PART- 66
TRAINER MEDIAS

MODULE 15

GAS TURBINE ENGINE
B1 category

Lesson 03

INLET

Edition: 10 November, 2008

11 September, 2009

GAS TURBINE ENGINE

INLET

B1 category

TABLE OF CONTENTS

Edition: 10 November, 2008

11 September, 2009

COMPRESSOR INLET DUCTS

Location

- The air intake (inlet) is the part of the engine shroud which is upstream of the compressor.
- It is the first engine component crossed by the airstream before it enters the turbojet engine.
  - ✓ For reasons of efficiency, the air intake is located near the engine and in its axis. This architecture is the most widespread.
  - ✓ In certain cases, the air intake can be off-set above, below or on the sides of the longitudinal axis of the engine.

Table of contents
Study and Operation
Pedagogical guide

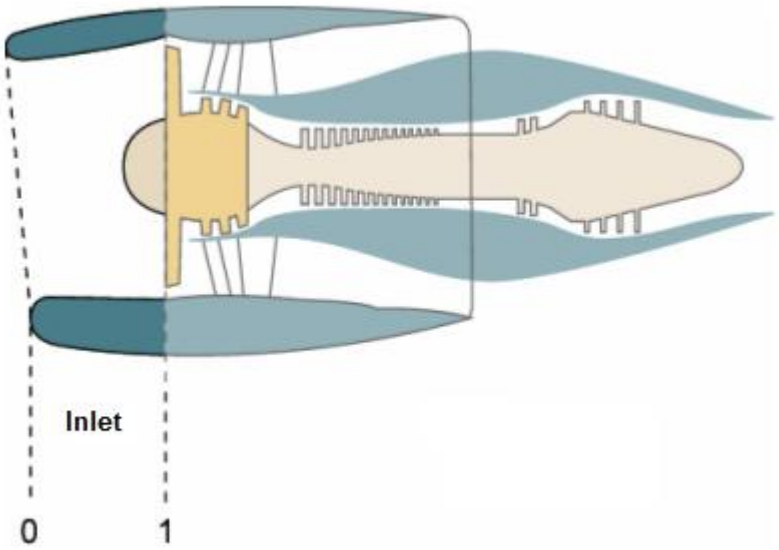
Edition: 10 November, 2008

11 September, 2009

Edition: 10 November, 2008

11 September, 2009

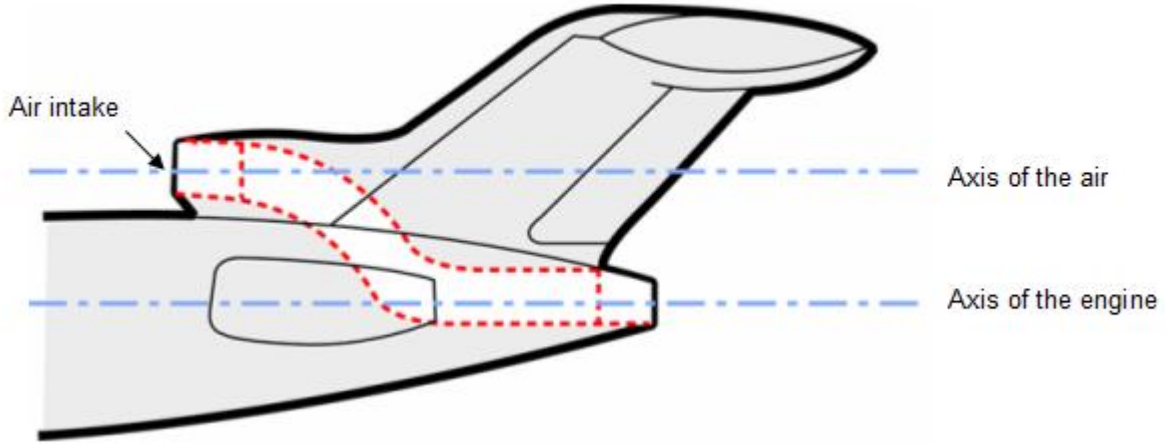
COMPRESSOR INLET DUCTS



Station 0: air intake leading edge
Station 1: junction between air intake and compressor case

