AIRCRAFT FUEL HYDRANT SYSTEM DESIGN ISSUES

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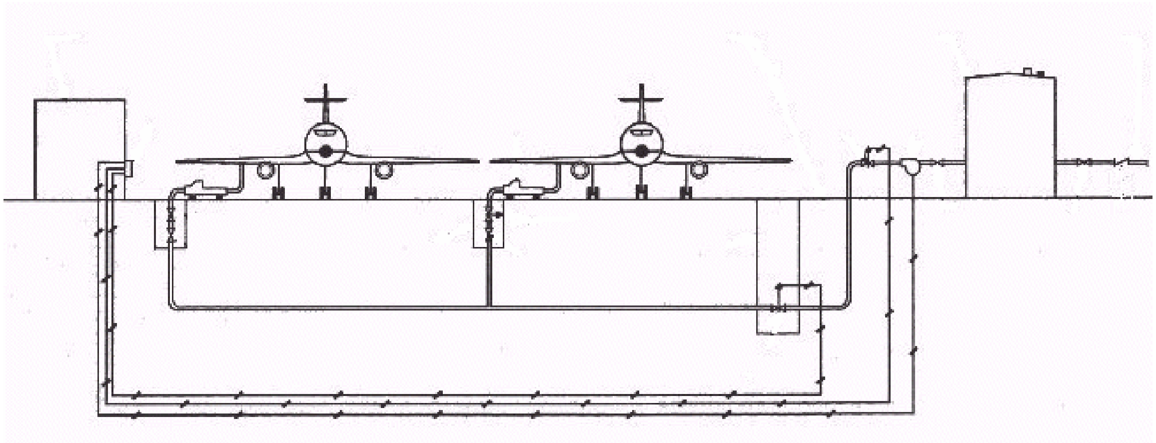
Presented At:
The International Forum on Emergency and Risk Management
Singapore Aviation Academy
10 – 12 January 2005

Several major international publications have recently suggested that in order for the aviation industry to return to profitable levels the airlines will have to reduce fuel consumption or lower the cost of aviation fuel. Indeed, the Chief Operating Officer of one major international air carrier recently declared fuel to be "the crisis of the year" and the Director General of IATA referred to the record fuel costs levels as the "fifth horseman of the apocalypse."

In light of these issues and with the rising cost of petroleum and in particular refined jet fuel, providing a safe and efficient means of fueling aircraft has become a key element of every major airport design. This session will focus on the design features of Fixed Airport Hydrant Fueling Systems to minimize life safety risks.

The National Fire Protection Association NFPA 407 Standard for Aircraft Fuel Servicing describes aircraft fuel servicing as the transfer of a flammable or combustible liquid fuel between a bulk storage system and the fuel tanks of an aircraft. The transfer is usually accomplished by using a tank vehicle, a hydrant vehicle, a hydrant cart, a fuel servicing cabinet, or a fueling pit. Drums and pumps are sometimes used. Acknowledging there are other alternatives to hydrant fueling of aircraft, we will focus only on the fixed system in our discussion. Fixed hydrant systems are typically found at larger international airports. A cost benefit analysis should be performed to determine the best type of system for any given situation. Where large volumes of fuel are being regularly transferred into aircraft the fixed hydrant system should be strongly considered. However, a fixed hydrant system can often be justified by providing a safer means of fueling aircraft than can be achieved by having large refueler trucks negotiate very congested aircraft parking aprons or tarmacs.

The typical Airport Hydrant System can be divided into three major subsystems; 1) Inbound or receiving system, 2) storage system, and 3) dispensing or delivery system.



Typical Fixed Aircraft Fuel Hydrant System

Before we get into design aspects of hydrant systems, an understanding of the basic characteristics of jet fuel will be helpful. Jet fuel for modern jet and turbo-prop aircraft is kerosene based and typically falls into three classifications, Jet A, Jet A-1, and JP-8. Aviation gasoline is used for smaller internal combustion piston engine powered aircraft and is typically dispensed via refueler trucks. Jet A and Jet A-1 are commercial designations and JP-8 is typically used by the military. Jet A is used in the United States and Jet A-1 is used by most of the rest of the world.

