THE POWER
OF FLIGHT

CFM56

TREND INTERPRETATION

PRESENTATION

OVERVIEW

THE POWER OF FLIGHT

1. INTRODUCTION

ENGINE CONDITION MONITORING OBJECTIVES

- **Extend engine on-wing life performing optimized engine removals**
- **Reduce maintenance cost**
- **Prevent:**
  - **- Major operational events**
  - **- High cost failures**
  - **- Unscheduled removals**

ENGINE CONDITION MONITORING OBJECTIVES (con 't)

- **How to achieve them**
  - ✓ **Trouble shoot to identify cause of any significant shift of trend parameters**
    - **- Concurrently with aircraft maintenance system reports**
  - ✓ **Forecast engine removal based on EGT margin levels and LLP**
    - **- Avoid the removal of engine with enough remaining EGT margin**

ENGINE CONDITION MONITORING OBJECTIVES (con 't)

- **EGT Margin Deterioration**

  - ✓ **Good knowledge of EGT margin deterioration rate for each engine model helps**

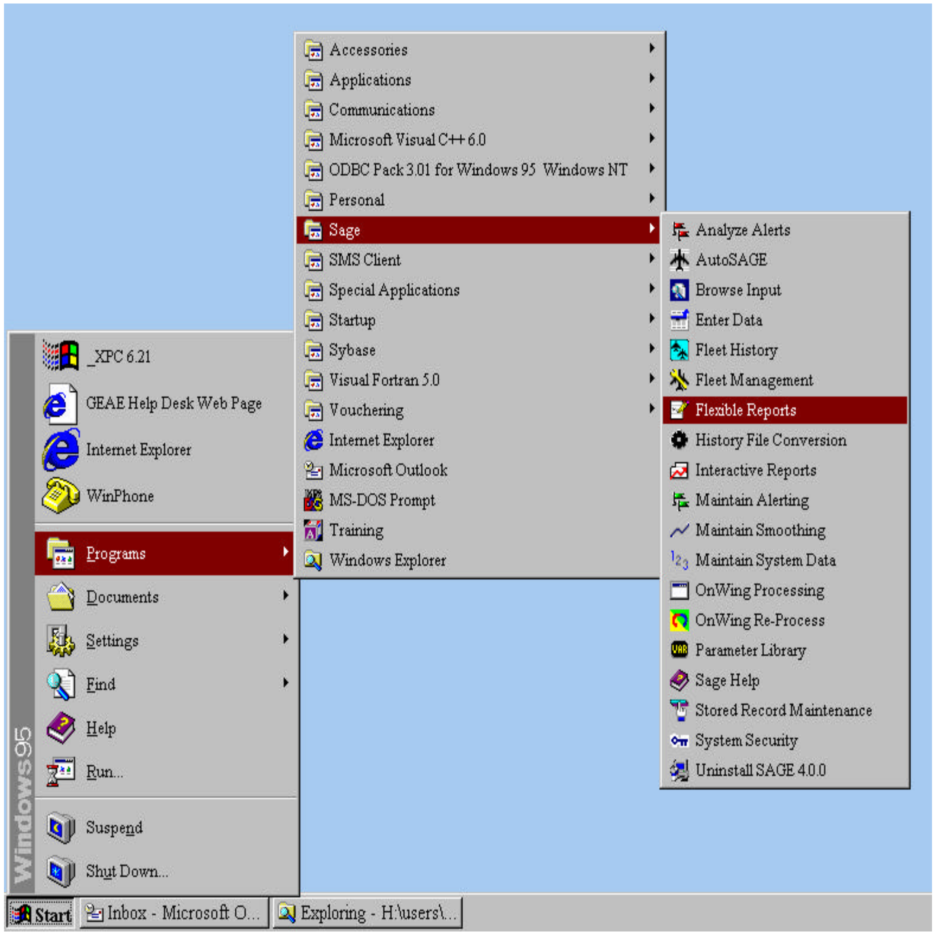
    - To identify engines with unusual behavior

    - To estimate potential engine on-wing life (new and refurbished engines)

    - To define workscope objectives, in terms of restored EGT margin & EGT margin retention

ENGINE CONDITION MONITORING TOOL: SAGE

- ✓ **Cruise, climb and takeoff performance trending**
- ✓ **Divergence monitoring**



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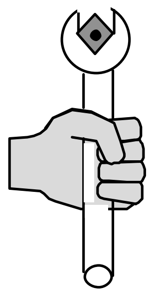
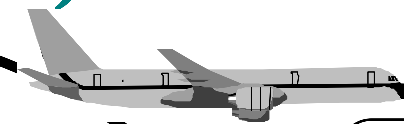
ENGINE CONDITION MONITORING PROCESS

- **Record data at cruise and takeoff**
- **Process data using SAGE (Engine Condition Monitoring program developped for GE/CFM56 applications)**
  - ✓ **Calculate deviation from reference for cruise data**
  - ✓ **Calculate Sea Level OATL and EGT Margin for takeoff data**
- **Review data**
  - ✓ **Trend plots / tabular reports / alerts summaries**
- **Recommend maintenance actions/troubleshooting**

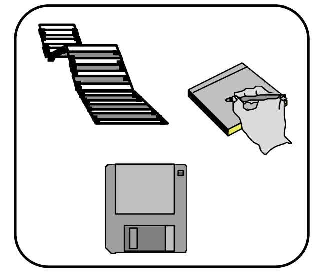
ENGINE CONDITION MONITORING PROCESS (con't)

Communicate results and perform any required inspections or maintenance





Acquire flight data



Corrective action
(if required)

- Inspections
- Engine maintenance
- Engine watch list

Record data

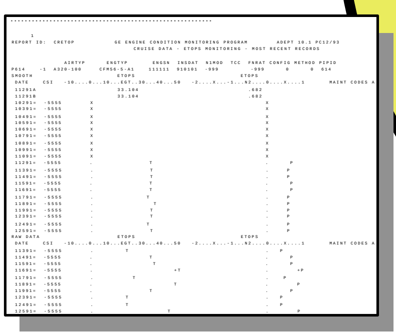
- Cruise & takeoff
- Std. instrumentation
- Automatic acquisition (or log-by-hand)

Analyze monitoring data

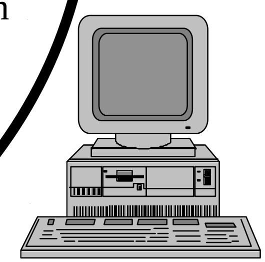
- Process with SAGE program
- Examine results (trends & levels)
- Communicate Results
  - Flight Operations
  - Maintenance

Transfer data

- Transmit to ground system (floppy disk, ACARS, etc.)
- Input data to PC
- Format input for SAGE
  - software from vendor for acquisition system
  - screen input menu



Examine ECM software reports



Enter flight data into ECM software

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2. TREND MONITORING PARAMETERS

SUMMARY

2.1 Aircraft parameters

2.2 Engine parameters

2.3 Parameters classification

2.4 Data acquisition criteria

TYPICAL DATA FOR MONITORING TRENDS

- **Input record identification**
  - ✓ **aircraft identification, date, GMT**
- **Aircraft operating condition**
  - ✓ **flight phase, altitude, Mach Nb., TAT**
- **Air-conditioning and bleed information**
- **Engine performance and mechanical measurements**
  - ✓ **N1, N2, EGT, fuel flow**
  - ✓ **vibration, oil pressure and temperature, VSV position**
- **Engine configuration**
  - ✓ **Rating, TCC timer, N1 modifier, EGT shunt**

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AIRCRAFT PARAMETERS

- **The most important parameters related to aircraft operating condition are :**

  - Flight phase

  - Altitude

  - Mach number

  - Total air temperature (TAT)

  - Bleed status

  - Anti-ice status

  - Isolation valve status

MACH NUMBER AND TOTAL AIR TEMPERATURE

- **The Mach number, and TAT are analitycal function of the aircraft speed and the air temperature :**

$$M = \frac{v}{\sqrt{g \cdot R \cdot SAT}}$$

Where:

g=***Cp/Cv=1,4***

R=8,3143 (J/mol.K) / Gas molar mass

SAT (static) air temperature

TAT(°K) can be expressed using the Mach number :

$$TAT = SAT \cdot \left(1 + \frac{g-1}{2} \cdot M^2\right)$$

TOTAL AIR PRESSURE

- **The total air pressure is expressed using TAT, SAT**

$$Total\_Pressure = P.\left(\frac{TAT}{SAT}\right)^{\frac{g}{g-1}} = P.\left(1+\frac{g-1}{2}.M^2\right)^{\frac{g}{g-1}}$$

- **The total air temperature or pressure is the value measured when the air flow is adiabatically arrested. It is always greater than the static (real) value.**

BLEED AND ANTI-ICE DATA

- **Bleed data consist of all discretes and measurements which determine ECS bleed:**
  - ✓ **Engine bleed discretes**
  - ✓ **Aircraft pack discretes or Aircraft pack flows**
  - ✓ **Isolation valve**
- **ECS bleed data required for baseline and limit line adjustments in analytical functions**
  - ✓ **Gas Path Parameter Deviations (cruise)**
  - ✓ **Sea Level OATL (takeoff)**
  - ✓ **Derate**

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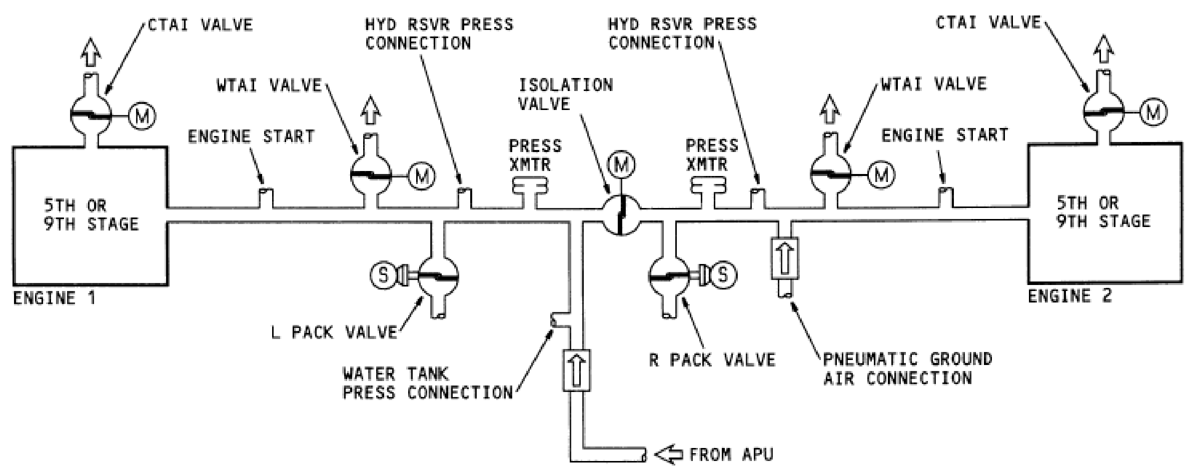
BLEED AND ANTI-ICE DATA

- **Two types of anti-ice discretes:**
  - ✓ **Engine (or nacelle) anti-ice (1 value per engine)**
  - ✓ **Wing anti-ice (only 1 input value per aircraft)**

- **Anti-ice adjustments used for takeoff calculations**
  - ✓ **Sea Level OATL / EGT Margin**
  - ✓ **Derate**

AIR DISTRIBUTION CIRCUIT

BOEING 737-600/700/800/900 MAINTENANCE MANUAL



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EFFECTIVITY ALL

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ENGINE PARAMETERS

- **The minimum engine parameters that we use to perform engine condition monitoring are :**
  - ✓ **Engine measurements**

    N1

    N2

    EGT

    Fuel flow
  - ✓ **Engine configuration**

    Thrust rating (CFM56-3)

    TCC timer (CFM56-3 & -2)

    N1 modifier (CFM56-5B, 5C & -7)

    EGT Shunt

TCC TIMER & N1 MODIFIER

➢ N1 MODIFIER

- ✓ Increases the EGT margin by reducing the thrust margin
- ✓ Reduces engine-to-engine thrust variation
- ✓ Fan speed output in the cockpit and on the DMU are modified

➢ TCC TIMER

- ✓ Turbine clearance control timer system modifies the HPTACC for the first T/O after engine start
- ✓ It decreases transient EGT overshoot during the first T/O

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PARAMETERS CLASSIFICATION

- **The parameters that we can entry in SAGE for each flight phase are classified in mandatory, recommended and optional.**

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TYPICAL CRUISE DATA

SAGE Enter Data Panel	Priority	CFM56-2	Priority	CFM56-3	Priority	CFM56-5B	Priority	CFM56-5A	Priority	CFM56-7B	Priority	CFM56-5C
Aircraft Identification	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID
Flight phase	M	takeoff/cruise/climb	M	takeoff/cruise/climb	M	takeoff/cruise/climb	M	takeoff/cruise/climb	M	takeoff/cruise/climb	M	takeoff/cruise/climb
Date	M	Date (Day/Month/ year/ hour)	M	Date (Day/Month/ year/ hour)	M	Date (Day/Month/ year/ hour)	M	Date (Day/Month/ year/ hour)	M	Date (Day/Month/ year/ hour)	M	Date (Day/Month/ year/ hour)
Actual Gross Weight	O	GW (Kg or lbs)	O	GW (Kg or lbs)	O	GW (Kg or lbs)	O	GW (Kg or lbs)	O	GW (Kg or lbs)	O	GW (Kg or lbs)
Altitude	M	ALT (ft)	M	ALT (ft)	M	ALT (ft)	M	ALT (ft)	M	ALT (ft)	M	ALT (ft)
TAT	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)
Mach Number	M	MN	M	MN	M	MN	M	MN	M	MN	M	MN
ECS Pack Flow per Sec.					M	Kg or Lbs/s	M	Kg or Lbs/s			M	Kg or Lbs/s
ATS (Auto Throttle Switch)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)
Engine Bleed Valve Pos.	M	open/closed	M	open/closed	M	open/closed	M	open/closed	M	open/closed	M	open/closed
Isolation Valve Pos.	M	open/closed	M	open/closed	M	open/closed/auto	M	open/closed/auto	M	open/closed/auto	M	open/closed
ECS Pack Valve Pos.	M	closed/econ/full	M	closed/econ/auto/full	O	closed/econ/engout/high/normal	O	closed/econ/engout/high/normal	M	closed/econ/auto/full	O	closed/econ/high/normal
Hours Since Installed	R	Hours	R	Hours	R	Hours	R	Hours	R	Hours	R	Hours
Cycles Since Installed	R	Cycles	R	Cycles	R	Cycles	R	Cycles	R	Cycles	R	Cycles
FAN SPEED	M	N1 (%)	M	N1 (%)	M	N1 (%)	M	N1 (%)	M	N1 (%)	M	N1 (%)
CORE SPEED	M	N2 (%)	M	N2 (%)	M	N2 (%)	M	N2 (%)	M	N2 (%)	M	N2 (%)
EGT	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)
Fuel Flow	M	FF (kg/h or lbs/h)	M	FF (kg/h or lbs/h)	M	FF (kg/h or lbs/h)	M	FF (kg/h or lbs/h)	M	FF (kg/h or lbs/h)	M	FF (kg/h or lbs/h)

TYPICAL CRUISE DATA

SAGE Enter Data panel	Priority	CFM56-2	Priority	CFM56-3	Priority	CFM56-5B	Priority	CFM56-5A	Priority	CFM56-7B	Priority	CFM56-5C
Fan Speed (Actual)					O	% rpm			O	% rpm	O	% rpm
Variable Stator Vane pos.					O	VSV (Variable)	O	VSV (Variable)	O	VSV (Variable)	O	VSV (Variable)
Throtlle LeverAngle	O	TLA (deg)	O	TLA (deg)	O	TLA (deg)	O	TLA (deg)	O	TLA (deg)	O	TLA (deg)
Phase Angle (Front)	O	deg	O	deg	O	deg	O	deg	O	deg	O	deg
Phase Angle (Rear)	O	deg	O	deg	O	deg	O	deg	O	deg	O	deg
Nacelle Temperature	R	NT (°C)	R	NT (°C)	R	NT (°C)	R	NT (°C)	R	NT (°C)	R	NT (°C)
Oil Pressure	R	OIP (PSID)	R	OIP (PSID)	R	OIP (PSID)	R	OIP (PSID)	R	OIP (PSID)	R	OIP (PSID)
Oil Temperature	R	OIT (°C)	R	OIT (°C)	R	OIT (°C)	R	OIT (°C)	R	OIT (°C)	R	OIT (°C)
HPT Active Clearance					O	%	O	%	O	%	O	%
LPT Active Clearance					O	%	O	%	O	%	O	%
Rotor Active Clearance					O	%	O	%	O	%	O	%
Dual Annular Mod Valve					O	%			O	%		
IBSV					O	IBSV (0-9)			O	IBSV (0-9)		
Fan vib.(Fan pickup)	R	Variable	R	Variable	R	Variable	R	Variable	R	Variable	R	Variable
Core vib.(Rear pickup)	R	Variable	R	Variable	R	Variable	R	Variable	R	Variable	R	Variable
Core vib.(Fan pickup)	O	Variable	O	Variable	O	Variable	O	Variable	O	Variable	O	Variable
Fan vib.(Rear pickup)	O	Variable	O	Variable	O	Variable	O	Variable	O	Variable	O	Variable

TYPICAL TAKEOFF DATA

SAGE Enter Data Panel	Priority	CFM56-2	Priority	CFM56-3	Priority	CFM56-5B	Priority	CFM56-5A	Priority	CFM56-7B	Priority	CFM56-5C
Aircraft Identification	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID	M	Aircraft ID
Flight phase	M	Takeoff/cruise/climb	M	Takeoff/cruise/climb	M	Takeoff/cruise/climb	M	Takeoff/cruise/climb	M	Takeoff/cruise/climb	M	Takeoff/cruise/climb
Date	M	Date (Day/Month/Year/Hour)	M	Date (Day/Month/Year/Hour)	M	Date (Day/Month/Year/Hour)	M	Date (Day/Month/Year/Hour)	M	Date (Day/Month/Year/Hour)	M	Date (Day/Month/Year/Hour)
Altitude	R	ALT (ft)	R	ALT (ft)	R	ALT (ft)	R	ALT (ft)	R	ALT (ft)	R	ALT (ft)
TAT	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)	M	TAT (°C)
Mach Number	R	MN	R	MN	R	MN	R	MN	R	MN	M	MN
CAS (Computed Air Speed)	O	CAS (kts)	O	CAS (kts)	O	CAS (kts)	O	CAS (kts)	O	CAS (kts)	O	CAS (kts)
SAT (Static Air Temperature)	O	SAT (°C)	O	SAT (°C)	O	SAT (°C)	O	SAT (°C)	O	SAT (°C)	O	SAT (°C)
ECS Pack Flow per Sec.					M	Kg or Lbs/s	M	Kg or Lbs/s	O	Kg or Lbs/s	M	Kg or Lbs/s
Auto Throttle Switch (ATS)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)	O	ATS (0-10)
Actual Gross Weight	O	Kg or Lbs	O	Kg or Lbs	O	Kg or Lbs	O	Kg or Lbs	O	Kg or Lbs	O	Kg or Lbs
Engine Bleed Valve Pos.	M	open/closed	M	open/closed	M	open/closed	M	open/closed	M	open/closed	M	open/closed
ECS Pack Valve Pos.	M	closed/econ/full	M	closed/econ/auto/full	O	closed/econ/engout/high/normal	O	closed/econ/full	M	closed/econ/auto/full	O	closed/econ/high/normal
Nacelle anti-ice	R	open/closed	R	open/closed	R	open/closed	R	open/closed	R	open/closed	R	open/closed
Wing anti-ice	R	open/closed	R	open/closed	R	open/closed	R	open/closed	R	open/closed	R	open/closed
Isolation Valve Pos.	M	open/closed	M	open/closed	M	open/closed/auto	M	open/closed/auto	M	open/closed/auto	M	open/closed

TYPICAL TAKEOFF DATA

SAGE Enter Data Panel	Prio rity	CFM56-2	Prio rity	CFM56-3	Prio rity	CFM56-5B	Prio rity	CFM56-5A	Prio rity	CFM56-7B	Prio rity	CFM56-5C
Fan Speed (Indicated)	M	N1 (%)	M	N1 (%)	M	N1 (%)	M	N1 (%)	M	N1 (%)	M	N1 (%)
Fan Speed (Actual)					O	N1 (%)			O	N1 (%)		
Core Speed	M	N2 (%)	M	N2 (%)	M	N2 (%)	M	N2 (%)	M	N2 (%)	M	N2 (%)
Exhaust Gas Temp	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)	M	EGT (°C)
Hours Since Installed	R	Hours	R	Hours	R	Hours	R	Hours	R	Hours	R	Hours
Cycles Since Installed	R	Cycles	R	Cycles	R	Cycles	R	Cycles	R	Cycles	R	Cycles
Fan Vib (Fan Pickup)	O	(Mils-Da)	O	(Mils-Da)	O	Variable	O	(Mils-Da)	O	(Mils-Da)	O	(Mils-Da)
Core Vib (Rear Pickup)	O	(Mils-Da)	O	(Mils-Da)	O	Variable	O	(Mils-Da)	O	(Mils-Da)	O	(Mils-Da)
Core Vib (Fan Pickup)	O	(Mils-Da)	O	(Mils-Da)	O	Variable	O	(Mils-Da)	O	(Mils-Da)	O	(Mils-Da)
Fan Vib (Rear Pickup)	O	(Mils-Da)	O	(Mils-Da)	O	Variable	O	(Mils-Da)	O	(Mils-Da)	O	(Mils-Da)
Phase Angle (Front)	O	deg	O	deg	O	deg	O	deg	O	deg	O	deg
Phase Angle (Rear)	O	deg	O	deg	O	deg	O	deg	O	deg	O	deg
Dual Annular Mod Valve					O	%			O	%		

TYPICAL CLIMB DATA

SAGE Enter Data Panel	Priority	CFM56-3/B737
Aircraft Identification	M	Aircraft ID
Flight phase	M	takeoff/cruise/climb
Date	M	Date (Day/Month/year/ hour)
Actual Gross Weight	O	GW (Kg)
Altitude	M	ALT (ft)
TAT	M	TAT (°C)
Mach Number	M	MN
Engine Bleed Valve Pos.	M	open/closed
Isolation Valve Pos.	M	open/closed
ECS Pack Valve Pos.	M	closed/econ/full
Nacelle anti-ice	M	open/closed
Wing anti-ice	M	open/closed

SAGE Enter Data Panel	Priority	CFM56-3/B737
Fan Speed (Indicated)	M	N1 (%)
Core Speed	M	N2 (%)
Exhaust Gas Temp	M	EGT (°C)
Fuel Flow	O	FF (kg/h or lbs/h)
Phase Angle (Front)	O	deg
Phase Angle (Rear)	O	deg
Fan vib.(Fan pickup)	O	Variable
Core vib.(Rear pickup)	O	Variable
Core vib.(Fan pickup)	O	Variable
Fan vib.(Rear pickup)	O	Variable

PARAMETERS ACQUISITION CRITERIA

- **Disciplined Data Acquisition Is the Key**
  - ✓ **Stabilized flight condition**
  - ✓ **Stabilized engine condition (auto-throttle "off", if possible)**
  - ✓ **Data recording accuracy**
  - ✓ **Instrumentation accuracy**

- **Any action which reduces scatter in the data improves the ability to detect trends or shifts**

CRUISE STABILITY CRITERIA

➢ Recommendations Cruise

✓ **For hand recorded data**

- Stabilize in cruise for minimum of 5 minutes

- **Establish stable aircraft and engine operation (auto-throttle “off” preferred)**

- Record data

- **If the following conditions remain valid for 12 seconds:**

Altitude	**> 20,000 feet**
Mach number	**> 0.6 and < 0.9**
D**Mach number**	**< + 0.015**
D**TAT**	**< + 1° C**
D **N1**	**< 0.4 %**
D**Altitude**	**< + 100 feet**
D**N2**	**< + 0.8 %**

- **Engine bleed stable**
- **Cowl and wing anti-ice “off"**

TAKEOFF DATA ACQUISITION CRITERIA

- **Avoid using data from the "cold" engine takeoffs for CFM56--3/-7B/-5A/-5B (lower EGTHDM)**
  - ✓ **First takeoff of the day or after 4 to 6 hours shutdown**
- **The takeoff data should be recorded during the specific condition at which peak EGT levels typically occur (which differs among the various aircraft types)**

ENGINE TYPE	TYPICAL MEASUREMENT CONDITIONS
CFM56-2	50 seconds after weight off of wheels or 600 feet above runway
CFM56-3	9 seconds after rotation, or about 300 feet altitude
CFM56-5A	Maximum EGT ocurring between 40-60 seconds after 80 knots
CFM56-5B	Maximum EGT ocurring between 40-60 seconds after 80 knots
CFM56-5C	Maximum EGT occuring between 30-80 seconds after 80 knots
CFM56-7	Maximum EGT ocurring within 80 seconds after 100 knots

ANNEX

CRUISE STABILITY CRITERIA

- **Recommendations Cruise**
  - ✓ **For automatic data adquisition**

Parameter	Unit	CFM56-3/-7B	CFM56-5A/5B	CFM56-5C
IVV	ft/min	300	300	100
FPAC	G	0.03	0.03	0.012
ROLL	Deg	4	4	0.8
TAT	°C	2	2	0.5
N2	%	0.9	0.9	0.8
EGT	°C	18	18	19
VACC	G	0.1	0.1	0.02
Mach	-	0.01	0.01	0.006
N1	%	1.6	1.6	1.6
FF	Kg/h	100	100	90
PT2	Psia	0.1	0.1	0.04

- **Stable frame parameter values must be within the variations during a period of 100 seconds**

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3.- CFM56 ENGINE TYPE SPECIFICATIONS

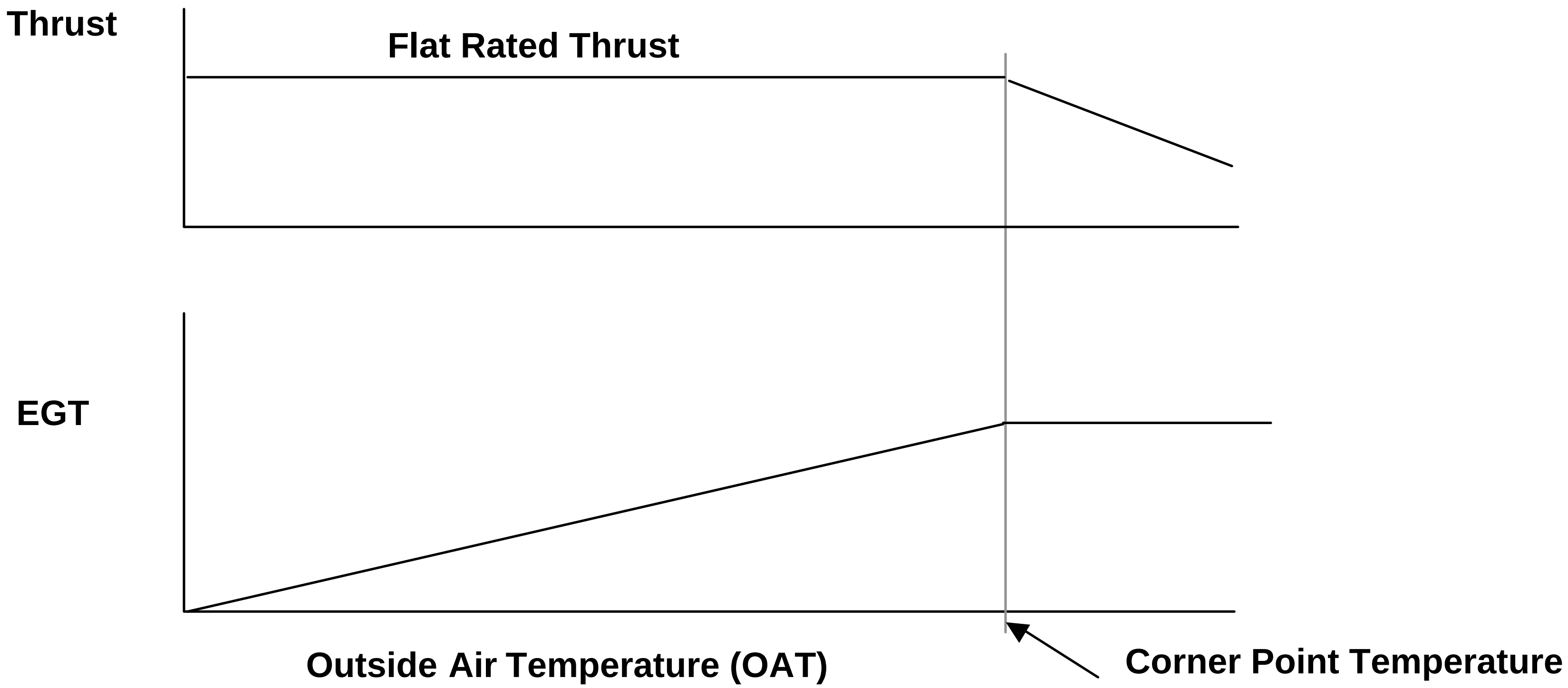
SUMMARY

CORNER POINT TEMPERATURE

- **The engine thrust setting is defined by the power management schedule. The power management schedule is designed to provide, for a given airport altitude, constant takeoff thrust for ambient temperatures up to the corner point temperature for that altitude.**

- **For ambience temperatures above the corner point, thrust is reduced in order to maintain approximately constant or decreasing EGT.**

CORNER POINT TEMPERATURE



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N1 MODIFIER AND PHYSICAL N1

- **For some FADEC-controlled engines the physical fan speed is modified when displayed in cockpit**
  - ✓ **N1 Modifier allows for more consistent indicated N1-to-thrust relationships among different engines of same family**
  - ✓ **Discrete levels of fan speed modification: 0 to 7**
  - ✓ **For these engines there are 3 possible parameters related to fan speed (used to calculate Sea level OATL/EGT Margin and Gas Path Parameter Deviations)**

    - Indicated fan speed

    - N1 modifier level

    - Physical (or unmodified) fan speed (Calculated by SAGE)

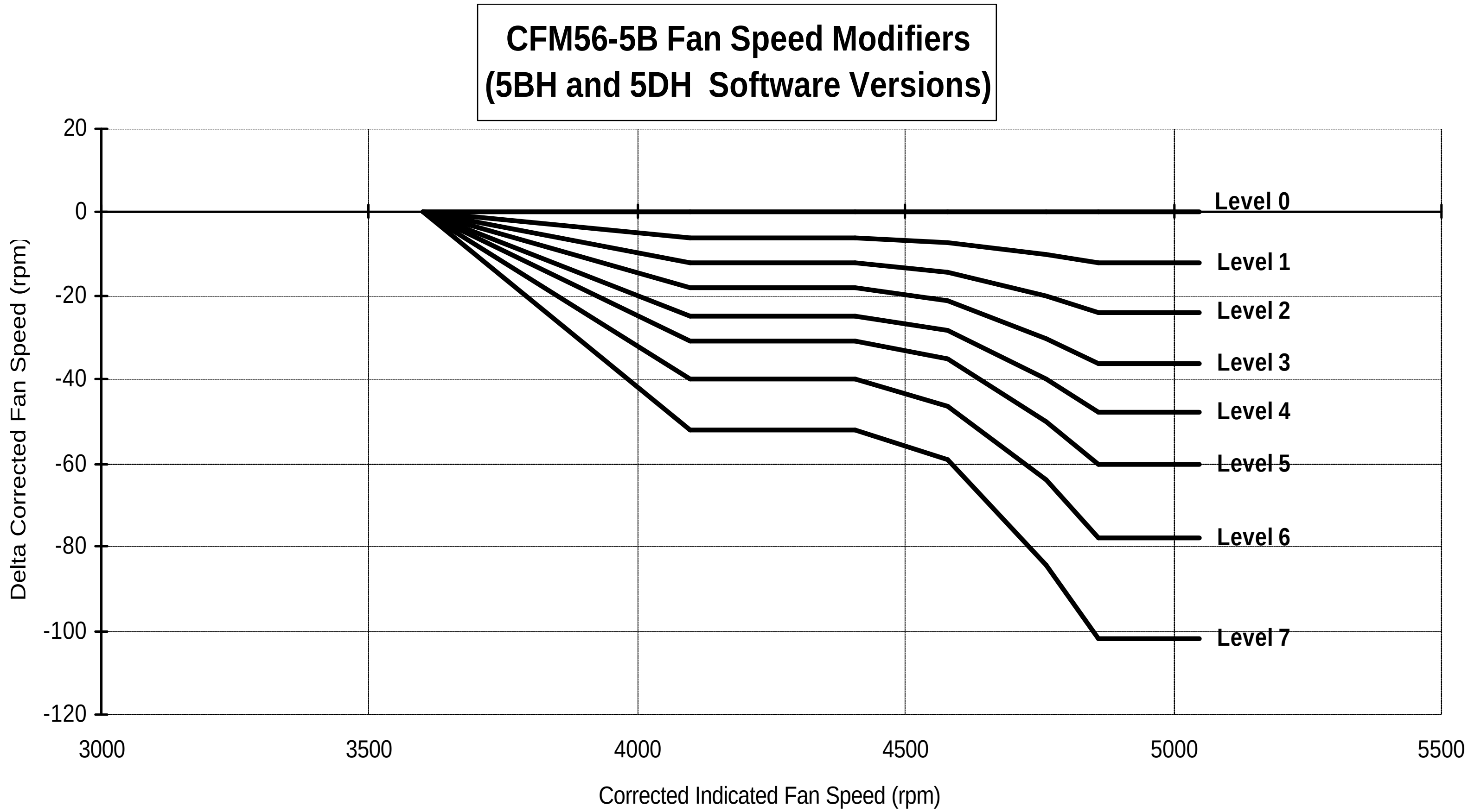
N1 MODIFIER LEVEL

- **The N1 modifier level is selected based on test cell results**
  - ✓ **Test performed with a 0 modifier level. Then based on the demonstrated thrust margin at takeoff power setting, a modifier level is selected**

CFM56-5C FADEC N1 Modifier Levels

Thrust Margin		Modifier
Equal to or Greater Than	But Less Than	Level
0%	1.399%	0
1.4%	1.799%	1
1.8%	2.199%	2
2.2%	2.599%	3
2.6%	2.999%	4
3.0%	3.599%	5
3.6%	4.199%	6
4.2%		7

N1 MODIFIER LEVEL



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HPTCC VALVE TIMER

- **TCC Timer**
  - ✓ **TCC (Turbine Clearance Control) timer adjustment made for CFM56-2A, -3C1 & -3B2**
  - ✓ **Adjustment to Sea Level OATL and EGT Margin made when**
    - **- TCC timer is "ON"**
    - **- Core speed less than TCC timer trigger point**
  - ✓ **Adjustment requires 2 parameters**
    - **- TCC timer switch value (maintenance data)**
    - **- Core speed (takeoff data)**

EGT SHUNT

- **For some engine models the EGT measurement is adjusted for cockpit display**
  - ✓ **The EGT Shunt modifies the EGT displayed in the cockpit**
  - ✓ **It allows a common display scale for different engine/hardware combinations on the same aircraft**
- **It is due to the different hardware configurations in some engine types (CFM56-5C, 5A, 5B) that originate different EGT redlines**
  - ✓ **Baseline hardware CFM56-5C 950°C**
  - ✓ **1st modified hardware CFM56-5C/F 965°C**
  - ✓ **2nd modified hardware CFM56-5C/G 975°C**
- **For CFMI engine, the hardware is described in the engine type, and does not need to be entered into SAGE**

