CREEP RESULTS OF STATE-OF-THE-ART MATERIALS IN CO_2 AND AIR

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COMPASsCO2 Second Stakeholders Workshop

Next generation advanced materials for particle/supercritical CO_2 heat exchangers

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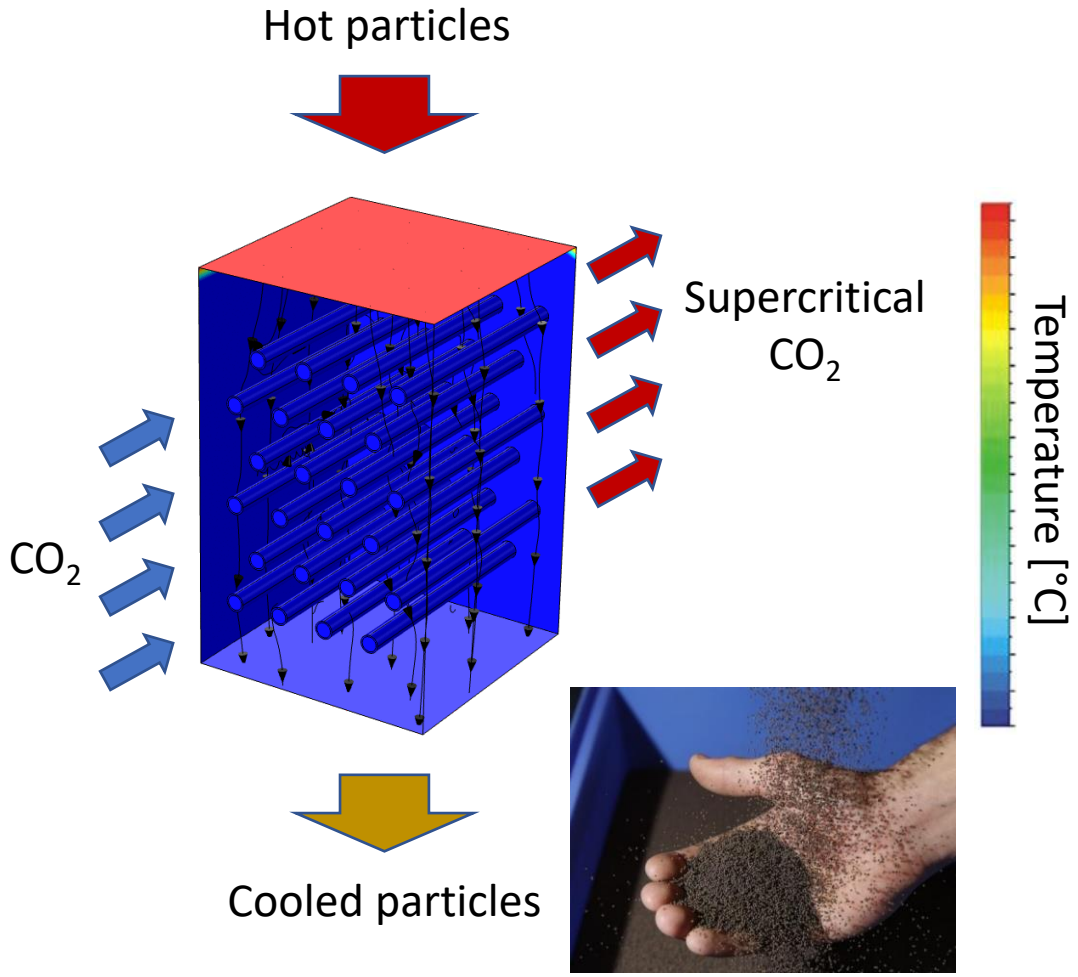
Objectives for Tube Material

- Outer Tube:
- Oxidation, corrosion & wear
  - Accelerated wear testing
  - Characterize materials and coatings to assess performance

- Inner Tube:
  - Understand the influence of CO_2 on creep behavior
  - Compare CO_2 creep data with creep tests performed in air



