

National Transportation Safety Board
Office of Railroad, Pipeline and Hazardous Materials
Washington, DC 20594



ERA25MA106

HAZARDOUS MATERIALS CARGO/GAS CYLINDERS

Specialist's Factual Report
April 2, 2026

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A. ACCIDENT

Location: Philadelphia PA
Date: January 31, 2025
Time: 18:07 local

Airplane: Learjet 55, XA-UCI

B. HAZARDOUS MATERIALS CARGO/GAS CYLINDERS

Specialist

[REDACTED]
Sr. Hazardous Materials Accident Investigator
NTSB, Washington, D.C.

C. ACCIDENT SUMMARY

On January 31, 2025, at 18:07 eastern standard time (EST), a Learjet 55, Mexican registration XA-UCI (call sign MTS056) crashed in Philadelphia, Pennsylvania. The two pilots, two medical crew members, and two passengers onboard were fatally injured. Additionally, one person on the ground was fatally injured, four people were seriously injured, and 20 others incurred minor injuries as a result of the accident. The aircraft was operated as a Title 14 Code of Federal Regulations (CFR) Part 129 air ambulance flight.

The flight departed runway 24 at Northeast Philadelphia Airport (PNE), Philadelphia, Pennsylvania, about 18:06, with the intended destination of Springfield-Branson National Airport (SGF), Springfield, Missouri. Night instrument meteorological conditions prevailed at PNE at the time of the accident, including an overcast ceiling at 400 ft above ground level, wind from 220° at 9 knots, and 6 miles visibility.

D. DETAILS OF THE INVESTIGATION

A total of 11 compressed gas cylinders were recovered from the Learjet 55 wreckage, including six cylinders containing oxygen for medical use, one cylinder containing crew oxygen, two cylinders containing halon used for aircraft engine fire suppression, one cylinder containing halon for main cabin emergency fire extinguishing purposes, and one cylinder containing carbon dioxide for life-raft inflation. On March 26 - 27, 2025, and on May 14, 2025, NTSB hazardous materials accident investigators participated in the visual examination of these gas cylinders and their associated

components. These examinations focused on assessing the post-accident integrity of the cylinders. NTSB investigators documented the condition of each cylinder.

1.0 Hazardous Materials Description

Compressed Gas Cylinders for Medical or Fire Extinguishing Purposes

Compressed oxygen (UN 1072), carbon dioxide (UN 1013) and fire extinguishers containing compressed or liquefied gas (UN 1044) are classified as division 2.2 non-flammable gas and are regulated under the U.S. Department of Transportation, Hazardous Materials Regulations (HMR; 49 CFR parts 100-185) with some exceptions.

Under 49 CFR 175.8, aircraft operators are excepted from the requirements of the HMR for medical use oxygen for passengers, which is furnished by the aircraft operator in accordance with FAA requirements, 14 CFR 121.574, 125.219, or 135.91. Cylinders for medical use oxygen provided by the aircraft operator for passengers may be carried in the cabin. No more than six oxygen cylinders belonging to the aircraft operator and no more than one cylinder per passenger needing oxygen may be transported in the cabin.¹

The handheld fire-extinguisher was not made to a DOT specification and meets the limited quantity exceptions regulation (49 CFR 172.315). The two other halon cylinders that are part of the engine fire protection system for the aircraft are not regulated under the HMR but fall under FAA requirements, 14 CFR parts 23 and 25.

Life Raft System

The life raft system, which included a carbon dioxide cylinder, is regulated under a FAA Technical Standard Order (TSO-C70a) that prescribes minimum performance standards for inflatable life rafts intended for use on an aircraft. These standards include testing for inflation speed, stability in high winds/waves, and structural durability.

Maintenance requirements on all the cylinders are discussed further in Section 5.0 of this report.

¹ 49 CFR 175.501 includes stowage requirements when oxygen cylinders are located in the cargo compartment of the aircraft not having fire or smoke detection. The oxygen cylinders must be stored horizontally on the floor of the cargo location. In this investigation, all the cylinders were stored in the cabin except for the two halon cylinders that were part of the engine fire protection system.

2.0 Compressed Gas Cylinders

2.1 Oxygen Cylinders

A total of seven compressed oxygen cylinders were onboard the aircraft. Six of these cylinders (Cylinder #1 - Cylinder #6) were used for medical oxygen service, and the remaining cylinder (Cylinder #8) was used for flight crew oxygen.

Table 1 summarizes the specifications for each of the seven compressed oxygen cylinders contained on the aircraft.

Table 1. Summary of Compressed Oxygen Cylinders onboard the aircraft²

Name	DOT Specification	Serial Number	Material	Diameter (in.)	Length (in.)	Working Pressure (psig)	Manufacturer	Manufacture Date
Cylinder #1	DOT-3AL-2216	MM-7736	Aluminum	8	35.75	2,216	Luxfer	July 1994
Cylinder #2	DOT-3AL-2216	AB0178438	Aluminum	8	35.75	2,216	Catalina	September 2013
Cylinder #3	DOT-3AL-2015	1T038803	Aluminum	4.38	29	2,015	Piper	August 2022
Cylinder #4	DOT-3AL-2015	SG98751	Aluminum	4.38	29	2,015	Zhejiang	August 2020
Cylinder #5	DOT-3AL-2015	IH996742	Aluminum	4.38	29	2,015	Piper	August 2022
Cylinder #6	DOT-3AL-2015	AS1180469	Aluminum	4.38	29	2,015	Catalina	October 2009
Cylinder #8	DOT-3AA-1800	K915439	Steel	6	19.5	2,015	Catalina	July 2007

2.1.1 Cylinder #1, NTSB Evidence No. ERA25MA106-HAZ-01

According to operator procedures, Cylinder #1 was likely installed in the bottom section of a *Lifeport 2* patient transport bed onboard the aircraft. The cylinder was found intact and under pressure.³ Visual inspection of the exterior of the cylinder revealed a bent valve stem and several scrapes and scratches on the cylinder crown and wall (Figure 1). The inspection also revealed several gouges in the cylinder wall, the most significant of which measured 0.22-inches in depth (Figure 2). No hazardous materials labels or hazard communications were found on the cylinder.

² In addition to the cylinders being stamped with the DOT specifications noted in Table 1, Cylinders #1 and #2 were also stamped TC-3ALM153, and Cylinders #3 - #6 and Cylinder #8 were stamped TC-3ALM139. A "TC" stamp refers to Transport Canada regulations, which are equivalent to DOT requirements for cylinders.

³ The cylinder was vented for approximately 5 minutes prior to completing the visual inspection.

In addition to completing external visual inspection of Cylinder #1, a borescope was used to complete an interior visual inspection of the cylinder. No cracks were observed in the valve threads or in the crown area, and the bottom of cylinder was clean and unremarkable. Investigators also x-rayed the cylinder and found no remarkable features. Additional stamps were found on the bottom of the cylinder (X5811, MM882), the valve stem (CGA540, B22, V18, EN849, CV05) and on the pressure relief device cap (3320, P625-19N) that refer to either manufacturing standards, internal tracking or serial numbers, or batch production codes.



