Hazards of Airplane Fuel-Tank Entry

A large percentage of the work involved in properly inspecting and modifying airplane fuel tanks and their associated systems must be done in the interior of the tanks. Performing the necessary tasks requires inspection and maintenance personnel to physically enter the tank, where many environmental hazards exist. These potential hazards include fire and explosion, toxic and irritating chemicals, oxygen deficiency, and the confined nature of the fuel tank itself. In order to prevent related injuries, operator and repair station maintenance organizations must develop specific procedures for identifying, controlling, or eliminating the hazards associated with fuel-tank entry.

Maintenance personnel who enter airplane fuel tanks to inspect or modify them face several potential hazards. These include exposure to flammable and toxic chemicals, potentially harmful atmospheric conditions, and the confined interior structure of the tank. Operators and repair stations can protect maintenance personnel from these hazards by developing safety procedures for fuel-tank entry personnel. To successfully prevent related injuries, both operators and maintenance personnel must understand the following:

1. Fuel-tank hazards.
2. Preparation for entry.
3. Conditions required for entry.
4. Emergency response plan.

Fuel-Tank Hazards
The potential dangers that fuel-tank personnel may experience present themselves in one of two forms:

- Chemical.
- Physical.

CHEMICAL
The most commonly recognized hazard of fuel-tank work is the jet fuel itself. Jet fuel is a flammable liquid and can be ignited given certain ambient conditions, primarily temperature and vapor concentration. The temperature at which the vapors of a flammable liquid can ignite is known as the "flash point." A hazardous vapor concentration is present when a fuel vapor reaches a level known as the lower flammability limit (LFL) or lower explosive limit (LEL). These limits are usually expressed as a percentage by volume. Fuels below the LFL/LEL are considered too lean to burn. If the fuel vapor concentration exceeds the upper flammability limit or upper explosive limit, the fuel is considered too rich to burn. A fuel vapor concentration between these two limits is considered to be in its flammable range and will ignite and burn if exposed to an ignition source. One of the best ways to control unwanted fires and explosions is to keep the fuel vapor concentration below the LFL/LEL, preventing it from reaching its flammable range (figure 1).Other flammable chemicals may also be present during fuel-tank work. Chemicals with a low flash point (less than 70ºF (21ºC)), such as methyl ethyl ketone (MEK), are even more hazardous than jet fuel, and their use must be strictly controlled.

Chemicals, including jet fuel, may also present toxic or irritant hazards. At high concentrations, jet fuel and other hydrocarbons can affect the nervous system, causing headache, dizziness, and lack of coordination. Chemicals may also cause chronic health problems, such as liver and kidney damage. Cleaning solvents, sealants, lubricants, and other chemicals used in fuel-tank work can also cause irritating effects to the skin if not controlled.

PHYSICAL

The physical characteristics of the tank itself can create hazards and can also exacerbate fire, explosion, and toxicity hazards. Entry into most airplane fuel tanks is through an oblong hole less than two ft (0.6 m) long and one ft (0.3 m) wide. Though the interior dimensions of fuel tanks vary considerably, with the wing center tanks in widebody jets the largest, all fuel tanks have a limited volume. A relatively small amount of a chemical inside one of these enclosed spaces can create significant levels of flammable or toxic vapor.

Wing tanks usually have a single access hole between each rib section. The inboard portion of the wing tank offers just enough clearance inside of the tank for a maintenance person's head, shoulders, and trunk, leaving the legs outside of the access hole. The tank becomes smaller as it progresses farther outboard on the wing, until it may accommodate only a maintenance person's head and shoulders. The most outboard sections of the wing may only have enough room for a maintenance person's hands and arms.

Wing-stub tanks and wing center-section tanks can be large enough to allow maintenance personnel to completely enter the tank. The access holes in these areas are usually the same shape and dimension as those in wing tanks. The inside of these tanks usually have spar and rib structures, equipped with various size and shape access holes between sections. In addition, some wing center tanks, as well as many auxiliary tanks, are equipped with flexible fuel bladders. These bladders must be fastened in some manner to the metal walls, floors, and ceiling of integral tanks.

Preparation for Entry

Several steps must be completed before a maintenance person enters an airplane fuel tank. These include electrically grounding and defueling the airplane according to standard practices, making adequate fire protection equipment readily available, and deactivating associated airplane systems, including fueling/defueling and fuel transfer systems.Three final steps must be performed to ensure a safe atmosphere for maintenance personnel:

- Ensure adequate ventilation.
- Follow recommended ventilation techniques.
- Properly monitor air in fuel tanks.

