NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

September 3, 2019

EMERGENCY FLOTATION SYSTEM GROUP FACTUAL REPORT

NTSB No: ERA18MA099

A. ACCIDENT

Operator: Liberty Helicopters, Inc.
Aircraft: Airbus Helicopters AS350 B2, Registration N350LH
Location: New York, New York
Date: March 11, 2018
Time: 1908 eastern daylight time

B. GROUP

Group Co-Chair: Chihoon Shin
National Transportation Safety Board
Washington, District of Columbia

Group Co-Chair Emily Gibson
National Transportation Safety Board
Washington, District of Columbia

Member: Pablo Bravo
Dart Aerospace
Vista, California

Member: Alex Quan
Dart Aerospace
Vista, California

Member: Matthew Rigsby
Federal Aviation Administration
Fort Worth, Texas

Member: Johann Magaña
Federal Aviation Administration
Los Angeles, California

Member: Rodrigo Goncalves
Liberty Helicopters, Inc.
Kearny, New Jersey

Member:	Erell Verleyen Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile Le Bourget, France
Member:	Seth Buttner Airbus Helicopters, Inc. Grand Prairie, Texas
Member:	Marc Belzile Transportation Safety Board of Canada Quebec, Canada
Member:	Hoss Golanbari Eurotec Canada Ontario, Canada
Member:	Tom Armstrong Transport Canada Ontario, Canada

LIST OF ACRONYMS

AC	Advisory Circular
ACO	Aircraft Certification Office
ALF	aft-looking-forward
ATT	aircraft total time
A&P	airframe and powerplant
CFR	*Code of Federal Regulations*
CT	computed tomography
dba	doing business as
EDT	eastern daylight time
FAA	Federal Aviation Administration
ICA	instructions for continued airworthiness
LA	Los Angeles
MDL	master drawing list
MG	Miscellaneous Guidance
NJ	New Jersey
NTSB	National Transportation Safety Board
NY	New York
NYPD	New York Police Department
PRV	pressure relief valve
psi	pounds per square inch
P/N	part number
RFM	rotorcraft flight manual
RFMS	rotorcraft flight manual supplement
STA	frame station
STC	Supplemental Type Certificate
S/N	serial number
TCDS	Type Certificate Data Sheet
TSO	Technical Standard Order
65NJ	Helo Kearny Heliport

C. SUMMARY

On March 11, 2018, about 1908 eastern daylight time (EDT), an Airbus Helicopters (formerly Eurocopter) AS350 B2, N350LH, was substantially damaged when it impacted the East River and subsequently rolled inverted after the pilot reported a loss of engine power near New York, New York (NY). The pilot egressed from the helicopter and sustained minor injuries. The five passengers did not egress and were fatally injured. The scheduled 30-minutes, doors-off aerial photography flight was operated by Liberty Helicopters, Inc. on behalf of FlyNYON, under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91. Visual meteorological conditions prevailed and no flight plan was filed for the flight which originated from Helo Kearny Heliport (65NJ), Kearny, New Jersey (NJ) about 1850 EDT.

The accident helicopter remained submerged within the East River until it was recovered on March 12, 2018. On March 12-15, 2018, portions of the emergency flotation system installed on the accident helicopter was examined and documented. On April 10-11, 2018, the emergency flotation system was examined further; the right valve and the activation pull cable assemblies were removed and retained for additional examination. On May 8, 2018, the right valve and the activation pull cable assemblies were disassembled and examined. On June 29, 2018, testing on an exemplar emergency flotation system was performed using different cross-feed hose configurations.

D. DETAILS OF THE INVESTIGATION

1.0 EMERGENCY FLOTATION SYSTEM DESCRIPTION

The FAA issued Supplemental Type Certificate (STC) No. SR00470LA to Apical Industries, Inc., doing business as (dba) Dart Aerospace, for the installation of an emergency flotation system on the following models from Type Certificate Data Sheet (TCDS) No. H9EU: AS350 C, AS350 D, AS350 D1, AS350 B, AS350 B1, AS350 B2, AS350 BA, and AS350 B3. As described in the rotorcraft flight manual supplement (RFMS) for STC No. SR00470LA, the system is "designed to allow both emergency landings and takeoffs from water or prepared hard surfaces if the emergency landing is executed in accordance with [emergency procedures]."

The emergency flotation system installed via STC No. SR00470LA contains two pressurized gas reservoir assemblies which inflate, via hoses, six skid-mounted floats. Three floats are mounted to each side of the skids; each float contains two chambers. The floats on both sides of the skids are identified as "forward", "mid", and "aft", i.e. "left-forward" identifies the forward-most float installed on the left skid. Each float is packaged within its own float cover.[1]

The reservoir assemblies are mounted to the airframe via loop clamps. One reservoir assembly is mounted underneath the left baggage compartment while the other is mounted underneath the right baggage compartment. Each reservoir assembly is composed of a valve and a cylinder. The valve is opened via a mechanical pull cable system that is pilot-activated by an activation handle mounted on the cyclic stick, near the base of the cyclic grip. The floats are deployed via the pilot pulling the activation handle aft. The float activation handle is offset from the cyclic grip by about 32 degrees to the right of the cyclic grip to prevent interference with the grip when the activation handle is pulled aft. A shear pin, installed within the activation handle, is intended to prevent inadvertent activation of the float system.

[1] The terms "left", "right", "up", and "down" are used when in the frame of reference of looking forward from the aft end of the helicopter, i.e. aft-looking-forward (ALF). All locations and directions will be viewed from ALF unless otherwise specified. Additionally, clock positions are in the ALF frame of reference unless otherwise specified.

There is no mechanical stop at the end of the stroke of the activation handle to provide a tactile response that the handle was pulled fully aft. According to Dart Aerospace, the design intent for the activation method to deploy the emergency float system is to pull the activation handle using only the right hand while that hand remains in contact with the cyclic grip.

For installations where the pilot cyclic stick is mounted on the right side of the helicopter (**Figure 1**), the activation handle is connected to a pull cable that is first routed underneath the cockpit floor, laterally across the underside of the airframe, and then routed aft to a junction box. This junction box, installed on the left frame rail, contains a dual cable block that transmits the motion of one pull cable to two separate pull cables. Specifically, the pull cable from the activation handle connects to the forward end of the dual cable block and two separate pull cables, identified as the aft-upper and aft-lower pull cables, are attached to the aft end of the dual cable block. When the activation handle is pulled aft, the activation handle pull cable moves the dual cable block forward. A spring attached to the dual cable block returns the block to its starting position when the activation handle is released. The aft-lower pull cable is first routed aft, then laterally across the underside of the airframe to the valve of the right reservoir assembly. The aft-upper pull cable is routed aft to the valve of the left reservoir assembly. The pull cables are typically secured to the airframe with cable ties or loop clamps.

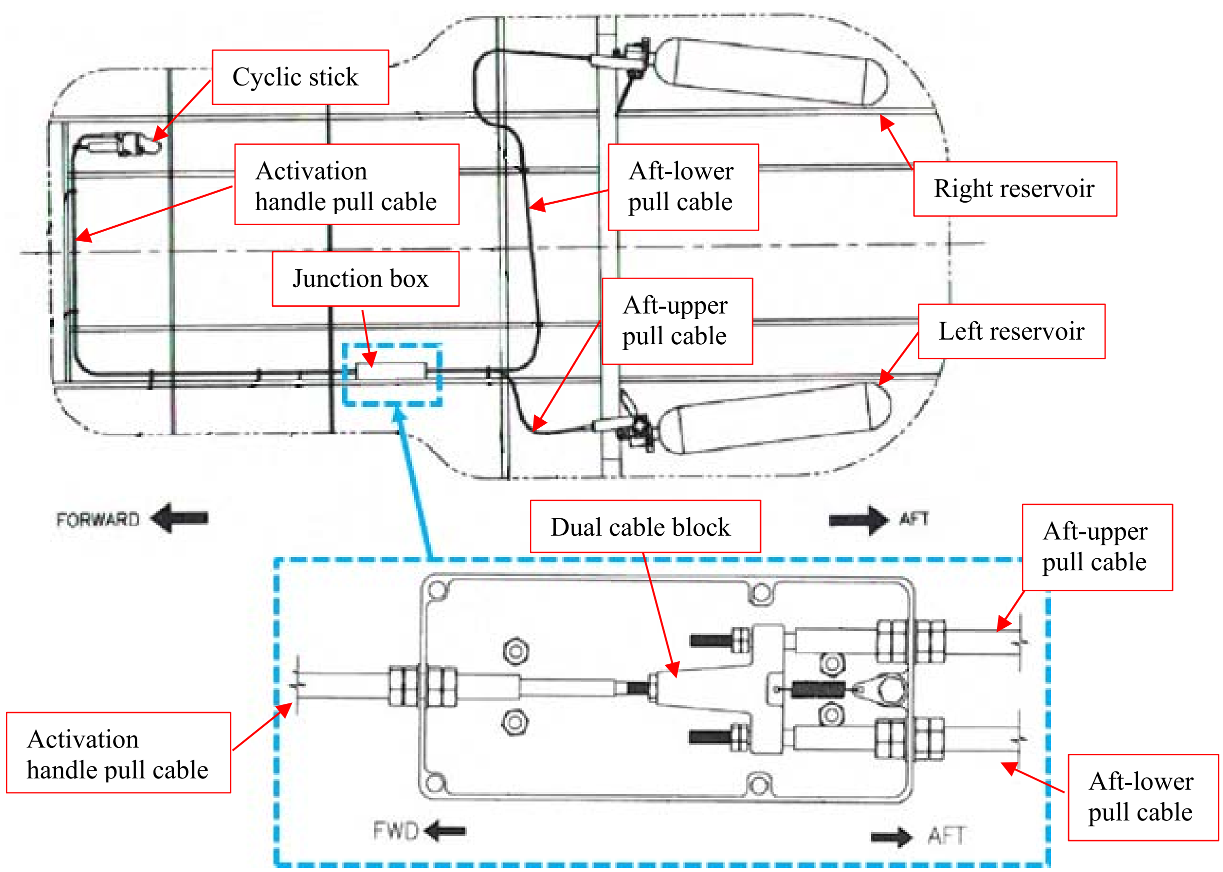

Figure 1. Typical routing of the activation pull cables when the pilot cyclic stick is installed on the right side of the helicopter, per Installation Instruction No. II350-600. (Image courtesy of Dart Aerospace)

Hoses connect the three left floats to the left manifold, the latter of which is supplied gas by the left reservoir assembly. Similarly, hoses connect the three right floats to the right manifold. A cross-feed hose, installed between the left and right manifolds, allows gas to traverse between the left and right sides, e.g. the right reservoir assembly can inflate the left floats (**Figure 2**). The hoses are secured to the skids with loop clamps.

