Current Issues with Grade 91

Hardfacing Delamination in High Temperature Valves

The Reduction in Allowable Stress Values for Grade 91

- Babcock Power Meeting
- January 2018
- Gatlinburg

Topics Reviewed

1. Hardfacing Delamination
   a. Failure characteristics
   b. Failure causes
   c. Recommendations for avoiding problem

2. ASME Action to Reduce Allowable Stress Values for Grade 91
   a. Review of how time-dependent allowable stress values originally are calculated
   b. The reason for modifications in the analysis procedure
   c. The impact of new long-term test results
   d. When will the new values take effect
   e. What actions should equipment operators take

Stellite Delamination

Stellite Delamination in Grade 91 Valves

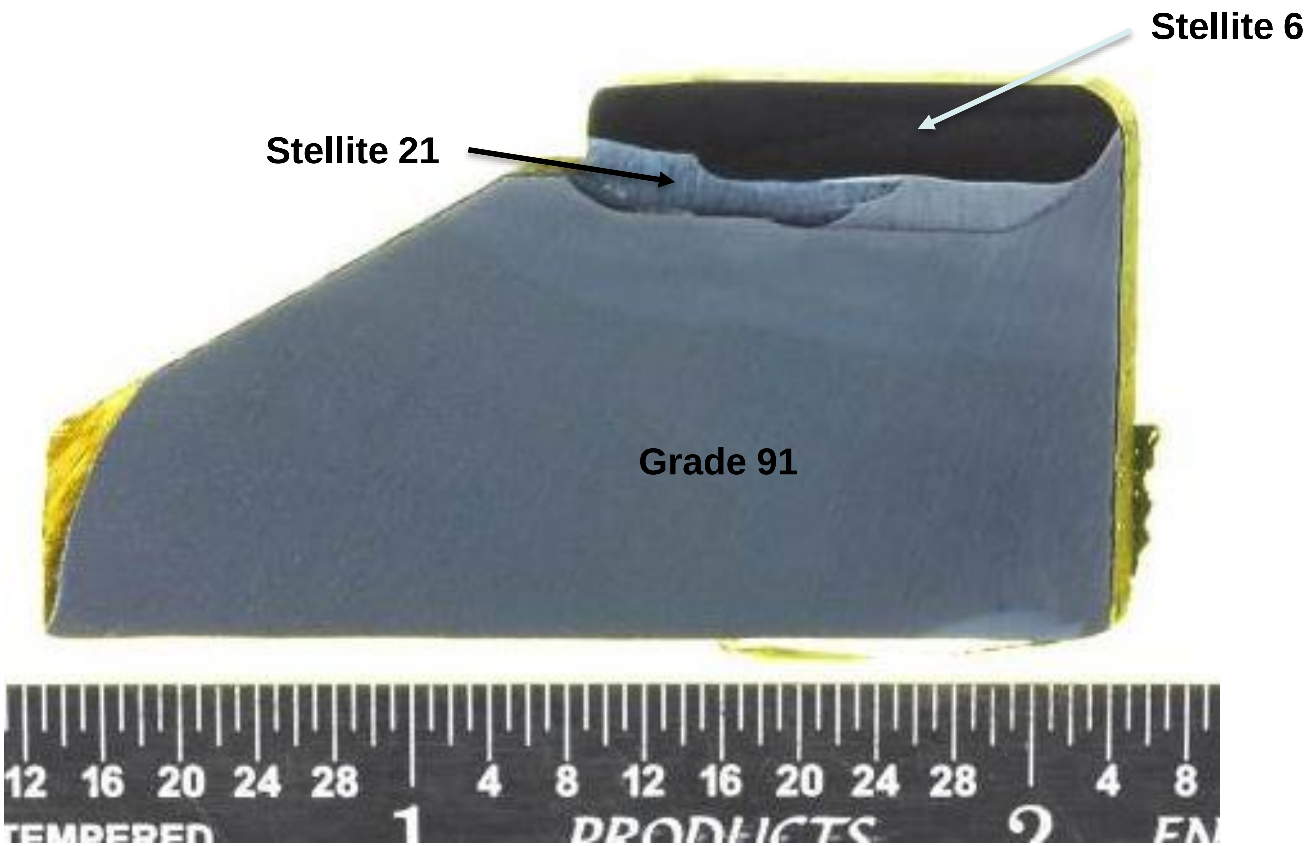
- Numerous reports of separation of hardfacing materials from sealing surfaces in valves, such as seats and disks; loss of proper sealing and consequential damage from dislodged material has been a significant problem for plant operators
- Most common hardfacing materials involved have been Stellite 21 and Stellite 6

