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Title Page

Document Title:

[PROGRAM\_CODE] — [ENGINE\_NAME]

High-Pressure Compressor Casing (HPCC) — Continuous Vibration / Out-of-Balance (OOB) Structural Integrity Report (CS-E)

Authoring Function: Module Structural Analysis (Static Compressor Parts)

Component: HP Compressor Casing (HPCC)

Part No.: [PART\_NO] Drawing: [DRW\_NO] Rev: [REV]

Material: [ALLOY/SPEC/HT]

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Record of Revisions

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[REV] [DATE] All Initial issue for HPCC OOB structural integrity (CS-E). [NAME] [NAME]

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Approval / Sign-off Sheet

Role Name Signature Date

Prepared (Module Structural Analyst) [NAME]

Reviewed (Checker/Peer) [NAME]

CVE (Structures) [NAME]

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Abbreviations & Definitions

CS-E: EASA Certification Specification for Engines

AMC: Acceptable Means of Compliance

CBO: Compressor Blade-Off (blade failure event producing OOB)

HPCC: High-Pressure Compressor Casing

OOB: Out-of-Balance

HCF: High-Cycle Fatigue

LIF: Limit Imbalance (manufacturing/service)

MAC: Modal Assurance Criterion

ζ: Modal damping ratio

α, β: Rayleigh mass/stiffness proportional damping coefficients

RBE3-like: Remote Point — Distributed, deformable coupling

CVE: Compliance Verification Engineer

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1. Introduction

1.1 Purpose

This report demonstrates the structural integrity of the High-Pressure Compressor Casing (HPCC) of [ENGINE\_NAME] under continuous vibration and out-of-balance (OOB) loading, including post-blade-failure transient operation and continued rotation, to support CS-E certification. It consumes validated engine-level inputs and shows that the HPCC meets strength and fatigue requirements with defined limitations and maintenance actions where applicable.

1.2 Scope and Responsibilities

The scope is limited to static compressor hardware: the HPCC as defined by [PART\_NO]/[DRW\_NO]/[REV]. The analysis covers:

CBO run-down (shutdown transient after blade loss),

CBO run-on/continued rotation (pre-shutdown),

Windmilling after shutdown,

Limit OOB (manufacturing/service) synchronous 1× envelope, and

Thermal pre-stress conditions.

The Engine Dynamics team provides validated engine-level forces/moments/accelerations, 1× envelopes, speeds, clearances, and alert thresholds. This report does not derive those inputs.

Table 1-1 — Responsibility & Interfaces (RACI) — HPCC vs Engine Dynamics

Topic Owner Consulted Informed Notes

Engine-level OOB loads (CBO run-down/run-on), 1× envelopes Engine Dynamics Structures Chief Engineer, Certification Inputs: [CBO\_RD\_IDS], [CBO\_RO\_IDS], [LIM\_OOB\_IDS]

Windmilling profiles and durations Engine Dynamics Structures Chief Engineer, Certification Inputs: [WINDMILL\_IDS]

Structural model & material allowables Structures Materials Engine Dynamics HPCC FE model; [ALLOY/SPEC/HT]

Thermal fields & pressures Thermals/Aero Structures Engine Dynamics Inputs: [THERMAL\_IDS]

Interface frames & mapping Structures Engine Dynamics Integration Frames: [FRAME\_A], [FRAME\_B]

Compliance evidence Structures CVE Chief Engineer CS-E 650/810/525, AMC E 520(c)(2)

1.3 Component Description — HP Compressor Casing (HPCC)

The HPCC is a [CAST/FORGED/FABRICATED] [ALLOY/SPEC/HT] static casing surrounding compressor stages [STAGE RANGE]. It provides rotor containment/retention features, houses stator vane platforms, and interfaces upstream with [UPSTREAM COMPONENT] and downstream with [DOWNSTREAM COMPONENT]. Interfaces are denoted [IFACE\_A] and [IFACE\_B] in frames [FRAME\_A] and [FRAME\_B] (see Figure 1-1).

