ATA2 飞机结构和系统笔记

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Contents

一种可取的学习方式作参考：

1. **首先阅读中文知识点/PPT/上课，建立对系统的感性认识；**
2. **之后，一边做题，一边找到英文笔记的对应知识点，发现题目考点对应的英文术语/解释方式，并作记忆。**

笔记正在整理完善中~~

机身、机翼、尾翼

Fuselage 机身

Truss Type: simple, not streamlined, less stiffness, less volume.

Modern aircraft fuselage structural types include **longeron-type fuselages**, **stringer-type fuselages**, and **skin-type fuselages**.

The **longeron-type** and **stringer-type** fuselages are generally referred to collectively as **semi-monocoque fuselages**, which are widely used in modern aircraft.
A **longeron-type fuselage** is composed of strong longerons, weak stringers, thin skin, and bulkheads. The fuselage bending moment is carried entirely or mostly by the **longerons.** This type is suitable for aircraft that require large fuselage openings.
A **stringer-type fuselage** consists of thicker **skin**, closely spaced and relatively strong **stringers** forming **wainscot(**stressed skin panels), and bulkheads. The bending moment of the fuselage is carried by these **wainscot (**stressed skin panels). This type has high material utilization efficiency and low structural weight.

A **Monocoque fuselage** is composed of thick skin and bulkheads. The bending moment, shear forces, and torsion loads are all carried by the **skin**. This type is generally used for fuselages with small diameters or for fuselage sections subject to high aerodynamic loads that require strong local skin stiffness.

Wings 机翼

机翼分为下列几种结构型式：梁式机翼、单块式机翼、多腹板式机翼、夹层结构机翼、整体结构机翼。

Wing structures can be classified into the following types:

spar-type wings,

monocoque/monoblock wings,

Multi-web wings,

sandwich-structure wings,

integral-structure wings.

【考 wings 的结构型式分类】

梁式机翼 **beam/spar-type wing** 主要构件包括翼梁、桁条、翼肋和蒙皮；结构特点是翼梁强、蒙皮薄、桁条少而弱；翼梁腹板承受绝大部分剪力，翼梁缘条承受绝大部分弯曲轴向力，蒙皮构成的闭合框承受绝大部分扭矩；梁式机翼生存力弱，机翼机身连接简单，开口方便。
单块式机翼 **monoblock wing** 主要构件有桁条、蒙皮、翼肋和纵墙；以较多较强的桁条和较厚的蒙皮所组成的多块壁板为主承受弯曲轴向力；单块式机翼生存力强，适合做成结构油箱，但不适合大开口，机翼机身连接接头多，检查维护不方便。
现代运输机通常采用复合式结构机翼，综合利用各种机翼结构的优点。

The main components of a **spar-type wing** include spars, stringers, ribs, and skin. Its structural characteristics **are strong spars, thin skin, and few, relatively weak stringers**. The **spar web** carries most of the shear load, the **spar caps/flanges** carry most of the bending axial load, and the closed torque box formed by the **skin** carries most of the torsion load. Beam-type wings have relatively low survivability, feature a simple wing-to-fuselage connection, and allow openings to be made easily.

The main components of a **monoblock wing** include stringers, skin, ribs, and longitudinal walls. Numerous, **strong stringers and thicker skin** form multiple panel walls that carry most of the bending axial load. (skin also resist torsional moment). Monoblock wings have high survivability and are suitable for use as integral fuel tanks, but they are not suited for large openings. They also have more joints at the wing-to-fuselage connection, making inspection and maintenance less convenient.

【考 spar-type 和 monoblock 的特性】

Modern transport aircraft typically use **hybrid/composite wing structures**, combining the advantages of various wing structural types.

To accommodate the external loads that increase progressively from the wingtip toward the wing root, the structure of modern transport aircraft wings becomes gradually wider and thicker along that direction. The installation of components and equipment on the wing also has an off-loading effect on the wing structure.

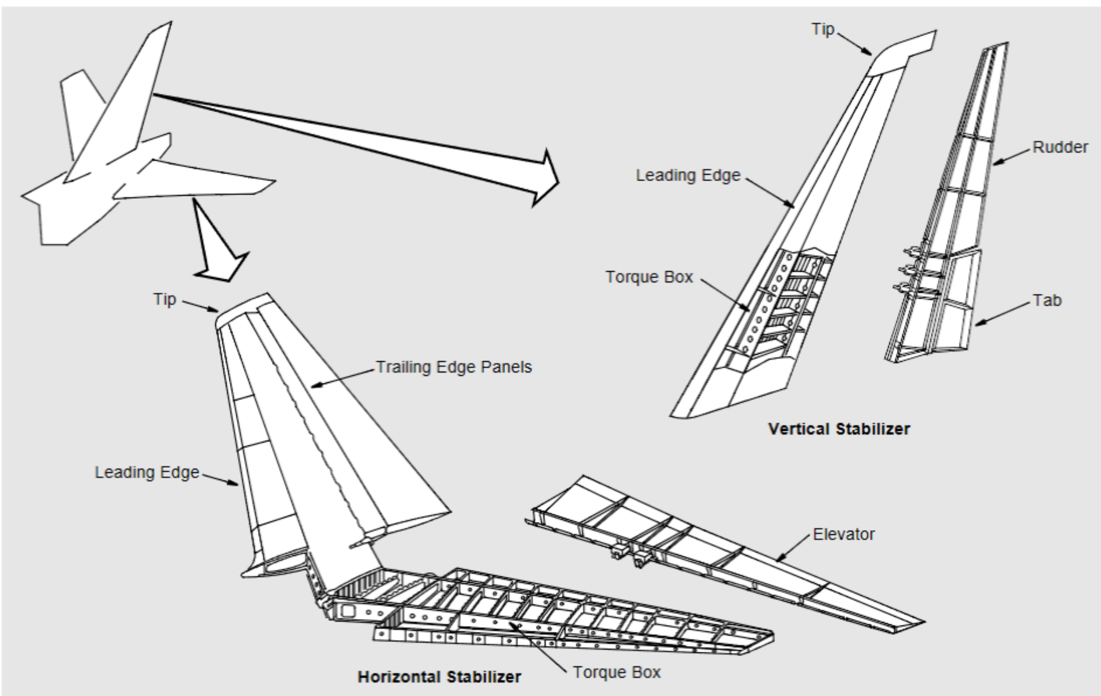
【考 wingroot 到 wingtip 的变化趋势和 equipment off-loading】

Empennage 尾翼

尾翼包括整个的尾部，由垂直尾翼和水平尾翼组成
垂直尾翼包括垂直安定面和方向舵
水平尾翼包括水平安定面和升降舵
方向舵、升降舵上通常有一个或者多个配平片

Grider/longeron，
rib，
purlin(stringer)，
skin

参考 777 的尾翼结构



Stabilizers

设计限制

设计过载 Design Load Factor 与使用过载 Operational Load Factor
民用运输机过载一般由突风决定

$$DUL = DLL \times safety\ factor$$

$$Design\ Ultimate\ Load\ /\ Design\ Limit\ Load\ =\ Safety\ Factor$$

$$The\ ratio\ of\ structural\ failing\ load\ to\ ultimate\ load:\ Residual\ strength\ coefficient$$

飞机结构失效 Aircraft structural failure 是指飞机结构在外载荷作用下变形超过规定或失去承载能力。
飞机结构抵抗破坏 resist damage 的能力称为结构强度 structural strength；
飞机结构抵抗变形 resist deformation 的能力称为结构刚度 structural stiffness；强度和刚度是表征飞机结构承载能力的主要标志。

飞机结构承载余量的主要指标是安全系数和剩余强度系数。
安全系数是结构设计载荷与使用时允许的最大载荷的比值；其值通常为 1.5 倍。
剩余强度系数是结构破坏载荷与设计载荷的比值。The ratio of structural failing load to ultimate load

疲劳破坏 Fatigue failure 是飞机结构失效的主要形式之一。疲劳破坏是结构件在交变载荷作用下发生的断裂和破损；交变载荷是大小、方向随时间周期性或不规则变化的载荷。Fatigue failure refers to the fracture and damage of structural components under alternating loads. Alternating loads are loads whose magnitude and direction change periodically or irregularly over time.
疲劳破坏过程可分为三个阶段：产生初始裂纹，裂纹扩展，达到临界裂纹状态而断裂。
the generation of initial cracks, the propagation of cracks, and the fracture when reaching the critical crack state
疲劳裂纹开始一般不易发现，因此疲劳破坏具有突然性 suddenness。
Fatigue life of the fuselage is based on: Number of pressurization cycles

Hydraulic system 液压系统

液压油种类

Plant based: blue/yellow, low ignition point, early ACFT

Mineral based: red, ignitable, small ACFT

Phosphate easter based: purple, artificial, highest ignition point, low temp, high pressure, corrosive, modern transport ACFT

液压系统组件

Hydraulic Reservoir: bleed air compression, prevent cavitation

Pump -> filter -> pressure module

Pumps: Modern transport ACFT uses Constant pressure variable volume

Filter: outlet of pumps, remove metals; with bypass

Pressure module: (filtering), distributing hydraulic to each pressure system.

Accumulator: gas compression absorb energy, expansion outputs energy; additional/EMRG supply, absorb shock/heat expansion, ensure pressure/fuild

Actuators(linear): hydraulic or gas(bleed) actuators; **hydraulic motor**(angular); pressure energy->mechanical energy

Check Valves: Ensure one-way flow

Directional Control Valves: Control the direction

Unloading Valves: idle pump loop when not needed**, unload the pump**

Pressure Relief/safety Valves: restrict **max** pressure

Restrictor valve: controls the **rate** at which the **pressure increases** in system

Multi-source hydraulic system

Multi-source hydraulic system: Individual hydraulic components

EDP Engine-Driven Pump;

EMDP Electric Motor Driven Pump/ACMP Alternating Current Motor Driven Pump

Backup: **ADP Air-Driven Pump; RAT Ram Air Turbine**

PTU-power transfer unit (hydraulic motor and a pump) one sys drive the pump of another sys.

