Duplex stainless steels for water treatment applications

October 7, 2009 Kielce

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Outokumpu in brief

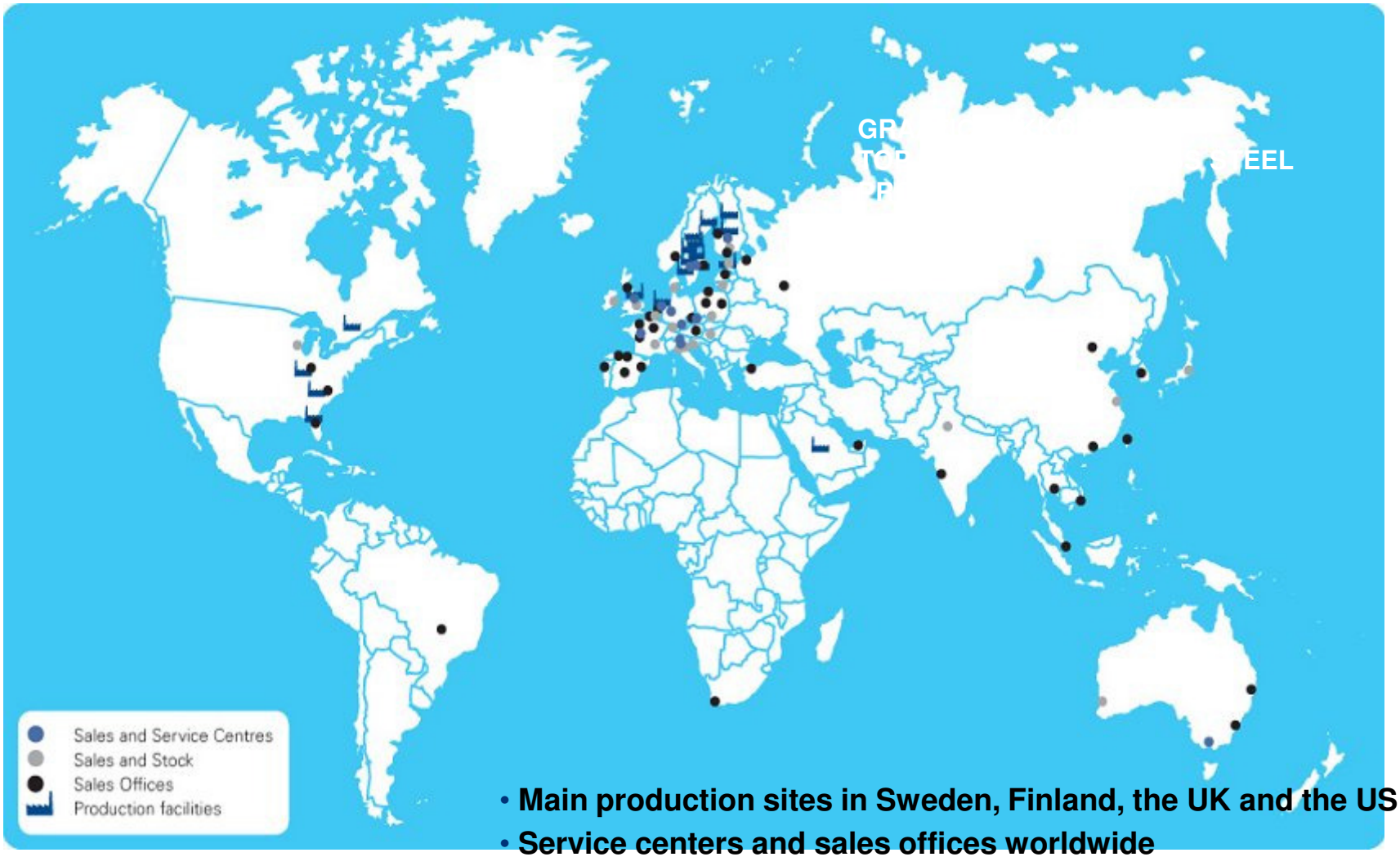
Duplex grades

Corrosion in water treatment

Applications of duplex grades in water treatment

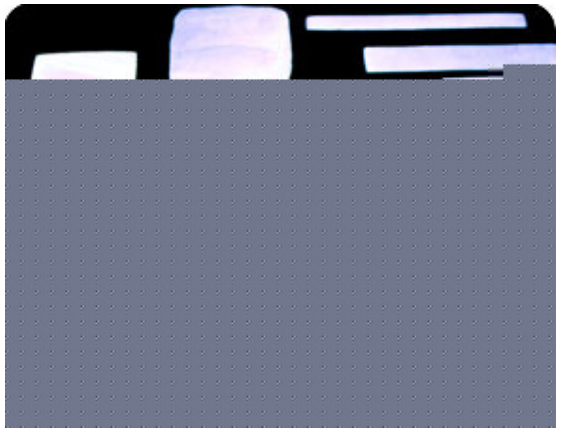
Summary

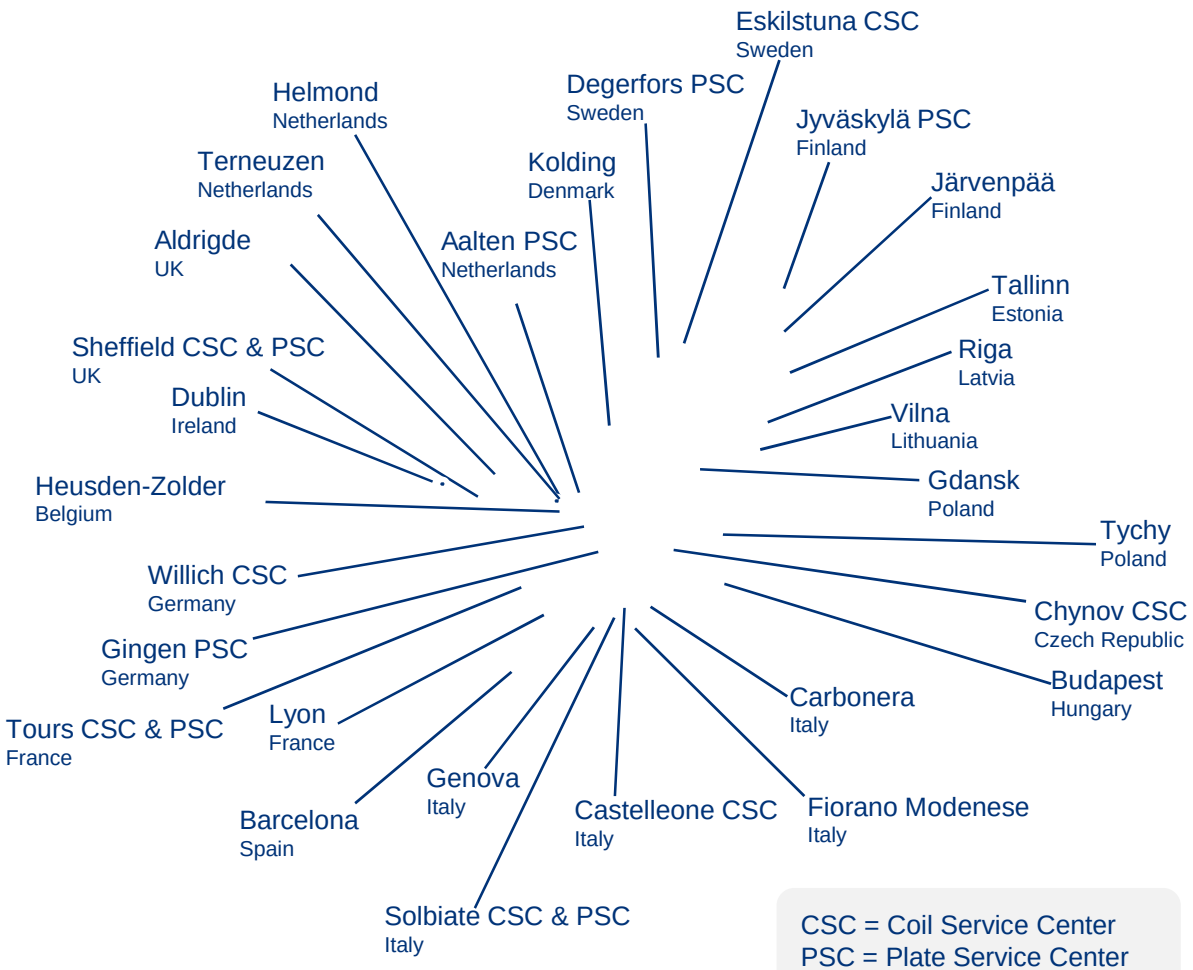
Geographical presence



- **Main production sites in Sweden, Finland, the UK and the US**
- **Service centers and sales offices worldwide**

- Coil, strip, sheet and plate
- Tailor made sheets and plates
- Tubes, Pipes & Fittings
- Round, hexagonal and square bars
- Square hollow sections





30 Locations
7 Coil Service Centers
6 Plate Service Centers
17 Stock Locations

