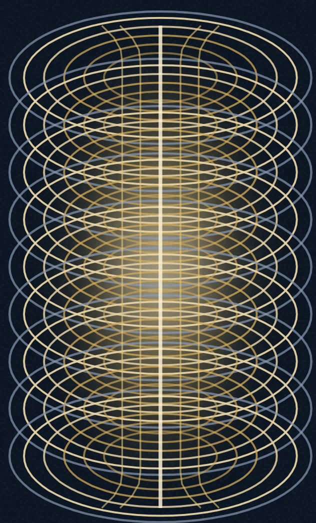
KRONOS FUSION ENERGY



PAPER III OF THE 2026 KRONOS SET

High-Field REBCO Magnets & Tape

Bore-Resolved Mechanics

One bore-resolved mechanics applied to two machines — a strain-first, stress-managed conductor architecture and an honest feasibility map.

REBCO · system-field 35 T · breeder centre-post 16.84 T · plug 26.49 T (resolved, FEA pending)

Explore it live — 3-D model · physics validator · film series

PREPARED BY P. I. FORD · R. J. WEGGEL · C. WEGGEL

2026 · EDITORIAL

KRONOS FUSION ENERGY · 2026

The Kronos Fleet

Fuel follows purpose, not platform.

Hyperion · Aegis · MetroVolt

THE OFFICIAL RECORD

What this document is, and how to read its numbers

This is a combined editorial. It gathers, in one volume, the two design studies Kronos Fusion Energy released in 2026 — a compact spherical-tokamak tritium/helium-3 breeder and a deuterium–helium-3 tandem-mirror generator — together with the intellectual-property estate, the people, and, in the internal edition, the full commercial case. The scientific text is the same text that appears in the arXiv preprints and the journal submissions; the editorial adds the apparatus a reader needs to hold the whole program at once, and nothing in the physics is altered to fit it.

THE HONESTY STANCE IS THE ASSET

Every headline quantity carries an **evidence class** — DERIVED RECOMPUTED MEASURED REQUIREMENT — and, where a number is a modelled extrapolation rather than a demonstrated value, it is labelled as such and its downside is shown next to it. Several quantities in the underlying corpus moved after first publication; where a value has been withdrawn or restated, the record says so plainly. This is deliberate: a diligence team will find the load-bearing assumptions, so the document surfaces them first.

TITLE	The Kronos Fleet — Hyperion · Aegis · MetroVolt: A Combined Design & Commercialization Study
AUTHOR	Priyanca Ford, Founder & CEO, on behalf of Kronos Fusion Energy
EDITION	2026 Combined Editorial · first issue
COMPANION WORKS	The five-paper arXiv drop — (1) Breeder, (2) Burner, (3) REBCO magnet & tape, (4) Direct Energy Conversion, (5) AI/ML/Quantum control — with matching numbered Zenodo deposits, plus the IOP journal and IAEA-FEC submissions. Patents were filed before the drop.
NAMING	Hyperion = the breeder; Aegis (defense) and MetroVolt (data-center) = one generator in two housings. Internal mode letters (D1, L) do not appear on public surfaces.
STATUS	Conceptual design & simulation study. Nothing herein is a construction commitment.

HOW TO READ THIS VOLUME

The fleet at a glance, and the way its numbers are marked

This volume opens with *Orientation*, presents the five research papers as a bound sequence, and closes with the *Apparatus*. *Foundations* sets out the three general results both machines rest on. *Paper One* is the Hyperion breeder; *Paper Two* the Aegis / MetroVolt generator; *Papers Three, Four and Five* are the enabling science — high-field REBCO magnets and tape, direct energy conversion, and the AI / ML / quantum control stack. A *Digital Twin & 3-D Model* part follows, then the *Environmental* profile. The *Economics* and levelized cost and the *Business Case* and diligence record appear in the internal edition only; the *Simulations* proof record and the Apparatus — patent portfolio, team, limitations, and sources — close both editions.

THE FLEET AT A GLANCE

	HYPERION	AEGIS	METROVOLT
Role	Strategic-isotope foundry	Defense installation power	Campus power
Machine	**Spherical tokamak**	**Tandem mirror**	**Tandem mirror**
Fuel	Deuterium–tritium	Deuterium–helium-3	Deuterium–helium-3
Delivers	Tritium · ^{3}He · 14 MeV n	Resilient installation power	Firm campus power
Physics bar	**Fusion gain only**	Closure (gates named)	Closure + lunar ^{3}He
In the fleet	Breeds the fuel	Proves the generator	Commercial destination

HOW THE NUMBERS ARE MARKED

Every headline quantity carries an evidence class — DERIVED from first principles, RECOMPUTED from raw data, MEASURED in hardware, or a REQUIREMENT yet to be met. Financial figures carry a case label and are confined to the internal (confidential) edition. Values that moved after first publication are shown as withdrawn or restated rather than quietly changed. A capability you can evaluate is one whose limits are on the page.

ABSTRACT

High-Field REBCO Magnets & Tape — Bore-Resolved Mechanics

The magnet paper does one thing carefully and applies it twice: bore-resolved hoop stress, which scales with the winding bore — exactly what worst-case derating hides. Applied to the two machines, the binding constraint flips: the breeder's centre-post is stress-comfortable at 16.84 T, while the burner's small-bore plug coil is infeasible *as a bare winding*. That bound is then resolved by a stress-managed structural shield that closes the full 26.49 T plug at ~60% strain margin, feasible-pending-FEA. Two claims kept strictly apart: 35 T is a field-capability claim about the conductor, not a coil record.

Companion deposit (code & data, reproducible under CC BY 4.0): DOI 10.5281/zenodo.21842514 · Zenodo community *kronos_fusion_energy*.

Explore it live: interactive 3-D model · run the physics validator · companion film series (the deposited solvers, in the browser).

Keywords: REBCO · high-field magnets · bore-resolved mechanics · structural shield · feasibility map

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PORTFOLIO, PEOPLE & RECORD

NOMENCLATURE

Symbols, units, and the names of things

Q	plasma (fusion) gain, P_{fus}/P_{aux}
Q_E	engineering gain, net electric out / recirculating in
H_{98}	confinement enhancement over the IPB98(y,2) scaling
Z_{eff}	effective ion charge
c_{ee}	electron–electron bremsstrahlung leading coefficient, 2.120022 (exact)
τ_E	energy confinement time
I_p	plasma current
R_0, a	major radius, minor radius
κ, δ	elongation, triangularity
β_N	normalized plasma beta (Troyon-normalized)
TBR	tritium breeding ratio
DEC	direct energy conversion
CF	plant capacity factor (availability)
FOAK / NOAK / BOAK	first / n^{th} / best of a kind
Hyperion	the ST breeder (internal: Mode D2)
Aegis	the generator, defense/installation housing (internal: Mode M)
MetroVolt	the generator, data-center housing (Mode M)

§ 1

The enabling technology, and the limit that is not the current

The enabling technology of compact fusion is the high-field REBCO magnet, and the first thing to say about it is that its binding engineering limit is *not* the conductor's critical current. REBCO coated conductors carry supercurrent at fields above 20 T and temperatures above 20 K that low-temperature superconductors cannot reach, and that capability underlies essentially every compact-fusion concept now under development. Laboratory REBCO magnets have reached **32.35 T** all-superconducting and **45.5 T** in a small no-insulation test coil; the fusion-relevant demonstrated record is the ≈ **20 T** SPARC toroidal-field model coil. In this regime the limiting engineering quantity is the *mechanical strain* the winding may carry: REBCO degrades irreversibly above $\epsilon \approx 0.4–0.6\%$ and delaminates under transverse tension, and the Lorentz hoop stress that drives that strain scales, for a solenoidal winding, as

$$\sigma_\theta \approx \tfrac{1}{2} J_{wp} B a \qquad (1)$$

the product of winding-pack current density, field, and coil *radius*. Managing strain, not chasing field, is the design problem — and because the stress carries an explicit factor of the bore radius *a*, the same conductor and the same field can be comfortable in one machine and impossible in another. That single dependence is the spine of this paper. DERIVED

WHAT IS NEW HERE, AND WHAT IS NOT

This paper treats the conductor and the winding as one system, and it is deliberate — unusually so — about the boundary between analysis and invention. Three things are made explicit. First, the **conductor**: a multilayer "S.M.A.R.T." REBCO architecture built to a strain-first philosophy. Its three distinguishing ideas — a V_2O_3 metal–insulator-transition "smart" quench interlayer, a graphene-reinforced aluminium bypass stabiliser, and a work-hardened MP35N reinforcement — are each grounded in prior art by others; the contribution is analysis, not invention. Two of those ideas are reported as failing their own premise: the aluminium bypass is *unsupported* at the operating field, and MP35N as the epitaxial growth substrate is *infeasible*. Second, the **winding method** — a per-turn, as-built-data-driven preload placement and a per-coil qualification that replaces worst-case derating. This is the genuinely new, separately filed contribution, and it is the commercial core. Third, an honest **two-machine feasibility map**.

THE CENTRAL RESULT IS AN HONEST NEGATIVE

Applying one bore-resolved mechanics — validated to **0.8%** against a closed-form elasticity solution — across two dissimilar Kronos machines, the binding constraint *flips*. The spherical-tokamak centrepost is stress-comfortable with a realisable design point but is coil-field and neutron-lifetime limited. The tandem-mirror end-plug, at its physically required bore of **0.648 m**, is stress- and strain-bound: a bare winding gives a peak hoop stress **2.7–3.9**× the reinforced allowable and an inner-turn strain **4.6–6.5**× the 0.40% irreversible cap, with engineered pre-load reducing peak strain by only ≈ **11%**. We regard that quantified negative as the most useful single output, because it states precisely what a buildable plug would require — and, in the resolution that follows, how a stress-managed structural shield closes it.

TWO CLAIMS, KEPT APART THROUGHOUT

The paper separates cleanly what the conductor *enables* from what a coil can *realise*. REBCO's upper critical field exceeds 100 T at 4.2 K, so a 35 T operating point is one-third of the material limit — a **field-capability statement about the conductor**, which may be made without qualification. What a coil realises is bore- and stress-dependent and is a different claim entirely. The 35 T figure is never a coil record; conflating the two is the error this paper is built to avoid.

THE PROVENANCE DISCIPLINE

Kronos operates no magnet and has measured no tape. Every conductor number is public data applied to a winding; every geometric input is labelled sourced or design-assumption; and the two field records used only as capability bounds were retrievable in abstract only. Where a quantitative verdict is drawn, analytic scalings are replaced by a two-dimensional axisymmetric finite-element solution, mesh-converged and validated against the Lamé thick-cylinder result. Nothing here is a Kronos measurement.

NOMENCLATURE FOR THIS PAPER

Σ_{Θ}	winding hoop (azimuthal) stress; bore-resolved form $\sigma_\theta \approx \frac{1}{2} J_{wp} B a$
J_{WP}, J_C	winding-pack engineering current density; conductor critical current density
B, A, A_1	magnetic field; coil radius; coil inner bore radius
E_{OP}, E_{ALLOW}	operating strain (0.233%); irreversible-strain cap (0.40%)
H_{C2}	upper critical field (> 100 T for REBCO at 4.2 K)
Λ	superconductor fill factor of the winding pack (≈ 0.0134)
Φ, Φ_{THR}	fast-neutron fluence; REBCO I_c-degradation threshold (≈ 3.9×10^{22} m^{-2})
MIT · NI	metal–insulator transition (of the V_2O_3 layer) · no-insulation winding

Managing strain, not chasing field, is the design problem — and the bore is what decides it.

