

Shipboard Coatings Developments, and Emerging Surface Technologies

Farrel Martin

U. S. Naval Research Laboratory, Washington, DC

Mark Ingle

NAVSEA 05P2, Washington Navy Yard, Washington, DC



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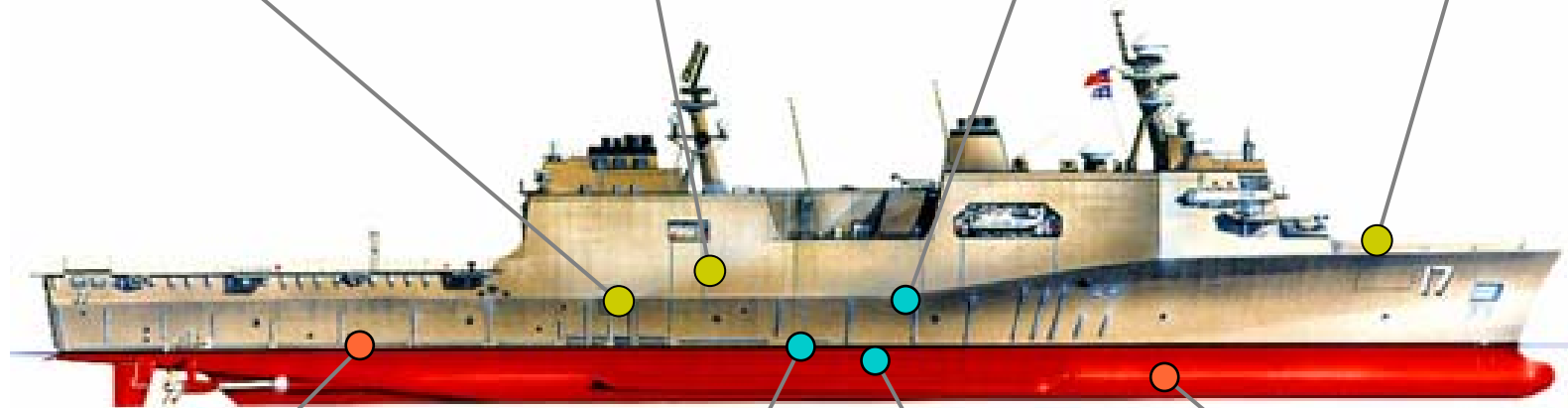
Shipboard Coatings

Topside Coatings
Polyesters
Silicone-Alkyds
Polyurethanes
LSA/Antistain

Special Treatments
Nitriles
Urethanes

Interior Coatings
Chlorinated Alkyds
Chlorinated Vinyls
Polyimides

Deck Coatings
Acrylic Epoxies
Polyurethanes
Polysulfides



Anti Corrosion Coatings
Epoxy-Polyamides
Epoxy-Amines
Epoxy-Amidoamines

Tank Coatings
Epoxy-Polyamides
Novolac Epoxies
Solvent Free
Edge Retentive

Bilge Coatings
Epoxy-Amidoamines
Epoxy-Polyamides

Anti Foulant Coatings
Vinyls
Silicones
Fluoroelastomers

VOIDS
Inorganic Zinc
Zinc Rich Epoxy

Single Coat Preservation System Portsmouth Naval Shipyard / SEA 05P23

- Application of rapid-cure, high-solids paints in a single-coat is more cost effective than applying paints in two or three discrete steps.

PROBLEM: Ultra-high-solids coatings require three coats (i.e., primer, stripe coat, and top coat) = Excessive Labor. Legacy coatings require 24-hours between coats and seven days before service, for total process time of >14 days.

SOLUTION: Single-coat system based on application of a single color of paint, during a single coating evolution in the tank, with multiple passes of the paint gun. Cure time only four hours at 77F and one day to service.

Accomplishments:

1. Change 1 to FY-10, Standard Item 009-32, allowing only use of single-coat paints in ballast tanks, voids, and chain lockers issued on 9 March 2009.
2. Completed single-coat ballast tank/void installations on carriers, submarines, amphibious ships and combatant tanks/spaces.
3. Completed demonstration installation of single-coat paints in three fuel and two CHT tanks.
4. Completed one-year inspection of single-coat paints in ballast tanks on submarines and amphibious ships.



CWP reports savings of up to 20% possible for CVN (\$433K) availability.

Contractors report job cost savings of 26% possible.

BUSINESS CASE FOR SINGLE COAT PAINTS

Cost Estimate Summary

- Cost estimates based data from shipyards, contractors, and paint vendors. Costs estimates are for painting a “representative” 5,000 ft² tank and do not include consistent costs like cleaning, staging set-up, blasting, and clean-up. NAVSEA business case consistent with:

Cumbersome work practices, single-coat project

20% paint application cost reduction
after CWP demonstration

\$433K possible savings DPIA.

15% to 30%

Contractor reports savings:

MODEL RESULTS:

- Single-coat paint total application costs lower than other coating systems.

Solvent-based paints (MIL-PRF-23236, V or MIL-DTL-24441) 15 mils DFT	\$31,128 to \$30,888
100% Solids paints at 17 mils DFT	\$24,833
100% Solids, single-coat paints at 25 mils DFT	\$19,250

} 22% reduction
- Single-coat paint material costs higher for 5,000 square foot tank.

Solvent-based paints	\$1,296 to \$1,056
100% Solids paints	\$2,898
100% Solids, single-coat paints	\$6,292
- Facilities & utilities costs lower for single-coat paints.

Solvent-based paints	\$13,100
100% Solids paints	\$8,300
100% Solids, single-coat paints	\$7,300
- Labor for single-coat paint lower than other paints.

Solvent-based paints	\$16,732
100% Solids paints	\$13,635
100% Solids, single-coat paints	\$5,658

Induction Heating Coating Removal

Portsmouth Naval Shipyard / SEA 05P23

Issue:

Current methods of coatings removal require media (e.g., mineral grit, shot, water, etc.), or cumbersome hand tools.

Problem: Removal of thick, tough paints takes too much time.

Solution: Use the Induction Heating (IH) Coatings Removal system to “pop” paint up from heated substrate, no need to wear paint away.



Accomplishments:

- NAVSEA Ltr Ser 5000 - 07T/0226 dtd 3 July 07 provided interim approval to PNSY, with conditional requirements addressing substrates, controls, etc.
- Uniform Industrial Process Instruction (UIPI) 1905-115 signed on 31 July 2008.
- Each Naval shipyard has at least one induction heat unit. Qualification in process at all yards.
- Units used to remove rubber in battery boxes on submarine in April 2009.

PSNY projects, potential cost reduction:

Submarine - \$93K / availability.

Carrier - \$57K / availability.

[Development of Automatic Control Head Key to Expand Applications for Units](#)

ANTIFOULING COATING PROGRAM

Overall Goals

- Navy needs to control underwater-hull fouling using environmentally acceptable methods.

Fouling control is important to allow Navy ships to:

- Attain critical speed – 2% speed loss.
- Reduce noise.
- Minimize operating expenses:
 - 6% to 45% increase in fuel cost (\$910K/year per DDG).
 - \$22M to \$44M spent annually on underwater-hull coating & diver cleanings.
- Last for up to 12-years with no docking or touch-up.



- NAVSEA goal is to adopt new, advanced coating systems for fleet-wide implementation.
 - Current Navy fleet underwater-hull area, 99% coated with copper ablative – 12,434,472 ft² or 1,155,200 m²
 - Foul-release coatings on 26,635 ft² or 2,660 m²

Effective, copper-free or foul-release will become new Navy standard.

