



Aviation Investigation Final Report

Location:	Page, Arizona	Occurrence Number:	WPR23LA167
Date & Time:	April 23, 2023, 17:29 Local	Registration:	N135SH
Aircraft:	GATES LEARJET CORP. 35A	Aircraft Damage:	None
Defining Event:	Fuel contamination	Injuries:	4 None
Flight Conducted Under:	Part 91: General aviation - Positioning		

Analysis

The flight crew requested the airplane be topped off with fuel that included a fuel system icing inhibitor additive (FSII/PRIST). The fixed-base operator serviced the airplane with 674 gallons of Jet A and FSII that had inadvertently been mixed with diesel exhaust fluid (DEF). The airplane then departed on a repositioning flight. About 30 minutes after departure, while level at flight level (FL) 350, the captain observed erratic temperature indications on the left engine inlet turbine temperature (ITT) gauge. The right engine indications were normal at the time. Shortly thereafter, he observed noticeable variations in fuel flow accompanied by small variations in the right engine N1 (fan rotational speed) and N2 (turbine rotational speed). The captain reported that the right engine variations became significant and resulted in “yaw issues”; according to the first officer, the right engine was “pulsing.”

The flight crew informed air traffic control (ATC) that they wanted to return to the departure airport. During this time the right engine power decreased to idle. The captain stated that about this time the right engine fuel flow indicator indicated 0 lbs/hr, indicating the engine flamed out. They declared an emergency and informed ATC they were unable to maintain altitude and would have to descend. The controller gave them an immediate clearance to descend. The captain stated they did not try to restart the right engine at this time because their altitude was above the restart envelope. He stated that as they descended the variations in parameters for the left engine were increasing and, after descending through FL300, they unsuccessfully attempted to restart the right engine. The variations in the left engine parameters continued to increase along with a decay in the max N1 and the engine was unresponsive to thrust lever movements. The crew then informed ATC that they needed to land at the nearest airport. The flight crew completed a successful emergency landing to a nearby airport, which resulted in no damage to the airplane and no injuries to the crew.

The investigation found that the refueler had erroneously deposited diesel exhaust fluid into the FSII tank of his fuel truck, which he subsequently used to refuel 5 airplanes, including the incident airplane. Crystalline deposits were discovered in the fuel tank.

Postaccident examination of the airframe and engines did not reveal contamination of the airframe filter elements; however, crystalline deposits began to appear on the elements about 5 months later. The reason for the latency was not determined. The rest of the fuel systems exhibited various quantities of crystalline deposits, with extensive formation at the fuel nozzles of both engines. The contamination at the nozzles would have interfered with the spray pattern of the affected nozzles, inhibiting their ability to atomize the fuel and resulting in the loss of power to both engines.

Probable Cause and Findings

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

The fueler's inadvertent addition of diesel exhaust fluid (DEF) to the FSII reservoir on the fuel truck, and its subsequent mixture with the JET A that was used to fuel the airplane, resulting in a total loss of power to the right engine and a partial loss of power to the left engine.

Findings

Aircraft	Fuel - Incorrect use/operation
Aircraft	Fuel additive - Incorrect use/operation
Aircraft	Fuel - Fluid condition
Personnel issues	Use of equip/system - Ground crew

Factual Information

History of Flight

Enroute-cruise	Fuel contamination (Defining event)
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On April 23, 2023, about 1729 Pacific daylight time, a Learjet 35A, N135SH, sustained an uncommanded decrease in power on both engines near Page, Arizona. The captain, first officer, and two medical crewmembers were not injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 positioning flight.

According to the captain, the flight was a non-patient MEDEVAC flight destined for Chicago, Illinois. The captain placed a fuel order before the flight with Signature Aviation at Harry Reid International Airport (LAS), Las Vegas, Nevada, that included PRIST, a FSII; he observed the attendant write "T/O +" on the paperwork that pertained to his fuel order. The airplane was subsequently refueled with 674 gallons of JET A fuel.

