Lean Alloy Alternatives for 300 Series Stainless Steels

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ATI Allegheny Ludlum

AL 2003™
Lean Duplex Stainless Steel

AGENDA

- Introduction
- Raw Materials & Surcharges
- Alloy Substitution Options
  - Properties
  - Fabrication
  - Applications
  - Codes & Standards
- Summary & Conclusions

INTRODUCTION

- **The austenitic stainless steels are popular because they exhibit a combination of corrosion resistance, moderate strength, high ductility, good formability, and high toughness.**
- **This makes these alloys versatile and easy to use.**
- **The austenitic structure of the 300-series stainless steels is a consequence of their nickel content.**

RAW MATERIALS

- **Nickel is typically the greatest single component of the cost of the 300-series stainless steels.**
- **Nickel prices are subject to periodic large fluctuations that cause similar large fluctuations in the costs of using 300-series stainless steels.**
- **The volatility associated with the price of Nickel is frequently discussed.**

Monthly Nickel LME Cash Prices

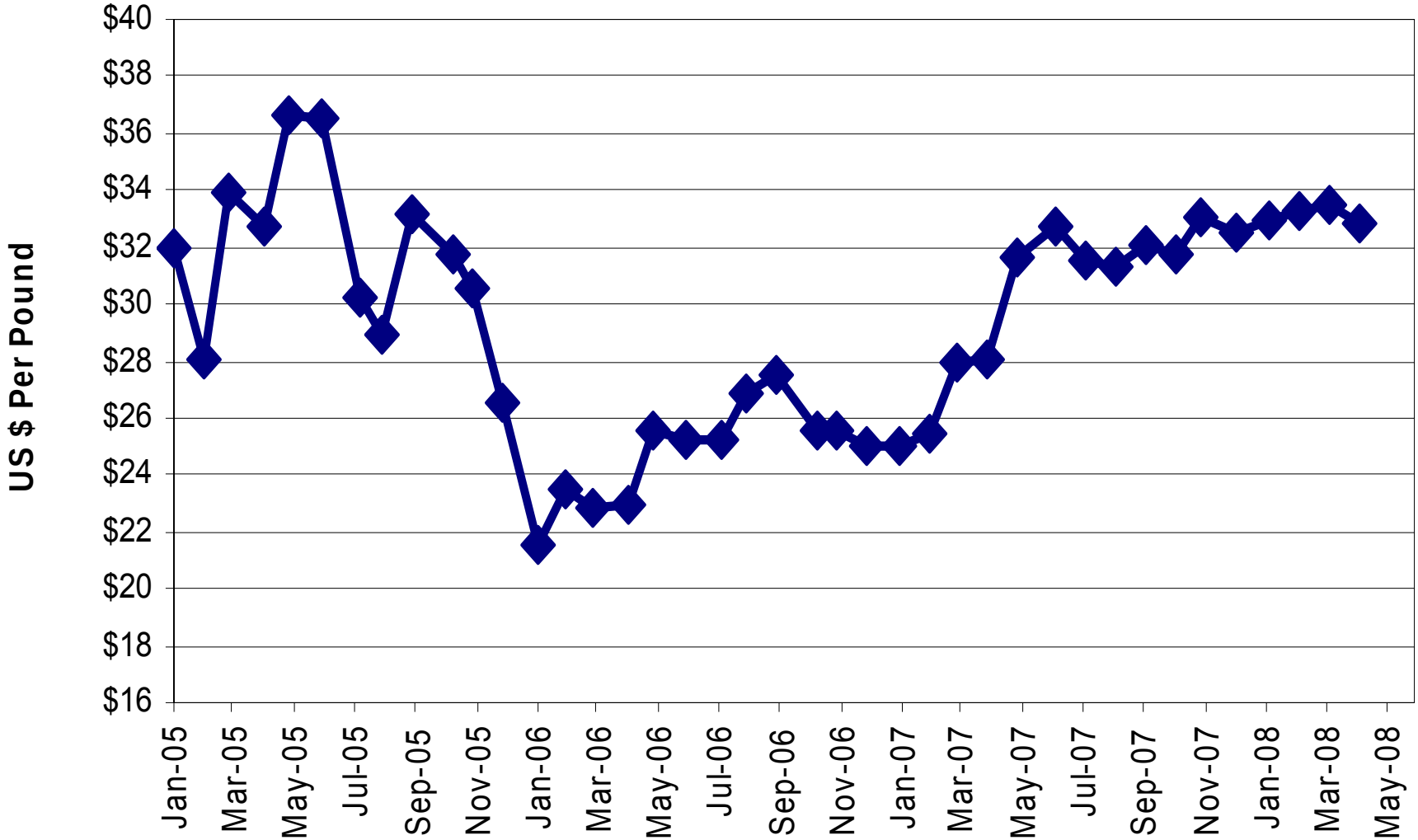
RAW MATERIALS

- **Molybdenum has shown recent increases in demand which has in turn affected the price.**
- **This increase in price has also played a significant cost in the use of 300-series stainless steels.**
- **Until recently Nickel was the alloying element most frequently discussed.**

RAW MATERIALS

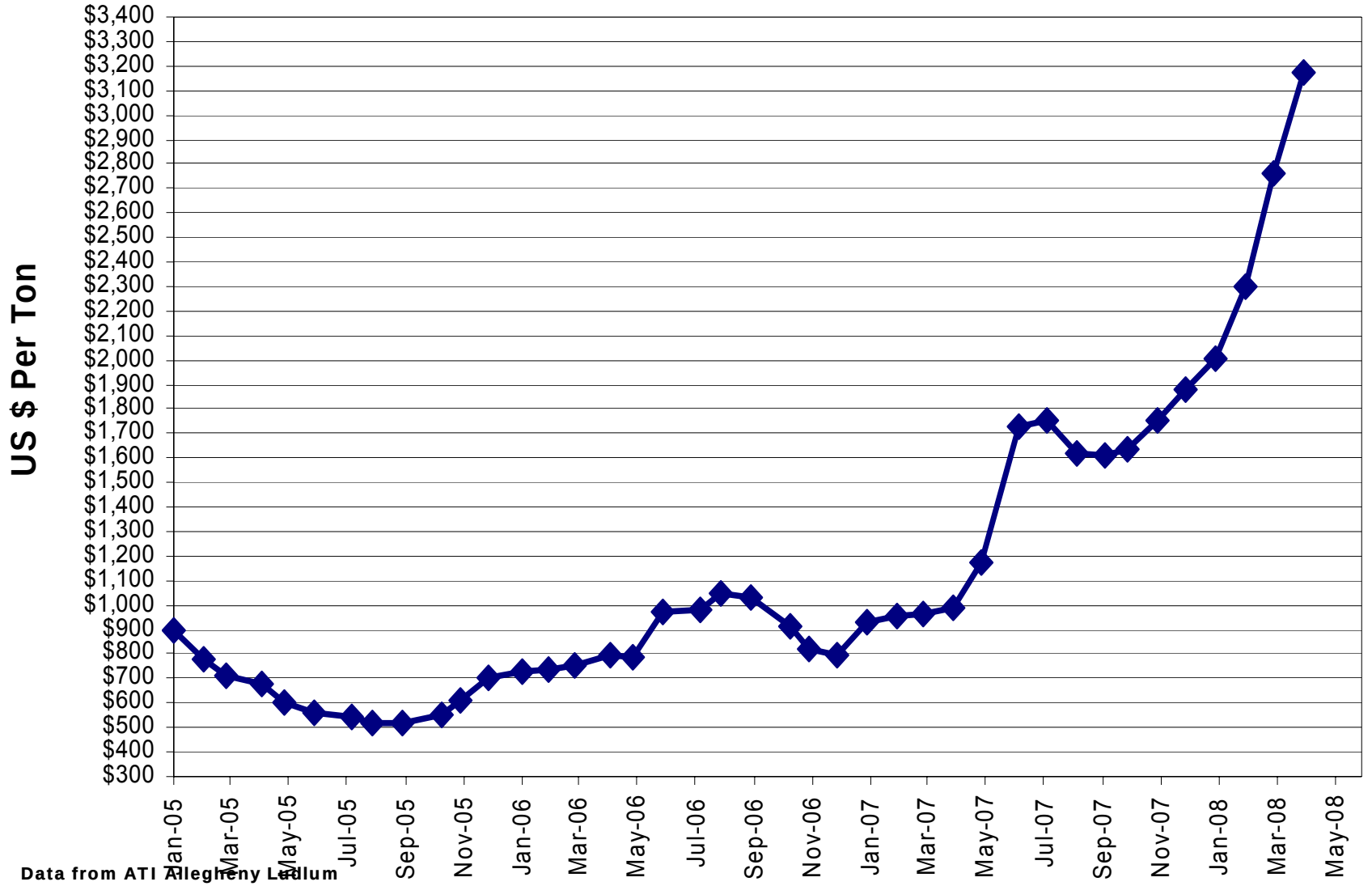
- **Traditional demand for Molybdenum has followed cycles of capital investments in raw material, processing and manufacturing industries.**
- **Supply has not been able to follow due to production limitations, length of time to develop and start new mining facilities and roasting capabilities.**

