BRESHEV ENGINEERING

AURA

ENGINEERING PLATFORM

RELEASE EVIDENCE

Field Guide for Gas-Bearing Rotor Systems

A practical framework for turning bearing calculations, rotor-dynamic screening, validation traces, and operating limits into defensible engineering decisions.

CORE RULE A calculation result should not support a release decision beyond the evidence envelope that produced it.

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START HERE

Executive path

If you have three minutes, use this page before entering the technical sequence. It separates the engineering question, the five-gate review path, and the authority of the final status.

CATEGORY LINE Most tools give coefficients. AURA records what those coefficients are allowed to prove.

THREE-STEP READING PATH

1. **Name the decision.** Define the irreversible engineering step that the evidence is expected to authorise.
2. **Test the five gates.** Review application and architecture; geometry and manufactured state; coefficient provenance and validation; rotor, balance, and dynamic evidence; then operating envelope and decision.
3. **Read the status literally.** PASS inherits a stated envelope; REVIEW needs documented expert judgement; SCREENING ONLY cannot authorise freeze; TEST REQUIRED creates evidence; HOLD stops the decision.

DECISION LEVELS AT A GLANCE

PASS	Proceed inside the stated evidence envelope.
REVIEW	Document expert judgement before proceeding.
SCREENING ONLY	Compare, prioritise, or plan; do not freeze.
TEST REQUIRED	Generate the missing decision-critical evidence.
HOLD	Do not proceed until the conflict or critical gap is resolved.

PUBLICATION BOUNDARY Version 1.1 supersedes v1.0 by extending the balancing-evidence treatment in Gate 4, the worked example, reusable templates, checklist, and source basis. It is not a product certification or a substitute for prototype testing, coupled analysis, measurement, or the client organisation's release authority. DOI assignment remains pending until the canonical deposit is minted.

Contents

Executive summary

Gas-bearing engineering tools are usually judged by the numbers they compute: load capacity, stiffness, damping, flow, critical speeds, forced response, and stability indicators. Those numbers are necessary. They are not, by themselves, release evidence.

A release decision concerns a manufactured rotor-bearing system in a defined operating context. Decision authority therefore depends on more than numerical completion. The geometry and clearance must be known; coefficient provenance must be visible; the rotor model, balance state, assembly state, and measurement setup must be traceable; the validation basis must match the claim; and the operating envelope must be recorded.

This guide consolidates AURA Technical Notes TN01–TN05 [9], the release-evidence architecture, real AURA product screens, public validation traces, and worked evidence reviews into one connected framework. The proprietary solver remains closed; the evidence surface is made inspectable.

CATEGORY LINE Most tools give coefficients. AURA records what those coefficients are allowed to prove.

The five release gates

GATE	DECISION OBJECT	RELEASE QUESTION
1	**Application and architecture**	Is gas-static support justified, and what support topology carries the machine requirements?
2	**Geometry and manufactured state**	Which radius, length, clearance, restrictor, surface, adjustment, and assembly state does the result represent?
3	**Coefficient provenance and validation**	How were K/C, cross-coupling, load, and flow produced, compared, and bounded?
4	**Rotor, balance, and dynamic evidence**	What do critical-speed separation, response, orbit, stability, balance path, and assembly state support?
5	**Operating envelope and decision**	Inside which speed, load, thermal, ambient, duty-cycle, mounting, and control conditions is the claim valid?

The evidence object

AURA treats each release-relevant result as an evidence object rather than an isolated number. The minimum record is:

- **Claim -** the engineering statement the result is expected to support.
- **Decision -** the irreversible step or review gate under consideration.
- **Result -** the computed, measured, or reviewed value and status.
- **Provenance -** method, solver mode, source data, configuration, and version.
- **Applicability -** geometry, operating state, assumptions, and exclusions.
- **Validation trace -** benchmark family, residuals, holdout status, and review level.
- **Uncertainty or gap -** what remains assumed, partial, unverified, or context-sensitive.
- **Decision level -** PASS, REVIEW, SCREENING ONLY, TEST REQUIRED, or HOLD.
- **Next action and claim boundary -** what closes the gap and what the result cannot yet prove.

DECIDE BEFORE SIZING

Gate 1 - Application fit and support architecture

Gas-bearing design should start before radius, clearance, supply pressure, restrictor diameter, feed-hole count, or flow rate are selected. Non-contact gas-static support is justified only when the application rewards low friction, cleanliness, repeatability, and non-contact operation - and the organisation can control clearance, air quality, damping evidence, and validation.

Fit signals and risk signals

GOOD FIT SIGNALS	RISK SIGNALS
High cleanliness requirement	Weak damping evidence
Low friction and wear sensitivity	Uncontrolled clearance variation
Precision repeatability	Unknown surface-finish sensitivity
High-speed rotating or positioning duty	No measurement or validation path

Architecture precedes parameter synthesis

Journal, thrust, conical, hybrid, and multi-support layouts are not small variations of one calculation. They establish different load paths, adjustment mechanisms, failure sensitivities, and validation requirements. A coefficient becomes useful only after the support topology and decision scope are stable enough to give it context.

1. Application fit	Should the machine use non-contact gas-static support?
2. Machine requirements	Speed, load, stiffness, cleanliness, thermal limits, flow, and tolerance risk.
3. Support architecture	Journal, thrust, conical, hybrid, or multi-support topology.
4. Load path and layout	Support positions, thrust reaction, tool overhang, assembly constraints.
5. Parameter synthesis	Radius, length, clearance, pressure, restrictors, rows, and feed zones.

GATE 1 OUTPUT A written application-fit decision, selected support architecture, explicit load path, and a stable requirement set for parameter synthesis.

Gate 2 - Geometry, clearance, and manufactured state

A stiffness or damping coefficient is not a free-standing truth. It belongs to a specific geometry, clearance state, feed arrangement, surface condition, pressure state, balance state, and operating envelope. Change those conditions and the same number may lose decision authority even if the calculation remains numerically correct.

