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Civil Aviation Authority of Singapore

Advisory Circular

AIRCRAFT CARGO COMPARTMENT SAFETY

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GENERAL

Advisory Circulars (ACs) are issued by the Director-General of Civil Aviation (DGCA) from time to time to provide practical guidance or certainty in respect of the statutory requirements for aviation safety. ACs contain information about standards, practices and procedures acceptable to CAAS. An AC may be used, in accordance with section 3C of the Air Navigation Act (Cap. 6) (ANA), to demonstrate compliance with a statutory requirement. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

PURPOSE

This AC provides guidance to AOC holders in demonstrating compliance with, and the information related to, managing safety in the carriage of items in aircraft cargo compartments.

APPLICABILITY

This AC is applicable to an AOC holder operating an aeroplane in accordance with Air Navigation (121 – Commercial Air Transport by Large Aeroplanes) Regulations 2018, ("ANR-121").

RELATED REGULATIONS

This AC relates specifically to Regulations 60A of ANR-121.

RELATED ADVISORY CIRCULARS

- AC 1-3 Safety Management Systems
- AC 119-2-4 Implementation of an AOC holder's Safety Performance System
- AC 119-2-2 Safety Management Systems – Safety Performance Indicators for an Air Operator Certificate Holder

- AC 121-2-7 Management of Lithium Batteries in the Aircraft Passenger Cabin
- AC DGR-2 Guidance for Carriage of Lithium Batteries by Air

CANCELLATION

This is the first AC issued on the subject.

EFFECTIVE DATE

This AC is effective from 17 November 2021.

OTHER REFERENCES

- ICAO Annex 6, Operation of Aircraft, Part I - International Commercial Air Transport – Aeroplanes
- ICAO Annex 18, The Safe Transport of Dangerous Goods by Air
- ICAO Annex 19, Safety Management
- ICAO Doc 10102, Guidance for Safe Operations Involving Aeroplane Cargo Compartments
- ICAO Doc 9859, Safety Management Manual
- ICAO Doc 9284, Technical Instructions for the Safe Transport of Dangerous Goods by Air (TI)
- ICAO Doc 9481, Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods

1 INTRODUCTION

1.1 Regulation 60A of ANR-121 requires the AOC holder to conduct a safety risk assessment prior to transporting items in the cargo compartments of its aircraft and correspondingly establish policies and procedures to ensure that, in the event of an inflight fire caused by items loaded in its aircraft cargo compartments, the fire can be detected and sufficiently suppressed or contained until the aircraft makes a safe landing. This takes into consideration that some items transported by air may have inherent hazardous properties that are not considered in the design of an aircraft and hence, the risks of transporting such items may not be sufficiently mitigated by aircraft systems alone.

1.2 This AC provides guidance to AOC holders on the conduct of a specific safety risk assessment for the transport of items in its aircraft cargo compartments. It should be noted that the scope of items involved is not limited to articles or substances that are classified as dangerous goods and also includes items having characteristics that would pose a hazard to the safe operations of aircraft such as the transport of large quantities of liquids, odd size cargo and live animals. Items transported in aircraft cargo compartments are also not limited to those that are carried as cargo but would also include items transported in baggage, mail or as stores (i.e. company material (COMAT)). Through a specific safety risk assessment, AOC holders will be able to identify the hazards and mitigate the risks in the transport of items in aircraft cargo compartments to an acceptable level of tolerance.

1.3 Identifying hazards, assessing and mitigating associated safety risks are elements within the second component of the Safety Management System (SMS) framework, hence this AC should be read in conjunction with AC 1-3 and AC 119-2-4 which provides guidance on SMS and its implementation by AOC holders. A specific safety risk assessment in the transport of items in its aircraft cargo compartments should be conducted according to its SMS manual accepted by CAAS.

2 IDENTIFYING HAZARDS AND THEIR CONSEQUENCES

Identifying Hazards

2.1 The first step in any Safety Risk Management (SRM) process is to identify hazards. The AOC holder should identify all reasonably foreseeable hazards based on the specific properties of items hazardous to the safe operations of aircraft that it routinely transports by air. They include, but are not limited, items having inherent explosive, flammable, toxic, corrosive and fluidity (applicable to the carriage of large quantities of liquids) characteristics. While such items are not limited to those classified as dangerous goods, it is envisaged that most items having such hazardous properties are dangerous goods. Hence, an AOC holder that regularly transports consignments of dangerous goods on its aircraft will be frequently exposed to such hazards and its associated safety risks.

