CFM56

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COMMERCIAL ENGINE SERVICE MEMORANDUM

TRANSMITTAL SHEET

CFM56 CESM REVISION

CESM (CFM56-3/3B/3C) NO. 015

T/O EGT MARGIN AND OATL DETERMINATION

December 18/92

This page transmits Revision 3 to CESM (CFM56-3) No. 015, dated December 15/87, and the revisions that follow:

- Revision 1, dated July 22/88
- Revision 2, dated June 12/92.

This revision is issued to change which CFM56-3 engine models are affected and to correct the values listed in table III, sheet 2.

Changes are shown by the letter R in the left margin of the revised pages.

Only pages 1, 5, and 18 are revised for the purposes described above. Pages 2, 6, and 17 are provided for printing backup.

2980S

ENGINE MODEL: CFM56-3/3B/3C

SECTION/NO: MAINTENANCE NO. 015

SUBJECT: T/O EGT MARGIN AND OATL DETERMINATION

1. DESCRIPTION OF PROBLEM

The takeoff EGT margin relative to the 930°C certified limit will decrease as engine condition deteriorates.

The determination of takeoff EGT margin relative to the certified limit gives a good indication of engine health. Cruise trend programs, such as the ADEPT or GEM, can also give an indication of engine health.

2. PURPOSE

The procedures for projecting EGT margins outlined in this CESM may be used as a guide in assessing the health of an engine. Projected EGT margins are not to be used as the sole criteria for engine removal, but may be considered along with other factors when making that determination.

3. BACKGROUND

R All CFM56-3 engine models are certified to a peak EGT of 930°C for takeoff operation. The actual peak EGT observed during takeoff is a function of engine health (condition), ambient temperature, engine power setting (N1) and PMC on or off. Altitude by itself does not affect EGT but the N1 power setting does.

For any altitude, maximum EGT occurs at corner point or higher ambient temperatures. Corner point is defined as the highest ambient temperature for full rate thrust at that altitude. Power management for the 18.5K and -3-B1 ratings is such that the maximum peak EGT occurs at OAT's greater than the flat rated corner point OAT as seen from figures 1 and 2. These figures show peak EGT expected with takeoff at any condition relative to the peak EGT at the sea level corner point. It can be noted from this figure that for the lower altitudes EGT increases above corner point which is the first bend in the EGT characteristics.

The 18.5K and -3-B1 (20K) ratings have a thrust increase at 4000 to 6000 feet which results in substantially higher EGT than at sea level. This rating was provided primarily for improved aircraft capability from Denver. The effect of this thrust increase on takeoff peak EGT is shown in figures 1 and 2. It can be seen from these figures that maximum EGT will occur at 4000 to 6000 feet at corner point temperatures and the N1 cutback at higher ambient temperatures results in nearly constant EGT.

3. (Continued)

For the CFM56-3B-2 (22K) and -3C-1 (23.5K) ratings, peak EGT above corner point is nearly constant with no altitude effect as can be seen from figures 3 and 5. The N1 power setting of -3-B1 and -3B-2 ratings is such that for the same engine, the -3-B1 rating at the Denver corner point results in the same EGT as for the -3B-2 rating at the sea level corner point (figure 4).

New production engines have substantial takeoff EGT margin relative to the 930°C certified limit, but this margin will decrease as the engine deteriorates. This CESM defines a procedure for determining takeoff EGT margin for full rated takeoff on a corner point day. For both 18.5K and the -3-B1 (20K) ratings, the margin is referenced to the Denver corner point and for the -3B-2 (22K) and -3C-1 (23.5K) ratings, it is referenced to sea level corner point. Engines with positive EGT margins at these conditions will have margins at all altitudes. For the 18.5K and -3-B1 engines, the EGT margin at lower altitudes can be determined from figures 1 and 2 respectively or by applying the corrections in table 1.

An indication of an engine's health can also be obtained from cruise data. Engines are considered to be at or near certified EGT limit (zero EGT margin) at or above corner points when they trend at about +40°C for -3-B1, -3B-2 and about 35° C for -3C-1 based on the ADEPT or GEM cruise trend program. For the 18.5K and -3-B1 to be EGT limited at sea level will require cruise trending of about 100°C and 80° C respectively. The relationship between cruise trend and takeoff EGT margin is not precise, and ± 10°C cruise EGT variation has been observed in this relationship. The above indicated trend levels are given as guidelines only and the on-wing EGT margin at take-off can more precisely be calculated using the take-off data.

Cruise trend levels and EGT margins determined by this procedure are intended to monitor the health of an engine and to initiate any maintenance action based on trend shifts and/or trend levels. For an engine removal, the physical condition of the engine hardware (on-wing borescope, vibration levels, etc.) and pilot squawks (EGT exceedances, etc.) should also be considered in addition to the trends.

4. RECOMMENDED PROCEDURE FOR EGT MARGIN DETERMINATION

The data required for determining EGT margin are: EGT, N1, N2, TAT, Anti-ice (on/off) and ECS or A/C bleed configuration. To get a good assessment of EGT margin about 5 to 10 takeoff data points are required. To reduce data scatter, none of these points are to be first takeoff of the day and all should be either with or without bleed. The required parameters are to be recorded by one of the following procedures:

4. (Continued)

TAT	EGT	N1	N2	A/C Bleed	Anti - Ice		TCC Timer
°C	°C	%	%	Auto, high or off	Cowl, On or off	Wing, On or off	Equipped With timer or no timer

- Nine seconds after rotation (Automated Data Acquisition).
- Thirty-five seconds after takeoff power is set, determined by N1 $\geq$ 70% or N2 $\geq$ 85% (Automated Data Acquisition).
- Hand-recorded parameters at 9 seconds after rotation or at 300 to 350 feet above runway.
- Or still camera picture of instrumentation panel at 9 seconds after rotation or at 300 to 350 feet above runway.