> **PRACTICAL RULE** A coefficient without a geometry and clearance basis is a model output, not a release object.

Geometry and clearance are evidence inputs

- Bearing family and load direction.
- Journal radius, bearing length, cone angle, and support span.
- Nominal, adjusted, measured, and allowable clearance states.
- Restrictor diameter, number, rows, and feed-zone placement.
- Surface finish, form error, concentricity, and assembly alignment.
- Supply pressure, gas state, temperature assumptions, and flow path.
- Manufacturing revision and as-built configuration represented by the model.

Adjustable stiffness is not magic stiffness

Opposed conical supports illustrate the sensitivity. Moving the pair changes the working gaps and redistributes stiffness between the two films. Under diagonal load, one film can open while the opposing film closes. The useful feature is controllable support state - but the same mechanism defines the risk boundary if one side unloads too far or the opposite side approaches an unsafe small-gap state. Adjustment therefore needs a permitted envelope, measurement basis, and traceable final state.

Gate 2 questions

Geometry identity	Does the model match the current drawing and as-built revision?
Clearance state	Is the clearance nominal, adjusted, measured, inferred, or assumed?
Tolerance sensitivity	Which dimensional changes materially alter load, K/C, flow, or stability?
Assembly and verification	Does the calculated state survive mounting, alignment, and reassembly - and which features can be verified before release?

> **GATE 2 OUTPUT** A geometry-and-clearance basis tied to a specific revision, manufactured state, tolerance envelope, and verification path.

Gate 3 - Coefficient provenance and validation

Load capacity, stiffness, damping, cross-coupling, and flow become decision evidence only when their production method and applicability are preserved. A clean value can still have weak authority if it depends on proxy damping, incomplete coupling, an undocumented solver mode, an unverified bridge, or a benchmark outside the current geometry and operating state.

Minimum coefficient record

Quantity	Load, flow, Kxx/Kyy, Kxy/Kyx, Cxx/Cyy, cross-coupling, or derived stability indicator.
Method	Analytical, finite-difference, perturbation, identified, measured, imported, or proxy/fallback.
State	Geometry, clearance, eccentricity, pressure, speed, gas, and thermal assumptions.
Numerical trace	Mesh, convergence, residuals, conditioning, regularisation, and solver version where relevant.
Validation family	Reference case, measured data family, calibration rows, holdout rows, and acceptance level.
Applicability boundary	The geometry, regime, and decision class for which the comparison is relevant.
Decision consequence	Which downstream dynamic or freeze decision consumes the coefficient.

Validation must match the claim

A validation statement is strongest when it preserves three separations: calibration versus holdout data, method verification versus case qualification, and physical plausibility versus release authority. A solver may have a sound regression foundation while a particular design remains SCREENING ONLY because its case-level damping, coupling, tolerance, or operating-envelope evidence is incomplete.

> **VALIDATION DISCIPLINE** Do not extrapolate from a benchmark success to a design freeze unless the geometry, coefficient family, regime, and decision consequence are inside the validated applicability boundary.

Open evidence surface, closed engineering engine

The exposed layer carries registry anchors, residuals, holdout status, applicability boundaries, technical notes, DOI records, and claim limits. The protected layer retains solver implementation, perturbation-method core, coefficient engine, scaling logic, and decision heuristics.

> **GATE 3 OUTPUT** Coefficient objects with method provenance, validation trace, applicability boundary, and an explicit statement of downstream decision authority.

Gate 4 - Rotor dynamics, balance, and assembly

Static bearing checks can pass while the rotor-bearing decision remains open. Critical-speed separation, forced response, orbit, stability, mode participation, damping provenance, balance state, and assembly transfer determine whether a plausible bearing candidate can support a rotor-level release decision.

Static PASS is not engineering freeze

Calculation completion and decision authority are separate states. A candidate may satisfy load, stiffness, clearance, and flow targets; its dynamic model may also run successfully. Yet the result can remain SCREENING ONLY if damping provenance, cross-coupling, case-level validation, mesh trace, tolerance basis, or two-way coupling maturity is insufficient for freeze.

> **CORE RULE** Nothing has to fail for engineering freeze to remain unjustified. Evidence can be useful, internally consistent, and still be too weak for an irreversible decision.

Dynamic evidence package

- Rotor model identity, mass and inertia basis, support positions, and boundary conditions.
- Natural frequencies and mode shapes with mesh and model-version trace.
- Campbell or speed-dependent critical-speed evidence with operating markers.
- Forced response, Bode, orbit, or runout indicators over the relevant speed range.
- Stability or whirl screening with coefficient provenance and limitation notes.
- Damping metric, its source, and the relationship between decrement, Q, or modal damping used by the workflow.
- Decision-facing summary: separation, peak response, evidence status, and next action.

Residual imbalance is not release evidence

A residual-imbalance value answers a narrow question: whether a rotor cleared a threshold under the balancing conditions used. It does not automatically justify the grade, prove the rotor regime, describe the correction path, transfer from component to assembly, quantify measurement error, or demonstrate service-speed response.

For rigid-behaviour rotors, ISO 21940-11 defines procedures and tolerances [1]; flexible-behaviour rotors are addressed by ISO 21940-12 [2]. ISO 21940-14 addresses identification and assessment of balance-measurement errors [3]. The broader balancing literature reinforces that rotor regime, correction planes, measurement configuration, and error treatment are part of the engineering problem [4]. The consequence is direct: these elements belong inside the evidence record, not in background notes.