2.2 Fire in the cargo compartment during flight may lead to severe consequences. When uncontrolled, fires caused by items transported in the cargo compartment can quickly overwhelm aircraft systems and have the potential of compromising the airworthiness

of an aircraft. Consequently, the AOC holder should expend more effort in identifying items that are inherently flammable and that it regularly transports on its aircraft.

2.3 Hazards associated with the transport of items in aircraft cargo compartments may be identified through the current hazard identification methods in the AOC holder's SMS. In addition, such hazards may also be identified through:

- discussions and assessments by subject matter experts;
- focus group discussions with internal and external stakeholders such as shippers, freight forwarders and service providers; and
- reviewing historical incidents and accidents involved in the transport of items in cargo compartments.

2.4 The AOC holder should also identify the hazards posed by other persons (e.g. shippers or passengers) who offer items for loading into its aircraft cargo compartments.

2.5 Some examples of hazards that may be present in the transport of items in aircraft cargo compartments are as follows:

(a) **Dangerous Goods** - Due to their inherent specific properties, dangerous goods are obvious hazards to the safe operations of aircraft when transported in cargo compartments. Many items classified as dangerous goods are flammable in nature, may contribute to fire on have other hazardous properties according to their classification.

(b) **Lithium Batteries** - While lithium batteries are also classified as dangerous goods, their ability to be both an ignition source and a fuel for subsequent fires are unique characteristics when compared to other dangerous goods. Lithium batteries may be offered as cargo, mail or in baggage, contained in data loggers to monitor sensitive cargo, or installed in devices used in "active" unit load devices (ULDs). Lithium batteries are sources of stored energy. When such batteries are not manufactured according to industry standards or are damaged, they have the potential of resulting in a thermal runway where fire, extreme heat and large quantities of flammable gases may be violently released which may affect adjacent lithium cells thereby triggering a chain reaction. If not mitigated, lithium batteries loaded in aircraft cargo compartments that are in a state of thermal runaway may escalate and overwhelm aircraft systems.

(c) **Data Loggers and Transmitting and Receiving Devices** - Shippers make use of data loggers and cargo tracking devices to monitor sensitive cargo transported in compartments. Such devices may remain active during flight by receiving and transmitting information regarding the condition of the cargo. In doing so, such devices have the potential of interfering with aircraft navigation or communication systems.

(d) **Undeclared Dangerous Goods** - Irrespective of whether an AOC holder is authorised to transport dangerous goods cargo by air, it will be exposed to the risk of transporting undeclared dangerous goods in cargo, mail, baggage and

COMAT. The hazard of undeclared dangerous goods in baggage should also be considered since passengers may not be aware of what items constitute as dangerous goods and the restrictions associated with transporting them in baggage.

(e) **Operator Company Material (COMAT)** - COMAT transported in the cargo compartments may include items intended for sale or consumption on subsequent flights or aircraft components transported as spares or those that were previously installed in the aircraft but for some reason had to be removed and transported as cargo in the cargo compartments. Some aircraft components (e.g. chemical oxygen generators and oxygen cylinders) are classified as dangerous goods and contain inherent hazards according to their classification. When transported in the cargo compartment, and in the absence of safeguards normally present when such equipment is installed for use in the aircraft, they pose a risk to the safe operations of aircraft. An AOC holder's personnel or service providers, having responsibilities in offering COMAT for transport by air, but who are not trained in the accordance with the dangerous goods regulations, may also cause or contribute to such hazards.

Consequences of Hazards

2.6 While identifying hazards, the AOC holder should also identify the potential consequences associated with each hazard based on the worst foreseeable situation. The AOC holder should also consider the specifications, capabilities and certification requirements of aircraft systems and how aircraft systems may be affected in the event of an in-flight incident. While it would be impractical to identify and assess every conceivable hazard and consequence in the transport of items in the cargo compartment, the AOC holder should nevertheless exercise reasonableness and due diligence in identifying those that are pertinent to the items it regularly transport by air.

2.7 A consequence is a potential outcome that is contributed by at least one hazard. A consequence may be an intermediate event such as smoke, start of a fire, failure of aircraft systems, or loss of control of aircraft. If unmitigated, it may lead to an ultimate consequence which could be an accident.