Stellite Hardfacing Alloys

Nominal Composition (mass%) and Physical Properties								
	Co	**Cr**	**Mo**	**W**	**C**	**Ni**	**Others**	**Hardness**
Stellite 21	Base	26.0-29.0	4.5-6.0	--	0.20-0.35	2.0-3.0	Fe, Si, Mn	27-40HRC 290-430HV
Stellite 6	Base	27.0-32.0	--	4.0-6.0	0.9-1.4	--	Ni, Fe, Si, Mn, Mo	36-45HRC 380-490HV

Use of Stellite Hardfacing Alloys

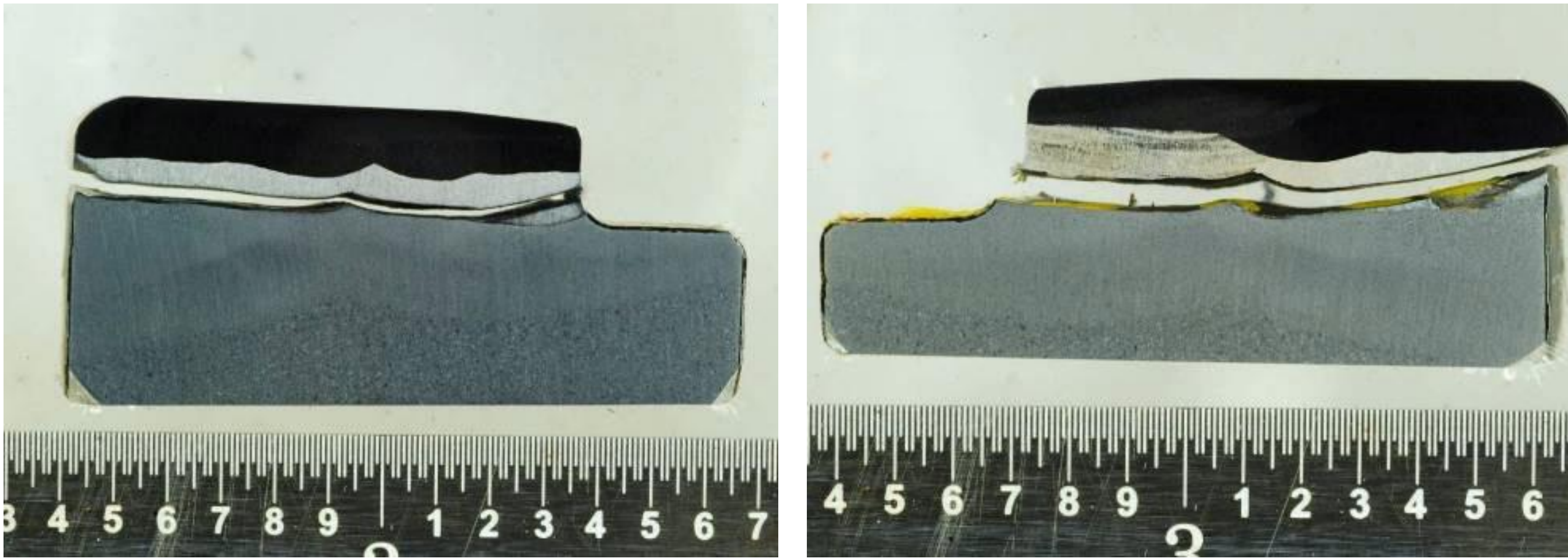
- For Grade 91 valves, practice has varied, but Stellite 21 frequently used as buttering layer to moderate difference in composition/properties between the Grade 91 and Stellite 6



Stellite Delamination in Grade 91 Valves

Fracture features consistent with separation at or near fusion boundary with base metal