CSC = Coil Service Center
PSC = Plate Service Center

Outside Europe:
- Shanghai (China)
- Kunshan CSC & PSC (China) 2010
- Melbourne CSC (Australia)
- New Dehli (India)
- Brockville (Canada)
- Wildwood (USA)
- Illinois (USA)
- Japan

Polishing

Slitting

Machining

Plasma cutting

Cut to size

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- Responding to your needs
- Assistance in choosing the most competitive materials
- Possibility to test materials in your own processes and tailor made tests at the Outokumpu laboratories.
- Assessing your specific needs with our R&D
- Providing added value with our wide product range

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Grade	Cr	Ni	Mo	N	PRE [1]	CPT [2]
304L/1.4307	18	8	-	-	18	<10
LDX 2101 /1.4162	21	1.5	0.3	0.22	26	17
316L/1.4404	17	10	2.1	0.06	25	20
2304/1.4362	23	4.8	0.3	0.10	26	22
317L/1.4438	18	13.7	3.2	0.06	30	35
904L/1.4539	20	25	4.3	0.04	35	62
2205/1.4462	22	5.7	3.1	0.17	35	52
2507/1.4410	25	7	4.0	0.27	43	84
25					43	87

1. PRE= %Cr + 3.3x%Mo + 16x%N (Wirksumme)
2. Critical Pitting Temperature, ASTM G 150 (the Avesta Cell)

Duplex grades contain less Ni and Mo, implying stab le price

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Outokumpu	EN	EN, min values - hot rolled strip		
		$R_{p0.2}$ [MPa]	R_m [Mpa]	A_5 [%]
304L	4307	200	500	45
316L	1.4404	220	520	45
904L	1.4539	220	530	35
254 SMO®	1.4547	300	650	35
LDX 2101®	1.4162*	480	680	30
2304	1.4362	400	650	20
2205	1.4462	460	700	25
2507	1.4410	530	750	15

