Furnace Heat Transfer

- Faster, Cheaper, Better

Curt Colopy

FNA 2014
Oct. 6-8, 2014 • Nashville, Tennessee

What is a Si-SiC Composite?

50% Si + 50% SiC by volume,
metallurgical grade Silicon metal
with 80 mesh SiC particles

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Rationale for Si-SiC Radiant Tubes

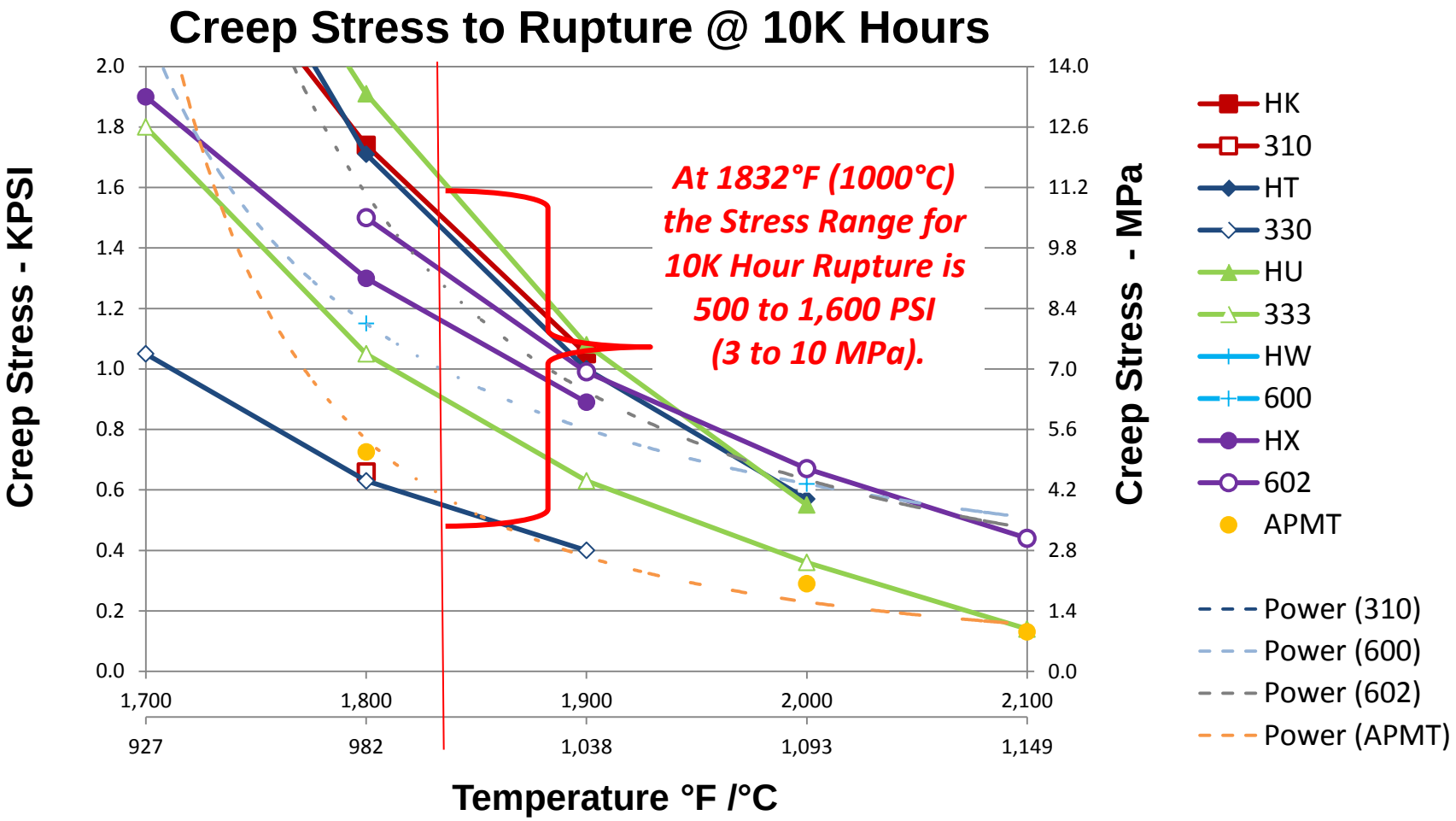
- Conventional = Very Long Life
- Enabling = Very High Temp
- **Productivity = Higher Throughput**

Conventional Savings

- Excellent Creep Properties to 2450°F
  = No Tube Droop or Distortion
- Excellent Resistance to Carburization
  = No Tube Corrosion or Embrittlement
- Excellent Thermal Shock & Low CTE
  = No Fracture in Heat-Up or Cool-Down

