Mesures de pressions et températures en écoulements compressibles, isentropiques

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Pression statique

= p dans l'équation de d'Euler ou de Navier-Stokes

= pression mesurée par un observateur au repos par rapport au fluide

= pression mesurée par un observateur se déplaçant avec l'écoulement (dans une montgolfière par exemple)

Vent

Vitesse du ballon = vitesse du vent

Dans la pratique, comment mesurer la pression statique

$$p$$

dans un écoulement

(si on n'a pas de montgolfière ☺)

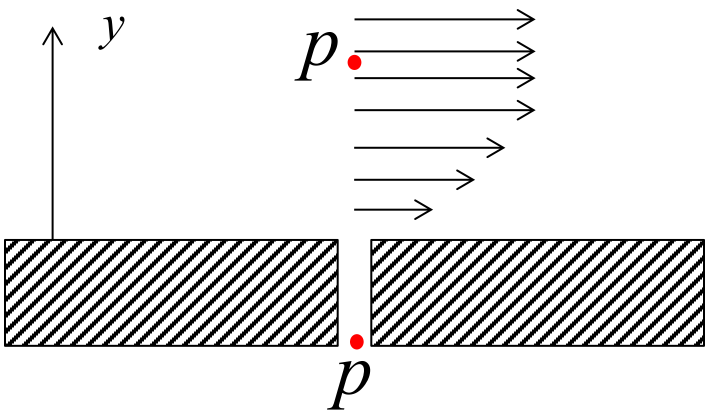
- On introduit une paroi <u>parallèle</u> à l'écoulement (et on néglige les variations de pression causées par la gravité dans une petite région proche de la paroi)

$$\frac{\partial u_x}{\partial t}+u_x\frac{\partial u_x}{\partial x}+u_y\frac{\partial u_x}{\partial y}+u_z\frac{\partial u_x}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u_x}{\partial x^2}+\frac{\partial^2 u_x}{\partial y^2}+\frac{\partial^2 u_x}{\partial z^2}\right)$$

$$\frac{\partial u_y}{\partial t}+u_x\frac{\partial u_y}{\partial x}+u_y\frac{\partial u_y}{\partial y}+u_z\frac{\partial u_y}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 u_y}{\partial x^2}+\frac{\partial^2 u_y}{\partial y^2}+\frac{\partial^2 u_y}{\partial z^2}\right)$$

$$\frac{\partial u_z}{\partial t}+u_x\frac{\partial u_z}{\partial x}+u_y\frac{\partial u_z}{\partial y}+u_z\frac{\partial u_z}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 u_z}{\partial x^2}+\frac{\partial^2 u_z}{\partial y^2}+\frac{\partial^2 u_z}{\partial z^2}\right)$$

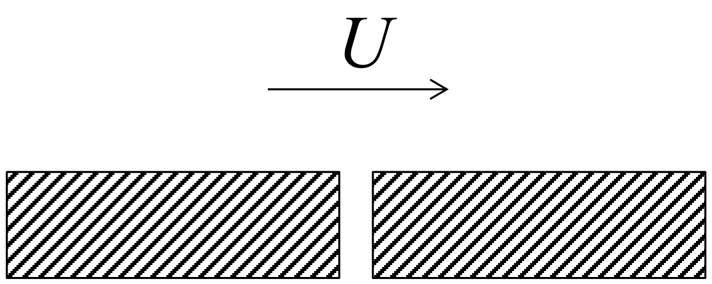
- Ecoulement parallèle à la paroi $\longrightarrow u_y=0$