§ 2

The S.M.A.R.T. multilayer conductor — a strain-first architecture

The conductor is a seven-layer coated conductor: a work-hardened MP35N reinforcement, a textured oxide buffer stack, the REBCO film, a silver cap, a V_2O_3 “smart” quench interlayer, a graphene-reinforced aluminium bypass, and a copper stabiliser. The design philosophy is **strain-first**: rather than constrain a conventional tape with massive external structure, the reinforcement and pre-compression are built in so the brittle REBCO film sees near-zero net tensile strain in operation. The architecture and each of its three distinguishing layers were previously disclosed by Kronos and are individually grounded in prior art by others; the contribution of this section is a reproducible, basis-tagged assessment, not a claim of new invention.

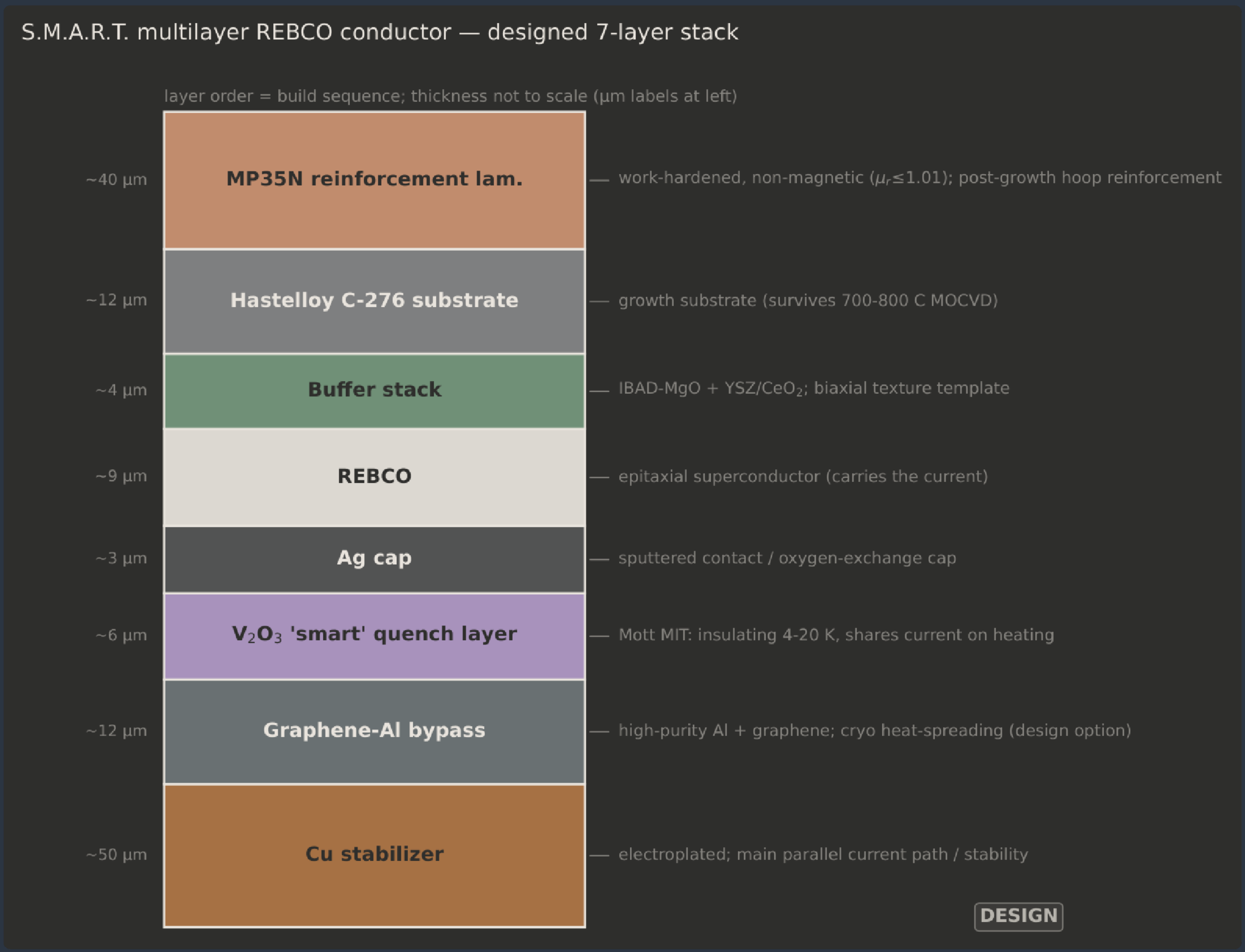

FIGURE 1. The S.M.A.R.T. multilayer REBCO coated-conductor architecture (schematic cross-section), each layer's role annotated: MP35N reinforcement, textured buffer stack, REBCO film, silver cap, V_2O_3 smart-quench interlayer, graphene-reinforced aluminium bypass, and copper stabiliser. No layer implies a Kronos-fabricated or measured sample. DESIGN ARCHITECTURE

THE V_2O_3 "SMART" QUENCH INTERLAYER — PRIOR ART, REANALYSED

The interlayer exploits the metal–insulator transition (MIT) of V_2O_3: insulating at the 4–20 K operating point and switching conductive as a local hot spot heats it through its transition (≈ 150–168 K bulk), so the winding behaves as no-insulation *only when it needs to* — self-protecting on quench, insulating (fast ramp, low screening loss) otherwise. **This concept is not new.** MIT-based "smart insulation" for REBCO coils, explicitly naming vanadium oxide, is claimed in prior patents, and vanadium-oxide coatings that self-regulate current sharing have been demonstrated on high-temperature superconductors by other groups. Our contribution is a reproducible switching-transient and comparative quench trade-space model, calibrated to public data. We present it as analysis of a known concept, not a Kronos invention. MODELLED · CONCEPT IS PRIOR ART

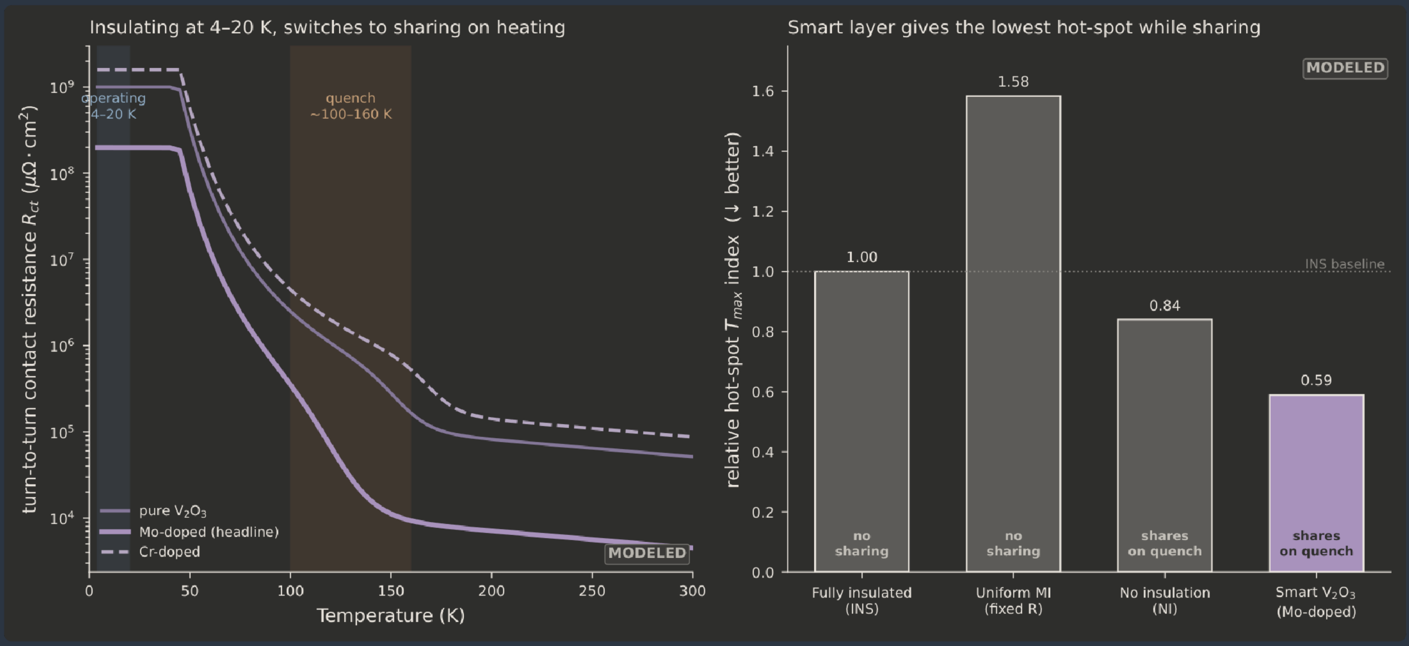

FIGURE 2. Modelled V_2O_3 turn-to-turn switching: resistivity versus temperature (insulating at operation, conductive across the transition) and the resulting quench self-protection trade-space against uniform NI and insulated baselines. MODELLED · PRIOR ART

THE GRAPHENE-REINFORCED ALUMINIUM BYPASS — AN HONEST REASSESSMENT

The architecture posits a high-RRR graphene-reinforced aluminium bypass to out-perform copper's magnetoresistance above 25 T. A Kohler-scaling analysis finds the premise misleading in exactly the regime that matters. Copper at 30 T with tape-grade RRR ≈ 100 has $\Delta\rho/\rho_0$ ≈ **9.5**, while RRR ≈ 1000 aluminium has ≈ **2.9** — but aluminium's smaller *relative* magnetoresistance is bought entirely by its ten-fold-higher RRR, not by any field insensitivity, and the advantage evaporates once the RRR is degraded by the reinforcement a structural conductor requires. We report this claim as **unsupported at the operating field**: copper is adequate. ~~CLAIM UNSUPPORTED~~

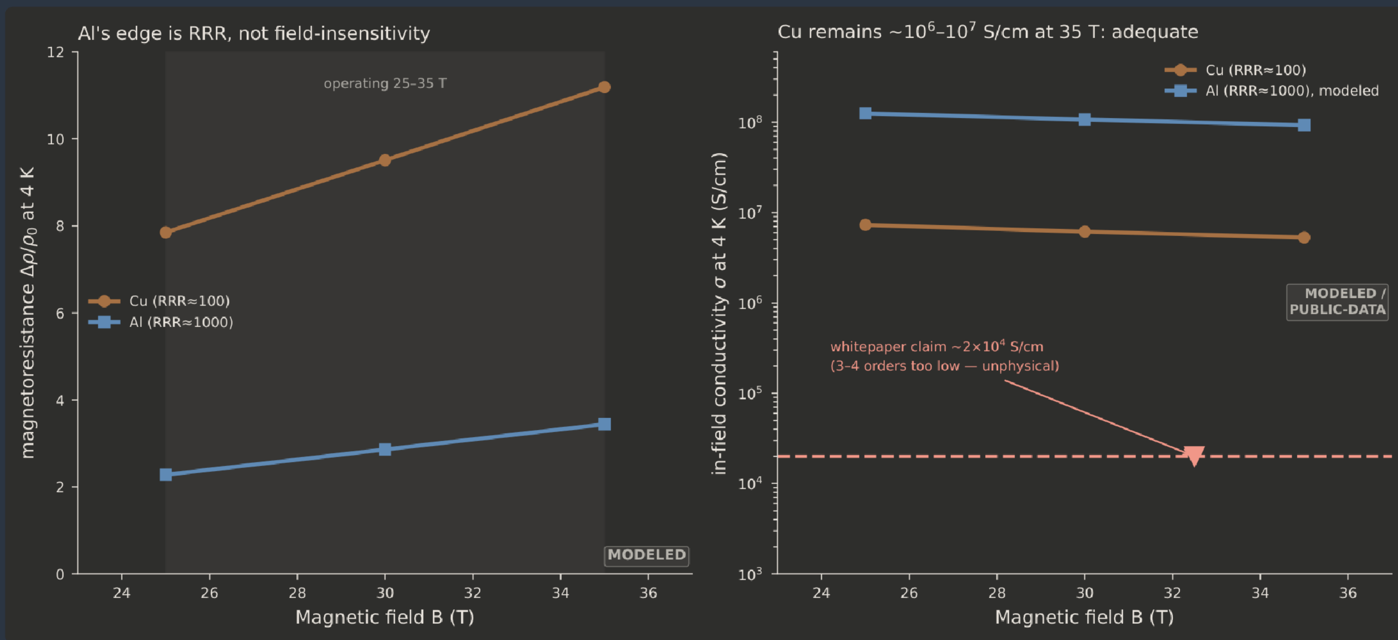

FIGURE 3. Magnetoresistance of copper versus high-RRR aluminium under Kohler scaling. The aluminium advantage is an RRR effect, not field insensitivity, and does not survive the reinforcement needed for a structural conductor. Modelled from public ρ(B, RRR) data; verdict: claim unsupported. ~~UNSUPPORTED~~

