



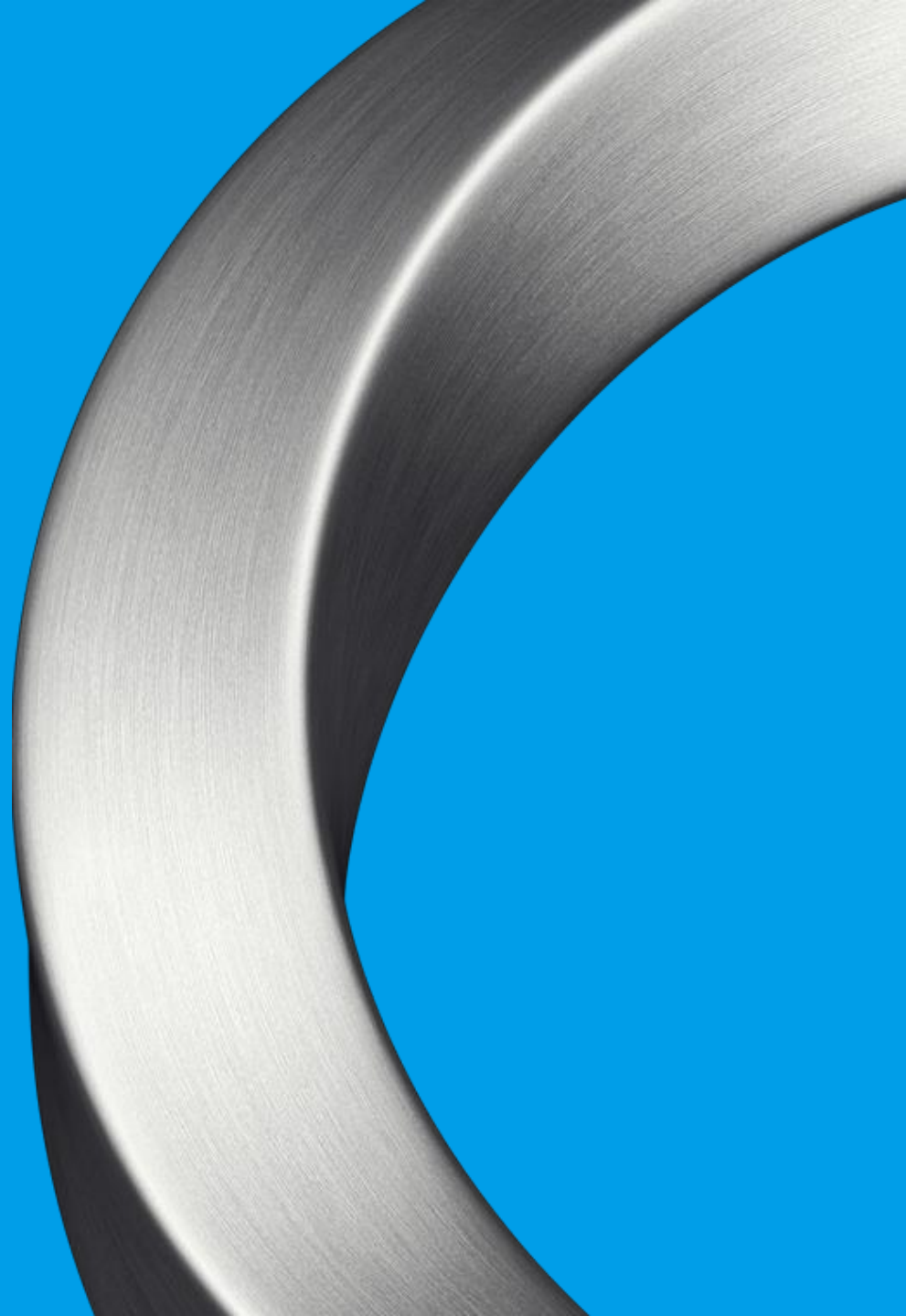
STAINLESS STEEL
The Forever Material

Century of Innovations in Stainless Steel

Yatinder Suri
MD & Country Head
Outokumpu India P Ltd

2nd April 2016
IIM Delhi

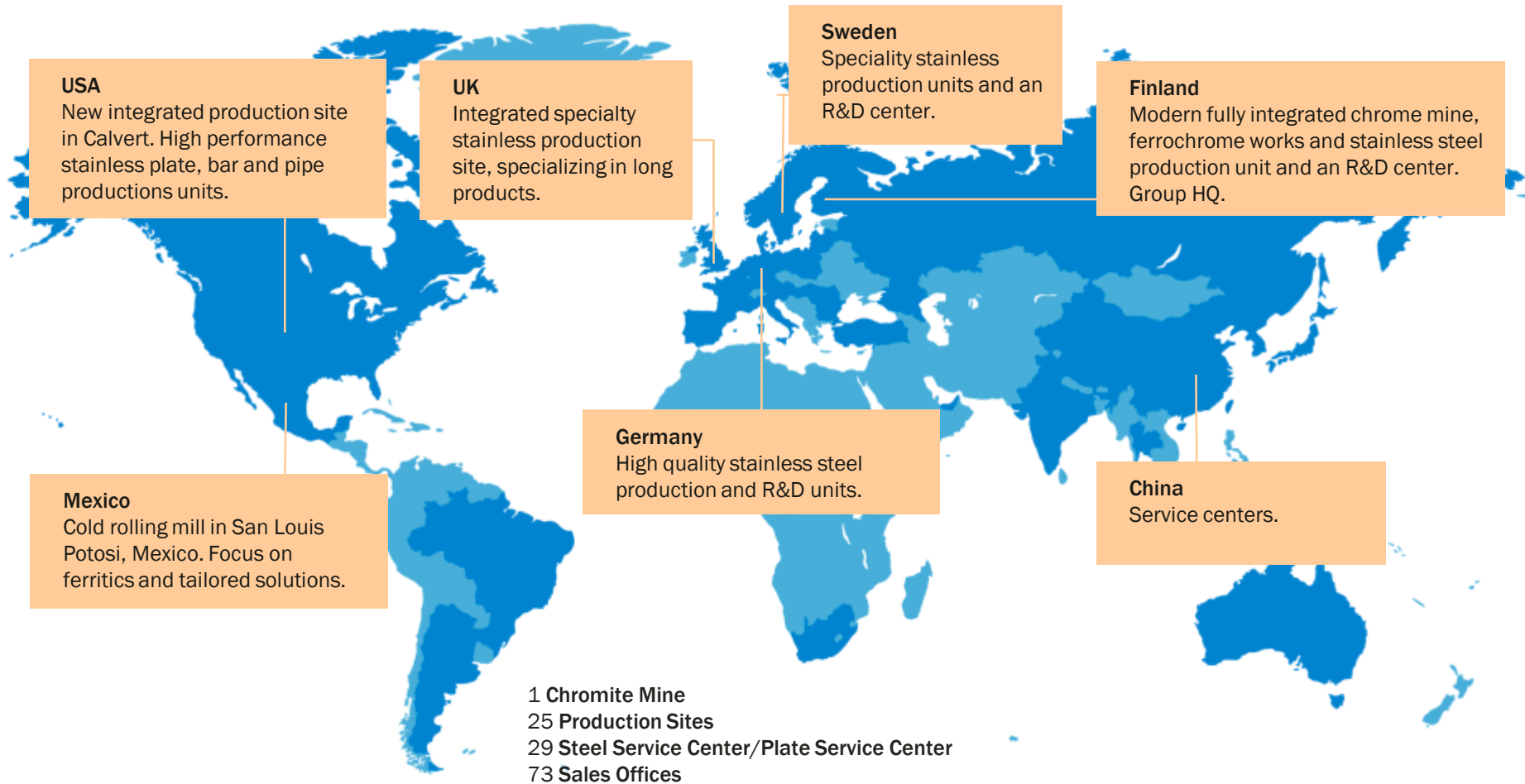
outokumpu 



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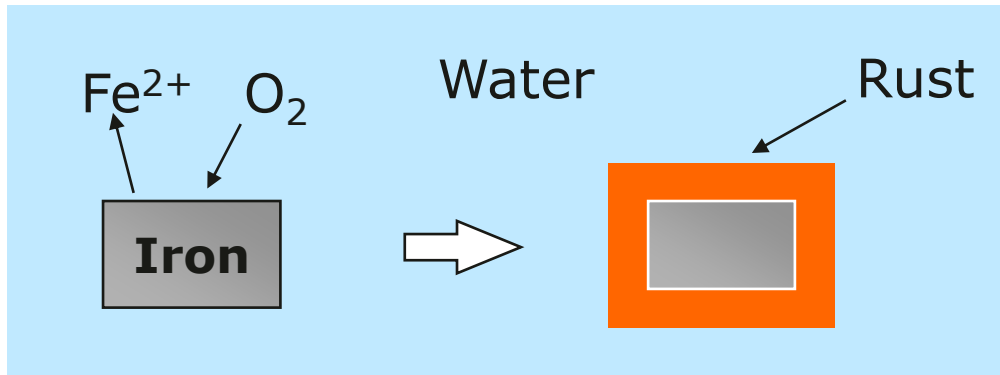
1. Introduction
2. Early Developments of Stainless Steel
3. A Century of Innovations
4. State of the Art
5. What can we say about the future?

We can serve our customers everywhere



Corrosion of steel - Rust

Degradation of a material by a chemical reaction with its environment

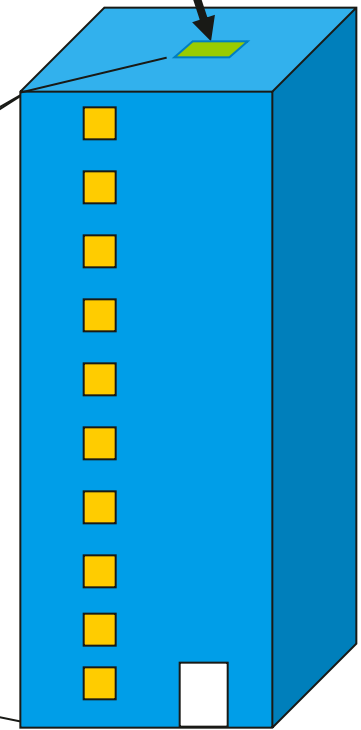


What is stainless steel?

- A steel that does not rust
 - Unthinkable to many in the 19th century!
- Steel with >10.5% chromium
 - 0.000 003 mm passive layer
 - Molybdenum, nickel, nitrogen etc.

Fe + >10.5% Cr
1 mm

Postage Stamp



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What happened in 1912?

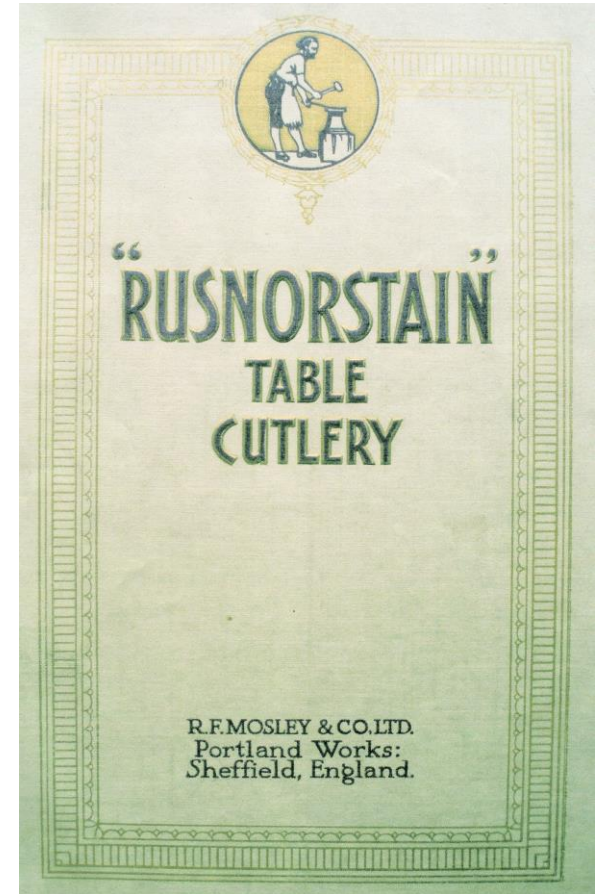
- German researcher patent stainless steel 1912