2.8 Some examples of consequences of hazards from items transported in aircraft cargo compartments are as follows:

(a) **Smoke and Fumes** - Smoke and fumes in the cabin and flight deck can affect the physical and mental performance of crew members in carrying out their responsibilities. Inhalation of smoke and fumes may cause discomfort, confusion and may lead to incapacitation of passengers and crew. Smoke can also obscure light leading to reduced visibility and impede the evacuation of passengers from an aircraft.

(b) **Fire** - An inflight fire onboard an aircraft may lead to a serious consequence. For a fire to ignite and persist, there must be fuel, a heat or ignition source and oxygen or oxidizing agent in appropriate proportions. Items classified as dangerous goods and having flammable properties and items made of material

that are combustible or packed using packaging material that are combustible (e.g. cardboard) are potential sources of fuel to any fire. Flammable liquids emit flammable vapor or have low flash points making them easily ignitable when an ignition source is present. Some flammable solids may auto-ignite when exposed to a heat source while others may ignite when in contact with air or water making them both a fuel and an ignition source. Concentrated organic peroxides liable to undergo exothermic reaction may also generate enough heat to ignite combustible material when in contact with them. Damaged and defective lithium batteries with the possibility of thermal runaway is another potential ignition source. In addition to items transported in cargo compartments which may provide an ignition or heat source, the AOC holder should also consider external sources (e.g. exposed aircraft wiring in cargo compartments) having the potential to ignite a fire. Available air in the aircraft which contains oxygen and items having oxidizing properties can provide the oxygen necessary to contribute and sustain a fire.

Ultimate Consequence

2.9 The start of smoke and fire may be regarded as an intermediate event proceeding from a hazard. If not effectively mitigated in a timely manner, they may escalate towards an ultimate consequence involving the loss of lives and/or the aircraft. In its SRM process, the AOC holder should identify all credible intermediate events and ultimate consequences for each hazard contributed by items transported in its aircraft cargo compartments so that appropriate and effective measures may be implemented to mitigate its severity and probability.

3 SAFETY RISK ASSESSMENT

3.1 Assessing safety risk involves determining the severity of a consequence and the probability of it occurring as a result of hazards from items transported in the cargo compartment. When assessing safety risks, the AOC holder should adhere to its processes as documented in its SMS manual.

3.2 Where available, relevant data should be used to support the assessment of safety risks. The AOC holder could gather data from its own operations to aid in quantifying and assessing of the probability of consequences associated with items transported in cargo compartments. Such data may include (but are not limited to):

- damage to items through any part of the supply chain;
- shippers deliberately or unintentionally offering dangerous goods for transport without declaring them;
- shippers improperly classifying, packing, marking or labelling dangerous goods;
- freight forwarders accepting undeclared dangerous goods from shippers;
- dangerous goods prohibited in the mail; and
- passengers carrying prohibited dangerous goods in baggage.

3.3 The AOC holder may also consider gathering safety data from external sources and public domains on dangerous goods accidents and incidents relating to fires in cargo compartments, leaks/spills from items transported in cargo compartments and the

discovery of undeclared or misdeclared dangerous goods transported as cargo or in mail and passenger or crew baggage.

3.4 The purpose of assessing safety risks is to determine if the risk of transporting items in the cargo compartments are within the AOC holder's acceptable, tolerable or intolerable ranges. When safety risk associated with the hazard of transporting certain items in the cargo compartment is deemed to fall within the intolerable range, the AOC holder will need to implement appropriate measures to mitigate the safety risks of the consequence to an acceptable level or alternatively prohibit the carriage of such items altogether.

AOC holders may refer to CAAS AC 1-3, Safety Management System for additional guidance on SRM processes.

4 MITIGATING SAFETY RISK

4.1 Safety risk in the transport of items in aircraft cargo compartments should be mitigated to as low as reasonably practicable. Mitigating safety risks require the AOC holder to implement safety risk controls to reduce the severity of a consequence, reduce the likelihood of its occurrence or reduce exposure to that safety risk.

Mitigating Likelihood of Occurrence

4.2 The AOC holder should consider the following mitigation strategies to reduce the likelihood that a consequence may occur as a result of hazards in the transport of items in the cargo compartment.

