



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 11, 2014

WEIGHT & BALANCE STUDY

DCA13MA121

A. ACCIDENT: DCA13MA121

Operator: Rediske Air, Inc.
Location: Soldotna, Alaska
Date: July 7, 2013
Time: 1120 Alaska Daylight Time
Aircraft: de Havilland DHC-3 Otter
Registration Number: N93PC

B. GROUP

No group was formed for this activity.

C. SUMMARY

On July 7, 2013, about 1120 Alaska daylight time, a single-engine, turbine powered de Havilland DHC-3 “Otter” airplane, N93PC, was destroyed after a collision with terrain shortly after takeoff from the Soldotna Airport, Soldotna, Alaska. The airplane was registered to Rediske Family Limited Partnership, Nikiski, Alaska, and was operated by Rediske Air, Inc. under the provisions of 14 CFR Part 135, as an on-demand charter flight. The commercial pilot and nine passengers were fatally injured. Visual meteorological conditions prevailed and no flight plan was filed for the flight destined to Bear Mountain Lodge, approximately 90 miles southwest of Soldotna.

D. DETAILS OF THE STUDY

The actual weight and balance of the airplane during the accident flight cannot be accurately determined with the limited available factual data. However, several possible scenarios can be calculated utilizing the known factual information along with logical, documented assumptions. The procedures used for calculating each of the scenarios are in accordance with those documented in the DHC-3 Airplane Flight Manual and any applicable Supplements. See the Airworthiness Group Chairman’s Factual Report in the public docket for the details of the factual information gathered during the investigation.

The total airplane empty weight was calculated to be 4287.99 pounds, the total moment was calculated to be 568523.82 lb-in, and the center of gravity (CG) location was calculated to be 132.59 inches as documented in the factual report. These values include residual fuel, full engine oil, and full hydraulic fluid. The established and certificated CG limits for the airplane were 135.8 inches to 152.2 inches.

The airplane suffered an extensive post-crash fire that consumed a substantial portion of the airplane structure and an unknown portion of the cargo and baggage on board the airplane. During the recovery, the items of baggage were separated from the items of cargo (food and lodge supplies) and weighed. The recovered baggage weighed 187 pounds and the recovered cargo weighed 613 pounds.

The lodge owner provided a receipt for a portion of the cargo carried on the accident airplane and assisted with the loading of the cargo at the Rediske facility in Nikiski, Alaska. The lodge owner estimated the weight of cargo at 300 pounds and this number was entered on the Rediske Air load manifest. Most of the food items listed on the provided receipt were conclusively identified in the debris, however, there were many items recovered that were not included on the receipt including produce, cheese, bedding and the wall art. A significant amount of meat products were also recovered and weighed with the cargo, none of which were included on the receipt. The group noted that the recovered canned or bottled liquids were all breached and no liquid remained. The following Table 1 lists the liquid items from the receipt with quantity and total weight as measured by the group. The remaining eggs and liquid containers recovered were included in the weight of the cargo measured so a factor was applied to each of the actual weights to more accurately represent the amount of weight lost due to the missing liquid and broken eggs.

Item	Qty	Wt (lbs)	Total Wt (lbs)	Factor	Wt (lbs)
Fresh Eggs	3	8.5	25.5	0.5	12.8
Real Lemon Juice	1	3.29	3.29	0.9	3.0
Welch's 100% Juice	1	20.0	20.0	0.9	18.0
Coffe Mate Pump	2	4.45	8.9	0.9	8.0
Coffe Mate Hazelnut	2	4.45	8.9	0.9	8.0
Gatorade Original	1	37.25	37.25	0.9	33.5
Kern's Variety Juice	1	24.8	24.8	0.9	22.3
Total			128.64		105.58