Moly Oxide Jan 2005 - Current
Platts Monthly Average



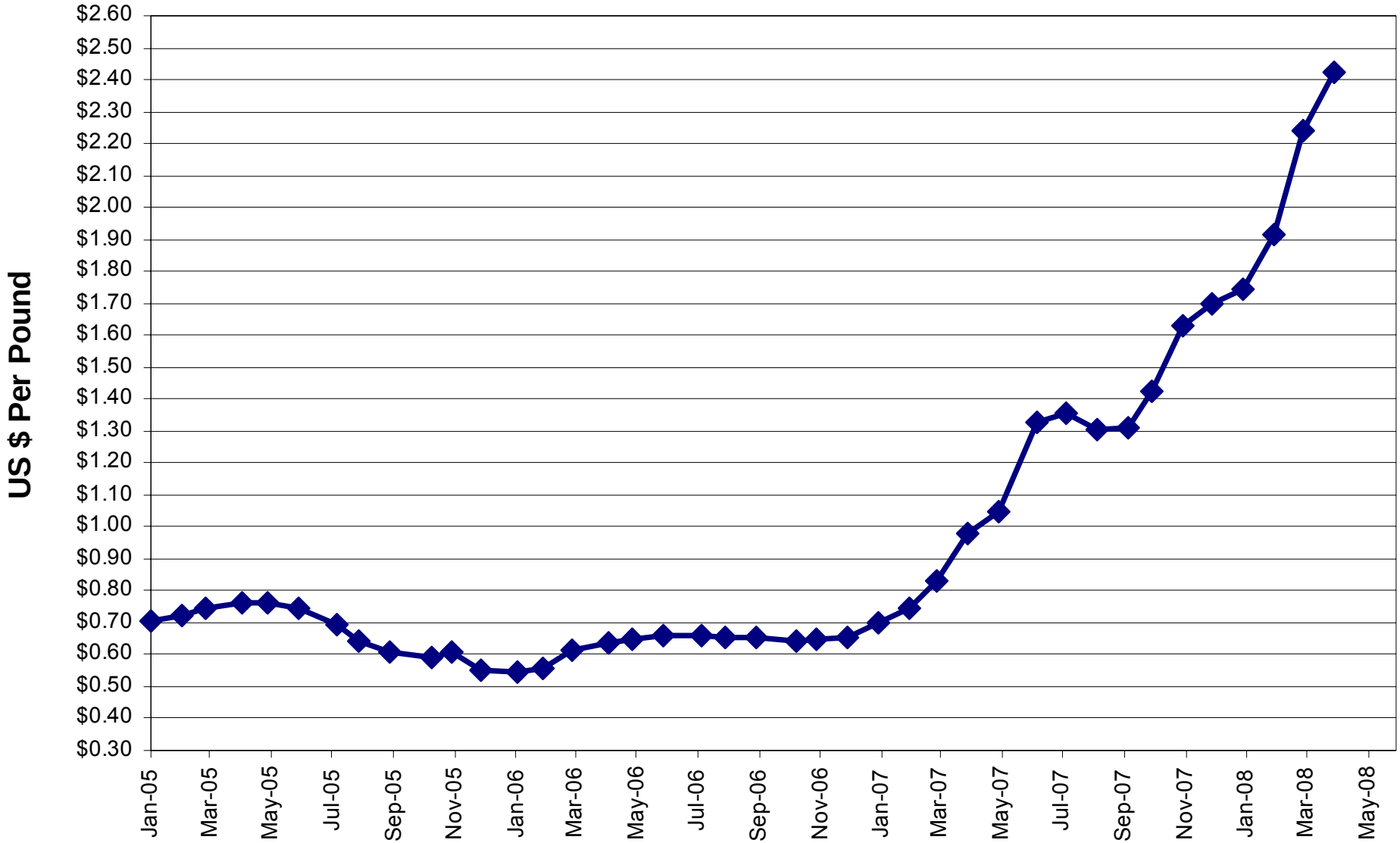
Data from ATI Allegheny Ludlum

Ferro Manganese Jan 2005 - Current
Platts Monthly Average



Data from ATI Allegheny Ludlum

Ferro Chrome Jan 2005 - Current
Platts Monthly Average



Data from ATI Allegheny Ludlum

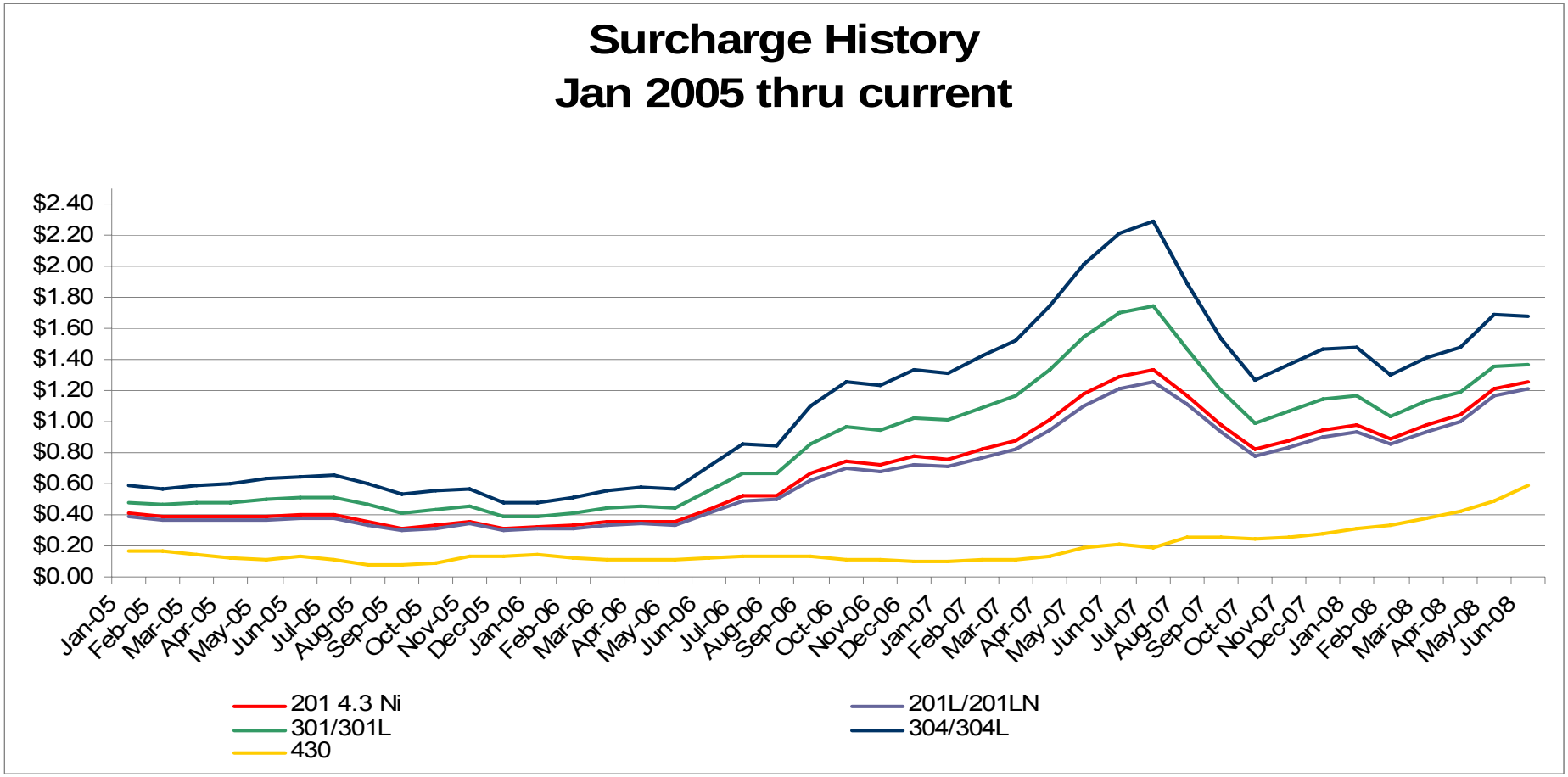
Alloy Surcharge Mechanism

- **In response to raw materials cost volatility, stainless steel producers typically quote selling price in two components: base price and an alloy surcharge.**
- **A common alloy surcharge formula is calculated from the sum of increase in each alloy component above a trigger price times the minimum specified content of that alloying element. A yield factor is used with some alloy components.**