ANTIFOULING COATING PROGRAM

Environmental Drivers Of Change

- World-wide antifouling coating environmental regulations are changing:
 - International Maritime Organization (IMO) tributyl tin (TBT) ban to come into force on 17 Sept. 2008 – TBT paints are banned.
 - Canada, 40 ug/cm²/day limit on copper emissions from antifouling paints.
 - Sweden has copper emissions limits on antifouling coatings in Baltic, 200 ug/cm²/14-day.
 - Netherlands bans cleaning or scrubbing of copper-bearing antifouling.

INTERNATIONAL PRECEDENTS ESTABLISHED FOR BIOCIDES & Cu REGULATION

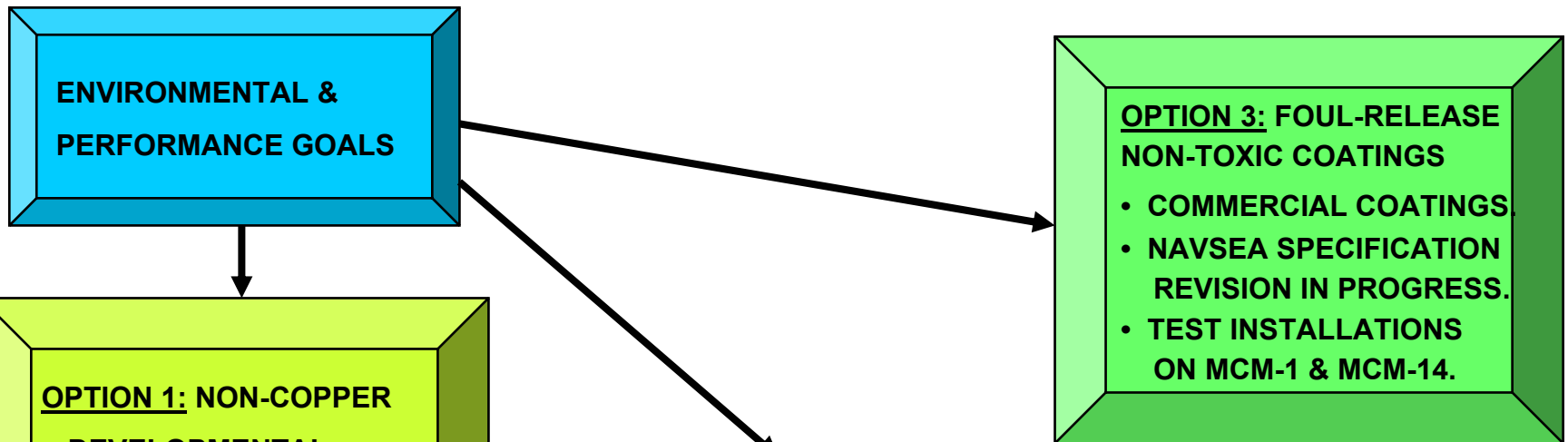
- Local water-quality issues in ports with military & civilian ships leading to new domestic regulations.
 - San Diego violates federal water quality standards – California evaluating new regulations. San Diego Regional Water Quality Board issued a 20-year plan to phase out copper-bearing paints (San Diego, *Times Union*, 28 April 2005), so phase out in 2025.
 - Puget Sound Naval Shipyard (PSNS) has had NOV's for copper discharge from drydocks.
 - Hull-coating leachate is identified UNDS discharge.

NUMERICAL UNDS COPPER EMISSION LIMIT TO BE PROPOSED IN 2009.

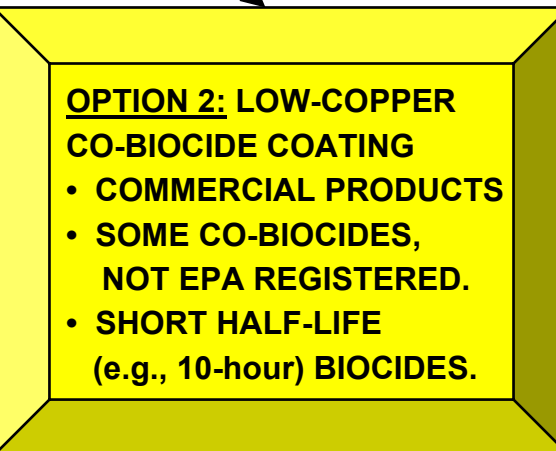
“NEW” COATING MUST SATISFY CURRENT & FUTURE ENVIRONMENTAL REQUIREMENTS

ANTIFOULING COATING PROGRAM

Program Approach



MIL-PRF-24647D category
Two products failed ship test.



BEST OPTION 2 PRODUCTS

Don't currently meet Navy needs.

No product of interest under testing

MIL-PRF-24647D INCLUDES CATEGORY.

International Intersleek 425 included on MIL-PRF-24647D Qualified Products List

International Intersleek 900 started ship trials.

ANTIFOULING COATING PATCH TESTING USCGC MLB 47256 with Copper-free Coating

ANTIFOULING SYSTEM: Copper-free product, ablative matrix,

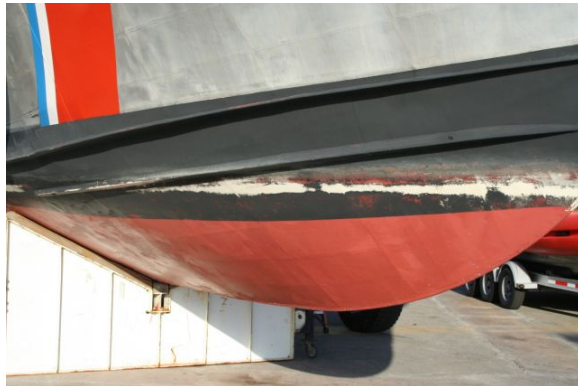
TEST SYSTEM APPLIED: January 9 - 22, 2005

LOCATION OF WORK: USCG STATION, SAN JUAN, PR

INSPECTED: Aug. 2005 LIGHT ALGAE GROWTH.

Other pulls not recorded, no complaints to NAVSEA about speed.

April 2008 Pulled for engine work, cleaned well, may have been over-coated.



**PRESSURE WASH, ALGAE
EASILY REMOVED, POLISHING
APPARENT.**



**SOME HARD FOULING ON
WELDS, NOT A SPEED PROBLEM,
BOAT CREWS WANT MORE
MATERIAL.**

**BATELLE TEST SITE, 58 MONTH, FULL
IMMERSION RESULTS**



Option 1



Cu Control

OPTION 1 SHIP TEST

Full ship Test of Option 1 Failed in 2006

Antifouling test system: red top coat of option 1 over Cu ablative. EPA EUP granted in Nov. 2004 for USCG KNIGHT ISLAND (WPB-1348) based in Tampa, FL.

Test system application: February, 2005
Master Marine – Bayou LaBatre, LA

Inspected: June 2005, & April 2006

- Soft fouling & hard fouling apparent.
USCG had speed problems.
- Hull only cleaned with abrasive pads.
- Option 1 not as good as Cu ablative.