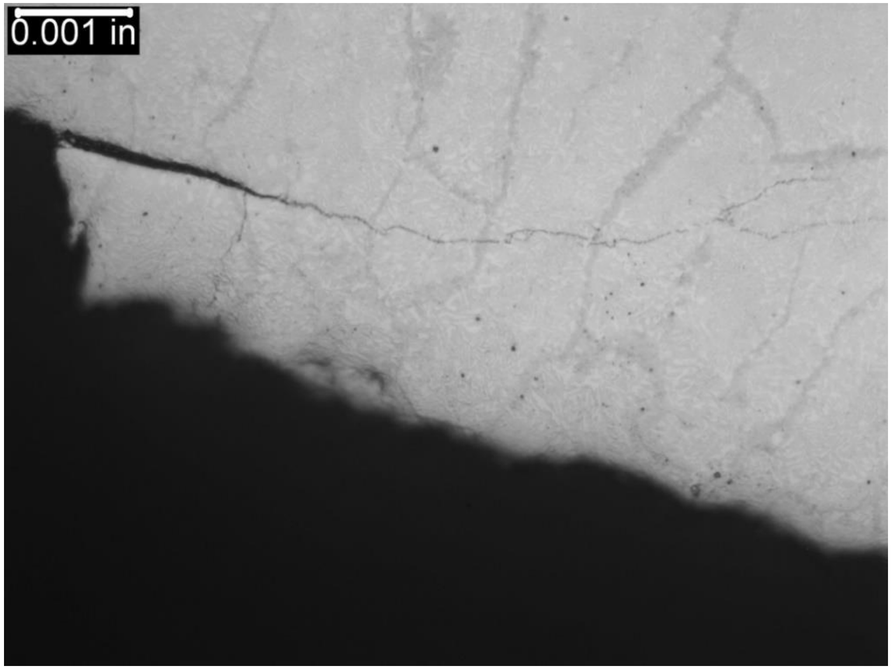
Stellite Delamination in Grade 91 Valves

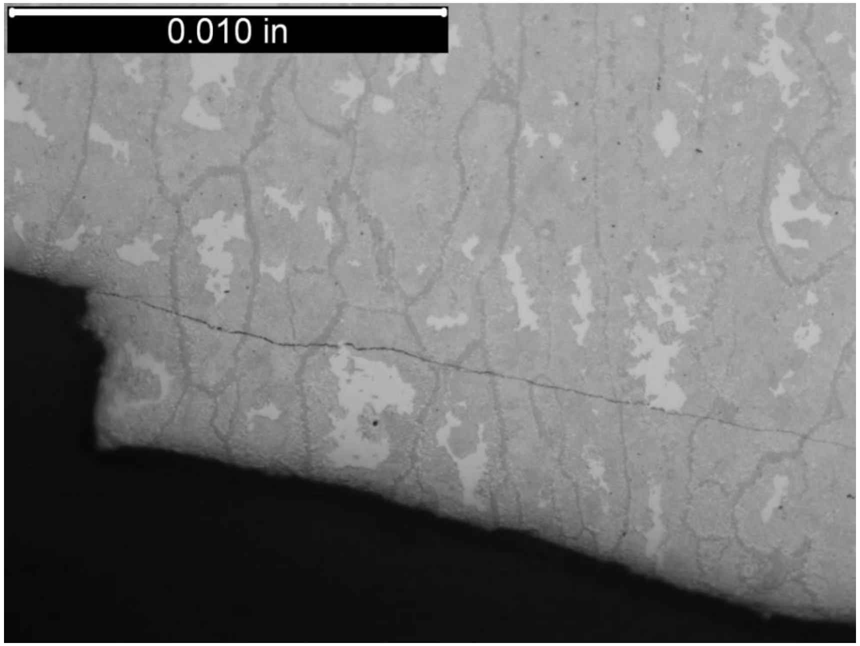


Fracture features consistent with separation at or near fusion boundary with base metal

Cracking in Stellite 21 Buttering Layer

Secondary cracking consistent with fast brittle fracture - a common feature of failures





Stellite Valve Seat Failures

- Crack initiation in the Stellite 21 butter layer
- Crack propagation close to the DMW interface in the butter layer or directly along the DMW interface
- DMW interface not uniquely susceptible to cracking and its presence has played no significant role in failures

