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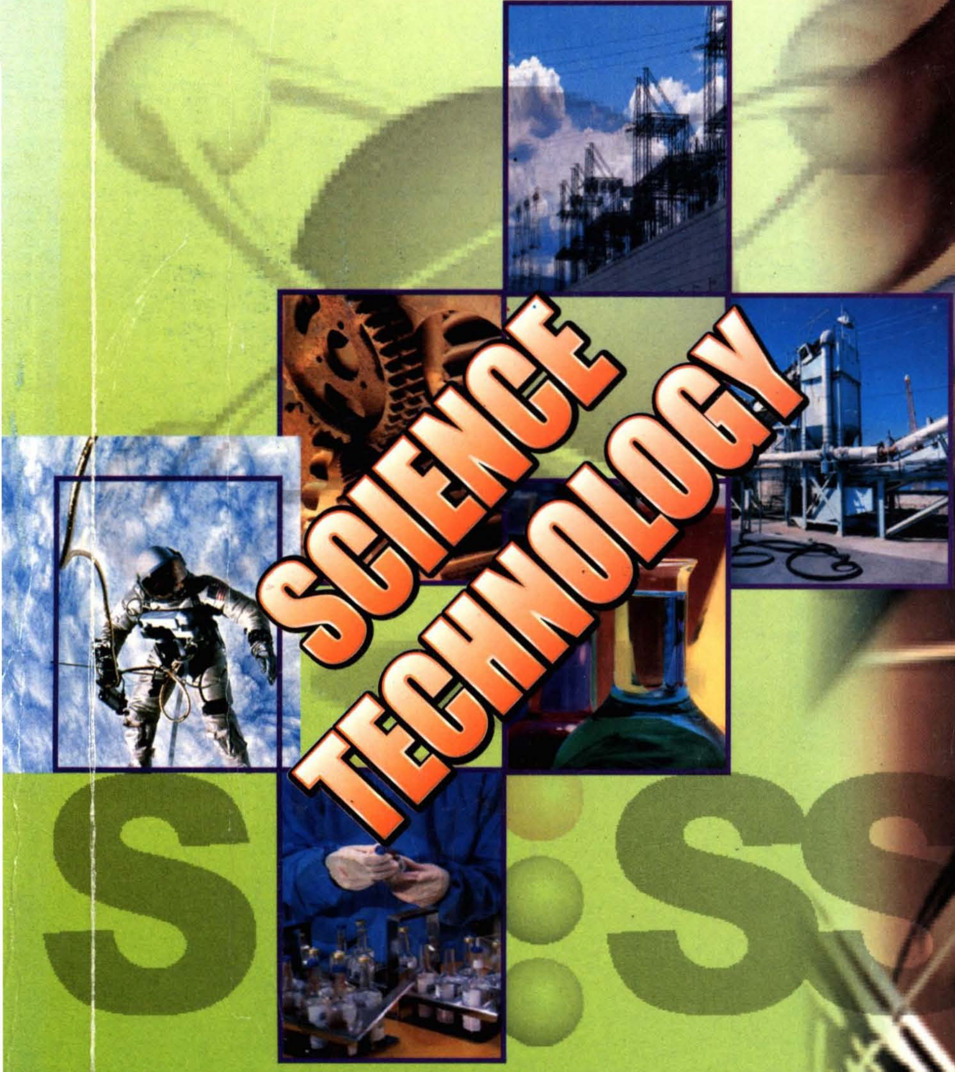

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Advances in Aircraft Cabin Atmospheric Control Systems

Ahmad Jais Alias
Nasrul Kamil Yatiban
Ramzu Salleh
Nor Amidi Mohamad
Shahrul Ahmad Shah

ABSTRACT

Aircraft technology is one of the most complex technologies and requires detailed and rigorous study. The complexity lies in the numerous systems, equipment and components that are inter-related and cross-functional inside the aircraft. Failure of even a minor system might cause the aircraft not safe to fly or 'grounded'. One of the systems studied in this paper is the Aircraft Cabin Atmospheric Control Systems. The system involves controlling the heating system, cabin cooling or air-conditioning system, pressurization system and oxygen supply system. All the sub-systems need to be monitored, controlled and maintained through-out the aircraft life to avoid any inconvenience, harm or even disaster. The paper will discuss the control system in brief, and highlights the current and latest developments in these aircraft systems. Reference to some cases on the effect of the system failure is also included.