It is expected that these procedures result in recording EGT before the peak value is reached and this is compensated for in margin determination. EGT margins can be calculated from these parameters using one of the following two procedures:

CFMI recommends recording of N2 during takeoff to account for TCC timer effects for engines equipped with TCC timer, and the timer triggers at a core speed N2 = 95.4 $\pm$ 0.4% (13,800 $\pm$ 60 RPM). For engines with timer, data points with N2 that fall between N2 = 95.0 to 95.8% may not be included for EGT margin calculation. However, in the absence of N2 recording, an estimated relationship of the corresponding N1 as a function of TAT required to trigger the timer is shown in figure 7. A tolerance band on N1 representing timer triggering range is also shown and data falling within the band is not to be used for EGT margin calculation, as they might increase data scatter.

It is necessary to note that when the TCC timer activation is based on N1, the relationship is considered an estimate or an approximation. When using the N1 relationship, it is possible that several data points may fall within the tolerance band and not be useable for analysis to accurately account for timer affects. It is therefore recommended that the N2 signal be used as the basis for timer adjustments.

(A) CORRECTED PARAMETERS COMPARED TO LIMIT LINE

This is the basic procedure used for margin determination. From recorded parameters, calculate the following corrected parameters:

$$\theta_2 = (TAT + 273.15)/288.15$$

$$N1K = N1/\theta_2^{.5}$$

$$EGTK = (EGT + 273.15)/\theta_2^{.84}$$

4. A. (Continued)

At N1K and ECS bleed configuration, obtain EGTK limit from figure 6 or straight line interpolate between points shown in the table included in figure 6. The EGTK limit line shown is for a -3C-1 configuration.

B. REFERENCE EGT MARGINS

Obtain EGTK limits from part A at N1K takeoff and determine ΔEGT at corner point as follows:

ΔEGT = [EGTK limit - EGTK at T/O] (1.05245) in °C

Adjust ΔEGT for the following:

- If cowl or nacelle anti-ice is "on", add 6°C (no adjustment for "off")
- If wing anti-ice is "on" add 6°C (no adjustment for "off")
- For engines equipped with TCC timer and if N2<95.0% (if N2 recorded) or if N1 <N1 lower (obtained from figure 7), add 17°C. For engines without timer, no adjustment is done.

ΔEGT ref = ΔEGT + ΔEGT adjustments

ΔEGT ref = ΔEGT + (ΔEGT cowl anti-ice + ΔEGT wing anti-ice + ΔEGT for TCC timer)

A sample calculation for the above procedure is included in tables II amd III respectively for engines operating at 23,500 pounds and 18,500 pounds thrust levels.

C. EGT MARGIN AT THRUST RATING

Based on the ΔEGT ref computed as in part B, the EGT margin at desired or operating thrust rating is calculated as follows:

Thrust Rating (pounds)	Takeoff EGT Margin (EGTK) °C
23500	ΔEGT ref
22000	ΔEGT ref + 20
20000	ΔEGT ref + 64 at sea level ΔEGT ref + 20 at 5000 feet
18500	ΔEGT ref + 89 at sea level ΔEGT ref + 45 at 5000 feet

5. ALTERNATE PROCEDURE FOR EGT MARGIN DETERMINATION

Some airlines on a regular basis record N1 at power set, takeoff peak EGT and runway ambient temperature (OAT). These parameters can be used for determining EGT margins but the results are considered less accurate than by the recommended procedure.

The procedure for determining EGT margin from these parameters is similar to Section 4, Part A with the following modifications:

R $\theta_2 = (OAT + 273.15)\ (1.01)/288.15$

$N1K = N1set/\theta_2^{.5} + .13$

$EGTK = (EGT - 3 + 273.15)/\theta_2^{.84}$

The -3 in above quotation is to make EGT compatible with part four and the EGT limit line in figure 6.

N1K and EGTK are then used with figure 6 to determine EGT margins as in procedure Number 4.

6. OATL DETERMINATION

For operators who prefer to monitor their fleet based on OATL, the EGTM can be converted to OATL by dividing EGTM by 3.2 and adding this to corner point temperature. For example, at sea level with corner point of 30^oC

OATL=30+EGTM/3.2. This is the sea level ambient temperature limit (SLOATL) for full rated takeoff without exceeding rated EGT limit.

Engines with negative EGTM will have OATL values less than corner point temperature. For these engines, full rated takeoff at ambient temperatures above the OATL value is likely to result in exceeding the 930^oC certified EGT limit. Engines with positive EGTM will have OATL values greater than corner point temperature and these engines should have no EGT problem above corner point temperature or at OAT above the OATL value because rated thrust is reduced above corner point temperature.

