Prevention of EGT Overlimit Events

A number of engine Exhaust Gas Temperature (EGT) overlimit events at takeoff were reported to Airbus, including dual events leading to a significant increase in flight crew workload at low altitude.

This article recalls the importance of monitoring the EGT margin of each engine to detect any degradation in engine performance early, and provides recommendations to Maintenance, Flight Operations, and flight crews to prevent EGT overlimit events. It also reminds us of what to do in the case of an EGT overlimit indication at takeoff.

This article is also available on safetyfirst.airbus.com and on the Safety first app for iOS and Android devices.

Among the reported events of EGT overlimit, 10 occurred on both engines between May and September 2021. Even if EGT overlimit events are common, they can increase the flight crew workload in a critical phase of flight, especially when they happen on both engines simultaneously. They can create operational disruptions (e.g. rejected takeoff or in-flight turnback) and require maintenance actions.

CASE STUDY

Event Description

An A321 aircraft, with a takeoff weight of 73 T (MTOW 98.7 T), was in CONF2 with packs ON and ready for takeoff on a relatively warm weather day (30°C OAT/ISA+15). The flight crew applied standard thrust stabilization and then TOGA thrust. The takeoff was uneventful until liftoff. At 90 ft RA, the ENG1 EGT OVER LIMIT and ENG2 EGT OVER LIMIT ECAM alerts triggered. The PF initially moved both thrust levers to MCT, then engaged the autopilot at 450 ft and moved the thrust levers to the CLB notch. At 890 ft, the PF set the ENG1 thrust lever to idle. The vertical speed began to decrease and the PF set the ENG2 thrust lever to MCT. The flight crew then set the ENG1 master switch to OFF when crossing 1 300 ft, leveled off at 1 500 ft, and decided to perform an in-flight turnback. The PF climbed to 4 000 ft. The flight crew started the APU and began descent to initiate the approach. The ENG1 master switch was set back to ON during the descent and Engine 1 successfully restarted at approximately 2 700 ft. The approach and landing were performed without any further events.

Event Analysis

The investigation confirmed that both engines had an EGT overlimit and compressor stall during the event. This was the combination of degraded performance on both engines, combined with a relatively high OAT (30°C), and the use of TOGA thrust with packs ON.

The inspection of both engines by the engine manufacturer stated, "*General dirty/eroded/corroded/worn condition of engine's flow path. Deteriorated airfoil profile and tip & seals clearance identified as major contributors to both engines EGT overtemperature.*" It was also noted that an interruption of in-flight engine data transmission between the Operator and the engine manufacturer did not facilitate a timely assessment of the engine degradation.

THE EGT PARAMETER

The EGT sensors are located either on the inlet or the outlet of the Low Pressure Turbine (LPT), depending on the engine type.

Parameters that Influence EGT

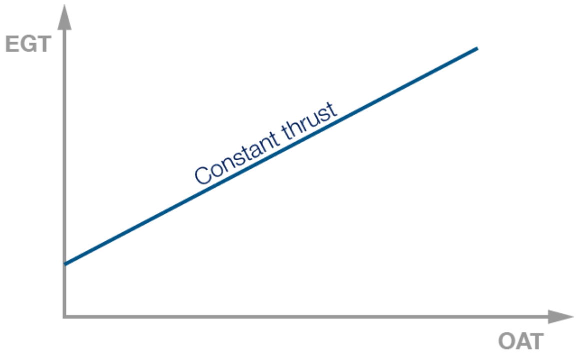
An engine with degraded performance is less efficient and requires more fuel to produce the same thrust leading to an increase in EGT. A number of parameters can cause temporary performance degradation that will have an influence on EGT or there can be a progressive degradation of engine performance.

