Materials Selection for Condensing Economizers

Gary M. Carinci, Ph.D. Outokumpu Stainless

Factors Influencing Materials Selection in Condensing Economizers

- Temperature
- pH control
- Sulfur content of combustion fuel
- Chloride content of fuel
- Fluoride content of fuel
- System design

Design Considerations to Limit Corrosion from Evaporation

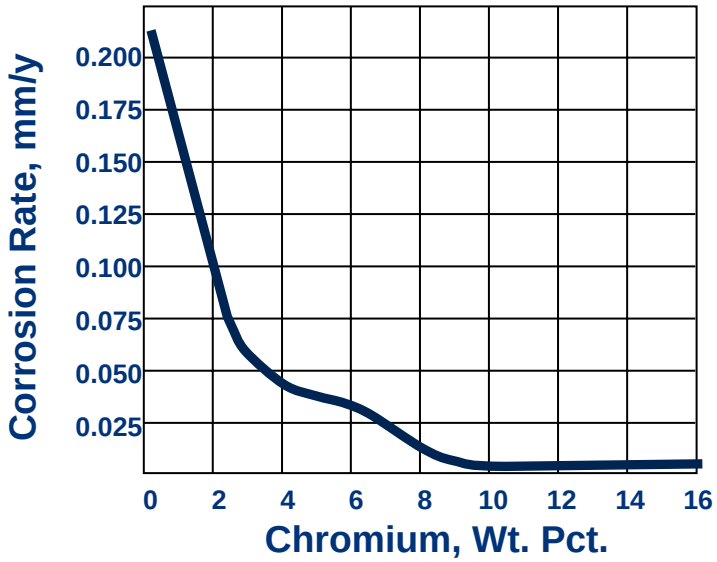
- Non-condensing portions of the heat exchanger:
  - Do not cool flue gas below 400˚F
  - Maintain elevated wall temperature
- Condensing heat exchanger:
  - Eliminate hot spots
  - Allow heat exchanger to heat up rapidly
- Condensate handling:
  - Condensate should flow towards a cooler region

Materials Selection for Condensing Economizers

- Dry Regions
  - Bare and coated carbon steels (aluminized)
- Wet Regions with Dilute Condensate
  - Stainless steels (304L, 316L, LDX 2101, 904L, 2205)
  - Aluminum alloys (1100, 3003, 12% Silicon, 6061)
- Wet Regions with Concentrated Condensate
  - High performance stainless steels (2507, 254 SMO, 4565)
  - Nickel alloys (625, 825, C-276, C-22, 686)

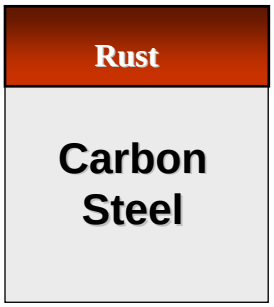
What is Stainless Steel?

Chromium Increases Corrosion Resistance



How Stainless Steel Works

< 11% Chromium



> 11% Chromium

Passive Film

OUTOKUMPU

Stainless Steel Families

Austenitic
Ferritic
Martensitic

Duplex
(Austenite + Ferrite)

OUTOKUMPU

Stainless Steel – Chemical Composition

UNS	Grade		Typical chemical composition, % by weight Cr	Ni	Mo	N	Others	PRE_{30}
S31603	316L	Austenitic	17.2	10.2	2.1			24
S31703	317L	Austenitic	18.2	13.7	3.1			28
S31726	317LMN	Austenitic	17.8	12.7	4.1	0.14		35
N08904	904L	Austenitic	20	25	4.3		1.5Cu	35
S31254	254 SMO	Austenitic	20	18	6.1	0.20	0.7Cu	46
S34565	4565	Austenitic	24	17	4.5	0.45	5.5Mn	52
S32101	**LDX 2101**	**Duplex**	**21.5**	**1.5**	**0.3**	**0.22**	**5Mn**	**29**
S32205	2205	Duplex	22	5.7	3.1	0.17		37
S32750	2507	Duplex	25	7	4	0.27		46

