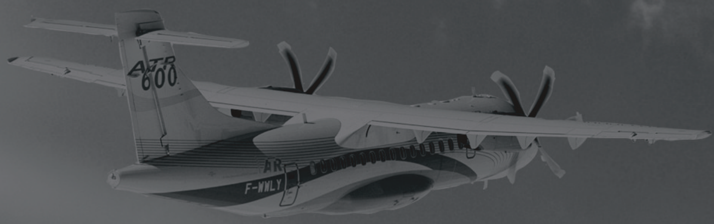
ATR CUSTOMER SERVICES



FUEL SAVING

CONTRIBUTING TO A SUSTAINABLE AIR TRANSPORT DEVELOPMENT

An Alenia Aeronautica and EADS joint venture

ATR

PROPELLING TOMORROW'S WORLD

Introduction

The very competitive and deregulated nature of the aviation market together with concerns over fuel price rises, means that more than ever before, airlines focus on how they can keep their fuel consumption down. Indeed, they seek out operational cost reductions on every single business facet. Fuel conservation has become a major preoccupation for all airlines and aircraft manufacturers. That is why one should consider using whichever ways and means there are to reduce fuel consumption, barring affecting safety; that, of course, must remain the number one priority, at any time and for any airline.
Already, ATR aircraft are recognised as the most fuel-efficient aircraft in their category, thanks to high-tech engines and propeller efficiency. Compared with an equivalent jet aircraft on a 300Nm average trip, the ATR 72-500 boasts a 35% block fuel saving per passenger.

This document depicts the many factors which affect fuel consumption and the latent gains or losses to be made. Its purpose is to examine the influence of flight operations on fuel conservation with a view to making recommendations that will enhance the potential for fuel economy.
Most of these factors are directly controlled by the airline's own employees (flight crews, operations/despatch and maintenance staff) during flight preparation and in-flight. Fuel and cost efficient airlines will consider the following main features to be paramount:

- Thorough flight planning from very accurate data;
- Correct aircraft loading (fuel weight and Center of Gravity);
- An aerodynamically clean aircraft;
- Flight procedures that set speeds and altitudes in relevance with the company's economic priorities;
- During flight planning, the use of performance factors derived from an ongoing aircraft performance monitoring programme.

None of the information herein is intended to replace procedures or recommendations contained in the Flight Crew Operating Manuals (FCOM) or any other approved ATR manual, but rather to highlight areas where maintenance, operations and flight crews can significantly contribute to fuel savings.

Contents

A. Flight preparation

1. Flight Planning

The fundamental requirement for achieving optimised fuel economy and reduction of operating costs is a quality Flight Planning System.

A good flight planning system will produce an optimized route, in terms of track, speeds and altitudes, which meets the operator's economic criteria. This track and vertical profile should be achieved during normal operations, given the constraints of ATC, climb rates, descent rates, etc. It will be based on good quality data (temperature, wind, aircraft weight, payload, etc).

The ATR Flight Operations Software (FOS) includes a Flight Plan computation module which meets the customers' needs for accurate fuel calculations.

1.1. Cost index

A technique that reduces fuel burn often requires more trip time. The choice of fuel saving is hence offset by its impact on time related cost (hourly maintenance costs, flight and cabin crew costs and marginal depreciation or leasing costs). The cost index is the cost of time ($/min) compared with the cost of fuel ($/kg) and is used to obtain the best economics.

The determination of the cost index, is specific to each airline, depending on its economic policy. If fuel costs were the overriding priority, i.e. fuel costs are much more significant than the cost of time, then the cost index would be low. The aircraft would then be chosen to fly at minimum fuel/ cruise at long-range speed.

However if the cost of fuel was very cheap compared to the cost of time, then speed would be important and the cost index would be high. The aircraft would then be chosen to fly at minimum time / cruise at maximum speed.

Best economics would be between these two speeds and would depend on the operator's cost structure and operating priorities. For ATR aircraft, the speed range between maximum and long-range speed is restricted. For instance, for an ATR 72-500 cruising at FL200; max cruise speed is 204 kt and long-range speed is 176 kt. Operators generally chose to cruise at max speed, long-range speed, or at given intermediate IAS.

The fuel saving between a minimum time and a minimum fuel policy is valuable and leads to important fuel consumption reduction. Let us consider the example of an average 300Nm trip performed with an ATR 72-500, for which the fuel consumption difference between a cruise at maximum speed and a cruise at long range speed was calculated with the FOS software, selecting an optimized cruise altitude. The fuel consumption reduction between those two policies is up to 8%.

These standard cases, minimum fuel at FL 230 and minimum time at FL 180 serve as the reference for all examples given in the following paragraphs.

Flight conditions	Airline Policy	Trip fuel (kg)	Delta (kg)	Delta (%)	Trip time	Delta (min)	FL	Mean IAS (kts)	Specific consump-tion (kg/Nm)	TOW (tons)
Standard (*)	Mini time	899			1h15		180	210	2.6	21
	Mini fuel	826	–73	–8.1	1h20	+5	230	175	2.2	21

Table A1: Fuel saving for a 300Nm trip with ATR72-500 depending on the airline policy (reference cases for the fuel consumption).

(*) The standard flight conditions correspond to Climb 170kts / Descent 240 kts with 3° gradient, CG 25% and no wind at cruise level.

To understand the trip fuel difference that can be attributed to the cruise flight level or to the cruise speed changes between the two reference cases, the following Figure shows the fuel consumption versus cruise speed at different flight level.

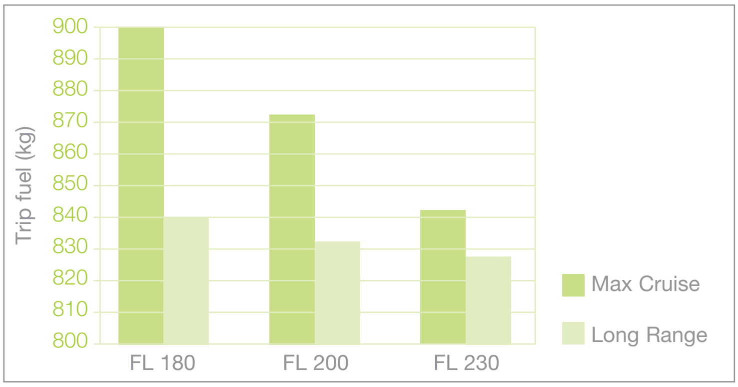


Figure A1: Fuel consumption for a 300Nm trip with ATR 72-500 versus cruise FL and speed

In addition to the fuel saving benefit, cruising at long-range speed reduces the temperature of the engine (ITT) and improves consequently the lifetime of the components of the engine. This thus leads to engine maintenance costs saving. Cruising at high flight levels has however an impact on the airframe structural fatigue. The airframe is more pressurized at higher level, and its structure is stressed by the higher difference in pressure between the cabin and the outside air. This may lead to more frequent maintenance inspections on the airframe, and may limit the total number of aircraft cycles.

1.2. Wind forecasting

Winds have a significant influence on fuel consumption and it is valuable to consider this meteorological effect in a fuel saving policy. The wind speed can vary with altitudes. For a given weight, when cruise altitude is lower than optimum altitude, the specific range (distance covered versus fuel burnt) decreases. Nevertheless, it is possible that, at a lower altitude with a favourable wind, the ground specific range improves. When the favourable wind difference between the optimum altitude and a lower one reaches a certain value, the ground-specific range at lower altitude is higher than the ground-specific range at optimum altitude. As a result, in such conditions, it is more economical to cruise at the lower altitude.

For instance, let us assume that the headwind at FL180 is 20 kts and 50kts at FL230, the wind gradient is thus +6kts/1000ft. In this case, in long-range speed, the specific range, is 0.39Nm/kg at FL 180 and 0.37 Nm/kg at FL230, it is thus more valuable to fly at lower altitude. At long-range speed, the transition wind gradient from which it is fuel economical to cruise at a lower flight level is about +4kts / 1000ft

However in max cruise speed, the specific range is 0.35Nm/kg for both FL 180 and FL230. It is thus equivalent to fly at any of those FL. The transition wind gradient is higher in case of max cruise speed, around +6kts/1000ft in average.