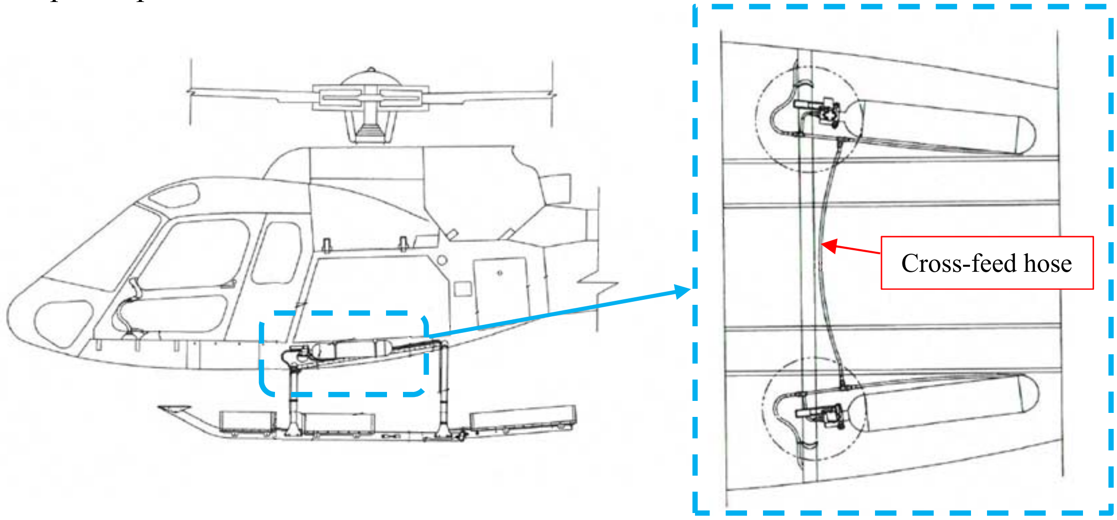

Figure 2. The cross-feed hose installation. (Image courtesy of Dart Aerospace)

2.0 DOCUMENTATION AT THE ACCIDENT SITE AND AFTER RECOVERY

On March 12, 2018, members of the Emergency Flotation System Group[2] convened at the East 23rd Street Pier in Manhattan, NY. The wreckage was submerged and inverted in the East River, with only the floats visible above the surface (**Figure 3**). All six floats were visible and each float contained residual gas. The wreckage was previously tethered to the pier by first responders. The wreckage was recovered and relocated to the New York Police Department (NYPD) Aviation Unit hangar at Floyd Bennett Field in Brooklyn, NY. From March 13-15, 2018, members of the Emergency Flotation System Group convened at the NYPD Aviation Unit hangar to document the recovered wreckage. Unless otherwise noted, all observations within this section were recorded after the helicopter was recovered and relocated to the NYPD Aviation Unit hangar.

Figure 3. The six visible floats while the helicopter remained inverted in the East River.

[2] Only members from the NTSB, FAA, Airbus Helicopters, and Liberty Helicopters were present during the on scene and post-recovery examination of the emergency flotation system in New York. Dart Aerospace, the Transportation Safety Board of Canada, Eurotec Canada, and Transport Canada were added into the Emergency Flotation System Group after the helicopter was relocated to Anglin Aircraft Recovery. NYONair was present during the emergency flotation system examination at Anglin Aircraft Recovery.

2.1 RESERVOIR ASSEMBLIES AND HOSES

The left reservoir assembly was found in its normally installed location. The forward loop clamp was about 6 inches from the neck of the left cylinder. The left reservoir assembly gauge was visible and indicated about 0 pounds per square inch (psi). A sticker on the left reservoir showed the following information: left reservoir serial number (S/N) 13003; left valve S/N 0164; and left cylinder S/N GZ249.[3]

The right reservoir assembly was found in its normally installed location. The forward loop clamp was about 6 inches from the neck of the right cylinder. The right reservoir assembly gauge was visible and indicated about 4,000 psi (**Figure 4**). A sticker on the right reservoir showed the following information: right valve S/N 0101; and right cylinder S/N GZ442.[3]

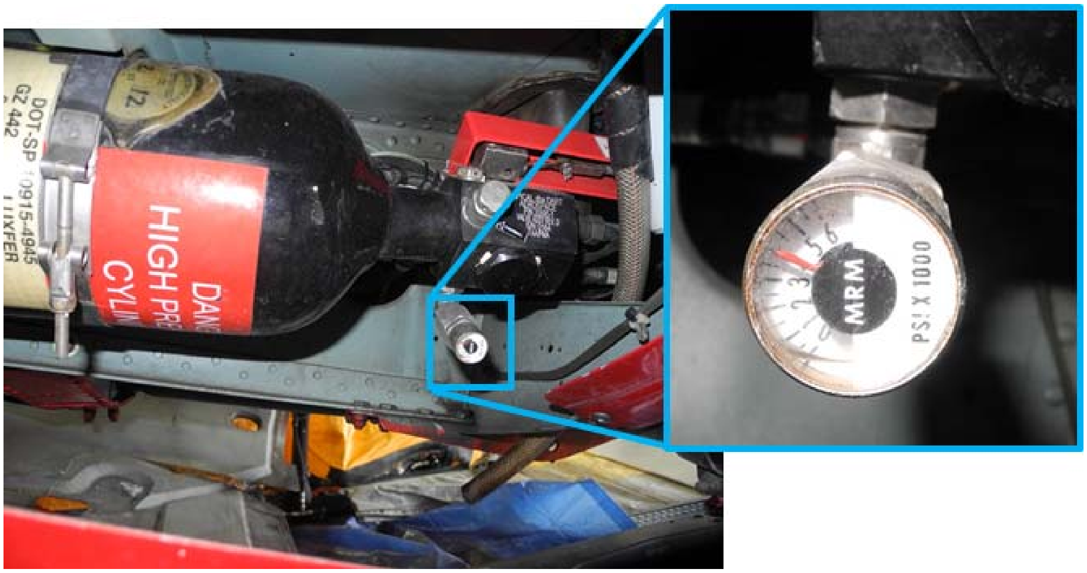

Figure 4. The right reservoir assembly showing the pressure gauge indicating about 4,000 psi.

The hoses remained installed between the left and right reservoir assemblies to the floats on their respective sides. Additionally, the cross-feed hose remained installed between the hoses routed from the left and right manifolds. Examination of the hose installation from the left and right reservoir assemblies to the six floats did not reveal evidence of disconnection nor evidence of cuts and tears.

The left valve and shroud remained installed on the cylinder. About 3/4 inch of the left valve cable, red in color, was visible (**Figure 5**); this measurement was taken from the silver-colored valve body to the aft end steel sleeve on the cable. The left valve cable remained connected to the clevis of the aft-upper pull cable from the junction box. The right valve and shroud remained installed on the reservoir. About 5/16 inch of the right valve cable was visible (**Figure 6**); this measurement was taken from the silver-colored valve body to the aft end of the steel sleeve on the cable. The right valve cable remained connected to the clevis of the aft-lower pull cable from the junction box.

[3] According to the cylinder fill sheet information provided by Dart Aerospace, cylinder S/Ns GZ249 and GZ442 were filled with nitrogen.

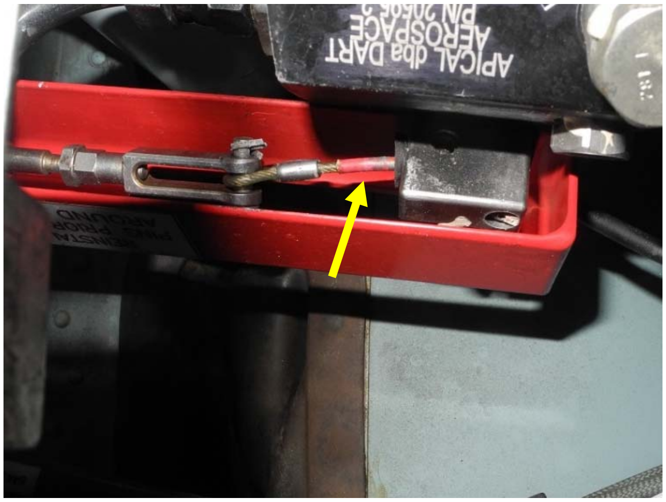

Figure 5. The left valve assembly. The yellow arrow points to the valve cable.

Figure 6. The right valve assembly. The yellow arrow points to the valve cable.

A safety pin was inserted into the right valve assembly by the investigation group in order to prevent inadvertent activation of the valve during the wreckage documentation.

2.2 FLOTATION ACTIVATION SYSTEM

The activation handle remained installed on the pilot cyclic stick (**Figure 7**). The activation handle shear pin was not present. The pull cable routing was continuous from the activation handle to the junction box. The junction box remained attached to the outboard side of the left frame rail and its cover remained attached with safety wiring between cover screws. The aft-upper and aft-lower cables were seen exiting the junction box and their routing were continuous to the left and right valves, respectively. The exterior cover (sheathing) of the pull cables did not exhibit evidence of anomalous damage.

Figure 7. The activation handle installed on the cyclic control.

The junction box cover screws and cover were removed, revealing the dual cable block and its pull cable connections (**Figure 8**). The forward pull cable, leading to the float activation handle, the aft-upper cable, aft-lower cable, and spring remained attached to the dual cable block. For the aft-upper cable, there was a gap of about 0.25 inches between the nut and the block surface. For the aft-lower cable, there was no apparent gap between the nut and the block surface to which the nut contacts. Orange-colored torque striping was present on all nuts within the junction box.

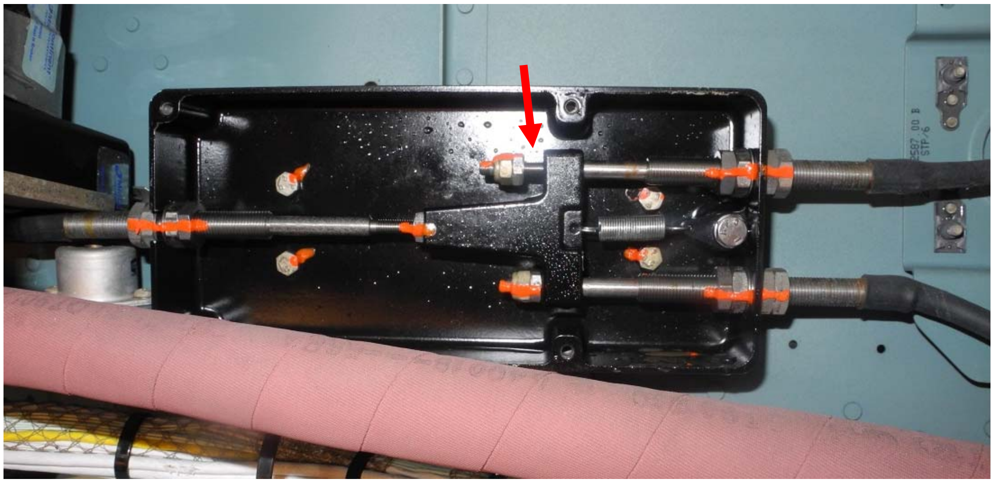

Figure 8. The junction box after removal of its cover. The red arrow points to the gap observed between the aft-upper cable nut, leading to the left reservoir assembly, and the dual cable block.

The aft-lower pull cable to the right valve was disconnected (by the group) from the right valve cable clevis connection by removing the pin. When attempting to remove the clevis pin securing the clevis connection between the aft-upper pull cable and the left valve cable, the latter came out of its shroud, consistent with prior activation of the left valve. After both pull cables were disconnected from the left and right valves, a continuity check of the pull cables was performed by pulling the float activation handle and simultaneously observing the dual cable block and the aft-upper and aft-lower pull cable clevis connections. Continuity of the pull cable mechanism from the activation handle to both clevis connections was confirmed. Movement of the activation handle was smooth with no evidence of binding. When the activation handle was released, the handle returned to its starting position; the dual cable block also returned to its starting position due to the spring between it and the junction box. A gap of about 0.75 inches was observed between aft-upper cable nut and the block surface. An identical gap of about 0.75 inches was observed between the aft-lower cable nut and the block surface (**Figure 9**).

