

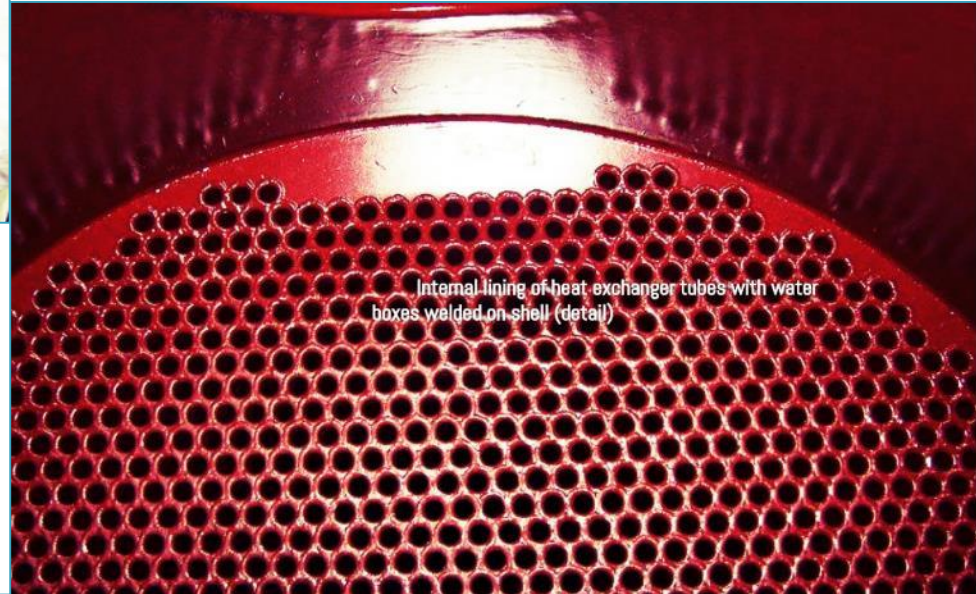


Internal lining and external lining of heat exchanger tubes (application in progress)



DONELLI

CORROSION PROTECTION
APPLICATIONS SINCE 1911



Internal lining of heat exchanger tubes with water boxes welded on shell (detail)

Webinar on Challenges and Solutions for Improved Durability of Materials

Shell & Tube Heat Exchanger Coatings

October 22nd, 2020

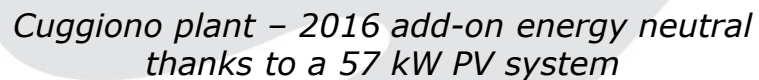
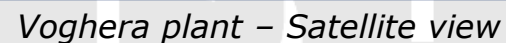
AGENDA

- Donelli Alexo in brief
- A general approach for steel structures
- Säkaphen in brief
- A deep dive on Shell & Tube heat exchangers

Donelli Alexo in Brief

- Donelli Alexo, part of the Donelli Group (established in 1911), is dedicated to meeting the **most demanding anticorrosion**, fireproofing and insulation needs of energy, petrochemical and chemical facilities onshore and offshore;
- Most coating applications are carried out in two **state-of-the-art painting facilities**:
 - **Cuggiono facility**, located 20 [km] North of Milan on the A4 Milan-Turin highway, nearby Malpensa International Airport. The facility's total area consists of **more than 20.000 [m²]**, of which **8.000 [m²] are closed shops** (1.500 [m²] completed in 2016 www.donelli.it/360).;
 - **Voghera facility**, located 50 [km] South of Milan on the A7 Milan-Genoa and A21 Turin-Piacenza highways. The facility's total **area consists of 5.000 [m²]**, of which **2.500 [m²] are closed shops**. An high-quality corrosion protection is guaranteed by one blasting cabinet, two closed and heated spraying boots and two large ovens for heat-curing at temperatures up to 300 [°C] connected to a industry 4.0 managed post burner efficiently minimizing plant emissions;
- All applications are carried out in strict compliance with clients' specifications by a **UNI EN ISO 9001 and ISO 14001 certified company**, with experienced and **trained personnel, certified NACE/FROSIO inspectors** and the most reliable inspection tools available in the industry. This ensures **schedule fulfillment**, and that projects meet **environmental, qualitative and safety standards. ISO 45001 certification in progress**;
- Since 2002 **Donelli Alexo is exclusive licensee for Italy of Sakaphen technologies and solutions.**

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Donelli Alexo - R&D Projects