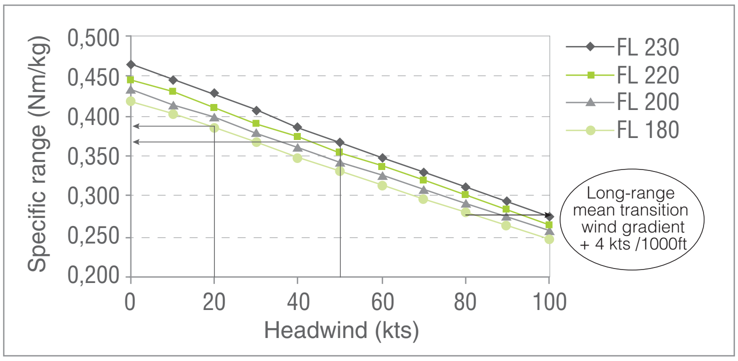


Figure A2: Wind altitude trade for optimised specific range at long-range speed

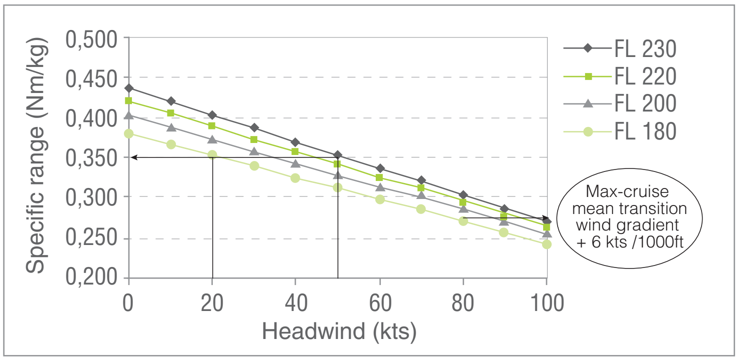


Figure A3: Wind altitude trade for optimised specific range at max cruise speed

The wind effect really depends on the day's weather conditions and the flight crew can optimize the specific range by monitoring their specific fuel consumption.

$$SFC = \frac{FuelFlow}{GS}$$

1.3. Centre of gravity position

The gross weight is the sum of the dry operating weight, payload and fuel and acts as one force through the centre of gravity (CG) of the aircraft. The load and trim chart allows the determination of the overall centre of gravity of the airplane taking into account the centre of gravity of the empty aircraft, the fuel and the payload distribution. It must be ensured that the centre of gravity is within the allowable range referred to as the centre of gravity operational envelope.

A more forward centre of gravity requires a nose up pitching moment obtained through reduced tail plane lift, which is compensated for by more wing lift. This creates more induced drag and leads to an increase in fuel consumption. It is better to have the centre of gravity as far aft as possible. As a rearward shift in CG position reduces the dynamic stability of the aircraft, the CG envelope defines the aft limit.

The position of the centre of gravity has a limited impact on the ATRs fuel saving. Nevertheless, choosing an aft rather than a forward balance leads to a slight gain in fuel consumption.

Let us consider the example of the reference 300Nm trip performed with an ATR 72-500.

The fuel consumption reduction with an aft balance of 34% is at the utmost 0.6% when comparing to the same flight in 25% CG conditions.

The aft balance conditions of flight are: standard procedures, CG 34% and no wind at cruise level.

Flight conditions	Airline Policy	Trip fuel (kg)	Delta (kg)	Delta (%)	Trip time	Delta (min)	Cruise FL
Aft balance 34%	Mini time	897	–2	–0.2	1h15	+0	180
	Mini fuel	821	–5	–0.6	1h20	+0	230

Table A2: Fuel saving for a 300Nm trip with ATR72-500 with aft balance

In the opposite, a forward balance of 17% leads to an extra fuel burn of 0.6% when comparing to the same flight in 25% CG conditions.

Flight conditions	Airline Policy	Trip fuel (kg)	Delta (kg)	Delta (%)	Trip time	Delta (min)	Cruise FL
Forward balance 17%	Mini time	901	+2	+0.2	1h15	+0	180
	Mini fuel	831	+5	+0.6	1h20	+0	230

Table A3: Extra fuel consumption for a 300Nm trip with ATR72-500 with forward balance

Globally, from the most forward to the most aft CG position, the fuel economy is only 1.2% in case of mini fuel, and 0.4% in case of mini time policy.

1. 4. ETOPS (Extended range with Twin-engines aircraft Operations)

The ETOPS concept aims to settle and support the operations of twin-engine aircraft on long distances.

It allows operating twins on routes containing points further than 60 minutes flying time from an adequate landing airport. When required to fly over water or deserted areas, ETOPS allows more direct routes and thus leads to fuel saving.

The ATR 42-500 and 72 aircraft are certified with an ETOPS capability of 120 minutes.

2. Fuel Reserves

Fuel is loaded onto the aircraft as follows:

- Taxi fuel
- Trip fuel
- Contingency fuel
- Alternate fuel
- Final reserve fuel
- Additional fuel
- Extra fuel
- Tankering fuel

In order to avoid unnecessary fuel weight, the flight must be planned very precisely to calculate the exact fuel quantity to be embarked. Flight preparation should be based on aircraft performance monitoring by taking into account performance factors derived from specific range variations.

The fuel reserves will be based on a policy that aims at obtaining the minimum values required within the regulations, a fuel saving can be especially achieved on the contingency fuel reserve.

To minimize the alternate fuel, the alternate airports should be chosen as near as possible to the destination. Both the JAA and FAA do not require the alternate fuel reserve in certain cases, depending on meteorological conditions and the suitability of the airport, but be aware than in that case an additional fuel of 15min is required.

Another part of the reserves is the extra fuel, which is at the Captain's discretion. There are many reasons why this extra fuel is necessary. It could be due to uncertain weather conditions or availability of alternate and destination airfields, leading to a probability of re-routing. It may also be due to lack of confidence in the flight planning and the natural desire to increase reserves. This is the one area where a significant impact can be made through accurate flight preparation.

2.1. Contingency fuel reduction

Within JAR OPS, there are several definitions of contingency fuel, depending on diversion airfields, fuel consumption monitoring, etc. but briefly the fuel is the greater of two quantities:

- 5 minutes hold fuel at 1500 feet above destination at ISA
- One of the following quantities:
  - 5% of trip fuel,
  - 3% of trip fuel with an available en-route alternate aerodrome,
  - an amount of fuel which ensures an appropriate statistical coverage of the deviation from the planned to the actual trip fuel,
  - 20 minutes trip fuel, based upon trip fuel consumption.

The last 3 options require Authority approval and the last 2 options require fuel consumption monitoring program.

One further method of reducing the contingency fuel is by using a decision point or redispatch procedure. This involves the selection of a decision point where the aircraft can either continue to the destination, as the remaining fuel is sufficient, or it can reach a suitable proximate diversion airport.

a) En-route alternate airport

The contingency fuel can be reduced from 5% to 3% providing an en-route alternate is available. Appendix 2 to OPS 1.255 defines the en-route alternate as an aerodrome which shall be located within a circle having a radius equal to 20% of the total flight distance, the centre of which lies on the planned route at a distance from the destination aerodrome of 25% of the total flight plan distance, or at least 20% of the total flight plan distance plus 50 Nm, whichever is greater.

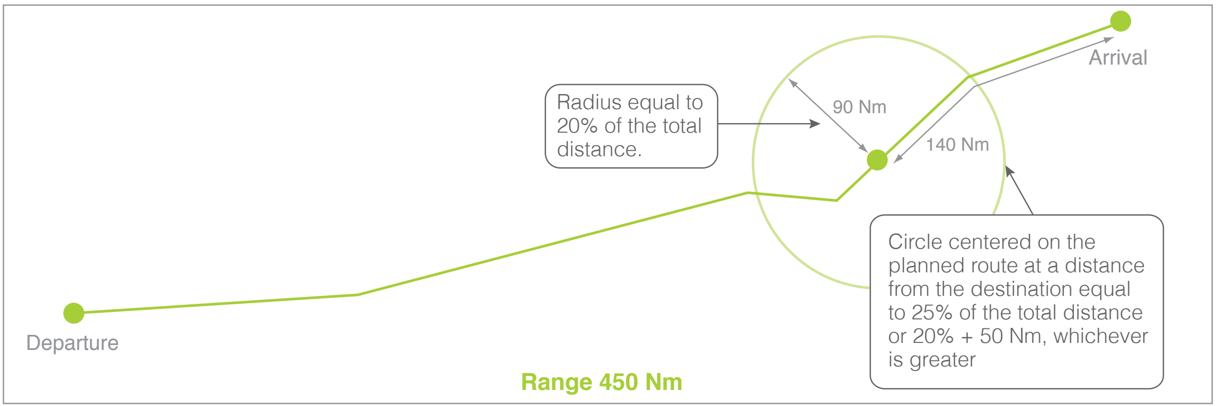


Figure A4: En-route alternate aerodrome location

The reduction of the contingency fuel from 5% to 3% has a limited impact on the ATR's fuel saving. Indeed, this aircraft operates on short trip distance and furthermore its transport coefficient (refer to § B. 2. 2.Tankering fuel) is very low.

