AIRCRAFT ASSEMBLY OPERATIONS

INTRODUCTION

Aircraft assembly plants can include several types and sized of aircraft production. These include military (fighter, transport, and bomber), commercial (airliner and commuter aircraft) and private. Helicopters are similarly handled. Security regulations and restrictions, particularly in regard to military aircraft component storage, assembly and test, may restrict access to some areas of the facilities, however, construction and occupancies types of these areas dictate protection features.

Individual aircraft constitute a significantly high value. Large facilities housing two, three or more aircraft in production assembly create major values under one roof. Offsetting this is the unusually large open building areas, often only with light or no combustible loading reflecting only intermittent continuity of combustibles. Evaluation of fire protection needs can become difficult. Protection needs for individual aircraft during assembly stages varies dependent upon interior finishing materials and specialty operations being undertaken. In some circumstances, such as mock up models, a full fixed pipe sprinkler system should be installed. In other cases full sprinkler protection supplied from portable, manifold or specially designed piping systems will be needed.

Combustibility is usually much lower in the military aircraft due to the lack of combustible finish, such as paneling, upholstery seating and carpeting. However, due to specialties in equipment and design values can be extremely high.

PROCESS AND HAZARDS

Process Storage

Parts and subassemblies are generally received and stored in a central warehouse. These usually contain a variety of parts including reciprocating or rotary engines (high value), rubber tires, plastic and rubber parts, electrical equipment, metal castings, sheet metal, subassemblies, and assorted small parts. Portions of any of these could be very high in value for the application as these can be one of a kind or very small production type items. Classification of parts stored range from Class I to Class IV, Group A plastics, and rubber tires to totally non combustible. Storage configuration could be in many methods, rack and palletized storage to storage in carousels. Storage may be packaged in cardboard, plastic tote bins, wooden crate or unpackaged wired baskets. Storage may be in bulk floor storage configurations or in various rack/bin storage systems. Typically high piled storage configurations will be encountered. Automated computer controlled storage and retrieval systems are common. These storage facilities represent large loss potentials and should be limited in size on a value basis.

Assembly

Assembly operations consist of the joining parts and subassemblies (some very large and often need protection within) from the warehouse, outside vendors or on the site fabricated components. The overall building structure is typically very large to accommodate the assembly. The complexity of aircraft requires the tracking of millions of components. Computer facilities are critical in production of aircraft as most parts are tracked “cradle to grave.” See PRC.17.10.1 for additional information.

Method of assembly varies to mechanical, welds, crimped, pressed, etc. Due to the size of aircraft, these are often done on the assembly floor with the pieces brought in as needed via overhead cranes and other portable lift methods. Dropping of subassemblies is a concern at all points of manufacturing.

Present consensus protection guides such as NFPA 409 do not address the subject of interior protection for aircraft while undergoing manufacture, maintenance or modification. The size and volume of the interior of many aircraft is comparable to installing moderately sized building fire protection within a hangar. For example the area interior of a Boeing 747-400 is near 10,000 ft^2 (3050 m^2). During manufacture, interior protection for the hull of an aircraft should be provided when the sections are joined and combustible materials are introduced. Combustible materials include coated wiring, avionics, hydraulics, insulation, paneling, upholstery and carpeting. This often is client specific based on their overall protection philosophy and the size of the fuselage. Typically, a flex hose is connected to a water supply that is then hard piped and extended to inside the plane.

Technology in materials, design and construction methods vary greatly between all metal construction, plastic, fiberglass and graphite carbon composites formed on tools in vacuum autoclaves. Protection requirements for aircraft during assembly vary greatly with the type of aircraft being produced.

Special staging, work platforms, rigs and tooling, custom made or modified can represent a potential business interruption if damaged as well as being of high value. Also, the materials these are constructed of, can drastically affect a fire. They should be of non-combustible construction and open grating whenever possible (or solid material that is 4 ft (1.2 m) or less).

Loss of computers involved in production can result in a large Property Damage (PD) and Time Element (TE) loss. This often results in an immediate stoppage of the assembly operation until data collection and accumulation can be recovered.

During inspection and test “live” equipment will increase loss potential. Fuel may be needed at the finished aircraft during “checkout.” A fueling spill or line leak may create potential hazards.

Design and Development

While design and development of aircraft may not be carried on in the assembly area hazards are unique to the process. Development stages often span several years and each stage represents an increasingly higher value, both in physical property as well as time. Computers and computer records are critical to progressive evaluations. Prototype components, section and complete aircraft are constructed as mock assemblies. These are often one of a kind and placing a value on a piece can be extremely difficult. Frequently mock-ups are constructed of combustible materials. Flight simulators are used for design evaluation as well as training.