Duplex grades are twice as strong as austenitic gra des

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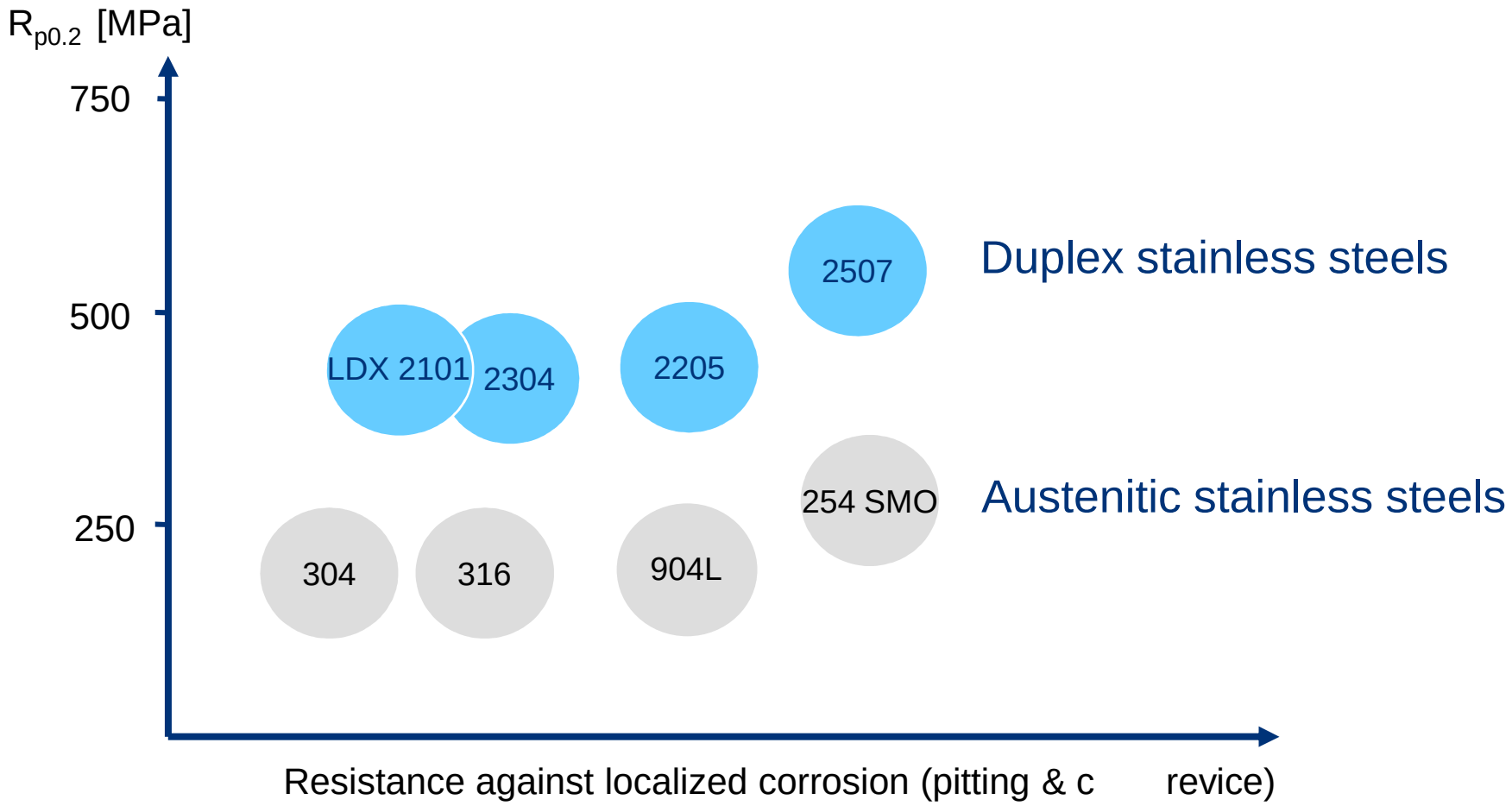

For each austenitic grade there is a duplex alterna tive with higher strength

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Avoiding corrosion in water treatment