ENGINE TYPE SPECIFICATIONS

Engine Models	Thrust (lbs)	Sea Level Corner Point OAT (°C)	Hardware EGT Redline (°C)	Shunt factor	Bump
CFM56-7-B18	19,500	ISA + 15 (30°C)	950		
CFM56-7-B20	20,600	ISA + 15 (30°C)	950		
CFM56-7-B22	22,700	ISA + 15 (30°C)	950		
CFM56-7-B22B1	22,700	ISA + 21 (36°C)	950		*
CFM56-7-B24	24,200	ISA + 15 (30°C)	950		
CFM56-7-B24B1	24,200	ISA + 26 (41°C)	950		*
CFM56-7-B26	26,300	ISA + 15 (30°C)	950		
CFM56-7-B26B1	26,300	ISA + 15 (30°C)	950		
CFM56-7-B27	27,300	ISA + 15 (30°C)	950		
CFM56-7-B27B1	27,300	ISA + 15 (30°C)	950		*
CFM56-7-B27B3	27,300	ISA + 15 (30°C)	950		
CFM56-2-C1	22,000	ISA + 15 (30°C)	870/905		
CFM56-2A2	24,000	ISA + 20 (35°C)	930		
CFM56-2A3	24,000	ISA + 17 (32°C)	930		
CFM56-2B-1	22,000	ISA + 17 (32°C)	905 (cert. 2000)		
CFM56-3C-1	18,500 to 23,500	ISA + 15 (30°C)	930		
CFM56-3B-2	18,500 to 22,000	ISA + 15 (30°C)	930		
CFM56-3B1	18,500 to 20,000	ISA + 15 (30°C)	930		
CFM56-5C2	31,200	ISA + 15 (30°C)	950		
CFM56-5C2/F	31,200	ISA + 15 (30°C)	965	950/965	
CFM56-5C2/G	31,200	ISA + 15 (30°C)	975	950/975	
CFM56-5C3/F	32,500	ISA + 15 (30°C)	965	950/965	
CFM56-5C3/G	32,500	ISA + 15 (30°C)	975	950/975	
CFM56-5C4	34,000	ISA + 15 (30°C)	975	950/975	*
CFM56-5C4/P	34,000	ISA + 15 (30°C)	975	950/975	

THE POWER OF FLIGHT

ENGINE TYPE SPECIFICATIONS (cont'd)

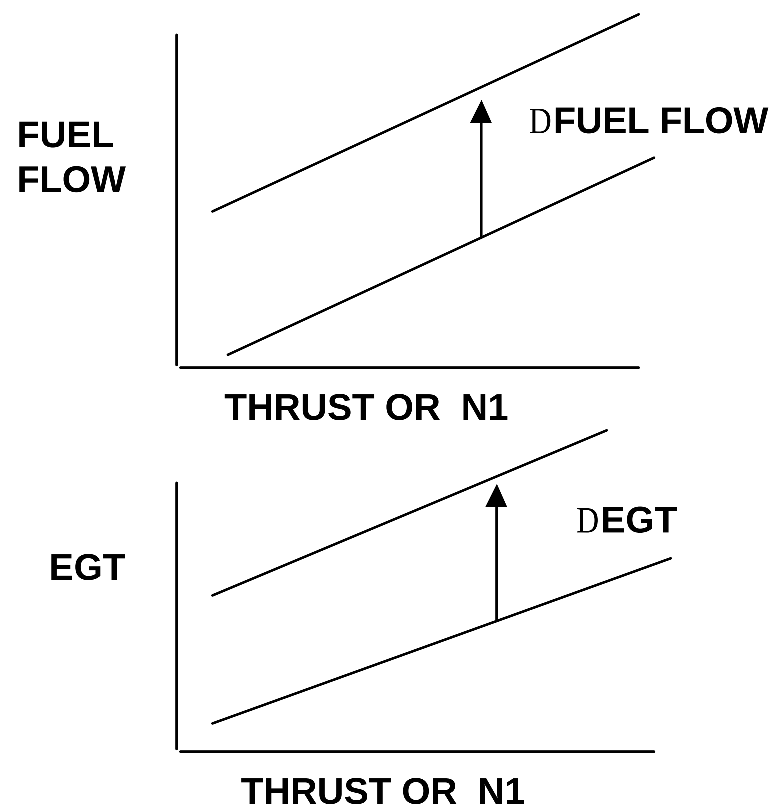
Engine Models	Thrust (lbs) (M=0)	Sea Level Corner Point OAT (°C)	Hardware EGT Redline (°C)	Shunt factor	Bump
CFM56-5-A1	25,000	ISA + 15 (30°C)	890		
CFM56-5-A1/F	25,000	ISA + 15 (30°C)	915	890/915	
CFM56-5A3	26,500	ISA + 15 (30°C)	915	890/915	*
CFM56-5A4	22,000	ISA + 30 (45°C)	890		*
CFM56-5A4/F	22,000	ISA + 30 (45°C)	915	890/915	*
CFM56-5A5	23,500	ISA + 22 (37°C)	890		*
CFM56-5A5/F	23,500	ISA + 22 (37°C)	915	890/915	*
CFM56-5B9/P	23,300	ISA + 30 (45°C)	940	950/940	
CFM56-5B8/P	21,600	ISA + 30 (45°C)	940	950/940	
CFM56-5B7/P	27,000	ISA + 29 (44°C)	940	950/940	
CFM56-5B6	23,500	ISA + 30 (45°C)	950		
CFM56-5B6/P	23,500	ISA + 30 (45°C)	940	950/940	
CFM56-5B5	22,000	ISA + 30 (45°C)	950		
CFM56-5B5/P	22,000	ISA + 30 (45°C)	940	950/940	
CFM56-5B4	27,000	ISA + 29 (44°C)	950		
CFM56-5B4/P	27,000	ISA + 29 (44°C)	940	950/940	
CFM56-5B4/P1	27,000	ISA + 35 (50°C)	940	950/940	*
CFM56-5B3/P	32,000	ISA + 15 (30°C)	940	950/940	*
CFM56-5B3/P1	32,000	ISA + 15 (30°C)	940	950/940	*
CFM56-5B2	31,000	ISA + 15 (30°C)	950		
CFM56-5B2/P	31,000	ISA + 15 (30°C)	940	950/940	
CFM56-5B1	30,000	ISA + 15 (30°C)	950		
CFM56-5B1/P	30,000	ISA + 15 (30°C)	940	950/940	

ENGINE DETERIORATION

As an engine deteriorates or damage occurs, the efficiency of the engine cycle is decreased.

Lower efficiency results in more fuel and higher temperature being required to achieve the same N1 or thrust.

Basic "performance monitoring" involves monitoring the change in these parameters (at constant fan speed)



THE POWER OF FLIGHT

ANNEX

INTERNATIONAL STANDARD ATMOSPHERE (ISA)

ALTITUDE (Feet)	TEMP. (°C)	PRESSURE			PRESSURE RATIO $\delta = P / P_0$	DENSITY $\sigma = \rho / \rho_0$	SPEED of SOUND (a) kt	ALTITUDE (meters)
		HPa	P.S.I.	In Hg.				
41,000	− 56.5	179	2.59	5.28	0.1764	0.2346	573	12,496
40,000	− 56.5	188	2.72	5.54	0.1851	0.2462	573	12,192
39,000	− 56.5	197	2.85	5.81	0.1942	0.2583	573	11,887
38,000	− 56.5	206	2.99	6.10	0.2038	0.2710	573	11,582
37,000	− 56.5	217	3.14	6.40	0.2138	0.2844	573	11,278
36,000	− 56.3	227	3.30	6.71	0.2243	0.2981	573	10,973
35,000	− 54.3	238	3.46	7.04	0.2353	0.3099	576	10,668
34,000	− 52.4	250	3.63	7.38	0.2467	0.3220	579	10,363
33,000	− 50.4	262	3.80	7.74	0.2586	0.3345	581	10,058
32,000	− 48.4	274	3.98	8.11	0.2709	0.3473	584	9,754
31,000	− 46.4	287	4.17	8.49	0.2837	0.3605	586	9,449
30,000	− 44.4	301	4.36	8.89	0.2970	0.3741	589	9,144
29,000	− 42.5	315	4.57	9.30	0.3107	0.3881	591	8,839
28,000	− 40.5	329	4.78	9.73	0.3250	0.4025	594	8,534
27,000	− 38.5	344	4.99	10.17	0.3398	0.4173	597	8,230
26,000	− 36.5	360	5.22	10.63	0.3552	0.4325	599	7,925
25,000	− 34.5	376	5.45	11.10	0.3711	0.4481	602	7,620
24,000	− 32.5	393	5.70	11.60	0.3876	0.4642	604	7,315
23,000	− 30.6	410	5.95	12.11	0.4046	0.4806	607	7,010
22,000	− 28.6	428	6.21	12.64	0.4223	0.4976	609	6,706
21,000	− 26.6	446	6.47	13.18	0.4406	0.5150	611	6,401
20,000	− 24.6	466	6.75	13.75	0.4595	0.5328	614	6,096
19,000	− 22.6	485	7.04	14.34	0.4791	0.5511	616	5,791
18,000	− 20.7	506	7.34	14.94	0.4994	0.5699	619	5,406
17,000	− 18.7	527	7.65	15.57	0.5203	0.5892	621	5,182
16,000	− 16.7	549	7.97	16.22	0.5420	0.6090	624	4,877
15,000	− 14.7	572	8.29	16.89	0.5643	0.6292	626	4,572
14,000	− 12.7	595	8.63	17.58	0.5875	0.6500	628	4,267
13,000	− 10.8	619	8.99	18.29	0.6113	0.6713	631	3,962
12,000	− 8.8	644	9.35	19.03	0.6360	0.6932	633	3,658
11,000	− 6.8	670	9.72	19.79	0.6614	0.7156	636	3,353
10,000	− 4.8	697	10.10	20.58	0.6877	0.7385	638	3,048
9,000	− 2.8	724	10.51	21.39	0.7148	0.7620	640	2,743
8,000	− 0.8	753	10.92	22.22	0.7428	0.7860	643	2,438
7,000	+ 1.1	782	11.34	23.09	0.7716	0.8106	645	2,134
6,000	+ 3.1	812	11.78	23.98	0.8014	0.8359	647	1,829
5,000	+ 5.1	843	12.23	24.90	0.8320	0.8617	650	1,524
4,000	+ 7.1	875	12.69	25.84	0.8637	0.8881	652	1,219
3,000	+ 9.1	908	13.17	26.82	0.8962	0.9151	654	914
2,000	+ 11.0	942	13.67	27.82	0.9298	0.9428	656	610
1,000	+ 13.0	977	14.17	28.86	0.9644	0.9711	659	305
0	+ 15.0	1013	14.70	29.92	1.0000	1.0000	661	0
− 1,000	+ 17.0	1050	15.23	31.02	1.0366	1.0295	664	− 305

THE POWER OF FLIGHT

4. PERFORMANCES EVALUATION

THE POWER OF FLIGHT

SUMMARY

CORRECTED PARAMETERS

Engine parameters like EGT, thrust, core speed, fuel flow depend on:

pressure (altitude), mach number, TAT, fan speed

To have a « simple » representation of the engine behaviour, the parameters are combined together to create « corrected parameters »

CORRECTED PARAMETERS

THETA FACTOR CORRECTION

$$\Theta_2 = \frac{(TAT + 273.15)}{288.15}$$

$$N_{1K} = \frac{N_1}{\Theta_2^a}$$

Where α is determined from the actual/indicated fan speed and TAT (Takeoff/Cruise calculations).It is close to 0,5.

$$EGT_K = \frac{(\mathrm{EGT} + 273.15)}{\Theta_2^b}$$

Where β is determined from the actual/indicated fan speed and TAT (Takeoff/Cruise calculations). It is close to 1.

$$FNK = \frac{FN}{d_2}$$

Where δ_2 = PT2 /14.696 PT2= Total Pressure at Fan Inlet (PSIA)

CORRECTED PARAMETERS

ADDITIONAL CORRECTED PARAMETERS

Corrected air flow

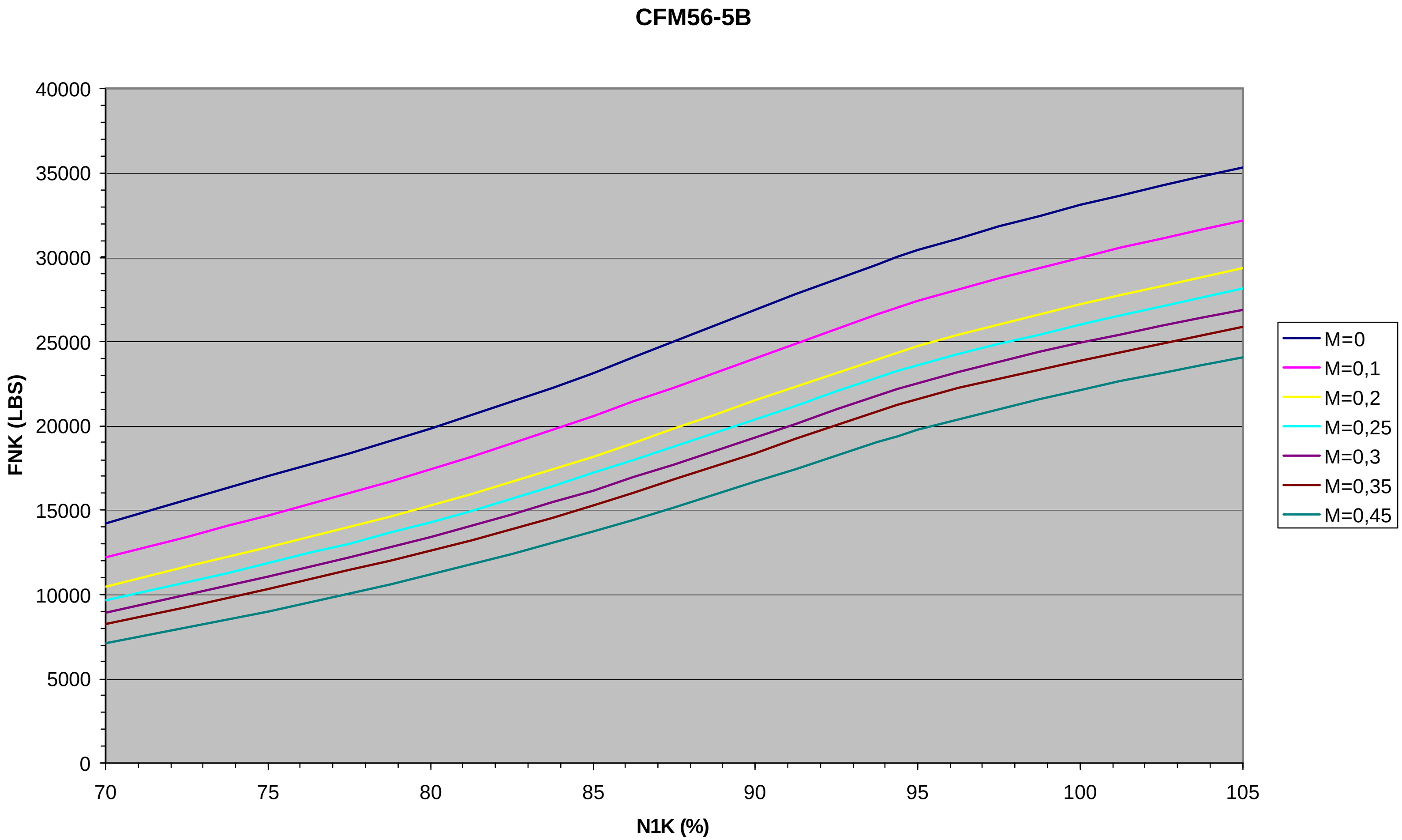
$$d = \frac{D.\sqrt{T}}{P} or \frac{D.\sqrt{q}}{d}$$

Corrected fuel flow

$$WF_K = \frac{WF}{d_2 * q_2^l} * \frac{LHV}{LHV_{ref}}$$

Where λ is determined from the actual or indicated fan speed. It is close to 0,5.
LHV is the fuel Lower Heating Value.

CORRECTED PARAMETER POWER MANAGEMENT



TOC

EGT MARGIN & SEA LEVEL OATL

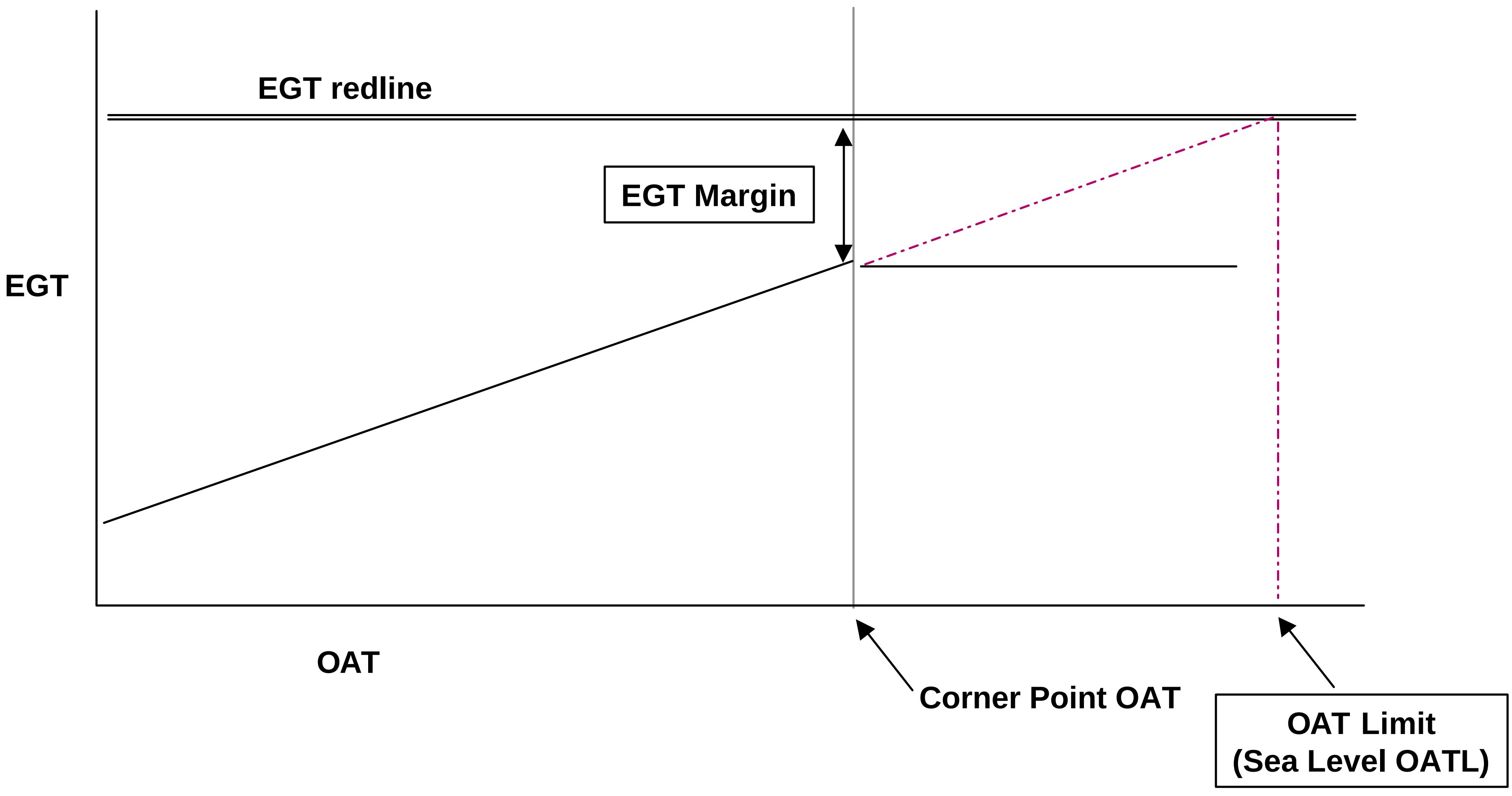
EGTHD Margin (Exhaust Gas Temperature Hot Day Margin)

- **The difference between the certified takeoff EGT limit and the peak EGT during a full power takeoff on sea level Corner Point day.**

Sea Level OATL (Sea Level Outside Air Temperature Limit)

- **The maximum sea level OAT at which a full power takeoff can occur without exceeding the certified takeoff EGT limit (redline EGT). If OATL is greater than corner point OAT then full power takeoff can occur at any OAT without exceeding the certified takeoff EGT limit.**

EGT MARGIN & SEA LEVEL OATL



THE POWER OF FLIGHT

EGT MARGIN & SEA LEVEL OATL

Hot day EGT margin is calculated from measured T/O parameters applying the corrections for air conditionning, bleed status, TCC timer...., the hot temperature ratio factor and an EGT shunt scalar (if applicable):

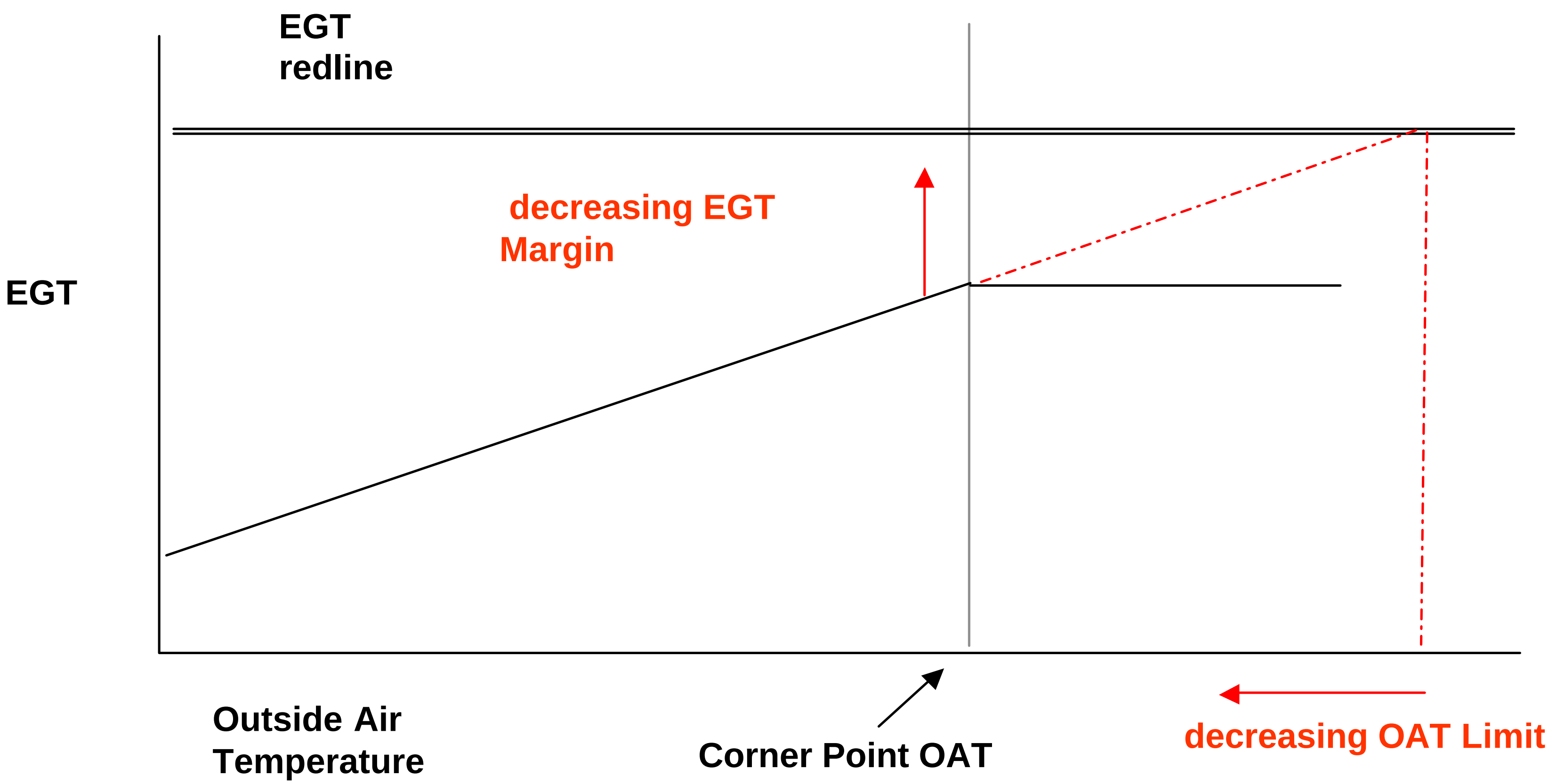
$$EGTHotDayMargin = (EGTKLimit - EGTK + MarginAdjustments) \times q_{hotday}$$

SLOATL can be calculated from the EGT hot day margin (approximation of another formula):

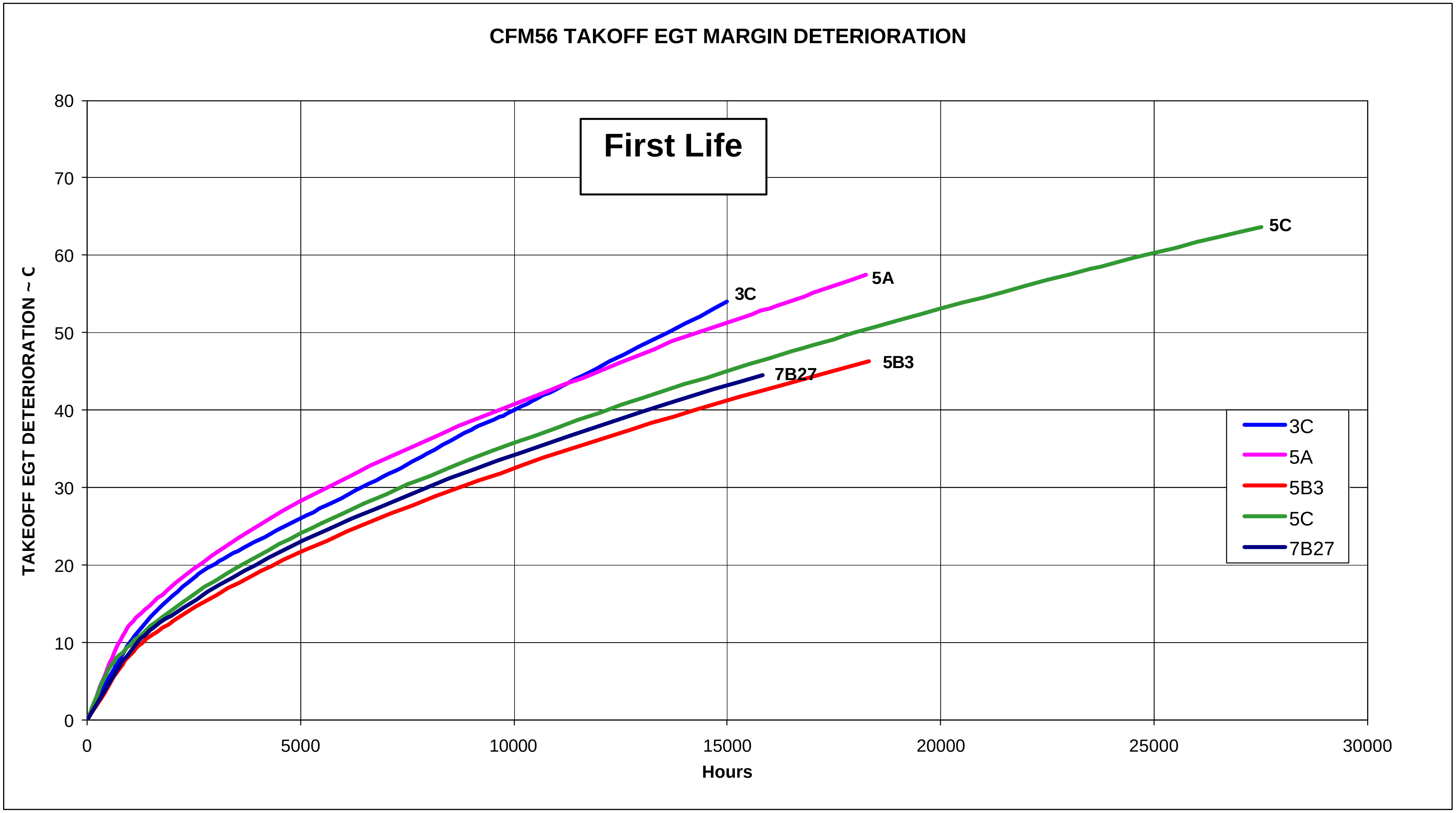
$$SeaLevelOATL = T_{cp} + \frac{EGTHDM}{l}$$

where Tcp is the corner point temperature and l is a coefficient depending on engine type (see annex for coefficient list)

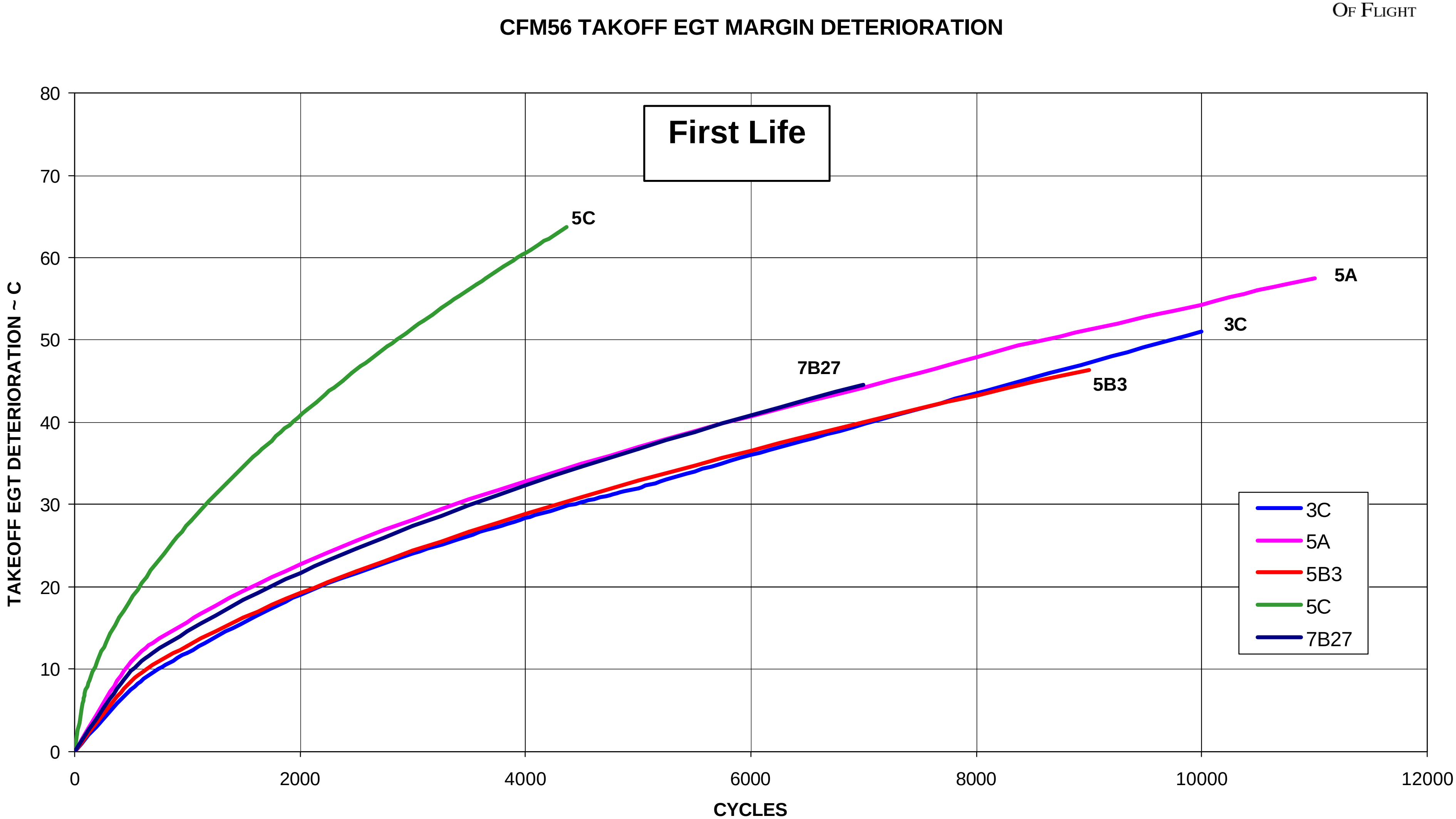
EFFECT OF DETERIORATION



When EGT margin = 0°C, then Sea Level OATL = $T_{corner\ point}$


CFM56 TAKOFF EGT MARGIN DETERIORATION
First Life
TAKEOFF EGT DETERIORATION ~ C
Hours
0
10
20
30
40
50
60
70
80
0
5000
10000
15000
20000
25000
30000
3C
5A
5B3
5C
7B27
3C
5A
5B3
5C
7B27

TOC


CFM56 TAKOFF EGT MARGIN DETERIORATION
First Life
TAKEOFF EGT DETERIORATION ~ C
CYCLES
0
10
20
30
40
50
60
70
80
0
2000
4000
6000
8000
10000
12000
5C
5A
3C
7B27
5B3
3C
5A
5B3
5C
7B27

TOC

EFFECT OF DETERIORATION

The deterioration curves are average on worldwide fleet. The 2 standard deviation interval (95% of the fleet) is about +/- 15°C.

