Aviation Investigation Final Report

Location:	Pacific Ocean, Pacific Ocean	**Accident Number:**	ANC21LA006
Date & Time:	November 6, 2020, 15:20 Local	**Registration:**	N400PW
Aircraft:	Pilatus PC12	**Aircraft Damage:**	Substantial
Defining Event:	Fuel starvation	**Injuries:**	2 None
Flight Conducted Under:	Part 91: General aviation - Ferry		

Analysis

The new production airplane was ditched in the ocean about 1,000 miles from its destination following a total loss of engine power during its first 10-hour transoceanic leg. The two pilots sustained no injuries, and the airplane was lost at sea.

A subsidiary of the aircraft manufacturer installed an auxiliary ferry fuel line and check valve in the left wing as a major alteration (per FAA Form 337) that stated, “The ferry tank provisions feed directly into the engine’s fuel supply line.” It also stated that “ferry tank installations should ensure that no air is introduced into the fuel system.”

Another company installed the ferry fuel system that initially consisted of two aluminum tanks, transfer and tank valves, and associated fuel lines and fittings. The company submitted a FAA Form 337 that stated, “The ferry fuel feed is directly to the left main tank.” The ferry fuel supply line was connected to the newly installed ferry fuel line fitting at the left-wing bulkhead, which then fed directly to the main fuel line through a check valve and directly to the engine fuel system.

The pilots’ first attempt at the transoceanic flight failed because the ferry fuel system did not transfer any fuel. The system was further modified with the addition of two 30 pounds-per-square-inch (psi) fuel pumps that could overcome aircraft’s ejector fuel pump pressure (10 psi) and the ferry system’s check valve. The airplane was returned to service. The pilots flew a positioning flight and tested the ferry fuel transfer process, with both the front (No. 1) and rear (No. 2) internal tanks and both transfer pumps, up to an altitude of 17,500 ft. The system worked as tested and there were no further tests conducted of the ferry fuel system.

The pilots departed on the 10-hour flight and the ferry fuel system worked initially as they used the operating procedures that were supplied by the installer. About 3.5 to 4 hours into the flight, the airplane was light enough to climb from flight level (FL) 200 to FL 280. About 5 hours into the flight, the No. 2 ferry tank was almost empty, and the No. 1 tank was about 1/2 full. The pilots were concerned about introducing air into the engine as they emptied the No. 2 ferry tank, so the pilot in command (PIC) placed the ignition switch to ON. The non-flying pilot then turned the ferry tank fuel transfer pump to off and soon after the engine surged and flamed out.

The pilots commenced the pilot operating handbook's emergency checklist procedures for emergency descent and then loss of engine power in flight. They attempted multiple engine air starts without success. About 8,000 ft mean sea level, the pilots committed to ditching and performed an emergency landing in the ocean. The pilots evacuated through the right over-wing exit, boarded the covered life raft, and were rescued about 22 hours later.

The installed ferry fuel system altered the fuel flow characteristics of the airplane when it was used to transfer fuel from the ferry fuel tanks. The delivery ejector pumps had a flap valve installed in the outlet to prevent reverse flow. However, the ferry system transfer pumps provided fuel at a higher pressure than the delivery ejector pumps, which closed the flap valve in the delivery ejector pumps. Also, the unused fuel returned to the wing tanks through the motive flow line would flow out the delivery ejector pumps' inlet because the delivery ejector pumps' flap valve was closed.

It is possible that the loss of engine power was due to air being introduced into the fuel line from the ferry system, although the boost pumps, if operating properly, should have compressed the air and forced it through the fuel line. It is also possible that ice built up in the aircraft fuel tanks during the fuel transfer operations, and when the ferry system was turned OFF, fuel flow to the engine stopped or was restricted because 1) the left- and right-wing fuel was too viscous; and/or 2) the ejector flap valves were stuck closed.

The aircraft was certified without an air separator in the engine fuel feed line. In addition, the production fuel system design of the accident airplane was such that a Fuel System Icing Inhibitor (FSII) was not required. Although not required, neither the aircraft manufacturer nor the company that installed the ferry fuel system evaluated 1) the ferry system's impact on the production fuel system operating temperature; 2) if an FSII should be required; and 3) if not having an air separator in the engine fuel feed line would impact the system.

The loss of engine power likely was caused by fuel starvation as a result of 1) air in the fuel line from operating on the ferry fuel system; or 2) a build-up of ice in the production fuel system due to operating on the ferry fuel system. However, because the airplane was lost at sea and was not available for postaccident examination, the exact cause of the fuel starvation could not be determined.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

A total loss of engine power due to fuel starvation for reasons that could not be determined based on the available evidence.