Applications of duplex grades in water treatment

Summary

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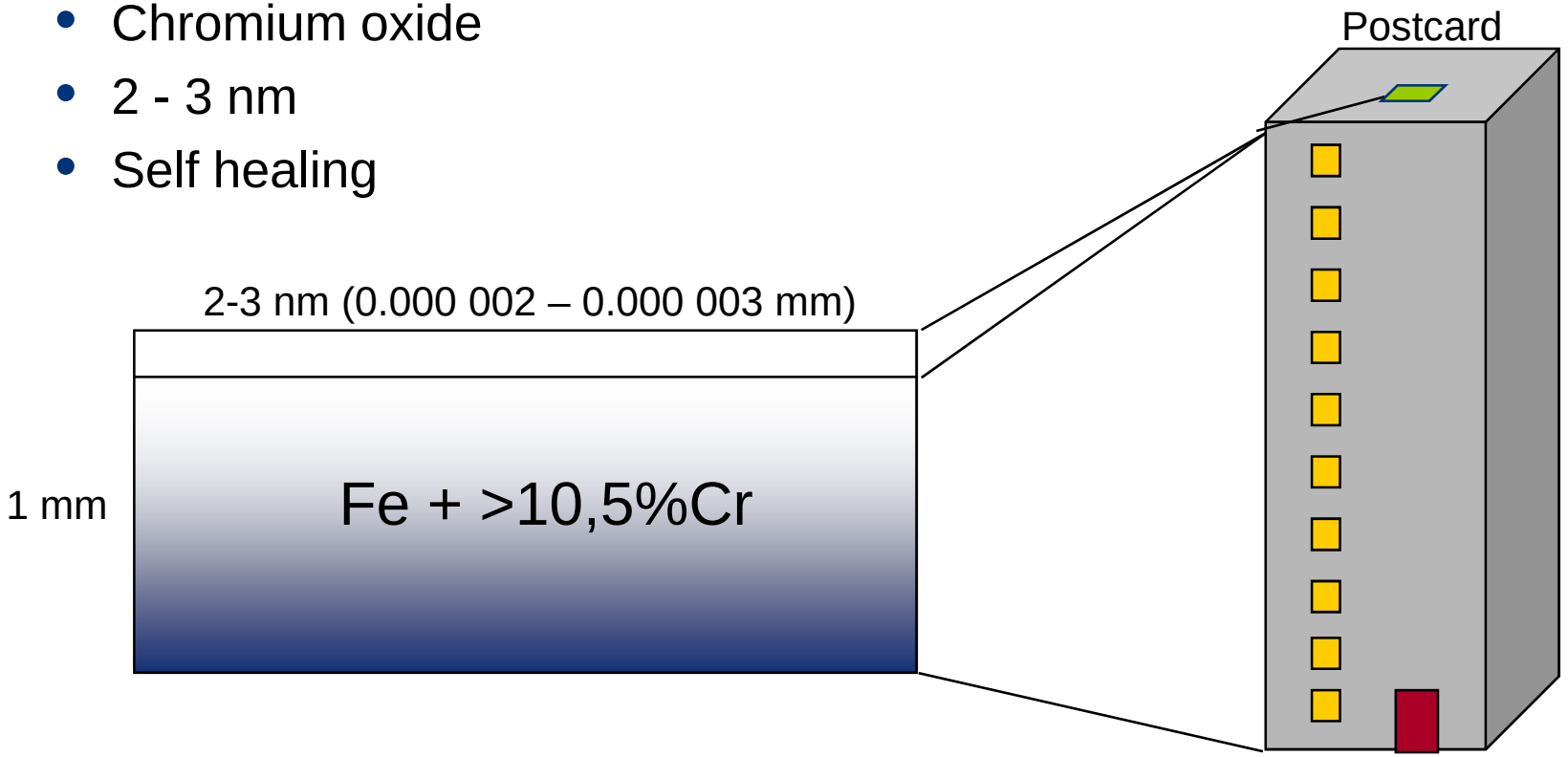
- Passive layer
  - Forms spontaneously
  - Chromium oxide
  - 2 - 3 nm
  - Self healing



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- Corrosion occurs if
  - A breakdown of the passive layer occurs
  - The environment prevents self healing

- It is a matter of
  - Selecting the correct grade for a given environment
  - Appropriate workshop handling including post fabrication treatment

Water is the most common corrosive liquid, but it is still hard to predict the corrosivity

- Different “types” of water with variable composition
- Corrosivity associated with e.g.
  - Chloride content
  - Temperature
  - Oxidants
  - Biological activity
  - pH
  - Welding oxides
  - Flow conditions

There are many corrosion types, the most common in water are:

- Pitting corrosion & Crevice corrosion
- Also Stress corrosion cracking and Galvanic corrosion

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- In neutral or acidic environments containing chlorides
- Chloride ions local breakdown of the passive layer
- Small discrete attacks, but can proceed rapidly
- + Cr, Mo, N increased resistance
- Reduced susceptibility with increasing pH (> ~11)

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- Occurs in same environments as pitting
- In shielded areas e.g.
  - In crevices
  - In threads
  - Under deposits
- Crevice corrosion occurs easier than pitting