Alloy Surcharge Mechanism

- **An alloy surcharge mechanism has been implemented by most producers around the world.**
- **When first implemented, the effect of the surcharge was relatively small.**
- **Since 2004 the surcharge component has grown such that it can exceed the base price of most 300-series and nickel-base alloys.**

Surcharge Histories



ATI Allegheny Ludlum data

Example of Mayor Surcharge Components *(for May 2008 deliveries)*

Grade	Nickel	Chromium	Manganese	Iron	Total
ATI 201HP™	$0.63	$0.37	$0.11	$0.09	$1.21
T301	$0.87	$0.37	$0.00	$0.10	$1.36
T304	$1.17	$0.42	$0.00	$0.09	$1.69
T430	$0.00	$0.37	$0.00	$0.10	$0.49

The Switch Is On!®

The Case for ATI 201HP™ Alloy Substitution

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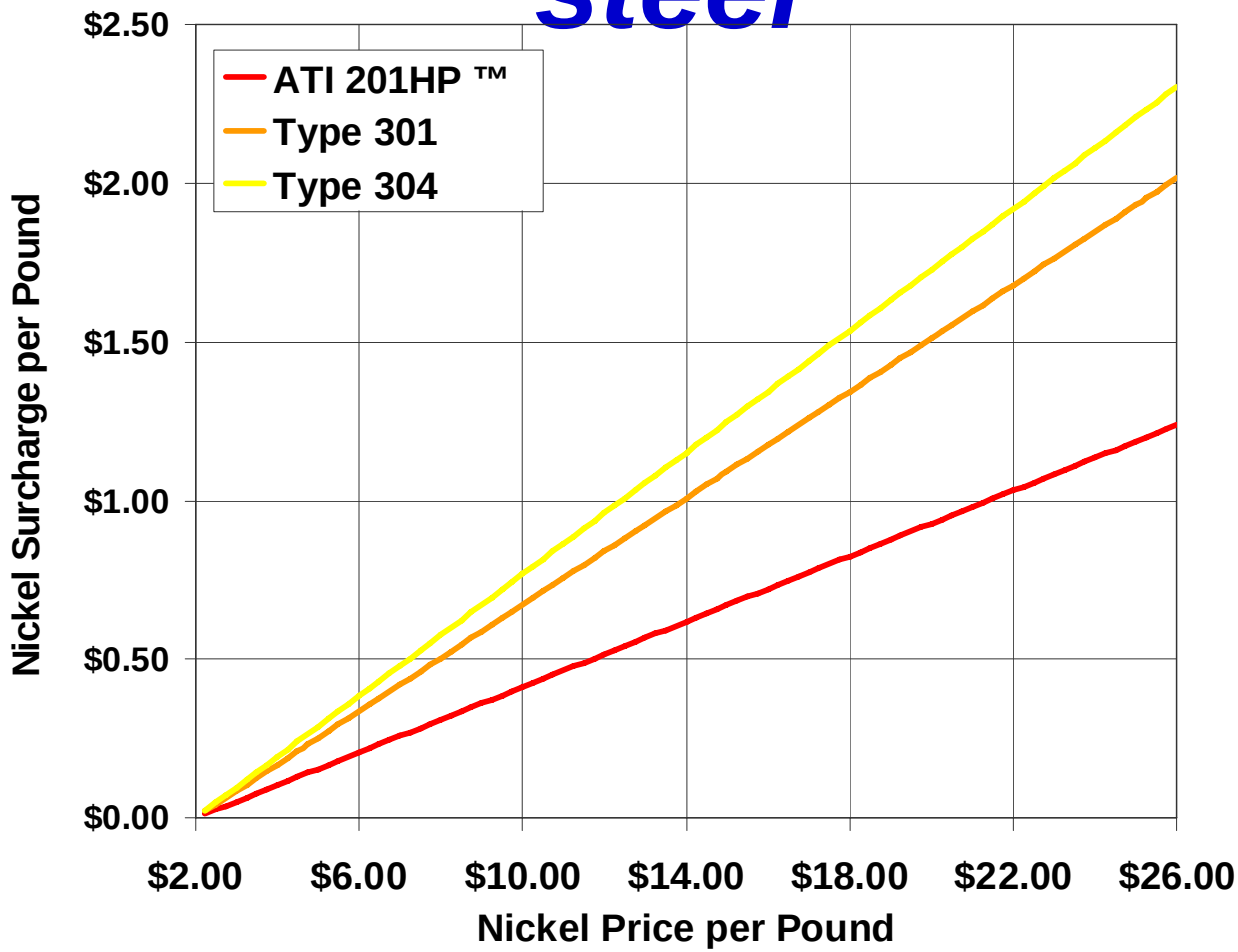
SUBSTITUTION OPTIONS:
200 Series Alloys for 300 Series

- **The first chrome-manganese grades were developed in the 1930s.**
- **Their use in America increased during the 1950s as a way of conserving scarce nickel.**
- **Historically, the popularity of these alloys has been linked to nickel price.**
- **The recent extreme escalation and volatility of nickel prices has led to unprecedented and continued interest in 200-series alloys.**

Effect on the alloy surcharge cost of using other alloys in place of Type 304 stainless steel



Chemical Composition Comparison

Typical Values, weight %

Grade	C	Mn	P	S	Si	Cr	Ni	N	Fe
ATI 201HP™	0.08	7.1	0.032	<0.001	0.48	16.3	4.5	0.07	balance
ATI 201LN™	0.02	6.8	0.032	<0.001	0.48	16.3	4.1	0.15	balance
T301	0.10	1.8	0.026	<0.001	0.45	17.3	6.7	0.04	balance
T304	0.06	1.0	0.031	<0.001	0.44	18.3	8.1	0.07	balance
T430	0.04	0.37	0.028	<0.001	0.45	16.4	0.4	0.04	balance

Mechanical properties of 200-series stainless steels

- **All of the Type 201 and 201LN stainless steels exhibit the ductility and toughness expected of austenitic stainless steels, even at low temperatures.**
- **The somewhat greater stability of the 201LN alloy lets it retain this toughness down to -320°F (-196°C), making it useful for liquid nitrogen (LN2), liquid natural gas (LNG) and liquid oxygen (LOX) handling equipment.**

Mechanical Properties Comparison

Typical Mechanical Properties for Annealed Sheet

Grade	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (% in 2”)	Hardness (R_B)
ATI 201HP™	105	45	58	88
ATI 201LN™	111	53	54	93
T301	105	45	58	85
T304	95	45	53	85
T430	74	50	29	82

Atmospheric Corrosion Resistance

Samples Exposed for 10 years 200 meters from the surf at Kure Beach, NC

Aqueous Corrosion Resistance

- In general, the corrosion resistance of 201 stainless steel is slightly inferior to that of 304 stainless steel, but superior to that of 430 stainless steel.
- In environments in which 304 exhibits negligible corrosion, 201 shows acceptably low rates of corrosion.

Aqueous Corrosion Resistance

- **In environments where 304 exhibits marginal or unacceptable corrosion resistance, the use of 201 materials typically should not be considered.**

Aqueous Corrosion Resistance

- The 201 alloys are susceptible to chloride stress corrosion cracking (SCC).
- Their susceptibility is approximately the same as that for 304 stainless steel – they all crack in boiling saturated solutions of magnesium chloride, calcium chloride, lithium chloride, and acidified sodium chloride.

Fabrication

- 201 and 201LN may be welded using the same methods and procedures used for S30400.
- The higher strength of 201LN exceeds the tensile strength that can be reliably provided by common 300-series filler metals such as 308L.
- Filler metals which may be used include 2209 for ambient and near-ambient temperature use, and ERNiCrMo-4 (alloy 276) for cryogenic use, depending on the specific application.

Fabrication

- 201 and 201LN can also be welded to 304 or 301 using 308L filler.
- No detrimental galvanic corrosion will occur when 200- and 300-series alloys are coupled.

