Performance

ATR TRAINING & FLIGHT OPERATIONS SERVICES

For ultra flight safety & operational efficiency

Edition 2009

An Alenia Aeronautica and EADS joint venture

Important notice

This guide is intended to provide general information regarding Performance.
In no case it is intended to replace the operational and flight manuals for ATR aircraft.
In all events, the information contained in the Aircraft Flight Manual shall prevail over the content of this guide.

Introduction

The safety of air transportation is a joint effort, with Government regulations on one hand, and manufacturers and airlines enactment on the other hand. The State is responsible for the supervision of civil aviation, to ensure that high safety standards are maintained throughout aircraft operations. Their primary means of enforcement is via the establishment of written regulations.

Every country has its own regulations, but the international aspect of air transportation takes into account the worldwide application of common rules. The **International Civil Aviation Organization** (ICAO) was therefore created in 1948, to provide a supranational council, to assist with an international definition of minimum recommended standards. The Chicago Convention was signed on December 7, 1944, and has become the legal foundation for civil aviation worldwide. Those standards are then integrated into national regulations. In this guide, only the **European Aviation Safety Agency** (EASA) and the **US Federal Aviation Administration** (FAA) regulations are developed.

The regulations concern all activities; aircraft design and certification, maintenance activities, licensing… Regarding more specifically aircraft initial **airworthiness** and **air operations**, the regulations to be applied are the following:

ICAO (Chicago convention)	
Airworthiness Annex 8	**Operations** Annex 6

↙ ↘

EASA	
Airworthiness IR 21 (CS 25)	**Operations** IR-OPS

FAA	
Airworthiness FAR[1] 25	**Operations** FAR 121

[1] Federal Aviation Regulations

Airworthiness and operations regulations

Airworthiness

This relates to all matters linked to the aircraft design and demonstrated by the manufacturer for the aircraft certification. The operational reference manual is the ATR produced **Aircraft Flight Manual** (AFM), specific for each aircraft, produced by ATR, and certified by the Authorities.

Air operations

This relates to all matters linked to operating rules and demonstrated by every airline in order to obtain its Air Operators Certificate (AOC). The reference manual is the **Operations Manual** (OM) produced by the airline. To help airlines with this task, the **Flight Crew Operating Manual** (FCOM) published by ATR, is of great assistance in the process of producing part B - *Aeroplane Operating Matters* of the OM.

European Regulation

EASA, created in 2003, took directly over the functions of **aircraft Airworthiness** previously performed by the Joint Aviation Authorities (JAA), with the publication of the Implementing Rules **IR 21**. This is the applicable regulation for initial airworthiness, while **CS 25**, part of in them, is the certification basis to which a manufacturer of large aircraft must demonstrate compliance.

EASA is working on the Implementing Rules for **Air Operations**, **IR-OPS** planned not latter than 2012. Meanwhile, the applicable regulation for Air Operations is **EU-OPS** published by the European Commission in 2008, a temporary text pending the EASA publication. While EU-OPS only concerns commercial air transport, the IR-OPS will cover any type of operations.

This **guide** is designed to address three different aspects of **aircraft performance**:

- The **physical aspect**, with numerous reminders on flight mechanics, aerodynamics, altimetry and influence of external parameters on aircraft performance.

- The **regulatory aspect**, with the description of the main **EASA and FAA** certification and operating rules, leading to the establishment of limitations.

- The **operational aspect**, with the description of aircraft navigation systems, operational procedures and pilot's actions.

This guide is the revised version of and replaces our previous 'Performance' publication dated 2004. It incorporates features of the ATR-600 aircraft type due for entry into service by 2011.

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A. General

1. The international standard atmosphere (ISA)

1.1. Standard Atmosphere Modeling

The atmosphere is a gaseous envelope surrounding the earth. Its characteristics are different throughout the world. For this reason, it is necessary to adopt an average set of conditions called the **International Standard Atmosphere** (ISA).

1.1.1. Temperature Modeling

The following diagram illustrates the temperature variations in the standard atmosphere:

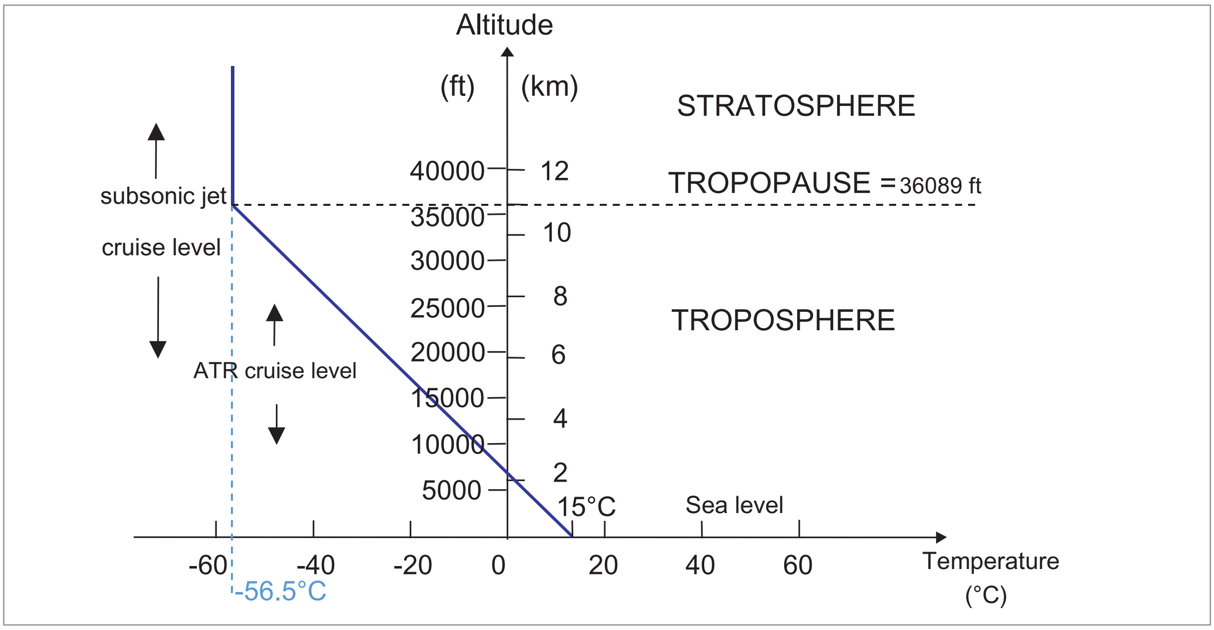

Figure A1: *ISA temperature model*

The international reference is based on the following standard assumptions at sea level:

- A temperature of **15°C**
- A pressure of **1013.25 hPa (29.92 in Hg)**
- An air density of 1.225 kg/m³.

Temperature decreases with altitude at a constant rate of –6.5°C/1000m or –1.98°C/1000ft up to the tropopause. The standard tropopause altitude is 11,000 m or 36,089 feet. From the tropopause upward, the temperature remains at a constant value of –56.5°C. The air, which is considered as a perfect gas in the ISA model, presents the following characteristics:

- **At Mean Sea Level (MSL):**

$$\text{ISA temperature} = T_0 = +15°C = 288.15\ K$$

(0° C = 273.15 K)

- **Above MSL and below the tropopause (36,089 feet):**

$$\text{ISA temperature (°C)} = T_0 - 1.98 \times \text{Alt(feet)}/1000$$

For a quick determination of the standard temperature at a given altitude, the following approximate formula can be used:

$$\text{ISA temperature (°C)} = 15 - 2 \times \text{Alt(feet)}/1000$$

- **Above the tropopause (36,089 feet):**

$$\text{ISA temperature} = -56.5°\text{C} = 216.65\ \text{K}$$

This ISA model is used as a reference to compare real atmospheric conditions and the corresponding engine/aircraft performance. The atmospheric conditions will therefore be expressed as **ISA ± ΔISA** at a given flight level.

Example:
Let us consider a flight in the following conditions:
Altitude = 33,000 feet
Actual Temperature = –41°C
The standard temperature at 33,000 feet is 15 – (2 × 33) = –51°C, whereas the actual temperature is –41°C, i.e. 10°C above the standard.
Conclusion: The flight is operated in **ISA + 10** conditions.

1.1.2. Pressure Modeling

To calculate the standard pressure **P** at a given altitude, the following assumptions are made:
- Temperature is standard, versus altitude.
- Air is a perfect gas.

The altitude obtained from the measurement of the pressure is called **Pressure Altitude** (PA), and a standard (ISA) table can be set up.