Air intake (inlet): Location

COMPRESSOR INLET DUCTS



Central flow turbojet air intake

Table of contents

Study and Operation

Pedagogical guide

Edition: 10 November, 2008

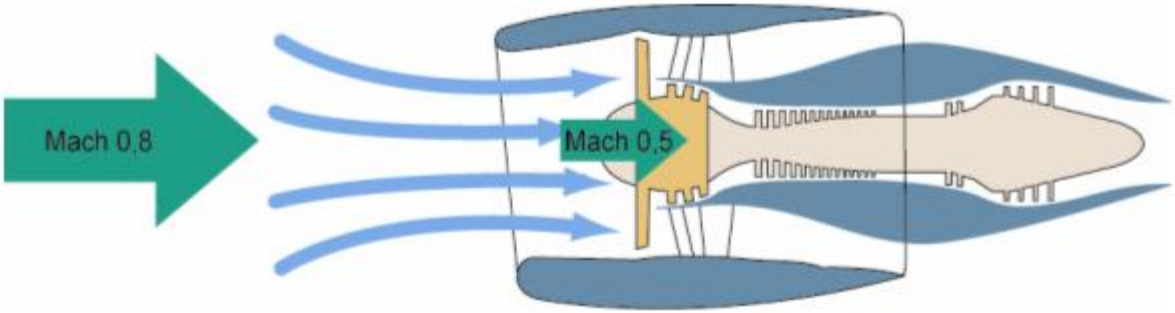
11 September, 2009

COMPRESSOR INLET DUCTS

Purpose

- The air intake function is:
  - ✓ to connect the external air stream with the compressor inlet.
  - ✓ to adjust the air stream to fit the compressor operation.
- The required Mach number in the compressor inlet is generally about 0.3 to 0.5 for a modern jet engine.
- The air intake, by its geometry, makes it possible to reduce the air flow speed (Mach 0.8 approximately for an aircraft in cruising flight) so as to supply the compressor with a maximum of efficiency.
- The air intake duct is generally of divergent shape type. Its walls have a surface condition which limits the turbulence inside and outside the duct.

COMPRESSOR INLET DUCTS



Compressor supply

Table of contents

Study and Operation

Pedagogical guide

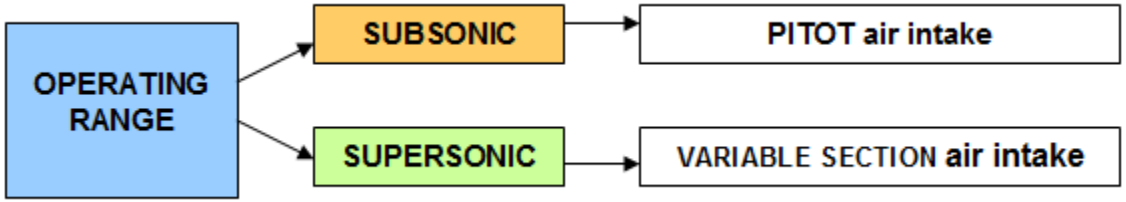
Edition: 10 November, 2008

11 September, 2009

COMPRESSOR INLET DUCTS

Various types of air intake

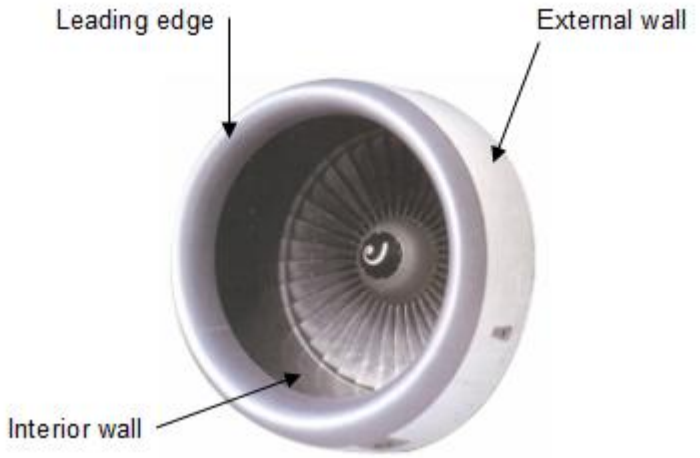
- Aircrafts operating in subsonic flight and those operating in subsonic and supersonic flight are distinguished between:
  - ✓ Pitot air intakes with divergent duct equip subsonic aircraft engines.
  - ✓ Variable area air intakes with convergent-divergent duct equip supersonic aircraft engines.