Figure 9. A view of the junction box showing the gap of about 0.75 inches between the cable nuts and the dual cable block after a continuity check was performed by pulling the activation handle. Prior to the continuity check, the pull cables were disconnected at the left and right valves.

2.3 FLOATS

When the helicopter was repositioned onto a dolly for wreckage examination purposes at the NYPD Aviation Unit hangar, the right-front and right-mod floats were partially underneath the right skid. The helicopter was later lifted, via ceiling crane, to remove these two floats from underneath the right skid. All six floats had stenciled data marked on their exterior. **Table 1** shows the stenciled data on each float. **Figure 10** and **Figure 11** show the left and right floats, respectively.

Table 1. Stenciled data on the six floats. (Note: The float position identifier is *italicized* and was not stenciled on the float.)

Left-Forward Float Apical Oceanside, CA 20327-400 Rev. 0 Serial No. 13015 Eurocopter-France AS350B, B1, B2, B3, BA, C, D, D1 AS355E, F, F1, F2, N, NP D.O.M. 11-13 FAA-PMA	*Right-Forward Float* Apical Oceanside, CA 20327-400 Rev. 0 Serial No. 13006 Eurocopter-France AS350B, B1, B2, B3, BA, C, D, D1 AS355E, F, F1, F2, N, NP D.O.M. 09-13 FAA-PMA
Left-Mid Float Apical Oceanside, CA 20328-400 Rev. 0 Serial No. 13005 Eurocopter-France AS350B, B1, B2, B3, BA, C, D, D1 AS355E, F, F1, F2, N, NP D.O.M. 09-13 FAA-PMA	*Right-Mid Float* Apical Oceanside, CA 20328-400 Rev. 0 Serial No. 13006 Eurocopter-France AS350B, B1, B2, B3, BA, C, D, D1 AS355E, F, F1, F2, N, NP D.O.M. 09-13 FAA-PMA

Left-Aft Float Apical Oceanside, CA 20329-400 Rev. 0 Serial No. 13003 Eurocopter-France AS350B, B1, B2, B3, BA, C, D, D1 AS355E, F, F1, F2, N, NP D.O.M. 09-13 FAA-PMA	*Right-Aft Float* Apical Oceanside, CA 20329-400 Rev. 0 Serial No. 13004 Eurocopter-France AS350B, B1, B2, B3, BA, C, D, D1 AS355E, F, F1, F2, N, NP D.O.M. 09-13 FAA-PMA

Figure 10. The three floats installed on the left skid.

Figure 11. The three floats installed on the right skid.

2.3.1 RIGHT-FORWARD FLOAT

The right-forward float remained attached to its float cover. The float cover remained installed on the right skid. Both pressure relief valves (PRV) were present. The float contained residual gas. When the float was compressed on either the forward or aft end, the residual gas appeared to remain contained within each chamber and no evidence of tears were observed. The float cover laces remained attached to its cover. The left and right Velcro tabs on the forward and aft ends of the float remained sewn into the float.

2.3.2 RIGHT-MID FLOAT

The right-mid float remained attached to its float cover. The float cover remained attached on the right skid. The forward chamber contained residual gas. No evidence of tears was observed on the forward chamber when the float was compressed. Water was observed within the aft chamber. An "L"-shaped tear was found on the aft chamber adjacent to the black abrasion strip near the aft-inboard corner of the float cover. The longitudinal portion of the tear was about 1.25 inches and the lateral portion of the tear was about 1.5 inches. The float cover laces remained attached to its cover. Both PRVs were present.

2.3.3 RIGHT-AFT FLOAT

The right-aft float remained attached to its float cover. The float cover remained attached to the right skid. The float contained residual gas. When the float was compressed on either the forward or aft end, the residual gas appeared to remain contained within each chamber and no evidence of tears were observed. The float cover laces remained attached to its cover. Three bungee straps remained attached (sewn) into the aft-upper surface of the float. The bungee straps did not exhibit anomalous damage. The forward end of the float contained three Velcro tabs sewn into the float. The straps and tabs had stenciled numbering adjacent to their sewn attachment on the float. Both PRVs were present.

2.3.4 LEFT-FORWARD FLOAT

The forward portion of the float was separated from the float cover, revealing the forward chamber supply hose. The aft portion of the float remained attached to the float cover. The float cover remained attached to the left skid. The float contained residual gas. When the float was compressed on either the forward or aft end, the residual gas appeared to remain contained within each chamber and no evidence of tears were observed. The left and right Velcro tabs on the forward and aft ends of the float remained sewn in. Both PRVs were present.

2.3.5 LEFT-MID FLOAT

The left-mid float remained attached to its float cover. The float cover remained attached to the left skid. The float contained residual gas. When the float was compressed on either the forward or aft end, the residual gas appeared to remain contained within each chamber and no evidence of tears were observed. Both PRVs were present.

2.3.6 LEFT-AFT FLOAT

The left-aft float remained attached to its float cover. The float cover remained attached to the left skid. On the forward chamber, a tear about 20 inches in length was found on the outboard side of the float; this tear was about 5 inches outboard of the abrasion strip. The aft chamber contained residual gas. No evidence of tears was observed on the aft chamber when the float was compressed. All three bungee straps remained attached to the aft-upper surface of the float. The bungee straps did not exhibit anomalous damage. All three Velcro tabs remained sewn into the forward end of the float. The straps and tabs had stenciled numbering adjacent to their sewn attachment on the float. Both PRVs were present.

3.0 DOCUMENTATION AT ANGLIN AIRCRAFT RECOVERY

On March 23, 2018, the accident helicopter was transported from the NYPD Aviation Unit hanger to Anglin Aircraft Recovery in Clayton, Delaware for further examination. On April 10-11, 2018, members of the Emergency Flotation System Group convened at Anglin Aircraft Recovery to further examine the emergency flotation system.

3.1 PULL CABLE INSTALLATION

The clevis connection between the left and right valve cables and the aft-upper and aft-lower pull cables remained disconnected. The pull cables were reset to their “non-activated” positions. The activation handle was pulled and the aft-upper and aft-lower pull cable clevis travel was measured to be 0.750 inches and 0.687 inches, respectively. According to Apical Industries Inc. Installation Instruction No. II350-600, the minimum travel required for the clevis is 0.625 inches. When the cyclic stick was moved in the fore-aft direction, without manipulation of the activation handle, no movement of the forward pull cable was observed at the junction box.

The pull cable bend radius was measured at 5 locations where the pull cable routing made directional turns. Each bend radius measurement was performed by tracing the pull cable bend radius on a piece of paper and subsequently measuring the radius of the curvature. **Figure 12** shows the location of each measurement. The radius measured at bend No. 1 was about 2.5 inches and the pull cable routing was curved about 90 degrees. The radius measured at bend No. 2 was about 2 inches and the pull cable routing was curved about 90 degrees. The No. 3 bend was not a curved bend but rather an angular bend, thus a radius was not measured; the cable was bent downward about 30 degrees (**Figure 13**). The radius measured at bend No. 4 was about 4.25 inches and the pull cable routing was curved about 90 degrees. The radius at bend No. 5 was about 3.25 inches and the pull cable routing was curved about 90 degrees.

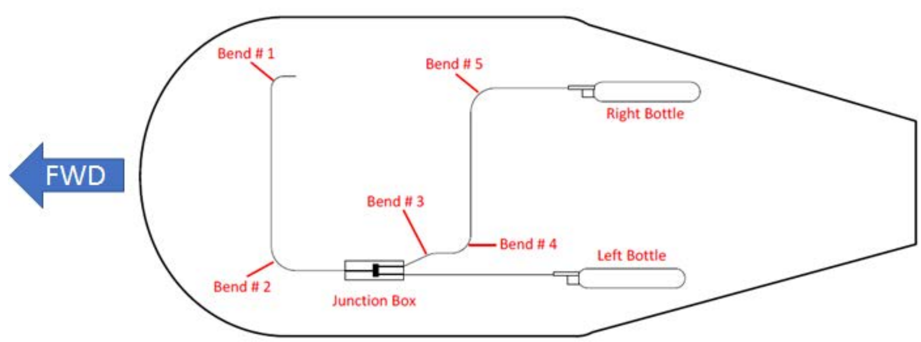

Figure 12. Location of each bend radius measurement for the pull cable installation on N350LH.

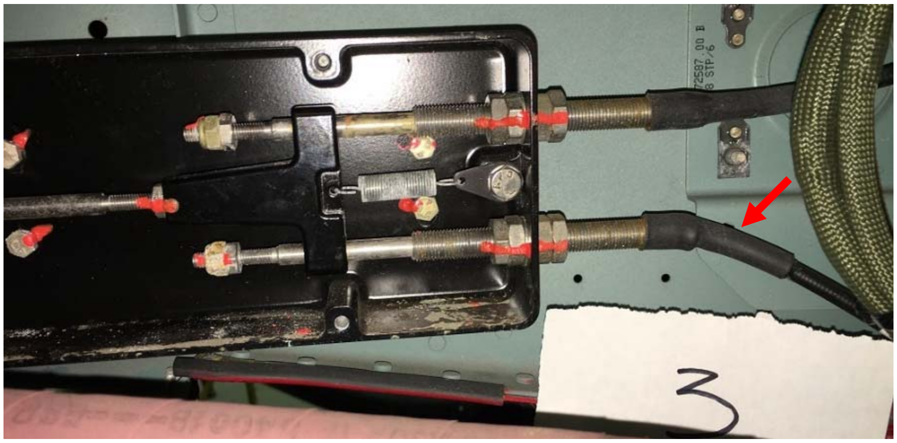

Figure 13. The downward bend (red arrow) observed on the aft-lower pull cable leading to the right reservoir assembly. (Note: Photograph was taken after the activation handle pull force test described in Section 3.3 of this report.)

3.2 RESERVOIR ASSEMBLIES

The left reservoir assembly gauge read 0 psi. The right reservoir assembly gauge read about 4,000 psi. The right reservoir assembly was depressurized until its gauge indicated 0 psi. During depressurization, an audible sound consistent with expelled gas was heard. The location of the left and right reservoir assemblies relative to the helicopter was index marked and subsequently the reservoir assemblies were removed from the helicopter. The valves were removed from their respective cylinders.

The left valve assembly, serial number (S/N) 0101, was opened to reveal the bayonet and spring. Moisture was observed within the cavity (where the bayonet resides) of the left valve assembly. The left valve cable, containing a trigger ball at its end, was reinstalled on the left valve assembly in order to reset the trigger mechanism. Using a digital force gauge, the force to pull the valve cable to activate the left valve assembly was measured to be about 6.68 pounds. Two subsequent tests were performed and found the valve cable pull force to be 10.62 and 8.63 pounds, respectively. According to Dart Aerospace, the required pull force to activate the valve assembly is between 6 to 15 pounds.

The safety pin, which had previously been installed by the group after recovery of the accident helicopter, remained installed on the right valve assembly, S/N 0164. The shroud was removed from the right valve assembly and shipped to Varex Inc. in Chicago, Illinois for computed tomography (CT) imaging. For details on the CT imaging of the right valve assembly, see the Computed Tomography Specialist's Factual Report in the docket for this investigation.