PRE_{30} =%Cr+3.3*%Mo+30*%N

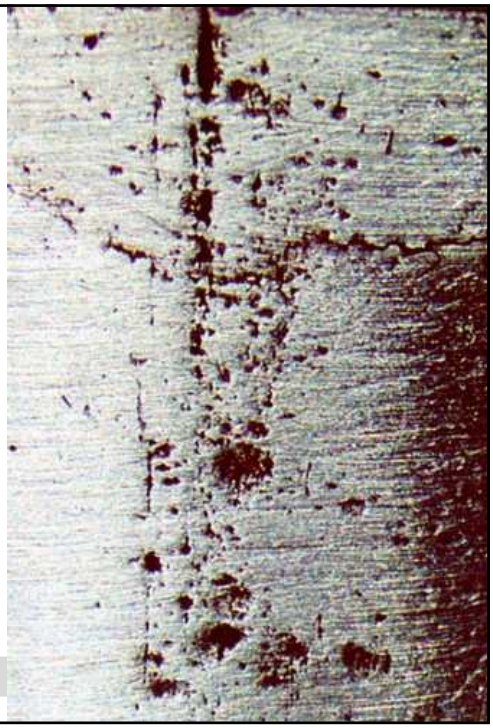
OUTOKUMPU

Corrosion in Condensing Economizers

- Uniform Attack
  - Low pH, acid condensing environments
- Pitting
  - PREn = %Cr + 3.3%Mo + 30%N
- Crevice Corrosion
  - Fabrication, Scale Deposits
- Stress Corrosion cracking
  - High Temperatures, Chlorides

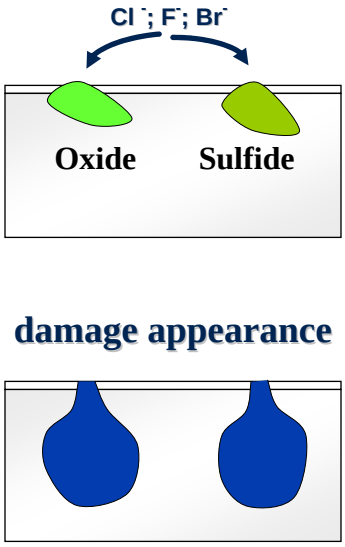
OUTOKUMPU

Pitting Corrosion



Pitting Corrosion

Basic Mechanism



OUTOKUMPU

316 L Corroded Weld

OUTOKUMPU

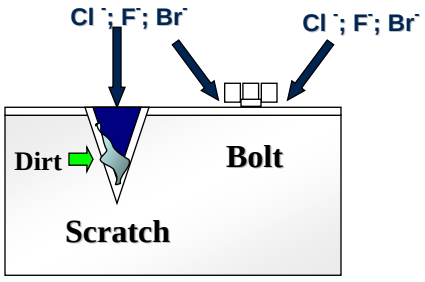
Crevice Corrosion

©TMR

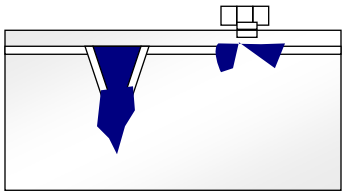
OUTOKUMPU

Crevice Corrosion

Basic Mechanism



damage appearance



OUTOKUMPU

Crevice Corrosion

- Like pitting except the anode is a crevice
- Occurs more easily than pitting
- Results from design (under bolts)
- Results from service (under deposits)
- Crevice geometry is critical
  - (deep and tight crevices are detrimental)

OUTOKUMPU

Pitting and Crevice Corrosion

Are affected by:

- Alloy composition
- Environment
- Metal surface conditions

Minimizing Localized Corrosion

- Reduce chlorides
- Reduce temperature
- Reduce oxygen
- Reduce bioactivity
- Avoid acid conditions
- Avoid stagnant conditions

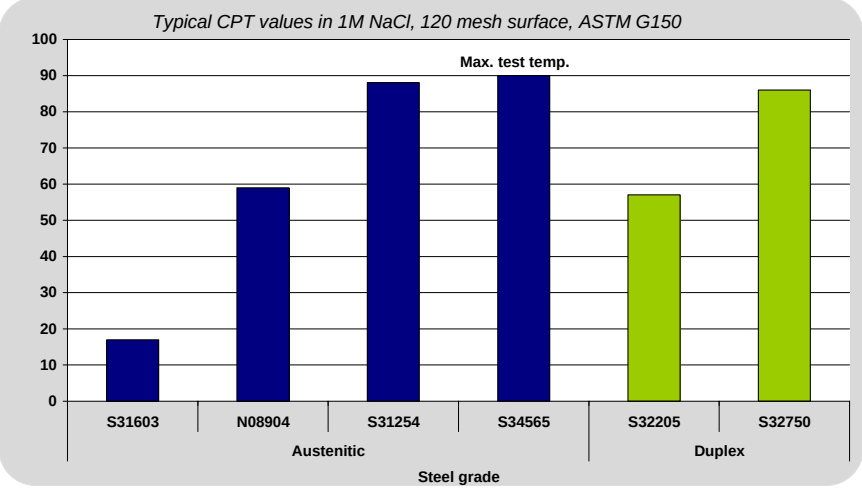
Critical Temperatures for Corrosion in Chloride Containing Environments

Below the critical temperature corrosion will not occur in a specific environment.

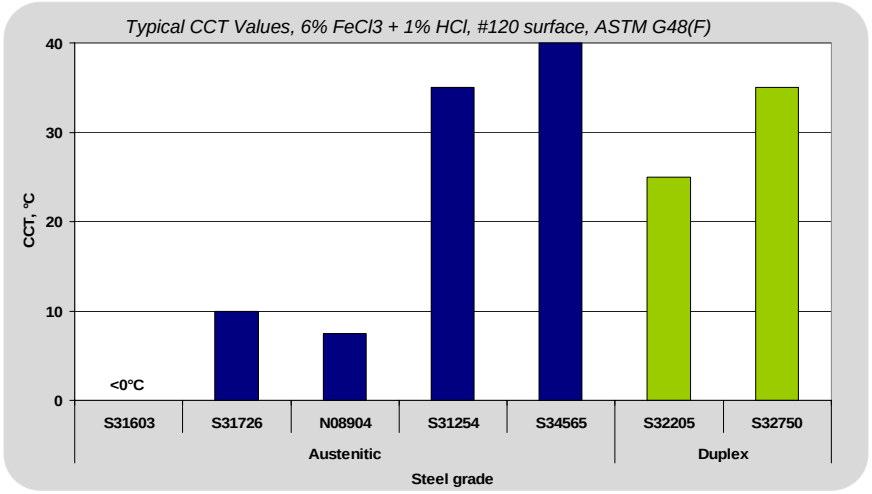
Critical **C**revice **T**emperature (CCT)
Critical **P**itting **T**emperature (CPT)

Avoid use of these temperatures for material selection !!!