1.4 Regulatory Basis & Means of Compliance (MoC Matrix — summary)

Applicable regulations and associated means of compliance:

CS-E 650 Vibration Surveys — correlation to engine ground vibration survey; model predictive consistency (Bode/Campbell), optional modal rig correlation.

CS-E 810 Blade Failure — structural integrity during run-on and run-down; continued safe operation to shutdown per engine procedure.

CS-E 525 Continued Rotation — windmilling fatigue evaluation.

AMC E 520(c)(2) — validated data concept: this analysis consumes engine-level validated data without re-derivation.

See §3 and Tables 3-1/3-2.

1.5 Inputs and Dependencies (Configuration-Controlled)

This report consumes configuration-controlled inputs: thermal fields [THERMAL\_IDS], CBO transients [CBO\_RD\_IDS], [CBO\_RO\_IDS], windmilling [WINDMILL\_IDS], limit OOB envelopes [LIM\_OOB\_IDS], interface definitions [INTERFACE\_IDS], and survey data [SURVEY\_IDS]. Minimal data pedigree is summarized in §2.2 and Figure 2-1.

1.6 Analysis and Validation Approach (Overview)

The HPCC FE model is pre-stressed by thermal/pressure loads, then evaluated under transient CBO inputs and synchronous 1× OOB excitation. Windmilling is assessed as either a harmonic 1× sweep over [RPM\_MIN–RPM\_MAX] or as a provided transient. Fatigue is screened via Goodman infinite-life; if exceeded, TLIFE (NASALIFE-based) damage with Miner’s rule is used. Model validity is demonstrated by overlaying engine survey Bode/Campbell responses at representative casing points against the model (acceptance in §1.7).

1.7 Acceptance Criteria (Summary)

Table 1-2 — Acceptance Criteria (Strength / Fatigue / Correlation) — Summary

Topic Criterion Pass/Fail Basis

Strength — CBO run-down σ\_vm,local(t) ≤ min[Yield(T) with [K] factor; allowable per [METHOD]] Peak transient von Mises vs temperature-dependent yield/ultimate; no gross plasticity

Fatigue — run-on / windmilling / limit OOB Goodman infinite-life screen: σ\_a vs endurance at T; else TLIFE damage D ≤ 1.0 If Goodman fails at any node, compute TLIFE damage; accumulated D ≤ 1.0 per case/mission

Correlation — survey overlay Amplitude ±[AMP\_TOL]% and Phase ±[PHASE\_TOL]° at 1× over [RPM\_MIN–RPM\_MAX] Across selected HPCC points [N]; crossings within ±[FREQ\_TOL]%

Modal optional f\_err ≤ [FREQ\_TOL]% and MAC ≥ [MAC\_MIN]; ζ within engineering judgement

1.8 Document Organization

Sections 1–9 provide assumptions, methods, loads, results, and derived limitations. Appendices (issued separately) provide mesh/material details, test artefact IDs, full MoC matrix, RACI, and file manifests.

1.9 Confidentiality / Export Notice

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2. Assumptions & Inputs

2.1 Configuration Identification (Hardware, Drawings, Solver)

Table 2-1 — Hardware & Drawing Set

Item ID Rev Notes

HPCC Part Number [PART\_NO] [REV] [SERIES/SN] applicability

Drawing [DRW\_NO] [REV] Controlled in [PDM SYSTEM]

Material [ALLOY/SPEC/HT] — See Appendix B (temp-dependent)

Coatings (if any) [COATING SPEC] — Assumed negligible structural effect

Solver ANSYS [VERSION] — Implicit Newmark; HHT-α acceptable if program uses it

2.2 External Inputs (Engine-Level Validated Data)

Table 2-2 — External Inputs — Load Packages & References

Package IDs / Revs Frames Units Notes

Thermal/Pressure base [THERMAL\_IDS] [GCS\_NAME] [UNITS] Steady OP field

CBO run-down transient [CBO\_RD\_IDS] [FRAME\_A]/[FRAME\_B] [UNITS] Shutdown after blade loss