Mock-ups of combustible construction need to be protected to mitigate potential loss of the mock-up and minimize the potential of damage to the building.

Aircraft hulls require protection because they are enclosed areas in which combustibles and potentially hazardous work is being done.

Computers and computer records need to be protected to minimize the potential for loss of vital records and mitigate damage to the equipment. This includes electronic industrial espionage. Some information is so sensitive that they are often stored only on site specific equipment and can not be transferred to any medium that communicates to outside of the site.

Flight simulators are enclosed volumes containing high value equipment and should have protection.

Painting/Spraying

Painting is done in a cutoff, separate section of the manufacturing building or in a separate building. The aircraft is still un-fueled at this point, but the combustible interior may be in place. Paint may be applied by hand in the case of small aircraft or by robots. For large aircraft, paint stations or gantries consisting of computer controlled platforms are manually positioned on each side of the aircraft.

Most paints are either flammable or combustible, but water based materials are being used. Long term, water based paints have shown to not hold up on the aircraft over time.

Other type of exterior coatings may also be applied by spraying or hand (especially for military applications) that have special characteristics and will most likely be proprietary mixes. These can be Radar Absorbing Materials (RAM), light shifting/reflecting, composite strength materials, etc. The materials are often resins and epoxy and give off volatile organic compounds (VOC). Regenerative thermal oxidizers (afterburners), water washing, chemical/acid treatments are methods to deal with VOC emissions.

Flammable and Combustible Liquids (Fuels)

Paints for aircraft, and 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. Fueling of aircraft is usually done at runway facilities and does not expose manufacturing facilities.

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.

Government Operations

These operations consist of the installation of classified or sensitive electronic equipment such as the “Black Box” specified by the FAA. In military aircraft the installation of weapons and weapons control systems require special handling. Weapon attachment consists of the mechanical methods, but does not have “live” armaments. Decoys or other simulated materials may be used for testing weapon mechanics.

Normally the aircraft is not fueled at this point. If the aircraft is fueled, special building protection, such as AFFF or HiEx Foam is needed for the protection of the craft and the building. The installation of this type of equipment is completed in the final assembly stage. The dollar value of the assembled unit can be very high and access to these areas can be strictly limited.

Hush House Operations

Fueled aircraft are brought into the Hush House which may be either a four walled roofless enclosure or a regular hangar with both roof and walls. The engines are run and checked along with cockpit instrumentation prior to the first flight for adjustment and/or repair. This same process will probably occur after the first flight as well.

Due to the introduction of fuel, protection for both building structure and airplane are needed as loss of the entire facility is possible. Protection methods can be widespread including foam deluge and HiEx foam.

Pre and Post-Flight Check Operations

In this process, aircraft are either prepared for first flight or checked-out following the first flight. This will usually occur in a separate building.

Damage from fire to both buildings and aircraft can be severe due to the fuel exposure.

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

Construction buildings of noncombustible material. NFPA 409 classifies (Group I – IV) hangar based on tail heights, overall construction, and size of the single fire are. Follow the construction requirements in NFPA 409 depending on the Group the hanger is classified as.

Design the buildings to wind loads per ASCE 7 or equivalent.[1] For pre-engineered buildings, follow the manufacturers’ recommendations for fastening and securement.

Provide automatic smoke and heat venting on a ratio of 1:100, with half the ratio provided by mechanical venting in all storage areas.

Cut-off paint storage, mix and application rooms; boiler room; and major storage areas (including pyrotechnics storage) by 3 h rated fire barriers and single, 3 h rated, automatic closing fire doors. Also provide proper drainage, ventilation, and electrics in the paint storage, mix, and application rooms per NFPA 30 and PRC.8.1.0.

Cut-off offices and switchgear areas by 2 h rated fire barrier walls and 1½ h rated, automatic closing fire doors.

Cut-off squibs storage, a Class C explosive and other pyrotechnics with 3 h fire resistive rated construction.

Interior Protection

Provide a wet pipe sprinkler systems throughout the facility including electrical and telephone rooms based on the following densities:

- Warehouse and central storage: Design the 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.

