What Fuels Large Aircraft Fueling Systems?

A 32-year veteran designer of aircraft fueling systems provides a bird's eye look at the design and operation of large airport fueling systems. In this first of a two-part series, Gary Austerman, CET, reports on fuel reception and storage.

A bird's-eye look at fuel reception and storage
This is the first part of a two-part article describing aircraft fueling systems at large airports. Part 1 describes the fundamentals of receiving and storing the fuel. Part 2 will describe the fundamentals of fuel distribution and aircraft fueling operations.

Large airport fueling facilities must run extremely efficiently to provide the fuel quality required for today's aircraft jet engines. Along with safety and efficiency, cost concerns determine every aspect of the design and operation of fuel storage, distribution and dispensing systems.

For example, the slogan "Fill it up" is seldom heard at large commercial aircraft airports for three primary reasons: (1) Fuel ranks second to labor as the highest operating cost for commercial airlines, and fuel costs are controlled very closely; (2) The more fuel that goes into an airplane, the heavier the plane becomes and the more fuel it will use. Therefore, generally speaking, a plane will fly with enough fuel to get to its destination point and an alternate airport to where the plane might be rerouted in case the first airport is closed; and (3) Since the cost of buying and delivering fuel varies, an aircraft may receive less fuel at one airport if fuel prices are lower at the plane's destination. The decision as to how much fuel will be carried is made by both the pilot and the airport station manager's operations staff.

Not filling up the tank is only one of many examples of cost consciousness for large airport fueling systems. Another area is tank selection. Field erected aboveground storage tanks (ASTs) are usually chosen because of their large size and environmental friendliness.

Types of fuels
Jet-A fuel—Jet-A fuel is most commonly used for turbine engine aircraft in the United States, while Jet-A-1 (with more additives and certain low temperature characteristics) is used in other countries. Since we are discussing large airport systems in the U.S., I will focus on Jet-A fuel in this article.

Jet-A is a combustible turbine fuel that conforms to the latest revision of the American Society for

Testing and Materials (ASTM) in: Standard Specification for Aviation Turbine Fuels (D-1655-95A). With a specific gravity of 0.81, Jet-A fuel is lighter than water and will float on it. National Fire Protection Association (NFPA) 30, Flammable and Combustible Liquids Code, identifies this fuel as a Class II liquid. This means it has a flash point at or above 100 degrees F (37.8 degrees C) and below 140 degrees F (60 degrees C). (Fire safety regulations are similar for diesel fuel and #2 heating oil.)

Although large airport fuel facilities mainly handle Jet-A fuel, they often store and dispense unleaded gasoline or propane to ground service equipment (GSE), as well. And sometimes, large airports also store and dispense Aviation gasoline (AVgas) at their fuel facilities for piston-driven engine aircraft. This is being done at National Airport in Washington, DC.

Alternate fuels

Although oil companies and engine manufacturers are investigating alternate fuels for aircraft operation, the present commercial aircraft fleet is still committed to Jet-A fuel. Alternate fuels would require aircraft engine modification or replacement, as well as upgrading of present fueling facilities and equipment. Since the new aircraft being constructed today continue to use Jet-A turbine engines, the use of alternate fuel seems unlikely to occur anytime soon.

The Los Angeles Airport (LAX) fuel facility stores more than 26 million gallons of fuel within 15 aboveground fuel storage tanks.

This pumping and filtration equipment supplies the aircraft hydrant fuel at O'Hare International Airport.

Fuel storage facilities

Ownership—Often, for reasons of economy, the major airlines collectively own and manage the fuel storage facilities at large airports. A committee member from each member airline staffs a fueling consortium, which is responsible for the fuel quality and fuel facility itself. Most of the large city airports—including Chicago, Los Angeles, Dallas/Fort Worth and Denver—use this approach.

In some cases, however, the airport owns the fuel storage system and employs a third-party operator to manage and maintain it. This is the case at such locations as LaGuardia, JFK International, Dulles and National (DC) airports.