Factors influencing deterioration are:

- **environment (sand, ice)**
- **derate**
- **maintenance practices (water-wash, EGT probe change, ..)**
- **flight leg (curve in cycles)**

ALTITUDE EFFECT ON EGT

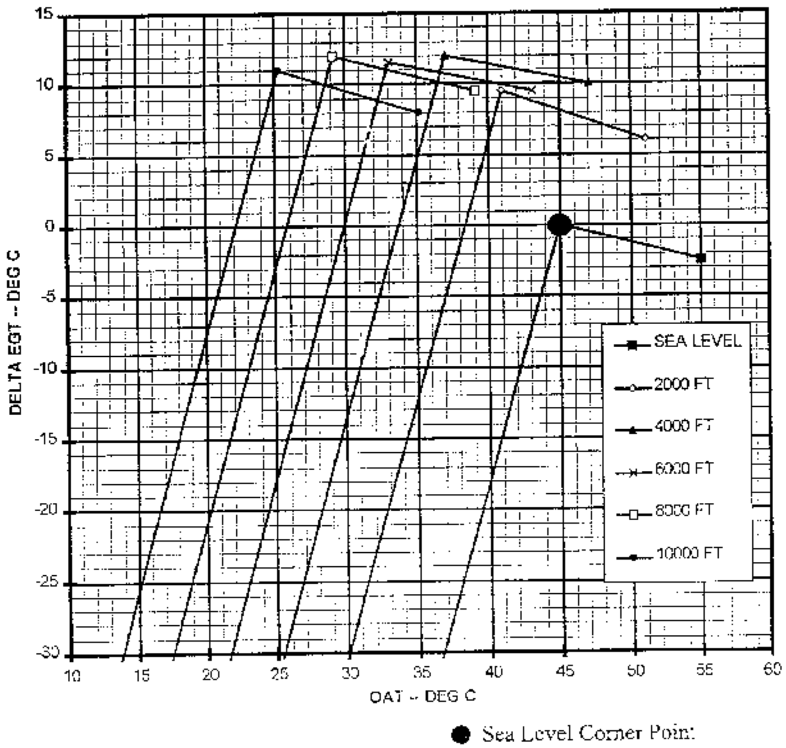
- **The ECM tool (SAGE) provides the projected EGT margin regardless of the Airport T/O altitude conditions. For models with altitude effect adjustments have to be handled external to the ECM tool.**
- **With altitude effect adjustments to the calculated S/L margin, EGT margin available for a given T/O at an altitude airport can be estimated.**
- **For example: CFM56-3B1**

SAGE calculated S/L Hot day EGT margin for a T/O on a S/L airport = 90 °C

For Denver T/O (Alt = 5330 ft):

- **Altitude effect = 44°C**
- **Projected margin for a full rated T/O on a Corner point day will be = 90°C - 44°C = 46°C.**

ALTITUDE EFFECT ON EGT



CFM56-5B6 - Peak EGT Relative to Sea Level Corner Point Peak EGT
Figure 7

DERATE

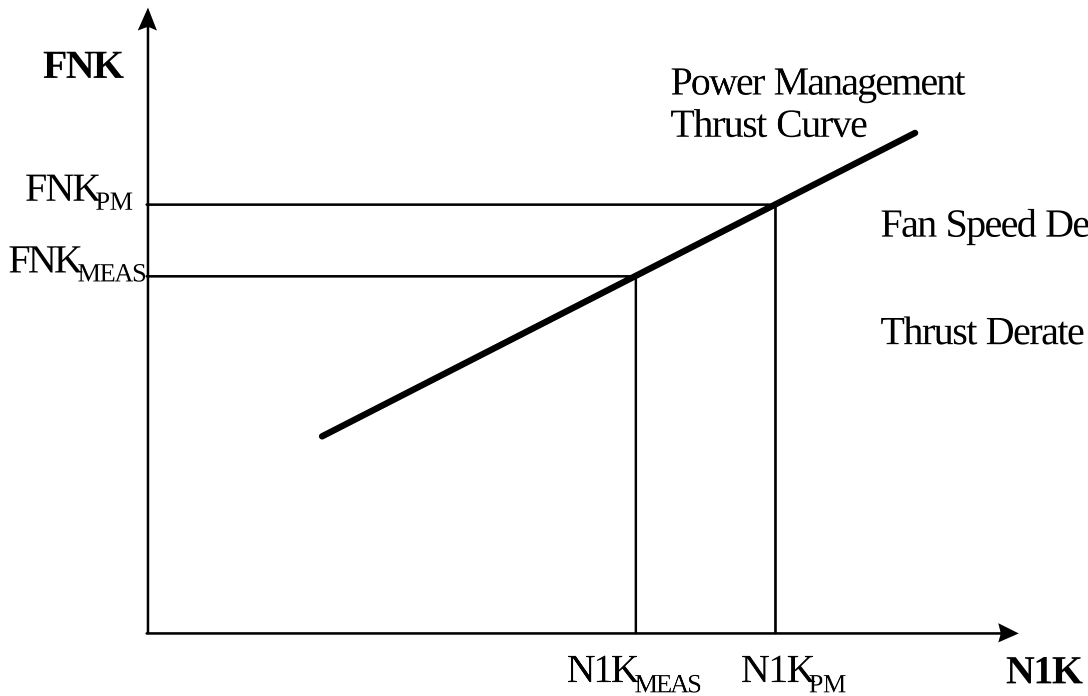
- **SAGE uses takeoff data to compute the amount of engine "derate" (operation below rated thrust)**

- **Two calculated derate values**
  - **Fan speed derate**
  - **Thrust derate**

- **Compares measured fan speed to the predicted fan speed necessary for "full-rated" thrust (power management fan speed)**

- **"Power-management" fan speed based on takeoff operating conditions**
  - **adjusted for air conditioning and anti-ice bleed**
  - **adjusted for any bump rating (CFM56-5 and -7 only)**

DERATE CALCULATIONS



Fan Speed Derate = $N1K_{PM} - N1K_{MEAS}$

Thrust Derate = $100\% \times [1-(FNK_{MEAS}/FNK_{PM})]$

FNK: Corrected Thrust
N1K: Corrected Fan Speed
PM: Power Management

CRUISE DATA MONITORING SYSTEM

- **Compare performance measurements to a “baseline” (Reference engine characteristic)**
- **Plot deltas from the “baseline”**
- **Review plots for trends / shifts**

CRUISE GAS-PATH PARAMETER DEVIATIONS

Monitor basic cockpit parameters: EGT, FF & N2

Measured values compared to expected values

- **Calculate deviation from "baseline"**
  - **Reference or theoretical engine characteristics for an engine model are typically:**
    - **Developed using data obtained during flight test**
    - **Consistent with information provided by aircraft manufacturer**
    - **Representative of average flight-test engine performance**
- **Baseline adjusted for operating conditions: Altitude, mach number,TAT & air conditioning bleed effects**

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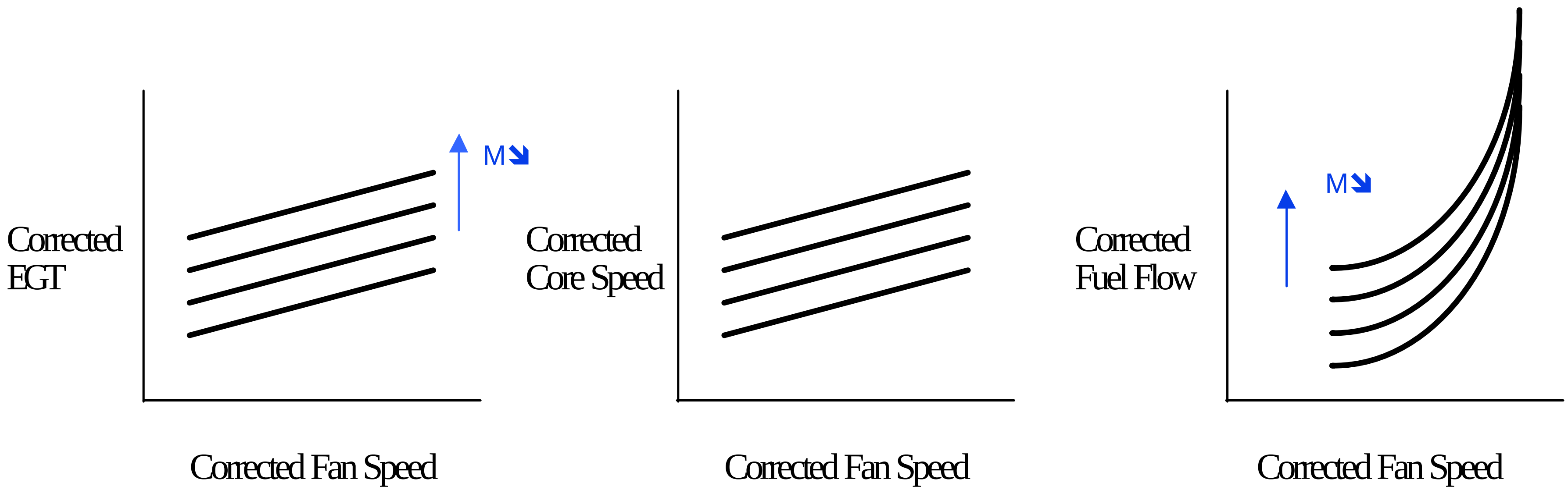
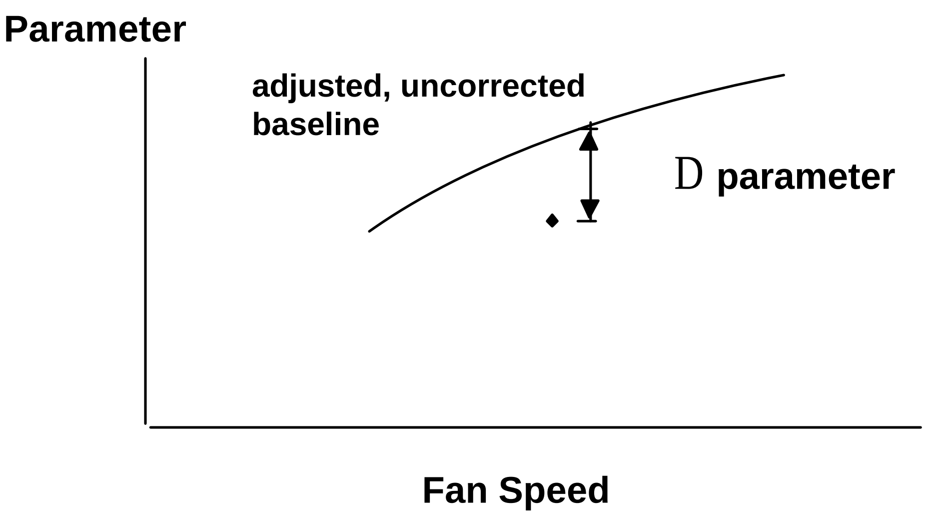
GAS PATH PARAMETER BASELINES



CRUISE CALCULATIONS



Definition of Deviations Shown on Reports

DEGT (ºC) = D EGT

GPCN25 = (D Core Speed / baseline Core Speed) X100

GWFM (%) = (D fuel flow / baseline fuel flow) X100

THE POWER OF FLIGHT

USER SELECTABLE FUNCTIONS

- **Oil Pressure Monitoring**
- **Delta VSV Calculation**
- **ETOPS Margin**
- **SLOATL With Cruise Update**

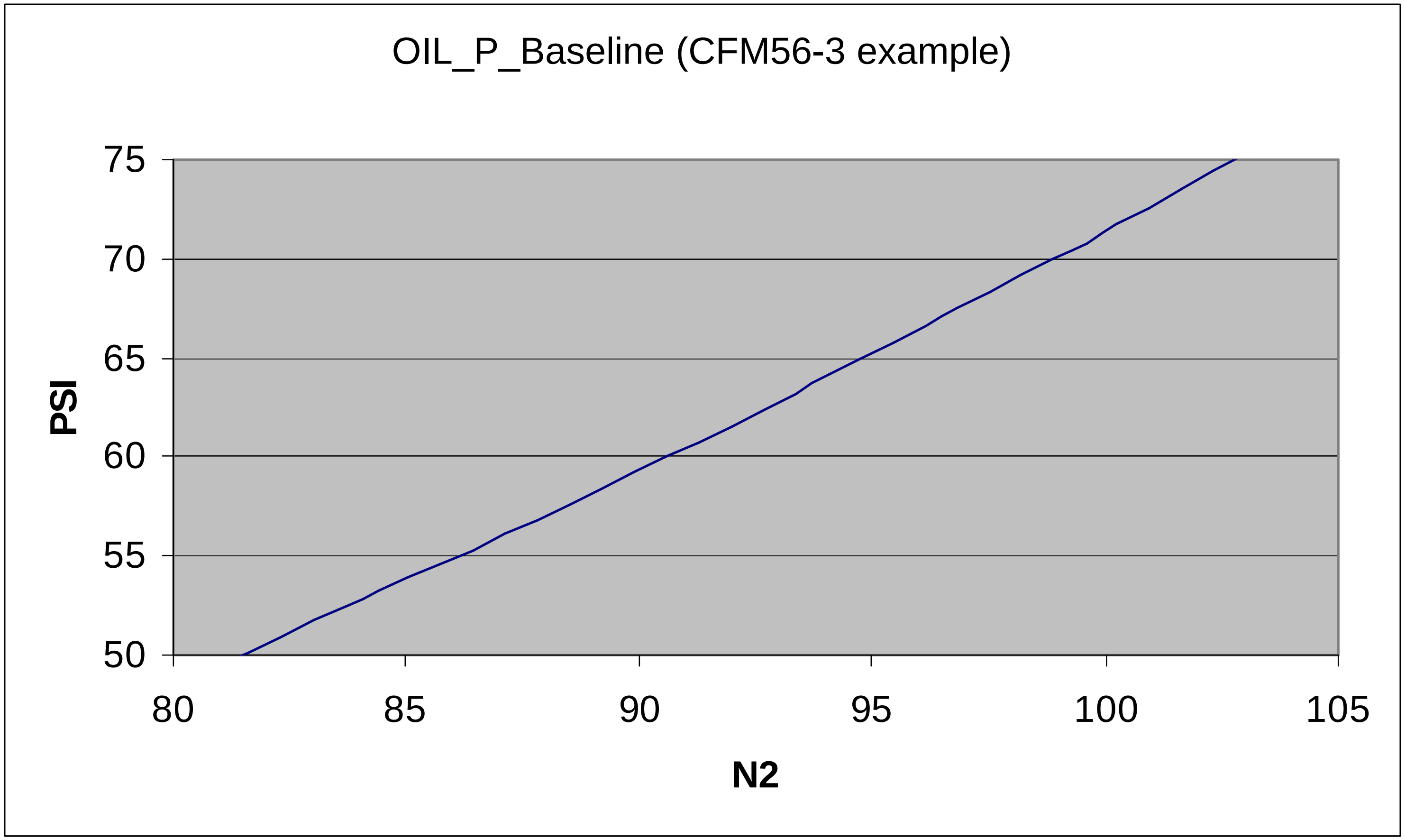
OIL PRESSURE MONITORING

SAGE oil monitoring function compares oil pressure data to a reference oil pressure line

- **Unique reference pressure curve for each engine family**
- **Reference oil pressure is function of core speed**

Allows for early detection of coking and other potential bearing failures

OIL PRESSURE MONITORING



THE POWER OF FLIGHT

DELTA VSV CALCULATION

Non-FADEC engines

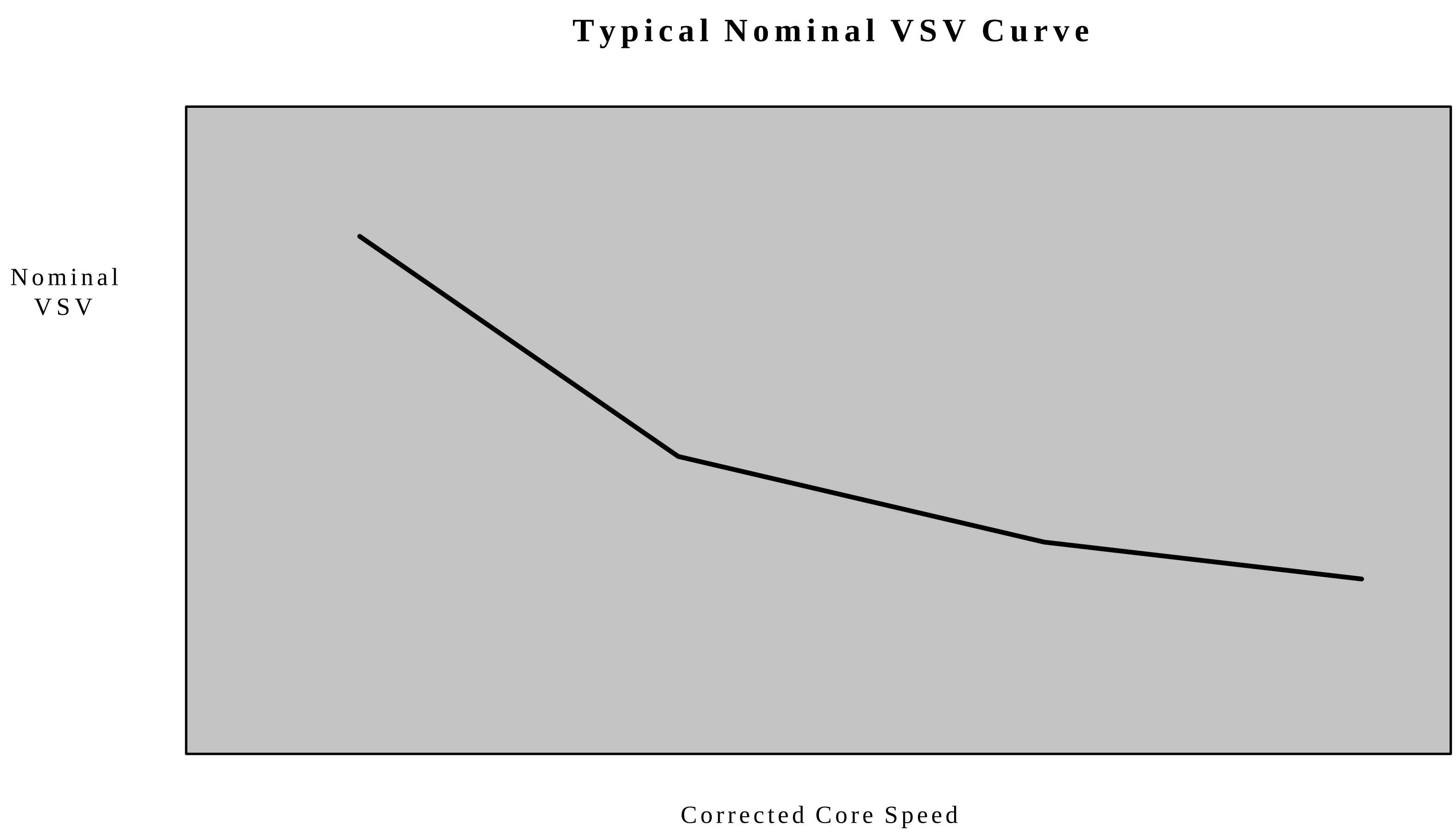
- **difference calculated between "measured" VSV (ZVSV) and a "nominal" VSV-schedule value**

  (The nominal VSV schedule value is obtained by evaluating the nominal VSV schedule at the corrected core speed. For this calculation, measured core speed is corrected using estimate of compressor inlet temperature based on total air temperature and fan speed.)

FADEC engines

- **FADEC engines always operate on the VSV schedule, so a VSV deviation calculation is not useful.**
- **"measured" VSV is output for trending purposes. If this feature is not desired, it can be turned off by the user.**

DELTA VSV CALCULATION



ETOPS MARGIN

Determines whether sufficient EGT and core speed margin exist for "Extended Twin Operations" (ETOPS)

Compares EGT and core speed deviations to pre-established cruise limits

- **limits represents approximately zero-margin values at maximum continuous operation (MAXCON)**
- **ETOPS margin obtained by subtracting cruise EGT and core speed deviations from their respective limits**

SLOATL with "Cruise Update" Method

- **Initial Sea Level OATL and EGT Margin calculated using a limited number of takeoff records**

- **Adjustments to "initial estimate" made based on EGT deviation from cruise trends**

- **Takeoff and cruise data recorded during an initial time are used to establish the relationship between the takeoff margin and the cruise deviation (at least 10 cruise and takeoff data)**

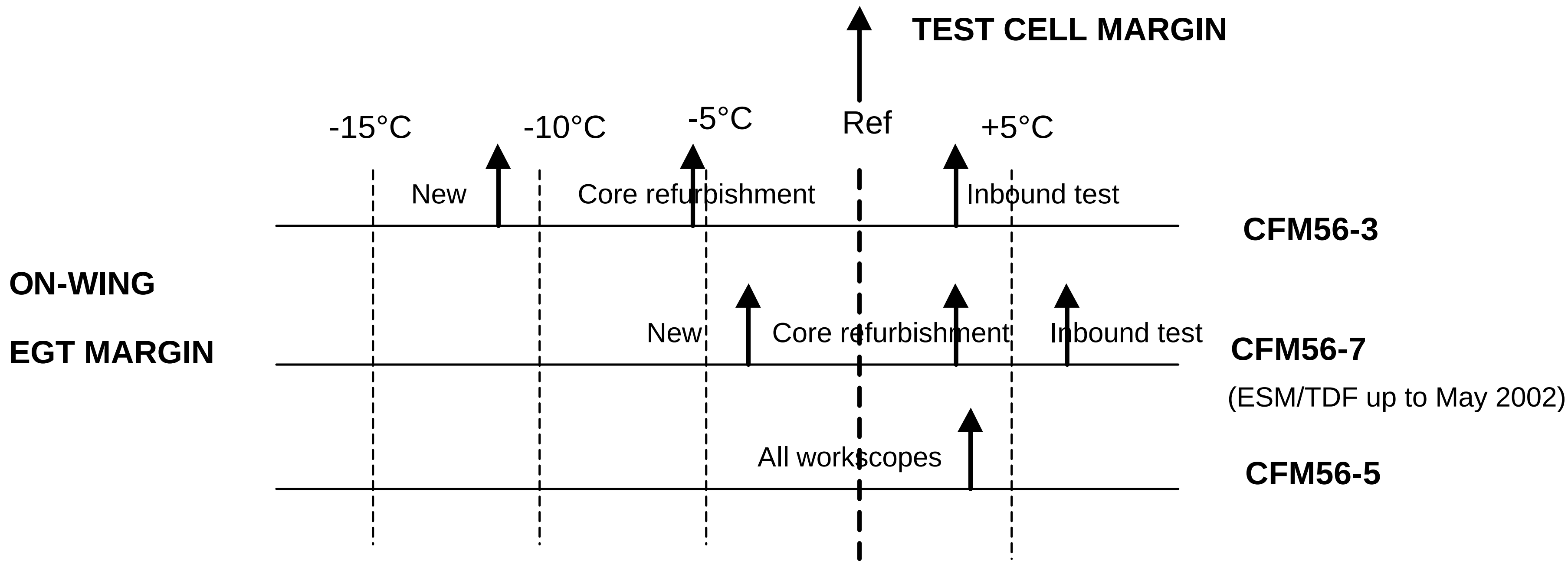
ANNEX

TEST CELL EGT MARGIN

EGTHDM is also calculated in test cell. The procedure is different from on-wing (ESM 72-00-00 Testing 3). In summary:

- **The corrected fan speed is set to a defined value (or at least is very close)**
- **The EGT is converted to hot day conditions and compared to a fixed limit**
- **For CFM56-5, the EGTHDM is then adjusted to take into account the workscope (Break-in-losses)**

TEST CELL EGT MARGIN

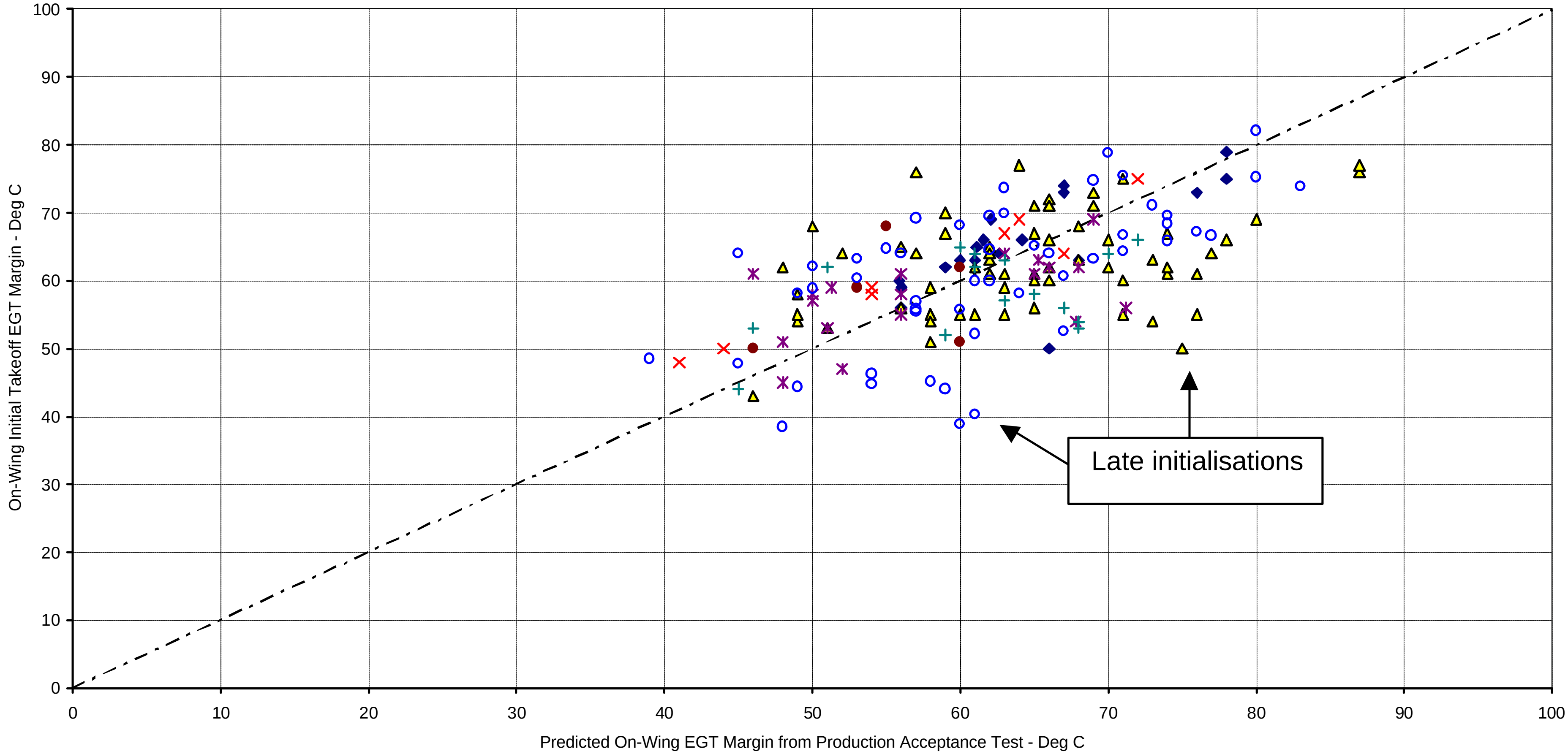


For CFM56-5 scatter exists due to

- **the difference of instrumentation between test cell and on wing (Temperature, Mach, humidity, ECS bleeds, sometimes N1)**
- **typical workscope deviations**
- **Operating conditions (warm-up time).**

TEST CELL EGT MARGIN

CFM56-5C4 New Engines Test Cell Vs On-Wing EGT Margin
(SA Zone)



THE POWER OF FLIGHT

1999 ON-WING PRODUCTION EGT MARGINS

	ESM EGT Limit (°C)	EGT Margin (°C)
CFM56-5B1/P	944	114
CFM56-5B2/P	946	95
CFM56-5B3/P	937	66
CFM56-5B4/P	939	111
CFM56-5B5/P	915	165
CFM56-5B6/P	919	147
CFM56-7B27	927	63
CFM56-7B26	920	83
CFM56-7B24	920	116
CFM56-7B22	919	120
CFM56-7B20	915	147
CFM56-7B18	919	142
CFM56-3C1	908	47 (Avg 1990-1997)
CFM56-3B1	851 (Denver CP)	52 (Avg 1986-1995)
CFM56-3B2	887	52 (Avg 1987-1992)
CFM56-5A1	861	64
CFM56-5A3	876	80
CFM56-5A4	862	62
CFM56-5A5	855	57
CFM56-5C4	940	63

TAKEOFF PERFORMANCE RATING CONVERSION

CFM56-5A Comparision of EGT margins between ratings

- **Positive sign indicates gain in EGT margin**

Delta EGT Margin Sea Level Corner Point							
From/To	CFM56-5A1	CFM56-5A1/F	CFM56-5A3	CFM56-5A4	CFM56-5A4/F	CFM56-5A5	CFM56-5A5/F
CFM56-5A1				-2		-7	
CFM56-5A1/F	-25		-9	-27	-2	-32	-7
CFM56-5A3	-16	9		-18	7	-23	2
CFM56-5A4	2					-5	
CFM56-5A4/F	-23	2	-7	-25		-30	-5
CFM56-5A5	7			5			
CFM56-5A5/F	-18	7	-2	-20	5	-25	

To

From

TAKEOFF PERFORMANCE RATING CONVERSION

CFM56-5B/P Comparision of EGT margins between ratings

- **Positive sign indicates gain in EGT margin**
- **Refer to SB-72-0003**

	Delta EGT Margin Sea Level Corner Point								
	CFM56-5B1/P	CFM56-5B2/P	CFM56-5B3/P	CFM56-5B4/P	CFM56-5B5/P	CFM56-5B6/P	CFM56-5B7/P	CFM56-5B8/P	CFM56-5B9/P
CFM56-5B1/P		-16	-45	-5	46	27	-5	63	30
CFM56-5B2/P	16		-29	11	62	43	11	79	46
CFM56-5B3/P	45	29		40	91	72	40	108	75
CFM56-5B4/P	5	-11	-40		51	32	0	68	35
CFM56-5B5/P	-46	-62	-91	-51		-19	-51	17	-16
CFM56-5B6/P	-27	-43	-72	-32	19		-32	36	3
CFM56-5B7/P	5	-11	-40	0	51	32		68	35
CFM56-5B8/P	-63	-79	-108	-68	-17	-36	-68		-33
CFM56-5B9/P	-30	-46	-75	-35	16	-3	-35	33	

To

From

THE POWER OF FLIGHT

TAKEOFF PERFORMANCE RATING CONVERSION

CFM56-5B Comparision of EGT margins between ratings

- Positive sign indicates gain in EGT margin

Delta EGT Margin Sea Level Corner Point					
	CFM56-5B1	CFM56-5B2	CFM56-5B4	CFM56-5B5	CFM56-5B6
CFM56-5B1		-14	8	58	39
CFM56-5B2	14		22	72	53
CFM56-5B4	-8	-22		50	31
CFM56-5B5	-58	-72	-50		-19
CFM56-5B6	-39	-53	-31	19	

To

From

cfm
THE POWER OF FLIGHT

TAKEOFF PERFORMANCE RATING CONVERSION

CFM56-7B Comparision of EGT margins between ratings

Delta EGT Margin Sea Level Corner Point						
	CFM56-7B18	CFM56-7B20	CFM56-7B22	CFM56-7B24	CFM56-7B26	CFM56-7B27
CFM56-7B18		8	-21	-20	-51	-72
CFM56-7B20	-8		-29	-28	-59	-80
CFM56-7B22	21	29		1	-30	-51
CFM56-7B24	20	28	-1		-31	-52
CFM56-7B26	51	59	30	31		-21
CFM56-7B27	72	80	51	52	21	

To

From

TAKEOFF PERFORMANCE RATING CONVERSION

CFM56-3 Comparision of EGT margins between ratings

Delta EGT Margin Sea Level Corner point				
	23500	**22000**	**20000**	**18500**
CFM56-3C-1		+20	+64	+89
CFM56-3B-2			+44	+69
CFM56-3B1				+25

To

From

For CFM56-3C1, remove 17°C to the EGT margin if the timer is on-wing desactivated.

For CFM56-3C1, the test cell EGT margin takes into account the timer.

For CFM56-3B2, the test cell EGT margin does not include a possible timer effect.

TAKEOFF PERFORMANCE RATING CONVERSION

CFM56-5C Comparision of EGT margins between ratings

Delta EGT Margin Sea Level Corner Point						
	CFM56-5C2	CFM56-5C2F	CFM56-5C2G	CFM56-5C3F	CFM56-5C3G	CFM56-5C4
CFM56-5C2						
CFM56-5C2F	-15			-15		
CFM56-5C2G	-25	-10		-25	-15	-30
CFM56-5C3F	0	15				
CFM56-5C3G	-10	5	15	-10		-15
CFM56-5C4	5	20	30	5	15	

To

From

TOC

THE POWER OF FLIGHT

EGT MARGIN/SEA LEVEL OATL COEFFICIENTS

ENGINE TYPE	EGTM-SLOATL COEFFICIENT
CFM56-7B27	3,5
CFM56-7B26	3,5
CFM56-7B24	3,5
CFM56-7B22	3,5
CFM56-7B20	3,5
CFM56-7B18	3,5
CFM56-5C4	3,7
CFM56-5C3	3,7
CFM56-5C2	3,7
CFM56-5B6	3,27
CFM56-5B5	3,27
CFM56-5B4	3,28
CFM56-5B3	3,43
CFM56-5B2	3,43
CFM56-5B1	3,43
CFM56-5A5	3
CFM56-5A4	2,9
CFM56-5A3	3,1
CFM56-5-A1	3,1
CFM56-3C-1	3,2
CFM56-3B-2	3,2
CFM56-3-B1	3,2
CFM56-2-C1	3,2
CFM56-2B-1	3,2
CFM56-2A	3,2

5. TREND DESCRIPTION

SUMMARY

THE POWER OF FLIGHT

INITIALIZATION

- **Average value of 10 cruise or takeoff filtered records**

- **Automatically calculated**

- **Results stored as "original" initialization values (denoted by "A" on trend reports)**

- **Re-initialization function available (denoted by "B" on trend reports)**

Takeoff Trend Report
"INITIALIZATION" POINT

```
1
 REPORT ID:  TKTRND           GE ENGINE CONDITION MONITORING PROGRAM       SAGE V3.0.3 PC - Jan 99      REPORT DATE:   8/25/99
                                   TAKEOFF PERFORMANCE MONITORING - MOST RECENT RECORDS                    PAGE:     1

              AIRTYP        ENGTYP       ENGSN     INSDAT  N1MOD   TCC  FNRAT  CONFIG        CONTROL      SELECTOR
 ABCD   -1  A321-100     CFM56-5B3     7794XX     990301   0        * *******                                           (SCALES VARIED)
 SMOOTH                           EGT      20...30...40..OATL..60...70...80                      N2                  ACTUAL           MAINT ALT
  DATE    CSI    40...50...60...MAR..80...90..100                                   0....5...MAR..15...20            N1K    FNDR  N1DR CODES CTR
  32499A                      69.35                    50.55                             -999.00
  32499B                      69.35                    50.55                             -999.00
  41299  -5555             H                            O                      X                           92.2-999.0-999.0        0
  41399  -5555             H                            O                      X                           89.0-999.0-999.0        0
  41499  -5555            H                             O                                                                          0
  41699  -5555             H                            O                                                                          0
  41799  -5555            H                             O                                                                          0
  41899  -5555            H                             O                                                                          0
  42199  -5555            H                             O                                                                          0
  42299  -5555            H                             O                      X                           87.6-999.0-999.0        0
  42399  -5555             H                            O                      X                           90.1-999.0-999.0        0
  42499  -5555            H                             O                      X                           88.3-999.0-999.0        0
  42599  -5555            H                             O                      X                           93.0  11.7   5.4        0
  42799  -5555            H                             O                      X                           92.5  13.6   6.2        0
  50199  -5555            H                             O                      X                           87.8-999.0-999.0        0
  50299  -5555             H                            O                      X                           89.1-999.0-999.0        0
  50399  -5555            H                             O                      X                           89.0-999.0-999.0        0
  50499  -5555            H                             O                      X                           89.4-999.0-999.0        0
  50699  -5555             H                            O                      X                           88.2-999.0-999.0        0
  50799  -5555             H                             O                     X                           91.5-999.0-999.0        0
  50899  -5555             H                             O                     X                           88.0-999.0-999.0        0
  50999  -5555              H                            O                     X                           89.3-999.0-999.0        0
  51199  -5555               H                           O                     X                           89.8-999.0-999.0        0
  51399  -5555               H                           O                     X                           90.3-999.0-999.0        0
  51599  -5555                H                          O                     X                           90.7-999.0-999.0        0
  51699  -5555                H                          O                     X                           91.9-999.0-999.0        0
  51799  -5555                H                          O                     X                           87.9-999.0-999.0        0
  51899  -5555                  H                         O                    X                           90.7-999.0-999.0        0
  52099  -5555                  H                         O                    X                           89.3-999.0-999.0        0
  52299  -5555                   H                        O                    X                           90.0-999.0-999.0        0
  52399  -5555                    H                        O                   X                           88.5-999.0-999.0        0
  52499  -5555                     H                       O                   X                           89.4-999.0-999.0        0
  52599  -5555                     H                       O                   X                           90.0-999.0-999.0        0
  52699  -5555                      H                      O                   X                           89.8-999.0-999.0        0
```

"Original" Initialization Values

Smoothed trend pts.

Line on the trend report is labeled with an "A"

Smoothed trends are not displayed, until the initialization process is complete.

