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In Aircraft Fueling, Fire Prevention Requires Strict Compliance With Routine Procedures

Universally recommended practices for fueling transport aircraft have helped to maintain a low incidence of jet-fuel fires on airport ramps. Despite the few accidents on record, complacency, poor training, inadequate compliance with procedures or neglected maintenance can cause serious consequences.

FSF Editorial Staff

To safely dispense Jet A-1 fuel and Jet A fuel — the main types used by civil transport aircraft — fuel service personnel must have a correct perception of the risk of fueling fires.[1] Few examples of fueling fires can be found in the aviation industry's safety record, and the typical fueler is unlikely to have witnessed a fueling fire. Nevertheless, a risk assessment of aircraft fueling operations in the United Kingdom and the fueling fires on record in other countries (Table 1, page 2) underscore the need for constant attention.

Although the report by the U.K. Health and Safety Executive (HSE) focused primarily on major Jet A-1 fuel spills at airports in the United Kingdom, significant findings about the causes and prevention of transport aircraft fueling fires were included.[2] The HSE report used the term "Jet A-1" (a kerosene grade of fuel that incorporates special low-temperature characteristics) but included Jet A fuel in its discussion of fuel spills and fueling fires. (Similarly, references to Jet A-1 in the remainder of this article include Jet A fuel unless otherwise noted.)

"The main consequence of a release of fuel was determined to be a pool fire if the spill were ignited," the report said. "In the event of a fuel spill, there is only a risk of fatality if the spill is ignited. The principal danger to the [fueler] and ground crew in such circumstances is that they may find themselves either soaked in fuel (due to a high-pressure spray) or … standing in a pool of fuel. In either case, if the spill were ignited, then such people would be likely to suffer severe injury or fatality."

None of the U.K. Jet A-1 fuel spills found in records resulted in a fire, and no U.K. airport contacted by researchers had experienced such a fire, the report said.

Table 1
Fueling Fire Occurrences, 1966–1998

Date	Location	Aircraft
Oct. 18, 1966	(no information)	Lockheed Constellation

"During a preflight servicing … a fire resulted when a tractor was inadvertently driven across a fueling hydrant, rupturing a hose connection and subsequently igniting the escaped fuel. … Damage from the fire was major at the underside of the right wing, no. 4 nacelle, flap and aileron, and ground equipment sustained major damage. Two men suffered sprained and broken ankles when they jumped from the right wing, and a third employee suffered minor burns. … [The U.S. Federal Aviation Administration, in its response, said in part,] "We share your concern over the hazards present in fueling operations, particularly those unavoidably conducted in congested ramp areas. Also, we concur that it may be beneficial to call special attention to the subject incident. A maintenance bulletin is being prepared to accomplish utmost safety discipline during fueling operations."[1]

Date	Location	Aircraft
May 3, 1970	Minneapolis, Minnesota, U.S.	Boeing 727

"The airplane was being refueled [with Jet A[2]] using a single-point fueling system. About 2,000 pounds [907 kilograms] of fuel had been loaded when a heavy muffled explosion occurred in the no. 2 [fuel tank] (cheek tank). A puff of gray smoke came from the [left] wing-tip vent. Fueling was immediately terminated, all electrical power on the airplane was cut off, the APU [auxiliary power unit] was shut down, and the aircraft was defueled. No injuries had occurred. No damage was apparent from an external check of the aircraft. The damage largely was confined to the secondary structure within the no. 2 tank on the [left] side of the airplane. When inspecting the tank, it was found that the structure above the top level of the fuel was heavily soot-blackened. … It is presumed, in the absence of any electrical sources, that ignition resulted from a static discharge within the no. 2 tank. … No mitigating action was taken since no root cause for an ignition source was found."[3]

Date	Location	Aircraft
Dec. 23, 1970	Minneapolis, Minnesota, U.S.	Boeing 727

"The airplane was being refueled using under-wing refueling at the [right] wing station. Approximately 3,000 pounds [1,361 kilograms] of fuel had been loaded when a muffled explosion was heard. Fueling was immediately stopped and a minor leak was noticed coming from the area of the inboard fuel boost pump in the [left] wing. There was no fire and no injuries to any of the servicing personnel. Over-pressure damage to the aircraft's no. 2 fuel tank was extensive but minor in nature. … Evidence of soot deposits was found within the left and [right] surge tanks, the no. 2 fuel tank and at each wing-tip tank vent-scoop area. The investigation that followed the incident indicated that the probable cause of the explosion was delivery by the ground fueling system of highly charged fuel into the airplane. However, the investigation was unable to pinpoint the exact source of the ignition that triggered the combustion of the fuel vapor. The evidence is very strong, however, that the source was static discharge internal to the no. 2 fuel tank. … The paper-element filter separators in the ground refueling equipment were replaced with filters that did not create electrostatic charging."[3]

Date	Location	Aircraft
1973	Denmark	(no information)

"Static electricity ignited fuel following a split in [the fueling] hose. Fire quickly was brought under control. No fatalities or casualties [occurred]."[4]

Date	Location	Aircraft
June 21, 1973	Toronto, Ontario, Canada	McDonnell Douglas DC-8

"The airplane was at the gate, and a ground power unit was connected to the airplane's electrical system. The aircraft was being fueled with Jet B (JP-4), but examination of the left wing tanks revealed a fairly even mix of Jet A-1 and Jet B. Some Jet A-1 was already in the tanks. … Shortly thereafter … a fuel-tank explosion [in the right wing] blew off pieces of the right wing top skin and spar structure. Burning fuel rapidly engulfed the right wing [and the aircraft was destroyed]. … Burning fuel ran from the ruptured no. 4 tank and fuel manifold over the leading and trailing edges of the wing. The fueler under the right wing ran toward the front of the aircraft through the fire that now extended to the ground, and he was doused with burning fuel. Both the [fueler] and the cargo handler were seriously burned. No passengers had boarded the aircraft. The nine crewmembers aboard evacuated through the loading bridge. The findings of the Canadian Department of Transportation were that the initial explosion occurred in the no. 3 alternate tank and that the fuel vapor was ignited in the wing vent system. The source of ignition of fuel vapor in the wing-tank vent system could not be definitely determined, but was suspected to have originated outside the aircraft."[3]

Date	Location	Aircraft
Oct. 24, 1973	New Zealand	(no information)

"During fueling operations, some fuel spilled onto the stub wing; at start-up, a sheet of flame from the exhaust ignited the fuel. The fire extinguisher was not in its normal position on the loading vehicle, and so there was no means of controlling the fire immediately."[4]

Date	Location	Aircraft
1977	United States	McDonnell Douglas DC-8-33F

"[The airplane] was destroyed by fire during fueling. No fatalities [occurred]."[4]

Date	Location	Aircraft
1983	Barbados	Boeing 747

"The nozzle came off the end of the deck hose during fueling; 30 liters [7.9 gallons] of [Jet A-1] fuel sprayed onto a hot engine (the engine just shut down) and caught fire. Prior to the incident, an internal mesh strainer had been inspected by opening a quick-connect coupling (designed to aid inspection) [with] only a single locking mechanism [that] did not lock/quick-connect properly. Two engines and a wing were damaged."[4]

Date	Location	Aircraft
1986	Antigua, West Indies	Lockheed L-1011

"The inlet hose burst at 125 pounds per square inch [(0.9 kilopascals) during hydrant fueling]. [Jet A-1 fuel] spilled onto the engine, resulting in a fire. The hose had just been tested [but fuelers had] not been testing hoses according to [appropriate] standards. The hose was in bad condition, [which had been] noticed visually before the failure. The cause was poor maintenance. [The total fuel spill was estimated to be 264 gallons (1,000 liters) based on the description in the U.K. Air Accidents Investigation Branch incident report]."[4]

Table 1
Fueling Fire Occurrences, 1966–1998 *(continued)*

Date	Location	Aircraft
July 14, 1988	Atlantic City, New Jersey, U.S.	Boeing 727-31
"Fuel truck exhaust fire [occurred] while refueling aircraft. [The crew] evacuated the aircraft via stairs. Faulty truck exhaust [was] not reported."[5]		
Aug. 10, 1989	Minneapolis, Minnesota, U.S.	Boeing 757-251
"[The aircraft] had a fire during refueling due to a pumper truck spraying fuel on the no. 2 engine. The fuel truck had a ruptured gasket."[5]		
1990	Canada	Boeing 737
"Failure of a fueling hose led to fire damaging the left wing and fuselage of [the] aircraft."[4]		
Sept. 17, 1995	United Kingdom	Fokker 70
"During Jet A-1 fueling (passengers being embarked), the refueler [fuel truck] engine caught fire. The fire was extinguished, and passengers were evacuated."[4]		
1996	Canada	Gulfstream I
"[The aircraft] caught fire during a defueling operation due to static discharge between the ground operator and the fuel tank. No fatalities [occurred]."[4]		
Dec. 1, 1998	Miami, Florida, U.S.	Boeing 747-259B
"A fuel truck fire spread to a wing during fueling."[4]		

[1] U.S. National Transportation Safety Board (NTSB). NTSB Recommendations to [U.S. Federal Aviation Administration (FAA)] and FAA Responses Report. Report no. A-67-9.