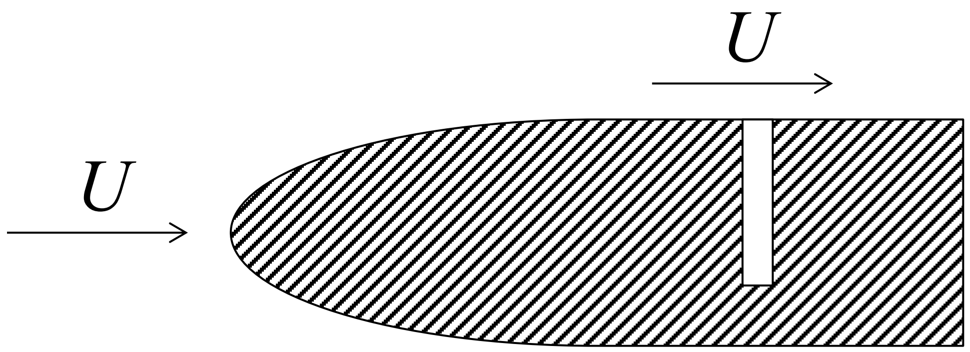
$$\frac{\partial p}{\partial y}=0$$

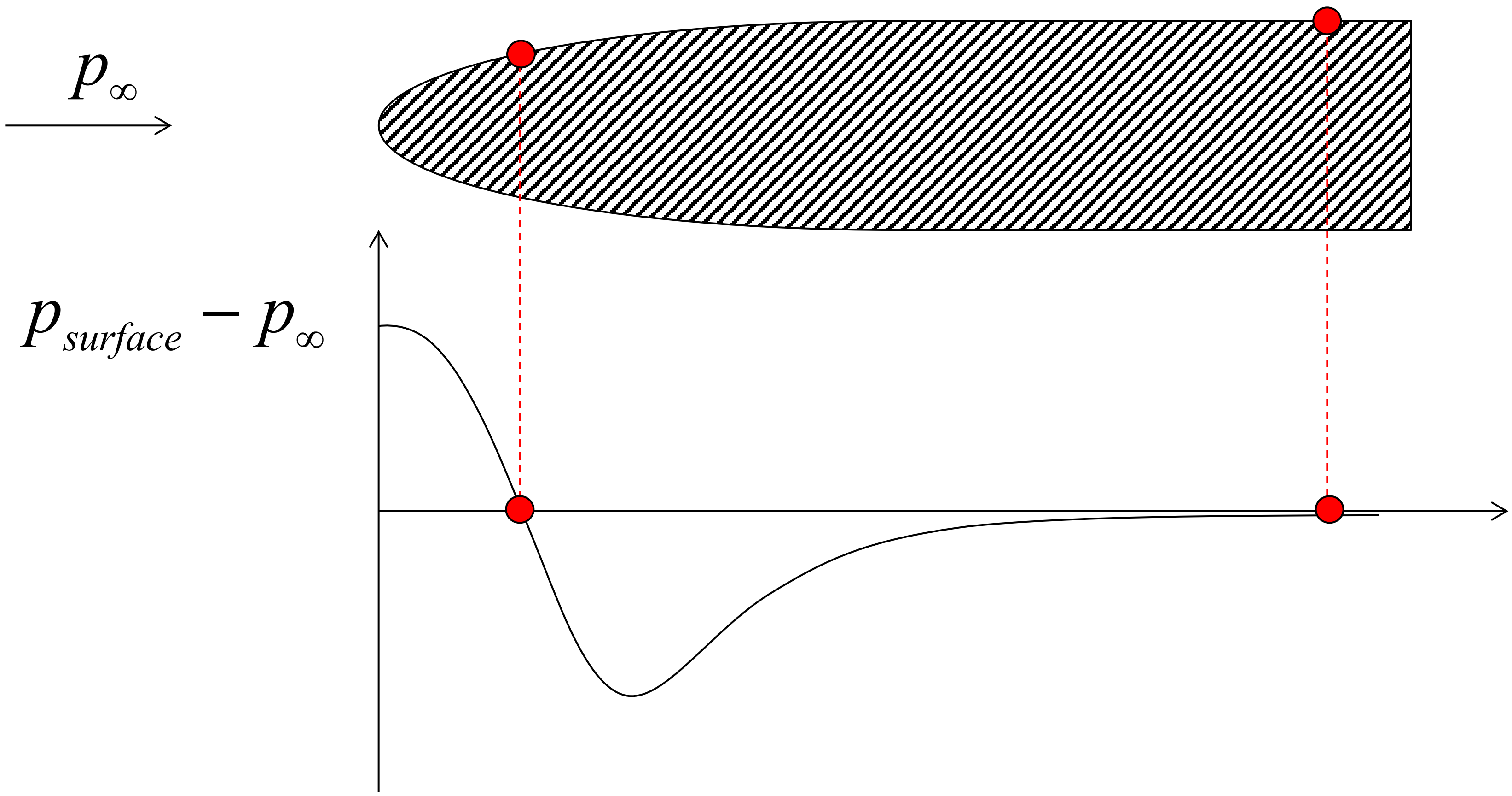
Un orifice normal à une paroi, parallèle à l'écoulement, permet de mesurer la pression statique dans l'écoulement à proximité de l'orifice