7. DEFINITIONS

ABBREVIATIONS	NOMENCLATURE	UNITS
N1	Fan Speed	%
EGT	Exhaust Gas Temperature	°C
TAT	Total Air Temperature	°C
OAT	Ambient Air Temperature	°C
OATL	Outside Air Temperature Limit	°C
SLOATL	Sea Level Outside Air Temperature Limit	°C
EGTM	EGT Margin relative to certified limit (930°C)	°C
EGTK	Corrected EGT	°K
N1K	Corrected N1	%
Corner Point	Max. Temperature for full rated thrust	°C
ADEPT	Aircraft Data Engine Performance Trending	
GEM	Ground Base Engine Monitoring Program	

NOTE: Internal Reference

DCIA: 87-098
DCIA: 88-088
DCIA: 92-014

CFM56-3 18.5K TAKEOFF PEAK EGT COMPARISION
ΔEGT REFERENCE TO SEA LEVEL CORNER POINT

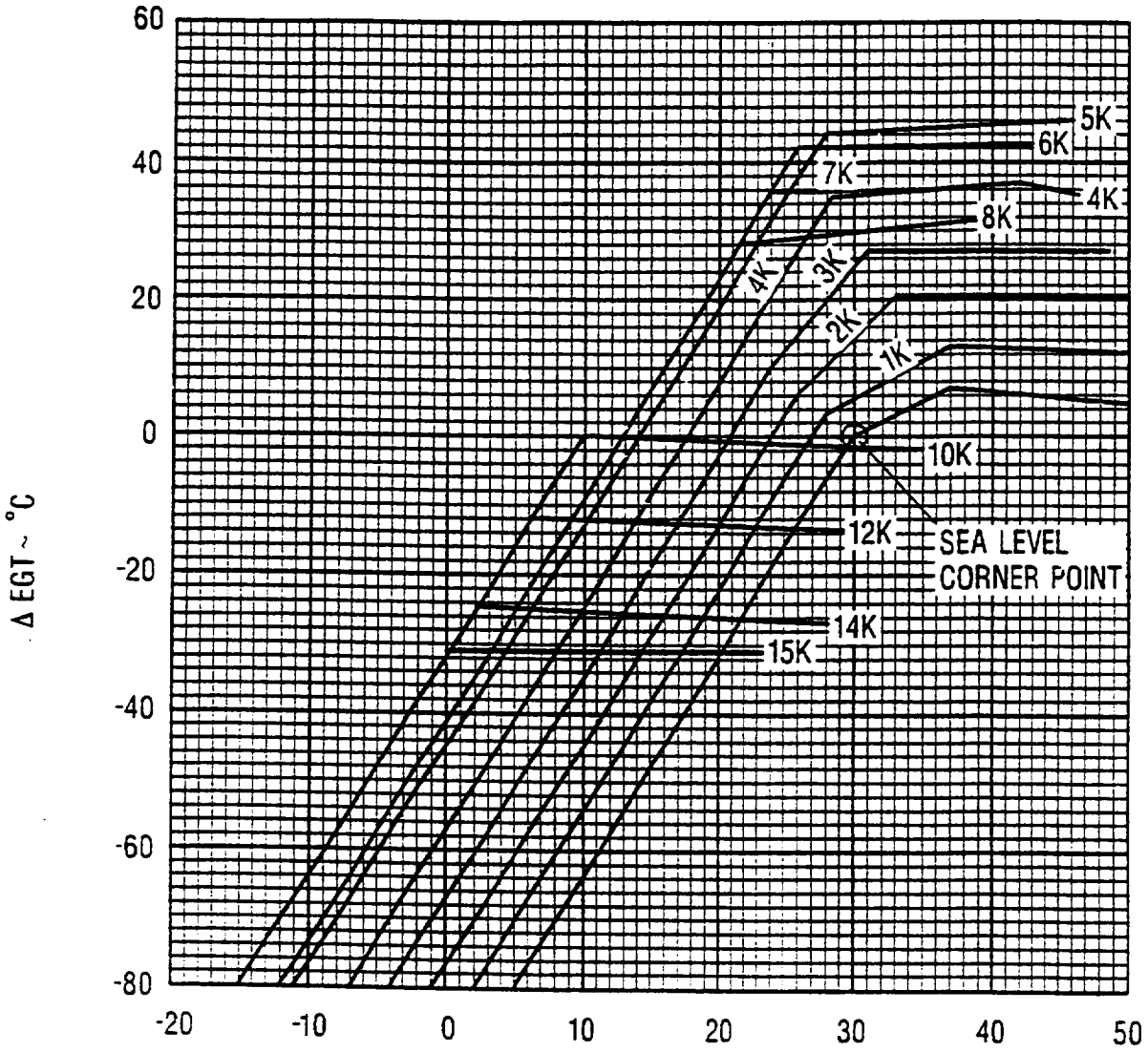
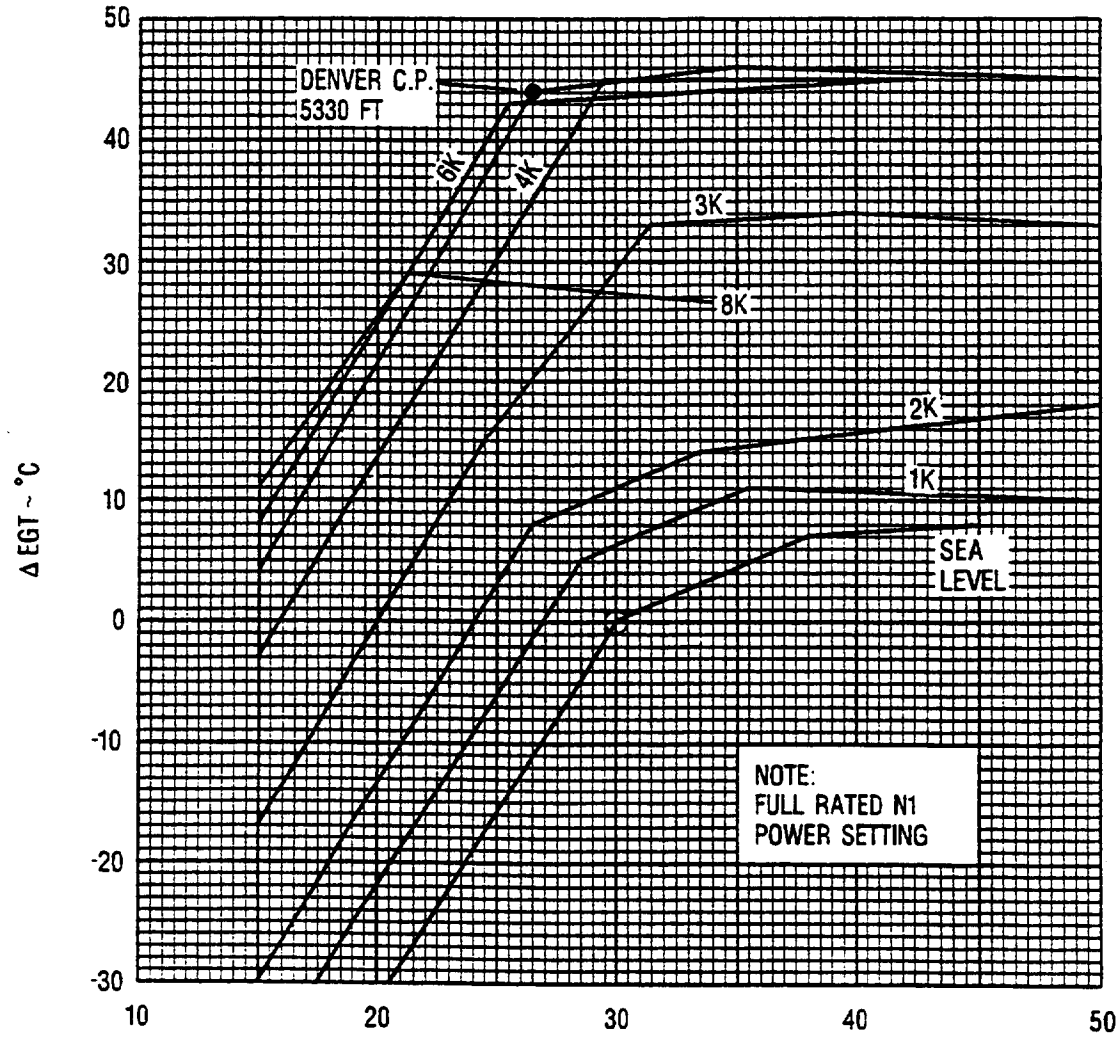