Keywords: *Aircraft technology, cabin atmosphere, control systems*

Introduction

The aircraft cabin is a challenging microenvironment for maintaining the health, comfort, and well-being of the passengers and crew. Space is limited, conditions can feel cramped, the outside environment is extreme, and travellers can experience anxiety because they have lost control over their situation and their environment. During flight, the passengers and crew experience noise, reduced atmospheric pressure, vibration, low relative humidity, somewhat variable temperature, and potential air quality degradation. In light of these facts, it is not surprising that passengers and crew have registered complaints about the aircraft cabin environment for decades.

Basic Concepts of Aircraft Cabin Atmosphere Control

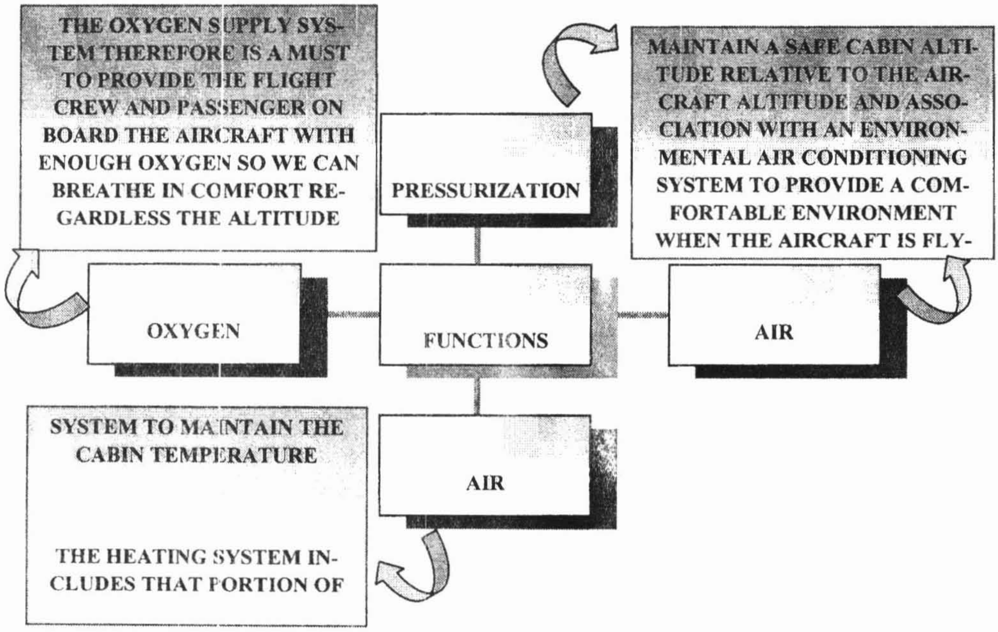
Pressurization and air conditioning of aircraft are necessary at high altitudes. With operational ceilings now in excess of 50,000 feet, flight personnel, and in some cases, aircraft components, are supplied with an artificial means of maintaining a reasonable pressure around the entire body and equipment. This is done by sealing off the entire cabin or cockpit and any equipment area that may require pressurization and maintaining an in-side air pressure equivalent to that at substantially lower altitudes. This is known as the pressurized cabin, cockpit, or compartment (Pallet 1992; Fortescue et al. 2003).

