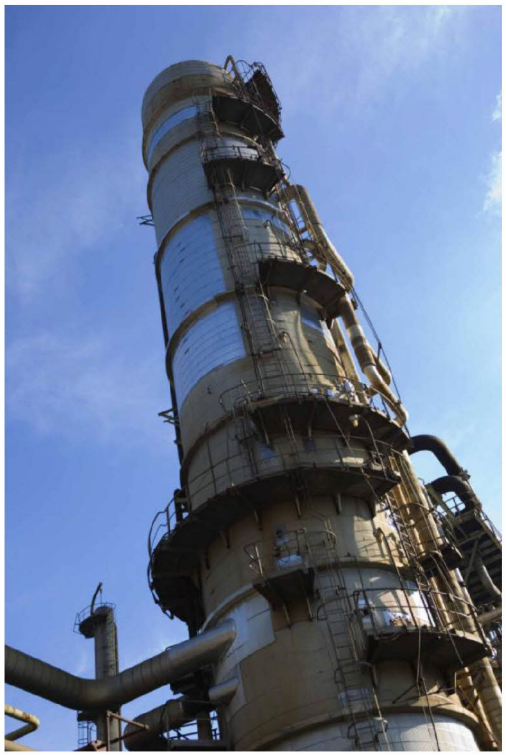
High Temperature Oxidation



Senior Analyst and Inspector Training
Crude Units

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High Temperature Oxidation

Characteristics

- Corrosion concern when temperatures exceed 1000°F (535°C)
- For carbon steel, rates can become very high at temperatures over ~1100°F (~590°C)
- Corrosion is usually uniform – scale can be tight and adherent but as it gets thicker often cracks and spalls; thermal cycling will accelerate spalling and penetration
- Most prevalent in the atmospheric and vacuum unit feed furnaces

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High Temperature Oxidation (Cont'd)

Characteristics (Cont'd)

- Requires oxygen and high temperatures – generally >1000°F (540°C)
- Oxide scale is black and metallic looking, making it difficult to visually determine that attack has occurred
  - Thickness of scale limits further oxidation (rate limiting)
- Thermal cycling will spall protective oxide scales and accelerate corrosion penetration
- All furnace components exposed to firebox conditions have potential to oxidize

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High Temperature Oxidation (Cont'd)

Prevention

- Use alloys high in Cr for fully exposed components
  - High alloy HK materials are commonly used for tubesheets, tube hangers, and tube supports
- Use refractory insulation to limit CS furnace skin temperatures to 600°F (316°C) max. (but stay above dew point)
- Do not externally insulate refractory lined pipe/equipment

Inspection

- UT is typical - visually look for spalled heavy oxide scales
  - Must remove scale prior to measuring thickness
  - Energetic beating with a hammer will remove oxide scales and reveal damage

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High Temperature Oxidation (Cont'd)

Prevention

- Insulate to lower metal temperature, or
- Use alloys containing high chromium – Cast stainless steel (HP Alloys) or specialty alloys (e.g., nickel aluminides) are used for furnace components directly exposed to firebox conditions

Inspection

- See API 571 Damage Mechanism #11
- Energetic beating with a hammer will remove oxide scales and reveal damage
- UT

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Approximate Temperatures Above Which Significant Oxidation Occurs for Various Alloys

Material	Grade	Oxidation Temperature, °F (°C)
Carbon Steel	B	1000 (535)
C-½ Mo Steel	T1 or P1	1000 (535)
1¼ Cr-½ Mo Steel	T11 or P11	1100 (590)
2¼ Cr-1 Mo Steel	T22 or P22	1150 (620)
3 Cr-1 Mo Steel	T21 or P21	1150 (620)
5 Cr-½ Mo Steel	T5 or P5	1200 (650)
7 Cr-½ Mo Steel	T7 or P7	1200 (650)
9 Cr-1 Mo Steel	T9 or P9	1250 (675)
18 Cr-8 Ni Steel	304 or 304H	1500 (815)
18 Cr-8 Ni Steel	316 or 316H	1500 (815)
18 Cr-8 Ni Steel	321 or 321H	1500 (815)
18 Cr-8 Ni Steel	347 or 347H	1500 (815)
Ni - Fe - Cr	Alloy 800H	1700 (925)
25 Cr-20 Ni	310/HK-40	1900 (1035)
25 Cr-35 Ni	HP-Alloys	1950 (1065)