MP35N REINFORCEMENT AND THE STRAIN-FIRST BUDGET

MP35N — a work-hardened Co–Ni–Cr–Mo alloy with cryogenic yield ≳ 2 GPa — is the strain-first backbone. A necessary correction travels with it: MP35N *cannot* serve as the epitaxial REBCO **growth** substrate. Textured-buffer growth requires a Hastelloy- or Ni–W-class base, so MP35N is defensible only as a post-growth reinforcement lamination, which is standard practice. With that correction, the strain-first budget — built-in pre-compression via a shrink-fit carbon-fibre overwrap and a bucking cylinder — closes with positive margin at a feasible bore, holding the REBCO film near its neutral point against the 0.40% irreversible cap. Its behaviour at the small mirror bore is the subject of the two-machine map below. ~~MP35N AS SUBSTRATE INFEASIBLE~~

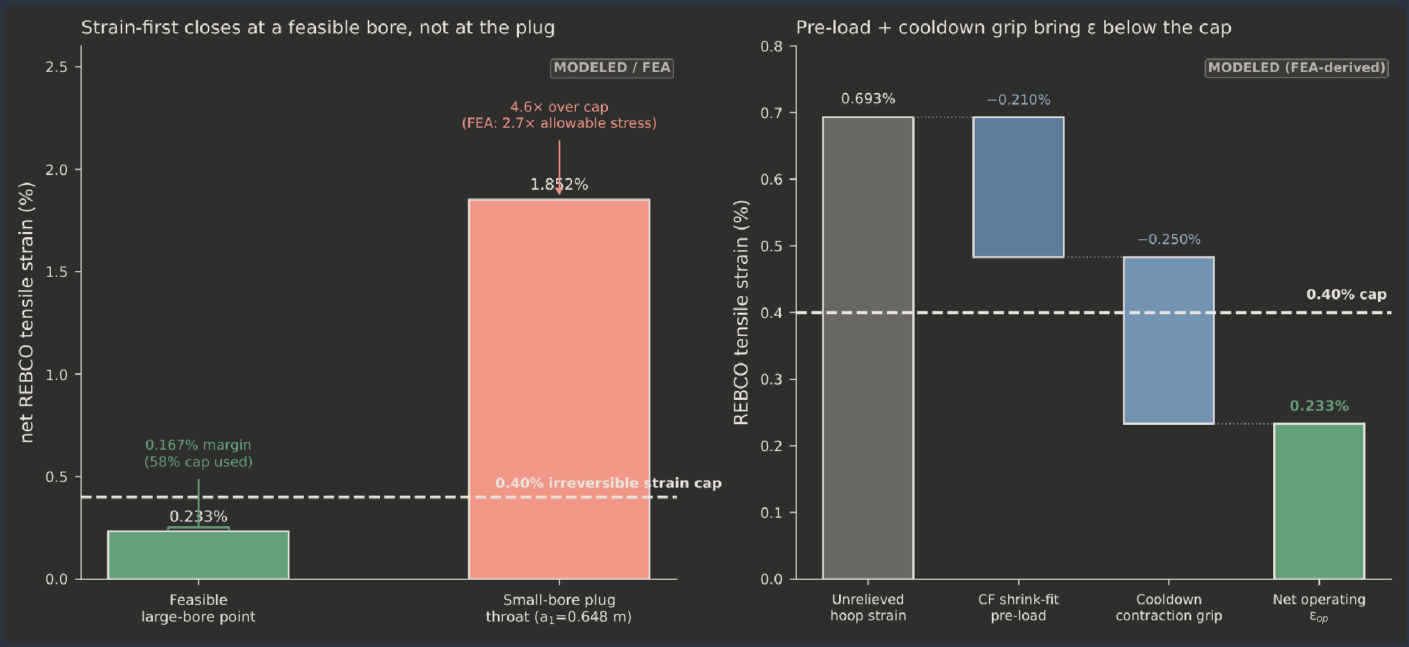

FIGURE 4. Strain-first budget: built-in pre-compression offsets the Lorentz tensile strain so the REBCO film operates near the neutral point, against the 0.40% irreversible cap. MP35N enters as reinforcement lamination, not growth substrate. DESIGN-STUDY

PERFORMANCE ENVELOPE — DESIGNED, NOT MEASURED

Two points on the performance envelope are load-bearing and honest. First, REBCO's upper critical field exceeds **100 T** at 4.2 K, so a **35 T** operating point is ≈ 1/3 of the material limit — and this is a field-capability statement about the conductor, which may be made without qualification. Second, no value shown is a Kronos measurement: Kronos has coated and characterised no tape, and the design's own documentation states its critical current is *inferred*, not measured. We preserve that discipline exactly.

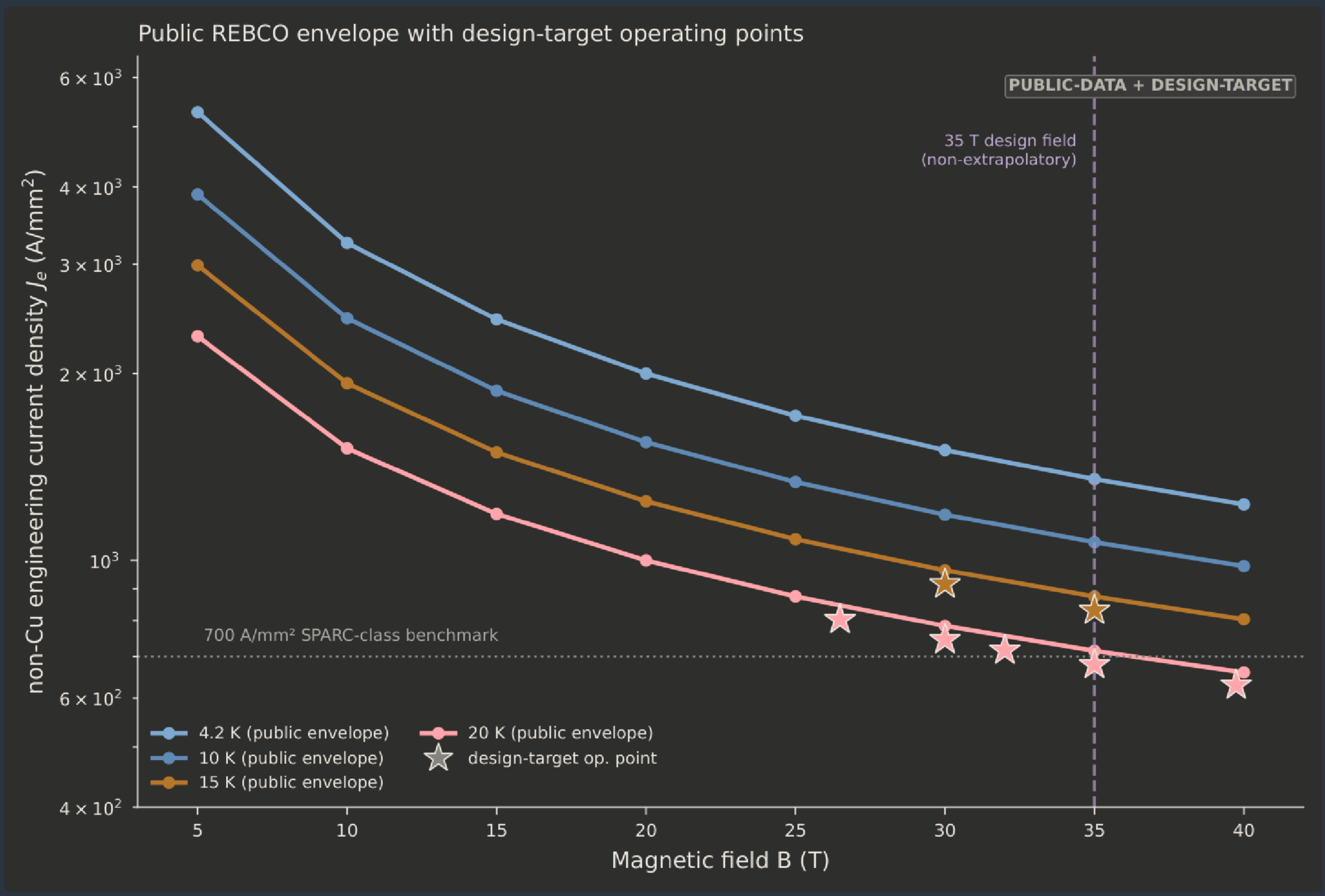

FIGURE 5. Conductor design targets on the public REBCO J_c(B,T) envelope, strain-derated to the operating point. REBCO H_{c2} > 100 T places 35 T at ≈ 1/3 of the material limit. Public data (envelope) plus design targets (points); no Kronos measurement. DESIGN TARGET

NOVELTY POSITION

The honest novelty adjudication of the conductor is unambiguous: the smart-quench concept is prior art; the aluminium bypass and the integrated stack are incremental; MP35N-as-substrate is infeasible; and the 35 T *field* capability is public REBCO physics. The conductor section is therefore explicitly one of *analysis*, not disclosure. The separately novel, filed contribution is the winding method, to which we now turn.

Novelty & defensibility of the S.M.A.R.T. tape's claimed innovations

Claimed innovation	Prior art exists (others)?	Verdict	Defensibility (1-5)	New patent filing?
V_2O_3 'smart' quench layer (headline)	Y	PRIOR-ART	●○○○○	N
Graphene-Al stabilizer	Y	INCREMENTAL	●●○○○	N
MP35N as growth substrate	Y	INFEASIBLE	●○○○○	N
MP35N reinforcement lamination	Y	INCREMENTAL	●●●○○	Weak-Y*
Integrated 7-layer architecture	Y	INCREMENTAL	●●●○○	N
REBCO field capability ($H_{c2} \gg 35$ T)	Y	PRIOR-ART	●●●●●	N

Novelty judged vs EXTERNAL prior art (others' patents/papers). Kronos's own design docs are INTERNAL — not prior public disclosure.
No innovation is Kronos-novel; the paper's contribution is reproducible ANALYSIS of already-known concepts. *Weak-Y: only the non-magnetic MP35N post-growth reinforcement lamination is a possible narrow filing (counsel review).

FIGURE 6. Novelty matrix for the conductor: each element against the closest public prior art, with an honest verdict — prior-art / incremental / infeasible / public-physics. Basis: DOI- and patent-resolved prior-art adjudication. PRIOR-ART ADJUDICATION

§ 3

The winding method — the genuinely new, filed contribution

Everything above is analysis of known art. The method is not. Two method elements are the paper's genuinely new, separately filed contribution, and they are the commercial core of the estate.

