Fluid Dynamics
Heat Exchange Solutions since 1981

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Kelvion

Kelvion Thermal Solution

DIESTA / GROOVY TECHNOLOGY

TABLE OF CONTENT

1.

GROOVY/DIESTA TECHNOLOGIES DESCRIPTION

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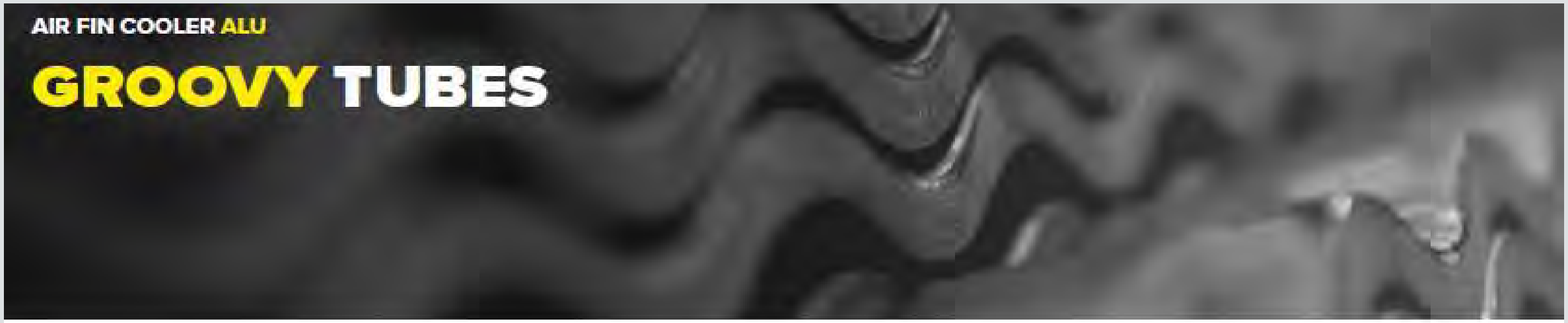
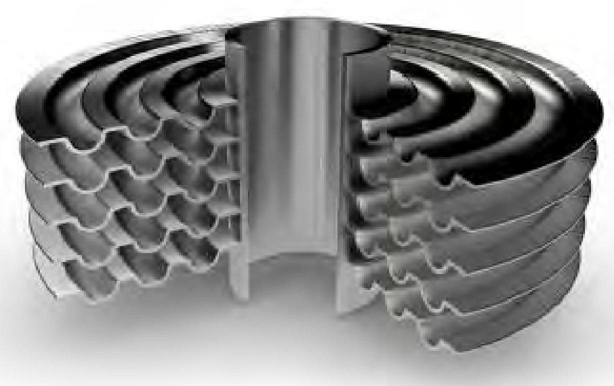
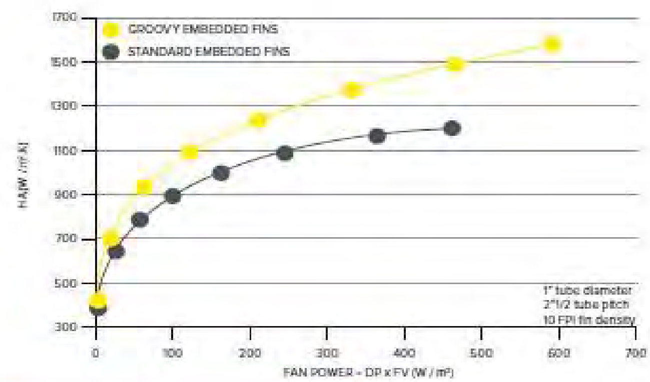
Groovy embedded fins:
Fins are embedded on core tube
Groovy extruded fins:
Fins are embedded on an aluminum sleeve covering the bare tube;
Groovy extruded is a commercial name highlighting the benefit being equivalent to regular bimetallic extruded. It is not the result of an extrusion process.
BIWA:
BImetallic **W**rapped **A**luminium finned tube







- Less plot area
- Less concrete rack construction
- Less piping
- Less cabling / wiring
- Less pipe rack modules
- Less trasportation costs
- Less site erection works
- Less OPEX

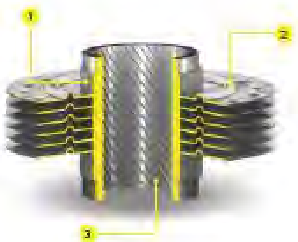
Groovy Fin
Groovy© fins have a grooved profile allowing an improvement in heat exchange of 8% to 15% for the same power consumption. Their pioneering and patented shape channels the air around the tube, maximizing the exchange surface. Products fitted with Groovy© fins require less space and use 10% less electricity.

While enhancing the performance, the Groovy Fins have still provide optimal fouling resistance and cleaning capability. Groovy Fins cause CAPEX / OPEX savings by increasing existing capacity with the same plot. Also they decrease the AFC cost for a given capacity and reduce the plot area on grassroot projects.

Kelvion

DIESTA finned tube:
Dual **I**nternal & **E**xternal **S**tructured tube for **A**ir Cooler
DIESTA is bimetallic:
Fins are embedded on an aluminum sleeve covering the bare tube as per groovy Extruded.

BIWA:
BImetallic **W**rapped **A**luminium finned tube



The DIESTA tube is a bimetallic finned tube with an aluminum sleeve (1) fully covering the base carbon steel tube. The outside aluminum fins are embedded into the grooves of the aluminum sleeve. To optimize the air-and tubeside heat transfer performance enhancement structures are applied on both sides. The aluminum fins on the airside combine both a groove and a dimple structure (2). Airside mechanical qualification confirmed robustness towards fouling, cleaning as well as mechanical strength of the fins equally to standard extruded finned tubes. The tubeside has an internally helical fin structure (3) ensuring an increased of tube side heat transfer coefficient while controlling the pressure drop.
DIESTA Technology is a development by the cooperation of Wieland®, TechnipFMC® and Kelvion.

DIESTA PRODUCTION PROGRAM

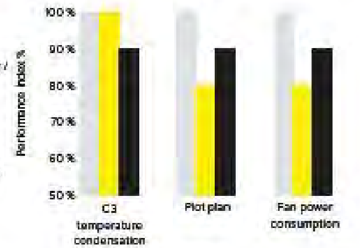
TUBE MATERIAL	TUBE OD	PLAIN END CORE TUBE THICKNESS	FIN MATERIAL	FIN DENSITY
Carbon steel (ASME SA179 & SA334 Grade 6)	1 inch 1 ¼ inch 1 ½ inch	2.11 mm (in accordance with API 661)	aluminium 1100	10 fpi (394 fpm)

DIFFERENT INTERNAL STRUCTURES ARE AVAILABLE FOR		
Gas cooling	Condensation	Liquid cooling (incl. high viscous fluid Pr < 100)

CASE STUDY FOR LNG AIR-COOLER FIELD

Assumptions:
- APCI type C_3/MR LNG process
- Design optimization for whole air-cooler field with services HP and LP MR after-coolers, C_3 ref. desuperheater / condenser / sub-cooler and others

3 potential benefits depending on project objective:
- Either maximize LNG production capacity or to minimize CO_2 footprint by optimizing C_3 condensation temperature
- Either CAPEX minimization by optimizing plot plan
- Or minimize CO_2 footprint by reducing fan power consumption



Standard Design 1: standard finned tubes

DIESTA Design 2: CAPEX reduction with plot plan optimization

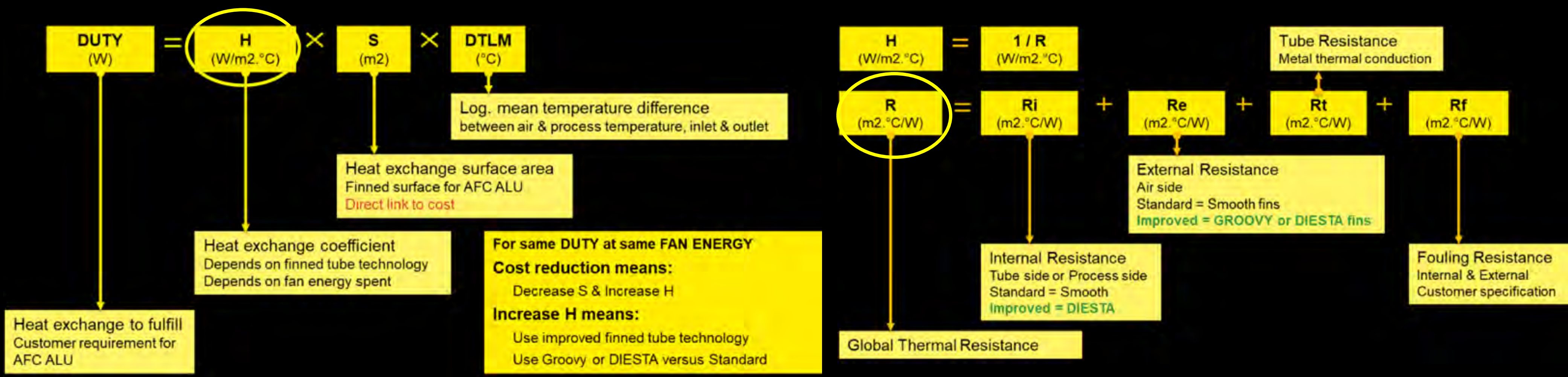
DIESTA Design 3: OPEX optimization by reducing the C_3 condensing temperature and CAPEX reduction by optimizing footprint of other services

2.

GROOVY/DIESTA DEVELOPMENT

WHERE DO GROOVY / DIESTA COME FROM?

Reminder of thermal rules for HX design



Focus on how to improve heat exchange coefficient on the air side and tube side

WHERE DO GROOVY / DIESTA COMES FROM?

