Candidate Alloys and Challenges for S-CO_2 Applications

DOE-EPRI S-CO_2 Workshop, October 15, 2015, San Diego

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HAYNES International

HAYNES® 230® and HAYNES® 282® Alloys

	Ni	Cr	Co	Mo	W	Fe	Mn	Si	Al	C	Other
230	57	22	5*	2	14	3*	0.5	0.4	0.3	0.10	La = 0.02; B=0.015
282	57	19	10	8.5	-	1.5*	0.5*	0.5*	1.5	0.06	Ti = 2.1; B=0.005

* Maximum content

HAYNES® 230® alloy

- UNS N06230

HAYNES® 282® Alloy

- UNS N07208

HAYNES® 230® alloy:

- Is solid-solution strengthened
- Excellent creep strength among solid-solution alloys
- Excellent long-term thermal stability
- Have outstanding oxidation resistance to 980°C
- Excellent thermal fatigue resistance
- Lowest thermal expansion characteristics
- Is readily formed, fabricated and weldable

HAYNES® 282® alloy:

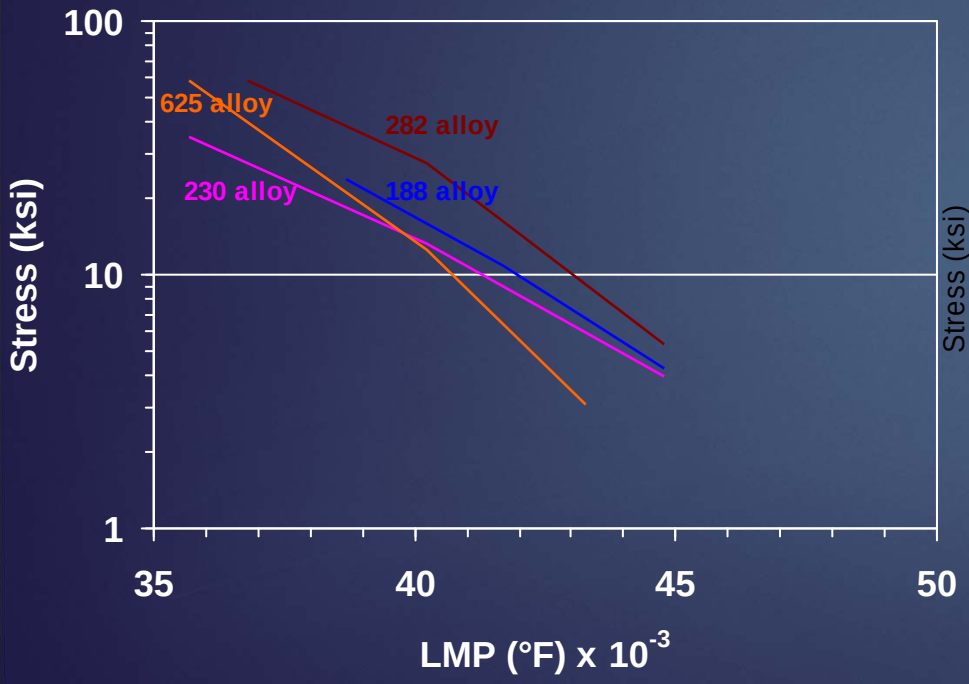
- Is γ' - $Ni_3(Al, Ti)$ strengthened alloy
- Excellent creep strength among age-hardenable alloys up to 900°C
- Resists strain-age cracking
- Excellent formability, fabricability, and castability
- Excellent long-term thermal stability
- Excellent low-cycle fatigue resistance

