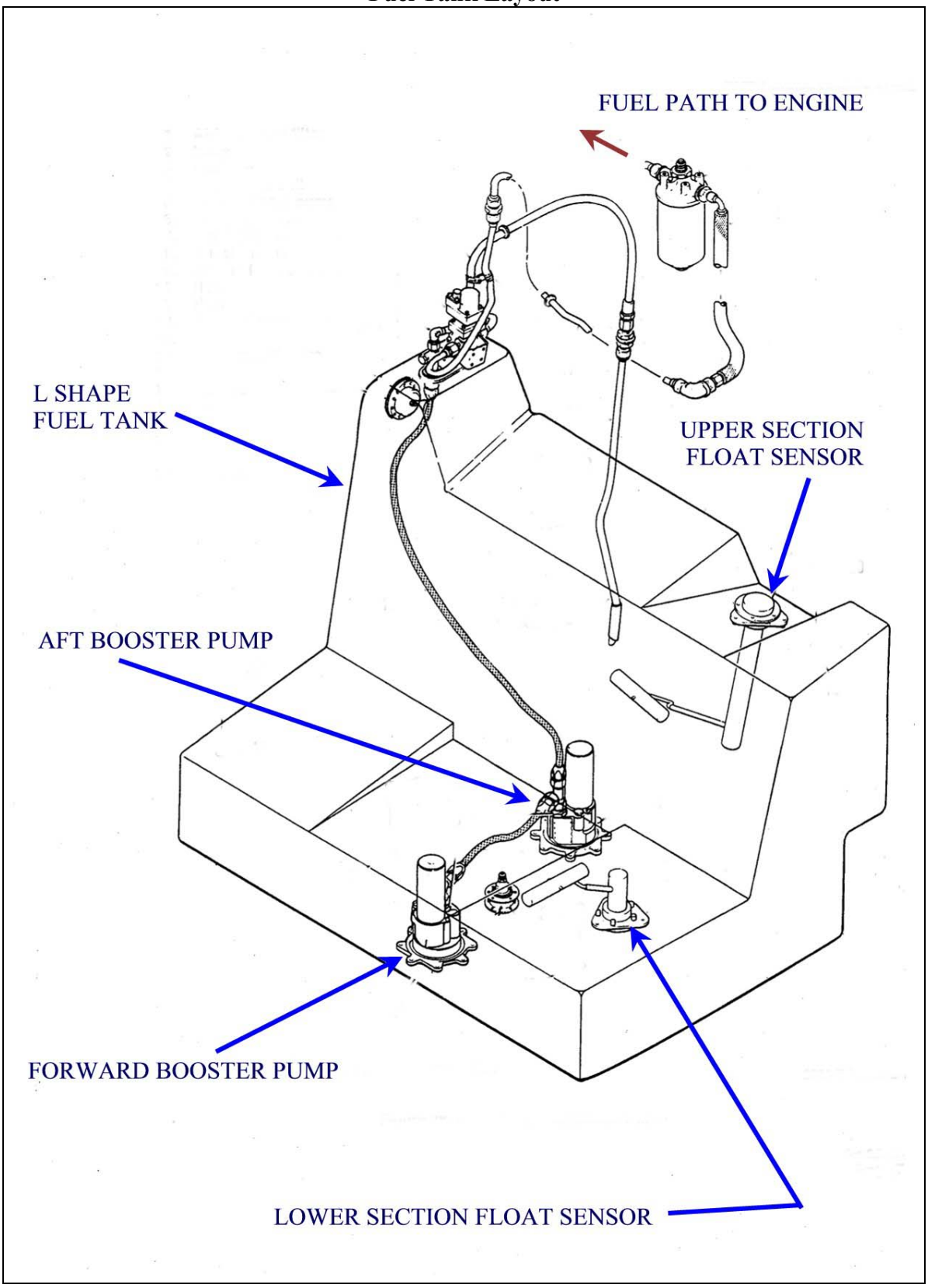
Fuel System Schematic



FINAL REPORT

APPENDIX B

Fuel Tank Layout



APPENDIX C

This photo shows a section on the instrument panel of EI-BYJ containing the fuel gauge, which is located at top centre. The photo is scaled at approximately full size. The gauge is located approximately 60 cm from the pilot's eye (an arm's length), below and to the left of his line of vision. The contents indication when this photo was taken was 15 US gallons. Empty is indicated by the orange line with the symbol E to the right of it. The graduation immediately above this zero mark is 5 US gallons and the next one up again is 10 US gallons.