- Trou dans une paroi

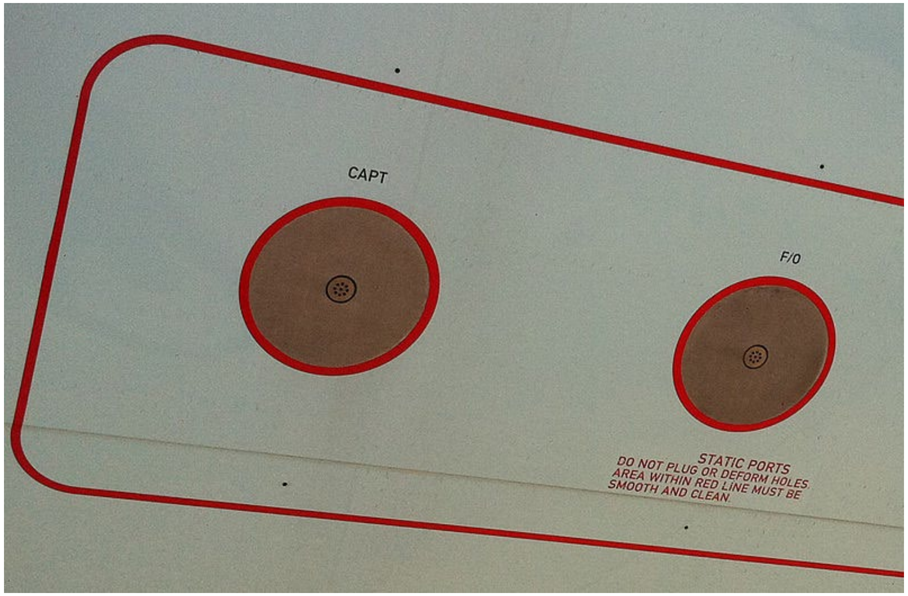


- Trou dans une sonde

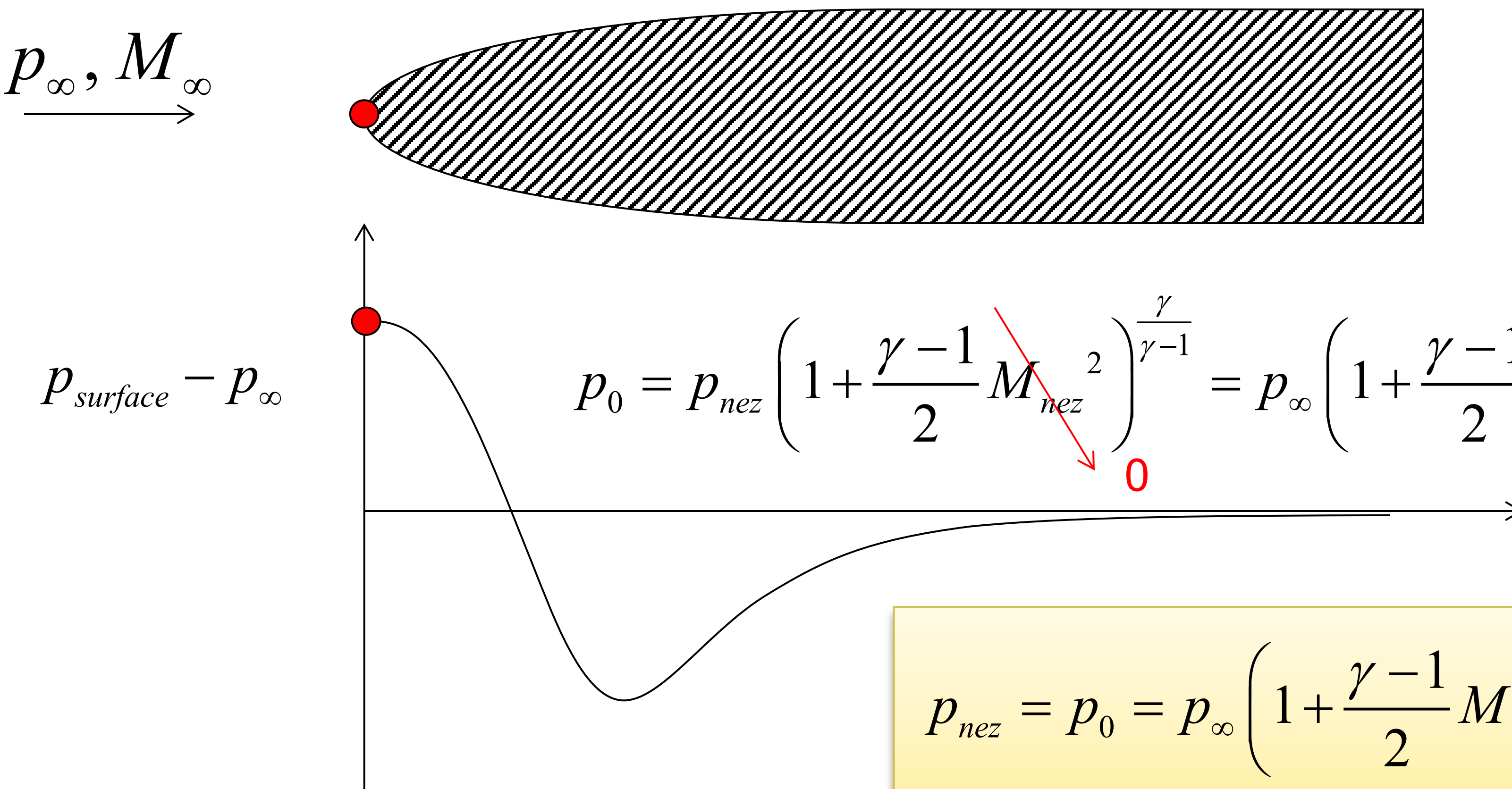



p_∞
$p_{surface} - p_\infty$