Control & indication

Engine driven pump switch: “on” pressure supply; “off”: manual unloading

Capacitive Quantity Sensor: low fluid level warning in reservoir

System pressure indication: downstream of check valve
Pump low pressure warning: upstream of check valve, outlet of pump
Over temperature warning: electric pump housing, pump return pipeline

Landing gear system 起落架系统

Types of landing gear

飞机起落架有三种基本结构型式：构架式、摇臂式、支柱套筒式
Trestle 构架式
Simple structure, lightweight, large external dimension; fixed landing gear
Levered suspension/ bell crank 摇臂式
Good shock absorption, both vertical and horizontal, uniform wear of sealing device, complex, heavy
Struct sleeve/brace telescope-feed 支柱套筒式
Simple structure, light weight, good buffering on vertical impacts, shock struct large bending moment, uneven wear.

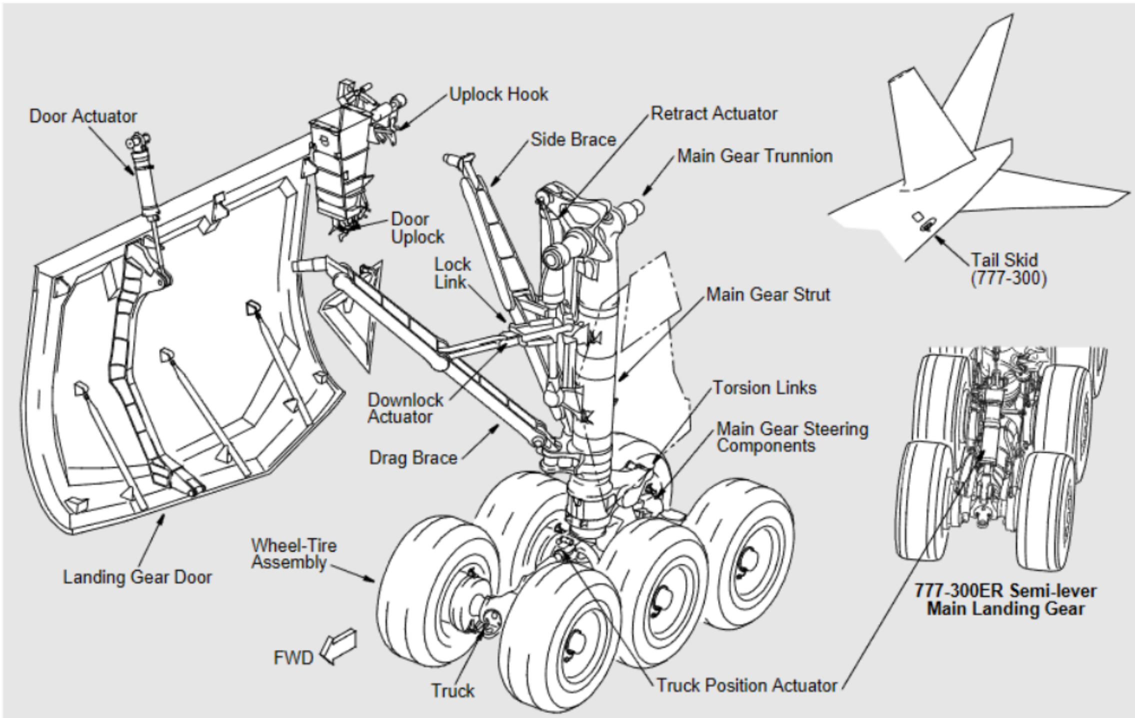
现代大型运输机起落架结构型式：Trolley landing gear
strut sleeve structure + four/six-wheel trolley; Modern transport ACFT

Trolley landing gear 结构

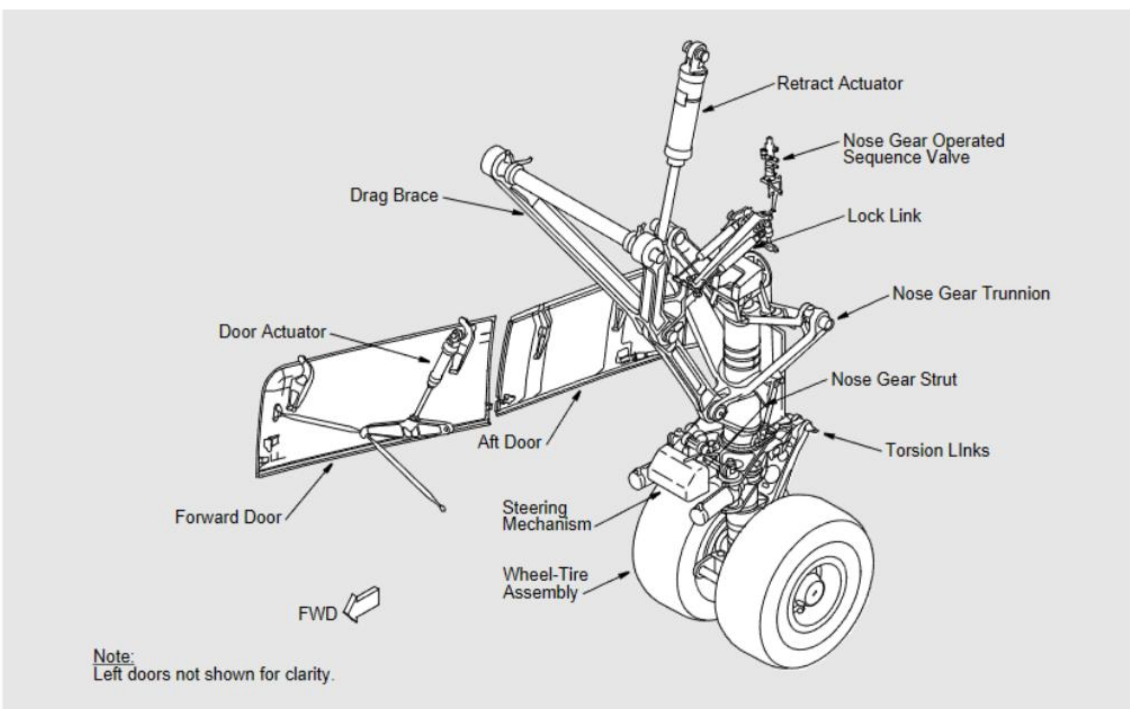
Modern large transport aircraft widely adopt trolley landing gear: strut sleeve structure + four/six-wheel trolley.

Shock strut: bear and transfer ground loads, reducing landing impacts and bump
Torque arm: bear and transmit torque and prevent the inner and outer cylinders of the shock-absorbing pillar from rotating relatively。
Side struts: reduce the lateral load of the struts, and some are components of the landing gear retraction and extension mechanism
Drag struts： reduce the longitudinal load of the pillar and ensure its stable longitudinal operation.
Stabilizing shock absorber: reduce the pitch vibration of the wheel frame on an uneven runway.
Wheel frame tilting mechanism: flips the landing gear at an Angle when it is retracted to facilitate the smooth retraction of the wheels into the cabin.

参考 777 的起落架结构



Main Landing Gear and Tail Skid



Nose Landing Gear

机轮

机轮由轮毂和轮胎组成。
一、轮毂
轮毂 rim 的作用是支撑轮胎，常由铝、镁合金制成。
(**Aluminum-magnesium alloy**，也可简称为 Al-Mg alloy)
二、轮胎
1、分类
（1）有内胎轮胎 Tubed tire
气密性较好，但当轮胎气压较低发生错动时，充气嘴可能被切断。通常在轮胎和轮毂上标注**红线**，便于检查轮胎是否错动 tire creep。
（2）无内胎轮胎 Tubeless tire
重量轻且冷却性好，充气嘴不会因轮胎错动而受损，但其密封较为困难，应注意检查其气密性。现代运输机通常采用此类型轮胎。
2、构造
轮胎主要由胎面层 tread layer,、缓冲层 cushion layer、帘线层 cord layer、气密层 airtight layer 和胎缘 bead edges 构成。胎面上沿圆周方向的胎纹具有防滑水的作用。胎面纵向花纹底部的横隔橡胶条用于观察胎面的磨损程度。The **transverse rubber strips** at the bottom of the **longitudinal tread patterns** are used to observe the wear **degree of the tread.**
帘线层 cord layer/carcass plies 是轮胎受力的主要部分，又称为胎体层，由多层涂胶的尼龙帘线构成 multiple layers of rubber-coated nylon cords，帘线层损坏可能引起爆胎 tire blowout。
层级 ply rating-帘布的公称层数。Ply rating refers to the nominal number of cord layers.
现代飞机采用通风式刹车盘或安装刹车风扇，**在轮毂 rim** 上装易熔塞 **fusible plug**，控制刹车使用和飞机过站时间等措施来防止轮胎过热。Prevent tire from overheat

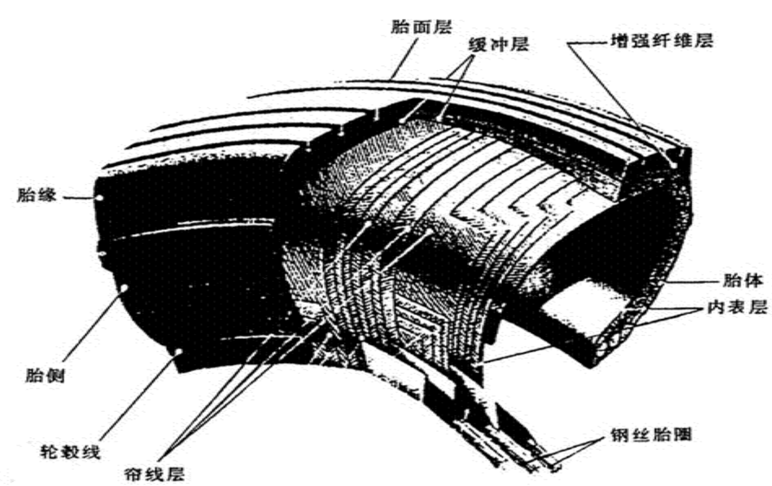


图 2-8　斜交型无内胎轮胎

防止意外收起

To prevent accidental landing gear retraction while the aircraft is on the ground, the landing gear extension/retraction system is equipped with ground safety protection. Safety measures to prevent inadvertent gear retraction on the ground include:

A landing gear lever designed to prevent unintentional movement.