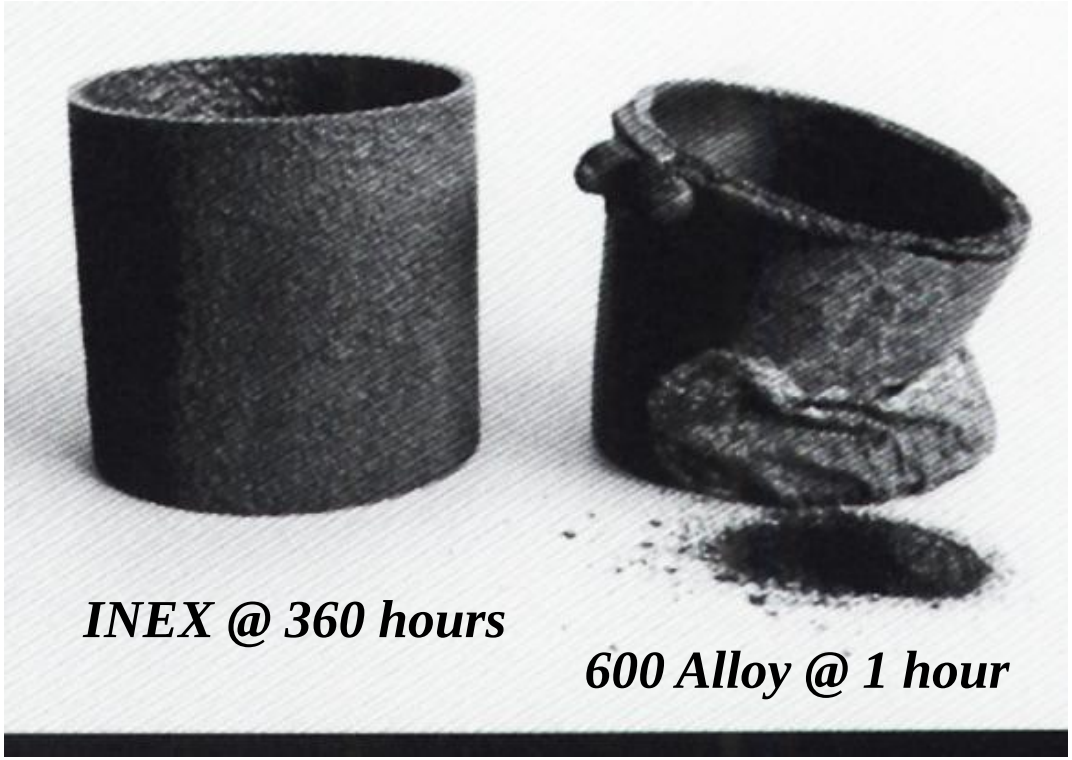
18+ Years Continuous Carburizing Service

Compare Alloys to Si-SiC @2450°F = ~8.5 KPSI Stress @ <0.6% Strain



Si-SiC Composite vs. 600 Alloy (after just 1 hour)

No deformation for the INEX tube tested 360 hours @ 2462°F.



Metal Alloy Tubes after <24 Months

Si-SiC Enables Processing >1800°F

- Stainless Steel Aging
- Powdered Metal Sintering
- Minerals Processing

What Limits Furnace Throughput ?

- Metallurgical Objectives
- Mechanical Constraints
- **Radiant Tube <u>Heat Flux</u>**
- NOT Refractory or Burners

What is Heat Flux ?

Heat flux or thermal **flux** is the rate of **heat** energy transfer through a given surface, per unit surface.

- $(BTU/hour)/inch^2$
- $kW/meter^2 = 2.2\ BTU/hr/in^2$

Design Criteria for Radiant Tubes

Metal Alloy Tubes @ 1800°F :