- Donelli Alexo has been involved in **numerous R&D projects**, mostly driven by **customer demands** as well as **employees' ideas** to improve quality and environmental impact of our applications;
- Most significant project is **S.W.O.C. on FBE application on bends and fittings**. Although not funded, it has received the **Seal of Excellence** under SME Instrument phase 2 framework;
- Other projects have dealt with:
 - **PTFE** applications on items for **pharma** industry as well as **rupture disks**;
 - **Icephobic coating** systems for **cold environments** and refrigeration;
 - **TSA** improvement via MicroArc Oxidation with **Technion University**.
- Close cooperation with **Säkaphen** has various joint R&D projects on topics such as:
 - Tube-lining of small OD pipes;
 - Preventing Microbacteria Induced corrosion.



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Main decisions for the equipment fabricator in relation to improved durability via coating systems

 Detailed next

1

Substrate material selection based on constraints such as weight, size, budget...

2

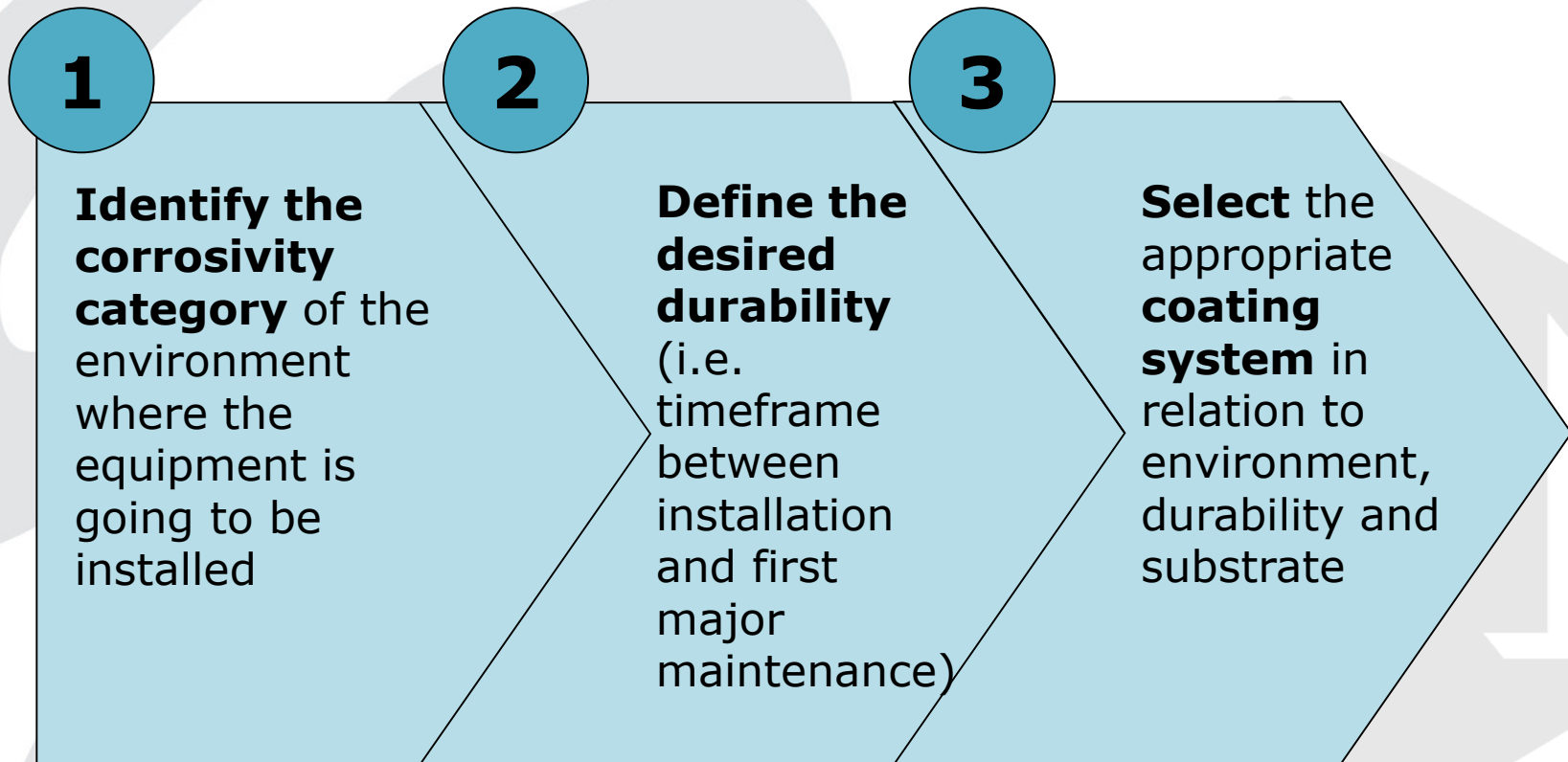
Design of goods in order to be properly coated as well as maintained. Relevance of steel preparation