Hardness Profiles in Failed Hardfacing Layers

Outer Surface

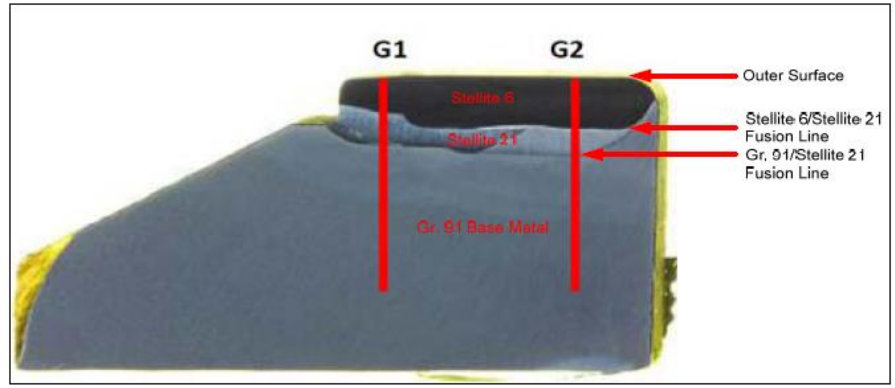
Stellite 6/Stellite 21 Fusion Line

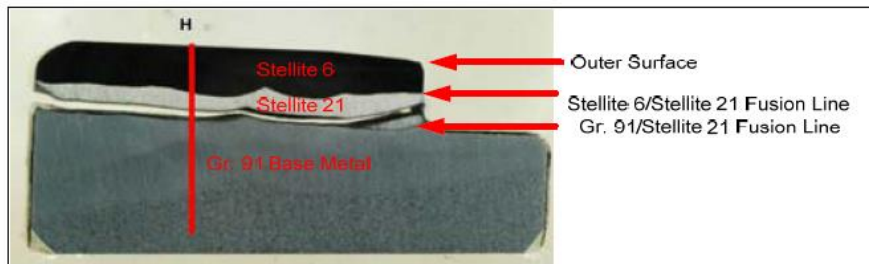
Gr. 91/ Stellite 21 Fusion Line

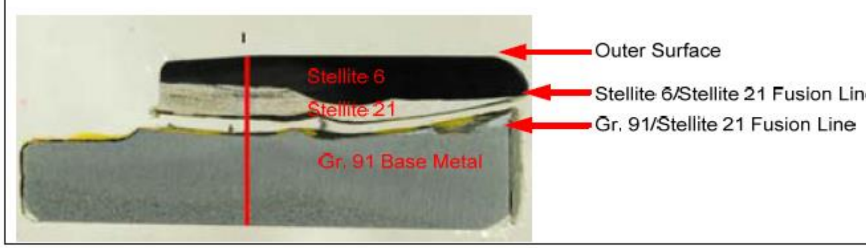
ROCKWELL C HARDNESS VALUES				
	SAMPLE NUMBER			
	G1	G2	H	I
Stellite 6	48	55	49	50
	49	53	48	45
	50	48	47	46
	49	48	48	47
	49	50	39	52
Stellite 21	60	48	36	52
	57	49	40	48
	58	49	58	53
	58	55	58	58
	58	39	21	23
Gr 91 Base Metal	96*	39	21	22
	20	39	97*	98*
	96*	21	95*	97*
	96*	97*	94*	96*
	94*	98*	95*	94*
	94*	97*	95*	92*

* Rockwell B Hardness

Typical Hardness Values:
Stellite 6: 36-45 HRC
Stellite 21: 27-40 HRC
Grade 91: 93-98 HRB