The airplane departed LAS at 1646 with the first officer flying and the captain monitoring the flight. They climbed to FL350 and accelerated to their cruise speed, which occurred about 19 minutes after takeoff. About 11 minutes later (30 minutes after departure), the captain observed erratic temperature indications between 0° and 750° from the left engine's ITT gauge. The other engine indications were normal at the time. About 2 minutes later he observed small variations in the left engine's ITT, followed by noticeable variations in fuel flow, as well as small variations in the right engine's N1 (fan rotational speed) and N2 (turbine rotational speed). The captain reported that the right-engine variations became significant and resulted in "yaw issues"; according to the first officer, the right engine was "pulsing."

The flight crew informed ATC that they wanted to return to LAS and the controller gave them instructions to make an immediate left turn. During this time the variations in the right engine's parameters increased and right-engine power decreased to idle. A review of digital electronic engine control (DEEC) data showed that the right engine reduced to idle power at 1719 and subsequently began to show fluctuations in N1 and N2 without corresponding movement of the power lever beginning at 1720. The right engine returned to idle thrust at 1721 without a consistent movement of the power lever. The captain stated that about this time the right engine's fuel flow indicator indicated 0 lbs/hr. They declared an emergency and informed ATC they were unable to maintain altitude and would have to descend. The controller gave them an immediate clearance to descend.

The DEEC data for the left engine showed fluctuations in N1 and N2 without a corresponding movement of the power lever beginning at 1717. The flight crew reported that the variations in the left engine's parameters became more erratic as the airplane passed through FL300 at 1725. The captain observed a slow decay in the left-engine N1 at this time and noted that the engine was unresponsive to thrust lever movements. He also reported that an attempt to

restart the right engine was unsuccessful. According to the first officer, the left engine also reduced to idle power at this time. At 1729, as the airplane passed through FL270, he advised the controller that they would make an emergency landing in Page, Arizona.

The captain dumped fuel to reduce the airplane’s landing weight, and the first officer started a circling descent. After they passed below 12,000 ft mean sea level, ATC cleared them for the visual approach to runway 15 at their destination airport. According to the first officer, after the captain secured the fuel jettison valves, the captain took over the flying duties. After the airplane was established on short final the captain lowered the landing gear at 220 KIAS. The captain noted that he was intentionally high and fast at this point, in order to perform a dead stick landing. At 1744, they touched down successfully at a slightly higher than normal speed and slightly long. The airplane came to rest about 650 ft from the runway end. The first officer noted that the left engine was still at idle and the right engine was off.

DEEC data showed the left-engine N2 between 50% and 60% for about 4 minutes, 23 seconds; about half of this time was before landing and the other half was after landing. In addition, after landing the ITT value dropped after the engine was shut down, when all the engine parameters decreased. According to the data, after the reduction in thrust to the right engine at 1719 until the end of the flight, the engine remained at an idle, sub-idle or non-operational condition and did not respond to pilot commands.