Findings

Not determined	(general) - Unknown/Not determined

Factual Information

History of Flight

Enroute-cruise	Fuel starvation (Defining event)
Emergency descent	Ditching

On November 6, 2020, about 1520 Pacific standard time, a Pilatus PC-12, N400PW, was substantially damaged when it was ditched in the Pacific Ocean about 1,000 miles east of Hilo, Hawaii, following a total loss of engine power. The two pilots sustained no injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 ferry flight.

According to the PIC, he and another pilot were ferrying a new airplane from California to Australia. The first transoceanic leg was planned for 10 hours, from Santa Maria Airport (KSMX), Santa Maria, California, to Hilo Airport (PHTO), Hilo, Hawaii. A subsidiary of the airframe manufacturer had an auxiliary ferry fuel line and check valve installed in the left wing after delivery of the aircraft to the United States. About 1 month before the trip, the PIC hired a ferry company to install an internal temporary ferry fuel system for the trip. The pilots attempted the first transoceanic flight on November 2, but the ferry fuel system did not transfer properly, so they diverted.

The system was modified with the addition of two 30-psi fuel transfer pumps that could overcome the airplane's ejector fuel pump pressure and the ferry system check valve. The final system consisted of two aluminum tanks, two transfer pumps, transfer and tank valves, and associated fuel lines and fittings. The ferry fuel supply line was connected to the newly installed ferry fuel line fitting at the left-wing bulkhead, which then fed directly to the main fuel line through a check valve and directly to the engine fuel system. The installed system was ground- and flight-checked before the trip.

According to Federal Aviation Administration (FAA) automatic dependent surveillance broadcast (ADS-B) data, the airplane departed KSMX about 1000. For the accident flight, the main fuel tanks were full with 402 gallons, the No. 1 ferry tank contained 100 gallons, and the No. 2 ferry tank contained 60 gallons. The fuel utilization procedure for the flight was:

1) Use main tanks until their quantity decreased to 300 gallons;

2) Transfer half of ferry tank number two or when the main tanks reach 350 gallons;

3) Use main tanks until their quantity decreased to 300 gallons;

4) Transfer half of ferry tank number one or when the main tanks reach 350 gallons;

5) Repeat until ferry tanks are empty.

The first halves of the ferry tanks were transferred without any issues except for the occasional illumination of the FUEL IMBALANCE caution light, but that was expected as excess transfer fuel was sent back to the main tanks after passing through the engine. Then the ferry system was used to transfer the remaining fuel from the No. 2 ferry tank. The airframe manufacturer noted that this ferry tank utilization procedure did not give the flight crew a reliable situational awareness of the airplane's fuel state, as it relied on information the crew did not have (motive flow rate) and on fuel quantity indications on the tanks that were not accessible to the crew while transferring fuel.

About 3.5 to 4 hours into the flight, the airplane was light enough to climb from FL 200 to FL 280. About 5 hours into the flight, the No. 2 ferry tank was almost empty so the pilots prepared to stop transferring fuel from that tank. The ignition switch was placed ON. After the transfer pump was turned OFF, with fuel still visible in the supply line, the FUEL LOW PRESSURE light illuminated.

The PIC had already placed the ignition switch to ON during the ferry transfer, and now set the two in-aircraft boost pumps to the ON position for the end of the transfer process and confirmed the pumps were on with the green L PUMP and R PUMP lights on the Fuel System Status Window and green IGNITION message on the Primary Flight Display (PFD) Engine Window. About 5 seconds after the low-pressure light illuminated, the engine surged and then completely shut down and feathered. The pilots estimated that the engine lost power about 20 seconds after turning the transfer pump off. The fuel quantity in the main tanks and No. 1 ferry tank was about 450 gallons at the time. The fuel temperature in the wing tanks was unknown.

The engine stopped while the aircraft was at FL 280. Although the pilots could not recall what altitude the air start procedures were performed, they knew that 20,000 ft was the maximum altitude for restart according to the Pilot's Operating Handbook. The pilots used the checklist to perform an air start and the engine started and the propeller unfeathered; however, the engine never reached idle rpm and manipulation of the power control lever did not affect the engine. The engine did not fully start. They shut off the engine per the checklist and then attempted another air start.

During the next start sequence, the engine made a loud grinding noise and then a loud catastrophic "bang." There was no evidence of smoke or flames from the exhaust on either side of the aircraft. The CAS panel had numerous messages. At some point, the Engine and Propeller Electric Control System (EPECS) FAIL light illuminated, but the pilots could not recall exactly when. As the airplane descended, they attempted multiple air starts, including the procedures for when the EPECS FAIL light was on. The propeller never moved and the engine never started. About 8,000 ft, the pilots committed to ditching the airplane and they commenced the ditching checklist.