For the reference 300Nm trip, taking 3% contingency fuel instead of 5% allows to transport around 20kg less fuel. But this fuel is almost entirely recoverable at destination as the ATR transport coefficient is low.

The longer the trip distance is, the more valuable is this contingency fuel reduction.

b) Decision point procedure

This procedure permits aircraft to carry less contingency fuel than in the standard case.

Operators select a point called the decision point along the planned route (Figure 2). At this point, the pilot has two possibilities:

- Reach a suitable proximate diversion airport, taking into account the maximum landing weight limitation,
- Continue the flight to the destination airport, when the remaining fuel is sufficient.

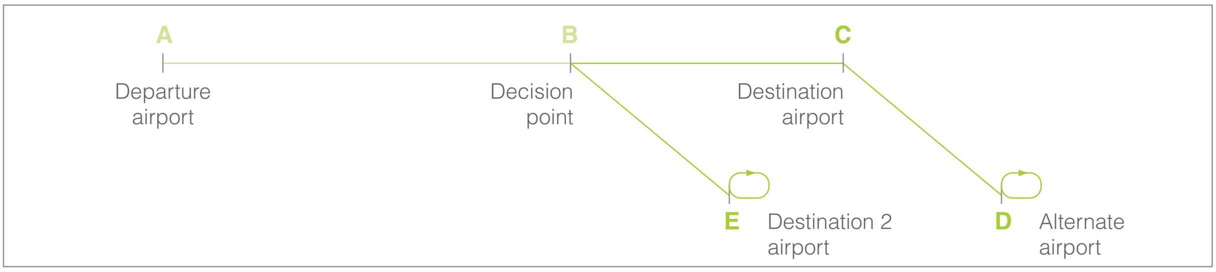
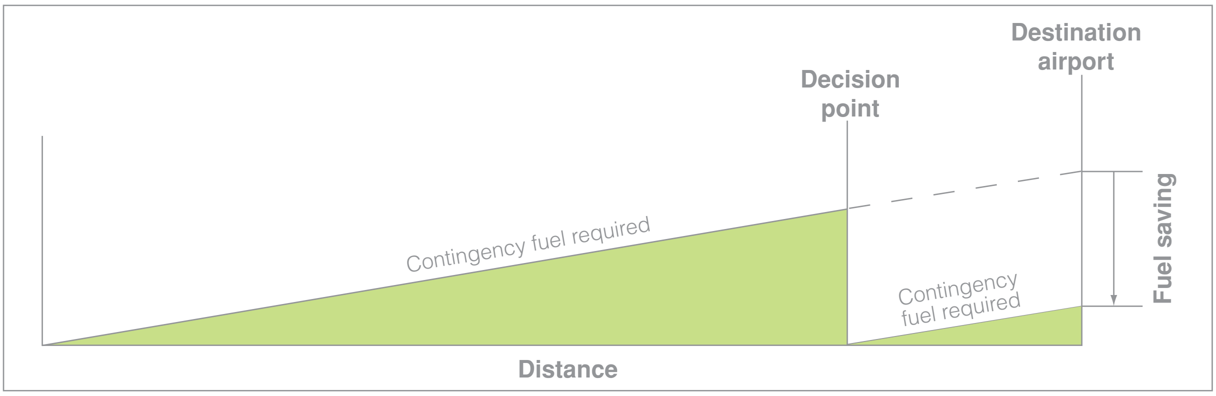


Figure A5: Decision point procedure

Comparing the standard fuel planning and the decision point procedure fuel planning, the maximum contingency fuel reduction is 5% of the trip fuel between departure airport A and decision point B.



2.2. Tankering fuel

The normal message regarding fuel burn is that it is more economical to carry the minimum amount required for the sector. However there are occasions when it is economic to carry more fuel. This is when the price of fuel at the destination airfield is significantly higher than the price at the departure airfield.

However, since the extra fuel on board leads to an increase in fuel consumption the breakeven point must be carefully determined.

$$K \text{ is the transport coefficient: } K = \frac{\Delta\, TOW}{\Delta\, LW}$$

The addition of one ton to the landing weight, means an addition of K tons to the take-off weight. For instance, if K=1.1 and 550 kg fuel is added at the departure, 500 kg of this fuel amount will remain at the destination. So carrying half a ton of fuel costs 50 kg fuel more.

Let us consider the example of the reference 300Nm trip performed with an ATR 72-500.

Flight conditions	Airline Policy	TOW (tons)	LW (tons)	K
Standard	Mini time	20 16	19.21 15.28	1.018
	Mini fuel	20 16	19.12 15.14	1.005

Table A4: Transport coefficient for a 300Nm trip with an ATR72-500

On ATR aircraft, the transport coefficient is actually very low, and even lower in case of a mini fuel policy. That means that almost all of the extra fuel carried will be recoverable at destination.

Tankering fuel may be valuable when a fuel price differential exists between two airports.

- **The extra-cost of the loaded fuel at departure is:**
  Extra fuel weight × departure fuel price: $\Delta TOW \cdot P_{departure} = K \cdot LW \cdot P_{departure}$
- **The cost saving of the transported fuel is:**
  Transported fuel × arrival fuel price: $LW \cdot P_{arrival}$
- **The cost due to a possible increase in flight time is:**
  Flight time increase × cost per hour: $T \cdot C_h$

It is thus profitable to carry extra fuel if the cost saving exceeds the extra fuel loaded cost plus the extra time cost.

That is to say: $\Delta LW \cdot P > K \cdot LW \cdot P + T \cdot C$

$$\Delta LW \, (P - K \cdot P) - T \cdot C > 0$$

Therefore, if $\Delta T = 0$, it is profitable to carry extra fuel if the arrival fuel price to departure fuel price ratio is higher than the transport coefficient K.

$$\frac{P_{arrival}}{P_{departure}} > K$$

3. Cruise performance monitoring

In order to avoid unnecessary fuel weight, the flight must be planned very precisely to calculate the exact fuel quantity to be embarked. Flight planning should be based on aircraft performance monitoring by taking into account performance factors derived from specific range variations.

In case of excessive fuel flow, or drag increment detected through the monitoring of the performance, an investigation can be carried out to determine their causes. Then the appropriate maintenance corrective action (surface clean up, engine wash…) can be done to improve the aircraft performance.

The Module 5 of the FOS, Cruise Performance Monitoring (CPM), is a valuable tool to assess the possible deviation in aircraft performance and to monitor the drag trend. It brings better insight to the airline analysts to identify engine performance degradation or fuselage drag. The CPM module enables comparison of aircraft cruise performance, mainly torque, fuel flow and IAS, measured in flight with theoretical data computed by the FOS.

For aircraft fitted with the Multi Purpose Computer (MPC), the parameters are recorded automatically during the stabilised cruise phase and stored in the PCMCIA card of the MPC. The downloading of the “Cruise report” files into FOS is then easily achieved by inserting the card in a laptop. A manual mode for data entry is available for other aircraft where the measurements are to be performed by the crew.

B. Flight management

The following paragraphs describe some applicable procedures that lead to fuel economy. Though, be careful that before applying those procedures, the changes induced to the flight management have to be studied and the SOP updated accordingly.

1. Hotel mode

When the aircraft stands at the ramp, in hotel mode, the fuel consumption is 110kg/hour for the PW127 engine. When the airport facilities allow it, the use of the GPU to deliver the required power supply on ground is fuel economical.

2. Taxiing

Good estimate of taxi times are required. Actual times need to be monitored and standard estimates changed as necessary. Engine performance is optimised for flight conditions, but all aircraft spend considerable time on the ground taxiing from the terminal out to the runway and back. This leads to a waste of precious time and fuel.

To optimise the taxiing distances, the flight crew shall choose to reach and leave the runway from intermediate taxiways when the entire runway length is not necessary according to the take-off and landing performance calculations.

2.1. Taxi procedure at take-off

The standard procedure recommended by ATR requires two-engines taxiing. Indeed, even if fuel economical, taxiing with one engine has the following disadvantages:

- this procedure is not recommended for uphill slopes or slippery runways
- no fire protection from ground staff is available when starting engine away from the ramp
- mechanical problems can occur during start up of the other engine, requiring a gate return for maintenance and delaying departure time.

2.2. Taxi procedure at landing

FCOM procedures require not less than a defined time before shutting down the engine after landing. The cool-down time after reverse operation, prior to shut down has a significant effect on engine life.

It is thus recommended that once the runway is cleared, engine 1 is feathered, and that once the appropriate cooling time has expired, it is shut down, even if the parking stand has not been reached.

When taxiing with one engine shut down, the electrical supply of the hydraulic system is done by one engine only. Some precautions have thus to be taken to check that the whole hydraulic system, notably in charge of the braking and the steering, remains correctly supplied by the remaining engine. The SOPs have to be changed accordingly. Besides, those procedures are absolutely not recommended in case of uphill slopes or slippery runways.