[2] U.S. Federal Aviation Administration (FAA). Advisory Circular (AC) 150/5230-4, *Aircraft Fuel Storage, Handling, and Dispensing on Airports.* August 27, 1982. The AC says, "Three classifications of aviation turbine fuels are universally referred to as 'jet fuels' and are generally described as Jet A, Jet A-1 and Jet B. They are used in 'turbojet' and 'turboprop' engines. These three classifications are: Jet A, a relatively high-flash-point distillate of the kerosene type, having a –40 degrees Fahrenheit [F] (–40 degrees Celsius [C]) freezing point (maximum); Jet A-1, a kerosene type similar to Jet A but incorporating special low-temperature characteristics for certain operations, i.e., –53 degrees F (–47 degrees C) freezing point (maximum); [and] Jet B, a relatively wide-boiling-range volatile distillate having a –58 degrees F (–50 degrees C) freezing point (maximum). The [U.S.] military terminology is JP-4 and it has a freezing point of –72 degrees F (–58 degrees C)."

[3] FAA. Aviation Rulemaking Advisory Committee, Fuel Tank Harmonization Working Group. *Final Report.* Task Group 1, "Service History/ Fuel Tank Safety Level Assessment." Appendix A, "Details of Previous Tank Explosions." July 1998. 27–30. The report was submitted jointly by the American Petroleum Institute; Aerospace Industries Association; Air Line Pilots Association, International; Air Transport Association of America; European Association of Aerospace Industries; FAA; General Aviation Manufacturers Association; International Air Transport Association; and Joint Aviation Authorities.

[4] U.K. Health and Safety Executive. "Quantified Risk Assessment of Aircraft Fueling Operations." Report no. AM5204. July 2000. 33–35.

[5] FAA. Incident Data System report no. 19880714054459C and report no. 19890810065269C.

Sources: U.S. National Transportation Safety Board; U.S. Federal Aviation Administration; U.K. Health and Safety Executive

Prevention of fueling fires involves compliance with the technical aspects of recommended procedures and recognition of risk factors of the typical ramp environment at airports serving air carriers.

"The fueling activity is the key safety-critical operation conducted during an aircraft [turnaround]," the report said. "From interviews with airport staff and observations made on the [ramp,] it seems that other handling agents involved in the [turnaround] need to be more aware of the safety implications of the fueling operation and be more accommodating around the aircraft. Ground-handling staff training needs to be improved with respect to ensuring that staff appreciate the importance and safety aspects of the fueling operation, and accept that fueling is a priority activity."

Among recent changes in U.K. fueling operations have been reductions of personnel used to fuel each aircraft and elimination by some airlines/contractors of an overseer who has explicit overall safety responsibility at every aircraft turnaround, the report said.

The report said that the use of more than one person enables the most rapid response to emergencies while fueling aircraft from the hydrant pits built into the ramp, for example. At airports with a distributed hydrant-fueling system, fuel stored in large tanks at an airport fuel farm is distributed under pressure via underground pipes to hydrant pits. Hydrant pits — typically two per aircraft fueling location — contain a hydrant pit valve that the fueler operates by opening and closing an attached pilot valve. To upload fuel from a hydrant pit, one fuel hose connects the hydrant pit valve to an aircraft fuel-servicing hydrant vehicle (hydrant dispenser) and another fuel hose connects the hydrant vehicle to the aircraft fuel system.[3]

In the United Kingdom, fuelers typically use a lanyard to operate the pilot valve in the hydrant pit. They unreel the required length of vinyl-coated-steel lanyard cable from the hydrant vehicle and attach this lanyard to a short lanyard on the pilot valve in the hydrant pit. The lanyard must be positioned on the ramp to be accessible in an emergency. In normal operation, or if a fuel leak or a fueling fire occurs, one pull on the lanyard closes the pilot valve, which closes the hydrant pit valve within two seconds to five seconds. In the United States, fuelers typically use a similar safety system but with an air-actuated pilot valve that can be operated from the same deadman control[4] that opens and closes the hydrant pit valve and the hydrant vehicle's inlet coupler (a quick-connect, hose-to-hydrant coupling), the report said.

"In the past [in the United Kingdom and in some other countries,] fueling was carried out by more than one person," the report said. "In this situation, the time for detection of a [fuel] release and the operation of the [hydrant pilot-valve] lanyard [was] likely to be relatively short. However, fueling in the United Kingdom is now a [one-person] operation and the [fueler's] time is split between looking at the gauges on the fueling vehicle and looking at the gauges in the aircraft wing (which, on a large aircraft, is accessed by standing on a raised platform). During the fuel transfer, the [fueler] is unlikely to visit the hydrant and, in some circumstances, [the fueler] might not even be able to see [the hydrant]. If the inlet coupler is hit [by a ramp vehicle] in this environment, the time for detection of the [fuel] release and operation of the lanyard is likely to be significantly longer. In this case, with a typical flow rate of 4,000 liters [1,057 gallons] per minute, a major spill is likely.

"Based on observations and discussions with various representatives from fuel companies and airport authorities, it appears that … requirements [for an overseer of fueling operations][5] are not met on all occasions. … There is not always someone supervising the technical aspects of the fueling operation, besides the fuel operator; whether that [overseer] be another fuel company representative, a member of the flight crew or a maintenance engineer. … It was not always apparent from observations of [turnaround] operations and fueling, during this study, that technical supervision of fueling and safety supervision of ground-servicing activities was present. … This approach is not structured and does not provide clear roles and responsibilities for staff."

Among U.K. airports, about half of the fueling operations use hydrant vehicles and about half of the fueling operations use fuel trucks (which pump fuel into aircraft directly from the storage tank on the truck).[6] Hydrant vehicles and fuel trucks both have systems to filter fuel, dispense fuel, regulate fuel pressure, measure fuel quantity and enable fuel-quality sampling. They also have emergency controls.

Typical hydrant fueling systems have three emergency controls: the deadman control (which the fueler grips to start/stop fuel flow), the hydrant pilot valve and emergency shutoff buttons (ESBs) located within a short distance from fueling areas to isolate a hydrant from its source of fuel.

Fuel truck safety features include brake-interlock systems (with emergency override) that automatically apply the brakes when equipment has not been stowed properly, a deadman control and devices to prevent operation of the engine-driven fuel-transfer pump if the parking brake has not been set. The fueler typically connects a hose from the fuel truck to the aircraft and begins pumping, while monitoring and controlling the fuel flow.

The maximum amount of fuel that can be dispensed safely into an aircraft has important implications for preventing fuel spills and avoiding fueling fires. Separate overfill-protection systems and fuel-metering systems typically are provided, but either system can malfunction, and human errors can contribute to fuel spilling from a fuel tank vent system.

"The maximum permitted uplift of fuel into a tank is 2 percent below the point at which the fuel would flood into the vent system," the report said. "This 2 percent provides a free space within the fuel tank to allow for thermal expansion of the fuel."

The HSE researchers were told during informal discussions with airports, fuel service companies and airlines that small fuel spills occur frequently.