Figure 1: Cylinder #1, crown, scrape, and intact bent valve stem (March 26, 2025).



Figure 2: Cylinder #1, exterior wall gouge (March 26, 2025).



Figure 3: Cylinder #1, maintenance overdue sticker (March 26, 2025).

2.1.2 Cylinder #2, NTSB Evidence No. ERA25MA106-HAZ-02

Based on a video obtained by the operator, Cylinder #2 was likely stored upright in a storage cabinet in the aft of the aircraft and strapped to the cabinet wall with a metal band.⁴ Cylinder #2 was recovered with the valve missing and the bottom portion of the valve stem fractured and remained within the cylinder threads (Figure 4). Post-accident visual inspection of the cylinder revealed a witness mark on the top surface of the cylinder collar, adjacent to the fractured valve stem. Several scrapes and gouges were observed on the cylinder, including a deep scrape and gouge in the crown. No through-wall breaches were observed on the cylinder. Labels affixed to cylinder wall included hazardous materials labels for non-flammable gas 2.2 and oxidizer 5.1 (in Spanish), along with partially legible hazardous materials warnings and hazard communications. Interior inspection of Cylinder #2 using a borescope revealed no remarkable features on the internal surfaces of the cylinder, and no remarkable features were identified in x-rays taken of the cylinder. An additional stamp was observed on the bottom of the cylinder (AF268) that refers to the batch production code.

The fractured valve stem was removed from the tank and submitted to the NTSB Materials Laboratory for metallurgical examination and failure analysis.

⁴ WhatsApp video dated February 3, 2025, shows the cylinder stored upright and strapped to the wall inside a storage cabinet onboard the aircraft.



Figure 4: Photos of Cylinder #2 crown and bottom portion of fractured valve stem (red arrow) (March 26, 2025).

2.1.3 Cylinder #3, NTSB Evidence No. ERA25MA106-HAZ-03

Based on a video obtained by the operator, Cylinder #3 was likely secured upright in a rack in the aft of the aircraft, with Cylinders #4, #5, #6. Cylinder #3 was found with the top portion of the valve stem missing and bottom portion of the valve stem fractured and still threaded into the neck of the cylinder (Figure 4). A witness mark was noted on the collar adjacent to the fractured valve stem. Post-accident visual inspection of the cylinder revealed a significant gouge and scrape on the crown of the cylinder (Figure 5). Additionally, the cylinder appeared to be bowed, and a significant dent was observed on the bottom of the cylinder (Figure 6). No wall breaching damage was observed. No hazardous materials labels or hazard communications were found on the cylinder. An internal visual inspection was not completed to protect the metallurgical evidentiary value of the fractured valve stem, however x-rays taken of the cylinder revealed no remarkable features. Additional stamps were found on the bottom of the cylinder (C7794, AB177) indicating batch production code and internal tracking numbers.

The entire cylinder was submitted to the NTSB Materials Laboratory for a metallurgical examination of the valve stem fracture and failure analysis.



Figure 5: Photos of Cylinder #3 showing observed crown gouge (left) and fractured valve stem (right) (March 26, 2025).



Figure 6: Photos of Cylinder #3 showing notable fabric impression on cylinder wall (March 26, 2025).

2.1.4 Cylinder #4, NTSB Evidence No. ERA25MA106-HAZ-04

Based on a video obtained by the operator, Cylinder #4 was likely secured upright in a rack in the aft of the aircraft, with Cylinders #3, #5, #6. The cylinder was found with the top portion of the valve stem missing and bottom portion of the valve stem fractured and remaining within the cylinder neck threads (Figure 7). Post-accident visual inspection of the cylinder revealed a witness mark was found on the collar adjacent to the fractured valve stem. Additionally, a scrape was observed on the

crown and collar near the valve stem, and black, blue, and red impressions were observed on the cylinder wall (Figure 8). No breaching of the cylinder wall was observed. No hazardous materials labels or hazard communications were found on the cylinder. Internal visual inspection using a borescope revealed slight pitting on cylinder wall. X-rays taken of the cylinder revealed no remarkable features.

The fractured bottom portion of the valve stem was removed from cylinder and was submitted to the NTSB laboratory for metallurgical examination and failure analysis.

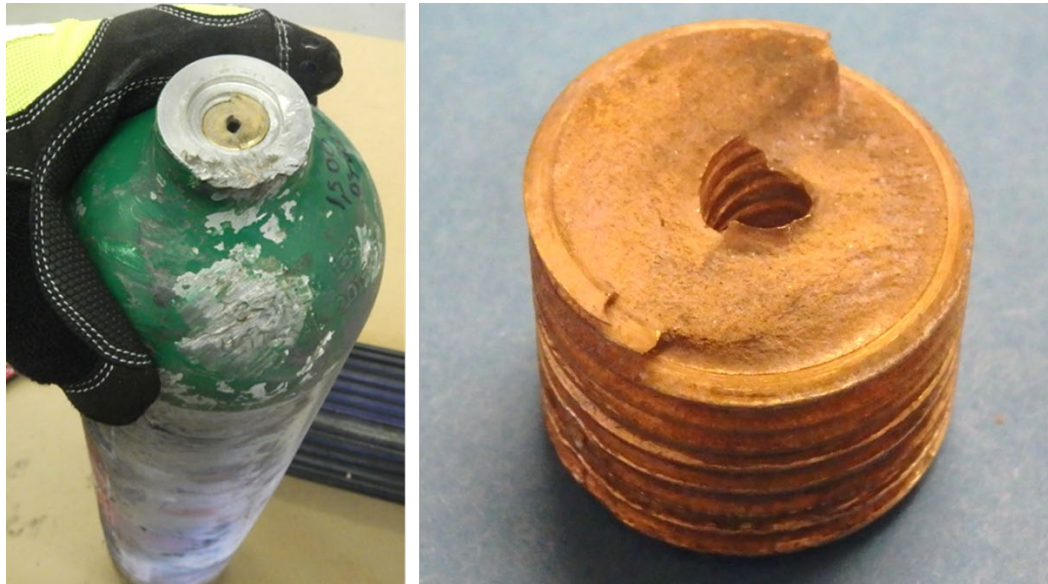


Figure 7: Photo of Cylinder #4 showing fractured valve stem and witness mark on collar (left), and fractured valve stem removed from cylinder (right) (March 26, 2025).



Figure 8: Photo of Cylinder #4 showing black, blue, and red impressions on cylinder wall (March 26, 2025).

