Stainless Steel University

Love Your Stainless - Overview

Why worry about Corrosion Issues?

Getting more value from Stainless Steels: You reduce corrosion's impact

What is Corrosion?

Corrosion is a natural phenomenon impacting all materials in structures important to our economic and national security.

The public infrastructure (highways, airports, water supply, waste treatment, energy supply, and power generation) is part of a complex system.

Corrosion y life- in the manufacturing of products, the transportation of people and goods, the provision of energy, the protection of our health and safety, and the defense of the nation.

The Cost of Corrosion

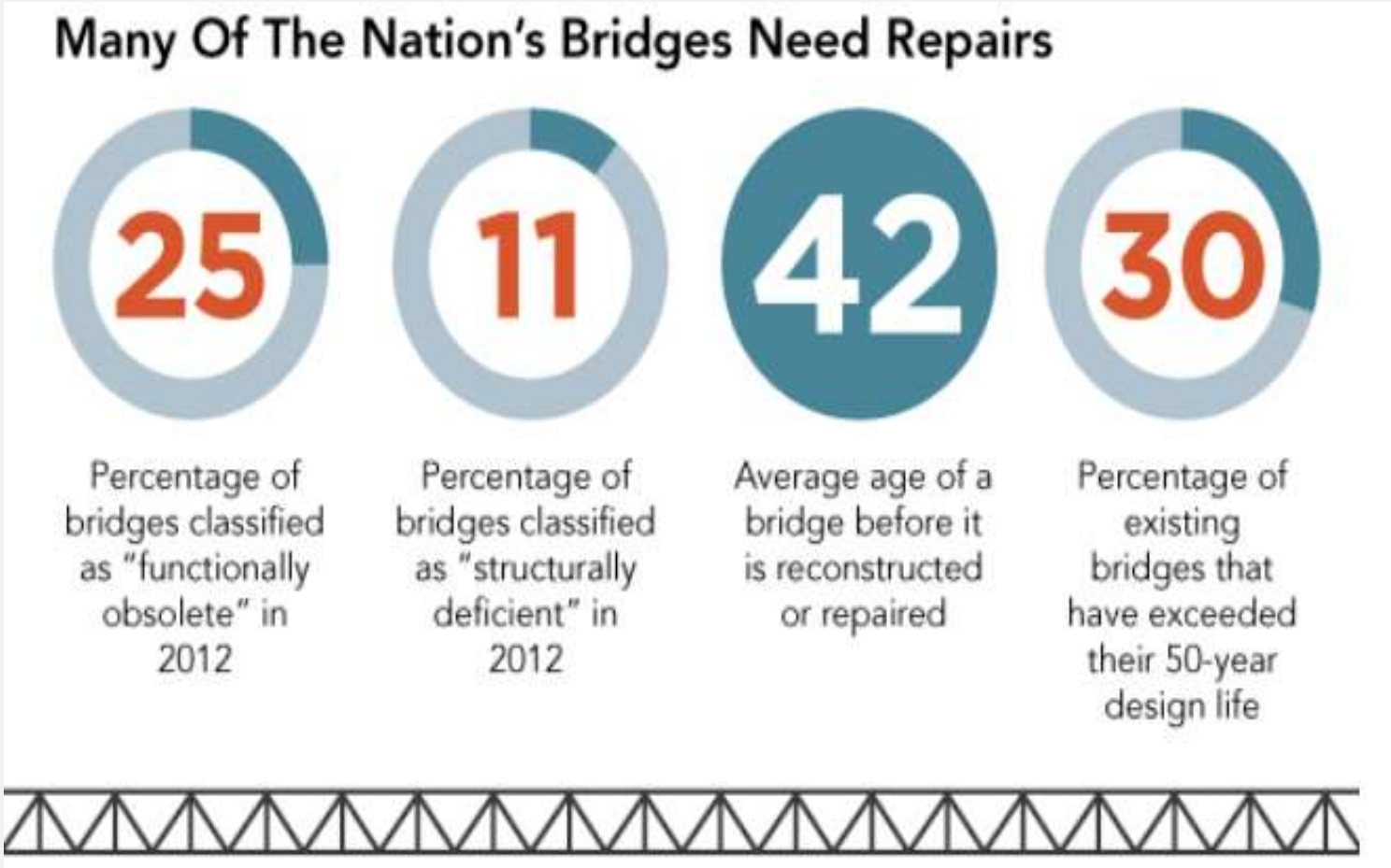
There are 583,000 bridges in the United States