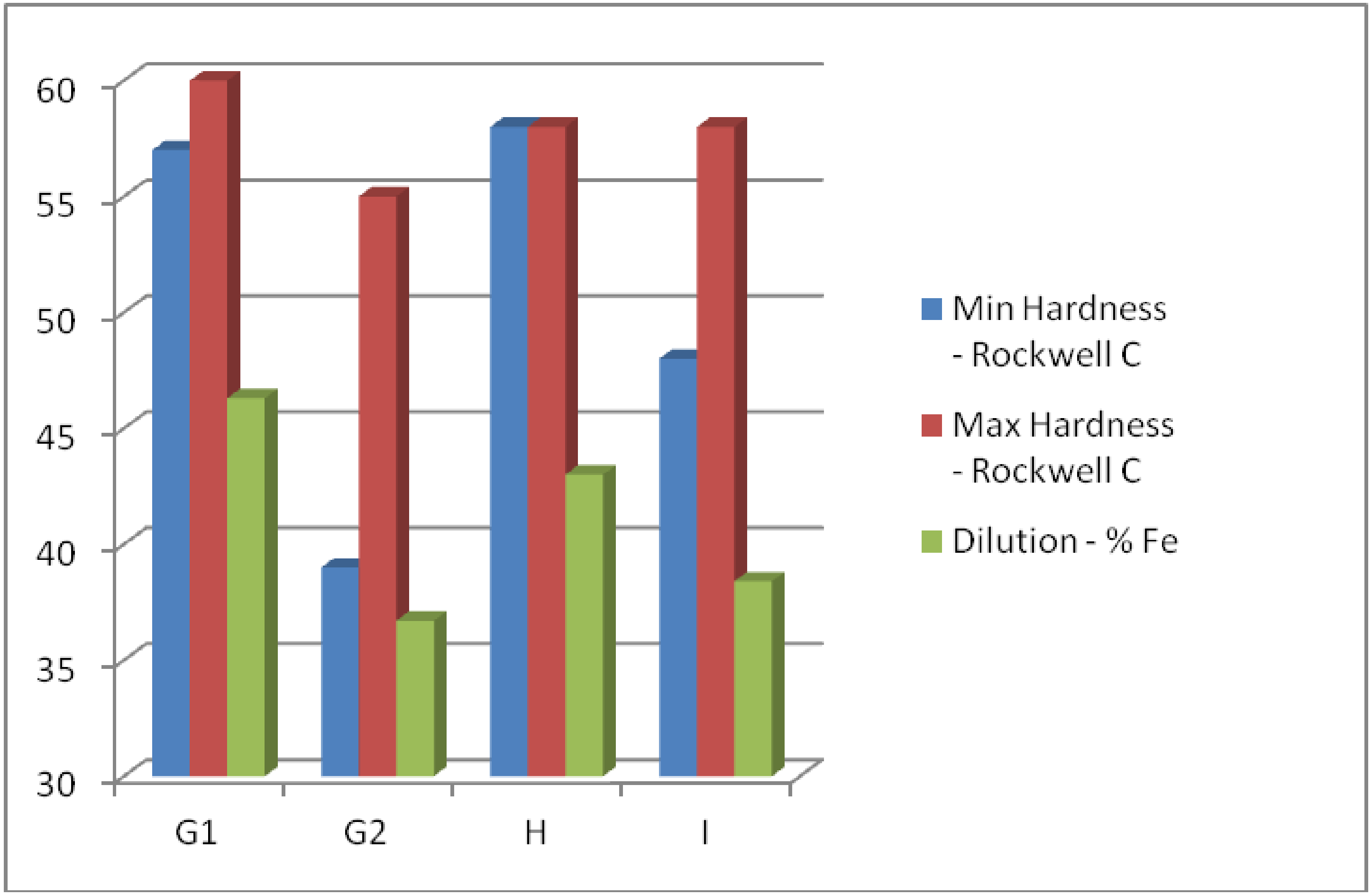






Study by Lolla, et.al., demonstrated that high hardness in diluted butter layer due to widespread formation of sigma phase

Dilution Effects in Butter Layer



Minimizing Crack Risk

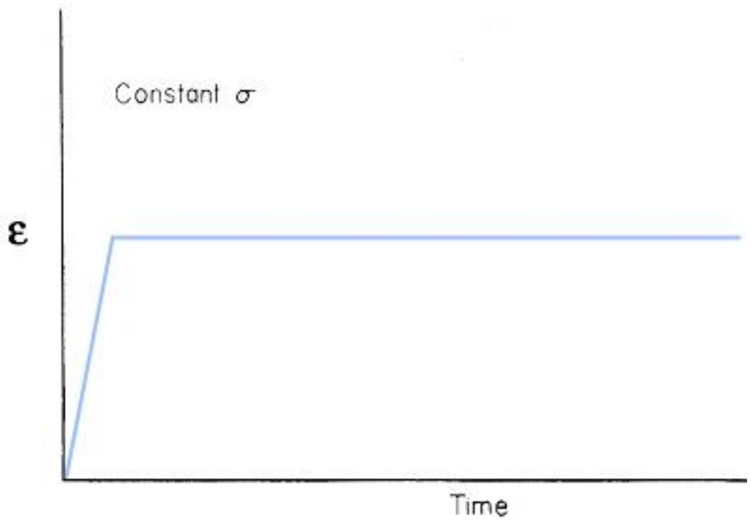
- Use “standard” nickel base filler metal for butter layer rather than Stellite 21 (e.g., ERNiCr-3, ERNiCrFe-2, ERNiCrFe-4)
  - Much less sensitive to the effects of base metal dilution and resistant to sigma phase formation
- Control preheat and heat input to minimize base metal dilution of the butter layer – maintain dilution <10%
- For field repairs, 2nd pass made with Stellite 21
- For shop repairs, 2nd pass made with Stellite 6
- For repairs of castings, machine extra 100 mils when removing existing material from seats or disks to accommodate butter layer and remove silica at surface of casting, which can promote hot cracking in the weld deposit