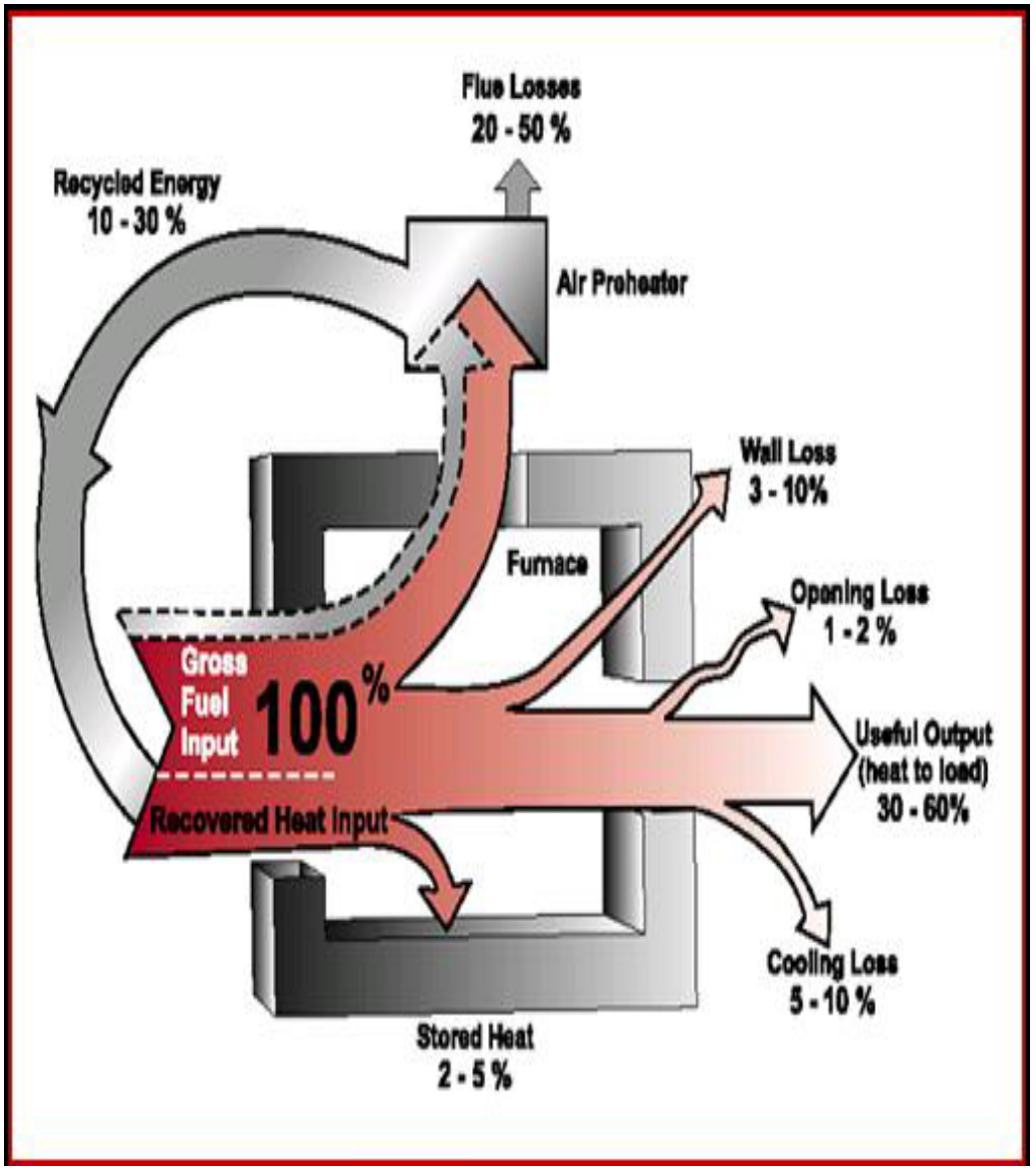
- Conservative = 50 BTU/hr/in^2
- **Nominal = 55 BTU/hr/in^2**
- Aggressive = 60 BTU/hr/in^2

Max Service °F depends on Alloy & Atmosphere

Si-SiC Composite Tubes @ 1800°F :

- **Nominal = 110 BTU/hr/in^2**

Maximum Service Temp is 2450°F !!!



SANKEY DIAGRAM

Typical Pusher Furnace

Parasitic or Standing Losses

average ~20%

- Wall Losses
- Opening Losses
- Cooling & Conveyor Losses
- Fixtures, Trays, Baskets
- Storage Losses (Batch Furnace)