TWO METHOD ELEMENTS

(i) Per-turn pre-load placement. A spatially graded, turn-by-turn residual compression is computed from the coil's own as-measured $J_c(B,T,\epsilon)$ and as-wound metrology, so each turn's pre-compression offsets *its* predicted operating strain — distinct from the uniform pre-stress of the public record.

(ii) As-built qualification. The same per-coil model certifies an operating envelope in place of worst-case conductor derating, recovering usable J_{wp}. We claim the method — the per-turn, as-built-data-driven placement and per-coil qualification — not a specific algorithm.

The distinction matters commercially as well as physically. The public record pre-stresses uniformly and then derates the whole coil to its worst turn; this method reads each coil as built and places compression where that coil actually needs it, then qualifies the coil against its own measured envelope. Where a worst-case derate throws away margin on every good turn, the as-built qualification recovers it. The method is general and sound; whether a *particular* geometry can be rescued by it is a separate question — and, as the mirror plug shows below, sometimes the answer is no.

§ 4

Bore-resolved winding mechanics — the bore-stress ceiling

The field is not the difficulty. The required plug throat field is reported as a pair — **26.49 T** (self-consistent) and **39.74 T** (thermal end of the bracket) — and both values sit *below* the laboratory REBCO records. WHAM, the SPARC toroidal-field model coil, the NHMFL 32.35 T all-superconducting magnet, and the 45.5 T no-insulation test coil all bracket or exceed the requirement. Two existing all-superconducting magnets already stand above it. The conductor can make the field; the question is whether a coil can survive the stress that field implies at the bore the machine demands.

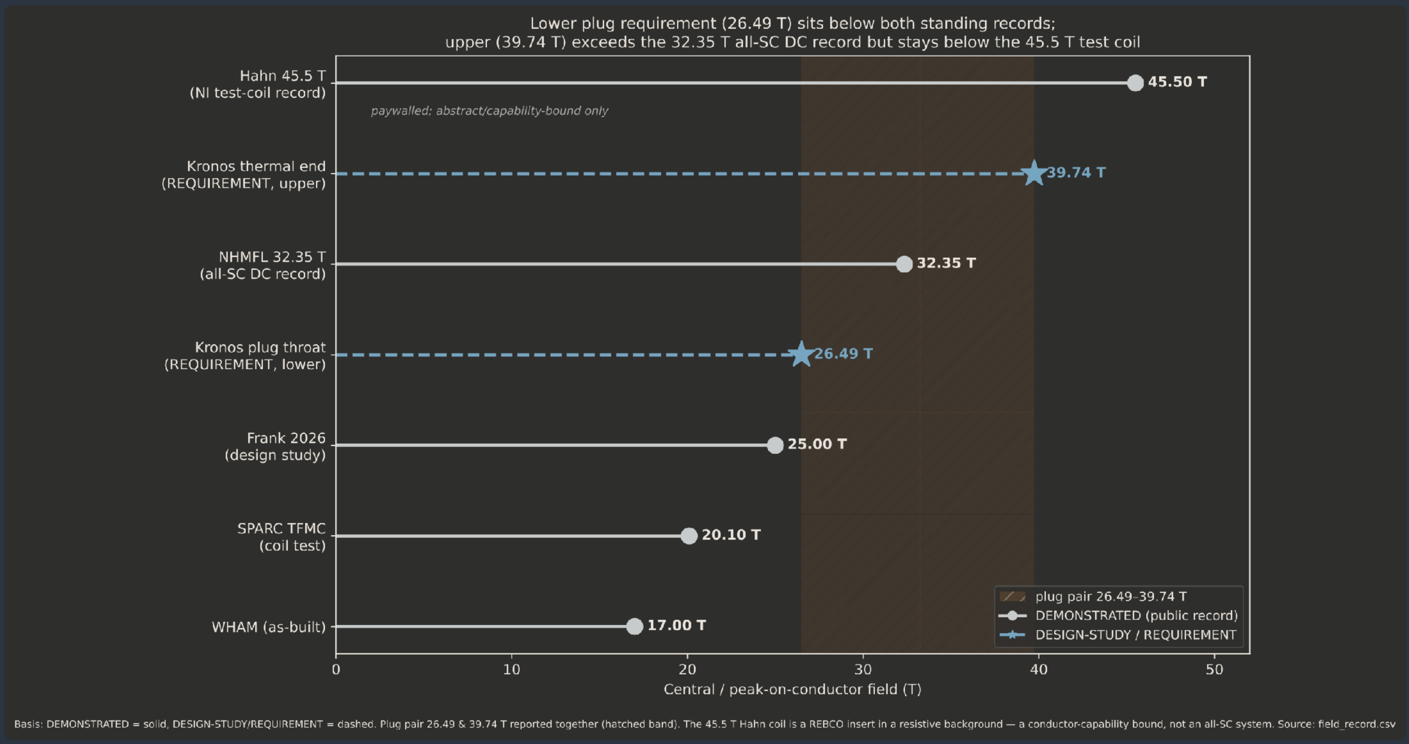

FIGURE 7. Field ladder: the required plug pair (26.49–39.74 T) against the public REBCO record — WHAM, the SPARC TFMC, the NHMFL 32.35 T all-superconducting magnet, and the 45.5 T NI test coil. The requirement sits below two existing all-superconducting magnets. Demonstrated records (public) vs requirement (Kronos). REQUIREMENT

CONDUCTOR J_C FIXES THE OPERATING TEMPERATURE AT 4.2 K

Strain-derated J_c(B,T) from the public record fixes the design temperature. At the 39.74 T thermal end the 20 K engineering J_c falls below the winding benchmark and recovers only at 4.2 K, so the design temperature is fixed at **4.2 K**. Twenty kelvin is infeasible at the thermal end of the bracket; the machine is a 4.2 K design. PUBLIC J_C DATA, STRAIN-DERATED

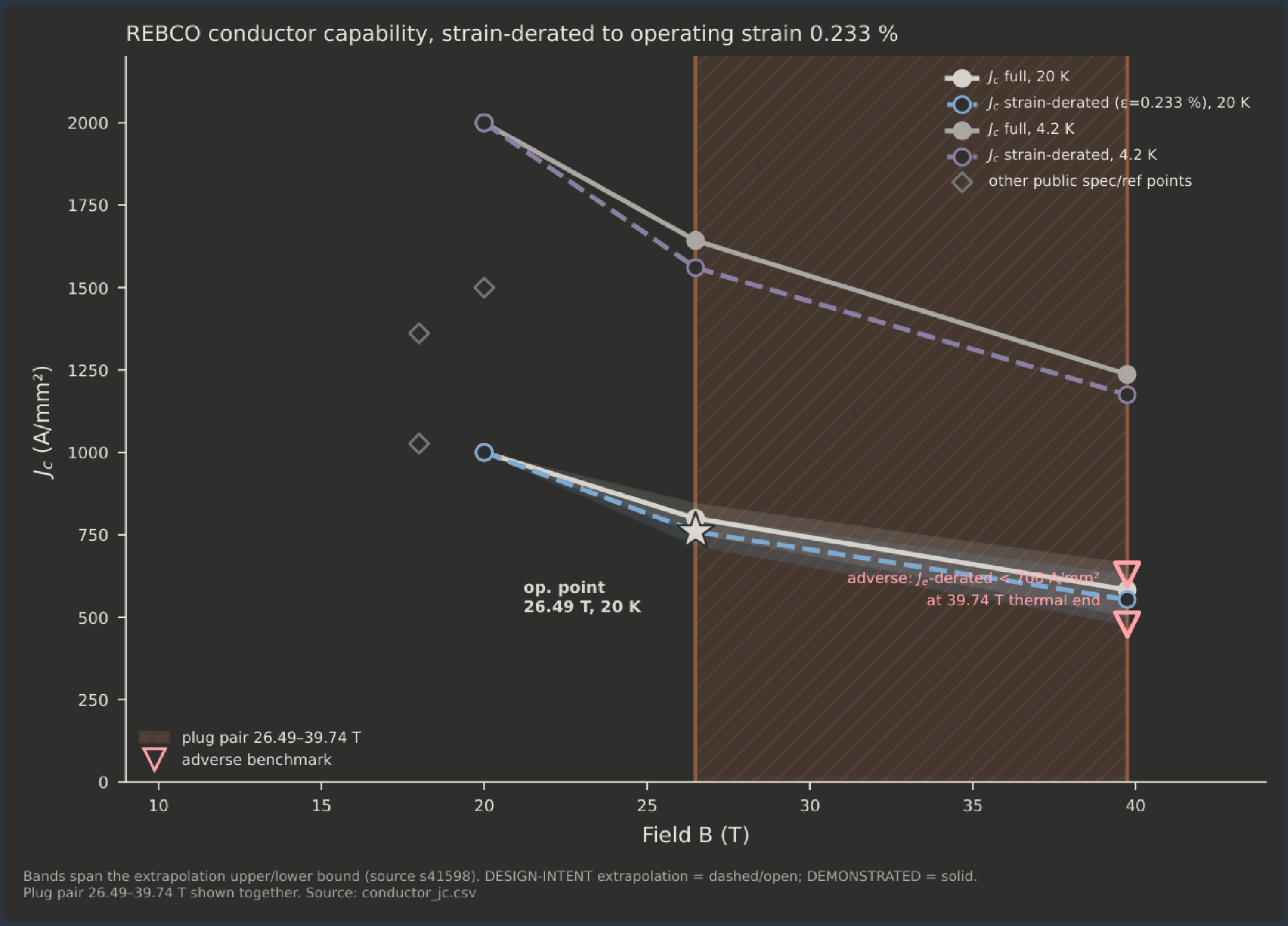

FIGURE 8. Strain-derated J_c(B,T) at 20 K and 4.2 K with the plug operating pair marked; 20 K is infeasible at the thermal end, fixing the 4.2 K design temperature. Public J_c data, strain-derated (design-intent). PUBLIC DATA · DESIGN-INTENT

BORE-RESOLVED STRESS, AND WHY A FIELD-ONLY SCALING MISLEADS

For a thin winding, force balance gives $\sigma_\theta \approx ½ J_{wp}Ba$; the essential feature is the explicit dependence on *bore* a. A field-only scaling $\propto B^2$ has no bore dependence and is not transportable between coils of different size. Applied to the operating NHMFL 32.35 T and 45.5 T magnets it demands **1561** and **3088 MPa** respectively — declaring built, operating coils “unbuildable.” We use the field-only scaling nowhere as a load model. Where a verdict is drawn, the analytic relation is replaced by a two-dimensional axisymmetric finite-element solution, mesh-converged and validated against the Lamé thick-cylinder solution to **0.8%**. The bore-resolved relation is standard thick-solenoid mechanics; it is stated here as the design basis precisely because its bore dependence is what discriminates the two applications.