- Thermal resistance ratio on typical AFC ALU application

Typical application	Internal Resistance Ri	External Resistance Re	Other Resistance Rt,f	Techno choice
Vacuum steam condenser	10%	80%	10%	GROOVY
Water cooler (pure)	20%	70%	10%	GROOVY
Water + Glycol	35%	55%	10%	DIESTA+GROOVY
Propane condenser	40%	50%	10%	DIESTA+GROOVY
MR compressor cooler	40%	50%	10%	DIESTA+GROOVY
Gas oil cooler (i.e. Kerosen)	60%	30%	10%	DIESTA+GROOVY
Lub oil cooler	80%	10%	10%	Turbulator

GROOVY		GROOVY fin
DIESTA	DIESTA tube	DIESTA fin
Turbulators (i.e. from CalGavin)	Turbulator	

DIESTA TUBES – A SUCCESFUL COOPERATION

T.EN TECHNIP ENERGIES

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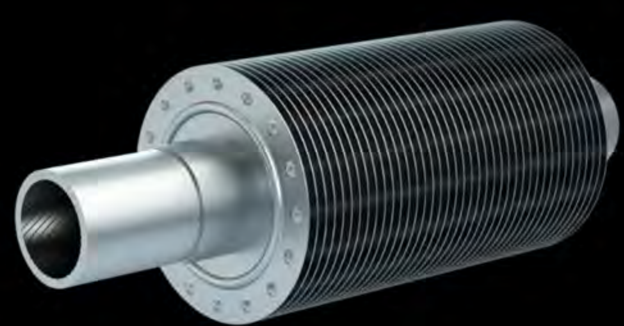
wieland



Use of DIESTA in Liquefaction

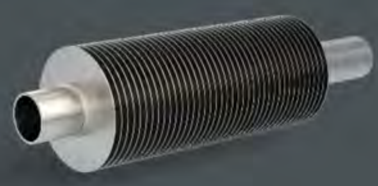
- MR compressor
- Inter- and aftercoolers
- C3 refrigerant coolers (desuperheater, condenser and subcooler)

DIESTA TUBES – THE ORIGIN

Air Fin Cooler

Shell & Tube Heat Exchanger

STANDARD



STANDARD FINNED TUBE

- Tube OD ≥ 1 in
- Smooth internal surface
- Smooth external surface

STANDARD TUBE

- Tube OD ≤ 3 / 4 in
- Smooth internal surface
- Smooth external surface

DEVELOPMENT STEP 1

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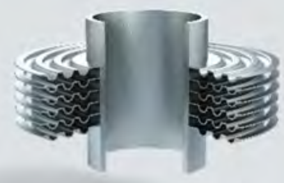

GROOVY FINNED TUBE

- Tube OD ≥ 1 in
- Smooth internal surface
- **GROOVY external surface**

wieland

T.EN TECHNIP ENERGIES

GEWA PB / -KS TUBE

- Tube OD ≤ 3 / 4 in
- **Structured internal surface**
- Smooth external surface

DEVELOPMENT STEP 2

DIESTA TUBE

- Groovy inspired fins
- GEWA PB / -KS internal tube

wieland

T.EN TECHNIP ENERGIES

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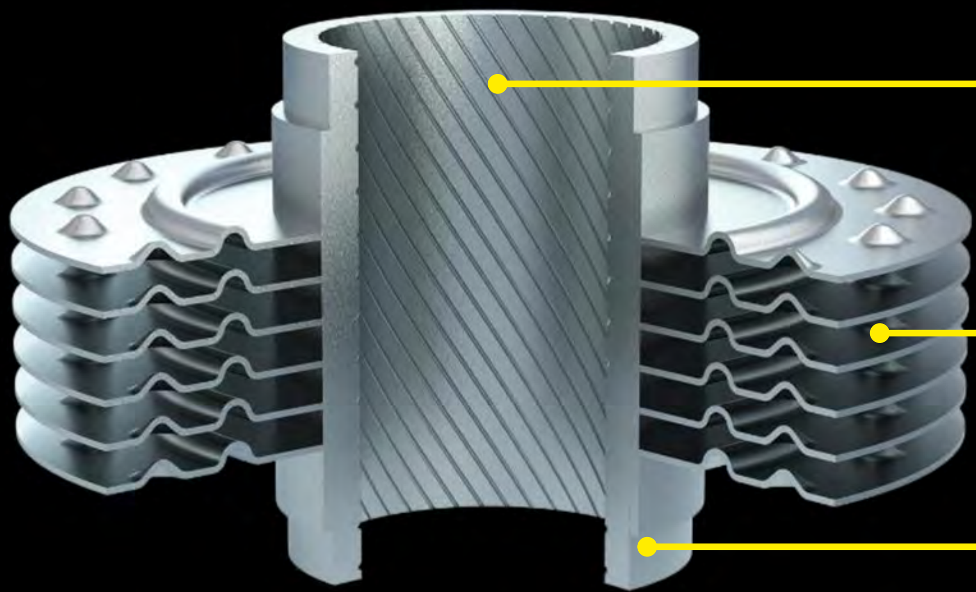
R&D Development with the Support of TOTAL Convention TOTAL / ADEME 0874C0140

DIESTA TUBES – DESIGN

DIESTA = Dual **I**nternal & **E**xternal **S**tructured **T**ube for **A**ir Fin Cooler



Enhanced internal tube surface using helicoidal structure

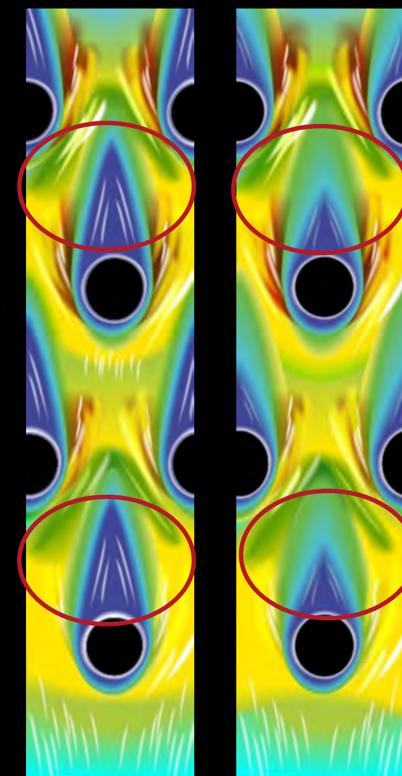
Enhanced external fin surface using grooves & dimples which increase turbulences & improve air distribution

Aluminum sleeve protection

GROOVY & DIESTA ARE ABLE TO BOOST YOUR EFFICIENCY

FIN SHAPE

- Reducing "dead zone" by air guidance
- Increasing turbulences on tube and air sides
- More than 20% increase of air side heat transfer coefficient at equivalent fan power and equivalent CO_2 emissions reduction



Kelvion patented technology

Smaller units

Over 5000 bundles installed worldwide

DIESTA APPLICATIONS

DIESTA FIN TUBE APPLICATIONS

DIESTA = Dual **I**nternal & **E**xternal **S**tructured **T**ube for **A**ir Fin Cooler

Carbon steel core tube only associated to all kind of aluminum fins

DIESTA is used in Air Fin Coolers (AFC)

Oil & Gas

LNG air-cooler fields

- MR compressor
- Inter- and aftercoolers
- C3 refrigerant coolers (desuperheater, condenser and subcooler) with Diesta C & G

Ethylene quench-water air cooler fields
(focus naphtha based crackers) with Diesta LLF

Other downstream app.

- High visco. 1 to 5 cP Diesta LLF
- Any Gas cooling with Diesta G
- Liquid cooling with Diesta C
- Refineries: VGO, Lean solvent, Kerozen, Lean Amine, with Diesta LLF

3.

GROOVY / DIESTA LNG TRAIN STUDY CASE

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DIESTA FOR PRODUCTION INCREASE

Revamping projects

- LNG production increase on existing pipe rack (1)
  - Based on 5.5 MMTPY LNG project
  - 1 € = 1.1 US$
  - LNG price = 2.0 US$/ MMBtu

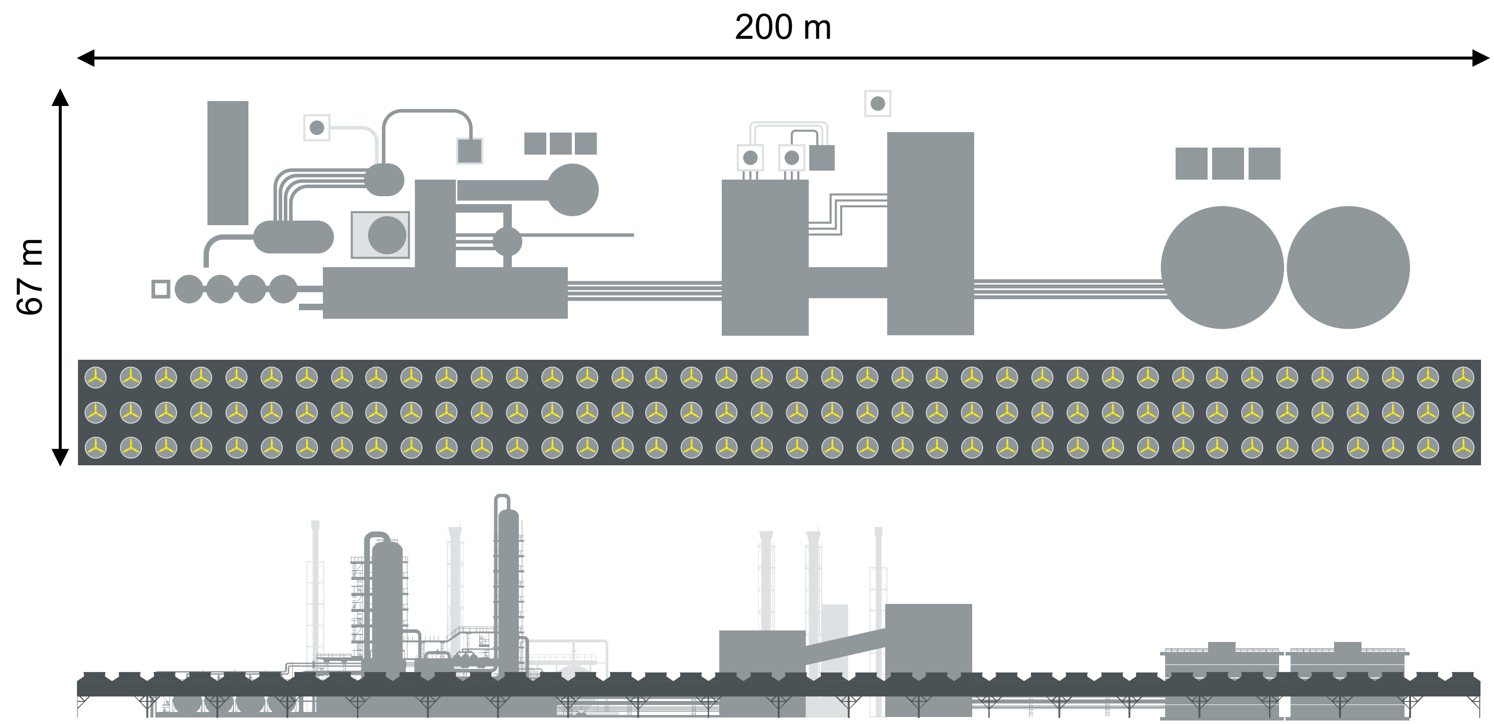
Tube Techno	ACHE Capex	ACHE Fan Power	ACHE Weight	Pipe Rack Length	C3 Outlet Temp. (1)
-	%	%	%	%	%
STD	100	100	100	100	45.0
GROOVY	105	100	100	100	44.2
DIESTA-C	120	100	100	100	42.0