(a) **Dangerous Goods** - The ICAO TI contains the guiding principles and requirements to mitigate safety risk in the transport of dangerous goods as cargo, in baggage and mail. Compliance with the requirements of ICAO TI provides an acceptable level of safety in transport of dangerous goods in cargo compartments. Notwithstanding this, the AOC holder should note that the mitigating measures prescribed in the ICAO TI (e.g. through packing and quantity restrictions) are usually at the item or package level and does not consider the volume of dangerous goods that may be transported on an aircraft based on an aircraft's capabilities or certification requirements. Compliance with the requirements of the ICAO TI also does not ensure that dangerous goods will be protected against external factors beyond the normal conditions encountered in transport and handling (e.g. external fire or damage caused by falling cargo or baggage).

(b) **Fire Mitigation** - Mitigating against an inflight fire focuses on preventing its occurrence. By removing any of the elements (fuel, oxygen and ignition / heat source) required to start and sustain a fire will prevent the start of a fire or a fire from persisting after has started. Identifying items having properties that may initiate or contribute to a fire and isolating or segregating them from each other when stowed in the cargo compartments will reduce the risk of a fire occurrence. Proper maintenance and upkeep of the aircraft will also prevent

aircraft components or its systems from becoming an external ignition source to items stowed in the cargo compartments.

(c) **Capabilities of the AOC Holder** - When assessing its safety risk in the transport of items in aircraft cargo compartments, the AOC holder must consider its own capabilities such as availability of resources, competency of personnel, robustness of operational systems, processes and procedures and the effectiveness of its safety oversight to ensure operational control including those services outsourced to service providers.

(d) **Commitment and Responsibility of the AOC Holder** - To effectively manage safety risk, the AOC holder must be able to deploy resources and exercise operational control in order to achieve performance-based outcomes. To achieve this, AOC holders have to:

- clearly identify applicable procedures, policies and tasking;
- establish procedures to perform activities and processes;
- hire, train and supervise employees;
- allocate appropriate resources; and
- ensure staff adhere to its standard operating procedures (SOPs).

Systems, polices, process and procedures to support flight operations and to manage safety risks in the transport of items by air have to be documented in the AOC holder's operations manuals. Applicable systems or processes include but are not limited to:

- acceptance of items for transport;
- loading, stowage, segregation and securing of cargo;
- in-flight emergency procedures;
- appointment of contractors such as ground service providers; and
- occurrence reporting and analysis.

(e) **Safety of Cargo Transport Supply Chain** - The cargo transport supply chain is often complex and involve multiple entities such as shippers, freight forwarders and their service providers, many of which may be regarded as customers of AOC holders. Considering that AOC holders are exposed to the hazards contributed by supply chain entities that offer items for transport on its aircraft and as part of interface management controls, the AOC holder should evaluate, quantify and mitigate their associated safety risks to operations of aircraft contributed by such entities. The AOC holder should also consider having formal agreements with interfacing entities in the supply chain to establish safety standards or controls which may include:

- restrictions on the nature of cargo that a shipper is permitted to offer for carriage by air;
- obligations on the freight forwarder to apply safety conditions to preceding entities in the supply chain;
- processes aimed at detecting hidden / undeclared dangerous goods;
- contracts obliging freight forwarders to be trained commensurate with their cargo transport responsibilities; and

- the entity monitoring their own safety performance and the sharing of safety data between entities.

Having implemented these interface management controls, the AOC holder should gather and analyse dangerous goods safety data to monitor the effectiveness of such controls in mitigating safety risks in the transport of items in cargo compartments.

(f) **Acceptance of Items by AOC Holders** - The process of accepting items from passengers, shippers, freight forwarders and postal operators provides critical opportunities for the AOC holder to mitigate safety risks in the transport of items by air. A combination of robust procedures and competent and vigilant ground staff responsible for accepting items for carriage on its aircraft can help identify items presenting inherent hazards to the safe operations of aircraft and prevent them from being transported by air unless their associated risks have been sufficiently mitigated.

Passenger baggage and cargo acceptance staff should actively lookout for signs (e.g. visible dangerous goods markings or labels, GHS[1] labels, smell of flammable fumes, descriptions of items suggesting the presence of hidden dangerous goods) that the contents of passenger baggage or packages of general cargo or air mail may contain undeclared or prohibited dangerous goods. When in doubt, ground staff should seek clarification from the passenger or the supply chain entity offering the item for transport. When in doubt, ground staff may request a visual inspection of the contents in a bag or package after taking the necessary precautions.