Fabrication

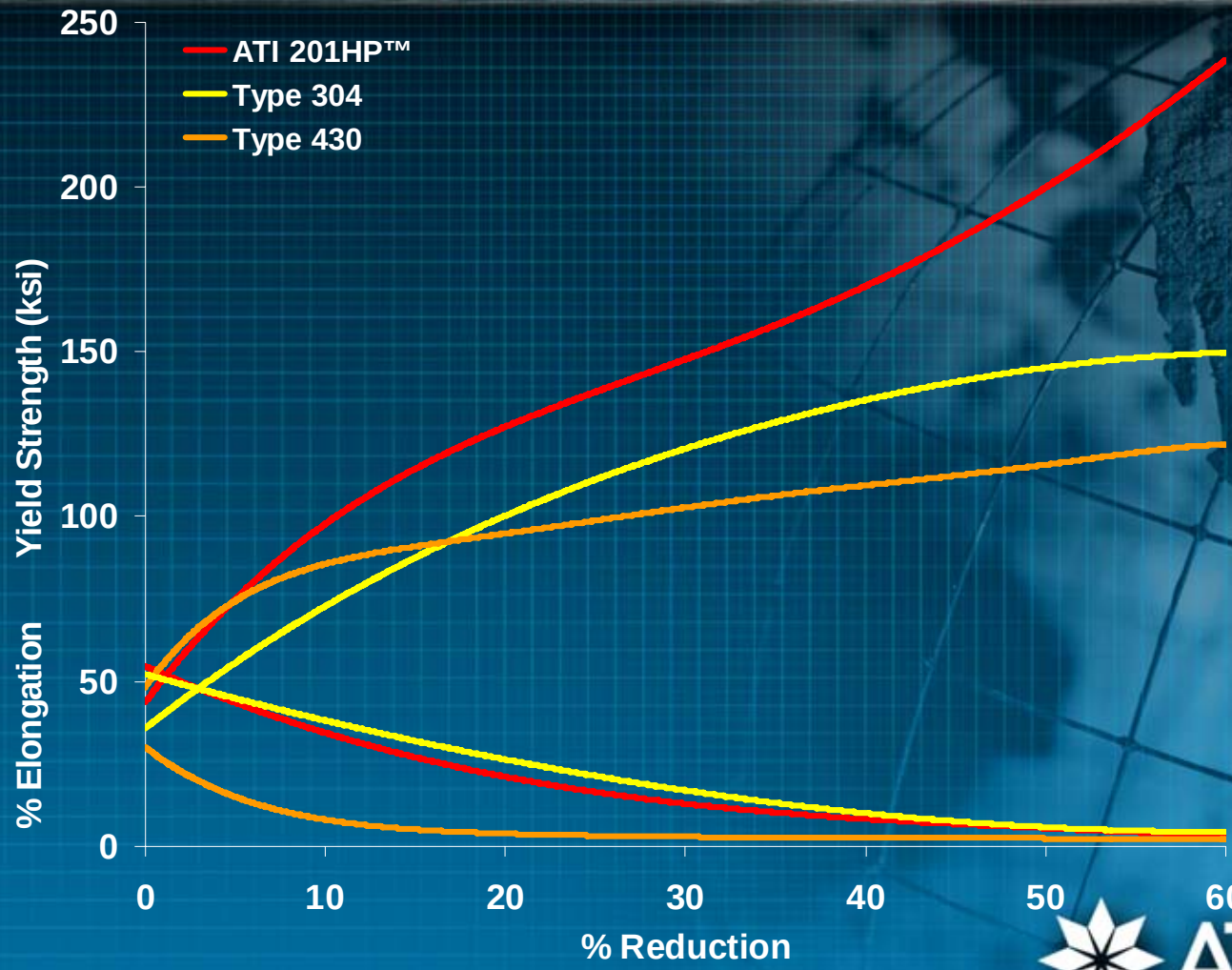
- **Because of its higher strength and work hardening rate, the formability of ATI 201HP™ alloy will be somewhat different than T304.**

- **ATI 201HP™alloy would be expected to perform better in stretch-forming applications than T304.**

Fabrication

- **The amount of springback between ATI 201 HP™ alloy and T304 will also differ due to the higher strength of ATI 201 HP™ alloy.**

Work Hardening Comparison



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Applications

- Beverage Dispensers
- Subways and Trolleys
- Toasters
- Disposals
- Washers

- Cookline
- Specialty Clamps
- Hot Food Wells
- Trucks / Trailers
- Ice & Water Dispensers

Applications

- **201LN was developed for use in cryogenic vessels for storage and transport of LN2, LNG, etc., and has been used in this application for over 20 years.**

Applications

- **Railcars built by the Budd Manufacturing Company in 1955 using Type 201 are still in service and still gleaming after 50 years. Today, 201LN stainless steel is an alloy commonly chosen for railcar construction.**
- **201LN alloy has long been used in the frames of truck trailers. The high strength of S 20153 allows for thinner sections to be used, thereby saving on material costs and improving fuel economy. And, it doesn’t need to be painted.**

Applications

Chemical Processing Tanks and Pipes

- 201LN alloy has similar corrosion resistance and higher strength compared to 304L. This makes it a natural substitute for most tank and pipe applications currently using 304L.
- Tanks are now being constructed of these alloys for fermentation and storage of fuel-grade ethanol.

Code Approvals

- **S20100 is covered by the following ASTM Specifications:**
  - A213 - Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
  - A240 - Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*
  - A249 - Welded Austenitic Steel Boiler, Superheater, Heat- Exchanger, and Condenser Tubes
  - A276 - Stainless Steel Bars and Shapes
  - A666 - Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar*
  - A473 - Stainless Steel Forgings
  - A959 - Standard Guide for Specifying Harmonized Standard Grade Compositions for Wrought Stainless Steels*

*** Includes S20153**

- **Work items have been initiated to add S20100 and S20153 to the following ASTM specifications:**
  - A 269 -Seamless and Welded Austenitic Stainless Steel Tubing for General Service
  - A 312 -Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
  - A 358 -Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications
  - A 409 -Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
  - A 813 -Single- or Double-Welded Austenitic Stainless Steel Pipe
  - A 814 -Cold-Worked Welded Austenitic Stainless Steel Pipe

Code Approvals

- **S20100 is approved for ASME Section VIII Division 1 use up to +300°F.**
- **S20153 is approved for ASME Section VIII Division 1 use up to +100°F.**

Code Approvals

- **ASME Code Case 2504-1 has expanded the permissible use temperature range for S20153 under Section VIII Divisions 1 & 2 to +800°F and Section XII (transport tanks) use was approved for -320°F to +650°F.**
- **This code case has been approved for incorporation into the stress tables in the 2008 Addendum.**

Code Changes

- Use of S20153 for API 620 for cryogenic tanks will be published soon.
- Use of S20153 and S20100 for API and 650 large storage tanks is in the final stages of the approval process.
- These API approvals will facilitate the use of S20100 and S20153 in ethanol production and storage.

Code Changes

- S20100 and S20153 are already covered in flat-rolled forms by ASTM A240.
- S20100 and S20153 are now included in the 2008 editions of ASTM Standards A249, A269, A312, A358, A409, and A814. They are expected to be added to Standard A813 withdrawn the next 6 months.