SKYTEAM
AIR FRANCE KLM

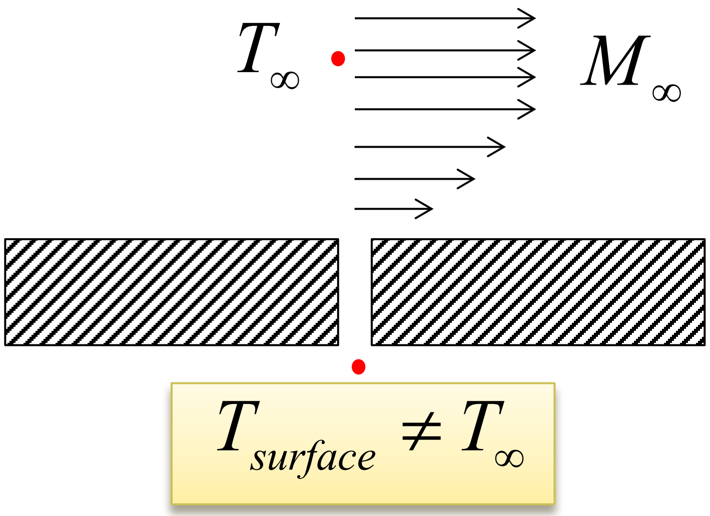

CAPT
F/O
STATIC PORTS
DO NOT PLUG OR DEFORM HOLES
AREA WITHIN RED LINE MUST BE
SMOOTH AND CLEAN.