- Harry Brearley in Sheffield, England, made similar findings at the same time
- Both birthplaces are part of Outokumpu.



	9prozentigen Nickelstahl	788,1,	
20	25 - - - - -	549,2,	
	Stahl mit rund 15 Prozent Chrom und 2 Prozent Nickel. . .	51,55,	
	- - - 23 - - - 9 - - -	6,042	55
und	- - - 25 - - - 20 - - -	11,32.	

The early days and applications

- The first applications were introduced by Brearley
 - Cutlery and knives
- Thorough characterization was required before stainless steel could find a broader use
- Research on stainless steel increased rapidly and improvements and data were coming fast.



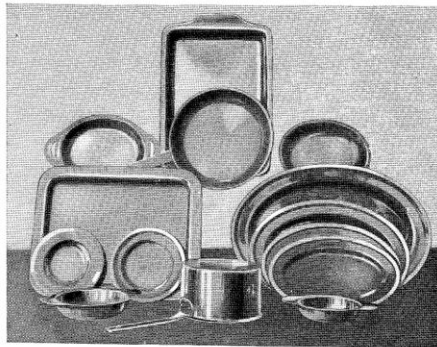
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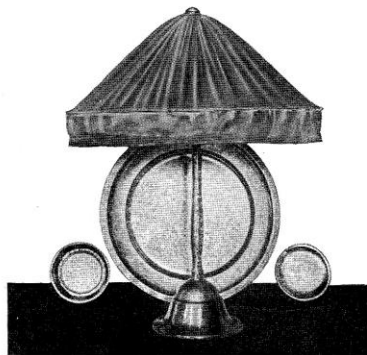
The 1920's

- The success came in the 1920's
- Efficient production processes were developed
- Many companies began producing the alloys
- The austenitic (nickel-alloyed) grades became dominating
- Intergranular corrosion was the big drawback for stainless steel
- The Avesta catalogue from 1927.