Pressure (hPa)	Pressure Altitude (PA)		FL= PA/100
	(feet)	(meters)	
360	26000	7925	260
500	18287	5574	180
850	4813	1467	50
1013	0	0	0

Table A1: *Example of Tabulated Pressure Altitude Value (generally used with weather charts)*

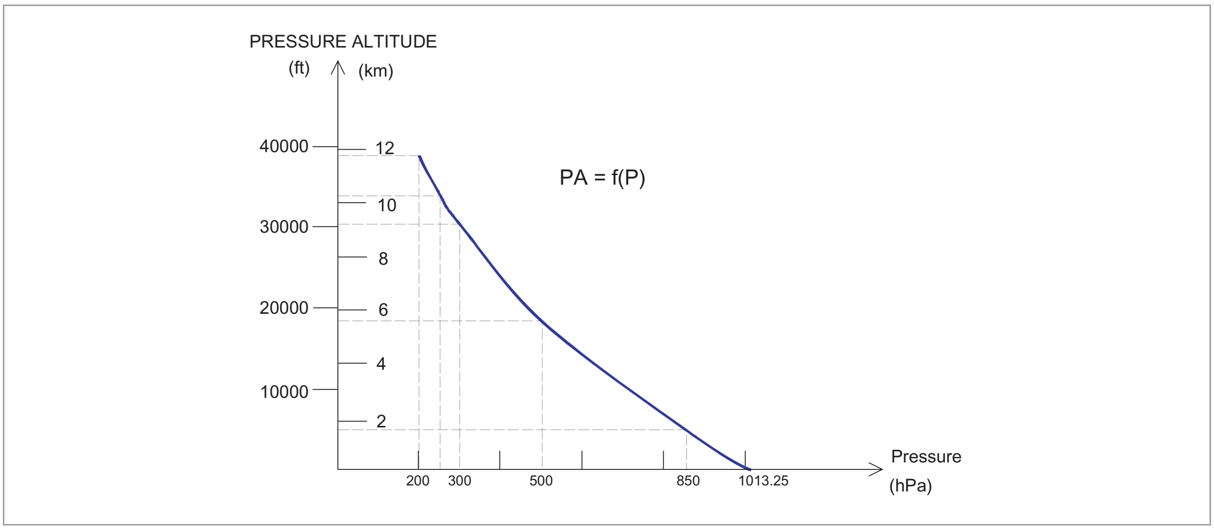

Figure A2: *Pressure Altitude versus Pressure*

A. General

Assuming a volume of air in static equilibrium, the aerostatics equation gives:

$$dP = -\rho g dh$$

With ρ = *air density*
g = *gravity acceleration*
dh = *height of the volume unit*
dP = *pressure variation on dh*

The perfect gas equation gives:

$$\frac{P}{\rho} = RT$$

With R = *universal gas constant*

Consequently:

- **At Mean Sea Level (MSL):**

$$P_0 = 1013.25 \text{ hPa}$$

- **Above MSL and below the tropopause (36,089 feet):**

$$P = P_0 \left(1 - \frac{\alpha}{T_0} h\right)^{\frac{g_0}{\alpha R}}$$

With P_0 = *1013.25 hPa (standard pressure at sea level)*
T_0 = *288 .15 K (standard temperature at sea level)*
α = *0.0065 °C/m (standard temperature gradient)*
g_0 = *9.80665 m/s² (gravity acceleration at sea level)*
R = *287.053 J/kg/K*
h = *Altitude (m)*

NOTE: For low altitudes, a reduction of **1 hPa** in the pressure approximately corresponds to a Pressure Altitude increase of **28 feet**.

- **Above the tropopause (36,089 feet):**

$$P = P_1 e^{\frac{-g_0 (h-h_1)}{RT_1}}$$

With P_1 = *226.32 hPa (standard pressure at 11,000 m)*
T_1 = *216.65 K (standard temperature at 11,000 m)*
h_1 = *11,000 m*
g_0 = *9.80665 m/s²*
R = *287.053 J/kg/K*
h = *Altitude (m)*

1.1.3. Density Modeling

To calculate the standard density ρ at a given altitude, the air is assumed to be a perfect gas. Therefore, at a given altitude, the standard density ρ (kg/m³) can be obtained as follows:

$$\rho = \frac{P}{RT}$$

With R = *universal gas constant (287.053 J/kg/K)*
P in Pascal
T in Kelvin

- **At Mean Sea Level (MSL):**

$$\rho_0 = 1.225 \text{ kg/m}^3$$

1.2. International Standard Atmosphere (ISA) Table

The International Standard Atmosphere parameters (temperature, pressure, and density) can be provided as a function of the altitude under a tabulated form.

ALTITUDE (Feet)	TEMP. (°C)	PRESSURE			PRESSURE RATIO δ = P/Po	DENSITY $\sigma = \rho/\rho o$	Speed of sound (kt)	ALTITUDE (meters)
		hPa	PSI	In.Hg				
25 000	- 34.5	376	5.45	11.10	0.3711	0.4481	602	7 620
24 000	- 32.5	393	5.70	11.60	0.3876	0.4642	604	7 315
23 000	- 30.6	410	5.95	12.11	0.4046	0.4806	607	7 010
22 000	- 28.6	428	6.21	12.64	0.4223	0.4976	609	6 706
21 000	- 26.6	446	6.47	13.18	0.4406	0.5150	611	6 401
20 000	- 24.6	466	6.75	13.75	0.4595	0.5328	614	6 096
19 000	- 22.6	485	7.04	14.34	0.4791	0.5511	616	5 791
18 000	- 20.7	506	7.34	14.94	0.4994	0.5699	619	5 406
17 000	- 18.7	527	7.65	15.57	0.5203	0.5892	621	5 182
16 000	- 16.7	549	7.97	16.22	0.5420	0.6090	624	4 877
15 000	- 14.7	572	8.29	16.89	0.5643	0.6292	626	4 572
14 000	- 12.7	595	8.63	17.58	0.5875	0.6500	628	4 267
13 000	- 10.8	619	8.99	18.29	0.6113	0.6713	631	3 962
12 000	- 8.8	644	9.35	19.03	0.6360	0.6932	633	3 658
11 000	- 6.8	670	9.72	19.79	0.6614	0.7156	636	3 353
10 000	- 4.8	697	10.10	20.58	0.6877	0.7385	638	3 048
9 000	- 2.8	724	10.51	21.39	0.7148	0.7620	640	2 743
8 000	- 0.8	753	10.92	22.22	0.7428	0.7860	643	2 438
7 000	+ 1.1	782	11.34	23.09	0.7716	0.8106	645	2 134
6 000	+ 3.1	812	11.78	23.98	0.8014	0.8359	647	1 829
5 000	+ 5.1	843	12.23	24.90	0.8320	0.8617	650	1 524
4 000	+ 7.1	875	12.69	25.84	0.8637	0.8881	652	1 219
3 000	+ 9.1	908	13.17	26.82	0.8962	0.9151	654	914
2 000	+ 11.0	942	13.67	27.82	0.9298	0.9428	656	610
1 000	+ 13.0	977	14.17	28.86	0.9644	0.9711	659	305
0	+ 15.0	1013	14.70	29.92	1.0000	1.0000	661	0
- 1 000	+ 17.0	1050	15.23	31.02	1.0366	1.0295	664	- 305

Table A2: *International Standard Atmosphere (ISA)*

2. Altimetry Principles

2.1. General

An altimeter is a manometer, which is calibrated following standard pressure and temperature laws. The ambient atmospheric pressure is the only input parameter used by the altimeter.

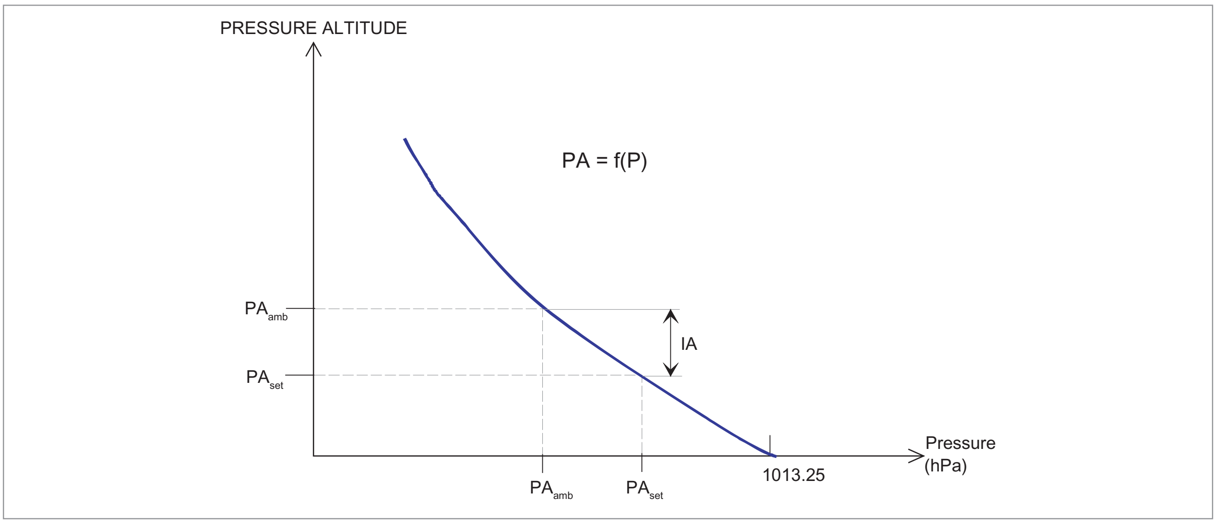

Figure A3: *Ambient Pressure and Pressure Setting*

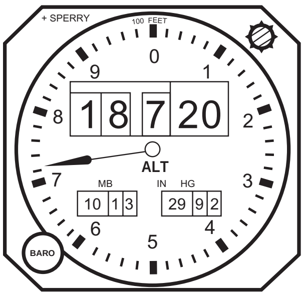

Figure A4: *ATR -500 altimeter*

Figure A5: *ATR -600 altimeter on PFD*

Assuming the conditions are standard, the Indicated Altitude (IA) is the vertical distance between the following two pressure surfaces:

- The **pressure surface** at which the **ambient pressure** is measured (current aircraft location), and
- The **reference pressure surface**, corresponding to the pressure selected by the pilot through the altimeter's **pressure setting** knob.

$$IA = f(P_{amb}) - f(P_{set})$$
$$IA = PA_{amb} - PA_{set}$$

2.2. Definitions

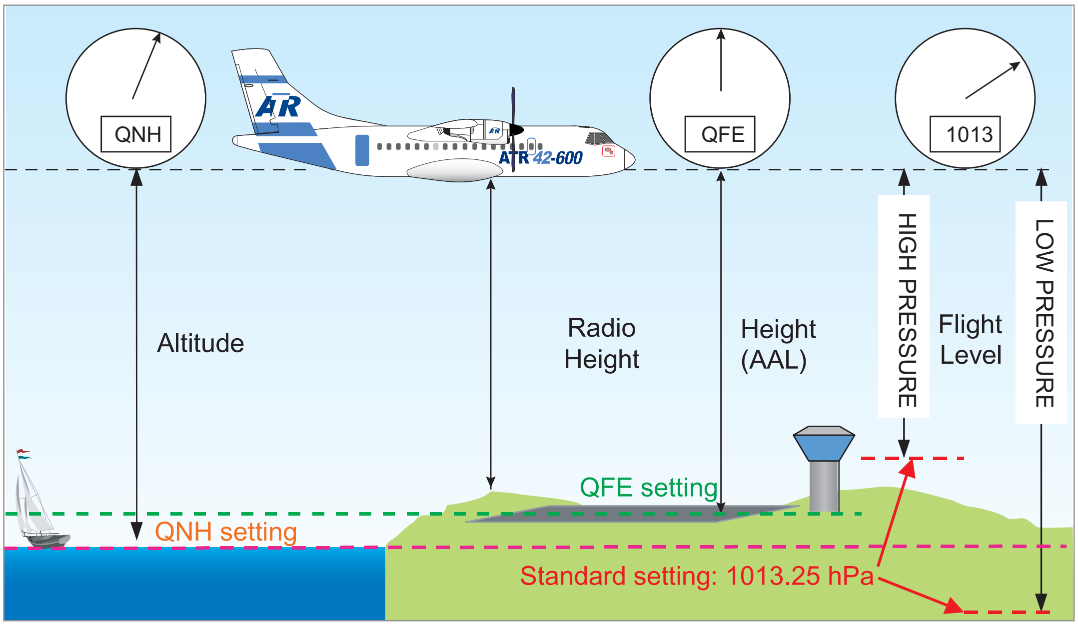

***Figure A6:** QNH and Pressure Altitude*

The aim of altimetry is to ensure relevant margins, above ground and between aircraft. For that purpose, different operational pressure settings can be selected through the altimeter's pressure setting knob:

- **QFE** is the pressure at the airport reference point. With the QFE setting, the altimeter indicates the height above the airport reference point (if the temperature is standard).
- **QNH** is the Mean Sea Level pressure. The QNH is calculated through the measurement of the pressure at the airport reference point moved to Mean Sea Level, assuming the standard pressure law. With the QNH setting, the altimeter indicates the altitude above Mean Sea Level (if temperature is standard). Consequently, at the airport level, the altimeter indicates the topographic altitude of the terrain.
- **Standard** corresponds to 1013 hPa. With the standard setting, the altimeter indicates the altitude above the 1013 hPa isobaric surface (if temperature is standard). The aim is to provide a vertical separation between aircraft while getting rid of the local pressure variations throughout the flight. After takeoff, crossing a given altitude referred to as Transition Altitude, the standard setting is selected.
  The **Flight Level** corresponds to the Indicated Altitude in feet divided by 100, according to the standard setting selected.
- The Transition Altitude is the indicated altitude above which the standard setting must be selected by the crew.
- The Transition Level is the first available flight level above the transition altitude.
- The change between the QNH setting and Standard setting occurs at the latest crossing transition altitude when climbing, and at transition level when descending.

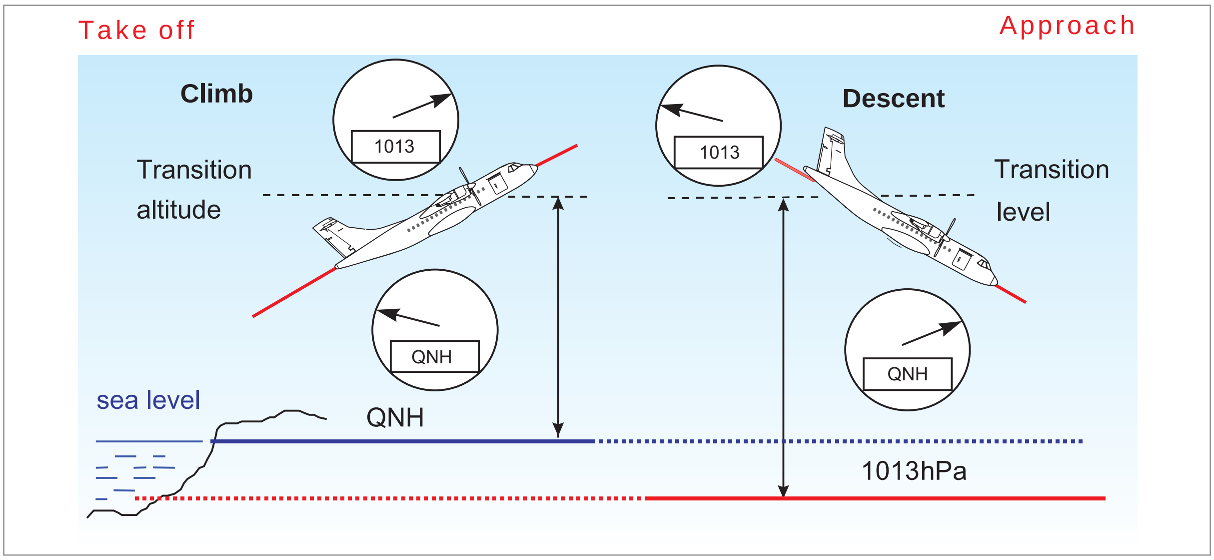

Figure A7: *Transition Altitude and Transition Level*

The transition altitude is given on the Standard Instrument Departure (SID), Standard Arrivals (STARS), Approach & Procedure charts, whereas the transition level is usually given by the Air Traffic Control (ATC)

2.3. Effects of Altimeter Setting and Temperature

The true altitude (or geometrical altitude) of an aircraft is rarely the same as the indicated altitude, when the altimeter setting is 1013 hPa. This is mainly due to the fact that the pressure at sea level is generally different from 1013 hPa, and/or that the temperature is different from ISA.

2.3.1. Altimeter Setting Correction

In case of ISA temperature conditions, and a standard altimetric setting, the aircraft true altitude can be obtained from the indicated altitude provided by the local QNH if known.

$$\text{True altitude} = \text{Indicated altitude} + 28 \times (\text{QNH}_{\text{hPa}} - 1013)$$

Example: An airport with an elevation iof 1000ft and a current QNH of 1005hPa, has a **pressure altitude** of 1000-28x(1005-1013)=1224ft.

NOTE: The pressure setting and the indicated altitude move in the same direction: any increase in the pressure setting leads to an increase in the corresponding Indicated Altitude (IA). For instance, increasing the QNH setting by 10hPa will increase the Indicated Altitude by 10x28=280ft.

For that purpose, the following figure is proposed in the FCOM 3.01.04, *Operating Data.*

ATR 72 F.C.O.M.	OPERATING DATA	3.01.04		
		P 1	001	
	QFE / QNH – ZP/ZG/ISA			DEC 94

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Example:

In QNH 1020 hPa conditions, a True altitude of 3000ft, corresponds to an Indicated pressure altitude of 2800ft.