➢ La pression d'arrêt est mesurable sur le «nez» d'une sonde, où l'écoulement est amené à l'**arrêt** d'une manière **isentrope**



$$p_0 = p_{nez}\left(1+\frac{\gamma-1}{2}M_{nez}^{\;2}\right)^{\frac{\gamma}{\gamma-1}} = p_\infty\left(1+\frac{\gamma-1}{2}M_\infty^{\;2}\right)^{\frac{\gamma}{\gamma-1}}$$

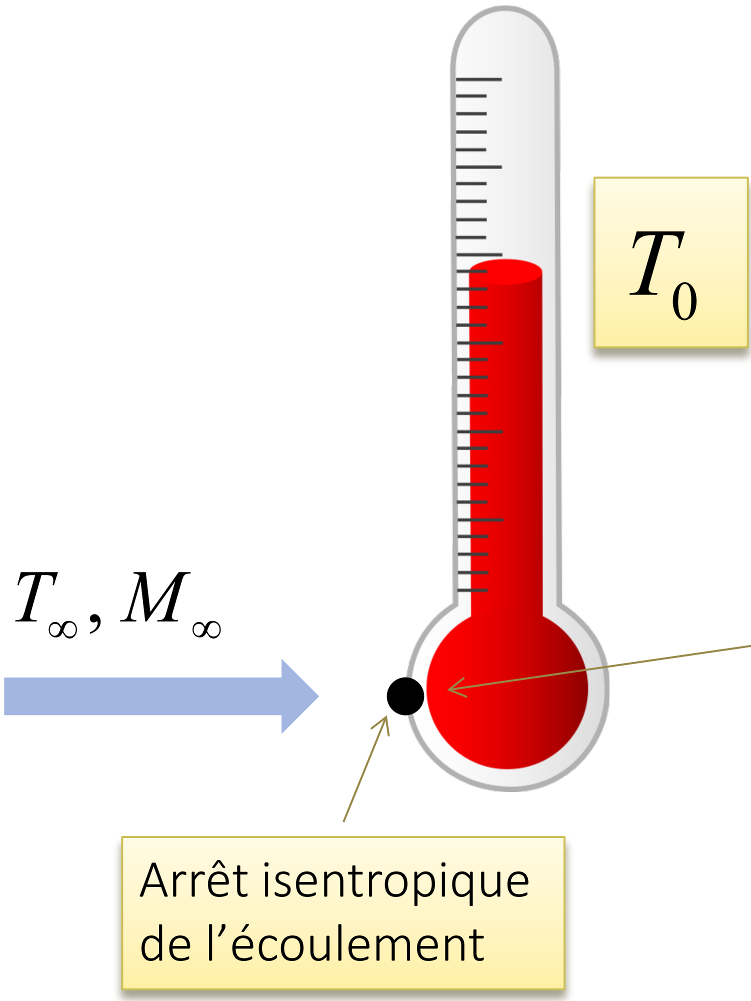
$$p_{nez} = p_0 = p_\infty\left(1+\frac{\gamma-1}{2}M_\infty^{\;2}\right)^{\frac{\gamma}{\gamma-1}}$$



Parenthèse:

Il s'avère que pour une paroi adiabatique et pour des fluides dont le nombre de Prandtl *P* est proche de 1, la température à la paroi est proche de la température totale:

$$T_{surface} = T_\infty \left(1 + \sqrt{P} \cdot \frac{\gamma - 1}{2} M_\infty^2 \right) \qquad P = \frac{\nu}{a} = \frac{\nu}{k / \left(\rho \cdot c_p \right)}$$



$$\frac{T_0}{T} = 1 + \frac{\gamma - 1}{2} M^2$$

Arrêt isentropique
de l'écoulement:

$$M = 0$$

$$\Rightarrow T = T_0 = T_\infty \left(1 + \frac{\gamma - 1}{2} M_\infty^2 \right)$$