Cold Pressed Goods of Qual. 832
(All pressed without intermediate heating)



Chased Goods of Qual. 832

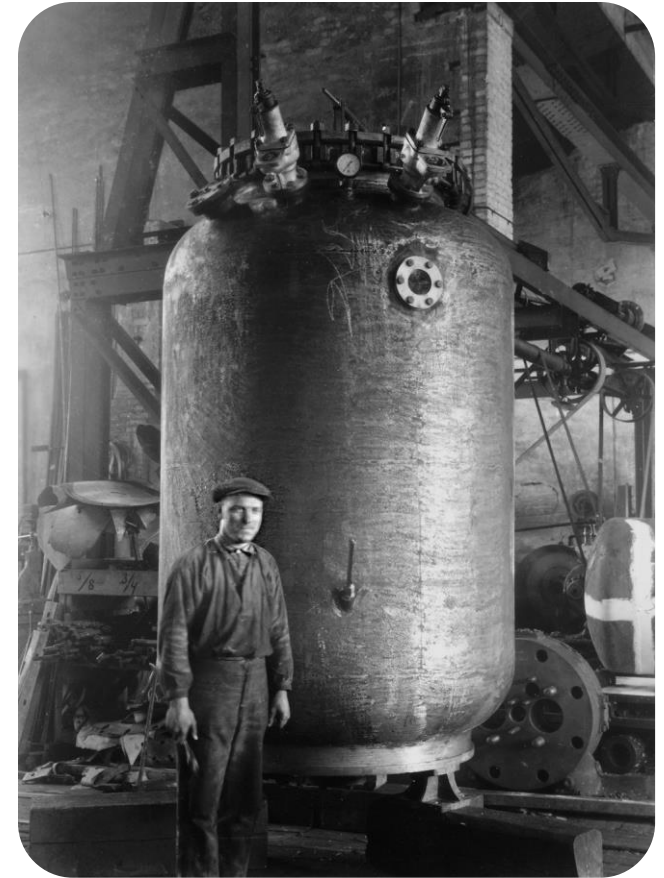
Avesta

Outokumpu's mill in Avesta

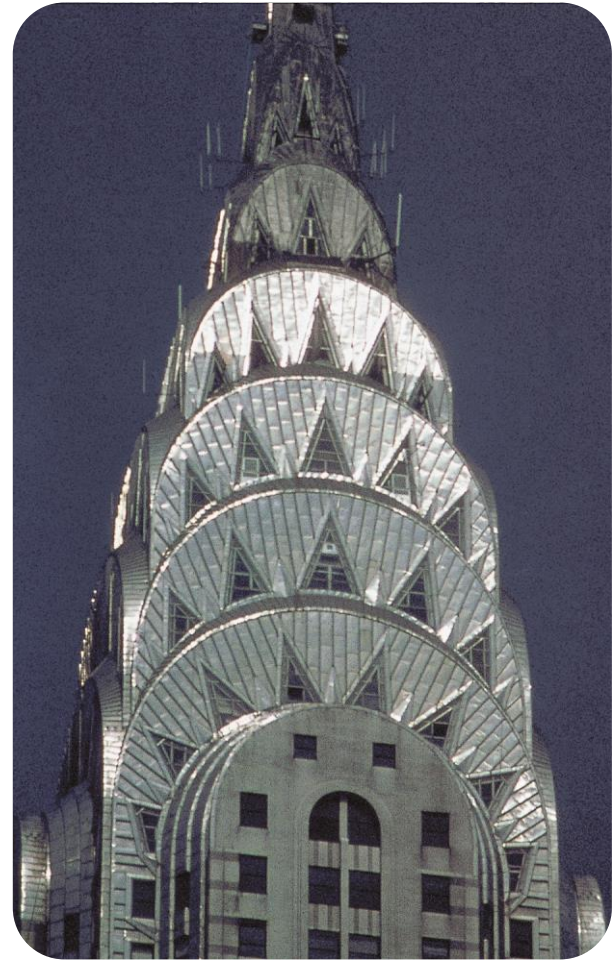


The 1930's

- Stainless steel becomes an established product
- Avesta introduce the Duplex Stainless Steel
 - Combines the beneficial properties of ferritic and austenitic steels
- The American Iron and Steel Institute (AISI) standardize stainless steel (e.g. 304, 316)
- R&D makes continuous improvements
 - E.g. the Ti and Nb stabilized grades solves the problem with intergranular corrosion until the low carbon grades



Autoclave in duplex 453S for production of gunpowder (1933).



Long life span with low service costs

Chrysler Building

- Completed in 1930
- Cleaned in 1961 and 1995
- Stainless steel panels still in very good condition