LNG production calculation rule of thumb gives -1°C on C3 temp. = +0.7% LNG increase
2% LNG production increase using DIESTA
9 M€/ yr additional incomes for 5.5 MMTPY LNG project
2 M€ additional ACHE cost for DIESTA revamping bundles compared to STD
Payback time < 3 months

AIR FIN COOLER IMPACT ON LNG PLANT SIZE

Air Fin Cooler condensing units are defining the size of the LNG train and are therefore critical items to be optimized in size.

LNG train with conventional tubes in Air Fin Coolers

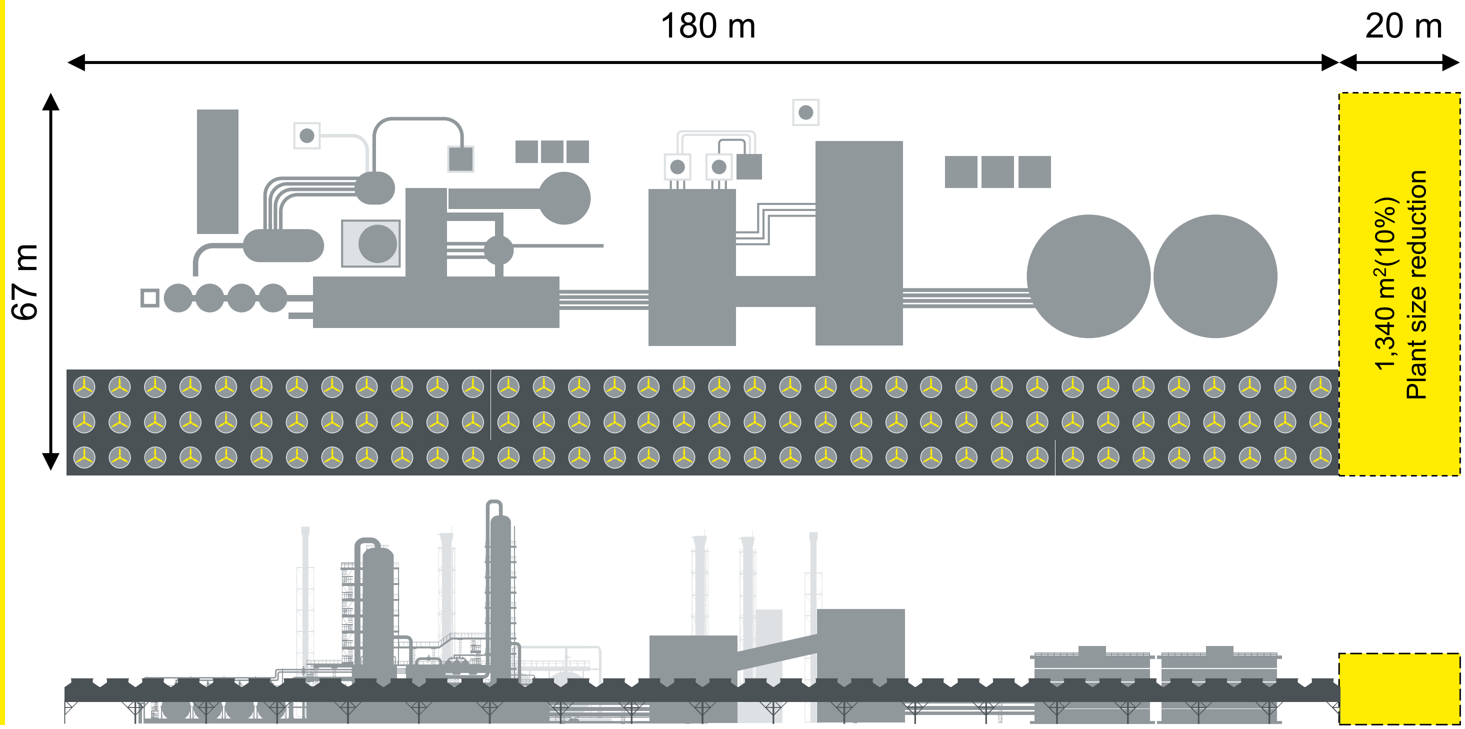


AIR FIN COOLER IMPACT ON LNG PLANT SIZE

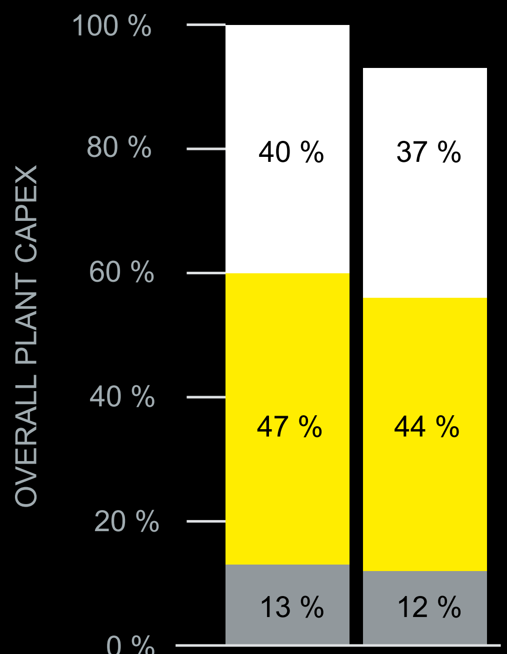
Less AFC surface means:

- Less foundations
- Less cabling
- Less piping
- Less weight of equipment
- Less power consumption
- Less construction cost

LNG train with **DIESTA** tubes in Air Fin Coolers



DIESTA CAPEX EFFICIENCY IN NUMBERS



STD
100% Pipe Rack Length

DIESTA
90% Pipe Rack length

7%

Overall plant costs saving through

10%

Pipe Rack savings by using **DIESTA**

Construction

Procurement

Engineering

CAPEX	STD	DIESTA
Instrum. & Control	6%	5%
Steel structure	6%	5%
Air Fin Cooler	7%	6%
Insulat. & Painting	8%	7%
Management	13%	12%
Site accomodation	17%	16%
Concrete	18%	17%
Piping	25%	24%

8%

Construction costs saving by using **DIESTA**

CAPEX	STD	DIESTA
Transport	7 %	6%
Steel Structure	15%	14%
Air Fin Cooler	17%	18%
Piping	18%	16%
Instrum. & Control	43%	40%

6%

Procurement costs saving by using **DIESTA**

DIESTA CAPEX EFFICIENCY IN NUMBERS

Base:

AFC cost of **$10M**

- Train CAPEX **$125M (100%)**

Save 7%:

Reducing 10% AFC surface by using **DIESTA**

- global savings on train CAPEX =**$8.75M (7%)**
- New Train CAPEX = **$116.25M (93%)**

Let's compare:

Using **DIESTA** leads to **$8.75M** global CAPEX savings

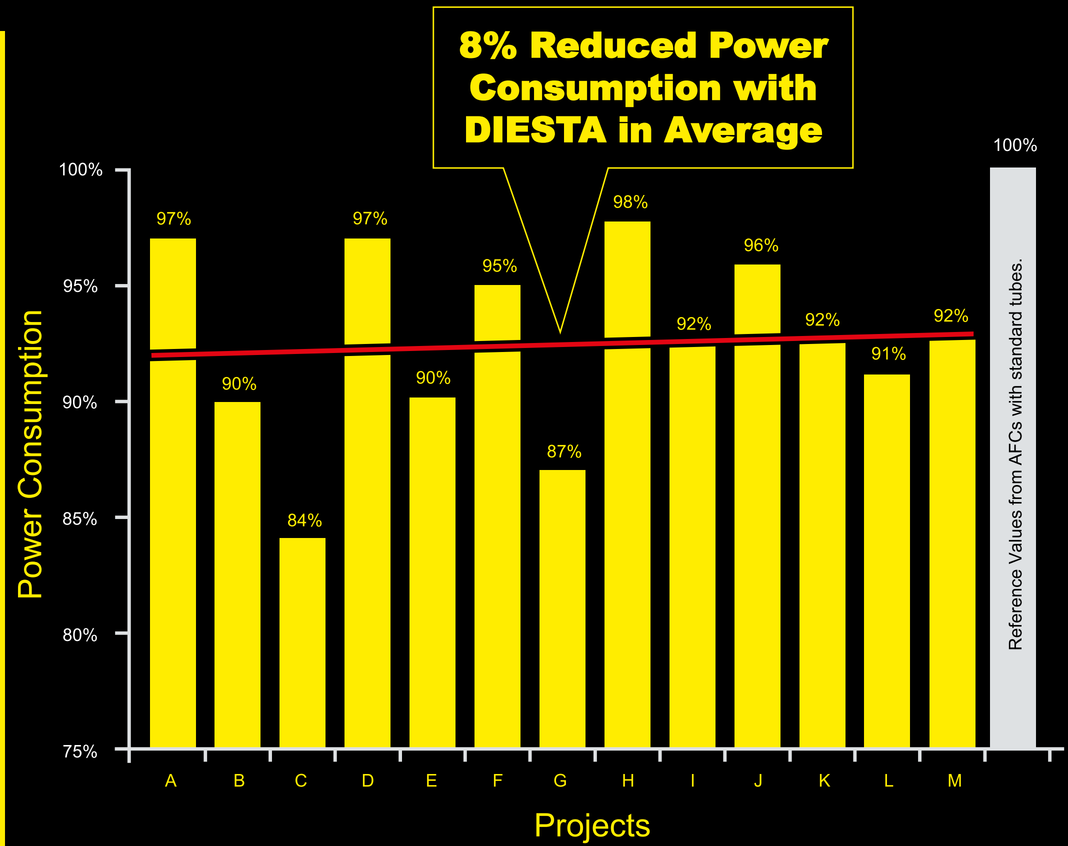
- **$8.75M** represents **87.5%** of the initial costs for Air Fin Coolers