Principe de mesures en écoulement isentropique

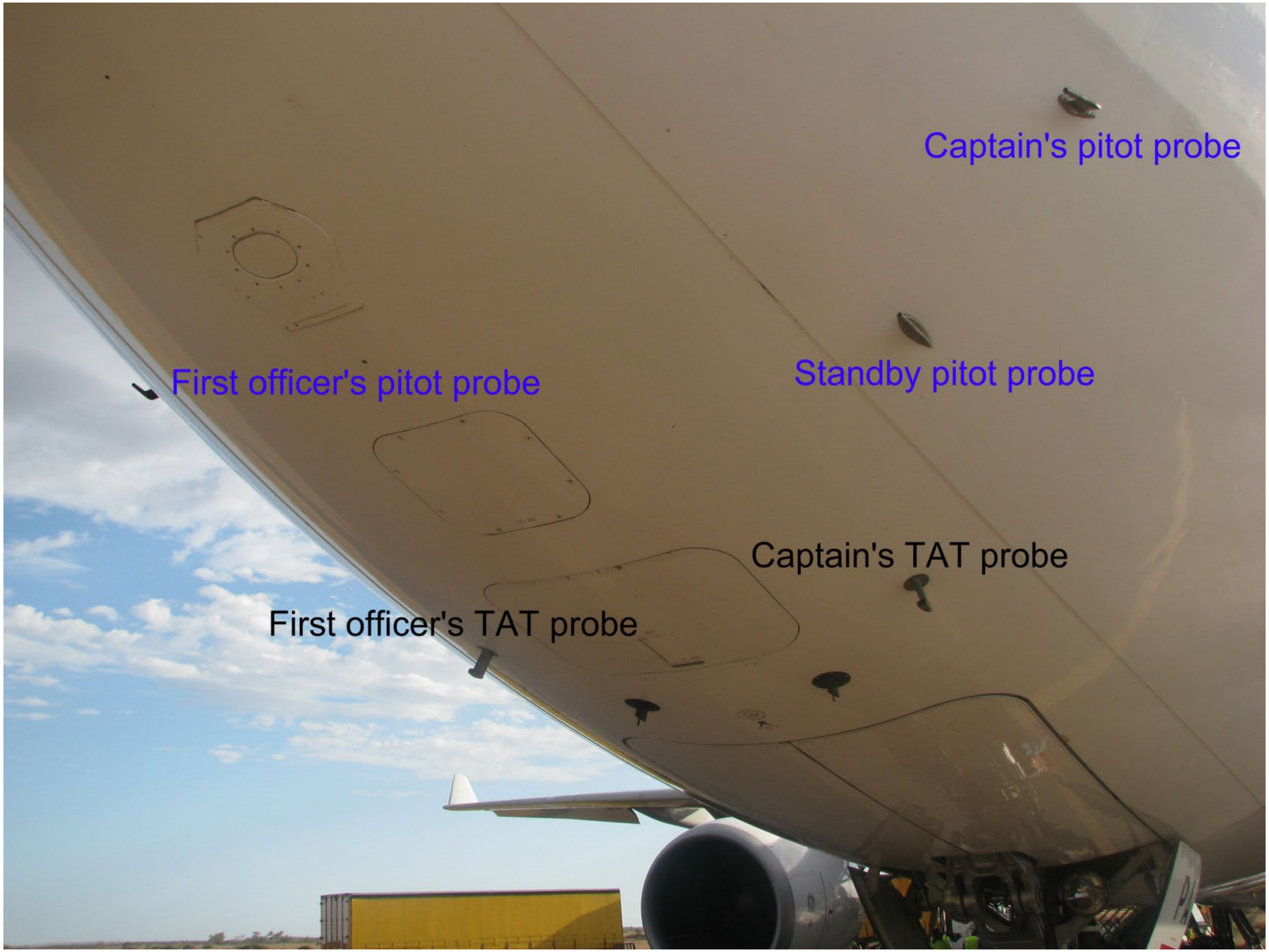
- $$\frac{p_0}{p} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma-1}}$$ → $$M = \sqrt{\frac{2}{\gamma - 1}\left[\left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