Jet A-1 has a lower freezing point than Jet A, making it more suitable for long international flights. The lower freezing point comes at a price and therefore, Jet A is preferred in the United States due to fuel price and availability. Other characteristics of Jet A and Jet A-1 are identical.

Kerosene based turbine fuels are considered to be combustible liquids while aviation gasoline (avgas) is a volatile flammable liquid. Aviation gasoline has a flash point of approximately -46^{o}C (-50^{o}F), while Jet A and other kerosene grade turbine fuels have a minimum flash point of 38^{o}C (100^{o}F). Flash point is the lowest temperature at which the vapors above a flammable liquid will ignite upon the application of an ignition source. Aviation gasoline produces large volumes of vapor and is capable of forming ignitable mixtures with air even at very low temperatures. Jet A and other kerosene grades of turbine fuel do not produce ignitable mixtures with air at normal temperatures and pressures, but when Jet A turbine fuel is heated above its flash point or exists in the form of a mist the mixture can be ignited. This condition can develop where temperatures are 38^{o}C (100^{o}F) or higher.

Aviation gasoline has an autoignition temperature approximating 449^{o}C (840^{o}F), while Jet A and other kerosene grade turbine fuels have autoignition temperatures of 246^{o}C (475^{o}F). Temperatures in this range can exist for a considerable period in turbine engines after shutdown or on brake surfaces following hard use. Autoignition temperature is the minimum temperature of a substance that will initiate or cause self-sustained combustion independently of any sparks or other means of ignition.

Jet A and other kerosene grade turbine fuels have higher energy content per unit volume than less dense aviation gasoline, making them more desirable for jet fuel use.

Jet fuel is sterile when it is produced at the refinery because of the high processing temperature; however, there are numerous opportunities to contaminate the fuel in its route from refinery to aircraft. Contamination can occur any time that fuel is transferred.

It is extremely important that jet fuel be delivered to the aircraft clean and on specification. This includes thermal stability, flash point, viscosity, conductivity lubricity, fluidity, and volatility.

Fuel cleanliness means the absence of solid particles such as rust and dirt and absence of free water. Particulates can plug fuel filters. Water in the fuel may enable corrosion of some metals and aid in the growth of microorganisms. Fuels that are out of specification can seriously impact engine life and performance.

Fuel quality control is outlined in several industry standards including Air Transport Association (ATA) 103 Standard for Jet Fuel Quality Control at Airports; International Air Transport Association (IATA) Fuel Quality Control and Fueling Service Guidance Material; and Joint Inspection Group (JIG) Guidelines.

Safety Considerations

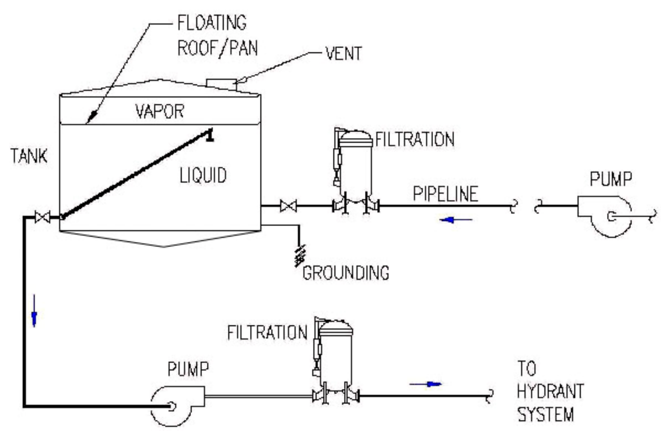
Fuel Types:
Jet A, Jet A-1, JP8

Fuel Delivery:
Static From Filtration
Surge Suppression

Tanks:
Static, Lightning, Vapor, Overfill

Pumps:
Bearings, Motors, Alignmen
Pressure Control

Filtration:
Static, Air Entrapment



Relaxation (NFPA 407):
"The design shall incorporate the provision of a 30-second relaxation period between the filter separator and the discharge outlet."