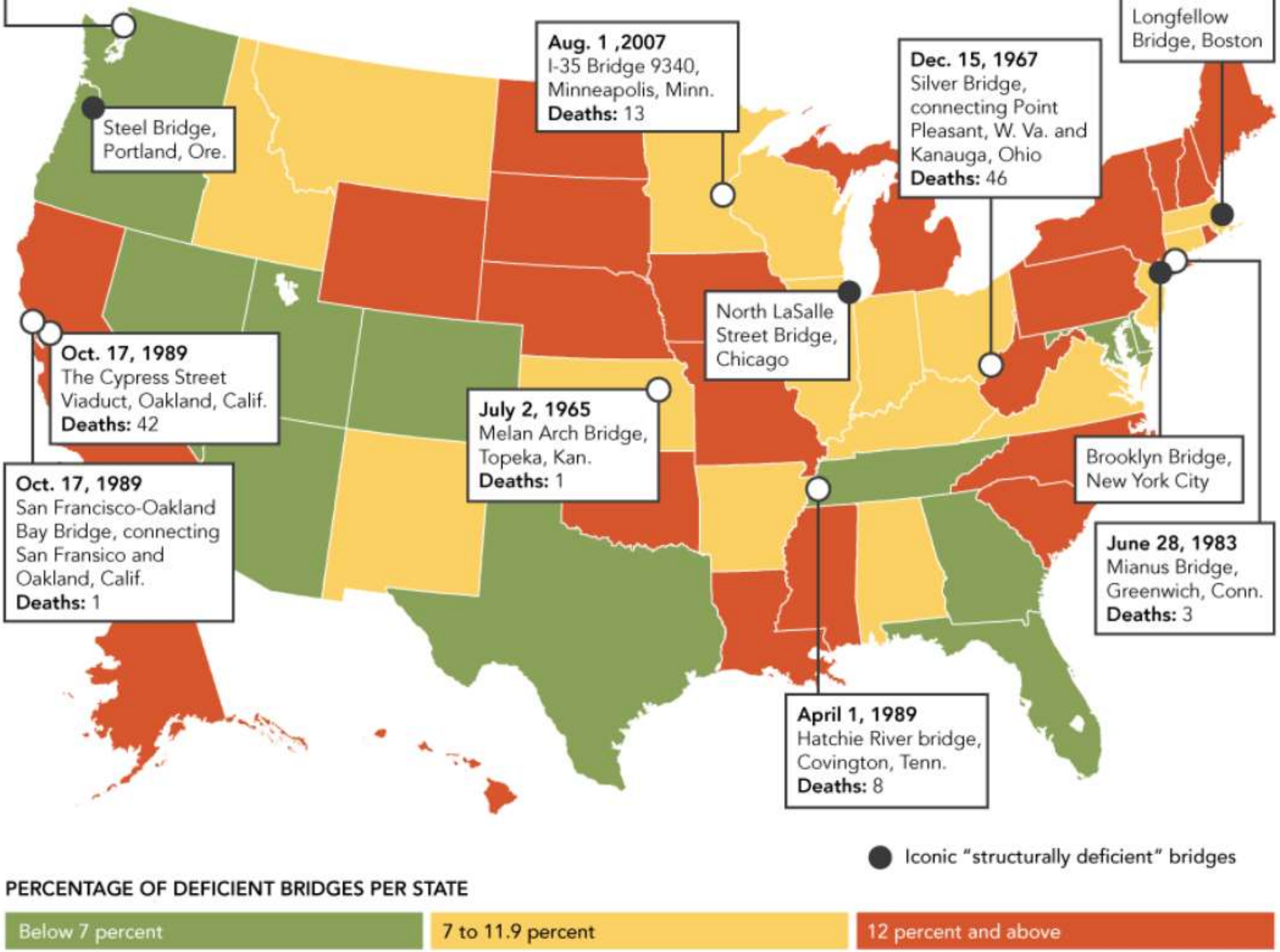
- **15% of bridges are structurally deficient due to steel corrosion (87,450 structures)**

Gas, water, electric utilities lose over $40 billion annually to corrosion

- **There are 876,000 miles of municipal water pipe in the United States**

Infrastructure & Corrosion




Steel Bridge, Portland, Ore.
Aug. 1 ,2007
I-35 Bridge 9340, Minneapolis, Minn.
Deaths: 13
Dec. 15, 1967
Silver Bridge, connecting Point Pleasant, W. Va. and Kanauga, Ohio
Deaths: 46
Longfellow Bridge, Boston
North LaSalle Street Bridge, Chicago
Oct. 17, 1989
The Cypress Street Viaduct, Oakland, Calif.
Deaths: 42
July 2, 1965
Melan Arch Bridge, Topeka, Kan.
Deaths: 1
Brooklyn Bridge, New York City
Oct. 17, 1989
San Francisco-Oakland Bay Bridge, connecting San Fransico and Oakland, Calif.
Deaths: 1
June 28, 1983
Mianus Bridge, Greenwich, Conn.
Deaths: 3
April 1, 1989
Hatchie River bridge, Covington, Tenn.
Deaths: 8
Iconic "structurally deficient" bridges
PERCENTAGE OF DEFICIENT BRIDGES PER STATE
Below 7 percent
7 to 11.9 percent
12 percent and above