Table 1 – Liquid item weights

A total of 9 unique pieces of baggage were recovered in the wreckage but one of these items was the survival gear normally carried in the baggage compartment which was not included in the total baggage weight measured on-scene. All of the baggage sustained some amount of fire damage with at least 6 pieces that had portions that were consumed by the fire. Photographic evidence showed 8 pieces of baggage in the cabin area of the airplane prior to takeoff. Three of the 9 pieces of recovered baggage (the green roller bag, the small black roller bag, and the black Tumi bag) were not carried in the cabin and assumed to be in the cargo compartment for the flight. The recovery location of these three bags supports this assumption. This shows that only 5 of the 8 pieces of baggage carried in the cabin were recovered. The remaining 3 pieces are assumed to have been consumed by fire. The Pelican case containing the handgun and the box of ammunition found in the red roller bag were given to the police department prior to the weighing of the baggage. The total weight of these items was calculated to be a minimum of 5.96 pounds. The available evidence indicates that the 3 missing pieces of cabin baggage were likely the black purse or satchel carried by the row 1, left seat passenger, the blue and black backpack carried by the row 3, left seat passenger and the black backpack carried by the row 4, right seat passenger. The 187 pounds of total baggage weight measured represents an absolute minimum due to the fire damage to the recovered bags and the 3 unrecovered cabin bags.

The investigation turned up two weights for each person on board the airplane. One was provided by the medical examiner and represented the victim weight with all clothing removed prior to autopsy with the caveat that each victim sustained thermal damage and degradation. The other weight, for the passengers, was provided by one of the passengers in an email prior to the flight and, for the pilot, was provided by the company. See Table 2 for a comparison of the victim weights. For 7 of the 10 victims the provided weight was higher than the autopsy weight. The average change between the individual autopsy weights and provided weights was calculated to be a 5.1% increase above the autopsy weights which agreed reasonably well with the percentage change in total weight of a 4.8% increase from the autopsy weight total.

Location	Autopsy Wt (lbs)	Provided Wt (lbs)	% change
Front Left	200	220	10.0
Front Right	160	145	-9.4
Row 1 Left	148	145	-2.0
Row 1 Right	133	145	9.0
Row 2 Left	128	145	13.3
Row 2 Right	102	100	-2.0
Row 3 Left	121	145	19.8
Row 3 Right	103	110	6.8
Row 4 Right	181	190	5.0
Row 5 Right	218	220	0.9
Total	1494	1565	4.8

Table 2 – Victim weight comparison

The airplane was equipped to carry up to 251 gallons of fuel in 3 tanks. A witness reported seeing the pilot fill up the forward tank and begin to fill the center tank before he walked away. It is unknown how much fuel was in the center and aft tanks. The limitations in the AFM supplement for the turbine engine conversion state that at least 20 gallons of fuel should remain in each tank to prevent introduction of air into the fuel system. Representatives from the operator indicated that the pilot would have carried some amount of fuel in each of the tanks at all times so that none of them would have been empty. A fuel density of 6.7 lb/gal was used to calculate the weight of the fuel.

Scenario 1

The airplane was fueled and the cargo was loaded at the Rediske facility in Nikiski before flying to Soldotna to pick up the passengers. For this leg of the flight the only person on board the airplane was the pilot. The recovered weight of the pilot of 200 pounds was used for this scenario. All of the cargo was loaded at this time and assumed to be loaded in the cargo compartment at the aft end of the cabin consistent with the photographic evidence from Soldotna. The reported cargo weight of 300 pounds was used for this scenario. The forward fuel tank was full with 62 gallons and it was assumed that the center tank was full with 102 gallons of fuel. The aft tank was assumed to contain the minimum required fuel of 20 gallons. The calculation (Table 1) for scenario 1 yields a weight of 6020.79 pounds with a CG at 141.84 inches.

Scenario 2

Scenario 2 is identical to scenario 1 with the exception of the cargo weight. The weight of the cargo was set to be the recovered weight (613 pounds) plus the weight of the liquid items (105.58 pounds). This cargo weight more accurately represents what was on board the airplane for the flight. The calculation (Table 2) for scenario 2 yields a weight of 6439.37 pounds with a CG at 150.76 inches.