- Assembly Building: Design for ordinary hazard Group 2 based upon no fuel being present. If fuel is present, provide either an AFFF foam-water, open head deluge protection system with under wing or “shadow” protection or HiEx Foam for the entire area. This includes floor discharge outlets in trench drains. As an alternative, provide a density or either 0.16 gpm/ft² (6.51 L/min/m²) over the entire area using non-air aspirating sprinklers or 0.20 gpm/ft² (8.14 L/min/m²) over the entire area using air aspirating sprinklers.
- Computer Rooms/Operations: Design for ordinary hazard Group 1. If the rooms have unusual installations, including high value or computers with sensitive information, provide additional protection. Additional protection includes: automatic fire detection system provided in the rooms, gaseous fire protection system installed in raised floor areas or strict adherences to under floor cable rating and type. VESDA sampling should be considered as any activation method for a gaseous flooding system.
- Flammable Liquids Storage: Provide protection per NFPA 30 and PRC.8.1.0 depending upon the size of area.
- Painting operations: Design for either an extra hazard Group 2 or a density of 0.16 gpm/ft² (6.51 L/min/m²) for the entire area using AFFF foam.
- Government Operations: Design for ordinary hazard Group 2 based upon no fuel being present. If fuel is present, provide a density of 0.16 gpm/ft² (6.51 L/min/m²) for the entire area using AFFF foam.
- Hush House Operations: Design for ordinary hazard Group 2 based upon no fuel being present. If fuel is present, provide a density of 0.16 gpm/ft² (6.51 L/min/m²) for the entire area using AFFF foam. Consider HiEx foam based upon application needs and site limitations.
- Pre and Post flight Check: Design for ordinary hazard Group 2 based upon no fuel being present. If fuel is present, provide a density of 0.16 gpm/ft² (6.51 L/min/m²) for the entire area using AFFF foam.
- Aircraft Hangars: Provide densities per NFPA 409.

Provide a temporary fire protection system for the aircraft hulls. Protection designs include an automatic sprinkler system, gaseous extinguishing system, water spray, or foam. Typically, a flex water hose is connected to a supply that is then hard piped and extended to inside the plane. Consider installing a very early smoke detection as the hull sections are assembled.

Hot site or back up operations are just as critical as any fire protection within the computer room. Test these sites annually and store the documents and plans in several locations. Often a back up operation site can be accomplished on a campus style production facility provided there are power back ups such as a second independent power supply or generators.

Special Hazards

Provide robotics paint spray operations with the following protection:

- Deluge protection system designed for a density of 0.16 gpm/ft² (6.51 L/min/m²) for the entire area using AFFF foam and activated by flame detection for the paint application areas.
- Carbon dioxide protection in the robotic enclosures and ancillary equipment.

In addition refer to NFPA 33 and PRC.9.2.3.1 relating to the design requirement for electric classification, ventilation, and handling.

Protect the paint mixing and storing areas require total flooding carbon dioxide protection in addition to sprinkler protection. Various other protections outlined in NFPA 30 also apply.

Design and protect computer rooms in accordance with PRC.17.10.

Where high valued electronics are stored, install an early warning, fast acting detection system. This type of detection may include VESDA, UV/IR, or other sampling methods.

Separate items with a long delivery time from other storage as much as possible.

Once the aircraft has been fueled, protect the area with either AFFF foam or HiEx foam system activated by a fast acting detection system. Provide proper ventilation, drainage, and electrics per NFPA 409.

Water Supplies

Design the water supply to supply the largest sprinkler demand plus 1000 gpm (3780 L/min) for hose streams.

Exterior Protection

Due to the large volumes of water used for fire protection devices in aircraft hangars, provide a 6 in. (150 mm) 3 way fire department connections at aircraft assembly properties.

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 varying applications of assembly operations, training for personnel is key to understand the issues at hand. Often floor areas have vertical wall separations for various reasons which isolate portions of the hulls and wings. This can give a false sense of security relating to the small area where the worker is located. This complacency can introduce flames and dangerous work in areas that should not have it.

Typically there is a certification level for employees and contractors working in the industry. This often is handled via a specific client or an off site training operation that is recognized in the industry. Frequently this is for regional areas that have several corporations doing similar work. 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 airplanes, therefore structures are limited. 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.

Larger sites would have onsite fire brigades or fire departments. When there is a private fire brigade or fire department coordination with local public authorities is needed. Some sites may be located near military operations and coordination with their operations is crucial as well. Much planning should be completed ahead of time to help in situations concerning who is in charge based on incidents. These plans should address types of aircrafts and responses needed. Often certain aircraft are considered military and only their support can be used in incidents. There are situations where military fire fighting capabilities may be used for non-military aircraft and is best determined ahead of any incidents.

Hazard Evaluation

Written programs need to clearly define the existing hazards including fuel, flammable and combustible liquids, and painting operations. 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, and management personnel to sign off on new equipment or methodologies when brought on site. See PRC.1.13.0 for further information.

Outside Contractors

Aircraft manufacturing is very complicated and requires many personnel for completion. This often involves bringing in contractors to complete specific tasks needed. All contractors should have on site training, records maintained, refresher/preferred contractor status, etc. and should follow all expected guidelines of any onsite employee. See PRC.1.0.4 for further information.

Management of Change

Producing large aircraft takes several months and longer to produce. Including development, design, production, and testing 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.17.17.2 and PRC.17.17.4.

REFERENCES

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