3.3 ACTIVATION HANDLE PULL FORCE TEST

Exemplar valve assemblies, provided by Dart, were installed on the left and right cylinders and the reservoir assemblies were reinstalled on the accident helicopter. The pull cable clevis travel was measured to be about 0.75 inches on both sides, meeting the minimum travel requirement of 0.625 inches. The aft-upper and aft-lower pull cables were reconnected to their respective valve cables. A fixture was installed near the upper end of the activation handle (**Figure 14**). A digital force gauge was connected to the fixture on the activation handle and used to measure the pull force of the cyclic-mounted activation handle.

Figure 14. The red arrow points to the fixture installed on top of the activation handle.

The cyclic was braced and the force gauge was pulled until a "pop" sound, consistent with a valve activation, was heard. The person pulling the force gauge noted the activation handle did not travel fully aft, but had stopped pulling the activation handle, when the pop sound was heard. The force gauge indicated a peak load of 45.1 pounds. The left valve cable and ball were found outside of its housing, consistent with activation of the left valve. The right valve cable and ball were still contained within their housing, consistent with the right valve not having activated. The dual cable block within the junction box returned to its resting position when the activation handle was released. A gap was visible between aft-upper cable nut, the aft-lower cable nut, and the block surface. However, the aft-upper cable nut was displaced further forward than the aft-lower cable nut, i.e. the aft-upper cable nut had a larger gap between it and the block surface. Without resetting the pull cable system, the force gauge was pulled again by the same person (using one hand to pull the force gauge and the other hand to brace the cyclic) but the right valve did not activate; the force gauge indicated a peak load of 58.4 pounds. Using the left hand to brace the cyclic grip and the right hand to pull the activation handle (without using the force gauge) the same person pulled the handle aft until a "pop" was heard; the right valve was visually confirmed to have activated.

The pull cables and valve were reset for a subsequent pull force test. The tester stated he would swiftly pull the activation handle fully aft, regardless of when a "pop" sound was heard. The cyclic was braced and the force gauge was used to pull the activation handle aft. A "pop" sound was heard. Both left and right valves were visually confirmed to have activated. The force gauge indicated a peak load of 46.8 pounds. The pull cable assemblies, including activation handle and junction box, were removed from the helicopter for further examination.

3.4 FLOAT EXAMINATION

The right-mid float exhibited an "L" shaped tear in an area of reinforced material. The left-forward float was ripped from the girt about 16.25 inches from the forward edge of the girt toward the aft end. The forward hose was pulled through the girt, resulting in a kink in that hose. The forward chamber of the left-aft float had a linear tear about 20 inches in length, with evidence of a puncture at the midpoint of the tear. All damage observed on the three floats were consistent with the damage observed during examination of the floats in the NYPD Aviation Unit hangar. The remaining floats did not exhibit anomalous damage.

Pressurized air was applied to the inlet hose to test he float inlet check valves. On the left-forward float, the inlet check valve closest to the pressurized air input actuated, but due to a kink in the hose, the aft inlet check valve did not actuate. The inlet check valves of the remaining five floats actuated with the application of pressurized air.

Using pressurized air, normal operation of the PRVs were observed on the remaining five floats. On the right-mid float, one PRV had debris with the appearance of salt crystals within the spring cavity. The debris was dispersed from the spring cavity with the application of pressurized air. None of the other PRVs exhibited similar debris.

With the exception of the left-mid float cover, the exterior of the remaining five float covers exhibited wear. On the right-forward float cover, the Velcro from the forward end cap was ripped from its stitching. On the right-aft float cover, two button snaps were pulled through the cover during inflation; the snaps were present on the other side of the cover. On the left-forward float cover, the Velcro was ripped from its stitching. On the left-mid and the left-aft float covers, one of the button snaps had pulled through the cover.

3.5 HOSE ASSEMBLIES

The hose assemblies were removed from the helicopter for examination. **Figure 15** shows the hose installation. The cross-feed hose, P/N 602.1508, exhibited no anomalous damage.

The hoses primarily supplied by the left reservoir assembly, and mounted on the left skid, were examined for condition. Hose part number (P/N) 602.1505 exhibited a kink at mid-length. A portion of hose P/N 602.1507 was observed to be collapsed but still allowed the passage of gas. Hose P/N 602.1506 exhibited bubbles on the black sheathing. Hose P/N 602.1503 exhibited no anomalous damage. Hose P/N 602.1502 exhibited two kinks.

The hoses primarily supplied by the right reservoir assembly, and mounted on the right skid, were examined for condition. Hose P/Ns 602.1505, 602.1502, and 602.1503 exhibited a kink. Hose P/N 602.1507 exhibited no anomalous damage. The sheathing on hose P/N 602.1506 had been chaffed through, exposing the underlying steel braided hose.

All hoses were checked for debris by applying pressurized air (about 60 psi) from one end of the hose and collecting any debris expelled from the other end of the hose. There was no evidence of substantial debris found in any of the hoses.

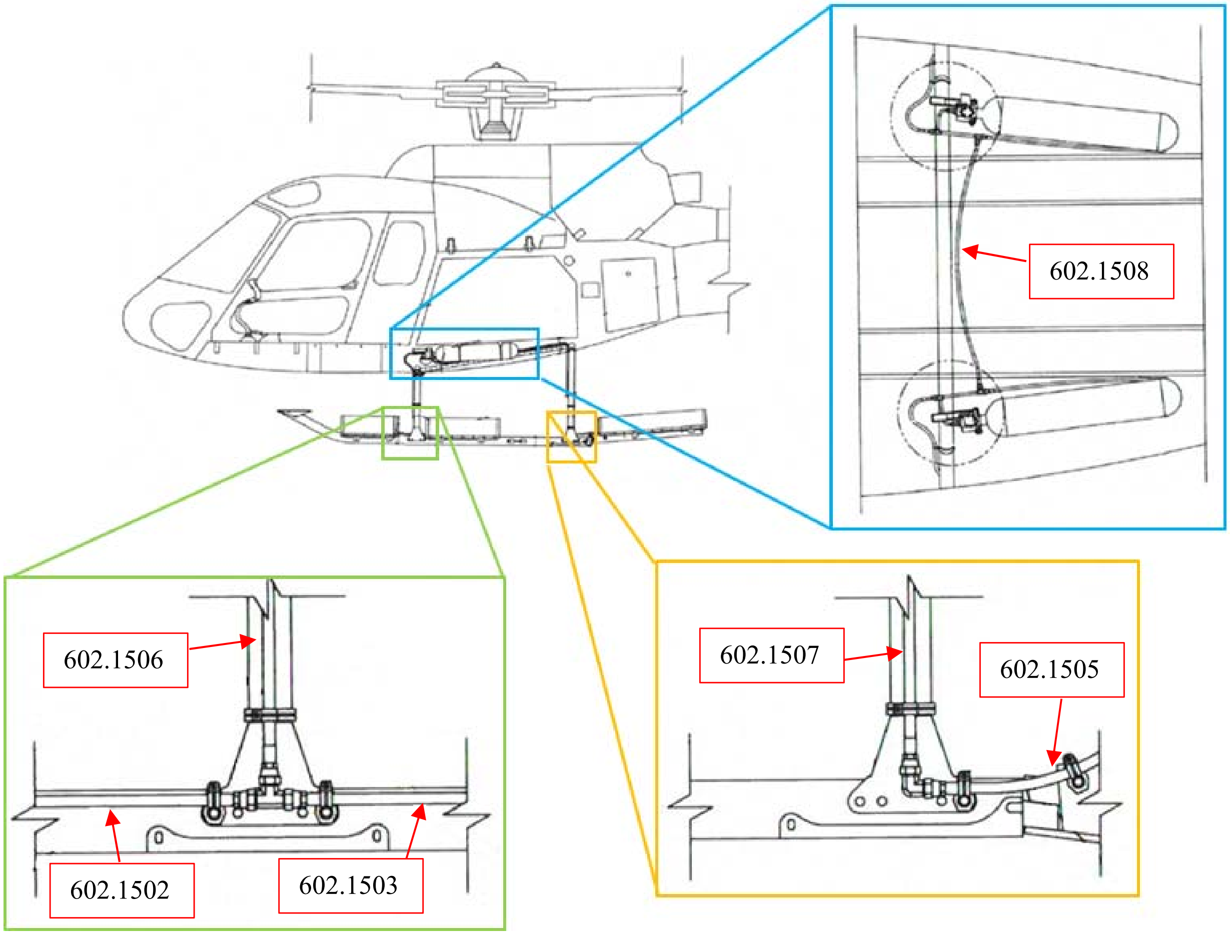

Figure 15. The hose installation P/Ns and their locations. **(Image courtesy of Dart Aerospace)**

4.0 EXAMINATION OF RIGHT VALVE ASSEMBLY AND ACTIVATION PULL CABLES

On May 8, 2018, members of the Emergency Flotation System Group convened at Dart Aerospace facilities in Vista, California to examine the right valve assembly and activation pull cables.

4.1 RIGHT VALVE ASSEMBLY

The CT imaging showed the position of the pull cable and ball for the right valve assembly was consistent with the valve not having been activated. No anomalous damage or internal component positioning was observed from the CT imaging.[4] The group made the decision to proceed with a test of the right valve assembly to measure the forces required to activate the valve.

Anti-seize compound was observed on the cylinder and hose attachment threads. Torque seal was observed on all required locations. The O-ring was present at the base of the cylinder

[4] The CT images showed the cavity, in which the ball from the ball and cable assembly was located, was about 0.35 inches in length. Once the ball exits the cavity, the piston is free to stroke, which allows the bayonet ball, and subsequently the bayonet, to move.

attachment threads. Scratches observed on the valve body was consistent with normal service wear. The valve cable plastic shrink wrap was present but fraying of the coating was observed.

The valve assembly was placed on a vice, the valve cable was connected to a digital force gauge, and the valve was activated, i.e. the cable was pulled via the force gauge. For the first test, the pull force was measured to be about 14.01 pounds. The prescribed pull force limit per the Dart Aerospace Valve Overhaul Procedure, document No. MPP-167, was 15 pounds. Anti-seize compound was observed on the ball and grommet. The length of the ball and cable assembly was about 2.25 inches. The grommet was installed backwards when compared to an exemplar ball and cable assembly as well as the drawing for the ball and cable assembly. The bayonet housing was removed, revealing the bayonet and spring. No obstructions were observed within the bayonet cavity and no anomalous damage was observed on the bayonet and its housing. The puncture disc was observed to be punctured.

The ball and cable assembly and the bayonet assembly was reinstalled in order to perform a second pull test. The second pull test yielded a measurement of 11.04 pounds. The valve assembly was reconstructed for a third pull test. The third pull test yielded a measurement of 10.72 pounds. A complete teardown of the valve assembly revealed no anomalous damage to the bayonet trigger piston, ball, spring, and ball housing.

4.2 ACTIVATION PULL CABLES

The pull cable assemblies comprised the cyclic-mounted activation handle, the pull cable from the activation handle to the junction box, the junction box assembly, and the aft-upper and aft-lower pull cables. The pull cable from the activation handle to the junction box measured about 98.25 inches in length; this pull cable was required to be 98.0 inches. The aft-upper pull cable was measured to be about 29.0 inches in length; this pull cable was required to be 28.88 inches. The aft-lower pull cable was measured to be about 68.6 inches in length; this pull cable was required to be 68.25 inches.