In addition to pressurizing them, the cabin, cockpit, and some compartments are also air-conditioned if the aircraft is to fly at high speeds. This requirement is partly due to the difference in temperatures at various altitudes and also aerodynamic heating. For example, an aircraft flying at supersonic speeds at an altitude of 35,000 feet may generate a temperature on its skin of 200° F, and twice that temperature at altitudes near sea level. In addition to aerodynamic heating, other factors affecting cabin or cockpit temperatures are engine heat, heat from the sun (solar heat), heat from the electrical units, and heat from the body. Through research and tests, it has been determined that the average total temperature of these five heat sources will raise the cabin or cockpit temperature to approximately 190° F (88°C). Through experiments, it has been determined that the maximum temperature that a person can withstand and maintain efficiency for extended periods is 80°F (27°C). Therefore, air conditioning of the cabin or cockpit area is just as essential as pressurization. Under low-speed operating conditions at low temperature, cabin or cockpit heating may be required.

Another concern is that the operation of much of today's aircraft electronic equipment is also dependent on maintaining a reasonable operating temperature that will prolong the life of various components. In most cases equipment cooling is provided by teeing off with ducting from the cabin or cockpit system. On other aircraft, a separate cooling system may be used primarily for equipment cooling (Wild 1996; Aviation Review 2005).

The Importance of Aircraft Cabin System

Figure 1 below summarizes the basic functions of the Aircraft Cabin System and their importance (Wasson 1994; Lombardo 1999; and Spoor 2004).



PERPUSTAKAAN UMP PAHANG AL-BUKHARI

Fig. 1: Aircraft Cabin System Functions

Cabin Atmospheric Control Systems

The system consists of four main sub-systems (Civil Aviation Authority 1998; Lombardo 1999; Boeing 737 Aircraft Maintenance Manual 2002; and Spoor 2004) as follows: 1) Heating Systems; 2) Cooling Systems; 3) Pressurization Systems; and 4) Oxygen Systems. These sub-systems are briefly described below.

Heating Systems

There are four major types of heating systems, namely; Exhaust Heating Systems, Combustion Heater Systems, Electric Heating Systems and Bleed Air Heating Systems.

Exhaust Heating Systems

Exhaust heating systems are the simplest of aircraft heating systems and are used on most light aircraft. The system's components include:

- a heater muff around the exhaust stacks
- an air scoop to direst ram air into the heater muff
- ducting to carry the heated air into the cabin

Combustion Heater Systems

Combustion heaters or surface combustion heaters are often used to heat the cabin of larger and more expensive aircraft. This type of heater burns the aircraft's fuel in a combustion chamber or tube to develop required heat. The air flowing around the tube is heated and ducted to the cabin.

Electric Heating Systems

These systems provide cabin heat when the aircraft is on the ground and engines are not running. Electric heaters are often used on small turbo-prop aircraft and the air is taken from the cabin, passed over electric heater coils, and returned to the cabin

Bleed Air Heating Systems

Bleed air heating systems are used on unpressurized turbine-engine aircraft. An extremely hot compressor bleed air is ducted into a chamber where it is mixed with ambient or re-circulated air to cool the air to a useable temperature. This air mixture is, then, ducted into the cabin. This system contains several safety features as follows:

- temperature sensors prevent excessive heat from entering the cabin
- check valves to prevent a loss of compressor bleed air when starting the engine and when full power is required
- engine sensors eliminate the bleed system if the engine becomes inoperative.

Cabin Cooling Systems

Aircraft-cooling systems are used to cool air inside the aircraft for passengers and crews comfort. There are two basic methods of cooling cabin air : 1) Freon Vapour-Cycle Cooling Systems; and 2) Air-Cycle Cooling Systems.

Vapour-Cycle Cooling Systems

Vapour-cycle cooling systems are used on reciprocating-engine aircraft and in some small turboprop aircraft. This is a closed system that uses the evaporation and condensation of freon to remove heat from the cabin

Air-Cycle Cooling Systems

Air-cycle cooling systems are used on modern large turbine-powered aircraft. These systems use the compression and expansion of air to adjust the temperature in passenger and crew compartments.