CBO run-on transient [CBO\_RO\_IDS] [FRAME\_A]/[FRAME\_B] [UNITS] Pre-shutdown continued rotation

Windmilling [WINDMILL\_IDS] [GCS\_NAME] [UNITS] 1× harmonic sweep or transient

Limit OOB envelope [LIM\_OOB\_IDS] [GCS\_NAME] [UNITS] Synchronous 1× vs speed

Interfaces (geometry/frames) [INTERFACE\_IDS] [FRAME\_A], [FRAME\_B] — Transform definitions

Ground vibration survey [SURVEY\_IDS] [ENGINE MOUNT FRAME] [UNITS] Channel list & processing windows

Minimal data pedigree: source test IDs, timestamps, frames, sampling [Δt or Δf], and basic filtering per engine dynamics data book [DOC ID].

2.3 Internal Modelling Assumptions (HPCC)

Table 2-3 — Internal Modelling Assumptions

Topic Assumption

Geometry fidelity Matches [DRW\_NO]/[REV]; fillet reliefs below [x mm] idealized

Mesh Solid elements with local refinement at [VANE HOLES / LUGS / SEALS]

Contacts Bolted flanges tied; [SEALS/SHROUDS] bonded; no separation under evaluated loads

Boundary conditions Interfaces [IFACE\_A]/[IFACE\_B] applied via Remote Point — Distributed mapping (RBE3-like)

Frames Interface frames: [FRAME\_A], [FRAME\_B]; global [GCS\_NAME]

Damping Per engine program: modal ζ = [ζ] (or Rayleigh α=[α], β=[β])

Material [ALLOY/SPEC/HT], isotropic, temp-dependent E, σ\_y, σ\_u, α, ν per Appendix B

Thermal pre-stress Apply [THERMAL\_IDS] + pressures before dynamic solves

Nonlinearities Small-strain with material nonlinearity off; plasticity screening via σ\_vm vs σ\_y(T)

Load mapping Input time/frequency histories mapped at [IFACE\_A]/[IFACE\_B] remote points

Numerics Implicit Newmark; auto-time step within stability and accuracy limits

2.4 Validation Artefacts (Part-Level)

Table 2-4 — Validation Artefacts — Channels / Targets

Artefact IDs Location(s) Metric Acceptance

Engine GVT (1× order) [SURVEY\_IDS] HPCC Points [SET\_A] Amplitude/Phase Bode ±[AMP\_TOL]% / ±[PHASE\_TOL]°; crossings ±[FREQ\_TOL]%

Optional modal rig [SURVEY\_IDS or RIG\_IDS] Points [SET\_B] f, MAC, ζ

2.5 Strength & Fatigue Criteria (Local)

Table 2-5 — Strength & Fatigue Criteria

Criterion Method Allowable / Input

Static strength Von Mises vs σ\_y(T) [K factor if used] Appendix B curves

Ultimate screen σ\_vm ≤ σ\_u(T) (screen only) Appendix B

Infinite-life screen Goodman at T: σ\_a vs S\_e(T) [ENDURANCE SPEC]

Finite life TLIFE (NASALIFE-based), Miner’s rule Material constants [TABLE B-1]

Stress extraction Surface principal/VM at [hot-spot sets] Structural nodes

2.6 Data Quality Checks

Table 2-6 — Data Quality Checks

Check Result

Completeness: all required packages received [YES/NO]

Frames consistent with [INTERFACE\_IDS] [YES/NO]

Units verified [YES/NO]

Sampling [Δt or Δf] adequate vs highest mode of interest [YES/NO]

Filtering consistent with program practice [YES/NO]

No gaps or NaNs in time/frequency vectors [YES/NO]

2.7 Uncertainty & Sensitivity Placeholders

Table 2-7 — Uncertainty & Sensitivity Ranges

Parameter Nominal Range for Sensitivity

Modal damping ζ [ζ] [ζ\_low]–[ζ\_high]