An electrically actuated gear-lever lock:(gear-lever lock, not gear lock) when the aircraft is on the ground, the air/ground switch on the landing gear strut opens the lever-lock relay circuit, causing the lock plunger to extend and preventing the gear lever from being raised to the **UP** position.

External mechanical locks:(not internal) movable components of the landing gear actuation mechanism are secured with lock pins or sleeves to restrict movement of the mechanism.

The air/ground switch interrupts the landing gear system control circuit when the aircraft is on the ground.

刹车

刹车装置的类型 brake devices

1、弯块式刹车装置 curved block type brake device

2、胶囊式刹车装置 capsule type brake device

3、圆盘式刹车装置 disc type brake device：现代运输机广泛采用多圆盘式刹车装置。**Multiple disc type brake**

刹车系统的类型 brake systems

1、独立刹车系统：由单独液压系统提供刹车动力。

2、液压增压刹车系统：由飞机液压系统压力帮助产生高刹车压力。

3、动力刹车系统 Power brake system（dynamic brake system）：控制飞机液压系统压力去刹车，现代运输机广泛采用。

刹车状态监控

包括刹车温度 brake temp、brake pressure、tire pressure 刹车压力和轮胎压力监控。

刹车方式

正常刹车：工作原理是当驾驶员踩下刹车时，系统压力经刹车调压器调节后流向刹车动作筒，使刹车装置产生刹车力矩，使飞机减速。

备用刹车：正常刹车失效时使用备用刹车动力源进行刹车。

防滞刹车 anti-skid brake：防滞刹车系统 Anti-skid brake systems 可分为电磁阀式 solenoid valve type 与电子式 **electronic type** 两种，现代运输机**广泛采用**电子式防滞刹车系统。

自动刹车 auto brake：通过自动刹车调压器调节刹车压力，从而满足选定减速率要求。

1、 T/O abortion(idle)
2、 after landing (throttles are at idle).
考试错误选项 “any time when idle”

停机刹车（停留刹车）：防止飞机在地面发生意外移动，刹车压力由刹车蓄压器提供。
收轮刹车：起落架收上时自动刹住机轮，减少振动。

前起落架

前轮摆振 **nose wheel shimmy**：弹性恢复力 **elastic restoring** 与地面摩擦力 **friction force** 交替作用
减摆器的工作原理是利用油液高速流过小孔摩擦生热消耗摆振能量，减弱或防止摆振。The working principle of the shimmy damper is to use the friction heat generated by oil flowing through small holes at high speed to consume the shimmy energy。**现代运输机前轮减摆通常采用液压系统减摆的方式。**

前轮转弯系统通常有 mechanical steering(only foot pedal)机械传动式和 hydraulic steering(foot pedal and hand wheel)液压传动式两种
机械传动式前轮转弯主要用于小型低速飞机，只能通过方向舵脚蹬控制前轮偏转
液压传动式前轮转弯系统常用于大中型运输机。脚蹬操纵时前轮偏角范围小，用于飞机高速滑跑时修正方向。手轮操纵时前轮偏角范围大，用于低速滑行时转弯。

飞机飞行操纵系统

Flight Control System Components

A flight control system consists of **control surfaces, control mechanisms, transmission mechanisms, and actuating mechanisms**.

1. Control Surfaces

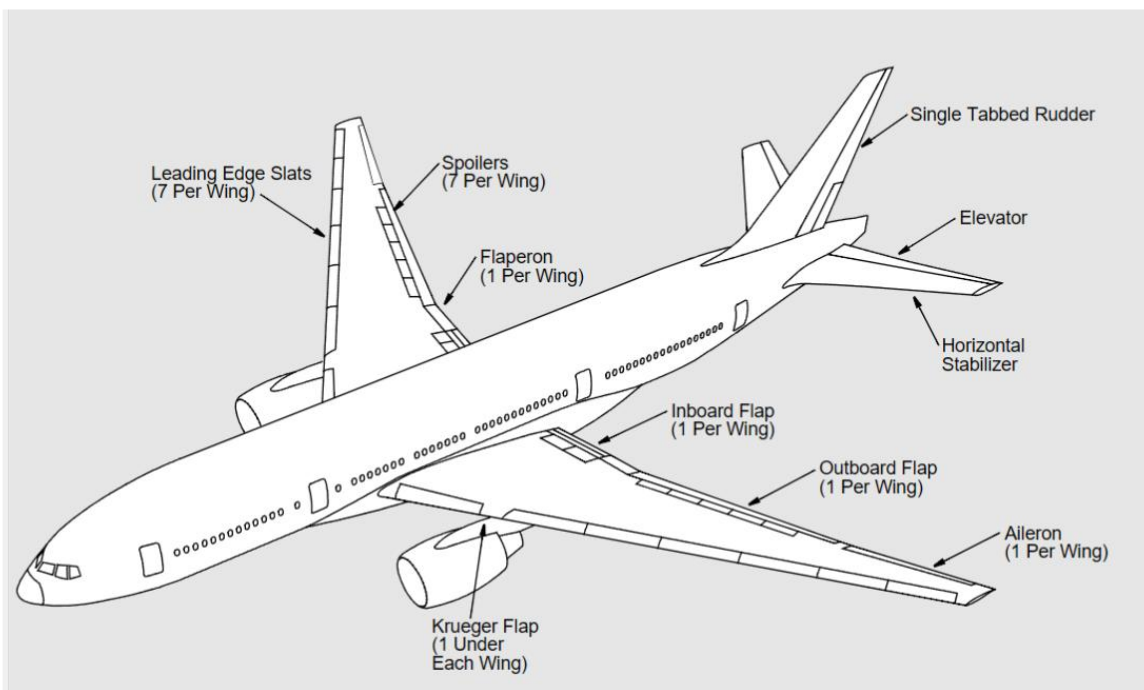
Control surfaces include **primary** and **secondary** surfaces.

Primary control surfaces

- Ailerons
- Elevators
- Rudder

Secondary control surfaces

- Leading-edge flaps
- Leading-edge slats
- Trailing-edge flaps
- Spoilers
- Trimmable horizontal stabilizer (THS)



参考 777 的飞行控制面

2. Control Mechanisms

Control mechanisms include:

- Control wheel/control column
- Rudder pedals
- Trim wheels or trim switches
- Flap control lever or flap switch
- Spoiler control lever

3. Transmission Mechanisms

Transmission mechanisms are divided into **soft (flexible)** and **hard (rigid)** types.
They connect the control mechanisms to the control surfaces in an appropriate manner, ensuring correct control relationships and desirable handling qualities.

4. Actuating Mechanisms

Actuating mechanisms include:

- Manual actuation
- Hydraulic-powered actuation
- Electric-powered actuation

They provide the force required to move the control surfaces.

操纵系统

【1.液压助力式主操纵系统 Hydraulic-assisted main control system

现代运输机采用助力式主操纵系统，即利用除驾驶员体力以外的能源（如气动助力、液压助力、电动助力或它们的组合），帮助或代替驾驶员的体力操纵舵面，其中液压助力最为常见。

液压助力式主操纵系统的工作特点：操纵信号由驾驶员发出，最终传递到舵面；驱动舵面所需的力主要或全部由液压助力器提供；驾驶员感受到的主操纵力由感力装置 Force feel device（或称为感力定中配平机构 feel and centering trim mechanism）提供。

驾驶盘柔性互联机构，可保证在一个驾驶盘卡阻时，另一驾驶盘仍能转动，以对飞机进行应急横侧操纵。】

1. Hydraulically Powered Primary Flight Control System

Modern transport aircraft commonly use **powered primary flight control systems**, where energy sources other than pilot physical force (such as pneumatic, hydraulic, electric, or combinations thereof) assist or replace manual inputs. Hydraulic power assistance is the most common.

Characteristics of hydraulically powered primary control systems

- Control signals originate from the pilot and are transmitted to the control surfaces.
- The force required to move the surfaces is provided primarily or entirely by the hydraulic actuators.
- The pilot's control feel is provided by a **feel and centering unit** (also known as a feel/trim mechanism).
- A **flexible interconnection** between dual control wheels ensures that, if one wheel becomes jammed, the other can still be moved for emergency roll control.

【2.电传操纵系统 Fly-by-wire system

电传操纵系统是把驾驶员发出的操纵指令转换为电信号并与飞机运动传感器反馈的信号综合，经计算机处理，把控制指令通过电缆输送给操纵面作动器，从而实现对操纵面驱动控制的系统。

单通道电传操纵系统的可靠性较低，为保证电传操纵系统的任务可靠性，现代运输机通常采用余度技术 redundancy technology，引入多重系统，如四余度电传操纵系统。四余度电传操纵系统具有故障监控、信号表决、故障隔离、系统重组功能和双故障工作安全能力。The four-redundancy fly-by-wire system has functions of fault monitoring, signal voting, fault isolation, system reconfiguration, and the capability of safe operation with double faults.】

2. Fly-by-Wire (FBW) System

A fly-by-wire system converts the pilot's inputs into electrical signals and combines them with feedback signals from aircraft motion sensors. After processing by computers, the resulting control commands are transmitted via electrical cables to the control surface actuators.

A **single-channel FBW system** has low reliability; therefore, modern transport aircraft employ **redundancy**, typically **quadruplex (four-channel) FBW systems**.

Features of a quadruplex FBW system

- Fault monitoring
- Signal voting
- Fault isolation
- System reconfiguration
- Capability to continue safe operation with up to two system failures

The advantages of Fly-by-wire system

It reduces the weight of the control system; The influence of friction, clearance and nonlinear factors in the mechanical control system as well as the deformation of the aircraft structure on the transmission performance has been eliminated. Simplified the combination of the main control system and the autopilot; The aircraft's handling stability characteristics have been fundamentally improved.