Availability

- **ATI 201HP™ and ATI 201LN™ alloys are available as sheet, strip, hot-rolled discrete plate, continuous mill plate, and cut plate shapes.**
- **ATI 201HP™ and ATI 201LN™ alloys are available in the same product forms and finishes as 304.**
- **ATI 201HP™ and ATI 201LN™ alloys have the same physical appearance as 304.**

200-Series Substitution: Summary

- **Substitution of 201or 201LN for 304 offers a lower cost (via its lower surcharge) and a more stable cost.**

The Switch Is On!®

The Case for ATI 2003™ Substitution

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SUBSTITUTION OPTIONS: Duplex stainless steels for austenitic stainless steels

- **Duplex stainless steels contain approximately 50% ferrite and 50% austenite, which results in a material that has properties representative of both classes of stainless steel.**
- **Like the nickel-free ferritic (400 series) grades, duplex grades are magnetic and are more resistant to chloride stress corrosion cracking than austenitic (200 and 300 series) grades.**

SUBSTITUTION OPTIONS: Duplex stainless steels for austenitic stainless steels

- **Duplex alloys have good ductility and toughness, approaching that of the austenitic grades. Also, duplex alloys are stronger than comparable austenitic and ferritic stainless steels.**
- **Lean duplex stainless steels like ATI 2003™alloy have been designed to have the properties of a duplex material, but contain less nickel and molybdenum than standard duplex grades, such as 2205, which results in a cost savings.**

SUBSTITUTION OPTIONS: Duplex stainless steels for austenitic stainless steels

- **Initially, the 2205 duplex alloy was viewed as a higher-strength, more capable substitute for 316L austenitic stainless steel.**
- **2205 often sold at a premium above the 316L price.**

SUBSTITUTION OPTIONS: Duplex stainless steels for austenitic stainless steels

- **The first duplex stainless steels were developed in the 1930s.**
- **Their use in America was limited until the introduction of the 2205 alloy during the early 1980s.**

SUBSTITUTION OPTIONS: *Duplex stainless steels for austenitic stainless steels*

- **Duplex stainless steel with significantly lower Ni and Mo contents than 2205 alloy could provide corrosion resistance equivalent to or better than 316L at a significantly lower cost.**
- **This recognition led to the invention early in this decade of ATI 2003™ alloy .**

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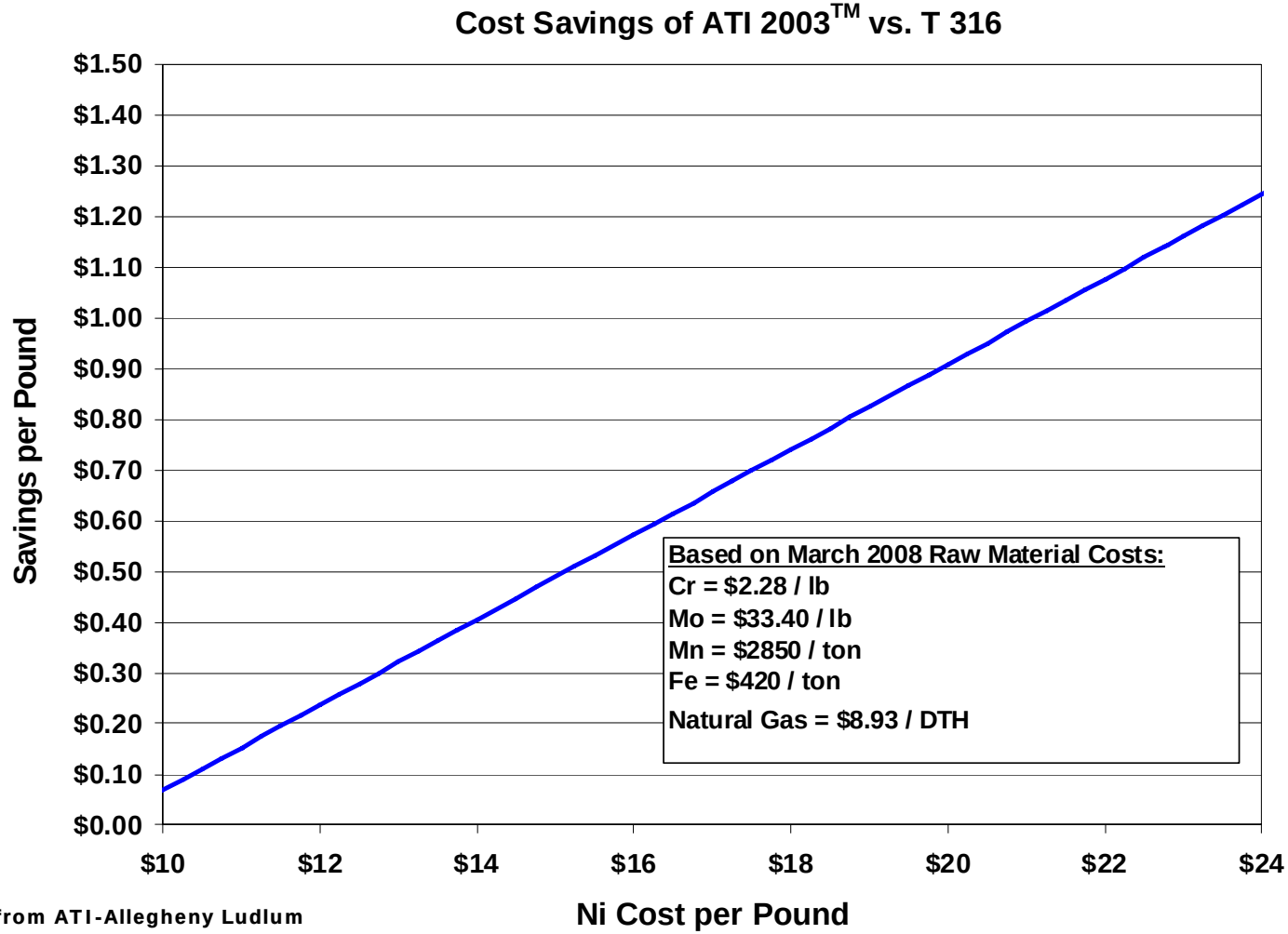
SUBSTITUTION OPTIONS: Duplex stainless steels for austenitic stainless steels

- **As with the 200-series austenitic alloys, volatile raw material prices provide a strong impetus for the use of these duplex stainless steels.**
- **Because of the leaner chemistry of ATI 2003™ alloy, the raw material surcharge is less volatile – resulting in a more stable purchase price.**

Cost Savings Attainable by Substitution of ATI 2003™ for 316



Data from ATI-Allegheny Ludlum

Typical Chemistry

Alloy	UNS	PRE_N	Cr	Ni	Mo	N	Other
ATI 201HP™	S20100	18	16.2	**4.3**	**0.2**	0.07	7 Mn
304	S30400	20	18.2	**8.1**	**0.3**	0.07	
316L	S31603	24	16.3	**10.1**	**2.1**	0.07	
317L	S31703	30	18.4	**12.4**	**3.2**	0.07	
ATI 2003™	S32003	30	21.8	**3.5**	**1.7**	0.17	
2205	S32205	36	22.5	**5.8**	3.2	0.17	

Mechanical Properties

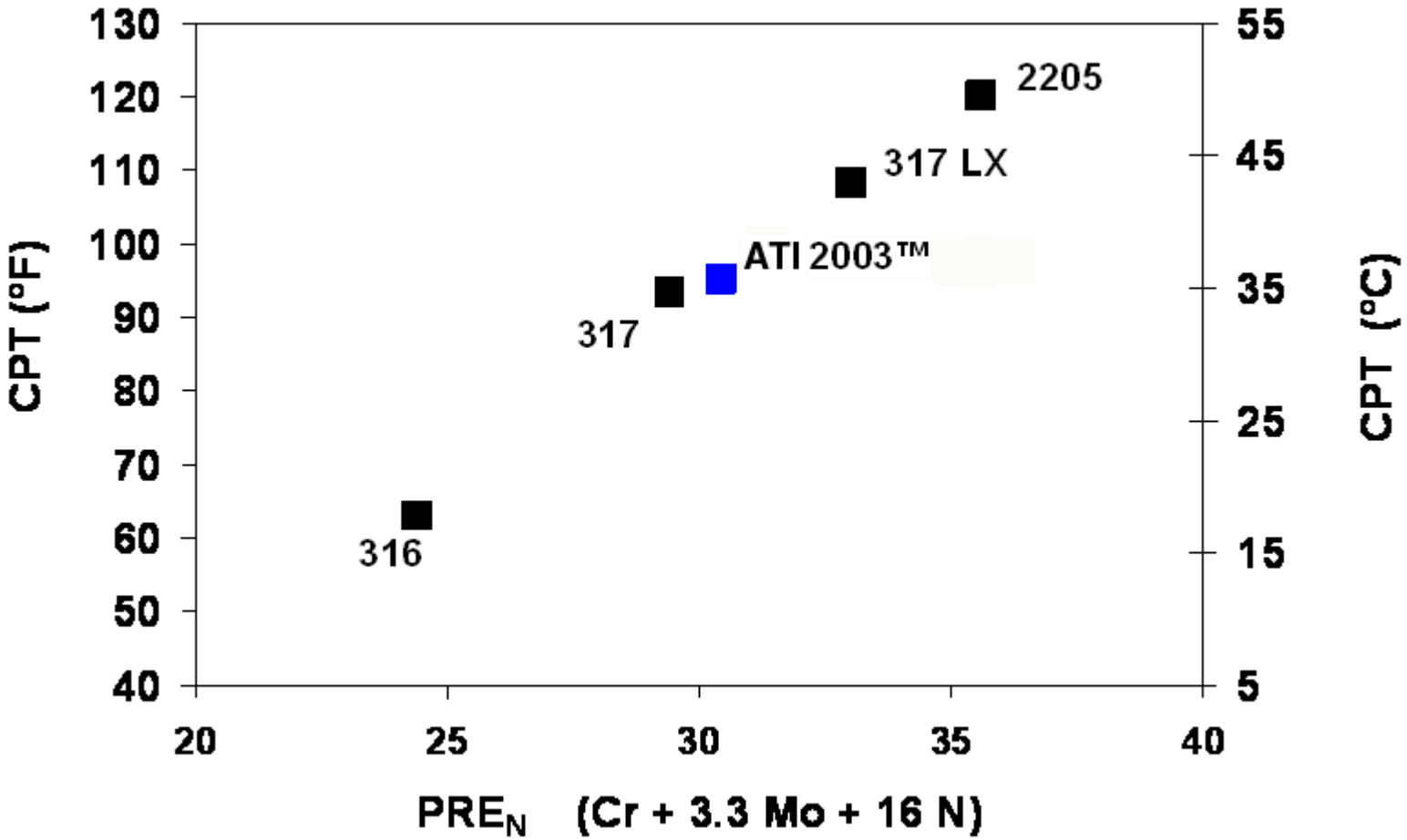
Typical Mechanical Properties for Annealed Sheet

