

CONF. REPORT 10/16

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GRCop-84 Development for Combustion Chamber Liners

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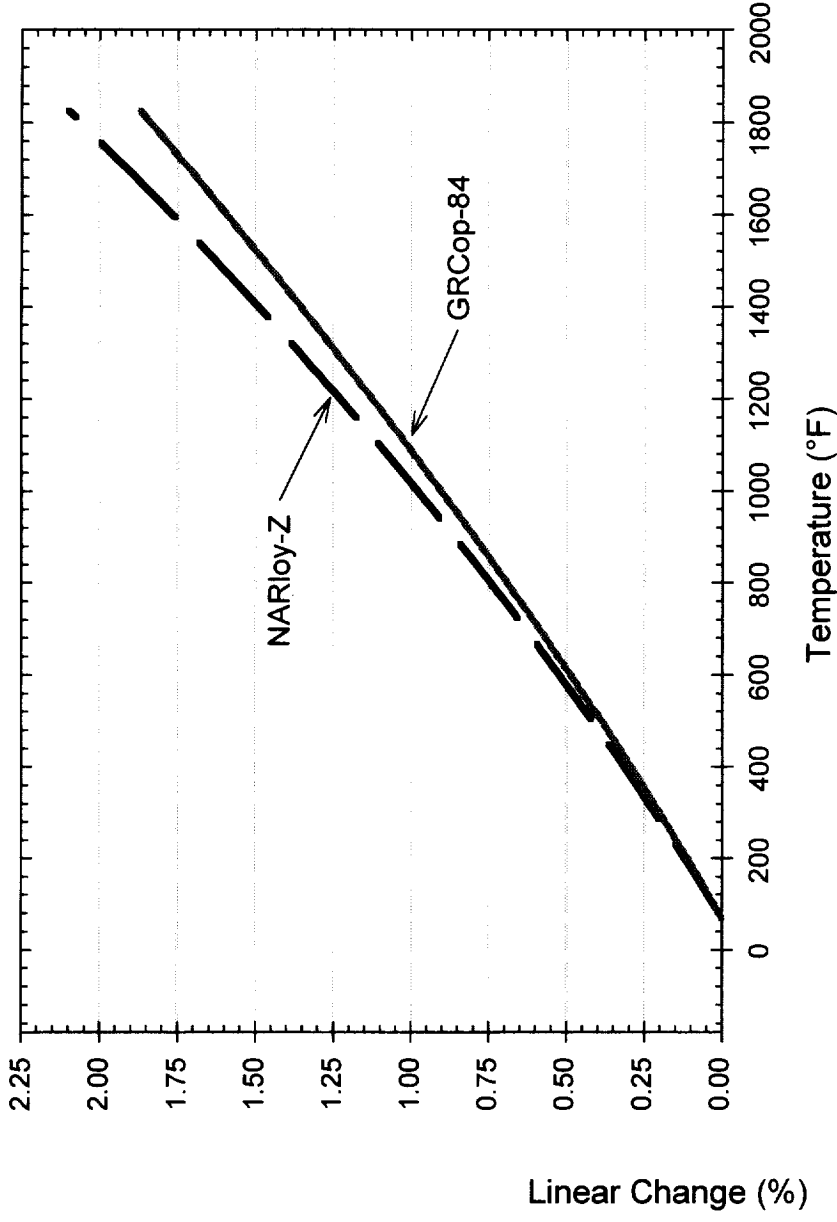
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⁵NASA Marshall Space Flight Center

- ◆ **Originally began as series of experimental Cu-Cr-Nb alloys produced by chill block melt spinning**
 - Focused on alloys with 2:1 atomic Cr to Nb ratios
 - Varied total amount of Cr+Nb to vary volume fraction of Cr₂Nb
 - Ribbons examined metallographically, tensile tested and electrical conductivity measured
- ◆ **Cu-8 at.% Cr-4 at.% Cr was selected as composition with best combination of conductivity and strength**
- ◆ **Composition scaled up using conventional argon gas atomization (Special Metals) and extrusion to verify good properties of alloy**
- ◆ **Full thermophysical and mechanical properties database developed on GRCop-84 under RLV Focused Program for GRCop-84 produced by Crucible Research**