【3.配平操纵：现代运输机普遍采用液压助力式主操纵系统，其配平操纵的基本原理是通过配平操纵机构控制感力定中配平机构（或称为调整片效应机构），使该机构重新定中，从而减小或消除操纵力，达到配平的目的。
配平操纵机构包括配平电门、配平轮或配平手柄等，配平操纵方向与主操纵方向一致。现代运输机俯仰配平包括人工机械配平、主电动配平和自动驾驶配平三种方式，其中人工机械配平方式的优先级别最高，自动驾驶配平的优先级别最低。
可调水平安定面按配平指令相应偏转，配平后升降舵回中，以减小阻力，保证操纵性。飞机起飞前应根据飞机的载重和平衡等情况进行水平安定面的预配平操作，即将可调水平安定面调节到"起飞（绿区）takeoff (green zone)"位置，以保证飞机的起飞性能，否则推油门起飞会发出起飞形态警告。】

3. Trim Control

In modern transport aircraft with hydraulically powered controls, trim control works by adjusting the **feel and centering (trim) mechanism**, changing its neutral position to reduce or eliminate control forces.
Trim control devices include:

- Trim switches
- Trim wheels
- Trim levers

Trim direction is consistent with the direction of primary control input.
Pitch trim on modern transport aircraft
Three pitch-trim methods are commonly used:

1. Manual mechanical trim (highest priority)
2. Main electric trim
3. Autopilot trim (lowest priority)

The **trimmable horizontal stabilizer (THS)** moves in response to trim commands. After trimming, the **elevator returns to neutral to reduce drag and maintain controllability.**
Before takeoff, the horizontal stabilizer must be preset according to the aircraft's weight, balance, and other relevant conditions. This means adjusting the trimmable horizontal stabilizer to the **"takeoff (green band)"** position to ensure proper takeoff performance. Otherwise, when the throttles are advanced for takeoff, a **takeoff configuration warning** will be triggered.

【4.增升装置操纵：现代运输机增升装置通常包括后缘襟翼和前缘缝翼，有时还有前缘襟翼（克努格襟翼 Krueger flaps），通常由襟翼手柄统一控制。增升装置收放的正常动力为液压，备用动力为电动或液压。驾驶员应根据襟翼指位表、灯、图形等指示来判断增升装置的工作位置。通常增升装置操纵系统具有襟翼过载保护和不对称保护功能。增升装置（包括后缘襟翼、前缘装置）应在起飞前放规定位置，否则推油门起飞会发出起飞形态警告。】

4. High-Lift Device Control

Modern transport aircraft use high-lift devices, typically:

- Trailing-edge flaps
- Leading-edge slats
- Sometimes leading-edge **Krueger** flaps

All are normally controlled by a single **flap lever**.

Power sources

- **Normal power:** hydraulic
- **Backup power:** electric or hydraulic

Pilots monitor flap/slat positions using indication tables, lights, or graphic displays. High-lift systems typically include:

- **Flap overload protection**
- **Asymmetry protection**

Before takeoff, high-lift devices must be set to the required position; otherwise, a **takeoff configuration warning** will sound when thrust is advanced.

扰流板

I. Functions of Speedbrakes/Spoilers

Speedbrakes are designed to disturb the airflow over the wing surface, increasing drag and reducing lift. Increasing drag allows the aircraft to decelerate, while reducing lift allows the landing gear to sense the aircraft's full weight more quickly, improving braking efficiency. On modern transport aircraft, spoilers and speedbrakes are also used for in-flight deceleration, increasing descent rate, assisting roll control, and providing emergency roll control.

Advantages of installing spoilers

1. **Roll-control augmentation.**
   Spoilers can be used as a roll-control device, spoilers allow the size of the outboard ailerons to be reduced, making it possible to install longer trailing-edge flaps, which in turn decreases the landing speed.
2. **Increased drag and reduced lift.**
   Spoilers enable the aircraft to reduce lift/airspeed and increase descent rate **without reducing engine power**. This is important for turbine engines, because after thrust is reduced, they require time to spool back up.
3. **Higher maximum controllable speed.**
   Compared with outboard ailerons, spoilers located on the mid- and inboard wing sections generate aerodynamic loads that produce less wing-twist deformation, allowing higher maneuvering speeds.

II. Use of Speedbrakes/Spoilers

1. In-flight Operation

a. Airspeed reduction and/or increasing descent rate

To decrease airspeed or increase descent rate, the pilot moves the spoiler lever from the DOWN detent to the FLIGHT detent, raising the spoilers to increase drag and reduce lift.

b. Roll-control assistance

Many aircraft automatically link control-wheel inputs to the outboard spoilers as well as the ailerons.
In such designs:

- On the **descending wing** (aileron up), the **spoiler also rises proportionally**, increasing drag and reducing lift.
- On the **rising wing** (aileron down), the corresponding spoiler **remains stowed**.

This helps counteract adverse yaw and improves roll rate.
2. Load-Alleviation Function
On some aircraft, when airspeed increases, the outboard ailerons and outboard spoilers are **automatically locked out**, so they no longer respond to roll command. Roll control is then provided by **inboard ailerons and mid-spoilers**, preventing excessive structural loads on the outboard wing.
3. In-flight Deceleration at High Speeds and High Altitudes
At high speeds and high altitudes, in-flight deceleration may be necessary to prevent exceeding the wing's **critical Mach number**, which could otherwise lead to shock-induced stall. Spoilers are used to aid this deceleration.
4. Ground Operation
During landing, the pilot may place the spoiler lever in the **ARM** position. When the aircraft touches down and a series of conditions are met (**the spoiler lever is armed, the thrust levers are at flight idle, and the main wheels are spinning**), all spoilers automatically deploy to the full-up position, and the spoiler lever moves to the **UP** detent. This rapidly reduces lift.
For any reason, if the pilot advances the thrust levers (as long as reverse thrust is not selected) to increase power, the spoilers automatically retract and the lever moves to the **DOWN** position.

In summary, the standard use of spoilers is as follows:

At low speeds, the **outboard spoilers** are used for roll control.
In flight, the **middle spoilers** are used for deceleration and lift dumping.
During landing or rejected takeoff, **all spoilers — outboard, middle, and inboard —** are deployed to reduce lift.
On some aircraft, when speed increases beyond a certain point, the outboard spoilers and ailerons stop operating together.
Spoilers must be retracted before takeoff; otherwise, when the thrust levers are advanced for takeoff, a takeoff-configuration warning will be triggered.

飞机燃油系统

飞机燃油系统的类型 Fuel System Types

【1.飞机燃油系统的类型及特点

飞机燃油系统的类型分为单发选择供油系统，双发独立与交输供油系统，多发总汇流管供油系统，其中单发选择供油系统用于单发飞机。

一、双发独立与交输供油系统

双发飞机采用正常独立供油方式、交输供油方式和抽吸供油方式。independent fuel supply mode, crossfeed fuel supply mode(mutuality), and pumping/suction fuel supply mode.

二、多发总汇流管供油系统 Multi-engine manifold fuel supply system（Multi Mainbus）

三发及以上飞机采用各主油箱可独立向相应发动机供油，也可向总汇流管供油再分配给其它各发动机。】

Types and Characteristics of Aircraft Fuel Systems

Aircraft fuel systems can be classified into **single-engine selective feed systems**, **twin-engine independent and crossfeed systems**, and **multi-engine manifold feed systems**. Among them, the **single-engine selective feed system** is used on single-engine aircraft.

I. Twin-Engine Independent and Crossfeed Fuel System

Twin-engine aircraft employ **normal independent feed**, **crossfeed**, and **suction feed** modes.

- **Normal independent feed:** Normal operation —The left and right fuel systems independently supply fuel to their respective engines.
- **Crossfeed mode:**
  Fuel from one tank may be supplied to the opposite engine as required. **Single-engine operation or fuel imbalance** —The crossfeed valve is opened to enable crossfeed fuel supply.
- **Suction feed mode:** Under certain conditions, the engine-driven pump can draw fuel without the boost pump.

II. Multi-Engine Manifold Fuel System

For aircraft with **three or more engines.** In a multi-engine manifold fuel system, fuel can be supplied to each engine directly from its corresponding tank, or fuel from the main tanks can first be routed through the **manifold valve** into a **common fuel manifold**, from which it is then distributed to all engines.

飞机燃油系统部件

Fuel Tanks 燃油箱

1、按位置分类：机翼油箱，机身（中央）油箱，机翼或机身辅助油箱。Wing tanks, fuselage (central) tanks, and wing or fuselage auxiliary tanks.
按结构分类：结构油箱，固定油箱（包括硬壳式油箱和软油箱）。
Structural tanks, fixed tanks (including rigid tanks and flexible tanks).
2、油箱通气 fuel tank ventilation 目的：消除油箱内外压差，保证供油和加油顺利；飞行中给油面提供正压，辅助供油；排出燃油蒸汽，防止形成爆燃条件。
Eliminate pressure differences between the inside and outside of the tank to ensure smooth fuel supply and refueling;
Provide positive pressure to the fuel surface during flight to **assist fuel supply;**考试错误选项 prevent cavitation(正压力不足，需要靠 air bleed pressurization)
Discharge fuel vapor to prevent the formation of **deflagration** conditions.
Baffle plats in wing fuel cells: prevent movement of the fuel(surging) in the tank during acceleration/deceleration or in turbulence.(using check valve)

Fuel Pumps 燃油泵

1、增压泵 booster pump：浸入式电动离心泵。Submerged electric centrifugal pump

2、超控泵 over-ride pump：出口处的单向活门打开压力低，控制油箱供油顺序。

3、引射泵 injection pump：用于将无泵油箱的燃油抽入消耗油箱，也可用于增压泵进口处防水分集中进入供油管。

4、搜油泵 scavenge pump：将辅助油箱剩余燃油抽入主油箱。

5、转输泵 transfer pump：将某油箱燃油转输至其他油箱或放油管路。

1. **Boost Pump:**
   A submerged **electric** centrifugal pump.(fuel tank)
2. **Override Pump:**
   Has a relatively low opening pressure at its outlet check valve and **is used to control the sequence in which tanks** supply fuel.
3. **Ejector Pump (Jet Pump):**
   Used to draw fuel from tanks without mechanical pumps into the feed (collector) tank; it can also prevent water accumulation from entering the feed line by improving suction at the boost pump inlet.
4. **Scavenge Pump:**
   Transfers the remaining fuel from auxiliary tanks into the main tank.
5. **Transfer Pump:**
   Moves fuel from one tank to another tank or to the fuel jettison line.