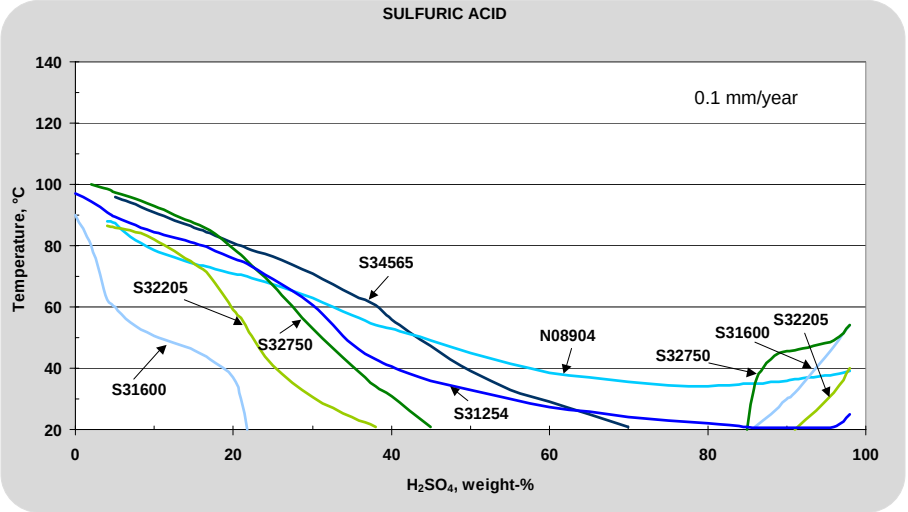
Stainless Steel – Pitting Corrosion



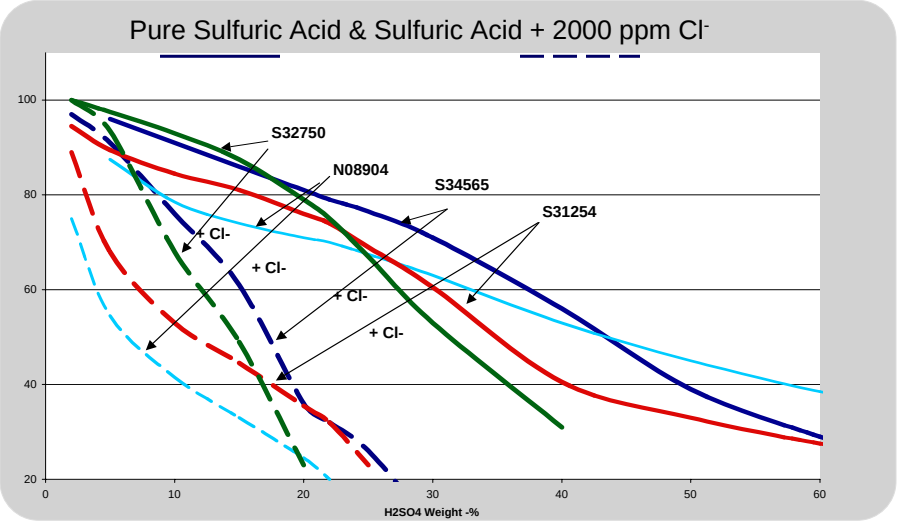
Stainless Steel – Crevice Corrosion



Stainless Steel – Uniform Corrosion



Stainless Steel – Uniform Corrosion



OUTOKUMPU

Materials Selection Economics

Corrosion Resistance ~ %Cr + 3.3%Mo + 30%N

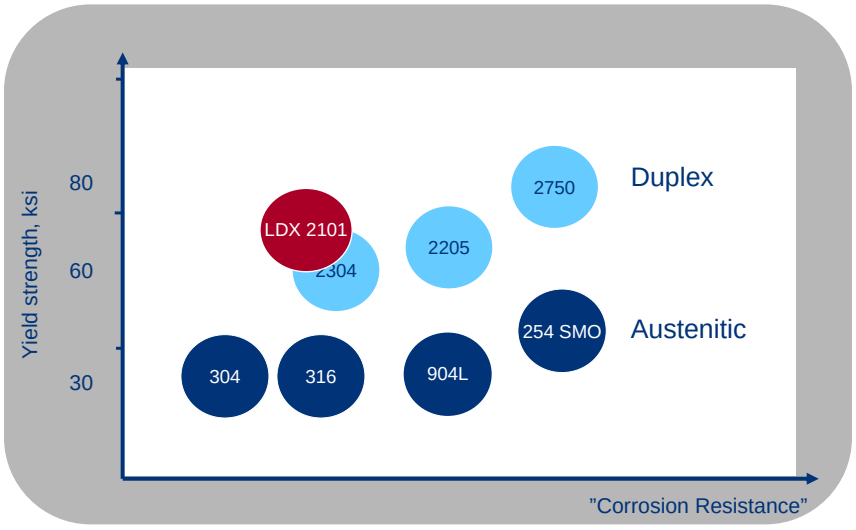
- Nickel content of stainless steel ($14/lbs)
- Molybdenum content ($33/lbs)
- Chromium content ($2/lbs)
- Nitrogen content - free
- Select stainless steel with high Cr, N content and low Ni and Mo content - Duplex stainless steel!