4.2.1 AFT-LOWER PULL CABLE

The aft-lower pull cable assembly was removed from the junction box. The pull cable was secured via a vice on one end and the other end was pulled, using a digital force gauge, to about 41.5 pounds with no evidence of the pull cable fracturing. The rubber sleeve (heat shrink tubing) was removed from the junction box-side of the pull cable, revealing the conduit was bent downward from the threaded cable rod about 20 degrees from the horizontal plane. The bend in the conduit opened up the conduit tubing, exposing the dark pink-colored plastic liner. Evidence of corrosion was observed adjacent to the plastic liner. The cable was cut by the group near the valve end containing the clevis connection. No restriction was felt when the cable was pulled from the conduit on the valve-end segment, but corrosion was observed at the cable interface with the cable rod. A small patch of corrosion was observed about 1.25 inches from the cable-to-cable rod interface. On the junction box-end segment, no restriction was felt when the cable was pulled from the conduit, but corrosion was observed about 0.75 inches from the cable-to-cable rod interface. This corrosion was about 1.25 inches in length. No evidence of fraying was observed on either segment of the pull cable.

4.2.2 AFT-UPPER PULL CABLE

The aft-upper pull cable assembly was removed from the junction box. The pull cable was secured via a vice on one end and the other end was pulled, using a digital force gauge, to about 41.0 pounds with no evidence of the pull cable fracturing. The rubber sleeve was removed, revealing corrosion on the conduit at its interface with the threaded cable rod on both the junction box-end and the valve-end. The pull cable was cut by the group near the valve end containing the clevis connection. No restriction was felt when the cables were removed from their respective conduits. On the valve-end segment, corrosion was observed. On the junction box-end segment, corrosion was observed on the cable rod and on the cable itself. There was no evidence of fraying on either segment of the pull cable.

4.2.3 ACTIVATION HANDLE PULL CABLE

The activation handle pull cable assembly was removed from the junction box. The pull cable was secured via a vice on one end and the other end was pulled, using a digital force gauge, to about 41.5 pounds with no evidence of the cable fracturing. The rubber sleeve was removed from both ends of the assembly. Corrosion was observed on the conduit at its interface with the cable rod, at both ends of the assembly. Corrosion was also observed at the lower swage of the threaded cable rod.

5.0 FLOAT SYSTEM INSTALLATION

5.1 INSTALLATION INSTRUCTIONS

Dart Installation Instruction No. II350-600 is used to install STC No. SR00470LA on an eligible helicopter. At the time of installation onto N350LH, revision E was the latest version of Installation Instruction No. II350-600. Section 8.0 of II350-600 addresses the installation of the pull cable system. The instructions allow for the use of tywraps or loop clamps to secure the pull cables to the aircraft as needed. At the conclusion of the pull cable installation instructions, the activation handle was to be pulled and the stroke of the clevis, normally connected to the valve cable but not connected at this point in the installation, was measured to ensure it met the minimum stroke of 0.625 inches. There was no requirement that the stroke of the clevis between the left and right reservoir assemblies be within a certain relative measurement from each other. The installation instructions did not require a check the activation handle pull forces and did not prescribe an inflation test at the conclusion of the emergency flotation system installation.

5.2 INSTALLATION ON N350LH

The accident helicopter maintenance records contained an entry of a work order by Eurotec Canada. The work order in the maintenance records, dated December 2, 2013, stated the Apical emergency float kit, P/N 20326-700, S/N 040, was installed new onto N350LH. A copy of the work order can be found in **Attachment 1** to this report.

During the examination of the emergency flotation system at Anglin Aircraft Recovery, the pull cable routing was examined and found to conform with the requirements of Installation Instruction No. II350-600 with the exception of the junction box location. According to Installation Instruction No. II350-600, the forward screws to mount the junction box to the airframe structure were required to be located on the left frame rail at frame station (STA) 77.222 and about 3.50 inches below the underside of the cabin floor (**Figure 16**).[5] The junction box of the accident helicopter was found at about STA 78.8 and about 3.25 inches from the underside of the cabin floor. The KG-102A directional gyro was observed to be mounted to the left and forward of the junction box.

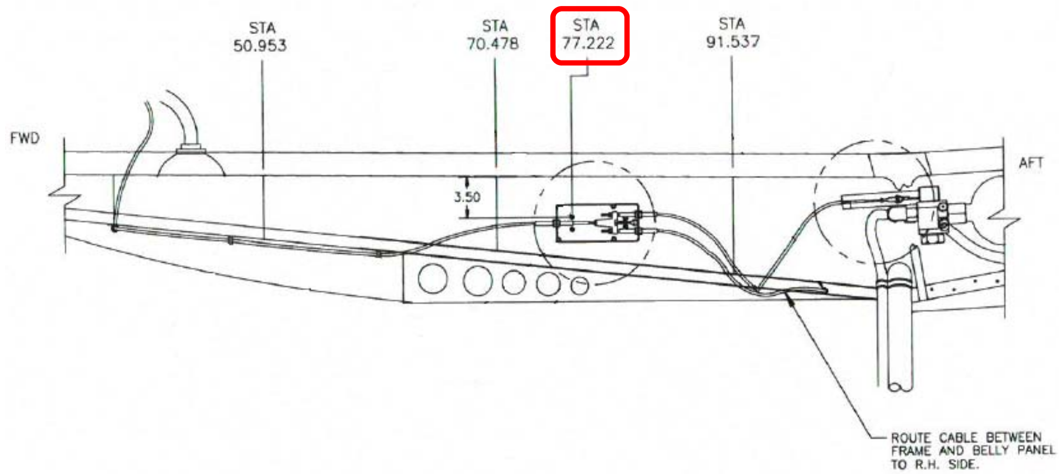

Figure 16. The junction box location (red box) prescribed by Installation Instruction No. II350-600. (Image courtesy of Dart Aerospace)

According to Eurotec Canada, the placement of the junction box at a location different than that prescribed by Installation Instruction No. II350-600 was discussed with a Dart engineer prior to installation of the junction box. On October 30, 2013, the Dart engineer provided Eurotec Canada with a letter which stated the dual cable plate assembly (junction box) was "typically installed on the inboard side of the [left hand frame rail]" and "for this installation the [junction box] and related [junction box] components will be installed on the outboard side of the [left hand frame rail].[6] No modifications or changes in the length of any cables was necessary for this discrepancy." There was no discussion of STA positioning of the junction box in the letter. A copy of the "no technical objection" letter from Dart Aerospace to Eurotec Canada can be found in **Attachment 2**.

5.3 INSTALLATION ON N351LH AND N353JS

On April 17, 2018, an NTSB investigator examined the activation pull cable and junction box installation on two exemplar helicopters, N351LH and N353JS, equipped with STC No. SR00470LA, at Liberty Helicopters' facility in Kearny, NJ. The junction box for both helicopters were installed on the inboard side of the left frame rail. The junction box for N351LH was located at about STA 78.228. The junction box for N353JS was located at about STA 79.978. The cabling exiting the junction box on both helicopters exhibited a similar downward turn as that observed on N350LH (**Figures 17 and 18**).

[5] The nose of the helicopter is located at STA 5.511. All STA values in this report are in inches.
[6] At the time of the accident, the current version of Installation Instruction No. II350-600, revision J, contained a provision that allows for the junction box to be installed on either the inboard or outboard side of the left frame rail.

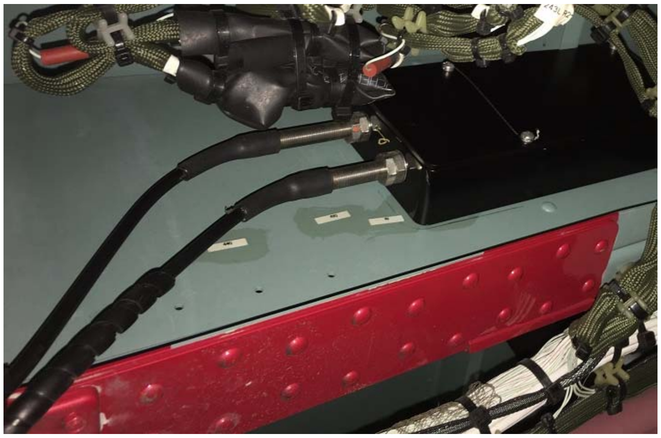

Figure 17. The junction box installation on N351LH.

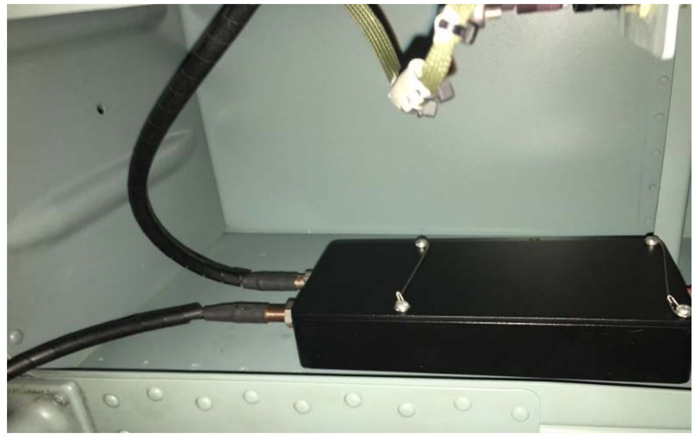

Figure 18. The junction box installation on N353JS.

6.0 FLOAT SYSTEM DEPLOYMENT

6.1 ROTORCRAFT FLIGHT MANUAL SUPPLEMENT (RFMS) FMS-350(2)

The RFMS for STC No. SR00470LA, document No. FMS-350(2), provides instructions on use of the emergency flotation system, describes the operational characteristics of the system, and provides limitations for the helicopter and the float system. At the time of the accident, Revision E was the latest version of the RFMS. The RFMS prescribes a maximum airspeed of 75 knots prior to inflation of the emergency flotation system. The RFMS recommended a 10 knot maximum speed for water contact.[7]

The RFMS stated that the shear pin within the activation handle required about 12 pounds of force to shear and recommended the upper portion of the activation handle be used to assist in breaking the shear pin. Furthermore, it stated that once the shear pin had been broken, the handle must be pulled further aft to inflate the floats. The RFMS did not contain information that the two cylinder valves could activate at different points of the activation handle travel or specified that the floats are designed to be deployed via the activation handle using one hand (the hand on the cyclic). An excerpt of the emergency procedures section of FMS-350(2) Revision E, applicable at the time of the accident, can be found in **Attachment 3** to this report.

According to the operator, a copy of FMS-350(2) resided within the rotorcraft flight manual (RFM) and was available to all pilots. Because the accident flight was flown with the doors removed, the RFM and the flight logbook were moved from the cockpit to the aft-left baggage compartment. After recovery of the accident helicopter, the aft-left baggage compartment door was found open and no items, including the RFM and the flight logbook, were found in the aft-left baggage compartment.