Balancing evidence trail

Rotor regime	Rigid, flexible, near-critical, supercritical, or support-sensitive.
Grade rationale	Why the selected tolerance is appropriate for the rotor and failure consequence.
Manufacturing baseline	Rotor quality before balancing; correction is not used to hide manufacturing defects.
Correction path	Planes, method, trial sequence, speed condition, and process constraints.
Assembly state	Component, assembly, service-equivalent state, and reassembly controls.
Measurement apparatus	Machine type, suspension, mounting, drive, filtering, sensors, and repeatability.
Dynamic response	Operating-speed vibration, orbit/runout, modal response, and transmitted vibration.
Release boundary	What the result proves and which states remain unverified.
Tolerance basis and planes	Standard edition, basis speed, total permissible residual unbalance, tolerance-plane coordinates, centre-of-mass location, and allocation rule.
Correction and measurement planes	Coordinates, radii, plane mapping, measurement reference, and the transformation used to judge the residual in the tolerance planes.
Machine and process capability	Minimum achievable residual unbalance, unbalance reduction ratio, plane separation, angular capability, correction accuracy, and job-specific applicability.
State repeatability	Vector repeatability across runs, starts, reassemblies, and relevant thermal or settling states; physical evidence floor compared with the requested tolerance.
Modal sensitivity and speed trajectory	Relevant critical speeds, damping provenance, modal participation, acceleration/deceleration through resonances, and response over the release-relevant speed path.

Tolerance planes are not correction planes

ISO 21940-11 allocates permissible residual unbalance to defined tolerance planes, while physical correction may be performed elsewhere [1]. Measurement planes can also differ. A valid PASS therefore requires the total tolerance, its allocation, the coordinates of all relevant planes, and a traceable transformation from the measured or corrected state back to the tolerance planes.

For an inboard rigid-behaviour rotor, a common lever allocation is $U_{per,A} = U_{per} \cdot L^{B}/L$ and $U_{per,B} = U_{per} \cdot L^{A}/L$. The equation is not a universal substitute for the applicable standard: overhung rotors, non-standard plane locations, flexible behaviour, and experimentally derived requirements need their own allocation and mapping basis [1,12].

PLANE RULE A single U/U-limit comparison is incomplete unless both values share the same reference planes and allocation basis.

Capability and the physical evidence floor

A current calibration label does not prove that a balancing system is capable of the present task. ISO 21940-21:2022 addresses balancing-machine performance, including minimum achievable residual unbalance and unbalance reduction ratio [11]. The evidence record must also cover fixture and drive influence, plane separation, angular accuracy, and the correction process actually used.

The release limit is also bounded by the rotor itself. If blades, fits, trapped material, thermal bow, bearing state, or reassembly cause vector changes larger than the requested residual tolerance, the target is not demonstrable even with an excellent machine [3,12-15]. The evidence floor is the combined machine, setup, rotor-state, assembly, and correction repeatability that remains after justified compensation.

CAPABILITY RULE Do not classify a rotor as PASS below the demonstrated evidence floor of the machine-process-rotor combination.

Assembly transfer and incremental correction

During stepwise assembly, a residual established in one pair of planes can appear as a much larger transfer unbalance when viewed in a later pair. The new component contribution must therefore be separated by measuring the prior assembly in the future planes before installation, repeating the measurement after installation, and correcting the vector difference rather than the total post-installation vector [12,14].

For modular or reassembled rotors, the evidence must preserve component identity, angular indexing, datum chain, bearing state, interface runout, fixture or dummy identity, and reassembly repeatability. BALANCED COMPONENT, BALANCED ASSEMBLY, and INTERCHANGEABLE MODULE are different claims and require different evidence [12-15].

Modal sensitivity and the complete speed path

Rigid or flexible behaviour is an assessed state, not a permanent label. It depends on the assembly, support dynamics, speed range, tolerance level, and relevant mode participation. Critical-speed separation alone is not a complete sensitivity measure: modal damping and the speed trajectory determine how strongly a given modal unbalance is amplified [2,12,13].

The release envelope must therefore include steady operating points and transients: acceleration, deceleration, resonance crossings, dwell, and the number of crossings where relevant. When damping is proxy or fallback evidence, a modal-sensitivity result remains screening-grade even if the critical-speed margin is numerically favourable.

DYNAMIC RULE Critical-speed margin does not replace modal sensitivity; sensitivity requires mode, damping, support, and speed-path evidence.

GATE 4 OUTPUT A rotor-level evidence package that joins bearing coefficients, dynamic response, tolerance-plane allocation, correction and measurement planes, machine/process capability, balance path, assembly fingerprint, vector repeatability, and the service-relevant speed trajectory.

Gate 5 - Operating envelope and decision boundary

A release decision made under factory conditions does not automatically survive transfer to a customer site. Gas-film load capacity, stiffness, damping contribution, and stability margin depend on gas state and machine boundary conditions. Ambient pressure, temperature, cleanliness, local heating, cooling flow, process demand, mounting, and controls are part of the evidence basis.

The transfer problem

A short, controlled factory acceptance run may be unloaded or lightly loaded. Site operation introduces process loads, transients, start-stop cycles, duty-cycle accumulation, mounting differences, surge events, and control behaviour that the test stand may not reproduce. This does not make factory evidence wrong. It gives the evidence a boundary. Gas-foil-bearing literature and public turbo-blower documentation illustrate how operating context, process demand, and controls vary across high-speed installations [7,8]; these sources provide application context only, not validation evidence for an aerostatic support.

> **OPERATING-ENVELOPE RULE** Outside the recorded envelope, the evidence does not predict failure. It simply no longer speaks with the same authority unless the extension was explicitly validated.

Minimum envelope statement

Speed	Normal range, transients, overspeed, start-up, shut-down, acceleration/deceleration, resonance crossings, and relevant dwell.
Load	Radial, axial, process, imbalance, overload, and disturbance conditions.
Thermal state	Ambient, gas, shaft, housing, gradient, warm-up, and steady-state limits.
Environment	Pressure, cleanliness, humidity or contamination assumptions, and supply quality.
Duty cycle	Continuous/intermittent operation, cycle count, dwell, and maintenance state.
Mounting and assembly	Support interfaces, alignment, foundation, adapter, and reassembly controls.
Controls and process	Control mode, surge avoidance, actuation, process demand, and trip behaviour.