OUTOKUMPU

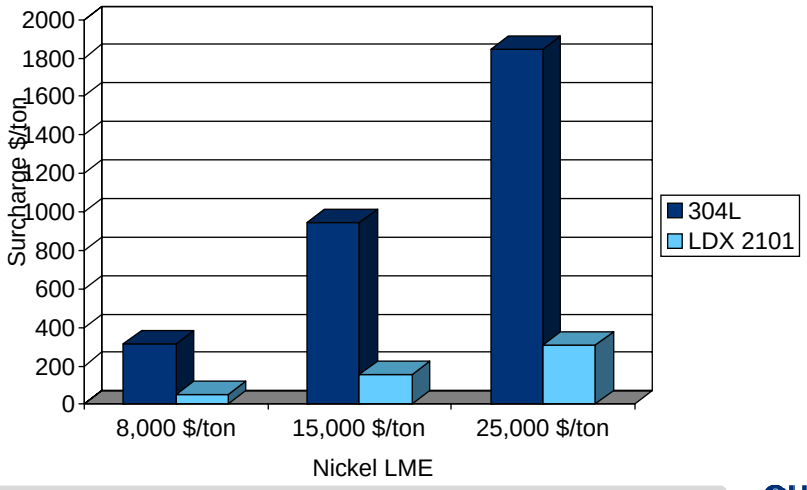
LDX 2101 Duplex Design Targets

- Corrosion resistance ~ 304L
- SCC resistance = “Resistant”
- Yield strength 65 – 80 ksi
- Good impact toughness –40 °F to 600 °F
- Availability – All product forms – Service centers
- Cost effective

Properties of LDX 2101®



LDX 2101®, Nickel price influence on alloy surcharge



OUTOKUMPU

Alloy Surcharges for May, 2008

Grade	Cr	Mo	Ni	Total
2507	$0.58	$1.46	$1.02	$3.16
2205	0.51	1.09	0.80	$2.51
LDX 2101®	**0.50**	**0.11**	**0.22**	**$0.93**
316L	0.37	0.73	1.46	$2.67
304L	0.42	0	1.17	$1.69

OUTOKUMPU

LDX 2101®

ADVANTAGES	DISADVANTAGES
• Stress Corrosion Cracking - Resistant	New
• Pitting Resistance - similar to 316L	
• Twice as Strong as 316L	
• Ease of Fabrication	
• Wear Resistant	
• Availability	
• Cost	

OUTOKUMPU

Conclusions

- Environments in wet condensing systems can be very aggressive - determine what is condensing out before making material decisions
- There can be variations in environments between different plants and material selection has to be done for each plant.
- The main risks for stainless steel are pitting and crevice corrosion in chloride containing environments.

OUTOKUMPU

Conclusions

- By choosing the correct stainless steel grade, it is possible to meet a wide range of demands on corrosion resistance.
- If the main risks are chloride pitting or crevice corrosion, the following ranking applies:

  304L<316L,~LDX2101<317LMN~904L~2205<2507~254SMO<4565

- Duplex stainless steels are a cost effective choice for corrosion resistance with high Cr, N and low Ni, Mo contents