Figure 1

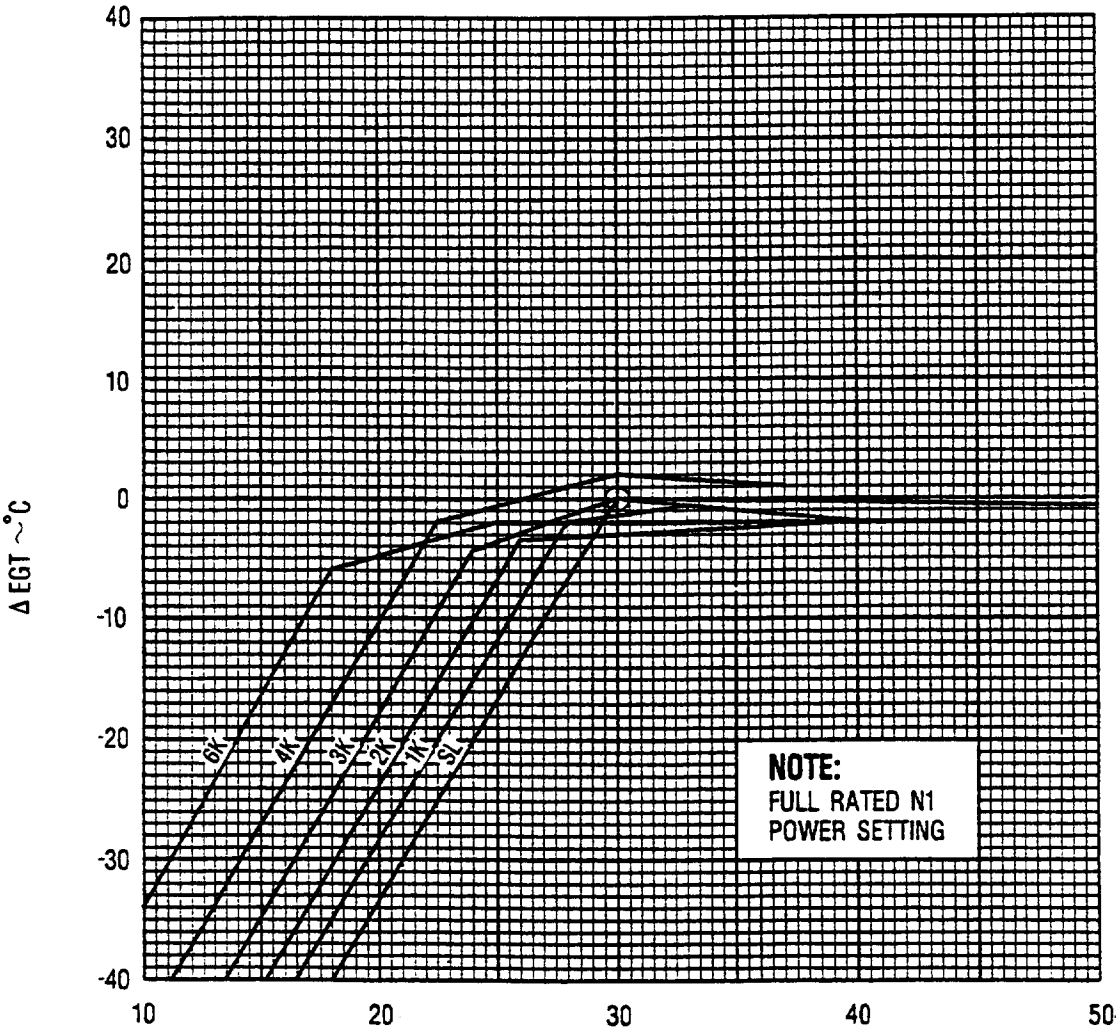
CFM56-3-B1 TAKEOFF PEAK EGT COMPARISION
ΔEGT REFERENCE TO SEA LEVEL CORNER POINT