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- Flocculation
  - $FeCl_3$ – Pitting & crevice corrosion
- Aerobic biological stages
  - Oxygen, biofilm & chloride ions – Pitting & crevice corrosion
- Digester
  - Oxidants under anaerobic conditions

Anaerobic

57-184 ppm
Cl^- 38℃
pH 6-8
+ $KMnO_4$

Grade 316

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- 304 is successfully used at chloride levels below 100 ppm.
- 316 is being specified at minimum chloride levels between 200 and 400 ppm (depending on engineering company).
- But duplex may be more cost effective.

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Final settling tanks

- 5 plants, Denmark & Sweden
- 3 steel grades, 304, 316L & 2205
- One anaerobic & 4 aerobic stages
- 11-14 months
- Potential measurements
- Laboratory examinations

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Plant	Cl^-, ppm	304	316	2205
1	515	Pitting	Pitting	No corrosion
2	225	Pitting	No corrosion	No corrosion
3	585	Pitting	No corrosion	No corrosion
4	58	No corrosion	No corrosion	No corrosion
5	78	No corrosion	No corrosion	No corrosion

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Biological activity in aerated stages can increase the risk of for pitting and crevice corrosion.

316L is safer than 304 but can be attacked at high chloride levels and high corrosion potentials.

Stages with high oxygen consumption and no other oxidants are harmless to stainless steels.

The duplex grade 2205 is far safer than standard austenitic grades.

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Laboratory tests

CL^-, ppm	Total residual chlorine, ppm	304L	316L	LDX 2101	2205
200	0.2	No corrosion	No corrosion	No corrosion	No corrosion
	0.5	Corrosion	No corrosion	No corrosion	No corrosion
	1	Corrosion	Corrosion	Corrosion	No corrosion
500	0.1	No corrosion*	No corrosion**	No corrosion	No corrosion
	0.2	Corrosion	No corrosion	No corrosion	No corrosion
	0.5	Corrosion	Corrosion	Corrosion	No corrosion
	1	Corrosion	Corrosion	Corrosion	No corrosion

*304 **316

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Storage tanks

Railings, walkways, stairs

Support beams

Up to 50% lighter in duplex than 304!

Collector lines

Load bearing concrete ducts, internally lined with stainless steel.

Stainless steel is tougher and more ductile than concrete and FRP

Tight systems even at e.g. settling of the ground caused by heavy traffic.

Duplex provide better abrasion resistance than austenitic grades.

Sewage collectors

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Energy recovery systems for reverse osmosis plants

Evaporation chambers for MSF desalination plants

2205 & LDX 2101

2507

Flood gates

LDX 2101

Bridge - Stockholm

2205

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Duplex stainless steel –

an ultimate material for storage tanks

Thinner gauges

- Less material
- Lower transportation costs
- Less filler material
- Less edge preparation
- Less welding