Safety Considerations of the Fixed Aircraft Fuel Hydrant System

Receiving System:

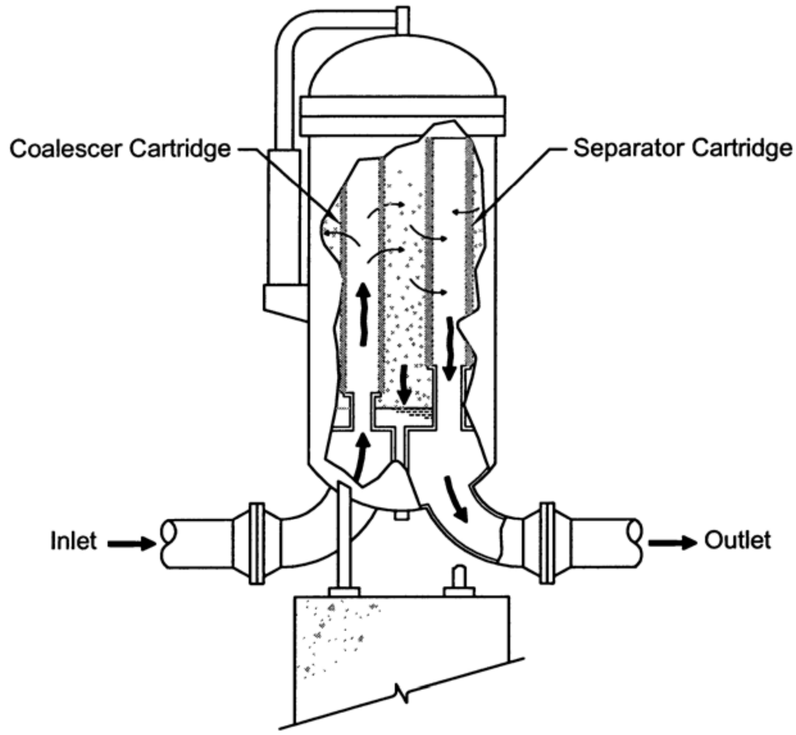
Fuel is received at airport fueling systems via one or more of several different delivery methods; dedicated pipeline, multi-product pipeline, over-the-road transports, rail car, and ship or barge.

Many large airports are served by one or more dedicated pipelines. In this case, Jet Fuel received at the pipeline terminal from a multi-product pipeline is placed into dedicated storage, where its quality is confirmed. The jet fuel is then transported via a dedicated pipeline to the airport.

In the case of fuel delivered to the airport via multi-product pipeline, “Break-out” storage tanks are required at the airport to receive batches of fuel that are sent along the pipeline. Facilities to handle the multi-product interface are also necessary at this location. Product received that is not “on-specification” is returned to the refinery for further processing. When rail car and ships or barges are used for the delivery of fuel, they should be dedicated to the shipment of jet fuel or contamination could occur and the entire shipment be rejected.

The amount and type of equipment required in the receiving system will vary by location and by the quality of the fuel received. For large airports, dedicated pipelines and for smaller airports, over-the-road transports are the most common delivery methods.

For pipeline delivery, the pipeline is connected to the airport storage system through a series of valves, meters and filters. Receipt of fuel is generally considered to occur at the pipeline connection valve on the airport receiving system. Received jet fuel is processed through a series of filters that can include pleated paper or synthetic fiber filter elements for removal of particulates, often called pre-filters or Micronics filters. The jet fuel is then passed through filter/separators for removal of free waters. These filters are equipped with water coalescing elements, which cause smaller droplets of water to combine into larger drops and then pass the fuel through water separator elements that allow the fuel to pass through and reject the larger water droplets.   Sumps are provided in the bottom of the vessel to collect and drain off the water. Heaters should be installed on the sumps in freezing climates. The filter/separator shall incorporate an automatic air eliminator. While filter/separators are generally considered to be the workhorse of the modern jet fuel system, they can in fact be one on the greatest contributors of safety issues.



