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How Large Aircraft Fuel Up

A large 747 aircraft can carry up to 55,000 gallons of fuel. Gary Austerman, CET, discusses how it gets there.

An in-depth look at fueling
This is the second part of a two-part article on aircraft fueling systems at large airports. In this installment, Gary Austerman discusses the fundamentals of fuel distribution and aircraft fueling operations. Part 1 explained the basics of receiving and storing the fuel. (PE&T, March/April 1997)

To gain a solid understanding of fueling operations at large airports, it is not necessary to focus on the fueling procedures of individual airline carriers. At most large airports, an independent company provides the personnel, management and servicing equipment to operate the fuel storage facility and fuel all aircraft. This reduces fueling costs for each user airline, since each airline does not need to operate its own facility.

From tank storage to flight—At most airports, an underground piping system transports Jet-A fuel from the fuel facility storage tanks to the aircraft. This piping, called a transfer fuel line, supplies the fuel to either underground hydrants near the aircraft or to refueler loading stations for truck (refueler) loading. The transfer fuel line is generally composed of a single pipe or a combination of pipes, 18 inches to 24 inches in diameter. The size and number of pipes depend upon the airport arrangement and aircraft fuel demand.

The fuel storage facilities are normally sited in remote locations at the airport, far from where the aircraft receive their fuel. So, transfer fuel lines often pass under aircraft runways or taxiways. This is a significant factor when piping is installed or repaired. For example, at San Diego International Airport, the fuel lines pass under the airport's only active runway and taxiways. Therefore, a 1,100-foot, 42-inch diameter pipe casing was installed by micro-tunneling methods. This casing contained the transfer line pipe and the electrical and control system conduits.

Micro-tunneling is a process by which a small tunnel boring machine, guided by lasers, bores a horizontal tunnel and installs a casing pipe without disturbing surface conditions or interrupting operations. In the case of the San Diego airport, the aircraft runway and taxiways remained in operation at all times during construction.

Pilot and refueler discuss the volume of Jet-A fuel being pumped into the craft

Keeping it clean—Clearly, the need to keep fuel clean is imperative for any aircraft fueling operations. The transfer fuel line needs periodic cleaning because of its design to maintain fuel quality. The line consists of a series of pipes that may slope up and down to avoid storm drain piping and other utility lines along its path. The two most commonly used cleaning methods are:

1. Pigging. A foam “bullet” is inserted into the fuel transfer line and pushed by pressure from one end of the pipe to the other end, pushing ahead of it water, rust or contaminants. This requires “pig launching and receiving equipment.”
2. Venting/Draining. High point vents and low point drains are used to remove water and scale. High point vents are small valved pipes that allow air to escape from the transfer fuel line. Low point drains are small pipes that drain pipe sumps provided to collect contaminants. A mobile sump vacuum truck is used to pump out the pipe sump.

The valves for both the vents and drains are generally contained within an underground fiberglass pit, with a 24-inch diameter and a 38-inch depth. These valve pits are flush with the surrounding grade and equipped with quick access aluminum covers.

Coating the pipeline The fuel pipe is constructed to ASTM A53, Grade B or API-5L, Grade B seamless or electric resistance welded steel pipe with a normal wall thickness of 0.375-inch.

The pipe joints are butt welded. The pipe is coated both inside and out to help provide clean fuel and to prevent corrosion. The internal coating of the pipe is a factory-applied epoxy. The external coating may be a fusion-bonded epoxy; cold-applied bituminous; hot-applied bituminous (with or without wrapping); or factory-applied polyethylene.

Airport Fueling Systems Overview

Figure 1:
Airport Refueler Fueling System

Figure 2:
Airport Hydrant Fueling System

Dispensing the fuel

There are two common ways of supplying fuel to the aircraft from the transfer fuel line, refuelers or hydrant carts.

Refueler dispensing—Refueler loading stations are located at the end of the transfer fuel line. They are usually large enough to serve four to six refuelers at one time. A refueler is a mobile vehicle with a 5,000 to 10,000-gallon size fuel storage tank. The refueler is equipped with pumps, filtration equipment, hoses and other equipment required to fuel aircraft.

Note the lift on the refueling truck above.

The refueler loading stations themselves are service islands with metering and filtration equipment. Since refueler dispensing is essentially a manual operation, most facilities have overfill protection equipment, consisting of level sensors mounted on the refueler and connected to the fill pipe control valve. Curb concrete paving and an oil/water separator are provided at refueling loading stations to control spills.

The refueler travels from the loading station to the aircraft where fuel is transferred by hose into the aircraft fuel tank. The flow rate of fuel to an aircraft ranges from 200 gpm to 600 gpm (gallons per minute). This type of dispensing is common at mid-size and some large airports, generally in the eastern United States; it is also common for cargo aircraft fueling.

A narrow-body aircraft can accept from 2,000 to 6,000 gallons of fuel; a large B747-400 aircraft can carry up to 55,000 gallons. An operations person for the user airline and the pilot determine the amount of fuel supplied to each aircraft based upon the total flight weight, the destination of the aircraft and alternate airports available.

Ten thousand gallon low profile jet refueler.
Courtesy of Garsite, Inc.

Hydrant dispensing—Hydrant fueling systems are more common in the midwest and western United States because of recent airport development of the larger airports. This dispensing method uses a hydrant at the end of the transfer fuel line. (See illustration on page 54.) The transfer fuel line usually terminates within a control valve vault, with the piping system control valves, electrical power and fueling system controls. The control valve, suitable for jet fuel service, has a working pressure of 275 psig. The electrical controls consist of motor-operated control valves and fuel system control monitoring functions. The fuel system operator monitors and maintains this equipment every day.