Option 1 / ablative full-immersion panels, 18 months Biscayne Bay, FL



Option 1

Cu-ablative



Option 1

Cu Ablative

Emerging Surface Technologies: Low-Temperature Colossal SuperSaturation (LTCSS) Surface Hardening on Alloy A286

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- **Acknowledge the contributions of Swagelok technical team members Peter Ehlers, William Richards, Jason Scherner and Steven Marx**

Background: LTCSS Process

Traditional Carburization

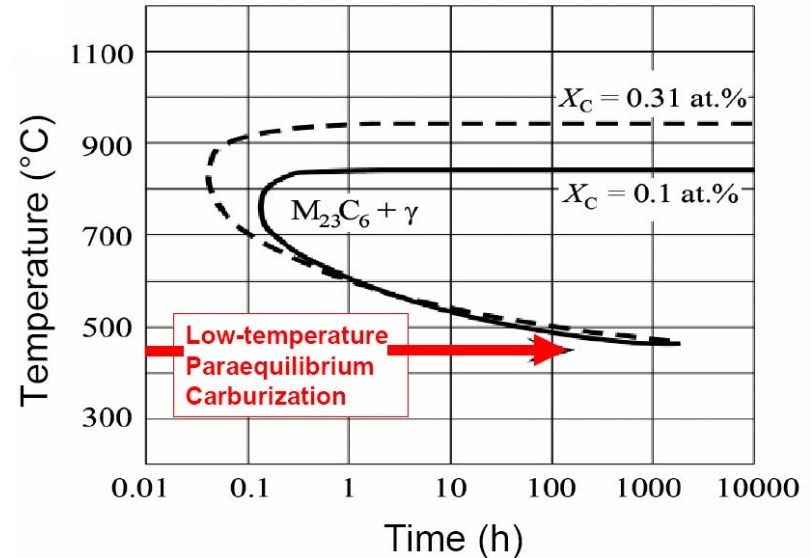
- ❖ Traditional carburization is a thermochemical surface treatment that is commonly used to increase the hardness and wear properties of steels
- ❖ Traditional carburization requires temperatures around 950°C, and in austenitic stainless steels this results in the formation of chromium carbides (Cr_{23}C_6) which significantly degrade corrosion resistance.

LTCSS Surface Modification

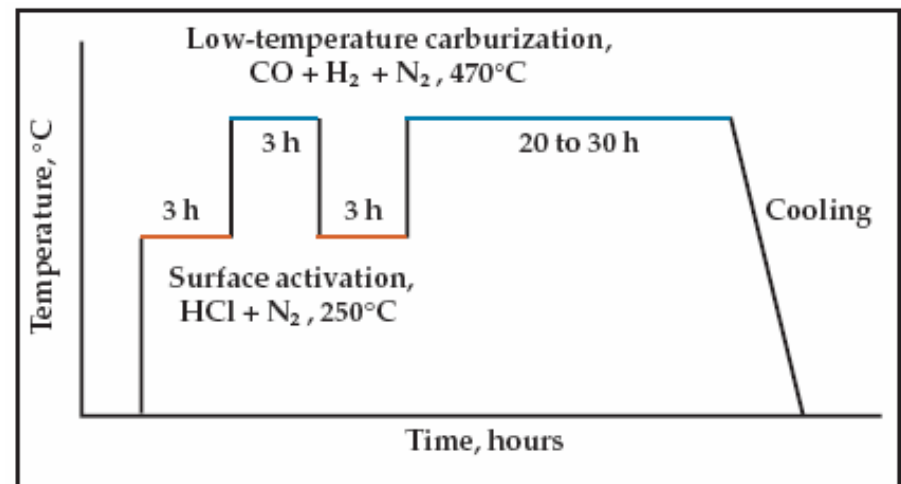
- ❖ Carbon concentrations > 12 at. % in 316 stainless steel while maintaining single phase austenite, i.e.. no detrimental precipitates.
- ❖ Treatment temperatures below 570°C
- ❖ Significant increases in surface hardness, wear and corrosion resistance.

Ref: G. M. Michal, et al., Acta Materialia 54, 1597 (2006).

TTT diagram



LTC Treatment Conditions

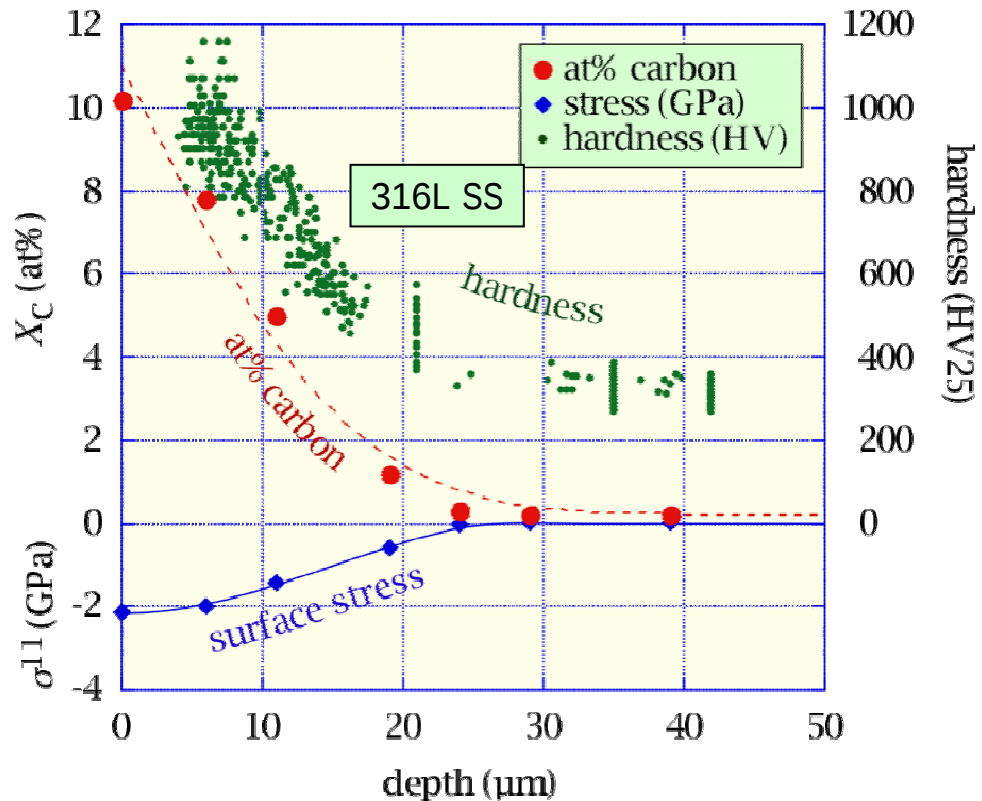


Correlation Between Carbon, Hardness and Surface Stress

- As much as 10-12 at% carbon is incorporated into grain structure near surface
- There is a significant surface compressive stress ($\sim 2\text{GPa}$) imparted by interstitial C
- Austenite surface hardness is tripled by treatment. 316L attains Vickers 1100 (Rockwell 70C).