Rayleigh α, β [α], [β] [α\_low]–[α\_high], [β\_low]–[β\_high]

Material scatter (S-N/Se) 1.0 [−x%…+y%]

Stress concentration Kt [Kt\_nom] [Kt\_low]–[Kt\_high]

2.8 Traceability Table

Table 2-8 — Traceability (Artefact → ID/Rev → Used in Section)

Artefact ID / Rev Used In

Thermal base [THERMAL\_IDS] §5.1, §6

CBO run-down [CBO\_RD\_IDS] §5.2, §6.1

CBO run-on [CBO\_RO\_IDS] §5.3, §6.2

Windmilling [WINDMILL\_IDS] §5.4, §6.3

Limit OOB [LIM\_OOB\_IDS] §5.5, §6.4

Engine survey [SURVEY\_IDS] §4.4, §6.5

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3. Requirements & Means of Compliance

3.1 Applicable Regulations (Summary)

CS-E 650 (Vibration Surveys)

CS-E 810 (Blade Failure—incl. running after failure)

CS-E 525 (Continued Rotation)

AMC E 520(c)(2) (Validated data concept)

3.2 Compliance Strategy

Use validated engine-level inputs and demonstrate: (i) no unacceptable stress/strain during CBO run-down, (ii) fatigue life adequacy during run-on, windmilling, and limit OOB 1×, and (iii) model predictive alignment to survey. Apply limitations/maintenance actions if needed.

3.3 MoC Matrix — Quick Reference

Table 3-1 — MoC Matrix — Quick Reference

Rule Applicability Owner Evidence

CS-E 650 All speeds per survey scope Structures §4.4, §6.5; Tables 6-6/6-7

CS-E 810 CBO run-on/run-down Structures §5.2–§5.3; Tables 6-1/6-2/6-3

CS-E 525 Windmilling Structures §5.4; Table 6-4

AMC E 520(c)(2) Validated inputs Engine Dynamics §2.2; traceability Table 2-8

3.4 MoC Matrix — Detailed (Acceptance & Traceability)

Table 3-2 — Detailed MoC

Rule Acceptance Method Evidence/Links

CS-E 650 Amp ±[AMP\_TOL]%, Phase ±[PHASE\_TOL]°, crossings ±[FREQ\_TOL]% Survey overlay at HPCC points §4.4, §6.5; Table 6-6; Figures 6-5a/b/c

CS-E 810 No gross plasticity; safe shutdown; HCF D≤1 Transient strength (run-down), HCF (run-on) §6.1, §6.2; Tables 6-1/6-2/6-3

CS-E 525 D≤1 for windmilling duty Harmonic sweep or transient damage §6.3; Table 6-4

AMC E 520(c)(2) Inputs are validated data Consume as-is, documented pedigree §2.2; Table 2-2

3.5 Acceptance Criteria (Explicit)

Strength: σ\_vm,peak ≤ σ\_y(T)×[MARGIN FACTOR], no progressive plasticity.

Fatigue (Goodman): σ\_a ≤ S\_e(T) at evaluated mean stress; else compute TLIFE.

Fatigue (TLIFE): Miner’s D\_sum ≤ 1.0 per event or mission segment.

Correlation: Amplitude and phase within [AMP\_TOL]%/[PHASE\_TOL]° at 1×; frequency crossings within ±[FREQ\_TOL]%; MAC≥[MAC\_MIN] if modal used.

3.6 References (for §3)

[CS-E BOOK ID/REV], [AMC E 520(c)(2) ID], [PROGRAM VIBRATION LIMITS DOC ID], [ENGINE SURVEY PLAN/REPORT IDs].

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4. Means of Compliance (Methods & Validation)

4.1 Overview (Statement of Approach)

The analysis follows the program’s standard workflow: Thermal/pressure pre-stress → Transient/Harmonic dynamic response → Fatigue evaluation, using program-standard solver settings and damping (Figure 4-1).