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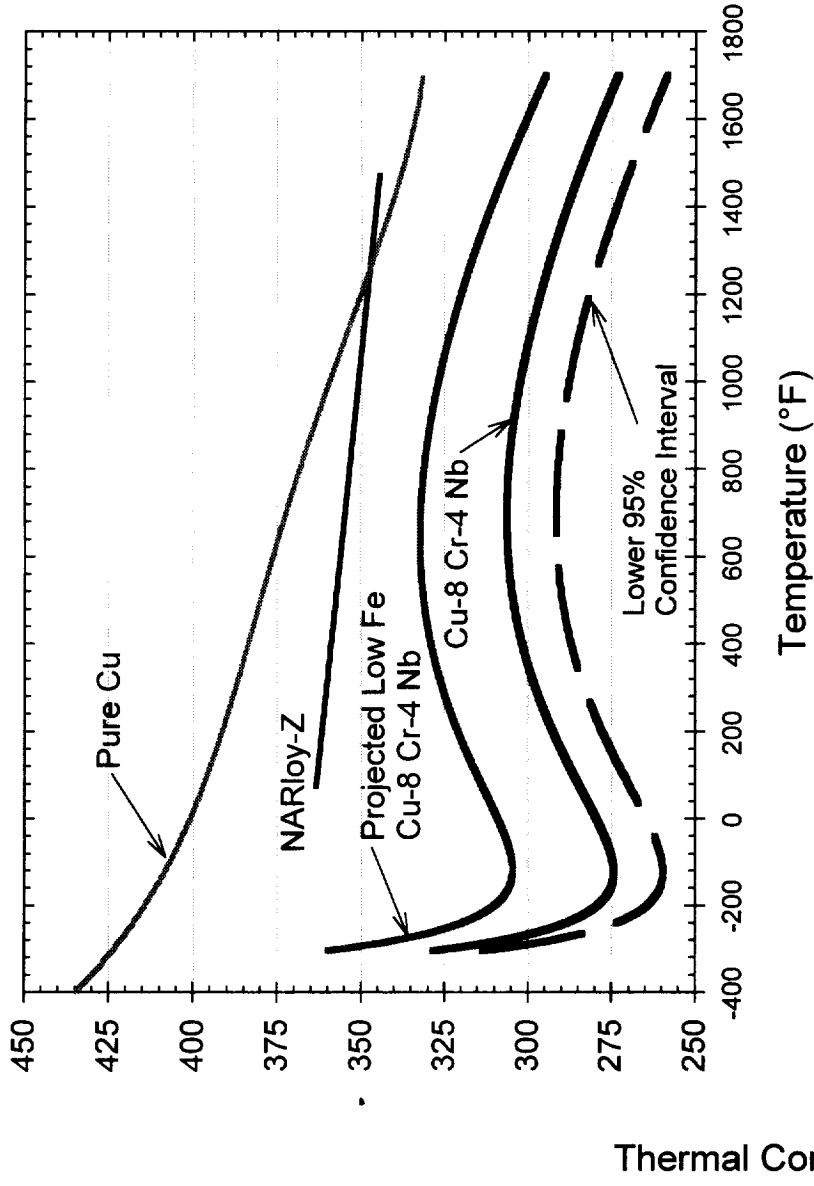
History of GRCop-84 Development



- ◆ **Thermally induced stresses from constrained thermal expansion dominate in liners**
- ◆ **Decreased thermal expansion decreases thermal stresses**
- ◆ **Decreased stresses and strains result in longer liner lives**