Scenario 3

The airplane landed at Soldotna to pick up the passengers. The photographic evidence shows where each passenger was seated. For this calculation, the reported (asked) weights of each person on board the airplane were used plus 10 pounds. This procedure was chosen based on the operations specifications and the similar size and gross weight of this airplane with the Islander. The recovered weight of the pilot, as provided by the medical examiner, was used. The total baggage weight of 187 pounds was divided among the 5 recovered bags carried by the passengers in the cabin and evident in the photographs and the 3 recovered bags that were not shown in any of the photographs and likely carried in the cargo compartment. The backpacks carried by the passengers in the row 1 right seat, row 3 right seat, and row 5 right seat were each assumed to weigh 12 pounds, the camera bag carried by the row 5 passenger was assumed to weigh 10 pounds, and the large red roller bag was assumed to weigh 50 pounds. The medium green roller bag, the small black roller bag, and the small black Tumi carry-on bag were assumed to weigh 91 pounds together (making up the 187 pounds of recovered baggage weight) and placed in the cargo area since they were not visible in any of the photographs of the cabin. An additional 5.96 pounds was added to the large red roller bag to account for the pelican case, gun, and ammunition that was removed prior to weighing. The weight of the cargo was set to be the recovered weight (613 pounds) plus the weight of the liquid items (105.58 pounds) similar to scenario 2. The three unrecovered bags carried in the cabin by the passengers in the row 1 left seat, row 3 left seat, and the row 4 left seat were each assumed to weigh 10 pounds. The flight between Nikiski and Soldotna was about 17 nautical miles which equates to a flight time of about 8 minutes assuming a nominal groundspeed of 125 knots. For the purposes of the calculation the aircraft was assumed to be at takeoff power for 2 minutes and at cruise power for 6 minutes. Utilizing a fuel burn rate of 72 gal/hr for takeoff and 55 gal/hr for cruise, the engine would use about 2.4 gallons for takeoff and about 5.5 gallons for cruise. The engine was assumed to use 1 gallon of fuel for start and taxi. Based on the recommended procedures for operating the airplane, the taxi and takeoff fuel used of 3.4 gallons was decremented from the forward tank and the cruise fuel used of 5.5 gallons was decremented from the aft tank. The calculation (Table 3) for scenario 3 yields a weight of 8037.70 pounds with a CG at 158.15 inches.

Scenario 4

A load manifest was obtained from Rediske Air for the accident flight that listed 9 total passengers with a combined weight of 1350 pounds, passenger bags with a combined total weight of 80 pounds and freight with a total weight of 300 pounds. For this scenario the reported (asked) weight of each passenger was used. The total of these weights was 1345 pounds. For unknown reasons there was 5 extra pounds added to the total passenger weight on the load manifest. This 5 extra pounds was added to the passenger seated in the right, front co-pilot's seat.

The reported pilot weight of 220 pounds was used for this scenario. The total baggage weight of 80 pounds on the load manifest was divided among the 11 known bags on the airplane. Each of the 7 carry-on bags were assumed to weigh 5 pounds, the large red roller bag was assumed to weigh 25 pounds and the 3 bags in the cargo compartment were assumed to weigh 20 pounds in total. The fuel was decremented based on the previous flight as detailed in scenario 3. This calculation represents the likely weight and balance based on the load manifest. The calculation (Table 4) for scenario 4 yields a weight of 7411.16 pounds with a CG at 149.18 inches.

Scenario 5

For this calculation, the actual recovered weights of the pilot and passengers were used. The recovered baggage weight with appropriate locations was used similar to scenario 3. The three unrecovered passenger bags were not included in this scenario. The cargo weight was set to the recovered weight of 613 pounds and the fuel was decremented based on the previous flight similar to scenario 3. The calculation (Table 5) for scenario 5 yields a weight of 7761.12 pounds with a CG at 155.89 inches. This scenario represents a likely minimum weight and balance for the accident flight based only on the known factual information.