Dangerous goods cargo should be accepted separately from general cargo since they require specific acceptance procedures to verify the shipper's compliance with the ICAO TI when preparing the consignment for transport. Upon acceptance, dangerous goods packages should also be stored separately from general cargo to protect against pilferage and damage and segregated from other incompatible dangerous goods.

Passengers are expected and permitted to carry some dangerous goods (e.g. toiletry articles containing aerosols or alcohols and portable electronic devices containing lithium batteries) in their baggage. To prevent passengers from transporting prohibited dangerous goods in baggage, the AOC holder should provide dangerous goods information at passenger touch points on the types of dangerous goods that may or may not be permitted in baggage.

Only certain types of dangerous goods as provided for in the ICAO TI may be offered by designated postal operators (DPOs) for transport in air mail. Prior to permitting any DPO from offering dangerous goods in air mail for transport on its aircraft, the AOC holder should verify that the DPO's relevant procedures were approved by the CAA where the air mail is accepted including specific

[1] Globally Harmonised System of Classification and Labelling of Chemicals

approvals to permit the offering of lithium batteries installed in equipment for transport.

(g) **Security Screening** – While the purpose of security screening is to detect and prevent items having a security risk to the operations of aircraft from being transported as cargo or in baggage and mail, security screening can also benefit aviation safety. The ICAO TI require security screening staff to be trained to recognise and detect dangerous goods. However, it should be recognised that, due to limitations in security screening technology, not all dangerous goods may be detected through such screening. Hence, the detection of dangerous goods though security screening may only be conducted on a best effort basis. Notwithstanding this, many items of dangerous goods can still be detected by recognition of its shape and other physical properties. For example, gases contained in cylinders or aerosol cans, fire extinguishers, wet batteries, and even lithium batteries may be detected through security screening using an x-ray machine. The AOC holder should consider the screening equipment used to screen its cargo, baggage and mail and assess its effectiveness in detecting and preventing hidden or undeclared dangerous goods from being transported on its aircraft. Consequential procedures after undeclared dangerous goods have been detected, including reporting to relevant authorities, gathering of safety data and taking appropriate action against entities offering undeclared dangerous goods for transport can further manage safety in the transport of items in aircraft cargo compartments.

(h) **Qualified Personnel** - The transport of items by air require processes involving a large number of personnel with varying competencies to carry out various operational tasks that they have been assigned. The AOC holder has to provide initial and recurrent training and assessment to ensure that its employees (e.g. crew members, ground staff and staff having safety oversight responsibilities) are competent and are empowered to carry out their responsibilities. Recognising that most of its operational activities in the acceptance, handling and loading of items into the aircraft have been outsourced to service providers, the AOC holder also has to ensure that staff of service providers are competent to undertake handling responsibilities in the transport of items on its aircraft. If the sole safety control to mitigate any safety risk is a manual process performed by individuals, chances are that it may fail at some point in the future due to a myriad of reasons (e.g. carelessness, complacency, loss of concentration, fatigue etc.). Considering the pit falls of human intensive processes, the AOC holder should ensure that there is adequate supervision of personnel engaged in such processes. Wherever possible, systemic controls should be identified and implemented to mitigate the shortcomings of human intensive processes.

(i) **Packing and Packaging** – The ICAO TI specifies that shippers must comply with the packing instructions applicable to the dangerous goods that they offer for transport by air. Packing and packaging can help mitigate the inherent hazards of items transported in aircraft cargo compartments. In addition to performing a containment function, packaging prevents articles and substances having hazardous properties from contact with persons or other

incompatible dangerous goods. Notwithstanding the benefits of packing and packaging of items classified as dangerous goods, it should be noted that compliance with the packing requirements of the ICAO TI does not guarantee the mitigation of every scenario.

For items not classified as dangerous goods, since there are no packing or packaging requirements applicable to such items, the AOC holder should determine the appropriate packaging necessary to mitigate any inherent hazards identified in such items.