Grade	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (% in 2”)	Hardness
316L	90	45	55	80 RB
ATI 2003™	110	80	35	20 RC
2205	125	85	30	27 RC

Mechanical Properties

- **The much higher usable strength of ATI 2003™ alloy compared to 316L may allow significant reductions in the quantity of material needed, providing even greater savings than indicated by price alone.**

Corrosion Pitting



Aqueous Corrosion Resistance

- Like 2205, ATI 2003™alloy stress corrosion cracks in magnesium chloride, but resists cracking in seawater and most other hot chlorides.
- In seawater, ATI 2003™ alloy appears slightly more SCC-resistant than 2205.
- Both alloys offer a practical solution to avoiding the SCC problems that trouble 316L stainless steel use.

Aqueous Corrosion Resistance

- **S32003 provides superior resistance in many environments compared to 316L stainless.**

Corrosion Resistance in Boiling Solutions and ASTM Tests

Test Solution	Corrosion Rate in Mils per Year (mm/y) for Cited Alloys			
	Type 316L	Type 317L	AL 2003™	AL 2205™
20% Acetic Acid*	0.10 (<0.01)	0.48 (0.01)	0.02 (<0.01)	0.01 (<0.01)
45% Formic Acid	23.4 (0.59)	18.4 (0.47)	14.9 (0.38)	0.50 (0.01)
10% Oxalic Acid	48.0 (1.22)	44.9 (1.14)	3.77 (0.10)	7.80 (0.20)
20% Phosphoric Acid	0.20 (<0.01)	0.72 (0.02)	0.34 (0.01)	0.80 (0.02)
10% Sulfuric Acid*	636 (16.2)	298 (7.57)	259 (6.58)	206 (5.23)
1% Hydrochloric Acid*	226 (5.47)	54.2 (1.38)	49.9 (1.27)	0.80 (0.02)
ASTM A262 Practice B ($Fe_2(SO_4)_3 \cdot H_2SO_4$)	26.0 (0.66)	20.8 (0.53)	20.8 (0.53)	19.9 (0.51)
ASTM A262 Practice C (65% HNO_3)	22.3 (0.57)	19.7 (0.50)	30.9 (0.78)	20.6 (0.53)
ASTM A262 Practice E ($Cu \cdot CuSO_4 \cdot H_2SO_4$)	Pass	Pass	Pass	Pass

* Samples Activated

Fabrication

- **ATI 2003™ alloy can be welded using the same methods and procedures used for 2205 material.**
- **Use of the readily-available 2209 filler metal is suggested.**

Fabrication

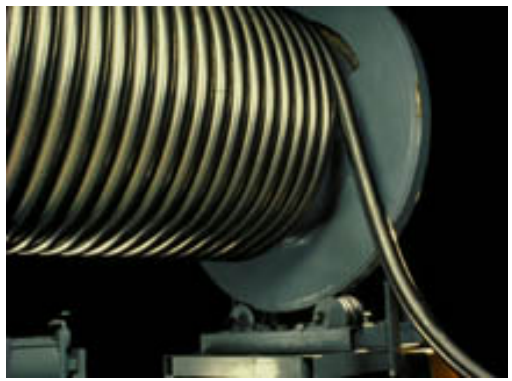
- ATI 2003™ alloy can be readily cold-bent and expanded, but greater loads will be required to deform ATI 2003™ alloy because of the higher strength of this duplex alloy in comparison to conventional austenitic materials.
- Due to the lower ductility of the ferrite phase, the alloy should be bent to more generous bend radii than fully austenitic materials.

Applications

Oil Rigs

Umbilical Tubes

Flexible Flowlines

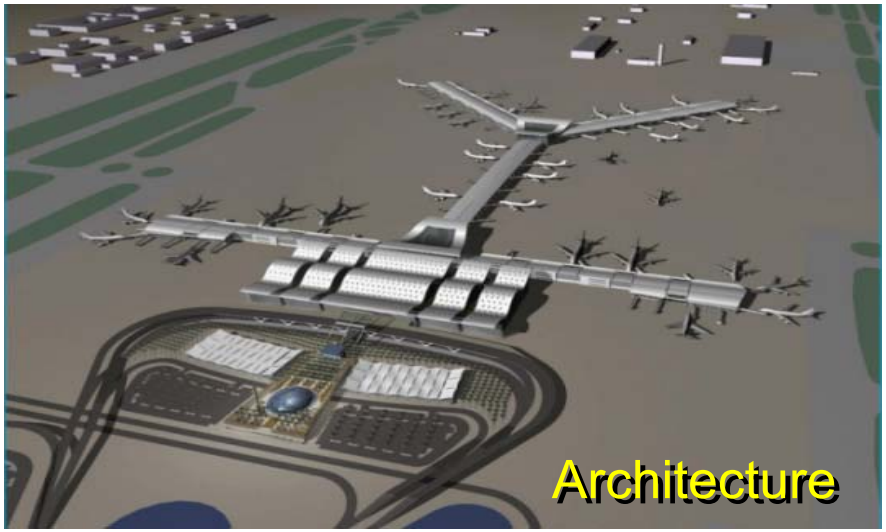


Blast-Resistant Firewalls

Applications

- An obvious application for ATI 2003™ alloy is as a replacement for 316L stainless steel tanks, pipes, and tubes in chemical process or pulp & paper equipment.
- Its higher strength and chloride SCC resistance promote use of ATI 2003™ alloy in architecture.

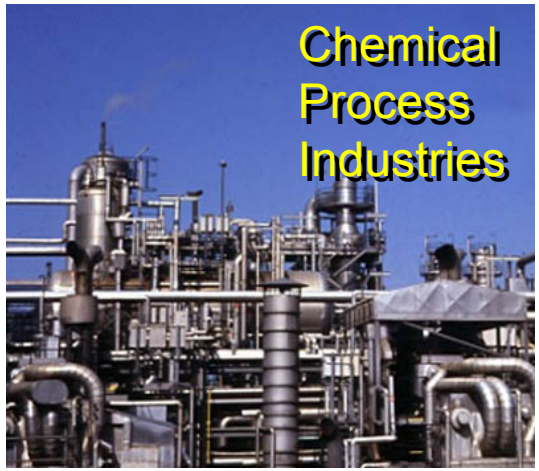
Applications



Applications

- **ATI 2003™ alloy also provides an economical alternative to the use of alloy 2205 in chemical process equipment in situations where 2205 has replaced 316L to provide SCC resistance but where the much greater corrosion resistance of 2205 is not needed.**

Applications



Applications

- **The higher strength of ATI 2003™ alloy also makes it an attractive candidate for applications such as Storage Tanks, Bridge Decking, Architectural Structures, Pressure Vessels and Transport Tanks.**

Code Approvals

- **S32003 is listed in ASTM A240 for plate, sheet and strip product forms.**
- **S32003 is approved for ASME Section VIII Division 1 use up to +650°F by Code Case 2503.**
- **Use of S32003 (and S32205) in API 620 and 650 has been approved, with publication of Appendix X to these documents expected as part of the next printing.**

Availability

- **ATI 2003™ alloy is available as sheet, strip, hot-rolled discrete plate, continuous mill plate, and cut plate shapes.**

2003 Substitution: Summary

- **ATI 2003™ alloy is an economical substitute for 316 and can be an economical substitute for 2205 where S32205 is used to avoid chloride SCC problems with 316, but where the other enhanced corrosion properties of 2205 are not required.**

So What Else Is New In Alloy Substitution?