After preparing the survival gear, donning life vests, and making mayday calls on VHF 121.5, the PIC performed a full-flaps, gear-up landing at an angle to the sea swells and into the wind. He estimated that the swells were 5 to 10 ft high with crests 20 feet apart. During the landing, the PIC held back elevator pressure for as long as possible and the airplane landed upright. The pilots evacuated through the right over-wing exit and boarded the six-person covered life raft. A photograph of the airplane revealed that the bottom of the rudder was substantially damaged. The airplane remained afloat after ditching.

The pilots used a satellite phone to communicate with Oakland Center. The United States Coast Guard (USCG) coordinated a rescue mission with a nearby oil tanker, the M/V Ariel, for rescue of the crew. According to the pilots, during the night, many rescue attempts were made by the M/V Ariel; however, the ship was too fast for them to grab lines and the seas were too rough. After a night of high seas, the M/V Ariel attempted rescue again; however, they were unsuccessful. That afternoon, a container ship in the area, the M/V Horizon Reliance, successfully maneuvered slowly to the raft, then the ship’s crew shot rope cannons that propelled lines to the raft, and they were able to assist the pilots onboard. They had been in the raft for about 22 hours. The airplane was lost at sea.

Aircraft Information

On April 15, 2020, the FAA issued a Standard Certificate of Airworthiness for the accident airplane. On this model Pilatus PC-12, the aircraft was certified without an air separator in the engine fuel feed line. An air separator in the engine fuel feed line was included on previous models of the PC-12. In addition, the production fuel system design of the accident airplane was such that a Fuel System Icing Inhibitor (FSII) was not required.

On June 9, 2020, the ferry fuel system provisions were designed and installed by the aircraft manufacturer as a major alteration per FAA Form 337. The FAA Form 337, in Section 2.0, stated “The ferry tank provisions feed directly into the engine's fuel supply line.” It also stated, “Ferry tank installations should ensure that no air is introduced into the fuel system.” In addition, the drawings and schematics showed the ferry system connected directly to the engine's fuel supply line.

The FAA Form 337 submitted by the company that installed the ferry system fuel tanks on October 28, 2020, stated in Section 3.0, “The ferry fuel feed is directly to the left main tank.”

During the positioning flight on November 1, 2020, and an attempted ferry flight on November 2, 2020, the ferry fuel system would not transfer any fuel from the ferry tanks. The ferry fuel system was further modified on November 2-5, 2020, by installing two pumps to provide enough fuel pressure (30 psi) to overcome the aircraft’s delivery fuel ejector pump pressure (10 psi) and supply fuel to the engine fuel supply line. The pumps were installed so that either pump could transfer fuel from either ferry tank. Due to the additional changes made to the airplane’s ferry fuel system, a new FAA Form 337 should have been submitted to the FAA before the flight.

On November 6, 2020, the airplane was returned to service. The pilots flew from Merced Airport (KMCE), Merced, California, to KSMX and tested the ferry fuel transfer process with both the front and rear internal tanks and both transfer pumps up to an altitude of 17,500 ft.

The system worked as tested. There were no further tests conducted of the ferry fuel system. They refueled at KSMX and departed for Hawaii about 1000.

Fuel System

The installed ferry fuel system altered the fuel flow characteristics of the airplane as compared to the production fuel distribution system. As originally designed, the fuel distribution system transferred fuel from the left and right main wing tanks into the respective collector tanks through one-way valves located between the two fuel tanks. The transfer was facilitated by a transfer ejector pump located in each main tank. Fuel was fed from the collector tanks, through a common manifold, toward the engine primarily via delivery ejector pumps. The nominal output pressure of the delivery ejector pumps was 10 psi. The ejectors were energized by heated, high pressure, regulated motive flow from the engine fuel system. The delivery ejector pumps have a flap valve installed in the outlet to prevent reverse flow through the delivery ejector pumps. An electric fuel boost pump, located in each collector tank, was used to provide fuel if either of the delivery ejector pumps could not supply the required fuel pressure. The nominal output pressure of the boost pumps was 31 psi. The boost pumps are also used to provide fuel pressure for engine start, and to laterally balance the fuel load. From the wing tanks, fuel flowed forward through a firewall shutoff valve, a low-pressure engine-driven pump, an oil/fuel heat exchanger, a fuel filter, and a high-pressure engine-driven pump to the fuel control unit. Unused fuel is returned to the wing tanks through the motive flow line.