Siting—The location of fuel storage tanks at a large airport depends on the efficiency and operational requirements of the airport's total fuel system (from storage to dispensing). The tank storage area is generally located in a remote area on the airport property because space near the terminals is required for safety and for revenue-producing functions. The tank storage area must be accessible to both the aircraft operation area (AOA) for fueling as well as to delivery trucks.

All airport fuel storage facilities must meet the requirements of the Air Transport Association (ATA) specification 103, Standard for Jet Fuel Quality Control at Airports. This specification includes requirements that tanks be equipped with floating suctions, fixed cone roofs and cone down bottoms.

Fuel Delivery—Fuel delivery to the fuel storage facility is by oil company pipeline, truck transport or a combination of each. Each airline has a fuel buyer who purchases millions of barrels of fuel annually, and determines how the fuel will be transported to the fuel facility.

Most large airports receive most of their fuel by pipeline. Fuels in a pipeline delivery system are metered and tested to ensure quality control. These are typically carbon steel pipelines ranging in size from four to 12 inches in diameter. The pipeline may be dedicated specifically to the delivery of jet fuel or it may be a shared pipeline that serves multiple users with multiple products.

Some airports have as many as 70 to 80 trucks per day transporting fuel to the fuel facility. As a result, truck transport loading/unloading stations are provided at the fuel storage facility as a part of the airport’s normal operations. Truck transport deliveries require on-site use of filtration equipment and monitoring to test the quality of fuel before it is accepted for storage. Pumping equipment to unload fuel from transport trucks generally consists of fixed positive displacement pumps that deliver a constant capacity of fluid at varying pressure conditions. These “off-loading” pumps are typically rated for 300 gpm of flow capacity each. A single pump and hose connection will empty a transport tanker truck in about 30 minutes.

Also part of the airport’s normal operations are refueler loading stations; these are areas that provide a fueling location in case the normal fueling process is interrupted (e.g., if a hydrant system is down). A specially equipped truck (a refueler) can be loaded at the refueler loading station. These stations have loading arms and valves as well as metering within the loading/unloading areas. Storm water effluent, spills and leaks from these areas are contained and routed to an oil/water separator.

Refueler loading station.

Overfill protection equipment on refueler.

Fuel Storage Tanks

Aboveground storage tanks Sizes—At large airports, fuel is stored most often in vertical ASTs that each contain between 7,500 barrels (BBL) and 80,000 BBL—which translates into 320,000 to 3.3 million gallons of fuel. The capacity and number of tanks required depends upon the volume of fuel needed daily for the aircraft (called the uplift volume) and the volume needed for three to seven days’ reserve.

For example, Los Angeles International Airport is one of the top three large airports in the U.S., as measured by the number of passengers and cargo handled, and second in annual fuel uplift volume. The LAX fuel facility has about 625,000 BBL (26.25 million gallons) of fuel within 15 aboveground fuel storage tanks.

Design—The aboveground vertical fuel storage tanks are sited and spaced according to NFPA 30 criteria with the approval of local authorities having jurisdiction (AHJ). Vertical ASTs are constructed to American Petroleum Institute (API) 650, Welded Steel Tanks for Oil Storage. Internally and externally coated, these tanks are made of welded steel and have a fixed cone roof and a cone down bottom that slopes to a center sump with a drain.

As previously mentioned, ATA specification 103 requires the use of floating suction piping for storage tanks for fuel cleanliness assurance (see photo bottom right). Floating suctions draw clean fuel from the top of the fuel level in a storage tank rather than from a tank bottom potentially containing settled dirt or water. However, due to improvements in delivered fuel cleanliness at some airports, the ATA member airlines have begun to review and relax the requirement for floating suction piping inside the tanks in favor of a fixed suction pipe. Where delivered fuel is extremely clean, a fixed suction pipe has the advantages of (1) lowered installation costs, and (2) the elimination of the operational and maintenance concerns of the moving parts of floating suctions.