HAYNES 230 and 282 Alloys

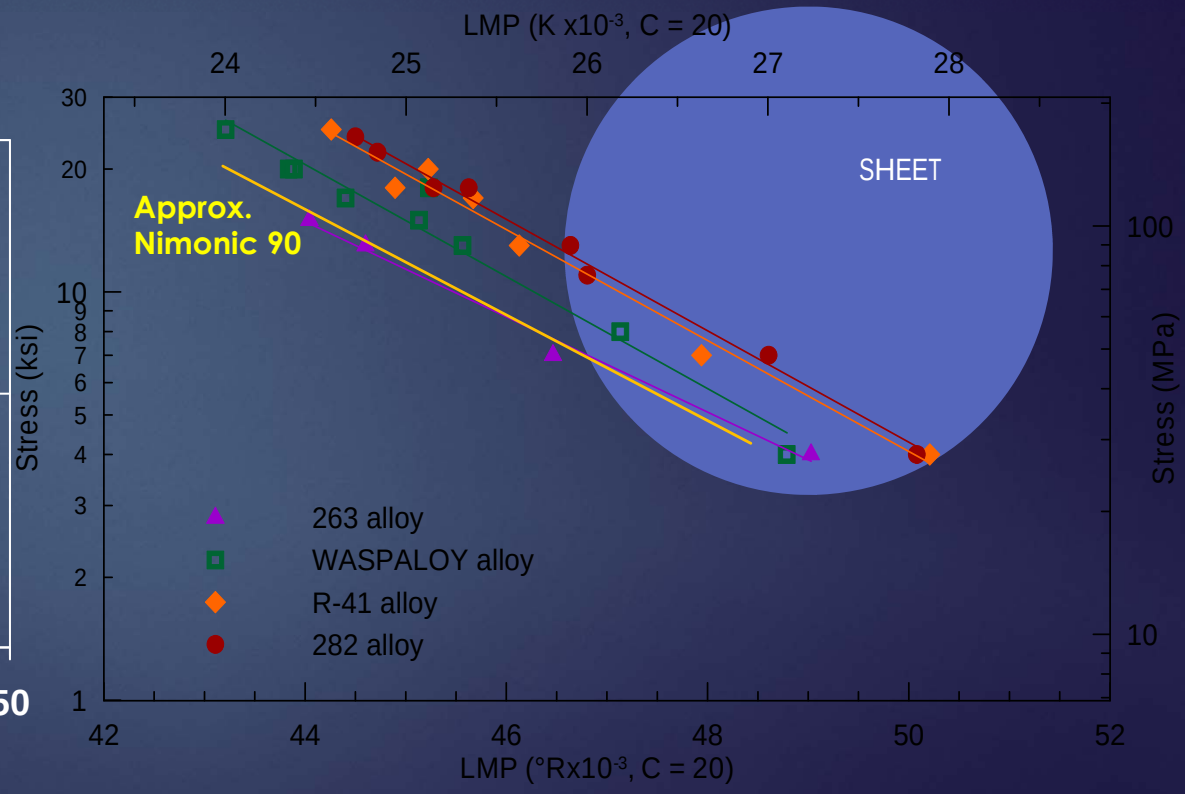
Creep Rupture Data Comparison

Stress Rupture Data

Sheet, T ≤ 1700°F (927°C)