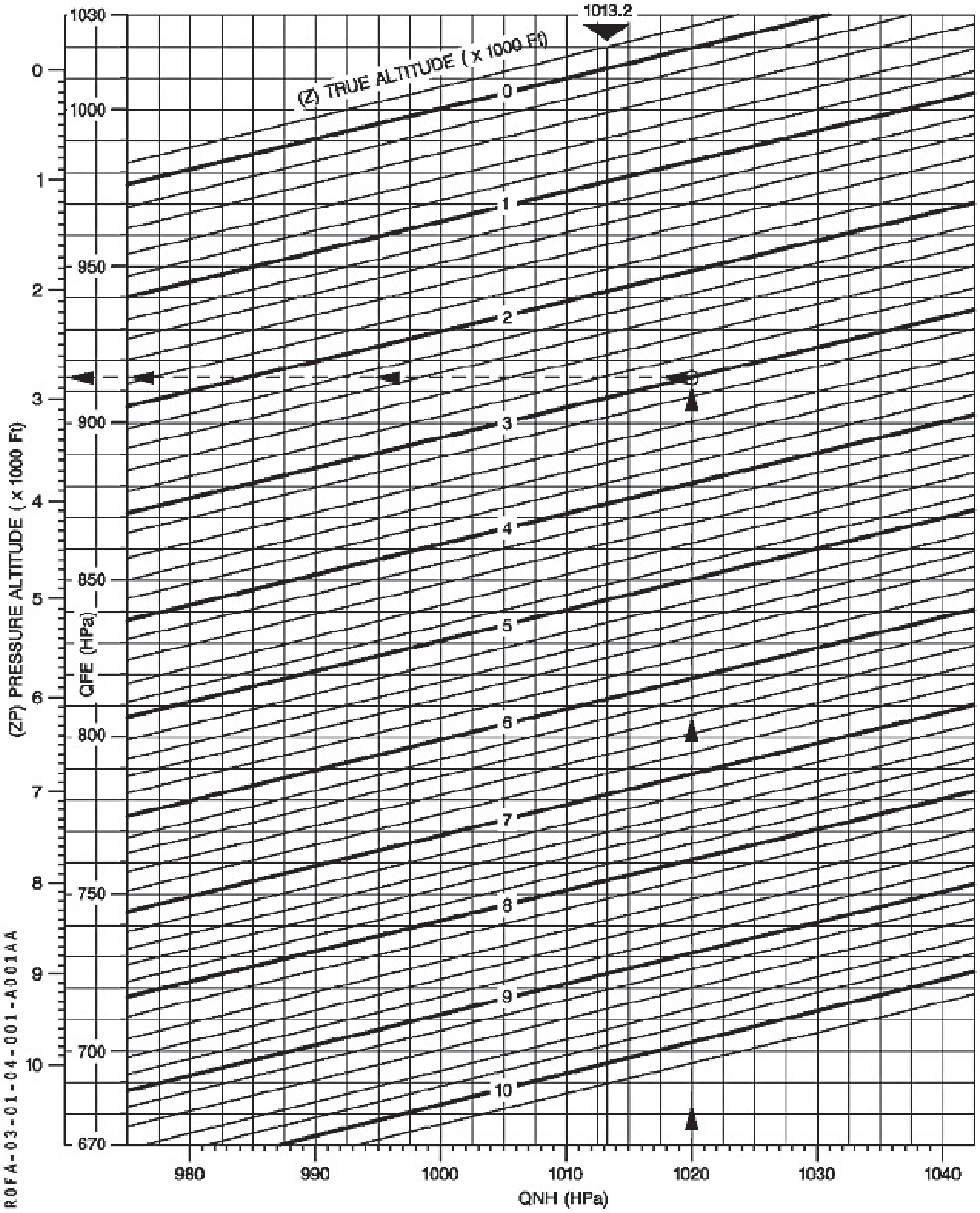

Table A3: Geometrical Altitude versus Pressure altitude and QNH

2.3.2. Temperature Correction

Flying at a given indicated altitude, the **true altitude increases with the temperature**. The relationship between true altitude and indicated altitude can be approximated as follows:

$$TA = IA \frac{T}{T_{ISA}}$$

With *TA = True altitude*
IA = Indicated altitude
T = Actual temperature (in Kelvin)
T_{ISA} *= Standard temperature (in Kelvin)*

An example is provided in Appendix 1, *Altimetry – Temperature effect*.

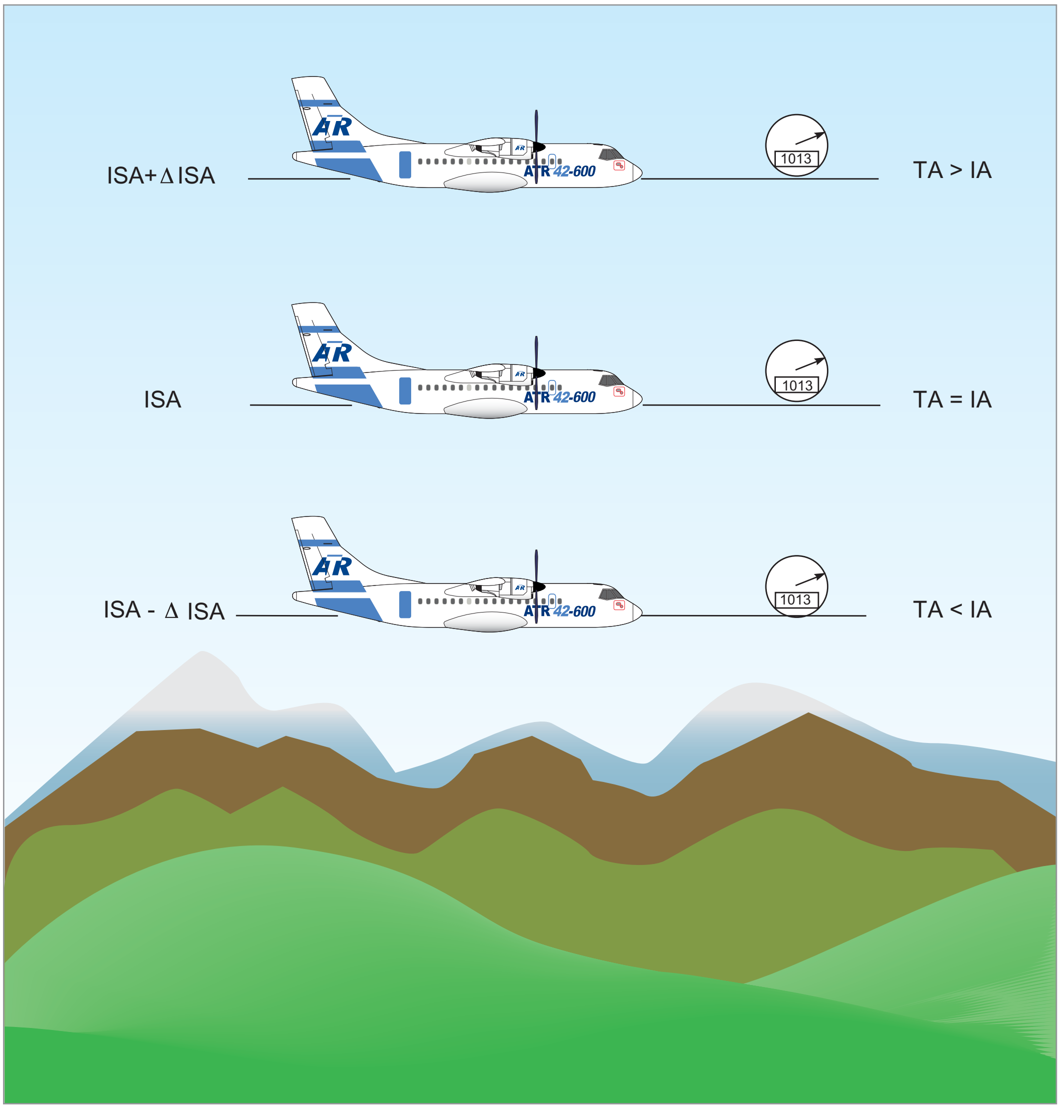

Figure A8: *Temperature effect on True Altitude, for a constant Indicated Altitude*

If the temperature is higher, you fly higher.
If the temperature is lower, you fly lower.