Decision levels

STATUS	DECISION USE	MEANING
PASS	Proceed inside the stated envelope	Requirement is met and the evidence basis is adequate for the stated decision. PASS is never universal; it inherits the recorded scope.
REVIEW	Expert review before proceeding	The result is plausible, but assumptions, partial evidence, or transfer questions require a documented engineering review.
SCREENING ONLY	Compare, prioritise, or plan	The result is useful for screening but does not authorise engineering freeze. The limitation must travel with every export.
TEST REQUIRED	Generate missing evidence	A measurement or higher-fidelity validation step is necessary to close a decision-critical gap.
HOLD	Do not proceed	Evidence conflicts with the release case or a critical uncontrolled gap blocks the decision.

GATE 5 OUTPUT A decision classification, the operating envelope it inherits, the reason for the status, the next required action, and an explicit claim boundary.

REAL PRODUCT EVIDENCE

AURA workflow in practice

The following screens are from the working AURA Engineering Platform. They are not generic illustrations. The architecture screen and the dynamic/decision screens represent separate internal demonstration contexts; they are shown to explain the workflow, not to imply that every displayed value belongs to one physical machine.

Architecture and load-path definition

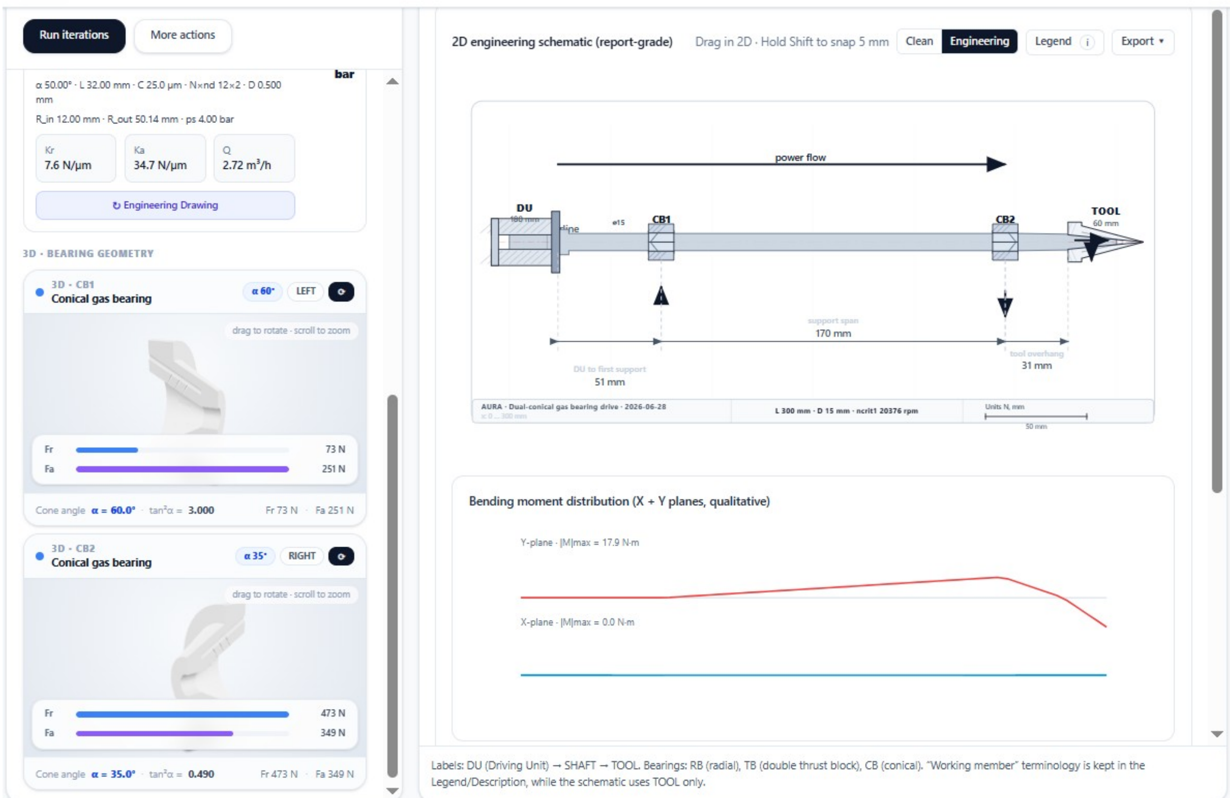

Figure 1. AURA engineering schematic for a dual-conical gas-bearing drive. The screen preserves support topology, support span, tool overhang, bearing reactions, and a qualitative bending-moment view. ***Separate architecture example; no client data is asserted.***

This screen demonstrates Gate 1 and Gate 2. Bearing geometry is not shown as an isolated calculator input: it is placed inside the machine architecture and load path. The document title block, units, support identities, dimensions, and reactions create a traceable basis for later rotor modelling.

Dynamic screening with operating markers

Figure 2. AURA Campbell-diagram screen with the operating-speed marker and modal evidence exposed. ***Dynamic-screening example supplied by Breshev Engineering*.**