1106564-00

Figure 2

CFM56-3-B2 TAKEOFF PEAK EGT COMPARISION
ΔEGT REFERENCE TO SEA LEVEL CORNER POINT



1106565-00

Figure 3

CFM56-3-B1 AND CFM56-3-B2 TAKEOFF PEAK EGT (MAXIMUM POWER)
REFERENCE TO CFM56-3-B1 AT DENVER CORNER POINT

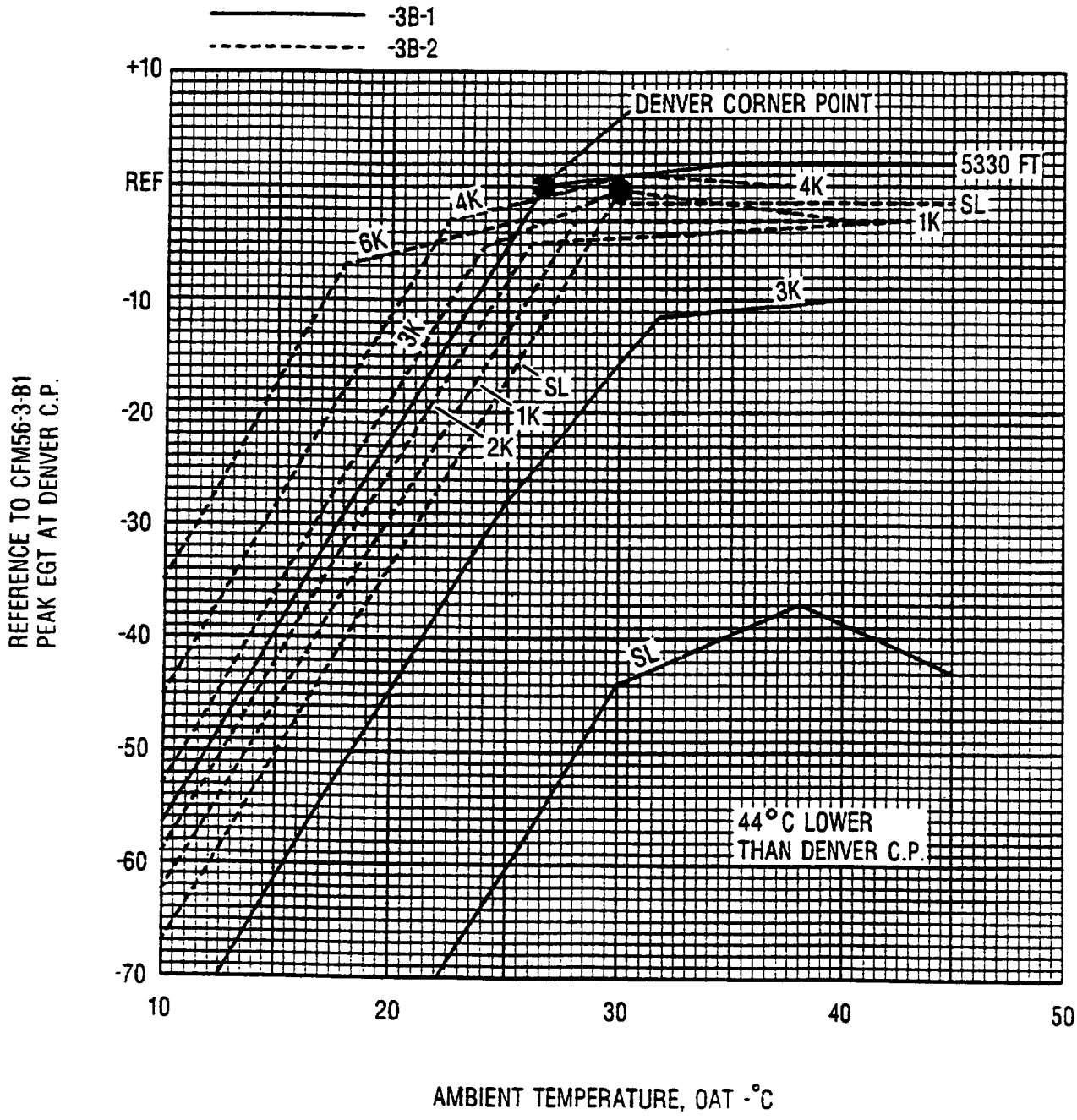


Figure 4

CFM56-3C-1 TAKEOFF PEAK EGT COMPARISION
ΔEGT REFERENCE TO SEA LEVEL CORNER POINT

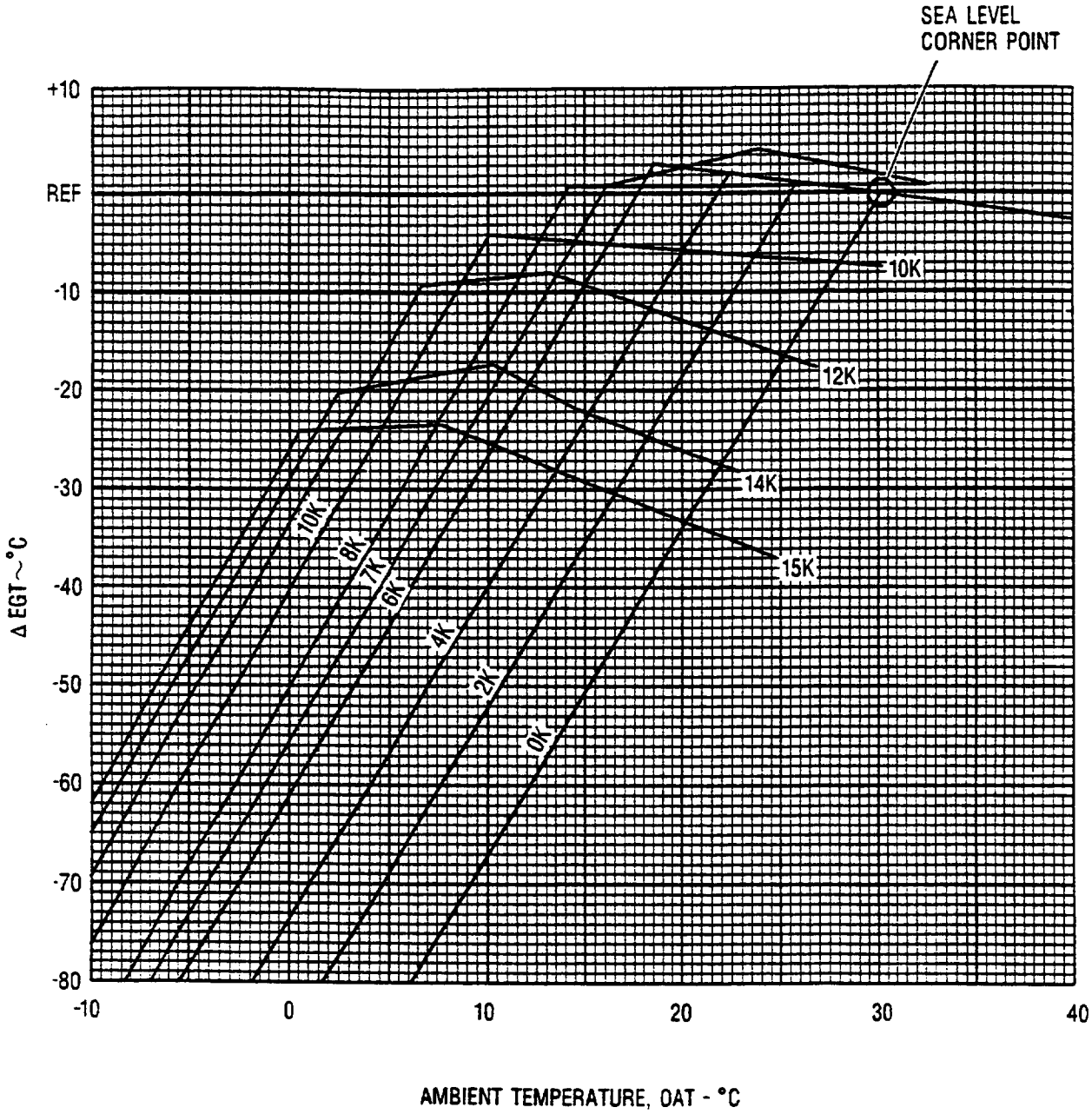


Figure 5

CFM56-3C-1 EGTK LIMIT LINE FOR MARGIN ANALYSIS

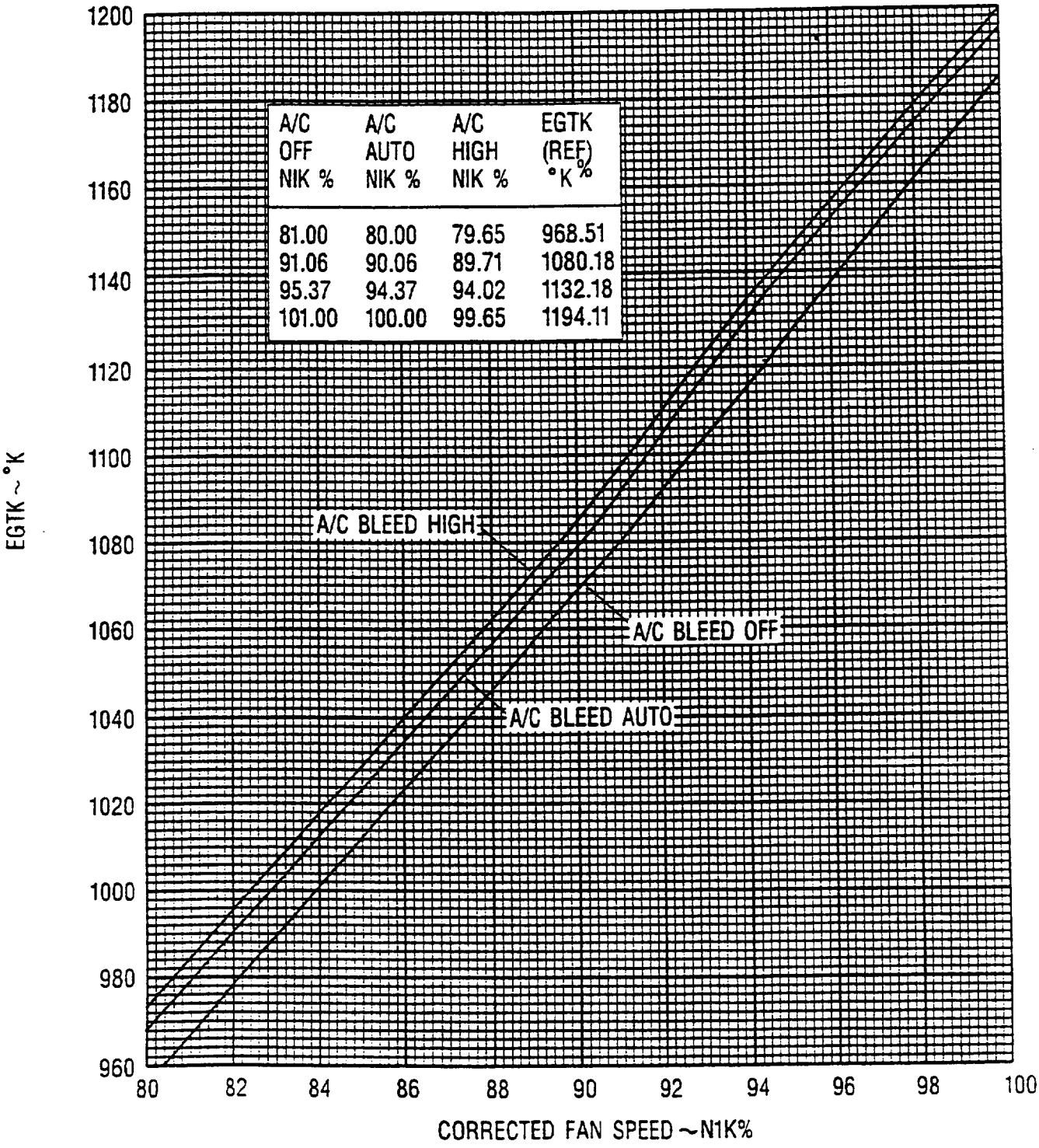


Figure 6

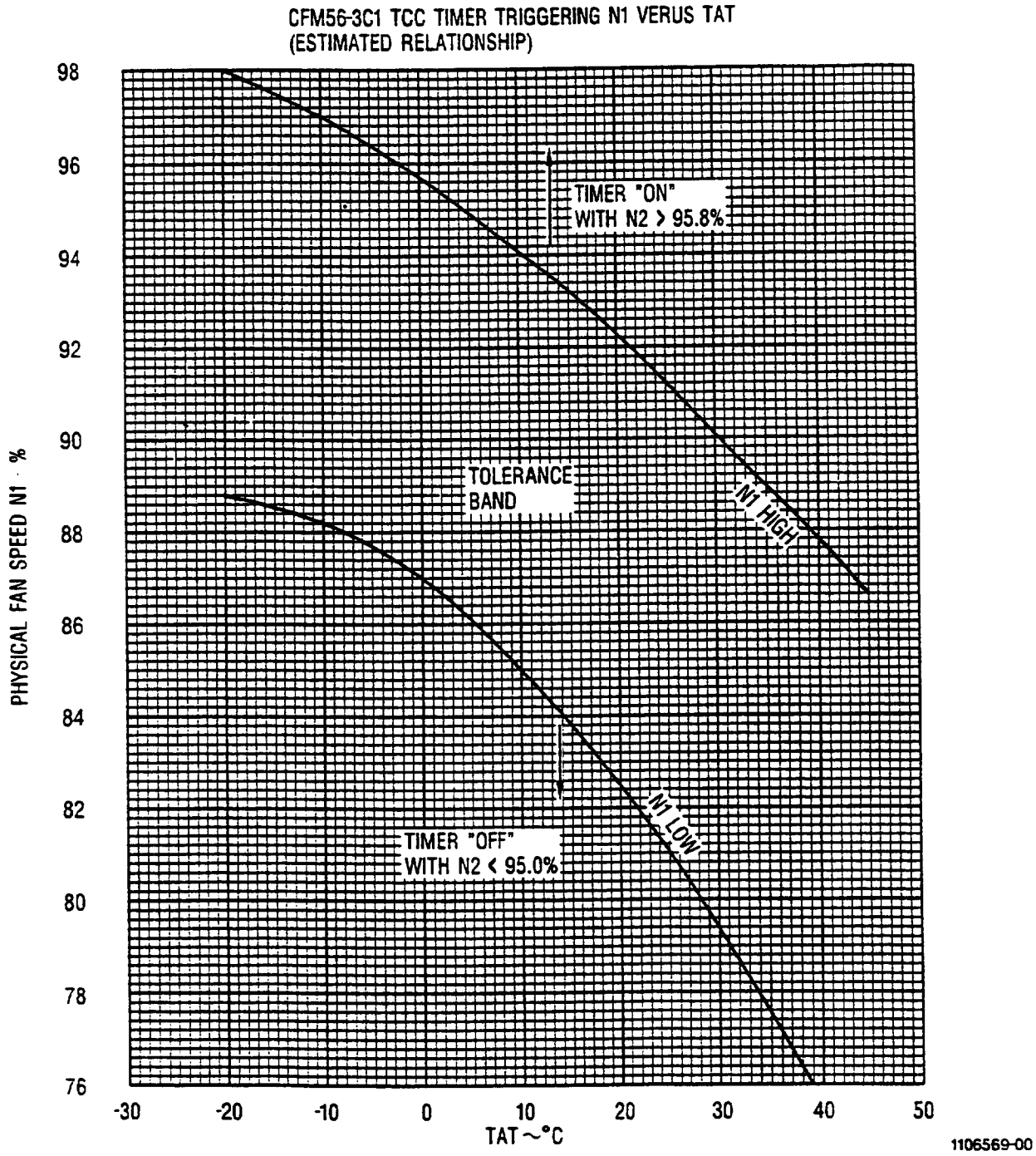

CFM56-3C1 TCC TIMER TRIGGERING N1 VERUS TAT
(ESTIMATED RELATIONSHIP)
PHYSICAL FAN SPEED N1 - %
98
96
94
92
90
88
86
84
82
80
78
76
TIMER "ON"
WITH N2 > 95.8%
TOLERANCE
BAND
N1 HIGH
N1 LOW
TIMER "OFF"