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GRCop-84 Thermal Expansion

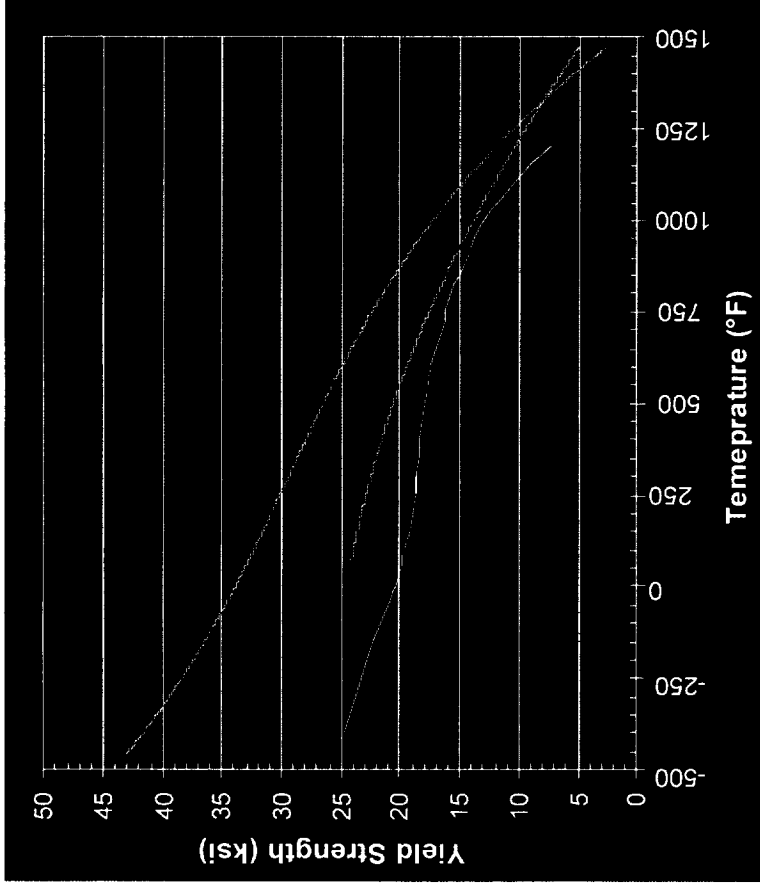


- ◆ **Statistical analysis allows determination of equations for average thermal conductivity and lower confidence interval**
- ◆ **Average conductivity is between 70% and 83% of pure Cu over temperature range of interest for liners**
- ◆ **Elimination of 200 ppm Fe contamination in alloy may increase thermal conductivity significantly**

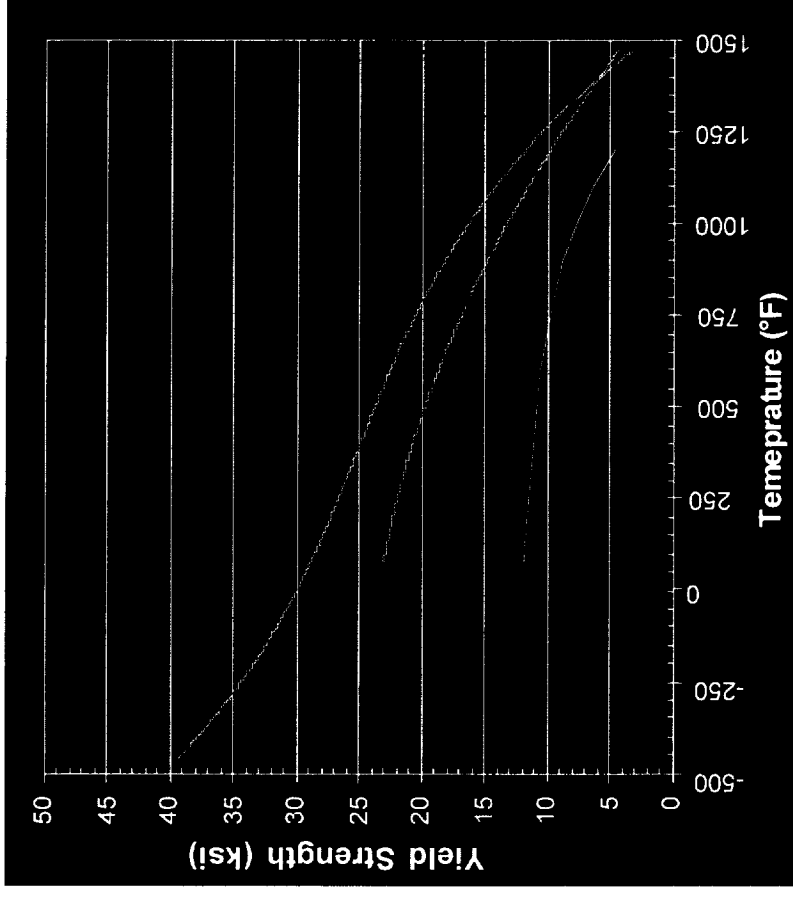
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Thermal Conductivity of GRCop-84