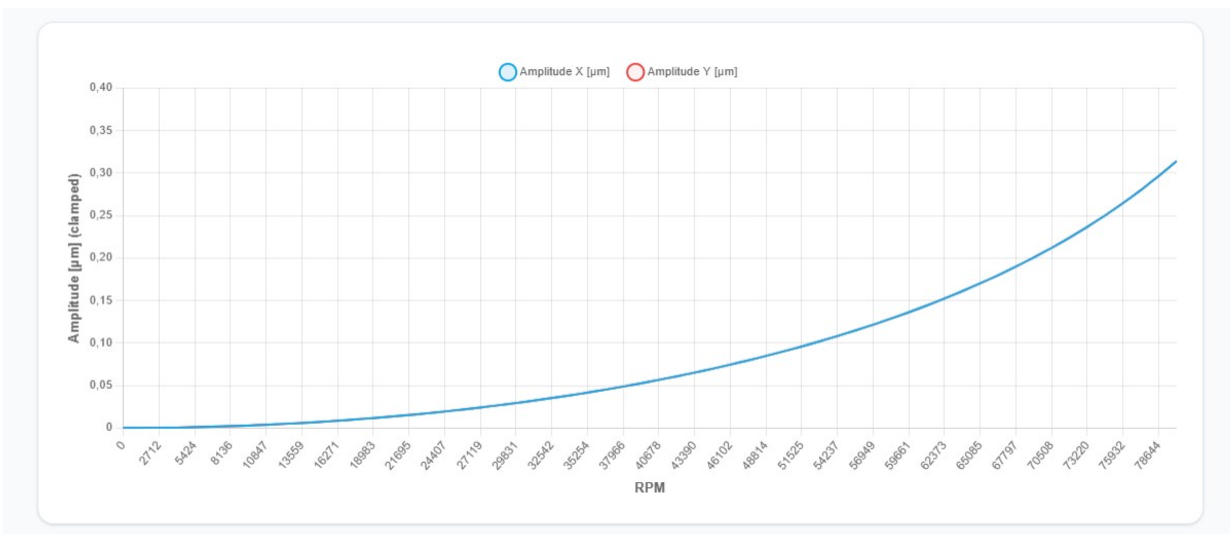

Figure 3. AURA forced-response amplitude trend over speed. X and Y traces remain visible and exportable. ***The plot is screening evidence; interpretation depends on model and coefficient provenance.***

The plots answer physical questions, but they do not make the release decision by themselves. Their authority depends on the rotor model, support coefficients, damping source, operating state, mesh trace, validation family, and acceptance criteria. A smooth curve is not automatically strong evidence.

The decision layer

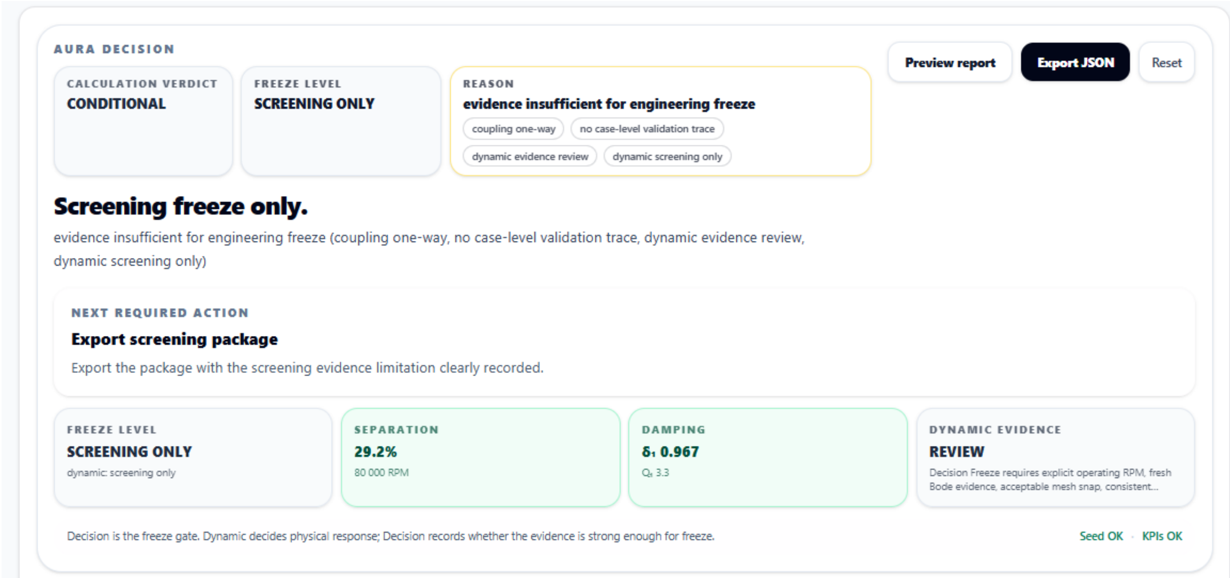

Figure 4. AURA Decision screen. The numerical result is CONDITIONAL while the freeze level remains SCREENING ONLY because the evidence basis is insufficient for engineering freeze. ***Dynamic-screening example; the limitation is preserved in the export action.***

The screen shows the central AURA separation: physical calculation and freeze authority are different objects. It records the reason, the next required action, the operating point, the damping indicator, and the dynamic-evidence status. The user can export a screening package with the limitation attached instead of turning a conditional calculation into a silent approval.

> **WHY THIS MATTERS** A professional decision system must be capable of returning a useful result and still refusing engineering freeze. That refusal is part of the product value, not a defect.

Evidence-object trace from the decision screen

The screen can be read as a compact evidence object. This is not a second machine case; it is the decision trace associated with Figures 2–4.

EVIDENCE FIELD	RECORDED TRACE
Claim	The dynamic result is sufficient to support engineering freeze at 80,000 rpm.
Visible result	Calculation verdict CONDITIONAL; separation 29.2%; δ_1 0.967; Q_1 3.3.
Evidence gaps	One-way coupling, no case-level validation trace, dynamic evidence under review, and dynamic screening only.
Decision level	SCREENING ONLY.
Next action	Export the screening package with its limitation; attach case-level validation and upgraded dynamic evidence before requesting freeze.
Claim boundary	The package may support comparison and evidence planning. It does not authorise an engineering freeze.

INTERPRETATION The numerical indicators remain useful. Their authority is limited because the evidence chain is incomplete for the requested decision.

Open evidence surface and validation lineage

AURA is designed around a closed engineering engine and an inspectable evidence surface. Public anchors expose validation identity, lifecycle state, residuals, holdout status, and applicability boundaries. This makes validation language checkable without publishing proprietary solver implementation or decision heuristics.

Current public evidence summary

EVIDENCE FAMILY	ROLE	VISIBLE TRACE
Conical aerostatic method chain	Public registry anchor	Method-chain residuals of 3.938%, 7.143%, and 7.692% are reported for the three published comparison steps [10].
Journal aerostatic L4 family	Public registry anchor	Kozánek 2009 [5] plus Fleming/NASA TN D-8270 [6]; 4/4 holdout rows reported closed, maximum residual 10.282%, leakage audit PASS [10].
Dynamic platform foundation	Internal/public diagnostic layer	Regression and contract evidence can support platform confidence while a specific design remains evidence-gated.