New Lean Austenitics

- **Duplex stainless steels provide strength and corrosion resistance while using less nickel and there offer lower and more stable costs during times of high and volatile nickel prices.**
- **But, duplex stainless steels provide less ductility, reduced formability and lower toughness than austenitic stainless steels.**

New Lean Austenitics

- Existing molybdenum-containing 200 series stainless steels have failed to provide significantly lower costs than 316.
- Therefore…ATI Allegheny Ludlum has created three, new 200-series austenitic stainless steels to provide corrosion resistance, formability and toughness at a lower & more stable cost.

New Lean Austenitics

Attributes

- ✓ **Lower Cost with Price Stability compared to 316L (and 317L, 316Ti)**
- ✓ **Similar Formability**
- ✓ **Equivalent or Better Corrosion Resistance**
- ✓ **Equivalent or Better Strength**
- ✓ ***Drop-ins for Existing Alloys***

New Lean Austenitics

Nominal Compositions

Alloy	Type	UNS	PRE	Cr	Ni	Mo	N	Other
316L	Austenitic	S31603	24	16.3	**10.1**	**2.1**	0.07	
ATI 216 HP™	Austenitic		25	18.2	**4.5**	**1.0**	0.20	Mn = 5
317L	Austenitic	S31703	29	18.4	**12.4**	**3.2**	0.07	
ATI 217 HP™	Austenitic		29	20.0	**6.0**	**1.5**	0.25	Mn = 6
316Ti	Austenitic	S31635	24	16.3	**10.1**	**2.1**	0.07	Ti = 0.3
ATI 216 Cb™	Austenitic		25	18.2	**4.5**	**1.0**	0.20	Mn = 5 Cb = 0.3

New Lean Austenitics

Potential End Uses For ATI 216 HP™Alloy

- ✓ Tubing
- ✓Piping
- ✓Heat Exchanger Plates

Code Approvals

- **UNS, ASTM & ASME specification coverage in process.**

Summary

- Prices of nickel and molybdenum in the past few years have led to unprecedented interest in substitution of leaner-content alloys for standard 300-series austenitic stainless steels.
- Use of duplex or 200-series stainless steels provides a method for achieving such cost savings.

Additional Information…

- **Go to www.alleghenyludlum.com and look in the Featured products section for additional technical information.**

ATI Allegheny Ludlum

Search: find it!

Friday, April 25, 2008

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SAFETY

At ATI Allegheny Ludlum, safety is a core business value

- Safety Results
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ATI Allegheny Ludlum Corporation is a world leader in the technology, production and marketing of specialty metals as well as other advanced alloys, these include:

- Stainless Steel
- Duplex
- Nickel Alloys
- Titanium
- Armor Materials
- Silicon Electrical Steels

ATI Allegheny Ludlum serves global customers in diversified consumer and capital goods markets.

Featured Products

The Switch is On!® To Lean Alloys

Lean Austenitic Stainless Alternatives NEW!

- AL 2003™ vs T316L
- AL 201HP™
- AL 201LN™
- AL 201LN™ vs 9% Ni Carbon Steel
- Titanium Alternatives

ATI Allegheny Ludlum – Specialty Metals That Make Our World™

Download Windows Media Player here: Windows Media

What's New?

April 11, 2008 - ATI Allegheny Ludlum Announces Silicon Electrical Steel Raw Materials Surcharge ...more

April 7, 2008 - Surcharge Changes ...more

March 28, 2008 - Sheet Price Announcement ...more

March 6, 2008 - ATI Allegheny Ludlum Announces Silicon Electrical Steel Raw Materials Surcharge ...more

AL 2003™ Lean Duplex Stainless Steel

Our Products

List All Alloys

Data Sheets

Contact Us

Find Product by Alloy:

AL 201HP™

Find

Final Conclusion

"The Switch Is On!" ®

ATI Allegheny Ludlum

Visit us online at www.alleghenyludlum.com

Expectations of Stainless Steel In Hygienic Service

- Corrosion Resistance
- Surface Texture
  - Cleanable
  - Sanitizable
  - Sterilizable

} Smooth (32µ-in Ra [0.8µ])
Uniform
Good Release

- Strength
- Fabricability
- Cost

Expectations of Stainless Steel In Hygienic Service

- **Alloys Listed in ASTM A270**

  Austenitic Stainless

  - 304, 304L (18-8) UNS S30400, S30403
  - 316, 316L (16-10-2) UNS S31600, S31603
  - 317, 317L (17-11-3) UNS S31700, S31703

Expectations of Stainless Steel In Hygienic Service

- **Alloys Listed in ASTM A270**

Super Austenitic Stainless

– AL-6XN	UNS N08367
– 25-6Mo	UNS N08926
– 904L	UNS N08904
– 254-SMo	UNS S31254

Expectations of Stainless Steel In Hygienic Service

- **Alloys Listed in ASTM A270**

  Duplex Stainless

  - 2205 UNS S31803 or S32205
  - 2507 UNS S32750

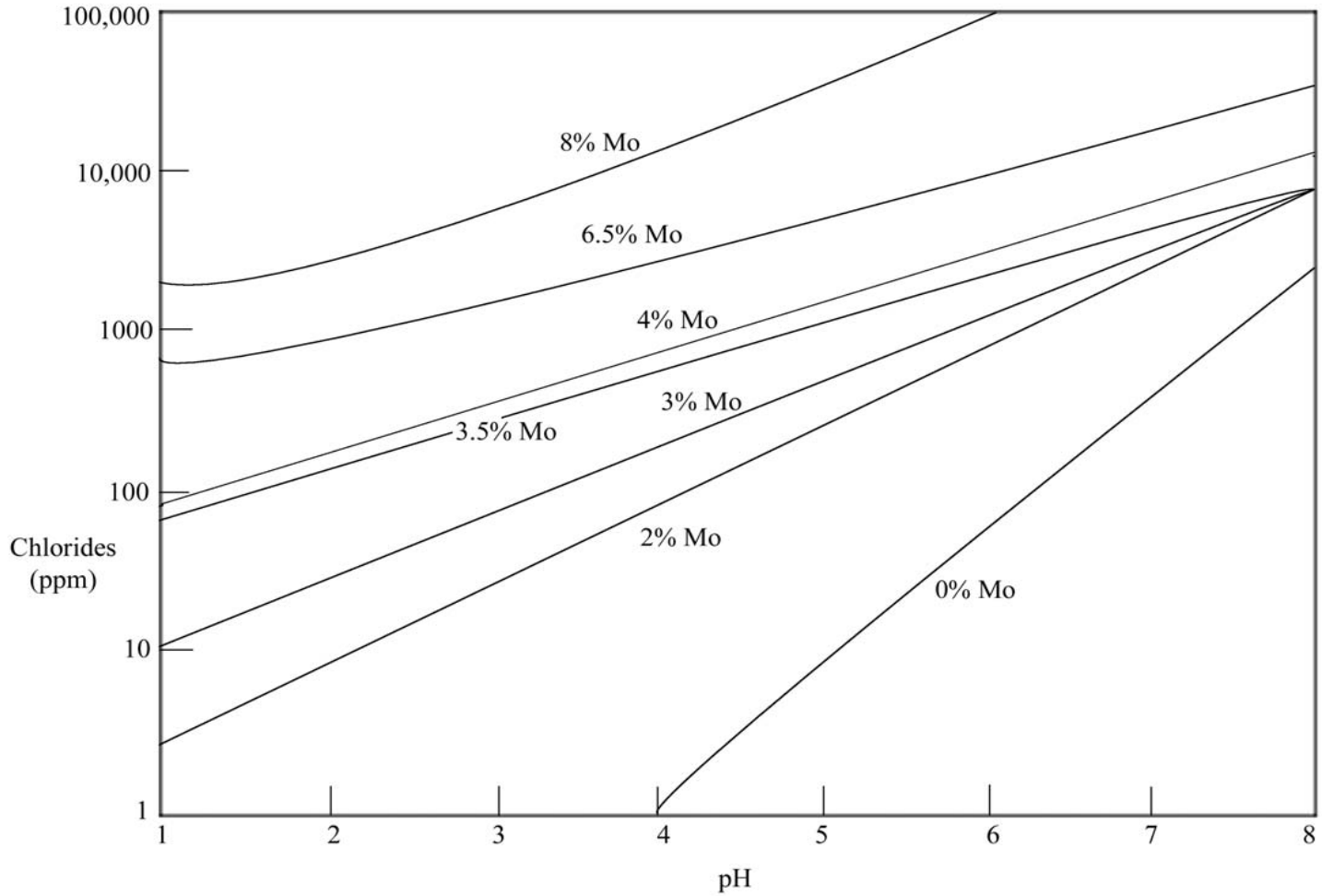
Most Common Modes of Corrosion In Hygienic Industry