Coalescer and Separator Cartridges in Filter/Separator

Fuel passing through the filter elements can generate static charges. Adequate relaxation time must be provided by the system design to allow the separated charges to recombine. The generally accepted relaxation time is 30 seconds between the filter and the discharge outlet. The required relaxation can be accomplished by utilizing adequate pipe length or through the use of relaxation chambers.

Improper filling of filter/separator vessels has also been known to cause fires or combustion in the vessel. The flash fires can occur by pumping fuel into the vessel when it is empty. The fuel flowing through the filters can create electrostatic charges and the empty vessel will have plenty of air inside to support combustion. Evidence of combustion can usually be seen in the form of burned areas on the elements or blackened spots on the walls or domed lid of the vessel. Operating personnel should be properly instructed in changing filters and refilling the vessel. Vessels should be refilled slowly. Filter vessel manufacturers should be consulted for their recommended practice. Static charging usually increases as fuel flow velocity increases through the element.

The receiving equipment requirement is similar for the other delivery methods, except the equipment needed to connect to the delivery vessel, be it transport, rail car or ship or barge must be provided. An off-load pump is usually required to strip the transport vessel and pump the jet fuel into storage tanks. Unloading pumps should be located as close as possible to the unloading vehicle to minimize suction line length. A bonding system should be provided to bond the transport vehicle to the unloading system. The unloading area should be provided with concrete aprons designed to contain spills and direct them to an oil/water collection system. The design and layout should be in accordance with all applicable local environmental codes. Raised concrete islands or curbs are recommended to help protect all associated unloading equipment from vehicular collision. Bollards may be used to further protect equipment from damage. Unloading hose adapters should be provided that are appropriate for the type of aviation fuel being received and should be non-sparking. These systems should be provided with Emergency Fuel Shut-off System to stop the flow of fuel in event of an emergency or fuel spills. Receiving systems should be interconnected to high-level alarms on the storage tank to prevent over-filling the tank.

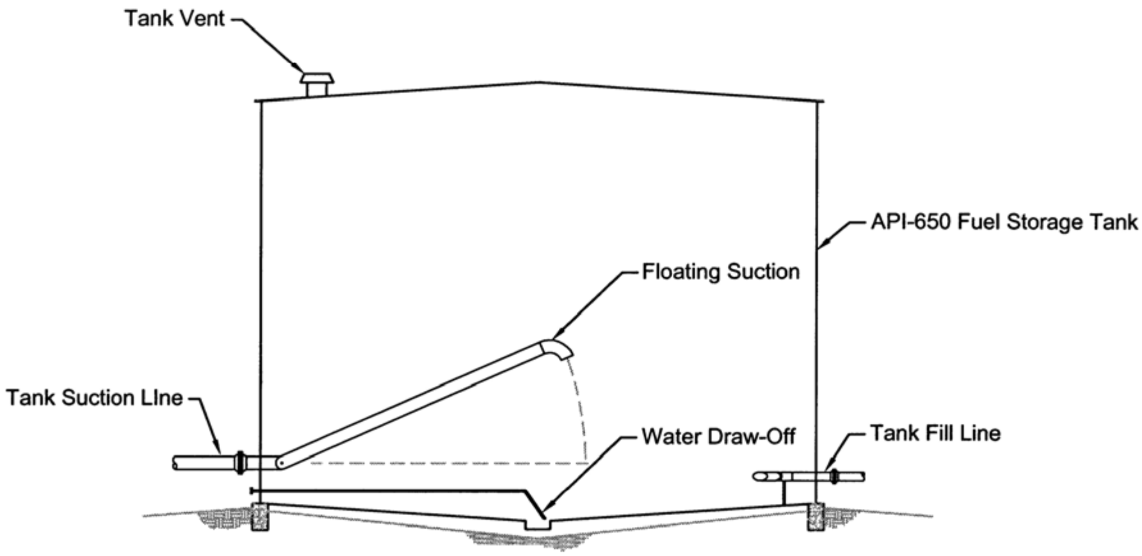
Electrical equipment used should be rated for the degree of hazard. Check with local and national codes to determine the requirements. Even though Jet A and Jet A-1 are combustible liquids, the National Fire Protection Association (NFPA) requires all electrical equipment and wiring to meet the requirements of the National Electrical Code NFPA 70, Article 515, utilizing the Class I liquids requirements for all applications. This is because jet fuel when heated or stored above its flash point can give off significant levels of flammable vapors. This would be especially true in the tropic or sub-tropic regions.