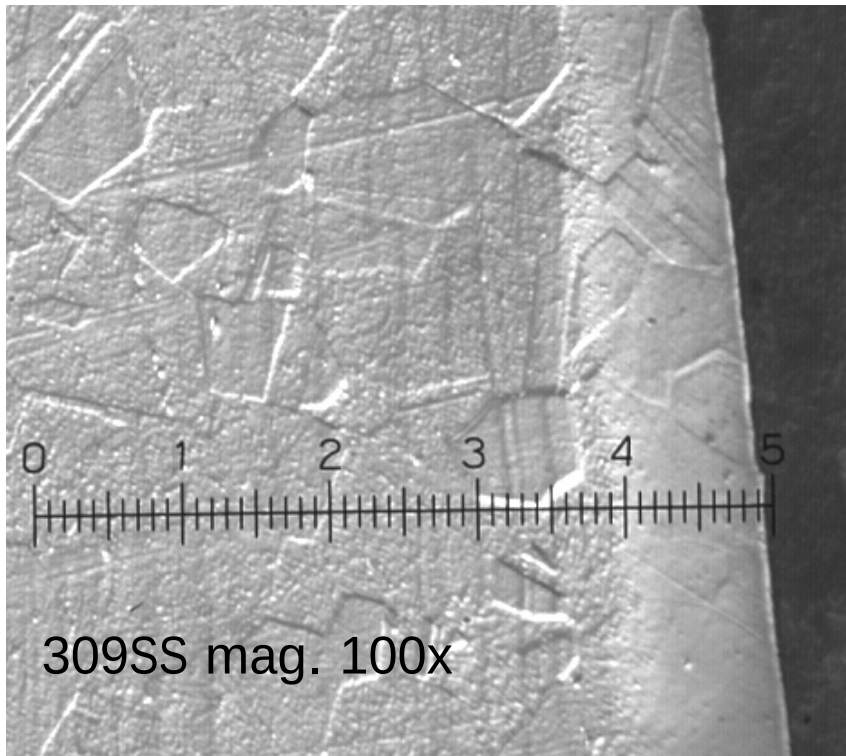
316L SS (UNS N31603)
Before treatment

Element	at%
Fe	64.94
Cr	18.45
Ni	11.62
Mn	1.79
Mo	1.19
Si	1.18
C	0.23

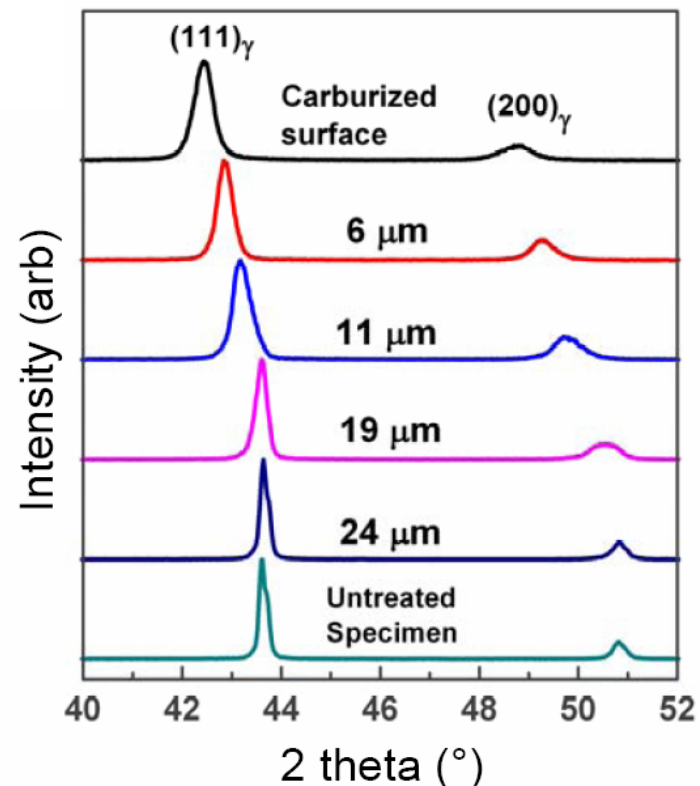


LTCSS Microstructure

- Original grain structures retained with significant interstitial carbon
- To date, no precipitates or carbides observed in 316L SS – carbon is interstitial with significant lattice expansion indicating residual compressive surface stress
- Interstitially carburized layer is referred to as “S-phase”



XRD on 316SS



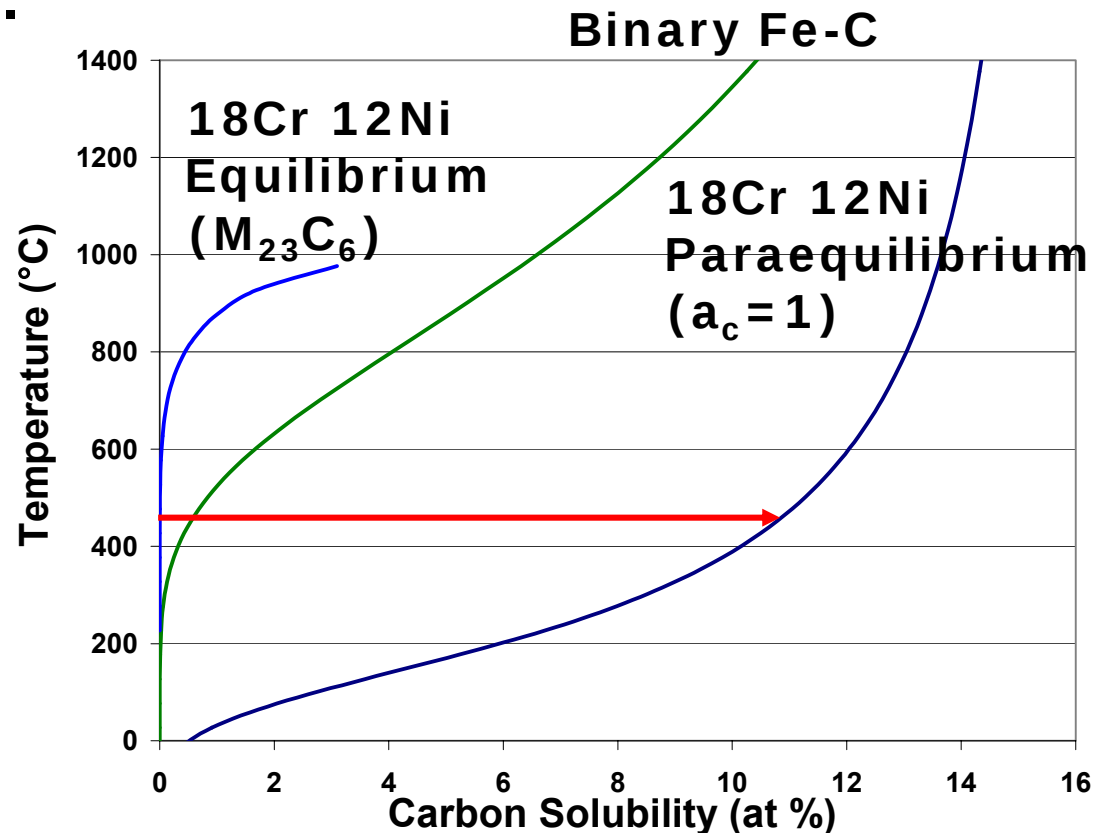
Ref: G. M. Michal, et al., Acta Materialia 54, 1597 (2006).

Low-Temperature Carburization

- LTCSS is one approach to low-temperature carburization. It occurs in a gas chamber at elevated temperatures. Temperatures are lower than conventional carburization.
- In order for chromium carbides to form in a stainless steel, BOTH the metal atoms AND carbon atoms must be mobile enough to form new compounds.
- Low-temperature carburization is hot enough to allow diffusion of carbon into metal lattice interstices, but cool enough that metal atoms are kinetically restricted from classic carbide recombinations to form precipitates.
- *Para-equilibrium* carbon diffusion can absorb MUCH more carbon into the metal host than normal diffusion processes.