Temperature correction is important when flying a departure or arrival procedure in very low temperature conditions. For that purpose, the following table is proposed in the FCOM 3.01.04, *Operating Data.*

ATR 72 F.C.O.M.	OPERATING DATA	3.01.04		
		P 2	001	
	QFE/QNH - ZP/ZG/ISA			JUN 95

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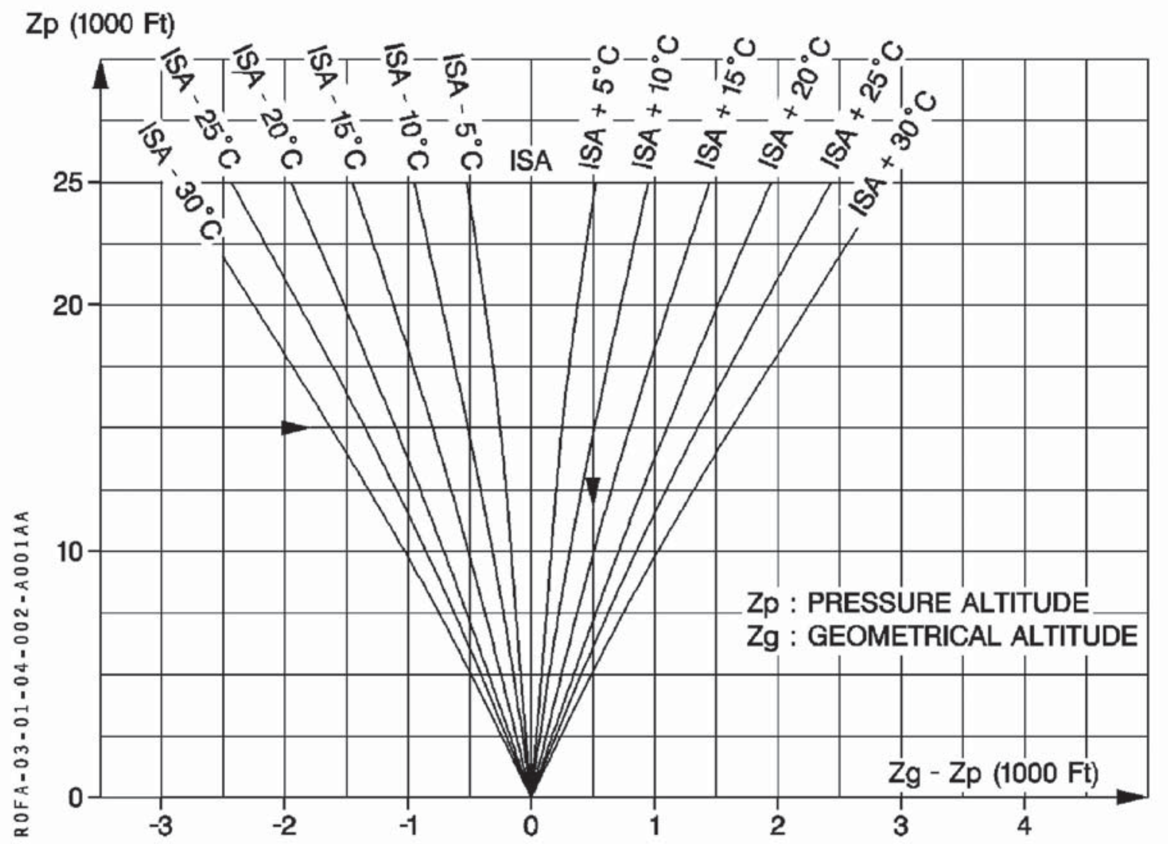
RELATION BETWEEN PRESSURE ALTITUDE AND GEOMETRICAL ALTITUDE



Example:
In ISA +10°C conditions, for a Indicated pressure altitude of 15000ft, the True geometrical altitude is 15500ft.

Table A4: *Geometrical Altitude Correction versus Temperature*

3. Operating speeds

Different speed types are used to operate an aircraft. Some of them enable the crew to manage the flight while maintaining some margins from critical areas, whereas others are mainly used for navigational and performance optimisation purposes. This is why the following sections aim to review the different speed types that are used in aeronautics.

3.1. Calibrated Air Speed (CAS)

The Calibrated Air Speed (CAS) is obtained from the difference between the total pressure (**P_t**) and the static pressure (**P_s**). This difference is called dynamic pressure (**q**). As the dynamic pressure cannot be measured directly, it is obtained thanks to two probes.

$$q = Pt\text{-}Ps$$

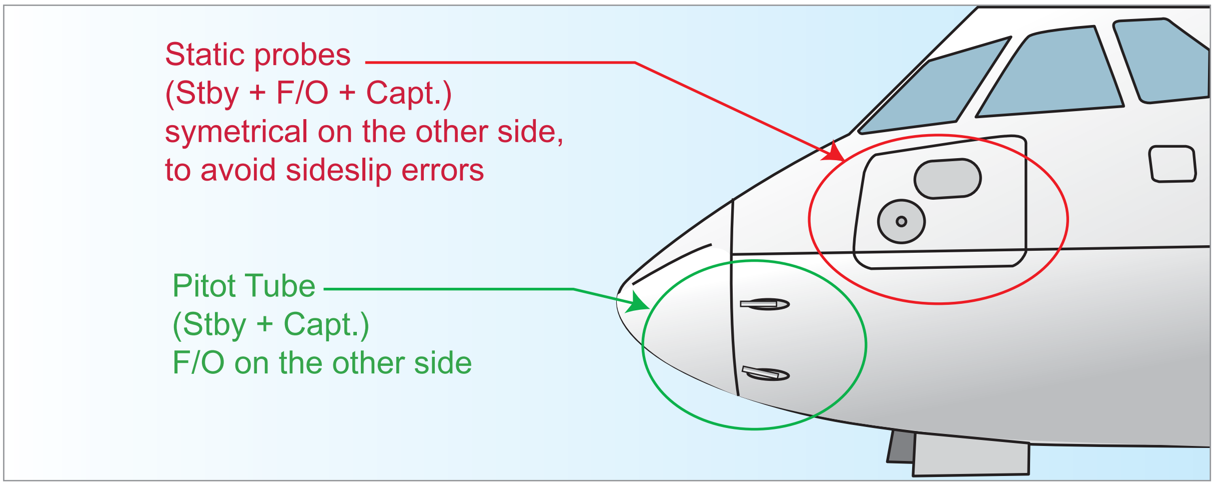


Figure A9: *Pitot Tube and Static Probes*

To obtain the total pressure Pt, airflow is stopped by means of a forward-facing tube, called the Pitot tube, which measures the impact pressure. This pressure measurement accounts for the ambient pressure (static aspect) at the given flight altitude plus the aircraft motion (dynamic aspect).
The static pressure Ps is measured by means of a series of symetrical static probes perpendicular to the airflow. This measurement represents the ambient pressure at the given flight altitude (static aspect).

$$CAS = f\ (Pt\text{-}Ps) = f\ (q)$$

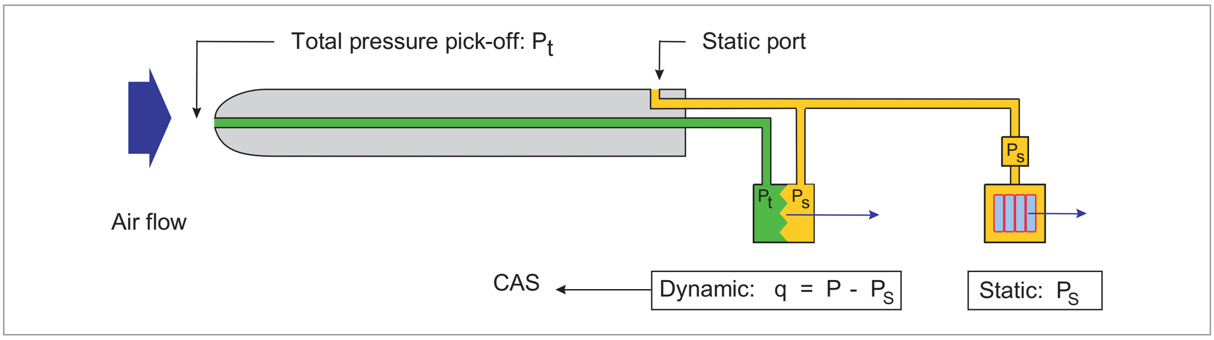


Figure A10: *CAS Determination Process*

3.2. Indicated Air Speed (IAS)

The Indicated Air Speed (IAS) is the speed indicated by the airspeed indicator. Whatever the flight conditions, if the pressure measurements were accurate, then the IAS would ideally be equal to the CAS. Nevertheless, depending on the aircraft angle of attack, the flaps configuration, the ground proximity (ground effect or not), the wind direction and other influent parameters, some measurement errors are introduced, mainly on the static pressure. This leads to a small difference between the CAS and the IAS values. This difference is called instrumental correction or antenna error (K_i).

$$IAS = CAS + Ki$$

3.3. True Air Speed (TAS)

An aircraft in flight moves in an air mass, which is itself in motion compared to the earth. The True Air Speed represents the aircraft speed in a moving reference system linked to this air mass, or simply the aircraft speed in the airflow. It can be obtained from the CAS, using the air density (ρ) and a compressibility correction (**K**).

$$TAS = \sqrt{(\rho_0/\rho)}\ K\ CAS$$

With ρ_0 = *MSL density*
ρ = *Level altitude density*

TAS is a function of the pressure altitude.