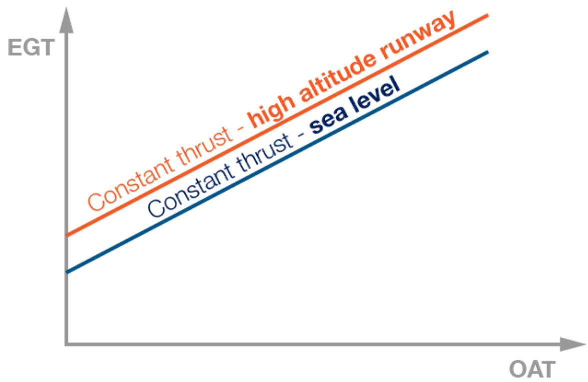
Temporary performance degradation

Several parameters can cause temporary engine performance degradation and result in increased EGT values:

- **Environmental parameters** such as Outside Air Temperature (OAT) **(fig.1)** and altitude **(fig.2)**. For example, every increase of 1°C in OAT can lead to an EGT increase of approximately 3°C to produce the same thrust at takeoff, depending on the engine type.

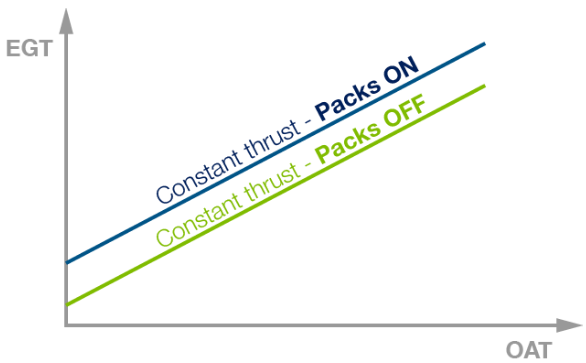
(fig.1) and **(fig.2)** Effect of OAT and altitude on the EGT for a constant thrust

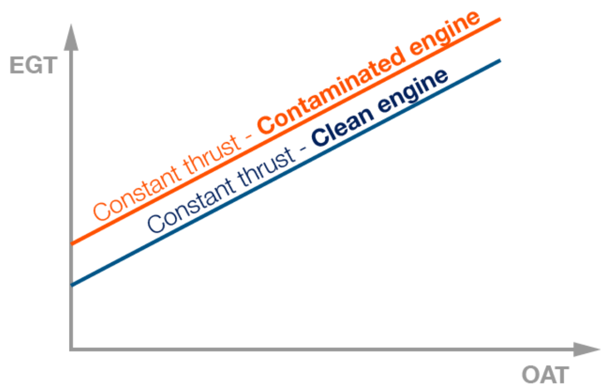




- **Bleed demand**: Use of air conditioning packs and anti-ice increases the bleed demand on the engine and will result in a higher EGT to produce the same thrust **(fig.3)**.
- **Engine contamination** (e.g. dust, pollution) can disturb the airflow through the engine, which affects the overall performance of the engine and results in higher EGT values **(fig.4)**.

(fig.3) and **(fig.4)** Effect of bleed demand (packs) and engine contamination on the EGT for a constant thrust

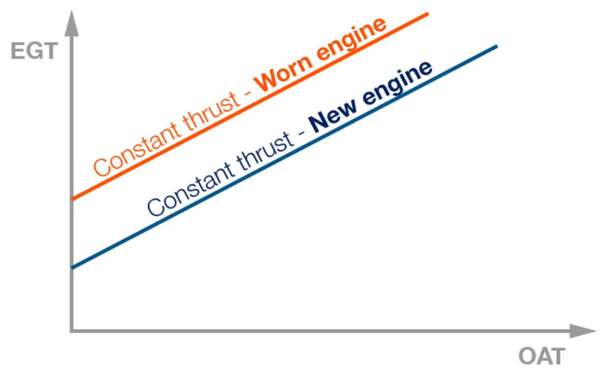




- **Engine temperature**: An engine is “cold” when the EGT is almost the same as the OAT at engine start. This can lead to an increased peak in the EGT during takeoff if the engine does not have sufficient time to warm up after starting.

Progressive Performance Degradation: Engine Wear

The performance of any engine progressively degrades with time due to inevitable wear of its components. This is generally due to eroded or damaged compressor foils, worn seals, and the increased clearance between rotor/stator blade tips and the stator/rotor in the compressor and turbine sections due to erosion.