Internal floating roofs are sometimes required by AHJs for environmental reasons. It is important to note that with the very low vapor pressure of Jet-A fuel (approximately 0.01 psig at 70 degrees F), it does not in itself contribute significantly to air emission problems. Nevertheless, fuel volume must be included by the airport along with all other calculations of total airport emissions. These emissions must meet the limited allowances as defined by federal, state and local regulatory agencies. The internal floating roofs most commonly now used in vertical ASTs are the full-surface contact type with aluminum metallic sandwich panels constructed in accordance with API-650, Appendix H. The internal floating roof employs a primary and secondary perimeter seal. Tank foundations for large airports are typically constructed of a concrete ring wall with an internal impervious liner, or on a solid concrete mat. Both of these constructions use a manual type of leak detection system (by observation) in which the fluids drain toward a pipe extending under the tank through which the testing can be done. Older tanks were made on a concrete ring wall or placed upon a compacted base material or asphalt concrete mat, without means for leak detection monitoring. Without such monitoring, the tank bottoms can leak, saturate the ground and possibly contaminate groundwater.

Aluminum floating roofs for petro-chemical tanks and outdoor oil/water separators. (Courtesy of Allentech, Inc., Bethlehem Pennsylvania)

Underground storage tanks

Sizes—Where local codes or conditions prevent use of ASTs, fuel is stored in tanks placed underground, such as at Lambert Field, St. Louis International Airport. These USTs usually hold between 20,000 and 60,000 gallons of fuel. In general, USTs are only used when codes prohibit ASTs. The military typically uses 50,000 gallon USTs.

Material—Underground tanks at large airports are usually made of welded steel, and conform to UL 58, Steel Underground Tanks for Flammable and Combustible Liquids. The tanks also can be fiberglass, conforming to UL 1316 Standard for Safety (Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products). Tanks must afford the strength needed for very large-volume storage, pumping and monitoring equipment required for airport fuel service. Today, most large airports are installing double wall tanks with leak detection systems, such as automatic tank level monitoring systems and electronic monitoring of the interstitial space between the tank's inner and outer walls.

Number and type—Many USTs are needed to handle an airport's daily uplift volume. For example, the jet fuel system at St. Louis International Airport has twenty-nine 30,000 gallon and twelve 60,000 gallon steel USTs. This is only a one-day supply of fuel, not the 3 to 7 day surplus recommended in this article. The USTs are internally and externally coated, utilizing a floating suction pipe with accessible manholes. At some facilities, the double or single wall tanks are lined before they are installed. USTs are often used to store gasoline for fueling ground support vehicles and for heating and used oil. These tanks range from 1,000 to 10,000 gallons.

A typical installation showing underground Jet A-fuel storage tanks.

Flanged, floating suction arm swivel for the fuel suction piping. This system is mounted/installed in an AST, which is supplying fuel through a hydrant system.

Fuel system pumping

Located outside the diked containment for the tanks, pumps for ASTs are accessible to loading operations for truck transports and aircraft refuelers. The AST pumping equipment meets the requirements of API 610, Centrifugal Pumps for General Refinery Service. Submersible pumps for USTs are usually installed directly into the tanks.

Pumps for Jet-A fuel—Often of a horizontal design, the pumps are manufactured specifically for continuous and intermittent operation for Jet-A Fuel. The pumps are programmed to allow only so many "starts" per day to avoid damaging the motors or starters. Continuous operation creates less wear than frequent starting and stopping at busy sites.

The fuel system pumps have flow capacities ranging from 400 gallons per minute (gpm) to 1,200 gpm; the pump motors' associated electrical devices and wiring meet the National Electric Code (NEC) for Class I, Division 2, Group D hazardous location service. The number and size of the fuel system pumps are based upon the airport flow demand and operating pressure needed to fuel the aircraft. Peak flow rates for fueling systems at large airports range from 10,000 to as high as 24,000 gpm, depending on the size and number of aircraft being fueled and their destinations.
(See photo)

A series of pumps and motors push the fuel down through the hydrant fuel supply system at Brussels Airport. In the foreground are the centrigual pumps, then the filters; a refueling pad is in the background.