"However, the quantity spilled in the majority of the cases is relatively small (less than 50 liters [13.2 gallons]) and as a result, these types of spills are not normally investigated further," the report said. "The literature search only identified a small number of major spill incidents. A major conclusion drawn from the completion of the literature search was that it is difficult to confirm anecdotal incidents and to obtain incident reports as there is no worldwide [body] or national body that specifically collects and stores information on aviation fuel spills."

The predominant use of Jet A-1 in the transport category aircraft fleet, superseding the large aircraft that used avgas, has been significant in reducing the risk of fueling fires but has not eliminated the risk, the report said. Two of the principal reasons are less likelihood of ignition in most circumstances and, if the fuel ignites, slower flame spread across a pool of Jet A-1 fuel, providing more time for people to escape injury. (See "Fire Department Monitors, Enforces Fueling Equipment Repairs," page 5).

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Fire Department Monitors, Enforces Fueling Equipment Repairs

A report by the U.K. Health and Safety Executive (HSE) said that several properties of Jet A-1 fuel are important in helping to prevent fueling fires in most scenarios — for example, a low-pressure spill onto a ramp at moderate ambient temperatures.[1] The HSE report focused on Jet A-1 (a kerosene grade of fuel that incorporates special low-temperature characteristics) but included Jet A fuel in its discussion of fuel spills and fueling fires. (Similarly, references to Jet A-1 in the remainder of this article include Jet A fuel unless otherwise noted.)

One property is that liquid Jet A-1 has to be heated above its flash-point temperature[2] (40 degrees Celsius [C], 104 degrees Fahrenheit [F]) for an external ignition source to cause the fuel to burn. Another property is that for spontaneous combustion to occur, liquid Jet A-1 must be heated to its autoignition temperature[3] (220 degrees C, 428 degrees F). A third property is that the spread of flame across a pool of Jet A-1 is relatively slow, compared with aviation gasoline (avgas).

Nevertheless, a spray of Jet A-1 that contacts an ignition source is more easily ignited than a pool (the spray temperature does not need to be above the fuel's flash point). Ignition of a flammable spray typically would result in a flash fire followed by a pool fire, the report said.

Jet A-1 has other properties that can have an adverse effect on safety, however. Among them are slow evaporation at moderate temperatures, slow dispersion of vapor (which is five times heavier than air) and low electrical conductivity, which means that hazardous sparks can be generated by the differences in electrical potential (static charges) in fuel, aircraft and vehicles.

"A bonding line is used to connect the fueling vehicle to the aircraft prior to commencing a fuel transfer," the report said. "This is to ensure that there is no difference in electrical potential between the two vehicles, which might otherwise cause static sparks, e.g., when the delivery hose is connected or disconnected from the aircraft. Also, Jet A-1 contains antistatic additives to aid the safe dissipation of any static charges which might be generated during the fueling process."

With these fuel properties in mind, fire departments identify diverse safety problems among aircraft fuelers and fueling equipment, said David Covington, training district chief of the San Antonio (Texas, U.S.) Fire Department. Covington served 11 years as the fire department's aircraft rescue and fire fighting (ARFF) coordinator at San Antonio International Airport.[4]

"Jet A fuel has a high flash point, but in a hose with a leak, the mist will ignite just as easily as avgas," Covington said. "The other problem with Jet A is its autoignition temperature. For avgas, this temperature is 840 degrees [F; 449 degrees C], so a hot surface has to be at that temperature to ignite the fuel without an external flame. Not a lot of things at an airport are at 840 degrees. For Jet A, the autoignition temperature is about 475 degrees [F; 246 degrees C]. But a lot of surfaces on a jet aircraft are approaching that temperature — an exhaust pipe, hot jet engine or hot brakes. A fueler may think safe fueling conditions exist, but a hot surface could cause Jet A to ignite."

Fuelers sometimes watch training demonstrations of lighted cigarettes or open flames that fail to ignite a small pool of Jet A fuel, but readily ignite avgas. To prevent complacency about fueling fire safety, fuelers must understand the unusual factors that can cause Jet A to burn more easily than in the typical demonstrations, Covington said.

"The most effective way to train fuelers is to make sure they understand that there is danger in the high-flash-point fuels as well as the low-flash-point fuels," he said. "In our training demonstration, we heat a small dish of Jet A to 100 degrees [F; 38 degrees C] to simulate San Antonio on a hot day and to show how much more easily hot fuel can be caused to ignite."

The airport's experience with fueling fires shows the value of practical training for fuelers in fire fighting and using all the equipment available.

"We create a three-foot-by-six-foot [0.9-meter-by-1.8-meter] pan fire in training," Covington said. "Each fueler puts out a Jet A fire with the extinguishers. We have had two cases where trained personnel put out fuel truck engine fires with an extinguisher before ARFF vehicles arrived." Neither fire spread to the fuel truck's Jet A tank. In one of the fires — which involved the engine compartment of the fuel truck — the fueler abandoned the truck and ran from the area, but a nearby maintenance technician put out the fire using an extinguisher and the methods learned in fire department training.

"The key part of training is making sure that fuelers do not become complacent," he said. "Once they realize that they have a big potential problem, they pay attention to their parking distances, to leaks, and to checking fuel-nozzle screens for rubber particles or debris — important steps in preventing fuel contamination, reducing static electricity and judging the susceptibility of the hose to a break or a leak."

Covington said that systematic checks of fuel hoses, gauges, connections and the entire fuel truck — daily, weekly and monthly — are important.

"We always are looking for the leak, the hose that gets kinked and does not get repaired, the hose that could blow under pressure," he said. "The fire department's quarterly checks only reveal what the fuelers are *not* doing. Operators sometimes rely on us as their sole quality control, which is not appropriate."

Some major fuel fires — such as a fuel farm fire at Denver Stapleton Airport, Colorado, U.S., in 1990 — have been cited widely by ARFF organizations as case studies and for considering procedural changes.[5]

"After the Denver Stapleton fire, all airport fire department inspectors were instructed to pay particular attention to fueling operations and to how to adapt ARFF trucks to fighting fires in fixed fuel-storage facilities," he said. "This was the only time in recent years, that I can remember, when it was emphasized that we really needed to more closely monitor the fueling operation. I have heard of no special alert or lessons from the 1998 Miami fueling truck fire, for example." (See "Fueling Fire Shows Importance of Equipment Condition, Training," page 12.)

Fueling vehicles in the United States typically must carry 20B:C-listed fire extinguishers (two per fuel truck; one per hydrant vehicle), each weighing about five pounds (2.3 kilograms). Under local fire codes, 80B:C-listed wheeled extinguishers with at least 125 pounds (57 kilograms) of extinguishing agent also must be available on the ramp. (U.S. Underwriters Laboratories rates with relative numbers the fire fighting capacity of such dry-chemical fire extinguishers, and designates with letters their suitability for attacking flammable-liquid fires [Class B fires] and electrical-equipment fires [Class C fires].)

"Fuelers are accustomed to handling 20B:C extinguishers or 40B:C extinguishers, but they may never get used to using the 80B:C wheeled extinguisher units, required every 300 feet [91.4 meters] on the ramp when fuel flows are greater that 200 gallons [757 liters] per minute," he said. "We monitor fuelers so that they do not block access to the wheeled unit, but sometimes we find that a fueler does not know where these wheeled units are located. When filling at a remote location, they typically will not take the wheeled unit to within 100 feet [30.5 meters] upwind of the aircraft, as required."

San Antonio firefighters have authority to issue citations for fire-code violations, to take out of service any of the more than 50 airport fueling vehicles and to require a fueler to cease fueling in the interest of public safety (for example, when lightning is in the airport vicinity), he said. Nevertheless, fire department inspectors do not interfere with fueling operations without cause, he said.

"Fueling vehicles are not in the same category as aircraft — not as highly maintained," Covington said. "Fuelers must be monitored to keep up on their maintenance and repairs. They have a lot of inspections by airlines on the fuel-quality side of fueling operations, but we are monitoring to see that they stay safe from the fire-safety aspect. Trucks often are old, and we have had to take them out of service just to clean the engine; we have had fires because of hydrocarbon buildup on the engine.

"Fuelers who have been around the airport a long time typically tell us when someone else has had a problem. Most fuelers are not intentionally trying to violate safety procedures — they believe that they are making something positive happen. But we see jury-rigging [temporary, nonstandard repairs].