Reduction in Allowable Stress Values for Grade 91 Material

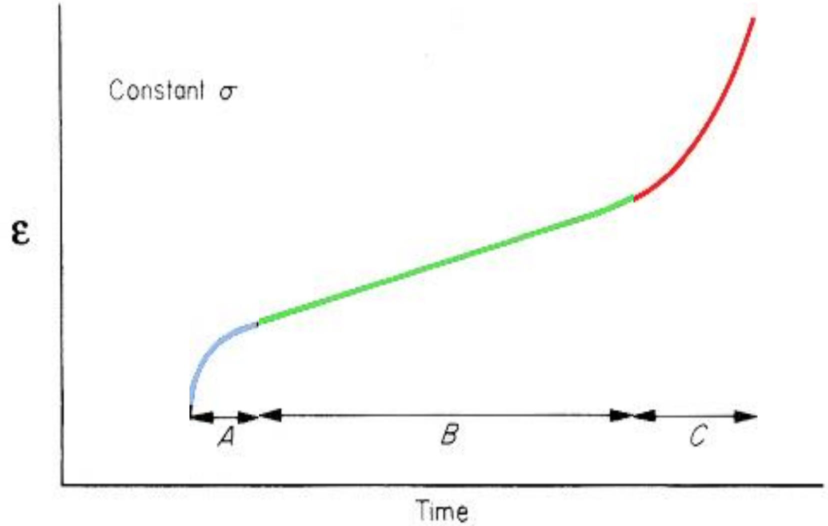
Creep – Principal Damage Mechanism in High Temperature Components

- **Definition**: Time-dependent strain occurring under a stress which is lower than the yield point

Room Temp.



Elev. Temp.



A – Primary Creep
B – Secondary Creep
C – Tertiary Creep

Strength Basis of Material Selection

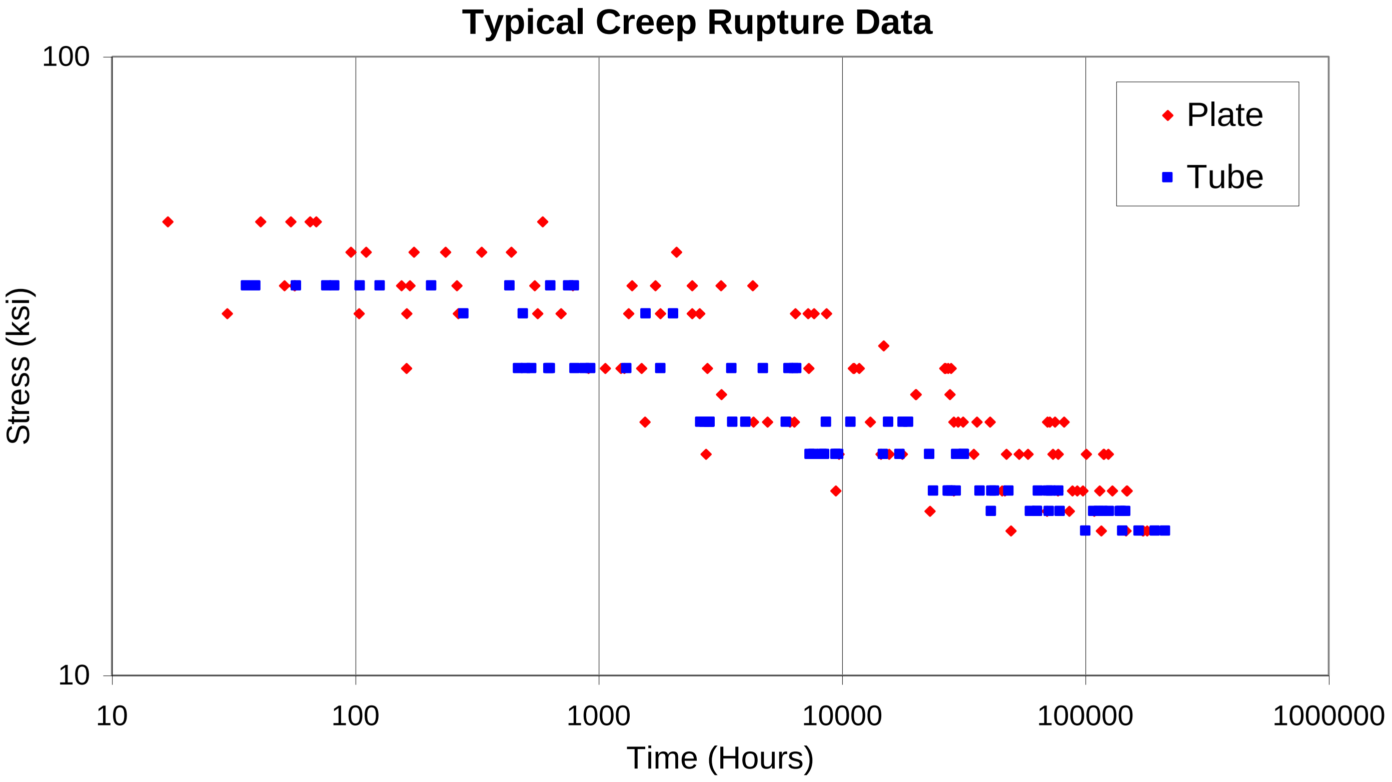
- In determining allowable stresses, the ASME Code reviews tensile, creep and stress rupture property data obtained over the temperature range of usage and applies the following criteria listed in paragraph 1-100 of Section II (Materials), Part D of the ASME code
  - 1/3.5 of the specified minimum tensile strength at room temperature
  - 1/3.5 of the tensile strength at elevated temperatures
  - ⅔ of the specified minimum yield strength at room temperature
  - ⅔ of the yield strength at elevated temperatures
  - 100% of the average stress to produce a creep rate of 0.01% in 1,000 hr
  - 67% of the average stress to produce rupture at the end of 100,000 hours or 80% of the minimum stress for rupture at the end of 100,000 hours as determined from the extrapolated data, whichever is lower