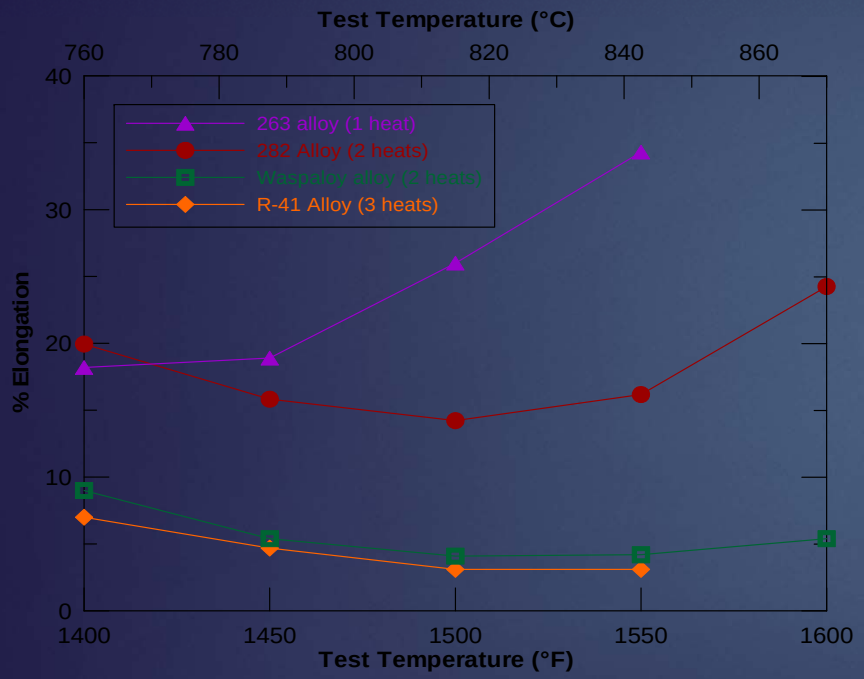


Larson-Miller Plot – 1% Creep Life

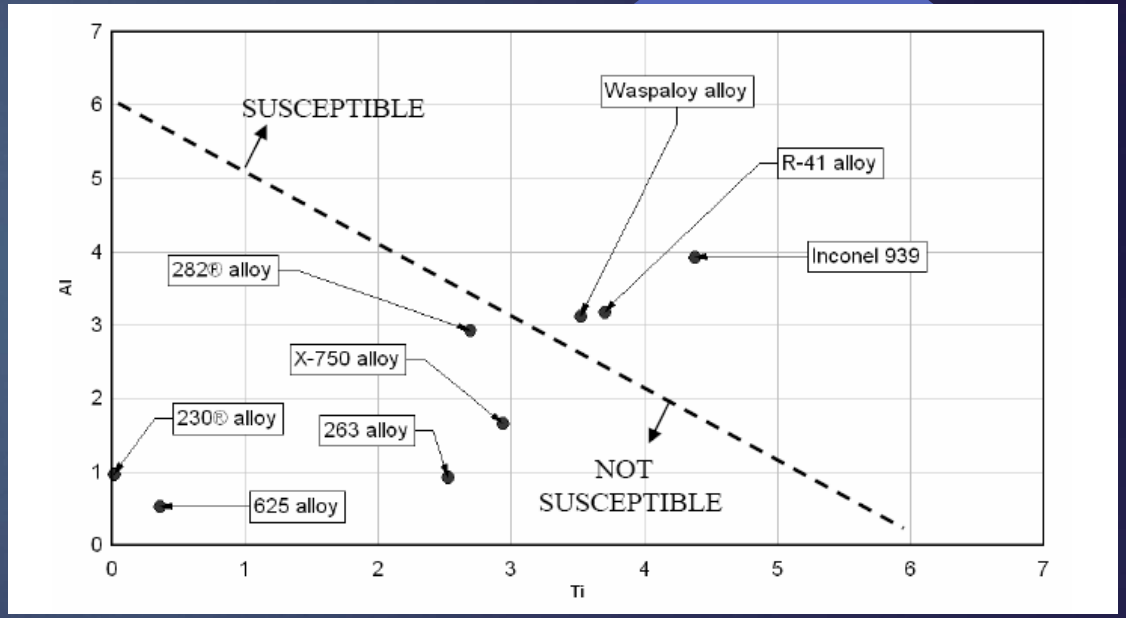


HAYNES 282 Alloy
Resistance to Strain-Age Cracking

CHRT Data



Prager & Shira plot (PS Plot) showing susceptibility of nickel based superalloys to strain age cracking / fabrication & weldability problems.