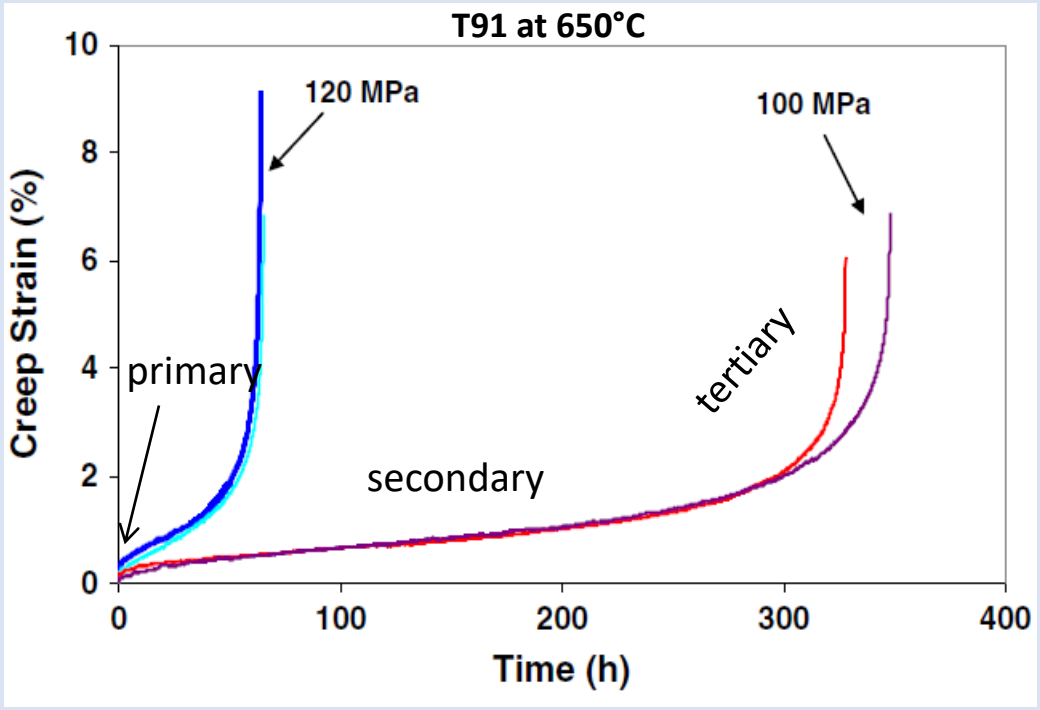
Creep in heat exchangers

Reformer Tube Failure due to Creep

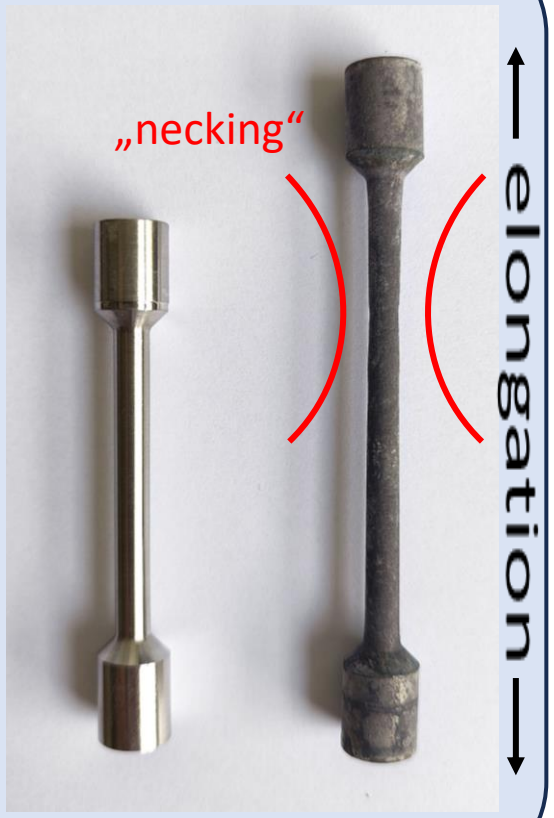
https://www.tcradvanced.com/reformer-tube.html

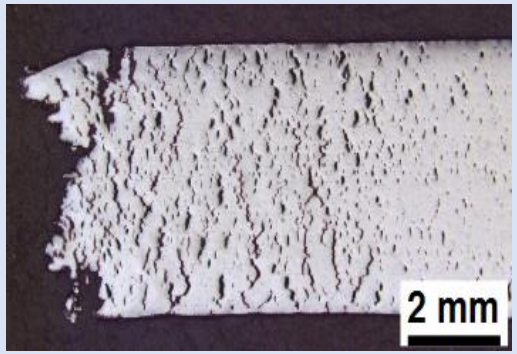
Creep Setup at DFI

Creep behavior of alloys



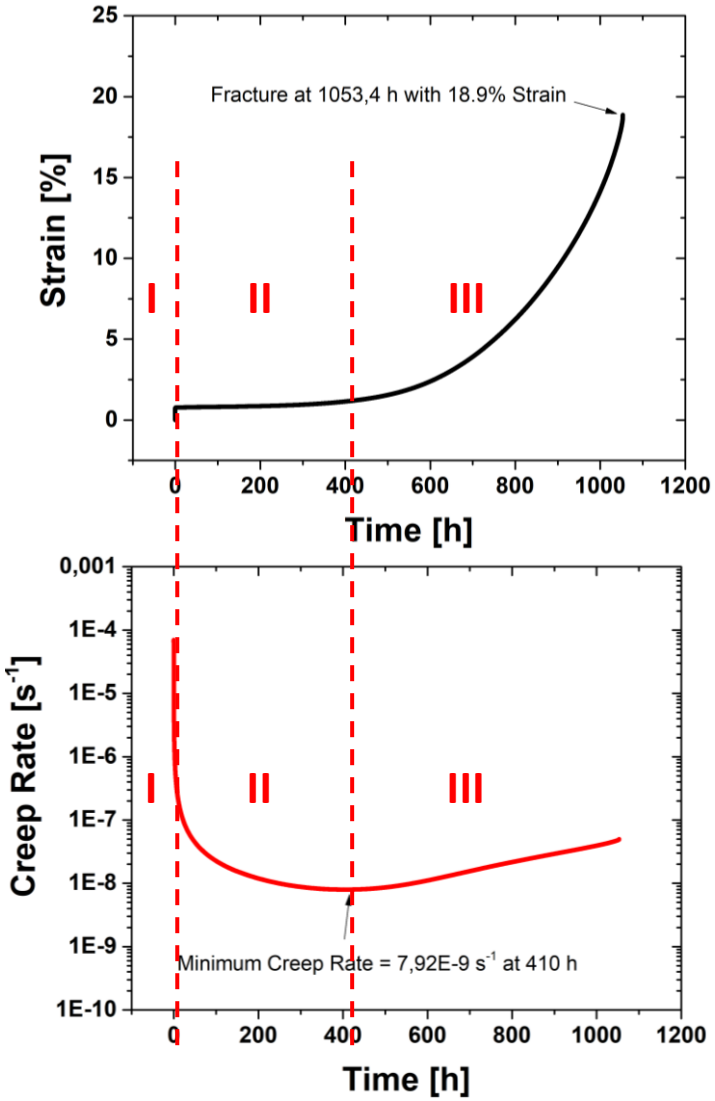
B.L. Bates et al. Surf. And Coat. Technol 240 (2014) 32-39.