APPENDIX D

Photo 1

This photo shows an unobstructed view of the operating handle of the RH door on EI-BYJ

Photo 2

This photo shows how the view of the operating handle of the RH door on EI-BYJ is obstructed when a person sits beside the door.

APPENDIX E

Operator's Safety Card

PASSENGER BRIEFING CARD

PLEASE READ THIS CARD CAREFULLY

THIS CARD HAS BEEN PREPARED FOR YOUR COMFORT AND SAFETY.
PLEASE FAMILIARISE YOURSELF WITH THE LOCATION OR OPERATION OF SAFETY EQUIPMENT

THANK YOU FOR FLYING WITH CELTIC HELICOPTERS

EMBARKING & DISEMBARKING:

WHEN IN MOTION, THE ROTORS ARE DIFFICULT TO SEE AND CAN BE EASILY MISJUDGED. THE PILOT HAS A RESTRICTED FIELD OF VISION AND IS ALWAYS MOST CONCERNED THAT HE IS UNABLE TO SEE THE TAIL ROTOR.

ALWAYS APPROACH FROM AND LEAVE TO POSITION FORWARD OF THE HELICOPTER, IN FULL VIEW OF THE PILOT, AND WITH HIS PRIOR PERMISSION

DOORS:

PLEASE DO NOT SLAM DOORS.
THE PILOT WILL DEMONSTRATE THE METHOD OF CLOSING THEM. ONCE CLOSED, DO NOT OPEN THEM DURING FLIGHT.

SMOKING:

ASHTRAYS ARE PROVIDED FOR THOSE WHO WISH TO SMOKE DURING FLIGHT. SMOKING IS NOT PERMITTED WHILST THE AIRCRAFT IS ON THE GROUND, DURING TAKE-OFF AND LANDING OR ANY OTHER TIME ON THE INSTRUCTION OF THE PILOT.

SAFETY BELTS:

YOUR SAFETY BELT MUST BE SECURELY FASTENED FOR EVERY TAKE-OFF AND LANDING AND WE ALSO RECOMMEND THAT YOU WEAR IT FOR THE DURATION OF THE FLIGHT.

SAFETY EQUIPMENT

LIFE JACKETS ARE POSITIONED ON THE SHELF BEHIND THE REAR SEAT. PLEASE STUDY THE PICTURES SO THAT IF YOUR FLIGHT IS OVER WATER YOU WILL BE FAMILIAR WITH THE PROCEDURE.

THE FIRE EXTINGUISHER IS BETWEEN THE FRONT SEATS.
THE DOORS ARE ALSO TO BE USED AS THE EMERGENCY EXITS.
THE FIRST AID KIT IS ALSO ON THE SHELF BEHIND THE REAR SEATS.
THE LIFE JACKETS: THIS IS WORN BY FOLLOWING THESE STEPS:

(1) PLACE HEAD THROUGH THE COLLAR (FIG 1.(2)) WRAP CORDS AROUND YOUR BACK (FIG 2.(3)) TIE CORDS AT THE FRONT (FIG 3.(4)) DO NOT INFLATE JACKET UNLESS YOU NEED TO LEAVE THE AIR CRAFT