"Every fueling-fire incident I can think of has involved some kind of noncompliance with procedures. Once, a fueler accepted delivery of an 8,000-gallon [30,283-liter] fuel load, hooked up the fuel hose and went away for a cup of coffee. He came back to the fuel truck to find that he had downloaded to a full tank instead of to an empty tank, causing a large fuel spill."♦

— FSF Editorial Staff

References

1. U.K. Health and Safety Executive. "Quantified Risk Assessment of Aircraft Fueling Operations." Report no. AM5204. July 2000.

2. U.S. National Fire Protection Association (NFPA). *NFPA 407 Standard for Aircraft Fuel Servicing, 1996 Edition* defines *flash point* as the fuel temperature at which kerosene-grade turbine fuels produce flammable vapors in ignitable amounts.

3. *NFPA 407* defines *autoignition temperature* as the minimum fuel temperature at which kerosene-grade turbine fuels will "initiate or cause self-sustaining combustion independently of any sparks or other means of ignition."

4. Covington, David. Telephone interview with Rosenkrans, Wayne. Alexandria, Virginia, U.S. March 21, 2001. Flight Safety Foundation, Alexandria, Virginia, U.S.

5. U.S. National Transportation Safety Board (NTSB). *NTSB Recommendations to [U.S. Federal Aviation Administration (FAA)] and FAA Responses.* Report no. A-91-99. The report said, "On Nov. 25, 1990, a fire erupted at a fuel storage and dispensing facility about 1.8 miles [2.9 kilometers] from the main terminal of Stapleton International Airport at Denver, Colorado[, U.S.]. From the time fire fighting efforts were initiated, immediately after the fire erupted, until the fire was extinguished, a total of 634 firefighters, 47 fire units, and four contract personnel expended 56 million gallons [212 million liters] of water and 28,000 gallons [105,992 liters] of foam concentrate. The fire burned for about 48 hours. Of the 5,185,000 gallons [19.6 million liters] of fuel stored in tanks at the farm before the fire, about three million gallons [11.4 million liters] either were consumed by the fire or lost as a result of leakage from the tanks. No injuries or fatalities occurred as a result of the fire."

Spill Scenarios Show Possible Seriousness of Fueling Fires

The report identified seven fuel spills — some involving fueling fires — of relevance to the study objectives. The spills included the following:

- In 1983, 30 liters [7.9 gallons] of Jet A fuel ignited during fueling of a Boeing 747 in Barbados. The report said, "A quick-connect coupling came apart, resulting in the nozzle coming off the end of the deck hose. Fuel sprayed onto a hot engine (engine just shut down) and caught fire. Prior to the incident, the internal mesh strainer had been inspected by opening the quick-connect coupling (designed to aid inspection). After inspection, [it was determined that] the single locking mechanism was not closed properly. Two engines and a wing [were] damaged.";

- In 1986, an estimated 1,000 liters [264 gallons] of Jet A fuel ignited during aircraft fueling in Antigua. The report said, "The inlet hose burst at 125 pounds per square inch [0.9 kilopascals] and fuel spilled onto the engine, resulting in a fire. The hose had just been tested; however, it was found that the hoses had not been tested according to [appropriate] standards. The hose was also in a bad condition, which was noticed visually before the failure.";

- On March 29, 1997, 7,500 liters [1,981 gallons] of Jet A fuel were spilled during aircraft fueling at an airport in Australia. The report said, "The fueling operator heard the gushing of the fuel and, on observing the spraying jet [fuel], released the [deadman] control and pulled the [hydrant pilot valve] lanyard to stop the [fuel] release. Neither of these actions stopped the fuel release. Eyewitness accounts put the jet of fuel at between 15 [meters] to 16 meters [49 feet to 53 feet] in the air. Fuel sprayed onto the front section of the aircraft, over the front and roof of the terminal building. The estimated ground spill area was 500 square meters [598 square yards]. Some fine wind-borne spray landed on a vehicle crossing the [ramp] area approximately 80 meters [263 feet] away.";

- In 1997, 6,500 liters [1,717 gallons] of Jet A fuel were spilled during hydrant aircraft fueling at an airport in the United Kingdom. The report said that a mobile baggage-belt loader, while being driven in reverse, struck the hydrant inlet coupler in a fuel hydrant pit. The impact fractured the connection. Witnesses described "a fountain of fuel gushing up some 12 meters to 15 meters [39.4 feet to 49.2 feet], which continued for several minutes until manual activation of the airport's fuel safety shutdown system isolated the release. … No ignition of the fuel occurred. However, during the incident several ground staff, members of the cabin crew and the aircraft were [soaked] with the fuel."; and,

- In 1997, 3,000 liters [792.5 gallons] of Jet A fuel were spilled during hydrant aircraft refueling at an airport in New Zealand. The report said, "During a fueling operation of a Boeing 747 aircraft, the elbow piece of the hydrant inlet coupler fractured, releasing fuel. Initially the fractured material partially opened and escaping high pressure fuel was directed horizontally. The crack propagated rapidly and within a few seconds the elbow broke away completely. Without any obstruction, the fuel was released as a vertical jet to a height of 25 meters [82 feet]. At first, the lanyard was caught up in the fuel jet and could not be reached by the [fueler]. Approximately 12 seconds later, the lanyard fell from the fuel flow and the [fueler] was able to pull it, isolating the release. The time from the initial fuel release to isolation was approximately 24 seconds."

The report said that researchers' observations and their review of other occurrences showed the following problems or unsafe practices:

- "There was a general lack of understanding by all operators of the hydrant pipeline system and fueling operation;

- "Permission was given by a fire officer at [an] incident scene to use a camera with a flash attachment;

- "There was a general lack of knowledge regarding the risks of static electricity generating a spark when removing certain types of clothing;

- "A fueler jammed the [deadman control] in place on a [fuel truck as researchers watched fueling operations at one U.K. airport] (rather than holding onto it) and moved away from the vehicle;

- "A fueler did not attach a lanyard to the pit valve during hydrant fueling [at the same U.K. airport];

- "There was a lack of immediate control of the incident area;

- "The owner of a portable generator … failed to keep a clear access around the [ESB] both visually and physically;

- "The [ESBs] were not highly visible; [and,]

- "The airline operator had not carried out a risk assessment on baggage vehicles driving between engines when a fueling vehicle was in position."

Aircraft rescue and fire fighting (ARFF) personnel attended 83 fuel spill incidents per year at Airport A — one of seven unidentified U.K. airports (three using hydrant fueling, four using truck fueling) that provided spill reports for the HSE study.

The report estimated that ARFF personnel were likely to be called out once in every 843 fueling operations at the airport.

"Reviewing the spill records of [Airport A] showed that the aircraft [fuel systems] caused 206 (78 percent) of the 264 spills [from January 1994 to June 1998]," said the report. "A 'faulty [volumetric] shutoff valve' was the most frequent cause … with a recorded 84 incidents (32 percent); this was followed by 'tanks failed to shut off,' with 48 incidents (18 percent)." The volumetric shutoff valve automatically stops fuel flow during fueling when the fuel gauge reaches a preset value on the aircraft fuel-control panel.

The report said that human-error incidents occurred less frequently than hardware failures but tended to result in relatively large spills of Jet A-1 fuel. Hardware failures occurred more frequently but the quantities of spilled fuel tended to be relatively small.

"This analysis shows that faults associated with the aircraft accounted for the majority of fuel spilled at [another U.K.] airport and aircraft venting was the main type of spill," the report said. "Some of the possible causes for an aircraft to vent fuel are as follows:

- "[Fueler] selects the wrong quantity on the fuel control panel resulting in overfilling, and the overfill protection system fails (human error and hardware failure);

- "Fuel control panel fails to stop fuel flow when the selected quantity [is] reached, resulting in overfilling, and the overfill protection system fails (hardware failure);

- "[Fueler] overrides [the volumetric shutoff valve] by opening the circuit breakers and then accidentally overfills the aircraft fuel tank (human error); [and,]

- "[Fueler] overrides [the volumetric shutoff valve] by opening the circuit breakers and fills the aircraft fuel tank completely (including free space). An increase in ambient temperature causes the fuel to expand, which results in fuel being vented (human error)."