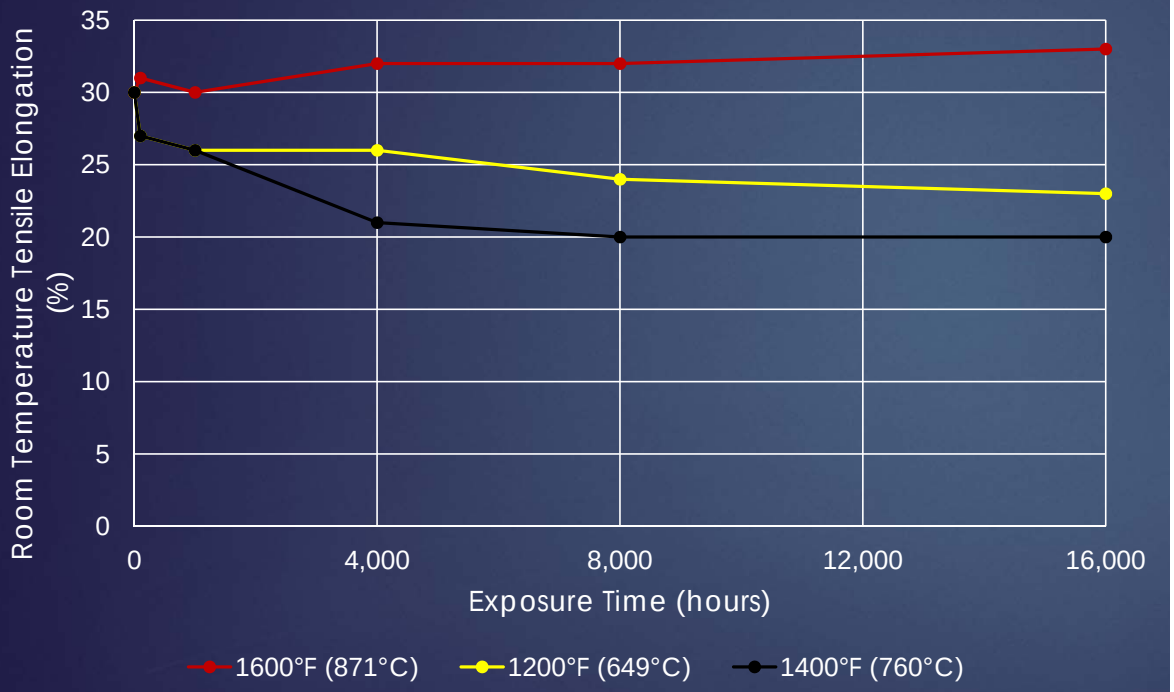


- **The relatively low volume fraction (19%) of gamma-prime (γ′) in 282® alloy, results in improved resistance to strain-age cracking**
- **282® alloy approaches the strain-age cracking resistance of 263 alloy and possesses much higher resistance than Waspaloy and R-41 alloys**