INITIALIZED PARAMETERS

- **Cruise parameters:**
  - ✓ **Fan and Core Vibration**
  - ✓ **EGT, Fuel Flow, and Core Speed Deviation**
  - ✓ **Delta VSV**
  - ✓ **Delta Oil Pressure**
  - ✓ **EGT and N2 ETOPS Margins**

- **Takeoff parameters:**
  - ✓ **Sea Level OATL**
  - ✓ **EGT Margin**

THE POWER OF FLIGHT

RE-INITIALIZATION

- **User requested**
- **Available for each flight phase and engine**
- **Same process as initialization**
- **Results stored as "current" initialization values (denoted by "B" on trend plots)**
- **Does not affect "original" initialization values**
- **Input values retained on user demand**

THE POWER OF FLIGHT

Takeoff Trend Report
"ORIGINAL" AND "CURRENT" INITIALIZATION VALUES

```
1
REPORT ID:  TKTRND           GE ENGINE CONDITION MONITORING PROGRAM       SAGE V3.0.3 PC - Jan 99      REPORT DATE:   8/25/99
                                  TAKEOFF PERFORMANCE MONITORING - MOST RECENT RECORDS                        PAGE:     1

             AIRTYP        ENGTYP       ENGSN     INSDAT  N1MOD    TCC  FNRAT  CONFIG        CONTROL      SELECTOR
ABCDE  -1  A321-100     CFM56-5B3     7794XX    990301   0        * *******                                            (SCALES VARIED)
SMOOTH                         EGT       20...30...40..OATL..60...70...80                N2                ACTUAL           MAINT ALT
 DATE    CSI    40...50...60...MAR..80...90..100                               0....5...MAR..15...20         N1K    FNDR  N1DR CODES CTR
 32499A                  69.35                     50.55                            -999.00
 32499B                  69.35                     50.55                            -999.00
 41299  -5555             H                            O                      X                            92.2-999.0-999.0        0
 41399  -5555             H                            O                      X                            89.0-999.0-999.0        0
 41499  -5555            H                             O                      X                            92.4-999.0-999.0        0
 41699  -5555             H                            O                      X                            89.5-999.0-999.0        0
 41799  -5555            H                             O                      X                            88.2-999.0-999.0        0
 41899  -5555            H                             O                      X                            90.5-999.0-999.0        0
 42199  -5555            H                             O                      X
 42299  -5555            H                             O                      X
 42399  -5555             H                            O                      X
 42499  -5555            H                             O                      X
 42599  -5555            H                             O                      X
 42799  -5555            H                             O                      X                            92.5  13.6   6.2        0
 50199  -5555            H                             O                      X                            87.8-999.0-999.0        0
 50299  -5555             H                            O                      X                            89.1-999.0-999.0        0
 50399  -5555            H                             O                      X                            89.0-999.0-999.0        0
 50499  -5555            H                             O                      X                            89.4-999.0-999.0        0
 50699  -5555             H                            O                      X                            88.2-999.0-999.0        0
 50799  -5555             H                             O                     X                            91.5-999.0-999.0        0
 50899  -5555             H
 50999  -5555              H
 51199  -5555               H
 51399  -5555               H
 51599  -5555                H
 51699  -5555                H                          O                     X                            91.9-999.0-999.0        0
 51799  -5555                H                          O                     X                            87.9-999.0-999.0        0
 51899  -5555                  H                         O                    X                            90.7-999.0-999.0        0
 52099  -5555                  H                         O                    X                            89.3-999.0-999.0        0
 52299  -5555                   H                        O                    X                            90.0-999.0-999.0        0
 52399  -5555                    H                        O                   X                            88.5-999.0-999.0        0
 52499  -5555                     H                       O                   X                            89.4-999.0-999.0        0
 52599  -5555                     H                       O                   X                            90.0-999.0-999.0        0
 52699  -5555                      H                      O                   X                            89.8-999.0-999.0        0
```

Initialization Values

Lines with "initialization" values are labeled "A" and "B"
(These have the same values until trends are "Re-initialized".)

DATA SMOOTHING

- **Provides a "running average" of calculated parameters**
  - ✓ **SAGE allows two levels of smoothing : short term (detection sudden shifts) and longer term (identify gradual changes)**

- **Smoothing technique is called exponential smoothing :**
  - ✓ **User can control outlier protection limits**
  - ✓ **User can control maximun and minimum raw values acceptable (same as on initialitation process)**
  - ✓ **User can define sensitivity of smoothing, default values are pre-configured**

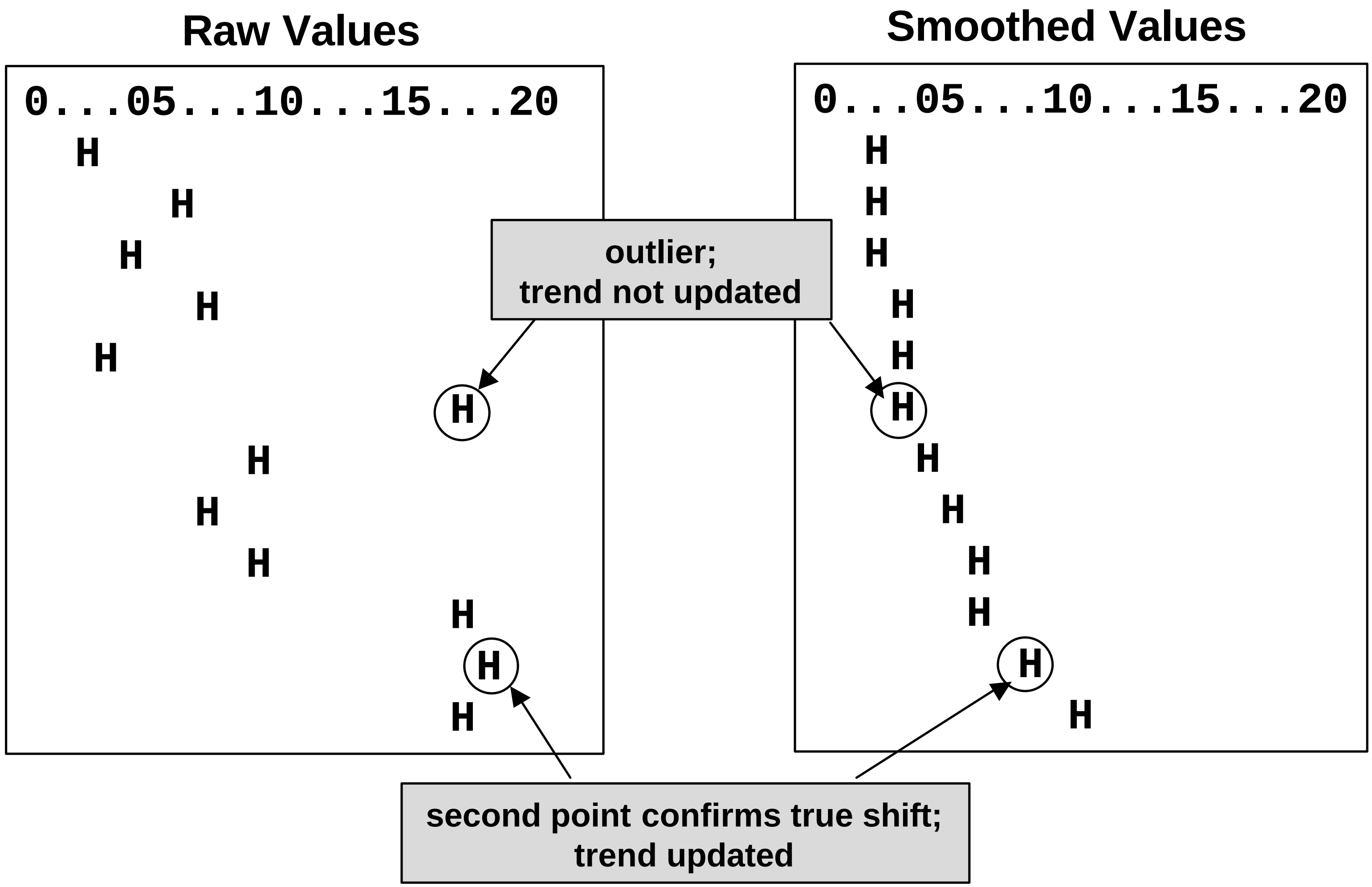
EXPONENTIAL SMOOTHING TECHNIQUE

$$\text{smoothed}_{\text{new}} = \text{smoothed}_{\text{old}} + a\ (\text{raw}_{\text{new}} - \text{smoothed}_{\text{old}})$$

Decreasing α less sensitivity to raw data variation

Increasing α more sensitivity to raw data variation

OUTLIER PROTECTION



SMOOTHED PARAMETERS

- **Cruise parameters:**
  - ✓ **Fan and Core Vibration**
  - ✓ **EGT, Fuel Flow, and Core Speed Deviation**
  - ✓ **Delta VSV**
  - ✓ **Delta Oil Pressure**
  - ✓ **EGT and N2 ETOPS Margins**
  - ✓ **Sea Level OATL & EGT Margin (from "Cruise Update")**

- **Takeoff parameters:**
  - ✓ **Sea Level OATL**
  - ✓ **EGT Margin**

THE POWER OF FLIGHT

COMPRESSION

- **The purpose of compression:**
  - ✓ **Free up database space**
  - ✓ **Speed up processing**
  - ✓ **Summarize historical data**

- **“Snapshots” of smoothed trends**
  - ✓ **One smoothed value kept per month**
  - ✓ **saves alert output quantities for the month**

COMPRESSION

- **There are three types of compression**
  - ✓ **Automatic compression :**
    - **When the number of records exceeds the maximum value (syscon variable)**
  - ✓ **Demand mode compression :**
    - **Based on user selections**
  - ✓ **Engine change compression**
- **Delete the data from input, output, smoothed and alert tables only if the delete flag for this engine is set to 'ON ' (default value)**

THE POWER OF FLIGHT

Cruise Trend Report
COMPRESSED DATA RECORDS

```
1
 REPORT ID:   CRTRND           GE ENGINE CONDITION MONITORING PROGRAM        SAGE  V3.0.3 PC - Jan 99     REPORT DATE:  10/18/99
                                     CRUISE PERFORMANCE MONITORING - MOST RECENT RECORDS                       PAGE:      1

             AIRTYP        ENGTYP       ENGSN    INSDAT  N1MOD    TCC  FNRAT  CONFIG      CONTROL      SELECTOR
 kmno   -1  B737-800     CFM56-7B26    874XXX    981212   0        * *******                                        (SCALES VARIED)
 SMOOTH         -20..-10....0...EGT..20...30...40                    -2....X...-1....X...N2....X....1....X....2  CRZ  OIL OIL MAINT ALT
  DATE   VIB..1....2....3                     -6...-4...-2...F/F...2....4....6    3....4...VSV...6....7        SLOATL TMP PRS CODES CTR
  10299A R=     0.2 V=     0.5   9.3                    0.24            VSV=-999.00 N2=    0.00                53.5
  10299B R=  -999.0 V=  -999.0-999.0                 -999.00            VSV=-999.00 N2=-999.00                53.5
  10399C .RV                .    G                   .F                       *                               53.7
  20499C .RV                .   G                    .F                       X2                              53.2
  30599C .RV                .    G                   .F                       X2                              53.0
  40299C .R V               .    G                   .F                       X2                              52.9
  81999  .*                 .      G                 .F                       *                               52.0 104  48.        0
  81999  .RV                .      G                 .F                       *                               51.8  90  53.        1
  82099  .RV                .       G                .F                       *                               51.4  98  49.        0
  82099  .RV                .       G                .F                       *                               51.5  93  54.        1
  82099  .RV                .       G                . F                      *                               51.4 101  48.        0
  82199  .*                 .       G                                                                         51.4 101  48.        0
  82199  .*                 .      G                                                                          51.6  96  48.        0
  82299  .RV                .       G                                                                         51.5  95  51.        0
  82299  . *                .      G                                                                          51.6 103  50.        0
  82399  . *                .      G                                                                          51.7  95  49.        0
  82399  . *                .      G                                                                          51.9  98  50.        0
  82499  .RV                .    G                                                                            52.2 102  52.        0
  82499  . *                .      G                                                                          52.0  97  51.        0
  82499  .RV                .      G                                                                          52.0  99  48.        0
  82499  . *                .      G                 . F                      *                               52.0 107  48.        0
  82599  .RV                .      G                 . F                      *                               51.9  94  48.        0
  82599  .VR                .      G                 .F                       *                               51.8  94  49.        0
  82699  . *                .      G                 .F                       *                               51.7  97  50.        0
  82699  . *                .      G                 .F                       *                               51.7 101  51.        0
  82799  .RV                .      G                 .F                       *                               51.9 106  48.        0
  82799  .RV                .      G                 .F                       *                               52.0 103  47.        0
  82799  .RV                .      G                 . F                      *                               51.8 101  48.        0
  82899  .RV                .       G                . F                      *                               51.3  96  47.        0
  82899  .RV                .      G                 . F                      *                               51.6 103  49.        0
  82999  .RV                .       G                . F                      *                               51.4  95  51.        0
  83099  .RV                .       G                . F                      *                               51.3  87  50.        0
  83199  .RV                .       G                .F                       *                               51.3  98  49.        0
  83199  .RV                .      G                 .F                       *                               51.6  99  47.        0
```

"Compressed "data records
- "representative" value for each month
- indicated by a "C"
- up to 5 records displayed on trend report

COMPRESSED DATA RECORD

- **Compressed data denoted by “C” on trend reports**
  - ✓ **Up to five records displayed on trend reports**

- **Tabular reports of compressed data can be selected**
  - ✓ **Compressed cruise records CRCOMP report**
  - ✓ **Compressed takeoff records TKCOMP report**
  - ✓ **Compressed climb records CLCOMP report**

THE POWER OF FLIGHT

PARAMETER DIVERGENCES

- **Divergences calculated for 5 parameters:**
  - ✓ **EGT**
  - ✓ **Core Speed**
  - ✓ **Nacelle temperature**
  - ✓ **Throttle Lever Angle**
  - ✓ **Fuel flow**
- **Divergence is difference between "measured" value and "average" value across all engine positions on aircraft**
- **Example (4 engine aircraft):**

$$\text{EGT Divergence (engine \#1)} = EGT_{eng\ 1} - \frac{EGT_{eng\ 1} + EGT_{eng\ 2} + EGT_{eng\ 3} + EGT_{eng\ 4}}{4}$$

REPORTS GENERATION

➢ **There are nineteen possible standard reports:**

✓ **3 Takeoff Reports**

- **TKSUMM « *Takeoff Summary* » Tabular report of input and calculated takeoff parameters**
- **TKCOMP « *Compressed Takeoff* » Tabular report of all compressed takeoff reports**
- **TKTREND « *Takeoff Trend* » Trend plot of takeoff performance of takeoff data only**

✓ **13 Cruise Reports**

- **CRDATA « *Cruise Data Tabular Report* » Tabular report containing input values and calculated raw deviations**
- **CRBASE « *Cruise Baseline* » Tabular reports containing some input values, baseline values, and calculated raw deviations**
- **CRPERF « *Cruise Performance* » Tabular report of Performance Input Parameters**
- **CRVBDG « *Cruise Vibration* » Tabular report of Vibration and Divergence Parameters**
- **CRCALC « *Cruise Calculation* » Tabular report of Cruise calculated parameters raw deviations, baseline values, ETOPS margins, and calculated divergences**

THE POWER OF FLIGHT

REPORTS GENERATION

✓ **13 Cruise Reports (con 't)**

- **CRDSCR « *Cruise Discrete* » Data Report: Tabular report of all discrete parameters, as well as both bleed and pack flows**
- **CRTRAW « *Cruise RAW Trend* » Trend report of raw performance parameters**
- **CRCOMP « *Compressed Cruise* » Tabular report of all compressed cruise reports**
- **CRTRND « *Cruise Trend* » Trend plot os smoothed and raw performance parameters**
- **CRETOP « *Cruise ETOPS* » Trend plot of Cruise ETOPS smoothed and raw parameters**
- **CRMECH « *Cruise Mechanical* » Trend plot of Cruise ETOPS smoothed and raw parameters**
- **CRDIVG « *Cruise Divergence* » Trend plot of Calculated divergence parameters**
- **CRSLCR « *Cruise SLCR* » Trend plot of Sea Level OATL Plus Cruise Update smoothed and raw parameters**

✓ **3 Climb Reports**

- **CLSUMM « *Climb Summary* » Tabular report of input and calculated climb parameters**
- **CLCOMP « *Compressed Climb* » Tabular report of compressed climb parameters**
- **CLTRND « *Climb Trend* » Trend of Climb Performance of climb data only**

REPORT HEADER

- **Each report header contains for each engine :**

  - Report name
  - SAGE version
  - Report date
  - Aircraft identifier
  - Engine position
  - Aircraft type
  - Engine type
  - Engine serial number
  - Installation Date
  - N1 modifier
  - TCC Timer Activation Switch
  - Thrust rating
  - Configuration
  - Control
  - Selector

- **If a data range was entered it will appear in the header. If not, the header includes the sentence 'FOR MOST RECENT RECORDS'**

Cruise Trend Report
SUMMARY OF DATA TYPES

```
1
 REPORT ID:  CRTRND          GE ENGINE CONDITION MONITORING PROGRAM       SAGE  V3.0.3 PC - Jan 99     REPORT DATE:  10/18/99
                                   CRUISE PERFORMANCE MONITORING - MOST RECENT RECORDS                  PAGE:     1

             AIRTYP       ENGTYP       ENGSN     INSDAT  N1MOD   TCC  FNRAT  CONFIG      CONTROL      SELECTOR
 kmno      -1  B737-800     CFM56-7B26    874XXX    981212   0       * *******                                   (SCALES VARIED)
 SMOOTH          -20..-10....0...EGT..20...30...40                         -2....X...-1....X...N2....X....1....X....2  CRZ  OIL  OIL MAINT ALT
  DATE        VIB..1....2....3                       -6...-4...-2...F/F...2...4....6     3....4...VSV...6....7       SLOATL  TMP  PRS  CODES CTR
  10299A R=      0.2 V=      0.5    9.3                       0.2                   VSV=-999.00 N2=    0.00          53.5
  10299B R=   -999.0 V=   -999.0-999.0                     -999.00                  VSV=-999.00 N2=-999.00          53.5
  10399C .RV                   .       G                    .F                          *                         53.7
  20499C .RV                   .      G                     .F                          X2                        53.2
  30599C .RV                   .       G                    .F                          X2                        53.0
  40299C .R V                  .       G                    .F                          X2                        52.9
  82599  .RV                   .         G                  . F                         *                         51.9   94   48.          0
  82599  .VR                   .         G                  .F                          *                         51.8   94   49.          0
  82699  . *                   .         G                  .F                          *                         51.7   97   50.          0
  82699  . *                                                .F                          *                         51.7  101   51.          0
  82799  .RV                                                .F                          *                         51.9  106   48.          0
  82799  .RV                                                .F                          *                         52.0  103   47.          0
  82799  .RV                                                . F                         *                         51.8  101   48.          0
  82899  .RV                                                . F                         *                         51.3   96   47.          0
  82899  .RV                                                . F                         *                         51.6  103   49.          0
  82999  .RV                                                . F                         *                         51.4   95   51.          0
  83099  .RV                                                . F                         *                         51.3   87   50.          0
  83199  .RV                                                .F                          *                         51.3   98   49.          0
  83199  .RV                                                .F                          *                         51.6   99   47.          0
  83199  .RV                   .         G                  .F                          *                         51.7   90   50.          0
  90199  .RV                   .          G                 .F                          *                         51.4   93   48.          0
  90199  .RV                   .          G                 .F                          *                         51.4   90   50.          0
  90299  .RV                   .          G                 .F                          *                         51.4  100   48.          0
  90299  .RV                   .          G                 .F                          *                         51.2  101   48.          0
  90399  .*                    .          G                 .F                          *                         51.0  101   48.          0
  90399  .RV                   .          G                 .F                          *                         51.0  101   48.          0
 RAW DATA        -20..-10....0...EGT..20...30...40                         -2....X...-1....X...N2....X....1....X....2 CRZ     MODULE CHG  ALT
  DATE        VIB..1....2....3                       -6...-4...-2...F/F...2...4....6     3....4...VSV...6....7       SLOATL     MAINT CODES CTR
  83099  .                     .          G                 F                          2X                         51.2                  0
  83199  .VR                   .          G                 F                           *                         51.4                  0
  83199  . RV                                               .F                          X2                        52.6                  0
  83199  .RV                                                . F                        2X                         52.0                  0
  90199  .RV                              G                 . F                         X2                        50.4                  0
  90199  .RV                   .          G                 . F                         *                         51.2                  0
```

Smoothed data

Scale

Data Type:
A: “original” initial.
B: “current” initial.
C: compressed
=: new data

Raw data

CRUISE DATA REPORT

```
1
REPORT ID:  CRDATA           GE ENGINE CONDITION MONITORING PROGRAM      SAGE V3.0.3 PC - Jan 99      REPORT DATE:  11/18/99
                                     CRUISE PERFORMANCE DATA - MOST RECENT RECORDS                         PAGE:      1


AIRCRAFT AIRCRAFT    ENG  SERIAL    ENGINE       INSTALL   N1  THRUST    TCC
   ID      TYPE      POS  NUMBER     TYPE         DATE    MOD  RATING    TMR  CONFIG        CONTROL      SELECTOR
ABCD    A321-100      1   779XXX   CFM56-5B3      990101   0   ******     *
                      2   779XXX   CFM56-5B3      990102   0   ******     *
          -------------------------- FLIGHT DATA -------------------------           ------ RAW DEVIATIONS  -------
                             ENG  A/C ISO                                                                       -MAX CONT--
 DATE/                       BLD  PK  VLV ADP      OIL   FUEL                                  BLEED       FF   VSV   N2    EGT  EGT    N2  ALT
 GMT      TAT   ALT    MACH 1234 123 LRC 12    N1  PRES  FLOW    VSV     N2  EGT  N1K      RATIO  DOP  (%)  ( )   (%)   (C)  MAR   MAR CTR
 52099-1 -27.7 35014.0.790 11       0         86.40-55. 3144.-55.55  93.0 621. 93.19   0.85  -99. -5.9-99.90 -0.3 -31.6 -99. -99.9  0
   600-2                                      86.40-55. 3117.-55.55  92.9 609. 93.19   0.85  -99. -6.7-99.90 -0.4 -43.2 -99. -99.9  0
 52099-1 -24.2 34987.0.787 11       0         86.30-55. 3071.-55.55  93.3 623. 92.48   0.85  -99. -6.1-99.90 -0.4 -34.1 -99. -99.9  0
  1514-2                                      86.30-55. 3038.-55.55  93.2 611. 92.48   0.85  -99. -7.1-99.90 -0.5 -45.7 -99. -99.9  0
 52199-1 -26.5 35004.0.797 11       0         87.10-55. 3219.-55.55  93.5 631. 93.71   0.85  -99. -6.5-99.90 -0.2 -31.9 -99. -99.9  0
   554-2                                      87.10-55. 3194.-55.55  93.5 619. 93.71   0.85  -99. -7.2-99.90 -0.2 -44.1 -99. -99.9  0
 52199-1 -23.7 35005.0.792 11       0         87.50-55. 3232.-55.55  94.0 640. 93.65   0.85  -99. -6.1-99.90 -0.2 -32.9 -99. -99.9  0
  1412-2                                      87.50-55. 3212.-55.55  94.0 628. 93.65   0.85  -99. -6.7-99.90 -0.2 -45.1 -99. -99.9  0
 52299-1 -19.2 31007.0.780 11       0         84.10-55. 3164.-55.55  92.5 593. 89.34   0.89  -99. -8.9-99.90 -0.8 -39.2 -99. -99.9  0
   749-2                                      84.10-55. 3133.-55.55  92.5 581. 89.34   0.89  -99. -9.8-99.90 -0.8 -51.1 -99. -99.9  0
 52299-1 -25.7 33003.0.782 11       0         84.80-55. 3126.-55.55  92.5 599. 91.16   0.89  -99. -7.4-99.90 -0.4 -35.1 -99. -99.9  0
  1137-2                                      84.80-55. 3097.-55.55  92.4 588. 91.16   0.89  -99. -8.2-99.90 -0.5 -46.3 -99. -99.9  0
 52399-1 -24.2 33008.0.780 11       0         84.80-55. 3084.-55.55  92.6 600. 90.91   0.89  -99. -7.8-99.90 -0.4 -36.5 -99. -99.9  0
  1048-2                                      84.70-55. 3056.-55.55  92.5 589. 90.80   0.89  -99. -8.3-99.90 -0.5 -46.5 -99. -99.9  0
 52599-1 -21.7 33010.0.798 11       0         85.10-55. 3124.-55.55  92.9 605. 90.80   0.70  -99. -8.0-99.90 -0.5 -35.4 -99. -99.9  0
   925-2                                      85.10-55. 3091.-55.55  92.9 594. 90.80   0.70  -99. -8.9-99.90 -0.5 -46.1 -99. -99.9  0
 52599-1 -28.5 33010.0.785 11       0         85.00-55. 3188.-55.55  92.4 594. 91.85   0.89  -99. -7.6-99.90 -0.2 -37.7 -99. -99.9  0
  1751-2                                      85.00-55. 3177.-55.55  92.3 585. 91.85   0.89  -99. -8.0-99.90 -0.3 -47.3 -99. -99.9  0
 52699-1 -30.5 35003.0.800 11       0         85.70-55. 3111.-55.55  92.4 608. 92.94   0.85  -99. -6.3-99.90 -0.3 -31.5 -99. -99.9  0
   619-2                                      85.70-55. 3086.-55.55  92.4 596. 92.94   0.85  -99. -7.0-99.90 -0.3 -43.0 -99. -99.9  0
 52699-1 -22.2 28981.0.769 11       0         80.70-55. 2956.-55.55  90.5 545. 86.27   0.71  -99. -9.4-99.90 -0.7 -36.6 -99. -99.9  0
  1117-2                                      80.70-55. 2928.-55.55  90.5 537. 86.27   0.71  -99.-10.2-99.90 -0.7 -44.8 -99. -99.9  0
 52799-1 -28.5 35005.0.799 11       0         86.50-55. 3179.-55.55  93.0 620. 93.43   0.85  -99. -6.4-99.90 -0.2 -32.5 -99. -99.9  0
   727-2                                      86.40-55. 3155.-55.55  93.0 608. 93.33   0.85  -99. -6.8-99.90 -0.2 -42.8 -99. -99.9  0
 52799-1 -28.7 35003.0.787 11       0         85.70-55. 3053.-55.55  92.6 611. 92.62   0.85  -99. -6.1-99.90 -0.3 -31.2 -99. -99.9  0
  1557-2                                      85.70-55. 3025.-55.55  92.5 600. 92.62   0.85  -99. -7.0-99.90 -0.4 -42.4 -99. -99.9  0
 52899-1 -25.7 32993.0.780 11       0         85.40-55. 3201.-55.55  92.8 607. 91.79   0.89  -99. -7.3-99.90 -0.3 -34.8 -99. -99.9  0
  2021-2                                      85.40-55. 3190.-55.55  92.8 597. 91.79   0.89  -99. -7.6-99.90 -0.3 -44.8 -99. -99.9  0
 52999-1 -28.2 35013.0.794 11       0         84.30-55. 2862.-55.55  91.8 594. 91.06   0.85  -99. -7.2-99.90 -0.6 -32.1 -99. -99.9  0
  1542-2                                      84.30-55. 2824.-55.55  91.8 582. 91.06   0.85  -99. -8.4-99.90 -0.6 -44.0 -99. -99.9  0
```

THE POWER OF FLIGHT

TAKEOFF SUMMARY REPORT

```
1
REPORT ID:  TKSUMM             GE ENGINE CONDITION MONITORING PROGRAM      SAGE V3.0.3 PC - Jan 99      REPORT DATE:  11/18/99
                                       TAKEOFF SUMMARY REPORT - MOST RECENT RECORDS                            PAGE:     1


AIRCRAFT AIRCRAFT     ENG   SERIAL       ENGINE        INSTALL   N1   THRUST     TCC
   ID      TYPE       POS   NUMBER        TYPE          DATE    MOD   RATING     TMR CONFIG       CONTROL      SELECTOR
ABC       MD11         1    702XXX       CF6-80C2D1F    971119   6   ******       *

INITIALIZATION VALUES: ------------- CURRENT VALUES -------------  ------------ ORIGINAL VALUES -------------
                        DATE   TIME   EGTMAR      OATL     N2MAR    DATE   TIME   EGTMAR      OATL     N2MAR
                        12499   503      6.90     32.00   -999.00   12499   503      6.90     32.00   -999.00
                                                    WING   ENG A/C ISO ANTI
                                                 ANTI-ICE  BLD PKS VLV ICE  ADP  BLEED   UNMOD      RAW    RAW     N2  THRUST  N1
 DATE  TIME ALTITUDE MACH  TAT    N2    EGT     N1   IN USED 1234 123 LRC 1234 12   RATIO     N1     SLOATL EGTMAR  MAR    DR     DR
 42899 1123    1360.0.292  16.6  103.7  860.  103.40  0   0  111  555 00  000          0.60 -5555.00   29.14   -3.0-999.0  12.2   6.6
 42899 2230     820.0.307  15.3  102.8  831.  101.20  0   0  111  555 00  000          0.60 -5555.00   31.46    5.1-999.0  16.1   8.2
 42999 1157    1680.0.290   9.6  103.4  852.  104.40  0   0  111  555 00  000          0.60 -5555.00   29.78   -0.8-999.0   8.1   4.7
 42999 2244    1140.0.292  15.6  102.8  832.  101.10  0   0  111  555 00  000          0.60 -5555.00   31.05    3.7-999.0  16.7   8.6
 43099 1151    1710.0.329   5.2  102.8  837.  103.80  0   0  111  555 00  111          0.60 -5555.00   32.17    7.6-999.0   5.7   3.1
 43099 2245     790.0.297  12.4  101.9  813.  100.00  0   0  111  555 00  000          0.60 -5555.00   32.15    7.5-999.0  17.7   8.9
 50199 1158    1700.0.299   8.9  104.3  877.  107.40  0   0  111  555 00  000          0.60 -5555.00   29.09   -3.2-999.0   2.5   1.6
 50199 2237    1110.0.279  14.3  103.9  855.  103.90  0   0  111  555 00  000          0.60 -5555.00   30.49    1.7-999.0  10.0   5.5
 50299 2029    1370.0.288   1.8  102.4  842.  104.60  0   0  111  555 00  000          0.60 -5555.00   28.63   -4.8-999.0   4.7   2.9
 50399 1708    1300.0.310  31.3  108.0  935.  109.80  0   0  111  555 00  000          0.60 -5555.00   30.99    3.4-999.0   4.6   2.8
 50499 1453    1130.0.315   9.1  104.4  870.  107.10  0   0  111  555 00  000          0.60 -5555.00   30.64    2.2-999.0   2.4   1.5
 50599  205    1860.0.287  23.0  103.5  838.  100.80  0   0  111  555 00  000          0.60 -5555.00   32.34    8.1-999.0  20.7  10.6
 50599 1451    1070.0.305   8.9  104.4  871.  107.40  0   0  111  555 00  000          0.60 -5555.00   30.94    3.3-999.0   1.8   1.1
 50699  204    1350.0.302  19.5  105.7  893.  107.20  0   0  111  555 00  000          0.60 -5555.00   30.21    0.8-999.0   5.6   3.3
 50699 2016    1230.0.312  10.9  103.4  846.  103.80  0   0  111  555 00  000          0.60 -5555.00   30.94    3.3-999.0   9.3   5.2
 50799  719    1490.0.282  32.9  104.5  865.  101.90  0   0  111  555 00  000          0.60 -5555.00   32.37    8.2-999.0  21.0  10.4
 50799 1354    1270.0.261  30.0  104.5  855.  101.80  0   0  111  555 00  000          0.60 -5555.00   33.58   12.4-999.0  20.2  10.3
 50799 1710    1420.0.310  31.6  108.2  938.  110.00  0   0  111  555 00  000          0.60 -5555.00   30.76    2.7-999.0   4.5   2.7
 50899  604    1380.0.275   1.4   99.5  765.   97.20  0   0  111  555 00  000          0.60 -5555.00   33.36   11.6-999.0  20.4  10.4
 50899 1021    1360.0.255  14.1  101.7  808.   99.40  0   0  111  555 00  000          0.60 -5555.00   32.93   10.2-999.0  19.8  10.2
 50999 1316    1310.0.296   5.0  100.0  775.   97.50  0   0  111  555 00  000          0.60 -5555.00   33.01   10.4-999.0  21.4  10.6
 50999 1507    1710.0.249   0.7   99.6  766.   97.50  0   0  111  555 00  000          0.60 -5555.00   33.51   12.1-999.0  19.3  10.2
 50999 2019    1280.0.288   5.3  101.6  824.  101.50  0   0  111  555 00  000          0.60 -5555.00   28.68   -4.6-999.0  12.1   6.6
 51099  722    1430.0.265  31.2  104.5  861.  101.90  0   0  111  555 00  000          0.60 -5555.00   32.69    9.3-999.0  20.6  10.5
 51099 1423    1310.0.285  29.9  104.3  855.  101.80  0   0  111  555 00  000          0.60 -5555.00   33.53   12.2-999.0  20.5  10.3
 51099 1755    1370.0.296  30.4  107.2  938.  109.10  0   0  111  555 00  000          0.60 -5555.00   27.95   -7.2-999.0   5.6   3.3
 51299 1132    1390.0.284   7.3  102.4  829.  102.30  0   0  111  555 00  000          0.60 -5555.00   30.31    1.1-999.0  11.2   6.2
```

TAKEOFF TREND REPORT

```
1
REPORT ID:  TKTRND           GE ENGINE CONDITION MONITORING PROGRAM       SAGE V3.0.3 PC - Jan 99      REPORT DATE:   8/25/99
                                  TAKEOFF PERFORMANCE MONITORING - MOST RECENT RECORDS                        PAGE:      1

             AIRTYP        ENGTYP       ENGSN    INSDAT  N1MOD   TCC  FNRAT  CONFIG         CONTROL      SELECTOR
ABCD   -1  B737-600      CFM56-7B20    874XXX    980713   0        * ******* DAC                                      (SCALES VARIED)
SMOOTH                         EGT        40...50...60..OATL..80...90..100                N2                ACTUAL            MAINT ALT
 DATE    CSI   100..110..120...MAR.140..150..160                               0....5...MAR..15...20       N1K   FNDR  N1DR CODES CTR
111598A                  149.64                 77.90                               -999.00
111598B                  149.64                 77.90                               -999.00
 10299C                             H                      O                  X
 20199C                               H                    O                  X
 30199C                             H                      O                  X
 40199C                           H                       O                   X
 41999  -5555                       H                      O                  X                            85.5  12.9   4.0         0
 41999  -5555                       H                      O                  X                            81.4  28.3   9.4         0
 41999  -5555                       H                      O                  X                            80.7  27.5   9.2         0
 41999  -5555                        H                     O                  X                            82.7  21.8   7.2         0
 41999  -                           H                      O                  X                            85.1  13.5   4.2         0
 42099  -                          H                       O                  X                            81.4  24.3   8.0         1
 42099  -                           H                      O                  X                            85.3  12.9   4.0         0
 42099  -5                          H                      O                  X                            84.9  17.4   5.5         0
 42099  -5555                       H                      O                  X                            90.7   0.0   0.0         0
 42099  -5555                       H                      O                  X                            87.0  10.4   3.1         0
 42199  -5555                      H                       O                  X                            82.8  21.1   6.9         0
 42199  -5555                      H                       O                  X                            86.6   9.3   2.8         0
 42199  -5555                       H                      O                  X                            90.4   1.5   0.5         0
 42199  -5555                       H                      O                  X                            84.0  17.6   5.5         0
 42199  -5555                       H                      O                  X                            90.7   0.0   0.0         0
 42199  -5555                       H                      O                  X                            84.3  16.7   5.3         0
 42299  -5555                     H                       O                   X                            86.9  12.1   3.8         1
 42299  -5555                      H                      O                   X                            81.9  23.2   7.6         0
 42299  -5555                      H                      O                   X                            85.3  14.0   4.3         0
 42299  -5555                      H                       O                  X                            86.7   8.9   2.7         0
 42299  -5555                       H                      O                  X                                         2.8         0
 42299  -5555                       H                      O                  X                                         1.9         0
 42399  -5555                      H                       O                  X                                         1.9         0
 42399  -5555                       H                      O                  X                            87.4   7.0   2.1         0
 42799  -5555                      H                       O                  X                            83.6  17.6   5.6         0
 42799  -5555                       H                      O                  X                            81.3  23.3   7.6         0
 42799  -5555                       H                      O                  X                            87.0  10.3   3.2         0
 42799  -5555                      H                       O                  X                            90.7   0.0   0.0         0
 42799  -5555                     H                       O                   X                            83.7  17.0   5.3         0
 42899  -5555                     H                       O                   X                            82.0  21.8   7.1         1
 42899  -5555                    H                        O                   X                            86.7   7.9   2.4         0
 42899  -5555                    H                        O                   X                            84.0  18.6   5.9         0
 42899  -5555                    H                        O                   X                            84.2  16.1   5.0         0
 42899  -5555                    H                        O                   X                            86.8  10.5   3.2         0
```