Ref: Nickel Development Institute

The pier story – Progreso, Mexico

Photo credit: Nickel Institute

Stainless steel solution built
in 1937-1941, still operating

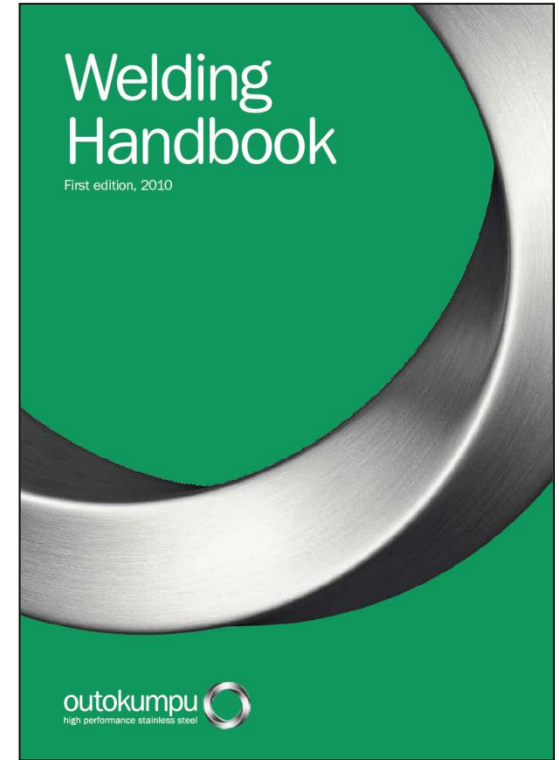
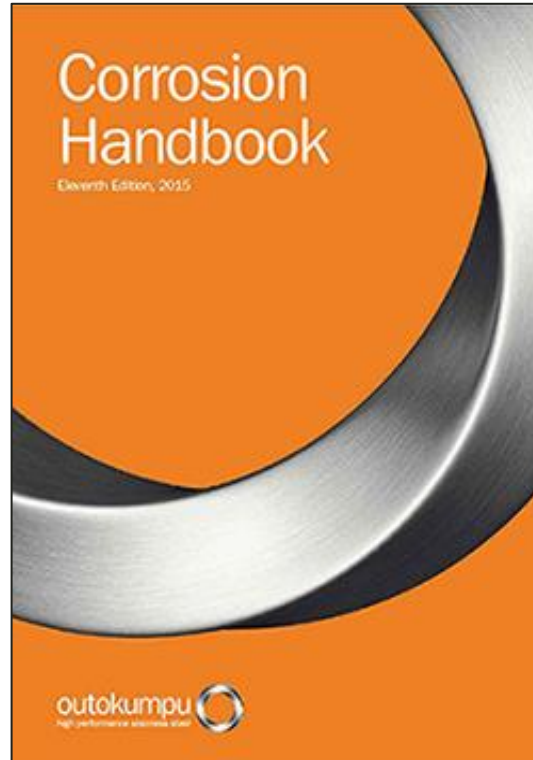
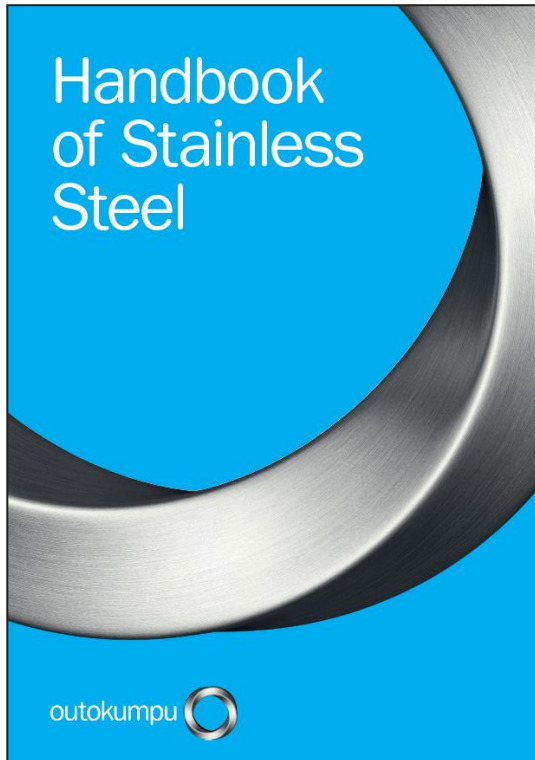
Carbon steel solution built in
the 1960s, not operating

1930's

Austenitic

Duplex

No other Stainless Steel producer can match Outokumpu's technical knowledge



The 1940's

- Precipitation hardened (PH) martensitic grades, e.g. 17-4 PH and 17-7 PH, are developed in the USA
 - High mechanical strength
 - E.g. aerospace and military applications, press plates, springs

The 1950's

- Nickel shortages led to development of less expensive manganese alloyed stainless steels
 - Manganese replace Nickel as austenite former
 - Strong but limited corrosion resistance
 - Used for cutlery, pots and pans

THE BUDD COMPANY
Manufacturers of automobile bodies, frames, wheel assemblies and brakes. Builders of stainless steel trains and highway trailers. Advanced engineering and research. A United States Defense resource.



Wonderful World On Rails

It's your train—your home, your hotel, scenic resort . . . and, if it must be business, your office.

Where you mingle with friends, make new ones. Treat and be treated. Your living room, dining room, bedroom—while somebody else takes care of everything, including delivering you to your destination, clean . . . rested . . . eager.

Great trains, with cars of stainless steel by Budd, invite you to this miracle of travel. Trains of the West, with dome cars—the California, Kansas City and Twin Cities Zephyrs; North Coast Limited; Empire Builder; El Capitan; San Francisco Chief; Eagle; Bluebird; and the transcontinental "Canadian". Trains of the East—Congressional; Senator; Empire

State Express; Capitol Limited. Trains of the South—Sunset Limited, Meteor, Champion.

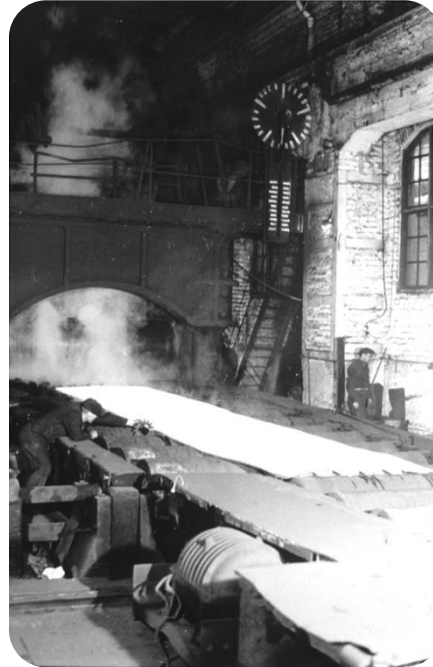
Never have you had such travel safety, certainty and enjoyment, moderately priced and perfectly performed, beckoning you to join America on the go. On a business trip, a vacation interlude. On vacation? It starts at the station.