3. Climb

Depending on speed laws, the climb profiles change. The higher the speed, the lower the climb path, the more time spent at low flight level, the longer the climb distance and the more fuel burnt.

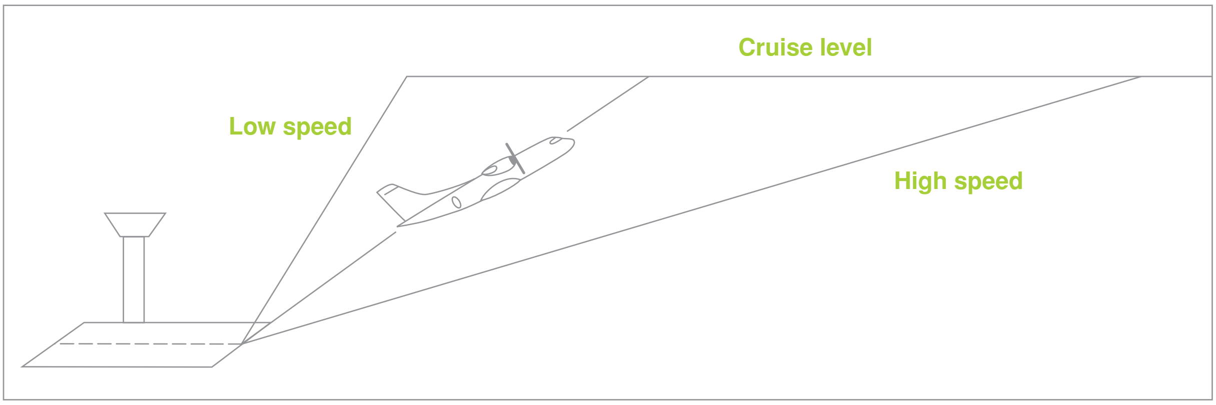


Figure B1: Climb profiles

In the FCOM, two climb speeds are proposed: 170kts and 190kts. The difference in fuel consumption between a low-speed and a high-speed climb to a fixed cruise level is valuable.

The fuel economy for a climb to FL180 between a 170kts-climb and a 190kts-climb is up to 58kg with an ATR 72-500 which represents an economy of 26% of the fuel used during the climb phase.

CLIMB 2 ENGINES - NP=86%

ISA — MINIMUM CLB RATE = 300 FT/MN — 170KT (IAS)

FL	WEIGHT AT START OF CLIMB (1000KG) 18	19	20	21	21.5
250					
240	24 290 86 216				
230	21 262 74 212	23 290 83 213			
220	19 239 65 209	21 263 72 209	23 291 80 210		
210	17 219 57 206	18 240 63 206	20 264 70 207	22 292 77 207	24 307 82 207
200	15 201 51 203	16 220 56 203	18 241 61 204	20 265 68 204	21 278 71 204
180	12 170 40 198	13 185 44 198	15 202 48 199	16 220 53 199	17 230 55 199
160	10 144 32 194	11 156 35 194	12 169 38 194	13 184 42 194	13 192 43 194
140	8 120 26 190	9 130 28 190	10 141 30 190	10 153 33 190	11 159 34 190
120	6 99 20 186	7 107 22 187	8 115 24 187	8 124 25 187	8 129 26 187
100	5 78 15 183	5 84 16 183	6 91 18 183	6 98 19 183	7 102 20 183
80	4 59 11 180	4 63 12 180	4 68 13 180	5 73 14 180	5 76 14 180
60	2 40 7 177	3 43 8 177	3 46 8 177	3 50 9 177	3 52 9 177
40	1 22 4 174	1 24 4 174	2 25 4 174	2 27 5 174	2 28 5 175
15	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0

FROM START OF CLIMB TIME (MIN) — FUEL (KG)
FROM START OF CLIMB DIST. (NM) — MEAN SPEED TAS.(KT)

CLIMB 2 ENGINES - NP=86%

ISA — MINIMUM CLB RATE = 300 FT/MN — 190KT (IAS)

FL	WEIGHT AT START OF CLIMB (1000KG) 18	19	20	21	21.5
250					
240					
230					
220					
210					
200	20 263 75 229	22 290 83 229			
180	15 214 57 223	17 233 62 223	18 255 68 223	20 278 75 224	21 291 78 224
[illegible]	12 176 [illegible]	13 191 48 218	14 208 52 218	16 225 57 218	16 235 59 218
[illegible]	[illegible]	11 157 37 213	11 169 41 213	12 183 44 213	13 191 46 213
120	[illegible] 27 209	8 126 29 209	9 136 31 209	10 147 34 209	10 152 35 209
100	6 91 20 205	6 98 21 205	7 106 23 205	7 114 25 205	8 118 26 205
80	4 68 14 201	5 73 15 202	5 78 16 202	5 84 18 202	5 87 18 202
60	3 46 9 198	3 49 10 198	3 53 11 198	3 57 11 198	4 59 12 198
40	2 25 5 195	2 27 5 195	2 29 6 195	2 31 6 195	2 32 6 195
15	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0

FROM START OF CLIMB TIME (MIN) — FUEL (KG)
FROM START OF CLIMB DIST. (NM) — MEAN SPEED TAS.(KT)

58kg fuel saved for a climb at low-speed

Table B1: Fuel consumption for different climb profiles for an ATR72-500

4. Cruise

In cruise, the torque set automatically by the power management corresponds to the maximum cruise rate. The use of a derated cruise torque, which corresponds to a long-range torque, is advisable in order to save fuel. The fuel economy done between a long-range and a max cruise is estimated in Table 3: Reference cases for the fuel consumption.

The condition to use a derated cruise power is that the corresponding cruise tables for IAS, TAS, TQ, FF are provided to the flight crew and that the operational procedures warn the fact the power lever is set out of the notch and that the torque management is no longer automatic.

The Module 2 of the FOS, In-flight performance, enables to compute twin or single-engine cruise performance charts, with the desired optimum cruise speed. The charts edited are similar to the ones published in the FCOM.

Another means to save fuel is to shorten the cruise routes. This can be achieved by asking Air Traffic Control for direct routings whenever possible in cruise.

5. Descent

There are two main parameters to act on when willing to lower the fuel burnt for the descent: the speed and the descent gradient whose combination determines the thrust required. The influence of both parameters is developed in the following paragraphs, and some recommendations are done to optimize at most the fuel consumption.

Whatever the type of descent chosen, a decisive point to consider during the flight management is to optimize the Top Of Descent (TOD) in order to reach the approach altitude as close as possible to the initial approach point to avoid leveling off far before this point, which is an important waste of fuel.

5.1. Steep descent

The normal procedure for a descent is to select 3° descent slope and to maintain the IAS by adjusting the thrust. Descending at a higher slope enables to save fuel, as less thrust is required for the descent. The TOD occurs later and the flight at cruise flight level is longer.

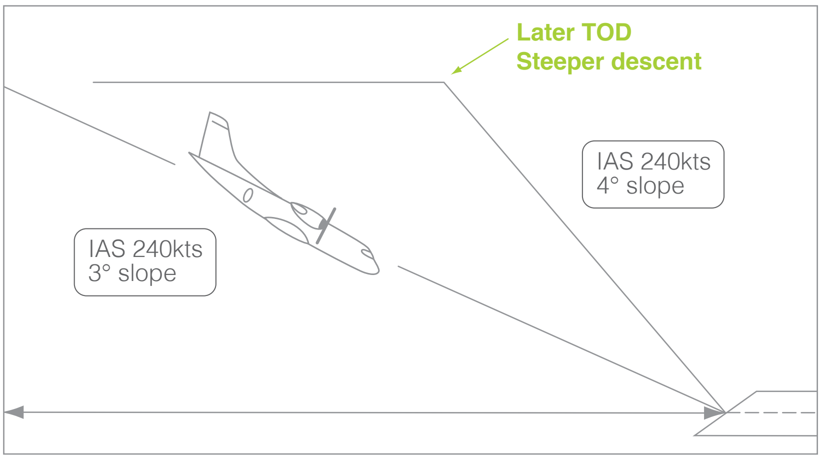


Figure B2: Descent profiles at given IAS

Besides, at a given gradient of descent, the slower the IAS selected, the less fuel is burnt during the descent, as less thrust is required.