DIESTA REDUCED POWER CONS.= LESS CO_2

Reduced power consumption = up to 30% CO_2 reduction on the ACHE production chain = less OPEX

Example: "African LNG project"

- Base design= 18250 kW
- DIESTA design= 16500 kW
- Leading to 1750 kW reduced power consumption per year
- **Which is -35 MW on a 20 years OPEX saving**



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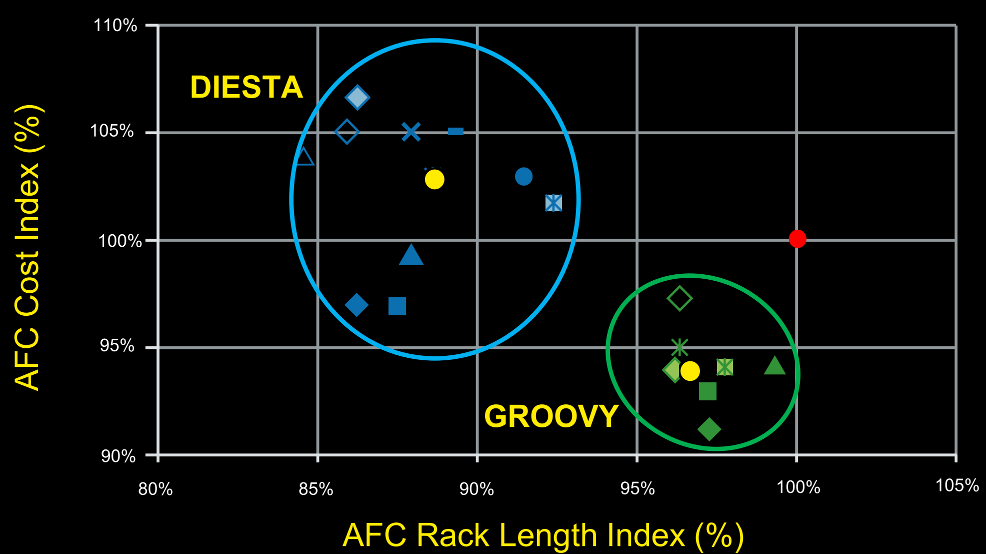
DIESTA REDUCED AFC SIZE = LESS CO_2



GROOVY

- AFRICAN LNG #1 (5 items)
- AFRICAN LNG #2 (3 items)
- CANADIAN LNG #1 (3 items)
- USA LNG #2 (5 items)
- USA LNG #4 (5 items)
- USA LNG #5 (5 items)
- ASIAN LNG (3 items)

STD TUBES

- Benchmark

DIESTA

- AFRICAN LNG #1 (5 items)
- AFRICAN LNG #2 (3 items)
- CANADIAN LNG #1 (3 items)
- CANADIAN LNG #2 (1 items)
- USA LNG #2 (5 items)
- USA LNG #3 (5 items)
- USA LNG #4 (5 items)
- USA LNG #5 (5 items)
- AFRICAN LNG #3 (5 items)
- ASIAN LNG (3 items)
- NORTH EUR. FLNG (3 items)

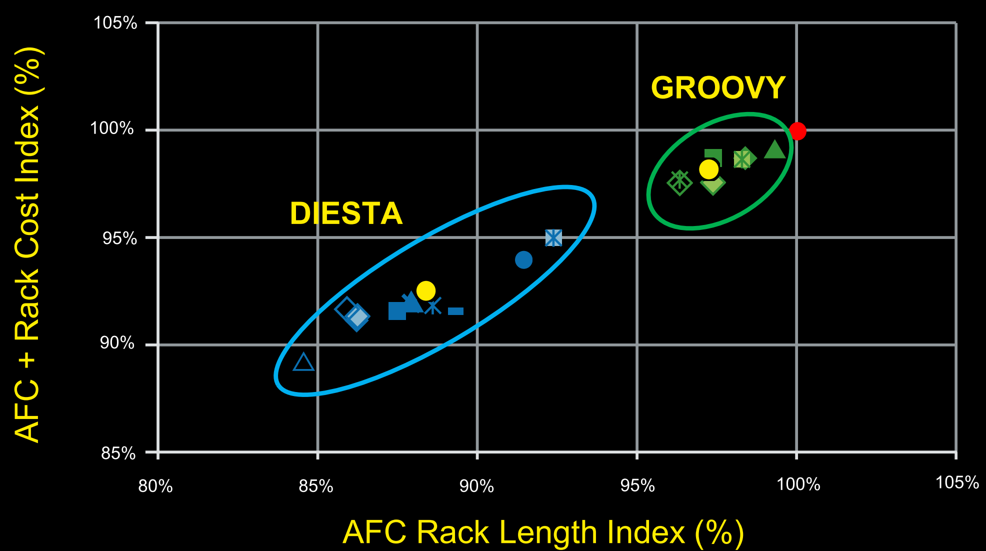
To respect NDAs project names were changed

Use of DIESTA reduces the AFC Size

GHG
Reduction in:

PRODUCTION → **DELIVERY** → **CONSTRUCTION** → **PLANT OPERATION**

DIESTA REDUCED AFC SIZE = LESS CAPEX



GROOVY

- AFRICAN LNG #1 (5 items)
- AFRICAN LNG #2 (3 items)
- CANADIAN LNG #1 (3 items)
- USA LNG #2 (5 items)
- USA LNG #4 (5 items)
- USA LNG #5 (5 items)
- ASIAN LNG (3 items)

STD TUBES

- Benchmark

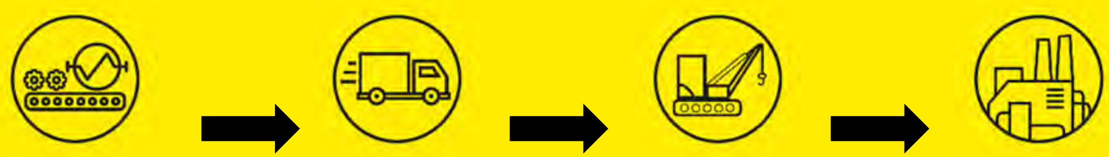
DIESTA

- AFRICAN LNG #1 (5 items)
- AFRICAN LNG #2 (3 items)
- CANADIAN LNG #1 (3 items)
- CANADIAN LNG #2 (1 items)
- USA LNG #2 (5 items)
- USA LNG #3 (5 items)
- USA LNG #4 (5 items)
- USA LNG #5 (5 items)
- AFRICAN LNG #3 (5 items)
- ASIAN LNG (3 items)
- NORTH EUR. FLNG (3 items)

To respect NDAs project names were changed

Use of DIESTA reduces the AFC Size

COST
Reduction in:



PRODUCTION → **DELIVERY** → **CONSTRUCTION** → **PLANT OPERATION**

DIESTA SUMMARY FOR NEW CAPITAL LNG

CAPEX / OPEX REDUCTION

- 10% AFC plot
- 8% Power OPEX
- 7% CAPEX on LNG train

CO_2 EMISSIONS REDUCTION IN:

- Production
- Delivery
- Construction
- Plant operation

DIESTA is the heart of leading AFC performance and **THE CORE OF EFFICIENCY** for LNG trains.

Kelvion

4.

TECHNOLOGY VALIDATION PROGRAM

Fluid Dynamics
Heat Exchange Solutions since 1981

DIESTA &GROOVY FINS PERFORMANCES

Thermal performance validation – Third party “APAVE” certification

Validation of the test bench and the Groovy performances

apave — Thermal performance certification — Aff. n°: 13 463 176 / Date : 07/02/2014 / Page : 1/12

APAVE Nord-Ouest SAS
51, av de l'Architecte Louis Cordonnier - BP247
59019 LILLE Cedex
France
Tel : +33.3.20.42.76.42 - Fax : +33.3.20.42.76.49

GEA BTT
25 rue du Ranzai
BP 902
44025 Nantes Cedex 03
France

Date of intervention : 18/07/2013

Thermal performance certification:

Thermal performance test on specific heat exchanger
EXTRUDED GROOVY and EXTRUDED STANDARD

Executed at “l'école des mines” of Douai

apave — Thermal performance certification — Aff. n°: 13 463 176 / Date : 07/02/2014 / Page : 10/12

8. CONCLUSION

We can attest that:

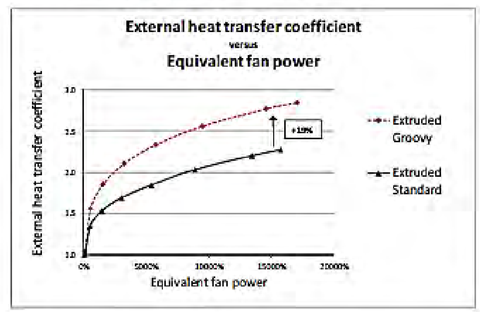
- Sensors calibration,
- The bench design,
- The acquisition system,
- The data processing,
- The sequence of tests,
- The results on the "Extruded standard" battery,
- The results of the "Extruded groovy" battery.

