AIRCRAFT ENGINE PLANTS

INTRODUCTION

Only a few companies in the world manufacture aircraft engines. The engines continue to improve in the fuel efficiency, performance and reduced noise. Thousands of parts are required for the assembly of an engine. These parts can be manufactured in-house or supplied from vendors. Large parts such as forgings and castings, as well as pre-assembled parts such as motors, switches, and bearings are generally purchased. Machining of rough castings and forgings, cleaning, heat treating of blades, assembly and testing are done by the engine company.

A large jet engine manufacturer can ship 400 – 500 type engines each year. This requires large warehousing facilities to contain the parts. Quality control is paramount. Parts and assembled units are inspected frequently and paperwork travels with the parts to final assembly. Failure of any component is identified, responsibility assigned and the component re-worked or scrapped.

PROCESS AND HAZARDS

Process Storage

A wide range of arrangements for storage of parts exist including plastic pallet totes bins at Work In Process (WIP) location to completely automated retrieval rack systems (hi-rise racks). Often WIP is in hand picking plastic bins with packaging to handle Electro Static Discharge (ESD) from personnel. The bins in these areas generally do not exceed 6 ft (1.8 m) in height without going beyond an Ordinary Hazard Group 2 design.

Large metal parts are frequently stored in wood crates on wood skids. Smaller parts are typically stored in KD cartons on wood skids or in plastic tote bins and divided metal bins. Parts are often pre-assembled into kits and stored in plastic tote bins.

Components and subassemblies are, in general, Class II and Class III commodities. The use of plastic tote bins or special plastic packaging usually raises the commodity class to a Group A plastic.

Major warehouses, with their high values, constitute large loss potential of involved in a fire. Parts and finished engines are extremely susceptible to damage from heat, smoke and water. Salvage will probably be slight due to the close tolerances of finished product required. Finished engines, worth well over $1M in value, are packed and shipped soon after final testing. Only a few engines are expected in a single area at one time. Based on production needs, parts and kits from vendors are ordered for coordinated arrival and are held in storage until actually needed.

Engine parts salvage is a tricky issue. Many engine producers would say they expect a high salvage rate. The parts are designed to be exposed to heat, etc.

The size of a loss to goods on the shop floor would depend on how many hours had been used to complete the assemblies. Storage is generally not extensive and combustible loading is limited.

Machining

The machining process is highly automated and ranges from ceramic finders to the machining of magnesium, aluminum and titanium. Much of the equipment may be of non-U.S. manufacture. One German made ceramic grinder automatically retrieves new grinding wheels via the Automatic Storage and Retrieval System (AS/RS) and delivers it to the grinder on an Automatic Guided Vehicle (AGV). Most equipment has individual hydraulic oil systems ranging from combustible to low hazard oils. Some departments may have common cooling oil systems supplying to all machines.

Light combustible loading tends to limit most loss exposures to one high value machine in a single fire incident. Magnesium, aluminum and titanium dust can explode and fines are ignitable. Honing operations are common and the cutting fluid may be mineral oil.

Dust collection and other chip collection are needed including oil separation. Certain metals react differently to protection and Class D extinguishing media should be near by. Oil mist collection units are often in these areas that condenses/distills oil mist from the air. Cleanliness of these units is a must along with proper fire protection which can be determined by the material being machined.

Hydraulic systems present a severe loss exposure as a pressurized oil leak, may be ignited by hot surfaces and become a direct flame fire. See PRC.9.2.4 for further information.

Cleaning

Cleaning is typically done in trichloroethylene or perchloroethylene vapor degreasers, acid and caustic chemical solutions and by dipping in solvents. Parts are usually in flow through plastic tote bins.

Chemical cleaning lines have plastic ducts and tanks or tank liners, and are subject to “plating” room fire caused by low liquid levels and overheated heating sources. Vapor degreasers, especially electric immersion heaters are prone to cause this fire. Fire involving degreasers and cleaning solvents also present a contamination exposure. These events usually result in large dollar loss incidents. See PRC.9.2.5.1 for further information.

Heat Treating

A variety of ovens and furnaces are used for drying and heat treating parts. Many will require a flammable atmosphere, usually hydrogen. Scrubbing systems for the atmospheres evacuated from the furnace are needed.

Damage to furnaces is likely to be from the combustible fuel or process atmosphere. The most likely occurrence from an issue in an atmospheric furnace is during start up and shut down. During this period, the concentration of the atmosphere passes through the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL). These can result in a large PD and TE losses. See PRC.4.0.1 for further information.