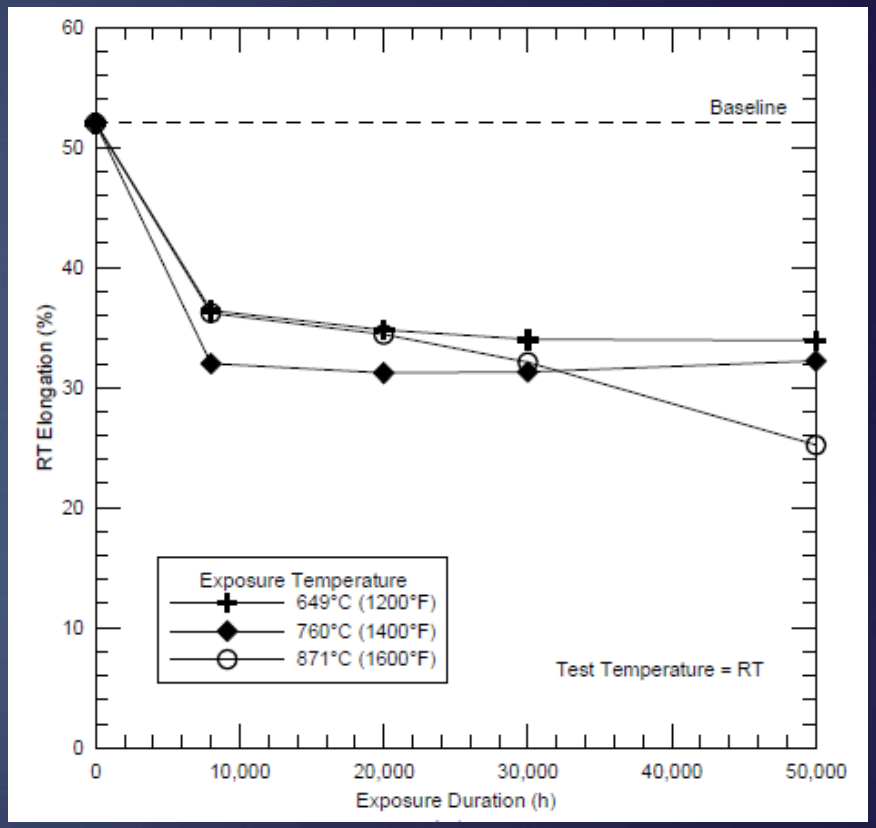
HAYNES 282 and 230 Alloys

Long-Term Thermal Stability

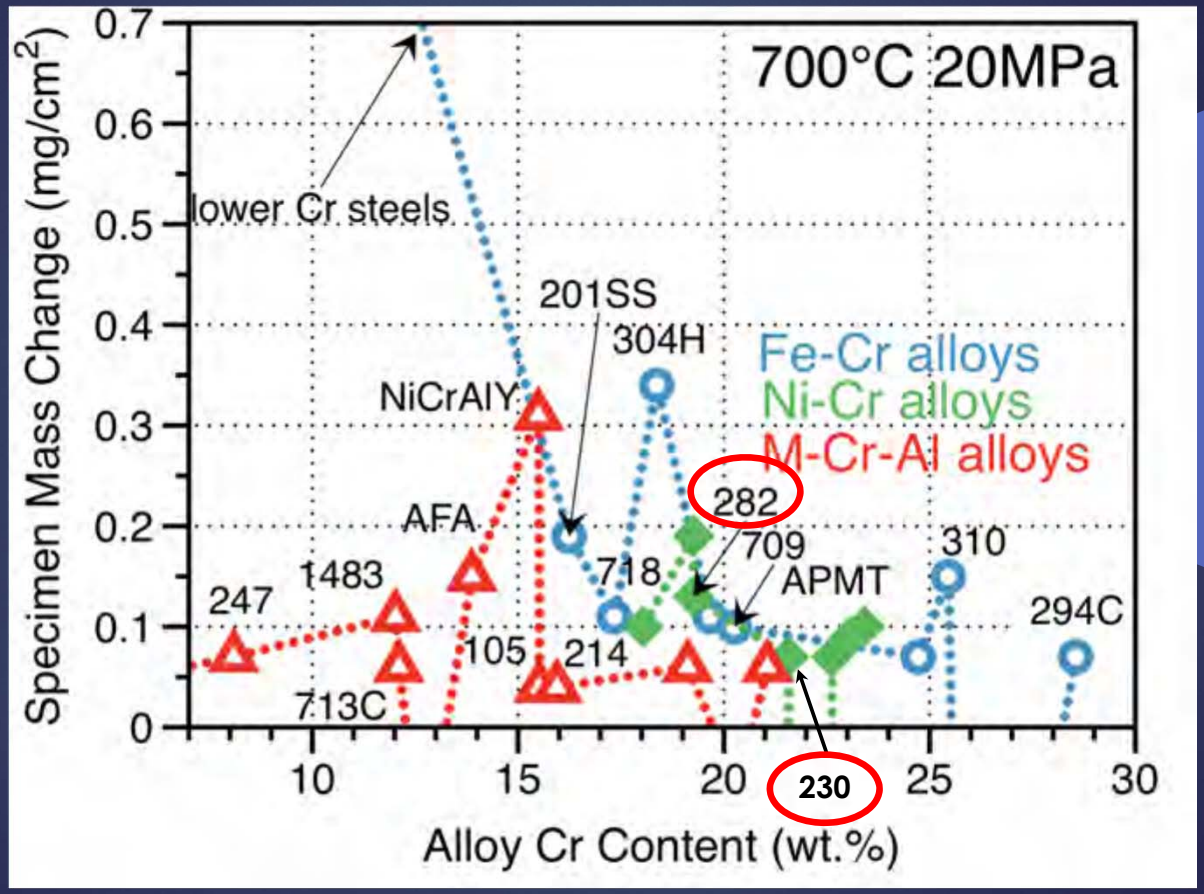
282 Alloy



230 Alloy



Supercritical CO_2 Corrosion Resistance
at 700°C/20 MPa



Pint and Keiser, ORNL; The 4th International Symposium - Supercritical CO_2 Power Cycles

Current Status of the Alloys and Challenges for S-CO_2 Tech.

- Wrought Product Forms: Standard commercial products are produced in billet, bar, plate, sheet, and welding wire.
- Both Alloys are fully commercialized. Currently being used in industrial applications.
- 230 Alloy covered by ASME Section VIII Div. 1 up to 982°C.
- 282 Alloy Products have been produced for evaluation in U.S., European and China A-USC programs.
  - ASME Code Case is currently being pursued in collaboration with ORNL for 282 alloy.
- Cost: - Sheet and Plate: Cut parts – Reduces scrap;

  - Work closely with alloy manufacturers during the heat exchanger designing stages to define sizes to lower costs early on;

  - "Standard" vs "non-standard" Product forms; "In-house" capability

  - Tubular product forms – Seamless vs welded tubulars

  - Qty for already defined product forms
- Challenges: - Offering product forms for the prototype testing, which are not "standard product forms"

  - Code Case and Standards Acceptance (Three Heats)

  - Commercialization of New Alloys
- Information Needed: - Design Parameters – Stress/Temp and Environmental conditions; Product Forms