Budd
Philadelphia Detroit Gary

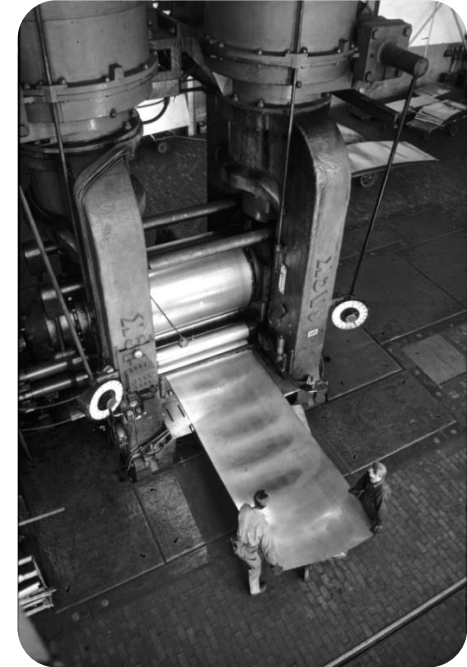
The 1950's – The Avesta mill



Ingot casting



Hot rolling



Cold rolling

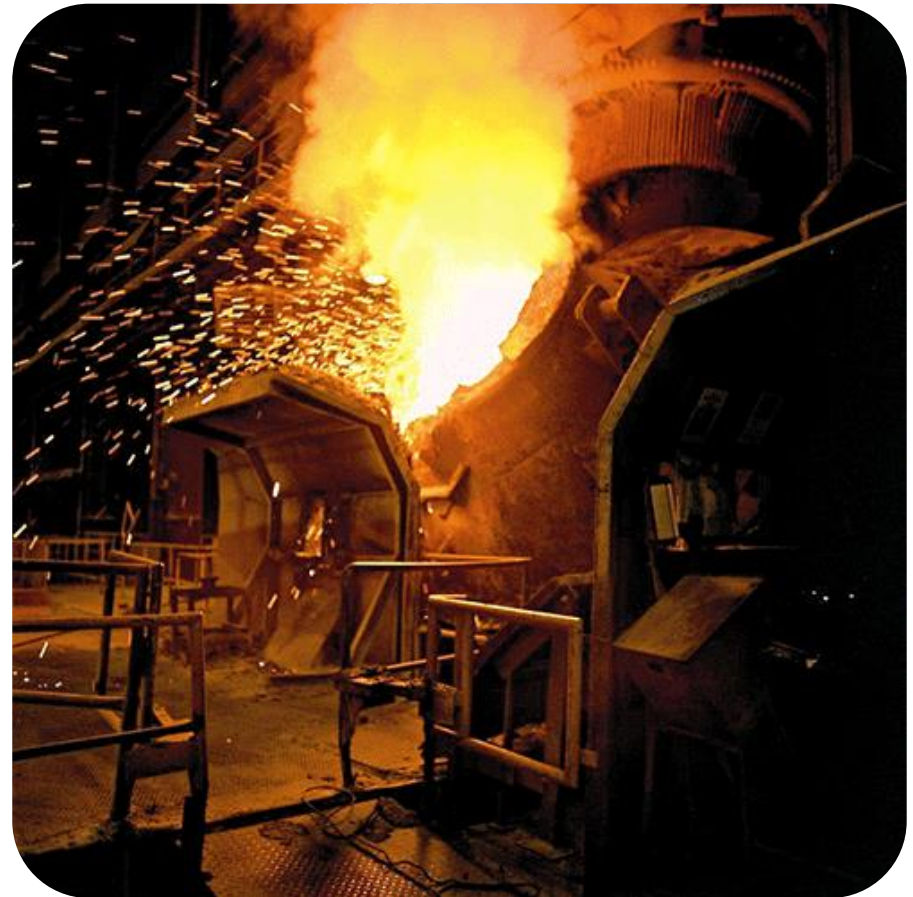
The 1950's - Process innovations

- Process development
 - Steckel mill – thinner and faster hot rolling
 - Sendzimir mill – thinner cold rolling with better tolerances



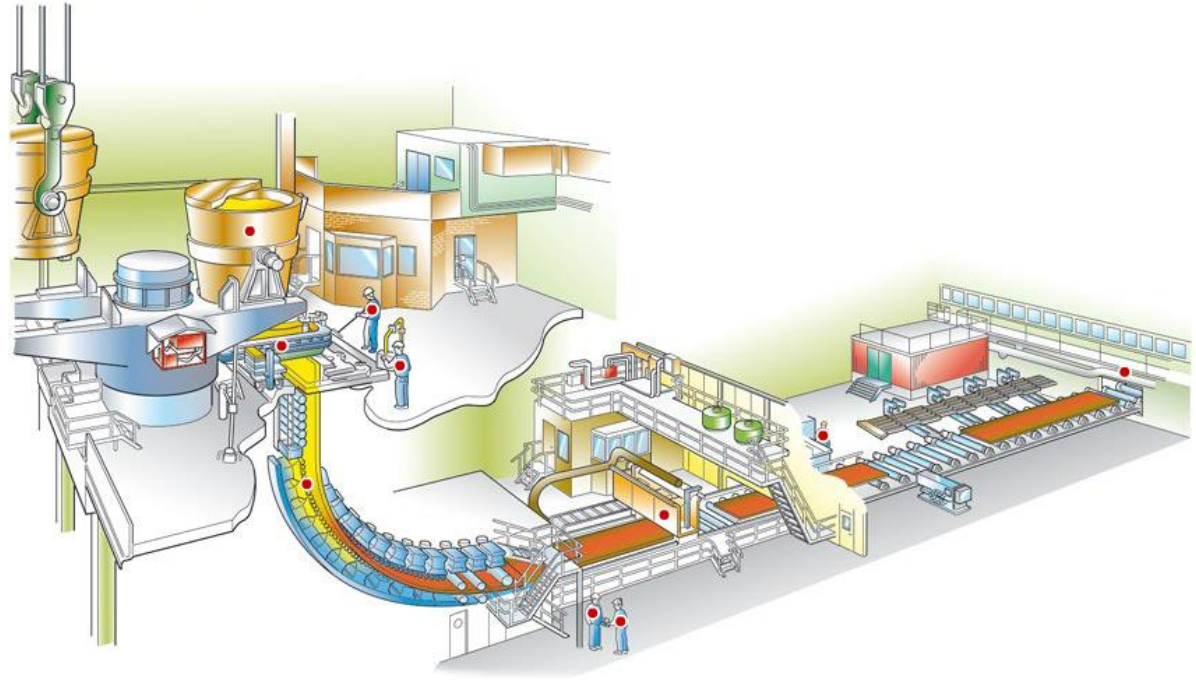
The 1960's – Process innovations

- The AOD converter is introduced
 - Low carbon “L”-grades are made possible
 - 304L & 316L - $C \leq 0,030\%$
 - “L” grades can replace Ti and Nb alloyed grades with respect to preventing intergranular corrosion
 - Alloying with nitrogen made possible which leads to new possibilities