DESCENT 2 ENGINES

NP=86%

15000KG — NORMAL CONDITIONS

FL	200KT 3°	200KT 4°	200KT 5°	220KT 3°	220KT 4°	220KT 5°	240KT 3°	240KT 4°	240KT 5°
250	21 141 / 74	17 100 / 55	14 74 / 44	20 159 / 74	16 108 / 55	13 81 / 44	18 176 / 74	15 122 / 55	12 89 / 44
240	21 138 / 71	16 98 / 53	14 72 / 42	19 154 / 71	15 106 / 53	13 79 / 42	18 171 / 71	14 118 / 53	12 87 / 42
230	20 134 / 68	16 96 / 51	13 71 / 40	19 150 / 68	15 103 / 51	12 78 / 40	17 166 / 68	14 115 / 51	12 85 / 40
220	19 131 / 64	15 94 / 48	13 70 / 39	18 146 / 64	14 101 / 48	12 76 / 39	17 160 / 64	13 112 / 48	11 83 / 39
210	19 127 / 61	15 92 / 46	12 68 / 37	17 141 / 61	14 98 / 46	12 75 / 37	16 155 / 61	13 108 / 46	11 81 / 37
200	18 123 / 58	14 89 / 44	12 67 / 35	17 137 / 58	13 95 / 44	11 73 / 35	16 149 / 58	12 105 / 44	11 79 / 35
180	17 115 / 52	13 84 / 39	11 64 / 31	15 127 / 52	12 89 / 39	10 69 / 31	14 138 / 52	12 98 / 39	10 74 / 31
160	15 106 / 46	12 79 / 34	10 60 / 27	14 117 / 46	11 83 / 34	10 65 / 27	13 127 / 46	11 91 / 34	9 69 / 27
140	14 97 / 39	11 73 / 29	9 57 / 24	13 106 / 39	10 76 / 29	9 60 / 24	12 115 / 39	10 83 / 29	8 64 / 24
120	12 87 / 33	10 67 / 25	8 53 / 20	11 95 / 33	9 69 / 25	8 56 / 20	11 102 / 33	9 75 / 25	8 59 / 20
100	10 77 / 27	9 60 / 20	7 48 / 16	10 83 / 27	8 62 / 20	7 51 / 16	9 89 / 27	8 67 / 20	7 53 / 16
80	9 66 / 20	7 53 / 15	6 43 / 12	8 70 / 20	7 54 / 15	6 45 / 12	8 75 / 20	7 57 / 15	6 47 / 12
60	7 54 / 14	6 45 / 11	5 38 / 8	7 57 / 14	6 45 / 11	5 39 / 8	6 60 / 14	6 48 / 11	5 40 / 8
40	5 41 / 8	5 36 / 6	4 32 / 5	5 43 / 8	5 36 / 6	4 33 / 5	5 45 / 8	4 38 / 6	4 33 / 5
15	3 24 / 0	3 24 / 0	3 24 / 0	3 24 / 0	3 24 / 0	3 24 / 0	3 24 / 0	3 24 / 0	3 24 / 0

FROM START OF DESCENT TIME (MN) FUEL (KG)
FROM START OF DESCENT DIST (NM)

51kg fuel less for a descent at a steeper gradient

TOD reached 17Nm later

23kg fuel saved for a slower descent

The steeper descent means remaining in cruise power longer until the TOD is reached, thus increasing the cruise fuel consumption. However, the fuel saved during the descent, as shown in Table 8, is more important than the fuel required to cruise longer, and on the whole, there is a noticeable fuel reduction.

Table B2: Fuel consumption for different descent profiles for an ATR72-500

Flight conditions	Airline Policy	Trip fuel (kg)	Delta (kg)	Delta (%)	Trip time	Delta (min)	Descent IAS (kts)	Delta TOD (Nrm)	Cruise FL
Steep descent 4° slope	Mini time	894	–5	–0.6	1h16	+0	240	+13	180
	Mini fuel	813	–13	–1.3	1h21	+1	240	+17	230

Table B3: Fuel saving for a 300Nm trip with ATR72-500 with a steeper descent profile

5.2. Low-thrust descent

To optimize at most the fuel consumption during the descent, the torque should theoretically be reduced until the thrust is nil. In this case the propeller is said to be transparent, i.e. the propeller drag is reduced to the minimum achievable with a rotating propeller.

The associated operating procedure is to select a speed and a gradient for descent that requires low thrust to maintain them, which means a lower descent torque than the one for standard procedure.

Let us take the example of the reference 300Nm trip performed with an ATR 72-500.

A descent performed at 4°descent slope and IAS 200kts selected requires low TQ and allows important fuel saving compared to the same descent in standard conditions.

The low thrust descent is even more fuel economical than the steep descent when comparing the following values with the one from Table 9. However it can lead to operational limitation, as the speed selected for descent is too low to fit in with the local airport traffic.

Flight conditions	Airline Policy	Trip fuel (kg)	Delta (kg)	Delta (%)	Trip time	Delta (min)	Descent IAS (kts)	Delta TOD (Nrm)	Cruise FL
Low-trust descent	Mini time	880	–19	–2.1	1h16	+1	200	+13.1	180
4° slope	Mini fuel	793	–33	–4.0	1h23	+3	200	+17.3	230

Table B4: Fuel saving for a 300Nm trip with ATR72-500 with a low thrust descent profile

6. Approach

At landing, providing that the particular country's regulations permit, and when wind conditions allow it, the flight crew can request to the Air Traffic Control to change the QFU to shorten the approach procedure. Besides, visual approaches are generally shorter than instrument ones. The former have thus to be chosen in priority.

7. How to perform an ecological trip

When combining all the positive effects on fuel consumption detailed in the previous flight preparation and flight management parts, the resulting fuel saving is considerable. The following figure shows how the adoption of ecological reflexes can lead to great fuel economy.

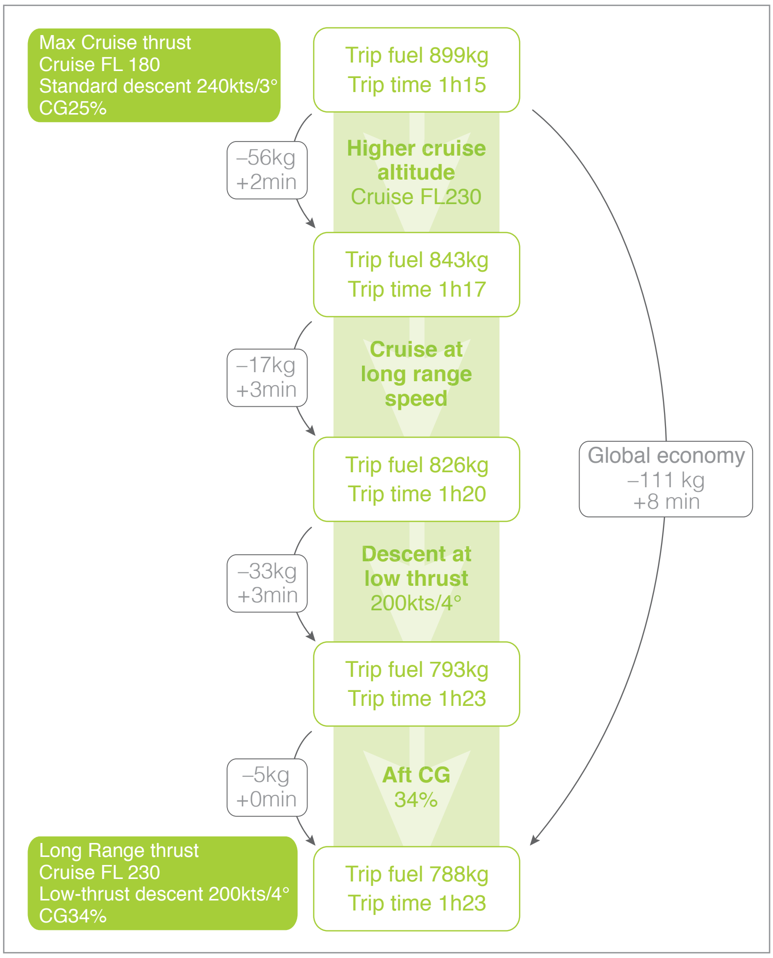


Figure B3: Fuel saving for a 300Nm ecological flight with an ATR 72-500

The same calculations have been carried out for ATR 42-500 on the same route, with TOW=18t.