FEA VALIDATED TO 0.8%

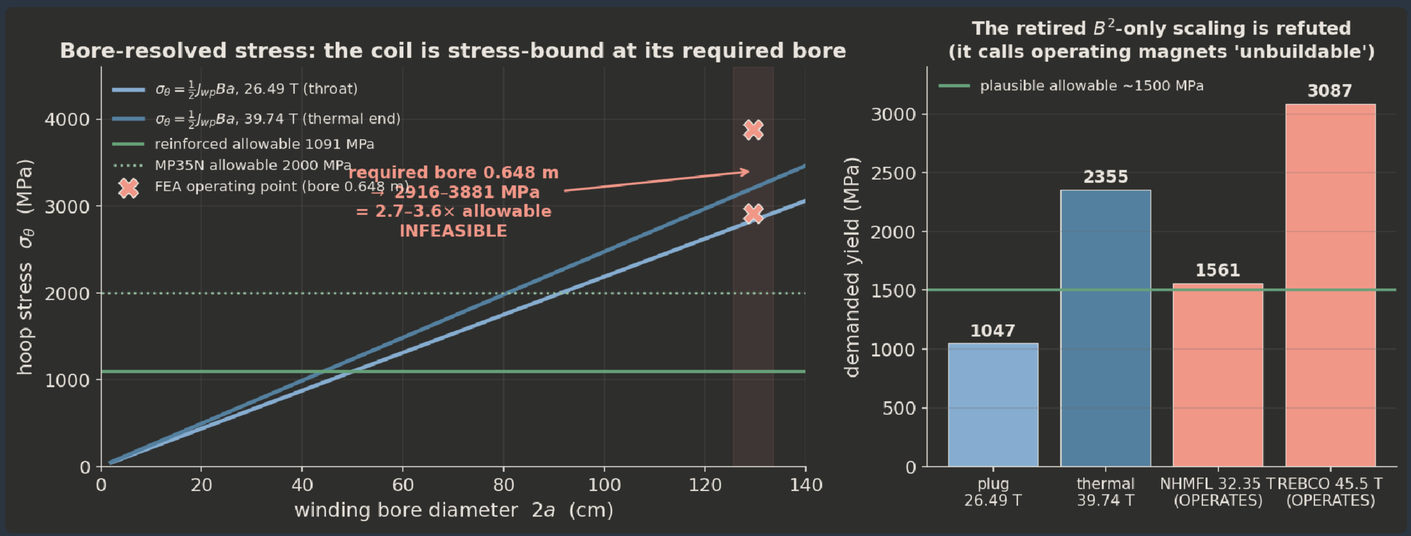

FIGURE 9. Bore-resolved hoop stress $\sigma_\theta \approx ½ J_{wp}Ba$ versus the refuted field-only B^2 scaling, which calls the operating 32.35 T and 45.5 T magnets unbuildable (1561 and 3088 MPa). The field-only scaling is shown only as the refuted comparison. DESIGN-STUDY

§ 5

Structural stack, fill factor, and achievable J_{wp}

The winding is a co-wound REBCO/MP35N pack with a carbon-fibre hoop overband and a composite bucking cylinder. The superconductor fill factor is **$\lambda \approx 0.0134$** — 1.34% of the pack cross-section is superconductor — which sets the achievable pack current density $J_{wp} = J_c\lambda$. The achievable J_{wp} exceeds the field-producing requirement across the full plug pair, with margin: the conductor supplies the field. The open question is not whether the field can be produced but whether the structure survives the resulting stress.

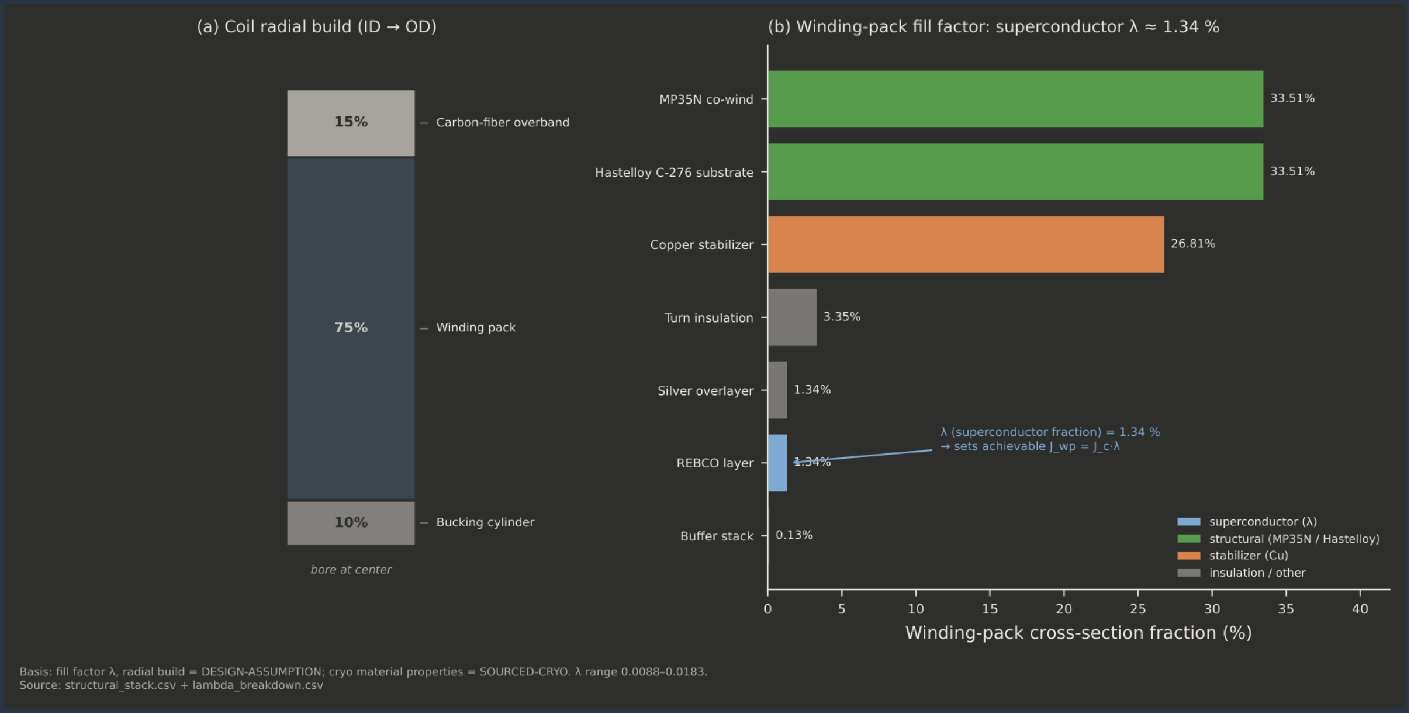

FIGURE 10. Structural stack (radial build) and winding-pack cross-section fractions; λ ≈ 1.34% superconductor fraction sets the achievable pack current density. Sourced-cryo material data plus design-assumption build. SOURCED + DESIGN-ASSUMPTION

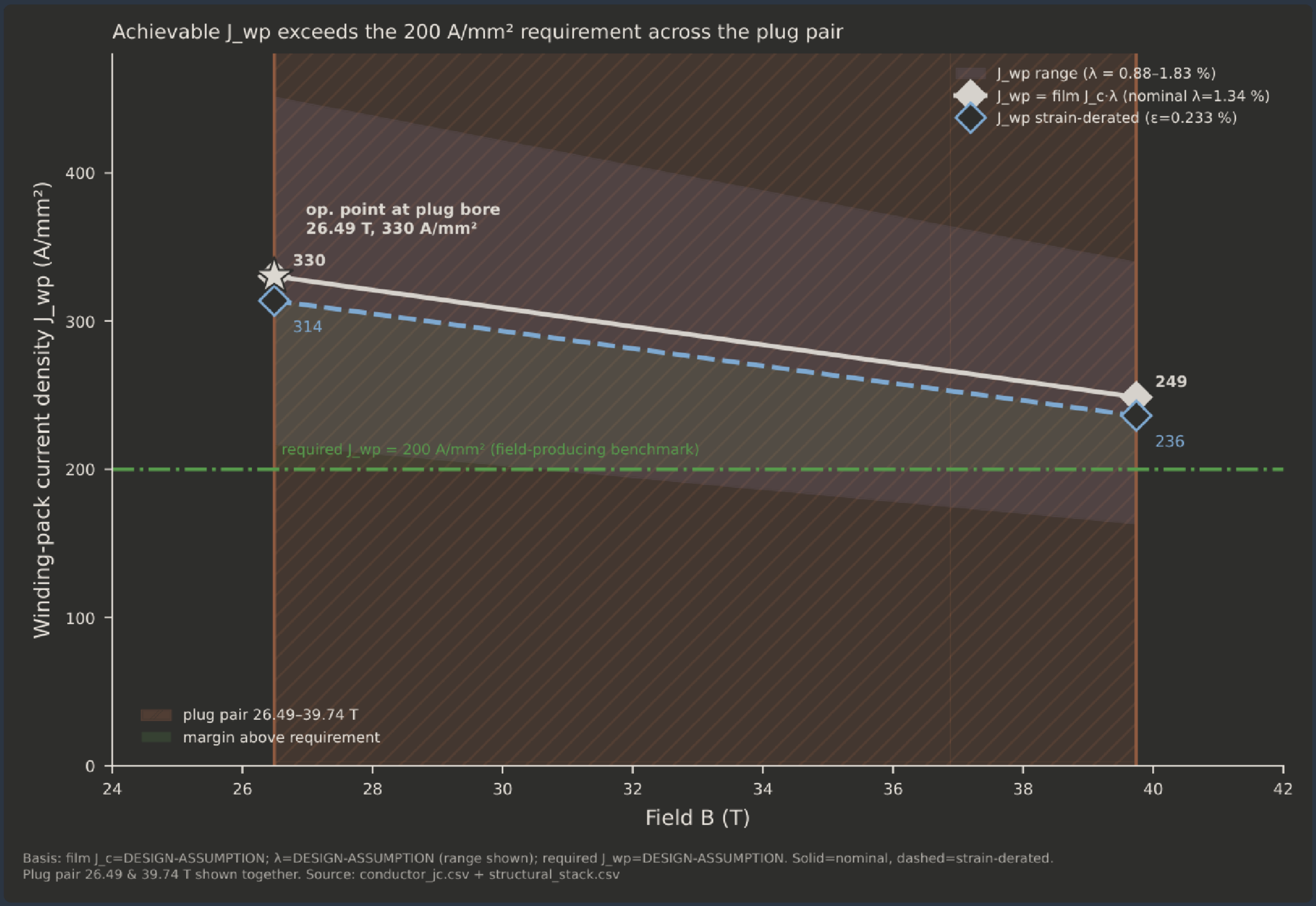

FIGURE 11. Achievable $J_{wp} = J_c\lambda$ versus field against the field-producing requirement; the conductor supplies the field across the plug pair with margin. DESIGN-STUDY

§ 6

The plug coil — bound at its bore, and its resolution

Here the study delivers its central quantitative result, and it is a negative. The plug's physically required bore is set by flux conservation from the central cell: $\mathbf{a_1 \approx 0.648}$ **m** — an order of magnitude larger than an early small-bore assumption, and because $\sigma_\theta \propto a$, decisive. The bore is the whole story.