Are comply with the requirements and trustworthy.

apave — Thermal performance certification — Aff. n°: 13 463 176 / Date : 07/02/2014 / Page : 9/12

7. RESULTS COMPARISON OF TWO BATTERIES:

Comparison between the exchange coefficient and the fan power:



Performance index:

Comparison of the two batteries to the equivalent fan power of 15 000%:

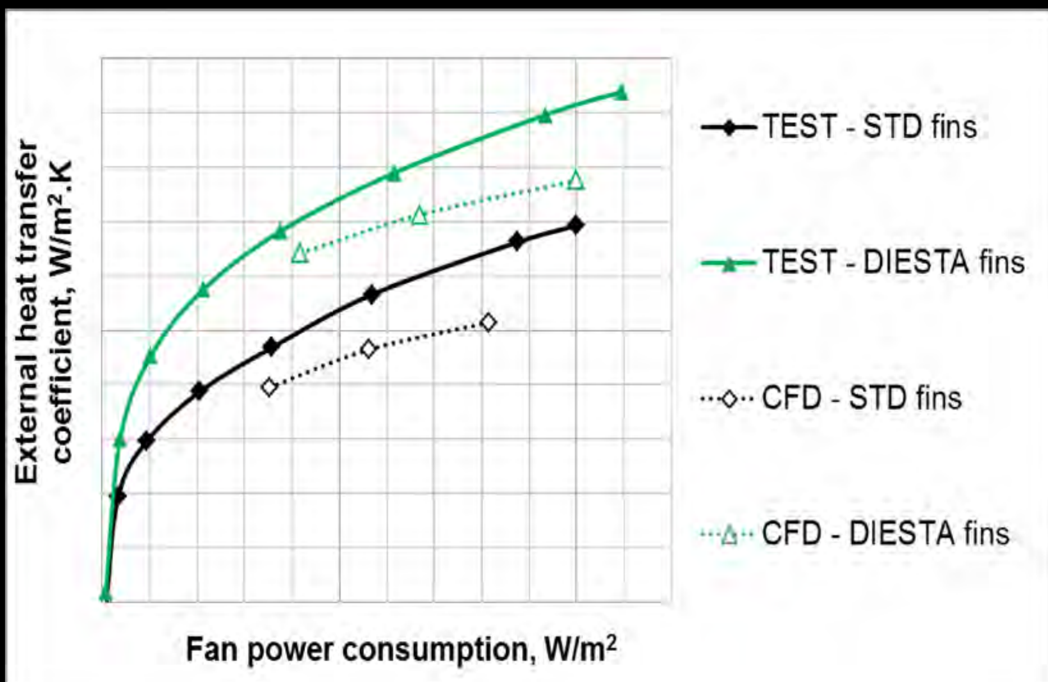
Tube technology	INDEX on external heat transfer coefficient
Extruded Standard	Référence
Extruded Groovy	+19%

The calculation method used in the HTRI software for thermal design calculations and using the characteristics of the "Extruded Groovy" technology shows conservative results compared with test results.

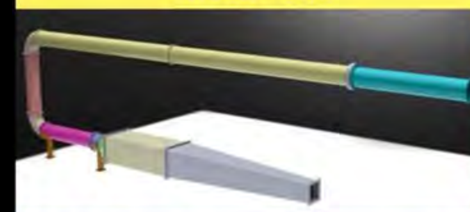
DIESTA & GROOVY FINS PERFORMANCES

External part/ Air side
Thermal performance validation

Up to +15% on external heat transfer coefficient at same fan energy



Test bench



Prototype

± 3% deviation on duty calculation (air vs process)
± 10% mean deviation on air inlet flow
± 1% mean deviation on air inlet temperature

apave — Thermal performance certification

8. CONCLUSION

We can attest that:

- Sensors calibration,
- The bench design,
- The acquisition system,
- The data processing,
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- The results on the "Extruded standard" battery,
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Are comply with the requirements and trustworthy.

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Heat Exchange Solutions since 1981

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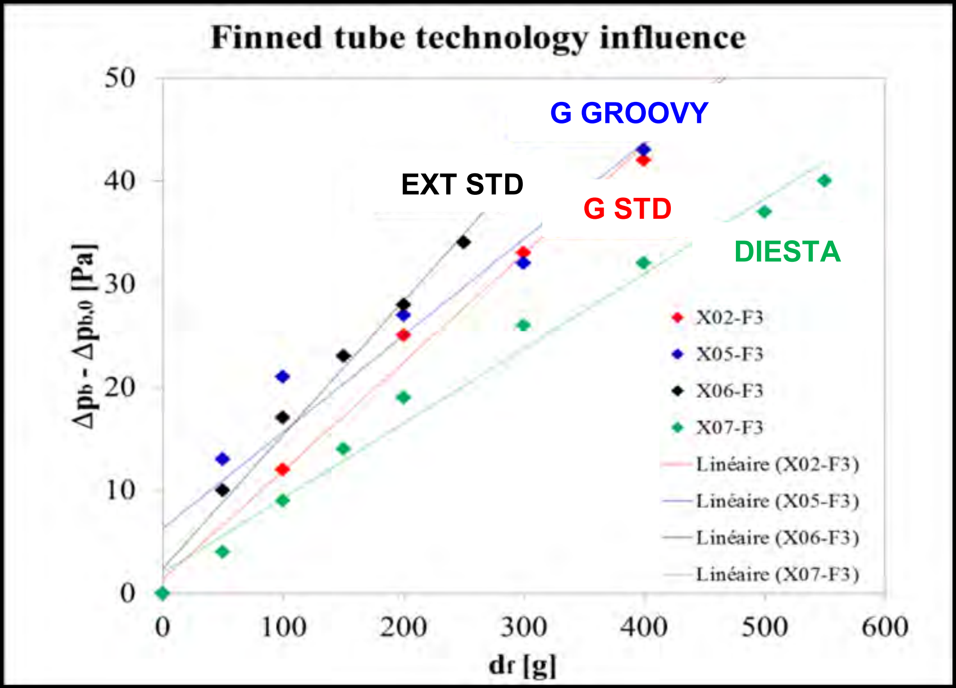
DIESTA & GROOVY FINS PERFORMANCES

External part/ Air side

Fouling performance validation



Test bench

Prototype

Finned tube technology influence on static pressure drop ΔPb – ΔPb,0, function of fouling mass dust df (Ua = 3.0 m/s; OD = 1 in)

Slope of interpolation linear curve represents Uf (Air side fouling growth velocity)

Fouling behavior seems slightly better for DIESTA than EXT STD

DIESTA & GROOVY FINS PERFORMANCES

External part/ Air side

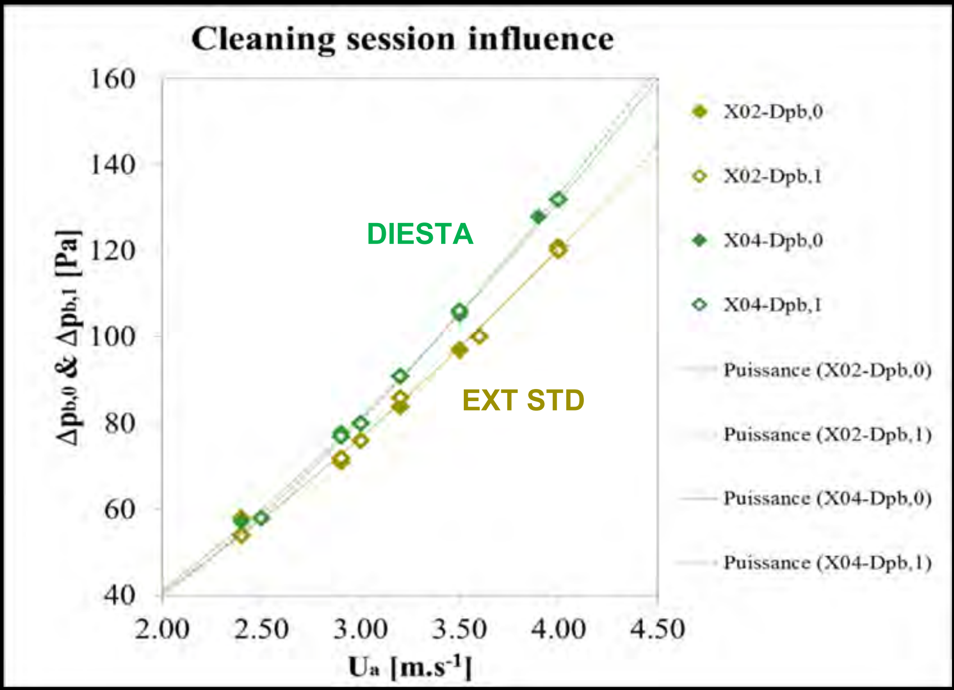
Fouling performance validation

- Dust characterization and spraying process
  - Use normative ASHRAE dust (air filter application)
    - 72% fine silica (particles from 1 to 80 mm)
    - 23% carbon black
    - 5% cotton fibers (ground #7)
  - Fouling process follows:
    - Cleaned prototype after manufacturing process
    - Spraying 50g oil
    - Spraying ASHRAE dust

Prototype view after fouling process

GROOVY FINS PERFORMANCES

- **Cleaning measurements**



Kelvion standard cleaning machine

High pressure water jet
80 bars
5 m3/hr

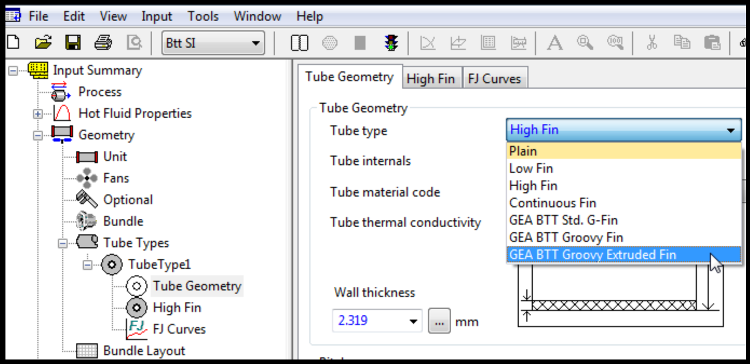
$\Delta Pb,0$ = static pressure drop before fouling
$\Delta Pb,1$ = static pressure drop after fouling and cleaning session