From the control valve vault, the hydrant fuel line is routed to the aircraft parking apron. This pipe is generally between 8 and 16 inches, depending upon airport fuel demand. The pipe has the same material requirements as those previously described.

From the hydrant fuel line, pipe laterals are used to serve individual hydrant fuel pits. One to three hydrant fuel pits are required for each aircraft parking position, depending on the type of aircraft parking at the position. Narrow body, wide body or jumbo aircraft each fuel at different positions. The 6-inch diameter lateral pipe provides a flow rate between 600 and 1,000 gpm at 7 fps (feet per second) to 10 fps velocity. Velocity is important because it affects the buildup of static electricity.

It generally takes between 300 and 400 gpm to fuel one narrow body aircraft or between 500 and 600 gpm to fuel a wide body/jumbo aircraft. When an aircraft has a dual fuel point, a fill rate of 1,000 gpm is likely. The hydrant fuel pit is an underground fiberglass pit in which the lateral fuel pipe connects into a hydrant valve (see above). The manually controlled hydrant valve controls fuel pressure and flow to the aircraft.

Prefabricated commercial fuel hydrant pit assembly that provides on and off pressure and flow control while dispensing fuel to an aircraft. Courtesy of Dabico, Inc.

The hydrant fuel pit has a removable cast aluminum cover for quick access to the hydrant valve. This cover is rated to accommodate the heaviest aircraft wheel loading situation.

When the cover is opened, the fueler connects to the hydrant pit valve and to the aircraft through a delivery hose and dry break nozzle. This hydrant cart is equipped with gauges, metering and fuel filtration equipment mounted on a one- or two-ton truck chassis to control, filter and measure the fuel flow to the aircraft.

Another type of hydrant cart is called a towable unit; it has basically the same fueling equipment, but does not utilize a truck chassis. These towable units generally remain at a dedicated aircraft gate to serve the aircraft. Aircraft hydrant fueling systems must comply with the requirements of NFPA 407 (Aircraft Fuel Servicing), NFPA 415 (Aircraft Fueling Ramp Drainage) and NFPA 416 (Construction and Protection of Airport Terminal Buildings). Compliance with the Air Transport Association of America (ATA) Guide Specifications is also required.

300 gpm towable hydrant cart.
Courtesy of Garsite, Inc.

In an emergency... An emergency fuel shutoff system is used with all hydrant fueling systems to provide an emergency shutdown in the event of a fuel spill or overfill. This system has a pull-type alarm station located at places along the exterior of the concourse or terminal buildings.

One emergency fuel shutoff station is provided at each aircraft gate. According to NFPA 407, the station must not be less than 20 feet, nor more than 100 feet from the fueling point (NFPA 407, paragraph 3-3). When an emergency shutoff occurs, the hydrant line control valve—located in the control valve vault—will close, stopping the flow of fuel to the hydrant fuel system. Also, the transfer fuel line pumps at the fuel storage facility can be stopped to provide extra protection from a fuel spill. The fire department must be notified and fueling restarted only after the cause of the shutdown is determined.

Underwing fuel connection and controls.

Leak detection today

Older hydrant fuel systems and transfer fuel lines were constructed of only single-wall pipe, without leak detection. New containment and monitoring technology. Airport hydrant fuel distribution systems are currently deferred from UST regulations (CFR 40, Part 280.11). Nevertheless, the interim prohibition for deferred UST systems requires:

1. No releases due to corrosion or structural failure for the operational life of the system.
2. Cathodic protection against corrosion, coated with a noncorrodible material or designed to prevent the release of a stored substance.
3. Construction or lining with material that is compatible with the stored substance.

Exceeding the federal standards, some states require that underground pressurized hydrant fuel systems be of double-wall pipe with monitoring safeguards. In other states, a line pressure detection method can be used. This method segments fuel transfer lines with block-and-bleed valves. Pressure readings are measured over a period of time to detect any leaks. Existing fuel systems can be retrofitted with this type of detection.

Double-wall pipe systems can employ several types of leak detection sensors or leak detection cable in the interstitial spaces. Monitoring wells also are used at some airports and are located along the fuel line. They will detect hydrocarbon product floating on the water surface, alerting the fuel system operator to a potential leak.

The wells are constructed of 4– or 6–inch diameter, slotted PVC pipe with surface caps that open for sampling. This type of detection is only effective if the groundwater is in the 5– to 20–foot range below the ground surface.

Single point underwing fueling from hydrant system

Cathodic Protection System The underground fuel piping system must have a cathodic protection system to prevent corrosion of steel pipes (40 CFR Part 280.11). An impressed current system is most commonly used with anodes and a rectifier designed to provide a continuous DC current. A sacrificial anode system is also sometimes used for underground hydrant fuel line and transfer fuel line piping systems. Hydrant fueling systems may require modifications due to changing airline requirements or when a terminal or concourse is remodeled.

This typically involves changes to the aircraft location, thus, requiring a new hydrant fuel pit to serve the relocated aircraft. For example, at Orlando International Airport, a nine-gate aircraft terminal was remodeled, necessitating the relocation of three aircraft positions and the addition of three new hydrant fuel pits. These changes were made during non-peak aircraft operation times to keep this terminal open for scheduled airline operations.

Large airport fueling systems must operate effectively in various weather conditions. These systems must not only comply with stringent engineering requirements and codes, they must satisfy safety and environmental concerns. Certain priorities must be kept in mind when designing an effective airport fueling system. First and foremost, they are to provide: (1) clean and quality fuel to the aircraft; (2) an economical and easily maintained system; and (3) adequate fueling rates.

In the state-of-the art systems being designed today, nothing is left to chance. They are physically safe, environmentally secure and cost effective. Everyone benefits!

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