As-Produced



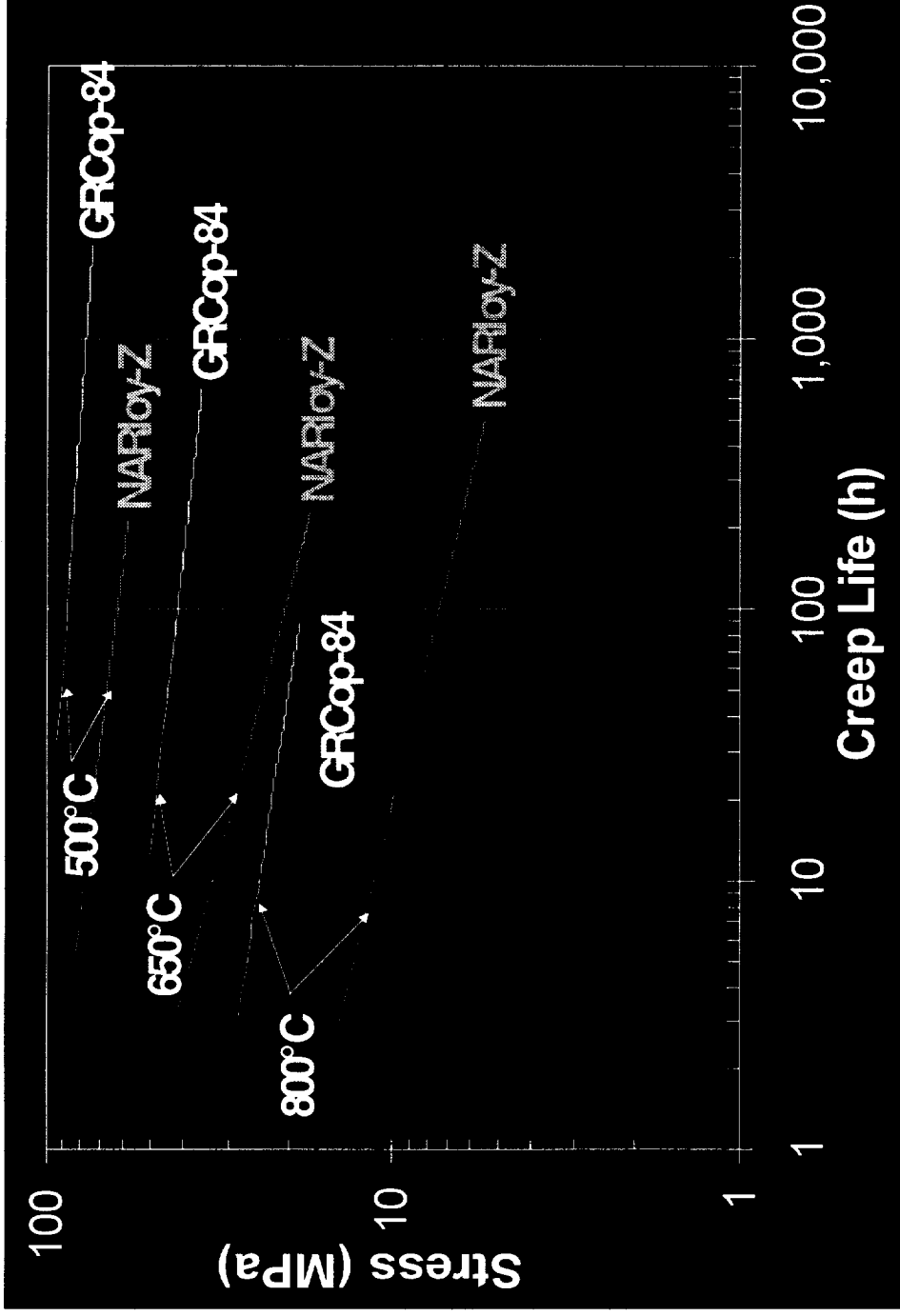
Brazed



- ◆ Following a simulated braze cycle at 935°C (1715°F), GRCop-84 exhibits a minimal decrease in 0.2% yield strength