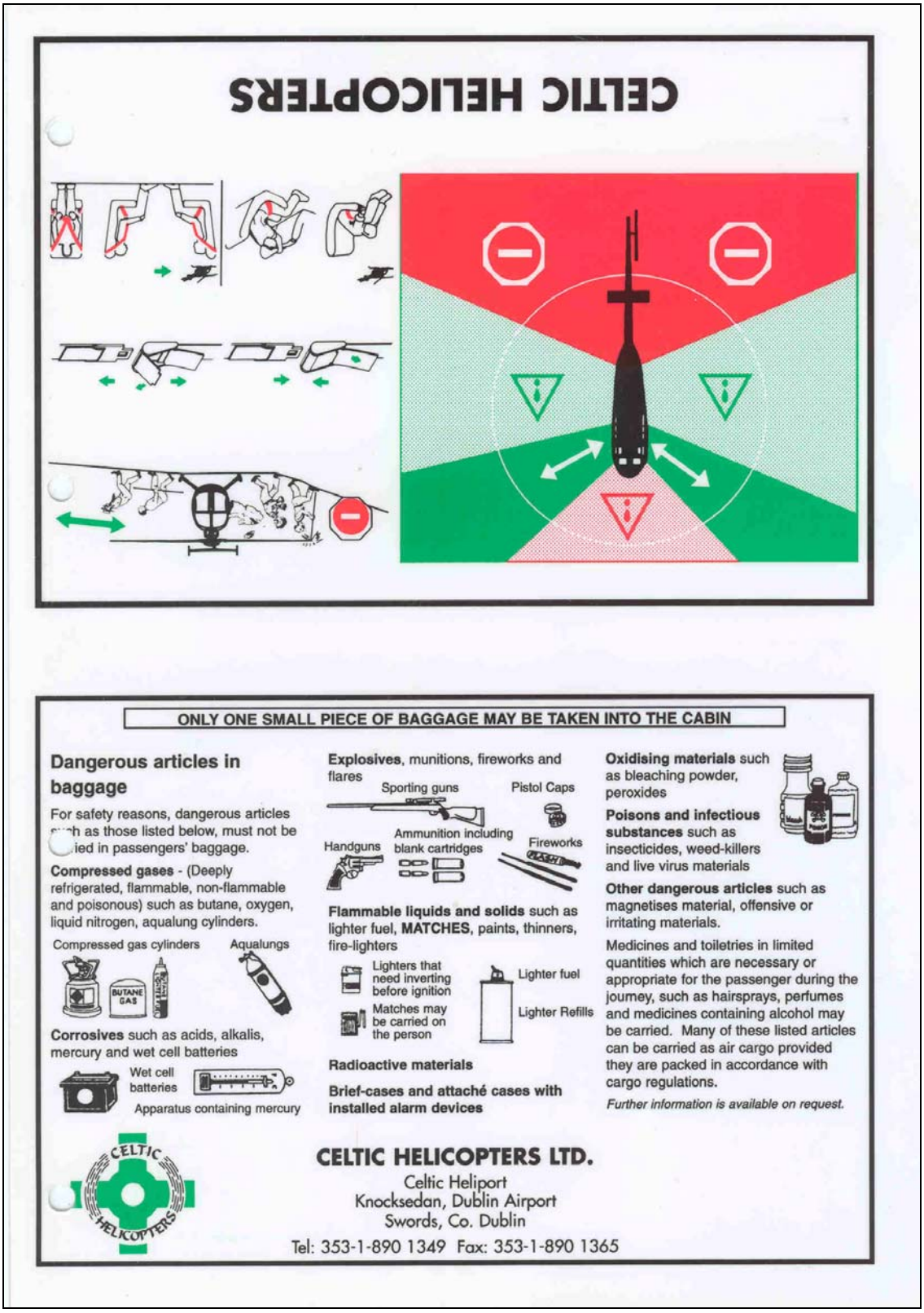
EMERGENCY PROCEDURES

IF THERE IS AN EMERGENCY OF ANY NATURE YOU WILL BE FOREWARNED BY THE PILOT WHENEVER POSSIBLE . CHECK THAT YOUR SEAT BELT IS SECURELY FASTENED. EXTINGUISH ANY CIGARETTES. OBEY ANY INSTRUCTIONS GIVEN BY THE PILOT.
WHEN THE AIRCRAFT HAS LANDED DO-NOT DISEMBARK UNTIL GIVEN PERMISSION TO DO SO BY THE PILOT. THE AIRCRAFT WILL FLOAT ON THE FLOTATION GEAR, BUT SHOULD IT BE NECESSARY TO LEAVE THE AIRCRAFT DO-NOT INFLATE THE JACKET UNTIL YOU HAVE LEFT THE AIRCRAFT.

BRACE POSITION:

IN THE EVENT OF A WARNING FROM THE PILOT, ADOPT THE BRACE POSITION.

Reverse Side of Safety Card



This side of the card is shown in the format of the original, with the top section inverted.

APPENDIX F

This photo shows the instrument panel as viewed from behind the head of a person seated in the front LH seat. This photograph was taken during the test runs noted in paragraph 1.12 of the main report. It represents what would have been seen by the pilot and front LH seat passenger when one booster pump was uncovered but before the second pump uncovered and the engine failed. The visible red light in the Warning Panel (upper centre) is the "FUEL PUMP" warning light. The main lighting of the warning light is red, while the logo "FUEL PUMP" is yellow. Because of the colour balance of the camera, the yellow is more visible in this digital photo, compared to the actual situation. In this test the low main rotor light was also on, as the rotor was running at idling speed. In this photograph, this warning light is hidden by the headphone cable to the right of centre. The fuel gauge is located on the left of the instrument panel. In this photograph it is hidden by the person seated in the LH seat.

- END -