ENSURE ADEQUATE VENTILATION

The single most important method of controlling the fire, explosion, and toxic hazards associated with working in an open fuel tank is ventilation. The more fresh air that is present in the fuel tank, the safer the environment will be for maintenance personnel. Continuously pushing fresh air into a fuel tank helps to prevent a fuel vapor concentration from reaching its LFL, thus preventing fires and explosions. Fresh air also dilutes the vapor concentration of toxic chemicals, reducing the risk of hazardous exposures. High volumes of fresh air will also prevent a condition known as oxygen deficiency. Normal concentration of atmospheric oxygen in air is about 21 percent. At oxygen-deficient levels (19.5 percent and below) a person will begin to exhibit signs of oxygen starvation, including headache, nausea, drowsiness, and slurred speech. At increasingly lower oxygen concentrations, more severe reactions occur. Ultimately, death by asphyxiation is possible.

Oxygen deficiency is often caused by physically displacing the oxygen in a space. For example, pumping nitrogen into a fuel tank to prevent fire ignition will cause the oxygen concentration to decrease. Oxygen deficiency can also be caused by the oxidation of some material, which can use up the available oxygen within a space. Oxidation is a chemical reaction that combines atmospheric oxygen with some other material to form an oxide. Iron oxide, commonly known as rust, is an example.

FOLLOW RECOMMENDED VENTILATION TECHNIQUES

The physical structure of airplane fuel tanks presents some unavoidable challenges in ensuring adequate ventilation. Some of the challenges include dead air spaces and small openings between tank sections that inhibit air flow, ventilation equipment that may not be selected or set up properly, or suspension of ventilation before the entry work is completed. Planning and execution are critical to providing adequate ventilation.

The recommended practice for conducting tank ventilation is the push-pull technique. First, an upstream "push" access hole should be opened. Next, a downstream "pull" hole should be opened. Finally, a blower should be located at the push hole, forcing fresh air into the tank. Exhaust equipment can be located at the pull hole to supplement the airflow through the tank.

PROPERLY MONITOR AIR IN FUEL TANKS

No maintenance personnel should enter a fuel tank until it has been adequately ventilated. To determine if the atmosphere in the tank is suitable for entry, the atmospheric conditions should be checked and continuously monitored for oxygen concentration, flammable vapor concentration, and toxic vapor concentration.

Entry should not be permitted unless the oxygen concentration is between 19.5 and 23.5 percent. Concentrations below 19.5 percent are considered oxygen-deficient. Concentrations above 23.5 percent are considered oxygen-enriched and significantly increase the risk of fire and explosion. Maintenance personnel should not be permitted to enter the tank if either of these conditions exists.

Instruments are available that can simultaneously monitor the oxygen concentration and flammable vapor concentration, but the measurement of oxygen concentration is the most critical. Any measurements outside of the permitted range can significantly threaten the safety of entry personnel and can cause faulty readings of other monitoring devices, especially those used to detect flammable vapors.

Instruments used to monitor flammability must be calibrated for the type of flammable vapor determined to be present. For Jet-A-type jet fuels, a flammable gas monitor calibrated with hexane will be reasonably accurate. If other types of jet fuels are present, the monitor must be calibrated according to the characteristics of the fuel. In many cases, the specific characteristics of the fuel may be unknown, so allowances in instrument accuracy should be considered. If other flammable chemicals are present, such as MEK, specifically calibrated devices will be needed to monitor for the presence of these vapors.

Instruments are also available for monitoring potentially toxic atmospheres. Again, specific instruments and monitoring techniques must be selected based on the type of chemical present. Operators and repair stations should consult safety and industrial-hygiene professionals for recommendations on dealing with toxic chemicals.

Conditions Required For Entry

The most important factor in preventing injury during fuel-tank work is a properly trained and equipped entry crew. The entry crew is composed of the entry supervisor, the standby attendant, and the entry personnel. The entry supervisor authorizes the work and ensures that it is conducted according to procedure. The standby attendant stays outside of the fuel tank to monitor conditions in and around the work area. The standby attendant is authorized to order evacuation of the fuel tank if conditions change and put the entry personnel at risk. Entry personnel enter the fuel tank and perform the work. They must be able to recognize potential hazards and evacuate the tank if working conditions deteriorate.Individually and together, the members of the fuel-tank entry crew must be aware of the following requirements for safe working conditions:

- Communication.
- Respiratory protection.
- Ventilation and air monitoring.
- Electrically powered equipment.
- Airplane damage considerations.