The 1960's

- Continuous casting of stainless steel is introduced



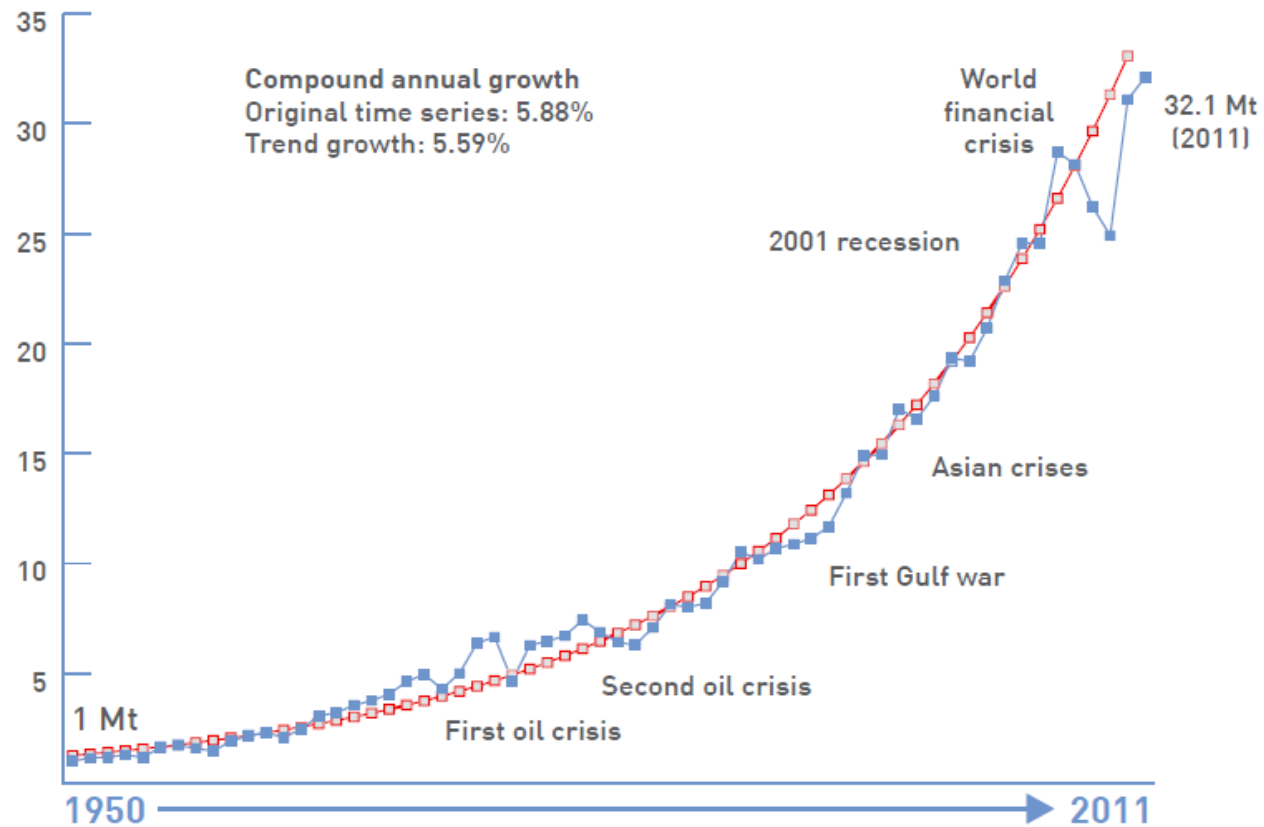
Indian Growth Story starts with SAIL

Stainless steel is hygienic and safe

- Billions of people use stainless every day
- The number one material for food processing
- Extensively used to provide clean water
- No migration of metals in harmful concentrations
- Easy to keep clean and hygienic

Stainless steel growth 1950 - 2010

- ~5.5% annual growth



Source: ISSF – International Stainless Steel Forum

The 1970's

- Micro alloying lead to innovations in high temperature grades, e.g. 253 MA
 - Twice the strength of 310S
 - e.g. automotive, energy and heat treatment application

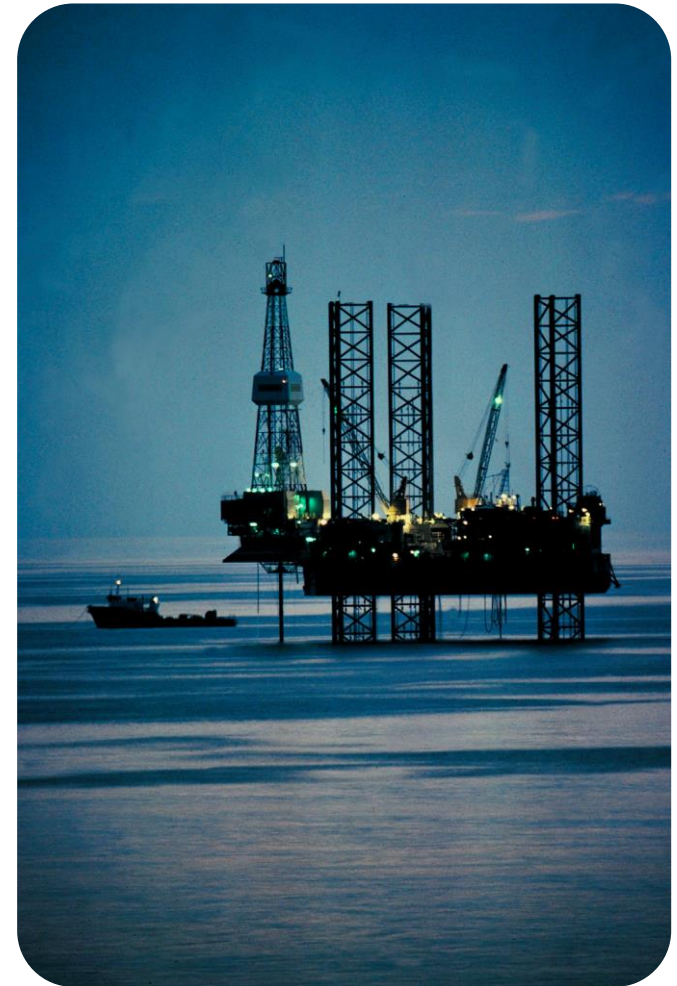




Courtesy of Mitsubishi Hitachi Power Systems Europe GmbH

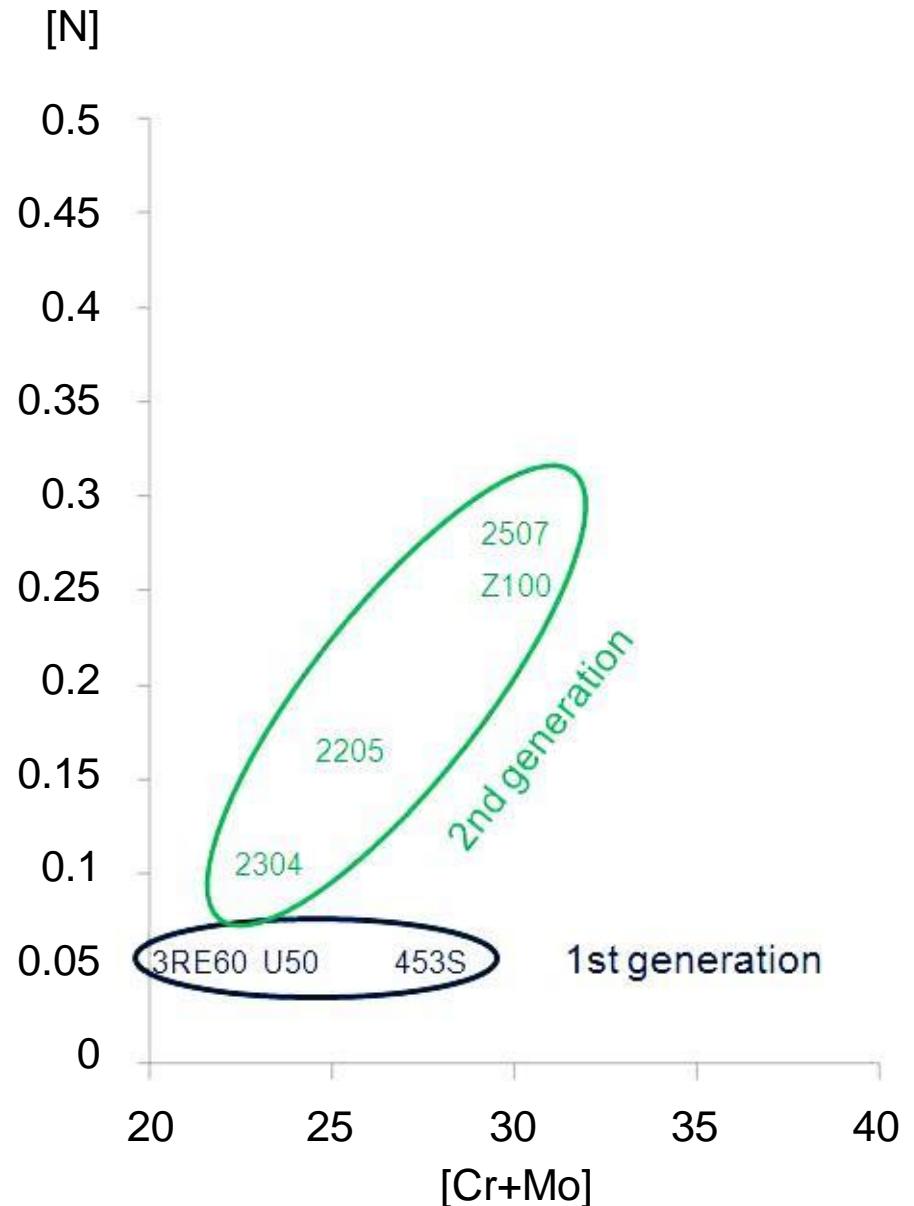
The 1980's – Innovations reach a new level