Filter&valve

燃油滤
分为粗油滤和细油滤，作用是滤除燃油中的机械杂质和水分，保证油液清洁。燃油滤具有旁通功能 bypass function，油滤旁通时驾驶舱中提供有油滤堵塞信号灯指示。

控制活门
1、油箱选择活门：用于选择供油油箱。
2、燃油关断活门：正常供油时打开，发动机停车或灭火时被关断。
3、交输活门：正常供油时关断，交输供油时打开。

飞机燃油系统的供油方式 **Fuel Supply Modes**

[一、独立供油方式

独立供油为正常供油方式，供油可靠性最高。在该方式下，交输活门关断，所有电动增压泵打开，先把机身油箱燃油供给发动机，再把机翼油箱燃油供给相对应的发动机。

二、交输供油方式

在双发变单发或需要进行左右机翼油箱油量平衡时采用交输供油，供油可靠性稍差。在转换供油方式过程中要严格按照手册规定的操作顺序，防止供油中断导致发动机停车。

三、抽吸供油方式

某机翼油箱所有增压泵都失效时，相应发动机处于抽吸供油方式，由发动机驱动燃油泵通过旁通活门从机翼油箱抽吸燃油。抽吸供油方式供油可靠性较差，驾驶员应注意观察发动机工作状态。]

Fuel Supply Modes of Aircraft Fuel Systems

I. Independent Feed Mode
Independent feed is the normal fuel supply mode and provides the highest reliability.
In this mode, the **crossfeed valve remains closed**, and **all electric boost pumps are on**.
Fuel from the **fuselage tanks** is supplied to the engines first, followed by fuel from the **wing tanks**, each feeding i
II. Crossfeed Mode
Crossfeed is used during **twin-engine to single-engine operation** or when **wing tank fuel imbalance** needs to be corrected.
Its reliability is slightly lower than independent feed.
When switching to crossfeed mode, the pilot must follow the procedure specified in the aircraft manual to avoid fuel supply interruption, which could cause **engine flameout**.
III. Suction Feed Mode
When **all boost pumps in a wing tank fail**, the corresponding engine operates in suction feed.
In this mode, the **engine-driven pump** draws fuel from the wing tank through a bypass valve.

Suction feed has relatively low reliability, so the pilot must closely monitor engine performance.

加油，放油

油箱加油

飞机燃油系统油箱加油方式包括重力加油 Gravity Refueling 和压力加油 Pressure Refueling。

重力加油通常是小型飞机唯一的加油方式，也可作为大中型运输机的备用加油方式。而压力加油是运输机加油的主要方式，其优点是加油速度快，受外界污染少。

Pressure refueling is the main method for refueling transport aircraft. Its advantages include fast refueling speed and less contamination from the outside world.

油箱加油顺序是先加机翼主油箱，后加机身油箱，并保证左右机翼油量平衡。 The sequence for refueling the fuel tank is to add the main fuel tank of the wing first, then the fuselage fuel tank, and ensure the fuel balance between the left and right wings

加油时注意事项：严禁烟火，车辆远离；三接地防静电；雷达关，高频通信关，不能检查电器设备；防污染；加油一段时间后放沉淀或取样化验；燃油牌号、计量单位、油量正确；加油后盖好加油口盖。

空中放油

很多中远程飞机设有空中放油系统，飞机空中放油的主要目的是减小重量，防止飞机超重着陆，在紧急迫降时避免爆炸起火。

空中放油系统的型式包括重力放油系统和动力放油系统。

Fuel chute dump, fuel valve dump

飞机空中放油的注意事项：

- 遵从空中交通管制的指挥，到指定空域、规定高度放油；
- 放油时注意避开居民区和工业区，以确保地面人员和财产安全；
- 放油时飞机应处于净外形状态 clean configuration.，防止污染飞机、防止飞机着火；
- 确保留有足够的剩余油量。

飞机燃油系统的控制与指示

【一、增压泵电门

控制电动增压泵的接通与断开。

二、交输供油选择器

控制交输活门的打开与关闭。

三、燃油量表

通常采用电容式油量传感器，以磅或公斤为单位指示油量。

- 浮子式油量表（Float-type fuel gauge）：利用浮子把油箱液面高度转变成电阻（resistance），通过测量电阻从而进行油量指示。存在较大的姿态误差。
- 电容式油量表（Capacitance-type fuel gauge）Normally use this：利用电容传感器把油面高度转换成电容 capacitance.，通过测量**电容**从而指示油量。存在温度误差和换油误差。

四、增压泵工作灯与低压警告灯

有些飞机增压泵工作正常时有相应绿灯指示。当泵出口压力低于正常值时低压警告灯亮。】

Control and Indication of Aircraft Fuel Systems

I. Boost Pump Switches
Used to control the **ON/OFF** status of the electric boost pumps.
II. Crossfeed Selector
Used to control the **opening and closing** of the crossfeed valve.
III. Fuel Quantity Indicators
Fuel quantity is usually indicated using **capacitive-type fuel quantity sensors**, with readings displayed in **pounds** or **kilograms**.

- **Float-Type Fuel Quantity Indicator:**
  Uses a float to convert fuel surface height into an electrical resistance value.
  Fuel quantity is indicated by measuring this resistance.
  It is subject to **significant attitude errors**.
- **Capacitive-Type Fuel Quantity Indicator:**
  Uses capacitive probes to convert fuel level into capacitance.
  Fuel quantity is indicated by measuring capacitance.
  It is subject to **temperature errors** and **fuel-type (dielectric) errors**.

IV. Boost Pump ON Lights and Low-Pressure Warning Lights
Some aircraft have a **green light** indicating normal boost pump operation.
When the pump outlet pressure falls below the required value, a **low-pressure warning light** illuminates.

飞机气源系统 Aircraft Pneumatic System

引气来源及控制

【现代运输机气源系统的引气来源包括

engine compressor

APU compressor

ground air supply。

通常用于座舱空调增压供气、液压油箱增压、飞机机翼除/防冰、发动机防冰、水箱增压、发动机起动等。

气源系统中的引气控制包括压力控制、温度控制和通断控制。主要控制活门包括调压关断活门和预冷器控制活门。】

Sources and Control of Bleed Air

In modern transport aircraft, the sources of bleed air include:

- **Engine bleed air**
- **APU bleed air**
- **Ground pneumatic air**

Bleed air is typically used for cabin air-conditioning and pressurization, hydraulic reservoir pressurization, wing anti-ice/de-ice, engine anti-ice, potable-water tank pressurization, engine starting (air starter), etc.

Control of bleed air: pressure control, temperature control, on/off (shutoff) control.

Main control valves: **pressure-regulating shutoff valves (PRSOV), precooler control valves**.

飞机气源系统的控制与指示

【一、引气电门

打开或关断相应发动机或 APU 引气活门。

二、隔离电门

控制隔离活门的工作。

三、跳开复位按钮

用于引气跳开等警戒灯的复位。

四、气源压力表

气源压力表指示引气管道压力。

五、机翼机身过热灯 overheat light

指示引气管道漏气。Indicates air leakage in the bleed air duct.

六、引气跳开灯

指示引气 overheat 或 overpressure 导致引气活门自动关断。】

Control and Indication of the Aircraft Pneumatic System

1. **Bleed Air Switches**
   Used to open or close the corresponding engine or APU bleed air valves.
2. **Isolation Switch**
   Controls the operation of the isolation valve.
3. **Trip Reset Button**
   Used to reset bleed trip or related **caution lights.**
4. **Bleed Air Pressure Gauge**
   Indicates the pressure in the bleed air duct.
5. **Wing/Body Overheat Light**
   Indicates a **bleed air leak in the ducting**.
6. **Bleed Trip Off Light**
   Indicates a **bleed air overtemperature or overpressure** condition that has caused the **bleed valve to automatically shut off.**

【流程示意】

ENG/APU→ **Pre-cooler(temp)** → **PRSOV(P, on/off)** → Common bleed-air manifold

Function	Device	Purpose
Pressure Control	**PRSOV**	Maintains correct bleed pressure to the manifold
Temperature Control	**Pre-cooler control valve (heat exchanger)**	Ensures bleed-air temperature stays within limits
On/Off (Shutoff)	**PRSOV, engine/APU bleed valves**	Isolates bleed source when needed

Bleed Air Switches → Command the bleed valves (including PRSOV, ENG, APU) to open/close.
Bleed Trip OFF Light → PRSOV automatically closed due to overheat/overpressure.
Wing/Body Overheat Light → Possible bleed-duct leak.
Trip Reset Button → Used to reset PRSOV and caution lights after a trip.
Bleed Air Pressure Gauge → Shows manifold pressure (PRSOV regulates this).

飞机座舱空调系统

基本原理

Basic Principles of Cabin Temperature Regulation

The fundamental method of regulating aircraft cabin temperature is to **maintain a generally constant supply of air(air demand)** to the cabin while controlling the temperature of the supplied air (i.e., the conditioned air temperature) to meet the desired cabin comfort requirements.
The basic principle of cabin temperature adjustment and control is to regulate the **opening positions of the air-mixing valves** (hot-air valve and cold-air valve). By adjusting these openings, the proportion of hot and cold air is controlled to produce the required supply-air temperature, ensuring that the cabin temperature meets the selected settings.

基本方法

Bleed-Air Refrigeration Methods, Components, and Functions

Aircraft air-conditioning bleed-air refrigeration methods include **vapor-cycle refrigeration** and **air-cycle refrigeration**.

I. Vapor-Cycle Refrigeration
Working principle: refrigerant absorbs heat during **phase change**
Components: compressor, condenser, expansion valve, evaporator
（Used in tropical Area, high PWR）

II. Air-Cycle Refrigeration
1. Basic Working Principle
High-temperature, high-pressure bleed air drawn from the engine is first **pre-cooled** by a heat exchanger. It then undergoes **expansion in the cooling turbine**, reducing its temperature and producing cold air.
2. Composition
modern transport aircraft. Components:

- **Heat Exchanger**
  Uses ram air for heat exchange to **reduce the temperature of the bleed air**

- **Compressor**
  Driven by the cooling turbine. It absorbs turbine power, increasing the turbine inlet pressure to improve the cooling efficiency of the turbine.
- **Cooling Turbine**
  Driven by the expansion work of hot bleed air. It reduces the temperature by consuming the internal energy of the hot air. It is coaxial with the compressor, and together they form the **Air Cycle Machine (ACM)**.
- **Fan**
  Draws in cold air and increases airflow through the heat exchanger. In a **three-wheel ACM**, the fan is also turbine-driven.
- **Water Separator**
  Removes moisture from the cold air at the cooling turbine outlet (or inlet) and sprays it into the ram-air inlet to improve heat-exchanger efficiency, reduce supply-air humidity, and prevent icing at the turbine outlet.