2.1.5 Cylinder #5, NTSB Evidence No. ERA25MA106-HAZ-05

Based on a video obtained by the operator, Cylinder #5 was likely secured upright in a rack in the aft of the aircraft, with Cylinders #3, #4, #6. The cylinder was found with the top portion of the valve stem missing and the bottom portion of the valve stem fractured and remained within the cylinder neck threads (Figure 9). Post-accident visual examination of the cylinder revealed a witness mark on the collar adjacent to the fractured valve stem. Additionally, a scrape and gouge that extended from the collar across the crown of the cylinder were observed, as well as dents in the wall at the base of the crown (Figure 9). No breaching damage was observed. No hazardous materials labels or hazard communications were found on the cylinder. Internal visual inspection of the cylinder using a borescope found no thread damage, however some scaling and minor pitting was observed on the interior surface of the cylinder. X-ray examination identified no additional features.

The fractured bottom portion of the valve stem was removed from cylinder and was submitted to the NTSB Materials Laboratory for metallurgical examination and failure analysis.



Figure 9: Photos of Cylinder #5 showing fractured valve stem and collar witness mark (left), and fractured valve stem removed (right).

2.1.6 Cylinder #6, NTSB Evidence No. ERA25MA106-HAZ-06

Based on a video obtained by the operator, Cylinder #6 was likely secured upright in a rack in the aft of the aircraft, with cylinders #3, #4, #5. The cylinder was found with the top portion of the valve stem missing and the bottom portion of the valve stem fractured and remaining within the cylinder threads (Figure 9). Post-accident inspection of the cylinder revealed a witness mark on the collar adjacent to the fractured valve stem. Additionally, a scrape and gouges were observed in crown and collar adjacent to broken valve stem. Black fabric impressions were observed, and a

piece of blue fabric was found adhered to the tank wall (Figure 10). Further, the cylinder appeared to bowed. No breaching damage was observed. No hazardous materials labels or hazard communications were found on the cylinder. Internal borescope inspection of the cylinder revealed thread corrosion and evidence of scaling on the interior walls of the cylinder. The X-ray examination of the cylinder revealed no remarkable features.

The fractured bottom portion of the valve stem was removed from cylinder and was submitted to the NTSB laboratory for metallurgical examination.



Figure 10: Photos of Cylinder #6 showing fractured valve stem remaining in cylinder neck (left), gouge observed in crown (center), and fractured valve stem removed from cylinder (right).



Figure 11: Photo of Cylinder #6 showing dents observed on the wall of the cylinder at the base of the crown and fabric adhered to tank wall.

2.1.7 Cylinder #8, NTSB No. ERA25MA106-HAZ-08

Cylinder #8 was likely in the tail of the aircraft in the vertical stabilizer, according to Illustrated Parts Catalogue (IPC) for the Learjet 55. The cylinder was found with the top portion valve stem missing and the bottom portion of the valve stem fractured and remaining within the cylinder threads. Post-accident examination of the cylinder revealed dents on all sides, including the crown and bottom. Additionally, a through-wall crack was observed in the cylinder near the crown and adjacent to two dents (Figure 12). No hazardous materials labels or hazard communications were found on the cylinder. An internal borescope examination revealed the area near the through-wall crack had evidence of stress cracking to either side. Rust was observed throughout the interior surfaces of the cylinder walls and crown, including a “bathtub ring” feature near the bottom of the cylinder (Figure 13). X-ray examination identified no additional features. The cylinder was submitted to the NTSB laboratory for metallurgical examination and failure analysis.

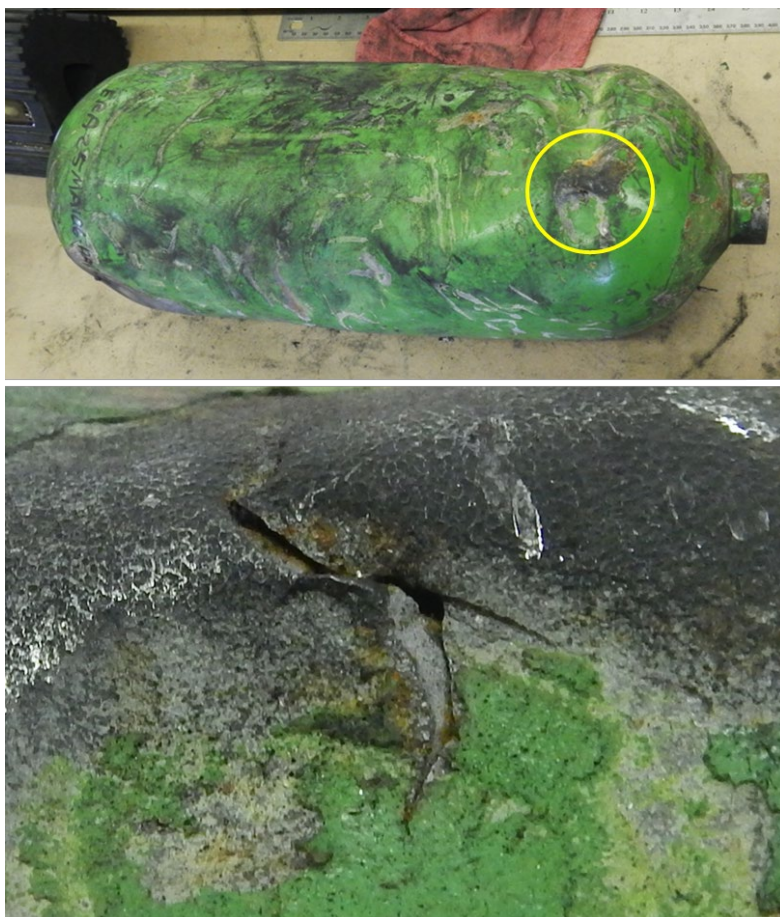


Figure 12: Photos of Cylinder #8 showing dents observed on cylinder (top) and through-wall crack (bottom)(March 26, 2025).

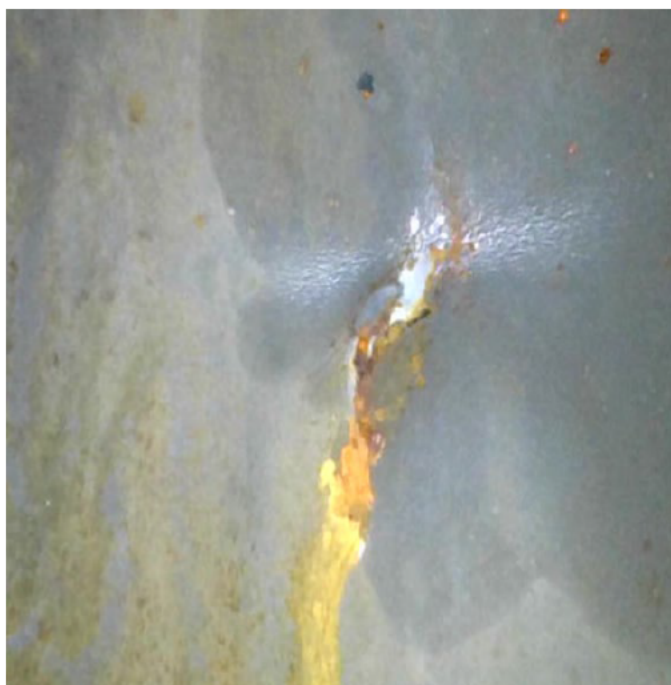


Figure 13: Photo of Cylinder #8, showing internal view of through-wall crack and rust observed on interior surface of cylinder during borescope examination (March 26, 2025).