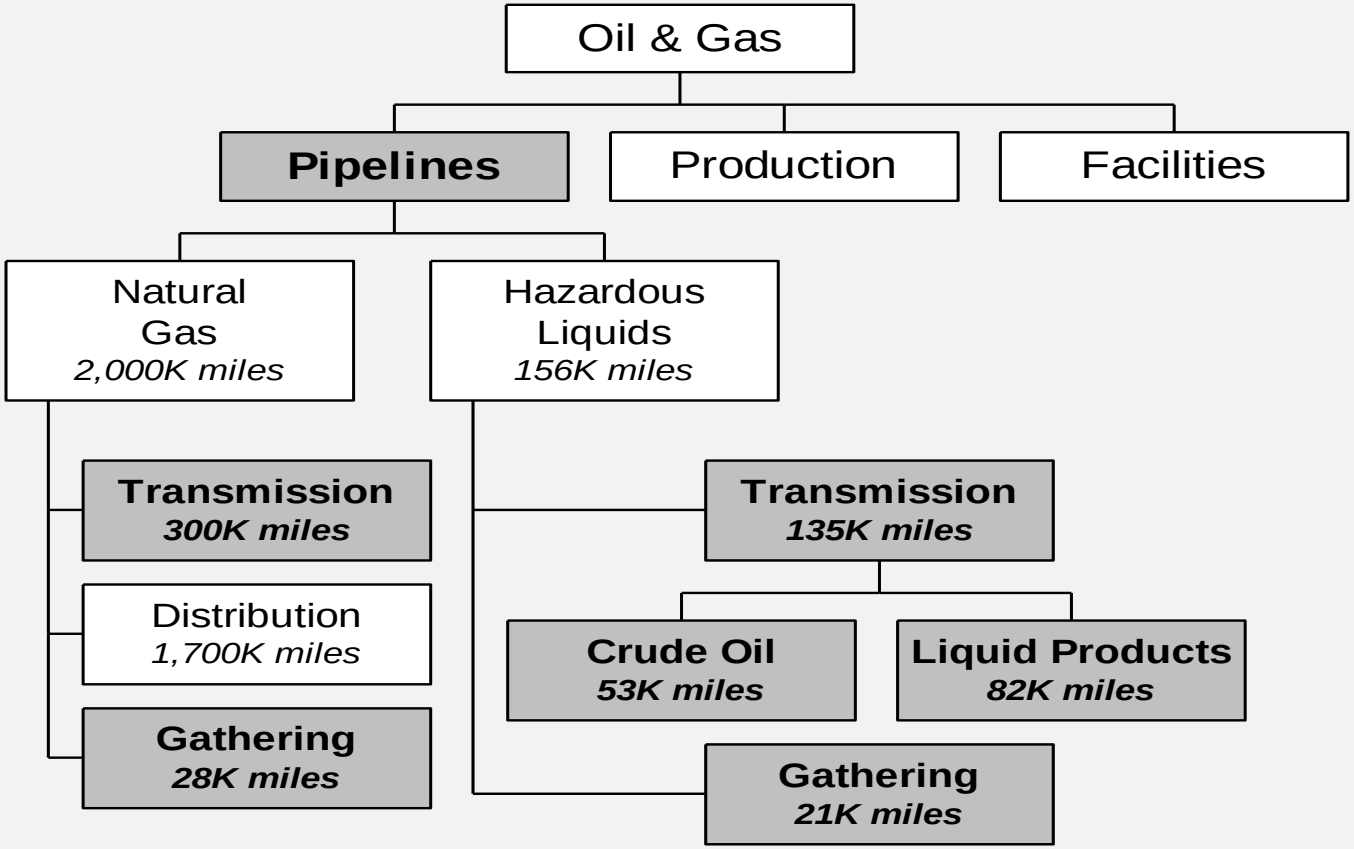
The Cost of Corrosion – Gas Pipelines

480,000 miles of natural gas and related liquid pipelines

60% of pipelines are 40 years order or more

Pipeline related corrosion costs exceed $7 Billion

Pipeline Infrastructure



Flint Water Crisis

Terese Olson
Associate Professor of Civil and Environmental Engineering , University of Michigan

Flint Water Crisis - Continued

Science of corrosion

Because of Flint's method of treating Flint River water, it experienced problems with elevated trihalomethanes, a regulated class of disinfection by-products that are known carcinogens. A domino series of causes and effects were responsible for this problem.

The Flint River is naturally high in corrosive chloride. Therefore, iron pipes in the water distribution system began corroding immediately after the initial switch from Detroit water. The iron that was released from the corroding pipes reacted with residual chlorine that is added to kill microorganisms, making it unavailable to function as a disinfectant.

Because chlorine, which reacted with the iron pipes, could not act as as disinfectant, bacteria levels spiked. When coliform bacteria were detected in distribution system water samples, water utility managers were obliged by law to increase the levels of chlorine. The higher levels of chlorine, while reducing coliform counts, led to the formation of more trihalomethanes.

Flint Water Crisis - Continued

Providing adequate disinfection while minimizing disinfection by-products is a challenge faced by most utilities even under the best of circumstances. The problems became intractable in Flint due to the excessive corrosion of the pipes that deliver water to people's homes.

The science of pipe corrosion in drinking water systems is complex and not completely understood. Corrosion control occurs when naturally forming minerals deposit on pipe walls, thereby protecting the iron pipe surfaces from exposure to oxidants in the water. Changes in water quality sometimes dissolve these mineral coatings, exposing the pipe to corrosion.

In iron pipe systems, the released iron corrosion particles are visible, causing colored and turbid water. In older distribution systems, where lead service lines are often still in place, corrosion then releases lead and copper. Corrosion rates can be affected by many factors that are not well-understood, including the presence of bacteria that colonize the pipe wall, as well as pipe age and water flow rates.

Because of the uncertainties around leaching, the majority of utilities treating surface water add phosphate corrosion inhibitors to control corrosion. They devise doses based on the water industry's experience, rather than on rigorous scientific calculations.

Flint Water Crisis - Continued

False economies

Empirical tests known as "loop tests" are commonly used to assess the effectiveness of corrosion control strategies applied to a given water distribution system. There is no record that such tests were performed in Flint.

A critical cost-saving decision made by Flint not to use corrosion inhibitors, especially when water previously supplied by Detroit did contain them, should have raised concerns. Evidence to demonstrate that inhibitors were unnecessary was a minimum common-sense requirement.

Ignorance among utility personnel and water quality engineers of the importance of corrosion control management and its subtle linkage to decisions made elsewhere in the treatment plant unfortunately also played a role in this story of unintended consequences.

In many water treatment textbooks, the topic of pipeline corrosion is covered as an afterthought. Flint's experience should serve as a siren call to the profession of water quality engineers to remedy this oversight.

By not adding a corrosion inhibitor, Flint was going to save about $140 per day. But the inestimable costs of the errors made in Flint will reverberate through the community for a long time and their magnitude will dwarf the original planned savings.

Replacement of Flint's lead service lines, which is the only permanent solution to address its lead vulnerability, is estimated to cost up to $1.5 billion, according to Flint's mayor, Karen Weaver.