6.2 PILOT TRAINING FOR USE OF THE FLOAT SYSTEM

According to an interview with the operator's Chief Pilot, the pilots were trained to activate the emergency floats as soon as practicable and land on the water after an engine

[7] The NTSB Video Study of two hand-held smartphone videos, provided by ground witnesses, found the water impact velocity of the accident helicopter was about 23±2.5 knots. The Video Study can be found in the docket for this investigation.

failure.[8] He also stated that while there was no "hands on" practice of activating the emergency floats, the operator's director of training would "show them" the emergency float system. Additionally, if there was a need to activate the floats in association with a maintenance action, the director of training would coordinate with maintenance to have pilots witness activation of the floats.

According to an interview with the operator's Director of Training, the pilots were trained via demonstration on how to operate the emergency float [activation] handles; the training included use of ground instruction and videos. Additionally, he stated the training mentioned the possibility of an incomplete inflation of the emergency floats as well as the possibility of a "rollover" once the helicopter was on the water. He further stated that he taught that the emergency floats should be deployed earlier rather than later so that if "nothing happened" after pulling the activation handle, "you could make something better of it." Additionally, he recalled never having had any maintenance issues with the float system.

According to section K-1 (AS350) of the operator's training program, dated November 1, 2005, paragraph Y discusses ditching, when equipped with an emergency flotation system, in the event of an engine failure or other need that requires ditching the helicopter. The instructions include, but are not limited to, guidance that the maximum firing speed is 80 knots and the touchdown speed must be below 10 knots. The operator also provided copies of slides used to train pilots on the emergency flotation system. A copy of the ditching procedures from the operator's training program and training slides are found in **Attachment 4** to this report.

According to the accident pilot, he had previously deployed the helicopter float system in December 2016 during ground maintenance on N350LH.[9] He stated he had pulled the float activation handle, that no malfunctions occurred, and that there were no difficulties in activating the floats. He stated that he had to ensure the handle was pulled with sufficient force and that Liberty Helicopters' pilots are trained to do so. He stated that the hand positioning to activate the floats was not ideal. The accident pilot also stated that he had seen videos of two separate instances of the float system having been activated during ground maintenance. These two instances occurred at Liberty Helicopters, involved AS350 B2 helicopters, and involved mechanical activation systems. He stated that no malfunctions occurred in either instance, but that in one instance the floats had "only partially deployed at first because the [activation] handle was only partially pulled. In that one instance, the handle was then pulled the rest of the way and the floats then fully deployed. As a result, Liberty [Helicopters] routinely enforced in its training the importance and necessity of pulling the float [activation] handle fully and to completion."

6.3 ACCIDENT FLIGHT FLOAT DEPLOYMENT

When asked to describe how the float system was deployed during the accident flight, the accident pilot stated that when it came time to deploy the floats, he "took [his] left hand off of the collective and placed it on top of the cyclic… and gripped the [activation] handle with [his] right hand and pulled it back fully and completely." He stated hearing a "pop" sound, which to him indicated that the float system deployed, and that "after pulling the [activation] handle, [he] returned [his] hands to the regular positioning and grip on the collective and cyclic." He further

[8] The Operations Group conducted the interviews of the Chief Pilot and the Director of Training for Liberty Helicopters. The record of conversation for these interviews can be found in the docket for this investigation.

[9] **Attachment 5** contains written responses from the accident pilot for questions asked by the Emergency Flotation System Group Co-Chairs.

stated there was extra drag after the floats had deployed and that he could see parts of the left front float and right front float after deployment of the floats.

The accident pilot stated he had a bruise on his right hand between his thumb and index finger that was caused by squeezing the cyclic prior to impact. He also had a cut at the bottom of the knuckle for his left index finger that caused when he actuated the emergency fuel shutoff lever back to the cockpit floor.

7.0 MAINTENANCE AND INSPECTIONS

7.1 INSTRUCTIONS FOR CONTINUED AIRWORTHINESS (ICA)

The ICA for STC No. SR00470LA, document No. ICA350-21, provided information on the operation, disassembly, inspection, assembly, repair, and testing instructions. At the time of the accident, revision P was the most current version of ICA350-21. The ICA prescribed a preflight check, referencing FMS-350(2), comprising a general visual inspection of the float assemblies, hoses, and the pressure of the left and right reservoir assemblies.

A 6-month inspection prescribed a visual inspection of the pull cables and junction box as well as a check for pull cable ease of movement by pulling on the activation handle with a “small amount” of tension applied to the clevis at both the left and right valves. (The clevises are disconnected from the valve assemblies at the beginning of the 6-month inspection.) Any evidence of binding required replacement of the pull cables.

An 18-month inspection required inspection of the floats for tears or cuts, a leak test of the floats, inspection of the cylinder and valves for damage or corrosion, inspection of the pull cables for corrosion and proper rigging, and inspection of the hoses for corrosion, damage, or kinks.

A 36-month inspection required an inflation test of the system by pulling the activation handle in the cockpit. The inspection required the pressure in each float chamber to be at a minimum of 1.75 psi at 70 degrees Fahrenheit after 10 minutes and a subsequent leak check. Additionally, the skid extension was to be inspected for corrosion or damage, the float covers inspected for cuts or tears, the hoses are inspected for cuts, abrasions, or kinks, and the float reservoirs were to be removed and replaced. An exterior pull cable replacement, due to a service life limitation, was required. According to Dart, the exterior pull cables apply to the emergency flotation system equipped with a separate life raft installed on top of the aft floats. The pull cables used for activation of the emergency floats are considered internal cables by Dart. There was no specific inspection prescribed or instruction within the ICA to ensure the activation handle forces were low enough to deploy the floats, via the activation handle, using only one hand.

7.2 FLOAT SYSTEM MAINTENANCE AND INSPECTION HISTORY FOR N350LH

According to maintenance records for the accident helicopter, the last 6-month inspection for the emergency flotation system was performed on October 26, 2017, about aircraft total time (ATT) 5,204.2 hours. The last 18-month inspection was performed on April 25, 2016, about ATT 3,283.1 hours. The last 36-month inspection was performed on December 14, 2016, about ATT 4,228.0 hours; during the 36-month inspection, the left and right reservoir assemblies were replaced with overhauled reservoir assemblies. The next 36-month inspection was due on December 14, 2019. **Attachment 6** contains the maintenance record entry for the 36-month inspection performed on December 14, 2016.

7.3 OPERATOR'S 36-MONTH INSPECTION RESULTS AND VIDEOS

During the 36-month inspection of the emergency flotation system, the operator stated that they would use the opportunity as training for pilots. Copies of videos taken during previous 36-month inspections were provided to the NTSB by the operator. A total of six videos were provided: three videos were of an inflation test on N353JS[10]; two videos were from an inflation test on March 1, 2017; and one video was from an inflation test on December 14, 2016.

Of the three videos from N353JS, two videos were taken from the cockpit and showed the cyclic stick and activation handle with a person at the front-right seat of the helicopter. The third video showed an external view of the helicopter (forward-looking-aft). In the first of the two cockpit videos for N353JS, the right-seated person's left hand was seen bracing the cyclic grip while the right hand was pulling the activation handle aft (**Figure 19**). A "pop" was heard, followed by a hissing sound, at which time the person ceased pulling the activation handle. The person said "that's it" followed by another attempt to pull the activation handle aft with their right hand while the cyclic grip remained held with their left hand. The activation handle began to rotate outboard relative to the cyclic grip. The first cockpit video ended at this point. In the second cockpit video, the activation handle appeared pulled further aft than compared to the first cockpit video, with a hissing sound heard in the background. The second cockpit video ended at this point.

Figure 19. A screen-capture from the video for the emergency float system deployment as part of the 36-month inspection on N353JS. The image shows the cyclic grip was braced with the left hand while the right hand pulled aft on the emergency float system activation handle. (Video courtesy of Liberty Helicopters)

The third video of N353JS showed the floats were initially packed inside their covers, which were mounted to the skids. A "bang" was heard and all floats partially inflated, but the

[10] Metadata from the video files showed these videos were created on May 2, 2016.

left-aft float was not visible. Based on the position of the videographer, the condition of the left-aft float could not be determined. The three floats on the right skid appeared qualitatively more inflated than the visible floats on the left skid. The video ends at this point.

The two videos of the inflation test on March 1, 2017 were taken from the cockpit showing the cyclic stick and activation handle with a person at the front-right seat of the helicopter. The vantage point of the videographer was similar to that of the cockpit videos from N353JS. In one of the two videos, the right-seated person had their right hand on the activation handle and their left hand braced the cyclic grip. A countdown was heard starting at "four", and at the end of the countdown the right-seated person pulled the activation handle aft while simultaneously pushing the cyclic grip slightly forward (**Figure 20**). A loud "bang" was heard, followed by a hissing sound. The person continued to hold the activation handle aft for about 20 seconds, at which time the video ended. In the second of the two videos, the right-seated person had their left hand braced on top of the cyclic head and their right hand on the activation handle. A countdown was heard starting at "two". At the end of the countdown, an attempt was made to pull the activation handle aft, but a "click" sound was heard. The right-seated person then removed a safety pin from the activation handle. After removal of the safety pin, the activation handle was pulled aft again but ended up contacting the cyclic head, followed by the comment "nope, you can't do it" while removing their left hand from the cyclic head. The right-seated person pulls the activation handle back two times, using only their right hand, with only a "tap" sound of the activation handle contacting the cyclic head (**Figure 21**). The second video ended at this point. Compared to the positioning of the activation handle in the first video discussed in this paragraph, it appeared the activation handle was in-line with the cyclic head in the second video, i.e. without the 32 degree offset from the cyclic grip.

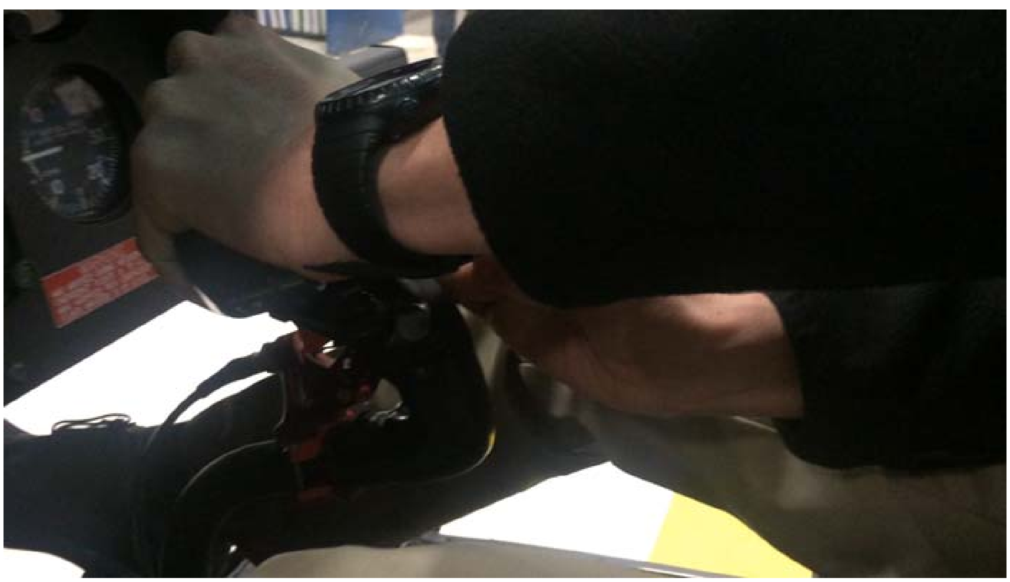

Figure 20. A screen-capture from the video for the emergency float system deployment as part of a 36-month inspection performed on March 1, 2017. The image shows the cyclic grip was braced with the left hand while the right hand pulled aft on the emergency float system activation handle.
(Video courtesy of Liberty Helicopters)

Figure 21. A screen-capture from a second video on March 1, 2017. The image shows the activation handle was in-line with the cyclic grip, resulting in contact with the cyclic head when the activation handle was pulled aft. **(Video courtesy of Liberty Helicopters)**

In the video of the inflation test on December 14, 2016, the vantage point was similar to that of the previously discussed cockpit videos. The video was likely of the inflation test for the emergency flotation system installed on N350LH, given the maintenance record showed the 36-month inspection was performed on the same day. The right-seated person had their left hand bracing the cyclic grip and their right hand on the activation handle (**Figure 22**). A countdown starting at "three" was heard, and at the end of the countdown the activation handle was pulled aft while the cyclic stick did not appear to have been displaced noticeably from its starting position. A muted "bang" was heard, followed by hissing sounds. The front-right person continued to hold the activation handle aft until the end of the video.