温度控制方法

Cabin Temperature Control Methods

Cabin temperature control methods include **automatic mode** and **manual mode**.

I. Automatic Mode
Under normal conditions, the flight crew should select **automatic cabin temperature control**.
In this mode, the **temperature controller** automatically adjusts the opening of the **air-mixing valves** (hot-air valve and cold-air valve) based on signals such as the pilot's pre-selected cabin temperature and the actual cabin temperature.
By regulating the airflow of the hot and cold air paths, the system controls the **air-conditioning supply temperature** and the **cabin temperature**.

II. Manual Mode
When the automatic mode fails, the flight crew should select **manual cabin temperature control**.
In this mode, the pilot directly controls the opening of the **air-mixing valves** (hot and cold) using the **manual temperature control knob**, without using the automatic temperature controller.

控制和指示

Operation and Indication of the Cabin Air-Conditioning System

1. Air-Conditioning Pack Switch

Controls the power supply to the air-conditioning pack valves; essentially the ON/OFF control for the pack.

2. Air-Conditioning Pack Trip-Off Light

Indicates that the pack **valve has automatically closed due to excessively high pack operating temperature.**

3. Cabin Temperature Selector

- In automatic cabin temperature-control mode, it provides the selected cabin temperature signal to the automatic temperature controller.
- In manual temperature-control mode, it directly controls the opening of the air-mixing valves (hot-air and cold-air valves).

4. Air Temperature Indicator

Indicates the actual cabin temperature or the conditioned-air supply temperature.

5. Air-Mixing Valve Position Indicator

Shows the actual operating positions of the air-mixing valves (hot and cold).

6. Duct Overheat Light

Indicates excessively high temperature in the conditioned-air supply duct.

飞机座舱增压系统

Cabin Pressurization Control Parameters

1. Cabin Altitude

Cabin altitude refers to the **equivalent altitude** corresponding to the **absolute air pressure** inside the cockpit/cabin.

According to **CCAR-25.841(a)**, when a transport-category airplane is flying at its **maximum operating altitude**, the pressurization system must ensure that under **normal conditions**, the **cabin altitude** does **not exceed 2,438 meters** **(8,000 ft)**.

If the aircraft must operate **above 7,620 meters (FL250)**, it must be ensured that **in the event of a pressurization system failure**, the **cabin altitude** does **not exceed 4,572 meters** **(15,000 ft)**.

2. Cabin Altitude Change Rate

The cabin altitude change rate refers to **how fast** the cabin altitude increases or decreases.

Modern medium- and large-sized commercial aircraft typically limit:

- **Cabin climb rate:** ≤ **500 ft/min**
- **Cabin descent rate:** ≤ **350 ft/min**

These limits ensure passengers' comfort and prevent ear or sinus discomfort.

3. Differential Pressure / Overpressure

Differential pressure refers to the **difference between the pressure inside the pressurized cabin and the ambient pressure outside the aircraft**.

Differential pressure is also called **cabin pressure differential** or **pressurization load**.

The **maximum differential pressure** an airplane can withstand depends on the **structural strength** of the pressure vessel.

Modern large commercial aircraft typically limit maximum **overpressure** (differential pressure) to about **7–9 psi**.

Basic Principles of Cabin Pressurization Control

The purpose of aircraft cabin pressurization control is to ensure that, within the aircraft's operating altitude range, the **cabin altitude** and its **rate of change** meet the requirements for comfortable and safe conditions for occupants, while also ensuring the **structural safety (overpressure)** of the aircraft.

The basic principle of cabin pressurization control is: **maintain air flux/air demand, adjust exhaust valve opening**

To **maintain a relatively constant supply of conditioned air** into the sealed cabin, and to regulate **cabin pressure** by **controlling the opening of the outflow valve**, thereby adjusting the **amount of air discharged** from the cabin.
Through this method, the system satisfies operational requirements for **cabin altitude**, **cabin altitude change rate**, and **differential pressure** during flight.

Note:
Normal Atomosphere 14.7 PSI
BLW 8000ft: cabin does not require constant oxygen supply

Cabin Pressurization Safety Measures

1. Positive Pressure Relief Valve
The **positive pressure relief valve** opens automatically when the **cabin differential pressure** exceeds a specified limit.
Its purpose is to release excessive cabin pressure and prevent structural damage caused by **over-pressurization**.
2. Inward Relief Valve / Negative Pressure Relief Valve
The **inward relief valve** (also called the **negative pressure relief valve**) opens when the **ambient (outside) pressure becomes higher than the cabin pressure**.
Example:

- On a **B737-300**, the valve opens when ambient pressure exceeds cabin pressure by **0.2 psi**. 【题目】

This valve prevents structural damage that could occur if the fuselage is subjected to **excessive negative differential pressure** (i.e., cabin pressure lower than outside pressure).

3. Cabin Altitude Warning
If structural leakage, loss of pressurization, or bleed-air system failure causes the **cabin altitude to exceed 10,000 ft**, the cockpit warning system activates, providing **aural and/or visual alerts** to the flight crew.

Operation and Indication of the Cabin Pressurization System

1. Pressurization Mode Selector
The **pressurization mode selector** is used to choose the operating mode of the cabin pressure control system, such as **AUTO**, **STANDBY**, or **MANUAL** mode.

If the **automatic** pressurization system fails, the selector can be switched to the **standby (semi-automatic)** system.
If the standby system fails, operation can be switched to **manual control**.
Pressurization mode priority: Automatic → Standby → Manual
【易错，这里逻辑是优先使用的模式。不要混淆了飞行操纵系统的权限优先级 manual>auto】

2. Pressurization Mode Fault or Operation Lights
These lights indicate whether a particular mode is operating normally or if a fault has occurred in that mode.

- **FAULT light:** indicates malfunction in the current mode
- **ON/ACTIVE light:** indicates the mode is operating normally

3. Cabin Altitude, Cabin Altitude Change Rate, and Differential Pressure Indicators
These indicators show the real-time values of the three primary cabin pressurization control parameters:

- **Cabin Altitude** – the current cabin altitude
- **Cabin Altitude Change Rate** – the rate at which the cabin altitude is climbing or descending
- **Differential Pressure (Cabin Overpressure)** – the pressure difference between the cabin and ambient air

3. Cabin Pressurization Profiles (Regimes)
The cabin pressurization profile refers to the pattern in which the absolute air pressure (or cabin altitude) and differential pressure inside the aircraft's pressurized cabin change with the aircraft's flight altitude. It is also called the cabin pressure schedule.
According to the characteristics of pressurization control during different phases of flight, passenger aircraft generally use three types of cabin pressure schedules:
1. Free Ventilation + Altitude Hold + Differential-Pressure Hold

- During takeoff and landing, engine power loss is small.
- Passenger comfort during takeoff and landing is relatively poor.

2. Altitude Hold + Differential-Pressure Hold

- During takeoff and landing, engine power loss is large.
- Passenger comfort during takeoff and landing is relatively good.

3. Pre-Pressurization + Proportional Control + Differential-Pressure Hold

- Provides good passenger comfort during takeoff and landing.
- Causes relatively large engine power loss during takeoff and landing, requiring higher engine performance.↳
- Widely used in modern transport aircraft.

To help us understand the meaning of the Three Profiles (Regimes)

1. Free Ventilation + Altitude Hold + Differential-Pressure Hold

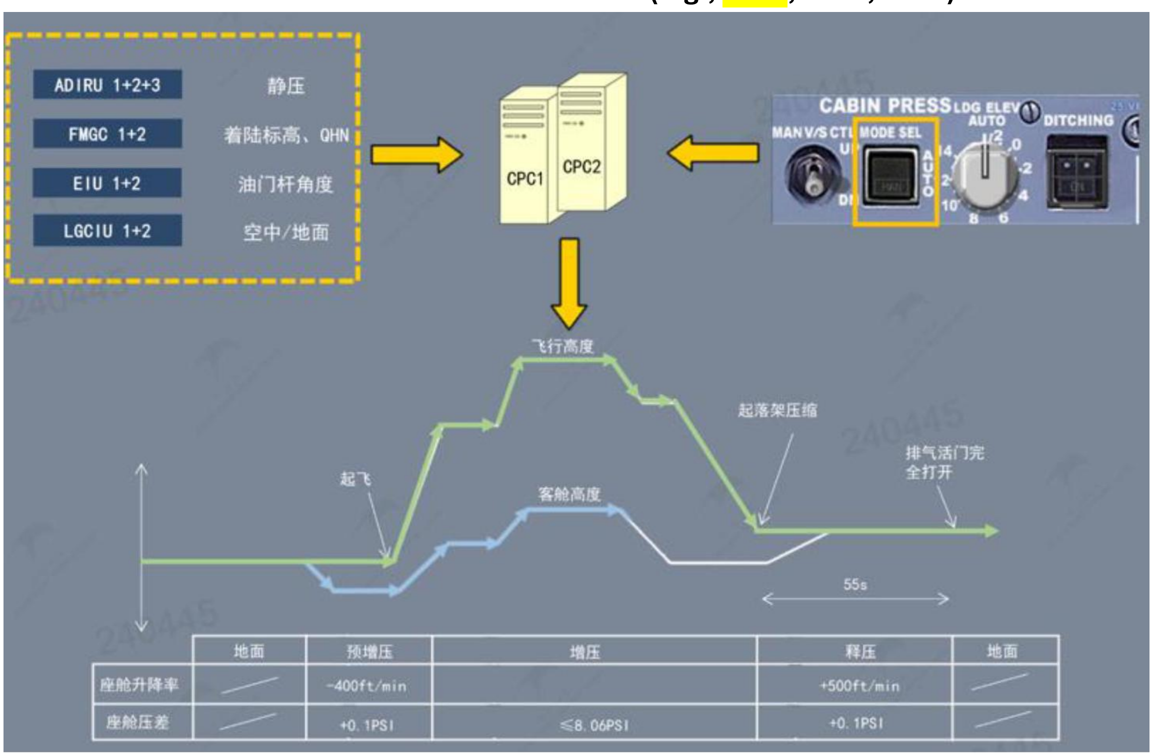
- **Free ventilation** at low altitude means the cabin is initially unpressurized.↳
- The system starts controlling after a certain altitude.
- This results in **noticeable pressure changes**, making passengers uncomfortable during takeoff/landing.
- Advantage: **Less engine bleed-air needed → less power loss.**