The Costs of Corrosion

Direct and indirect costs to the US Economy will exceed $1.1 trillion in 2017

Over 6% of US annual GDP “corrodes” directly or indirectly from corrosion.

How Do we stop flushing $$$ down the you know what?

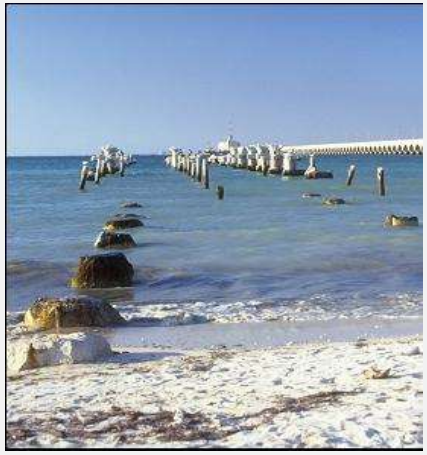
Understanding?

"Approximately one-third of these costs could be reduced by broader application of corrosion resistant materials and the application of best corrosion-related practices" 2002 NACE Study.

"Virtually all premature corrosion failures occur for reasons which were already well known and these failures can be prevented" Dr. *Mars Fontana*

Progreso Pier Mexico: Applying Better Practices

- The 6,980 foot pier was constructed from 1937 – 1941 using 304 stainless rebar
- In 1998, Ramboll consulting engineers inspected the pier and reported minimal structural fatigue



What is Stainless Steel?
What makes it “Stain” “less”?

- **Stainless steel must have at least 11% chromium in its content to be classified as a stainless steel.**
- **Nickel, Molybdenum and other elements are often combined with chromium to improve the corrosion resistance, strength, or heat resistance of the material.**
- **There are over 50 different “flavors” of stainless steels that can be selected for different applications and processes.**

Let’s take a step back. What Makes Stainless Steel work and how do we make stainless steel work better on our projects?

Carbon Steels Vs Stainless

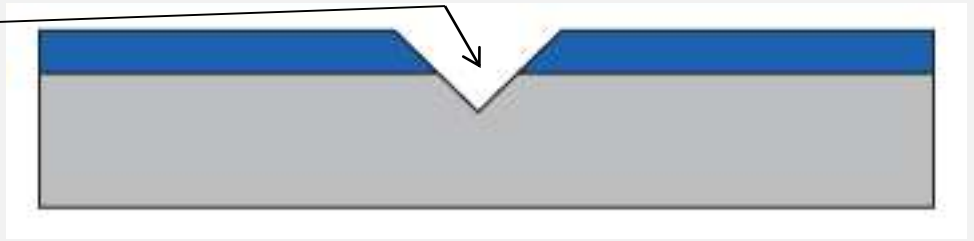
Stainless steel is iron plus at least 11% chromium. If enough chromium is added, a protective passive film will form.

Iron Oxide or “Rust” continues to digest the steel. The passive layer in stainless steels prevents corrosion

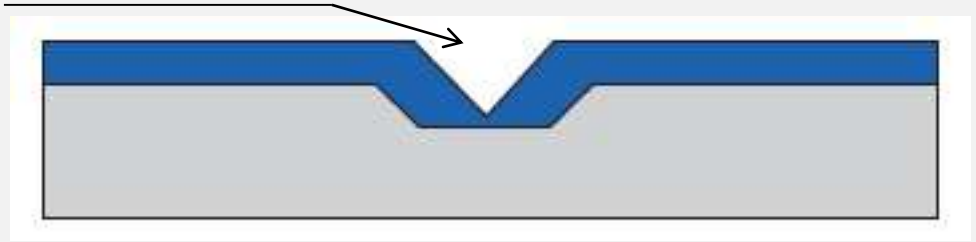
What Makes Stainless Work?