Assembly

Assembly operations are usually remote from machining. As parts are assembled, sequential testing occurs. Much of the assembly is done in climate control areas.

With light combustible loading, large fire losses are not expected. Depending on type of engine being produced, overhead cranes and similar assembly equipment may be used. Therefore, pieces are subject to dropping and other forms of impact.

Test Cells

An assembled engine fired on Jet-A fuel is tested in a specially constructed cell. Performance and fuel consumption tests are run for up to 6 h. All test data is recorded in the Control Room. These rooms are typically isolated from the rest of the building due to noise and fire concerns.

Ignition of a fuel spill or failure of an engine under test could results in loss of the engine and severe damage to the test cell if protection does not operate. Depending on the number of engines requiring immediate testing and delivery time frame, a large TE loss may develop.

Computer Systems

Computer operations are critical to the entire operation. Retrieving parts, operating machines, scheduling, storing test information, tracking parts in process, engineering design and general accounting are all essential computer functions.

The loss of the data processing controlling the process will severely curtail operations in most instances if there are not redundant systems. The loss may be a very large TE incident. It is critical to have duplicate data systems with extensive pre-planning making sure the back up works just as well.

Flammable and Combustible Liquids Storage

Solvents, hydraulic fluids and lubricating oils are used throughout the buildings. Suitable arranged one day’s supply holding areas should be designated. Bulk storage, drum storage and dispensing facilities are provided for tanks, 55 gal (14.5 L) drums, and assorted containers in separate fully protected buildings.

Hazardous waste storage facilities also exist and are typically detached. 90 day storage areas need to be clearly identified and protected accordingly.

Fires involving these liquids could be severe. These fires will develop quickly and can spread beyond the area of origin causing major damage. Location of the storage areas in relationship to machining, testing, etc. should be evaluated for a fire that could spread. Take into accounts wash over from fire fighting, lay of the land and if necessary the prevailing winds.

Outdoor Storage of Jet-A Fuel

The testing of jet engines requires a large amount of fuel. It is stored in large outside tanks, usually with floating roofs. The fuel is generally pumped to “Day Tanks” for use in the test cells.

Unless there is good separation and tanks are in their own dike, multiple tanks can become involved in a fire. Common ignition sources include lightning and hot work.

The need for fuel and several types of hydraulic fluids and lubricants require the storage and handling of large volumes of combustible and flammable liquids may be needed based on the production plant. Fueling of aircraft is usually done at runway facilities and does not expose manufacturing facilities, but there may be volumes needed for testing.

Any fire involving flammable and/or combustible liquids can lead to serious damage. Sites with Jet-A fuel tanks should be Pre-planned accordingly.

There are several types of jet fuels with varying degree of flash points and uses. See Table 1 for flash points of the fuels.

TABLE 1
Flash Point of Fuels

Name of Fuel	Flash Point °F
Jet A-1	> 100
Jet A (typical commercial fuel)	120
Jet B	< close to JP-4 for colder climates
JP-4	0
JP-5	140
JP-8	100

SI Units: °C = °(F-32)

Jet fuels are a kerosene based product with varying additives to lower the flash point and to lower the freezing point, especially for military grade fuels. Jet A has virtually the same flash point as Jet A-1 but a much higher freeze temperature.

JP-4 is typically considered military grade fuel. It is a blend of gasoline, kerosene and light distillates for corrosion inhibitors and low freezing points. The additive of gasoline drastically reduces the flash point. JP-5 is also a military grade fuel with a much higher flash point than JP-4.

Jet B is a blend of gasoline/naphtha and kerosene to lower the freezing point and is rarely used except for colder climates. The addition of the gasoline reduces the flash point as well. JP-8 is the military equivalent of Jet A-1 with additives for corrosion and de-icing.

LOSS PREVENTION AND CONTROL

The protection guidelines are not all inclusive. Where hazards or construction features are unusual to the occupancy covered, the protection for that hazard or construction is discussed. Care should be taken in applying the protection guidelines given since they are written with an “average” hazard level in mind. Increased levels would warrant increased protection. The protection standards contained in the Reference section should be consulted.

Construction

Construct buildings of noncombustible material. Construct engine test cells of fire resistive material and designed with blast resistant walls and roof capable of withstanding an internal pressure of 100 psf (4.79 kPa).