The report said that in hydrant-fueling scenarios, vehicle impact damage was the most significant contributor to major fuel spills because of likely damage to the hydrant delivery hose, the hydrant inlet coupler or the hydrant pipe (with a possible high-flow fuel release).

"The main factors affecting the likelihood of vehicle impact damage are concerned with aspects of the safety management on the ramp and the visibility of the hydrant coupler and the hose," the report said. "Congestion around the aircraft and time pressure can also be significant contributory factors."

Among fuel-truck scenarios, the major fuel spills occurred from the aircraft surge tank vent. The fuelers were the last line of defense in noticing the overflow through the aircraft surge tank vents and in taking corrective action. Nevertheless, a fueler may not detect such an overflow in a timely manner, the report said.

The report said, "Careful consideration needs to be given to the regular testing of the safety features on the fueling vehicle.

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Written Procedures, Integrated Training Help Prevent Fueling Fires

Each aircraft fueler has a significant responsibility for ramp safety, but an individual's effectiveness in preventing fueling fires is influenced by hiring practices, training, the safety orientation of supervisors and the fuel-service company's procedures, said Ronald Pattie, vice president of technical services for Aircraft Service International Group (ASIG), a U.S. company that also has operations in Europe and the Caribbean. Pattie has served on aircraft fueling standards committees of the Air Transport Association of America (ATA) and the U.S. National Fire Protection Association (NFPA); he began his career as an aircraft fueler in 1968.[1]

"Different industry standards groups publish recommended practices," Pattie said. "Complying with those — and ensuring that every piece of equipment is cycled through maintenance every 30 days for inspections and testing — is by far the best fire protection. Most fueling fires that occur on the ground will be generated by a fuel drip, fuel system leak or an engine leak on a truck. During regular flow testing and checking of each piece of aircraft fueling equipment is the best time to inspect engines, brakes, lights, drips, etc."[2]

Although fueling fires have been rare, attention to the management of risks must be reemphasized periodically, he said.

"Our industry has come under a lot of scrutiny in the last four years to five years," said Pattie. "Increasing awareness of what we do has created more safety audits and studies of the procedures that we follow. The fueling industry is much more observant of recommended fire-safety practices today than 25 years ago. Safety is paramount because an airport ramp can be an extremely hazardous place: aircraft service vehicles — moving in all directions and carrying freight, baggage, food service and maintenance equipment — create congestion. Air traffic is busier, aircraft are bigger, and everyone is in more of a hurry now. We stress with all employees that they be very well aware of their circumstances at all times while working in the congestion and constant traffic on the flight line. The individual fueler affects the safety of his or her operation on a daily basis."

In the United States, Federal Aviation Regulations prescribe the minimum training required for fueling supervisors and for other employees involved in fueling operations at specific airports.[3]

"I have participated in industry standards committees with airline-fueling competitors — all of them are doing approximately the same things to comply with current safety standards," Pattie said.

Among current challenges to the safety practices of U.S. fuel-service companies are customer turnover and employee turnover.

"Customer turnover does have an effect, particularly the need to solidify training of fuelers in customer-specific procedures," he said. "Every time a fuel-service company turns over a contract, there are new technical procedures and adjustments to the fueler training program and to the technical aspects of the job.

"Aircraft service companies recognize that we have to manage fueler turnover; in our service niche, we will not eliminate it — but we must slow it down."

Some companies have responded to employee turnover by providing realistic information before hiring, training appropriately and writing procedures to help fuelers work confidently and safely, he said.

The pre-interview process assesses technical aptitude and interest in operating fueling equipment, trucks and aircraft fuel controls; and explains to applicants that their work environment can be cold, wet, tightly scheduled and intolerant of safety violations.

"We do not want to hire anybody who does not want to work under those conditions," said Pattie. "We would rather discourage people at an early stage so that they do not quit after three days."

Fuelers at ASIG, for example, receive two weeks of classroom instruction that includes more than a day of instruction on fire safety, he said.

"After they go through the first week of classroom instruction, trainees get the opportunity to see and touch the equipment, and ride with an experienced fueler," he said. "They are put back with the fueler after the second week of classroom work. They perform limited work with the experienced fueler, then take a check ride with a supervisor from general fueling, maintenance or quality control. The complete walk-around fueling process varies because of many different aircraft and customer requirements, but new fuelers typically are not allowed to work alone for 10 days to two weeks, then the trainer does a check-off to certify completion of training. Among U.S. airline fuel-service companies, this type of training is the norm."

ASIG standards require fuelers to demonstrate required knowledge of aircraft fuel systems and airport fuel systems. Much of the training involves calculating fuel loads, testing on proper methods of completing paperwork and invoices in different circumstances, and quizzes on daily operator inspections of fueling equipment, said Pattie.

"Instructors teach aviation acronyms, fire safety, handling hazardous materials, what to do for a spill or a leak and how to stop and contain a fuel release," Pattie said. "Whether teaching environmental hazards or fire hazards, subjects are all interrelated and integrated."

Fuelers also are warned about deliberate/negligent procedural violations that are considered cause for termination of employment. Prominent on the list are improper use of the deadman control[4] and overfilling of the fueling vehicles.

"We do not terminate employment for inadvertent accidents," Pattie said. "But if you tie off the deadman control or you are caught overfilling a fuel truck because of negligent behavior, your employment will be terminated.

"Our basic operating manuals provide instruction for the individual employee showing step-by-step how each job is performed. We have incorporated operational procedures required on the flight line. The manuals contain all training references and tell the employee, for example, how to get more information on using a fire bottle. Quality certification has value for marketing; more importantly, it forces you to put written procedures in place and to keep them updated."

Supervisors have an important role in demonstrating compliance with safety procedures and monitoring compliance by fuelers.

Pattie said, "The key to individual employee behavior is the front-line supervisor. Most supervisors are individuals who have come up through the rank and file. They have gone through fueling safety programs and have experience as a fueler."

Significant variations exist in the fueler-employment practices of different countries and regions.

"Most fuelers in the United States are new entrants into the work force; for many, this is their first job," Pattie said. "U.S. airlines hire companies to provide services that oil companies used to provide. As we have gone through this evolution, fuel-service companies have become more sophisticated and safety conscious — and airlines more willing to pay a better rate for safety and higher quality."

Continual improvement of fueling equipment technology also is important to fire safety, he said.

"Refueling hoses, for example, have been improved by using more carbon to help with the dissipation of static electricity," he said. "There also is less likelihood of current hoses breaking and causing fuel spills."

International standards for filtration, and fuel additives that improve static electricity dissipation also have advanced in the 1990s.

"The potential liability exceeds the cost of preventive measures," Pattie said. "The true competitive advantage is in limiting your liability by effective training programs and providing equipment and job functions that meet all of the current safety standards."♦

— FSF Editorial Staff

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2. These procedures are part of Air Transport Association of America Standard 103 (ATA 103), which consolidated the fueling safety requirements and technical requirements of all major U.S. air carriers. ATA 103 also requires fuel-service companies to notify customers about any changes in their fueling system or equipment, and to allow inspections by airline technical auditors. Most U.S. airlines also conduct a pre-audit using ATA 103 when contracting for fuel service, Pattie said.