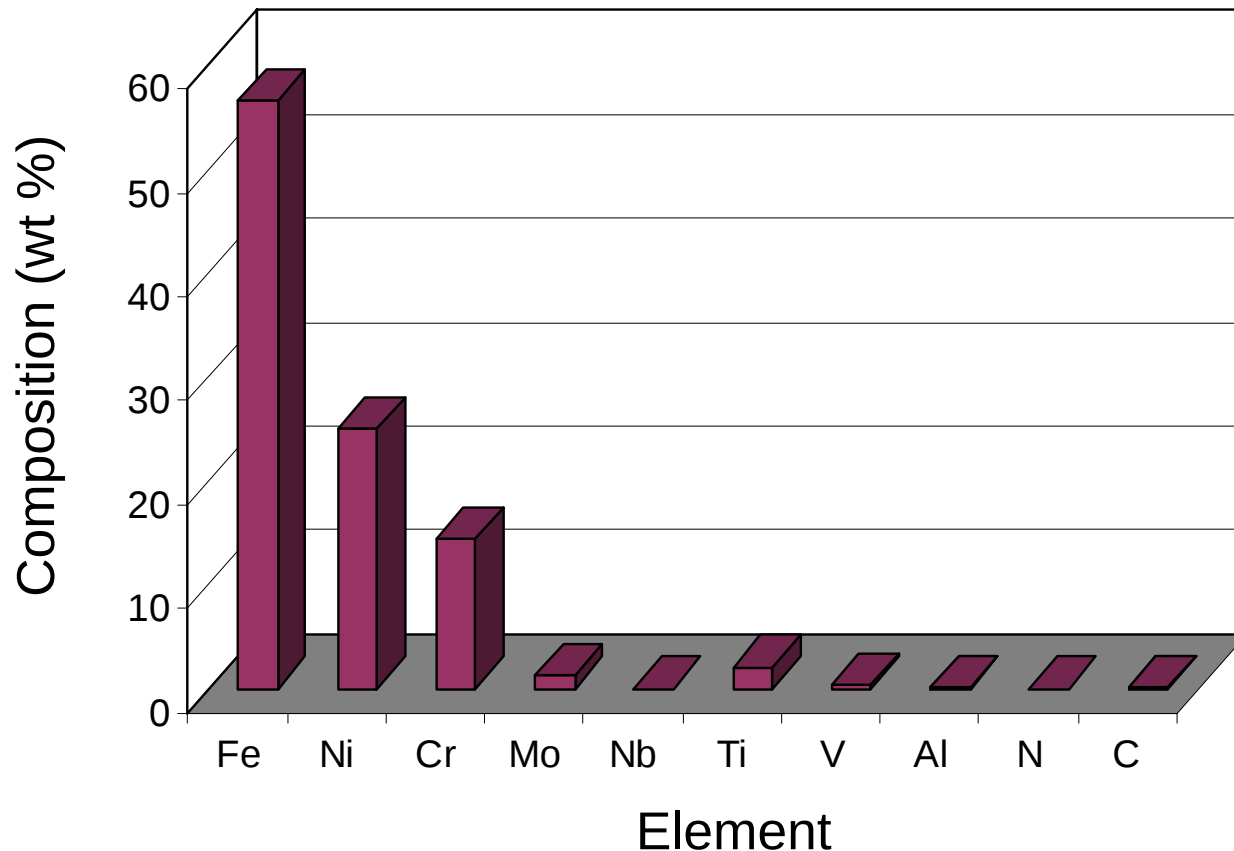
How are high carbon concentrations possible?

- Saturation limits for equilibrium and para-equilibrium carbon diffusion in stainless steel. At 450°C, equilibrium-based diffusion allows about 0.1% C into stainless steel while *para-equilibrium* diffusion supports up to 11% carbon (or more).



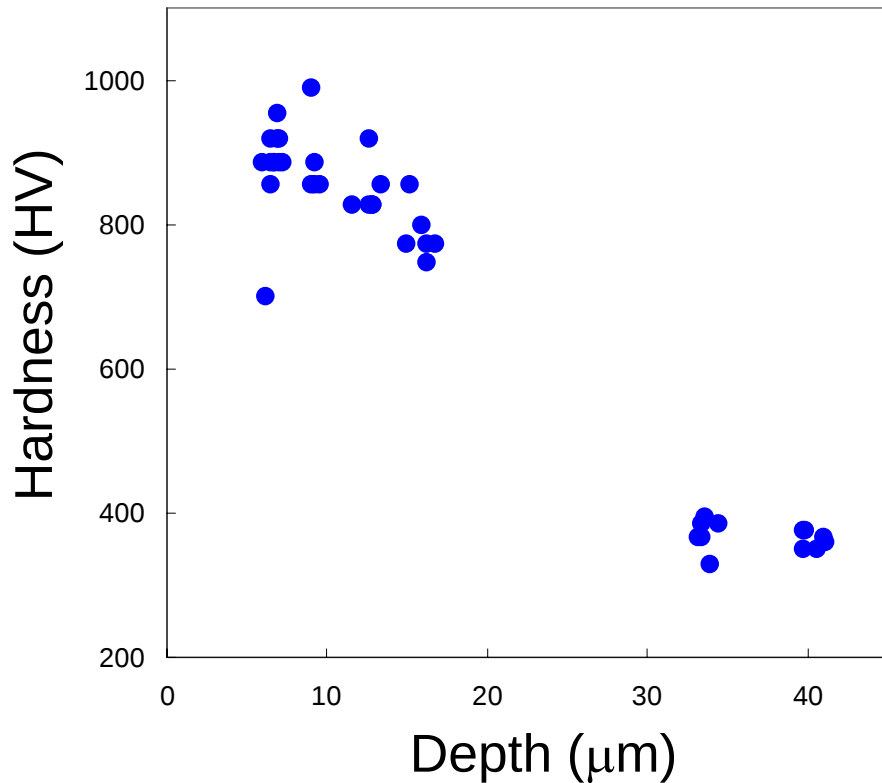
Alloy A286 Composition

- Alloy A286 (UNS 666286) is a high strength, austenitic stainless steel, age hardenable.
- Present work uses A286 in fully aged condition