Storage System:

Storage tanks for typical fixed hydrant fueling systems are usually aboveground vertical welded steel storage tanks. Some smaller systems may employ the use of horizontal tanks either aboveground or underground. However, the fuel volumes for large commercial airports will generally necessitate multiple large capacity aboveground vertical storage tanks. The number of tanks and size of tanks will be determined by the daily up-lifted volume of jet fuel. Most facilities provide for 5 to 7 days of onsite storage. Factors such as frequency of pipeline delivery can impact the amount of onsite storage required.

The design of tanks for jet fuel storage is the topic of a lot of discussion. I feel the best design for large aboveground vertical tanks is a cone roof and cone bottom tank with a center sump meeting API 650 standards. The tank should have an internal diffuser on the tank inlet to slow the velocity of incoming fuel and to avoid splashing. The outlet should be equipped with an internal floating suction so that fuel can be drawn from near the top of the tank instead of lower in the tank where water and particulate matter may still be settling out of the fuel. The design of the tank bottom should allow for easy extraction of water and is probably the most debated element of tank design in the industry. Many different designs have evolved over the years for pipeline terminal and bulk storage tanks. I feel the use of a center sump in tanks dedicated to on-airport dispensing of jet fuel allows for the shortest path for any condensation developing on the wall of the tank to reach the sump. This is especially important where delivery cycles dictate the shortest possible settling times. The tank should be fitted with a water draw-off and smaller sampling lines.

Adequate means must be provided to allow personnel entry into the tank for periodic inspections and cleaning. ATA, IATA quality standards, and other local standards will define the frequency of these inspections and cleanings.



Typical Jet Fuel Storage Tank

For lightning protection and for personnel safety, the tank should be grounded, as should all aboveground piping and equipment.

The tank should be fitted with proper venting utilizing either gravity or pressure vacuum vents to prevent a build-up of pressure in the tank beyond the design parameters.

Not long ago, almost all tanks in the United States for jet fuel service were equipped with internal floating pans. The pans were used to reduce vapor losses and were required to meet air quality requirements. Gravity vents were used to prevent over pressurizing the tank. Experience has taught us that floating pans are usually unnecessary for use with Jet A and Jet A-1. Jet A and Jet A-1 are relatively dense fuels and do not under normal conditions give off significant vapors. However, you should consult local codes and environmental regulations to determine if floating pans will be required.

In fact, the use of floating pans and open gravity vents has been found to be the source of particulate contamination of jet fuel in some instances. Several years ago, I received a call regarding fuel contamination at a major airport fuel facility. The system had been in operation for over five years and had always supplied quality, clean, and on-spec fuel. The tanks at this facility were equipped with internal floating pans and gravity tank vents. It was observed that the filter cartridges on the hydrant pumping system had to be replaced at a frequent rate, while the filters on the receiving system stayed on their normally expected schedule. We found that particulate matter was entering the storage tanks and collecting around the tank wall and floating pan seal. With every fill and withdraw cycle of the tank, particulate matter would be swept into the fuel by the pan seal. The particulate matter was wind blown concrete dust from a nearby concrete batch plant that was set up for a major runway development project. The floating pan was acting like a large piston and was sucking dust into the tank as the fuel level was drawn down. In this case, the internal floating pans were removed and the gravity vents were sealed and pressure vacuum vents installed in their place. These steps solved the contamination problem.

Other safety features required for storage tanks include level switches or sensors to prevent over-filling and gauging systems for level and inventory control.