Cabin Pressurization Systems

Cabin pressurization provides a comfortable environment for passengers and crew while allowing the aircraft to fly at higher altitudes. Flying at high altitudes is more fuel efficient and it allows the aircraft to fly above most undesirable weather conditions.

Aircraft Structures

If an aircraft is to be pressurized, the pressurized section (pressure vessel) must be strong enough to withstand operational stresses. In general, the maximum altitude at which an aircraft can fly is limited by the maximum allowable cabin differential pressure. Cabin differential pressure is the pressure difference between ambient air and the air inside the pressure vessel. The stronger the aircraft structure, the higher the allowed differential pressure will be. General cabin pressure differentials allowed by different aircraft types, for example:

- Light aircraft – approx. 3-5 psi
- Large reciprocating-engine aircraft – approx. 5.5 psi
- Turbine-powered transport aircraft – approx. 9 psi

Sources of Pressurization

The source of aircraft pressure varies depending on the type of engine installed on the aircraft and aircraft design. Although the specific method of pressurizing cabin air varies between different aircraft, pressurization is always done, in some form, by the aircraft engines.

Reciprocating Engines
Reciprocating engines can pressurize cabin air through the use of:

- Superchargers
- Turbochargers
- Engine-driven air pumps

Some setbacks of these engines are it may introduce fumes and oil into the cabin air and it can greatly reduce engine power output.

Turbine-engines
Turbine-engine aircraft usually utilize engine bleed air for pressurization. In these systems, high pressure air is "bled" from the turbine-engines compressor. This also causes a reduction in engine power but it is not as significant of a loss.

Independent Cabin Compressors
Some aircraft use independent cabin compressors for pressurization which are used to eliminate the problem of air contamination. Independent cabin compressors are driven by either the engine accessory section, or the turbine-engine bleed air. These compressors may use one of two types of pumps:

- Roots-type positive displacement pumps
- Centrifugal cabin compressors

Pressurization System Components

Other important components of the pressurization system and their functions are described below:

Heat exchanger	- used to cool the hot pressurized air to a usable temperature
Outflow valve	- primary cabin pressure control, regulates the amount of pressurized air that is allowed to exit the cabin
Safety valve (positive pressure relief	- prevents cabin over-pressurization by opening automatically at a predeter-
Negative pressure-relief valve	- prevents cabin pressure from going below that of the ambient air
Dump valve	- releases all cabin pressure when aircraft lands, controlled by landing gear squat switch

Oxygen Systems

Oxygen systems are required on aircraft that operates for extended periods above 10,000 feet. There are two types of oxygen systems used on private and commercial aircraft: 1) Stored-gas Oxygen Systems; and 2) Chemical or Solid State Oxygen Systems

Stored-Gas Oxygen Systems
Stored-gas oxygen systems use oxygen cylinders (bottles) to hold the aircraft's oxygen supply. The oxygen bottles may be in high-pressure or low-pressure types. The high-pressure bottles contain oxygen at 1800psi in Green color and labelled "Aviator's Breathing Oxygen". The low-pressure bottles contain oxygen at 450psi in Yellow color and labelled "Aviator's Breathing Oxygen"

Chemical or Solid State Oxygen Systems
There are many advantages of using solid-state oxygen systems such as safer, lower in cost than stored-gas systems and comparatively maintenance free.

Major Potential Accidents due to Cabin System Failure

Figure 2 below summarizes the potential disaster on an aircraft due to failure in the cabin system (Anderson 1989; Wild 1996; and Anderson 2003).