4.2 External Validated Inputs (Consumed As-Is)

Inputs provided by Engine Dynamics are used as-received (AMC E 520(c)(2)): data packages [CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS], [THERMAL\_IDS], frames [INTERFACE\_IDS], survey [SURVEY\_IDS]. No reinterpretation beyond frame/unit checks (§2.6).

4.3 Analysis Method (Thermal / Transient / Harmonic)

Thermal base: Apply [THERMAL\_IDS] to HPCC; solve steady pre-stress.

CBO transients: Implicit Newmark time integration; step control [Δt]; damping per §4.7; interface loads applied at [IFACE\_A]/[IFACE\_B].

Windmilling: If harmonic package supplied, solve a 1× order sweep over [RPM\_MIN–RPM\_MAX] with grid [RPM\_LIST or STEP] and [Δf]; else run provided transient and extract 1× response.

Limit OOB 1×: Harmonic 1× sweep per [LIM\_OOB\_IDS].

4.4 Model Validation (Engine Survey; Optional Rig/Modal)

Overlay model-predicted 1× responses at HPCC measurement-analog points [SET\_A] with engine survey [SURVEY\_IDS]. Acceptance: amplitude ±[AMP\_TOL]%, phase ±[PHASE\_TOL]°, crossing frequencies ±[FREQ\_TOL]%. Optional: modal rig correlation with f error ≤[FREQ\_TOL]% and MAC≥[MAC\_MIN].

4.5 Fatigue Evaluation Method (Goodman → TLIFE → Miner)

Compute stress amplitude σ\_a and mean σ\_m at critical nodes. If the Goodman infinite-life screen passes, mark Pass. If not, compute TLIFE (NASALIFE-based) cycles to failure at T and evaluate Miner’s cumulative damage D; require D≤1. Mission segmentation for windmilling per §5.4.

4.6 Acceptance Criteria (Used in §6)

As listed in §3.5 and Table 1-2. Allowables are temperature-dependent (Appendix B). For casing features with local Kt, use hot-spot stress methodology consistent with program practice.

4.7 Frames, Mapping, Integrator, Damping, Numerics

Frames: Global [GCS\_NAME]; interfaces [FRAME\_A], [FRAME\_B].

Mapping: Remote Point — Distributed (RBE3-like).

Integrator: Implicit Newmark (HHT-α acceptable if used by program).

Damping: [ζ] (modal) or Rayleigh α=[α], β=[β].

Time/Frequency: [Δt or Δf] per input sets; convergence tolerances per solver defaults.

4.8 Deliverables

FE model and decks [FILE IDS], result sets, post-processing scripts, and CSV summaries.

Figures and tables referenced in §6.

Correlation overlays (Bode/Campbell).

Config and hash manifest (Appendix G — separate issue).

4.9 Compliance Linkage (Regulatory Hooks)

Methods above directly support CS-E 650/810/525 compliance as mapped in Tables 3-1/3-2.

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5. Analysis Load Cases

5.1 Thermal Base Load (Pre-Stress)

Apply [THERMAL\_IDS] at operating point [OP]. Pressure boundary: [VALUE/MAP]. See Figure 5-1.

Table 5-1 — Thermal Base — Setup

File(s) OP Pressures Frame

[THERMAL\_IDS] [OP] [PRESSURE MAP/VALUES] [GCS\_NAME]

5.2 CBO Run-Down (Post-Failure Shutdown Transient)

Use [CBO\_RD\_IDS] loads at [IFACE\_A]/[IFACE\_B] with frames [FRAME\_A]/[FRAME\_B]. Integrate over [DURATION] with time step [Δt].

Table 5-2 — CBO Run-Down — Run Controls

Profile Duration Δt Damping Acceptance

[CBO\_RD\_IDS] [DURATION] [Δt] [ζ or α,β] Strength per §3.5

5.3 CBO Run-On / Continued Rotation (Pre-Shutdown Transient)

Use [CBO\_RO\_IDS]; evaluate HCF in the [t0–t1] window with dominant 1× content (Figure 5-3).