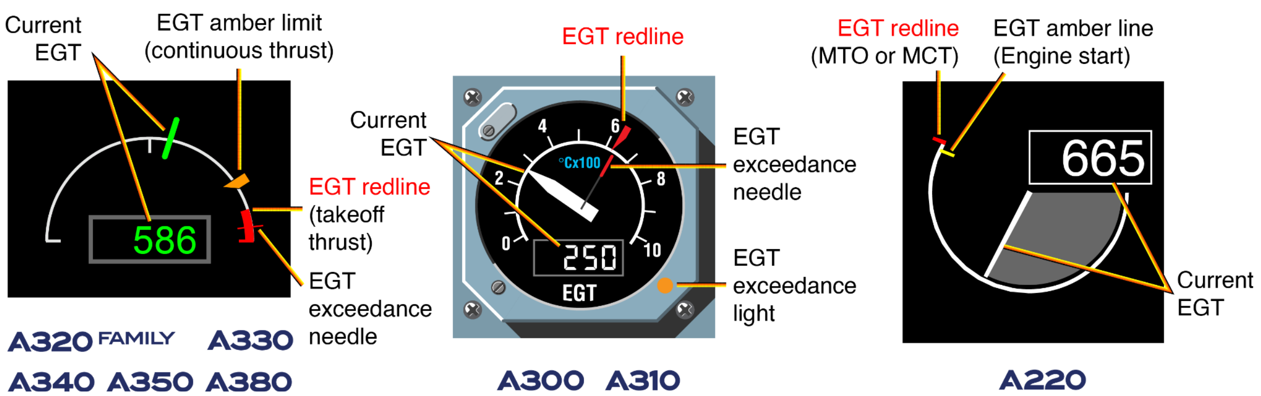


(fig.5) Effect of engine wear on the EGT

EGT Redline

The “EGT redline” is defined as the engine operational limit that prevents damage to the engine due to an excessively high temperature. EGT limits for each flight phase are provided in the *“AFM - LIMITATIONS - POWER PLANT - Engine Parameters”* and *“FCOM - Limitation - Engines - Thrust Setting/EGT Limits”.* **The EGT redline corresponds to the EGT limit for takeoff and go-around.**

The EGT redline appears as a red line on the EGT indicator of A300/A310 aircraft and on the engine display of A220 aircraft. On A320 family, A330, A340, A350, and A380 aircraft, the EGT redline is the start of the red zone of the EGT arc on the engine display **(fig.6)**. An EGT amber limit indicates the EGT limit for maximum continuous thrust or engine start provided in the FCOM on A320 family, A330, A340, A350, and A380 aircraft. This amber limit indication is hidden when takeoff power is applied. On A220 aircraft, an amber line indicates the EGT limit during engine start.



(fig.6) EGT indication

The EGT redline is not a “hard” limit

In the absence of severe damage, an engine is capable of operating above the EGT redline without thrust loss, but at the cost of an accelerated engine wear. This was demonstrated during the engine certification tests. It is why an amber caution alert is used to inform the flight crew of an EGT overlimit rather than a red warning alert.

- The ENG1(2) EGT OVER LIMIT ECAM alert is combined with an amber or red EGT indication for A320 family, A330, A340, A350, and A380 aircraft or an amber light on the EGT indicator for A300-600 and A310 aircraft. The alert is inhibited from 80 kt (70kt for A300-600/A310) during takeoff roll until liftoff to prevent a high-energy rejected takeoff and from touchdown down to 80 kt at landing to prevent the flight crew from stopping the use of thrust reversers.
- The ENG EGT warning light on the Master Warning Panel is combined with an amber light on the EGT indicator for A300 aircraft

“In the absence of severe damage, an engine is capable of operating above the EGT redline without thrust loss, but at the cost of an accelerated engine wear.”