- $$\frac{T_0}{T} = \left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}$$ → $$T = T_0\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}$$

- $$u = M\sqrt{\gamma r T}$$ → $$u = \sqrt{\frac{2\gamma r T_0}{\gamma - 1}\left[1 - \left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right]} = \sqrt{2 c_p T_0\left[1 - \left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

- $$\frac{1}{2}\rho u^2 = \frac{\gamma p}{2} M^2$$ → $$\frac{1}{2}\rho u^2 = \frac{\gamma p}{\gamma - 1}\left[\left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

Pitot et Total Air Temperature probe (TAT)



Pitot

EPFL

GOODRICH

SENSOR SYSTEMS

AIRBUS A318/319/320/321/330/340
MODEL 0851HL
PITOT PROBE

- Certified on A318/319/320/321/330/340 aircraft through Type Certificate Amendment with Airbus
- Interchangeable and Intermixable with existing Rosemount Pitot Probe
- Enhanced de-icing performance

INTRODUCTION

Sensor Systems, Goodrich Corporation has introduced the Model 0851HL Pitot Probe for Airbus A318/319/320/321/330/340 aircraft. This pitot was developed by Sensor Systems and Airbus to enhance de-icing performance of the current Model 0851GR Pitot Probe, while still maintaining the proven reliability of the existing probe.

The Model 0851HL Pitot Probe complies with the requirements of Airworthiness Directives 2001-353(B) and 2001-354(B) issued by the French DGAC in August 2001.

FEATURES OF MODEL 0851HL

Improved Design Features

In order to meet the Airbus extreme icing conditions specification, the Model 0851HL Pitot Probe has been designed as a replacement for the Model 0851GR. These performance enhancements were accomplished by increasing the power density in the tip region by 35% over the existing probe, and incorporating the high power density in the drain hole region to ensure proper drainage during severe icing conditions.

Form and Function Interchangeability

Since the Model 0851HL Pitot Probe has been designed to replace the existing sensor, it may be installed on any Airbus A318/319/320/321/330/340 airplane with no modifications to the aircraft required. The Model 0851HL Pitot Probe is certified fully interchangeable and intermixable with the current Rosemount Model 0851GR probe. The 0851HL pitot is also functionally interchangeable with existing pitot probes certified on A318/319/320/321/330/340 manufactured by Goodrich competitors.

Proven Performance & Reliability

The Model 0851HL Pitot Probe is based on over 40 years of experience designing and manufacturing Air Data Probes. Each pitot probe is engineered to meet the exact requirements of its specific application, and its performance and repeatability are verified by the calibration of each production unit. To ensure that pressure measurement is not degraded over the service life, Sensor Systems continues to develop robust pitot inlets that are less susceptible to damage and erosion. Extensive wind tunnel and flight evaluation data enables Sensor Systems to fully understand the effects of wear on aerodynamic performance and minimize those effects in their probe designs.

SPECIFICATIONS

Heater Power Required:	115VAC
Icing Performance:	Qualified to FAA TSO-C16 and AS 393
Pressure Connection:	Three pin quick-disconnect air fitting, Hydraflow P/N IQMI-3-54A or equivalent
Electrical Connector:	Three pin connector per MIL-C-5015

AEROSPACE DIVISION

THALES

>> AIRBUS SENSORS AND PROBES
UNRIVALLED EXPERIENCE

PITOT PROBES

Thales developed a brand-new range of Pitot probes for all Airbus aircraft families, featuring an innovative design with enhanced performance, especially in adverse weather conditions such as heavy rain, large droplets or frost/severe icing.

An efficient electrical heating system and aerodynamic shape limit the risk of icing.