Life Cycle Cost advantages

- No painting
- No coating
- 100% recyclable

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Height & diameter

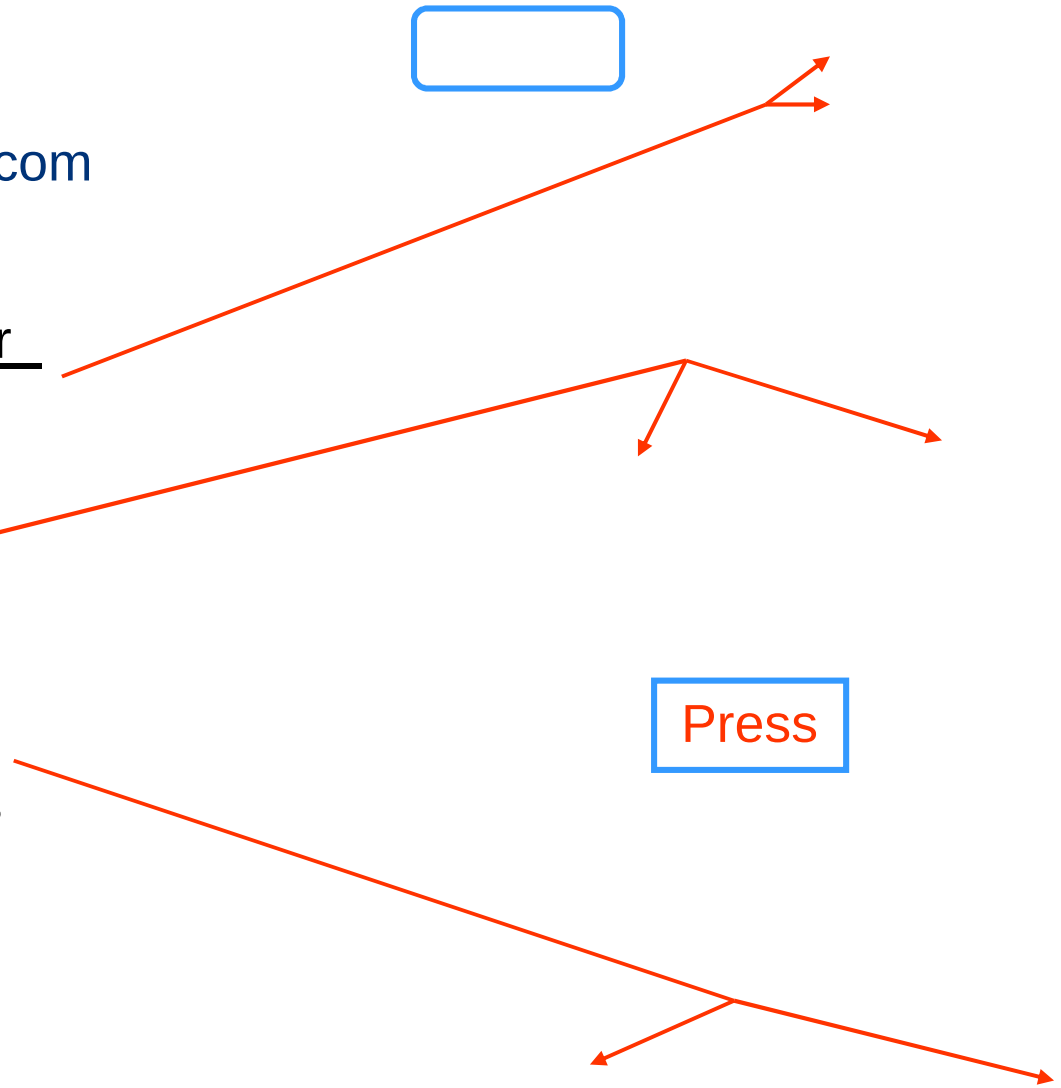
20 x 20 m

Grades

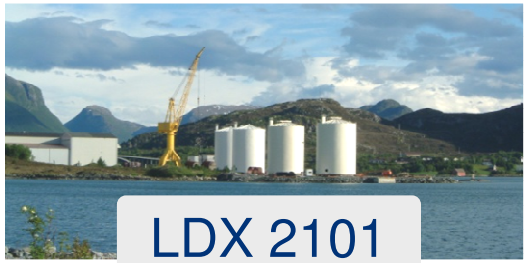
LDX 2101 & 304

Weight

73.5 & 106.2 tons respectively



Storage tanks in duplex stainless steel



LDX 2101

2304 + LDX 2101

LDX 2101

2304

2205

2304

LDX 2101

2507

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- There are duplex alternatives to conventional austenitic stainless grades with similar corrosion resistance and higher strength.
- Duplex grades often provide a cost effective alternative to austenitic grades.
- In sewage plants 304 & LDX 2101 are often good enough. 316 & 2304 or even 2205 can be required for more severe environments.
- There is data & experience for the selection of correct stainless steel grade.

Summary

- Stainless steel collectors will ensure a maintenance free system without leaks due to heavy traffic and ground settlement.
- Use of duplex grades for storage tanks can imply considerable cost benefits in terms of investments and and maintenance.
- Stainless steel is 100% recyclable.

Thank you!

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