Edition: 10 November, 2008

11 September, 2009

COMPRESSOR INLET DUCTS



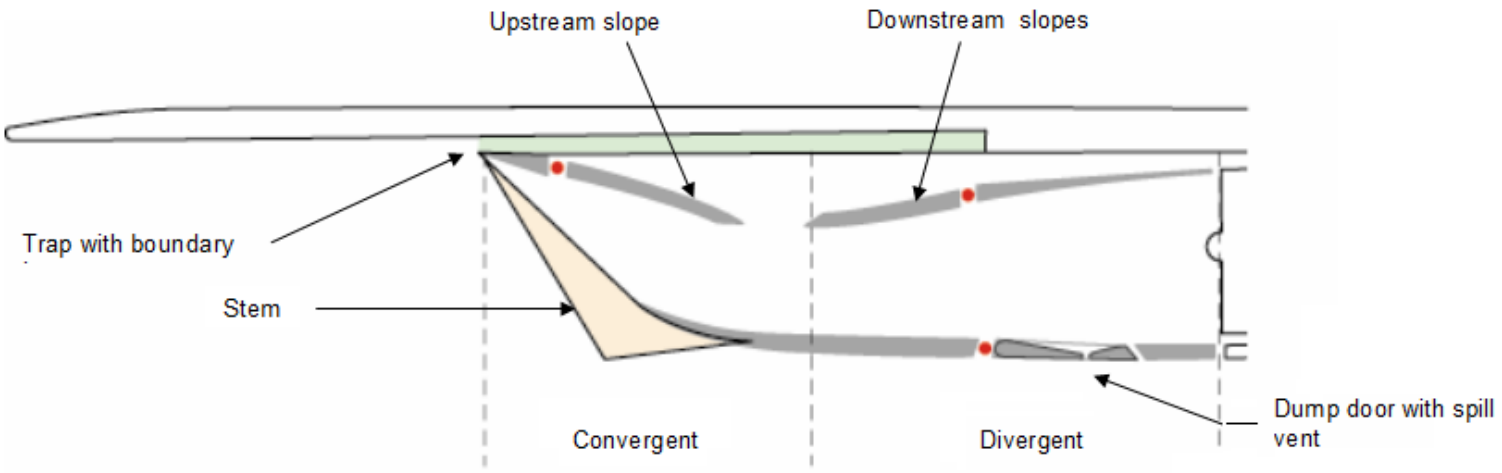
Pitot air intake of a Turbofan

Air intake shifted under the driving axis

Annular air intake

Pitot air intakes for turbo-propeller

COMPRESSOR INLET DUCTS



Variable section air intake: Concorde air intakes

Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Review (HUGONIOT theorem)

➢When a fluid runs out of a duct, the variation of its speed depends on the variation of the section and of the Mach number regime.

$$\frac{dS}{S} = \frac{dV}{V}(M^2 - 1)$$

$\frac{dS}{S}$ variation of section

$\frac{dV}{V}$ variation of speed

M: Mach number

Mach number	Convergent duct	Divergent duct
M < 1 (Subsonic)	Speed INCREASES	Speed DECREASES
M > 1 (Supersonic)	Speed DECREASES	Speed INCREASES