Failure of the material

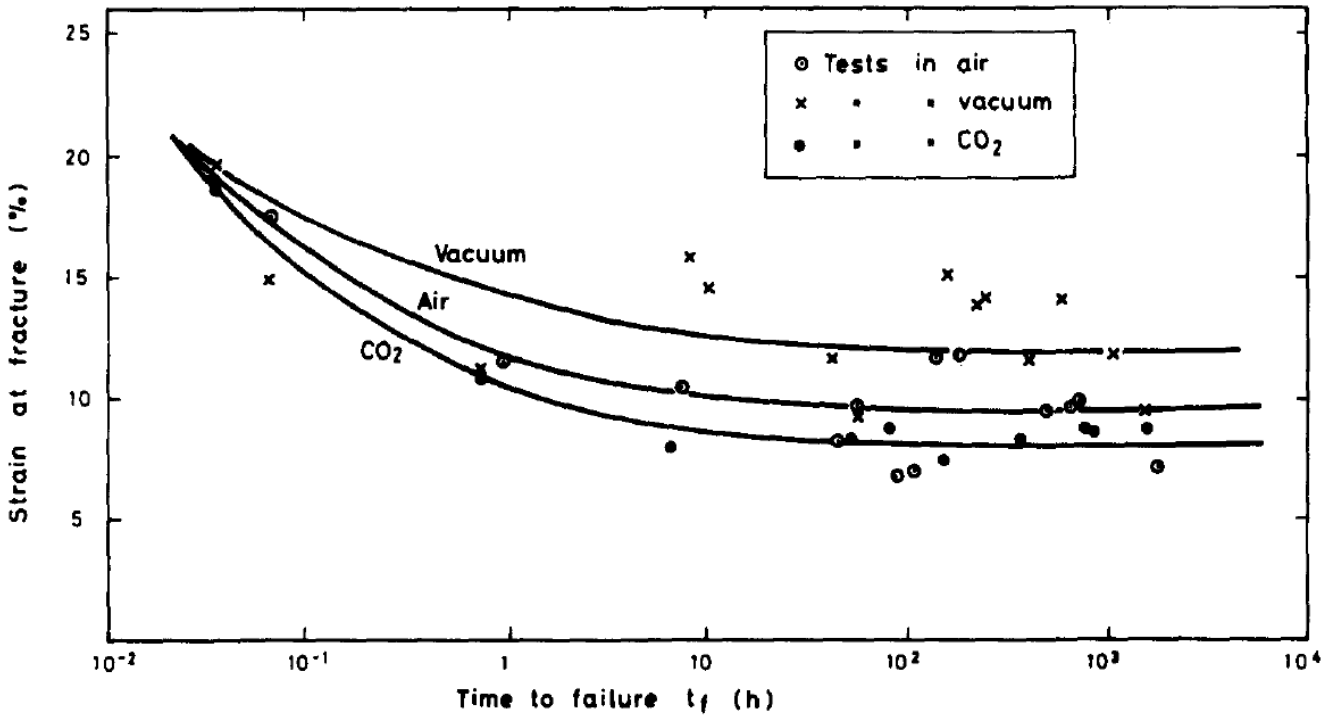
Minimum creep rate

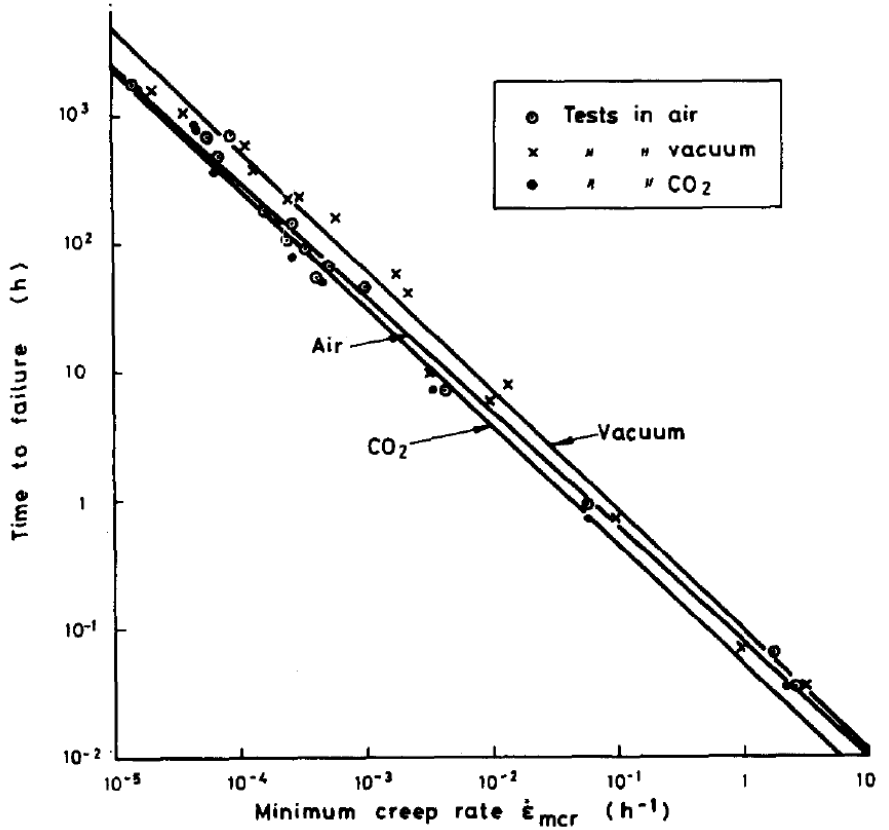


- Creep rupture times usually vary a lot!
- The minimum creep rate is easy to determine and subject to lower deviations
- The minimum creep rate allows for faster comparisons between materials than time to failure

Creep Test of Nimonic PE16 at 700 °C (Literature)

Ni	Cr	Mo	Co	Al	Ti
42-45	15.5-17.5	2.8-3.8	2.0	1.1-1.3	1.1-1.3