Pilot Information

Certificate:	Airline transport	Age:	68, Male
Airplane Rating(s):	Single-engine land; Multi-engine land	Seat Occupied:	Left
Other Aircraft Rating(s):	Glider	Restraint Used:	3-point
Instrument Rating(s):	Airplane	Second Pilot Present:	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine	Toxicology Performed:	
Medical Certification:	Class 1 With waivers/limitations	Last FAA Medical Exam:	February 16, 2023
Occupational Pilot:	Yes	Last Flight Review or Equivalent:	February 4, 2023
Flight Time:	5606 hours (Total, all aircraft), 3975 hours (Total, this make and model), 3705 hours (Pilot In Command, all aircraft), 174 hours (Last 90 days, all aircraft), 53 hours (Last 30 days, all aircraft), 6 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport	Age:	34, Male
Airplane Rating(s):	Single-engine land; Multi-engine land	Seat Occupied:	Right
Other Aircraft Rating(s):		Restraint Used:	3-point
Instrument Rating(s):	Airplane	Second Pilot Present:	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine	Toxicology Performed:	
Medical Certification:	Class 1 Without waivers/limitations	Last FAA Medical Exam:	September 6, 2022
Occupational Pilot:	Yes	Last Flight Review or Equivalent:	January 23, 2023
Flight Time:	1920 hours (Total, all aircraft), 190 hours (Total, this make and model), 1400 hours (Pilot In Command, all aircraft), 155 hours (Last 90 days, all aircraft), 61 hours (Last 30 days, all aircraft), 6 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	GATES LEARJET CORP.	Registration:	N135SH
Model/Series:	35A	Aircraft Category:	Airplane
Year of Manufacture:	1981	Amateur Built:	
Airworthiness Certificate:	Transport	Serial Number:	335
Landing Gear Type:	Retractable - Tricycle	Seats:	10
Date/Type of Last Inspection:	December 15, 2022 Continuous airworthiness	Certified Max Gross Wt.:	18300 lbs
Time Since Last Inspection:	63 Hrs	Engines:	2 Turbo fan
Airframe Total Time:	14243.9 Hrs at time of accident	Engine Manufacturer:	Garrett
ELT:	C126 installed, not activated	Engine Model/Series:	TFE731
Registered Owner:	MED AIR LLC	Rated Power:	3500 Lbs thrust
Operator:	Medway Air Ambulance	Operating Certificate(s) Held:	On-demand air taxi (135)
Operator Does Business As:		Operator Designator Code:	Y6WA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	Condition of Light:	Day
Observation Facility, Elevation:	KPGA,4288 ft msl	Distance from Accident Site:	0 Nautical Miles
Observation Time:	17:53 Local	Direction from Accident Site:	186°
Lowest Cloud Condition:		Visibility	10 miles
Lowest Ceiling:	Broken / 12000 ft AGL	Visibility (RVR):	
Wind Speed/Gusts:	11 knots / 17 knots	Turbulence Type Forecast/Actual:	/
Wind Direction:	330°	Turbulence Severity Forecast/Actual:	/
Altimeter Setting:	29.82 inches Hg	Temperature/Dew Point:	22°C / -3°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Las Vegas, NV (LAS)	Type of Flight Plan Filed:	IFR
Destination:	Chicago, IL (MDW)	Type of Clearance:	IFR
Departure Time:	16:46 Local	Type of Airspace:	Class A

Airport Information

Airport:	PAGE MUNI PGA	Runway Surface Type:	Asphalt
Airport Elevation:	4316 ft msl	Runway Surface Condition:	Dry
Runway Used:	15/33	IFR Approach:	None
Runway Length/Width:	1590 ft / 150 ft	VFR Approach/Landing:	Forced landing

Wreckage and Impact Information

Crew Injuries:	4 None	Aircraft Damage:	None
Passenger Injuries:	N/A	Aircraft Fire:	None
Ground Injuries:		Aircraft Explosion:	None
Total Injuries:	4 None	Latitude, Longitude:	36.926069,-111.44835

According to Safety Alert for Operators No. 18015, published November 13, 2018, by the Federal Aviation Administration:

"DEF forms crystalline deposits that are not soluble in fuel, so they cannot be removed by flushing the aircraft fuel systems with jet fuel. Although the deposits are soluble in water and

other polar solvents, use of these chemicals may have adverse consequences on aircraft and engine fuel system materials. Operators should contact Original Equipment Manufacturers (OEM) to develop inspection techniques and maintenance actions appropriate for each specific aircraft model type and its level of exposure.”

Fueler Investigation

According to the company that fueled the airplane, the fueling truck was quarantined immediately after the company was notified of the emergency landing. An immediate inspection of the quality records and analysis of JET A samples revealed that the fuel from the truck's tank was clean and met industry standards. A field test of the fluid within the truck's FSII reservoir showed a 30% concentration of DEF within the sample. According to the company, a laboratory test of a sample taken from the nozzle of the FSII tank showed a nitrogen content that exceeded 1.0, which suggests the presence of DEF.