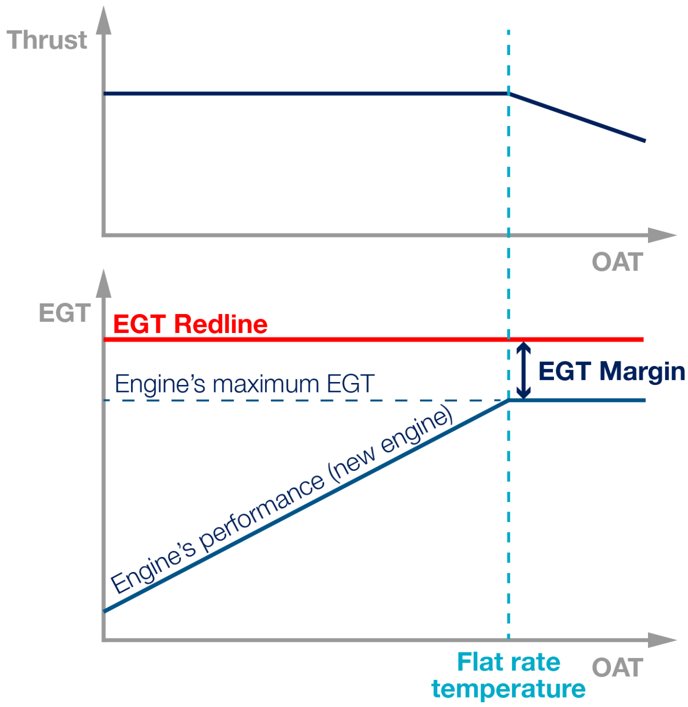
- The L(R) ENG EXCEEDANCE EICAS caution is combined with an AMBER or red EGT indication for A220. The caution is inhibited during the takeoff roll.

An EGT overlimit requires maintenance

After an EGT overlimit, inspection and troubleshooting are necessary to identify the root cause of the overlimit and assess the engine's health.

EGT MARGIN INDICATES ENGINE HEALTH

Engine manufacturers define the guaranteed maximum thrust of an engine based on its maximum limits (e.g. EGT, N1, N2) and up to a defined OAT. This OAT is called the flat rate temperature. It is also commonly called corner point temperature, breakpoint temperature, or kink point temperature. Above this OAT value, the engine control (FADEC) automatically manages the thrust to maintain a constant EGT. The maximum thrust and flat rate temperature are selected so that a new or overhauled engine has a sufficient EGT margin to the EGT redline **(fig.7)**. This will enable the engine to sustain a certain amount of engine wear and still be capable of producing its maximum thrust rating without reaching the EGT redline. An OAT of 30°C at sea level (ISA +15°C) is usually defined at max take-off by engine manufacturers as a compromise for flat rate temperature because it enables maximum thrust in a wide range of conditions.



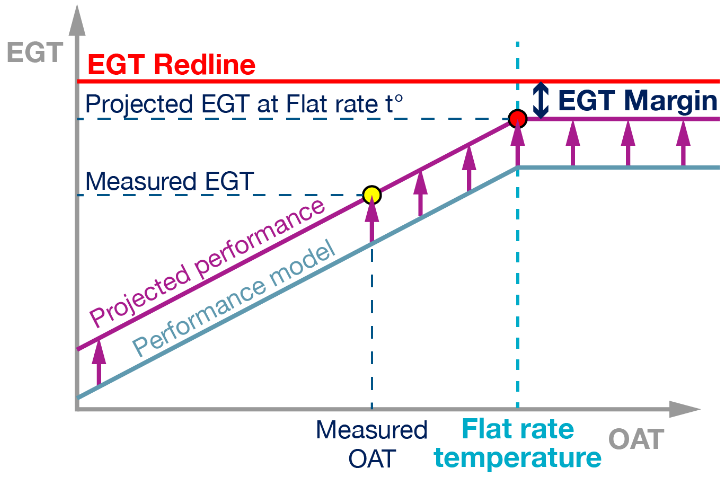
(fig.7) EGT margin

EGT monitoring

The EGT margin gradually decreases with the progressive degradation in the performance of an engine. Use of the Engine Condition Monitoring (ECM) tool to measure the EGT margin of an engine provides a good indication of its health and can highlight if there is a need for maintenance. EGT margin trends can also provide a useful forecast of the average time on wing remaining for an engine.

Calculating the Current EGT Margin of an Engine

Each time a takeoff is performed with TOGA thrust, the ECM tool takes a snapshot of the engine parameters and of the external conditions (e.g. OAT, pressure). The tool then uses this measurement to calculate a delta vs the engine performance model and project it to the worst condition to determine the projected EGT of the engine **(fig.8)**. The difference between this projected EGT and the EGT redline value is the current EGT margin of the engine.