Fire protection for the tank will be provided through either surface or surface injection of foam (AFFF). Foam is typically stored and generated onsite or is provided by manifold connections for airport fire fighting equipment. Foam turrets or cannons may also be required around the dike area.

Diking will be provided in accordance with local code requirements. NFPA 30 provides recommended practice for location and spacing of tanks.

Tanks and other components of the system require coating systems that are specially formulated for jet fuel service. Most fixed hydrant systems will use mild carbon steel for the tanks, filter vessels and piping systems. Vessels and piping are typically sand blasted to appropriate specifications and coated internally with factory applied epoxy resin coating systems. External coating for aboveground use will be epoxy resin or polyurethane. Tanks will have their coating systems field applied. External coating for underground pipe will typically be factory applied epoxy resin, polyurethane or bituminous primer paint and self-adhesive plastic wrapping. Local conditions and availability may determine the best option. The internal coating reduces the amount of particulate matter that enters the fuel by minimizing the amount of rust and weld slag in the system

Zinc-coated cast iron, copper, or copper alloy pipes and fittings shall not be used in contact with aviation fuel. Some systems have used more expensive stainless steel for piping and filter vessels; however, we have found that properly coated carbon steel is a much more economical solution.

All pipe joints should be welded, except for sections that may later need to be removed for maintenance. All buried piping should be 100% radiograph inspected conforming to national or international standards. The use of screwed fittings should be avoided. Flanged fittings should be kept to a minimum underground, and where used should be made accessible by installing them in pits or vaults with removable covers or lids capable of withstanding any loads that may be imposed.

All aboveground or exposed piping and equipment should be color coded for the proper Jet fuel in the system in accordance with API or IP Standards.

Dispensing System:

The typical hydrant pumping system consists of a bank of pumps operating in parallel, a bank of outbound filter/separators for water removal, and appropriate flow control valves and appropriate isolation valves as required by the system layout. Strainers should be used to protect the pumps. The pumps and filters are typically installed as sets on a manifold. This arrangement will ensure the flow capacity of the filter elements is not exceeded. A flow control valve should be used to regulate the flow through each set. These manifold sets will feed through some type of pressure and flow sensing device or devices to provide a means of controlling the pumping system.

The pump and filter pad area should be curbed or contained to minimize any spills from the system. Local codes will dictate the specific requirements.

The pump and filter manifold system will be provided with sampling points for fuel quality checks. Thermal reliefs shall be provided for any sections of piping that may be trapped to protect against excessive pressure caused by thermal expansion of the contents. The discharge of any relief valves should be collected and processed in accordance with local environmental regulations.

A positive means of isolation should be provided where the hydrant transfer line enters the ground. This should be in the form of double block of bleed valves to facilitate any periodic testing or isolation required of the lines.

The tank farm can often be separated by long distances and by significant elevation differences from the fueling apron or tarmac. A hydraulic analysis should be performed to determine the appropriate pump parameters and line size for each individual installation.

Modern jet aircraft, depending on the size and type, can receive fuel at flows between 150 and 1000 GPM. Each individual airport must be thoroughly evaluated to determine the proper pressure rates and flow capacity required of the system. The system layout and distances and elevation changes will impact pump size, filter/separator capacity and piping size for the pump manifolds and for the hydrant system transfer line(s) and apron piping system. The analysis should take into consideration, the number of gates, the type of aircraft, typical load factors, and length of flights and “turn-around” time for the flights.

This usually takes a great amount of experience in analyzing the optimum pressure and flow requirements for the hydrant system. Otherwise, the system may be grossly over-designed or on the other hand may not be able to supply the required jet fuel in the maximum flow situation. Our Engineers have developed a proprietary computer model that allows us to predict the optimum design based upon the specific location parameters.

You might say, well lets just throw in a safety factor to ensure we have enough fuel flow capacity. Experience has shown that an over-designed piping system can have detrimental effect on fuel quality. The system should be designed to provide extended periods of fuel flow in the 6 ft/sec range in order to provide a sweeping or cleansing action within the piping system. Otherwise, at lower velocities, condensate water may collect in the piping and promote microbial growth.