The AOC holder has to ensure that packages containing dangerous goods are inspected and verified to be free from damage or leakage prior to loading into a ULD or cargo compartment. Adequate supervision and oversight are also necessary to ensure that packages of dangerous goods are not damaged as a result of poor handling practices and are properly secured when stowed in ULDs and in cargo compartments to prevent damage due to movement of the package or adjacent items.

(j) **Quantity and Distribution of Items** - Items transported on an aircraft may contribute to either an ignition source, fuel or oxygen necessary to start and sustain a fire. Consequently, in general, reducing the quantity of items with inherent hazards capable of contributing to a fire (particularly as an ignition source, such as lithium batteries) to be transported can mitigate against the likelihood of an inflight fire in the cargo compartments of an aircraft.

Mitigating Severity of Consequences

4.3 Fire suppression and other aircraft systems built into aircraft cargo compartment typically focus on minimising damage to the aircraft in the event of a fire and hence provide some defences in mitigating the severity of consequences. However, the AOC holder should not assume that the fire suppression systems will mitigate the effects of every fire contributed by items transported in its cargo compartments since fires from some items (e.g. a single cell in a large consignment of lithium batteries experiencing a thermal runway) can quickly overwhelm aircraft fire suppression systems. Consequently, in its risk assessment, the AOC holder has to consider the effectiveness of aircraft fire suppression systems in mitigating fires originating from items it regularly transports in its cargo compartments such that any fire contributed by such items may be detected, extinguished or sufficiently suppressed to allow for the diversion of an aircraft based on its route planning.

(a) **Fire Protection Elements of Aeroplane Design** – Aircraft fire detection and suppression systems can mitigate the severity of a fire in a cargo compartment. However, depending on the classification of the cargo compartment, such systems vary in capabilities. The AOC holder should obtain information from its aircraft manufacturer to determine the classification of its aircraft cargo compartments used to transport items and account for its capabilities and limitations by reviewing the performance standards associated with its certification. Currently, such performance standards require extinguishing agents and cargo compartment liners to be capable of mitigating a fire caused

by combustible materials such as wood, cloth, paper and plastic (also known as a Class A fire). Hence, aircraft fire suppression systems may not be effective in mitigating a fire fuelled by dangerous goods such as lithium batteries. It should be noted that aircraft fire suppression systems are designed to suppress a cargo compartment fire sufficiently to allow the aircraft to make a safe landing and not to extinguish the fire completely. Therefore, the ability to do so is largely dependent on the magnitude of the fire involved.

The speed at which an inflight fire can be detected by the flight crew once it is initiated is also critical in mitigating any fire. Fire and smoke detection systems can alert flight crew to an inflight fire in the cargo compartments. However, packaging materials, pallet shrink wraps, ULDs and fire containment covers meant to provide containment for the items during transportation may also attempt to suppress the fire by oxygen starvation and prevent smoke from being detected by smoke detectors. To mitigate such factors, the AOC holder should consider additional safety controls, such as having smoke detectors in ULDs containing items having inherent flammable hazards, so that flight crew may be alerted to any signs of a fire originating from such items loaded in ULDs without delay.

The AOC holder should also be aware that defects such as damage to cargo compartment liners can reduce the effectiveness of a cargo compartments' fire mitigating capabilities. Hence, regular maintenance of the aircraft and its systems can ensure that the cargo compartment and fire and smoke detection systems continue to be capable of mitigating an inflight fire from items loaded in it.

(b) **Operational Considerations** – The AOC holder should consider aircraft route planning when conducting its risk assessment. The duration needed for an inflight fire in a cargo compartment to stay suppressed is directly related to the time needed for an aircraft to make a safe landing. Often, in an inflight fire in the cargo compartment, it is critical for the aircraft to land at an aerodrome in the shortest amount of time. Hence, in general, transporting items that may cause or contribute to a fire over large oceanic or remote regions has a higher risk as compared to similar operations over occupied land.

Crew members should comply with the AOC holder's emergency procedures which may include using oxygen masks, extinguishing agents, shutting off ventilation to the cargo compartments or depressurizing the aircraft, depending on the classification of the cargo compartments on the aircraft. In doing so, the AOC holder should also consider the impact of such actions on occupants (passengers or persons accompanying items transported on the aircraft) who are not trained on how to react in such an emergency.

(c) **Containment Characteristics of ULDs** - A ULDs' primary purpose is to contain cargo, baggage and mail and to facilitate their handling, loading, unloading and stowage on an aircraft. Depending on several factors, ULDs can

either serve to mitigate the severity of a fire or impede the detection of smoke and fire suppression efforts.