The fueler reported that a line service technician informed them that he was trying to be productive during a busy day and decided to make sure his truck had DEF. He located a container and inadvertently poured about 1 gallon of DEF into the FSII reservoir, which contained 1 gallon of FSII already inside the reservoir. The fueler stated that he was unfamiliar with DEF servicing as he had never serviced a truck with DEF before. The company's investigation also discovered that the fueler had not seen the company's internal bulletin on DEF contamination prevention and that he did not notice the label that showed the contents of the FSII tank. The fueler also noted that the position of the location of the FSII and DEF tanks on this truck were in opposite positions on another truck.

A total of five airplanes were refueled with FSII (PRIST) from the contaminated fuel truck; however, none of the other affected airplanes were inspected as the refueler did not disclose their contact information. The incident airplane was the only airplane that was supplied with the contaminated fuel that reported a loss of power. Three of the operators confirmed to the refueler that they drained their fuel tanks and engine filters to remove the fuel. One operator removed approximately 200 gallons of the contaminated fuel and discovered crystalline contaminants within the filter vessels.

Fuel System and Component Examinations

The airplane was equipped with two tip tanks (357 gallons total), two wing tanks (374 gallons total), and a 200-gallon fuselage tank. Fuel was driven to the engine fuel nozzles via a low-pressure airframe fuel pump that directed fuel through a fuel filter (the low-pressure filter), a high-pressure fuel pump, a fuel control unit, and then a flow divider.

Fuel Filters, Fuel Control Units, and Flow Dividers

The left and right airframe and engine fuel filter elements were void of any debris. The airframe and engine filters were subsequently shipped to a secure facility where they were stored for a

period of about 5 months, during which time there was extensive formation of crystalline deposits on all of the filters.

An examination of the left engine's fuel control unit (FCU), the left-engine fuel pump, and right- and left-engine flow dividers was completed 10 months after the incident. The left engine's FCU plate valve inlet screen associated with the main fuel flow metering valve was mostly obstructed. The inlet screen associated with the main fuel flow metering valve and the fuel flow divider screen exhibited trace amounts of a substance that was hard, brittle, and mixed with jet fuel, giving it a gelatinous appearance. The right engine's fuel flow divider inlet screen was mostly obstructed by the same substance.

A bench test of the right engine's FCU and fuel pump assembly showed that it was able to produce a fuel flow from 135 pph to 1985 pph. According to the engine manufacturer, max cruise flight requires a fuel flow of 615 pph.

Fuel Nozzles

According to the engine manufacturer, within each fuel nozzle there are two separate paths of fuel flow. The secondary fuel flows through the center of the fuel nozzle body while the primary fuel flows through a concentric path surrounding the center of the secondary fuel flow path. Both fuel flow paths contain a "last chance screen" for fuel to pass through before being introduced into the combustion chamber. During engine operation the primary and secondary fuel flows are directed to the 12 fuel nozzles. When the engine is started, fuel is directed through the primary fuel path, after which the secondary flow path is energized for engine acceleration. The primary and secondary flow paths, together, are used during all other times of engine operation.

Both the left- and right-engine fuel nozzle assemblies were flow tested under 100 psi with the primary and secondary flow paths tested separately.

A flow test and inspection of the right engine fuel nozzle assembly revealed that, during the primary flow test, nozzles 1, 3, 4 and 12 did not exhibit spray from either of the nozzle heads. Nozzles 5 and 6 dripped when tested. The secondary flow test revealed that nozzles 1, 3, and 11 did not spray, nozzles 2 and 12 exhibited an intermittent spray, nozzle 9 dripped, and nozzle 10 displayed as a stream. Four of the fuel nozzles were chosen for disassembly and further examination. All four fuel nozzles showed varying degrees of crystalline contaminants.