(fig.8) Computation principle of the current EGT margin of an engine (altitude and mach corrections are not represented)

The ECM also estimates the EGT margin when a FLEX or derated takeoff is performed, however, the computation is less accurate than when TOGA thrust is used. The need to perform a regular takeoff with TOGA thrust is therefore necessary to ensure efficient EGT monitoring. This is particularly important when the engine is near the EGT redline.

"The need to perform a regular takeoff with TOGA thrust is necessary to ensure efficient EGT monitoring."

All parameters should be considered to prevent EGT overlimit

Several parameters such as altitude, OAT, takeoff thrust used, and bleed demand can affect the peak EGT value at takeoff. Therefore, an engine with a slightly positive EGT margin may experience an EGT overlimit at takeoff but an engine with a slightly negative EGT margin may not necessarily experience EGT overlimit at takeoff.

PREVENTION OF EGT OVERLIMIT EVENTS

Maintenance, Flight Operations and flight crews can all play a role to prevent EGT overlimit events.

Role of Maintenance

Monitoring engine performance degradation

The engine manufacturer Instructions for Continued Airworthiness (ICA) manual requests Operators to monitor the EGT Margin of their aircraft engines. This monitoring may be performed by the Operators or through a service provided by the engine manufacturer. The Operator should check the maximum thrust (TOGA) by performing full-rated takeoffs at regular intervals, in order to detect a reduced EGT margin, or maintaining an adequate engine monitoring program, in order to follow up on the engine parameters.

Maintenance should inform Flight Operations and request that flight crews perform a takeoff with TOGA thrust when it is necessary to ensure an accurate computation of the EGT margin.

Avoid fitting two performance limited engines to the same aircraft

Operators should manage their fleet to ensure as much as possible that aircraft have no more than one engine with low EGT margin. An aircraft that has two performance-limited engines increases the probability of a dual EGT overlimit event.

Regular engine washes

Performing regular engine washes will remove particles from the compressor such as dirt, oil, sand, and salt that reduce the engine efficiency. The engine wash procedure is available in the AMM/MP. Operators can request additional or specific recommendations directly from the engine manufacturer.

Sharing engine performance information

It is important to ensure there is good communication between Maintenance and Flight Operations about the conditions and performance of engines fitted to an aircraft. Maintenance must inform the Flight Operations department when an aircraft is fitted with performance-limited engine(s). This will enable operations to be adapted according to the limitations of each aircraft.

Role of Flight Operations

Adapting operations for aircraft with performance-limited engines

Flight Operations should adapt operations to avoid using aircraft with performance-limited engines on performance-demanding routes such as into airports with hot weather or high-altitude runways. Operators should take particular care during the summer season when EGT events are more likely to occur.

Informing flight crews

Flight Operations should provide information to the flight crew before they fly an aircraft with performance-limited engines, so that they can adapt their procedures accordingly. Flight Operations also need to plan and pass on the request from Maintenance to perform a TOGA takeoff for an accurate computation of the EGT margin.

Role of Flight Crew

Engine warm-up time

High EGT is often experienced when the engine is cold on the first takeoff of the day or after a long stay on the ground. When the EGT is almost the same as the OAT before engine start, the flight crew can extend the warm-up time to reduce the EGT peak during takeoff, especially at airports with hot weather and high-altitude runways, or if the aircraft engines have limited EGT margins. The usual warm-up time is between 2 and 5 minutes, however, a warm-up time of 10 minutes can reduce the takeoff EGT by approximately 10°C depending on the engine type. Some Operators have made it a policy to extend this warm-up time for each first flight of the day.

Use reduced takeoff thrust

If the flight crew uses reduced takeoff thrust, it can enable the engine to have an increased margin to the EGT redline. The use of “Flex” or “Derated” takeoff configuration can help to extend engine life and to save on maintenance costs.

Take off with packs OFF

If it is not possible for the flight crew to reduce the thrust takeoff, they can choose to take off with packs set to OFF, in order to reduce the bleed air demand on the engine.