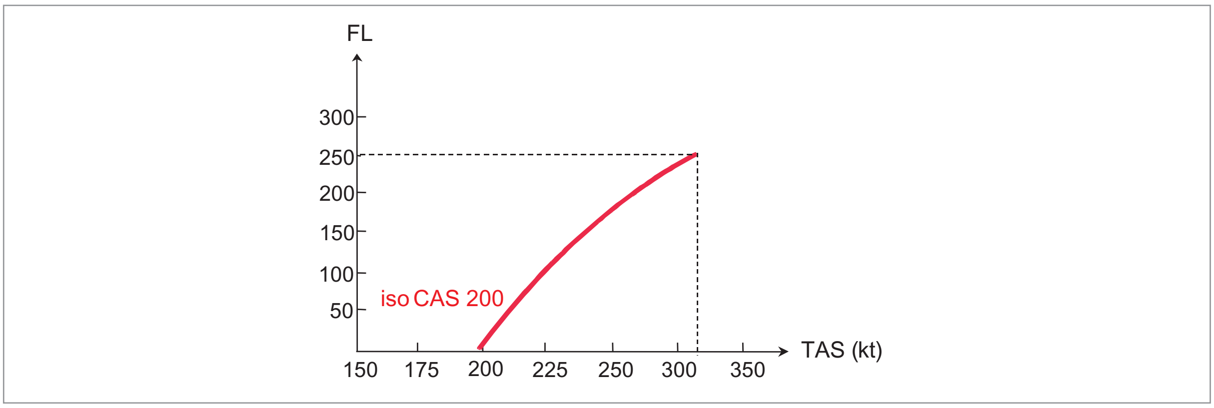


Figure A11: *True Air Speed Variations*

At given CAS (or IAS) higher PA ⇒ faster

3.4. Ground Speed (GS)

The ground speed (GS) represents the aircraft speed in a fixed ground reference system. It is the sum of the TAS and of the wind component.

Ground Speed = True Air Speed + Wind Component

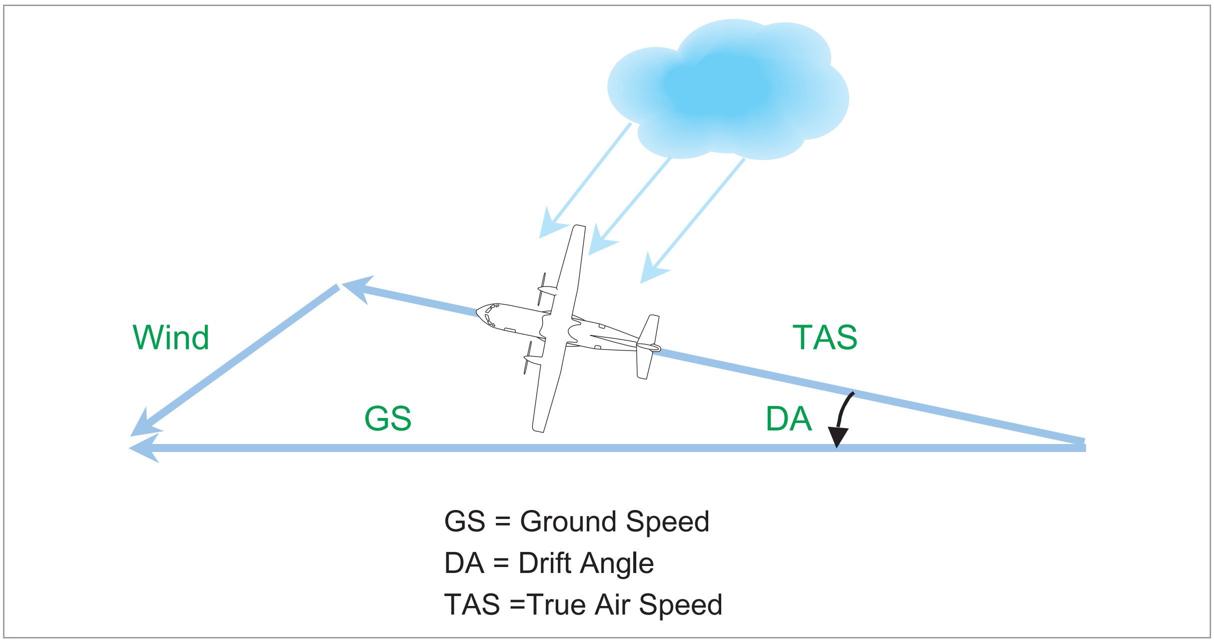


Figure A12: *Ground Speed and Drift Angle*

3.5. Mach Number

The Mach Number is a comparison between the TAS and the speed of sound.

$$M = \frac{TAS}{a}$$

With *TAS = True Air Speed*
a = speed of sound

The speed of sound in knots is:

$$a(kt) = 39\sqrt{SAT(K)}$$

With *SAT = Static Air Temperature in Kelvin*

The **speed of sound is solely dependent on temperature**. Consequently, the Mach number can be expressed as follows:

$$M = \frac{TAS\ (kt)}{39\sqrt{273+SAT(°C)}}$$

At a given Mach number, when the pressure altitude increases, the SAT decreases and thus the True Air Speed (TAS).

At a given Mach number, higher means slower

P_t and P_s, respectively measured by the aircraft pitot tube and static probes, are also used to compute the Mach number. Therefore,

$$M = f\left(\frac{P_t - P_s}{P_s}\right) = f\left(\frac{q}{P_s}\right)$$

The TAS indicated on the navigation display of modern aircraft is then obtained from the Mach number:

$$TAS(Kt) = 39M\sqrt{+SAT(°C)}$$

4. Flight mechanics

4.1. Angles definition

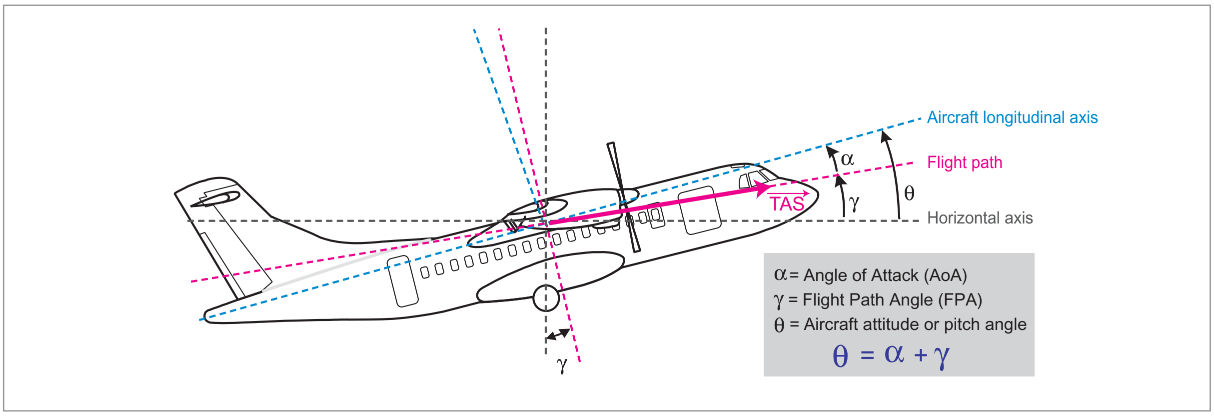


***Figure A13:** Aircraft longitudinal angles*

The Angle of Attack α is the angle between the flight path and the aircraft longitudinal axis.
The Flight Path Angle γ is the angle between the horizontal axis and the flight path.
The aircraft attitude or pitch angle θ is the angle between the horizontal axis and the longitudinal axis.

4.2. Forces diagram

There are four forces that act on an aircraft in flight:

- **Weight**, applied on the center of gravity of the aircraft, directly proportional to the mass of the aircraft

$$Weight = mg$$

- **Lift** and **drag** are aerodynamic forces that depend on the shape of the aircraft
  Lift is directed perpendicular to the flight path and applied on the center of pressure of the aircraft.

$$Lift = \frac{1}{2} \rho S (TAS)^2 \, C_L$$

  Drag is directed along the flight path.

$$Drag = \frac{1}{2} \rho S (TAS)^2 \, C_D$$

- the **thrust** is determined by the engine type and the power setting selected by the pilot, and is directed in the aircraft axis.

With   *m = aircraft mass*
ρ = air density
S = wing surface
TAS = True Air Speed
CL = lift coefficient
CD = drag coefficient

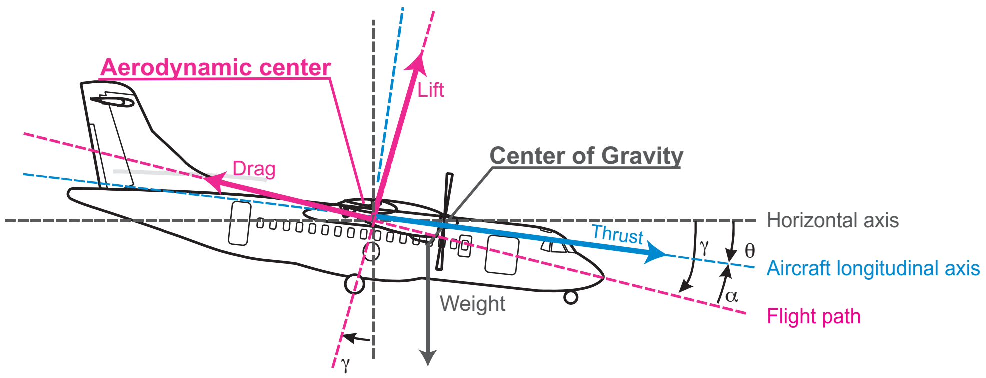


Figure A14: Aircraft forces diagram

NOTE: The lift and drag coefficients depend on the Angle of Attack (α), the aircraft aerodynamics (mainly flaps and landing gears configuration) and the True Air Speed.