3

Definition of appropriate corrosion protection system based on operating conditions, substrate, ease of maintenance, etc.. Proposed approach: ISO 12944

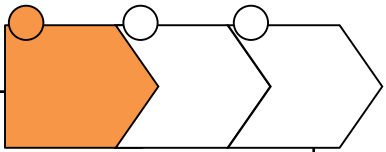


ISO 12944 – A useful, 3 step approach



ISO 12944 standard has been significantly revised, the following presentation is based on this latest revision

ISO 12944: Identify the corrosivity category...

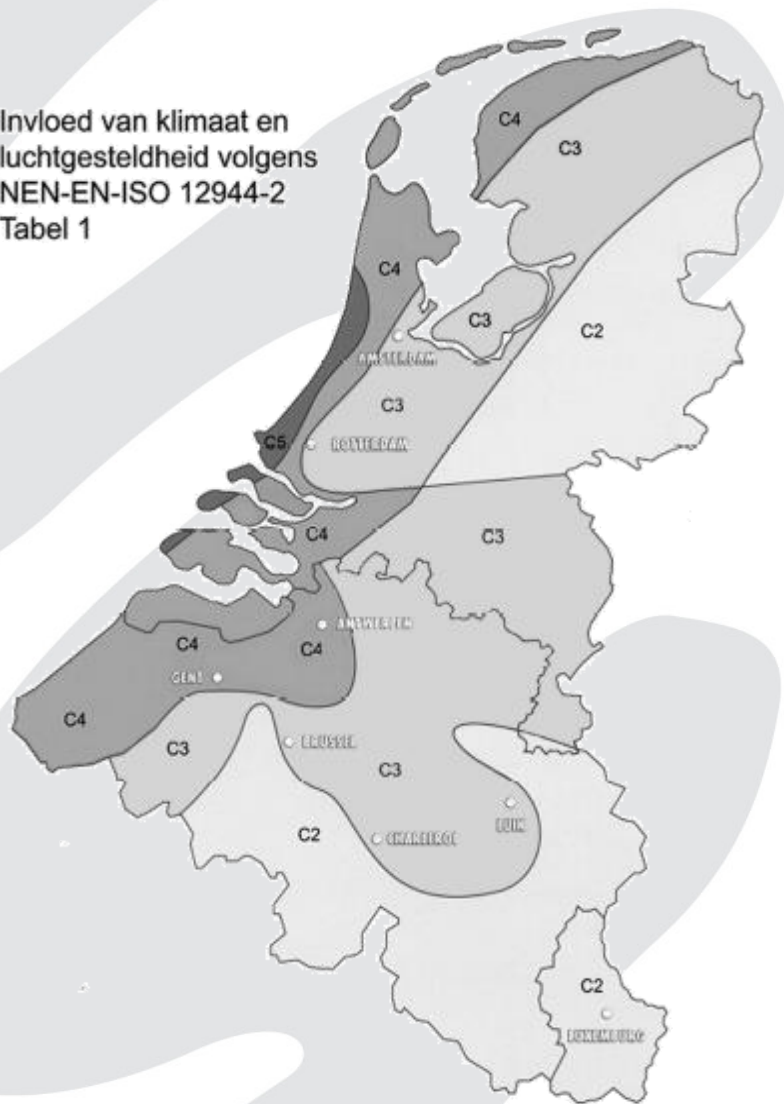


Corrosivity category	Environment examples	
	<u>Exterior</u>	<u>Interior</u>
C1 very low	-	Heated buildings with a clean atmosphere such as offices, shops, schools, hotels.
C2 low	Atmospheres contaminated to a small extent, mainly rural regions.	Buildings which are not heated, where condensation may occur e.g. storage facilities, sports halls.
C3 medium	Industrial and urban atmospheres with a low sulphur oxide (IV) contamination level. Inshore areas of low salinity.	Production halls to facilities humidity and certain air contamination e.g. foodstuff plants, laundries, breweries, dairies.
C4 high	Industrial areas and inshore areas of medium salinity.	Chemical plants, swimming pools, ship repair yards
C5 very high	Industrial areas of high humidity and aggressive atmosphere and inshore areas of high salinity.	Buildings and areas of almost constant condensation and high contamination.
CX extreme (of which part is offshore)	Offshore areas of high salinity or industrial areas of extremely high humidity and aggressive atmosphere or subtropical and tropical areas.	Buildings and areas of almost constant condensation and aggressive contamination.