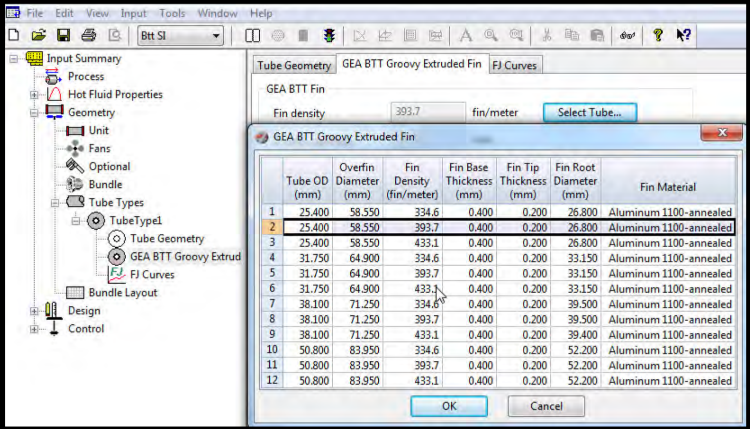
DIESTA fin can be easily cleaned using standard cleaning machine

HTRI DLL SIZING TOOL

Thermal performance validation – DLL Groovy on HTRI

- DLL Groovy developed by HTRI using Kelvion's measurements
  - Available for Xace 9.0
  - License agreement needed
  - Very simple to use
  - Available for Embedded Groovy & Extruded Groovy
- DLL DIESTA G, LLF & C Liquid cooling available by HTRI using Kelvion's measurements
  - Limited to DIESTA consortiumm use
  - Will be made available to limited end users





DIESTA TUBE PERFORMANCES

Thermal performance validation

Development based on unique test bench using high pressure propane loop

3 Different tube internal structures tested:

- Structures 1 and 2:
- Initial targeted application (DIESTA-G/ DIESTA-C)
  - LNG application (clean fluids, low internal fouling, i.e. C3 condenser)
  - Other application with clean fluid (gas compression, depropanizer column, etc.)

- 2nd targeted application (DIESTA-LLF)
  - Fluid viscosity from 1 to 5 cP
  - Naphtha Quench water application (low to medium internal fouling)
  - Other application with medium internal fouling and more viscous liquids (i.e. Gas Oil, Kerosen, lean solvent cooler, etc.)

DIESTA TUBE PERFORMANCES

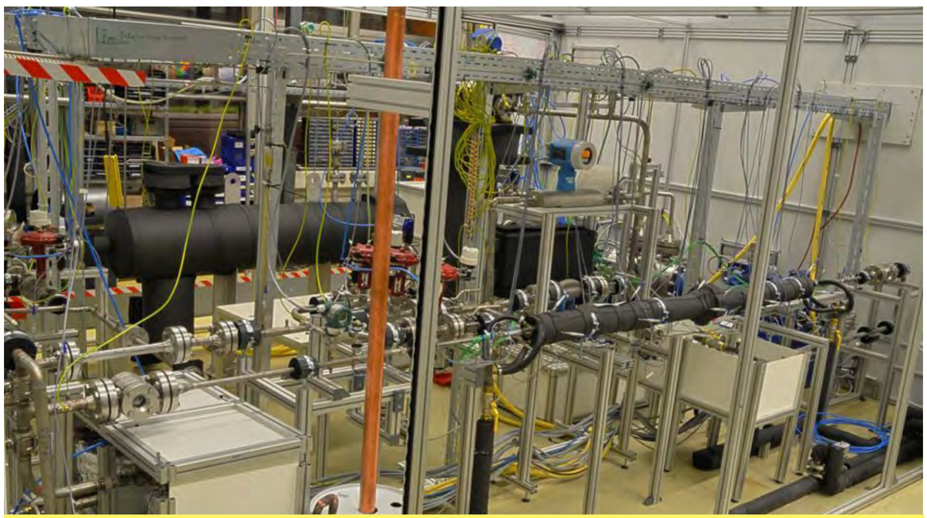
Performance comparison DIESTA tube versus SMOOTH tube

Internal structure	Fluid phase	1"	1"1/4	Comments
DIESTA-C	Liquid ✓	+35% Hi +45% ΔPi	Sept 2022	Constant increases
TOTAL ADEME Convention TOTAL/ADEME 0874C0140	Condensation ✓ Mainly Propane MR	+40% Hi +50% ΔPi Sept 2022	Sept 2022	Performance depends on inlet pressure, mass velocity and vapor fraction
DIESTA-LLF	Liquid ✓	+80% Hi +80% ΔPi	+40% Hi +70% ΔPi	Performance depends on Re and Pr
DIESTA-G	Gas cooling ✓	+40% Hi +35% ΔPi	+20% Hi +30% ΔPi	New development with validated structured Constant increases

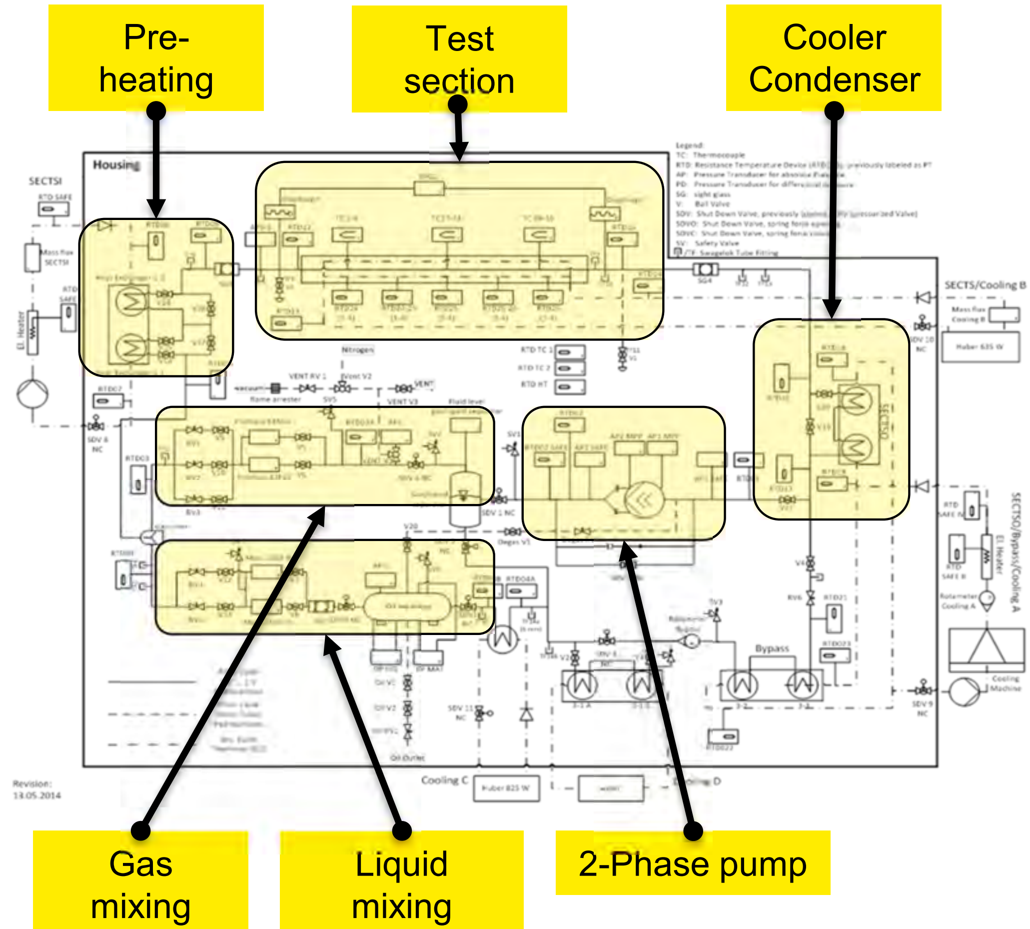
DIESTA TUBE PERFORMANCES

Thermal performance validation

Measurement set-up
Unique test bench using high pressure propane loop



± 6% deviation on duty calculation
Test capacity on propane liquid, gas & condensation
Up to 25 barg



DIESTA & GROOVY: FINS POSSIBILITIES

- DIESTA can now be associated to multiple external fin types depending on the service and thermal conditions:
- DIESTA + Groovy fins
- DIESTA + L flat fins or L Groovy fins
- DIESTA + LL fins
- DIESTA + integral Extruded fins

- Depending on the LMTD, the process temperature and the service in upstream or downstream applications, external heat resistance may change requiring different type of fins.