Other fuel facility pumps
Other fuel facility pumps are used for truck transport unloading and for small underground operating tanks. The pumps must: (1) meet API 676, Positive Displacement Pumps–Rotary requirements; (2) be self-priming; and (3) be manufactured specifically for handling hydrocarbons—namely, Jet-A fuel. The pumps range in size from 10 to 300 gpm flow capacity. The pump motors and associated electrical devices and wiring are rated to meet the requirements for NEC Class I, Division 2, Group D hazardous location service.

Fuel filtration
Great attention is paid to ensure that aircraft fuel is sufficiently filtered so that it is completely clean and "dry" when pumped into the aircraft. The cleanliness standards are measured at the airport on a qualitative (sampled fuel color) rather than a quantitative basis as defined in ASTM D-3830-93 and Air Transport Association (ATA) specification no. 103. (For more on filtration, read "Why Good Small Airport Fueling Systems Won't Hold Any Water" by James R. Pankonen in the Jan./Feb. issue of PE&T.)

Strainers are metal mesh screens placed in the fuel flow path to "catch" larger contaminants before the fuel passes through the fuel separators. They resemble metal colanders or metal buckets with many tiny holes. The strainers are placed in special fittings in the piping system, upstream of fuel system pumps, filters and meters. Periodically, the strainers are manually checked for contaminants and cleaned.

Fuel separators remove free or entrapped water, and solid contaminants from the fuel. The filter separators consist of a steel canister device containing removable coalescer and separator cartridges. The separators are installed downstream of the fuel system pumps.

Tank sump separators are used to maintain fuel quality in vertical ASTs. The tank must be "sumped" (i.e., a low spot is provided into which water will flow by gravity) to remove water contaminants. These contaminants are removed and sent to a waste tank. Because of the increased costs of fuel, the sample fuel is now reclaimed by using a tank sump separator. Located adjacent to the tank, the separator usually consists of a 50-gallon container with a self-contained centrifugal pump. The fuel is sampled in this equipment and clean fuel is returned to the fuel storage tank; the water and contaminants are sent to a waste tank.

Checking the systems

Tank gauging

The fuel storage tank must be gauged for a number of important reasons. They include: determining the tank product level; controlling the tank filling, discharge and control inventory; detecting bottom water level; and leak detection. Several gauging technologies are available, depending on the tank type and level of accuracy desired. They include systems employing resistive tape, floats and tape, hydrostatic, radar, and servo mechanisms. Gauges often work in conjunction with computerized control systems, and are described below:

Resistive tape gauge—Liquid hydraulic pressure compresses the jacket of the tape, increasing resistance. The level is derived from the tape's electrical resistance.

Float and tape gauge—A float follows the liquid level or interface level between liquids of differing specific gravity.

Hydrostatic gauge—Pressure and temperature measurements are made using liquid head and a tank capacity table. This gauge enables mass, density, volume and level to be derived or calculated.

Radar gauge—This gauge measures the time (frequency change) that it takes for a radar wave to go from a transmitter to the liquid surface and back again.

Servo gauge—A microprocessor measures the buoyancy of a displacer. As the buoyancy changes, the microprocessor adjusts a servo mechanism to adjust the level of the displacement and to maintain a constant buoyancy. Periodic hand gauging of storage tanks is required by fueling procedures of most airlines to accurately verify gauging accuracy.

The control center for the Brussels Airport fueling facility. The panel to the left shows the graphic fuel system and operation-indicating lights.

Systems control

Electrical power—Electrical power to a fuel storage facility is often provided as a separate sub-feed from the utility service for the airport. The use and sizing of emergency generators for the facility are based on the reliability of the primary power supply and the importance of providing continuous fueling operations at the site. During a power outage, a diesel generator would be sized and provided as a standby power supply for system pumping, controls and critical system components.

Electrical power is distributed at the facility in a manner similar to other industrial systems. Motor control centers provide the primary means of controlling and distributing power to the system pumps and other components.