According to the engine manufacturer, *"functional flow testing of the [right-engine] fuel manifolds showed limited to no flow in all the primary and secondary fuel nozzles. Functional flow testing of the fuel manifolds showed limited to no flow in all the primary and secondary fuel nozzles. The fuel flow blockages observed would have prevented normal engine operation. Disassembly of 4 of the 10 fuel nozzles displayed crystalline contaminants in the primary and secondary fuel circuits."*

The primary flow test of the left engine fuel nozzles showed that nozzles 1, 2, 4, 5, 6, and 12 exhibited no spray. Nozzles 3 and 10 displayed a “fair” spray quality and nozzle 9 was “dripping.” The secondary flow test revealed a “fair” spray quality from nozzles 2, 3, 4, 5, 9. Nozzles 1, 10, 11, and 12 exhibited “poor” spray quality. Only one of the 12 fuel nozzles met the specification requirements during testing. Four of the fuel nozzles were chosen for disassembly and further examination. All four fuel nozzles displayed crystalline contaminants in the primary and secondary fuel circuits.

In their evaluation of the left engine’s fuel nozzles, the engine manufacturer noted, *“Functional flow testing of the fuel manifolds from the left engine showed limited to no flow in all the primary and secondary fuel nozzles. The measured fuel flow and spray patterns observed would have prevented normal engine operation. Disassembly of 4 of the 10 fuel nozzles displayed crystalline contaminates in the primary and secondary fuel circuits.”*

Preventing Similar Accidents

Prevent DEF Jet Fuel Contamination (SA-079)

The Problem

Diesel exhaust fluid (DEF) is a urea-based chemical that is added to ground vehicle emissions systems to reduce nitrogen oxide (NOx) emissions. DEF is not designed, nor approved, for use in jet fuel. If it is inadvertently added to jet fuel, as has happened in several incidents over the last 2 years, DEF will react with certain chemical components to form crystalline deposits in the fuel system. The crystalline deposits can then accumulate on filters, engine fuel nozzles, and fuel metering components and result in a loss of engine power.

What can you do?

- Do not store or temporarily place chemicals into unlabeled containers; always use containers and labels that meet OSHA requirements.
- Ensure that all containers (including bulk storage tanks and larger cube tanks) are clearly marked with 4-inch or larger stenciled letters visible from all sides. Use “DIESEL

EMISSION FLUID (DEF)” for all DEF fluid and “JET FUEL SYSTEM ICIING INHIBITOR” for all FSII storage containers.

- Add a label to all DEF containers that says, “NOT FOR AVIATION USE.”
- Even when the containers are clearly marked, do not store DEF and FSII close to each other since it is hard to differentiate the clear, colorless liquids.
- All staff should be trained on the storage locations of DEF and FSII, the packaging and labeling of both chemicals, and the hazards associated with DEF fuel contamination.
- Fueling agents or operators should remove from aircraft and discard jet fuel or FSII suspected of being contaminated with DEF. Do not attempt to repurpose DEF contaminated fuel or FSII to other aircraft or vehicles.
- Review and consider implementing the recommendations contained within the June 11, 2019, [Aircraft Diesel Exhaust Fluid Contamination Working Group Report](#).

See <https://www.nts.gov/Advocacy/safety-alerts/Documents/SA-079.pdf> for additional resources.

The NTSB presents this information to prevent recurrence of similar accidents. Note that this should not be considered guidance from the regulator, nor does this supersede existing FAA Regulations (FARs).

Administrative Information

Investigator In Charge (IIC):	Stein, Stephen
Additional Participating Persons:	Scott Childs; Federal Aviation Administration; Atlanta, GA Michael Lemay; Bombardier; Montreal Jay Eller; Honeywell; Phoenix, AZ
Original Publish Date:	November 21, 2024
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this occurrence.
Investigation Docket:	https://data.nts.gov/Docket?ProjectID=107149

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The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, “accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person” (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available [here](#).