COMMUNICATION

Continuous voice communication should be maintained between entry personnel and the standby attendant throughout the entry process. Voice communication can be assisted by radio or electronic equipment, but these devices must be rated for use in potentially flammable (classified) atmospheres.

RESPIRATORY PROTECTION

Depending on the atmospheric hazards present, entry personnel may be required to wear respiratory protection. Air-purifying respirators can be used if the oxygen concentration is at least 19.5 percent. If the potential exists for oxygen depletion, or if chemical exposure levels are above the permissible exposure level (PEL), supplied-air respiratory protection may be required. In any situation, safety or industrial hygiene professionals should be consulted for specific recommendations.

VENTILATION AND AIR MONITORING

Fresh air should be supplied to the fuel tank throughout tank entry. If ventilation is suspended, tank entrants should evacuate the tank until the ventilation can be re-established. The atmospheric conditions of the tank should also be monitored throughout tank entry. If the oxygen concentration levels drop below 19.5 percent or rise above 23.5 percent, tank entrants should immediately evacuate the tank. If flammable vapor levels exceed 10 percent of the LFL or if toxic vapor concentrations exceed the PEL, tank entrants should evacuate the tank.

ELECTRICALLY POWERED EQUIPMENT

Maintenance technicians may need to use a variety of energized equipment, including lighting, testing equipment, and powered tools. All electrically powered equipment must be intrinsically safe or rated for use in a potentially flammable atmosphere. Pneumatic tools should be powered only by compressed air, not by nitrogen or other inert gas that could displace the oxygen inside the tank.

AIRPLANE DAMAGE CONSIDERATIONS

Personnel performing fuel-tank entry work may damage the airplane if they are not properly trained to avoid such damage. The mating surfaces of the access hole and covers should be protected during entry so that the surfaces are not scratched or otherwise damaged. The components inside fuel tanks, such as fuel pumps, fuel-quantity systems, and associated wiring and conduits, are also vulnerable to damage if they are struck or dislodged. Finally, the containment properties of the fuel tank can be compromised if the sealant is damaged or dislodged or if fuel-tank bladders are penetrated.

Emergency Response Plans

Fuel-tank work procedures must also address the potential for emergency situations. If specific response procedures are not developed, an emergency situation may result in severe injury or death to maintenance personnel. Operators and repair stations should prepare procedures for maintenance personnel to follow in the following four situations:

- Entrant self-evacuation.
- Attendant-ordered evacuation.
- Air monitor alarms.
- Unresponsive tank-entrant rescue.

ENTRANT SELF-EVACUATION
The tank entrant must be able to recognize the hazards of working in an airplane fuel tank and should be ready to evacuate if conditions change, including the entrant's own psychological state. Entry into enclosed spaces can induce uncontrollable claustrophobia, resulting in panic and an inability to function normally. Tank entrants should be trained to recognize the beginning stages of claustrophobia and what to do when this occurs.

ATTENDANT-ORDERED EVACUATION
The standby attendant must continually monitor conditions in and around the work area. If conditions change and potentially put the tank entrant at risk, the attendant should order the entrant to evacuate the fuel tank. The attendant should be trained to recognize symptoms of oxygen deficiency and overexposure to toxic chemicals and should closely monitor the physical state of the tank entrant. If the tank entrant exhibits adverse symptoms, the attendant should order the tank entrant to evacuate the tank.

AIR MONITOR ALARMS
If the instruments used to monitor atmospheric conditions in the tank go into an alarm mode, the tank entrant should immediately evacuate the tank. The specific condition causing the alarm should be identified and corrected before work inside of the tank can continue.

UNRESPONSIVE TANK-ENTRANT RESCUE
If for any reason the tank entrant becomes unresponsive, the standby attendant should immediately initiate rescue procedures, including immediate notification of emergency response assistance. The standby attendant should then ensure that fresh air is being supplied to the tank entrant. All ventilation equipment should be checked, and more ventilation should be supplied if available. Additional access holes should be opened if possible.

Personnel entering a fuel tank for rescue purposes must be specially trained in rescue techniques and should be provided with appropriate rescue equipment, including supplied air and self-contained breathing apparatus.