Fire resistant containers made of a suitable material and having fire resistant properties can protect items contained within from an external fire. It can also aid in containing a fire ignited by items within the ULD and offering better fire protection as compared to normal ULDs. Some ULDs also have inbuilt fire and smoke detection and suppression systems that can be integrated with aircraft systems allowing flight crew to quickly detect a fire ignited by items within the ULD and to initiate suppression of the fire from the flight deck. Fire containment covers may be used together with open pallet type ULDs to mitigate fires ignited by items contained within such ULDs. Such covers, made of fire-resistant materials, serve to suppress fires by staving it of oxygen. An AOC holder intending to utilise such equipment to mitigate against fire risks contributed by items carried in the cargo compartment should understand the performance standards associated with such equipment and assess its effectiveness in mitigating fires.

There are also unintended consequences associated with the containment effects of ULDs. Smoke from a fire may be contained in the ULD causing delays to their immediate detection by smoke detectors. ULDs may also prevent fire suppressing agents from reaching the source of a fire located in the ULD. In tests conducted by FAA on a ULD containing lithium batteries undergoing a thermal runaway, it was found that ULDs may also cause the accumulation of gases to create an explosion strong enough to dislodge cargo compartment liners or decompression panels thereby allowing suppression agents to escape and impeding efforts to suppress the fire.

(d) **Quantity and Distribution of Items** – Considering that some items having inherent hazards may contribute to a fire (by providing an ignition source, fuel or yielding oxygen to sustain a fire), reducing the quantity of such items transported in the cargo compartments can mitigate against the severity of an inflight fire. The ICAO TI provides quantity limits for the transport of items classified as dangerous goods. However, these limits are only applicable to items at the package level and does not restrict the total volume of dangerous goods that may be transported on an aircraft or in a cargo compartment. The AOC holder should consider the capabilities and limitations of aircraft fire suppression systems and ULDs used for the loading of dangerous goods and determine if additional safety controls need to be implemented to restrict the volume of dangerous goods that may be transported in each ULD, a cargo compartment or on an aircraft.

The AOC holder may also enquire with aircraft manufacturers on its recommended stowage locations of dangerous goods in cargo compartments to better mitigate against the severity of a fire. Critical aircraft systems may be situated near certain areas of cargo compartments hence, stowing items having inherent hazards away from such positions can mitigate against the

severity of consequences that have the potential of causing such critical systems to fail thereby affecting the airworthiness of the aircraft.

5 DEFINING THE CAPABILITIES OF THE AIRCRAFT AND ITS SYSTEMS

5.1 The AOC holder should obtain information from aircraft manufacturers on the performance capabilities and limitations of its cargo compartments and aircraft systems (e.g. cargo compartment classification and certification standards), in mitigating the risk of transporting items in cargo compartments. This information needs to be considered when conducting its specific safety risk assessment in the carriage of items by air, particularly in addressing an inflight fire caused by items stowed in cargo compartments. The AOC holder should also note that capabilities of fire suppression systems, cargo compartment liners, cargo door seals and ventilation shut-off may degrade over time and reduce their effectiveness in mitigating an inflight fire. Factors that may cause or contribute to degradation of such aircraft equipment and systems should also be identified and considered in its risk assessment.

Cargo Compartment Classification

5.2 Cargo compartments are classified between Class A and Class F depending on its accessibility to crew members, type of fire detection and suppression systems and ventilation control. A summary of the characteristics of each cargo compartment type is provided in Appendix A of this AC. Understanding the certification standards applicable to the classes of cargo compartments on its aircraft will allow the AOC holder to determine the capabilities and limitations of its aircraft cargo compartments in mitigating the hazards of items transported in them. The AOC holder should obtain from the aircraft manufacturer information on the cargo compartment certification standards including a demonstration of these standards for each aircraft type as documented in the aeroplane flight manual or in other suitable documents.

5.3 The AOC holder should plan a flight such that the maximum diversion time to an aerodrome where a safe landing can be made does not exceed the cargo compartment fire suppression time capacity of the aircraft minus an operational safety margin of 15 minutes. When extended diversion time operations (ETDO) is applicable, the maximum diversion time of an aircraft must not exceed the cargo compartment fire suppression time minus an operational safety margin of 15 minutes when the cargo compartment fire suppression time is the most limiting factor.