Design Life of ASME Boilers/Pressure Vessels

- ASME-designed boilers and pressure vessels do not have a defined design life
  - From the Foreword: “The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness.”
- To the extent that the life of major components operating in the time dependent regime (e.g., outlet headers, high temperature piping) influence decisions regarding the useful life of a boiler or pressure vessel designed to ASME rules, an inferred minimum life of approximately 300K hours can be rationalized

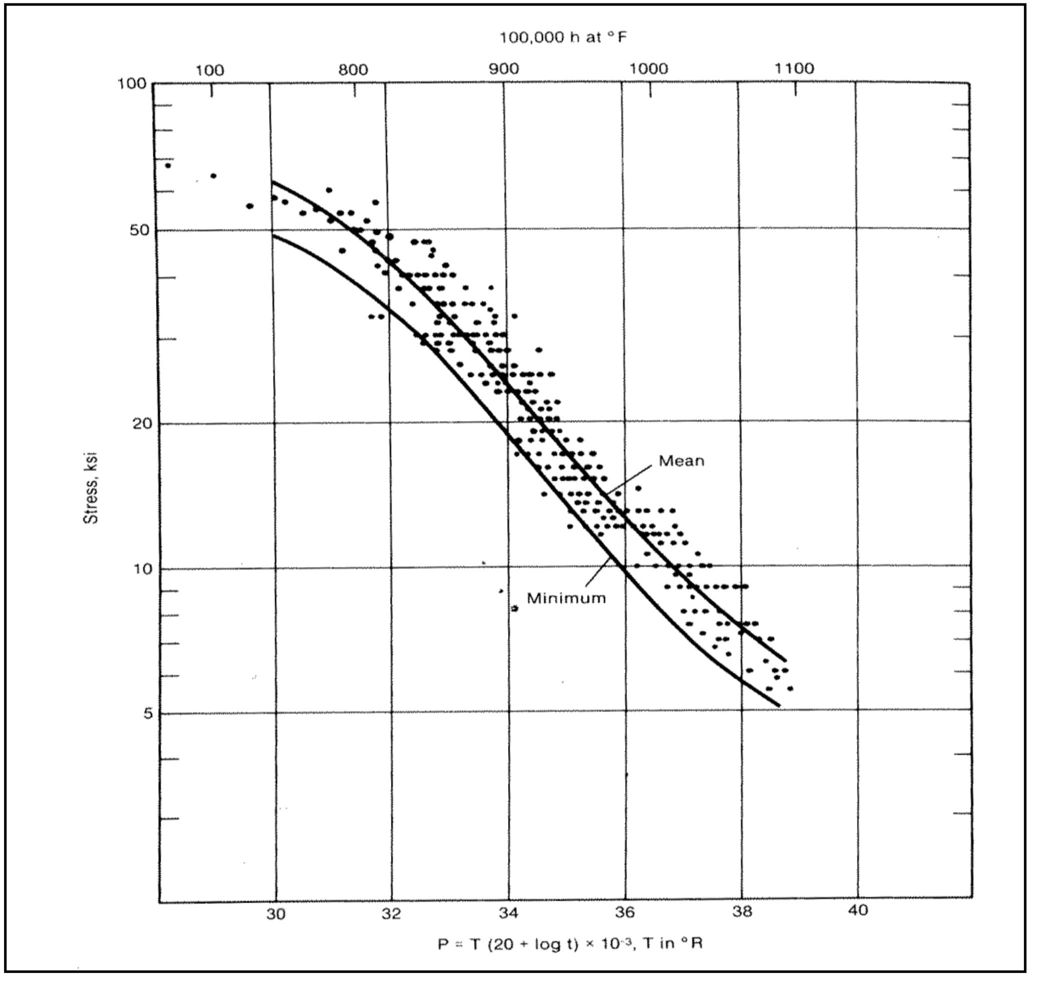
Creep - Data Scatter

- Creep data is inherently scattered:
  - Material variability (composition, processing history, etc.)
  - Test methods (specimen design, machine alignment, temperature control, etc.)



Predicting Creep Performance

- The results of creep tests on many different heats of a grade of steel under different conditions of temperature and stress can be plotted using any one of several parameters to serve as the basis for prediction of creep life



Changing Requirements - Code Case 2864

Chemical Requirements – Weight %		
	New	Existing
Carbon	0.08-0.12	Same
Manganese	0.30-0.50	0.30-0.60
Phosphorous, max.	0.020	Same
Sulfur, max.	0.005	0.010
Silicon	0.20-0.40	0.20-0.50
Chromium	8.0-9.5	Same
Molybdenum	0.85-1.05	Same
Tungsten, max.	0.05	--
Nickel, max.	0.20	0.40
Vanadium	0.18-0.25	Same
Columbium	0.06-0.10	Same
Nitrogen	0.035-0.070	0.30-0.70
Copper, max.	0.10	--
Aluminum, max.	0.020	0.02
Boron, max.	0.001	--
Titanium, max.	0.01	Same
Zirconium, max.	0.01	Same
Arsenic, max.	0.010	--
Tin, max.	0.010	--
Antimony, max.	0.003	--
N/Al ratio, min.	4.0	--

Elevated Temperature Performance – Grade 91