BOUNDARY These residuals describe specific published evidence families and acceptance logic. They are not universal accuracy claims for arbitrary gas-bearing geometries or rotor systems.

Validation data lineage - minimum record

Source identity	Author, title, date, report or DOI, and accessible source location.
Measured or computed quantity	What was actually reported: pressure, load, flow, K/C, response, critical speed, or another quantity.
Test/model state	Geometry, gas, pressure, speed, excitation, instrumentation, and processing.
Extraction trace	Table, figure, row, unit conversion, digitisation, or transcription method.
AURA mapping	Which input/output field and coefficient family the source is used to assess.
Role separation	Calibration, verification, holdout, plausibility, or contextual source.
Residual and acceptance	Metric, sign convention, tolerance, result, and review status.
Applicability boundary	What the source can and cannot validate for the present design.

Public access: AURA Validation Chain Registry

Platform and technical notes: breshevengineering.com

FICTIONAL CASE

Worked example - balancing evidence review

SAMPLE STATUS All parameters in this example describe a fictional rotor created to show the review method. No client data is used. The example is not a certification.

Case SBER-SAMPLE-01 concerns a 0.85 kg aerostatic optical grinding spindle intended to operate at 65,000 rpm. The disassembled rotor has been balanced to G0.4 and the spindle passed an unloaded factory vibration check. The release question is whether the available balancing evidence is sufficient for a surface-finish-critical application.

Decision under review

Machine class	Optical grinding spindle
Operating speed	65,000 rpm
Support	Aerostatic journal plus thrust support
Nominal G0.4 implication	$e_{per} \approx 0.059$ µm and $U_{per} \approx 0.050$ g·mm at 65,000 rpm for a 0.85 kg rotor, before plane allocation and measurement uncertainty [1]
Submitted claim	Balancing evidence is sufficient for release into the intended application
Review output	Evidence matrix, decision classification, next actions, and release-boundary statement
Tolerance-plane basis	Not supplied; the nominal total U_{per} has not been allocated or mapped to the correction planes.
Machine capability	Machine identified, but no task-specific minimum achievable residual unbalance or reduction-ratio evidence supplied.

The nominal grade conversion uses $e_{per} = G/\omega$ and $U_{per} = m \cdot e_{per}$. It checks arithmetic consistency only. It does not establish that G0.4 is the correct application requirement, define tolerance planes, allocate or map the permissible residual to correction planes, demonstrate machine/process capability, or account for the physical repeatability floor.

Evidence findings

EVIDENCE ITEM	STATUS	BASIS FOUND	RELEASE CONSEQUENCE
Rotor regime	**ASSUMED**	Early modal estimate predates two adapter revisions.	Low-speed balance may not represent the as-built operating-speed state.

EVIDENCE ITEM	STATUS	BASIS FOUND	RELEASE CONSEQUENCE
Grade rationale	**ASSUMED**	G0.4 follows company practice; no rotor-specific derivation supplied.	The grade is plausible but not yet justified against the release consequence.
Manufacturing baseline	**SUPPORTED**	Concentricity and journal roundness records are present.	Balancing is not being used to mask an uncontrolled incoming rotor.
Correction path	**SUPPORTED**	Two-plane material removal with plane locations and amounts recorded.	The correction route is traceable and repeatable.
Assembly state	**UNVERIFIED**	Certificate covers the rotor without the final tool adapter.	The release-relevant assembled state has not been directly checked.
Measurement apparatus	**UNVERIFIED**	Machine identified; filtering, runout handling, and repeatability are absent.	Tolerance consumption cannot be separated from measurement-chain contribution.
Factory vibration	**SUPPORTED**	Unloaded record at 65,000 rpm is within the internal limit.	Supports the unloaded factory state only.
Customer-site envelope	**ASSUMED**	Process load, mounting, and duty cycle differ from the factory check.	Factory behaviour does not automatically transfer to service conditions.
Tolerance-plane mapping	**UNVERIFIED**	A total grade-derived value is shown; tolerance-plane coordinates, allocation, and correction-plane mapping are absent.	The reported U/U-limit comparison is not yet plane-resolved.
Machine/process capability	**UNVERIFIED**	No task-specific minimum achievable residual, reduction ratio, plane-separation, or correction-capability record is attached.	The process has not demonstrated that G0.4 can be measured and achieved with adequate margin.
Rotor-state repeatability	**UNVERIFIED**	No vector spread across repeated starts, relevant thermal states, or reassembly is available.	The requested tolerance may sit below the physical evidence floor.
Assembly transfer	**UNVERIFIED**	The final adapter was not present and no before/after vector separation was performed in the future planes.	Component balance cannot be transferred silently to the final assembly.
Modal sensitivity	**ASSUMED**	An early critical-speed estimate exists, but current adapter, damping provenance, and transient speed-path evidence are incomplete.	A favourable separation value alone cannot close operating-speed sensitivity.

Decision classification - REVIEW

The balancing work shows useful process discipline: a pre-balance quality gate, a recorded correction path, and acceptable unloaded factory vibration. The result remains REVIEW because the two strongest claims are attached to states that differ from the release-relevant condition: component-level G0.4 and unloaded factory vibration do not directly prove the assembled, process-loaded state.

The decision is REVIEW rather than HOLD because no evidence contradicts the release case. The gaps are absences, not conflicts. A targeted assembled-state check can therefore upgrade confidence without stopping the programme.