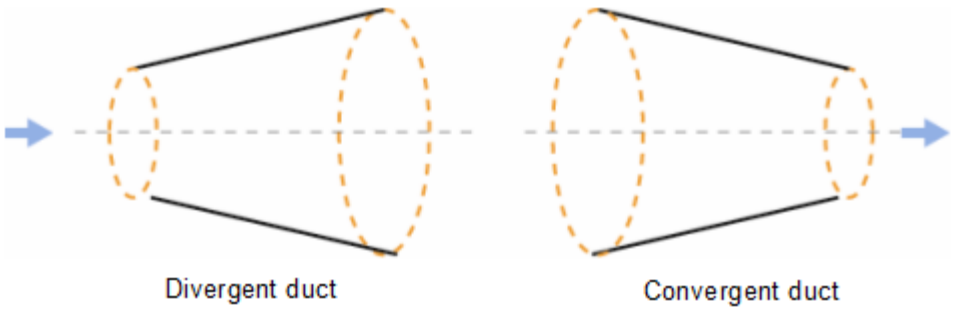


Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Pitot air intake

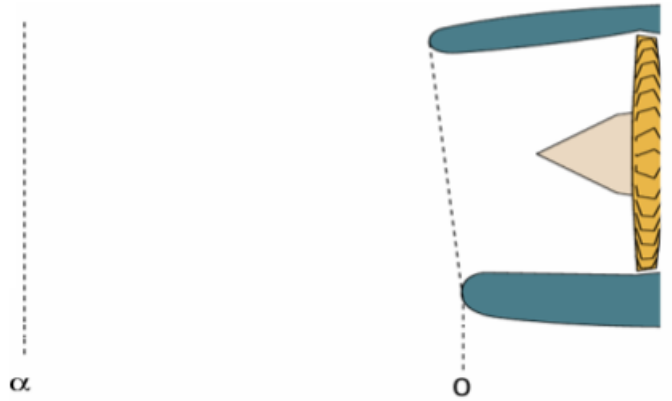
- Modern commercial aircrafts have a cruise speed close to Mach 0.8.
- Under conditions of normal operation, the air flow velocity in the compressor of a turbojet is about Mach 0.3.
- The **air flow velocity must be decreased** in the air intake.
- The theorem of Hugoniot shows that the **air intake duct must be of divergent shape**.

$$M < 1 \Rightarrow \textit{Decrease in speed} \Rightarrow \textit{divergent duct}$$

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Pitot air intake

➢ **Streamline flow behaviour.**



✓ Through the engine, the mass air flow remains constant, so:

$$Q = \rho.V.S = Cst$$

Q: mass flow rate
V: rate of flow
S: flow section
ρ: Air density

✓ α is a station far upstream from the air intake and 0 the station located at the leading edge. The mass flows associated with these stations can be different.

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Pitot air intake

➢ **Vα > V0**

- ✓ In this case, speed decreases between the stations α and 1.
- ✓ To satisfy the law of flow conservation, the section must increase.
- ✓ The air flow upstream from the air intake is thus divergent.

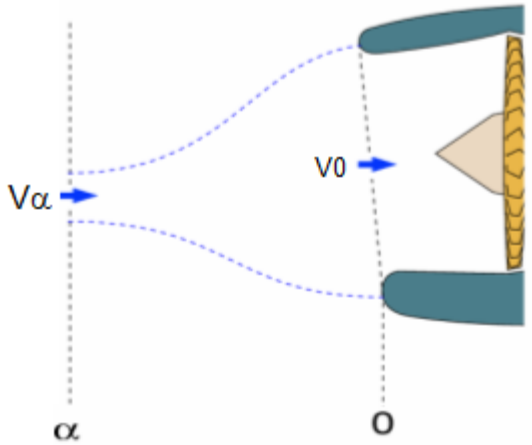


Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Pitot air intake

- $V\alpha = V0$
  - ✓ Speed upstream is equal to the speed of air intake at the leading edge.
  - ✓ For the flow to remain constant, the section must be constant.
  - ✓ The streamline flow upstream from the air intake then takes the shape of a cylinder.