- BPV II conducted a review of long-term performance of Grade 91 material based on newer data available in public domain and implementation of data censoring
- BPV II Task Group considered entire data set as well as a limited data set based on compliance with new compositional restrictions
  - As already noted, analysis of restricted chemistry heats was hampered by limited information available on full composition of individual heats

Proposed Modifications to Allowable Stress Values for Grade 91

- BPV II Task Group recommended that allowable stress values for both the existing Grade 91 and modified Grade 91 be reduced

MPa	**Temperature - °C**					
	525	550	575	600	625	650
ASME 2017 t ≤ 75mm	117	107	88.5	65.0	45.5	28.9
ASME 2017 t > 75mm	118	103	80.6	61.6	45.7	28.9
Proposal - Existing 91	*117*	*98.5*	*75.5*	*54.3*	*36.8*	*24.0*
Proposal – CC 2864	*117*	*102*	*78.2*	*57.6*	*39.2*	*25.1*

Implications of the Change

- New lower values for Grade 91 will become effective when the 2019 edition of the Code is issued (July of 2019); slightly higher Code Case values will become effective at the same time
- Until the 2019 edition is published, existing values can be used, although the impact of the use of the existing values on long-term serviceability should be considered
- Once new values are published, any equipment designed to the 2019 edition (and later) will be required to use lower values
- No action *required* for existing units
  - Review of operating history for particular units may be warranted to determine if more frequent inspection of critical Grade 91 pressure parts is warranted (e.g., based on extended operation at or above design conditions)

Thank you for your attention -

Questions?