2.2 Carbon Dioxide Cylinder

During the on-scene investigation, a representative from the airline operator observed the airplane's life raft on the roof of a nearby Dunkin' building and requested that the NTSB investigate whether a carbon dioxide (CO₂) leak may have occurred in the cabin during the accident flight.

2.2.1 Cylinder #7 and life raft components, NTSB No. ERA25MA106-HAZ-07 and ERA25MA106-HAZ-10

Table 2. Summary of Carbon Dioxide Cylinder Onboard Learjet 55

Name	DOT Specification	Serial Number	Material	Diameter (in.)	Length (in.)	Working Pressure (psig)	Manufacturer	Manufacture Date
Cylinder #7	DOT-3AL-2015	AR0499666	Aluminum	4.375	16.5	2,015	Catalina	February 2013

Cylinder #7 was associated with an onboard life raft manufactured by AVI Survival Products that was located next to the packaged life raft in its valise. The cylinder was found with the top portion of the valve stem missing and bottom portion of the valve stem fractured and remaining within the cylinder neck threads (Figure 14). The fractured valve stem was attached to a dip tube that extended to the bottom of the cylinder. Post-accident visual inspection of the cylinder revealed the cylinder walls

were flattened and dented, and the cylinder appeared to be bowed outward on one side and inward on the adjacent side (Figure 15). Some corrosion was observed on the external collar surface and black soot was observed on the cylinder walls. No breaching of the cylinder wall was observed. No hazardous materials labels or hazard communications were found on the cylinder. Internal visual inspection using a borescope revealed some corrosion on the top neck threads, but the remaining threads were clean. Evidence of cylinder wall scale and pitting were also observed, as was a "bathtub ring" at two levels in bottom half of the cylinder. X-rays taken of the cylinder revealed no remarkable features.

The valve stem/dip tube was removed from the cylinder and was submitted to the NTSB Materials Laboratory for metallurgical examination and failure analysis.



Figure 14: Photos of Cylinder #7 crown and collar (top left), fractured valve stem (top right), and dip tube (bottom) (March 26, 2025).



Figure 15: Photos of Cylinder #7 walls dented and bowed out (March 26, 2025).

2.3 Halon Cylinders

There was a total of three halon cylinders onboard the aircraft. Two of the spherical cylinders (Halon Cylinder #1 and Halon Cylinder #2) were used for aircraft engine fire suppression and each located in the engine nacelles. The remaining cylinder (Halon Cylinder #3) was a handheld USCG approved portable marine fire extinguisher intended for emergency use by personnel onboard the aircraft. According to the Illustrated Parts Catalog (IPC) for the Learjet 55, the two cylinders for the aircraft engine fire suppression were each equipped with two fire extinguishing cartridges with its squibs (detonation device). Table 2 summarizes the specifications for each of the three halon cylinders onboard the aircraft.

Table 3: Summary of Halon Cylinders Onboard Learjet 55

Specification	Serial Number	Material	Design	Name	Working Pressure (psig)	Manufacturer	Manufacture Date
DOT-4DS700	B10071	Stainless steel	Welded sphere	Halon Cylinder #1	700	Advanced Technology	February 1975
DOT-4DS700	B11510	Stainless steel	Welded sphere	Halon Cylinder #2	700	*Unreadable	October 1976
"DOT Approved"	n/a	Steel	Cylinder	Halon Cylinder #3	n/a	AMEREX Corp	2021

Following the accident, NTSB hazardous materials investigators completed a visual inspection of each of the three halon cylinders on March 26, 2025. The following subsections provide details observed during these inspections.

2.3.1 Halon Cylinder #1

Halon Cylinder #1 was a compressed gas welded stainless steel cylinder used for aircraft engine fire suppression and installed above the engines. The cylinder was found discharged (empty), as evidenced by a fractured diaphragm disc. Post-accident inspection of the cylinder revealed one of the fire extinguisher cartridges with its squib assembly missing and the other intact (Figure 16).



Figure 16: Photo of actuated Halon Cylinder #1 with one of its fire extinguisher cartridge and squib assembly missing (March 26, 2025).

2.3.2 Halon Cylinder #2

Halon Cylinder #2 was a compressed gas welded stainless steel cylinder used for aircraft engine fire suppression and installed above the engines. The cylinder was found fully charged, as evidenced by its weight and sloshing. Post-accident

inspection of the cylinder revealed the fire extinguisher actuation cartridge intact (Figure 17).