Tests were conducted under flowing CO_2

R. C. Lobb Mat. Sci Eng. (1979)

Creep tests in CO_2 @ 700°C

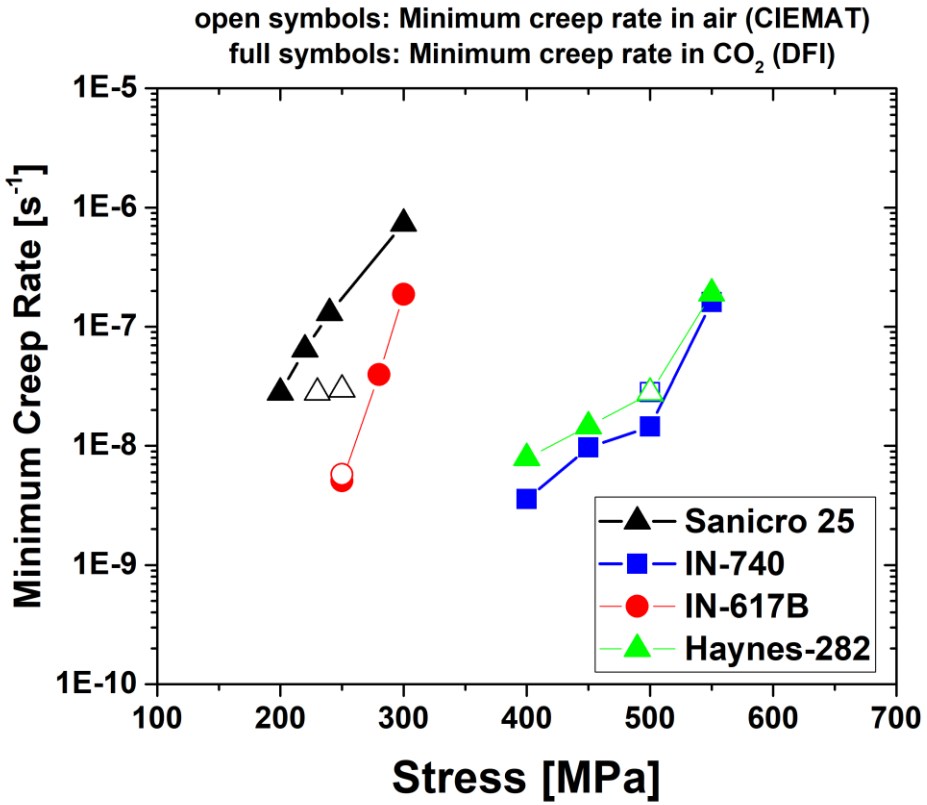
- Test temperature = 700°C
- Results will be compared to tests performed in air by CIEMAT

Material	σ [MPa]	Planned time [h]
Sanicro 25	300	100
	240	500
	220	700
	200	1000
IN617B	320	100
	300	500
	280	700
	250	1000
Haynes 282	550	100
	500	500
	450	700
	400	1000
IN740	550	100
	500	500
	450	700
	400	1000