Figure 22. A screen-capture from the video for the emergency float system deployment as part of a 36-month inspection performed on December 14, 2016. The image shows the cyclic grip was braced with the left hand with the right hand on the emergency float system activation handle. **(Video courtesy of Liberty Helicopters)**

7.4 OTHER HELICOPTER OPERATORS' EXPERIENCES

The Emergency Float System Group co-chairs interviewed the Director of Maintenance at Heli-Express, Inc. located in Quebec, Canada, on his experiences with STC No. SR00470LA installed on their AS350-series helicopters.[11] The director of maintenance described that during a previous 36-month inspection, they had experienced partial and asymmetric inflation when only one of the two reservoirs activated. Additionally, he stated that it was "common knowledge" among their pilots that it was difficult to pull the activation handle, and that they would have to take their hand off the collective in order to use two hands to use the activation handle. The director of maintenance provided copies of three videos of the 36-month inflation test performed on two helicopters. All videos show an external view of the helicopter, identified as "Video A", "Video B", and "Video C" for this report. Videos A and B are from the same 36-month inflation test, but at different viewpoints; Video A is forward-looking-aft and Video B is aft-looking-forward. Video C is of a 36-month inflation test on another helicopter. Video A starts with the floats initially packed inside their covers, which were mounted to the skids. About 20 seconds into Video A, a "bang" was heard and the left and right side floats inflated, but the right side floats visually appeared partially inflated while the left side floats visually appeared more inflated than the right side floats. About 19 seconds later another "bang" was heard and the left side floats appeared to inflate fully; the forward-most end of the right-forward float appeared to inflate more as wrinkles on its surface begin to smooth out. Video A ends 11 seconds after the second "bang" was heard. Video B starts with the floats initially packed inside their covers, which were mounted to the skids. About 4 seconds into Video B, a "bang" was heard and the left and right side floats inflated. On the left side, only the aft float was visible. Both the right-aft and the left-aft floats appeared similarly partially inflated. Video B ends 14 seconds after the "bang" was heard. In Video C, a "bang" was heard and the left and right side floats inflated, but the right side floats visually appeared partially inflated while the left side floats visually appeared more inflated than the right side floats. Video B ends 10 seconds after the "bang" was heard.

One of the Emergency Float System Group co-chairs interviewed a maintenance manager and an airframe and powerplant (A&P) mechanic at TEMSCO Helicopters, Inc. based in Juneau, Alaska, on their experiences with STC No. SR00470LA installed on their AS350-series helicopters.[12] During previous 36-month inflation tests, the operator generally experienced no difficulty in pulling the activation handle and that the activation handle could be pulled with "two fingers". They recalled one instance of high pull forces on the activation handle which was due to a "bad cable" which likely had binding within it.

8.0 CROSS-FEED HOSE

8.1 INTRODUCTION OF CROSS-FEED HOSE

Dart Aerospace Service Bulletin No. 99001, dated April 10, 2000, introduced a cross-feed hose to the emergency flotation system, P/N 20326-100, applicable to emergency flotation system S/Ns 001 through 036.[13] According to the service bulletin, the engineering design aspect of the service bulletin was FAA approved. The service bulletin states the following:

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[11] **Attachment 7** contains the record of conversation for the interview with the Heli-Express director of maintenance.

[12] **Attachment 8** contains the record of conversation for the interview with the TEMSCO maintenance manager and an A&P mechanic.

[13] According to the service bulletin, S/N 037 and future S/Ns would include the cross-feed hose.

> *This bulletin is in response to upgrade the AS-350 series to prevent asymmetrical inflation. During an Emergency Float Deployment, it is remotely possible that one valve/cylinder combination may not function. This would cause the floats on one side of the helicopter to deploy but not the other side. With the addition of two tee's and a cross over hose, both sides would deploy, but at a lower pressure.*

The NTSB requested information from the FAA and Dart on any testing performed to substantiate the introduction of the cross-feed hose to STC No. SR00470LA as well as the circumstances that led to its introduction, e.g. a report of asymmetric inflation by an operator with the emergency flotation system. The FAA and Dart could not find the requested documentation. Dart provided a copy of a memo, dated July 26, 1999, which stated that the master drawing list (MDL) for STC No. SR00470LA would be revised to include a cross over hose. The memo stated that a similar installation was used on STC No. SR00831LA for the same model helicopter.[14] In a flight test report provided by the FAA to the NTSB for FAA Project Number ST6318LA-R, applicable to STC No. SR00831LA, a section titled "partial inflation" stated that if one cylinder failed to function, that the remaining cylinder would inflate all six floats to 0.28 psi and that the drop test fixture rode 2.7 inches higher in the water with the floats inflated to 0.28 psi.

8.2 INVESTIGATION TESTING OF THE CROSS-FEED HOSE DESIGN

On June 29, 2018, members of the Emergency Flotation System Group convened at Dart Aerospace facilities in Vista, California to witness testing of different configurations of the cross-feed hose installation to determine the effect of partial inflation. An exemplar emergency float system was installed on a high skid, which was installed on a frame, the totality which was called the "test rig". All tests were performed using nitrogen as the inflation gas, unless otherwise specified. A total of six tests were performed: three inflation tests and three buoyancy stability tests. Three inflation tests consisted of three different configurations using only a single reservoir to inflate all six floats. The first inflation test configuration was of a standard float installation with the cross-feed hose installation. The second inflation test configuration was of the standard float installation without the cross-feed hose installation, i.e. the original STC configuration. The third inflation test configuration was of a modified cross-feed hose installation that distributed the gas from a central point about the midplane of the forward cross tube in order to evenly distribute pressurized gas to all six floats. The ambient temperature was about 62 degrees Fahrenheit (16.6 degrees Celsius) when the inflation tests were performed. Three buoyancy stability tests consisted of three different configurations to determine if the test rig would float and not capsize when the floats were partially, but evenly, inflated. The first two buoyancy stability test configuration used the float inflation results of the third inflation test at two different rig weights. The third buoyancy stability test configuration inflated each float to 1 psi, the designed minimum operating pressure for the floats.

8.2.1 INFLATION TESTS

For the first inflation test, the three floats on the left skid appeared visually more inflated than the three floats on the right skid (**Figure 23**). The pattern of inflation

[14] STC No. SR00831LA, held by Dart Aerospace, provides provisions to install an emergency flotation system on AS350-series and AS355-series helicopters. STC No. SR00831LA is marketed by Dart as the "Tri-bag" float system.

appeared similar to that of the accident helicopter floats. **Table 2** contains the measured inflation of each float chamber for the first inflation test.

Figure 23. The inflated floats at the conclusion of the first inflation test.

Table 2. Measured inflation of each float chamber after the first inflation test (left reservoir gauge read slightly under 5,000 psi).

		Left Float	Right Float
Forward Float	Chamber 1	1.195 psi	0.052 psi
Forward Float	Chamber 2	1.191 psi	0.055 psi
Mid Float	Chamber 1	0.465 psi	0.050 psi
Mid Float	Chamber 2	0.456 psi	0.030 psi
Aft Float	Chamber 1	0.084 psi	0.023 psi
Aft Float	Chamber 2	0.061 psi	0.020 psi

For the second inflation test, the floats on the left side appeared fully inflated and felt rigid to the touch (**Figure 24**); the floats on the right side did not inflate. **Table 3** contains the measured inflation of each float chamber for the second inflation test.

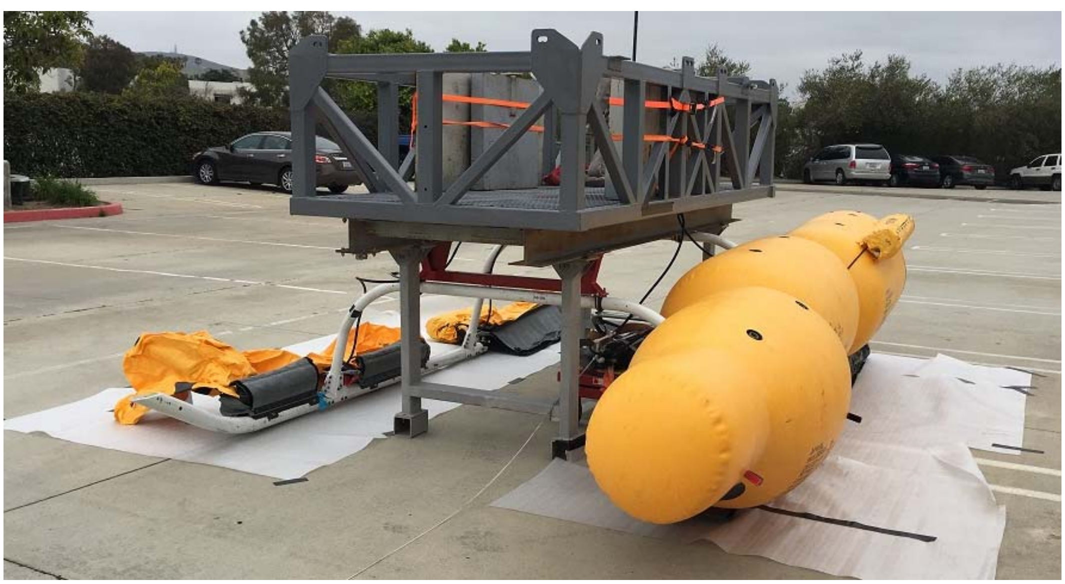

Figure 24. The inflated floats at the conclusion of the second inflation test.

Table 3. Measured inflation of each float chamber after the second inflation test (left reservoir gauge read slightly about 4,500 psi)

		Left Float	Right Float
Forward Float	Chamber 1	3.605 psi	N/A
Forward Float	Chamber 2	3.595 psi	N/A
Mid Float	Chamber 1	4.373 psi	N/A
Mid Float	Chamber 2	4.374 psi	N/A
Aft Float	Chamber 1	3.817 psi	N/A
Aft Float	Chamber 2	3.803 psi	N/A

For the third inflation test, the floats on the left and right sides visually appeared similar in fullness (**Figure 25**). **Table 4** contains the measured inflation of each float chamber for the third inflation test.

Figure 25. The inflated floats at the conclusion of the third inflation test.