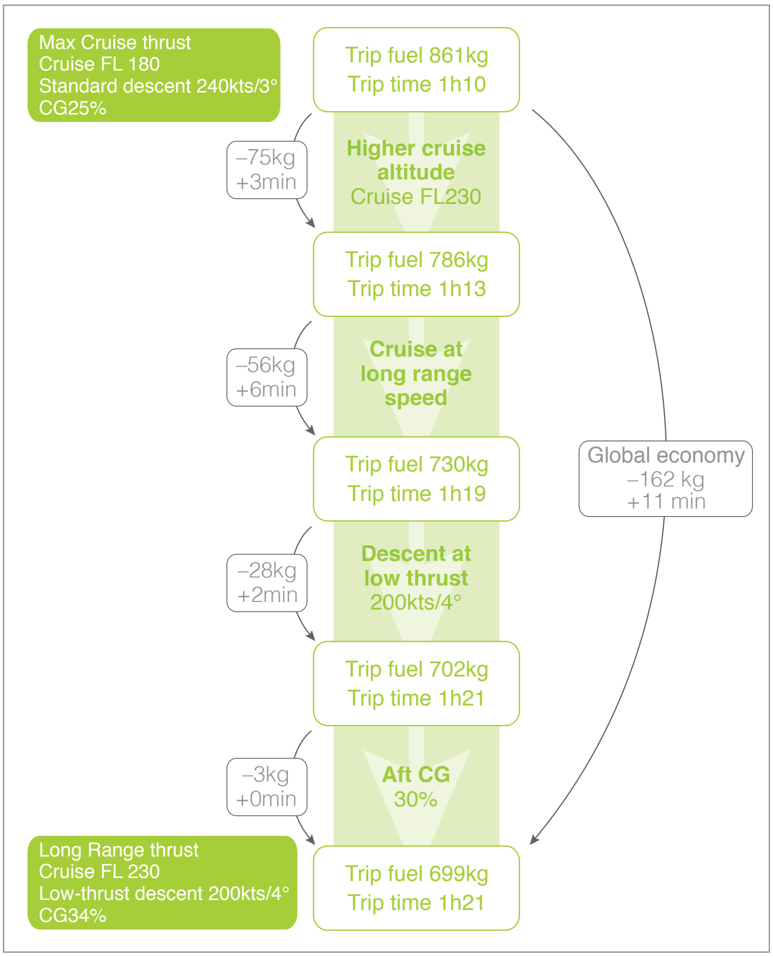


Figure B4: Fuel saving for a 300Nm ecological flight with an ATR 42-500

In addition to those actions, other economies can be done during the ground phase, when parked at the ramp or when taxiing, especially at congested airports.

C. Maintenance

1. Implications of dispatching under MEL and CDL

Operators are provided with a Master Minimum Equipment List (MMEL) that is the basis for their MEL (Minimum Equipment List).

The MEL is a valuable tool for optimizing dispatch reliability because it defines the conditions under which the aircraft may be dispatched with specified equipment inoperative. The conditions include the period during which the aircraft can be operated with the system inoperative and, in some cases, requirements for additional fuel load.

The Configuration Deviation List (CDL) in chapter 7 of the Aircraft Flight Manual (AFM) also allows the aircraft to be dispatched with specified components not fitted. All components must be re-installed at the earliest maintenance opportunity (nominally within 1 week, subject to local airworthiness authority approval). For items whose loss or failure will bring a fuel consumption penalty it is beneficial to make special efforts to replace them as soon as possible.

The following table indicates the MMEL and CDL items that will have a noticeable negative impact on fuel cost.

System / Component	MMEL Condition	Remarks
21-23-1 Overboard valve	Flight level is limited to FL 170	No flight level optimization for the trip fuel calculation
21-23-2 Underfloor valve	Flight level is limited to FL 170	No flight level optimization for the trip fuel calculation
21-23-3 Extract Fan	Flight level is limited to FL 170	No flight level optimization for the trip fuel calculation
21-30-1 Pressurization system	Maximum operating altitude 10 000 ft	High fuel consumption due to low flight altitude
21-50-1 Packs	Flight level is limited to FL 170	An in-flight failure could imply total loss of pressurization; fuel consumption at FL100 must be taken into account to compute the trip fuel.
21-61-1 Pack Auto temperature controls		If pack is not used, an in-flight failure could imply total loss of pressurization, fuel consumption at FL100 must be taken into account to compute the trip fuel.
28-23-1 X feed valve		Alternate route study must be performed taking into account the lowest tank value only.
32-31-3 Landing gear lever retraction system and uplocking system	Flight with landing gear down	
31-48-1 MFC module 2A	Flight level is limited to FL 170	No flight level optimization for the trip fuel calculation
36-11-2 Bleed valves	Flight level is limited to FL 170	An in-flight failure could imply total loss of pressurization; fuel consumption at FL100 must be taken into account to compute the trip fuel.

Table C1: MEL items impact on fuel consumption

System / Component	CDL Items	Remarks
32-1, 1bis, 3 & 4	Main gear door	Increased drag
32-2	Nose gear forward door	Refer to 32-31-3 in MEL
52-1 to 9	Doors	Increased drag
61-1	Propeller spinner	Decreased efficiency Increased drag
79-1	Engine oil cooler flap	Refer to 32-31-3 in MEL

Table C2: CDL item impact on fuel consumption

2. Airframe maintenance

The airframe is a complex shape and includes many panels, doors and flight control surfaces.

In order for the aircraft to perform at its optimum efficiency (i.e. to create the lowest amount of drag), the airframe must be free from any irregularities. This means that surfaces should be as smooth as possible, panels and doors should be flush with surrounding structure and all control surfaces should be rigged to their specified positions.

Deterioration of the aircraft's external surface is a normal consequence of its use. One objective of the maintenance schedule is to preserve aircraft's operational efficiency by the most economic means possible. This is achieved through inspection, and subsequent repair as necessary, in specified areas at specified intervals. These intervals are the minimum allowable and the industry is constantly seeking to extend all task intervals. Carrying out any maintenance task more regularly will inevitably increase maintenance costs. However, in this section we consider tasks that can bring considerable reductions in fuel consumption when the need for repair is discovered.

In terms of overall airframe condition (dents, panel gaps, under or over filled panel joints, etc…) particular attention should be paid to areas of the airframe that air impinges on first (e.g. forward portion of the fuselage, the nacelles, the wings, the fin, etc).

The following sections highlight airframe problems that are both typical in-service and have a particularly negative impact on aerodynamic performance.

2.1. Flight controls

Correct rigging of all flight control surfaces is important to aerodynamic efficiency. Specific caution should be paid to the spoiler on upper surface indeed. These flight controls are only occasionally deployed during the flight, but are fitted to areas of the wing that are particularly sensitive to imperfections. Such imperfections occur when a spoiler is not flush with the wing profile. The effect on aircraft performance varies with the size of the gap.

Refer to:

- Adjustment of aileron control — JIC 27-10-00-ADJ-10000
- Adjustment of rudder control — JIC 27-20-00 ADJ-10000
- Adjustment of elevator control — JIC 27-30-00 ADJ-10000
- Adjustment of flap control — JIC 27-51-00 ADJ-10000
- Adjustment of spoilers control — JIC 27-61-00 ADJ-10000

2.2. Wing root fairing panel seals

The aircraft exterior transitions, between the wing root and the fuselage are performed via many fairing panels. These panels are not part of the aircraft's primary structure but they perform an important role in managing the airflow in this aerodynamically critical area. Flexible seals, which are sometimes referred to as "Karman seals", cover gaps between the panels and the adjacent wing or fuselage structure.

Refer to:

- Removal and installation of wing-to-fuselage fairing — JIC 53-93-00 RAI 10000

2.3. Moving surface seals

Gaps between the various sections of the aircraft's structure can disrupt local airflow and this will generate unnecessary drag, and have a consequent impact on fuel consumption. Flexible seals are often used to fill external gaps between moving surfaces and access panels and their surrounding structure.

The effect on fuel consumption of moving surface seals that are often found missing or damaged in-service, has a particularly negative impact on aerodynamic performance.

2.4. Doors, landing gear doors, main landing gear fairing and engine cowls

Mis-alignment or mis-rigging on any doors and main or nose landing gear door will lead to unnecessary drag being generated.