- Halide Ion Pitting (Chlorine)
- Crevice Corrosion
- Stress Corrosion Cracking (SCC)

Pitting Corrosion

- Minimized by increasing molybdenum
- Minimized by good manufacturing, installation, and operation
- A good candidate for “better alloy”

Pitting Corrosion
Chlorides, pH and Mo Content

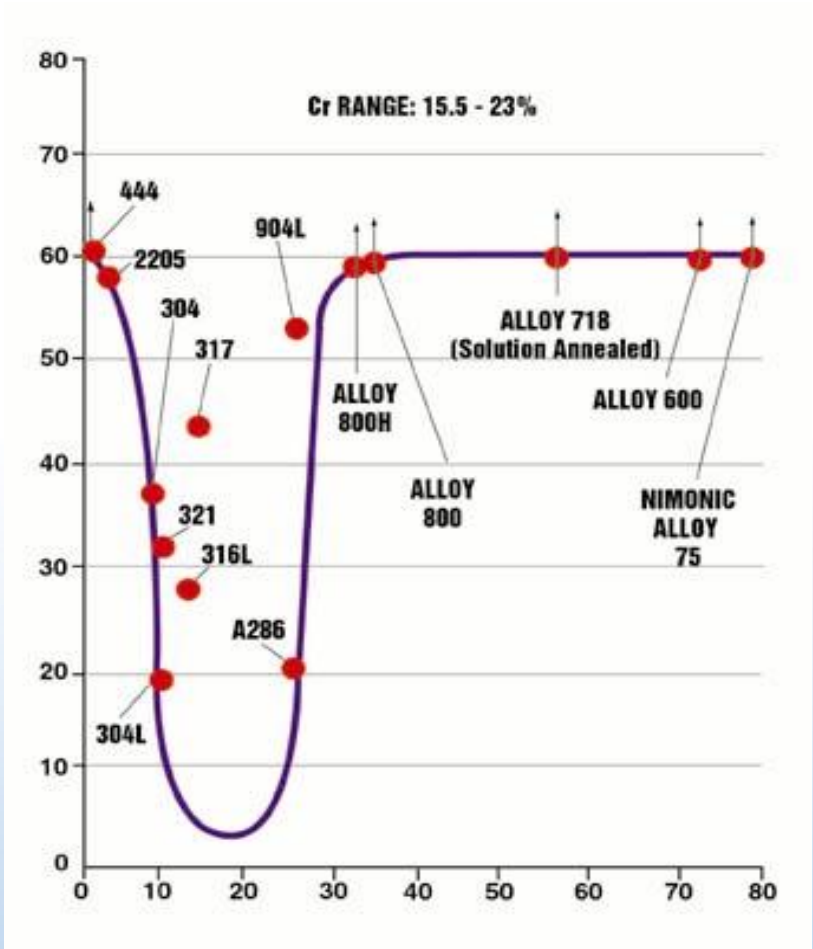


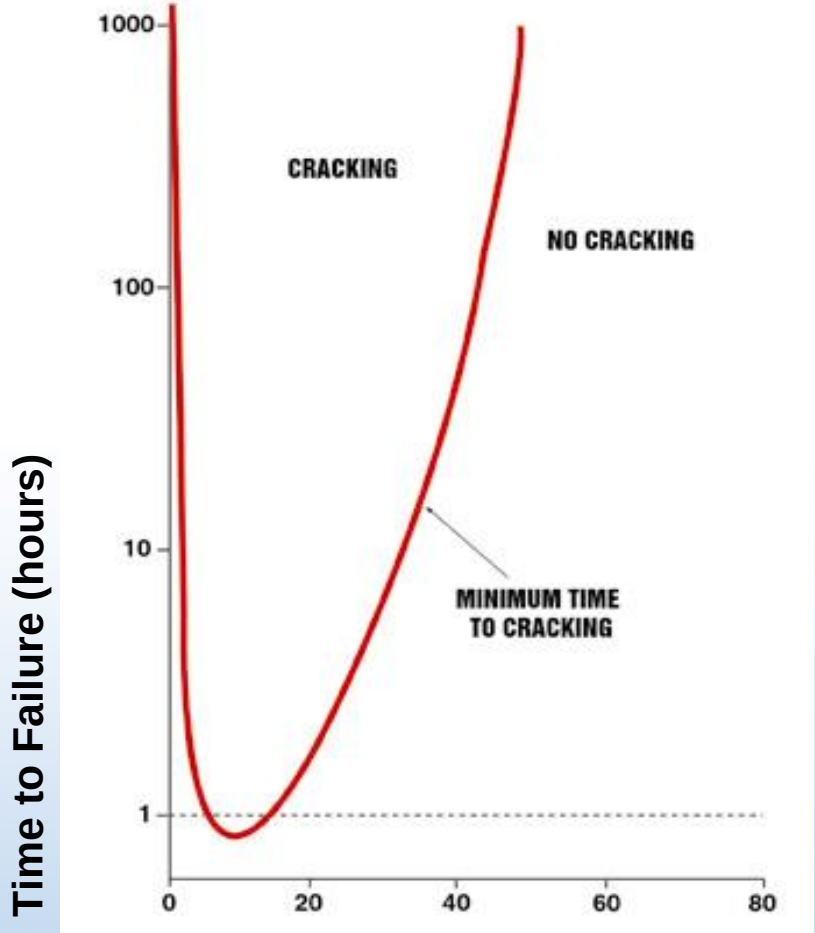
Crevice Corrosion

- Prevented by good design, manufacturing, installation, and operation
- Prevented by good aeration
- By itself, not a good candidate for “better alloy”

Stress Corrosion

- Alloys with 8-20% Nickel most susceptible
- Minimized by good manufacturing, installation, and operation
- A good candidate for “better alloy”


Threshold stress Intensity (K_{ISCC}), MPa m ^{½}
Cr RANGE: 15.5 - 23%
444
2205
304
317
321
316L
304L
A286
904L
ALLOY 800H
ALLOY 800
ALLOY 718 (Solution Annealed)
ALLOY 600
NIMONIC ALLOY 75
0
10
20
30
40
50
60
70
80
Nickel Content (wt. %)


Time to Failure (hours)
1000
100
10
1
CRACKING
NO CRACKING
MINIMUM TIME TO CRACKING
0
20
40
60
80
Nickel Content (wt. %)

Fabrication - Polishing

- Grain Size
  - Larger grain size = Orange Peel
  - Higher heat treat temperature / longer time at temperature = larger grain size
- Ability to electro-polish
  - Most austenitic stainless grades are ok

Fabrication - Weldability

- Joining Different Compositions
  - Mis-match in chemistry of mating components can cause weld seam wander
    - Differences in nickel, sulfur, others
  - Dilution of alloying elements

Fabrication - Weldability

- Extreme differences in tensile strength
  - Dimensional distortion
  - Design issues of same wall thickness
- Some compositions subject to undesirable vapor films
  - Require more attention to shielding

Fabrication - Forming

- Higher tensile strengths
  - More spring back – over form up to 20°
  - More horse power
  - More susceptible to wrinkling in thinner sections

Fabrication - Forming

- Higher Mo content
  - Increased galling / pickup
  - Increased work hardening rates
  - Requires better lubrication
  - More difficult to mechanically polish
  - Tendency to plug abrasives

Fabrication

In tubing and fittings, little prospect for thinner wall in domestic hygienic applications
(Retooling costs prohibitive)

European or Asian applications - limited

Opportunities for material cost savings on sheet & plate, cast and wrought forms

Field Performance

- Corrosion test data is readily available for most alloys – Use it to evaluate a proposed material change
- Conduct field simulation trials to verify
- A combination of short (24 hrs) and long exposure times (e.g. 1,000 hrs) may reveal useful information for predicting service life

Lean Alternatives Can be a Sound Engineering Choice

if

Change is Based on Good Inforamtion & Understanding