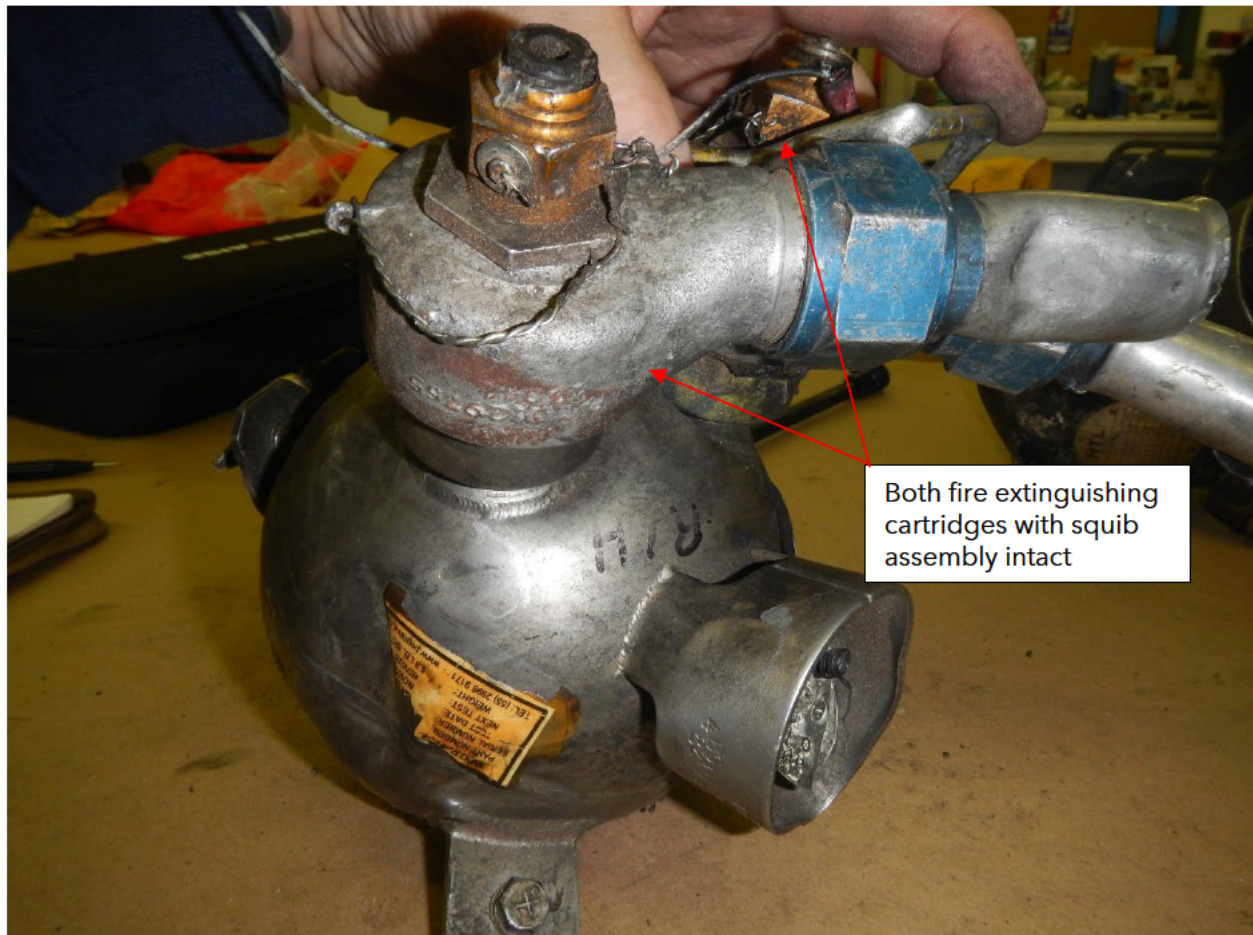


Figure 17: Photo of non-actuated Halon Cylinder #2 with both fire extinguisher cartridges intact (March 26, 2025).

2.3.3 Halon Cylinder #3

Halon Cylinder #3 was a "DOT approved" liquefied gas type handheld portable marine fire extinguisher installed on the aircraft for emergency use. Post-accident inspection of the cylinder revealed severe dents on all sides of the cylinder (Figure 18). Additionally, the valve stem was bent. The top valve stem was intact but the operating handle and pressure gauge were missing and the discharge port was open.



Figure 18: Photo of Halon Cylinder #3 (March 26, 2025).

3.0 Life Raft Assembly

An AVI Survival Products model RAF1210 Life Raft was onboard the accident aircraft. According to the manufacturer, the life raft was manufactured in 2013 and approved for certification in compliance with FAA requirements for Technical Standard Order (TSO) C70a, Type I. It was a 10-person life raft that included a carbon dioxide automatic inflation system that inflated the device in 21 seconds (allowed up to 60 seconds). The life raft was also equipped with a manually activated, lanyard triggered self-inflating system. The inflation system was composed of an aluminum gas cylinder (Cylinder #7) that was 172 in³ and charged with 4.2 lbs. of carbon dioxide; an inflation valve which controls the actuation of the raft inflation and two flexible hoses connected to two molded inlet check valves (see Figure 19).

The AVI Survival Products safety data sheet (SDS) states the life raft contains Flares, Aerial, UN0403, 1.4G, and one cylinder of UN1013 Carbon Dioxide, Compressed, a pressurized gas that may discharge or rupture under extreme temperatures and “may displace oxygen and cause rapid suffocation. May cause frostbite.” The SDS further states:

Do not drop the packed life raft. Do not pull the inflation lanyard (painter line) on the raft. Only lift the packed raft by its handles if packed in a fabric valise. If raft is packed in a hard container, lift from bottom. Opening the raft valise or hard container may cause the raft to inflate. Life raft can cause injury if inflated close to people or in a confined area. The life raft's compressed gas cylinder is equipped with a pressure relief device. The device will vent gas from the cylinder if stored at temperatures above 130°F. The raft may partially or fully inflate if the pressure relief device activates.

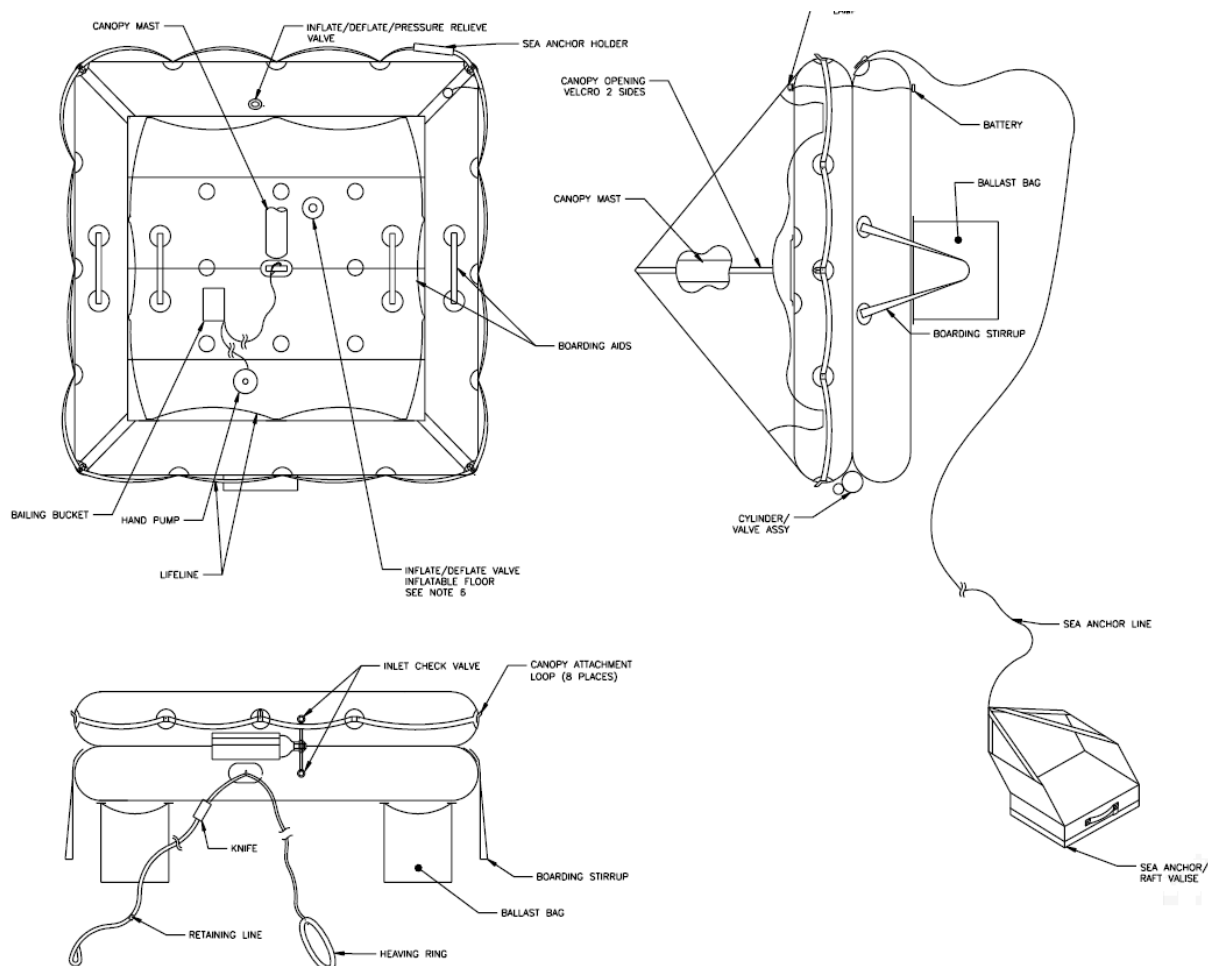


Figure 19: AVI Survival Products Model RAF 1210 Life raft assembly, parts nomenclature (AVI Survival Products Component Maintenance Manual Life Raft RAF1210).