Refer to:

- Pax/crew door adjustment — JIC 52-11-00-ADJ-10000
- Flt compt ovhd hatch adjustment — JIC 52-22-00-ADJ-10000
- Pax compt emer exit adjustment — JIC 52-21-00-ADJ-10000
- Cargo door adjustment — JIC 52-31-00-ADJ-10000
- Service door adjustment — JIC 52-42-00-ADJ-10000
- MLG doors adjustment — JIC 52-81-00-ADJ-10000
- NLG doors adjustment — JIC 52-82-00-ADJ-10000

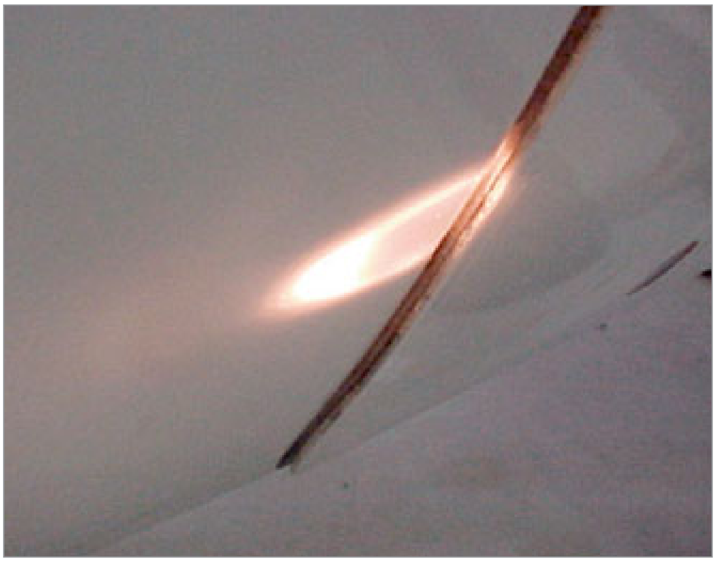


Figure C1: Example of misrigged door

2.5. Door seal

The passenger, service and cargo doors seals serve a dual function.

These seals not only fill the gap between the door and its surrounding structure but they also render the door airtight. This allows the aircraft to be pressurized efficiently. A damaged, leaking seal allows pressurized cabin air to escape in a direction perpendicular to the fuselage skin. The effect on the local airflow can be quite significant.

2.6. Paint condition

Deterioration of the aircraft's exterior surface is to be expected on any aircraft in service.

The rate of deterioration can vary with the intensity of the utilization and environmental conditions. Although the thickness of paint is typically around 1/3 millimeter its loss in critical areas of the airframe will upset the local airflow to an extent that overall drag can be increased. Particular attention should be paid to the nose and cockpit area and the wing upper and lower surfaces.

2.7. Aircraft exterior cleaning

The natural accumulation of dirt on the aircraft's external surface will introduce a slight roughness that, overall, can induce significant additional drag.

Refer to: › Aircraft exterior cleaning JIC 12-21-11-CLN-10000

2.8. Airframe repair

Damage to the airframe, due to impact during handling or taxi, or following collision with birds, have to be repaired. These repairs generate some additional drag, and add some extra load.

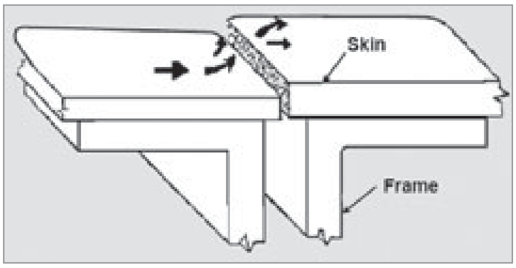


Figure C2: Steps and Gaps at skin joints

Figure C3: Example of repair on the airframe

3. Engine maintenance

An enhanced relationship between pilots and maintenance crews can be very beneficial towards engine durability. The proper engine handling behaviors will reduce the maximum or sustained engine temperatures towards increased hot section life. Some airlines have implemented yearly meetings/training with pilots to enhance awareness and increase collaboration.

During normal operations all engines will experience rubbing, thermal stress, mechanical stress, dirt accumulation, foreign object ingestion and so on. These effects will eventually result in a measurable decrease in performance.

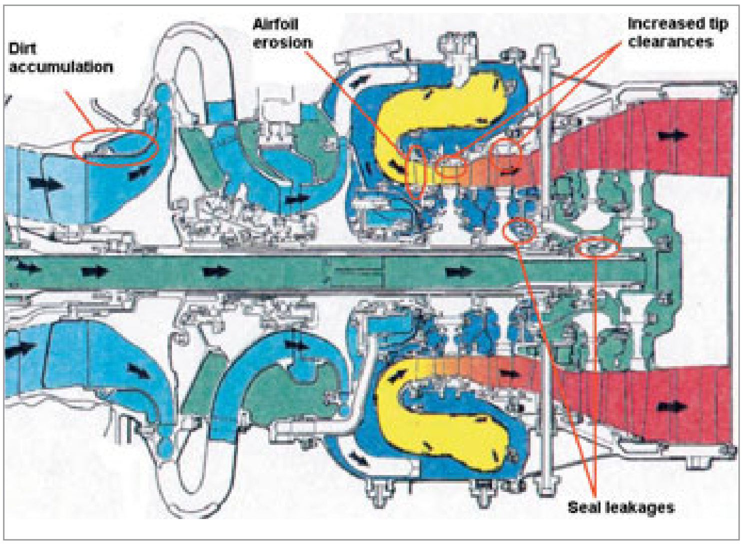


Figure C4: Example of engine degradations

Typical indicators of engine performance are:

- interturbine temperature (ITT) increases as engine efficiency decreases. More fuel is required to achieve a given power. An increase in fuel required will typically produce an increase in ITT. Monitoring ITT margin at take-off is a good indicator of engine deterioration. This can easily be done using data recorded during the flight that is subsequently processed on the ground by engine condition trend monitoring software.
- Specific Fuel Consumption (SFC) also typically increases as engine efficiency declines (again, due to the need for more fuel to achieve a given power). This SFC degradation has a direct impact on aircraft performance in terms of Specific Range and thus on the fuel burnt for a given mission.

The degradation of parameters and the consequences for fuel consumption must be balanced against the significant costs that will be incurred when the engine is eventually removed from the aircraft for overhaul. The moment of the engine's overhaul may be postponed through careful maintenance of the engine while it remains on wing.

When the time to remove the engine arrives, the extent and cost of the overhaul and refurbishment must be carefully balanced against the improvements in ITT margin and fuel consumption it will bring. These aspects should be carefully assessed and regularly reviewed with the engine manufacturer or using the services of one of the many third party engine support companies.

Routine monitoring of engine and aircraft performance using the tool provided by the engine manufacturer and Cruise Performance Monitoring software (see § A. 3 Cruise performance monitoring) will not only allow long-term performance degradation to be assessed but also permit detection of unexpected shifts in engine/aircraft performance. Timely detection will allow appropriate maintenance actions to be launched and minimize any additional fuel consumption associated with the problem.

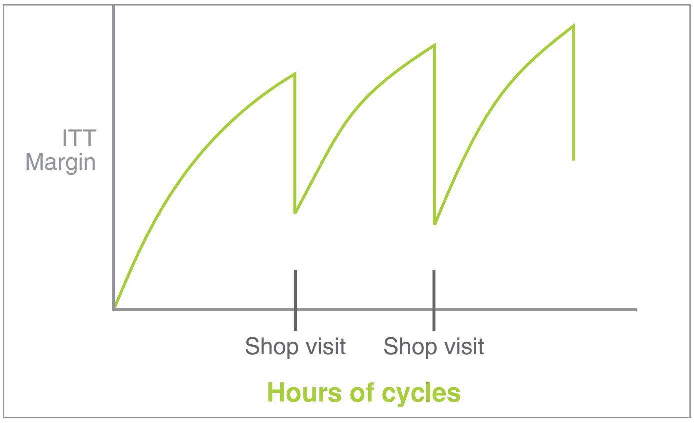


Figure C5: Recovery of the ITT margin, after shop visits

The Performance Recovery Wash is a valuable fuel saving method that should be considered for all operations.

This method uses cleaning agents to wash gas path components followed by a thorough rinse. The purpose is to remove baked-on deposits in environments with severe air contaminants. The benefits are a small recovery of ITT margin (typically 5 to 8°C) but, more importantly, reducing the accumulation of baked-on deposits with proper wash frequency i.e. continuously remove small build-ups. The frequency is a function of environment / mission and varies in the field from bi-weekly to monthly or more.

Typically, operators in harsh environments will have a higher frequency and complement with other washing methods. Operators in benign environments tend not to implement this wash method in their program. As a small recovery of ITT margin is expected, some operators also perform this wash near the end of the hot section life to further extend time-on-wing.

Engine washing is labor intensive and the washing method(s) and frequency need to be adjusted by trial and error to optimize the investment in consideration of hot section life.

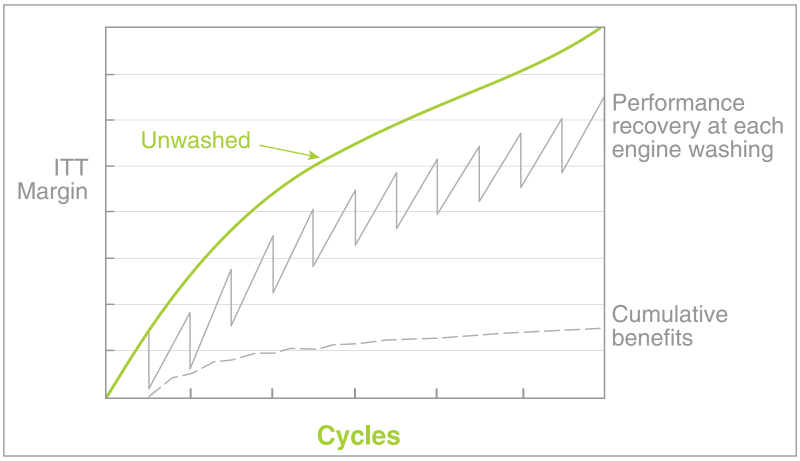


Figure C6: Performance recovery after engine washing

For further information on the engine wash, refer to the Pratt&Whitney Maintenance Manual chapter 72-00-00 Engine Cleaning/Painting.