Table 4. Measured inflation of each float chamber for the third inflation test (left reservoir gauge read slightly under 4,250 psi).

		Left Float	Right Float
Forward Float	Chamber 1	0.047 psi	0.052 psi
Forward Float	Chamber 2	0.057 psi	0.059 psi
Mid Float	Chamber 1	0.039 psi	0.038 psi
Mid Float	Chamber 2	0.029 psi	0.041 psi
Aft Float	Chamber 1	0.034 psi	0.062 psi
Aft Float	Chamber 2	0.039 psi	0.047 psi

8.2.2 BUOYANCY STABILITY TESTS

For the first buoyancy stability test, the test rig weighed about 5,410 pounds. The pressure within each float chamber was measured prior to placement of the test rig into the pool; the measured pressures can be found in **Table 5**. Straps were used to lift the test rig using a crane. The straps were installed laterally on the left and right upper rails of the frame. The test rig was slowly lowered into the pool.[15] There was no evidence of significant gas leakage from any of the floats. The rig initially listed to the right with a nose-down attitude. After the right-front float became submerged, the rig listed further to the right. Testing was stopped at this point as it appeared the rig would continue listing and would not demonstrate buoyancy stability.

Table 5. Measured inflation of each float chamber prior to the first buoyancy stability test.

		Left Float	Right Float
Forward Float	Chamber 1	0.045 psi	0.064 psi
Forward Float	Chamber 2	0.040 psi	0.069 psi
Mid Float	Chamber 1	0.027 psi	0.042 psi
Mid Float	Chamber 2	0.031 psi	0.038 psi
Aft Float	Chamber 1	0.053 psi	0.055 psi
Aft Float	Chamber 2	0.055 psi	0.042 psi

For the second buoyancy stability test, weight was removed from the test rig until it weighed about 5,220 pounds[16] and the straps were installed longitudinally on the forward and aft upper rails of the frame. The pressure within each float chamber was measured prior to placement of the test rig into the pool; the measured pressures can be found in **Table 6**. The test rig was slowly lowered into the pool (**Figure 26**). There was no evidence of significant gas leakage from any of the floats. The test rig floated in the pool for at least 26 seconds (but less than 1 minute), after which it began to roll to the right. The right roll was arrested by the straps attached to the crane, preventing the test rig inverting in the pool. The test rig was raised out of the pool and water was allowed to drain from the test rig for about 1-2 minutes. The test rig was placed back into the pool and the straps were allowed to completely slack, after which the test rig quickly rolled to the right and the right skid hit the bottom of the pool. Testing was stopped at this point.

Table 6. Measured inflation of each float chamber prior to the second buoyancy stability test.

		Left Float	Right Float
Forward Float	Chamber 1	0.053 psi	0.062 psi
Forward Float	Chamber 2	0.042 psi	0.065 psi
Mid Float	Chamber 1	0.036 psi	0.038 psi
Mid Float	Chamber 2	0.042 psi	0.034 psi
Aft Float	Chamber 1	0.023 psi	0.019 psi
Aft Float	Chamber 2	0.024 psi	0.018 psi

For the third buoyancy stability test, the test rig weight remained about 5,220 pounds. Shop air was used to inflate all six floats to about 1 psi. The test rig was lowered into the pool and the test rig floated with apparent stability. After several minutes, there was no evidence of the test rig listing. It was noted that none of the six floats became completely submerged at any point in the test. Testing was stopped at this point as this configuration had demonstrated buoyancy stability.

[15] The buoyancy stability test did not attempt to recreate the accident circumstances or autorotation impact speeds.
[16] According to TCDS No. H9EU, the maximum gross weight of the AS350 B3 helicopter is 5,220 pounds (when modification OP-3369 is applied). The AS350 B3 helicopter is the heaviest variant of the AS350-series helicopter that is eligible for STC No. SR00470LA.

Figure 26. The test rig after placement into the pool.

9.0 CERTIFICATION OF EMERGENCY FLOTATION SYSTEMS

14 CFR Part 27 contains provisions for ditching certification. According to FAA Advisory Circular (AC) 27-1B[17], section AC 27.801, ditching certification is accomplished only if requested by the applicant. Additionally, AC 27.801 states:

> *Ditching may be defined as an emergency landing on the water, deliberately executed, with the intent of abandoning the rotorcraft as soon as practical. The rotorcraft is assumed to be intact prior to water entry with all controls and essential systems, except engines, functioning properly.*

AC 27-1B contains Miscellaneous Guidance (MG) 10, "Advisory Material for Substantiation of Emergency Flotation System." The introductory paragraph of MG 10 states:

> *There are no airworthiness requirements specifying minimum standards for emergency flotation systems on rotorcraft not certificated for ditching requirements. Equipment presented for evaluation must perform its intended function and not create a hazard for the rotorcraft or occupants. The objective in evaluating emergency flotation systems is safe flight and evacuation of the rotorcraft in emergency situations. Adequate emergency flotation systems would aid in keeping the rotorcraft sufficiently upright and in adequate trim to permit safe and orderly evacuation in an emergency water landing.*

MG-10 was included as part of AC 27-1B but was not present in analogous sections of versions preceding AC 27-1B, such as AC 27-1 and AC 27-1A.[18] **Attachment 9** contains a copy of AC 27-1B MG 10.

[17] At the time of this report, Change 8, dated June 29, 2018, was the latest revision of AC 27-1B.

9.1 CERTIFICATION OF STC NO. SR00470LA

According to STC No. SR00470LA, the date of application for the STC was July 1, 1996 and the date of issuance was November 17, 1997. According to the FAA, STC No. SR00470LA was required to meet the certification basis applicable to the AS350-series helicopter, which was 14 CFR Part 27 including Amendment Nos. 27-1 through 27-10.

According to the FAA Los Angeles (LA) Aircraft Certification Office (ACO) aircraft safety engineer assigned as the project manager for the certification review of STC No. SR00470LA, MG 10 did not exist at the time of the STC application and review. Furthermore, the LA ACO determined the applicable sections of Part 27 which the design needed to satisfy in order to be granted the STC.[19] **Attachment 11** contains the applicable sections of Part 27 that were assessed by the LA ACO for approval of STC No. SR00470LA.[20]

9.2 CURRENT GUIDANCE ON EMERGENCY FLOTATION SYSTEM INFLATION

Within AC 27-1B MG 10, a subparagraph titled "proper inflation" provides guidance regarding proper inflation of the emergency floats. The paragraph states in part:

> *The inflation system design should minimize the probability of the floats not inflating properly or inflating asymmetrically. This may be accomplished by use of a single inflation agent container or multiple container system interconnected together.*

At the time of this report, AC 27-1B MG 10 contains no guidance on considerations for crew cueing to ensure complete activation of all necessary gas reservoirs in designs containing multiple container system interconnected together.

9.3 CURRENT GUIDANCE ON ACTIVATION MEANS FOR EMERGENCY FLOTATION SYSTEMS

Within AC 27-1B MG 10, a subparagraph titled "float actuation" provides guidance regarding emergency flotation system activation means. The paragraph states:

> *The float activation means may be fully automatic or manual with a means to verify primary actuation system prior to each flight. If manually inflated, the float activation switch should be located on one of the primary flight controls. These activation means should be safeguarded against spontaneous or inadvertent actuation for all flight conditions.*

[18] The original version of AC 27-1B was released on September 30, 1999. AC 27-1A, which preceded AC 27-1B, was released on July 30, 1997. AC 27-1 Change 4 preceded AC 27-1A and was released on August 18, 1995.

[19] **Attachment 10** contains the record of conversation of the interview with the FAA LA ACO project manager and aviation safety engineer who participated in the certification review and approval of STC No. SR00470LA.

[20] Memos from Apical Industries, Inc. to the FAA LA ACO from August to October 1997 for project ST5327LA-R, which later became STC No. SR00470LA, contained an attachment titled "Statement of Compliance with the Federal Aviation Regulations." This attachment contained a section listing the following Part 27 requirements: 27.1, 27.301(a)(b)(c), 27.303, 27.305(a)(b), 27.307(a)(b)(5), 27.309(a)(e), 27.473(a)(b), 27.501(a) thru (f), 27.521(a)(b), 27.549(a)(b), 27.563(b), 27.571(a) thru (e), 27.601(a)(b), 27.603(a)(b)(c), 27.605(a)(b), 27.607(a)(b), 27.609(a)(b), 27.611(a)(b), 27.613(a) thru (e), 27.723, 27.725(a) thru (d), 27.727(a)(b)(c), 27.751(a)(b), 27.753(a)(1), 27.801(b)(c), 27.807(d), 27.1301(a) thru (d).

The LA ACO project manager for the certification review and approval for STC No. SR00470LA recalled that at the time of the STC application, Apical had proposed a 30-pound pull force limit for the activation handle and that the LA ACO had accepted the proposed pull force limit.[21] The project manager stated the 30-pound pull force limit was a reference to the limitation prescribed for the emergency evacuation slide activation normally installed on Transport Category airplanes (14 CFR Part 25).

The FAA LA ACO provided the NTSB with a copy of Technical Standard Order (TSO)-C69c, titled "Emergency Evacuation Slides, Ramps, Ramp/Slides, and Slide/Rafts", which contained minimum performance standards for equipment intended to provide emergency evacuation or evacuation/flotation for aircraft occupants. The primary application of TSO-C69c was intended for Transport Category airplanes. TSO-C69c, Appendix I, paragraph 4.14, titled "manual inflation actuation controls", contains the following:

> *4.14.4 Inflation actuation controls must be so designed that the maximum required pulling force will not pull the deployed device back into the doorway. The pulling force required must not exceed 30 pounds.*

At the time of this report, AC 27-1B MG 10 contains no guidance regarding limitations or performance standards with respect to the force limits for manual activation systems used to deploy an emergency flotation system.

10. CORRECTIVE ACTIONS

On July 2, 2018, Dart released service bulletin No. SB-2018-03 to provide clarification on the activation method for STC Nos. SR00470LA and SR00645LA. The service bulletin explains that, to prevent asymmetric inflation, the activation handle needs to be pulled full travel aft even when initial float inflation is observed. Additionally, the service bulletin explains that if one side of floats appear fluttering, further travel of the activation handle may be required. Revision F to the RFMS, No. FMS-350(2), contained the information provided in SB-2018-03.

During the course of the investigation, Dart developed an inspection tool intended to replicate the valve cable assembly to allow for a check of the activation handle pull forces, without deploying the floats, and to provide positive indication of sufficient travel in pull cable rigging. Revision K of Installation Instruction No. II350-600 was released on November 12, 2018 to include procedures to utilize the inspection tool at the end of the pull cable installation. Additionally, Revision R of ICA350-21 was released on November 26, 2018 to include procedures to utilize the inspection tool during the 6-, 18-, and 36-month recurrent inspections. At the time of this report, a Dart service bulletin to utilize the inspection tool was pending.

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[21] Human engineering standards promulgated by the United States Department of Defense establish criteria for the design and development military systems, equipment, and facilities. When designing hand controls, these standards specify a maximum grip force of 33 pounds (left hand) to 35 pounds (right hand) for a "sustained hold" and 56 to 59 pounds for a "momentary hold". These maximum forces are based on the 5th percentile grip strength of adult males. (Department of Defense design criteria standard: Human Engineering. MIL-STD-1472G, 11, January 2012, p. 90.)