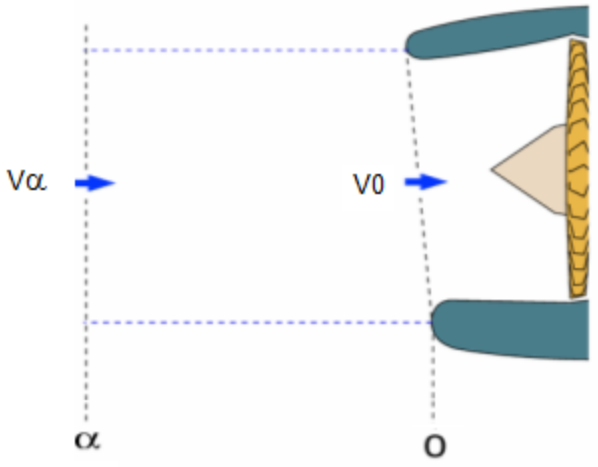


Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Pitot air intake

➢ **$V\alpha < V0$**

- ✓ Speed decreases between α and 1.
- ✓ To preserve the flow constant, the section must increase.
- ✓ The streamline flow upstream from the air intake is thus convergent.
- ✓ This configuration is that of the engine during run up, taxiing, take off, … when the aircraft speed is low

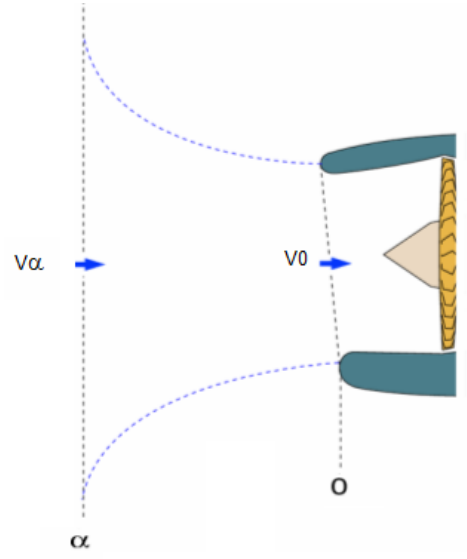


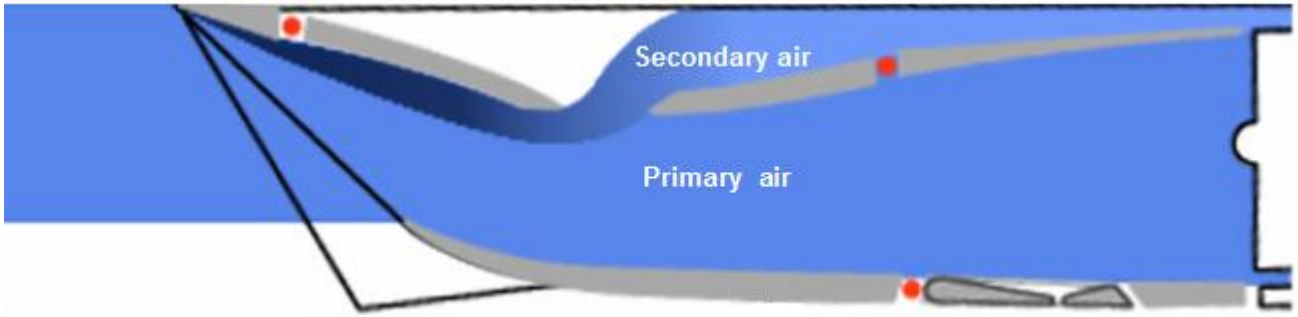
Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