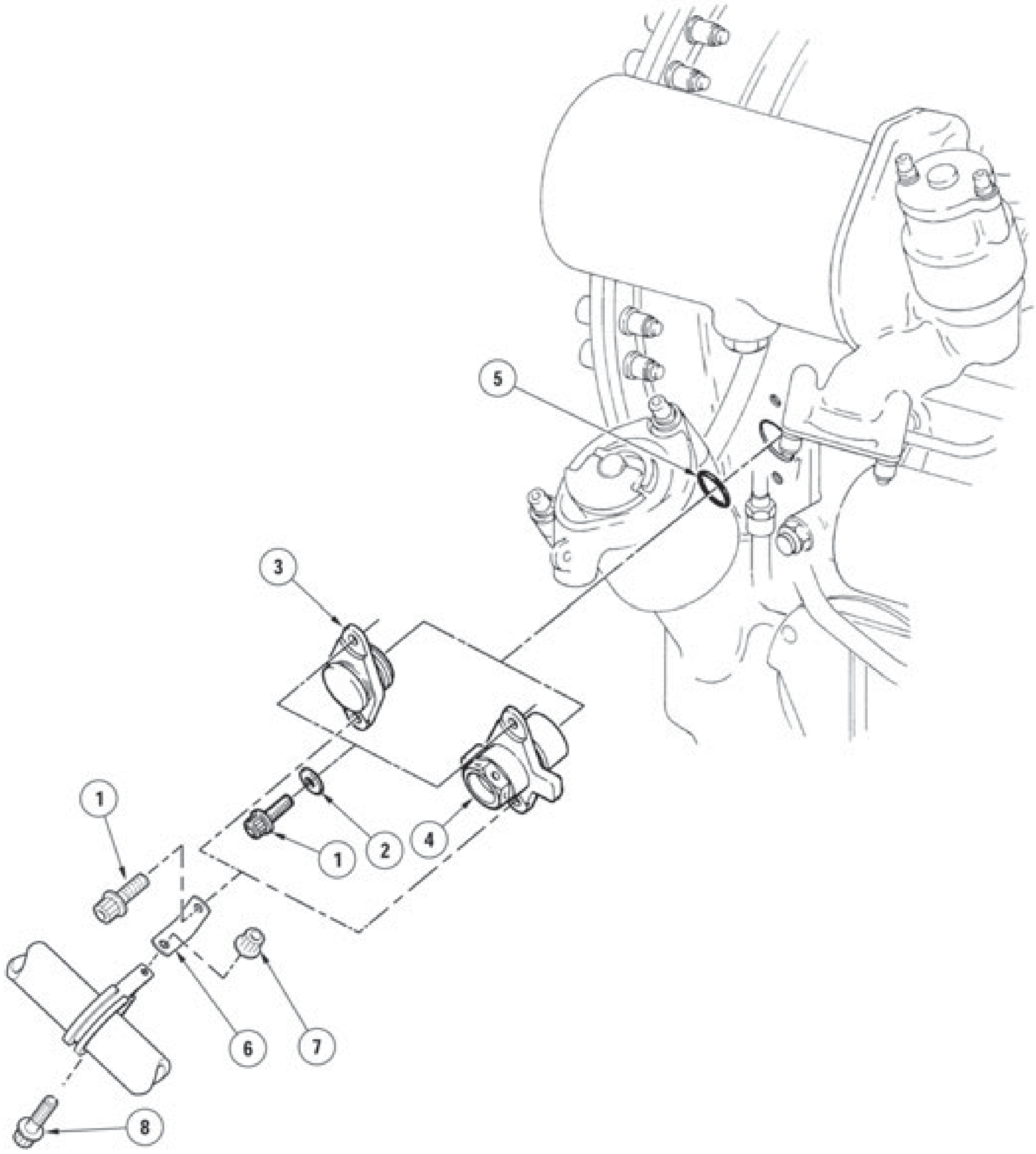


Figure C7: Wash nozzle connection

4. Systems maintenance

Repair of the leaking on the pneumatic system and deicing systems, saves fuel.

Problems of leaks are identified with the aircraft performance monitoring software (FOS module 5).

Refer to: ‣ Check of bleed duct tightness JIC 36-11-00-CHK-10000

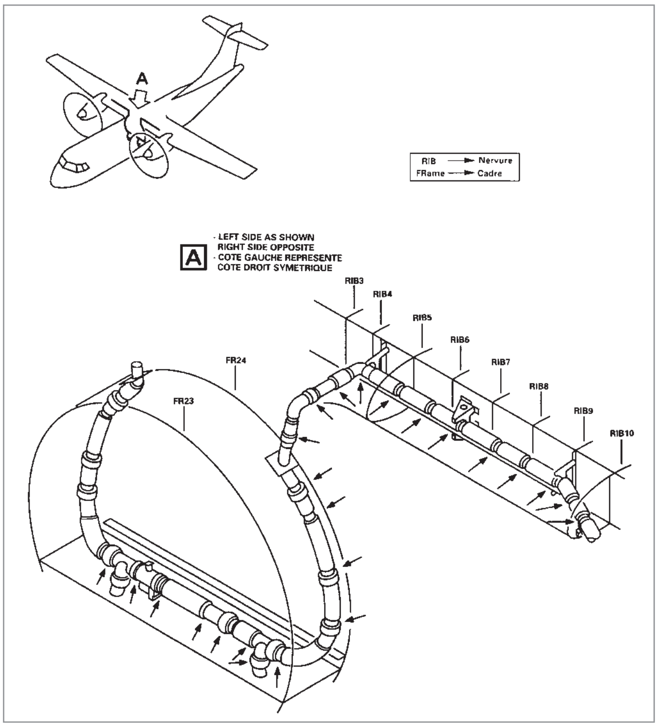


Figure C8: leak inspection of the pneumatic duct

Refer to: ‣ Operational test of regulator and shut off valve by using fire handle JIC 30-11-61-OPS-10000

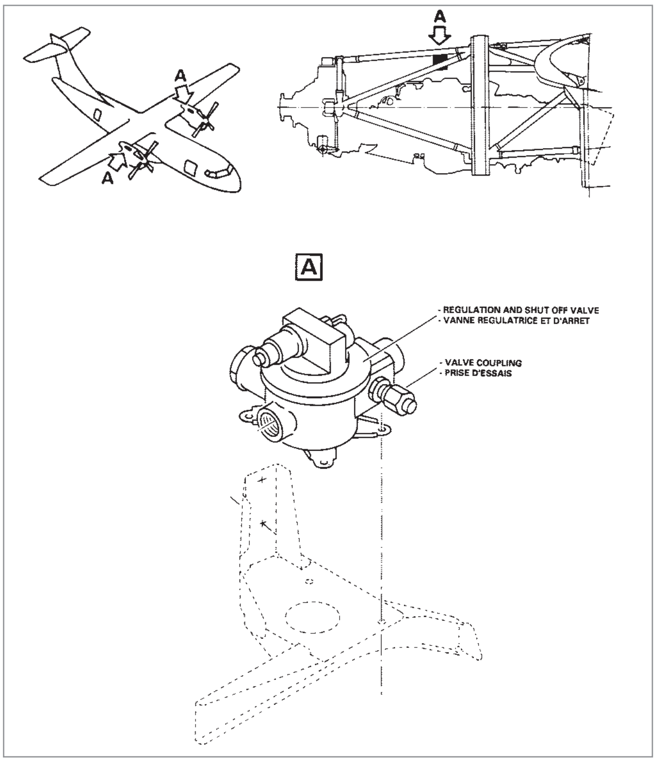


Figure C9: Test port on the deicing valve

Conclusion

There are many factors that influence the fuel used by aircraft, and this report highlights how a combined effort of the different actors of the airline, flight dispatchers, pilots and maintenance engineer, can lead to considerable saving on the fuel burnt each year by an airline, and thus minimizing the environmental impact of their fleet.

ATR has made the choice of advanced technologies providing fuel-efficient aircraft to the airline which is consistent with its willing to reinforce its contribution to ensure a sustainable future for the air transport.

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