3. U.S. Federal Aviation Regulations (FARs) Part 139.321, "Handling and Storing of Hazardous Substances and Materials," says, in part, that each airport certificate holder must "establish and maintain standards acceptable to the [U.S. Federal Aviation Administration (FAA)] administrator for protecting against fire and explosions in storing, dispensing, and otherwise handling fuel, lubricants and oxygen (other than articles and materials that are, or are intended to be, aircraft cargo) on the airport." The regulation says that the airport's standards must cover facilities, procedures and personnel training, and must address at least grounding and bonding; public protection; control of access to storage areas; fire safety in fuel farm and storage areas; fire safety in mobile fuelers, fueling pits, and fueling cabinets; and the fire code of the public body having jurisdiction over the airport. Since Jan. 1, 1989, the regulation also has required that at least one supervisor with each fueling agent must complete an aviation fuel training course in fire safety that is acceptable to the FAA administrator and that all other employees who fuel aircraft, accept fuel shipments or otherwise handle fuel must receive at least on-the-job training in fire safety from a supervisor who has completed an aviation-fuel training course in fire safety that is acceptable to the FAA administrator. Each airport certificate holder must, as a fueling agent, require all other fueling agents operating on the airport to comply with the airport's standards and must "perform reasonable surveillance" of all fueling activities on the airport. The regulation says, "A certificate holder need not require an air carrier operating under FARs Part 121 or FARs Part 135 of this chapter to comply with the standards required by [Part 139.321]." Each airport certificate holder must inspect the physical facilities of each airport tenant fueling agent at least once every three months for compliance with Part 139.321(b) standards and maintain a record of that inspection for at least 12 months. An independent organization may perform this inspection if acceptable to the FAA administrator and if the independent organization prepares a record of its inspection sufficiently detailed to assure the certificate holder and FAA that the inspection is adequate. Each certificate holder must obtain certification once a year from each airport tenant fueling agent that the training required by Part 139.321(e) has been accomplished. The regulation says, "Unless otherwise authorized by the [FAA] administrator, each certificate holder shall require each airport tenant fueling agent to take immediate corrective action whenever the certificate holder becomes aware of noncompliance with a standard required by [Part 139.321(b)]. The certificate holder shall notify the appropriate FAA regional airports division manager immediately when noncompliance is discovered and corrective action cannot be accomplished within a reasonable period of time."

4. A *deadman control* is a device that requires a positive continuing action by an operator to allow the flow of fuel.

Safety systems typically reside in a dormant condition for most of their operating time. Only when a fault occurs will they be called on to function. For this reason, it is important to ensure that the test interval and the test procedures of the fuel vehicle's safety devices are sufficient to meet the required level of reliability."

Human Judgment Determines Deadman Control Effectiveness

By design, the majority of leak sources during fueling of aircraft — from either a hydrant fueling system or from a fueling truck — can be isolated using the deadman control. (See "Written Procedures, Integrated Training Help Prevent Fueling Fires," page 8.) Nevertheless, fuelers sometimes have failed to operate the deadman control at the correct time (usually because the operator has not detected the fuel release or the operator has committed a procedural violation such as "tying off the deadman" for unattended fueling). Failure to detect a fuel release sometimes occurs because there is a small release that is not readily detectable, or because weather or darkness reduce visibility, the report said.

"It is possible for the [fueler] to jam the [deadman] control in the closed position and walk away," the report said. "In these circumstances, the [fueler] is unable to respond immediately to a fuel spill and, depending on his/her location, may not be aware that there is a [fuel] release. This action, however, constitutes a violation of the procedure (as it cannot be done inadvertently) and, as such, would be considered gross negligence."

In hydrant fueling, the lanyard-actuated pilot valve typically is the next line of defense in preventing a major fuel spill. Nevertheless, the fueler may fail to operate the pilot device (most often, by failing to connect the lanyard as specified in the standard operating procedures) or the pilot valve may fail to close on demand.

"If the lanyard is not connected, there is no other way to close the pit valve from a remote location [i.e., a ramp position 30 feet to 50 feet (15.2 meters to 10.7 meters) from the hydrant pit]," the report said. "Such an omission by the [fueler] is considered to be one of gross negligence … this unsafe act should be considered a distinct possibility and effective safety management measures implemented to reduce its occurrence. … Trapping [snagging] of a lanyard is considered to be the most likely event rendering this safety device inoperable."

The fuel shut-down system stops the fuel pumps and closes the valves to isolate part of the underground distribution system, but the ESB system is unlikely to prevent a major spill, the report said.

"There is evidence from past incident reports that personnel on the [ramp] may fail to activate the ESB when required," the report said. "This may be due to either a lack of knowledge about the fueling system and the operation of the ESBs, or it may simply be due to not being able to locate the ESB. … It is important to ensure that all the individuals on the [ramp] know when and how to isolate the fuel using an ESB, in the event that the [fueler] is unable to activate it. … A major leak at a fuel hydrant will be interpreted by the [system's programmable logic controllers] as a high demand for fuel. As a result, more pumps will be started, making the situation worse."

Controlling Ignition Sources Is Essential To Reduce Risk

Controlling ignition sources within the aircraft-fueling zone is a major risk-reduction measure. (See "Fueling Fire Shows Importance of Equipment Condition, Training," page 12.) In general, individual fuel companies and the airlines produce their own fueling procedures — incorporating the regulatory requirements — and warn fuelers of the following potential ignition sources around an aircraft:

- "Hot surfaces on auxiliary power units (APUs);
- "Electrical sparks due to connection/disconnection of ground power units;
- "Internal combustion engines on vehicles;
- "Hot surfaces on aircraft engines and brakes;
- "Electrical sparks due to communication systems, switch gear, radar;
- "Starting engines, operating switches, mobile phones;
- "Static sparks due to the discharge of accumulated electrostatic charges generated during fueling;
- "Welding and cutting operations;
- "[Open] flames; [and,]
- "Procedural violations [e.g., smoking where smoking is prohibited]."

The report said, "Controls to prevent ignition sources within the fueling zone include:

- "Smoking and [open] lights are prohibited;
- "Operation of switches on nonintrinsically safe lighting systems is prohibited;
- "Radios, radio telephones, pagers, etc., should be certified for use or 'intrinsically safe';
- "Fueling operators should not carry matches or other means of ignition (this includes wearing footwear with metal studs);
- "Only authorized persons and vehicles allowed in the fueling zone;
- "If an aircraft's APU is required to be operating during fueling and the exhaust duct would discharge into the fueling zone, the APU should be started before the fuel connection is made;
- "Ground power units should not be operated within the fuel zone;
- "Equipment with wheels that are capable of generating a spark should not be moved in the fueling zone;
- "Hand [flashlights] and inspection lamps should be certified for use [during fueling] or [must be] 'intrinsically safe';
- "Electronic instruments on the fueling vehicle are certified 'intrinsically safe';

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Fueling Fire Shows Importance of Equipment Condition, Training

Available reports list a small number of fueling-fire accidents among transport aircraft since the international adoption of Jet A/Jet A-1 fuels.[1] The accidents, however, provide insights into possible fueling-fire scenarios, consequences and the effectiveness of safety practices. An accident involving a cargo aircraft on Dec. 1, 1998, at Miami (Florida, U.S.) International Airport has been cited by U.S. aircraft rescue and fire fighting (ARFF) authorities involved in the training and monitoring of aircraft fueling personnel.[2]

The U.S. National Transportation Safety Board (NTSB), in its final report, said that at about 0413 local time, a Boeing 747-259B, operated by Tower Air, received substantial fire damage to the right wing during refueling. No injuries were reported to four aircraft crewmembers or to one ground fueler. NTSB said that the probable cause was "a fire that started under the fuel truck's cab from an undetermined fuel leak, resulting in fire damage to the airplane." NTSB cited a Miami Dade Aviation Department report, which said that fire damage to the fuel truck's engine "was possibly due to burning jet fuel from fueling operations at the time of the fire. The truck driver stated that he saw smoke and then fire from under the vehicle in the area between the cab and tank. The fire damage is consistent with the information. Due to severe damage to the area [between the tank and cab], the source of the fuel leak could not be determined."

While waiting for cargo to be loaded and anticipating a delay, the first officer and flight engineer entered the airplane and rested in the bunk beds at the aft end of the upper deck, the report said. Later, the captain entered the airplane; at the time of the fire, a fourth crewmember was on board. The aircraft auxiliary power unit (APU) was operating for cabin cooling.

A Tower Air maintenance technical representative told NTSB that he had conducted a walk-around inspection of the airplane, checked its logbook and checked to see that the two Signature fuel trucks, one under each wing, were grounded (bonded by wires to prevent a spark caused by differences in static-electricity charges between the aircraft/fuel and the trucks).

A Boeing 747-259B received substantial fire damage to the right wing during refueling Dec. 1, 1998, at Miami International Airport, Florida, U.S. (Photograph by Timothy Swick)

"He found that both trucks were grounded," the report said. "He then went with another ground person and stood on the left side of the airplane, near the nose. He then said that he noticed 'sparks' at the lower right side of the fuel truck, that was located under the right wing, near the [upper deck] ladder. He quickly ran to the fuel truck on the left of the airplane and told the fueler to stop fueling. The [left-side] fueler stopped and [drove] the truck away."