Date DDMMYY

EGTHDM

SLOATL

Thrust Derate

N1 derate

X: Result not available

THE POWER OF FLIGHT

CRUISE PERFORMANCE TREND REPORT

```
1
 REPORT ID:  CRTRND          GE ENGINE CONDITION MONITORING PROGRAM       SAGE  V3.0.3 PC - Jan 99     REPORT DATE:   8/25/99
                                   CRUISE PERFORMANCE MONITORING - FROM 990606 TO 990630                    PAGE:     1

              AIRTYP         ENGTYP       ENGSN     INSDAT  N1MOD   TCC  FNRAT  CONFIG      CONTROL      SELECTOR
 ABCD   -1  B737-800      CFM56-7B26    8742XX    980728    0        * *******                                       (SCALES VARIED)
 SMOOTH          -20..-10....0...EGT..20...30...40                   -2....X...-1....X...N2....X....1....X....2  CRZ  OIL OIL MAINT ALT
  DATE   VIB..1....2....3                          -6...-4...-2...F/F...2....4....6    3....4...VSV...6....7          SLOATL TMP PRS CODES CTR
  92098A R=     0.3 V=     1.0  19.0                              1.61              VSV=-999.00 N2=   0.20            50.2
  92098B R=  -999.0 V=  -999.0-999.0                          -999.00              VSV=-999.00 N2=-999.00            50.2
  91998C . R V                .         G                    .    F                        X 2                      -999.0
 100198C .R    V              .         G                    .    F                        X 2                        49.8
  60699  . RV                 .         G                    .    F                        X 2                        49.5 100  48.        0
  60699  . RV                 .         G                    .    F                        X 2                        49.5  80  47.        0
  60699  . *                  .          G                   .    F                        X 2                        49.3  96  48.        0
  60699  . *                  .         G                    .    F                        X 2                        49.7 102  47.        0
  60799  . *                  .                              .    F                        X2                         49.6  92  48.        0
  60799  . *                  .                              .    F                        X2                         50.0 101  50.        0
  60799  . *                  .                              .    F                        X2                         49.8  94  49.        0
  60799  . *                  .                              .    F                        X 2                        49.4 100  45.        0
  60799  . *                  .          G                   .    F                        X 2                                             0
  60999  . *                             G                   .                             X 2                                             0
  60999  . *                             G                   .    F                        X 2                                             0
  61199  . *                             G                   .    F                        X 2                                             0
  61199  . *                                                 .    F                        X 2                                             0
  61299  . *                                                 .    F                        X 2                        49.9 100  44.        0
  61299  . *                  .         G                    .    F                        X 2                        50.1 104  44.        0
  61399  . *                  .        G                     .    F                        X 2                        50.3 101  45.        0
  61399  . *                  .        G                     .    F                        X 2                        50.3  97  47.        0
  61499  . *                  .        G                     .    F                        X2                         50.3  87  46.        0
  61599  . *                  .        G                     .    F                        X 2                        49.7  93  46.        0
  61699  . RV                 .        G                     .    F                        X 2                        49.9  99  49.        0
  61799  . RV                 .        G                     .    F                        X 2                        50.3 104  48.        0
  61799  . RV                                                .    F                        X 2                        50.0  92  44.        0
  61999  . RV                                                .    F                        X 2                        49.6  94  49.        0
  61999  . RV                                                .    F                        X 2                        49.7 102  45.        0
  62099  . RV                                                .    F                        X 2                        50.6 101  51.        0
  62099  . RV                                                .    F                        X 2                        51.2 101  51.        0
  62199  . RV                                                .    F                        X 2                        51.0  94  50.        0
  62199  . RV                                                .    F                        X 2                        50.8 100  46.        0
  62299  . RV                                                .    F                        X 2                        50.7 104  45.        0
  62399  . RV                                                .    F                        X 2                        50.2  98  46.        0
  RAW DATA       -20..-10....0...EGT..20...30...40                   -2....X...-1....X...N2....X....1....X....2 CRZ     MODULE CHG  ALT
  DATE   VIB..1....2....3                          -6...-4...-2...F/F...2....4....6    3....4...VSV...6....7          SLOATL   MAINT CODES CTR
  62299  . R V                .        G                     .  F                          X2                         50.3                 0
  62399  . VR                 .             G                .      F                      X  2                       48.3                 0
  62399  . R V                .    G                         .    F                        X  2                       51.5                 0
  62499  . *                  .              G               .    F                        X2                         47.7                 0
  62699  . R           V      .             G                .      F                      X  2                       48.2                 0
  62799  .R            +V     .                  G           .       F                     X  2                       46.3                 1
```

FUEL FLOW

* coincidence

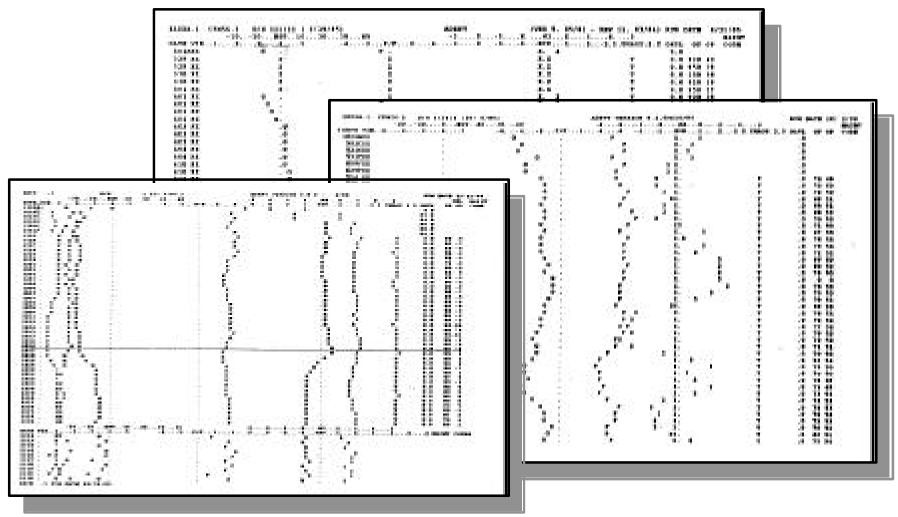
DEGT

CORE SPEED N2

. 0 Line

VIBRATIONS
V fan vib front pickup
R core vib rear pickup

TREND MONITORING INTERPRETATION



THE POWER OF FLIGHT

SUMMARY

1.- The LOGIC

- **Trend Interpretation Logic**

2.- The TREND ANALYSIS

- **Wrong Input Data**
- **Instrumentation**
- **Mechanical**

3.- The ACTIONS

- **Maintenance Actions**

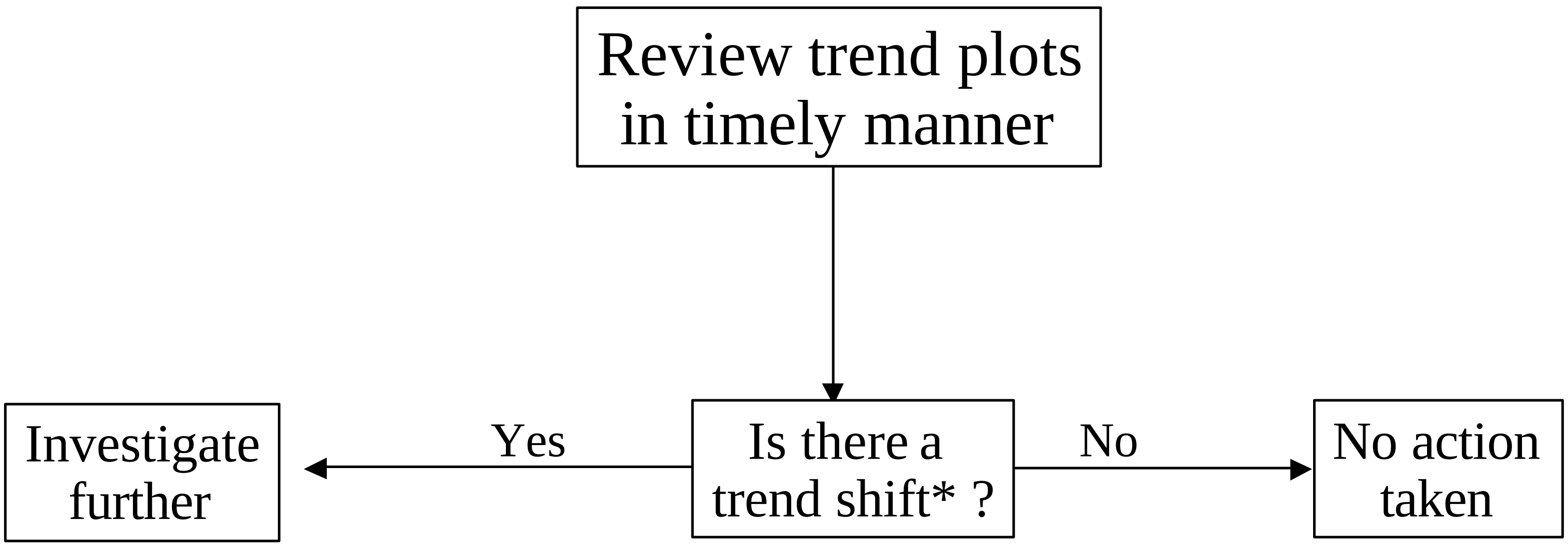
LOGIC

INTERPRETATION OF ENGINE TRENDS

- **Evaluate both engine performance and hardware condition**
  - ✓ **based on assessment of trends (without engine disassembly)**
- **Engine / instrumentation faults have "characteristic" trends**
  - ✓ **similar for most engine models**
- **Assessment of trends provides early detection of basic engine or instrumentation faults**

TOC

TREND INTERPRETATION



* Shift: deviation from most recent "smoothed" trend
(a shift can also be detected through consistent individual points)

TREND INTERPRETATION (cont'd)

Investigate further

Check other engines on aircraft

Do all engines have similar shifts at same time ?

Yes

Problem induced by aircraft
- instrumentation
- input error

No (Other engine(s) stable)

Problem induced by engine or engine instrumentation

TREND INTERPRETATION (cont'd)

Problem appears to be due to engine or instrumentation

Are parameter shifts consistent ?

Yes

- Instrumentation
- Engine control
- Hardware failure
- Performance deterioration

No

- Instrumentation problem
- Input error

Take appropriate maintenance action

THE POWER OF FLIGHT

TREND ANALYSIS

TREND SHIFT CATEGORIES

- **3 MAIN TYPES OF TREND SHIFT SOURCE**

  1. **Wrong Input Data**
  2. **Instrumentation**
  3. **Mechanical**

WRONG INPUT DATA

- **Engine monitoring is very sensitive to accurate data recording**
  - ✓ **SAGE works well with both hand-logged and automatically recorded data (good quality data required)**

- **Scatter in the data could be introduced by wrong manual input or bad acquisition criteria**

Acquisition of "good" quality monitoring data is essential in order to effectively interpret engine trends

IMPACT OF DATA RECORDING ACCURACY

➢ Impact of parameter accuracy on trend results

Error :aircraft parameters	Δ (DEGT° C)? ?	Δ(DWF%)	Δ(DN2%)
+ 100 ft altitude	?0	+ 0.5	0
+ 1° C TAT	-1	+ 0.5	- 0.2
+ 0.01 Mach	+ 0.4	- 0.8	0
Bleed "on" to "off"	- 10	- 1.2	- 0.4

Error: engine parameters	Δ (DEGT° C)? ?	Δ (DWF%)	Δ(DN2%)
+ 1 % N1	?- 10	- 4	- 0.6
+ 1 % N2	0	0	+ 1
+ 10 °C EGT	+10	0	0
+ 1 % WF	0	+ 1	0

THE POWER OF FLIGHT

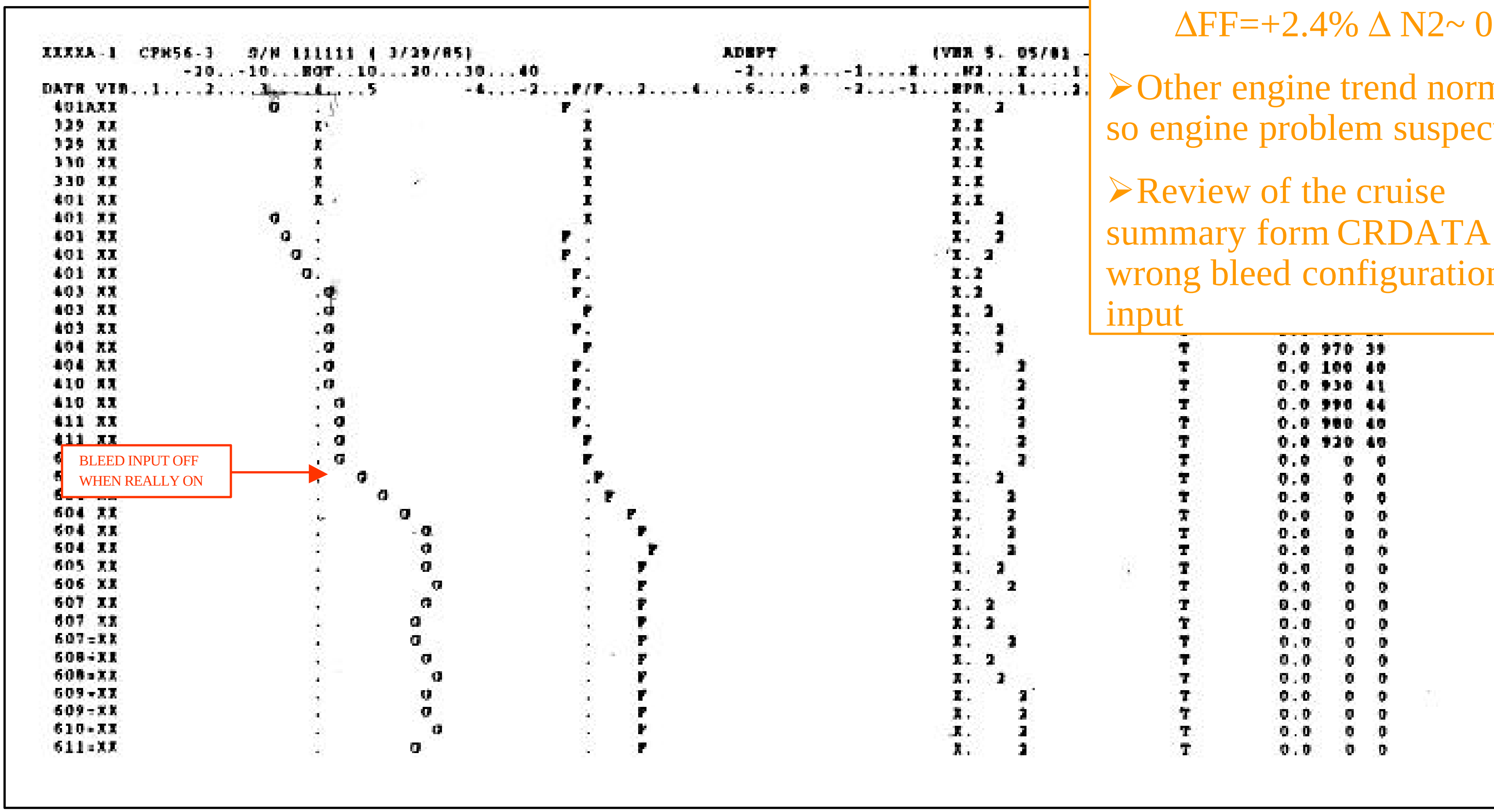
WRONG INPUT DATA

	Δ DEGT (°C)	Δ FF(%)	Δ N2(%)	Problem
Chart D.1	+26	+2,5	+0.7	Wrong Bleed Input
Chart D.2	+15	+1,5	+1	Engine Change Not Recorded
Chart D.3	scatter	scatter	scatter	Inaccurate Data Recording
Chart D.4	0	out of scale	0	Fuel Flow Indication

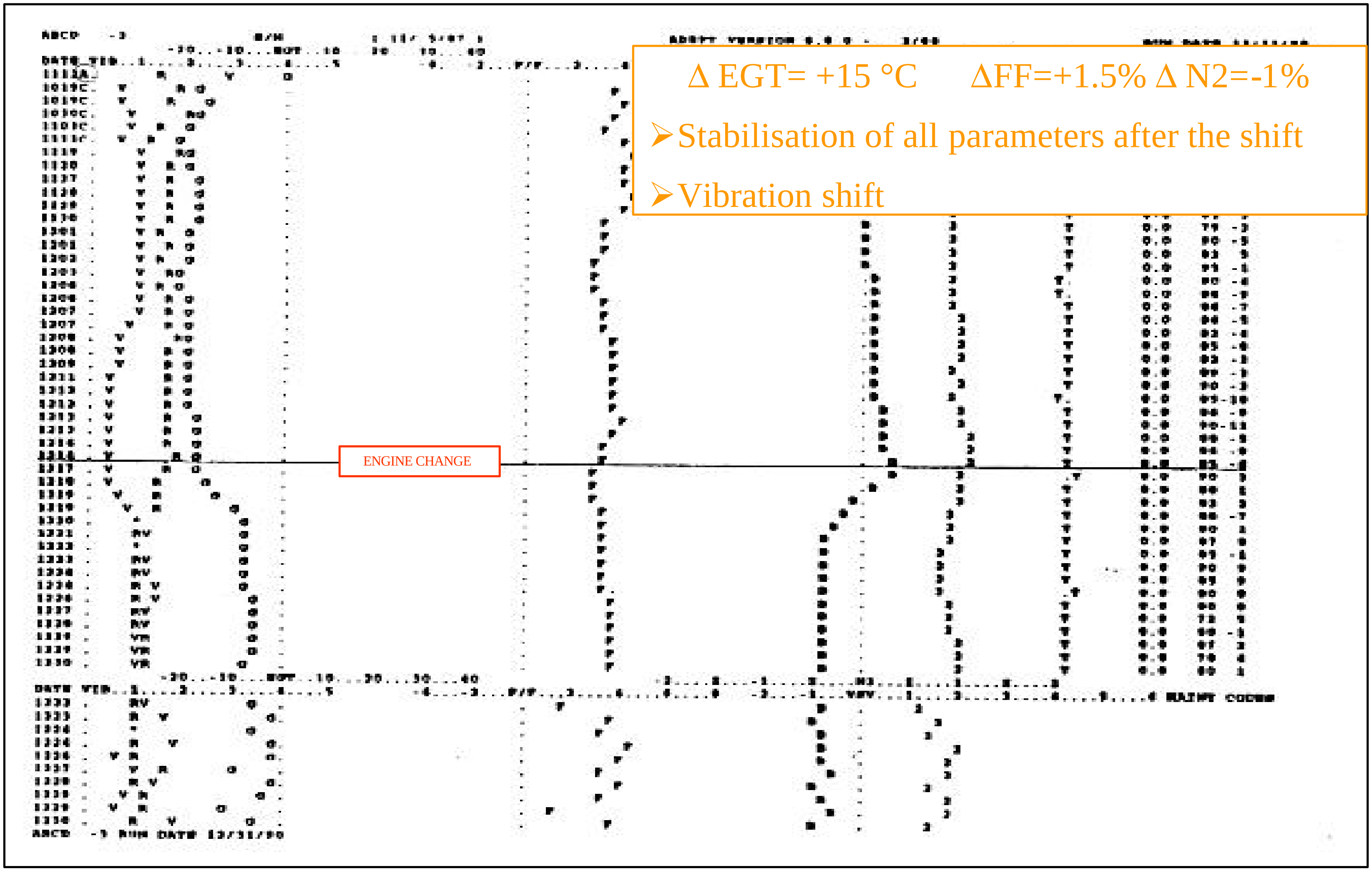
Wrong Bleed Input (Chart D.1)

Δ EGT= +20 °C
ΔFF=+2.4% Δ N2~ 0

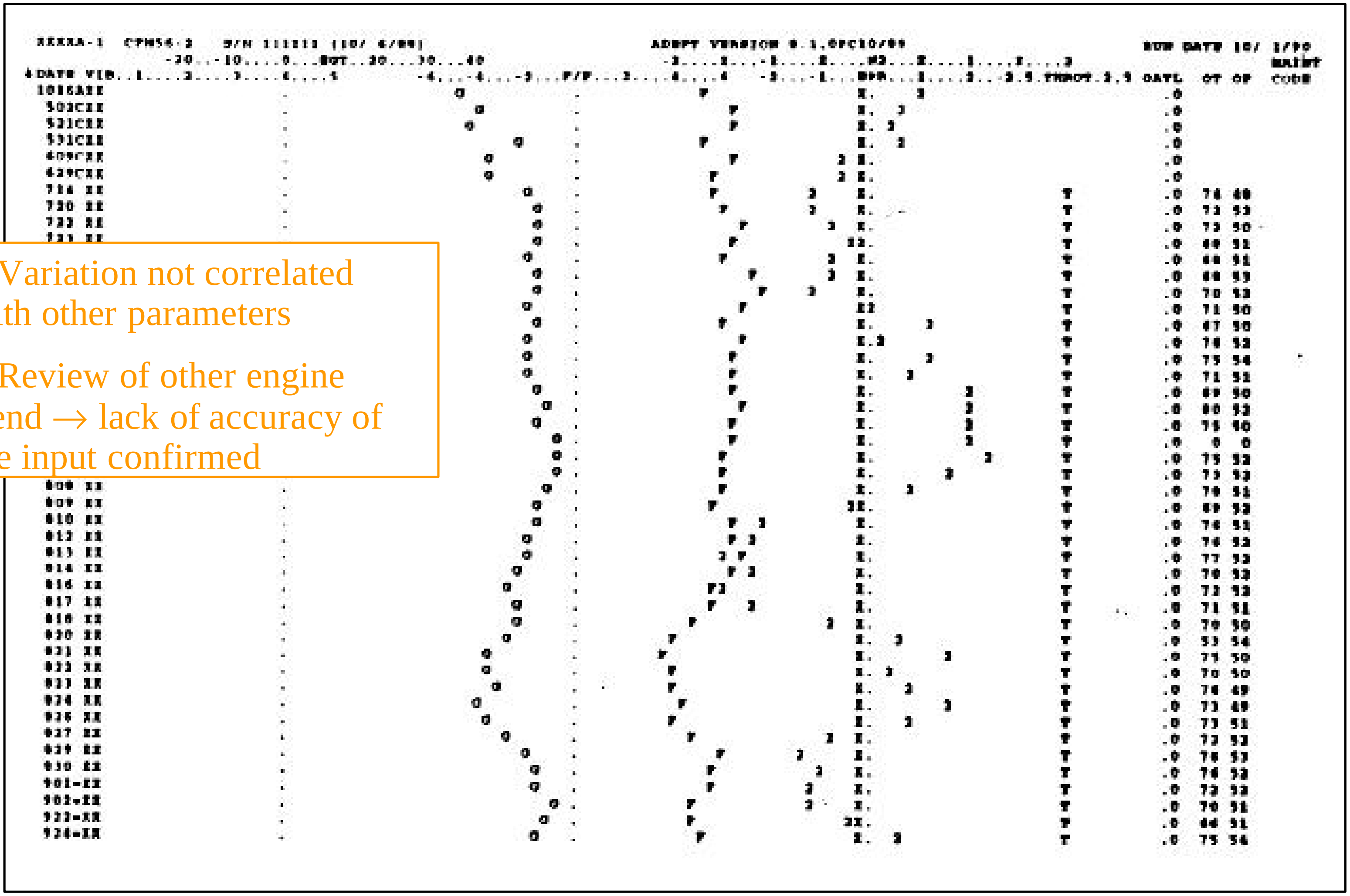
- Other engine trend normal so engine problem suspected
- Review of the cruise summary form CRDATA → wrong bleed configuration input



Engine change Not Recorded (Chart D.2)



Inaccurate Data Recording (Chart D.3)



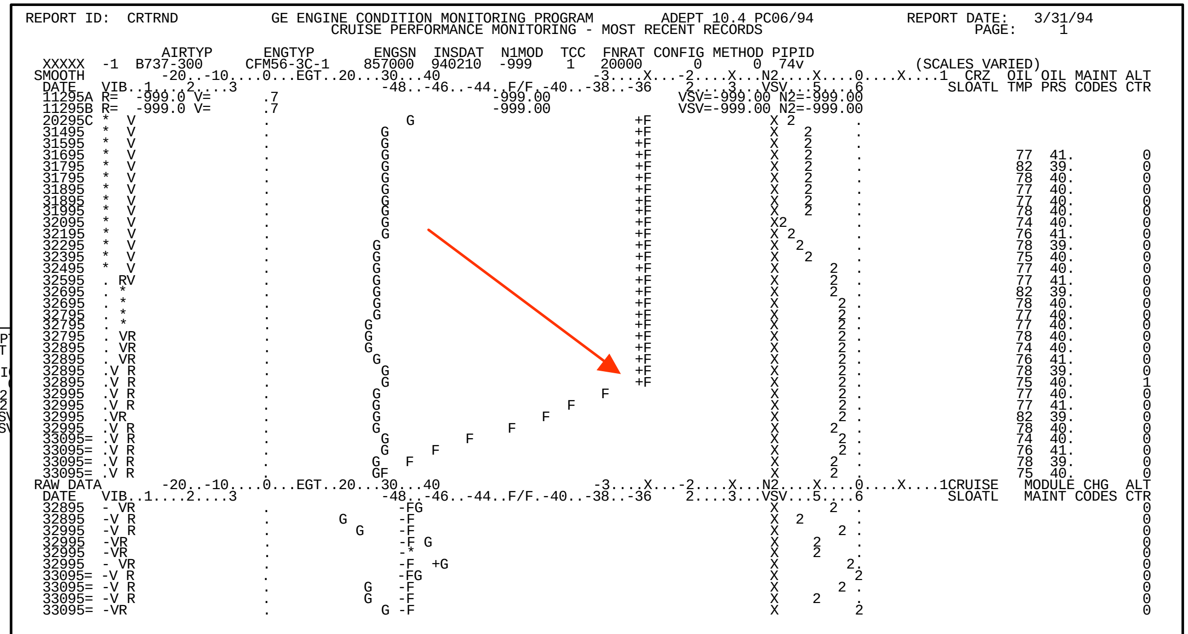
- Variation not correlated with other parameters
- Review of other engine trend ⟶ lack of accuracy of the input confirmed

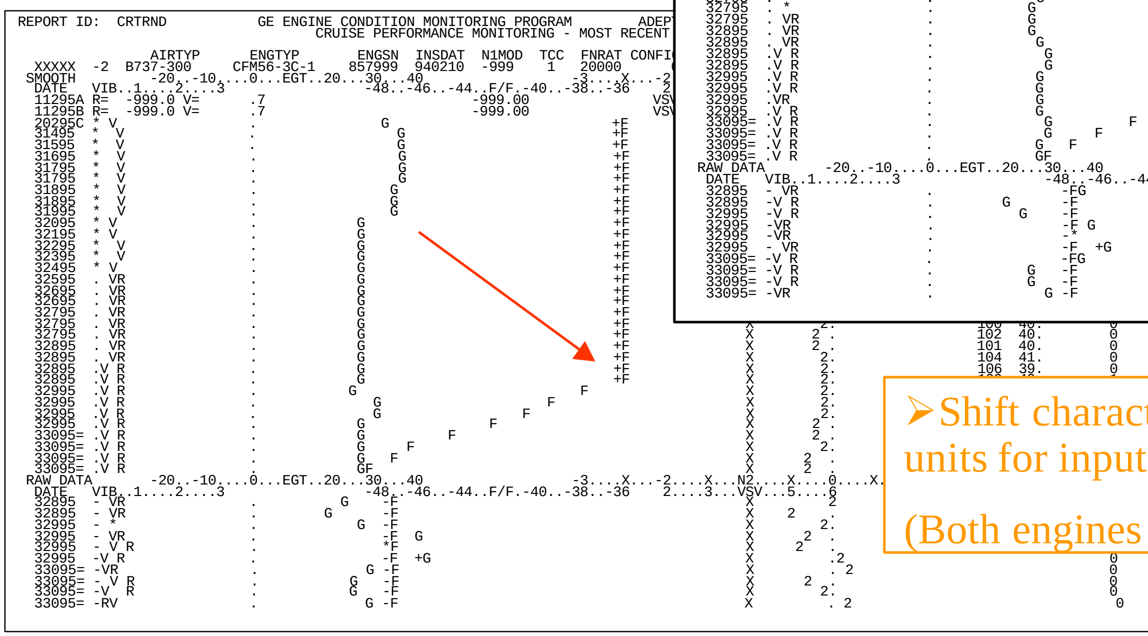
Poor Data Accuracy Results in “Highly” Scattered Trend

```
REPORT ID:   CRTRND              GE ENGINE CONDITION MONITORING PROGRAM         ADEPT 10.5 PC05/95            REPORT DATE:  10/10/96
                                          CRUISE PERFORMANCE MONITORING - FROM 800101 TO 961010                        PAGE:      1

                AIRTYP         ENGTYP          ENGSN   INSDAT   N1MOD   TCC   FNRAT  CONFIG  METHOD  PIPID
 XXXXX    -2   DC-8           CFM56-2          69300   941015   -999               -999      0        0   611               (SCALES VARIED)
 SMOOTH              -20..-10....0...EGT..20...30...40                                 -1....X....0....X...N2....X....2....X....3    CRZ    OIL  OIL  MAINT  ALT
  DATE      VIB..1....2....3                       -6...-4...-2...F/F...2....4....6      3....4...VSV...6....7                      SLOATL  TMP  PRS  CODES  CTR
112294A  R=   -999.0  V=   -999.0   18.1                               .42                VSV=-999.00  N2=     1.22                -999.0
112294B  R=   -999.0  V=   -999.0   18.1                               .42                VSV=-999.00  N2=     1.22                -999.0
111094     X                          X                                        X                           X              X                           -999.0     68    55.              0
111494     X                          X                                        X                           X              X                           -999.0     69    55.              0
111594     X                          X                                        X                           X              X                           -999.0     66    54.              0
111594     X                          X                                        X                           X              X                           -999.0     75    54.              0
111794     X                          X                                        X                           X              X                           -999.0     68    52.              0
111994     X                          X                                        X                           X              X                           -999.0     63    54.              0
111994     X                          X                                        X                           X              X                           -999.0     80    55.              0
112094     X                          X                                        X                           X              X                           -999.0     68    53.              0
112194     X                          X                                        X                           X              X                           -999.0     71    55.              0
112294     X                          .            G                           . F                         .              X 2                         -999.0     86    55.              0
112594     X                          .          G                             . F                         .              X 2                         -999.0     62    55.              0
112694     X                          .          G                             .            F              .              X 2                         -999.0     64    55.              2
112894     X                          .            G                           .           F               .              X 2                         -999.0     70    58.              1
112994     X                          .            G                           .        F                  .              X 2                         -999.0     75    55.              1
120194     X                          .            G                           .         F                 .             *                            -999.0     70    54.              1
120194     X                          .            G                           .         F                 .            2 X                           -999.0     78    54.              0
120294     X                          .            G                           .         F                 .          2   X                           -999.0     65    55.              2
120494     X                          .            G                           .        F                  .       2      X                           -999.0     64    55.              0
120594     X                          .            G                           .  F                        .          2   X                           -999.0     80    55.              1
120694     X                          .         G                              .  F                        .       2      X                           -999.0     75    54.              0
120894     X                          .         G                              .  F                        .            2 X                           -999.0     55    55.              1
121394     X                          .      G                                 . F                         .              X2                          -999.0     60    55.              1
121794     X                          .      G                                 . F                         .              X   2                       -999.0     68    56.              1
121894     X                          .      G                                 . F                         .              X 2                         -999.0     71    54.              0
121994     X                          .        G                               . F                         .              X 2                         -999.0     63    55.              0
122094     X                          .         G                              . F                         .              X   2                       -999.0     62    55.              0
122194     X                          .         G                             F.                           .              X   2                       -999.0     82    55.              0
122294     X                          .        G                              F.                           .              X 2                         -999.0     67    55.              0
122594     X                          .         G                             F.                           .              X 2                         -999.0     68    57.              0
122594     X                          .         G                            F .                           .         2    X                           -999.0     73    54.              0
122694     X                          .         G                            F .                           .      2       X                           -999.0     85    54.              0
122794     X                          .         G                            F .                           .      2       X                           -999.0     70    55.              0
122994=    X                          .         G                          F   .                           .     2        X                           -999.0     72    55.              0
123094=    X                          .         G                          F   .                           .     2        X                           -999.0     56    56.              0
123094=    X                          .      G                             F   .                           . 2            X                           -999.0     75    52.              0
123194=    X                          .        G                          F    .                           2              X                           -999.0     66    55.              0
123194=    X                          .        G                          F    .                           .   2          X                           -999.0     63    55.              2
```

Fuel Flow Indication / Engine #2 Problem with Input Units (Chart D.4)





➢Shift characteristic of a change in fuel flow units for input

(Both engines show same characteristic)

THE POWER OF FLIGHT

INSTRUMENTATION PROBLEMS

	DEGT (°C)	DFF%	DN2%	Problem
Chart I.1	**+14**	**-3.8**	**0.7**	**TAT gage failure**
Chart I.2	**+20**	**~0**	**~0**	**EGT connector problem**
Chart I.3	**+30**	**~0**	**~0**	**EGT indication problem**
Chart I.4	**~0**	**+2**	**~0**	**Fuel indicator accuracy / failure**
Chart I.5	**-20**	**-6**	**-1.4**	**N1 Indicator accuracy / failure**
Chart I.6	**~0**	**~0**	**+2.5**	**CIT Sensor Fittings Clogged**
Chart I.7	**+20**	**+1**	**-0.2**	**HPTACC Sensor Cable Switch**

TAT Gage Failure (Chart I.1)

ΔEGT= -10 °C   ΔFF=+4%   ΔN2=-1%

- Review of the other engine trend: same deviation profile
- Review of Cruise Summary form (CRDATA) → no correlation between TAT and normal temperature at those altitudes
- Replacement of equipment → back to initial values on the trend

```
1
REPORT ID:  CRTRND

             AIRTYP
XX-XXX -2  B737-700
SMOOTH           -10....
 DATE   VIB..1....2....
 52999A R=  -999.0 V=
 52999B R=  -999.0 V=
 10102C *    V        .
 20102C *  V          .
 30102C *  V          .
 40102C *   V         .
 51402  * V           .
 51502  * V           .
 51602  * V           .           G                 .    F                          2 X                    -999.0 105  45.         0
 51702  * V           .           G                 .    F                           2X                    -999.0 105  48.         0
 51802  * V           .           G                 .   F                            2X                    -999.0 102  46.         0
 51902  *  V          .           G                 .   F                            2X                    -999.0 105  45.         0
 52002  *  V          .           G                 .   F                            2X                    -999.0 100  45.         0
 52102  * V           .           G                 .   F                            2X                    -999.0 110  45.         0
 52202  * V           .           G                 .   F                            2X                    -999.0 100  48.         0
 52302  * V           .           G                 .    F                           2X                    -999.0 100  46.         0
 52402  * V           .           G                 .    F                           2X                    -999.0 101  46.         0
 52502  * V           .            G                .    F                           2X                    -999.0 110  45.         1
 52702  * V           .             G               .    F                           2X                    -999.0 120  45.         0
 52802  * V           .            G                .   F                            2X                    -999.0 110  45.         0
 52902  * V           .            G                .   F                              *                   -999.0 110  45.         0
 53002  *  V          .            G                .   F                              *                   -999.0 110  45.         0
 53102  * V           .            G                .    F                             *                   -999.0 110  45.         0
 60102  * V           .            G                .   F                              *                   -999.0 102  45.         0
 60302  *  V          .            G                .   F                              *                   -999.0 120  40.         0
 60402  *  V          .            G                .   F                              *                   -999.0 100  40.         0
 60502  *  V          .             G               .   F                             X2                   -999.0 105  45.         0
 60602  *  V          .            G                .   F                             X2                   -999.0 110  45.         0
 60702  *   V         .            G                .   F                             X2                   -999.0 105  46.         0
 60802  *  V          .            G                .   F                             X2                   -999.0 100  45.         0
 61202  *  V          .            G                .   F                              *                   -999.0 100  45.         0
 61302  *   V         .            G                .   F                              *                   -999.0 110  45.         0
 61402  *   V         .            G                .   F                             X2                   -999.0 103  47.         0
 61502  *   V         .            G                .   F                             X2                   -999.0 110  45.         0
 61602  *   V         .            G                . F                               X2                   -999.0 110  45.         0
 61702  *   V         .             G               . F                               X2                   -999.0 105  44.         0
 61802  *   V         .            G                . F                                *                   -999.0 105  48.         0
 62002  *   V         .           G                 .  F                            2 X                   -999.0 102  44.         1
 62102  *   V         .         G                   .   F                        2    X                   -999.0 105  47.         1
 62202  *  V          .         G                   .    F                     2      X                   -999.0 110  45.         1
 62302= *  V          .        G                    .      F                  2       X                   -999.0 100  45.         1
RAW DATA       -10....0...10...EGT..30...40...50                  -2....X...-1....X...N2....X....1....X....2 CRZ     MODULE CHG  ALT
 DATE   VIB..1....2....3                         -4...-2....0...F/F...4....6....8    3....4...VSV...6....7          SLOATL    MAINT CODES CTR
 61302  -R  V         .             G               .  F                             2X                    -999.0                    0
```