- 6 Mo grades for the booming off-shore industry
 - Superaustenitic 254 SMO
 - High molybdenum and nitrogen



The 1980's

- Development of the 2nd generation of Nitrogen alloyed duplex grades were made possible by the AOD converter
 - 2304
 - 2205
 - 2507
- Duplexes are found suitable for many applications thanks to excellent strength and corrosion resistance



Duplex Era starts in 1980's

Drinking Water from sea water

Desalination needs Super Duplex Stainless Steel



2205 have great success in chemical tankers



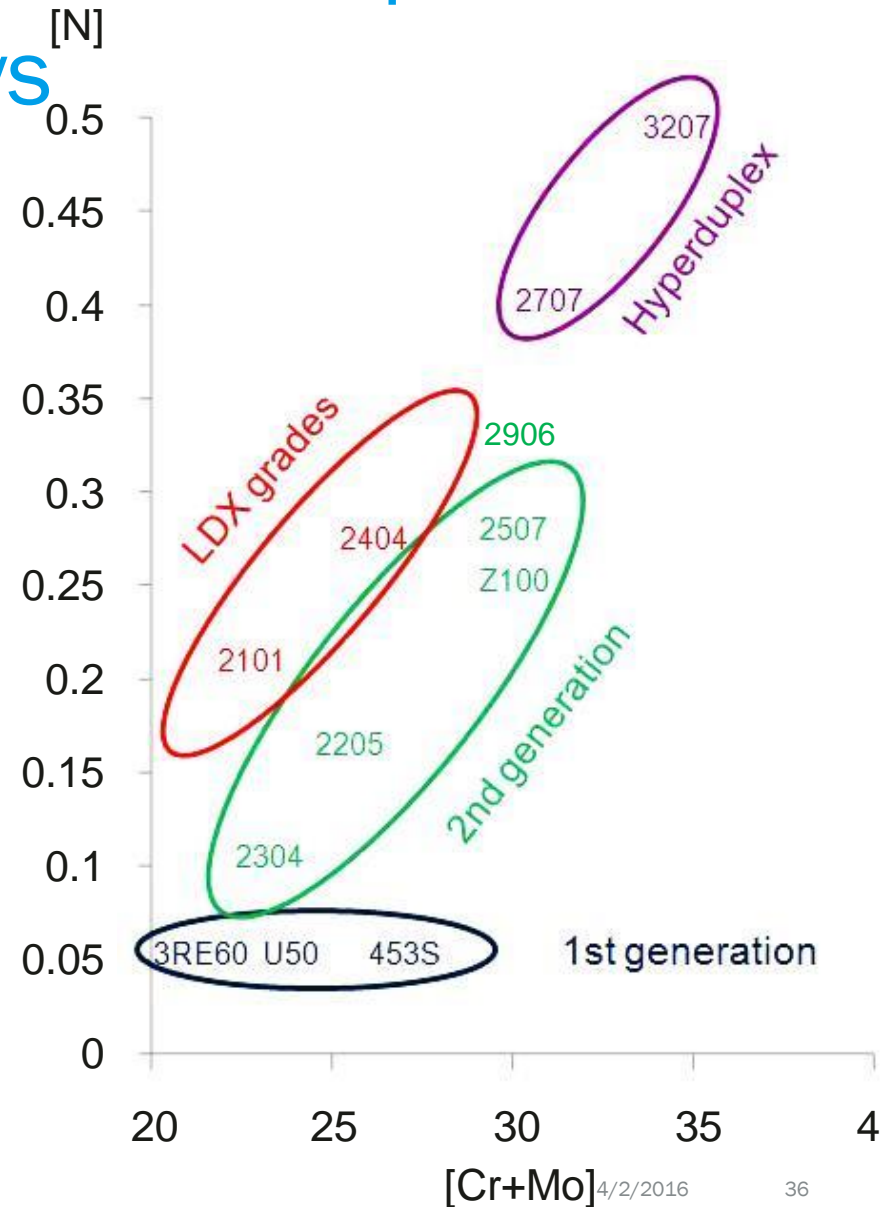
The 1980's

- Life Cycle Cost considerations starts to make stainless steel interesting as a substitute to coated carbon steel
- Continued development of the successful micro alloyed grade for high temperature applications
 - 153 MA
 - 353 MA



The 1990's – Stainless steel competes with nickel and titanium alloys

- Continued development of duplex grades
 - Hyperduplex
 - 2707 HD
 - 3207 HD
 - Lean Duplex grades
- Super austenitic grades
 - 654 SMO
 - B66