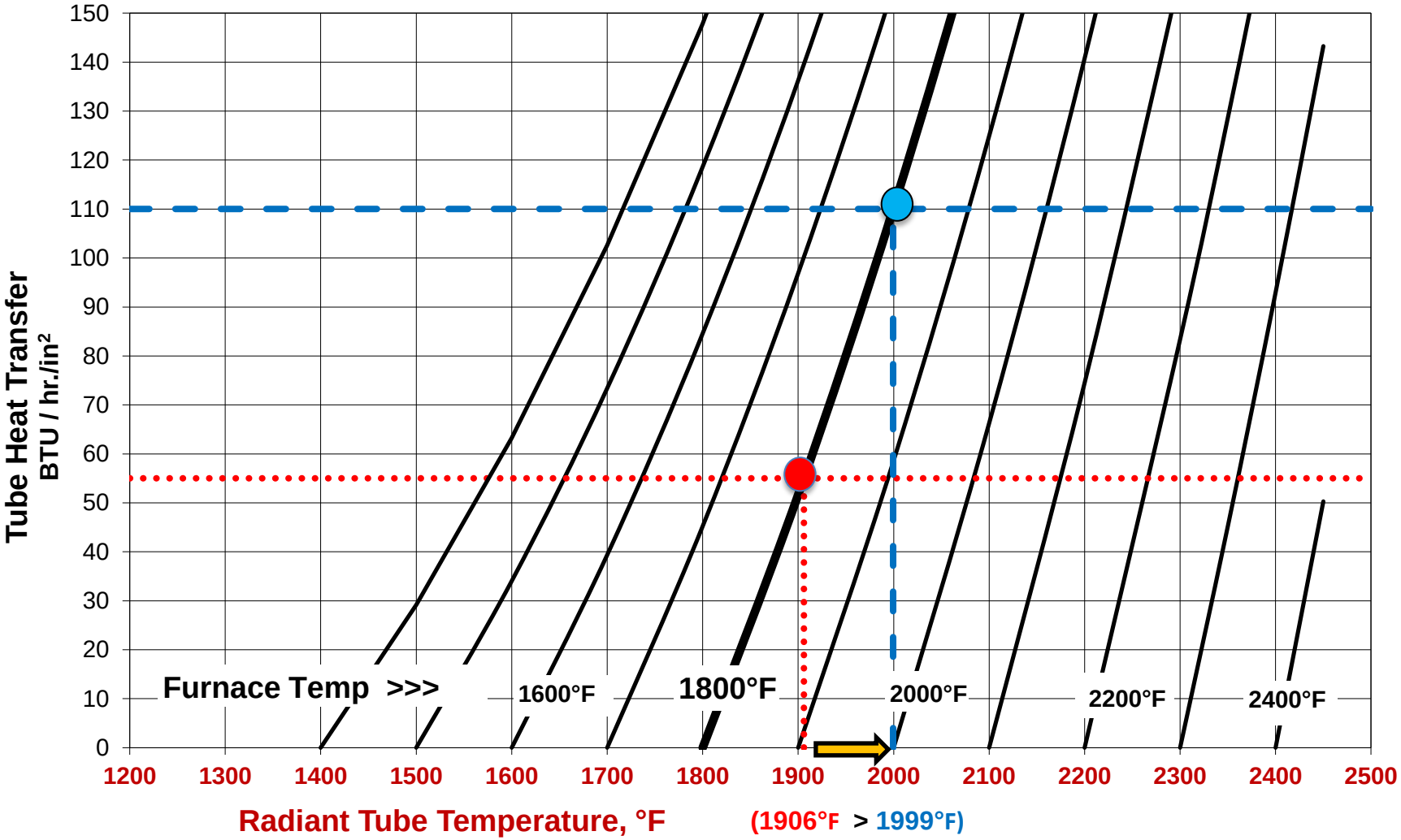
FASTER Cycle Time

- Increases furnace throughput
- Reduces per unit standing (parasitic) losses
- Does NOT reduce process energy required
- Does NOT improve combustion efficiency