The life raft did not have an expiration date. According to the maintenance manual, the life raft was required to be inspected every 12 months. The package weight of the life raft was listed as 30 pounds, with packed dimensions of 20 in. x 15 in. x 9 in. The manufacturer provided pictures of an exemplar packed 10-person life raft (Figure 20) and exemplar unpacked, uninflated 10-person life raft (Figure 21).



Figure 20: Photo of exemplar packed 10-person life raft (Photo courtesy by AVI Survival Products).

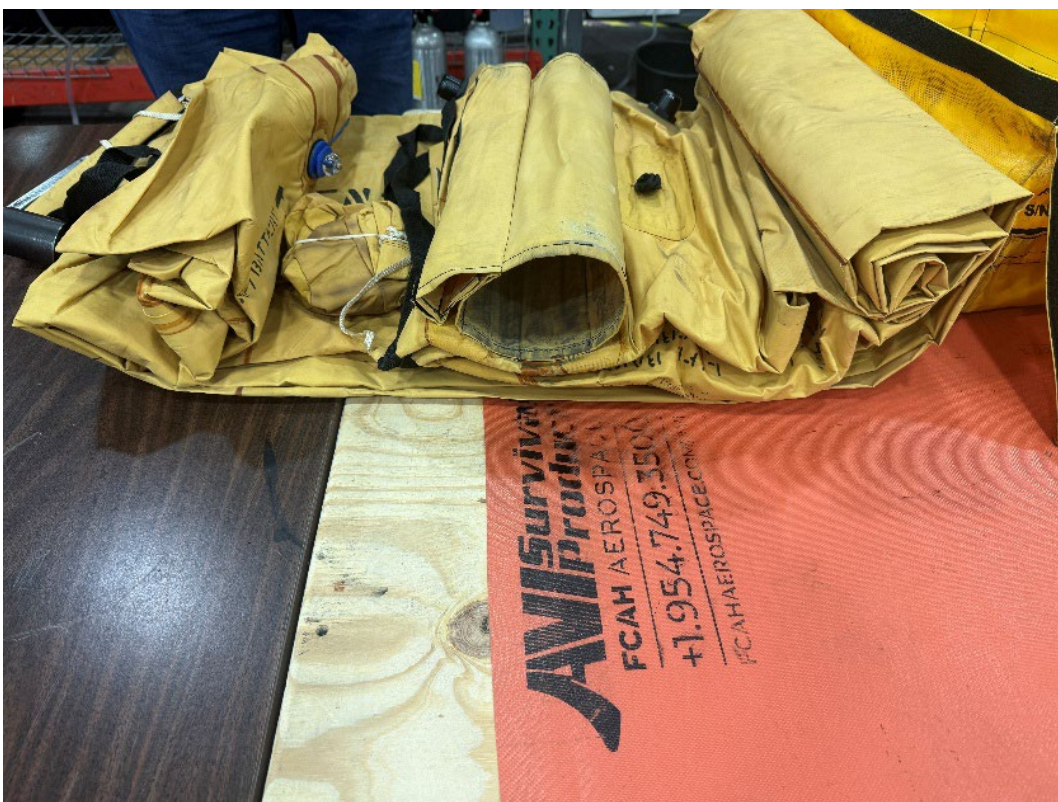


Figure 21: Photo of exemplar unpacked, uninflated 10-person life raft (Photo courtesy by AVI Survival Products).

3.1 AVI Survival Products Model RAF 1210 Life Raft

Following the accident, the life raft came to rest on the northeast side roof of the Dunkin', 1230 Cottman Avenue, Philadelphia PA, adjacent to the crash site (Figure 22 and Figure 23). A lanyard was stretched along the edge of the roof and draped over the side of the building. The inflation lanyard was found coiled next to the raft.



Figure 22: Aerial view of the aircraft's life raft on the roof of the Dunkin', 1230 Cottman Avenue, Philadelphia, PA, looking north. (February 2, 2025, annotation by NTSB).

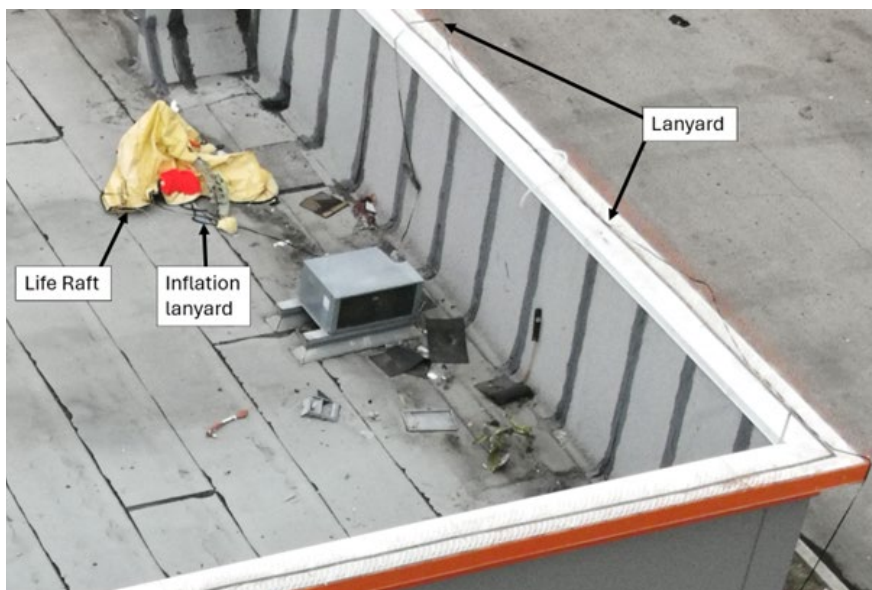


Figure 23: Close-up aerial view of life raft and components on the roof of the Dunkin', 1230 Cottman Avenue, Philadelphia, PA. (February 2, 2025, annotations by NTSB).

On May 14, 2025, life raft was laid out for examination by NTSB hazardous materials accident investigators. The life raft was found stenciled "Survival Products, Inc., Hollywood, Florida, USA. TSO C70A Type 1 Life Raft, Rated Capacity 10 Persons, Overload Capacity 15 Persons. P/N RAF1210-101, DOM (date of manufacture) AUG 2013, S/N 2367KBA."