Newly introduced in 2018

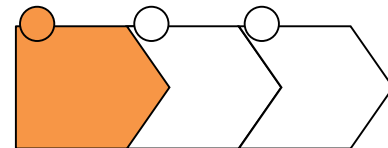
...often it is a qualitative analysis whereas at times a map is also available

Invloed van klimaat en
luchtgesteldheid volgens
NEN-EN-ISO 12944-2
Tabel 1

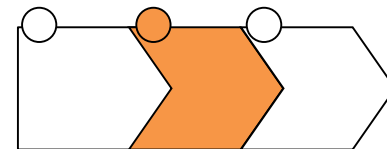


These information (if available) are a useful guideline, but do not exempt the specifier from a more accurate analysis. In fact, there exist macroclimate (as shown in the map), but also specific microclimates with possibly significantly different corrosivity categories from the surroundings (i.e. waste treatment plant, airport, etc...)

Source: Filiforme Corrosie Van Aluminum –
Aluminum Centrum 01/07/2011



ISO 12944: ...define the desired durability...



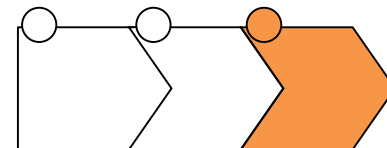
Durability is expressed in terms of time intervals from the installation of the equipment to the first major extraordinary maintenance

Low - L	From 2 to 7 years
Medium - M	From 7 to 15 years
High - H	From 15 to 25 years
Very high - VH	More than 25 years

Newly introduced in 2018 for all categories except CX

Durability is not a **warranty** (commercial terms) and does not exempt asset owner from **ordinary maintenance**.

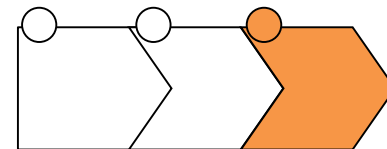
ISO 12944: ...select the appropriate coating system – Example for carbon steel – C4, C5 category



Example of coating systems suitable for carbon steel (min. 3 [mm]) . Surface preparation is blasting to SA 2 ½ (i.e. near white metal) with synthetic or metallic abrasive.

Layer	Product type	C4 (H)	C4 (VH)	C5 (H)	C5 (VH)
		<i>NDFT</i> [μm]	<i>NDFT</i> [μm]	<i>NDFT</i> [μm]	<i>NDFT</i> [μm]
Primer	Organic zinc	60	60	60	60
Inter- mediate	Epoxy intermediate	90	150	150	210
Finish	Acrylic polyurethane	50	50	50	50
Total NDFT [μm]		200	260	260	320

ISO 12944: ...select the appropriate coating system – Example for carbon steel – CX category



Example of coating systems suitable for carbon steel (min. 3 [mm]) . Surface preparation is blasting to SA 2 ½ (i.e. near white metal) with synthetic or metallic abrasive.

Type of environment	CX Offshore (H)		Splash & Tidal zones CX Offshore H		
	<i>Zinc</i>	<i>Other</i>	<i>Zinc</i>	<i>Other</i>	
Primer NDFT [μm]	≥ 40	≥ 60	≥ 40	≥ 60	≥ 200
Minimum [nr] of coats	3	3	3	3	2
Total NDFT [μm]	≥ 280	≥ 350	≥ 450	≥ 450	≥ 600

Performance of a coating system suitable for C3 environment after 3 years in a C5 environment



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Säkaphen in Brief

SÄKAPHEN® is a 3rd generation family-owned company which stands for excellent quality and premium coating systems. SÄKAPHEN® distinguishes itself through its individual coating solutions for customer-specific requirements.



Säkaphen in Brief – Product Range

The product range comprises two groups of products:

- SÄKAPHEN® **heat-cured coatings:** one component thermally hardening coatings, which are cured in special polymerization ovens at temperatures up to 220°C. This technology is applied only in SÄKAPHEN®'s own plant as well as in Authorized Applicators' plants.
