Scenario 6

This scenario more closely approximates the actual weight and balance of the airplane during the accident flight. Since the autopsy weights for each of the victims were without clothes and with some thermal damage and degradation, the reported autopsy weight is less than the actual weight during the flight. As a conservative estimate and based on the calculations above, each victim weight was increased by 5% to account for degradation and 5 pounds was added to each victim to account for clothing and shoes. The baggage weights and locations were left the same as in scenario 3 with all the recovered and unrecovered baggage included. Since all of the recovered bags had portions that were consumed by fire they would likely be less than the actual weight. However, the clothing items in the baggage retained some water from the firefighting efforts that would likely account for the weight of the missing portions. The weight of the cargo was set to be the recovered weight (613 pounds) plus the weight of the liquid items (105.58 pounds) similar to scenario 2. The cargo was subjected to the post-crash fire that consumed an unknown portion so the total weight used for the calculation likely is less than the actual weight. The fuel was decremented based on the previous flight similar to scenario 3. The calculation (Table 5) for scenario 5 yields a weight of 8021.40 pounds with a CG at 157.78 inches.

The airplane was certificated for a maximum gross weight of 8000 pounds with a CG range from 13508 to 152.2 inches. A summary of the calculations for the 6 scenarios is shown below. Red text indicates values outside the certified limits.

Scenario	Gross Weight (pounds)	CG location (inches)
1	6020.79	141.84
2	6439.37	150.76
3	8037.70	158.15
4	7411.16	149.18
5	7761.12	155.89
6	8021.40	157.78

Based on the calculated CG locations, some general facts can be deduced. Any amount of fuel more than the required minimum in the aft tank prior to the first flight would move the CG location further aft for all scenarios since the arm is behind the CG. Further reduction of fuel in the forward tank or a starting value less than full would move the CG location further aft since the weight would decrease and the arm is forward of the CG location for all scenarios. Errors in the assumed baggage weights for those bags included as part of the total recovered weight of 187 pounds and placed at row 2 or behind would have a negligible effect on the CG location but would not move the CG location forward since the arms are all behind the calculated CG locations for all scenarios. Of the three unrecovered bags, one would likely have been located in row 1 which would move the CG location forward for all scenarios but the other two were likely located at rows 3 and 4 which would move the CG location aft for all scenarios. Finally, any increase in the weight of cargo would move the CG location further aft for all scenarios since the arm is aft of the calculated CG locations.

It is possible that the arm and moment for the aft tank could be in error. All of the calculations done for the STC compliance assumed all three cells of the extended range aft tank were full and the airplane was in a level attitude. The fuel distribution between the three cells would likely be different with a partially full tank and the airplane in a tail-down attitude. The takeoff acceleration may also cause the fuel in the aft tank to move towards the aft-most cell. To gage this effect, scenario 6 was recalculated using the assumption that the partial aft tank fuel (14.5 gallons) was in the aft-most cell at an arm of 228.0 inches. The resulting CG location moved further aft by 0.35 inch.

Submitted by:
Clinton R. Crookshanks
Aerospace Engineer (Structures)

N93PC Weight & Balance				
		Weight (lbs)	Arm (in)	Moment (lb in)
Empty Weight		4287.99	132.59	568523.82
Pilot/Pax	Bags			
Pilot		200	98	19600.00
Right Front Seat	0	0	98	0.00
Row 1 (2 seats)	0	0	137	0.00
Row 2 (2 seats)	0	0	165	0.00
Row 3 (2 seats)	0	0	195	0.00
Row 4 (1 seat)	0	0	218	0.00
Row 5 (2 seats)	0	0	250	0.00
Cargo	0	300	279	83700.00
Fuel	Qty (gal)			
Forward Tank	62	415.40	121.0	50263.40
Center Tank	102	683.40	154.0	105243.60
Aft Tank	20	134.00	199.0	26666.00
A/C Total		6020.79	141.84	853996.82

Table 1 – Scenario 1 weight and balance calculation

N93PC Weight & Balance				
		Weight (lbs)	Arm (in)	Moment (lb in)
Empty Weight		4287.99	132.59	568523.82
Pilot/Pax	Bags			
Pilot		200	98	19600.00
Right Front Seat	0	0	98	0.00
Row 1 (2 seats)	0	0	137	0.00
Row 2 (2 seats)	0	0	165	0.00
Row 3 (2 seats)	0	0	195	0.00
Row 4 (1 seat)	0	0	218	0.00
Row 5 (2 seats)	0	0	250	0.00
Cargo	0	718.58	279	200483.82
Fuel	Qty (gal)			
Forward Tank	62	415.40	121.0	50263.40
Center Tank	102	683.40	154.0	105243.60
Aft Tank	20	134.00	199.0	26666.00
A/C Total		6439.37	150.76	970780.64