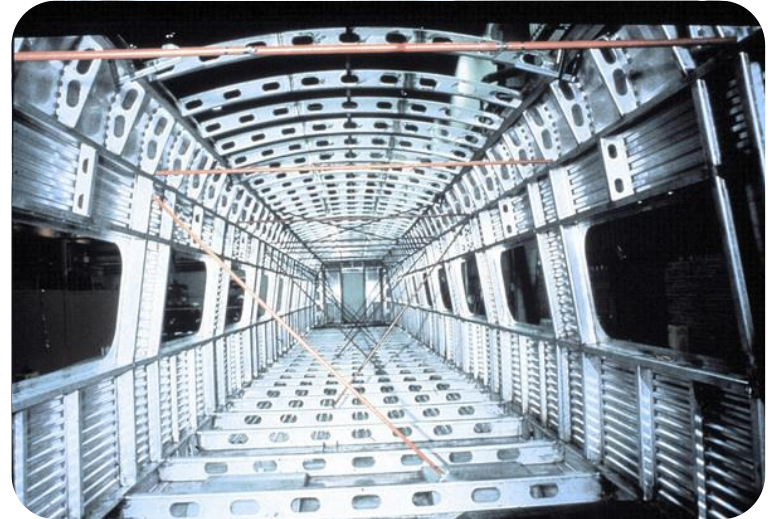
Superaustenitic stainless steel

- Improving the chemical industry



The 1990's – Stainless steel competes with carbon steel as a construction material

- Stainless viewed as a construction material
- A result of
 - More efficient production – price relation to other materials improve
 - High strength duplex grades
 - Life Cycle Cost thinking
 - Applications varies from
 - Beams in trams and trains
 - Bridges
 - Car components
 - Storage tanks



The 2000's – Lean Duplex grades

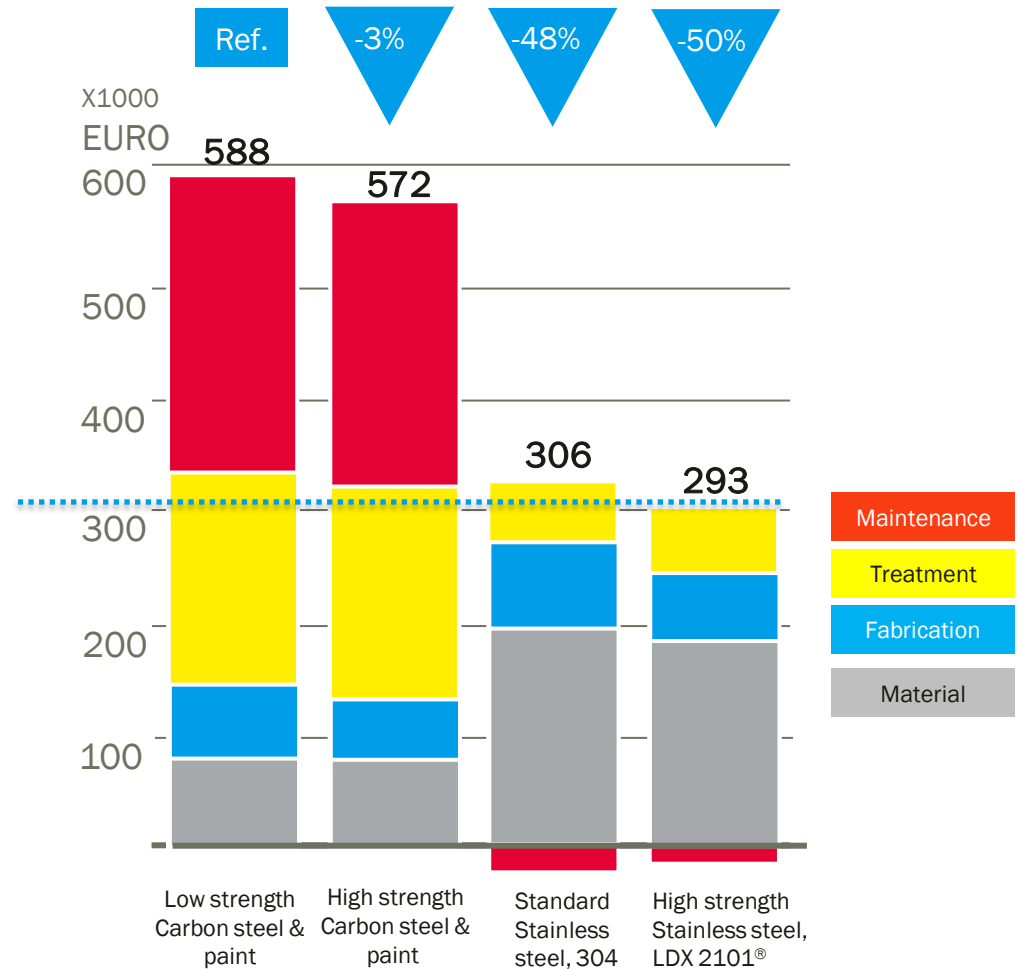
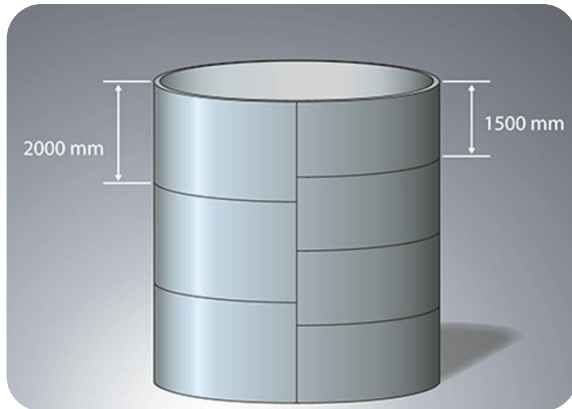


Benefit with high strength stainless steel

Life cycle cost comparing with painted carbon steel, real case

Customer benefits:

- Stainless steel = No paint
- High strength = Lower cost
- 2 meter wide = Lower cost
- Maintenance free
- Higher flexibility of utilization of the tank
- More environmentally friendly



The 2000's

- Stainless steel makes solar power affordable



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State of the Art

- Formable duplex - A new duplex concept from Outokumpu
 - Outokumpu FDX 25 and FDX 27
- Outokumpu 4420 – New improved alternative to 316
- EDX 2304 – Improved 2304
- Outokumpu 4622 – New ferritic grade from Outokumpu
- New surface finishes – 2R² and more!

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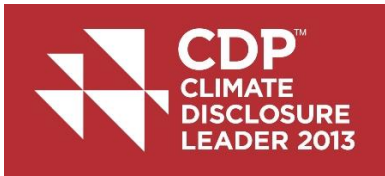
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Outokumpu products contribute to a sustainable world

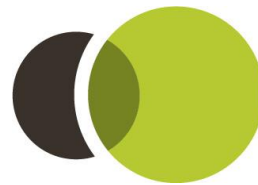
Outokumpu mission:

“Creating advanced materials that are efficient, long lasting and recyclable”

Outokumpu performance widely recognized



- Performance in sustainability is evaluated by a wide variety of indexes and by independent ratings institutions
- Outokumpu is consistently rated as one of the leaders within our industry
 - For most recent indexes and ratings please see:
<http://www.outokumpu.com/en/sustainability/corporate-responsibility/indexes-and-recognition/Pages/default.aspx>



ROBECOSAM
Sustainability Award
Silver Class 2014



To be continued!

Outokumpu

Working toward a world that lasts forever





STAINLESS STEEL
The Forever Material