Priority next actions

1. **Tolerance-plane definition. Define the tolerance planes, centre-of-mass basis, plane allocation, and mapping to the actual correction planes.**
2. **Machine capability and guard band. Attach task-specific minimum achievable residual unbalance, reduction-ratio evidence, plane separation, and the uncorrected total deviation for each tolerance plane.**
3. **Assembled-state verification. Repeat the balance check with the final tool adapter fitted and preserve the complete assembly fingerprint.**
4. **Vector repeatability record. Capture Ux/Uy or magnitude/phase over repeated starts, relevant settling states, and any required reassembly; report mean vector and spread.**
5. Modal-sensitivity refresh. Update critical speeds, mode participation, damping provenance, and the acceleration/deceleration path for the current adapter revision.
6. Grade rationale note. Link G0.4 to surface-finish sensitivity, bearing integrity, or another rotor-specific consequence.
7. Transfer and reassembly check. If the adapter is installed incrementally or may be replaced, separate the added vector and demonstrate repeatable reassembly.

CURRENT EVIDENCE CAN PROVE The disassembled rotor met the recorded machine indication associated with the nominal G0.4 target, the manufacturing baseline was controlled, and the unloaded spindle remained within the factory vibration limit at 65,000 rpm.

CURRENT EVIDENCE CANNOT YET PROVE The residual is inside correctly allocated tolerance-plane limits after uncertainty; the machine-process combination is capable of demonstrating G0.4; the assembled rotor meets the balancing intent; the rigid-behaviour assumption holds for the current adapter; modal sensitivity is acceptable over the complete speed path; or factory behaviour transfers to loaded customer-site operation.

APPENDIX A

Reusable evidence object template

Use one record for each release-relevant result. Do not merge several independent claims into one evidence object.

FIELD	REQUIRED RECORD
Evidence ID	Unique case and object identifier
Decision under review	What irreversible step is being considered?
Claim	What exactly is the result expected to prove?
Quantity and result	Value, units, status, and acceptance criterion
Method provenance	Solver mode, source, model, test, instrumentation, or review method
Configuration identity	Geometry, revision, clearance, assembly, and software/model version
Operating state	Speed, load, pressure, thermal state, gas, duty, and controls
Validation trace	Benchmark family, calibration/holdout role, residuals, and review state
Evidence level	SUPPORTED / ASSUMED / UNVERIFIED / CONFLICTING
Applicability boundary	Where does the evidence speak with authority?
Decision classification	PASS / REVIEW / SCREENING ONLY / TEST REQUIRED / HOLD
Next required action	Specific measurement, model upgrade, document, or accepted limitation
Claim boundary	What the result is and is not allowed to prove
Owner and date	Reviewer, organisation, version, and review date
Tolerance basis and planes	Standard/requirement edition, basis speed, total permissible residual, plane coordinates, centre of mass, allocation rule, and mapped plane limits
Correction and measurement planes	Coordinates, radii, permissible correction zones, measurement references, and plane-transformation method

FIELD	REQUIRED RECORD
Machine/process capability	Machine/configuration ID, minimum achievable residual, unbalance reduction ratio, plane separation, angle accuracy, and correction capability
Rotor-state repeatability floor	Mean vector, spread, start-angle plan, settling/thermal state, reassembly spread, and comparison with tolerance
Assembly fingerprint	Component IDs, clocking/indexing, bearings, interfaces, datum chain, fixture/dummy, fastener or assembly state, and revision
Modal sensitivity and speed path	Relevant modes, critical speeds, damping provenance, amplification/sensitivity, acceleration/deceleration, crossings, and dwell
Correction as performed	Actual mass/volume, centroid radius, angle, plane, method, integrity inspection, and independent verification run

APPENDIX B

Freeze-readiness checklist

DECISION DEFINITION

- ☐ The irreversible decision is named.
- ☐ The acceptance criterion and consequence of error are defined.
- ☐ The release authority and reviewers are identified.

APPLICATION AND ARCHITECTURE

- ☐ Gas-static support is justified against realistic alternatives.
- ☐ Load path, support topology, and machine requirements are stable.
- ☐ The support layout matches the decision-relevant assembly.

GEOMETRY AND MANUFACTURED STATE

- ☐ Model geometry matches the current drawing/as-built revision.
- ☐ Clearance state and adjustment method are known.
- ☐ Tolerance sensitivity and surface/assembly assumptions are recorded.

COEFFICIENTS AND VALIDATION

- ☐ K/C, cross-coupling, load, and flow carry method provenance.
- ☐ Calibration and holdout roles are separated.
- ☐ Residuals, acceptance levels, and applicability boundaries are visible.
- ☐ Proxy or fallback values cannot silently support engineering freeze.

ROTOR DYNAMICS, BALANCE, AND ASSEMBLY

- ☐ Rotor model, supports, mesh, mass/inertia, and boundary conditions are traceable.
- ☐ Critical-speed, response, orbit/runout, and stability evidence cover the relevant speed range.
- ☐ Damping source and coupling maturity support the requested decision level.
- ☐ Balance grade, correction path, assembly state, measurement setup, and repeatability are recorded.
- ☐ Tolerance planes, total permissible residual, allocation, and correction-plane mapping are explicit.
- ☐ Machine and correction capability are demonstrated for the requested residual, not inferred from calibration status alone.
- ☐ The requested tolerance is above the demonstrated machine-process-rotor evidence floor.
- ☐ Repeatability is evaluated as vector data; a small mean cannot hide large run-to-run scatter.
- ☐ Incremental assembly separates transfer unbalance from the newly added component vector.
- ☐ Assembly fingerprint, clocking, bearings, fixtures/dummies, and reassembly controls are preserved.
- ☐ Rigid/flexible behaviour is assessed for the actual support, tolerance, assembly, and speed range.
- ☐ Modal sensitivity joins critical-speed separation, damping provenance, and the complete speed trajectory.

OPERATING ENVELOPE AND DECISION

- ☐ Speed, load, thermal, ambient, duty-cycle, mounting, and control limits are stated.

- ☐ The decision inherits the narrowest envelope of its supporting evidence.
- ☐ Next actions are assigned for every decision-critical gap.
- ☐ The final package states what is supported and what remains screening-only.