PRE-LOAD MANAGEMENT RETURNS A NEAR-NULL IMPROVEMENT AT THIS BORE

The per-turn pre-load shifts inner-turn strain from tension toward compression, and a differential-evolution optimiser converges the placement cleanly. But at the plug's physically required bore the pre-load reduces the peak inner-turn strain by only **≈ 11%**. The optimiser *converges* — and then floors the max-strain/allowable objective at **4.6–6.0**, far above the feasibility limit of unity. This is the honest null of the study: a sound, general method, applied to this geometry, cannot move the answer across the feasibility line. The method is not at fault; the bore is. The accumulated peak strain stays 4.6–6.5× over the 0.40% cap across load cycles. DESIGN-STUDY (2-D FEA)

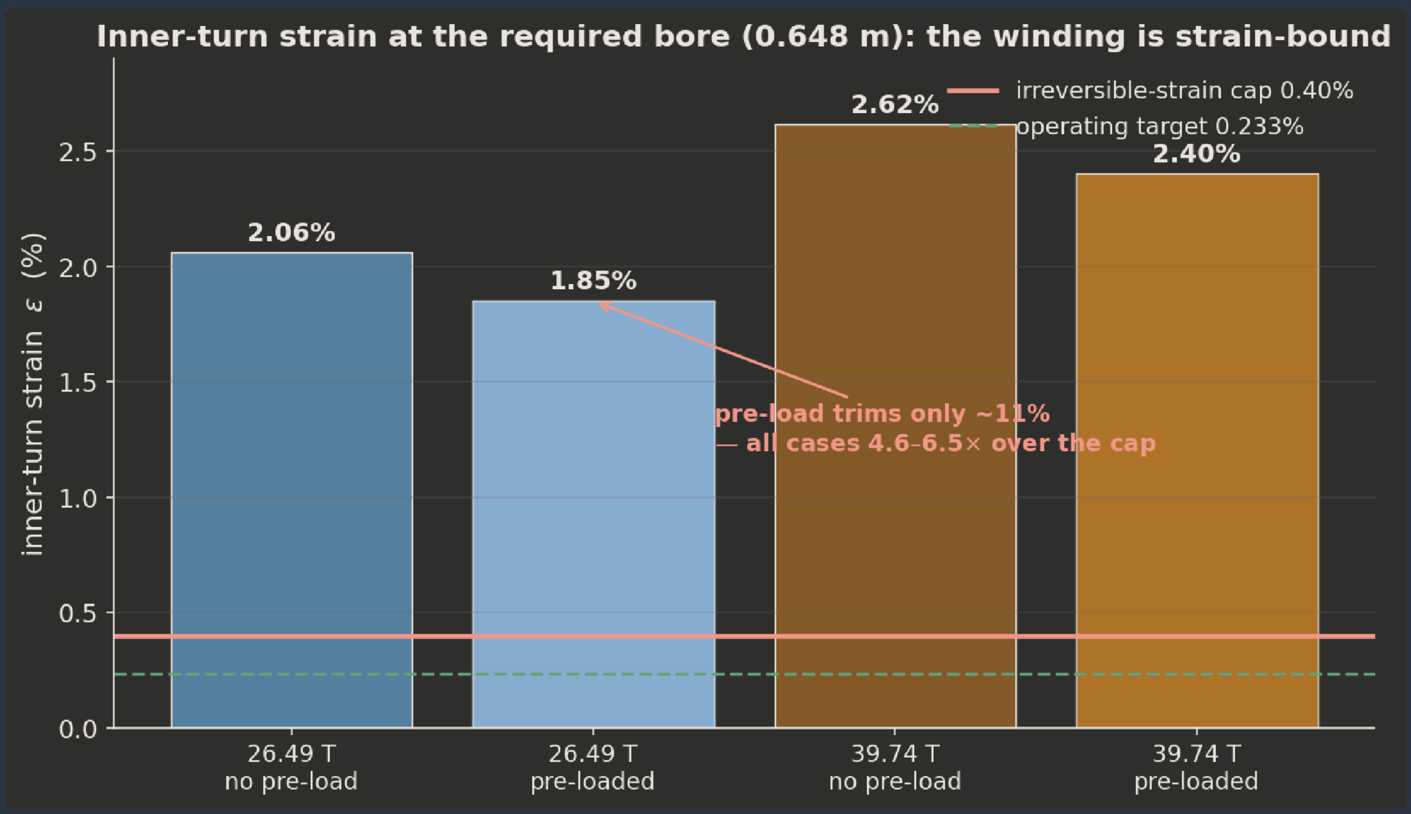

FIGURE 12. Inner-turn strain at the required plug bore (0.648 m), no-pre-load versus pre-loaded, for both plug fields against the 0.40% irreversible cap. Pre-load trims the peak by only ≈ 11%; every case sits 4.6–6.5× over the cap — the winding is strain-bound. DESIGN-STUDY (2-D FEA)

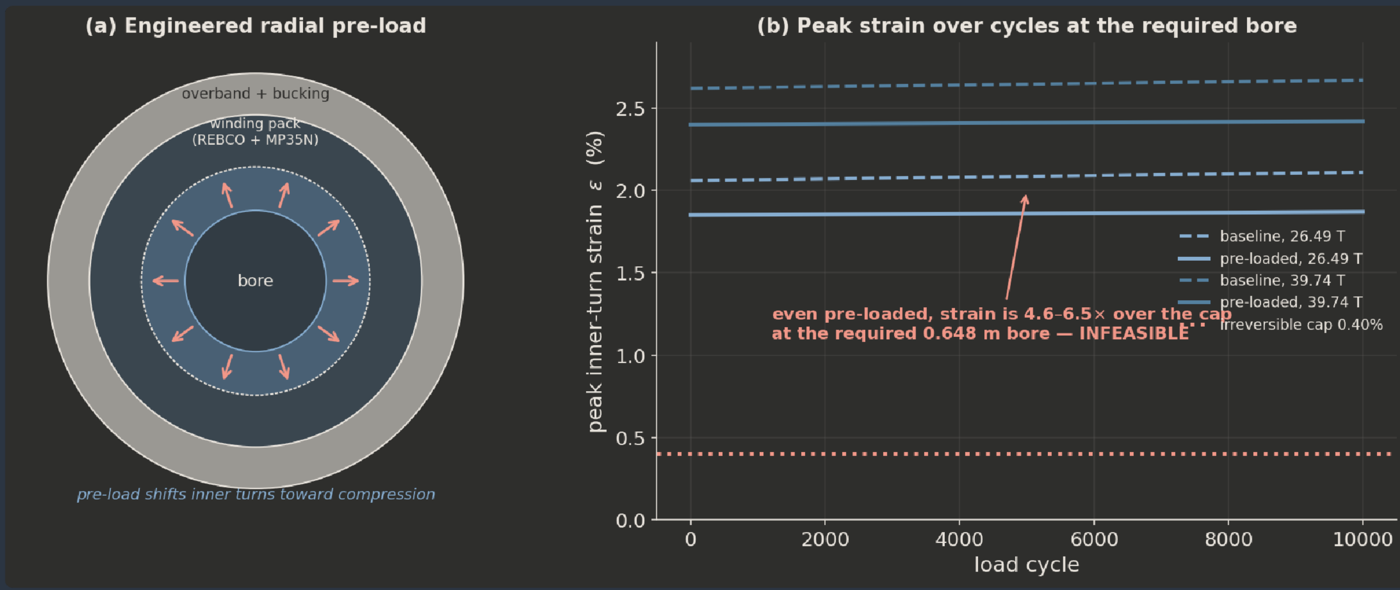

FIGURE 13. Engineered radial pre-load (schematic) and peak inner-turn strain over load cycles at the required 0.648 m bore. Even pre-loaded, strain remains 4.6–6.5× over the 0.40% cap. DESIGN-STUDY

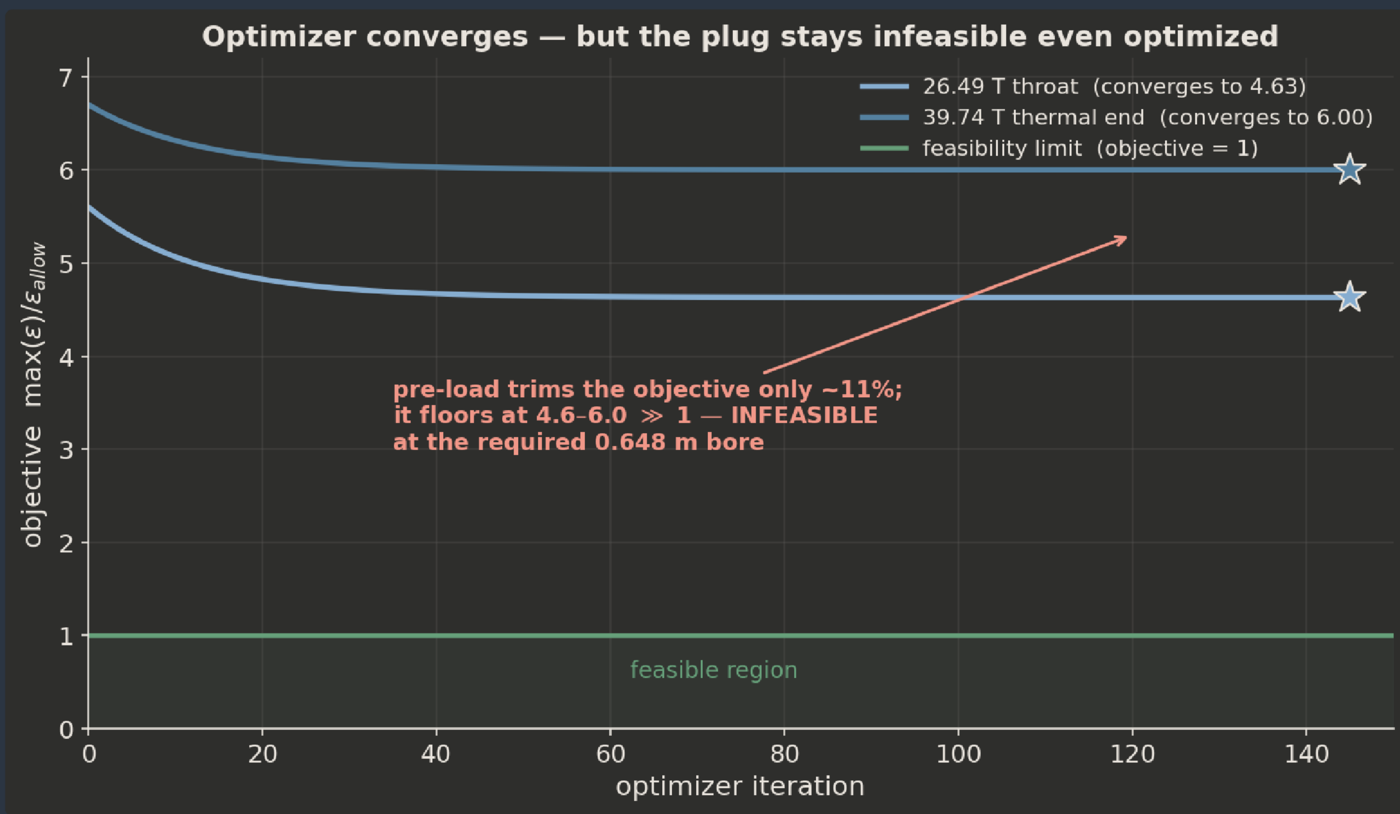

FIGURE 14. Differential-evolution convergence of the max-strain/allowable objective. The optimiser converges but the objective floors at 4.6–6.0 — far above the feasibility limit of unity — so the plug remains infeasible even optimised. DESIGN-STUDY

THE BARE-WINDING VERDICT

The two-dimensional FEA at a_1 = 0.648 m gives a peak hoop stress of **2916–4253 MPa** — **2.7–3.9**× the reinforced allowable — and an inner-turn strain of **1.85–2.62%**, which is **4.6–6.5**× the 0.40% irreversible onset, with engineered pre-load reducing peak strain by only ≈ 11%. Stated without softening: **at its physical bore the small-bore mirror plug coil is structurally infeasible as a bare winding** with the assumed pack current density and reinforcement.