Visual inspection of the life raft revealed that the yellow tube life raft walls were not inflated. No loss of integrity was identified in the life raft walls. A tear was observed in the center of the raft floor. The inflator pin on the life raft was observed as separated from the inflation valve but still attached to its lanyard (Figure 24). Beyond the inflator pin, the lanyard was tied off to a hardpoint on a patch of reinforced life raft wall. The red inflation valve pouch Velcro closure was unfastened. The inflation valve contained a portion of the fractured valve stem that would have been connected to Cylinder #7. The inflation pin actuator port was observed as open, within which was a protruding a spring-loaded pin/valve. The pressure relief device discharge port contained a silver-colored disc. The portion of the disc visible within the exposed discharge port was not ruptured and its fitting was still secured (Figure 25). The two ¼-inch-diameter inflation tubes attached to the life raft chambers were crushed, and beneath the rubber sleeve of one of these tubes crushed/frayed stainless-steel braided tubing was observed. Additionally, a representative from AVI examined photos of the life-raft in situ on the roof and stated that the raft appeared to not be inflated.

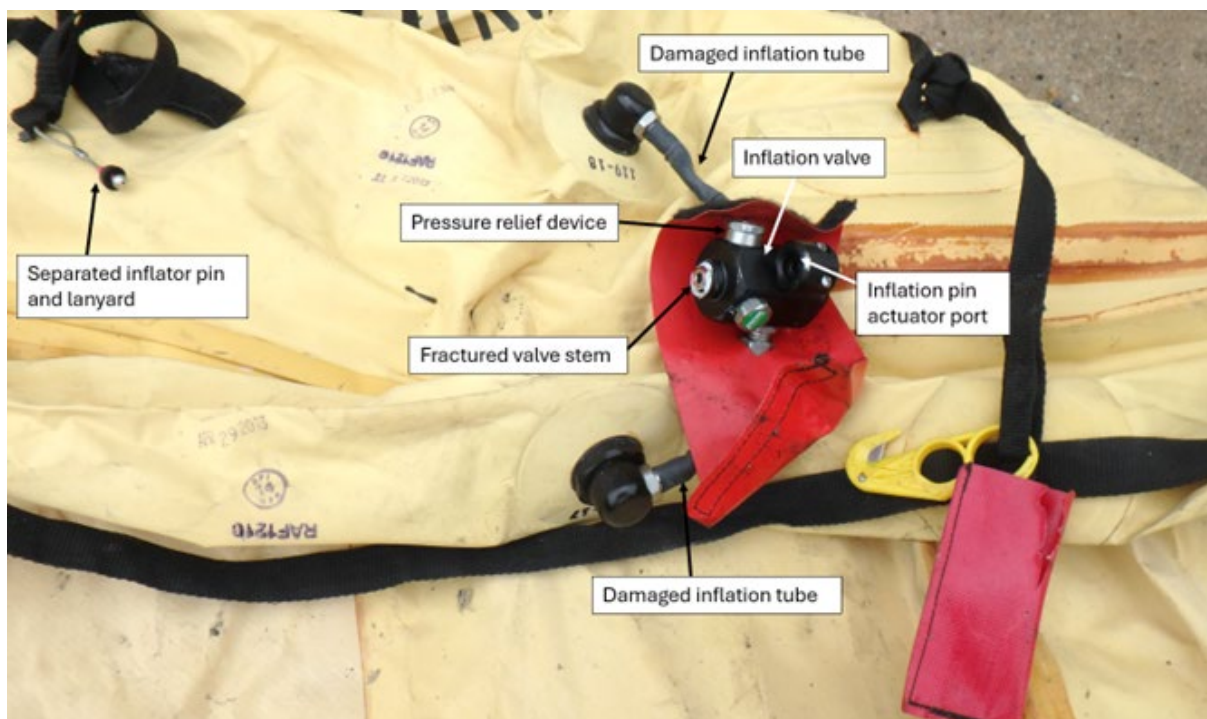


Figure 24: Close-up aerial view of life raft inflation valve assembly on the roof of the Dunkin', 1230 Cottman Avenue, Philadelphia, PA, (February 2, 2025, annotations by NTSB).



Figure 25: Close-up of pressure relief device discharge port with disc visibly in place (February 2, 2025, annotation by NTSB).

3.2 Previous air cargo carbon dioxide incident

Crew incapacitation from carbon dioxide exposure has previously been a concern with the transportation of dry ice, shipped as UN 1845, Carbon Dioxide, solid, Class 9. On April 29, 1998, a Douglas DC-8-51 cargo airplane, N507DC, was taxiing to take off at the Brownsville/South Padre Island International Airport in Brownsville, TX, when all four occupants (three flight crewmembers and a jumpseat rider) became short of breath. All occupants donned oxygen masks, and the captain taxied the airplane back to the ramp. As a result, the NTSB issued Safety Recommendation A-01-14 to the FAA, calling for the Administration to conduct testing during all phases of ground operation and flight using varying quantities and forms of dry ice as typically loaded aboard commercial cargo aircraft to determine appropriate sublimation rates for the calculation of acceptable dry ice loads and the potential effects of various aircraft ventilation conditions on crew exposure to carbon dioxide. In response the FAA published a technical report in August 2006, which states that unconsciousness can occur if the carbon dioxide concentration reaches 12-15%.⁵

4.0 Additional Item of Interest

Among the recovered wreckage were a single oxygen valve body and the oxygen pressure regulator described below. The valve was submitted to the NTSB laboratory for CT scanning to determine if the valve was open.

⁵ *Sublimation Rate of Dry Ice Packaged in Commonly Used Quantities by the Air Cargo Industry.* (Washington, DC: Federal Aviation Administration, 2006).

4.1 Oxygen Cylinder Valve Body and Oxygen Pressure Regulator, NTSB No. ERA25MA106-HAZ-09

The oxygen valve body was manufactured by Harrison MFG and was stamped "2104015 21/04 V9 ISO V U12." The valve body was also stamped "CGA870 Oxygen" referring to the manufacturing standard. The valve is used as a high-pressure control point to open and close cylinder gas flow.

A recovered oxygen pressure regulator, used to reduce pressure from an oxygen tank and typically attached to the oxygen valve body, was marked "Property of St. Johns R.M.S." It also displayed a bar code with property number 1681. Additional stampings included "AM2901, 0528." The ports were stamped "IN", "HP." Labeled "Western, model No. M?70-FG1, Made in USA, Medical Oxygen" (Figure 26).



Figure 26: Photos of oxygen valve body stamped CGA870 (top) and an oxygen pressure regulator (bottom) (March 26, 2025).