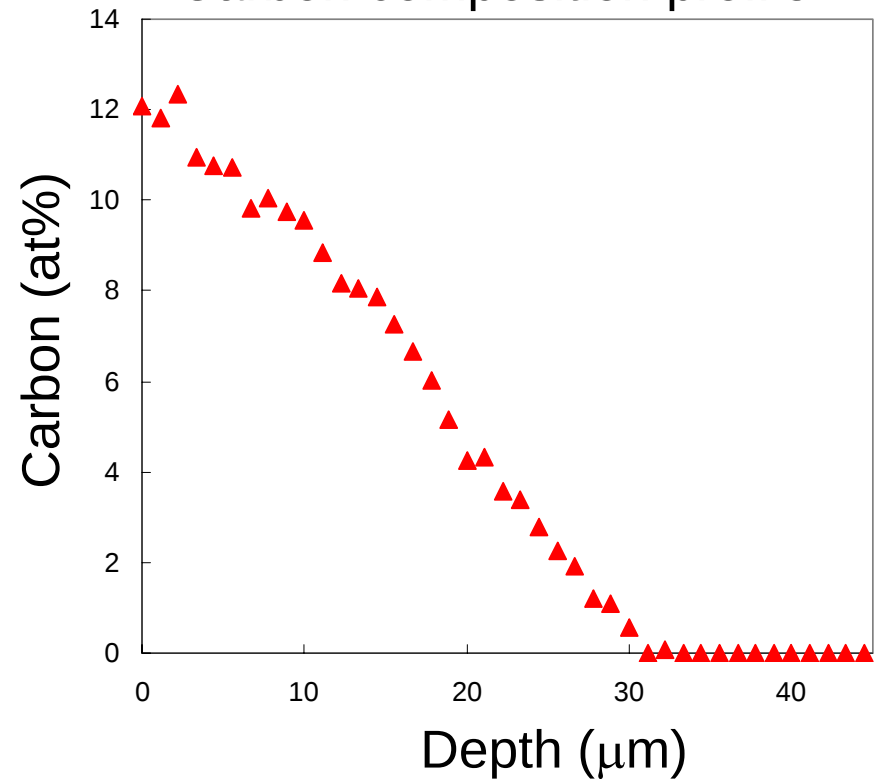


LTCSS Alloy A286 Case Depth and Carbon Profile

Microindentation –
Hardness profile



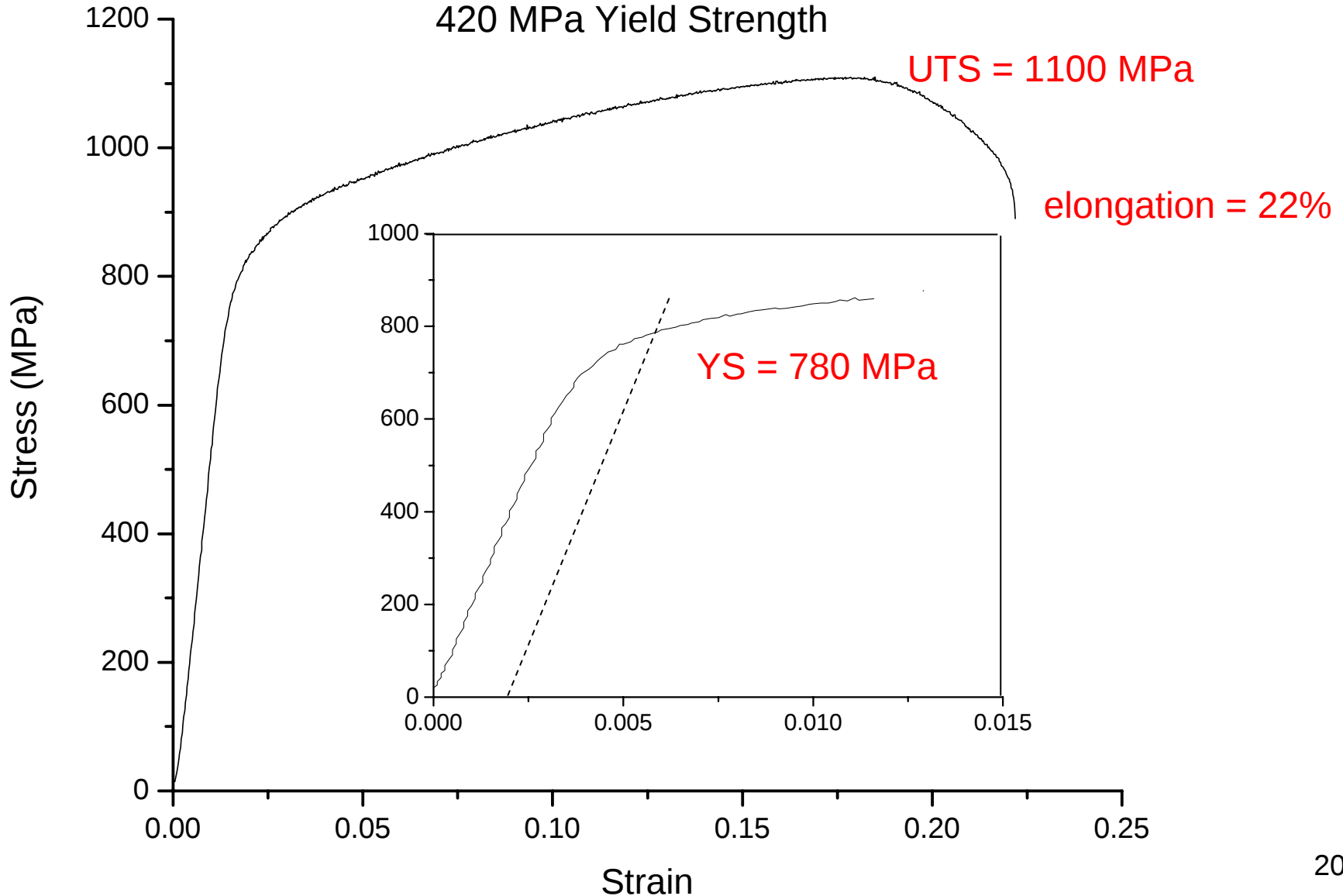
Auger electron spectroscopy –
Carbon composition profile



Microhardness and carbon concentration profiles
indicate 32 μm case depth

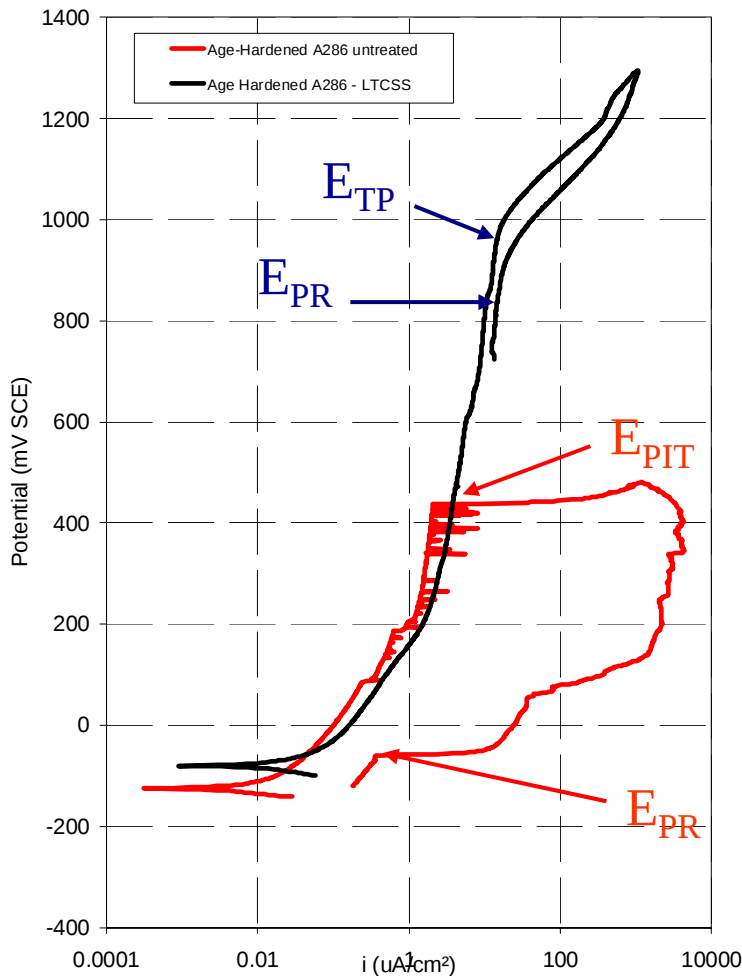
LTCSS A286 Mechanical Properties

Metric = 600 MPa Ultimate Tensile Strength, 15% Elongation at Rupture,
420 MPa Yield Strength