Chromium Oxide Layer

Oxide Layer Damaged



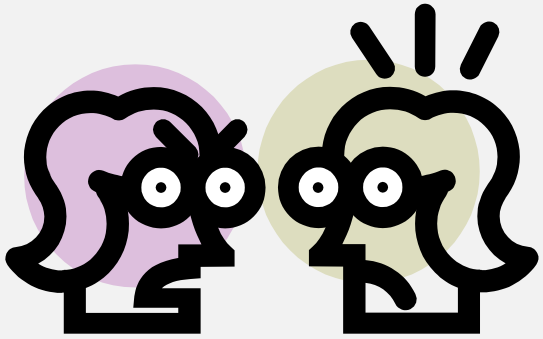
Chromium Oxide Layer Repaired

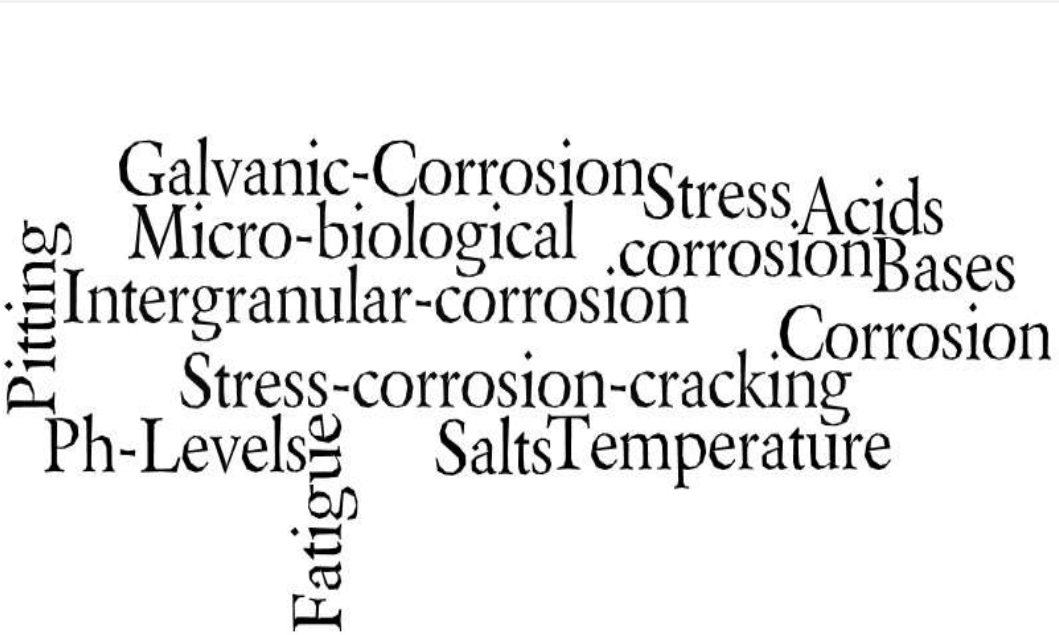


For the Chromium oxide to repair—oxygen must be present!

This Chemistry "stuff" matters…a

We need to understand Types Corrosion!?





Lets Review Corrosion & Stainless Steels

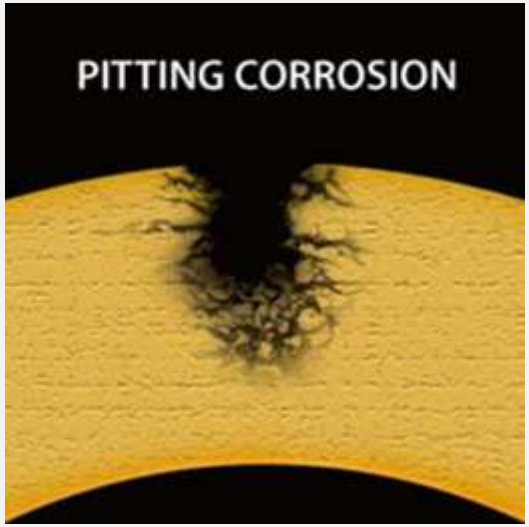
Types of Corrosion

- **<u>Uniform Corrosion</u>: Also known as general corrosion, is characterized by an even, general wasting away of metal from the corroding surface.**

Was the correct material selected?

Pitting Corrosion

- **<u>Pitting Corrosion</u>: described as an extreme case of localized attack which produces cavities or pits in the material.**



- **Was the stainless steel maintained correctly?**
- **Stainless Steels are susceptible to pitting corrosion.**
- **Avoid Chlorides.**

Crevice Corrosion

- **<u>Crevice Corrosion</u>: a particular form of localized corrosion which occurs in crevices formed between two surfaces.**

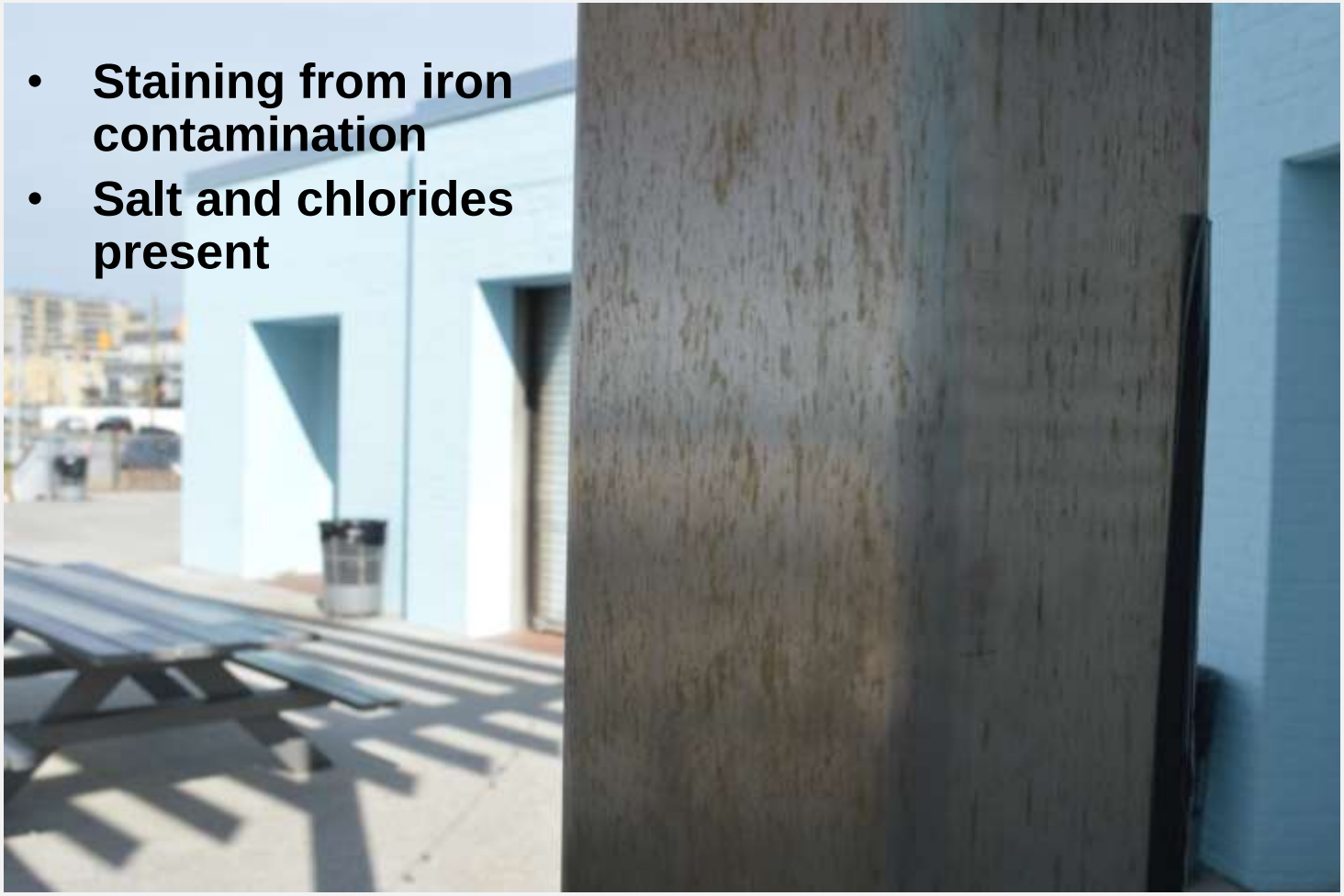
- **When possible, avoid tight corners or crevices in design**
- **Avoid spot welding, use continued welds when possible**
- **Use non absorbent gaskets, avoid chlorides**