Summary

Airplane fuel-tank entry is necessary for inspection and modification but can pose hazards to maintenance personnel performing the work. Fuel-tank work can be accomplished as required without placing personnel at risk through effective preparation and training. Operator and repair station airplane maintenance organizations can provide a safe, healthy work environment for fuel-tank personnel by identifying potential hazards, developing control measures, and instructing personnel in the specific procedures to be followed during fuel-tank work.-------------------------------------

Glossary of Terms

FLAMMABLE RANGE
The fuel vapor/air concentrations between the lower and upper flammability limit. A fuel-vapor concentration in the flammable range will support combustion.

FLASH POINT
The minimum temperature at which the vapors of a flammable liquid will ignite.

INTRINSICALLY SAFE
Electrically powered equipment that has been designed and built to eliminate and/or contain potential ignition sources due to the electricity in the device. Also known as "explosion proof."

LOWER EXPLOSIVE LIMIT (LEL)
Same as lower flammability limit.

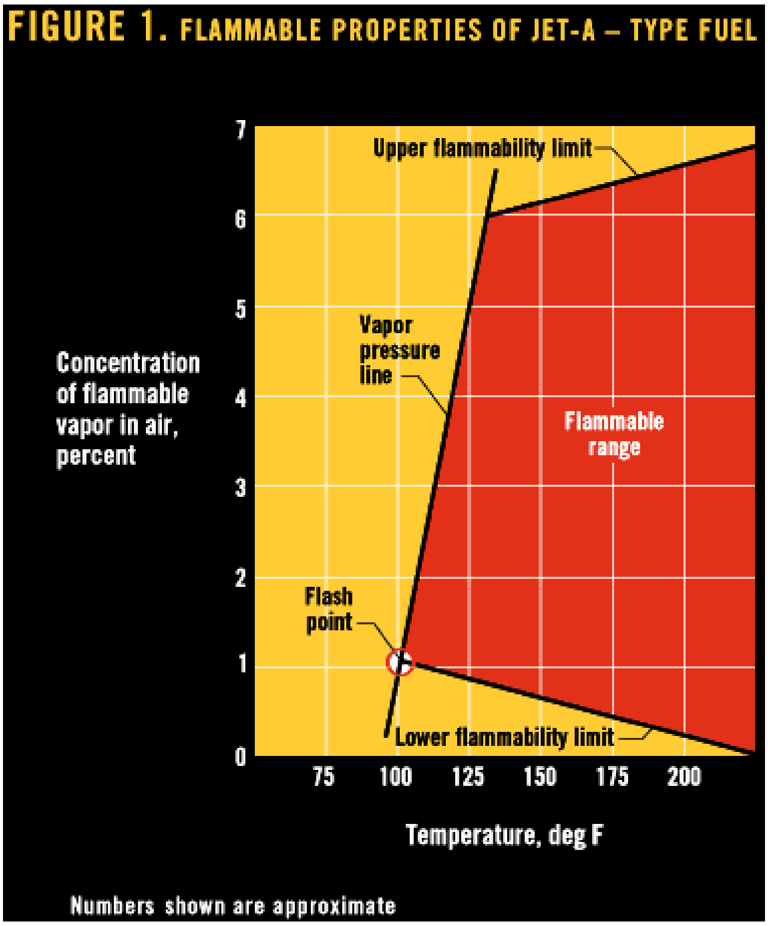
LOWER FLAMMABILITY LIMIT (LFL)
The minimum concentration of a fuel vapor in air that will support combustion, usually expressed as a percentage. Fuel vapor-concentrations below the LFL are considered too lean to burn.

OXYGEN DEFICIENCY
The normal atmospheric concentration of oxygen in air is approximately 21 percent. By definition, an oxygen concentration of 19.5 percent or lower is considered oxygen deficient. Oxygen deficiency can cause increasingly severe reactions.

PERMISSIBLE EXPOSURE LIMIT (PEL)
The maximum concentration of an airborne chemical that a person may be exposed to over an eight-hour work shift. Usually expressed as a time-weighted average.

UPPER EXPLOSIVE LIMIT (UEL)
Same as upper flammability limit.

UPPER FLAMMABILITY LIMIT (UFL)
The maximum concentration of a fuel vapor in air that will support combustion, usually expressed as a percentage. Fuel-vapor concentrations above the UFL are considered too rich to burn.



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