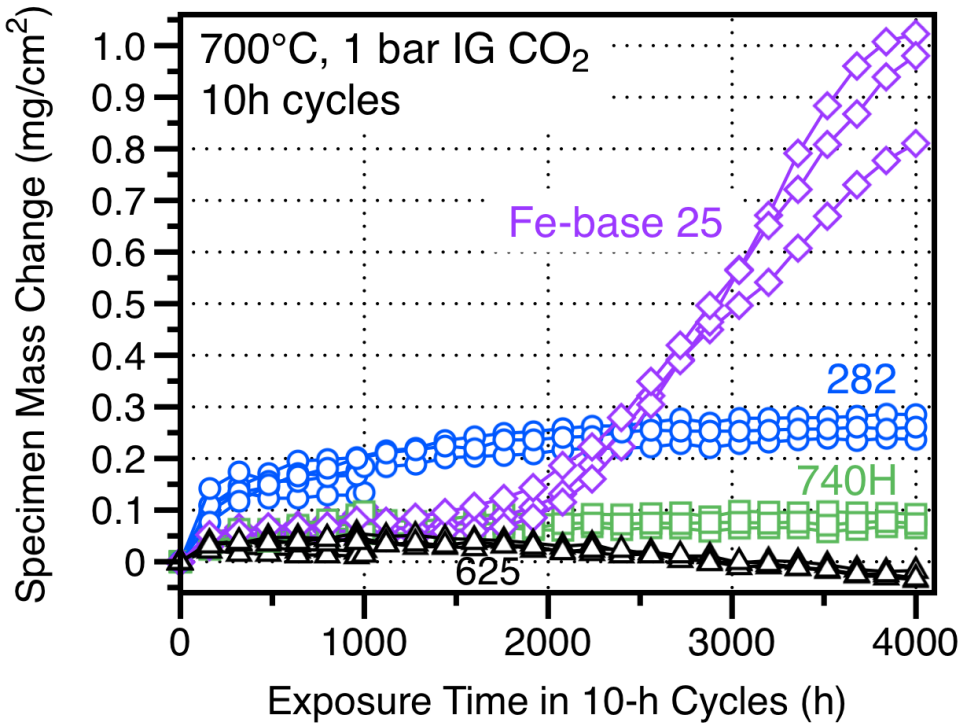
Chemical composition [wt.-%]

Sanicro 25	Ni	Cr	Co	W	Cu	Nb	Fe
	25	22.5	1.5	3.6	3	0.5	Bal.
IN617B	Ni	Cr	Co	Mo	Al	Ti	
	Bal.	22	12	9	1	0.35	
Haynes 282	Ni	Cr	Co	Mo	Ti	Al	Fe
	Bal.	20	10	8.5	2.1	1.5	1.5
IN-740	Ni	Cr	Co	Mo	Ti	Al	
	Bal.	24.5	20	0.1	1.35	1.35	