- SÄKAPHEN® **cold-cured coatings:** two or more component catalytically hardening coatings, which are applied in a multilayer process by spraying, rolling or troweling



Säkaphen in Brief – Worldwide network

- SÄKAPHEN® works together with powerful partners, who offer expert advice, service and reliability when it comes to optimum corrosion protection;
- The Authorized Applicator are located around the world and are carefully selected by their skills and abilities;
- Donelli Alexo is a core partner for market development in Europe and Africa and a valued R&D partner. R&D projects with Donelli Alexo:
 - Tube Lining for small ID tubes
 - MIC reducing coating
- Other R&D:
 - Girth Weld Coating material
 - MIC reducing coatings with active fillers
 - Onsite coating solutions of marine coolers

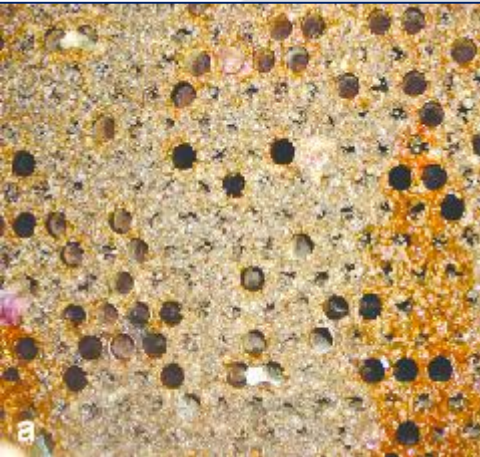
ALL	ASIA	EUROPE	MIDDLEEAST	USA	WORLDWIDE
					
GERMANY	PAKISTAN	WORLDWIDE	KINGDOM OF SAUDI ARABIA		
Europe	MIDDLEEAST	Worldwide	MIDDLEEAST		
					
USA	NORWAY	ITALY	UNITED KINGDOM		
USA	Europe	Europe	Europe		
					
SPAIN	AUSTRIA	INDIA	SOUTH KOREA		
Europe	Europe	Asia	Asia		
					
CHINA					
Asia					

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Fouling as source of reduced performance

- Fouling is the deposition of an unwanted layer of material on the heat transfer surface, it is usually caused by multiple factors:
 - Crystallization
 - Deposition of particles
 - Chemical reactions
 - Biological fouling
 - Corrosion
- The above described phenomenon can be found in particular in sea-water and river-water operated HE but also in other units, e.g. where paraffin or crude oil are part of the process.



Fouling consequences and coating as a solution

- Fouling, incrustation and corrosion cause an increase in surface roughness and the formation of a layer of unwanted material on the exchange surface, leading to:
 - Over dimensioning of the HE to take into account **corrosion allowance**;
 - Selection of **chemical resistant alloys** (Hastelloy, stainless steel, super duplex), normally less heat conductive than carbon steel;
 - **Higher energy consumption** of pumps to overcome the reduced internal diameter & increased roughness;
 - **Frequent cleaning** procedures by UHPWJ resulting in increased downtime.
- **SÄKAPHEN® technologies** applied tube side and/or shell side results in smoother surfaces, hence limiting above described phenomena, and result in corrosion protection even in aggressive environment.
- Comparative **roughness** of various surfaces:
 - New HE: 25-50 [μm] (as structural steel)
 - Fouled/corroded HE: 150 [μm] (as cast iron)
 - **Coated HE:** 5 [μm] (as plastic)



Real world case study and implications

- A section of a cooler unit in the steel mill was coated with SÄKAPHEN® Si 17® TC (left picture). In direct comparison the uncoated tubes (right picture). Both pictures show the tubes after 14 month in service;
- It can be safely stated that the fouling reduction was higher than 15-20% and probably close to 90%.