0.648 m
REQUIRED PLUG BORE A_1
flux-conserved from the central cell — decisive because $\sigma \propto a$

2.7–3.9×
PEAK HOOP / REINFORCED ALLOWABLE
2916–4253 MPa, bare winding

4.6–6.5×
INNER-TURN STRAIN / 0.40% CAP
1.85–2.62% strain

≈ 11%
PEAK-STRAIN REDUCTION FROM PRE-LOAD
a near-null — the method cannot rescue this geometry

THE RESOLUTION — A STRESS-MANAGED STRUCTURAL SHIELD

The bare-winding number is a ceiling, not a dead end. The resolution is to stop treating the neutron shield and the coil structure as separate parts. A **stress-managed structural shield** — a tungsten jacket serving simultaneously as neutron shield, pre-compression shell, and structural reinforcement — shrinks the effective bore from 0.648 m to ≈ **0.50 m**, and because $\sigma_\theta \propto a$, that bore reduction alone recovers most of the deficit. With the jacket carrying pre-compression and hoop load, the full **26.49 T** ion-end plug closes at ≈ **60% strain margin** — strain at ≈ 0.4× the cap — as a demountable cartridge. The verdict is therefore *feasible-pending-FEA*: the plug becomes the burner's hardest open **engineering** gate rather than a physics dead end. REQUIREMENT · RESOLVED PENDING FEA

TABLE 1 · THE PLUG COIL IN THREE TIERS — FROM INFEASIBLE TO FRONTIER

TIER	EFFECTIVE BORE	JACKET / SHIELD	JACKET ROLE	INNER-TURN STRAIN VS 0.40% CAP	V
Bare winding	0.648 m	30 cm	Passive shield only	4.6–6.5× over	I
Stress-managed	≈ 0.50 m	15 cm	Structural (shield + pre-compression + reinforcement)	0.4× (60% margin)	D s F p
Frontier	≈ 0.45 m	10 cm	Advanced	0.4×	N q

The stress-managed and frontier tiers are the editorial resolution of the bare-winding negative: they quantify the “nested / stress-managed magnet” route the source paper names but does not size. Both are requirement-class — feasible-pending finite-element analysis, not demonstrated hardware.

WHAT WOULD MOVE THE CEILING

We report the bare-winding result as a ceiling and state what moves it: a lower required field, a materially smaller bore, a nested / stress-managed magnet, or a higher-J_c conductor permitting more structural fraction. Each is a programme, not a parameter change — but the stress-managed structural shield above is the concrete route, and it closes the 26.49 T plug with margin, pending FEA.

§ 7

Quench protection, neutron lifetime, and the shield

Two further subsystems complete the plug's engineering picture, and each is carried with its hazard stated rather than dismissed.

QUENCH — SELF-PROTECTING, BUT THE DUMP TIME IS IMPRACTICAL PASSIVELY

As no-insulation windings, both plug cases are hot-spot self-protecting: peak post-quench temperatures of **145 K** and **109 K** sit below the self-protecting benchmark. But the NI charge/discharge L/R time is **2.2–5.2 hours** — impractical passively, and requiring active ramp assistance — and the slow normal-zone propagation velocity characteristic of NI windings remains a monitored hazard. Self-protection is not the same as fast dump, and the paper keeps the two distinct. DESIGN-STUDY (MIITS)

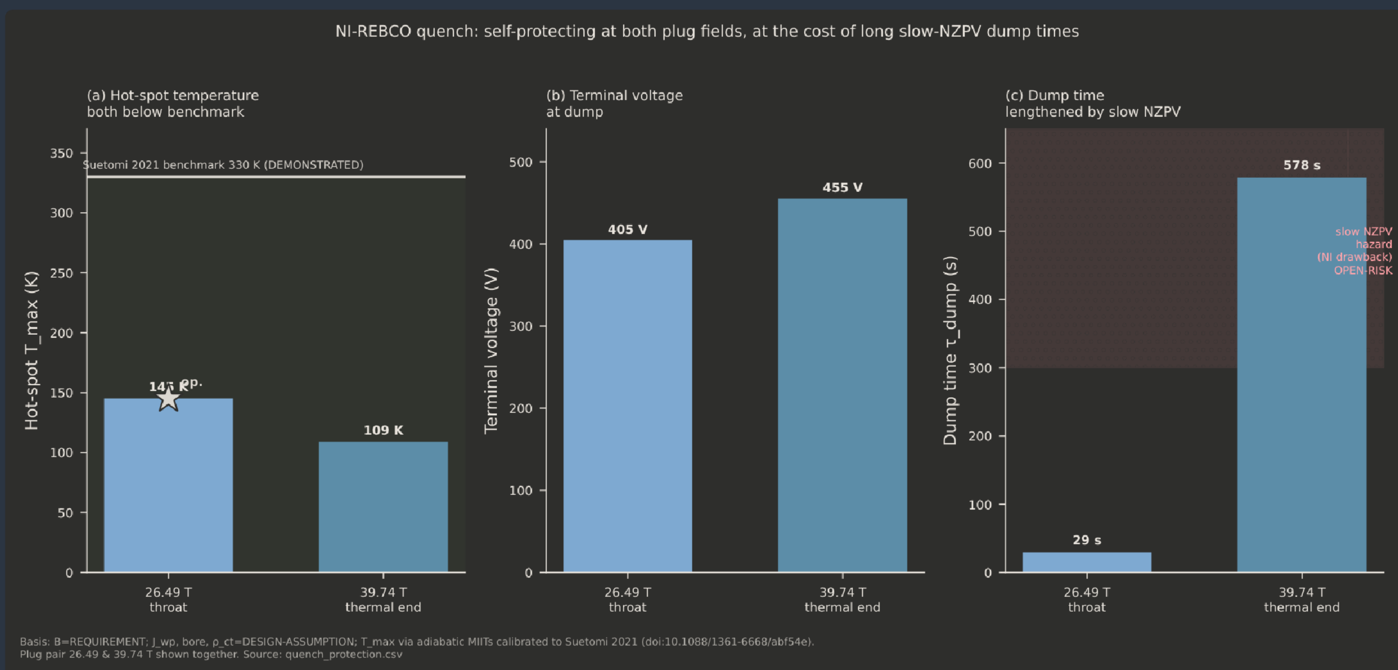

FIGURE 15. NI-REBCO quench: hot-spot T_{max} (145 / 109 K), terminal voltage, and dump time (L/R 2.2–5.2 h) for both plug fields, with the self-protecting benchmark and the slow-NZPV hazard band. DESIGN-STUDY

NEUTRON LIFETIME — THE SHIELD CLOSES A TWO-FULL-POWER-YEAR LIFE

The D–^{3}He plug is low-neutron: **0.0324 MW m^{-2}** uncollided at 2.45 MeV. Against the REBCO I_c-degradation onset ($\Phi_{thr} \approx 3.9\times10^{22}$ m^{-2}), the *unshielded* coil life is short. A **30.4 cm** layered tungsten / borated-polyethylene shield reaches the required attenuation and clears a **two-full-power-year** life with envelope margin. This is a one-dimensional removal-cross-section estimate carrying a 2× buildup safety factor, and it requires Monte-Carlo confirmation; it is reported as an open-risk threshold plus a design-study transport estimate, not a closed result. OPEN-RISK THRESHOLD + 1-D TRANSPORT

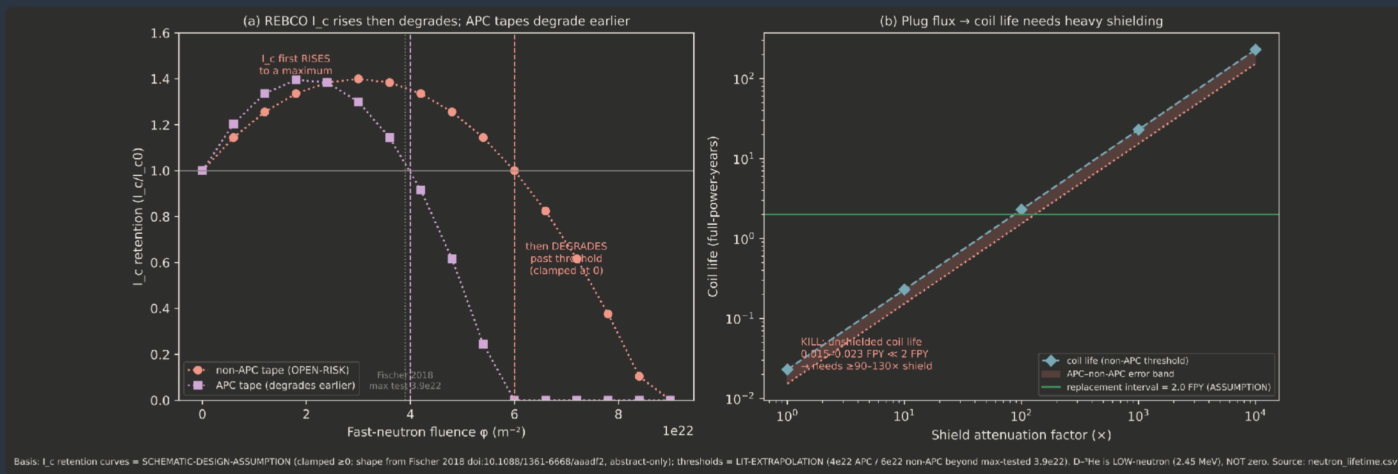

FIGURE 16. REBCO I_c retention versus fast-neutron fluence with the degradation onset, and the coil-life closure by a 30.4 cm W / borated-poly shield. Open-risk threshold (public) plus 1-D transport (design-study). OPEN-RISK + DESIGN-STUDY

§ 8

The two-machine feasibility map — the binding constraint flips

Applying the identical method to two dissimilar machines reveals opposite binding physics. This is the paper's organising result: one winding method, two machines, and the constraint that binds is not the same constraint.

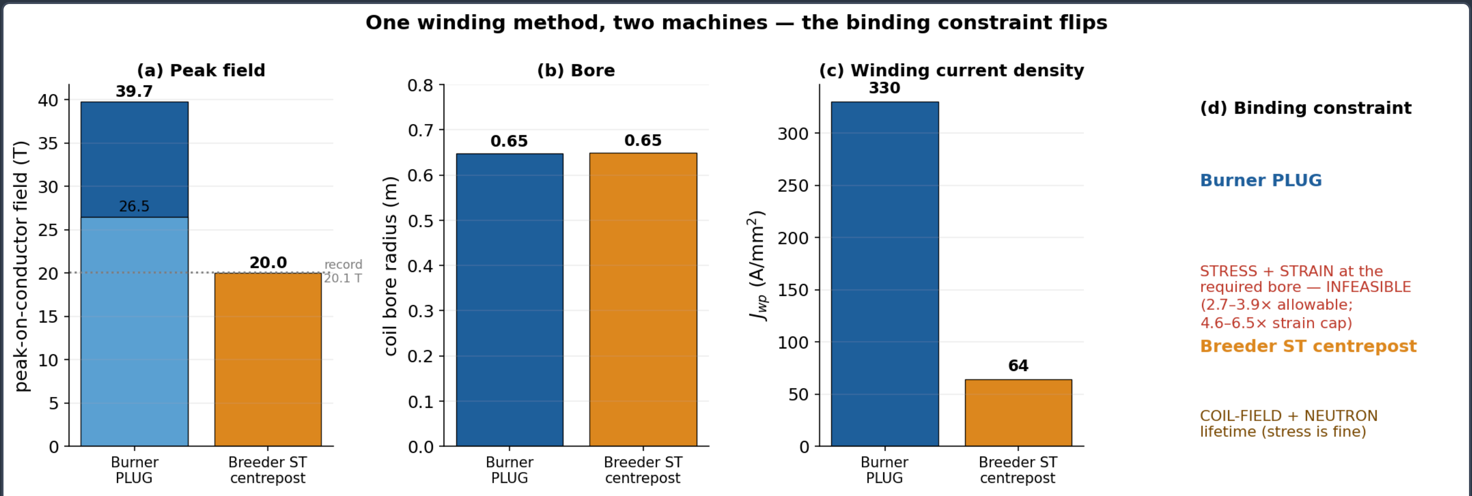

FIGURE 17. The same bore-resolved method on both machines: the spherical-tokamak centrepost (stress-comfortable, field- and neutron-limited) versus the mirror plug (stress- and strain-bound at its bore). The binding constraint flips. The field the conductor enables and the field a coil can realise are two different claims, kept separate throughout. DESIGN-STUDY

BREEDER ST CENTREPOST — STRESS IS NOT THE LIMIT

The toroidal-field centrepost is a large-bore, low-J winding: it carries the rod current over a large area, so the hoop stress stays at **110–1834 MPa** across the full swept field space — below the MP35N allowable even at the extreme 48 T-peak corner. The centrepost is **stress-comfortable across the full swept field space** — the breeder's ≈ 16.84 T centre-post operating field sits well inside the MP35N allowable — and a *realisable* design point exists at on-axis B_0 ≈ 5 T, giving ≈ **20 T on conductor** — within the demonstrated fusion-scale record — at only ≈ **318 MPa**. Stress does not bind this machine.