Comparison of minimum creep rate in CO_2 and air

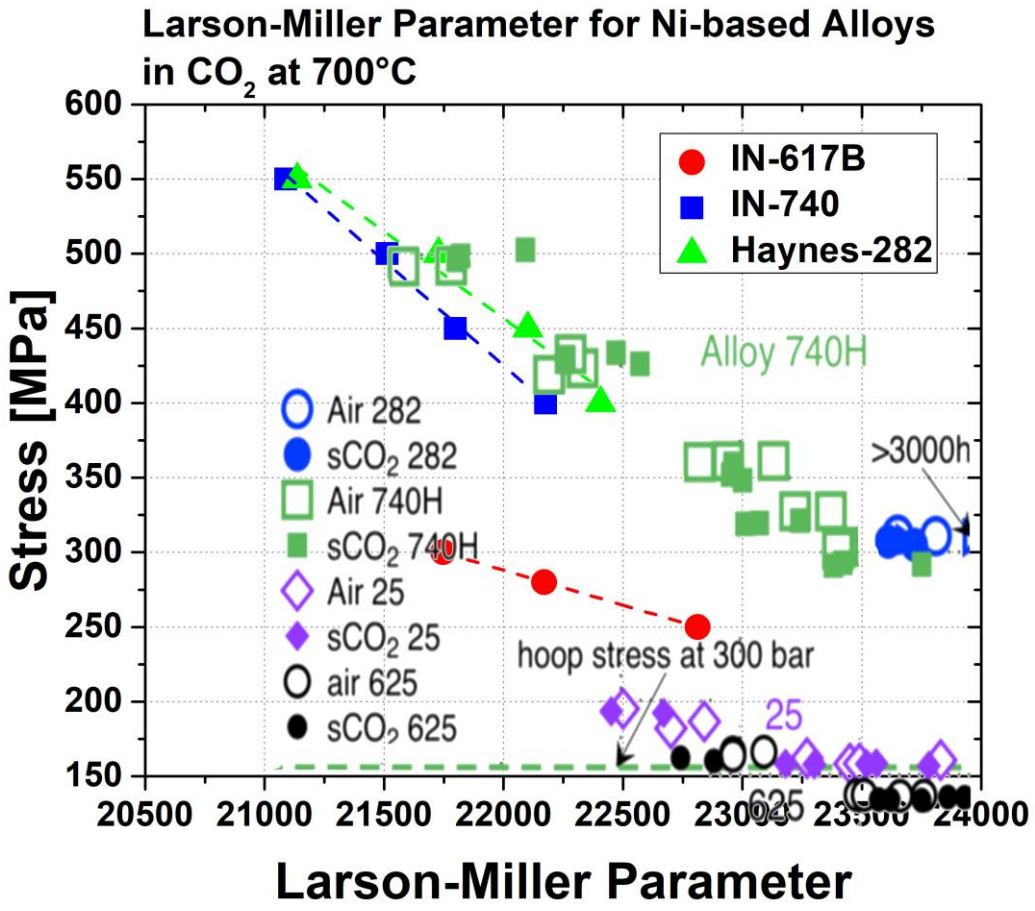


Pint et al. (2017) ASME, pp. 26-30

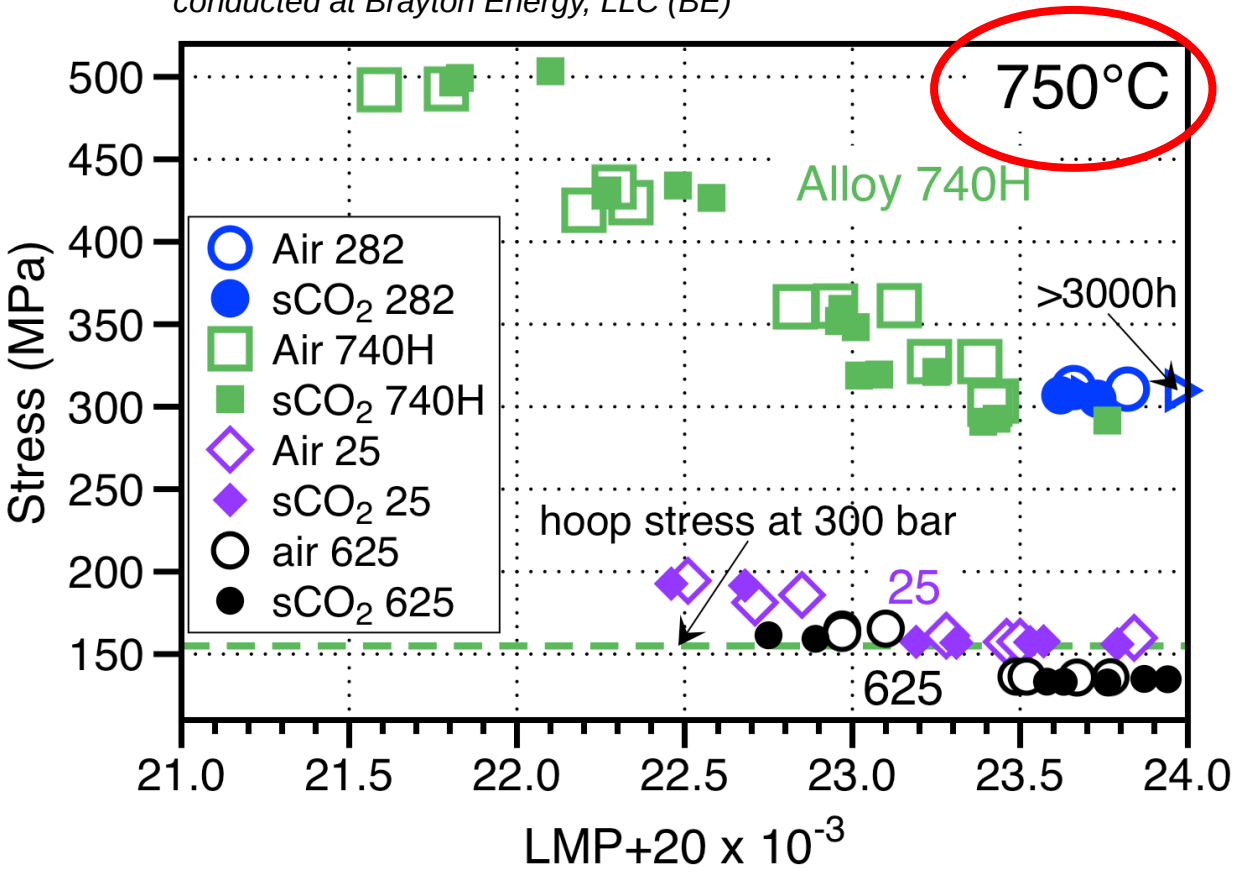


- Comparable Minimum Creep Rates
- Most sigificant difference is present for Sanicro 25

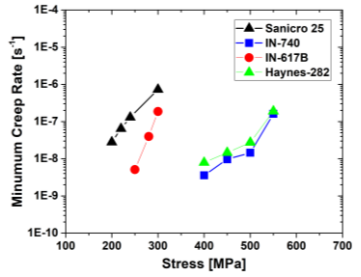
Larson-Miller Parameter of Ni-based alloys



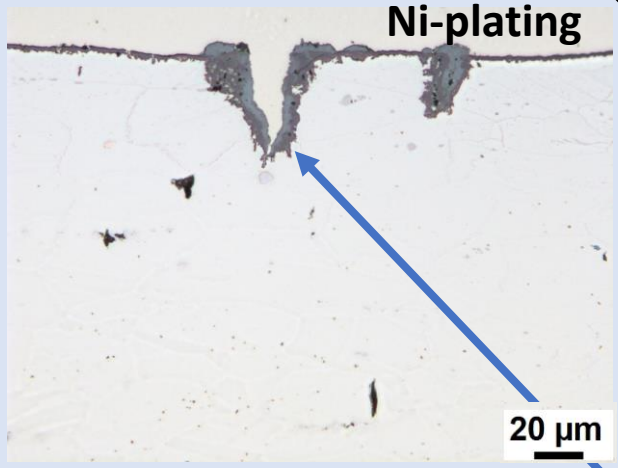
Pint & Pillai (2019) ORNL/SPR-2019/1134, conducted at Brayton Energy, LLC (BE)