SHARED VOCABULARY

Definitions

Applicability boundary	The geometry, method, regime, and operating context within which evidence is relevant to a claim.
Claim boundary	The explicit statement of what a result can and cannot support.
Coefficient provenance	The method, source, configuration, assumptions, and validation trace behind a bearing coefficient.
Decision authority	The level of engineering action that the available evidence may legitimately authorise.
Evidence envelope	The combined geometry, validation, operating, measurement, and decision scope inherited by a result.
Evidence object	A result packaged with claim, provenance, applicability, validation, status, and decision limits.
Operating envelope	The speed, load, thermal, ambient, duty-cycle, mounting, assembly, and control state inside which the evidence was produced.
Release evidence	The traceable basis that determines what a calculated, measured, or reviewed result is allowed to prove.
SCREENING ONLY	A useful result that may support comparison, prioritisation, or test planning but not engineering freeze.
Validation trace	The chain from a source or benchmark through mapping, residual calculation, acceptance logic, and lifecycle state.
Tolerance plane	A reference plane in which permissible residual unbalance is allocated and acceptance is judged; it need not coincide with a correction or measurement plane.
Correction plane	A physical plane in which material can be added, removed, or relocated to change the rotor's unbalance state.
Machine capability	Demonstrated ability of a defined balancing-machine configuration to measure and reduce unbalance for the stated task and range.
Physical evidence floor	The residual level below which machine, setup, rotor-state, assembly, or correction variability prevents a defensible distinction from zero.

Transfer unbalance	The apparent unbalance created when a previously established state is represented in displaced planes; it must be separated during incremental assembly.
Assembly fingerprint	The traceable identity of parts, angular positions, bearings, interfaces, fixtures, datum chain, and revision that defines the balanced state.
Modal sensitivity	The change in a mode-related response caused by a change in modal unbalance, bounded by mode shape, support state, damping, and speed path.

References

[1]	ISO 21940-11:2016. Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour. Amendment 1:2022. Current standard; under systematic review as of 11 July 2026.
[2]	ISO 21940-12:2016. Mechanical vibration — Rotor balancing — Part 12: Procedures and tolerances for rotors with flexible behaviour. Confirmed current in 2025.
[3]	ISO 21940-14:2012. Mechanical vibration — Rotor balancing — Part 14: Procedures for assessing balance errors. Amendment 1:2022. Current standard; ISO/FDIS 21940-14 is under development as its intended replacement as of 11 July 2026.
[4]	Foiles, W. C.; Allaire, P. E.; Gunter, E. J. Review: Rotor Balancing. Shock and Vibration, 5(5–6), 1998, 325–336. DOI: 10.1155/1998/648518.
[5]	Kozánek, J.; Šimek, J.; Steinbauer, P.; Bílkovský, A. Identification of Stiffness and Damping Coefficients of Aerostatic Journal Bearing. Engineering Mechanics, 16(3), 2009, 209–220.
[6]	Fleming, D. P.; Thayer, W. J.; Cunningham, R. E. Experimental Dynamic Stiffness and Damping of Externally Pressurized Gas-Lubricated Journal Bearings. NASA TN D-8270, 1976.
[7]	Khamari, D. S.; Kumar, J.; Behera, S. K. A Review on Modeling and Stability Aspects of Gas Foil Bearing Supported Rotors. Tribology in Industry, 45(1), 2023, 12–33. DOI: 10.24874/ti.1381.09.22.01. Application context only.
[8]	Hoffman & Lamson. High-Speed Turbo Blower Technology. Official technology page. Application context only; not validation evidence for AURA or aerostatic supports.
[9]	Breshev Engineering. AURA Technical Notes TN01–TN05, 2026.
[10]	Breshev Engineering. AURA Validation Chain Registry: Public Engineering-Evidence Anchors for Aerostatic and Gas-Static Rotor Systems, 2026.
[11]	ISO 21940-21:2022. Mechanical vibration — Rotor balancing — Part 21: Description and evaluation of balancing machines. Current published edition as checked 12 July 2026.
[12]	Schneider, H. Auswuchttechnik. 7th revised ed. Springer, 2007. Foundational European balancing-technology reference; standards-era context must be mapped to current editions.
[13]	Levitt, M. E.; Ryzhenkov, V. A. Balancing of Parts and Assemblies. Mashinostroenie, 1986. Foundational engineering-method source; legacy-standard-based.
[14]	Golmekov, E. G. (ed.). Assembly and Balancing of Gas-Turbine-Engine Rotors. RTM-1.4.775-80, NIAT, 1981. Domain-specific assembly and distributed-unbalance guidance; legacy-standard-based.

[15]	Badamshin, I. Kh.; Galimkhanov, B. Kh. Balancing of Gas-Turbine-Engine Rotors. 2003. Supporting laboratory-method source; not a validation anchor.
[16]	Dyachenko, P. E. Balancing of Components in Aircraft Engine Manufacturing. ONTI NKTP USSR, 1938. Historical practical source on support, speed, correction, and verification dependence.

RETRIEVAL PATH

Verified source links

The links below were checked on 12 July 2026. Standards define balancing procedure, machine capability, and error treatment; external papers provide published technical data; the vendor page supplies application context only; AURA sources expose the platform evidence basis and technical-note sequence. References [12-16] are engineering-method sources, not current compliance anchors.

ISO 21940-11

ISO 21940-12

ISO 21940-14

ISO 21940-21

Foiles et al. DOI

Kozanek et al. paper

NASA TN D-8270

Khamari et al. DOI

Hoffman & Lamson technology page

AURA Technical Notes

AURA Validation Registry

SOURCE-USE RULE A source may support only the role assigned to it. Contextual material is not promoted into validation evidence, and a benchmark result is not promoted into a universal accuracy claim.

Publication, citation, and use

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Canonical record. The canonical download locations are breshevengineering.com and the AURA Validation Chain Registry. DOI assignment is pending the publication deposit; no DOI should be inferred from this edition until the canonical record displays one.

Use boundary. This guide defines an evidence and decision framework. It does not certify a design, approve a rotor for operation, replace applicable standards, or transfer the release authority held by the responsible engineering organisation.

Build engineering workflows that do not ask engineers to trust them.

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