- ◆ NARloy-Z shows significant strength loss

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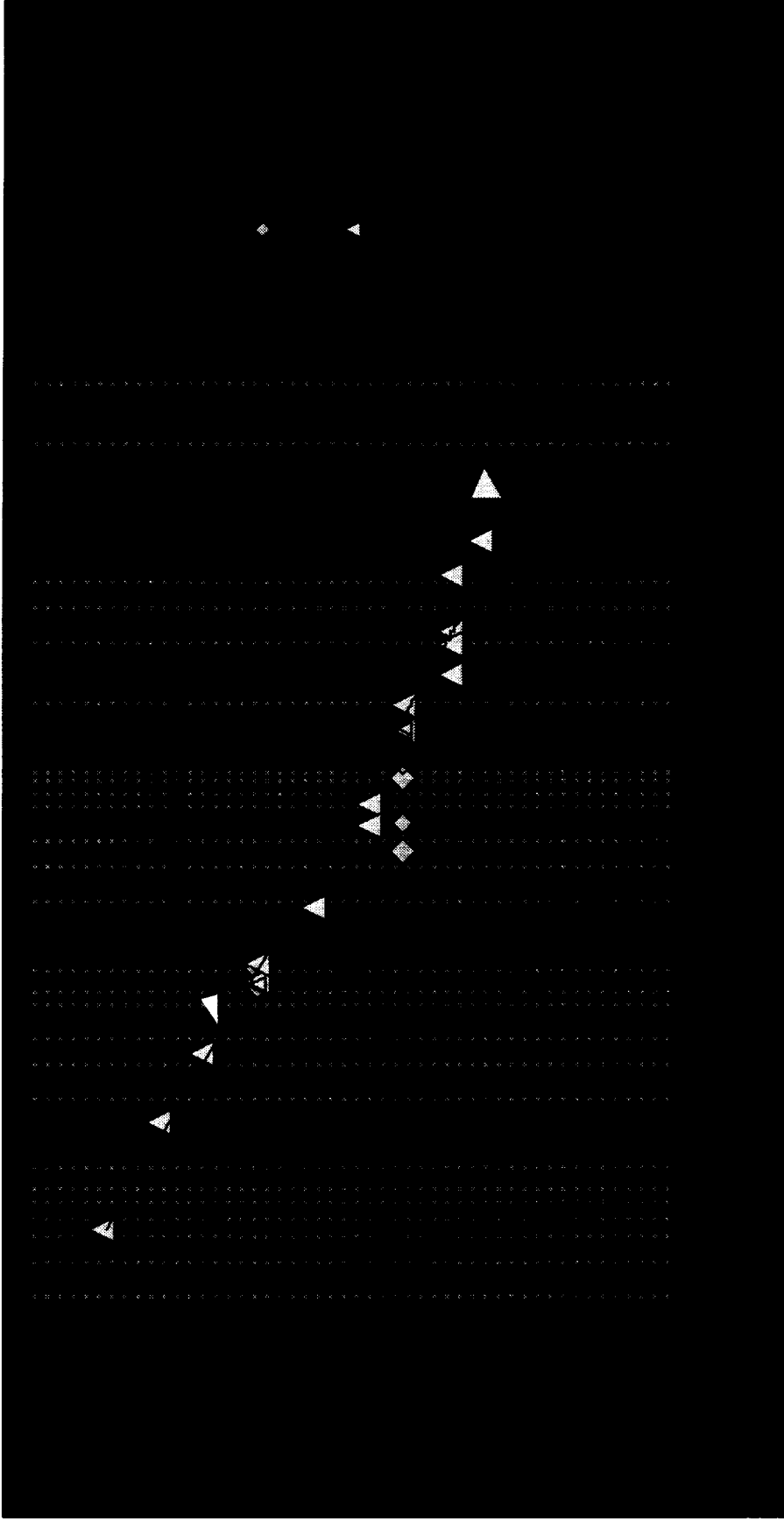
0.2% Yield Strength of GRCop-84