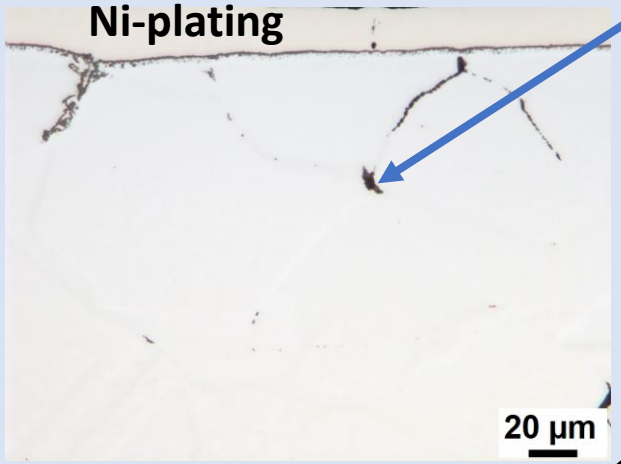
Degradation mechanisms: Oxidation



Sanicro 25 / 339 h / 240 MPa



IN-617B / 221 h / 300 MPa

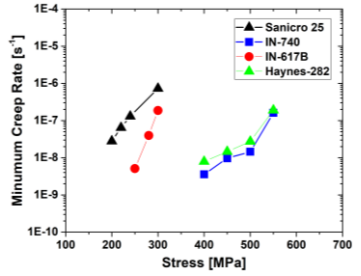


Oxidation

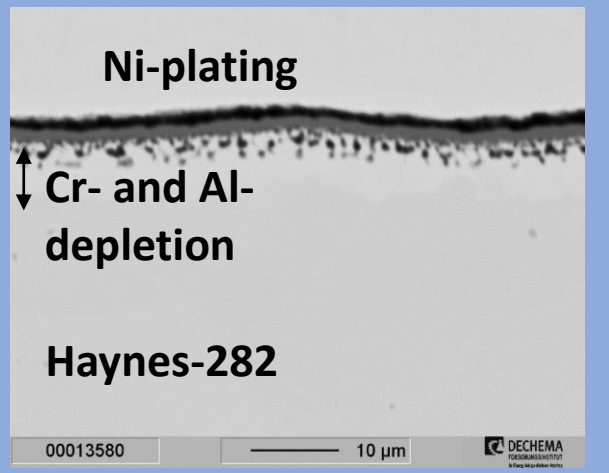
Depletion of stable oxide formers

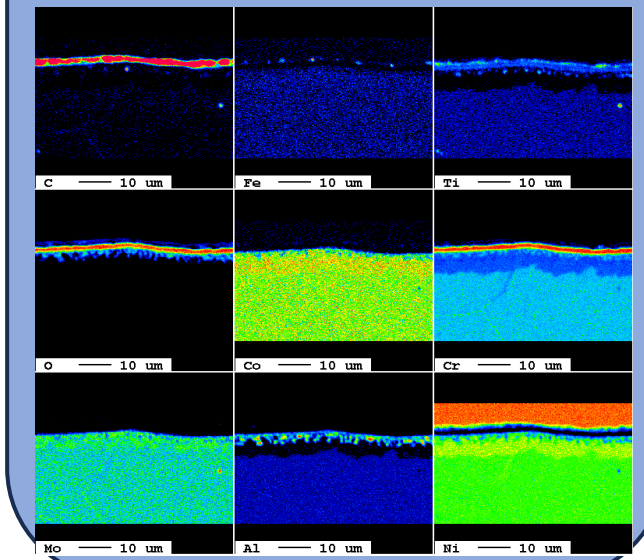
➔ non-protective oxides
➔ dissolution of carbides
➔ crack propagation