Take off with APU BLEED ON

If the OAT is high and it does not enable the flight crew to take off with packs set to OFF, then they can perform the takeoff with APU BLEED ON to remove the bleed air demand from the engines and maintain passenger comfort.

WHAT TO DO IN THE CASE OF AN EGT OVERLIMIT DURING TAKEOFF

Despite applying all of the prevention measures, EGT overlimits can still happen and especially during hot weather. The EGT usually reaches a peak at the end of the takeoff roll, near rotation, or just after liftoff. If an EGT overlimit is combined with vibrations and happens shortly after the application of takeoff power, this can be an indication of more severe engine damage.

EGT overlimit between takeoff power application and 100 kt

If the EGT overlimit alert is triggered or if the flight crew notices that the EGT value becomes red on the engine display (on A220/A320/A330/A340/A350/A380 when the alert is inhibited) between takeoff power application and 100 kt, they should consider rejecting the takeoff.

EGT overlimit between 100 kt and V1

If the flight crew notices that the EGT value becomes red on the engine display (on A220/A320/A330/A340/A350/A380) or if the EGT overlimit warning light comes on (on A300/A310) between 100 kt and V1, they should continue the takeoff to establish the aircraft on the initial climb path. The flight crew should then wait to be above 400 ft before they apply the ECAM/FCOM procedure. However, the decision to perform a rejected takeoff is at the captain's discretion and it depends on the situation, especially in the case of a dual EGT overlimit event or if the aircraft is in a mountainous area, for example.

EGT overlimit after V1 or after liftoff

If the EGT overlimit happens after V1 or after liftoff, the flight crew must continue the takeoff. They should wait until the aircraft is safely established on its climb path above 400 ft before they apply the ECAM/FCOM procedure and gently reduce the thrust of the affected engine. If the temperature goes above a given threshold or if the overlimit situation persists after reduction of the thrust, the flight crew may shut down the affected engine as requested in the ECAM/FCOM procedure.

Reporting EGT overlimit events

Each time the flight crew experiences an EGT overlimit event, they must report it to maintenance, so that the necessary inspections and troubleshooting can be performed.

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Engine performance progressively degrades over time, which leads to an increase in EGT to produce the same thrust. Operators must monitor the performance of their aircraft engines and the evolution of the EGT margin. This will allow for maintenance or removal of an engine, if necessary, before engine performance degrades too much.

Maintenance, Flight Operations and flight crews all have a role to play to prevent EGT overlimit events on their aircraft in operations. In addition to monitoring the EGT margin, regular engine washes should be performed. Maintenance should avoid installing more than one engine with an EGT margin close to the EGT redline or a negative margin. Flight operations and flight crews should be informed when an aircraft is fitted with performance-limited engines. Maintenance should also request that Flight Operations plan for, and ask flight crews to perform, regular TOGA thrust takeoffs to ensure efficient monitoring of the EGT margin of the engines.

Flight Operations should avoid scheduling performance-limited aircraft on demanding routes and inform flight crews before they fly on a performance-limited aircraft, so that they can adapt their procedures accordingly. This can be done, for example, by extending the engine warm-up time before takeoff, using reduced-thrust takeoff, or performing the takeoff with packs set to OFF or APU bleed ON to gain extra EGT margin.

Flight crews should keep in mind that the EGT red line is not a hard limit. An engine can still produce thrust above the redline but with more wear on the engine components. As a result, if an EGT overlimit occurs during takeoff:

- **Before 100 kt**, the takeoff should be aborted, because an EGT overlimit in the early stage of the takeoff roll can be a sign of engine damage, especially if associated with vibrations.
- **Between 100 kt and V1**, the flight crew should continue the takeoff, establish the aircraft on the initial climb path, and wait until the aircraft is above 400 ft before they apply the ECAM/FCOM procedure. However, the captain may decide to reject the takeoff depending on the situation.
- **After V1 or after liftoff**, the flight crew must continue the takeoff and wait until the aircraft is above 400 ft before they apply the ECAM/FCOM procedure.

The flight crew must report any EGT overlimit to the Maintenance personnel and make a logbook entry so that appropriate troubleshooting and inspection are performed before the aircraft returns to service.

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