What binds instead is a coupled pair. The centrepost binds on **coil-field feasibility** — pushing to the B_0 = 10 T design point forces ≈ 40 T on conductor, twice the record — and on **neutron lifetime**, where the D–T first-wall load is **34.8**× the plug's. The two couple adversely through the centrepost shield gap: more field wants a thinner centre stack, while neutron life wants a thicker shield, and the space is shared. The binding limit here is neutron lifetime, which points the design toward a *demountable, consumable centre-post* — a centre stack engineered to be replaced on the neutron-damage clock rather than to survive the plant life. DESIGN-STUDY

BURNER MIRROR PLUG — THE STRESS CEILING, AND WHERE IT MOVES

The plug is the mirror image of the centrepost. Its bore is fixed by flux conservation at $a_1 \approx 0.648$ m; because $\sigma_\theta \propto a$, that bore makes the same conductor and a lower field structurally infeasible as a bare winding — 2916–4253 MPa hoop, 1.85–2.62% strain, pre-load worth only ≈ 11%. The resolution is the stress-managed structural shield of §6: shrink the effective bore to ≈ 0.50 m and let a tungsten jacket carry shield, pre-compression, and reinforcement together, closing the 26.49 T plug at ≈ 60% strain margin, FEA pending. Stress binds this machine; the fix is structural, not a parameter change.

Verdict matrix — subsystem × machine, by basis tier

Subsystem	Burner PLUG	Breeder ST centrepost
Field capability	35 T < REBCO record	~20 T @ B_0=5 T realisable
Conductor J_c	public-data proxy	public-data proxy
Bore-resolved stress	2.7–3.9× over → infeasible	under allowable (OK)
Winding strain	4.6–6.5× over cap	under cap (OK)
Pre-load method	per-turn, filed (novel)	same method transfers
Quench protection	self-protecting; slow NZPV	self-protecting
Neutron lifetime	shielded to 2 FPY	centrepost-limited
Novelty	method only (narrow)	method only (narrow)

DEMONSTRATED / OK · DESIGN-STUDY · OPEN-RISK / binding

FIGURE 18. Verdict matrix: each subsystem tagged DEMONSTRATED-FIELD / DESIGN-STUDY / OPEN-RISK across the two machines — the paper's honesty summary in one figure. Basis: the claim ledger. CLAIM LEDGER

The method transfers; the binding constraint does not.

§ 9

Discussion, limitations, and the one measurement that would convert the method

This is a design study, and its results are reduced-order and finite-element, not experimental. Kronos has built no coil and measured no tape. Every conductor number is public data applied to a winding; the plug bore and pack current density are labelled design-assumptions; the shield is a one-dimensional transport estimate with a 2× buildup factor; and two field records were retrievable in abstract only. The winding method is therefore *modelled, not demonstrated*.

THE HIGHEST-VALUE NEXT STEP IS A SINGLE MEASUREMENT

The single measurement that would convert the method — and the one we identify as the highest-value next step — is a **short-sample strain-to-delamination test** on the intended conductor, with and without the placed pre-load, establishing the strain-limit margin the method manages. Everything the paper claims for the per-turn placement rests on that margin; measuring it turns the method from modelled to demonstrated.

The study is accompanied by a generic, self-proposed validation roadmap: short-sample $I_c(B,T,\epsilon)$; a wound-coil quench test of the V_2O_3 switching; and the strain-to-degradation measurement above. No facility, programme, or partner is named, and no test is claimed as performed. The honest inventory of what is *not* demonstrated is deliberate, and it is the same discipline the aluminium-bypass and MP35N-substrate verdicts express: where a claim fails, the paper says so.

TAPE QUALIFICATION, AND THE HONEST NEGATIVES COLLECTED

ALUMINIUM BYPASS	**Unsupported at the operating field.** The RRR advantage does not survive the reinforcement a structural conductor needs; copper is adequate.
MP35N AS GROWTH SUBSTRATE	**Infeasible.** Textured-buffer growth needs a Hastelloy- or Ni–W-class base; MP35N is defensible only as a post-growth reinforcement lamination.
V_2O_3 SMART QUENCH	**Prior art.** MIT-based smart insulation naming vanadium oxide is claimed in prior patents and demonstrated by other groups; our contribution is analysis.
PRE-LOAD AT THE PLUG BORE	**Near-null (≈ 11%).** The optimiser converges but floors at 4.6–6.0; the sound, general method cannot rescue this particular geometry — the bore does.
35 T CLAIM	**A field-capability statement, not a coil record.** H_{c2} > 100 T at 4.2 K places 35 T at ≈ 1/3 of the material limit — never presented as a coil that has been wound.

§ 10

Conclusion — one method, two machines, an honest map

We have treated a high-field REBCO conductor and its winding as one system and applied a single reproducible bore-resolved mechanics across a spherical-tokamak centrepost and a tandem-mirror plug. The method transfers; the binding constraint does not. The ST centrepost is stress-comfortable with a realisable ≈ 20 T-on-conductor design point and a coupled field / neutron limit that favours a lower-field breeder and a demountable, consumable centre-post. The small-bore mirror plug is stress- and strain-bound at its physical 0.648 m bore and does not close as a bare winding — a quantified ceiling that names what a buildable plug would require, and that the stress-managed structural shield resolves to a feasible-pending-FEA cartridge at ≈ 0.50 m.

The conductor's three distinguishing ideas are prior-art or incremental; the aluminium bypass is unsupported and MP35N-as-substrate is infeasible; and the 35 T figure is a conductor field-capability claim, not a coil record. The genuinely new, filed contribution is the per-turn, as-built-data-driven winding method and its per-coil qualification. The path to a demonstrated result is a single strain-to-delamination measurement on the intended conductor.

DATA AVAILABILITY & PROVENANCE

Headline quantities are regenerable by named scripts reading declared-parameter tables (deterministic seed 20260726). Code and validation data (physics/engineering only) are archived at Zenodo, **doi:10.5281/zenodo.21842514** (CC BY 4.0), cross-linked to the companion breeder (10.5281/zenodo.21746157) and burner (10.5281/zenodo.21746479) deposits. No performance figure is a Kronos measurement; every value is a design target, a model output, or an inference from public literature. Provisional patent applications relating to aspects of this work have been filed.

APPARATUS

Portfolio, People & Record

The intellectual-property estate, the people who built it, the limitations that gate it, and the sources it rests on.

1	4	40	27
GRANTED PATENT	2026 PROVISIONALS	TEAM MEMBERS	2022 PROVISIONALS

INTELLECTUAL PROPERTY

The patent portfolio

The estate spans a granted high-field magnet patent, pending utility and 2026 provisional filings that map to the two products, a digital-twin control provisional, a registered trademark application, and the original 2022 provisional family. Every patentable disclosure in the five-paper arXiv drop was protected **before** publication: the breeder and burner provisionals were filed 1–2 August, and a publication-gap omnibus filing the evening before the drop swept up the DEC, plasma-control, and REBCO-winding matter of the three otherwise-unprotected papers. Patent numbers and application serials are matters of public record; claim scope is summarised, not reproduced.

GRANTED & PENDING UTILITY

US 12,009,112	High-field tilted graded-REBCO magnet architecture (KRONO-002A) · *app. 17/878,550*	GRANTED
US 17/878,507	Core device / method (KRONO-001A) · *utility*	PENDING

2026 PROVISIONAL FILINGS — MAPPED TO THE PRODUCTS

64/124,209	Hyperion — spherical-tokamak tritium / helium-3 foundry · *breeder · filed Aug 2026*	FILED
64/124,220	Aegis / MetroVolt — synchrotron-cutoff, fuel-selection & plug-winding · *generator · filed Aug 2026*	FILED
64/115,167	KRONOS-CTRL digital-twin plant control · *provisional · filed Jul 2026*	FILED
64/005,440	Integrated spherical-tokamak fusion architecture · *early integrated-architecture filing · filed Mar 2026*	FILED
64/105,530	Negative-triangularity spherical-tokamak architecture · *foundational ST filing · filed Jul 2026*	FILED
64/128,097	Publication-gap omnibus — quasineutral two-species expander DEC · provenance-gated / latency-split plasma control · as-built high-field winding & conductor architecture · *filed 7 Aug 2026, the evening before the arXiv drop*	FILED

TRADEMARK & ORIGIN

FTK-98801894	Kronos Fusion Energy — trademark application	FILED
KR-2022-*	Original provisional family (KR-2022-00001 … 00027) · *27 filings, 2022*	PRIORITY

The narrow, defensible magnet novelty — the specific conductor and the digital-twin winding optimisation, not high-field REBCO as a category — is the commercial core that can earn ahead of any Q > 1 milestone, with markets in fusion magnet supply, MRI/NMR, accelerators, and proton therapy. The claim is scoped honestly: the high field is a *system field* result, not a stand-alone-coil record; the small-bore plug coil is structurally infeasible as a bare winding but resolved by a stress-managed structural shield (feasible-pending-FEA); and the winding-tape experiment returned a *null result*. The value is the method, not a field record.

THE TEAM

Founding partners, board, advisors & auditors

Kronos is built by a bench of advanced-fuel-fusion, high-field-magnet, direct-conversion, and materials specialists, with a board and operations team drawn from defense, national laboratories, and industry. Dates are shown as ranges; where a tenure has ended or is term-ending, the range says so.

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Legal counsel is retained; those roles are held on the internal roster and are not listed here.

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COLOPHON

How this document was made

The Kronos Fleet — Combined Editorial, 2026 is set in **Fraunces** (display), **Gelasio** (text), and **IBM Plex Mono** (data & equations), carried forward from the Kronos editorial design system.

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THE 2026 KRONOS SET

One programme, in five papers

This editorial is one of five that together describe the Kronos fusion programme — a breeder that funds a generator, and the magnet, conversion, and control science that enable both. Each is published open-access with a reproducible companion deposit.

PAPER I	**Hyperion — The Tritium Foundry** · 10.5281/zenodo.21746157
PAPER II	**Aegis & MetroVolt — The Generator** · 10.5281/zenodo.21746479
PAPER III	**High-Field REBCO Magnets & Tape** *(this paper)* · 10.5281/zenodo.21842514
PAPER IV	**Direct Energy Conversion** · 10.5281/zenodo.21842864
PAPER V	**AI, ML & Quantum Control** · 10.5281/zenodo.21842371

Explore the whole programme live: the interactive 3-D model, the in-browser physics validator, and the companion film series.

KRONOS FUSION ENERGY

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Zenodo · DOI 10.5281/zenodo.21842514