Technical Whitepaper: Invar 36 (UNS K93600) – Mastering Near-Zero Thermal Expansion

Executive Summary

Invar 36 (UNS K93600 / W.Nr. 1.3912) is a 36% nickel-iron alloy celebrated for its uniquely low coefficient of thermal expansion (CTE). From its discovery by Nobel laureate Charles Guillaume in 1896 to its critical role in 2026 LNG transport and hypersonic aerospace tooling, Invar 36 remains the material of choice for dimensional stability. This whitepaper analyzes the "Invar Effect," strict ASTM F1684 composition compliance, and the thermal stabilization treatments required to prevent micro-dimensional drift over time.

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1. Global Standard Compliance

Shanghai Hangbo Alloy Group ensures that every batch of Invar 36 meets the tightest tolerances required by international precision standards.

Standard Body	Specification	Application Focus
ASTM (International)	**ASTM F1684**	Iron-Nickel Low Expansion Alloys
DIN (German)	**DIN 1715**	Ni36 for Measuring & Control
GOST (Russia)	**36■ (36N)**	Precision Alloys with Low Expansion
GB (China)	**4J36**	Expansion Alloys for Precision Instrumentation
ISO (Global)	**ISO 9445**	Precision Sheet and Strip

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2. Melting & Homogeneity: VIM-VAR for CTE Stability

The performance of Invar 36 depends entirely on the chemical homogeneity of the Nickel distribution. A 0.5% shift in Nickel can double the CTE.

2.1 Vacuum Induction Melting (VIM)

Primary melting in a vacuum ensures that trace impurities like Phosphorus and Sulfur are minimized, while Nitrogen and Oxygen are eliminated. This is critical because inclusions act as stress concentrators that can distort the material during thermal cycling.

2.2 Vacuum Arc Remelting (VAR)

Secondary VAR refining is mandatory for aerospace and optical components. It ensures a highly uniform distribution of Nickel and Iron across the entire ingot cross-section, eliminating the macro-segregation that leads to uneven thermal expansion.

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3. Strict Chemical Composition (ASTM F1684)

Exact control of trace elements is the difference between "Steel" and "Invar."

Element	Symbol	Typical (%)	Max (%)	Critical Role in Invar 36
Nickel	**Ni**	**36.00**	**37.00**	**The expansion driver.** Must be exactly 36.0%.
Iron	**Fe**	**Balance**	**Balance**	Structural matrix.
Manganese	**Mn**	**0.35**	**0.60**	Improves hot workability and forgeability.
Silicon	**Si**	**0.20**	**0.40**	Deoxidizer; kept low to prevent expansion instability.
Carbon	**C**	-	**0.05**	Kept low to prevent carbide-induced dimensional drift.
Chromium	**Cr**	-	**0.25**	Trace control; high Cr increases expansion.
Cobalt	**Co**	-	**0.50**	Trace control.
Phosphorus	**P**	-	**0.020**	Impurity; strictly restricted.
Sulfur	**S**	-	**0.010**	Impurity; restricted for weld integrity.
Aluminum	**Al**	-	**0.10**	Deoxidation residue control.
Magnesium	**Mg**	-	**0.10**	Impurity control.

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4. Mechanical & Physical Properties

Mastering the Invar 36 physical profile is essential for engineering design.

4.1 Physical Properties (Low Expansion Focus)

Temperature Range	CTE (Typical)	Comparison (Carbon Steel)
-163°C to 20°C (LNG)	**1.5 x 10■■/°C**	11.0 x 10■■/°C
20°C to 100°C	**1.2 x 10■■/°C**	12.1 x 10■■/°C
20°C to 200°C	**2.2 x 10■■/°C**	13.0 x 10■■/°C

4.2 Mechanical Properties (Typical Annealed)

- **Tensile Strength**: 490 MPa (71 ksi)
- **Yield Strength**: 240 MPa (35 ksi)
- **Elongation**: 35%
- **Curie Temperature**: **230°C (446°F)** — Above this, Invar expands like normal steel.

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5. Heat Treatment for Dimensional Stability

Precision components must undergo a stability treatment to prevent "drift" over years of service.

1. **Stress Relief**: 830°C for 30 minutes, followed by water quench.

2. **Intermediate Soak**: 315°C for 1 hour, air cool.

3. **Artificial Ageing**: 95°C for 48 hours, air cool.

This process stabilizes the microstructure and minimizes the "temporal expansion" effect.

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6. Industrial Applications & Case Studies

6.1 LNG Transport: GTT NO96 Membrane Tanks

Scenario: Containment barriers on ocean-going LNG carriers at -163°C.

Why Invar 36?: Because the material does not contract significantly, the membrane can be installed as flat sheets with simple lap welds, rather than complex corrugated structures.

Case Study: A comparison between Mark III (Stainless) and NO96 (Invar) systems found that NO96 vessels allow for a 15% increase in cargo capacity due to thinner insulation requirements and flatter membrane profiles.

6.2 Aerospace: CFRP Molds

Scenario: Molds for curing carbon-fiber parts in autoclaves at 180°C.

Why Invar 36?: Carbon fiber reinforced polymer (CFRP) has a near-zero CTE. If steel or aluminum molds are used, the part will warp as it cools. Invar 36 molds match the expansion of the composite, ensuring "Net-Shape" precision.

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7. Technical FAQ

****Q: Is Invar 36 magnetic?****
A: Yes, it is ferromagnetic at room temperature. It becomes non-magnetic above 230°C.

****Q: Can I weld Invar 36?****
A: Yes, using **ERNi-1 (FeNi36)** matching filler. Extreme cleanliness is required to avoid "hot cracking" caused by sulfur.

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