NYC Far Rockaway

- **Carbon Contamination from grinding**
- **Deicing salt**

316/L 7” SQ x ½ Wall Structurals, Polished with Minor Pitting Corrosion

Pitting / Surface Corrosion

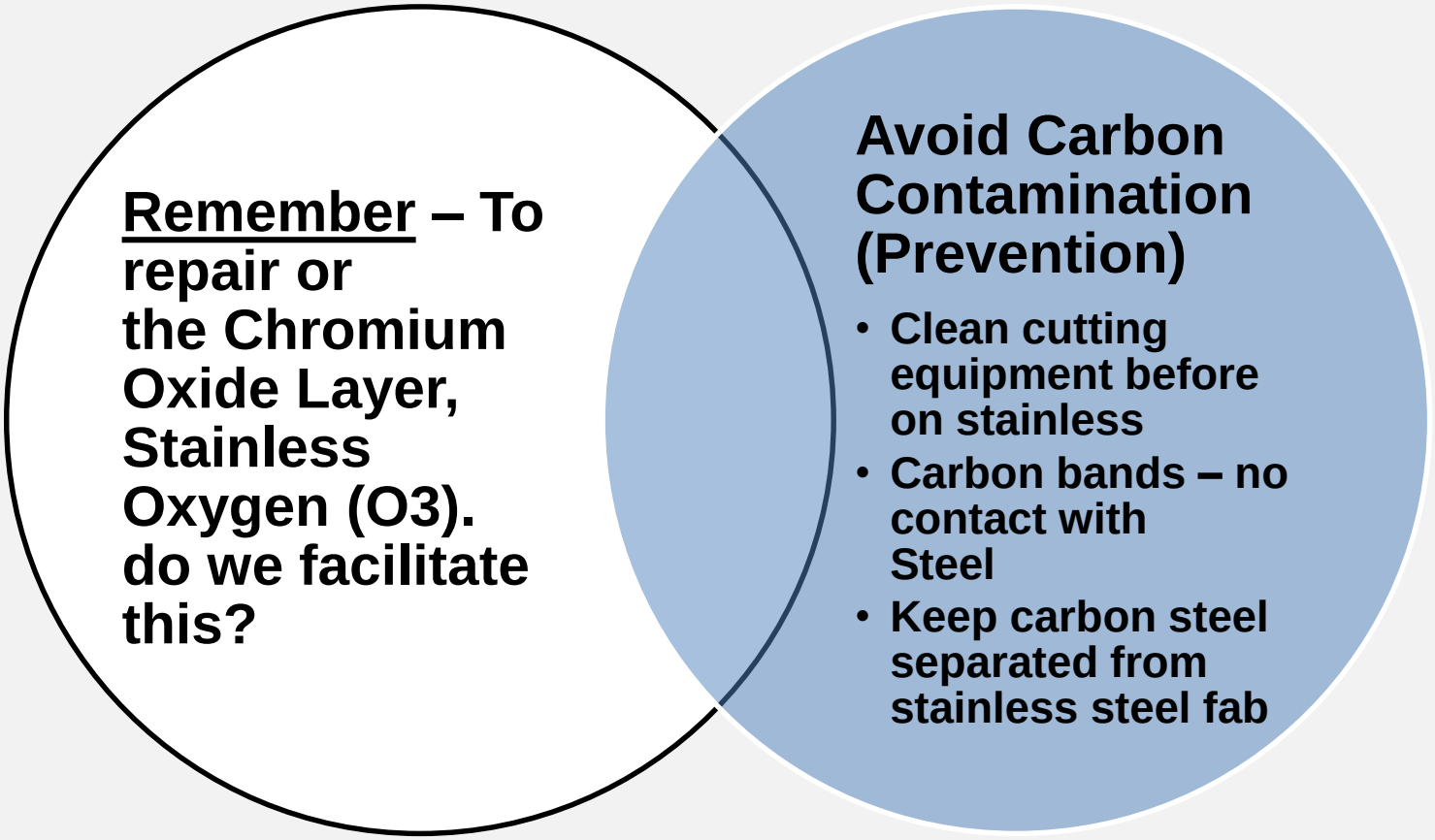


- **Staining from iron contamination**
- **Salt and chlorides present**

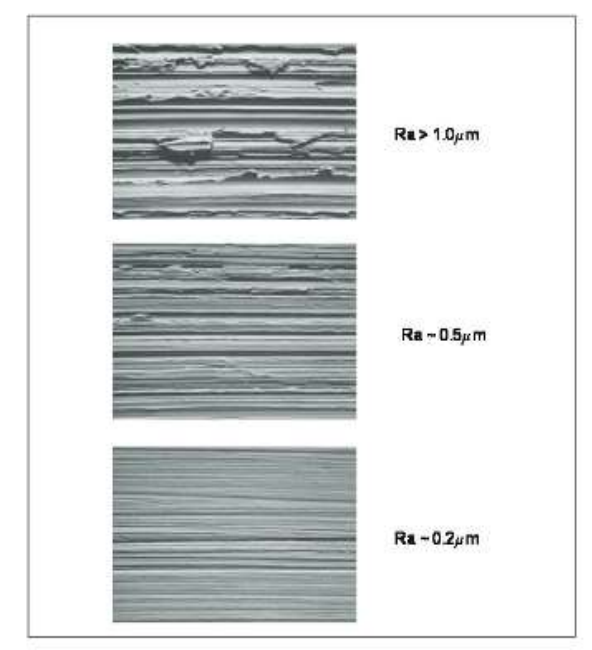
Surface after passivation

Do not allow grinding to take place near stainless fabrication.

How to Preserve the Chromium Oxide Layer