2. Altitude Hold + Differential-Pressure Hold

- Pressurization starts earlier than in method 1.
- Passengers experience **smoother pressure changes**.
- But this requires more **bleed air**, reducing engine efficiency during takeoff/landing.↳

3. Pre-Pressurization + Proportional Control + Differential-Pressure Hold

- The cabin begins to pressurize **before takeoff roll** (“pre-pressurization”).↳
- Uses smooth, proportional control throughout climb and descent.↳
- Provides **the most comfortable experience**.↳
- Requires more bleed air → **greater engine power demand**.↳
- **Standard in modern commercial airliners (e.g., A320, B737, B787).**



参考 A320 自动方式增压控制

飞机氧气系统

Oxygen cylinders (gaseous)

99.5% pure oxygen, with a water content of no more **than 0.005 milligrams** per liter

High-pressure oxygen cylinder: **green**;**1800 ~** 1850 PSI

Low-pressure oxygen cylinder: **light yellow**; **400** ~ 425 PSI。

chemical oxygen generators (solid)

Sodium chlorate, Iron powder; 12min

PBE，Portable Breathing Equipment

Protective oxygen supply or emergency medical oxygen; **crew or pax**

Crew oxygen supply:

intermittent 100% pure oxygen or,

normal diluted intermittent oxygen supply

PAX oxygen supply

Continuous dilution of oxygen supply

There are three **activation methods for the passenger oxygen** system: **manual, automatic, and mechanical.**

In automatic mode, the passenger oxygen masks typically drop automatically when the **cabin altitude reaches 14,000 feet**. Pulling down on the oxygen mask then triggers the chemical oxygen generator.

An oxygen supply installation must be kept absolutely free of oil or grease trace(油或油脂), as these substances catch fire spontaneously in the presence of oxygen

Oxygen cylinder is equipped with an **overheat release function.** There is **an indication diaphragm** outside the aircraft.

Some way of oxygen **does not have smoke prevention function**: **(diluted) Crew normal diluted; Pax continuous dilution**

飞机除/防冰系统

【提示：这一章题目和 ATA1 的 OPS 中除冰防冰/MET 中的题目都有重合，并且题库有时题目比较混乱，题目知识点穿插其它科目】

Aircraft Icing-Prone Areas and Associated Hazards

Aircraft surfaces and components that are **prone to icing** include:

- **Wing and tailplane leading edges**
- **Windshield / flight deck windows**
- **Engine inlets / nacelles**
- **Pitot tubes**
- **Angle-of-attack sensors**
- **Total air temperature (TAT) probes**
- Other exposed sensors and probes

Hazards of Aircraft Icing

The dangers associated with aircraft icing include:

- **Degraded aerodynamic performance** (reduced lift, increased drag, possible stall)
- **Reduced windshield visibility**
- **Decreased engine performance** or engine damage
- **Incorrect or unreliable instrument indications**, due to blocked or iced sensors/probes

飞机除/防冰方式及原理

飞机的除/防冰方式主要有

Pneumatic, gas-thermal, electro-thermal, liquid

气动除冰、气热除/防冰、电热除/防冰、液体除/防冰。

Pneumatic: to break up ice by air inflation in deicer boot 气动除冰的原理是让铺设在防护表面的除冰带充气膨胀使已结冰层破碎，并利用外界气流吹除。

Gas-thermal: to heat protection position using hot airflow 气热除/防冰的原理是利用热空气进入防护表面内的防冰腔加热防护部位而防止其结冰或除冰。

Electric-heating: electrifying resistance heating-element 电热除/防冰的原理是让电阻加热元件通电发热而对防护部位加温防冰或除冰。

Anti-icing fluid: decrease freezing point 液体除/防冰的原理是将冰点较低的除/防冰液体喷洒在防护表面与水或过冷水混合而进一步降低冰点温度，防止结冰或让冰层松动而除冰。

Deicing Systems:

Electronic Impact System ,

Electro thermal System

Pneumatic Boots System

Anti icing Systems:

Electric Heating System ,

Hot Air System

Chemical System

Difference between deicing and anti-icing system:

Anti-icing does not permit ice accumulation,

Deicing permits a certain amount before operation

Large transport ACFT:

Wings Deice/Anti-ice: gas-thermal; ENG anti-ice: gas-thermal

Windshield: electro-thermal(Defogging and enhancing impact toughness)

Atmospheric probes: electro-thermal

Leading edge slat: retractable sleeve/ Telescopic pipe

飞机结冰探测

飞机结冰探测装置的功用是探测、显示飞机、发动机结冰情况，有时也用以自动接通飞机除/防冰装置。

一、Visualized Icing indicator 直观式结冰探测装置

即结冰探棒，可靠性高，便于观察。

二、Automatic Icing indicator 自动式结冰信号器

包括振荡式、压差式、放射性同位素结冰探测器

Oscillating ice detector : when ice accumulate, mass changes, frequency increases.

differential pressure ice detector,

radioactive isotope ice detector

conductive ice detector 等，其中 Oscillating ice detector,**振荡式结冰探测器**在现代大中型民航运输机上得到了广泛应用。

Ice detector: only serves as visual reference in icing condition,

ice may first accumulate on critical position(pilot may not first observe ice on icing probes)

Normally 1 min, these detectors can be activated

In **light icing** conditions, outboard wing ice accumulation rate 0.6 – 2.5 cm per hour. Occasionally use deicing, pilot should consider leave the environment
Moderate Icing, 2.5-7.5 cm per hour. Frequently use, leave as quickly as possible
Heavy Icing, > 7.5 cm per hour. Max use. Leave immediately

飞机除/防冰系统的工作与指示

一、Wings Deice/Anti-ice 飞机机翼除/防冰系统
现代运输机机翼通常采用 gas-thermal 气热除/防冰方式，可靠性高，但消耗能量较多，会导致发动机耗油量增大。
机翼防冰活门可由机翼防冰电门人工控制打开，也可由机翼防冰计算机自动控制打开。由活门位置指示灯指示机翼防冰活门的开关状态。
可伸缩套管 retractable sleeve 保证了前缘缝翼在不同位置都能进行除/防冰工作。
二、ENG Anti-ice 发动机防冰系统
现代运输机的发动机通常采用 gas-thermal 气热防冰方式。
发动机防冰活门可由发动机防冰电门人工控制打开，也可由发动机防冰计算机自动控制打开。由活门位置指示灯指示发动机防冰活门的开关状态。
三、Windsheild Anti-ice 风挡玻璃防冰系统
现代飞机座舱风挡玻璃（特别是前部风挡玻璃）通常采用 electro-thermal 电热防冰方式。
风挡电加温元件埋设在风挡玻璃夹层当中，分为电阻丝式和电热膜式。由风挡加温电门控制系统打开，由风挡加温控制组件控制风挡温度在适当范围内。
风挡玻璃加温也有 Defogging and enhancing impact toughness 除雾和提高抗冲击韧性的作用。
由“接通”灯的亮灭指示加温电路通电与否。由“过热”灯指示风挡工作温度过高的状态。
四、 Anti-icing for atmospheric data probes 大气数据探头防冰系统
空速管、迎角传感器、大气总温传感器等大气数据探头采用 electro-thermal 电热防冰方式。

飞机地面运行时注意事项

1. 在启动时任何不正常的情况：都应该停止启动发动机。
2. 冬天运行时需要暖机：加热发动机和座舱。
3. 冬天长时间地面慢车容易造成垫火花极上结霜，易发动机停车。
4. 冬天低温，容易导致燃油注入过量，所以需要注意防火。
5. 在地面运行时，应该定时按照 AFM （ Aircraft Flight Manual）/POH （Pilot's Operating Handbook）适当增大 **N1 转速到 70 - 80%。**
6. 对于夜间停放时飞机液体电池：充满电或者从飞机上移除

7. 夜间停放飞机油箱需加满：当油箱温度高于 OAT，且油箱不满时，容易发生燃油污染。Aircraft temperature is highr than external, fuel tank isn't full, lead to fuel contamination more easily

飞机在进近时注意事项

1. 进近时怀疑**机翼结冰**：减小飞机迎角，适当增大油门（阻力变大），着陆之后可以暂缓收上操纵面。
2. 进近时发现**尾翼结冰**：收回襟翼。(downwash—-> increase tail AOA->closer to stall AOA)
3. 螺旋桨在顺桨之前：检查滑油未冻结。
4. 当引气防冰时：应当增大 N1 转速，所以推力增大，下降率和下降角变小。

When can anti-icing system be started:
In icing conditions and moist air
(According to AFM or POH is most accurate)

飞机地面除/防冰

当外界气温接近摄氏零度，特别是飞机在停机坪过夜或短停时间过长，或飞机在有雪水的跑道上滑行过时，应进行飞机起飞前结冰情况检查，如有冰、雪或霜存在时，应按要求彻底除去，并保持一定的防冰时间，以确保飞机安全起飞。
飞机地面除/防冰的主要材料是热水、各种类型的化学除冰液和防冰液。除冰液和防冰液通常为冻结温度远低于冰点的化学溶液，例如甲醇、乙醇、乙二醇、异丙基酒精或它们的混合溶液。Methanol, ethanol, ethylene glycol, isopropyl alcohol, or their mixed solutions