HEAT TRANSFER RATE

Radiant Tube vs Furnace Temperature

$$Q / A = \sigma e (T^4_{Tube} - T^4_{Furnace})$$



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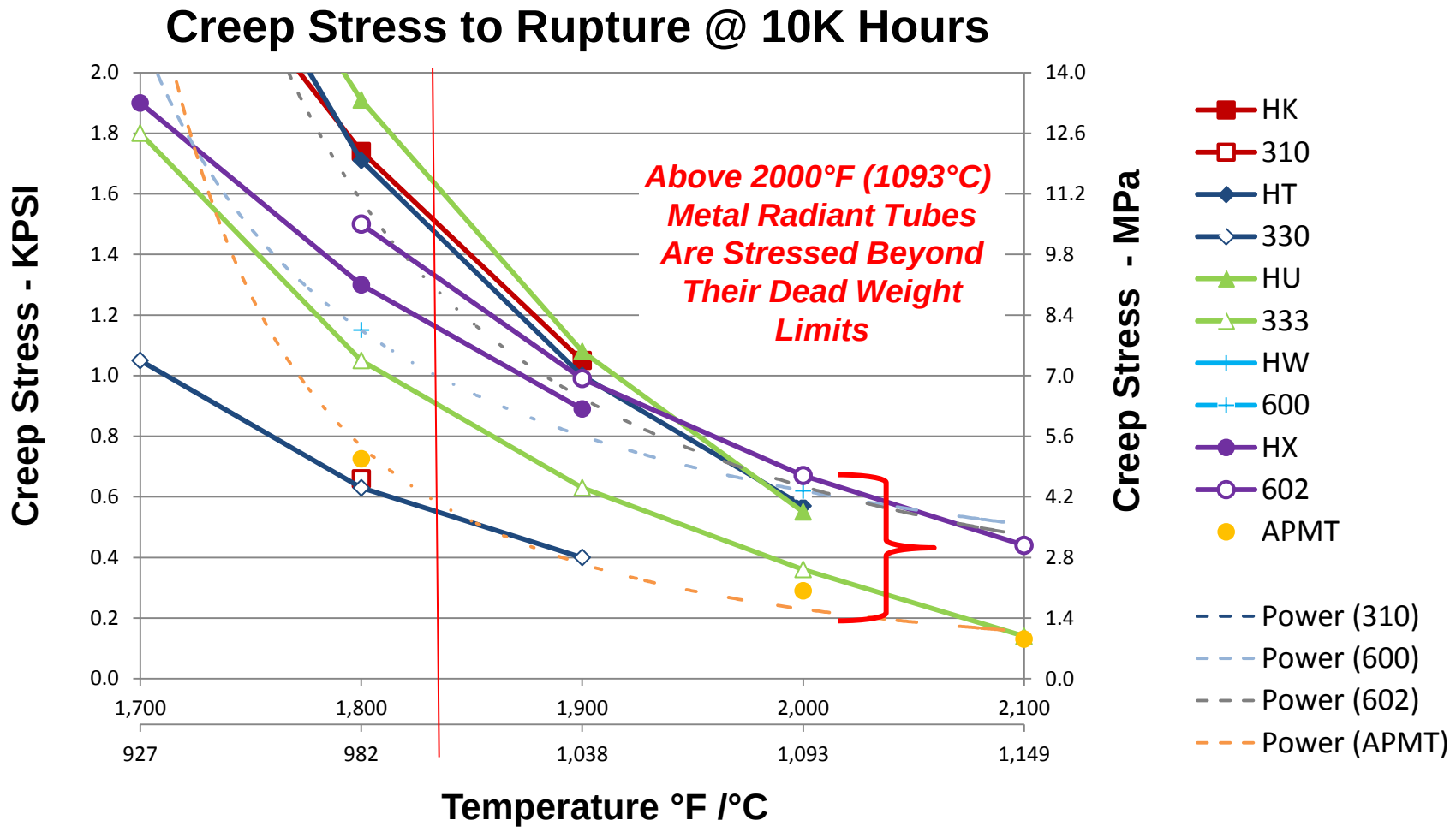

CHEAPER Furnace Operation

- 25% Increase in Throughput = 25% More Load
  (reducing Furnace Operating Hours by 20%)

- Process Energy Required Remains the Same
  i.e. Work on Load is Unchanged **= 0.0%**

- Standing Energy Losses of 20% Eliminated for
  the 20% of Furnace Hours Reduced = **+4.0%**

- Offset Somewhat by Higher Exhaust Losses
  (1906°F > 1999°F) Available Heat **= -2.0%**

"SAME-WORK" SCENARIO

Load Cycle	BASELINE Hours	BASELINE BTU/hour	25% FASTER Hours	25% FASTER BTU/hour
Ramp-Up	**4.0**	1,000,000	**2.7**	1,385,185
Soak	**2.0**	600,000	**2.0**	600,000
Turn-Around	**0.5**	0	**0.5**	0
	6.5 hours/load		**5.2** hours/load	
			-20% fewer hours	

… for the "SAME-WORK":

500	hours/month	400
76.9	**cycles/month**	**76.9**
5,200,000	BTU/cycle	4,940,000
400,000,000	**BTU/month**	**380,000,000**
		-5.0% Energy, Un-Adjusted
		+2.0% Exhaust Loss

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“Back of the Envelope” Savings

1200 more hours/year/furnace
5.2 hours/cycle
231 cycles/year
2,000 lbs/cycle
461,538 lbs/year
$1.10 Sales Value / lb
$507,692 Increased Sales
50% Variable Cost
$253,846 EBIT / furnace

Compare with:

- New Si-SiC Radiant Tubes <$25,000
- New EGR-type Burners, if Needed <$25,000
- Used or New Furnace

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Why Are Si-SiC Tubes BETTER ?

- Proven Life >18 Years in Carburizing
- High Temp Processing to 2300°F
- 25% More Product Throughput
- < 12 Months Payback

FASTER, CHEAPER, BETTER @ 1400°F - 2300°F

QUESTIONS ?

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