Cut-off parts storage warehouses from other buildings by a 4 h fire rated, parapeted fire walls and double 3 h fire rated, automatic closing fire doors. There should be no other wall penetrations. Provide automatic heat and smoke venting on a ratio of 1:100, with half the ratio supplied by mechanical venting. Segregate major shop floor storage areas by curtain boards and with similar roof venting.

Cut-off flammable and combustible liquid storage vaults with 3 h fire rated walls and 3 h fire rated, automatic closing fire doors.

Interior Protection

Install wet pipe sprinkler systems throughout the buildings.

- Production and Assembly: Ordinary Hazard Group 2 based on usual occupancy.
- Offices, Control Rooms and Computer Rooms: Ordinary Hazard Group 1 based on upon usual occupancy. Unusual installation, critical equipment or usage requires improvement.
- Parts Storage: Sprinkler densities per NFPA 13, and PRC.12.1.1.0 based on storage height, commodity classifications, and storage arrangement. Maximum reliability may be needed based upon storage height or total values, see PRC.10.1.2.1
- Test Cells: Deluge water spray protection providing 0.50 gpm/ft^2 (20.35 L/min/m^2) over the entire area. Actuation should be both automatic and manual. Provide an automatic total flooding carbon dioxide system using a concentration of at least 36%. Provide stations for manual actuation. Use only materials that are UL Listed/FM Approved for the application and have a flame spread less than 25.
- Dust Collection: Sprinkler protection is preferred, but the material involved and the type of fire expected MUST be considered. Carbon dioxide local application is normal approach to smaller operations.
- Oil Mist Collection: Sprinkler protection inside collector following Extra Hazard Group 2 minimum with ducts greater than 100 in.^{2} (65,400 mm^2) with sprinklers installed inside.
- Oil Storage: Arrange per NFPA 30 and PRC.8.1.0 and install an Extra Hazard Group 2 sprinkler protection.

Special Hazards

Provide Class D fire extinguishers in areas where machining combustible metals (titanium, magnesium, zirconium, etc.) or storing the fines occurs. Separate chips from other metals. Consider using special cutting oils as to the type of hand fire fighting tactics.

Install local application carbon dioxide system in large computerized machines using combustible cutting oils. Provide the carbon dioxide system with a connected reserve and arranged for manual and automatic activation.

Interlock the test cells to shut-down tests upon loss of fuel pressure, high temperature or fire suppression actuation. Refer to NFPA 423 for additional information.

Protect computer and control rooms in accordance with PRC.17.10.

Exterior Protection

Hydrant spacing should follow typical layout with locations strategic to fighting a Jet-A fuel tank fire. This includes on site foam quantities and all necessary equipment for the responding fire department to use.

Management Programs

Management program administrators should report to top management through the minimum number of steps. They should also institute adequate loss prevention inspection and audit programs to communicate program effectiveness to top management. This management feedback is a key feature of PRC.1.0.1. In developing a program, pay particular attention to the following important areas that can be unique to this industry:

Employee Training

Due to the varied materials being processed including metal fines (magnesium, titanium, etc.); strict training is needed for the method of attack in case of a fire. The program should include identifying a metal type fire and methods of extinguishment. This also is true for fuels used on site. Written programs with follow up refreshers are needed. See PRC.1.4.0 for further information.

Pre-Emergency Planning

There are not that many companies that build aircraft engines. Understanding the relationship ahead of a major incident helps to address current concerns now and supports the need for local protection at the property. Vital paper and electronic records should be secured as needed with a secondary storage location or recovery operation. See PRC.1.7.0 for further information.

Hazard Evaluation

Written programs need to clearly define the existing hazards including fuel, flammable/combustible liquids, heat treating, plating operations, etc. There also needs to be a clear responsibility chart of personnel with defined roles for new hazards brought on site. This includes safety, engineering, facilities, management, etc. personnel to sign off on new equipment/methodologies when brought on site. See PRC.1.13.0 for further information.

Management of Change

Producing aircraft engines can take several weeks and longer to produce. Including development, design, production, testing, etc. can be several years. During this period, personnel may change frequently at all levels of management. This change can introduce misconceptions of the direction of a project and pre-agreed to loss prevention measures. This should have a clearly defined method to capture issues that may cause good prevention measures to be lost. See PRC.1.0.2 for further information.

Other References

Many other sources of information can be found in PRC.17.17.3 and PRC.17.17.4.