The fueler on the right side said that he had pumped 6,000 gallons (22,713 liters) of Jet A fuel into the right wing tank, and was standing on the deck over the pump when he noticed "white to a light gray" smoke coming from the bottom of the truck's cab, and directly under him.

"[The right-side fueler] tried to disconnect the upper-deck hoses from the airplane, but before he could [disconnect the hoses], he saw flames coming from the same area of the truck," the report said. "He attempted to put out the fire with a hand-held extinguisher, without success." The fueler then called his dispatcher, and ARFF personnel were dispatched.

The report said, "By the time [the maintenance technical representative] got back to the nose of the airplane on the left side, he could see flames on the lower side of the truck under the right wing. He immediately [alerted] the flight deck crew [by pressing the call switch (ringing bell), located on the nose gear, several times and the crew responded with a call signal] … and realized they were probably not aware of the urgency, so he decided to run up the stairs and yelled 'fire.' … When the Tower Air employee got back down the stairs, the fuel truck and wing were on fire."

The captain said that he heard the ground crew call signal while preparing the aircraft for a scheduled cargo flight under U.S. Federal Aviation Regulations (FARs) Part 121, and then was told that the aircraft was on fire. The captain ordered the crew to evacuate the aircraft, and all crewmembers exited through the forward-left boarding door.

The captain told NTSB, "On my way out, I pulled the APU fire handle, as this seemed to be the only logical conclusion [about] a fire without any indication of a fire in the cockpit, and [I] placed the battery switch to the OFF position … on my way out, running down the stairs to the ramp, I saw a huge fire under the right wing of the aircraft. There were flames shooting from the fuel truck over the wing between the no. 3 and the no. 4 engines. These flames were so high and widespread that I firmly believed that the entire airplane and fuel truck were going to explode any second … in my professional judgment, it is a miracle that the fuel truck with 40,000-plus pounds [18,148 kilograms of fuel] and the airplane with 200,000-plus pounds [90,719 kilograms] of fuel on board at that time did not explode."

NTSB's examination of the fuel truck revealed that there was intense fire damage near the truck's transmission.

"A hole was found in the fuel line from the pump to the hose, directly above the area of the most intense fire damage," the report said. "The truck was burned in the engine [area], passenger [area] and pump area. Severe fire damage to the area between the cab and tank was found. The fuel piping found in this same area had some severe damage. The fuel meter and other metal parts had been completely consumed by fire [or] melted. Fire damage to the engine was to the rear and on the top."

The airplane fire damage was concentrated on the right wing.

"The leading edge of the right wing, between the no. 3 [engine] and [no.] 4 engine, was [burned] completely through," the report said. "The leading-edge flaps were melted as were numerous panels. The trailing-edge flaps between engines [no.] 3 and [no.] 4, plus the underside skin, [were burned]. The no. 3 engine had a large section of the strut and pylon burned away. The cowling on the no. 4 engine was scored and burned."

Fueling fires underscore the need for vigilance, proper maintenance of equipment and adherence to procedures during every aircraft turnaround, said Timothy Swick, special projects chief of the Fire Rescue Division, Miami Dade Aviation Department.[3]

"The Tower Air accident involved a limited fuel spill because most of the fuel came from a burned hose," Swick said. "Nevertheless, the aircraft was full of fuel, and fire was impinging on the aircraft wing fuel tanks. There was a possibility of a major spill from the aircraft. The fire burned through one layer of outer aluminum skin and honeycomb collapsible layer and almost burned through the fuel-cell inspection plates, but was extinguished before burning through the plates. In another 30 seconds, we would have had a much more difficult problem. Aluminum can withstand that amount of heat only so long. If the fuel-cell inspection door had burned through, the contents of the wing tank would have spilled. The first fire truck crew attacked this fire quickly, however, and put down 3,000 gallons [11,356 liters] of foam/water extinguishing agent in a hurry."

The fact that the wing tank was almost full also extended briefly the period of time available to extinguish the truck fire before it burned through the wing tank, a scenario that would have endangered other aircraft and personnel in the cargo area and adjacent warehouses, he said.

"Heat was being absorbed by the liquid fuel, which provided a longer time to metal failure by drawing heat away from the spot where the fire was impinging," he said. The time log on a security camera videotape showed an elapsed "free burn time" of more than three minutes prior to the arrival of the ARFF equipment, he said. The distance from the responding airport fire station to the aircraft was 1.9 miles (3.1 kilometers).

After this accident, the fire department conducted detailed inspections of the other fueling vehicles at Miami International Airport and found some equipment problems that were not being identified between fire inspectors' quarterly vehicle inspections, despite enforcement conducted during routine surveillance of ramp operations, he said.

"This accident investigation also generated the attention of FAA aviation safety inspectors, who looked into fueler training, practices in inspecting equipment and FAA staffing at Miami International Airport and at area general aviation airports," Swick said. "Training of fuel service personnel and serviceability of equipment were their biggest issues. We added one inspector at the airport after this accident, and FAA added inspectors to help make sure that fueling equipment meets requirements."

The fire department inspectors enforce Chapter 25 of the *Miami Dade Aviation Department Rules and Regulations,* which incorporate recommended practices for fueling safety of the U.S. National Fire Protection Association (NFPA). FAA inspectors oversee compliance with FARs Part 139 requirements for the training of fueling supervisors and line fuelers, he said.

"We can issue citations and can pull the airport operations area access permit off a truck if the truck is found to be deficient, then require that the problem be fixed before issuing another permit," Swick said. "Airlines are in a hurry, but we tell airlines that unsafe practices by their fueling contractors will not be tolerated. We have been getting a lot more cooperation since the 1998 fire. That time, there was a problem with a truck — a piping rupture, a mechanical failure. In another local fire incident, the fueler had a hose leak that sprayed Jet A fuel in a mist. The biggest problem is the potential hazard because of the occurrence of frequent spills of jet fuel on summer days when the temperature of the asphalt on the ramp is well within the flash point of 100 degrees Fahrenheit (38 degrees Celsius) for Jet A fuel."[4]

Fuel-service companies annually certify to FAA their compliance with FARs Part 139, and FAA spot-checks their operations, he said. The fire department is aware of the fuel spills that required its services; nevertheless, many smaller fuel spills are not reported and the incidence of all spills and minor fires is uncertain.

Swick, who has 25 years of fire fighting experience with the department (including seven years of ARFF experience), said that fuel service personnel typically follow fire-safety procedures.

"Fuelers do a good job of positioning their vehicles, for example, although sometimes they may be blocked by airline ground crews," Swick said. "They also carry spill kits as part of standard inventory on trucks for preventing fuel from entering storm water drains, and they have training to use the spill kits."

Nevertheless, fire department inspectors have identified and addressed the following problems:

- Unserviceable fueling equipment gauges involved in repeated fuel spills;
- Use of a wire or other methods of defeating the deadman control[5] of a fueling system;
- Unserviceable "spark-proof" parts on fueling vehicle electrical systems;
- Broken electric-light parts, including lamps/bulbs, on fueling vehicles;
- Use of short pieces of wire in place of electrical system fuses in fueling vehicle fuse boxes;
- Failure to place vehicle wheel chocks;
- Unserviceable fire extinguishers; and,
- Absence of fire-safety placards.♦

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2. U.S. National Transportation Safety Board (NTSB). Aviation Accident/Incident Database. Report no. MIA99FA038.
3. Swick, Timothy. Telephone interview with Rosenkrans, Wayne. Alexandria, Virginia, U.S. March 8, 2001. Flight Safety Foundation, Alexandria, Virginia, U.S.
4. U.S. National Fire Protection Association (NFPA). *NFPA 407 Standard for Aircraft Fuel Servicing, 1996 Edition.* NFPA defines *flash point* as the fuel temperature at which kerosene-grade turbine fuels produce flammable vapors in ignitable amounts.
5. A *deadman control* is a device that requires a positive continuing action by an operator to allow the flow of fuel.

- "Vehicle engines should not be left running unnecessarily;
- "Vehicles must not be parked underneath the wing-tank vents;
- "Photographic flash equipment should not be used in the fuel zone;
- "No maintenance work which may create a source of ignition should be carried out;
- "[Air traffic control] should issue guidance on whether fueling should be suspended during electrical storms;
- "An aircraft's external lighting and strobe system should not be operated; [and,]
- "Connection and disconnection of electrical equipment should not be carried out."[7]

Preventing jet fuel from contacting hot surfaces receives less attention than other standard fire-prevention recommendations.