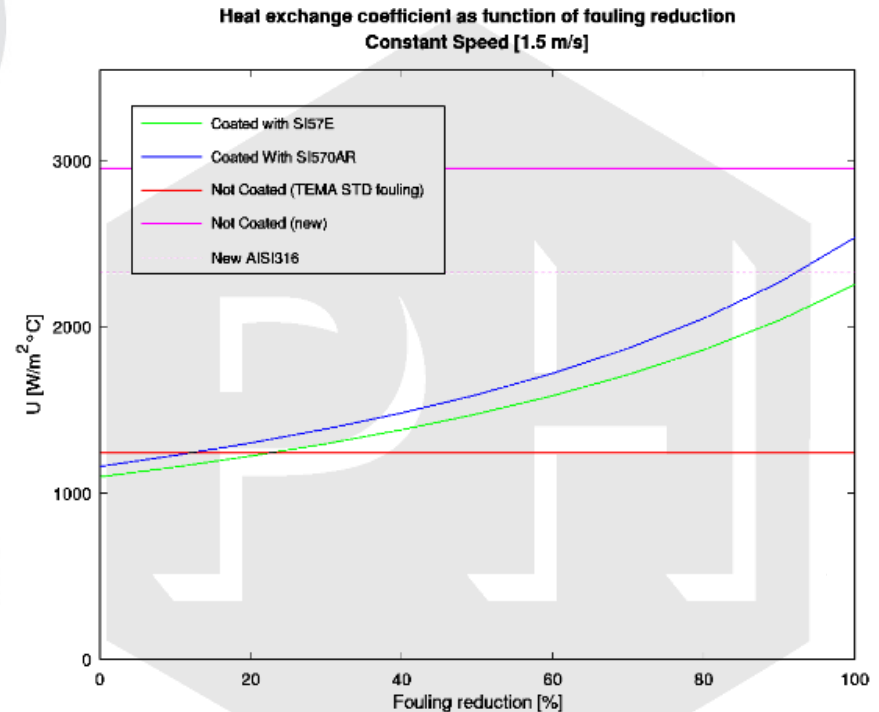
SÄKAPHEN® Si 17® TC coated section



Uncoated section

Influence of coating on heat transfer rate

- Different alloys have different **heat conductivity**:
 - λ_{eff} Carbon steel = 35-45 W/mK
 - λ_{eff} Stainless steel = 16 W/mK [*]
 - λ_{eff} Super duplex = 15 W/mK [**]
 - λ_{eff} Hastelloy = 12 W/mK [***]
- Carbon steel is the ideal solution for heat exchangers, if properly protected against corrosion.
- **SÄKAPHEN® technologies** allow the use of carbon steel in aggressive environments and, even if coating have poor heat conductivity, the coated CS HE:
 - has a **better** heat transfer rate than a **new bare SS HE**;
 - has an initial loss in heat transfer rate than a new bare CS HE, rapidly eliminated by the **beneficial reduction of fouling** (see graph).



Sources:

[*] https://en.wikipedia.org/wiki/List_of_thermal_conductivities

[**] <https://www.finetubes.co.uk/products/materials/duplex-stainless-steel-tubes/super-duplex-uns-s32750-wnr-1-4410>

[***] https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

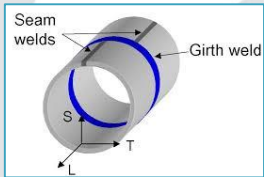
CO2 reduction – A preliminary assessment

- Assuming a HE with 490 [m²] of heat exchange area, the **CO2 footprint** throughout its production and its end of life is the following:
 - **Stainless steel HE:** 73 [tons of CO2 equiv.]
 - **SÄKAPHEN® coated carbon steel HE:** 26 [tons of CO2 equiv.]
- Reduction of CO2 emissions result also from the operation of a **SÄKAPHEN® coated carbon steel HE** thanks to the lower pressure drop. This can be estimated in emission reduction of 35% or 17 [tons CO2 equiv. per year];
- Above calculations are done also considering that:
 - Additional Capex for coating application is €25k, resulting in SS HE still with 40% higher CAPEX than CS HE;
 - Additional emission for coating application is 4.5 [tons of CO2 equiv.];

Ideas for future discussion with audience



- More refined CO2 reduction analysis;



- Girth weld coating material;



- MIC reducing coatings with active fillers;



- Onsite coating solutions of marine coolers.

Donelli & Säkaphen are jointly looking forward for interest in carrying on further analysis on the above topics!

Thanks for the attention!



SÄKAPHEN GmbH

Bottroper Straße 275

Gladbeck Germany

Tel. +49 2043 947 0

Email: info@saekaphen.de



DONELLI

CORROSION PROTECTION
APPLICATIONS SINCE 1911

Impresa DONELLI srl

Via F.lli Cervi, 7

Legnano (MI) Italia

Tel. +39 0331 408511

Email: impresa@donelli.it