Degradation mechanisms: γ‘-dissolution

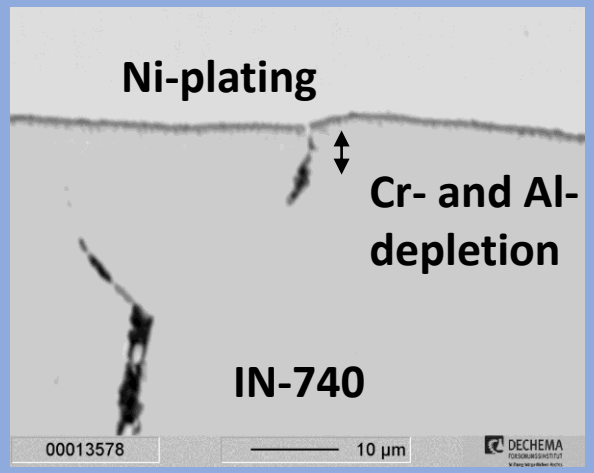


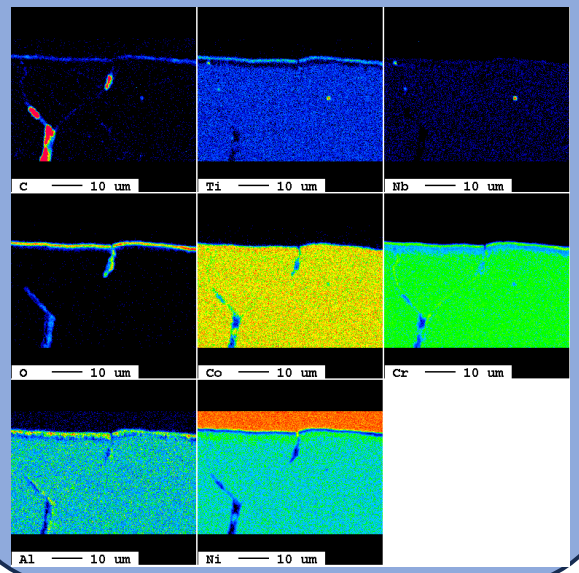
Haynes 282 / 500 MPa / 212 h





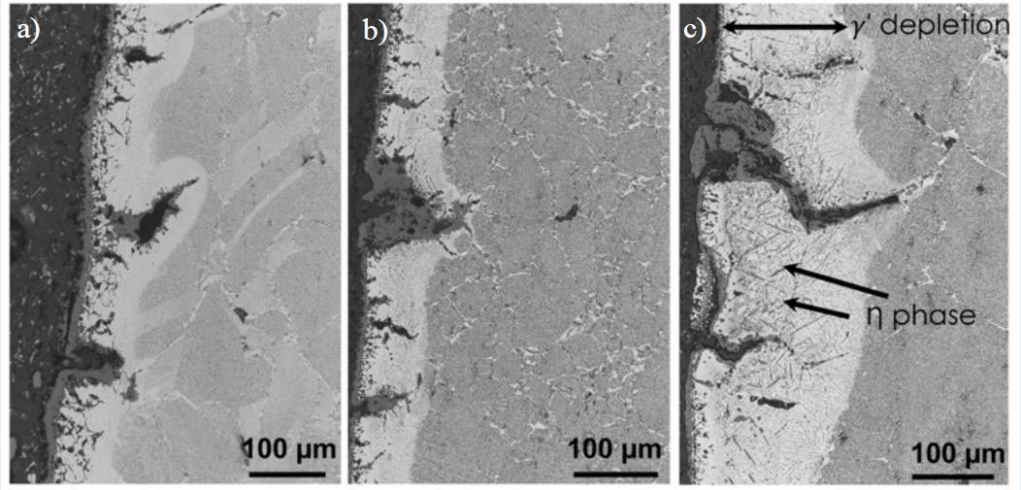
IN-740 / 500 MPa / 127 h





Haynes 282, 816 °C, lab air

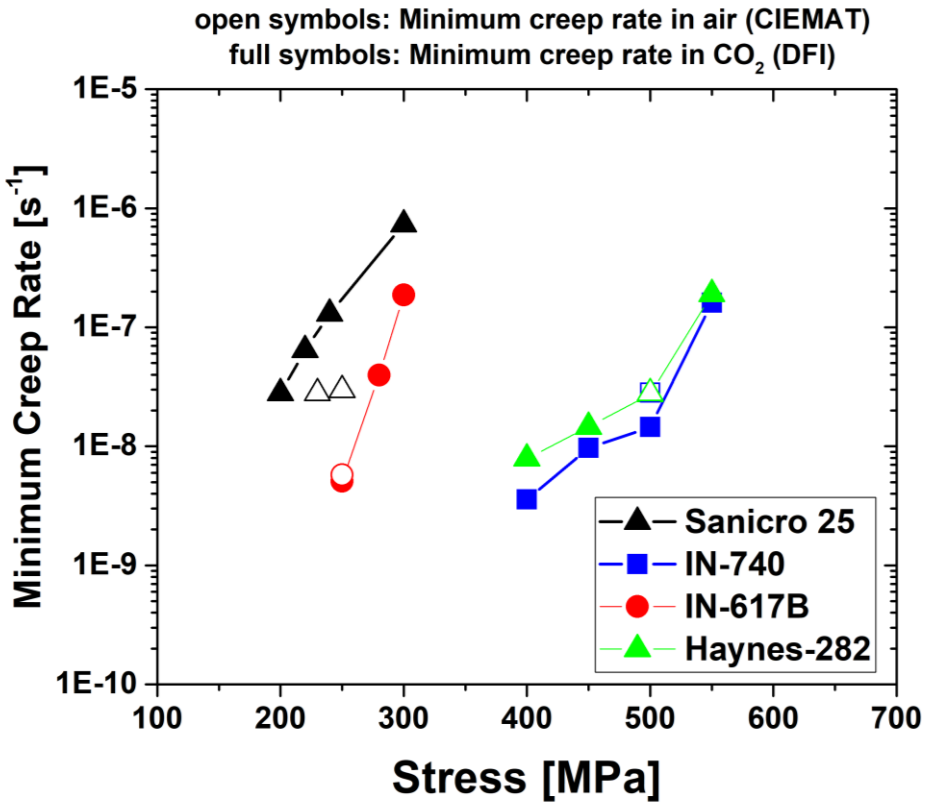
a) 102 MPa for 7912 h
b) 101 MPa for 14182 h
c) 100 MPa for 16914 h



Pint et al. ORNL (2020)

Conclusion

- Creep tests in CO_2 led to the formation of Cr-rich oxide scales and internal oxidation of Al
- Depletion of Cr and Al led to dissolution of γ‘-precipitates and carbides
- The materials tested show a comparable creep behavior in CO_2 to air



- Outlook: In depth comparison of air data to CO_2 tests

Thank you!

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