除冰/防冰液的**保持时间表**由**航空公司综合考虑** AEA、ISO 等相关国际标准和民航维修行业标准以及除冰/防冰液生产厂家的推荐来制订，经局方批准后实施。除冰/防冰液的预计保持时间从除冰/防冰操作的开始时刻计算（单步骤程序，亦称"一步法"）或从第二步操作开始时刻计算（双步骤程序，亦称"两步法"）。The effective duration: from the last time to spray the FPD
除冰/防冰液的**保持时间会因天气条件、使用方法和存放控制等条件的不同而改变** weather conditions, application methods, storage conditions, and other factors**。**应根据所使用的除冰/防冰液型号，选用相应保持时间表，根据外界大气温度、液体浓度和气象条件的对应关系得出相应保持时间。

One-phase process:
Hot fluid, limited effect

Two-phase process:
Heated Type I fluid, followed by cold Type II fluid
Anti-icing fluid should be used before the first step fluid freezes. Typically within 3 min

Deicing anti-icing near the end of the departure runway：
Reduce the time between deicing/anti-icing and takeoff
decrease the potential environmental impact(less FPD less repeats, More contained collection)

FPD（Freezing Point Depressant 防冰液分类： 【部分数字和 ATA1 可能有出入】

Ⅰ 型：80% ethylene glycol（乙二醇） mainly used for deicing

Ⅱ 型：50% maintain at least 45 min ; Vr> 85 kt

Ⅳ 型：50% （ thickening agent ） T>45min; longer than II

正常 Ⅱ 型和 Ⅳ 型防冰液用于 Vr≥110kt 的高速飞机，Ⅰ 型用于低速飞机。

FPD（Freezing Point Depressant）（防冰液）decrease the freeze point。

May have effect on FPD abilities: OAT, wind speed, aircraft skin temperature, FPD fluid temperature

Ethylene and diethylene glycol are moderately toxic

FPD are intended to provide ice protection on the ground only, would cause ENG performance degradation, cause surging and or compressor stalls.

Highly soluble in water, but ice is slow to absorb it, and ice to melt when in contact with it.
Snow on top of deicing or anti-icing fluids must be considered as adhering to aircraft
防冰液易溶于水，不易溶于冰，所以防冰液上的雪视为附着在飞机上

The purpose of diluting ethylene glycol deicing fluid with water in non-precipitation condition is to decrease the freezing point

At temperature less than -10, **undiluted propylene glycol** having a strength of about 88% glycol can lead to lift reductions of about 20%
-> **propylene glycol not recommend to use without dilution**

Type II *- **75/25 - 45min** - 01 Mar 2013*
Type II：指防冰液的类型（II 型防冰液，适用于起飞前在一定滑行时间内防止结冰，具有较好的流动性和抗冲刷性）；
75/25：表示防冰液中主要成分的比例（如 75% ethylene glycol 与 25% 水的混合，或其他有效成分与添加剂的配比）；
45min：指防冰液的保持时间;
01 Mar 2013：是生产日期、有效期起始日或相关标准的生效日期。

ISO I: Freeze Point Margin 防冰夜冰点裕度越大越好，>10°C
ISO II：**OAT<-7 时，7°C；OAT>-7 时 3°C**

Heated fluid increase deicing effect
For anti-icing: not heated fluid better

Don't spray the windows and windshield with heated FPD: Thermal shock(cracks)

Concentrated ISO II (no water)should not be used in: Pitot static, AOA indicator, ENG etc.

地面除冰防冰作业

① 机翼除冰应该从翼尖到翼根。
【题目：先完成机组从驾驶舱可见的位置，然后完成其它位置。这样先结冰的部分能被机组观察到】
②除冰时 APU 可以工作，发动机不可以工作，但是所有引气必须关闭。
ENG shut down, APU could turn on, But **switch off all air intakes**
③FPD 需采用 manufacturer 批准;
Use multiple aircraft deicing units for faster and more uniform management during precipitation
④正常防冰在起飞跑道附近：减少防冰与起飞之间的时间, decrease impact on environment
【题目：在 takeoff position 附近。错误选项 threshold，它不一定是 takeoff position】
⑤起飞前 PIC 负责检查积冰情况 preflight contamination check：visual inspection 和 physical inspection 的方法，如果有积冰，应 return for additional deice procedure。
PIC have the ultimate responsiblity
To check critical surface for clean airplane before takeoff:
- **Visual inspection**
- **Physical inspection:** tactile inspection of the ACFT on ground is valuable for detecting clear ice or other contaminants by touching the surface

Dry powdery snow or frost: blowing cold air, Nitrogen
Heavy wet snow or ice：heated FPD and water or mechanical means(扫帚，刷子)

飞机风挡排雨

飞机风挡排雨方式主要有：

风挡雨刷 Windshield Wipers

排雨液 Rain Repellent Fluids

厌水涂层 Hydrophobic Coatings

Pneumatic Rain Removal Systems

一、风挡雨刷排雨原理是由 electric/hydraulic motor 电机或液压马达驱动雨刷来回运动从而刷除风挡玻璃表面雨水。

二、排雨液排雨原理是将排雨液喷洒在玻璃表面与雨水混合形成透明薄膜，雨水在薄膜上不能形成水膜而成水珠，由气流吹除或雨刷刷除后，使风挡保持透明。

三、厌水涂层排雨原理是在风挡玻璃外表面形成一层不吸附雨水、对雨水有强排斥作用、使雨水呈珠状从玻璃上快速滚落的涂层。

飞机防火系统

失火种类及灭火剂

常见失火种类
1、A 类火： Flammable items such as paper, wood, fibers, rubber and plastic caught fire. 纸、木材、纤维、橡胶、塑料等易燃物品着火。
2、B 类火： Fuel oil, lubricating oil and other oils or flammable liquid/gases caught fire 燃油、滑油等油类或易燃气体着火。
3、C【记 Circuit】类火： A fire caused by a short circuit in an electrified appliance 通电电器短路引起的着火。
4、D 类火： Flammable metal catches fire 易燃金属着火。通常由 A、B 或 C 类火引起。

Types of fires and fire extinguishing agents
- **Water or water-based** ： suitable for Class A 。
- **Halocarbon** 卤代烃如溴氯二氟甲烷和溴三氟甲烷 suitable for Class A, B, C 。（喷完没有残留）（有毒性）
- **Inert cooling gas**： Carbon dioxide and nitrogen ， 适用于 A、B、C 类火的灭火。
- **Dry powder**： 如碳酸氢钠 NaHCO2 sodium bicarbonate， Particularly Class D， aircraft wheel brakes, aircraft cargo holds。(喷完一层灰。有一定腐蚀作用)

火警探测系统

火警探测系统通常由火警探测器、火警监控组件和火警信号装置 **Fire detectors, fire monitoring components and fire signal devices** 三个部分组成。
火警探测器主要是通过温度和烟雾来探测火情，
通常用**温度敏感探测器**监测发动机、APU、起落架舱和热空气管道的过热及火警，
用**烟雾探测器**监测货舱、电子设备舱和厕所的火警 Smoke detector: cargo compartment, avionics bay, lavatory
飞机上常用的火警探测器类型主要有： Thermal switch fire detectors, thermocouple fire detectors, gas-type fire detectors, photoelectric smoke detectors, ionization smoke detectors, etc.。
火警信号装置将监控组件的输出信号转换为目视和声响警告信息，包括主警告（红色火警灯及火警铃）和 ECAM 或 EICAS 上的文字警告信息。

飞机灭火系统

飞机灭火系统分为固定式灭火系统和手提式灭火器。

一、 **stationary fire extinguishing system**

是固定安装的专用灭火系统，由灭火瓶、喷射导管和灭火控制组件组成。主要用于 ENG 和 APU 灭火，某些飞机货舱和卫生间也采用固定灭火系统。机体上有红色指示膜片和黄色指示膜片分别表示灭火瓶是否发生了过热释放和正常释放。The red indicator diaphragm and the yellow indicator diaphragm respectively indicate whether the fire extinguishing cylinder has undergone overheat release and normal release.

飞机上的卫生间灭火一般自动进行，其它区域当出现火警，可通过驾驶舱内相应的灭火开关控制各区域的灭火，即驾驶员操纵灭火电门控制灭火瓶释放灭火剂，灭火管路将灭火剂导向灭火区喷出。

二、 **portable fire extinguisher**

用于飞机舱内灭火，

主要采用 **Halocarbon** 卤代烃灭火剂或 **Water Based**。

飞机应急设备

飞机应急出口/滑梯/救生筏

一、应急出口

现代运输机上可作为应急出口使用的包括旅客登机门 Passenger Entry Door、勤务门 Service Door，专用应急出口 Dedicated Emergency Exit，如翼上应急出口、驾驶舱侧窗户等。

二、滑梯 Emergency Slide

供在陆地着陆的飞机乘员在紧急情况下快速撤离飞机使用。

滑梯处于预位状态下打开舱门将导致滑梯放出并自动充气鼓胀。 Must be armed for taxi, takeoff, landing. **If not armed, aircraft cannot be pushed back**

三、救生筏 inflatable life raft

用于迫降水上的机上乘员撤离飞机使用。

有些飞机有专用的水上救生筏，有些飞机把充气正常的滑梯作为救生筏使用，称为滑梯/救生筏。

其它应急设备

飞机其它应急设备主要包括：紧急出口灯、救生绳、急救药箱和氧气瓶、扩音喇叭、紧急定位发射机、应急斧等。

1、紧急出口灯分布于整个客舱内部和外部 entire cabin inside and outside，为许可的应急出口路线提供照明。 Must be **armed/or on during taxi, takeoff, landing; be operable manually from the crew station and a point in PAX compartment**

The life line /rescue rope is used to help the crew members slide from the side window of the cockpit to the ground outside the aircraft.救生绳用于帮助机组成员从驾驶舱侧窗户滑到机外地面。

2、急救药箱和氧气瓶用于抢救急症病人或紧急情况下抢救乘客。

3、**megaphone** 扩音喇叭方便机组成员在紧急情况下指挥旅客快速撤离危险区。**机舱一前一后，一个就在后面**

4、紧急定位发射机（ELT）帮助营救人员查找降落在机场外的飞机位置。

5、应急斧 crash axe 用于舱门变形打不开时破门而出。A location inaccessible to PAX during normal ops

Flying over uninhabited terrain

- Pyrotechnic signaling 烟火信号；
- Automatic ELT；
- survival ELT