- ◆ GRCop-84 enjoys significant creep life advantages over NARloy-Z
- ◆ Additional data for Crucible Research material being generated under RLV Focused program

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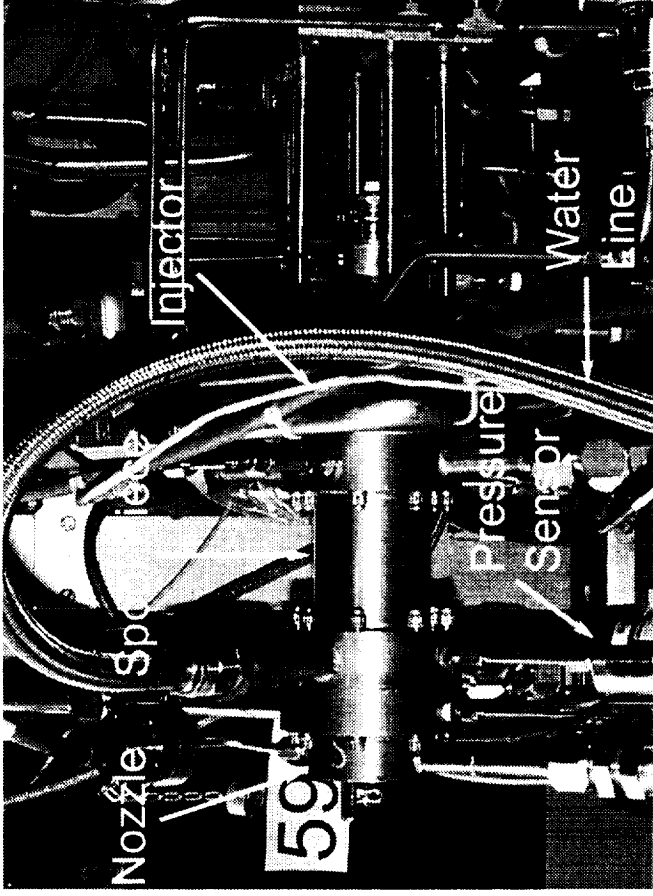
GRCop-84 Creep Lives



- ◆ GRCop-84 has significantly longer LCF lives than NARloy-Z
- ◆ The simulated braze has minimal effects on LCF lives