5.0 Applicable Regulations

The DOT and the FAA allow foreign air carriers to conduct operations within the United States in accordance with its Air Operator Certificate (AOC) and FAA Foreign Operations Specification (OpSpecs). In general, the FAA's authority to regulate foreign operators using foreign-registered aircraft is limited to assuring compliance with all the applicable operating rules, the ability to safely navigate and communicate within the U.S. National Airspace System (NAS) and protecting persons and property on the ground.

The Federal Civil Aviation Agency (AFAC), a division of the Secretariat of Communications and Transportation, is the government body that regulates and oversees civil aviation in Mexico. The agency is also responsible for investigating aviation accidents and incidents. AFAC replaced the former Dirección General de Aeronautica Civil (DGAC) in 2019.

5.1 Maintenance Inspections

Cylinders used for transportation of hazardous materials in the U.S. must be authorized packaging, conforming to U.S. DOT or UN Standards, and be properly maintained, marked and requalified by an authorized DOT cylinder requalifier that receives a RIN approval number from the Pipeline and Hazardous Materials Administration (PHMSA).⁶ For DOT specification cylinders, testing and inspection requirements fall under the U.S. DOT, under 49 CFR 180.205, "General requirements for requalification of specification cylinders" and "Requirements for requalification for specification cylinders" fall under 49 CFR 180.209. The oxygen (O₂) and carbon dioxide (CO₂) cylinders require hydrostatic testing at a minimum of 5/3 times their service pressure, every five years. The halon cylinders installed in the engines involve hydrostatic testing at a minimum of two times their service pressure, every five years.

Because this was a Mexican carrier, Mexican regulations applied to the cylinders, which follow the same maintenance requirements under NOM-020-STPS-2011. The last requalification inspections for ten cylinders aboard the accident aircraft are found in Table 4.⁷ Jet Rescue safety guidelines require the medical team to determine whether sufficient air and oxygen are available for each transport. Before departure, compressed gas cylinders must be inspected to verify a minimum pressure of 700 psi for M, G, and H tanks and 1,000 psi for D and E tanks. All compressed gas cylinders must be turned off prior to disembarking.

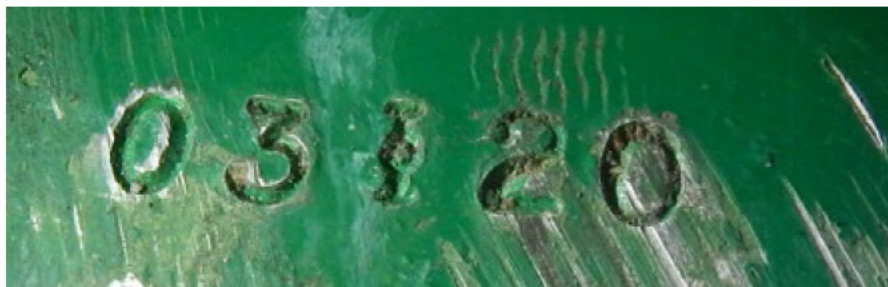
⁶ "Cylinder Requalifiers," <https://www.phmsa.dot.gov/hazmat/pressure-vessels-approvals/cylinder-requalifiers>.

⁷ The handheld fire-extinguisher (Halon Cylinder #3) was not a DOT specification cylinder and meets the limited quantity exceptions regulation (49 CFR 172.315), which requires no requalification period. It is issued an approval number and rated for marine use under 46 CFR 162.028.

Table 4: Last inspection of cylinders aboard Learjet 55

Oxygen Cylinder	Requalification Date	RIN No.
Cylinder #1	Mar-20	Requalifier Stamp
Cylinder #2	Mar-20	Requalifier Stamp
Cylinder #3	n/a	n/a ⁸
Cylinder #4	n/a	n/a
Cylinder #5	n/a	n/a
Cylinder #6	Jun-21	Requalifier Stamp
Cylinder #8	Apr-24	I022
Life Raft Cylinder		
CO2 Cylinder # 7	Jun-2017	A340
Fire Suppression		
Halon #1	Nov-21	I022
Halon #2	Nov-16	I022

Three of the oxygen cylinders were marked with a requalifier stamp, which identifies the facility that certified the cylinder on the date of the inspection (see Figure 27). The operator reported that the three oxygen cylinders were qualified in March 2020 by Infra Toluca, a facility in Santa Maria Totoltepec, Mexico. This facility did not receive an approval through PHMSA, indicating that the requalification was not done in compliance with U.S. regulations. The operator also reported that the medical oxygen cylinders were installed inside the aircraft and therefore recharged through a reservoir tank, but did not provide a date of the last refill.⁹ The two halon cylinders for the fire protection systems and the crew oxygen cylinder were requalified by a PHMSA approved cylinder requalifier, "I022", listed as Mantenimiento Aereo Y Partes Pegrava, S.A. DE C.V.

**Figure 27: Requalifier stamp found on oxygen Cylinder #1.**

⁸ In cases where cylinder requalification was not due at the time of the accident, the requalification date is listed as n/a.

⁹ According to 49 CFR 173.301(a)(6), a cylinder may not be filled if it is overdue for periodic requalification.

The carbon dioxide cylinder was stamped with its last requalification date of June 2017 by PHMSA-approved cylinder requalifier, "A340", listed as City Fire, Inc., in Hollywood, Florida. It was due for requalification in 2022. The aircraft operator told the NTSB that though they keep inventory of their life rafts and carbon dioxide cylinders, they have no record of this life raft or cylinder aboard the accident aircraft. They believe an unidentified crew member installed the equipment without authorization.

6.0 Evidence collected for laboratory examination

As previously mentioned, the following evidence collected during post-accident inspections of the compressed gas cylinders and onboard life raft conducted by NTSB investigators was submitted to the NTSB Materials Laboratory:

1. ERA25MA106-HAZ-02: Broken valve stem removed from Cylinder #2
2. ERA25MA106-HAZ-03: Compressed oxygen cylinder with broken valve stem from Cylinder #3
3. ERA25MA106-HAZ-04: Broken valve stem removed from Cylinder #4
4. ERA25MA106-HAZ-05: Broken valve stem removed from Cylinder #5
5. ERA25MA106-HAZ-06: Broken valve stem removed from Cylinder #6
6. ERA25MA106-HAZ-07: Broken valve stem and dip tube removed from Cylinder #7
7. ERA25MA106-HAZ-08: Compressed oxygen cylinder with through wall fracture and broken valve stem from Cylinder #8
8. ERA25MA106-HAZ-09: Valve body type CGA870
9. ERA25MA106-HAZ-10: Life raft inflation valve assembly

E. ATTACHMENTS

Attachment 1 - Maintenance Records of Life Raft RAF1210, Serial No. 2367KBA

Attachment 2 - Operations and Maintenance Manual of Life Raft RAF1210

Attachment 3 - Safety Data Sheet Aviation Life Rafts

Attachment 4 - Operator Maintenance Records of Cylinders

Attachment 5 - Learjet 55 Illustrated Parts Catalog

Attachment 6 - Jet Rescue Safety Guidelines

Submitted by:

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Sr. Hazardous Materials Accident Investigator