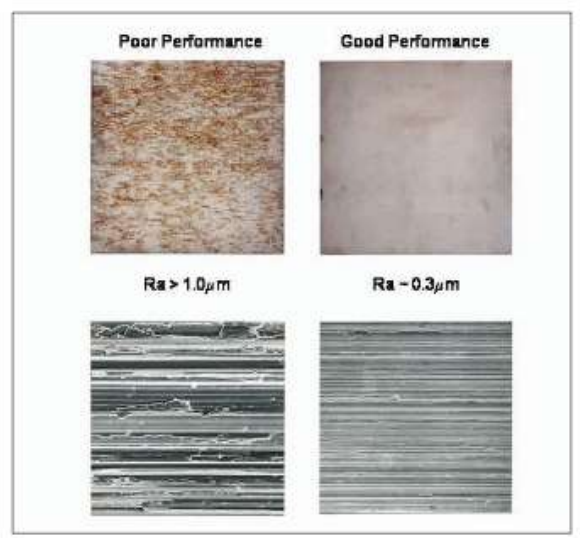


It’s All About the Surface Finish



Source: British Stainless Steel Association

Rougher surface is harder to clean, harder to remove contamination and more prone to corrosion



Accelerated salt spray test

Polished 304/L Stainless Steel I Beams (Cornell University)

Dairy Processing Facility: polished surface improves appearance while enhancing corrosion

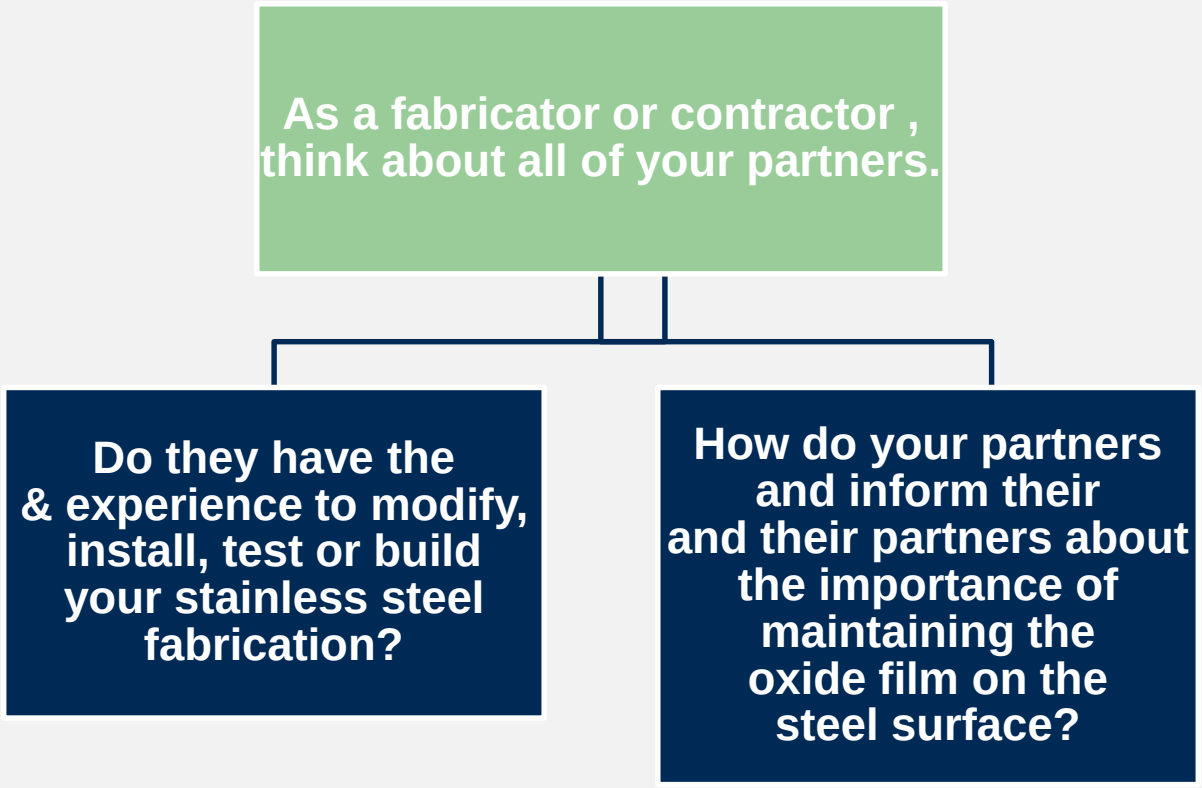
Summary of Best Practices for Handling Stainless Materials

