
EMBRAER
EXTENDING
ENGINE
LIFE

EMB145

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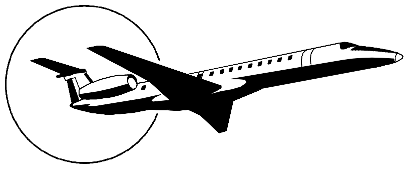

EXTENDING ENGINE LIFE

EMPRESA BRASILEIRA DE AERONÁUTICA S.A.

THIS DOCUMENT HAS BEEN PREPARED AS AN INFORMATIVE GUIDE TO ASPECTS OF ENGINE OPERATION. IT APPLIES TO ALL AE3007 ENGINE MODELS. IT DOES NOT SUPERSEDE OR REPLACE THE APPROVED AFM PROCEDURES INFORMATION. USE OF THE MATTER PUBLISHED HEREIN IS OPTIONAL. IT SHOULD NOT BE CONSTRUED THAT PROCEDURES PREVAIL OVER THE AFM INFORMATION.

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INTRODUCTION

Experience has shown that there is a definite relationship between engine operating (internal) temperature and engine life. One may reduce an engine's life greatly if uniform standards of operation are not established.

Engine manufacturers are able to predict how long the engine parts will last at each thrust rating, and establish thrust levels for the typical operation to which the aircraft will be subjected. That is, the length of time an engine is operated at a thrust rating (and corresponding gas temperatures and rotor speeds) is established to result in a commercially acceptable engine life. Operating the engine above the published operational thrust or inappropriate thrust rating will shorten engine life considerably and will lead to premature engine service difficulties and removals.

It is reasonable to consider an abuse to operate the engine at higher than necessary ITT.
It is strongly recommended that the engines are operated at the lowest possible operating temperature.

Developing the sense that excessive engine internal temperature can shorten engine life considerably, understanding how much engine life can be saved when engine is properly operated, and learning how to avoid excessive temperature will be discussed herein.

PURPOSE

The information contained herein is the result of a joint effort of EMBRAER and Rolls-Royce. It has been published to support the EMB-145 family operators' efforts to reduce engine operating and maintenance costs.

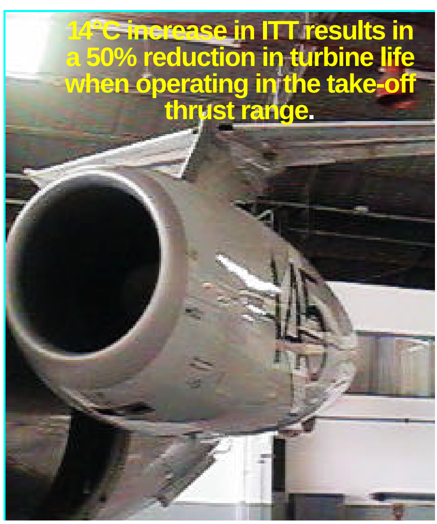
The temperatures and times shown in the examples are taken from real (typical) flights actually flown by airlines. Life saving results are derived from a program developed by Rolls-Royce Design Engineering Group.

A benefit index has been added, whenever applicable, to show importance of a given technique. Benefit Index 1 is considered marginally beneficial and Benefit Index 10 is considered highly beneficial to reduce engine operating and maintenance costs.

EFFECT OF ITT ON ENGINE LIFE

The operating cost of all turbine engines is closely related to engine life, and engine life is directly related to Interstage Turbine Temperature (ITT). For example, a 14°C increase in ITT results in a 50% reduction in turbine life when operating in the take-off thrust range. As is evident, considerable life reduction can result from operating an engine at higher than necessary temperatures for the prevailing conditions.

Wear can be monitored by borescope inspection, or when turbine blades are carefully measured at overhauls. Those blades found out of the prescribed tolerances must be replaced. In service engine condition can also be monitored through trend analysis by comparing the engine performance data with average, known data for a new engine.



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The life reduction impacts the operating cost in two ways: more frequent removals and more extensive maintenance work upon removal. Cost is also impacted by airplane down-time.