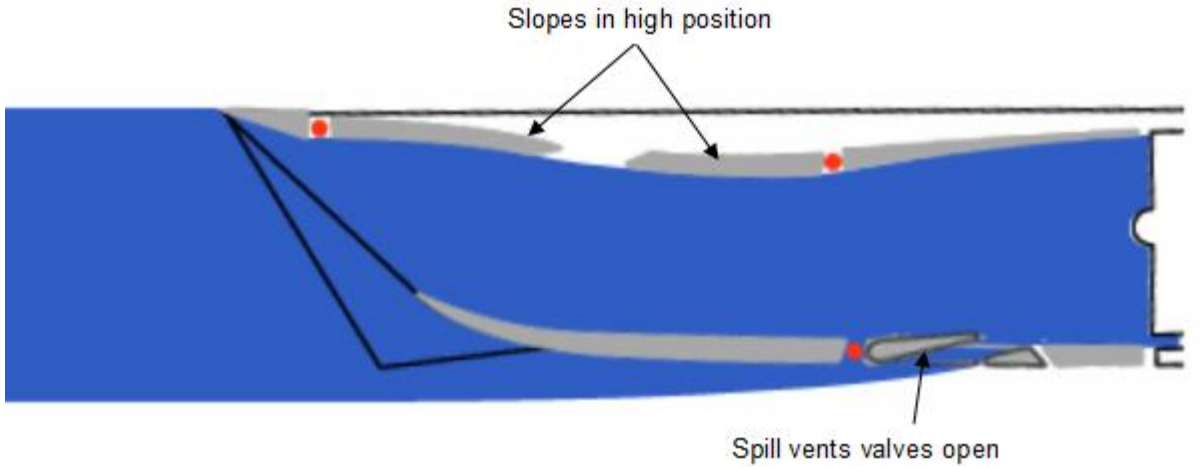
11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Variable Geometry Air Intake