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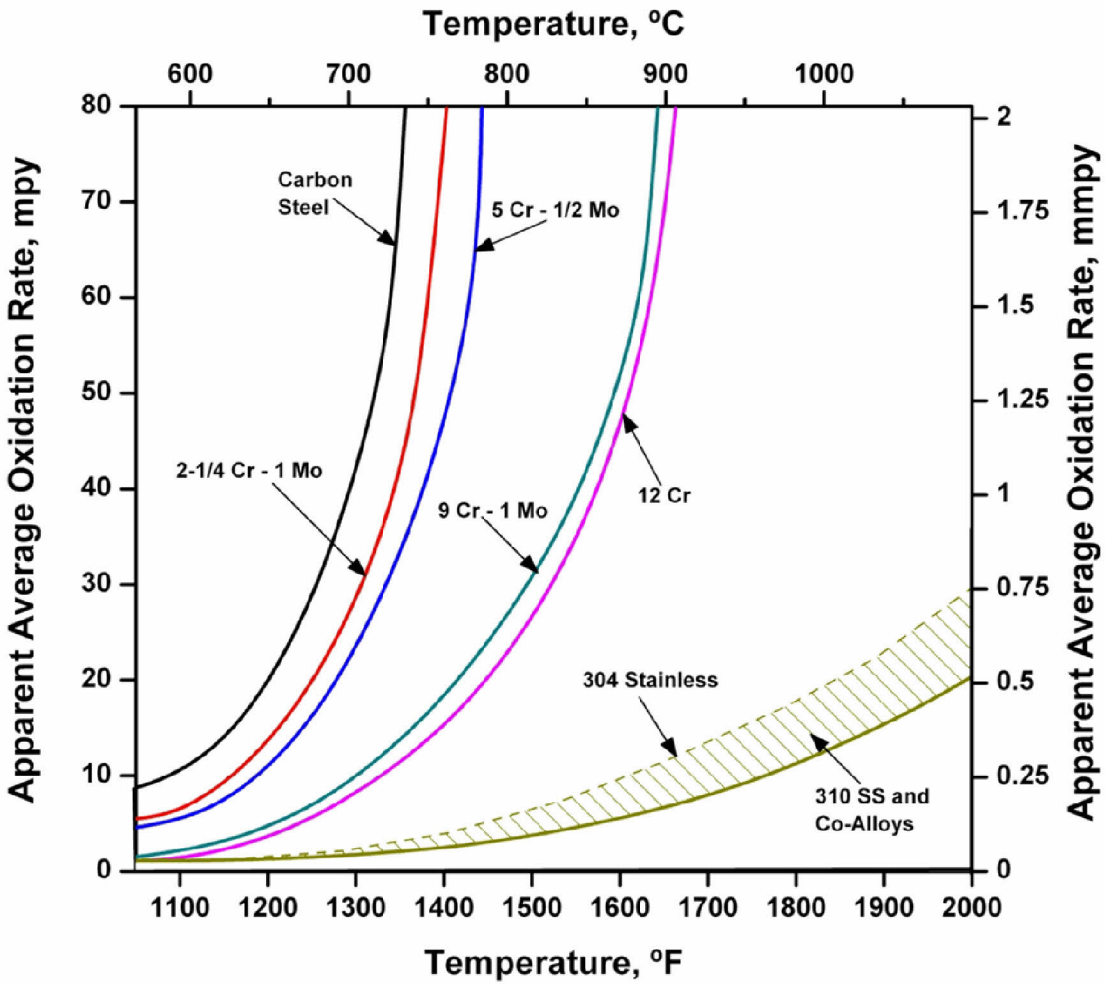
Effect of Temperature on Oxidation Rate of Steels



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Thick Oxide is a Sure Sign That Tube Metal Temperature Limits Have Been Exceeded

35% bulge in sagging carbon steel tube showing cracks in thick external oxide

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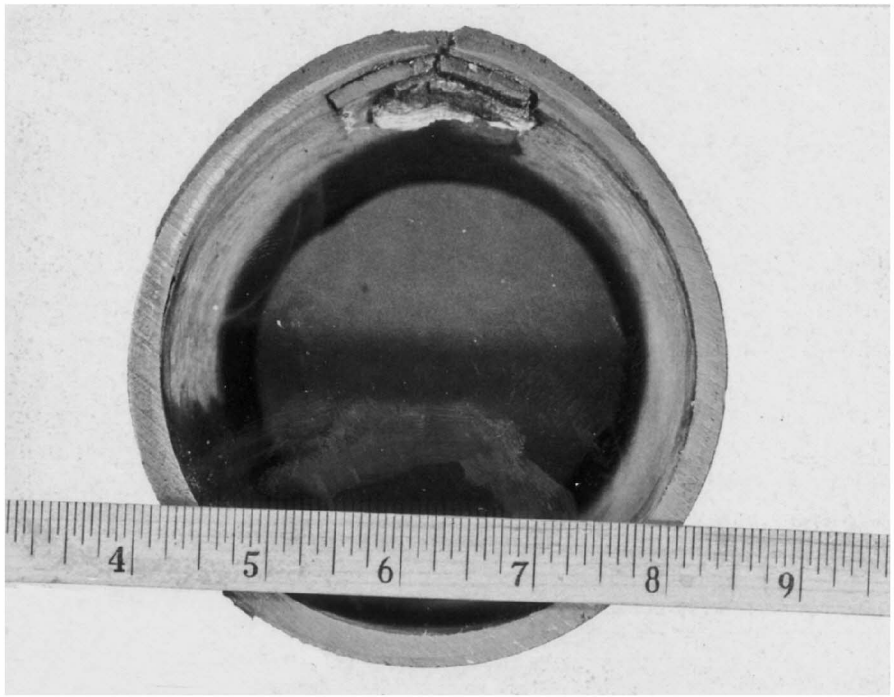
Oxidation of 5 Cr Superheated Steam Coil Tube From a Crude Furnace

Note Oxidation on Both ID and OD



E202.52 (not in info repos, 30.15.02: F-1601 Superheat Steam Coil Rupture No. 6 Crude Unit, El Paso, T.E. Rippel, 11/8/1982

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Oxide Scale on Furnace Tubes Removed to Allow Accurate Strapping & UT

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Close-up of Oxide Scale on Furnace Tube Thin Layered Scale Was Easily Chipped Off With a Hammer

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