Table 2 – Scenario 2 weight and balance calculation

N93PC Weight & Balance				
		Weight (lbs)	Arm (in)	Moment (lb in)
Empty Weight		4287.99	132.59	568523.82
Pilot/Pax	Bags			
Pilot		200	98	19600.00
Right Front Seat	0	155	98	15190.00
Row 1 (2 seats)	22	310	137	45484.00
Row 2 (2 seats)	0	265	165	43725.00
Row 3 (2 seats)	22	275	195	57915.00
Row 4 (1 seat)	10	200	218	45780.00
Row 5 (2 seats)	77.96	230	250	76990.00
Cargo	91	718.58	279	225872.82
Fuel	Qty (gal)			
Forward Tank	58.6	392.62	121.0	47507.02
Center Tank	102	683.40	154.0	105243.60
Aft Tank	14.5	97.15	199.0	19332.85
A/C Total		8037.70	158.15	1271164.11

Table 3 – Scenario 3 weight and balance calculation

N93PC Weight & Balance				
		Weight (lbs)	Arm (in)	Moment (lb in)
Empty Weight		4287.99	132.59	568523.82
Pilot/Pax	Bags			
Pilot		220	98	21560.00
Right Front Seat	0	150	98	14700.00
Row 1 (2 seats)	10	290	137	41100.00
Row 2 (2 seats)	0	245	165	40425.00
Row 3 (2 seats)	10	255	195	51675.00
Row 4 (1 seat)	5	190	218	42510.00
Row 5 (2 seats)	35	220	250	63750.00
Cargo	20	300	279	89280.00
Fuel	Qty (gal)			
Forward Tank	58.6	392.62	121.0	47507.02
Center Tank	102	683.40	154.0	105243.60
Aft Tank	14.5	97.15	199.0	19332.85
A/C Total		7411.16	149.18	1105607.29

Table 4 – Scenario 4 weight and balance calculation

N93PC Weight & Balance				
		Weight (lbs)	Arm (in)	Moment (lb in)
Empty Weight		4287.99	132.59	568523.82
Pilot/Pax	Bags			
Pilot		200	98	19600.00
Right Front Seat	0	160	98	15680.00
Row 1 (2 seats)	12	281	137	40141.00
Row 2 (2 seats)	0	230	165	37950.00
Row 3 (2 seats)	12	224	195	46020.00
Row 4 (1 seat)	0	181	218	39458.00
Row 5 (2 seats)	77.96	218	250	73990.00
Cargo	91	613	279	196416.00
Fuel	Qty (gal)			
Forward Tank	58.6	392.62	121.0	47507.02
Center Tank	102	683.40	154.0	105243.60
Aft Tank	14.5	97.15	199.0	19332.85
A/C Total		7761.12	155.89	1209862.29

Table 5 – Scenario 5 weight and balance calculation

N93PC Weight & Balance				
		Weight (lbs)	Arm (in)	Moment (lb in)
Empty Weight		4287.99	132.59	568523.82
Pilot/Pax	Bags			
Pilot		215	98	21070.00
Right Front Seat	0	173	98	16954.00
Row 1 (2 seats)	22	305	137	44799.00
Row 2 (2 seats)	0	251.5	165	41497.50
Row 3 (2 seats)	22	245.2	195	52104.00
Row 4 (1 seat)	10	195	218	44690.00
Row 5 (2 seats)	77.96	234	250	77990.00
Cargo	91	718.58	279	225872.82
Fuel	Qty (gal)			
Forward Tank	58.6	392.62	121.0	47507.02
Center Tank	102	683.40	154.0	105243.60
Aft Tank	14.5	97.15	199.0	19332.85
A/C Total		8021.40	157.78	1265584.61

Table 6 – Scenario 6 weight and balance calculation