Table 5-3 — CBO Run-On — Evaluation Fields

Window [t0–t1] Counting Method Output Acceptance

[t0–t1] Rainflow / 1× extraction σ\_a, σ\_m, D Goodman/TLIFE; D≤1

5.4 Windmilling After Shutdown (Continued Rotation)

Evaluate 1× response during windmilling across [RPM\_MIN–RPM\_MAX] with grid [RPM\_LIST or STEP]. Segment durations per [WINDMILL\_IDS] (Figure 5-4).

Table 5-4 — Windmilling — Setup

RPM Band Duration Method Acceptance

[Band 1] [DURATION] Harmonic 1× / Transient D≤1 per band and total

[Band 2] [DURATION]

Total [TOTAL DURATION]

5.5 Limit Out-of-Balance (Manufacturing/Service) — Synchronous 1×

Apply [LIM\_OOB\_IDS] 1× envelope vs speed (Figure 5-5). Sweep [RPM\_MIN–RPM\_MAX] with [RPM\_LIST or STEP]; extract σ\_a vs RPM.

Table 5-5 — Limit OOB — Sweep

RPM Grid Solution Acceptance

[RPM\_LIST or STEP] Harmonic 1× Goodman/TLIFE; D≤1

5.6 Alert-Level Imbalance / Vibration Thresholds (Reference)

By reference to [PROGRAM VIBRATION LIMITS DOC ID]. No restatement herein.

Table 5-6 — Alert-Level References

Document ID/Rev

Vibration alert limits [DOC ID]

Engine ops after alert [DOC ID]

5.7 Frames & Load Mapping (Traceability)

Table 5-7 — Frames / Transforms / Application (Interfaces A/B)

Interface Frame Application Notes

[IFACE\_A] [FRAME\_A] Remote Point — Distributed Deformable, preserves local flexibility

[IFACE\_B] [FRAME\_B] Remote Point — Distributed

5.8 Run Controls & Numerics (Per Case)

Table 5-8 — Solver Settings (Per Case)

Case Integrator Damping Δt/Δf Convergence

Thermal base — — — Steady

CBO run-down Newmark [ζ or α,β] [Δt] Default

CBO run-on Newmark [ζ or α,β] [Δt] Default

Windmilling Harmonic [ζ or α,β] [Δf] Default

Limit OOB 1× Harmonic [ζ or α,β] [Δf] Default

5.9 Evidence Links (Cross-References)

Table 5-9 — Evidence Links

Evidence Figure/Table File/Path (Placeholder)

Thermal contour Fig. 5-1 [PATH/FILE]

CBO run-down loads Fig. 5-2 [PATH/FILE]

CBO run-on window Fig. 5-3 [PATH/FILE]

Windmilling envelope Fig. 5-4 [PATH/FILE]

Limit OOB 1× Fig. 5-5 [PATH/FILE]

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6. Results

> Note: Numeric values are placeholders pending program-specific inputs. Tables/figures are structured for direct population.

6.1 CBO Run-Down — Strength (Transient)

Peak transient responses are summarized below. Detailed time histories are provided in Figure 6-1a/1b/1c.

Table 6-1 — CBO Run-Down — Peak Response Summary

Location Time @ Peak σ\_vm,peak [MPa] T [°C] σ\_y(T) [MPa] Margin (σ\_y/σ\_vm−1)

[LOC-1] [t] [ ] [ ] [ ] [ ]

[LOC-2] [t] [ ] [ ] [ ] [ ]

[LOC-3] [t] [ ] [ ] [ ] [ ]

Result: [PASS/SCREEN/NOTE]. No gross plasticity observed; interface reactions consistent with inputs (Figure 6-1c).

6.2 CBO Run-On — Fatigue (Transient)

Goodman screen at critical locations during [t0–t1]. If any point exceeds infinite-life, TLIFE damage is computed (Table 6-3).