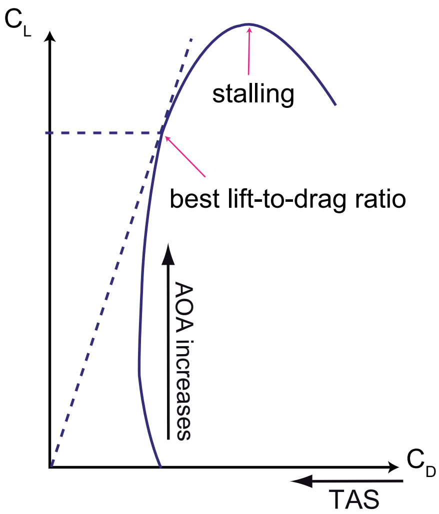


Figure A15: C_L versus C_D

Along the flight path, the balance is expressed as:

$$\text{Lift} + \text{Thrust} \cdot \sin \alpha = \text{weight} \cdot \cos \gamma$$

and

$$\text{Thrust} \cdot \cos \alpha = \text{drag} + \text{weight} \cdot \sin \gamma$$

The motion of the aircraft through the air depends on the relative magnitude and direction of the various forces:

- For a flight at **constant** speed and in **level flight**, the drag force balances the engine thrust. And the lift balances the weight.
- When engine thrust is higher than drag, the aircraft can use the excess thrust to **accelerate** and/or **climb**.
- On the opposite, when the thrust is insufficient to balance the drag, the aircraft is forced to **decelerate** and/or **descent**.

4.3. Load factor

During a turn, an aircraft is not only subjected to its weight (W), but also to a horizontal acceleration force (Fa) directed towards the center of the turn to counteract the centrifugal force.
The resulting force is called **apparent weight** (Wa), and its magnitude is equal to the load factor times the weight.

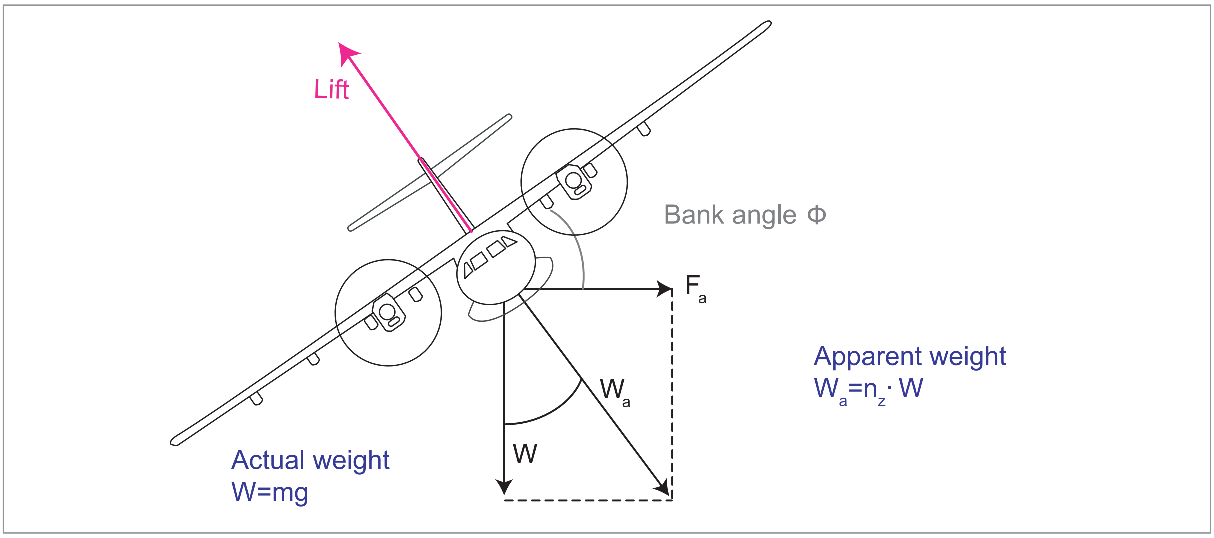


Figure A16: Apparent weight

The load factor can be expressed versus the bank angle:

$$n_z = \frac{1}{\cos\Phi}$$

During a balance turn, the lift equals the apparent weight.

4.4. Lift-to-drag ratio

Because lift and drag are both aerodynamic forces, the ratio of lift to drag is an indication of the aerodynamic efficiency of the aeroplane. The **lift-to-drag ratio** L/D is the amount of lift generated by a wing, divided by the drag it creates by moving through the air.
A higher or more favorable lift-to-drag ratio is typically one of the major goals in aircraft design; since a particular aircraft required lift is set by its weight, delivering that lift with lower drag leads directly to better fuel economy and performance.

5. Turboprop engine

5.1. Engine description

The turboprop is a gas turbine engine where all the energy is transmitted by means of a shaft from the turbine and through a **reduction gearbox** to the propeller. The residual thrust in the exhaust nozzle is very low, contrary to the jet engine. The gas generator works at very high RPM incompatible with average propeller speeds: a reduction gear box is thus installed. Disconnecting the propeller from the gas generator by means of a specific shaft and a **turbine** allows more flexible control of propulsion. The Pratt and Whitney engine fitted on ATR aircraft is composed of two gas generator spools the gases of which are directed towards the two free turbines which provide rotational force to the propeller through a reduction gearbox.

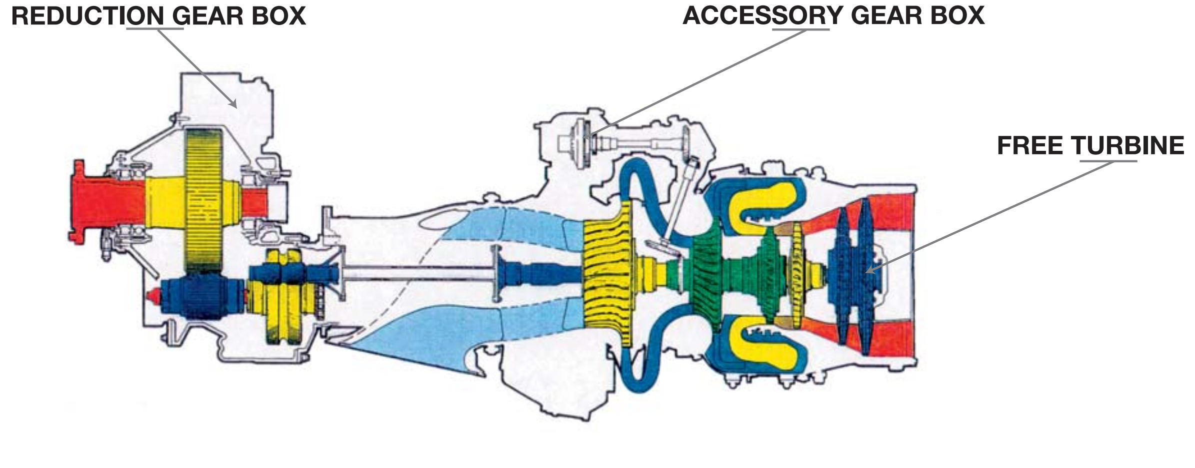


Figure A17: *Pratt & Whitney turboprop engine*

5.2. Propeller

A propeller blade is a rotating wing which is submitted to a resulting air flow due to the aircraft motion and the propeller rotation: each blade section is an airfoil for which the angle of attack depends on the resulting blade motion.

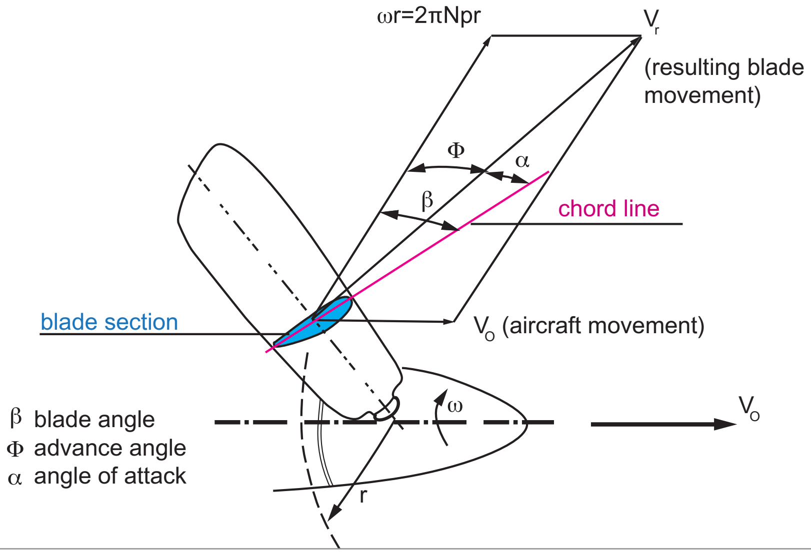


Figure A18: *Propeller blade motion*

For a given aircraft motion, the blade is accelerated from the hub to the blade tip. The blade is twisted strongly from the hub to the blade tip to decrease the blade angle β and in this way counteract the increasing advance angle Φ: the angle of attack α is thus kept at a convenient value.