The hydrant transfer piping and apron piping should be sloped at a minimum of ½ of 1 percent to low point drains installed in the system to facilitate water removal and also to facilitate pump-down of the system for any periodic repairs. National and International Standards should be consulted for required slopes. High point vents should also be installed at the system high points for venting of air from the system. Care should be exercised in locating these points to avoid placing them in areas that will not be readily accessible or may require closure or shutdown of critical airport operations.

Control of the hydrant system is typically accomplished on a pressure and flow basis. A drop in pressure on the system will start one pump, and an increase in flow in the system will bring on additional pumps as required to meet the flow demand. The system will shut down as flow decreases and the final pump will shutdown when system pressure has been satisfied. These systems vary in complexity depending on budget, operator/airline requirements and other factors. The large airport hydrant system is usually provided with computer based systems that not only control the flow of fuel and provide the operator with an interface to remotely operate system valves, etc. Some systems also provide a significant level of inventory control. The control systems can be is simple or complex as the user desires.

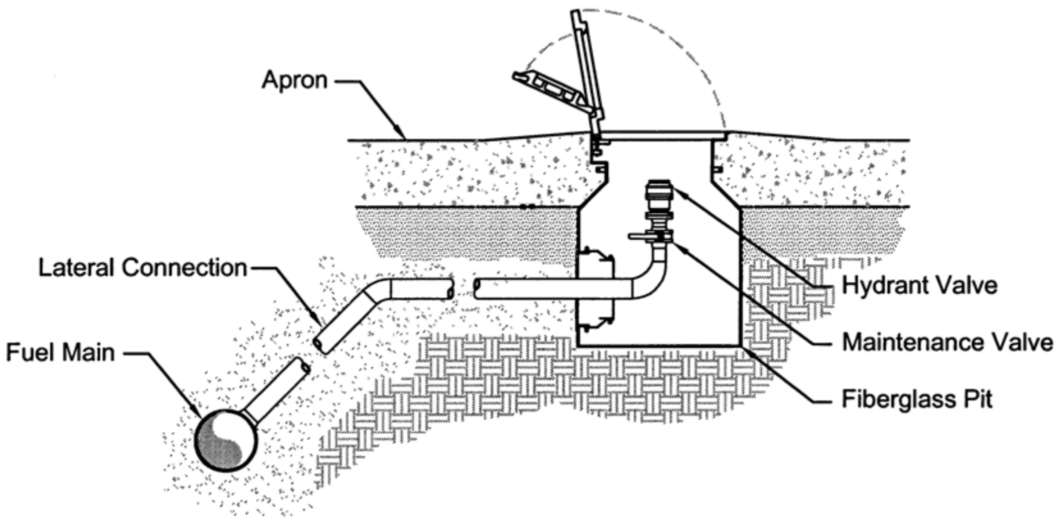
Hydrant systems shall be cathodically protected and shall be isolated from all aboveground piping and grounded systems by utilizing isolating flanges at the point where the underground piping emerges from the ground.

The hydrant transfer line/lines should be routed to the fueling apron in such a manner to minimize interruption to the system in the event of future development. The depth of bury should be consistent with API/IP requirements. Ideally, the transfer line would consist of two parallel lines sized for the required flow. This arrangement allows for a return path to the Tank Farm in the event fuel needs to be circulated, and also assists tremendously in the initial flushing process.

The hydrant system would ideally be a looped system encircling the terminal, concourse or fueling apron. This arrangement allows for the greatest flexibility in the operation of the system, facilitates the flushing process, and can help to maximize fueling operations in the event a portion of the line is shutdown for maintenance or repair.

Hydrant pit valves are used and located on the fueling apron to connect the fuel servicing vehicle or cart to the hydrant system. The fueling vehicle or cart provides the interface between the system and the fueling point on the aircraft. Hydrant pits should be designed to withstand all expected wheel loadings from aircraft, tugs and all other ground service equipment.

Pits should be installed at least 1 inch above surrounding apron and should be uniformly sloped back to apron grade, to minimize the entrance of surface water into the hydrant pit. Local conditions or codes may dictate different degrees of slope.