DIESTA & GROOVY: FINS SELECTION

Parameters	GROOVY fin	DIESTA fin	Comments
Thermal performance	Good for LMTD > 10°C Good for high tube OD	Good for LMTD < 10°C Good for small tube OD	- Slight difference on thermal performance
Patent	Yes, granted in several countries (NA, EU, APAC)	No	- DIESTA fin cannot be patented while GROOVY is patent
Property	Kelvion	Kelvion T.EN TECHNIP ENERGIES Wieland	
Manufacturing possibility	FRA (NAN), USA (CAT), CHI (CHA), QAT (DOH)	DIESTA tube : CHA (China) Alu finning: Catoosa in USA Nantes in France, Doha in Qatar and Changshu in China	- DIESTA fin needs McElroy machine + dedicating tooling - DIESTA tube needs Wieland machine + BIWA machine

DIESTA DESIGN SELECTION CRITERION

Parameters	DIESTA	Comments
Code applicable	API 661 and ASME VIII Div. 1	
Aluminum bare tube protection	Yes (Al 1050 or 1060)	Replacement for extruded finned tube
Bare tube OD	1'' and 1''1/4	1''1/2 and 2'' not available
Bare tube length max.	18.15 m	
Bare tube material	A179, A334 GR6	Testing ongoing for SS
Bare tube type	Seamless	
Bare tube thickness at plain ends	BWG14 mini (2.108 mm mini)	No change for the tube to tubesheet possibilities (expansion or welded) Expansion tests have been successfuly passed
Minimum bare tube thickness	1.808 mm mini	
Bare tube thickness taken for mechanical calculation	1.808 mm mini	Burst tests could be done to increase maximal pressure acceptability
Fin density	10 FPI max	
Fin base thickness	0.4 mm	
Fin material	Al 1100 or 1060	

DIESTA DESIGN SELECTION CRITERION

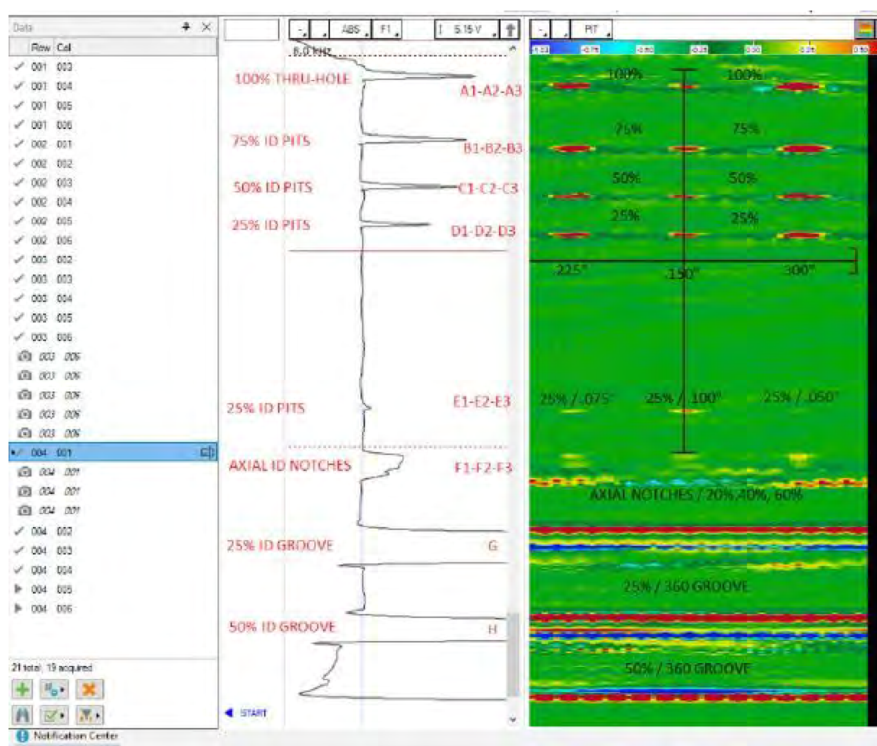
Parameters	DIESTA-LLF	DIESTA-C		DIESTA-G	Comments
Fluid phase	Liquid	Liquid	Condensation	Gas	
Fluid type	All kind (1)	All kind	Light HC (Propane, Propylene, Ethane, MR, etc.)	All kind	(1) If water, it shall be treated in order to avoid corrosion and fouling (ok when closed circuit with fresh or demineralized water)
Internal fouling m2.K/W	Low/ Medium < 0.00050	Clean < 0.00015	Clean < 0.00015	Clean < 0.00015	
Inlet pressure (bar)	-	-	[8; 22]	-	
Re	[5.0^{E03}; 5.0^{E04}]	[4.0^{E04}; 4.0^{E05}]	-	[5.0^{E04}; 1.2^{E06}]	
Pr	[3; 100]	[2.8; 10] (1)	-	[0.6; 1.2]	(1) Tests shall be necessary for Pr > 8
Mass flow (kg/m2.s)	-	-	[100; 750]	-	
Internal thermal resistance Ri	> 30%	> 20%	> 20%	> 20%	DIESTA is not convenient for steam condenser

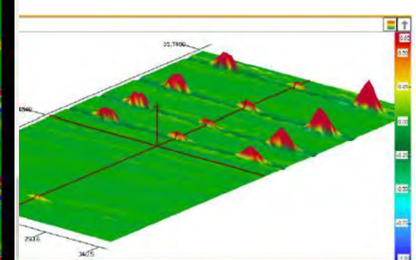
DIESTA TUBES INSPECTION

<u>Final product</u>

Inspection

- Standard hydro-testing
  - Additional inhibitor into hydro-test water
  - Adequate tilting of HEX
  - High pressure air blowing
  - High volume air circulation until tubes are completely dry (warm air 40-50°C)
- Internal **Near Field Array** testing for wall thickness reduction and cracks
  - Tested on DIESTA inner tube





Kelvion

5.

HISTORY / REFERENCES

DIESTA HISTORY

2021-2022

2005 - 2010 | 2010 - 2015 | 2015 - 2020 | 2020 -2025

Start of R&D cooperation Kelvion – TechnipFMC – Wieland (2008)

Market Presentation of DIESTA at 26th WGC, Paris (2015)

Prix Franco-Allemande (2015)

Hydrocarbon Processing publication (2014)

DIESTA Total ADEME Convention (2016)

LNG Industry Journal 1st publication (2015)

1st Reference DIESTA-LLF. VGO cooler at PTT Thailand (2018)

GPA Spring Meeting, Paris (2016)

TOTAL web site highlight & CNBC video (2019)

LNG 18 Perth. TechnipFMC, Improvements of C3 Cycle

13 large LNG projects proposed with DIESTA to date. 3 projects considering it at FEED stage (2017/2020)

LNG Industry Journal 2nd & 3rd Publications (2017)

2nd Reference DIESTA-C&G. Test Plant. Air Liquide (2022)

3rd Reference DIESTA-LLF. Glycol cooler. Arctic-2 (2023)

4th Reference DIESTA G Gas Coolers Compression station (GER) (2021)

5th Reference DIESTA LLF Water Glycol coolers SHELL (2021)

6th Reference DIESTA LLF Lean Amine coolers ADNOC (2021)

7th Reference DIESTA C & G C3 Cond. MR cooler Woodfiber LNG

8th Reference DIESTA C Debutanizer condenser TOTAL E.

9th Reference DIESTA G Gas Cooler CNPC China

DIESTA REFERENCES = « GEWA-PB » + « GROOVY » REFERENCES

1. WIELAND references for GEWA-PB/C/K Bare Tubes for Shell and Tubes application in the Oil and Gas Industry :
   - 150 projects supplied with Shell & tubes structured bare tubes installed in oil & gas Industry projects

2. WIELAND references for GEWA-PB/C/K Bare Tubes for Shell and Tubes application in the LNG Industry:
   - 25 LNG projects supplied with propane chillers and propane condensers

3. KELVION references for Groovy Fins for Air Fin Coolers in the Oil and Gas Industry :
   - 5000 tube bundles installed in Oil & Gas industry to date

4. KELVION references for Groovy Fins for Air Fin Coolers for Gas Condensation & Gas cooling applications :
   - 496 tube bundles installed

5. KELVION DIESTA reference list reaching **103 bundles**
   - PTT Thailand VGO cooler 2 tube bundles (DIESTA LLF)
   - Arctic LNG2 Water Glycol cooling 39 tube bundles (DIESTA LLF)
   - Air Liquide LNG testing plant in France 4 bundles (DIESTA C & G)
   - Vorwerk for ThyssenGas compression station plant Germany 6 bundles (DIESTA G)
   - Shell Water cooler DLNG Germany (8 bundles)
   - ADNOC lean Amine cooler (10 bundles)
   - Total Energies (Normandie) Debutanizer Condenser (2 bundles)
   - Woodfibre LNG C3 condenser and MR cooler (30 bundles)
   - CNPC gas compression station (2 bundles)

Experts in heat exchange – Since 1920

OUR VISION & VALUES

HEAT X-CHANGING THE WORLD WITH SUSTAINABLE ENGINEERED SOLUTIONS

- WE ARE ONE GLOBAL KELVION — ONE KELVION
- WE ARE CUSTOMER DRIVEN — CUSTOMER DRIVEN
- WE ARE OPEN AND TRANSPARENT — TRANSPARENT
- WE KEEP OUR COMMITMENTS — COMMITTED
- WE LEAD BY EXAMPLE — LEAD BY EXAMPLE

RESEARCH & DEVELOPMENT

- 76 R&D Experts
- Innovative Solutions
- Commercial Competitiveness

Innovative Kelvion Technologies (Excerpt)

- DIESTA Tube
- ComFin Safety
- Groovy Tube
- CW Tube
- Optiwave Design
- Ecoloc Gasket System
- Posloc Assembly

YOUR ADDED VALUES

- On Time Delivery
- Global Supply Options
- Commercial Competitiveness
- Energy Efficiency
- Short Lead-Time
- Production Capacity

Fluid Dynamics
Heat Exchange Solutions since 1981

Kelvion

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OUR VISION

HEAT X-CHANGING THE WORLD WITH SUSTAINABLE ENGINEERED SOLUTIONS

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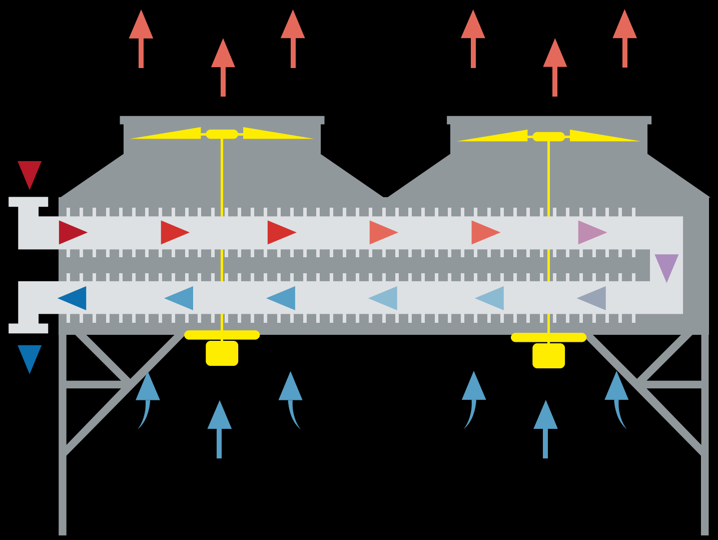
BACK UP INFO AFC