1. **Keep your stainless and carbon steel fabrication areas separate.**
2. **Separate stainless and carbon inventories.**
3. **Use stainless steel processing and handling equipment when possible.**
4. **Remember, non-stainless lifting 'dogs' and chain marks can introduce iron contamination. Non-metallic contact materials and vacuum lifting equipment should be used.**
5. **Packing & Shipping – Tarp your stainless steel fabrications**
6. **Carbon strapping bands should not come in contact with stainless**
7. **Avoid walking on stainless plates and surfaces.**
8. **Communicate with your partners about the proper treatment of stainless steel.**
9. **Depending on application, PVC protection can be used**

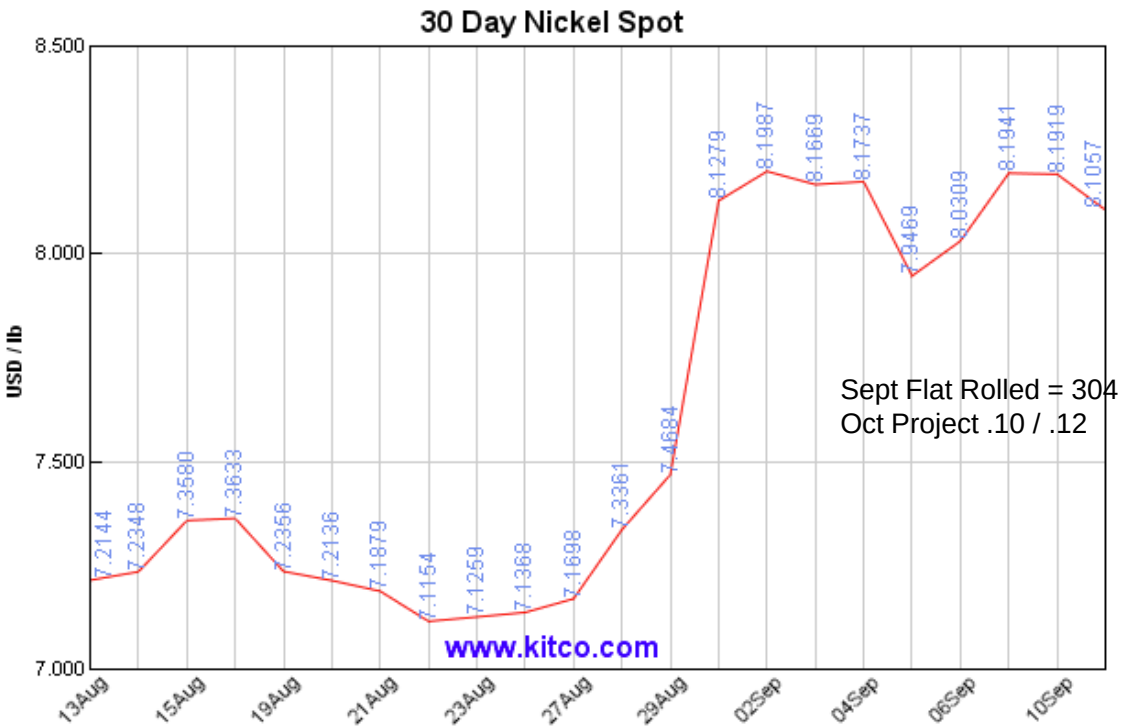
Cleaning Stainless Steels

Issue	Product	Cleaning Process
Routine Cleaning All finishes	Use soap or mild detergent and water (preferably warm)	Sponge, rinse with clean water, wipe dry if necessary. Follow polish lines.
Fingerprints All finishes	Soap and warm water or organic solvent (e.g., acetone, alcohol, methylated spirits)	Rinse with clean water and wipe dry. Follow polish. Follow polish lines
Stubborn Stains and Discoloration All finishes	Mild cleaning solutions, specialty stainless steel cleaners	Use a sponge, rag or fiber brush (soft nylon or natural bristle). Rinse complete with clean water. Wipe dry. Follow polish lines.
Lime deposits from hard water	Solution of one part vinegar to three parts water	Soak in solution then brush to loosen. Rinse well with clean water.
Oil / Grease marks all finishes	Organic solvents (e.g., acetone, alcohol, methylated spirits, proprietary "safety solvents"); baked-on grease can be softened beforehand with ammonia	Clean after with soap and water, rinse with clean water and dry. Follow polish lines.
Rust and other Corrosion Products Embedded or Adhering "Free Iron"	Rust stains can be removed by adding one part of nitric acid to nine parts of warm water. Leave for 30 to 60 minutes, then wash off with plenty of water, and flush any drains thoroughly. See also previous section on Passivating.	Rinse well with clean water. Wear rubber gloves, mix the solution in a glass container, and be very careful with the acid. (See Precautions for acid cleaners.)
Dark Oxide From Welding or Heat Treatment	"Pickling Paste" or pickling solutions	Must rinse carefully, and use care in handling. Dispose of solutions according to environmental regulations.
Scratches on Polished (Satin) Finish	Slight scratches – use impregnated nylon pads. Polish with scuffs dressed with iron-free abrasives for deeper scratches. Follow polish lines. Then clean with soap or detergent as for routine cleaning	Do not use ordinary steel wool – iron particles can become embedded in stainless steel and cause further surface problems. Stainless steel and "Scotch-brite" scouring pads are satisfactory.

Now you know what to do. Does everyone else?



Stainless Pricing Trends



Sept Flat Rolled = 304 = .10/lbs
Oct Project .10 / .12

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