Unlike the production fuel system, the ferry fuel system moved fuel to the engine feed line from ferry tanks through a check valve. The ferry system transfer pumps provided fuel at a higher pressure than the delivery ejector pumps, which closed the flap valve in the delivery ejector pumps. The ferry system provided fuel to the engine through a firewall shutoff valve, a low-pressure engine-driven pump, an oil/fuel heat exchanger, a fuel filter, and a high-pressure engine-driven pump to the fuel control unit. The excess fuel was then returned to the wing tanks through the motive flow circuit. Unlike the production fuel system, the motive flow fuel going to the delivery ejector pumps would flow out the pump inlet because the flap valve was closed. The fuel in the motive flow line refilled the wing fuel tanks.

FAA Advisory Circular 23-10

The FAA Advisory Circular 23-10 “Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes” states the following:

“The requirements for a direct feed auxiliary fuel system are considerably more stringent than those for a transfer auxiliary fuel system. In general, these requirements ensure that an uninterrupted flow of fuel at the required pressure and flow rate is provided to each engine for all operating conditions of the airplane. For turbine engine airplanes, these provisions should be automatic to meet the requirements of §23.955(f)(2). These requirements also address altitude performance effects and low and high temperature fuel aspects as well as providing fuel system independence in at least one configuration. Failure Mode and Effects Analyses

(FMEA) are needed to ensure that no hazardous conditions exist due to a failure of the auxiliary system. Continuous engine operation should be verified when the auxiliary tank system is depleted of fuel in order to prevent engine flameout or other unacceptable operating conditions." The Advisory Circular 23-10 also stated that the auxiliary tank depletion characteristics should also be evaluated to ensure that air entrainment, etc., do not alter main tank performance.

After the ferry fuel system was installed on the airplane, there were no tests or evaluations that 1) addressed altitude performance effects and low and high temperature fuel aspects on the production system due to the ferry system operation; 2) completed an FMEA to ensure that no hazardous conditions existed due to a failure of the auxiliary system; or 3) verified continuous engine operation when the auxiliary tank system was depleted of fuel in order to prevent engine flameout or other unacceptable operating conditions as required in Advisory Circular 23-10.

There was no evaluation of 1) the ferry system's impact on the production fuel system operating temperature; 2) whether an FSII should be required; and 3) if not having an air separator in the engine fuel feed line would impact the system. Although such an evaluation was not required and was advisory, the underlying certification provisions are required to ensure continuous operation of the fuel system.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	25,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	September 11, 2020
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	2740 hours (Total, all aircraft), 22 hours (Total, this make and model), 1988 hours (Pilot In Command, all aircraft), 146 hours (Last 90 days, all aircraft), 35 hours (Last 30 days, all aircraft), 8 hours (Last 24 hours, all aircraft)		

Other flight crew Information

Certificate:	Commercial; Flight instructor	**Age:**	61,Female
Airplane Rating(s):		**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	4-point
Instrument Rating(s):		**Second Pilot Present:**	Yes
Instructor Rating(s):		**Toxicology Performed:**	
Medical Certification:		**Last FAA Medical Exam:**	
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	October 2, 2020
Flight Time:			

Aircraft and Owner/Operator Information

Aircraft Make:	Pilatus	**Registration:**	N400PW
Model/Series:	PC12 47E	**Aircraft Category:**	Airplane
Year of Manufacture:	2020	**Amateur Built:**	
Airworthiness Certificate:	Special flight (Special)	**Serial Number:**	2003
Landing Gear Type:	Retractable - Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	1 Turbo prop
Airframe Total Time:		**Engine Manufacturer:**	P&W Canada
ELT:	C126 installed, activated	**Engine Model/Series:**	PT6E-67XP
Registered Owner:	Fairhaven Pilatus LLC	**Rated Power:**	
Operator:	On file	**Operating Certificate(s) Held:**	None

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KSMX	**Distance from Accident Site:**	1050 Nautical Miles
Observation Time:	09:00 Local	**Direction from Accident Site:**	90°
Lowest Cloud Condition:	Few / 2000 ft AGL	**Visibility**	
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	None /
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Santa Maria , CA (KSMX)	**Type of Flight Plan Filed:**	IFR
Destination:	Hilo, HI (PHTO)	**Type of Clearance:**	IFR
Departure Time:	10:00 Local	**Type of Airspace:**	Class A

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	2 None	**Latitude, Longitude:**	27.5937,-139.6529

Administrative Information

Investigator In Charge (IIC):	Price, Noreen
Additional Participating Persons:	David Welch; Federal Aviation Administration; Honolulu, HI Markus Kohler; Pilatus Aircraft Ltd.; Stans Jeremy Ganivet; Pratt & Whitney Canada; Quebec
Original Publish Date:	September 29, 2023
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=102247