The pitch is the distance covered by the blade during one rotation.

$$\text{pitch} = 2\pi r \cdot \tan \beta$$

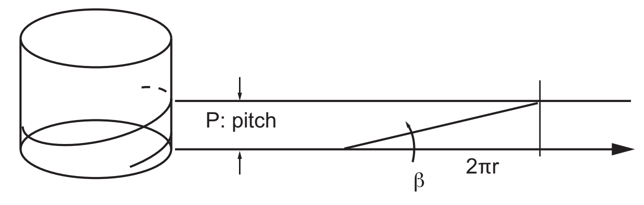


Figure A19: *Blade pitch*

5.3. Pitch control

On PW127M engine, the propeller speed (Np) is fixed to 86% or 100%[1], depending on the power management selection, and the blade speed is adjusted through the **control of the pitch** or equally the blade angle β. This adjustment is made electronically and is not discernable by the pilot. The PW127M variation range is:

$$-19° \ \textit{(reverse)} \le \beta \le 78.5° \ \textit{(feather)}$$

[1] Np 100% represents 1200 RPM.

The blade angle setting depends on the aircraft speed, the engine power delivered and the propeller rotation speed.

		blade angle
increase in	aircraft speed	↗
	engine power (TQ)	↗
	propeller speed (Np)	↘

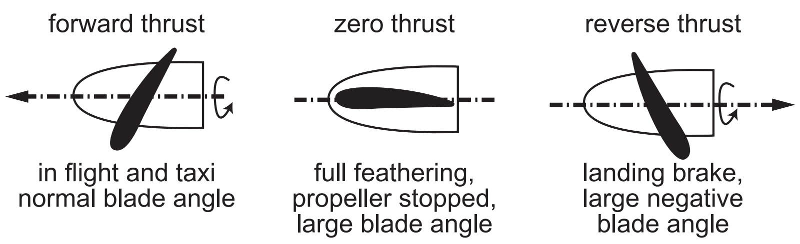


Figure A20: *Pitch control*

The engine is equipped with an automatic feathering in case of engine failure at take-off (ATPCS), to reduce the dead engine drag.

5.4. Available and required power

The **thrust** is the result of the force developed on the engine shaft by the **efficiency** of the propeller, which depends notably on the blade pitch angle.
The **available power** delivered by the engine is the thrust multiplied by the True Air Speed of the aircraft.

$$P_a = \text{Thrust} \cdot \text{TAS}$$

The available power is determined by the atmospheric conditions (pressure altitude, OAT) and has a mechanical and a thermodynamic limit.
In the Pratt and Whitney documentation, the power is expressed in Shaft Horse Power.

$$1 \text{ SHp} = 745 \text{ Watts}$$

The **Equivalent Shaft Horse Power** is commonly used in the Pratt and Whitney documentation. This parameter considers the jet thrust provided by the propeller.

$$ESHP = SHP + \frac{\text{jet Thrust}}{2.5}$$

Example: For the PW 120, SHP = 2000 SHP and,
jet thrust = 250 lbs, which leads to a total ESHP of 2100SHP.

The shaft power delivered by the engine is assessed with the torque (TQ) and the propeller speed (Np).

$$P_a = TQ \cdot Np$$

The **power required** is the drag multiplied by the True Air Speed.

$$P_r = \text{Drag} \cdot TAS$$

$$P_r = \tfrac{1}{2}\,\rho \cdot TAS^3 \cdot C_D$$

With the assumption that $TAS = \sqrt{\dfrac{2 \cdot \text{weight}}{\rho \cdot S \cdot C_L}}$

$$P_r = \sqrt{\frac{2}{\rho S}} \left(\frac{\text{weight}}{C_L}\right)^{3/2} C_D$$

The power required is minimum when the ratio C_L^3 / C_D^2 is maximum.

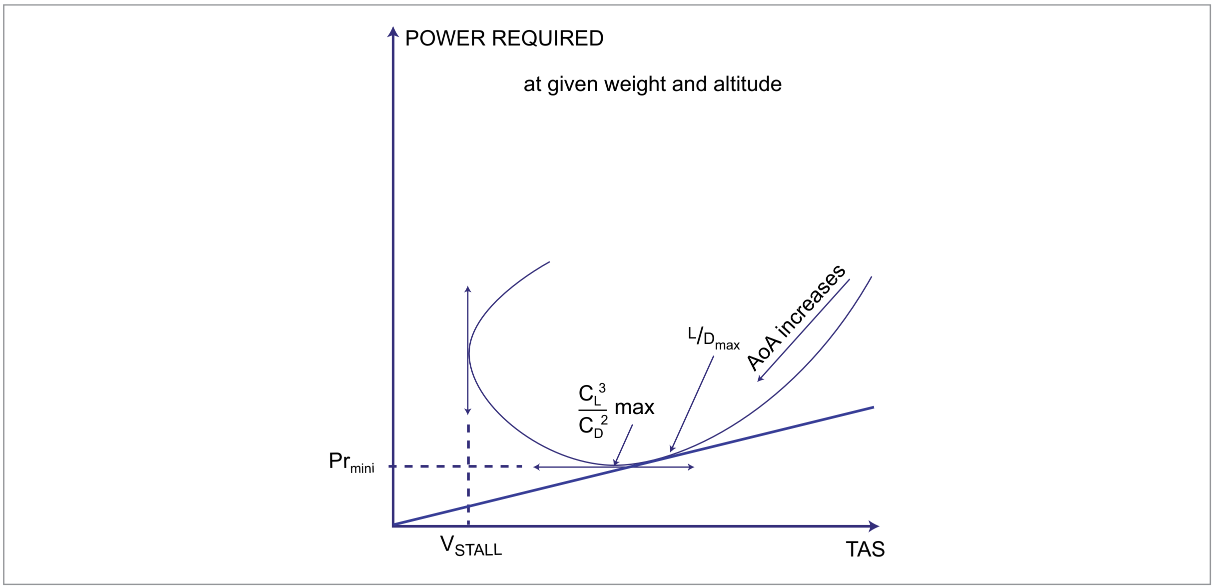


Figure A21: *Power required versus TAS*

B. Aircraft Limitations

FCOM 2.01

1. Flight Limitations

During aircraft operation, the airframe must endure the forces generated by engines, aerodynamic loads, and inertial forces. In still air, when manoeuvering of the aircraft, or during flight turbulence, load factors appear and thereby increase loads on the aircraft. This leads to the establishment of **maximum weights** and **maximum speeds**.

1.1. Limit Load Factors

CS / FAR 25.301 Loads

(a) Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

CS / FAR 25.321 Flight Loads

*(a) **Flight Load Factors represent the ratio of the aerodynamic force component** (acting normal to the assumed longitudinal axis of the aeroplane) **to the weight of the aeroplane**. A positive load factor is one in which the aerodynamic force acts upward with respect to the aeroplane.*

$$n_z = \frac{\text{Lift}}{\text{Weight}}$$

Except when the lift force is equal to the weight and n_z=1 (for instance in straight and level flight), **the aircraft apparent weight is different from its real weight (mg):**

$$\text{Apparent weight} = n_z.m.g = \text{Lift}$$

In some cases, the load factor is greater than 1 (turn, resource, turbulence). In other cases, it may be less than 1 (rough air). The aircraft structure is obviously designed to resist to such load factors, up to the limits imposed by regulations. Consequently, load factor limits are defined so that an aircraft can operate within these limits without suffering permanent distortion of its structure. The ultimate loads, leading to rupture, are generally 1.5 times the load factor limits.

CS / FAR 25.1531 Manoeuvring flight load factors

Load factor limitations, not exceeding the positive limit load factors determined from the manoeuvring diagram in section 25.333 (b).

For all ATR types, the flight manœuvring load acceleration limits are established as follows:

Clean configuration .... $-1g \le n \le +2.5g$
Flaps extended .... $0g \le n \le +2g$

Dear Customer,

This is an extract of the ATR Performance - 2009 edition, available in paper or electronic copy.
Should you need any further information, please contact the ATR Training Center atc@atr.fr

Yours faithfully,

Your ATR Training a Flight Operations support team