Electronic controls—Fuel facility system controls can include a variety of components. In most modern large airport fueling systems, there are computer workstations and/or graphic panels with alarm lights and operator interface switches, which are controlled by microcomputers and dual redundant programmable logic controllers.

Today's control system components consist of personal computers with high resolution CRT screens with software that provides an operator interface for fuel system control functions. The control system monitors, controls and reports on the following: tank levels, motor operated valves, pump operations, emergency shutdown of fueling operations, alarms, pump runtime, system pressure and flow instrumentation and other items as required by the individual system. An uninterruptible power supply (UPS) system provides continuous, conditioned on-line power to the control system.

Environmental and safety concerns

Environmental

There are many environmental concerns at a fuel storage facility. Measures are required to maintain a pollution-free facility by containing any leaks or spills from the tank/piping system. A spill prevention control and counter measure plan (SPCC) and a National Pollution Discharge Elimination System (NPDES) discharge permit are required by EPA 40 CFR Part 122 for the facility operation. A storm water pollution prevention plan also is required by some local AHJs.

Diking—Diking for a vertical AST is provided as a part of this containment system, as required by NFPA 30 (Flammable and Combustible Liquids Code) and EPA regulations (EPA 40 CFR Part 112 and Part 122).

One commonly used diking system is made of cast-in-place vertical concrete walls that are six feet high. This diking method is frequently used in lieu of earthen berms available land area. Where the facility area permits, the diking system is often constructed of earth berm walls with an internal concrete slope protection facing. An impervious liner material in the diked containment area is often employed.

Fuel facility personnel take extra precautions to protect against spillage and leaking equipment at their mechanical equipment areas (i.e., the areas that contain pumps, filter and valving) by installing secondary containment to prevent soil and groundwater pollution. Containment for spills or leaks in these areas generally consists of curbed concrete slabs.

Oil/water separator—An underground oil/water separator is used to process storm water effluent from the fuel storage facility containment areas. The size of the separator will be between 10,000 and 12,000 gallons in capacity, based on the “watershed area” and potential spill volumes. Storm water from the diked containment area, the equipment pad areas and the truck transport load/unloading stations must be routed through the oil/water separator.

Inground monitoring wells—Placed in and around the facility, these wells are commonly used and periodically tested as a means to monitor groundwater conditions for signs of hydrocarbon pollution.

Fire Protection

The fuel storage facility must be provided with a fire protection system. The types and components of these systems can vary, depending on conditions. The fire protection systems consist of fire water systems and fixed or semi-fixed foam fire suppression systems.

NFPA 30, Flammable and Combustible Liquids Code, NFPA 11, Standard for Low Expansion Foam, and regulations of the local AHJ are the primary codes on fuel storage facilities. Firefighting water demand typically ranges between 3,000 gpm and 4,000 gpm peak flow rate. A fuel facility firefighting water loop encircling the facility with fire hydrants and/or monitors is generally provided.

For vertical AST protection, a fixed or semi-fixed fire suppression system is used. The semi-fixed system consists of a remote fire department connection stand and dry piping system to each tank in the facility. A portable foam tank unit provides the foam and injection equipment for the system. The tanks are equipped with external vertical piping to a top foam maker or makers. A fixed fire suppression system has basically the same equipment with the addition of a fire pump house with firewater pumps, foam storage and injection equipment, and if required, a water storage tank.

Water monitors are often used, with either water or water/foam nozzle dispersing means, for both external tank fire protection and for providing cooling water for adjacent structures. Portable fire extinguishers are used throughout the facility at various locations.

Coming up next...

In the next issue of PE&T, I will cover the fundamentals of fuel distribution and the fueling process at large airports. If you have any questions or comments, please contact me through PE&T Magazine.

A foam test for AST required by the local fire authorities.

Gary Austerman is a senior facility planner of airport fueling systems with Burns & McDonnell. He was heavily involved in planning and design for the DFW project. His email is gauster@burnsmcd.com.