Typical Apron Hydrant Pit Assembly

Isolation valve pits or vaults should be located to provide ability to isolate or segment portions of the hydrant system. System layout will dictate the best location for isolation.

The typical hydrant system employs the use of surge suppression to minimize excessive pressure surges created by the rapid closure of hydrant pit valves and emergency fuel shutoff valves. A surge analysis should be performed to determine the amount and location of surge suppression. Surge suppression at the fueling apron may be installed in the isolation valve vaults below grade. Underground vaults shall have access covers designed for anticipated wheel loading and of adequate size to safely permit personnel entry. Adequate means of ventilation inside the pit shall be provided.

Hydrant pits shall not be located within 50 feet of any terminal, concourse, hangar or cargo building, other than movable passenger loading bridges. Pits shall be located to allow fueling operations such that fueling equipment/vehicles and aircraft tank vents are not within 50 feet from any building other than passenger loading bridges.

All hydrant systems shall include an emergency fuel shutoff system to positively stop the flow of fuel in the event of a spill or emergency. The system shall include adequately marked signage to locate pull or break-glass (EFSO) stations around the terminal, concourse or cargo building. Signage shall be in accordance with NFPA 407 requirements. The EFSO stations shall close valves and/or shutoff pumps to positively stop the flow of fuel. EFSO valves shall be fast closing and of the fail-safe type.

Fuel Servicing Vehicles or Carts shall be provided with metering, filtration and control valves to safely control the flow of fuel into the aircraft. The Fuel Servicing Vehicle/Cart shall be equipped with a dead-man type system in accordance with NFPA 407 to stop the flow of fuel. Fuel is typically dispensed into the aircraft at pressures not to exceed 50 psi. The vehicle or cart should be provided with pressure controls to regulate the pressure into the aircraft.

Fuel Servicing Vehicles/Cart shall be equipped with a bonding cable that shall be connected to the aircraft before beginning any fueling operations. Vehicles/Carts shall not be grounded to any point on the hydrant system or to any point on the apron. If grounding is required to the aircraft for other operations/reasons, it shall not be accomplished through connection to the Vehicle/Cart.

In addition to system design, many operational factors affect the safe fueling of aircraft. Several factors that should be addressed by the system operator include:

- Fueling during lightning storms. The local authority having jurisdiction may provide guidelines of when to cease fueling operation.

- Use of mobile communication equipment should be used in the vicinity of fueling operations unless specifically approved for that purpose.

- Operators should be restricted from carry matches or lighters.

- Clothing/Uniforms worn by fueling personnel should be of materials that do not generate static charges.

Operators should be trained in the safe operation of their equipment, including location of EFSO stations and should be trained in locating a safe route of egress in event of an emergency. EFSO stations should always remain accessible, and signage and stations should not be blocked by apron equipment.

Each facility shall be provided with a Spill Prevention Control and Countermeasure Plan (SPCC) and Facility Response Plan (FRP). The plans should provide contact information, outline possible hazards and provide operator guidance in handling spills and emergencies.

Flushing/Commissioning of System:

You have now designed the perfect Fixed Aircraft Hydrant Fueling System. How do you ensure you are going to deliver clean fuel to the aircraft? You will have to do extensive flushing of the system to ensure the tanks, piping and vessels have been cleaned and are free of any contamination. The best advice I can give is to take every precaution during construction to ensure that water or debris cannot enter the system. All pipe ends should always be covered with shipping covers and once placed in the trench, open ends should be protected with watertight plugs. The cleaner you keep the system, the easier it will be to flush. System design will dictate how the system should be flushed prior to placing into operation. Ideally the flushing media would be drawn from one tank through the pumping system at relatively high velocities through the transfer line around the hydrant loop and back to a receiving tank. Hydrant lateral and dead-ended sections of piping should be individually flushed into appropriate mobile tanks or over-the-road transports. Equipment such as hydrant pit valves, metering equipment and filter cartridges should not be installed during initial flushing.