Table 6-2 — CBO Run-On — Goodman Screen

Location σ\_a [MPa] σ\_m [MPa] S\_e(T) [MPa] Result

[LOC-1] [ ] [ ] [ ] [PASS/FAIL]

[LOC-2] [ ] [ ] [ ] [PASS/FAIL]

Table 6-3 — CBO Run-On — Fatigue Damage (if applicable)

Location Cycles Life N\_f Damage D

[LOC-x] [ ] [ ] [ ]

Result: [PASS/Requires TLIFE / D=…].

6.3 Windmilling — Fatigue

Segmented damage across RPM bands; cumulative D reported.

Table 6-4 — Windmilling — Grid/Segment Damage and Accumulated Result

RPM Band Duration σ\_a,crit [MPa] N\_f Damage D Notes

[Band 1] [ ] [ ] [ ] [ ] Worst band? [Y/N]

[Band 2] [ ] [ ] [ ] [ ]

Total [TOTAL] — — [D\_sum] Must be ≤1

Result: [PASS/Conditional].

6.4 Limit OOB — Synchronous 1× Sweep

Identify worst RPM for σ\_a and damage.

Table 6-5 — Limit OOB — Worst-RPM Stress & Fatigue Summary

RPM\* σ\_a,crit [MPa] Goodman Result N\_f Damage D

[RPM\*] [ ] [PASS/FAIL] [ ] [ ]

Result: [PASS/Conditional limits per §7].

6.5 Vibration Survey Correlation (Bode/Campbell; Modal Optional)

Table 6-6 — Bode / Campbell Correlation — Test vs Model (HPCC Points)

Point Amp Err [%] Phase Err [°] Crossing Err [%] Result

[A] [ ] [ ] [ ] [PASS/FAIL]

[B] [ ] [ ] [ ] [PASS/FAIL]

Table 6-7 — Modal Correlation — f, Δf, MAC, ζ (Optional)

Mode f\_test [Hz] f\_model [Hz] Δf [%] MAC ζ\_test [%] Result

[1] [ ] [ ] [ ] [ ] [ ] [PASS/FAIL]

Overall correlation result: [PASS/Conditional] within ±[AMP\_TOL]% amplitude and ±[PHASE\_TOL]° phase; crossings within ±[FREQ\_TOL]%.

6.6 Margin-Comparison Summary (All Cases)

Table 6-8 — Margin-Comparison — Strength (CBO Run-Down)

Location σ\_vm,peak / σ\_y(T) Margin Result

[LOC-1] [ ] [ ] [PASS/SCREEN]

[LOC-2] [ ] [ ] [PASS/SCREEN]

Table 6-9 — Margin-Comparison — Fatigue (Run-On / Windmilling / Limit OOB)

Case Location Goodman D (if TLIFE) Result

Run-On [LOC- ] [PASS/FAIL] [ ] [ ]

Windmilling [LOC- ] [PASS/FAIL] [ ] [ ]

Limit OOB [LOC- ] [PASS/FAIL] [ ] [ ]

6.7 Sensitivity & Uncertainty (If Performed)

Sensitivity to ζ and α/β shows [Δ] variation in σ\_a and D within [x%]. Material scatter per Table 2-7 does [not] change the pass/fail status at critical points.

6.8 Derived Limitations & Maintenance Actions (Feed to §7)

Where margins are conditional, define operational limits (speed bands/dwell) and inspection actions by reference to §7. Draft items: [LIST PLACEHOLDER].

6.9 Evidence Cross-References

Figures: 6-1a/b/c, 6-2a/b, 6-3a/b, 6-4a/b, 6-5a/b/c, 6-6.

Tables: 6-1 … 6-9.

Files: see Table 5-9 and Appendix G (separate issue).

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7. Limitations & Maintenance Actions

> Issued only if required by §6 results. If not required, state “None”.