Reducing ITT and consequently saving engine life may be achieved by the following:

Engine Starting (Benefit Index: 2)

The cooler the starting, the better. Hot starts are not common in FADEC controlled engines, but whenever they occur they can usually be stopped in time by constantly observing ITT and N2 acceleration. During starting, and at all times, engine instruments must be monitored carefully. If the temperature exceeds the control temperature reference, the FADEC reduces fuel flow, but beware that there is no automatic engine shut-down by the FADEC for overtemperature during starts.

An important consideration is that the bleed source must assist the engine in accelerating to the self-sustaining speed to avoid a hot or hung start. Ground starts assisted by an LPU can result in shorter starts, as LPU bleed is normally at higher pressure and flow than APU's.

Start attempts with high residual ITT at time of fuel introduction into the combustion chamber, or outside the approved starting envelope, may result in hot or hung start.

The engine manufacturer has found that 210°C is a good reference. Starts with residual temperatures lower than 210°C will most likely be successful. The lower the residual temperature the better. Thus, a start with 185°C of residual ITT for example will be completed faster and will have lower ITT's.

Starts with residual temperatures above 210°C at the moment of fuel introduction are much likely to result in a hung start. They may be successful depending on several factors such as altitude, ambient temperature and engine status.

The crew can observe the residual ITT before start commences, but does not know how it will be just prior to light up. As the engine is rotated by the starter, the flow of air through core lowers the residual temperature. Experience shows how cooler (compared to prior to start) the engine is at light up. The operators should establish their own procedures in terms of which prior-to-start residual temperature range is acceptable, based on their operating environments.

Alternate Takeoff (ALT T/O-1) Instead of Takeoff (T/O-1) (Benefit Index: 10)

The AE3007 engine is certified for takeoff at two thrust ratings: ALT T/O-1 and T/O-1.

The ALT T/O-1 rating, which is 90% of maximum rated thrust, is the normal and usual rating to be used for all takeoffs. There will be times when a takeoff in ALT T/O-1 cannot be used due to performance limitations, as for instance, aircraft weight exceeding obstacle, climb or runway limitations, but this should be the exception rather than the rule.

The T/O-1 rating, which is the maximum rated thrust of the engine, is to be selected only when ALT T/O-1 is not usable due to performance constraints.

Engine life degradation in T/O-1 is 4 times that of ALT T/O-1.

As stated above, each 14°C increase in ITT reduces engine life by 50% for that portion of the flight. Normally, ITT in T/O-1 is 28°C hotter than ALT T/O-1, which results in 75% decrease in life (½ x ½ = ¼).

This leads to a conclusion that degradation in T/O-1 is 4 times that of ALT T/O-1. For a 70-minute flight, it means a 21% reduction in engine life considering that both takeoff modes are used during 1 minute.

The Inappropriate Use of the Maximum Continuous (CON) Rating (Benefit Index: 10)

The longer the time or the higher the temperature is, the more life will be reduced. If these two are combined, the reduction in engine life is tremendous.

The ITT increase from CLB to CON is greater than the increase from ALT T/O-1 to T/O-1, which results in increased degradation. Additionally climb and cruise phases last longer, which exposes the engine for a longer period in relation to the takeoff phase.

If CON is used for just 6 minutes during climb instead of CLB, a 37°C increase in ITT may be observed, producing an expected engine life reduction to 39%.

At certain altitudes, CON thrust is 50°C hotter than CLB mode. If this difference is maintained for 6 minutes, engine life would be reduced by 87%. Because using CON is so detrimental to engine life, its use should only be considered in emergencies.

Severe engine deterioration occurs if CON mode is selected. CON should be restricted only to those situations where it is really required.

Maximum Speed Cruise versus Long Range Cruise (Benefit Index: 6)

During cruise, when the Thrust Lever is left at Thrust Set position, the FADEC automatically selects the maximum speed cruise mode if CRZ button is pressed. Placing the Thrust Lever back, out of the Thrust Set position, adjusts a lower N1 and consequently a lower speed. ITT is cooler than that provided during use of the maximum cruise mode. Adjusting N1 manually to the Long Range Cruise setting (refer to the Supplementary Performance Manual tables) causes ITT to be 10°C cooler than the Maximum Speed Cruise setting, which involves some 15% life savings if the cruise phase extends to 33 minutes.