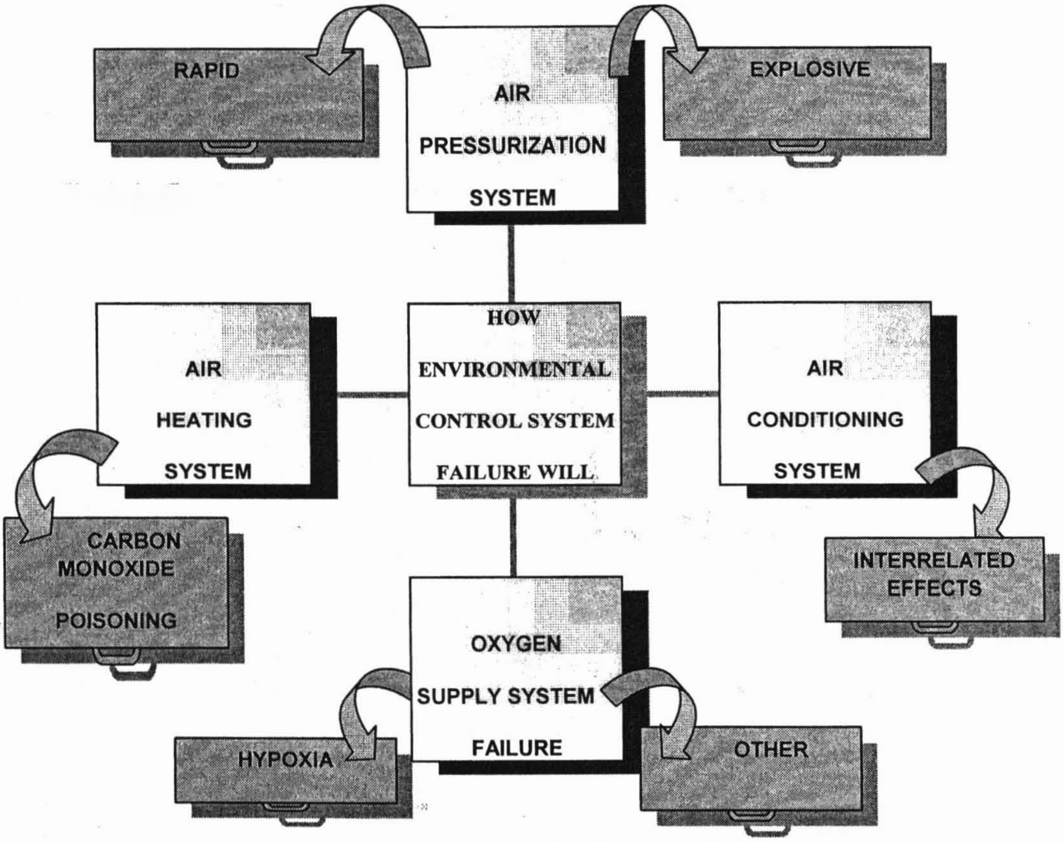


Fig. 2: Potential Accident due to Cabin System Failure

Rapid Decompression

A hole only five feet across will depressurize a jetliner in a fraction of a second. Rapid decompression of commercial aircraft is extremely rare, but dangerous. People directly next to a hole may be sucked out or injured by flying debris. Floors and internal panel may deform. Hypoxia will result in loss of consciousness in seconds without emergency oxygen, and the air temperature will plummet due to expansion, potentially resulting in frostbite.