7.1 Operating Limitations

Table 7-1 — Operating Limitations (Speed Bands / Dwell / Accel-Decel) (if used)

Condition Limitation Rationale (Evidence)

[Speed band A] Avoid/limit dwell >[x s] Table 6-5 worst-RPM; Fig. 6-4b

[Accel/decel] Rate ≥[x RPM/s] through [band] D sensitivity

7.2 Maintenance Actions

Table 7-2 — Maintenance Actions (Triggers / Areas / Methods / Limits) (if used)

Trigger Area Method Limit / Action

Imbalance alert exceedance HPCC hot-spots [LOC-x] NDT [METHOD] Inspect within [x FH/FC]

7.3 Monitoring & Alert Thresholds (By Reference)

Table 7-3 — Monitoring & Alert Thresholds — References (if used)

Document ID/Rev Usage

Vibration alert & exceedance handling [DOC ID] Ops/maintenance linkage

7.4 Continued Rotation (Windmilling) — Operational Considerations

If applicable, limit cumulative windmilling time per RPM band.

Table 7-4 — Windmilling Time Limits by RPM Band (if used)

RPM Band Max Time Basis

[Band] [hh:mm] Table 6-4 D=1 line

7.5 Applicability & Configuration Control

Table 7-5 — Applicability & Configuration Control (if used)

Item Applicability Control

This report [SERIES/SN] [CONFIG DOC]

7.6 Rationale & Traceability

Table 7-6 — Rationale & Traceability — Limitation → Evidence (if used)

Limitation Evidence Rule/Requirement

[Item] [Figure/Table] [CS-E clause]

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8. Conclusions

8.1 Statement of Compliance

Based on the analyses and validations presented herein and consumption of validated engine-level inputs, the HPCC [COMPLIES / COMPLIES WITH LIMITATIONS] with CS-E 650, CS-E 810, and CS-E 525, using AMC E 520(c)(2) for data pedigree.

8.2 Overall Technical Outcome

CBO run-down: Strength margins [adequate/notes].

CBO run-on: Fatigue [passes / requires TLIFE] with cumulative D= [ ].

Windmilling: Cumulative D\_total = [ ] [≤/>/] 1.

Limit OOB: Worst-RPM [passes/conditional].

8.3 Residual Risks & Assumptions

Residual sensitivities to ζ and material scatter are [low/moderate] and bounded by §6.7. No additional risks identified beyond standard program monitoring and alerts.

8.4 Deliverables Produced

FE model and result sets [FILE IDS].

Figures/Tables §5–§6.

Correlation overlays (Bode/Campbell).

Data pedigree and manifests (Appendix G to follow).

8.5 Certification Sign-off

Prepared by: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_

Reviewed by: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_

CVE (Structures): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_

8.6 Distribution & Records

Distributed per front-matter list. Configuration managed by [CM SYSTEM/ID]. Retain per [RECORDS POLICY ID] for [x years].

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9. References

[1] [CS-E BOOK ID/REV] — EASA CS-E.

[2] [AMC E 520(c)(2) ID] — Validated Data Concept.

[3] [PROGRAM VIBRATION LIMITS DOC ID] — Alert thresholds.

[4] [SURVEY\_IDS] — Engine Ground Vibration Survey (Data Book/Report).

[5] [THERMAL\_IDS] — Thermal/Pressure Field Package.

[6] [CBO\_RD\_IDS] — CBO Run-Down Loads Package.

[7] [CBO\_RO\_IDS] — CBO Run-On Loads Package.

[8] [WINDMILL\_IDS] — Windmilling Package.

[9] [LIM\_OOB\_IDS] — Limit OOB Envelope.

[10] [INTERFACE\_IDS] — Interface Frames/Transforms.

[11] [MATERIAL ALLOWABLES DOC ID] — HPCC [ALLOY/SPEC/HT] Properties.

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> Note: Appendices A–G (FE Mesh & Materials; Survey & Rig IDs; Full MoC Matrix; RACI; File Manifests) will be provided in a separate issue as requested.