TOC

EGT Connector Problem (Chart I.2)

ΔEGT= +20 °C ΔFF~ 0 ΔN2~ 0

- ➢Troubleshooting showed an engine problem →EGT harness connector

```
1
 REPORT ID:  CRTRND           GE ENGINE CONDITION MONITORING PROGRAM
                                    CRUISE PERFORMANCE MONITORING - MOST RECE

             AIRTYP        ENGTYP        ENGSN     INSDAT   N1MOD    TCC   FNRAT
 G-ABCD -2  B737-400     CFM56-3C1     875XXX    981212    0        *  *******
 SMOOTH         -20..-10....0...EGT..20...30...40                   -2....X...
  DATE   VIB..1....2....3                  -6...-4...-2...F/F...2....4....6
 122498A R=      0.1 V=      0.6   5.3                -0.35                VSV=-999.00 N2=  -0.06            55.4
 122498B R=      0.1 V=      0.6   5.3                -0.35                VSV=-999.00 N2=  -0.06          -999.0
  10399C *   V                 . G                     F.                            2X                     55.9
  20499C .*                    . G                     F.                             *                     55.3
  30599C .*                    . G                     F.                            2X                     55.2
  40299C .*                    .   G                   F.                            2X                     53.7
  81999  .RV                   .      G                F                             2X                     52.4 105  49.        0
  81999  .*                    .       G               F                             2X                     51.8  91  52.        1
  82099  . *                   .       G               F                             2X                     51.4  99  49.        0
  82099  .RV                   .       G               F                             2X                     51.7  94  52.        0
  82099  .RV                   .       G               F                             2X                     51.7 102  49.        0
  82199  .RV                   .       G               F                             2X                     51.9 102  48.        0
  82199  .RV                   .      G                F                             2X                     52.2  96  48.        0
  82299  .RV                   .       G               F                             2X                     51.9  95  51.        0
  82299  .RV                   .      G                F                             2X                     52.0 103  51.        0
  82399  .RV                   .       G               F                             2X                     51.9  97  50.        0
  82399  .RV                   .         G             F                             2X                     52.1  99  50.        0
  82499  .*                    .            G          F                             2X                     52.4 103  52.        0
  82499  .*                    .                 G     F                             2X                     52.1  97  51.        0
  82499  .RV                   .            G          F                             2X                     52.2 100  48.        0
  82499  .RV                   .          G            F                             2X                     52.1 107  49.        0
  82599  .RV                   .        G              F                             2X                     52.0  96  48.        0
  82599  .*                    .       G               F                             2X                     52.1  95  50.        0
  82699  .*                    .      G                F                             2X                     52.2  98  50.        0
  82699  .*                    .      G                F                             2X                     52.2 102  51.        0
  82799  .*                    .      G                F                             2X                     52.4 107  49.        0
  82799  .*                    .      G                F                             2X                     52.5 105  48.        0
  82799  .RV                   .      G                F                             2X                     52.1 102  48.        0
  82899  .RV                   .      G                 .F                           2X                     51.5  97  48.        1
  82899  .*                    .      G                F                             2X                     51.4 104  50.        0
  82999  .RV                   .       G               F                             2X                     51.2  96  50.        0
  83099  .*                    .       G               F                             2X                     51.4  88  50.        0
  83199  .*                    .      G                F                             2X                     51.7 100  49.        0
  83199  .*                    .      G                F                             2X                     51.9 100  48.        0
  83199  .*                    .      G                 .F                           2X                     52.1  91  50.        0
  90199  .*                    .      G                 .F                           2X                     52.0  95  48.        0
  90199  .*                    .      G                 .F                           2X                     52.4  91  50.        0
  90299  .*                    .     G                  .F                           2X                     52.6 100  49.        0
  90299  .*                    .      G                 .F                            *                     52.5 102  48.        0
  90399  .*                    .      G                 .F                            *                     52.5 102  48.        0
  90399  .*                    .      G                 .F                            *                     52.5 101  49.        0
```

EGT Connector cleaned

EGT Indication Problem (Chart I.3A)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                       ADEPT VERSION 8.3.6PC01/92                       RUN DATE 11/25/92
              -20..-10....0...EGT..20...30...40                 -2....X...-1....X....N2...X....1....X....2                   MAINT
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6  -2...-1...EPR...1....2..-2.5.THROT.2.5 OATL  OT OP  CODE
  506A.R V                .            G                .                    F    2 X.                            0.0
 1006C.R  V               .              G              .                     F     X2                            0.0
 1012C.R  V               .             G               .                       F   X2                            0.0
 1018C.R  V               .             G               .                       F   X.2
 1023C.R   V              .           G                 .                       F   X.2
 1029C.R  V               .          G                  .                       F   X.2
 1110 .R V                .            G                .                        F X.2
 1110 .R  V               .           G                 .                       F   X. 2
 1111 .R  V               .           G                 .                         F X. 2
 1111 .R  V               .            G                .                        F  X.2
 1111 .R  V               .            G                .                        F  X.2
 1112 .R  V               .            G                .                         F X.2
 1113 .R  V               .             G               .                          *X.
 1114 .R  V               .             G               .                          *X.
 1114 .R  V               .             G               .                        F X2.
 1115 .R  V               .             G               .                         FX2.
 1115 .R  V               .             G               .                        F X2.
 1116 .R  V               .             G               .                        F X2.
 1116 .R  V               .             G               .                        F X2.
 1117 .R  V               .           G                 .                       F  X2.
 1117 .R  V               .           G                 .                       F  X2.
 1118 .R  V               .              G              .                         FX2.
 1118=.R  V               .                 G           .                         F X2
 1119=.R  V               .                     G       .                        F  X2
 1119=.R  V               .                          G  .                       F  X.2
 1120=.R  V               .                            G.                        F X.2
 1120=.R  V               .                            G.                        F X.2

              -20..-10....0...EGT..20...30...40                 -2....X...-1....X....N2...X....1....X....2
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6  -2...-1...EPR...1....2....3....4....5....6 MAINT. CODES
 1116                     .             G               .                          2X.    F
 1116 X   V               .      G                      .                         F X.        2
 1117                     . G                           .                           X.*
 1117=X    V              .                    G        .                         F X2
 1118=.R  V               .                            G.                           X. 2    F
 1118=.R   V              .                            G.                       F   X. 2
 1119=X   V               .                             . G                   F 2   X.
 1119=.R  V               .                             .G                          X2F
 1120=.R V                .                             G                       F   X. 2
 1120=.R  V               .                            G.                         F X.   2
```

ΔEGT= +30 °C

ΔFF~ 0   ΔN2~ 0

- EGT exceedance reported
- Troubleshooting revealed LPT stage-2 nozzle rotation and thermocouple probe damage
- ECM trend showed a shift on EGT three-days prior to event

EGT Indication Problem (Chart I.3B)

```
1
REPORT ID:  TKTRND           GE ENGINE CONDITION MONITORING PROGRAM        SAGE V3.0.3 PC - Jan 99      REPORT DATE:   8/25/99
                                  TAKEOFF PERFORMANCE MONITORING - MOST RECENT RECORDS                         PAGE:     1

             AIRTYP        ENGTYP       ENGSN    INSDAT  N1MOD   TCC  FNRAT  CONFIG        CONTROL      SELECTOR
KJHKK  -1  A321-100      CFM56-5B3     779XXX    990301   0       * *******                                          (SCALES VARIED)
SMOOTH                         EGT       20...30...40..OATL..60...70...80              N2               ACTUAL             MAINT ALT
 DATE    CSI    40...50...60...MAR..80...90..100                              0....5...MAR..15...20       N1K   FNDR  N1DR CODES CTR
 32499A                      69.35                    50.55                        -999.00
 32499B                      69.35                    50.55                        -999.00
 41299  -5555             H
 41399  -5555             H
 41499  -5555            H
 41699  -5555             H
 41799  -5555            H
 41899  -5555            H
 42199  -5555            H
 42299  -5555            H
 42399  -5555             H
 42499  -5555            H
 42599  -5555            H
 42799  -5555            H
 50199  -5555            H
 50299  -5555             H
 50399  -5555            H
 50499  -5555            H
 50699  -5555             H
 50799  -5555             H
 50899  -5555             H
 50999  -5555              H
 51199  -5555               H
 51399  -5555               H
 51599  -5555                H
 51699  -5555                H
 51799  -5555                H
 51899  -5555                  H
 52099  -5555                  H
 52299  -5555                   H
 52399  -5555                    H
 52499  -5555                     H
 52599  -5555                     H
 52699  -5555                      H
```

```
1
REPORT ID:  CRTRND          GE ENGINE CONDITION MONITORING PROGRAM       SAGE  V3.0.3 PC - Jan 99    REPORT DATE:  8/25/99
                                  CRUISE PERFORMANCE MONITORING - MOST RECENT RECORDS                       PAGE:    1

             AIRTYP       ENGTYP       ENGSN    INSDAT  N1MOD   TCC  FNRAT  CONFIG       CONTROL      SELECTOR
KJHKK  -1  A321-100     CFM56-5B3     779XXX    990301   0       * *******                                      (SCALES VARIED)
SMOOTH         -90..-80..-70...EGT.-50..-40..-30                -2....X...-1....X...N2....X....1....X....2  CRZ  OIL OIL MAINT ALT
 DATE   VIB..1....2....3               -12..-10...-8...F/F..-4...-2....0   3....4...VSV...6....7         SLOATL TMP PRS CODES CTR
 32499A R=  -999.0 V=  -999.0 -42.1                   -9.06               VSV=-999.00 N2=  -0.73           50.6
 32499B R=  -999.0 V=  -999.0-999.0                 -999.00               VSV=-999.00 N2=-999.00           50.6
 31699C X                              G        F                     .       2      X                   -999.0
 40199C X                                G        F                   .         2    X                     49.3
 50199C X                               G         F                   .         2    X                     49.4
 51699  X                          G               F                  .         2    X                     53.7                0
 51799  X                          G               F                  .          2   X                     54.1                0
 51799  X                         G                F                  .         2    X                     54.5                0
 51899  X                         G                F                  .          2   X                     54.7                0
 51899  X                         G                F                  .         2    X                     55.1                0
 51999  X                         G                F                  .         2    X                     55.8                0
 51999  X                        G                 F                  .         2    X                     56.1                0
 52099  X                        G                 F                  .          2   X                     56.2                0
 52099  X                       G                   F                 .          2   X                     56.5                1
 52199  X                        G                  F                 .           2  X                     56.3                0
 52199  X                       G                   F                 .           2  X                     56.5                0
 52299  X                       G                   F                 .           2  X                     56.8                0
 52299  X                      G                    F                 .          2   X                     57.6                0
 52399  X                     G                    F                  .         2    X                     58.4                0
 52399  X                     G                    F                  .          2   X                     58.5                0
 52499  X                    G                     F                  .          2   X                     58.7                0
 52499  X                     G                    F                  .          2   X                     58.5                0
 52599  X                     G                    F                  .          2   X                     58.5                0
 52599  X                     G                    F                  .          2   X                     58.1                0
 52699  X                     G                    F                  .          2   X                     58.0                0
 52699  X                     G                    F                  .          2   X                     58.2                0
 52799  X                      G                    F                 .          2   X                     57.7                0
 52799  X                     G                    F                  .          2   X                     57.8                0
 52899  X                      G                    F                 .          2   X                     57.5                0
 52899  X                      G                    F                 .          2   X                     57.7                0
 52999  X                     G                     F                 .          2   X                     58.0                0
 52999  X                     G                     F                 .          2   X                     58.2                0
 53099  X                    G                     F                  .         2    X                     59.2                0
 53099  X                   G                     F                   .        2     X                     59.6                0
 60199  X                  G                      F                   .        2     X                     60.4                0
 60199  X                 G                        F                  .        2     X                     61.1                0
 60299  X                 G                        F                  .         2    X                     61.0                0
 60299  X                 G                        F                  .         2    X                     61.2                0
 60399  X                 G                        F                  .         2    X                     61.6                0
 60399  X                 G                        F                  .         2    X                     62.2                0
RAW DATA       -90..-80..-70...EGT.-50..-40..-30                -2....X...-1....X...N2....X....1....X....2 CRZ   MODULE CHG  ALT
 DATE   VIB..1....2....3               -12..-10...-8...F/F..-4...-2....0   3....4...VSV...6....7         SLOATL  MAINT CODES CTR
```

Fuel Flow Indicator Accuracy / Failure (Chart I.4)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                       ADEPT VERSION 8.3.6PC01/92                       RUN DATE 11/25/92
              -20..-10....0...EGT..20...30...40                 -2....X...-1....X....N2...X....1....X....2                   MAINT
 DATE VIB..1....2....3....4....5       -6...-4...-2...F/F...2....4....6   -2...-1...EPR...1....2..-2.5.THROT.2.5 OATL  OT OP  CODE
  506A.R V                .  G                          F                         2 X.                          0.0
 1006C.R  V               .         G                   .         F        2        X.                          0.0
 1012C.R  V               .        G                    .          F          2     X.                          0.0
 1018C.R  V               .         G                   .         F           2     X.                          0.0
 1023C.R   V              .         G                   .          F         2      X.                          0.0
 1029C.R  V               .       G                     .          F           2    X.                          0.0
 1111 .R  V               .         G                   .           F          2    X.                  T       0.0    0  0
 1111 .R  V               .         G                   .           F          2    X.                  T       0.0    0  0
 1111 .R  V               .         G                   .           F          2    X.                  T       0.0    0  0
 1112 .R  V               .          G                  .           F         2     X.                  T       0.0    0  0
 1113 .R  V               .          G                  .           F          2    X.                  T       0.0    0  0
 1114 .R  V               .         G                   .           F          2    X.                  T       0.0    0  0
 1114 .R  V               .          G                  .           F         2     X.                  T       0.0    0  0
 1115 .R  V               .          G                  .           F         2      X.                  T       0.0    0  0
 1115 .R  V               .         G                   .          F        2       X.                  T       0.0    0  0
 1116 .R  V               .         G                   .       F            2      X.                  T       0.0    0  0
 1116 .R  V               .         G                   .       F
 1117 .R  V               .         G                   .    F
 1117 .R  V               .        G                    .   F
 1118 .R  V               .         G                   .   F
 1118=.R  V               .         G                   .   F
 1119=.R  V               .        G                    .   F
 1119=.R  V               .       G                     .   F
 1120=.R  V               .       G                     .  F
 1120=.R  V               .       G                     .  F
 1121 X   V               .       G                     .  F
 1121=X    V              .       G                     .  F
 1122=.R  V               .        G                    . F
 1122=.R   V              .         G                   F
 1123=X   V               .        G                    F
 1123=.R  V               .        G                    F
 1123=.R V                .        G                    .F
 1124=.R  V               .        G                    . F
```

Suspected

Fuel Indicator Swapping

Swapped form engine #2

$\Delta EGT \sim 0$ $\Delta FF = +4.5\%$ $\Delta N2 \sim 0$

- Lack of correlation in between EGT and Fuel Flow
- Troubleshooting initiated to find out source of fuel flow indicating problem
- Swap of tha aircraft fuel flow indicator ® back to original fuel flow value

cfm THE POWER OF FLIGHT

N1 Indication Accuracy / Failure (Chart I.5)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92                       RUN DATE 11/25/92
              -20..-10....0...EGT..20...30...40                 -2....X...-1....X....N2...X....1....X....2                    MAINT
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6  -2...-1...EPR...1....2..-2.5.THROT.2.5 OATL  OT OP  CODE
  506A.R V                .      G                  F   .                    2      X.                            0.0
 1006C.R  V               .      G                 F    .                   2       X.                            0.0
 1012C.R  V               .      G                F     .                  2        X.
 1018C.R  V               .      G               F      .                  2        X.
 1023C.R   V              .    G                 F      .                   2       X.
 1029C.R  V               .    G                  F     .                   2       X.
 1111 .R  V               .     G                F      .                   2       X.
 1111 .R  V               .   G                F        .                   2       X.
 1111 .R  V               .  G                  F       .                   2       X.
 1112 .R  V               .   G                   F     .                   2       X.
 1113 .R  V               .     G                 F     .                  2        X.
 1114 .R  V               .     G               F       .                 2         X.
 1114 .R  V               .    G                F       .                2          X.
 1115 .R  V               .    G                F       .                2          X.
 1115 .R  V               .      G            F         .               2           X.                   T        0.0   0  0
 1116 .R  V               .    G             F          .              2            X.                   T        0.0   0  0
 1116 .R  V               .   G            F            .             2             X.                   T        0.0   0  0
 1117 .R  V               . G                F          .              2            X.                   T        0.0   0  0
 1117 .R  V              G.                 F           .              2            X.                   T        0.0   0  0
 1118 .R  V             G .              F              .            2              X.                   T        0.0   0  0
 1118=.R  V              G.            F                .           2               X.                   T        0.0   0  0
 1119=.R  V         G     .          F                  .         2                 X.                   T        0.0   0  0
 1119=.R  V        G      .          F                  .          2                X.                   T        0.0   0  0
 1120=.R  V         G     .    F                        .       2                   X.                   T        0.0   0  0
 1120=.R  V          G    .     -F                      .      2                    X.                   T        0.0   0  0
 1121 X   V            G  .     -F                      .      2                    X.                   T        0.0   0  0
 1121=X    V             G.     -F                      .       2                   X.                   T        0.0   0  0
 1122=.R  V               G.        F                   .         2                 X.                   T        0.0   0  0
 1122=.R   V              .    G       F                .           2               X.                   T        0.0   0  0
 1123=X   V               .       G            F        .             2             X.                   T        0.0   0  0
 1123=.R  V               .       G                 F   .               2           X.                   T        0.0   0  0
 1123=.R V                .        G                F   .                  2        X.                   T        0.0   0  0
 1124=.R  V               .       G                F    .                   2       X.                   T        0.0   0  0
```

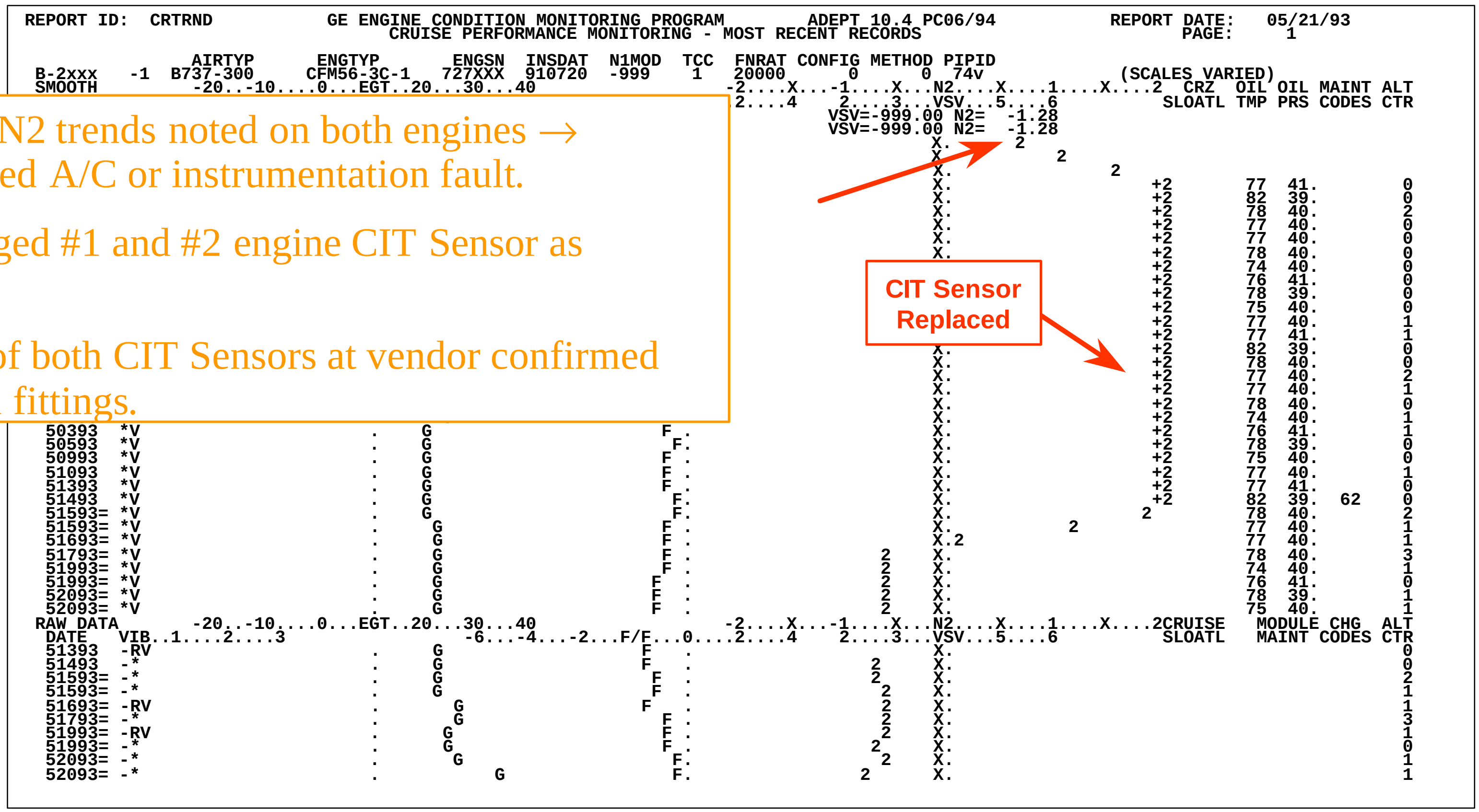
ΔEGT= -35 °C ΔFF<-4%
ΔN2=-1.5%

➢Troubleshooting showed an engine problem ® N1 indication

TOC

Engine CIT Sensor Fittings Clogged - Engine #1 (Chart I.6)

- High N2 trends noted on both engines → Suspected A/C or instrumentation fault.
- Changed #1 and #2 engine CIT Sensor as suspect
- Test of both CIT Sensors at vendor confirmed clogged fittings.



HPTACC Sensor cable switch(Chart I.7)

THE POWER OF FLIGHT

- Sudden EGT increase. No problem on the other engine
- Engine fault found stored in the CDU → TCC sensor signal out of range
- Troubleshooting showed a switch between T5 sensor cable and TCC sensor cable → HPTCC valve in failsafe position

ΔEGT = +16°C   ΔFF = +1%   ΔN2 = -0.2%

```
REPORT ID:  TKTRND              GE ENGINE CONDITION MON
                                     TAKEOFF PERFORMANC
                 AIRTYP         ENGTYP         ENGSN     INS
XXX      -1  B737-800       CFM56-7B27      874XXX     990
SMOOTH                             EGT          0...10...2
 DATE     CSI    -30..-20..-10...MAR..10...20...30
 61899A                         52.51
 61899B                         52.51
 50100C                            .         .    H
 60100C                            .         .    H
 70100C                            .         .    H
 80100C                            .         .H
81400    1041                     .         .  H
 81400    1042                     .         . H
 81400    1047                     .         . H
 81500    1051                     .         . H
 81500    1053                     .         . H
 81500    1054                     .         . H
 81500    1055                               . H
 81600    1056                               *
 81600    1057                             H.
 81700    1058                     .     H   .
 81700    1059                     .    H    .
 81700    1060                     .   H     .
 81700    1061                     .   H     .
 81800    1062                     .  H      .
 81800    1065                     .   H     .
 81800    1068                     .   H     .
 81800    1070                     .   H     .
```

TAKEOFF TREND

```
REF                                                   SAGE
                                                    RECENT

                                                    RAT   C
XXX                                                 ***
SMO                                                 X...-1
 DA                                                 8     3
 61                                                      VS
 61                                                      VS
 50
 60
 70
 80
 81
 81400  .RV      .       G                 .     F
 81400  .R V     .       G                 .     F
 81400  .R V     .       G                 .     F
 81400  .R V     .       G                 .     F
 81500  .R V     .       G                 .     F
 81500  .R V     .       G                 .     F
 81500  .R V     .       G                 .     F
 81500  .R V     .       G                 .     F
 81500  .R V     .       G                 .     F
 81500  .R V     .       G                 .     F                2X             42.4  91  48.        0
 81600  .R V     .         G               .     F                2X             41.4  91  46.        2
 81600  .R V     .          G              .     F               2 X             40.8 105  45.        1
 81700  .R V     .           G             .     F               2 X             39.9  96  48.        2
 81700  .R V     .            G            .      F              2 X             39.3  87  49.        1
 81700  .R V     .            G            .      F              2 X             38.9 104  46.        0
 81700  .R V     .             G           .      F             2  X             38.6 103  46.        0
 81800  .R V     .             G           .      F             2  X             38.2 101  46.        0
 81800  .R V     .              G          .       F            2  X             37.7 104  46.        0
 81900  .R V     .               G         .       F            2  X             37.3  88  48.        0
 81900  .R V     .               G         .       F            2  X             37.1 108  45.        0
 81900  .R V     .               G         .       F            2  X             36.9 101  46.        0
```

Cable switch

MECHANICAL PROBLEMS

- **Theoretical parameter shifts and potential engine problems**

- **Trend examples showing effective engine problems**

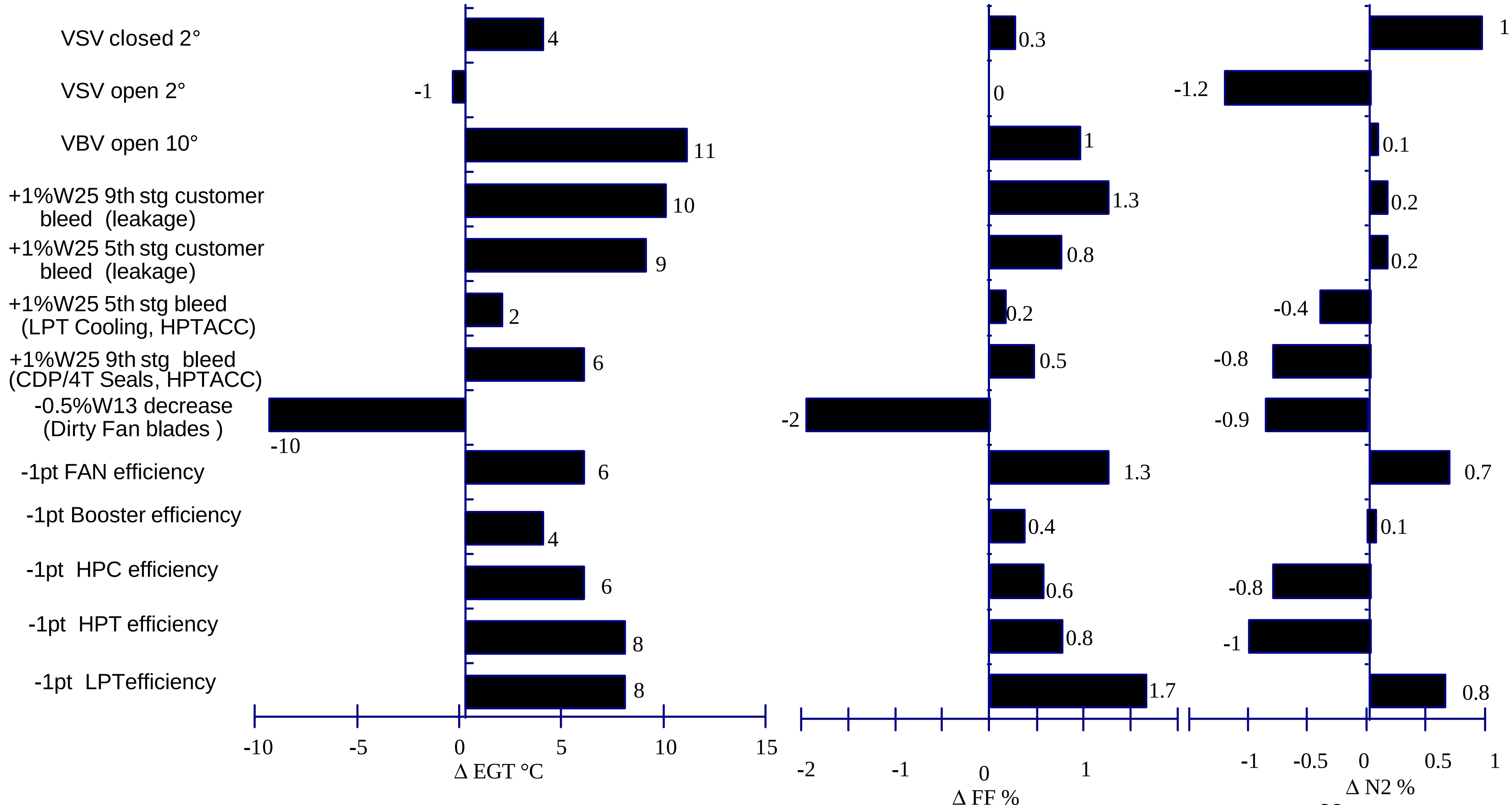
CFM56 THEORETICAL PARAMETER SHIFTS

- **Cruise influence coefficient at constant N1**
  - ✓ **CFM56-3/-5A/-5B/-7 : separated flow**
    - **- cruise 35,000 ft / 0.76 / ISA**
  - ✓ **CFM56-5C : mixed flow**
    - **- cruise 35,000 ft / 0.82 / ISA**

- **The following values are guidelines for assessing engine monitoring trends, and are valid around a specified operating point**

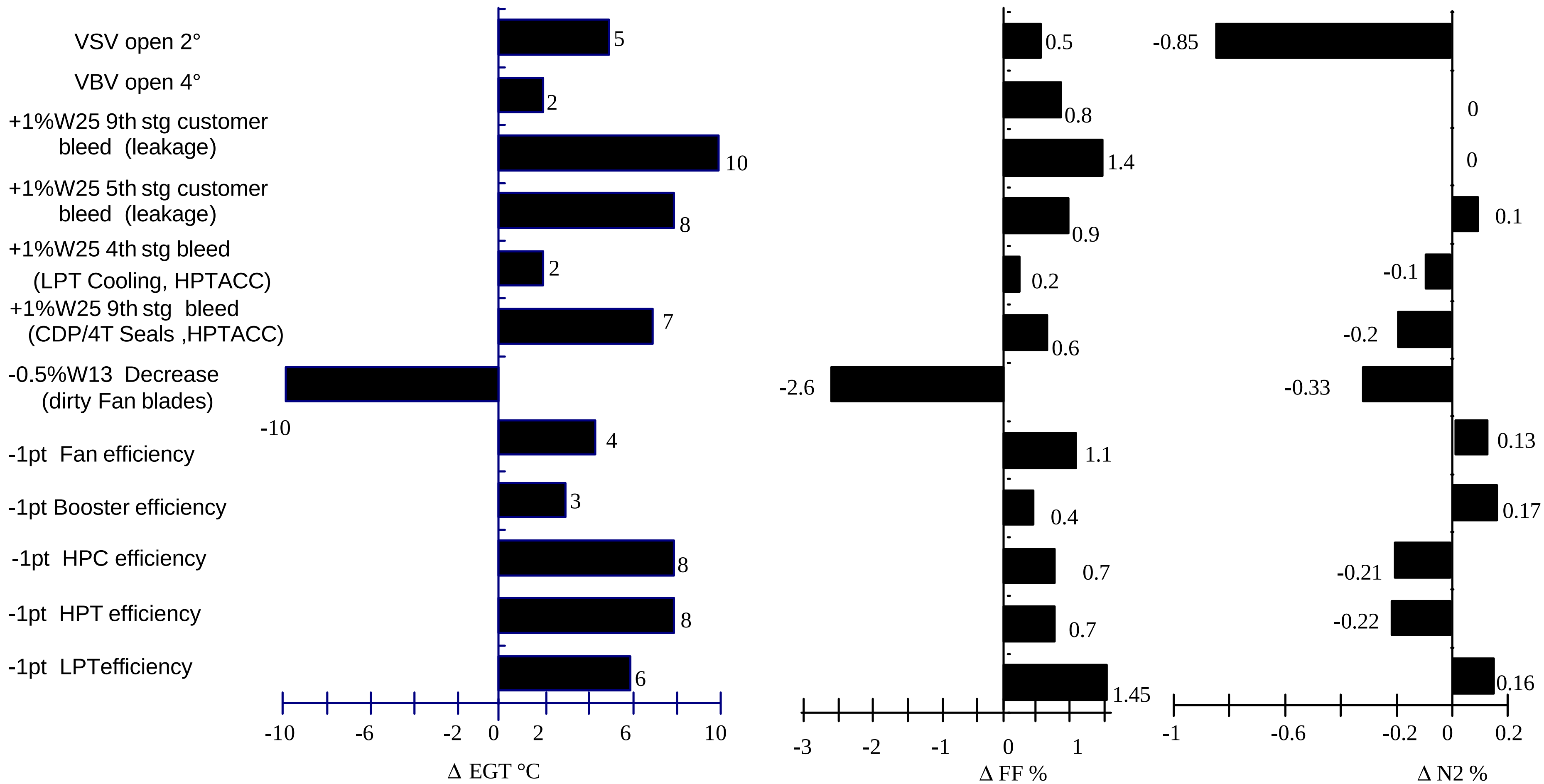
CFM56-2/-3/-5A/-5B/-7 Theoretical Parameter Shifts

(35000 ft / 0.76 /ISA/ constant N1)



CFM56-5C Theoretical Parameter Shifts

(35000 ft / 0.82 /ISA/ constant N1)



CFM56 INDICATORS OF POTENTIAL ENGINE PROBLEMS

Based on Engine Monitoring Trends

- **Some "universal" trend interpretation principles to use when analyzing trend data:**

  - ✓ **EGT "up' shifts or "down' shifts of greater then 15 degrees, will be accompanied by a corresponding "up' or "down" shift of fuel flow**
  - ✓ ***VBV trend shift in the "open" direction, will result in a corresponding shift "up" in the N2 trend (VBV not monitored with CFMI engines)***
  - ✓ ***VSV trend shift in the "closed" direction, will result in a corresponding shift "up" in the N2 trend (VSV not monitored with CFMI engines)***
  - ✓ ***VSV trend shift in the "open" direction, will result in a corresponding shift "down" in the N2 trend (VSV not monitored with CFMI engines)***

CFM56 INDICATORS OF POTENTIAL ENGINE PROBLEMS

Based on Engine Monitoring Trends

- **Typical deterioration of CFM56 engines is in HP system**
  - **with EGT and FF up-shift and N2 down-shift**
- **LP deterioration is unusual**
  - **would result in up-shift of EGT, FF and N2**
- **VBV problem and air leakage**
  - **lead to parameter up-shifts**

CFM56 INDICATORS OF POTENTIAL ENGINE PROBLEMS

Based on Engine Monitoring Trends

- **VSV problems**
  - ✓ **- result in significant N2 shifts**
  - ✓ **- small change in EGT and FF**
- **VSV off schedule**
  - ✓ **- may be associated with**
    - **slow start, slow acceleration, high N2 at takeoff (VSV too closed)**
    - **slow deceleration, low HPC stall margin (VSV too open)**

NOTE: VSV position has to off-schedule more than 5° for 4 Sec. to set an A/C Maintenance Message on FADEC powered A/C

THE POWER OF FLIGHT

EXAMPLES OF ENGINE PARAMETER TRENDS

(Related to Hardware Condition)

Four Categories of "Characteristic" Trend Shifts				Most probable problem source
1.	D **EGT -**	D**FF -**	D**N2 -**	VBV / Air Leakage
2.	D **EGT»0**	D**FF»0**	D**N2** ¯	VSV Open
3.	D **EGT»0**	D**FF»0**	D**N2 -**	VSV Close
4.	D **EGT -**	D **FF -**	D**N2** ¯	HP / LP Deterioration

Trend Analysis

ENGINE PARAMETER TRENDS *(cont'd)*

D EGT ↑ **D FF ↑** **D N2 ↑**

CFM56-3

Trend signature	Troubleshooting Result	
VBV open	Stop mechanism	Chart M.1
Air leakage	Fuel nozzle seals	Chart M.2

CFM56-5A

Trend signature	Troubleshooting Result	
VBV failure	2 VBV doors open	Chart M.3
Air leakage	HPV open	Chart M.4
Air leakage	PRV failure	Chart M.5
Air leakage	Pack valve failure	Chart M.6
	VSV lever arm failure	Chart M.7A

CFM56-5B

Trend signature	Troubleshooting Result	
VBV failure	Flexible shaft failure	Chart M.7B

CFM56-3

VBV Gear-Motor Stop-Mechanism Seized

(Chart M.1)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X.
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...EPR...1.
  506A.R V                .      G                      .   F                        X.2
 1006C.R  V               .       G                     .   F                      2 X.
 1012C.R  V               .            G                .    F                     2 X.
 1018C.R  V               .         G                   .    F                    2  X.
 1023C.R   V              .      G                      .    F                      2X.
 1029C.R  V               .       G                     .   F                     2  X.
 1111 .R  V               .       G                     .  F                       2 X.
 1111 .R  V               .       G                     .   F                      2 X.
 1111 .R  V               .        G                    .   F                      2 X.
 1112 .R  V               .      G                      .   F                       2X.
 1113 .R  V               .       G                     .    F                       X2
 1114 .R  V               .       G                     .    F                      2X.
 1114 .R  V               .          G                  .     F                      X2
 1115 .R  V               .          G                  .     F                      X2
 1115 .R  V               .            G                .      F                     X.  2
 1116 .R  V               .                G            .       F                    X.    2
 1116 .R  V               .                G            .       F                    X.    2              T        0.0   0  0
 1117 .R  V               .                    G        .        F                   X.        2          T        0.0   0  0
 1117 .R  V               .                     G       .         F                  X.         2         T        0.0   0  0
 1118 .R  V               .                      G      .          F                 X.          2        T        0.0   0  0
 1118=.R  V               .                     G       .         F                  X.         2         T        0.0   0  0
 1119=.R  V               .                     G       .         F                  X.          2        T        0.0   0  0
 1119=.R  V               .                      G      .          F                 X.          2        T        0.0   0  0
 1120=.R  V               .                      G      .         F                  X.         2         T        0.0   0  0
 1120=.R  V               .                      G      .         F                  X.        2          T        0.0   0  0
 1121 X   V               .                     G       .          F                 X.         2         T        0.0   0  0
 1121=X    V              .                      G      .         F                  X.         2         T        0.0   0  0
 1122=.R  V               .                      G      .         F                  X.         2         T        0.0   0  0
 1122=.R   V              .                     G       .        F                   X.         2         T        0.0   0  0
 1123=X   V               .                      G      .         F                  X.          2        T        0.0   0  0
 1123=.R  V               .                     G       .          F                 X.         2         T        0.0   0  0
 1123=.R V                .                     G       .         F                  X.         2         T        0.0   0  0
 1124=.R  V               .                      G      .         F                  X.         2         T        0.0   0  0
```