Cargo Compartment Certification Standards

5.4 The AOC holder should be aware that the fire detection systems for cargo compartments in Class B, C, E and F must be approved by the State of Design of the aircraft. Such systems allow any fire in the cargo compartment to be detected by the crew, typically within a minute after the start of a fire, at temperatures well below what would affect the structural integrity of the aircraft. For the purpose of conducting its risk assessment, the AOC holder should take into account the following requirements and specifications relating to the various elements of a fire detection system:

- Regulation 84 of ANR-91, CAAS Advisory Circular, AC91-6-2 - *Halon Replacement for Fire Extinguishing Agents*, and any Technical Standard Order

(TSO) or airworthiness standards applicable to extinguishing agents of hand-held fire extinguishers.

- FAA's 14 CFR or EASA's CS Part 25 Appendix F requirements applicable to cargo compartment liners installed to prevent the spread of a fire.

- FAA's TSO, 14 CFR or EASA's CS Part 25.858 requirements applicable to the fire or smoke detection system installed in cargo compartments.

- FAA's TSO-C203, 14 CFR or EASA's CS Part 25.857 requirements applicable to fire containment covers used in Class F compartments.

5.5 The AOC holder should also note that the effectiveness of the suppressing agent in its fire suppression systems in cargo compartments (e.g. Halon 1301 used for Class C compartments) is dependent on the concentration of the agent, type of material fuelling the fire, rate of burning and manner in which the goods are stowed in the compartment. Typically, Class A fires are used to demonstrate achievement of compartment classification standards and the time capability of a fire suppression system is the duration that the cargo compartment is able to maintain a level of halon concentration (at least 3%) necessary to keep fires suppressed. If a cargo compartment is equipped with a built-in fire extinguisher, the capacity of the extinguishing agent must also be sufficient to extinguish or suppress a fire anywhere within the compartment for the duration corresponding to the suppression time capability of the system.

Information Provided in Aeroplane Documentation

5.6 Regulation 60A(3) of ANR-121 states that the AOC holder must ensure that elements of the cargo compartment fire protection system for a large aircraft, and a summary of the demonstrated fire protection certification standards applicable to each class of cargo compartment in its aircraft, are contained in the aircraft's flight manual or other documentation supporting the operations of its aircraft. The location of cargo compartments in its aircraft should also be provided in such documentation. Having knowledge and understanding of the capabilities of the cargo compartments on its aircraft, the AOC holder should utilise this information to assess the safety risk of transporting items on its aircraft. The AOC holder should also request from the aircraft manufacturer other information that it deems as necessary to aid in its assessment.

APPENDIX A

Summary of Different Commonly Classified Cargo Compartments Characteristics

Class of Cargo Compartment / Characteristics	Class A	Class B	Class C	Class D	Class E	Class F
Fire detection	Detection via crew/passenger	Automatic fire (smoke) detection	Automatic fire (smoke) detection	No (automatic) detection except if compartment is ventilated	Automatic fire (smoke) detection	Automatic fire (smoke) detection
Principal crew action	Hand-held fire extinguishing	Hand-held fire extinguishing	Activate fire suppression system	No action unless indication of fire is present	Depressurize and set to a prescribed flight level	Depends on design
Aeroplane fire fighting means	Active fire-fighting via hand-held extinguisher	Active fire-fighting via hand-held extinguisher	Built-in fire suppression system	Isolation	Flight level procedure, reducing oxygen partial pressure	Depends on design
Fire fighting principle	Extinguishing	Extinguishing	Fire suppression via extinguishing agent	Fire containment and oxygen consumption	Oxygen starvation	Depends on design
Post-fire suppression conditions or actions	Monitoring	Monitoring	Suppressed environment until end of flight	(Small) increase of oxygen partial pressure during descent phase	(Large) increase of oxygen partial pressure during descent phase	Depends on design
Design steady-state conditions	Extinguished	Extinguished	Suppressed fire with cargo compartment temperature potentially above 200°C	Smoldering fire depending on oxygen concentration left	Similar condition as Class C cargo	Depends on design

Source: ICAO Doc 10102 - Guidance for Safe Operations Involving Aeroplane Cargo Compartments