LTCSS Alloy A286

Pitting Corrosion Behavior

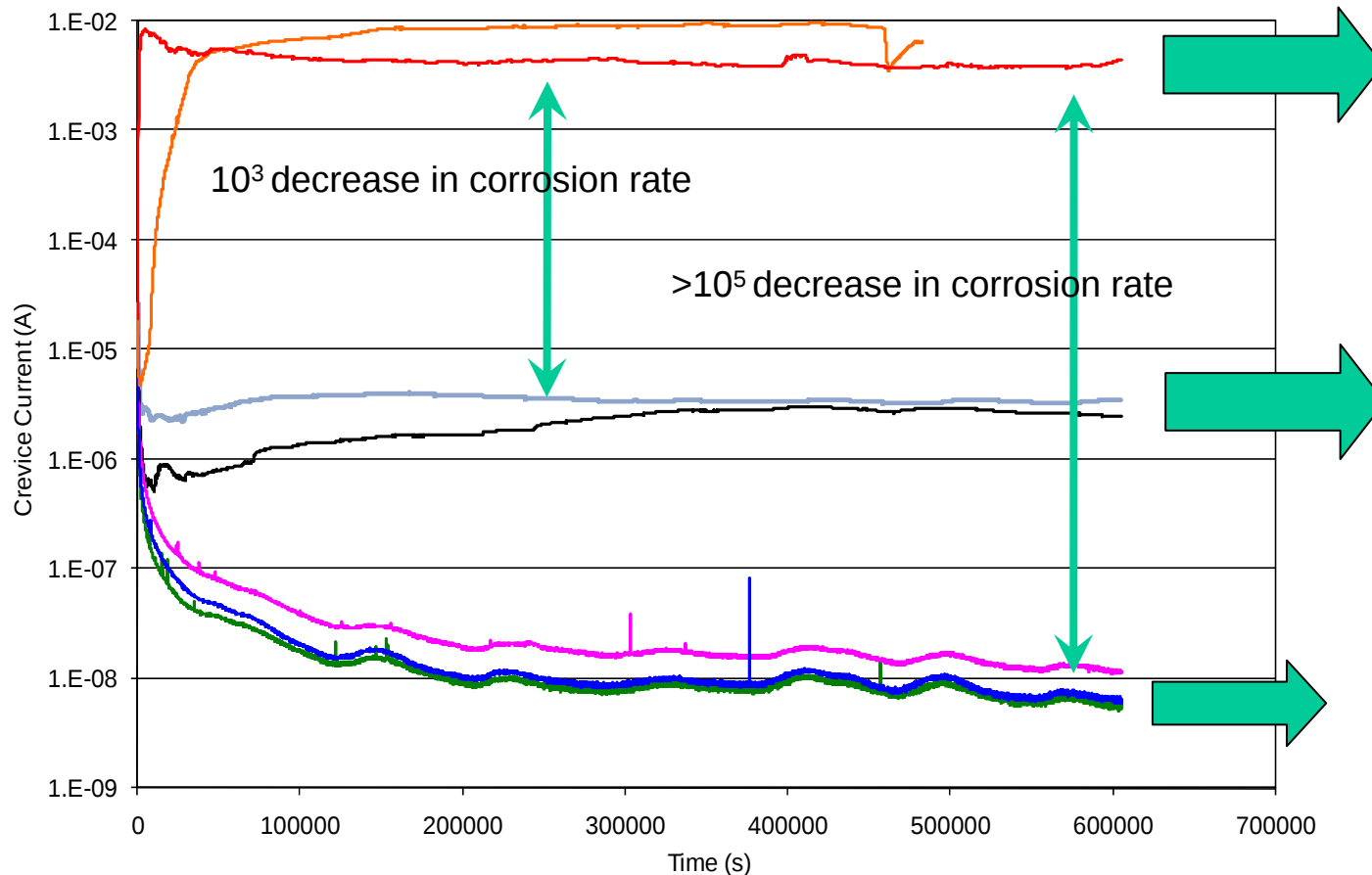


- **Unmodified Alloy A286**
 - Short-term* E_{OC} – 120mV
 - E_B +430 mV (pitting)
 - E_{PR} –100mV
 - **LTCSS A286**
 - Short-term* E_{OC} – 75mV
 - E_{TP} +950 mV (transpassive)
 - E_{PR} +800 mV
 - **Breakdown potential increased by ~500 mV**
 - **Protection potential increased by ~1000mV**
- * Short-term E_{OC} does not take into account seawater biofilm corrosion potential ennoblement, which elevates E_{OC} to values approaching +300mV in ~30 days

LTCSS Alloy A286

Seawater Crevice Corrosion Resistance

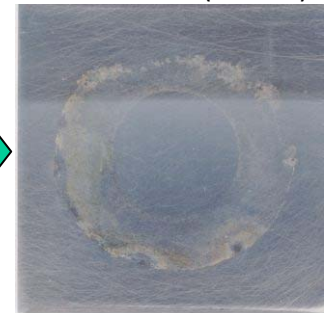
Ambient temperature seawater crevice current, potentials maintained at +300mV for one week.



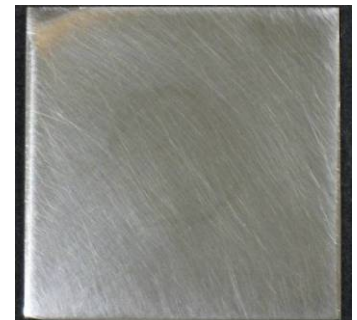
Alloy A286
~100 mil crevice depth



LTCSS Alloy A286
Crevice etch (< 1 mil)

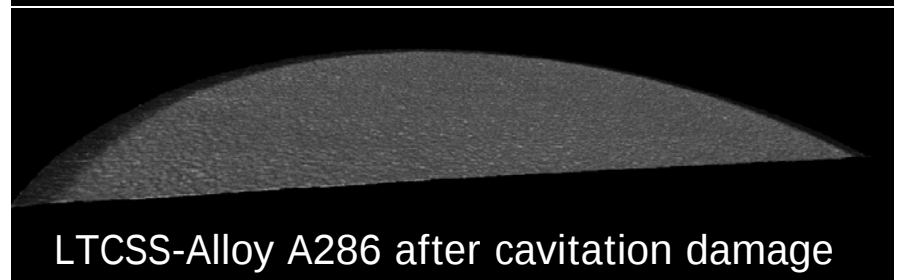
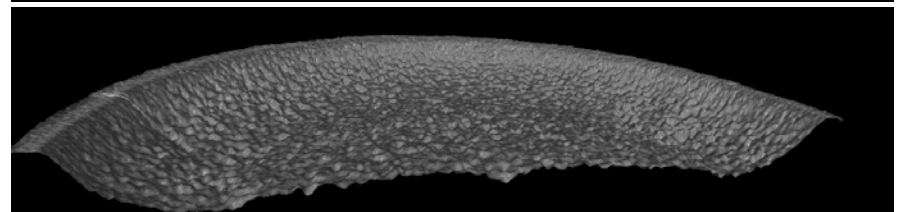
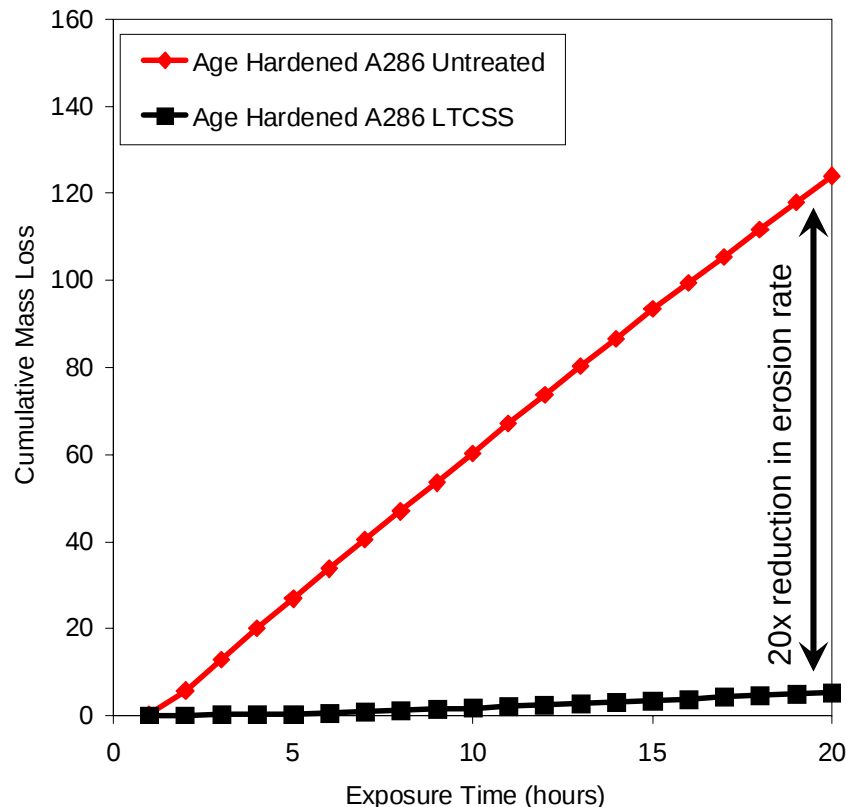