ΔEGT = +30 °C ΔFF = +3 %
ΔN2 = +1.4 %

- Troubleshooting revealed VBV stuck open (~10°)
- Replacement of fuel gear-motor and stop-mechanism corrected the problem
- Stop-mechanism was later found seized

cfm
THE POWER OF FLIGHT

Air Leakage throughFuel Nozzle Seals (Chart M.2)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92                        RUN DATE 11/25/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X..
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1..
  506A.R V                .    G                    F   .                2
 1006C.R  V               .    G                   F    .               2
 1012C.R  V               .    G                    F   .               2
 1018C.R  V               .     G                   F   .              2
 1023C.R   V              .    G                    F   .              2
 1029C.R  V               .    G                    F   .              2
 1111 .R  V               .    G                    F   .              2
 1111 .R  V               .    G                     F  .              2
 1111 .R  V               .     G                    F  .              2
 1112 .R  V               .    G                     F  .              2
 1113 .R  V               .    G                     F  .              2
 1114 .R  V               .    G                     F  .              2
 1114 .R  V               .     G                    F  .              2
 1115 .R  V               .      G                   F  .              2
 1115 .R  V               .       G                   F .               2
 1116 .R  V               .         G                  F.               2
 1116 .R  V               .          G                 F.                2
 1117 .R  V               .          G                  F                2
 1117 .R  V               .          G                 F.                2
 1118 .R  V               .          G                 F.                2
 1118 .R  V               .          G                 F.                2
 1119 .R  V               .         G                  F.                2
 1119 .R  V               .          G                 F.                2
 1120 .R  V               .          G                F .                2
 1120 .R  V               .          G                F .               2

              -20..-10....0...EGT..20...30...40                  -2....X...-1....X..
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1..
 1116 X   V               .        G                F   .                 2          X.
 1116 X                   .          G                  . F                2         X.
 1117 .R                  .       G                    F.                    2       X.
 1117 X    V              .        G                    F              2             X.
 1118 .R  V               .      G                  F   .                 2          X.
 1118 .R   V              .                   G         .             F              X.     2
 1119 X   V               .       G                    F.                 2          X.
 1119 .R  V               .      G                    F .                2           X.
 1120 .R V                .       G                  F  .               2            X.
 1120 .R  V               .       G                   F .                2           X.
```

➢ Sixteen fuel nozzles were changed for potential risk (on 14th November) → Since then, shifts were noticed

ΔEGT = +12°C

ΔFF = + 1.8 %

ΔN2 = + 0.3 %

➢ Two metallic seals under fuel nozzles were not correctly installed, causing CDP air leakage

➢ Seals were replaced → trend returned to normal

CFM56-5A

VBV System Failure (Chart M.3)

```
1ABCD-1  CFM -5    S/N 111111 ( 9/ 9/89)                       ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....2
  506A.  R  V             .      G                      .  F                          .2  B
 1006C.   R V             .        G                    .   F                         .2  B
 1012C.   R V             .       G                     .    F                        .2  B
 1018C.  R  V             .       G                     .   F                         .2   B
 1023C.   R V             .       G                     .   F                         .2  B
 1029C.   R V             .       G                     .   F                         .2   B
 1111 .   R V             .       G                     .   F                         . 2  B
 1111 .   R V             .       G                     .   F                         . 2  B
 1111 .  R  V             .       G                     .   F                         .  2 B
 1112 . R   V             .        G                    .   F                         .  2 B
 1113 . R  V              .         G                   .    F                        .  2B
 1114 . R  V              .          G                  .     F                       .   2B
 1114 . R   V             .            G                .      F                      .   *
 1115 . R   V             .              G              .       F                     .   *
 1115 . R   V             .              G              .       F                     .  B2
 1116 . R   V             .              G              .      F                      .  B 2
 1116 .  R  V             .             G               .       F                     .  B 2              T       0.0   0  0
 1117 .  R  V             .              G              .       F                     .  B2               T       0.0   0  0
 1117 .  R  V             .              G              .       F                     .  B2               T       0.0   0  0
 1118 .  R  V             .             G               .       F                     .  B 2              T       0.0   0  0
 1118 .  R V              .             G               .      F                      .  B 2              T       0.0   0  0
 1119 .  R V              .             G               .       F                     .  B 2              T       0.0   0  0
 1119 .  R V              .              G              .       F                     .  B 2              T       0.0   0  0
 1120 .  R  V              .             G              .       F                     .  B 2              T       0.0   0  0
 1120 .  R  V              .             G              .      F                      .  B 2              T       0.0   0  0
```

- Two VBV doors seized in open position during the cruise phase
- Effect on engine performance trending

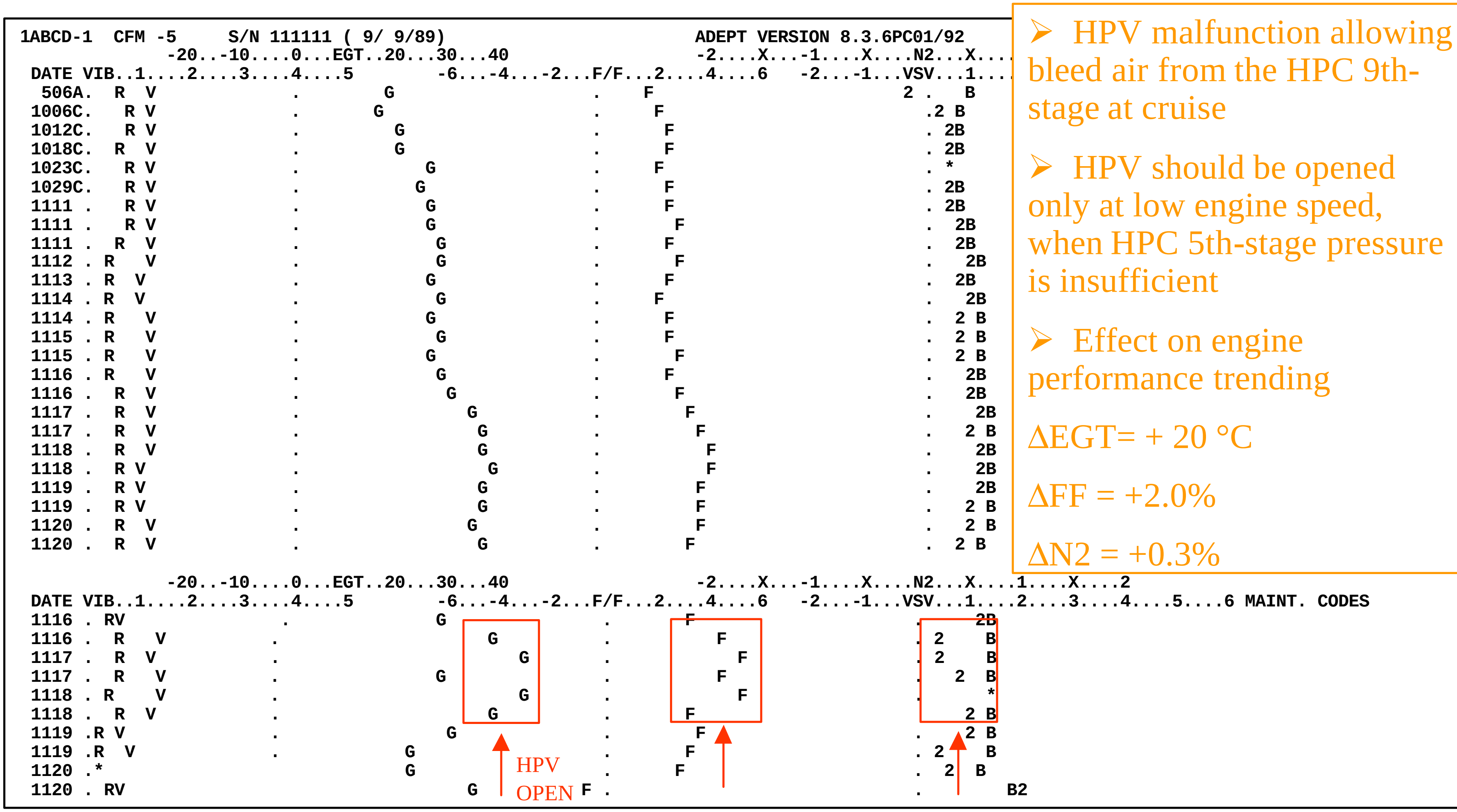
ΔEGT = +15 °C

ΔFF = + 1.2 %

ΔN2 = +0.8%

CFM56-5A

High Pressure Valve (HPV) Control Malfunction (Chart M.4)



- ➢ HPV malfunction allowing bleed air from the HPC 9th-stage at cruise
- ➢ HPV should be opened only at low engine speed, when HPC 5th-stage pressure is insufficient
- ➢ Effect on engine performance trending

ΔEGT= + 20 °C

ΔFF = +2.0%

ΔN2 = +0.3%

CFM56-5A

Bleed-Flow Control Valve (PRV) Failure (Chart M.5)

```
1ABCD-1  CFM56 -5     S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....
  506A.  *                G                             .         F                  X.    2
 1006C. R  V              .G                            .          F                 X. 2
 1012C.   RV              .G                            .         F                  X. 2
 1018C. R  V              . G                           .         F                  X.  2
 1023C. R   V             .      G                      .         F                  X.  2
 1029C. *                 .      G                      .          F                 X.   2
 1111 . *                 .         G                   .          F                 X.    2
 1111 . *                 .        G                    .          F                 X.    2
 1111 .VR                 .        G                    .          F                 X.    2
 1112 .VR                 .       G                     .          F                 X.     2
 1113 .*                  .       G                     .           F                X.    2
 1114 .*                  .       G                     .           F                X.    2
 1114 .*                  .       G                     .           F                X.    2
 1115 .*                  .       G                     .           F                X.    2
 1115 .*                  .       G                     .           F                X.    2
 1116 .*                  .         G                   .            F               X.    2
 1116 .*                  .         G                   .             F              X.     2
 1117 .*                  .          G                  .             F              X.      2            T        0.0   0  0
 1117 .*                  .           G                 .             F              X.      2            T        0.0   0  0
 1118 .VR                 .           G                 .             F              X.      2            T        0.0   0  0
 1118 . *                 .           G                 .             F              X.      2            T        0.0   0  0
 1119 . *                 .           G                 .             F              X.     2             T        0.0   0  0
 1119 . *                 .           G                 .             F              X.      2            T        0.0   0  0
 1120 . *                 .           G                 .             F              X.     2             T        0.0   0  0
 1120 . *                 .          G                  .           F                X.     2             T        0.0   0  0

              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1....X....2
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....2....3....4....5....6 MAINT. CODES
 1116 .*                  .       G                     .             F              X.      2
 1116 .*                  .          G                  .             F              X.       2
 1117 .VR                 .          G                  .            F               X.       2
 1117 . *                 .         G                   .              F             X.      2
 1118 .VR                 .         G                   .            F             2 X.
 1118 . *                 .      G                      .          F                 X.    2
 1119 .XR                 .       G                     .            F               X.        2
 1119 . *                 .         G                   .            F               X.     2
 1120 .RV                 .       G                     .            F               X.      2
 1120 . *                 .   G                         .        F                   X.   2
```

- PRV malfunction leads to increased HPC 5th-stage bleed-flow
- Effect on performance trending

ΔEGT = + 8°C

ΔFF = + 0.8%

ΔN2 = +0.2%

THE POWER OF FLIGHT

CFM56-5A
Pack Valve Failure (Chart M.6)

```
1ABCD-1  CFM -5   S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92                       RUN DATE 11/25/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X...
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1...
  506A.  *                     G                        . F                          X2    2
 1006C. R  V              .G                            .  F                         X. 2
 1012C.   RV              .G                            .  F                         X. 2
 1018C. R V               . G                           . F                          X. 2
 1023C. R V               . G                           . F                          X. 2
 1029C. *                 . G                           . F                          X. 2
 1111 . *                 . G                           . F                          X. 2
 1111 . *                 . G                           . F                          X. 2
 1111 .VR                 .  G                          .F                           X. 2
 1112 .VR                 .  G                          . F                          X. 2
 1113 .*                  .    G                        .  F                         X. 2
 1114 .*                  .     G                       .  F                         X. 2
 1114 .*                  .      G                      .   F                        X.  2
 1115 .*                  .       G                     .   F                        X.  2
 1115 .*                  .        G                    .   F                        X.  2
 1116 .*                  .        G                    .   F                        X. 2
 1116 .*                  .        G                    .   F                        X. 2
 1117 .*                  .        G                    .   F                        X. 2
 1117 .*                  .        G                    .   F                        X. 2
 1118 .VR                 .        G                    .   F                        X. 2                  T      0.0    0  0
 1118 . *                 .        G                    .    F                       X. 2                  T      0.0    0  0
 1119 . *                 .        G                    .    F                       X.  2                 T      0.0    0  0
 1119 . *                 .         G                   .    F                       X.  2                 T      0.0    0  0
 1120 . *                 .         G                   .   F                        X.  2                 T      0.0    0  0
 1120 . *                 .         G                   .   F                        X.  2                 T      0.0    0  0

              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1....X....2
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....2....3....4....5....6 MAINT. CODES
 1116 .*                  .           G                 .  F                         X.  2
 1116 .*                  .       G  G                  .  F                         X.  2
 1117 .VR                 .         G                   .     F                      X.   2
 1117 . *                 .        G                    .   F                        X.  2
 1118 .VR                 .       G                     .   F                        X.   2
 1118 . *                 .       G                     .     F                      X.   2
 1119 .XR                 .        G                    .      F                     X.   2
 1119 . *                 .          G                  .      F                     X.   2
 1120 .RV                 .        G                    .      F                     X.   2
 1120 . *                 .         G                   .      F                     X.   2
```

- Pack-valve malfunction leads to increase bleed from 5th-stage
- Effect on engine performance trending

ΔEGT = +16 °C

ΔFF = + 1.8 %

ΔN2 = + 0.1%

CFM56-5A
VSV Lever-Arm Failure (Chart M.7A)

```
1ABCD-1   CFM -5    S/N 111111 ( 9/ 9/89)                       ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1....
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....2..-2
  506A.  R  V             .        G                    .           F                X.     2
 1006C.   R V             .         G                   .          F                 X.     2
 1012C.   R V             .      G                      .           F                X.    2
 1018C.  R  V             .         G                   .           F                X.     2
 1023C.   R V             .          G                  .            F               X.     2
 1029C.   R V             .          G                  .           F                X.     2
 1111 .   R V             .              G              .        F                   X.     2
 1111 .   R V             .              G              .        F                   X.     2
 1111 .  R  V             .              G              .           F                X.      2
 1112 . R   V             .               G             .           F                X.      2
 1113 . R  V              .                G            .           F                X.      2
 1114 . R  V              .                G            .           F                X.      2
 1114 . R   V             .               G             .           F                X.      2
 1115 . R   V             .               G             .          F                 X.     2
 1115 . R   V             .                G            .          F                 X.     2
 1116 . R   V             .                G            .          F                 X.     2
 1116 .  R  V             .               G             .          F                 X.     2
 1117 .  R  V             .               G             .          F                 X.     2
 1117 .  R  V             .               G             .          F                 X.     2
 1118 .  R  V             .               G             .          F                 X.    2              T        0.0   0  0
 1118 .  R V              .               G             .          F                 X.     2             T        0.0   0  0
 1119 .  R V              .               G             .          F                 X.     2             T        0.0   0  0
 1119 .  R V              .               G             .          F                 X.      2            T        0.0   0  0
 1120 .  R  V             .               G             .          F                 X.     2             T        0.0   0  0
 1120 .  R  V             .                G            .          F                 X.      2            T        0.0   0  0
 1121 . RV                .                 G           .          F                 X.       2           T        0.0   0  0
 1121 .  R    V           .                   G         .          F                 X.        2          T        0.0   0  0
 1122 .  R   V            .                    G        .           F                X.        2          T        0.0   0  0
 1122 .  R    V           .                    G        .            F               X.        2          T        0.0   0  0
 1123 . R     V           .                    G        .            F               X.        2          T        0.0   0  0
 1123 .  R  V             .                    G        .            F               X.        2          T        0.0   0  0
 1124 .R V                .                    G        .            F               X.        2          T        0.0   0  0
 1124 .R  V               .                    G        .            F               X.        2          T        0.0   0  0
 1125 .  *                .                    G        .            F               X.        2          T        0.0   0  0
 1125 . R  V              .                    G        .           F                X.        2          T        0.0   0  0
```

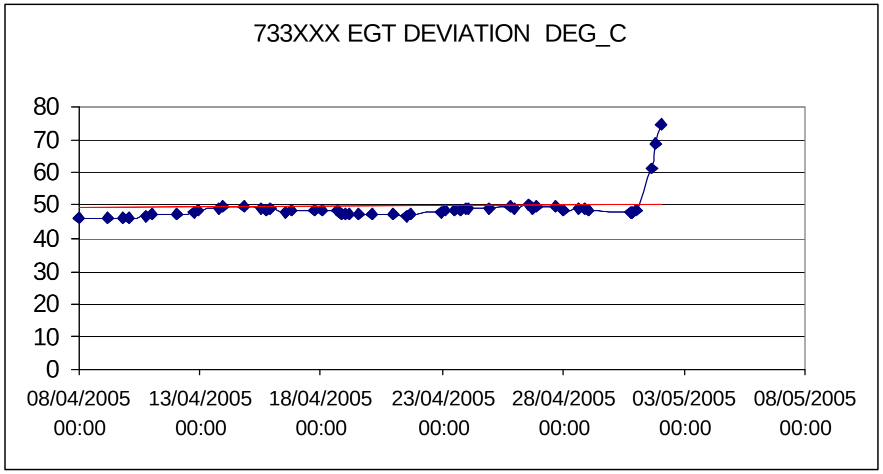
- ➢HPC stage-1 blade failure consecutive to a broken VSV lever-arm
- ➢At 140 flights prior to event, ADEPT showed a shift

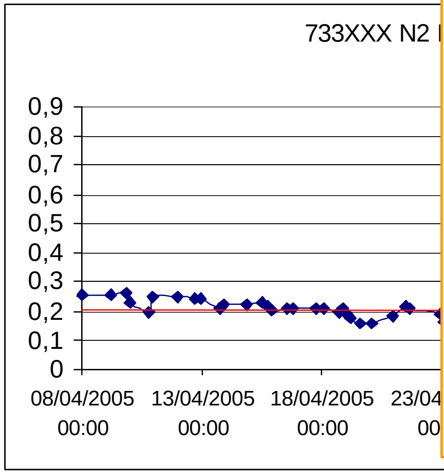
$\Delta EGT = +\ 12\ °C$

$\Delta FF = +\ 0.8\%$

$\Delta N2 = +\ 0.3\%$

CFM56-5B
VBV Flexible shaft failure (Chart M.7B)



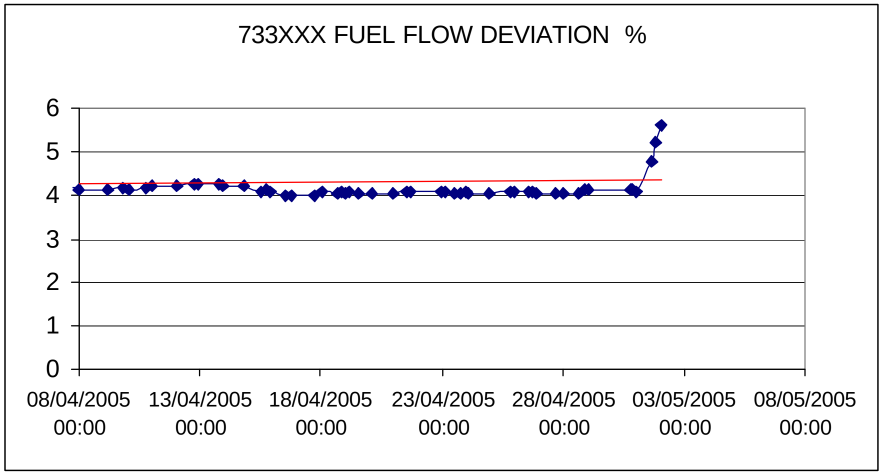


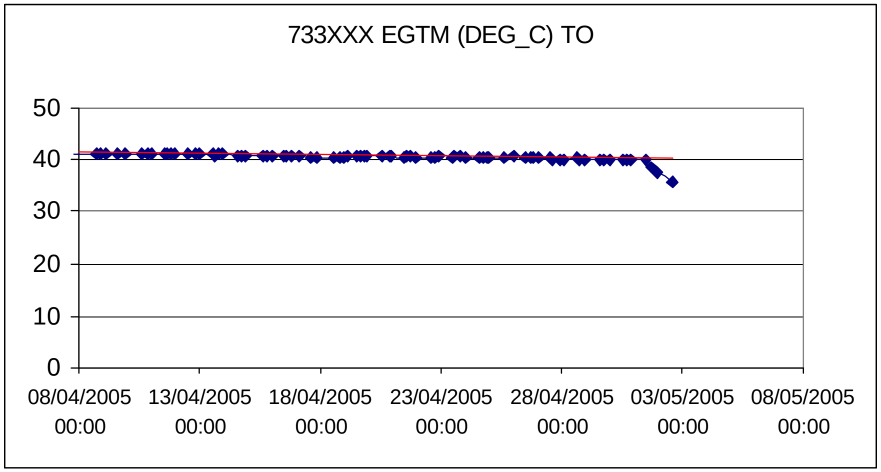
- One VBV flexible shaft found sheared leading to air leakage to the doors partially open

ΔEGT = + 25 °C

ΔFF = + 2%

ΔN2 = + 0.6%





ENGINE PARAMETER SHIFTS (cont'd)

D EGT (°C) ~ 0 **D FF (%) ~ 0** **DN2 (%) ↓**

CFM56-3

Trend signature	Troubleshooting Result	
VSV open	MEC change	Chart M.8 A&B
VSV open	CIT sensor	Chart M..9

CFM56-3
MEC Change (Chart M.8A)

- MEC changed due to fuel leakage
- Shift observed

ΔEGT = + 5 °C

ΔFF = + 0.6%

ΔN2= - 0.8 %

```
1ABCD-1   CFM -3B2  S/N 111111 ( 9/ 9/89)                       ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1.
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...EPR...1....2.
  506A.R V                .G                       F    .                            X.    2
 1006C.R  V               .    G                    F   .                            X.   2
 1012C.R  V               .  G                     F    .                            X.   2
 1018C.R  V               .  G                     F    .                            X.    2
 1023C.R   V              .    G                   F    .                            X.    2
 1029C.R  V               .  G                      F   .                            X.    2
 1111 .R  V               .  G                      F   .                            X.   2
 1111 .R  V               .  G                      F   .                            X.   2               T        0.0   0  0
 1111 .R  V               .  G                      F   .                            X.   2               T        0.0   0  0
 1112 .R  V               .  G                      F   .                            X.    2              T        0.0   0  0
 1113 .R  V               .   G                    F    .                            X.   2               T        0.0   0  0
 1114 .R  V               .   G                     F   .                            X.   2               T        0.0   0  0
 1114 .R  V               .   G                     F   .                            X.  2                T        0.0   0  0
 1115 .R  V               .   G                     F   .                            X.   2               T        0.0   0  0
 1115 .R  V               .  G                     F    .                            X.   2               T        0.0   0  0
 1116 .R  V               .   G                     F   .                            X.  2                T        0.0   0  0
 1116 .R  V               .  G                      F   .                            X. 2                 T        0.0   0  0
 1117 .R  V               .  G                     F    .                            X2                   T        0.0   0  0
 1117 .R  V               . G                       F   .                            X2                   T        0.0   0  0
 1118 .R  V               .    G                    F   .                          2 X.                   T        0.0   0  0
 1118 .R  V               .     G                    F  .                         2  X.                   T        0.0   0  0
 1119 .R  V               .     G                    F  .                          2 X.                   T        0.0   0  0
 1119 .R  V               .      G                   F  .                         2  X.                   T        0.0   0  0
 1120 .R  V               .      G                    F .                          2 X.                   T        0.0   0  0
 1120 .R  V               .      G                    F .                         2  X.                   T        0.0   0  0
 1121 .R  V               .     G                     F .                          2 X.                   T        0.0   0  0
 1121 .R  V               .      G                    F .                          2 X.                   T        0.0   0  0
 1122 .R V                .     G                     F .                         2  X.                   T        0.0   0  0
```

MEC Change

CFM56-3
MEC Change (Chart M.8B)

➢In order to restore the initial N2 level, the following troubleshooting was performed:

✓CIT sensor was replaced : no effect

✓A static rigging was performed : no change

✓VSV dynamic rigging was performed :

- N2 went up, and EGT / FF changed slightly

```
ION 8.3.6PC01/92                                  RUN DATE 11/25/92
.-1....X....N2...X....1....X....2                          MAINT
 -2...-1...EPR...1....2..-2.5.THROT.2.5 OATL   OT OP   CODE
                        X.     2                 0.0
                      2 X.                       0.0
                     2  X.                       0.0
                     2  X.                       0.0
                    2   X.                       0.0
                     2  X.                       0.0
                     2  X.               T       0.0    0  0
                     2  X.               T       0.0    0  0
                     2  X.               T       0.0    0  0
                    2   X.               T       0.0    0  0
                    2   X.               T       0.0    0  0
                    2   X.               T       0.0    0  0
                    2   X.               T       0.0    0  0
                   2    X.               T       0.0    0  0
                   2    X.               T       0.0    0  0
316  .R  V          .     G          F  .          2    X.               T       0.0    0  0
316  .R  V          .     G          F  .          2    X.               T       0.0    0  0
317  .R  V          .     G          F  .          2    X.               T       0.0    0  0
317  .R  V          .    G            F .          2    X.               T       0.0    0  0
318  .R  V          .   G            F  .           2   X.               T       0.0    0  0
318  .R  V          .   G            F  .             2 X.               T       0.0    0  0
319  .R  V          .   G           F   .              2X.               T       0.0    0  0
319  .R  V          .   G            F  .               X2               T       0.0    0  0
320  .R  V          .    G          F   .               X.2              T       0.0    0  0
320  .R  V          .    G          F   .               X.2              T       0.0    0  0
321  .R  V          .    G          F   .               X.2              T       0.0    0  0
321  .R  V          .    G           F  .               X2               T       0.0    0  0
322  .R V           .   G             F .               X.2              T       0.0    0  0
322  .R  V          .   G             F .               X.2              T       0.0    0  0
323  .R  V          .  G              F .               X.2              T       0.0    0  0
323  .R V           .  G               F.               X. 2             T       0.0    0  0
324  .R  V          . G                F.               X. 2             T       0.0    0  0
324  .R  V          . G               F .               X. 2             T       0.0    0  0
325  .R  V          .  G             F  .               X. 2             T       0.0    0  0
325  .R V           .  G             F  .               X. 2             T       0.0    0  0
326  .R  V          .  G             F  .               X.  2            T       0.0    0  0
```

Dynamic Rigging

CFM56-3
CIT Sensor Problem (Chart M.9)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2..
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...EPR..
  506A.R V          G     .                 F          .                            X2
1006C.R  V          G    .                    F       .                        2   X.
 101C .R  V         G     .                    F      .                       2    X.
 118C .R  V        G      .                 F         .                      2     X.
 203C .R   V          G   .                    F      .                    2       X.
 229C .R  V            G  .                    F      .                     2      X.
 311  .R  V              G.                      F    .                  2         X.
 311  .R  V              G.                      F    .                  2         X.
 311  .R  V             G .                     F     .                2           X.
 312  .R  V             G .                     F     .                2           X.
 313  .R  V             G .                     F     .                 2          X.
 314  .R  V             G .                     F     .                2           X.
 314  .R  V            G  .                     F     .               2            X.
 315  .R  V             G .                     F     .                2           X.
 315  .R  V             G .                     F     .                2           X.                    T        0.0   0  0
 316  .R  V            G  .                     F     .                2           X.                    T        0.0   0  0
 316  .R  V            G  .                     F     .                2           X.                    T        0.0   0  0
 317  .R  V           G   .                     F     .                2           X.                    T        0.0   0  0
 317  .R  V            G  .                     F     .                 2          X.                    T        0.0   0  0
 318  .R  V           G   .                     F     .                 2          X.                    T        0.0   0  0
 318  .R  V           G   .                     F     .                 2          X.                    T        0.0   0  0
 319  .R  V            G  .                     F     .                 2          X.                    T        0.0   0  0
 319  .R  V            G  .                     F     .                  2         X.                    T        0.0   0  0
 320  .R  V             G .                      F    .                2           X.                    T        0.0   0  0
 320  .R  V            G  .                      F    .               2            X.                    T        0.0   0  0
 321  .R  V             G .                      F    .               2            X.                    T        0.0   0  0
 321  .R  V             G .                      F    .              2             X.                    T        0.0   0  0
 322  .R V              G .                      F    .              2             X.                    T        0.0   0  0
 322  .R  V            G  .                     F     .            2               X.                    T        0.0   0  0
 323  .R  V            G  .                     F     .            2               X.                    T        0.0   0  0
 323  .R V              G .                     F     .            2               X.                    T        0.0   0  0
 324  .R  V            G  .                      F    .            2               X.                    T        0.0   0  0
 324  .R  V             G .                     F     .           2                X.                    T        0.0   0  0
```

- CIT- sensor loss of Helium-charge leads to VSV tracking more open
- Effects on trend monitoring

ΔEGT ~ 0

ΔFF ~ 0

ΔN2 = - 0.7 %

ENGINE PARAMETER SHIFTS (cont'd)

DEGT ~ 0 D FF (%) ~ 0 DN2 (%) ↑

CFM56-3

Trend signature	Troubleshooting Result	
VSV Closed	VSV off schedule	Chart M.10
VSV Closed	MEC change	Chart M.11

CFM56-5A

Trend signature	Troubleshooting Result	
Closed VSV	ECU P17 change	Chart M.12

CFM56-3
VSV Off Schedule (Chart M.10)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                        ADEPT VERSION 8.3.6PC01/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...EPR...1....
  506A.R V                .G                       F    .                          2 X.
 1006C.R  V               . G                      F   .                          2 X.
 1012C.R  V               . G                      F   .                           2X.
 1018C.R  V               . G                      F   .                          2 X.
 1023C.R   V              .  G                     F   .                          2 X.
 1029C.R  V               . G                      F   .                           X2.
 1111 .R  V               .  G                     F   .                           2X.
 1111 .R  V               .  G                     F   .                           2X.
 1111 .R  V               .   G                    F   .                           X2.
 1112 .R  V               .   G                    F   .                            X2
 1113 .R  V               .   G                    F   .                            X2
 1114 .R  V               .    G                   F   .                           X2.
 1114 .R  V               .     G                   F  .                           2X.
 1115 .R  V               .      G                  F  .                           2X.
 1115 .R  V               .     G                   F  .                          2 X.
 1116 .R  V               .    G                    F  .                          2 X.                   T       0.0   0  0
 1116 .R  V               .    G                    F  .                          2 X.                   T       0.0   0  0
 1117 .R  V               .    G                    F  .                          2 X.                   T       0.0   0  0
 1117 .R  V               .    G                     F .                           2X.                   T       0.0   0  0
 1118 .R  V               .    G                     F .                           X2.                   T       0.0   0  0
 1118=.R  V               .    G                     F .                            X.2                  T       0.0   0  0
 1119=.R  V               .    G                     F .                            X. 2                 T       0.0   0  0
 1119=.R  V               .    G                     F .                            X.  2                T       0.0   0  0
 1120=.R  V               .   G                      F .                            X.   2               T       0.0   0  0
 1120=.R  V               .     G                    F .                            X.   2               T       0.0   0  0
 1121 X   V               .     G                    F .                            X.   2               T       0.0   0  0
 1121=X    V              .      G                  F  .                            X.   2               T       0.0   0  0
 1122=.R  V               .      G                  F  .                            X.   2               T       0.0   0  0
 1122=.R   V              .      G                  F  .                            X.   2               T       0.0   0  0
 1123=X   V               .      G                   F .                            X.   2               T       0.0   0  0
 1123=.R  V               .      G                   F .                            X.   2               T       0.0   0  0
 1123=.R V                .     G                     F                             X.   2               T       0.0   0  0
 1124=.R  V               .    G                        F                           X.     2             T       0.0   0  0
```

- ➢ VSV off schedule (closed)
- ➢ Effect on trend monitoring

ΔEGT ~ 0

ΔFF ~ 0

ΔN2 =+1%

CFM56-3
Change of MEC (chart M.11)

- Hot start problem
- CIT Changed : no effect
- MEC Changed : shifts observed

  ΔEGT ~ 0 ΔFF ~ 0

  ΔN2 = - 0.7 % (and returned to baseline)

- Old MEC scheduled VSV closed (N2 was +1% higher)

  ✓contributed to hot start problem

(further investigations confirmed that the likely cause of the hot start problem was the old MEC scheduling VSV's closed)