Insignificant engine deterioration takes place at ITT's of 790°C and below. Therefore, operating the engine at 790°C or below whenever possible will extend engine life substantially.

Retarding thrust levers will also save fuel, and will result in cruise phase being extended by 3-7 additional minutes if Long Range Cruise setting is used.

Bleed Utilization (Benefit Index: 5)

Selecting bleed off whenever possible decreases engine operating temperature, resulting in increased engine life.

With bleed off, ITT is from 5 to 10°C cooler than it is with bleed on (for ECS operation) both in ALT T/O-1 and T/O-1 modes, and it can save up to 5% of life. During CLB and CON modes, this difference can reach up to 25°C, and if this punishment is not applied to the engine it can save up to 65% of life.

Bleeding air for anti-icing purposes also increases ITT. Keeping anti-icing on only during flight segments where ice is actually present, i.e. leaving the anti-icing system to operate automatically as it is intended to do, will similarly benefit the engine life.

Sharing bleed equally also optimizes engine life. When bleed is not shared equally, one engine will work harder than the other, with correspondingly higher temperature.

Judicious Use of Reverse (Benefit Index: 10)

Whenever the runway does not require use of the full reverse, setting the proper amount of thrust according to the runway length, or even limiting the use of the reverse to the necessary cases only contributes to engine preservation. However, the operator should evaluate the impact of increased brake usage against the reduced engine operating cost.

To take advantage of the use of thrust reversers, it should be applied at high ground speed soon after touchdown. Applying reverse at low ground speeds may cause exhaust gases to recirculate around the nacelle and re-enter the air inlet, which can result in increased ITT. It can also cause ingestion of fine sand and debris which can damage the engine.

Not using reverse can save up to 18% of engine life.

Calculations to assess the actual benefits of not using reverse thrust on landing run were done. The worst case, in which full reverse was used during 15 seconds, causing a 117°C ITT difference between using and not using reverse, resulted in a 18% life degradation. Consequently, not using reverse can save up to 18% of engine life.

APU Use (Benefit Index: 5)

APU bleed can be used to supply air to the environmental control system, replacing the engines in this job. It can save engine life due to the correspondingly cooler ITT when engine bleed is off.

The operator should evaluate APU fuel consumption increased cost against the reduced engine operating cost to take the proper picture before applying this procedure. It is also important to consider some limitations when operating with only the APU bleed on.

Engine Condition Trend Monitoring (Benefit Index: 10)

Engine internal operating conditions should be monitored by observing aircraft instruments. Trend shifts in engine parameters, properly analyzed and interpreted, can detect many imminent difficulties, providing good means of identifying potential engine troubles before any serious difficulty occurs.

By watching the engine trend, operators can also predict when the engine will have lost performance margin and must have maintenance or overhaul performed. Hot section inspections (HSI) can be planned and, provided the results show good engine condition, HSI can be even eliminated.

THINGS TO REMEMBER

- Engine life is closely related to internal temperature, even when the allowable limits are not exceeded.
- The best assurance for a long and dependable life is to maintain engine operation within temperature limits.
- There is no operational technique to reverse the effect of operating the engine too hard for too long.
- Several momentary high temperatures will damage the engine as deeply as a single long exposure to a lesser temperature.
- Whenever possible, thrust should be set so as not to be higher than the value necessary to accomplish the mission.
- Minimum turbine deterioration occurs at ITT's of 790°C and below. Each 10°C above 790°C will degrade life by 7% (+20°C for 10 minutes result in 17% degradation, +30°C for 10 minutes result in 29% degradation, +40°C for 10 minutes result in 43% degradation).
- To comply with an AFM limitation, if ALT T/O-1 thrust setting is used extensively, once a week a takeoff using T/O-1 must be made to check that engine parameters are within limits. This period may be extended if an approved engine condition monitoring program is used (AC 25-13, AMJ 25-13).

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