"Surfaces, if they are hot enough, can heat a spill to a temperature where spontaneous combustion [autoignition] can occur," the report said. "Currently, there are no control measures for this source of ignition. … One way of controlling this ignition source would be to delay fueling until the engines had cooled down to a safe temperature."

United Kingdom Recommends Methods to Prevent Fueling Fires

Based on its analysis of major fuel spills, including possible fueling-fire scenarios, HSE recommended the following methods of addressing the risks:

- Increase the visibility of fueling hydrants to help avoid contact by ramp vehicles;
- Position fuel-servicing hydrant vehicles to provide maximum protection for the hydrant (the control panel should be facing the near side of the aircraft so that the fueler can see both the control panel and the aircraft);
- Require the use of an observer whenever a ramp vehicle is driven in reverse during aircraft fueling;
- When possible during new construction or facility improvements, replace or supplement the lanyard-actuated pilot valve at fuel hydrants with an air-actuated pilot valve (or dual air/lanyard-actuated pilot valve) so that releasing the deadman control closes the pilot valve, the hydrant pit valve and the hydrant vehicle's inlet coupler;
- Although safety measures exist for most ignition sources on the ramp, airports and airlines should address in their safety procedures methods of preventing Jet A-1 from contacting the hot surface of an engine that has just been shut down;

- Regulatory requirements to have an overseer supervise each fueling operation and manage traffic around an aircraft during each fueling operation should be reconciled with current practices to ensure that a level of safety equivalent to regulatory requirements is provided;

- ESBs should be located and marked to be identifiable immediately during a fuel spill or fire, and vehicle parking should be restricted to prevent any vehicle or load from obstructing the fueler's view;

- A sign at each ESB should show brief instructions that would enable anyone on the ramp to isolate fuel flow if the fueler cannot activate the [ESB];

- The work of fuelers should be coordinated with the work of other ramp personnel during aircraft turnarounds through formal airport committees that review fueling safety;

- Airport ground handling agents, in addition to fuel service companies, should provide training to their personnel to increase awareness and understanding of fueling operations, including facts about the prevention of fueling fires;

- Airport authorities should systematically conduct inspections and audits of all aircraft turnaround activities — not just fueling — to address noncompliance, to monitor trends in procedural compliance and to enforce regulations with sanctions against persistent offenders to deter repeat violations;

- Records of fuel spills and fueling fires should be kept by fueling operators for a period of time long enough to enable quantitative analysis of safety trends;

- Regulations should be updated in response to the changing ramp environment for a more structured method of managing aircraft turnarounds and to define/allocate safety responsibilities more appropriately for the current environment;

- International safety recommendations of the Institute of Petroleum (IP) and Joint Inspection Group (JIG) or similar civil aviation authority guidance should be implemented by airlines and their contractors (e.g., to increase hydrant pit visibility, IP/JIG specifies four-winged flags; pit barriers; painted area markings; expandable fencing and plastic cones around hydrant pits, reflective paint, signs and light-emitting diode light systems along fueling hoses; and spotlighting of hydrant pits by hydrant vehicles);

- Airports should enforce strictly ramp speed limits as a significant method of preventing fuel spills and fueling fires;

- Fueling-equipment maintenance should include regular inspection and testing of the hoses, and routine inspection, maintenance, recalibration and testing of hydrant pit valves;

- Procedures and training should enable fuelers working alone to detect promptly and respond immediately to an aircraft venting fuel, unplanned aircraft movement or fueling equipment movement, fuel truck engine fire, fuel leaking from a seal/flexible coupling or flange face on a vehicle, mist/spray from a fuel-pump leak on a fuel truck, or inadvertent disconnection of a fuel hose; and,

- Fuelers should be trained to understand the fire-safety implications of overfilling an aircraft tank (e.g., by entering incorrect amounts on the fuel computer, by failing to detect an airline representative's request for too much fuel or by failing to detect a sensor failure) — all of which can lead to a fuel spill from the aircraft's surge tank via the vent-scoop valve, forming a pool of fuel underneath the wing.

Of dozens of actions during an aircraft turnaround, fueling inherently involves the highest risk in terms of the possible consequences of a fueling fire. Airport personnel other than fuelers must understand that their actions either may increase or decrease their own safety — despite the apparently routine safety of daily operations.♦

Notes and References

1. U.S. Federal Aviation Administration (FAA). Advisory Circular (AC) 150/5230-4, *Aircraft Fuel Storage, Handling, and Dispensing on Airports.* August 27, 1982. The AC says, "Three classifications of aviation turbine fuels are universally referred to as 'jet fuels' and are generally described as Jet A, Jet A-1 and Jet B. They are used in 'turbojet' and 'turboprop' engines. These three classifications are: Jet A, a relatively high-flash-point distillate of the kerosene type, having a –40 degrees Fahrenheit [F] (–40 degrees Celsius [C]) freezing point (maximum); Jet A-1, a kerosene type similar to Jet A but incorporating special low-temperature characteristics for certain operations, i.e., –53 degrees F (–47 degrees C) freezing point (maximum); [and] Jet B, a relatively wide-boiling-range volatile distillate having a –58 degrees F (–50 degrees C) freezing point (maximum). The [U.S.] military terminology is JP-4 and it has a freezing point of –72 degrees F (–58 degrees C)."

2. U.K. Health and Safety Executive (HSE). "Quantified Risk Assessment of Aircraft Fueling Operations." Report no. AM5204. July 2000. 32, 41. The report, prepared for HSE by W.S. Atkins Safety & Reliability, included a review of historical fueling accidents/incidents (including fuel spills and fueling fires) from 17 categories

of international data sources. Researchers conducted a quantified risk assessment of the two common methods of aircraft fueling: from hydrants and fuel trucks. The literature search identified occurrences involving major spills of Jet A/Jet A-1 fuel in the United Kingdom and in other parts of the world. *Major spill* was defined as "approximately 100 liters [26.4 gallons] or more fuel was spilled or the spill resulted in a major loss." The report said, "There have been anecdotal reports that particular airports around the world have had major fuel spills. Part of the literature search involved trying to confirm these reports and to obtain further information, in particular, on the cause of the spill and any lessons learned."

3. The HSE report said, "A hydrant-fueling operation requires some form of bulk fuel storage facilities, such as a fuel farm or tank farm, pumping equipment, pipework distribution system and hydrant outlets within the [ramp] area. Fuel is transferred from the fuel farm to each hydrant point. When an aircraft is to be fueled, a [hydrant vehicle] (hydrant dispenser) connects … to the hydrant point in the ground and connects … to the aircraft fueling point."

4. A *deadman control* is a device that requires a positive continuing action by an operator to allow the flow of fuel. The safety function of some deadman controls can be defeated by the operator — for example, by jamming the control or by wrapping tape or wire around the control so that fuel will flow without the operator's continuous manual force ("tying off the deadman "). This practice is hazardous because the time to stop a fuel spill or isolate a fueling fire is reduced significantly if the fueling operator moves away from the fueling vehicle.

5. U.K. Civil Aviation Authority (U.K. CAA). CAP 74 *Aircraft Fueling: Fire Prevention and Safety Measures.* 1991. CAP 74 contains U.K. CAA's recommended procedures for fueling operations and defueling operations to minimize the potential for a fire; guidance in CAP 74 supplements a fuel service company's operating procedures.

6. The HSE report said, "The hydrant dispenser [hydrant vehicle] does not carry any jet fuel; its function is to filter out solids/water, monitor the quantity transferred, allow for sampling and to regulate the pressure of the fuel entering the aircraft. The hydrant dispenser has no pumping capability as the fuel is pressurized by the pumps located at the fuel farm. Where airports do not have the facility for a distributed fuel pipework system, fueling is carried out using a refueler [fuel truck]. … The [fuel truck] carries the jet fuel in a tank mounted on its chassis. It connects … to the aircraft and pumps, monitors and controls the fuel entering the aircraft."

7. CAP 74.

Airport Operations

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