LTCSS Alloy A286
Surface Cleaned Postprocess
No attack



LTCSS Alloy A286 Cavitation Erosion Resistance

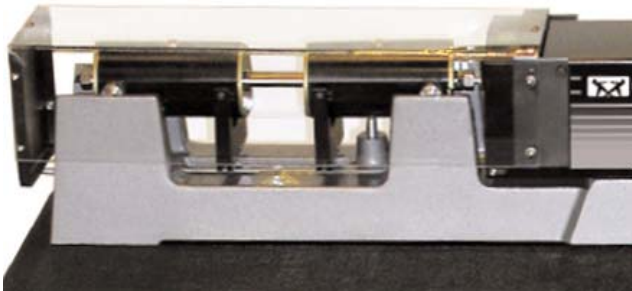
- ASTM G32 Cavitation Erosion using ultrasonic horn at 20kHz.
- LTCSS-Alloy A286 erosion rate is 20 times lower than untreated Alloy A286 in ASTM G32 cavitation testing



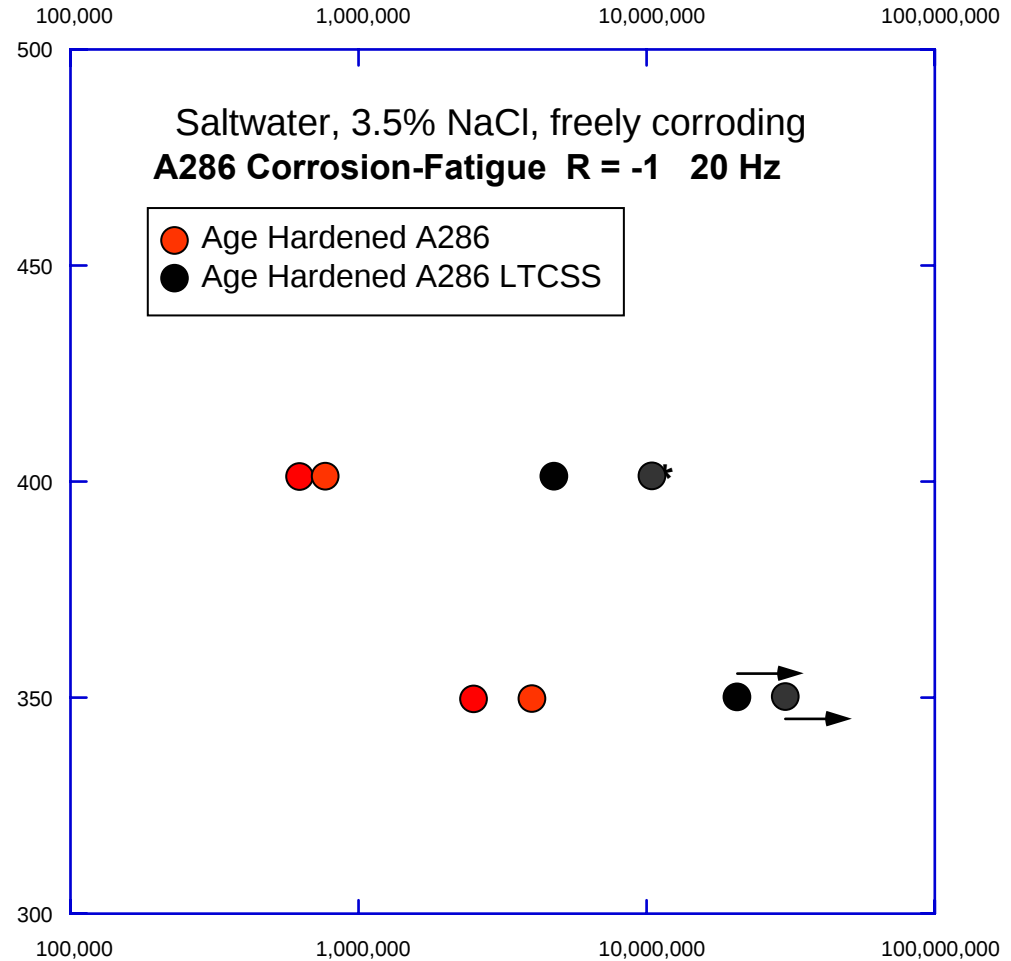
Field of view: 3D surface profile on 5/8" diameter testing coupon (10x)
20 hours exposure to ASTM G32 ultrasonic cavitation source

Corrosion Fatigue Response of LTCSS A286

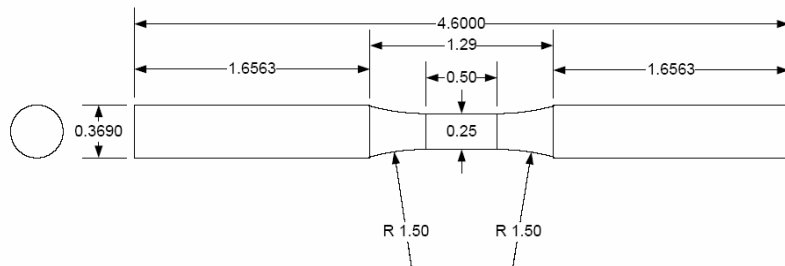
- Rotating Bending Fatigue
- Fully reversed loading at 20Hz
- Immersion cell containing 3.5% NaCl solution
- Smooth surface corrosion fatigue
- LTCSS A286 corrosion fatigue life is 10x longer than untreated alloy.



Stress amplitude (MPa)



Untreated (cycles)



Summary

- **Alloy A286 low-temperature carburization surface treatments have been investigated using Low-Temperature Colossal SuperSaturation method.**
- **A carburized case of about 30 microns resulted, with indications that a second metallurgical phase had developed.**
- **LTCSS modifications to Alloy A286 surface appear to increase seawater pitting and crevice corrosion resistance, increase corrosion fatigue life, and increase cavitation resistance.**
- **LTCSS-treated Alloy A286 appears not to influence hydrogen embrittlement sensitivity of the alloy.**