WITH N2 < 95.0%
-30
-20
-10
0
10
20
30
40
50
TAT ~°C
1106569-00

Figure 7

TABLE I

18.5K RATING

CORRECTION TO DENVER EGTM

EGTM = EGTM at 5000 To 6000 Feet + ΔEGTM

Altitude (Feet)	ΔEGTM - °C
8000	16
7000	9
5000 To 6000 feet	0
4000	9
3000	18
2000	24
100	31
SL	44

CFM56-3-B1 RATING

CORRECTION TO DENVER EGTM

EGTM = EGTM at 4000 To 6000 Feet + ΔEGTM

Altitude (Feet)	ΔEGTM - °C
8000	15
4000 To 6000 feet	0
3000	11
2000	29
1000	34
SL	44

TABLE II
CALCULATION OF EGT MARGIN

EXAMPLE: 1

Input Data

A/C	Date	Name Plate Model	ESN/ Pos	N1 %	TAT °C	EGT °C	N2 %	ECS (or) A/C Bleed	Cowl (or) Nacelle Anti-Ice	Wing Anti-Ice	Engine With (or) Without TCC Timer
xxxx	xx-xx-xx	-3C1	72x-xxx /1	83.5	8.3	725.0	93.6	Auto (or) Economy	On	Off	With Timer

(SAMPLE CALCULATION)