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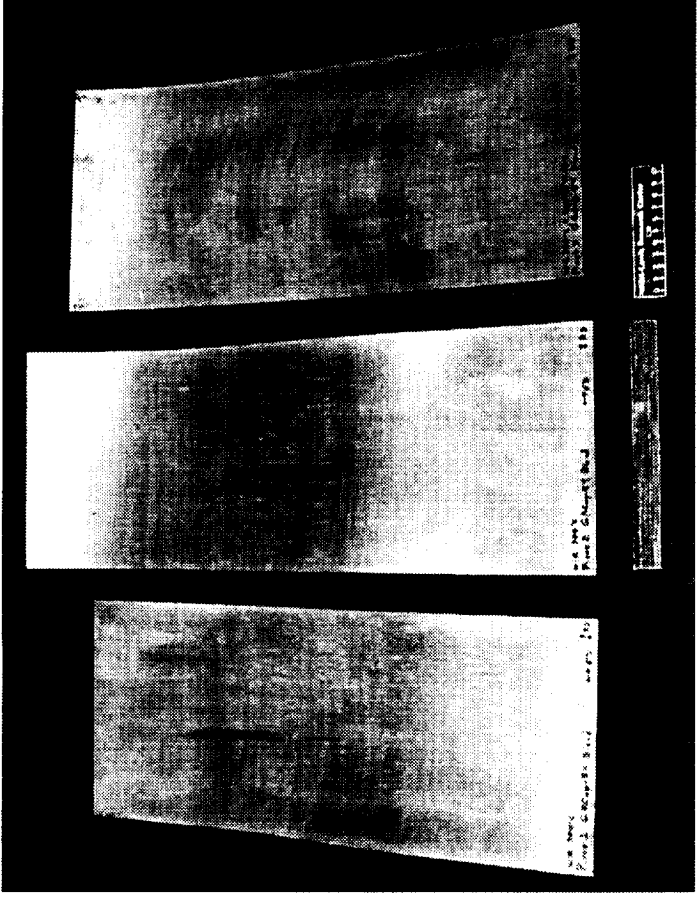
GRCop-84 Low Cycle Fatigue (LCF) Lives



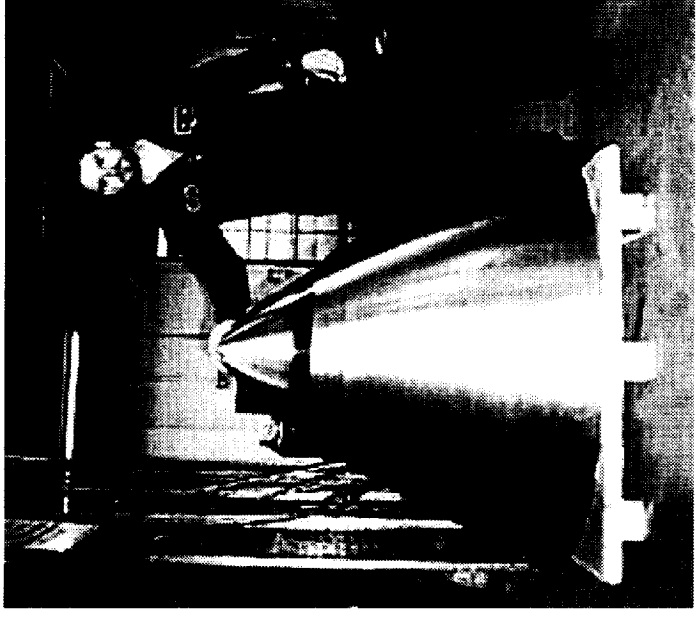
- ◆ Spool pieces produced at MSFC using vacuum plasma spraying to produce 2" ID x 6" long liners with and without NiCrAlY coatings
- ◆ Twenty-seven hot fire tests totaling 482 seconds of hot fire testing conducted on uncoated and coated spool pieces
- ◆ No degradation of liner or coating observed
- ◆ Further testing of liners under RLV Focused program to be done at MSFC

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Hot Fire Testing of GRCop-84 Spool Pieces



Warm rolled GRCop-84 sheet
(~9" x 20")



Example of metal spun part

- ◆ Metal spinning represents possible low cost, quick turnaround method of producing large thrust cell liners
- ◆ Plan to produce large (~3'x15') sheet under RLV 2nd Generation Program

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Production of Large GRCop-84 Sheet Product

- ◆ **GRCop-84 offers many advantages over NARloy-Z and other copper-based alloys**
 - Lower thermal expansion
 - Good conductivity
 - High yield strength up to 1300°F (700°C)
 - Increased creep lives/stresses
 - Superior LCF lives
- ◆ **GRCop-84 spool piece testing demonstrated GRCop-84 as a liner material with and without a coating**
- ◆ **Alternative fabrication techniques can reduce costs and manufacturing times**
- ◆ **Coatings can be used to stop environmental attack and increase liner life and engine performance**
- ◆ **Copper-based MMC composites have the potential for higher strength and conductivity**

GRCop-84

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Coatings

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