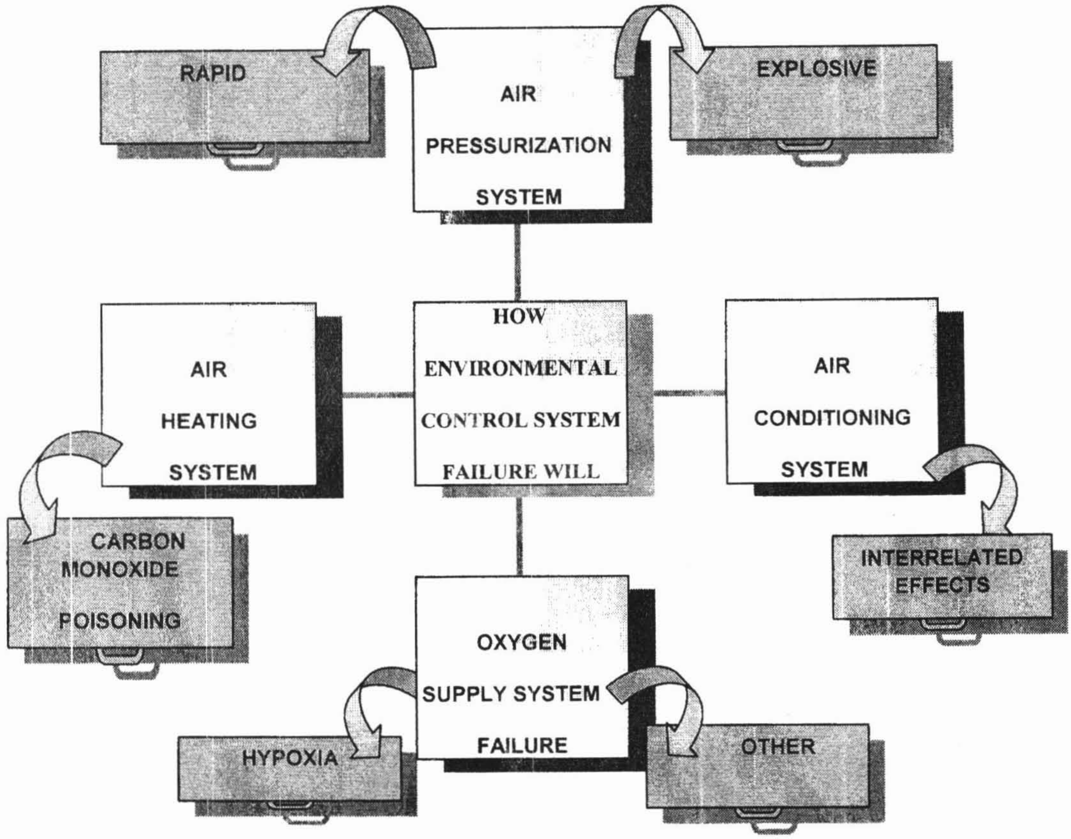
Explosive Decompression

Explosive decompression (ED) refers to a sudden marked drop in the pressure of a system that occurs in less than 0.1 seconds, associated with explosive violence. Generally it results from some sort of material fatigue or engineering failure, causing a contained system to suddenly vent into the external atmosphere. Seals in high pressure vessels are also susceptible to explosive decompression and also the rubber gaskets to seal pressurized pipelines tend to become saturated with high-pressure gases. If the pressure inside the vessel is suddenly released, then the gases within the rubber gasket may expand violently, causing blistering or explosion of the material.

Hypoxia

By medical reference, hypoxia is a condition where the patient has lack of oxygen supplied to the cells inside human body. This is severe especially when the most important organ in our body, the brain does not receive adequate oxygen to function normally. The failure to supply oxygen to the brain will damage the brain cell if long enough, and unconsciousness will start to occur since brain activities are disturbed.

Besides hypoxia, the failure of aircraft oxygen supply system will also affect the crews and passengers by other medical effects. It may be in terms of light headedness, dizziness, vision impairment and sleepiness. The lack of oxygen in human body will also impair the flight crew's coordination and judgment in making critical decision although they are still awake.



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AHMAD JAIS ALIAS, NASRUL KAMIL YATIBAN, RAMZU SALLEH, NOR AMIDI MOHAMAD & SHAHRUL AHMAD SHAH, Universiti Kuala Lumpur Malaysian Institute of Aviation Technology, Kampus UniKL-MIAT, Lot 2891, Jalan Jenderam Hulu, 43800 Dengkil, Sepang, Selangor Darul Ehsan. ahmadjais@miat.com.my