Concorde Air Intake



At low speed, Air intake section must be maximum

Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Construction

- **Structure**
  - ✓ **Turbojet.**

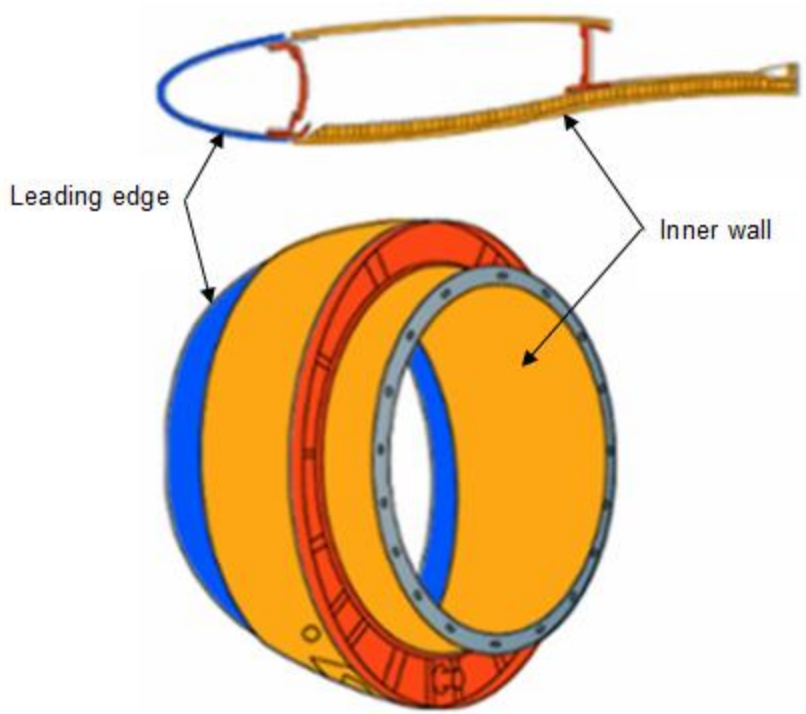


Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Construction

- Structure
  - ✓ **Turbo-propeller.**

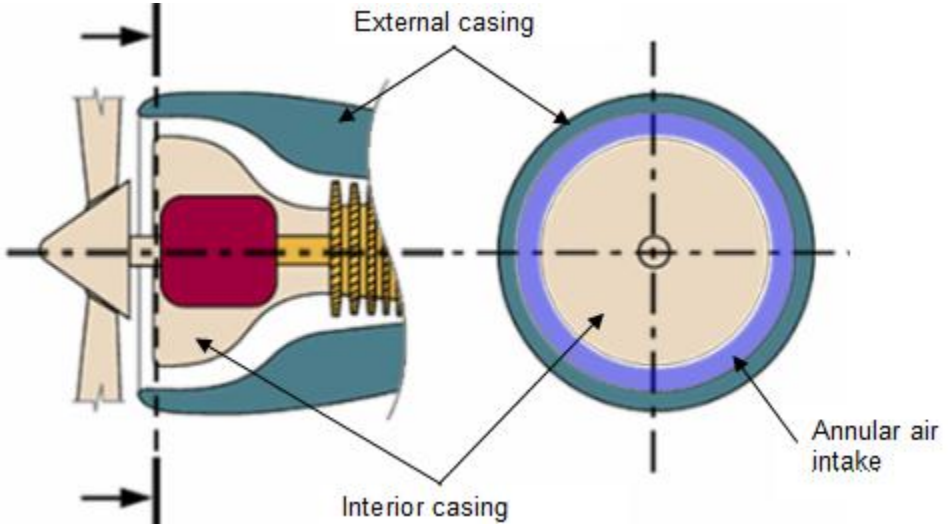


Table of contents
Study and Operation
Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

EFFECTS OF VARIOUS INLET CONFIGURATIONS

Construction

- **Assembly**

Table of contents

Study and Operation

Pedagogical guide

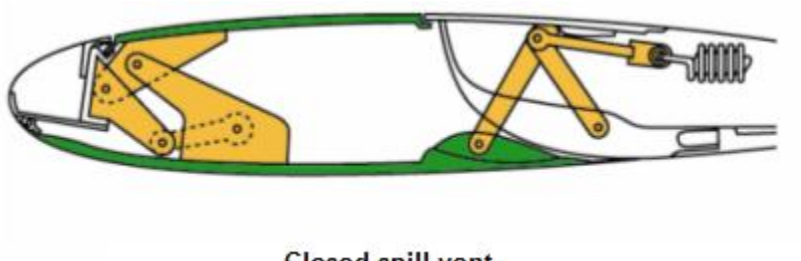
Edition: 10 November, 2008

11 September, 2009

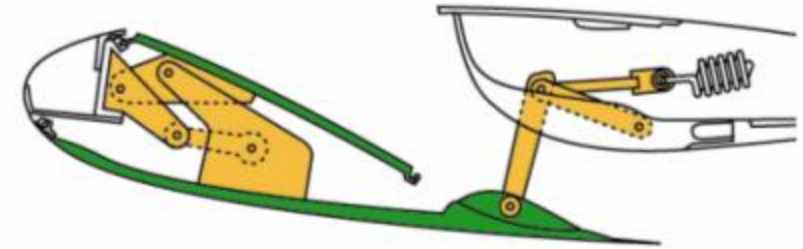
EFFECTS OF VARIOUS INLET CONFIGURATIONS

Construction

- **Spill vents**



Closed spill vent



Opened spill vent

Table of contents

Study and Operation

Pedagogical guide

Edition: 10 November, 2008

11 September, 2009

ICE PROTECTION

Introduction

- **Recall.**
  - ✓ When an aircraft flies at a level where the temperature is equal or lower than the freezing point, the droplet freezes and adheres to its surface (stagnation point).
  - ✓ All air intakes, from turbojets to turbopropellers, are subjected to the phenomenon of icing.
- **Hazards.**
  - ✓ The formation of ice is dangerous, because initially it modifies the quality of the area concerned, involving a loss of air intake efficiency.
  - ✓ Its evolution can then lead to the ingestion of pieces of ice by the compressor, making it possible to involve dysfunctions of the engine (vibrations, deterioration of the bladings, extinction).
  - ✓ To mitigate this problem, the manufacturers invented various devices of a preventive or curative nature. They are called respectively: **Anti-icing system** and **de-icing system.**