At the same time, a new water trap and drainage system prevents water from accumulating in the Pitot tube. These design features ensure highly reliable airspeed data and a stability of airspeed information.

Long operating experience on Airbus jetliners provides further proof of these products efficiency.

By taking advantage of this outstanding reliability and performance, along with Pitot probe commonality across the A320 and A330/A340 families, aircraft manufacturers and airlines alike enjoy considerable operational, technical and economic benefits.

TECHNICAL DATA

P/N C16195BA	
APPLICATIONS	• Airbus single-aisle and long-range families
POWER SUPPLY	• 115 VAC/400 Hz
ELECTRICAL CHARACTERISTICS FULLY COMPATIBLE WITH AIRCRAFT SYSTEMS	
INTERCHAGEABLE AND MIXABLE WITH PREVIOUS P/N C16195AA	
WEIGHT	• 500 g. (max.)

TAT
Total Air Temperature

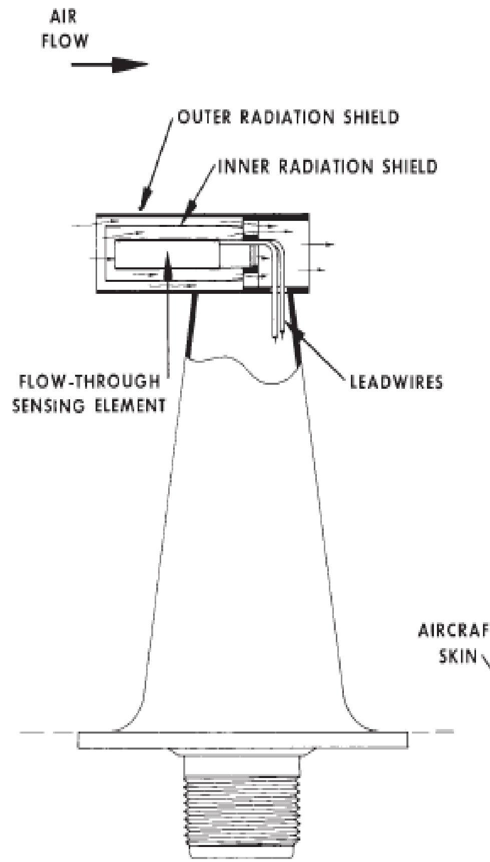


Figure 2: Model 101 Type (Non-deiced)

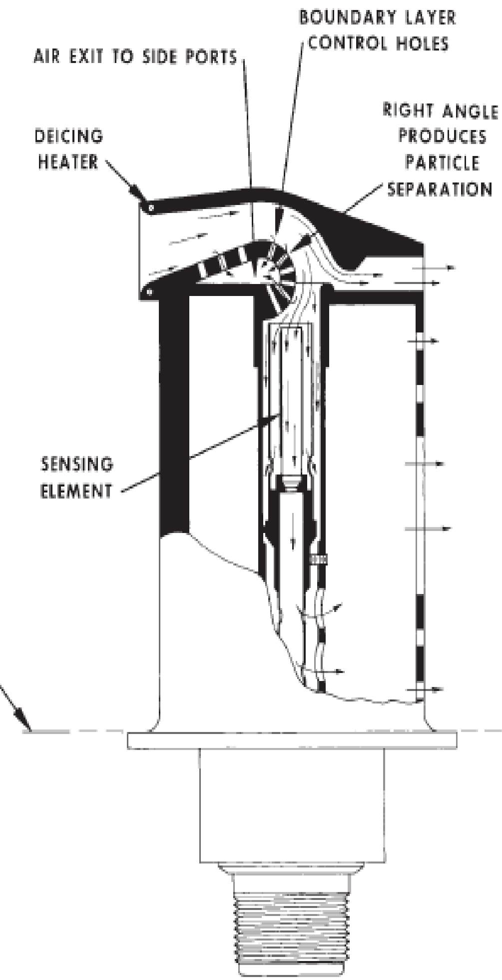


Figure 3: Model 102 Type (Deiced) (configuration "a")

NASA DC-8