*Take-off EGT margin for an engine operating at 23,500 pounds thrust rating

TABLE II
CALCULATION OF EGT MARGIN

EXAMPLE: 1 (Continued)

Calculated										
N1 Low Figure 7	θ2	N1K %	EGTK °K	Figure 6 EGTK Limit °K	EGT Adjustments			T/O EGT Margin °C (EGTM)	SLOATL °C	OATL At 5000 Feet Altitude °C
					Cowl Anti-Ice	Wing Anti-Ice	TCC Timer			
---	0.9767	84.5	1018.1	1018.5	+6	0	+17	*23.4	37.3	---
				(SAMPLE CALCULATION)						

*Take-off EGT margin for an engine operating at 23,500 pounds thrust rating

TABLE III
CALCULATION OF EGT MARGIN

EXAMPLE: 2

Input Data											
A/C	Date	Name Plate Model	ESN/ Pos	N1 %	TAT °C	EGT °C	N2 %	ECS (or) A/C Bleed	Cowl (or) Nacelle Anti-Ice	Wing Anti-Ice	Engine With (or) Without TCC Timer
xxxx	xx-xx-xx	-3C1	72x-xxx /1	89.3	8.8	759.0	95.9	Auto (or) Economy	On	Off	With

(SAMPLE CALCULATION)

*Take-off EGT margin for an engine operating at 18,500 pounds thrust rating (737-500 application)

TABLE III
CALCULATION OF EGT MARGIN

EXAMPLE: 2

(Continued)

Calculated										
N1 Low Figure 7	δ2	N1K %	EGTK °K	Figure 6 EGTK Limit °K	EGT Adjustments			T/O EGT Margin °C (EGTM)	SLOATL °C	OATL At 5000 Feet Altitude °C
					Cowl Anti-Ice	Wing Anti-Ice	TCC Timer			
—	0.9785	90.28	1051.2	1082.8	+6	0	0	*128 at sea level (or) 90.6 at 5000 ft altitude	70	53

R (SAMPLE CALCULATION)

*Take-off EGT margin for an engine operating at 18,500 pounds thrust rating (737-500 application)

Same Engine If Operated at Thrust Rating (Pounds)	T/O EGT Margin - °C	
	Sea Level	At 5000 Ft
23,500	39	39
22,000	59	59
20,000	103	59
18,500	128	84