```
ADEPT VERSION 8.3.6PC01/92                                 RUN DATE 11/25/92
  -2....X...-1....X....N2...X....1....X....2                            MAINT
..2....4....6   -2...-1...EPR...1....2..-2.5.THROT.2.5 OATL   OT OP   CODE
                          X.    2                        0.0
                          X.   2                         0.0
                          X.   2                         0.0
                          X.    2                        0.0
                          X.   2                         0.0
                          X.   2                         0.0
                          X.        2           T        0.0    0  0
                          X.        2           T        0.0    0  0
                          X.        2           T        0.0    0  0
                          X.        2           T        0.0    0  0
                          X.        2           T        0.0    0  0
                          X.        2           T        0.0    0  0
                          X.        2           T        0.0    0  0
                          X.         2          T        0.0    0  0
                          X.         2          T        0.0    0  0
                          X.         2          T        0.0    0  0
                          X.         2          T        0.0    0  0
                          X.         2          T        0.0    0  0
                          X.         2          T        0.0    0  0
                          X.        2                    0.0    0  0
                          X.       2            T        0.0    0  0
                          X.     2              T        0.0    0  0
                          X.   2                T        0.0    0  0
                          X.  2                 T        0.0    0  0
                          X. 2                  T        0.0    0  0

  -2....X...-1....X....N2...X....1....X....2
..2....4....6   -2...-1...EPR...1....2....3....4....5....6 MAINT. CODES
                          X.       2
                          X.           2
                          X.          2
1117 .R   V         .       G                  F   .     X.       2
1118 X    V         .    G                    F    .     X.     2
1118 .R   V         . G                      F     .     2X.
1119 .R V           . G                        F   .     X.2
1119 .R   V         .   G                    F     .     X2.
1120 .RV         G  .                      F       .     X.  2
1120 .R   V         . G                      F     .     X2.
```

MEC Change

MEC Change

CFM56-5A
P17 ECU Change (Chart M.12)

- ➢P17 ECU (with new software version) introduced to improve reliability and performance
- ➢VSV's and HPTACC schedule have been changed

Effect on the trend   ΔEGT = - 8°C   ΔFF = -0.8 %   ΔN2 = + 1%

- ✓EGT and FF shifts down reflects an HP core efficiency improvement
- ✓N2 shift is due to VSV closure (2°)

```
1ABCD-1   CFM

 DATE VIB..1.
  506A.   R  V
 1006C.    R V
 1012C.    R V
 1018C.   R  V
 1023C.    R V
 1029C.    R V
 1111 .    R V
 1111 .    R V
 1111 .   R  V
 1112 . R    V
 1113 . R  V
 1114 . R  V              .          G              .     F                       .2   B             T         0.0   0  0
 1114 . R   V             .          G              .    F                        .2   B             T         0.0   0  0
 1115 . R   V             .         G               .    F                        .2   B             T         0.0   0  0
 1115 . R   V             .          G              .    F                        .2   B             T         0.0   0  0
 1116 . R   V             .           G             .     F                       .2   B             T         0.0   0  0
 1116 .  R  V             .           G             .     F                       .2   B             T         0.0   0  0
 1117 .  R  V             .          G              .     F                       .2    B            T         0.0   0  0
 1117 .  R  V             .        G                .    F                        .  2    B          T         0.0   0  0
 1118 .  R  V             .        G                .    F                        .    2    B        T         0.0   0  0
 1118 .  R V              .        G                .   F                         .       2    B     T         0.0   0  0
 1119 .  R V              .      G                  .   F                         .         2    B   T         0.0   0  0
 1119 .  R V              .      G                  .   F                         .          2   B   T         0.0   0  0
 1120 .  R  V              .       G                .    F                        .          2    B  T         0.0   0  0
 1120 .  R  V              .        G               .    F                        .         2     B  T         0.0   0  0

             -20..-10....0...EGT..20...30...40                    -2....X...-1....X....N2...X....1....X....2
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....2....3....4....5....6 MAINT. CODES
 1116 . RV               .                              .       +G                  2.   B
 1116 .  R    V          .        G                     .       F                   .2 B
 1117 .  R   V           .         G                    .     F                     .          2    B
 1117 .  R    V          .        G                     .    F                      .          2    B
 1118 . R     V          .               G              .       F                   .        2        B
 1118 .  R  V            .          G                   .    F                      .          2     B
 1119 .R V               .          G                   .       F                   .         2     B
 1119 .R  V              .        G                     .   F                       .         2     B
 1120 .  *               .         G                    .    F                      .          2    B
 1120 . R  V             .         G                    .  F                        .           2    B
```

ECU Change
VSV 2° Closed

TOC

THE POWER OF FLIGHT

ENGINE PARAMETER SHIFTS (cont'd)

D **EGT (°C)** ↑ D **FF (%)** ↑ D **N2(%)** ↓

CFM56-2

Trend signature	Troubleshooting Result	
Core deterioration	HPT deterioration/ C clip failure	Chart M.13

CFM56-3

Trend signature	Troubleshooting Result	
Core deterioration	HPT Deterioration/C clip failure	Chart M.14A
Core deterioration	FOD event / HPT deterioration	Chart M.15
Core deterioration	FOD event / HPC deterioration	Chart M.16

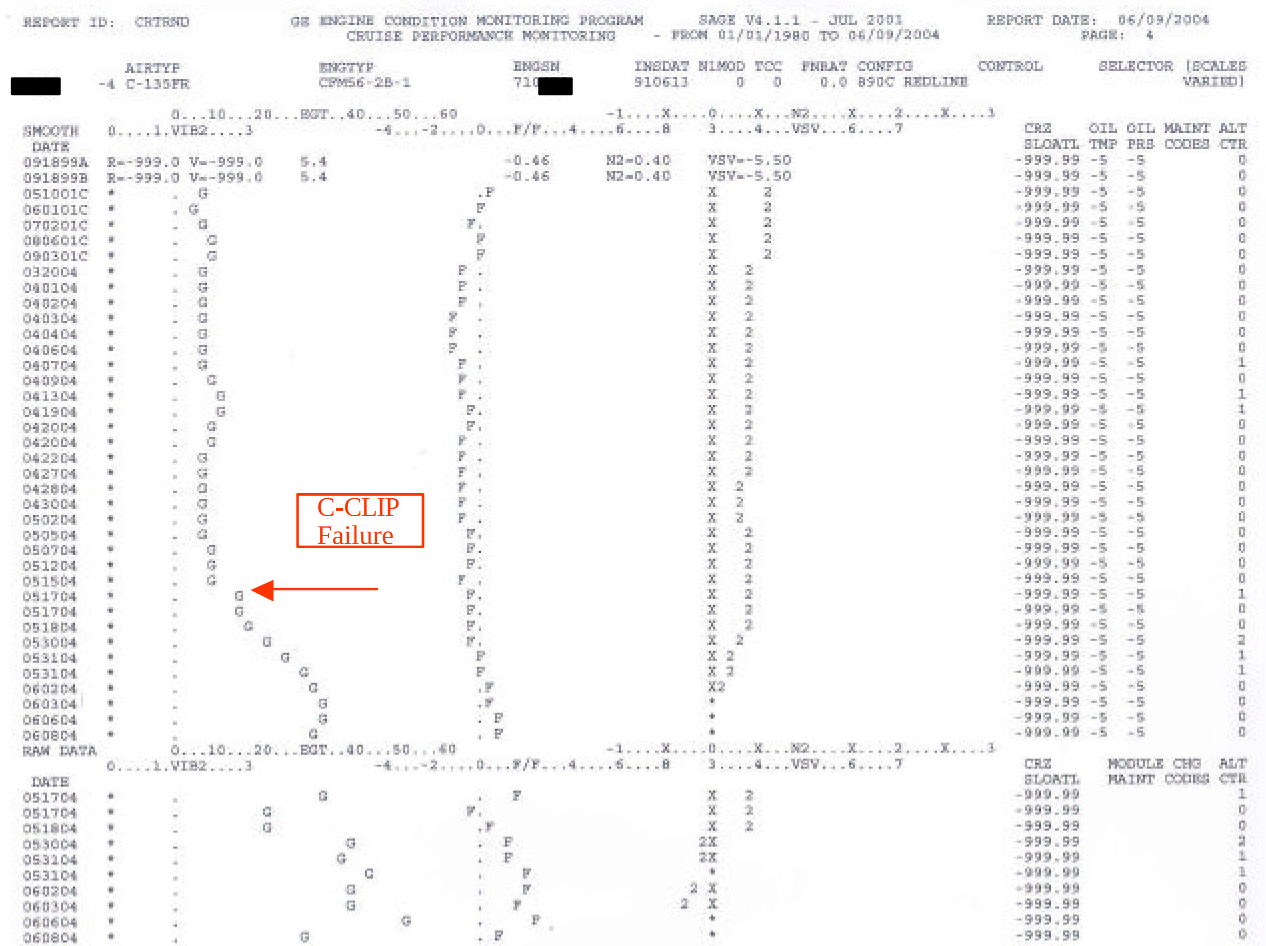
CFM56-5

Trend signature	Troubleshooting Result	
Core deterioration	HPT Deterioration/ C clip failure	Chart M.14B
Core deterioration	Liberation of 1 HPT blade	Chart M.14C
Core deterioration	HPT + LPT deterioration	Chart M.14D

CFM56-7

Trend signature	Troubleshooting Result	
LPT failure	Liberation of LPT blades	Chart M.17

CFM56-2
HPT Deterioration/C-CLIP Failure (Chart M.13)



CFM56-3
HPT Deterioration/C-Clip Failure (chart M.14A)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                       ADEPT VERSION 8.3.6PC01/92                        RUN DATE 11/25/92
              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1....X....2                    MAINT
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...EPR...1....2..-2.5.THROT.2.5 OATL  OT OP  CODE
  506A.R V                .            G                .      F                     X.  2                         0.0
 1006C.R  V               .            G                .     F                      X. 2                          0.0
 1012C.R  V               .             G               .       F                    X. 2                          0.0
 1018C.R  V               .            G                .       F                    X.   2                        0.0
 1023C.R   V              .             G               .       F                    X.  2                         0.0
 1029C.R  V               .             G               .       F                    X.   2                        0.0
 1111 .R  V               .             G               .        F                   X.  2                T        0.0   0  0
 1111 .R  V               .             G               .        F                   X. 2                 T        0.0   0  0
 1111 .R  V               .             G               .        F                   X. 2                 T        0.0   0  0
 1112 .R  V               .             G               .         F                  X. 2                 T        0.0   0  0
 1113 .R  V               .             G               .          F                 X.  2                T        0.0   0  0
 1114 .R  V               .             G               .         F                  X. 2                 T        0.0   0  0
 1114 .R  V               .             G               .        F                   X.  2                T        0.0   0  0
 1115 .R  V               .             G               .       F                    X.  2                T        0.0   0  0
 1115 .R  V               .              G              .       F                    X.  2                T        0.0   0  0
 1116 .R  V               .              G              .        F                   X.  2                T        0.0   0  0
 1116 .R  V               .             G               .        F                   X. 2                 T        0.0   0  0
 1117 .R  V               .             G               .       F                    X. 2                 T        0.0   0  0
 1117 .R  V               .              G              .        F                   X.  2                T        0.0   0  0
 1118 .R  V               .              G              .        F                   X.  2                T        0.0   0  0
 1118 .R  V               .              G              .         F                  X. 2                 T        0.0   0  0
 1119 .R  V               .               G             .        F                   X.2                  T        0.0   0  0
 1119 .R  V               .                   G         .        F                   X2                   T        0.0   0  0
 1120 .R  V               .                        G    .         F                 2X.                   T        0.0   0  0
 1120 .R  V               .                             G          F                2X.                   T        0.0   0  0
 1121 X   V               .                             . G         F               2X.                   T        0.0   0  0
 1121 X    V              .                             .  G         F             2 X.                   T        0.0   0  0
 1122 .R  V               .                             .  G            F           2X.                   T        0.0   0  0
 1122 .R   V              .                             .   G           F          2 X.                   T        0.0   0  0
 1123 X   V               .                             .   G           F         2  X.                   T        0.0   0  0
 1123 .R  V               .                             .   G           F        2   X.                   T        0.0   0  0
 1123 .R V                .                             .  G            F        2   X.                   T        0.0   0  0
 1124 .R  V               .                             .  G            F        2   X.                   T        0.0   0  0
```

C-Clip Failure

CFM56-5C
HPT Deterioration/C-Clip Failure (Chart M.14B)

```
1
 REPORT ID:  CRTRND           GE ENGINE CONDITION MONITORING PROGRAM        SAGE  V3.0.3 PC - Jan 99     REPORT DATE:  11/24/99
                                    CRUISE PERFORMANCE MONITORING - MOST RECENT RECORDS                           PAGE:     1

              AIRTYP        ENGTYP       ENGSN    INSDAT  N1MOD   TCC  FNRAT  CONFIG      CONTROL      SELECTOR
 A340-1 -2  A340-300      CFM56-5C2/F   740XXX   981105   2       0   31.20                                         (SCALES VARIED)
 SMOOTH         -20..-10....0...EGT..20...30...40                  -2....X...-1....X...N2....X....1....X....2  CRZ  OIL OIL MAINT ALT
  DATE   VIB..1....2....3                -6...-4...-2...F/F...2....4....6    -3...-2...VSV...0....1          SLOATL TMP PRS CODES CTR
 111998A R=     0.4 V=     1.2   5.0                    0.03               VSV=  -1.03 N2=  -0.01
 111998B R=     0.4 V=     1.2   5.0                    0.03               VSV=  -1.03 N2=  -0.01
  10199C .R  V                .         G                . F                         B  2    .
  20299C .R V                 .       G                  . F                          B .2   .
  30199C . R  V               .       G                  . F                           B.2   .
  40199C . R V                .      G                   . F                            2    .B
  63099= . VR                 .    G                     .F                        B    .2   .                         73  47.        0
  70199= . VR                 .    G                     .F                         B   .2   .                         66  46.        0
  71199= . VR                 .    G                     .F                          B  .2   .                         73  46.        0
  71299= . VR                 .    G                     .F                             .*   .                         73  47.        0
  71499= . VR                 .    G                     .F                             .2B  .                         69  47.        0
  81099= . *                  .    G                     .F                            B.2   .                         67  46.        0
  81099= . VR                 .    G                     .F                            B.2   .                         69  48.        0
  81399= . *                  .    G                     .F                          B  .2   .                         72  44.        0
  81499= . *                  .    G                     .F                         B   .2   .                         72  47.        0
  81599= . VR                 .    G                     .F                         B   .2   .  C-Clip Failure         72  47.        0
  81699= . VR                 .    G                     .F                         B   .2   .                         72  47.        0
  81799= . VR                 .     G                    .F                         B   2   <-----------               72  47.        1
  81899= . VR                 .      G                   .F                         B   2    .                         72  47.        1
  81999= . VR                 .        G                 .F                         B   2    .                         72  47.        1
  82099= . VR                 .         G                . F                        B  2.    .                         72  47.        1
  82199= . VR                 .         G                . F                        B  2.    .                         72  47.        0
  82299= . VR                 .         G                . F                        B  2.    .                         72  47.        0
 RAW DATA       -20..-10....0...EGT..20...30...40                  -2....X...-1....X...N2....X....1....X....2 CRZ     MODULE CHG  ALT
  DATE   VIB..1....2....3                -6...-4...-2...F/F...2....4....6    -3...-2...VSV...0....1          SLOATL    MAINT CODES CTR
  81399= .VR                  .   G                     F                          B  .2   .                                      0
  81499= . VR                 .    G                    F                         B   . 2  .                                      0
  81599= . VR                 .          G               . F                        B  2.    .                                      0
  81699= . VR                 .       G                 .F                         B  2.    .                                      0
  81799= . VR                 .         G                .  F                       B 2 .    .                                      1
  81899= . VR                 .           G              . F                        B 2 .    .                                      1
  81999= . VR                 .             G            .  F                       B  2.    .                                      1
  82099= . VR                 .            G             .   F                      B 2 .    .                                      1
  82199= . VR                 .           G              .    F                     B  2.    .                                      0
```

THE POWER OF FLIGHT

CFM56-5C
HPT Deterioration/Liberation HPT blade
(Chart M.14C)

```
REPORT ID:  CRTRND           GE ENGINE CONDITION MONITORING PROGRAM        SAGE
                                    CRUISE PERFORMANCE MONITORING - MOST RECENT R

              AIRTYP        ENGTYP       ENGSN    INSDAT  N1MOD   TCC  FNRAT  CON
 Fly-1  -2  A340-200      CFM56-5C3     741XXX    981104   6       * *******
 SMOOTH           0...10...20...EGT..40...50...60                  -2....X...-1..
  DATE   VIB..1....2....3                 -6...-4...-2...F/F...2....4....6   -2..
 101898A R=     0.2 V=     0.4 -30.5                      0.20               VSV=
 101898B R=     0.2 V=     0.4 -30.5                      0.20               VSV=
  40101C .R     V .                G                      .  F
  50101C .R    V  .                G                      .  F
  60101C .R    V  .              G                        .  F
  70101C .R V     .             G                         . F
  91001  .R  V    .                 G                     . F
  91001  .R V     .                 G                     . F
  91201  .R  V    .                 G                     . F
  91201  .R V     .                 G                     . F
  91501  .R V     .                 G                     . F                       B   .   2                        68  43.        1
  91601  .R V     .                 G                     . F                       B   .   2                        82  44.        1
  91601  .R V     .                G                      . F                       B   .   2                        84  44.        1
  91701  .R  V    .                G                      . F                       B   .   2                        87  43.        1
  91701  .R  V    .                G                      . F                       B   .   2                        71  46.        1
  91801  .R V     .                G                      . F                       B   .   2                        71  46.        1
  91901  .R V     .                G                      . F                       B   .   2                        90  43.        1
  92001  .R  V    .                G                      . F                       B   .   2                        90  43.        1
  92001  .R  V    .                G                      . F                       B   .    2                       79  44.        1
  92101  .R V     .                G                      . F                       B   .   2                        69  45.        1
  92301  .R  V    .                 G                     . F                       B   .   2                        66  45.        1
  92301  .R  V    .                 G                     . F                       B   .    2                       79  43.        1
  92301  .R  V    .                 G                     .  F                      B   .    2                       76  44.        1
  92601  .R  V    .                  G                    .  F                      B   .    2                       68  45.        2
  92601  . R V    .                   G                   .  F                      B   .   2                        80  48.        3
  92701  . R  V   .                    G                  .   F                     B   .   2                        69  45.        3
  92701  . R  V   .                     G                 .   F                     B   .   2                        66  45.        0
 RAW DATA         0...10...20...EGT..40...50...60                  -2....X...-1....X...N2....X....1....X....2 CRZ     MODULE CHG  ALT
  DATE   VIB..1....2....3                 -6...-4...-2...F/F...2....4....6   -2...-1...VSV...1....2          SLOATL   MAINT CODES CTR
  92001  .R   V   .             G                         . F                           X    2                                      1
  92001  .R V     .                G                      .  F                          X    2                                      1
  92101  .RV      .                  G                    . F                           X   2                                       1
  92301  .R  V    .                  G                    .   F                         X    2                                      1
  92301  .R  V    .                    G             F    .                             X    2                                      1
  92301  .R  V    .                G                      .   F                         X   2                                       1
  92601  .  RV    .                       G               .     F                       X2                                          2
  92601  .  R  V  .                        G              .        F                    X 2                                         3
  92701  . R   V  .                         G             .        F                    X  2                                        3
  92701  .  R  V  .                      G                .      F                      *                                           0
```

- ➢Trend monitoring showed shift in EGT and FF

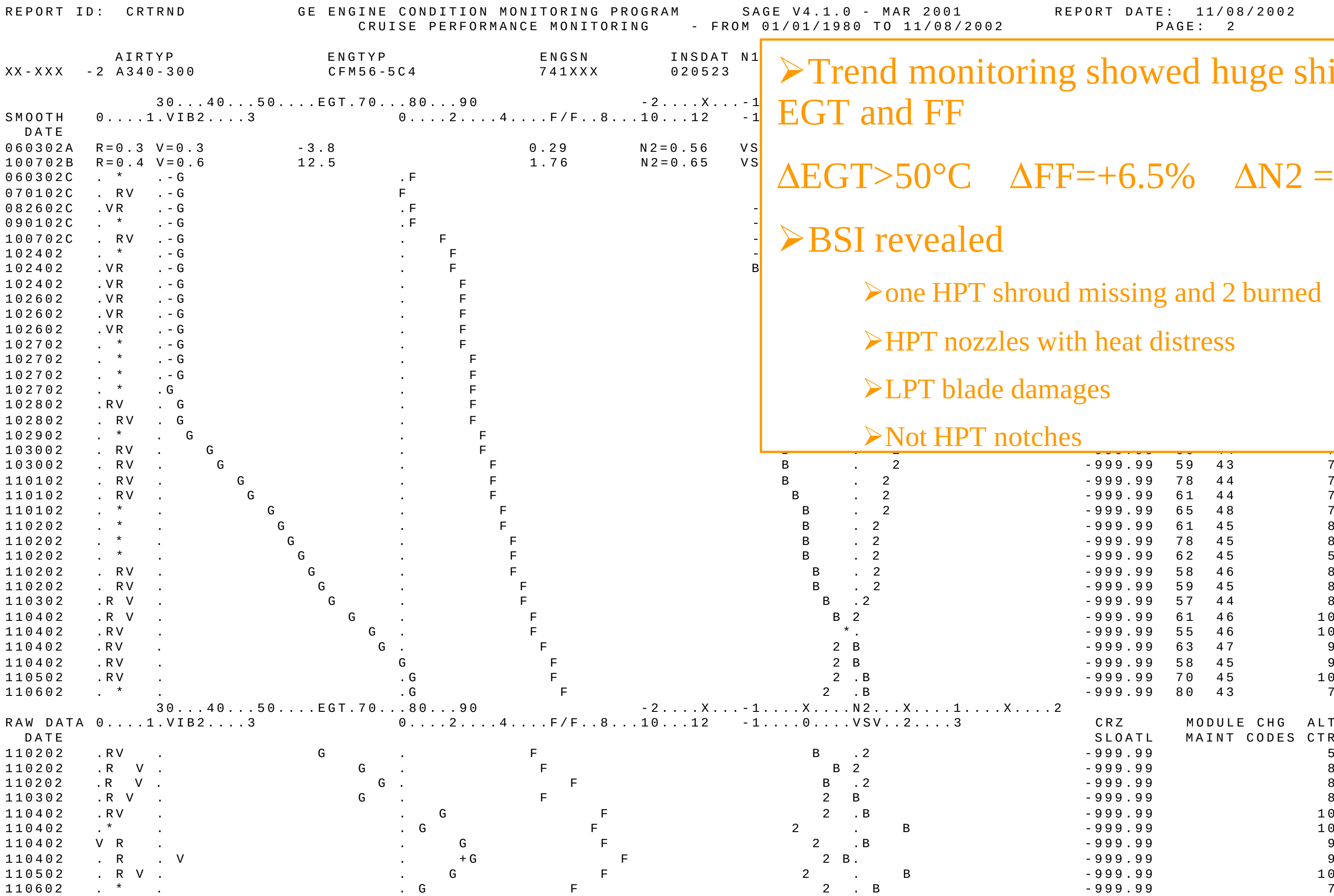
ΔEGT= 15°C ΔFF= 1% ΔN2 ~ -0,1%

- ➢Vibration level increased
- ➢BSI revealed the liberation of one HPT blade

TOC

THE POWER OF FLIGHT

CFM56-5C
HPT + LPT Deterioration (Chart M.14D)



- ➢Trend monitoring showed huge shift in EGT and FF

ΔEGT>50°C ΔFF=+6.5% ΔN2 = 1%

- ➢BSI revealed
  - ➢one HPT shroud missing and 2 burned
  - ➢HPT nozzles with heat distress
  - ➢LPT blade damages
  - ➢Not HPT notches

CFM56-3
F.O.D Event / HPT Deterioration (Chart M.15B)

```
1
 REPORT ID:  CRTRND          GE ENGINE CONDITION MONITORING PROGRAM        SAGE  V3.0.3 PC -
                                   CRUISE PERFORMANCE MONITORING - MOST RECENT RECORDS

             AIRTYP        ENGTYP       ENGSN    INSDAT  N1MOD   TCC  FNRAT  CONFIG      CON
 01235  -1  B737-400     CFM56-3C-1    724XXX    981112  **       1   23.50
 SMOOTH         -10....0...10...EGT..30...40...50                -2....X...-1....X...N2....
  DATE   VIB..1....2....3                 -6...-4...-2...F/F...2....4....6    3....4...VSV...
 112498A R=  -999.0 V=  -999.0   3.4                    -0.23                VSV=-999.00 N2=
 112498B R=  -999.0 V=  -999.0   3.4                    -0.23                VSV=-999.00 N2=
 120298C X             G                                F.                           2  X
  10199C X             .G                               F.                           2  X
  12599  X             . G                               F                           2  X
  12899  X             . G                               F                           2  X
  20599  X             .  G                              F                           2  X
  20599  X             .   G                             F                           2  X
  20699  X             .   G                             F                           2  X
  20699  X             .   G                             F                           2  X
  20799  X             .  G                              .F                          2  X
  20899  X             .  G                              .F                          2  X
  32099  X             .   G                             .F                          2  X
  32199  X             .   G                             .F                          2  X
  32399  X             .  G                              .F                          2  X
  32799  X             .   G                             .F                          2  X
  40299  X             .   G                             .F                          2  X
  40399  X             .    G                            .F                          2  X                             90  47.        0
  40399  X             .    G                            .F                         2   X                             95  45.        0
  40399  X             .    G                            .F                         2   X                             90  45.        0
  40399  X             .    G                            .F                        2    X                             75  45.        0
  40399  X             .       G                         .F                      2      X                             90  42.        0
  40399  X             .        G                        . F                    2       X                             80  45.        0
  40499  X             .        G                        . F                     2      X                             91  47.        0
  40499  X             .       G                         . F                      2     X                             85  45.        0
  40499  X             .       G                         . F                      2     X                             85  45.        0
  40499  X             .      G                          .F                       2     X                             85  45.        0
  40499  X             .     G                           .F                       2     X                             90  45.        0
  40499  X             .       G                         .F                       2     X                             90  45.        0
  40599  X             .       G                         .F                       2     X                             90  43.        0
  40599  X             .       G                         .F                       2     X                             85  45.        0
  40599  X             .         G                       .F                      2      X                             80  47.        0
  40599  X             .           G                     . F                     2      X                             80  45.        0
  40699  X             .          G                      . F                     2      X                             85  42.        0
  40699  X             .           G                     . F                     2      X                            100  47.        0
  40899  X             .           G                     .  F                   2       X                             80  48.        0
  40999  X             .            G                    .   F                 2        X                             83  47.        0
  40999  X             .             G                   .   F                 2        X                            100  45.        0
```

- ➢Shifts observed in EGT, FF and N2 trending

  ΔEGT= +28 °C

  ΔFF= +2%

  ΔN2= -0.3%

- ➢Deterioration of HPT (Performance restoration was carried out on this engine later)

CFM56-3
FOD Event / HPC Deterioration (Chart M.16)

```
1ABCD-1  CFM -3B2  S/N 111111 ( 9/ 9/89)                        SAGE V3.0.3 PC -
              -20..-10....0...EGT..20...30...40                  -2....X...-1...
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...
  506A.  V                .   g                         . F               2
 1006C.     V             .    G                        .  F              2
 1012C.    V              .    G                        .  F              2
 1018C.     V             .    G                        .  F             2
 1023C.    V              .     G                      .    F            2
 1029C.    V              .     G                       .   F          2
 1111 .    V              .    G                        .   F             2
 1111 .    V              .    G                        .   F             2
 1111 .     V             .   G                         .  F              2
 1112 .     V             .    G                        .  F               2
 1113 .     V             .     G                       .  F              2
 1114 .    V              .      G                      .  F              2
 1114 .    V              .     G                       .  F              2
 1115 .    V              .     G                       .  F              2
 1115 .    V              .         G                   .  F             2
 1116 .    V              .           G                 .   F           2
 1116 .    V              .              G              .    F         2
 1117 .    V              .               G             .     F         2
 1117 .    V              .                 G           .      F        2
 1118 .    V              .                   G         .       F       2            X.                   T       0.0   0  0
 1118 .    V              .                 G           .       F       2            X.                   T       0.0   0  0
 1119 .    V              .                 G           .    F          2            X.                   T       0.0   0  0
 1119 .    V              .                G            .    F          2            X.                   T       0.0   0  0
 1120 .    V              .                G            .    F          2            X.                   T       0.0   0  0
 1120 .     V             .               G             .    F          2            X.                   T       0.0   0  0

              -20..-10....0...EGT..20...30...40                  -2....X...-1....X....N2...X....1....X....2
 DATE VIB..1....2....3....4....5        -6...-4...-2...F/F...2....4....6   -2...-1...EPR...1....2....3....4....5....6 MAINT. CODES
 1116 .   V               .                         G   .     F          2           X.
 1116 .   V               .                       G     .      F         2           X.
 1117 .    V              .                         G   .       F       2            X.
 1117 .    V              .                  G          .   F             2          X.
 1118 .     V             .                       G     .      F      2              X.
 1118 . V                 .                          G F.                  2         X.
 1119 .  V                .              G              .     F        2             X.
 1119 .    V              .                  G          .      F          2          X.
 1120 .   V               .                    G        .     F         2            X.
 1120 .  V                .                  G          .      F          2          X.
```

➢Trend monitoring showed severe shift in EGT and FF

ΔEGT= 30°C   ΔFF= 2%

ΔN2 ~ -0.3%

➢BSI on Fan, Booster and HPT shroud: no damage

➢BSI of HPC and Combustion Chamber : 7th and 8th stage blades severely damaged

THE POWER OF FLIGHT

CFM56-7B
Liberation of LPT blades (Chart M.17)

```
1
 REPORT ID:  CRTRND          GE ENGINE CONDITION MONITORING PROGRAM       SAGE  V3.0.3 PC - Jan 99     REPORT DATE:   8/25/99
                                   CRUISE PERFORMANCE MONITORING - MOST REC

              AIRTYP        ENGTYP       ENGSN     INSDAT   N1MOD    TCC   FNRAT
 SDLFO  -1  B737-600     CFM56-7B20    874XXX    980713    0        * *******
 SMOOTH          -20..-10....0...EGT..20...30...40                  -2....X..
  DATE   VIB..1....2....3                    -6...-4...-2...F/F...2....4....6
 110198A R=     0.1 V=     0.3   1.7                -0.21
 110198B R=     0.1 V=     0.3   1.7                -0.21
  10299C *V                 .G                         .F
  20199C * V                .G                         F
  30199C .RV                .   G                      .F
  40299C .RV                . G                        .F
  42199  .R V               .   G                      F
  42199  .R V               .  G                       F
  42299  .R V               .  G                       F
  42299  .R V               .   G                      F
  42299  .R V               .   G                      F
  42299  .R V               .  G                       F                            2X                           94   44.        0
  42299  .R V               .  G                       F                           2 X                           94   43.        0
  42299  .R V               .  G                       F                            2X                           84   47.        1
  42399  .R V               . G                        F                           2 X                           85   47.        0
  42799  .R V               .  G                       F                            2X                           98   43.        0
  42799  .R V               .  G                       F                            2X                           91   45.        0
  42799  .R  V              .  G                       F                           2 X                           92   44.        0
  42799  .R V               .  G                       F                           2 X                           95   43.        0
  42799  .R  V              .    G                     F                           2 X                           88   44.        1
  42899  .R  V              .    G                     F                           2 X                           89   46.        0
  42899  .R  V              .    G                     F                           2 X                           93   43.        0
  42899  .R  V              .    G                     .F                          2 X                           97   42.        0
  42899  *   V              .     G                    .F                          2 X                          100   42.        0
  42899  *     V            .       G                  .F                          2 X                           82   46.        2
 RAW DATA        -20..-10....0...EGT..20...30...40                  -2....X...-1....X...N2....X....1....X....2 CRZ     MODULE CHG  ALT
  DATE   VIB..1....2....3                    -6...-4...-2...F/F...2....4....6    3....4...VSV...6....7          SLOATL   MAINT CODES CTR
  42799  .R  V              .   G                      .F                           2X                                         0
  42799  .R    V            . G                        F                            2X                                         0
  42799  *   V              .  G                       F                           2 X                                         0
  42799  .R V               .       G                  . F                         2 X                                         0
  42799  *     V            .            G             .   F                     2   X                                         1
  42899  *    V             .    G                     . F                          2X                                         0
  42899  .R  V              .    G                     .F                          2 X                                         0
  42899  *    V             .     G                    . F                          2X                                         0
  42899  *   V              .        G                 .  F                        2 X                                         0
  42899  *          V       .                G         .        F              2     X                                         2
1
```

- ➢Trend monitoring showed shift in EGT and FF

ΔEGT= 10°C ΔFF= 0,3% ΔN2 ~ -0,1%

- ➢Vibration level increased
- ➢BSI revealed the liberation of three LPT stage#1 blades

ACTIONS

MAINTENANCE ACTION RECOMMENDATIONS
Based on Engine Monitoring Trends

Maintenance Actions Based On Cruise Trends

- **The following maintenance actions based on trend shifts are:**
  - ✓ **general guidelines established over many years of operation**
  - ✓ **generic to the CFM56 engine models**

(These guidelines are generally in line with the A/C Maintenance Manual recommendations, but in all cases the A/C trouble-shooting procedures should be followed.)

CFM56-2/-3 TYPICAL MAINTENANCE ACTIONS

Based on Engine Monitoring Trends

Δ EGT (°C)	ΔFF (%)	ΔN2 (%)	Probable cause	Maintenance action
<+/- 10	<+/- 1	<+/- 0.5	-	No action
<+/- 10	<+/- 1	<- 0.5	VSV open	Check VSV rigging Search for CIT cold shift
<+/- 10	<+/- 1	>+ 0.5	VSV close	Check VSV rigging Search for CIT warm shift
(10,20)	(1,2)	(0 , + 0.5)	Excessive bleed or air leakage LP system deterioration*	Search for valve malfunction BSI LPT , inspection of fan, inlet and exhaust areas
>20	> 1.5	(+0.5, +1.5) (0, + 0.5)	VBV Open LP system deterioration*	Check VBV BSI LPT,inspection of fan, inlet and exhaust areas
>20	> 1.5	(0, - 0.8)	HPT deterioration HPC deterioration	BSI HPT BSI HPC

* Not observed in service

THE POWER OF FLIGHT

CFM56-5/-7 TYPICAL MAINTENANCE ACTIONS
Based on Engine Monitoring Trends

ΔEGT (°C)	ΔFF (%)	ΔN2 (%)	Probable cause	Maintenance action
<+/- 10	<+/- 1	<+/- 0.5	-	No action
(10,20)	(1,2)	(0, + 0.5)	Excessive bleed or air leakage VSV lever arm failure LP system deterioration*	Search for faulty valves, duct damage Check VSV Lever arm BSI LPT , inspection of fan, inlet and exhaust areas
>20	> 1.5	(+0.5, +1.5) (0, + 0.5)	VBV Open LP system deterioration*	Check VBV for defects BSI LPT, inspection of fan, inlet and exhaust areas
>20	> 1.5	(0, - 0.8)	HPT deterioration HPC deterioration	BSI HPT BSI HPC

* Not observed in service

THE POWER OF FLIGHT

MAINTENANCE ACTION RECOMMENDATIONS
Based on Engine Monitoring Trends

Fuel Flow

- **Flow trend shifts are useful in confirming EGT**

  (a significant fuel flow shift, without a corresponding EGT shift, is indicative of a fuel flow indication-error or inaccurate input data)

  - ✓ **Errors in altitude and Mach will result in large shifts in fuel flow" trend**