ICE PROTECTION

Various types of anti-icing or de-icing devices

- **Anti-iced air intake by warm air.**

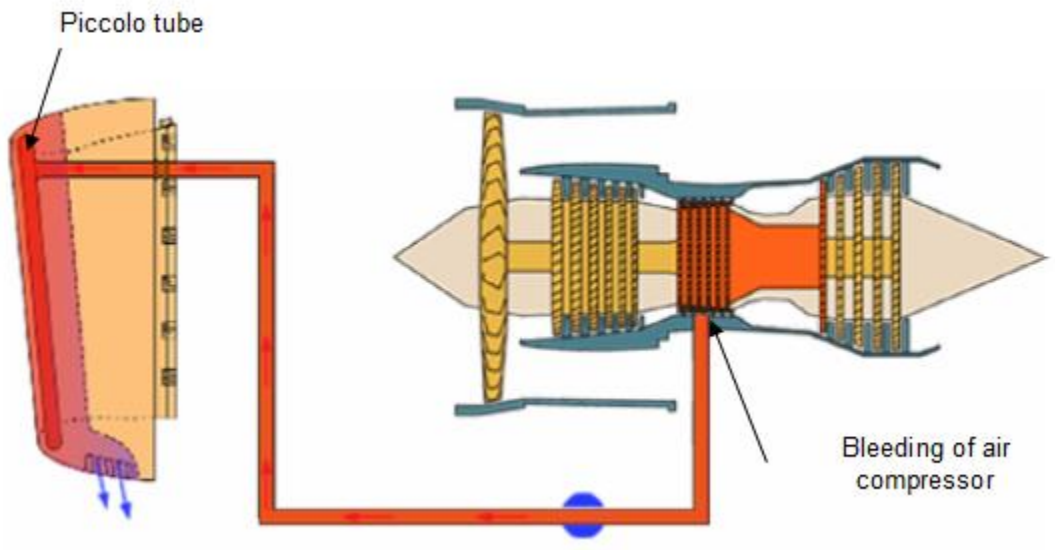


Table of contents
Study and Operation
Pedagogical guide

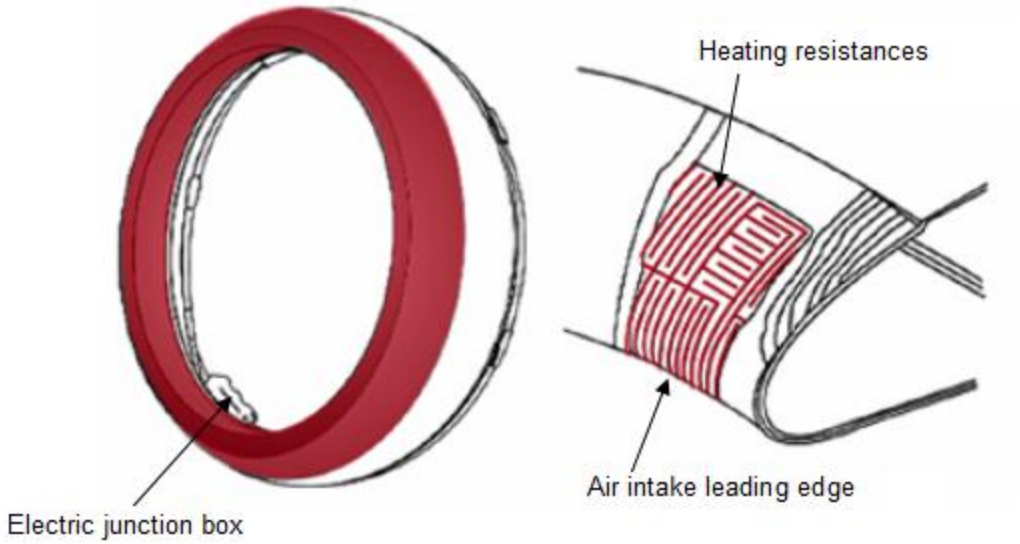
Edition: 10 November, 2008

11 September, 2009

ICE PROTECTION

Various types of anti-icing or de-icing devices

- **Anti-iced air intake by dielectric strength.**



Edition: 10 November, 2008

11 September, 2009

ICE PROTECTION

Various types of anti-icing or de-icing devices

- **De-iced air intake by de-icer boot.**