AIR FIN COOLER



OUR EXPERIENCE

15 PATENTS SINCE 2007

OVER 120,000 TUBE BUNDLES SOLD SINCE THE 1970'S

FIRST AIR FIN COOLER INSTALLED IN 1927

WORKING PRINCIPLE

- Working Fluid / Refrigerant flows inside the tubes
- Ambient Air is forced / induced through tube bundles

KEY FACTORS OF AIR FIN COOLER PERFORMANCE

FAN POWER CONSUMPTION

TUBES & FINS

PLOT SIZE

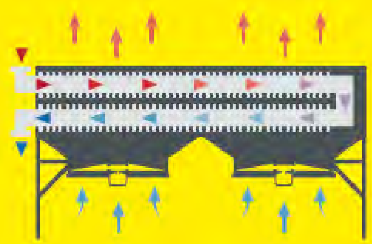
AMBIENT CONDITIONS

AFC FORCED DRAFT

AFC INDUCED DRAFT

MULTIPLE AFC DESIGNS

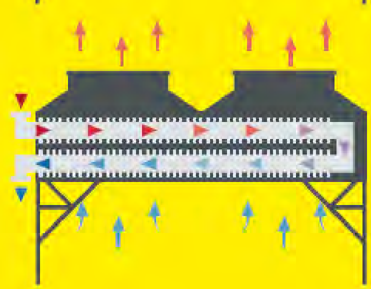
Forced Draft
Using the forced draft, the air is pushed through the tube bundles. This configiration provides easy access to the tube bundles, which supports cleaning, maintenance and replacement of the tubes. By using the forced draft an operation with high air outlet temperatures (>100°C) is possible. Working with cold air requires lower electrical consumption due to lower volume flow at the same mass flow.



Induced Draft
The fan pulls the ambient air through the tube bundle. Thus the chance of recirculation is reduced. Also the casing protects the fin bundles from atmospheric and environmental influences. The low structure design reveals cost and material saving effects.

Natural Draft
Natural ventilation does not need any mechanical device to operate (no fan). Air circulation is induced by convection, due to the temperature differences between the inside and outside and the differences in height. In order to increase the draft, additional rings are added.

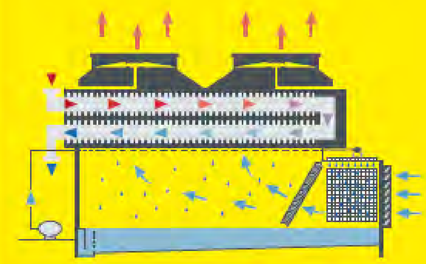
Natural draft is commonly called the "chimney effect". One of the advantages of natural draft is that of a silent and economical unit.

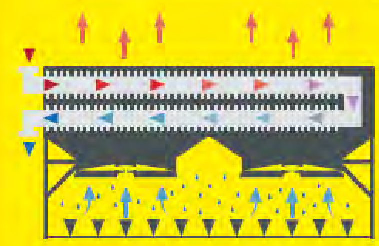


Recirculation
Air cooled heat exchangers with internal recirculation systems are used in extremely cold climates (Canada, Siberia, polar zones...). This system is used to control the cooling air temperature regardless of ambient air temperature. This prevents, for example, clogging of the fluids to be cooled. Internal recirculation systems require the use of positive and negative step autovariable fans.

Air cooled exchanger with air humidification by flow or spray
For certain extreme cases in hot countries with a fluid outlet temperature very close to the ambient air temperature, it is necessary to use water humidification systems by flow (Humidifier) or high pressure spraying (peak cooling / moisturizing). Air cooled heat exchangers with air humidification by flow currently represent a very marginal part of the production of atmospheric air cooled heat exchangers. They are intended to be installed in tropical countries where it is necessary to use the latent heat of evaporation of water to cool the ambient air. Much ancillary equipment, such as the circulation pump, the recovery sump and the humidifiers, is added to the air cooled exchanger to allow the humidification of the intake air.

The humidification systems can be installed after the fact on existing installations when the dry air cooled exchanger in no longer powerful enough (change in climatic conditions or process). This system is made up of humidification sprayers fed by a high pressure pump. The fineness of the droplets allows thermal exchange with the ambient air. This system generally operates without a recovery tank.





OUR MAIN HEADER DESIGNS

Plug headers – generally the most used
This is the most common design due to its high service pressure resistance. It allows as many passes as necessary. Each tube can be serviced by removing the 2 corresponding plugs for cleaning and/or inspection.

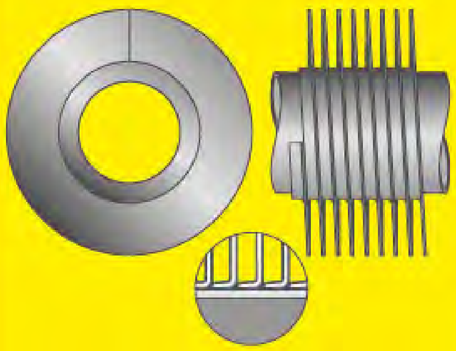
Cover plate header – For very dirty flows
As the name suggests, this design is in the form of a plate that can be removed in a single piece, thanks to its assembly, by bolting to the rectangular flange of the header. This design is ideal for very dirty flows as it is easily accessible for cleaning.

Pipe header
This is a cylindrical header used for high pressure (>200 bar): in such cases, the possibilities for distributing and circulating the fluid are very limited.

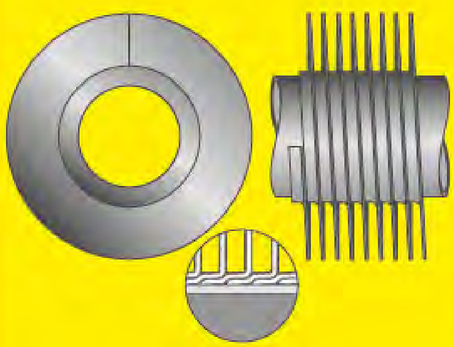
MULTIPLE FINNED TUBES

Rolled fin (type L and KL)
The base of the aluminum strip is folded to form an "L" then laminated and rolled onto the base tube. Then the feet of the fins are joined together to ensure continuous coverage of the base tube surface to protect it from corrosion. The large contact area between tube and fins promotes good heat transfer.

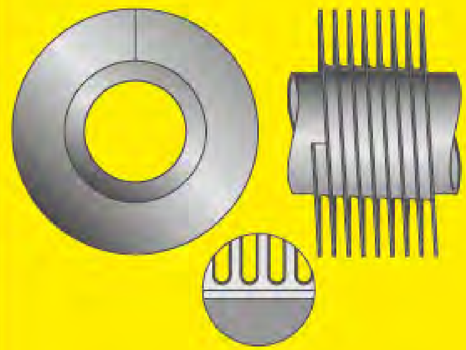
In the type KL version, the fin foot is knurled over its whole width, increasing the contact between the spiral fin and the base tube.



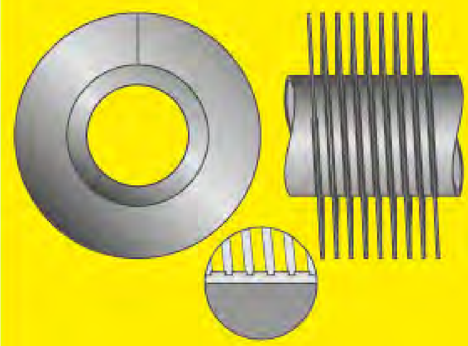
Double wrapped fin (type LL)
The base of the fin is formed into a double stepped "L", which is double the width of a single "L", then rolled around the base tube to overlap with the previous turn of the "LL" fin. The surface of the base tube is thus effectively and continuously protected against corrosion by a double thickness of the strip.



Bimetallic extruded fin (type EX)
The EX (extruded) type is well protected against corrosion as the base tube is entirely covered in aluminum. A smooth steel tube, carefully degreased, is inserted into an aluminum sleeve. The assembly is loaded into a finning machine equipped with three broaches, each spaced at 120 degrees and equipped with multiple disks. These disks, which are stepped in profile and diameter, extrude and profile the fin and then crimp the aluminum fin to the base tube. We have developed a high efficiency bimetallic extrusion with 11 fins per 2.5 cm. It combines a large cross flow section with an extended life expectancy.



Embedded fin (type G)
The fin is formed from a rolled aluminum strip and fitted into the wall of the base tube. A disk or tool creates a groove in the tube wall. A roller laminates the strip to form a spiral. A guide positions the aluminum strip into the groove, and a second disk solidly crimps the base of the strip into the groove by "mating" the edges of the groove.



STUDY CASE QUENCH WATER COOLING

Performance study case 3 for DIESTA-LLF

- **Case 3: Quench water cooler (NAPHTHA application)**
- Performance results

Tube techno	T air in °C	T water out °C	Duty Q	AFC cost	Fan power	Rack length	AFC weight
EXT STD	45.0	60.5	100%	100%	100%	100%	100%
DIESTA-1	45.0	60.5	100%	94%	90%	84%	73%
DIESTA-2	45.0	58.3	111%	112%	100%	100%	86%
DIESTA-3	48.4	60.5	100%	112%	100%	100%	86%

STUDY CASE VGO COOLER

Performance study case 4 for DIESTA-LLF

- **Case 4: Vacuum gas oil cooler**
- Revamping finned tube bundle on existing AFC structure
- Requirement to keep the same structure, same plot, same piping and same fan system
- Viscous product (μ_{in} = 1.74 cP, μ_{out} = 3.33 cP)

Tube techno	T air in °C	T gasoil out °C	Duty Q	AFC cost	Fan power	Rack length	AFC weight
EXT STD	40.0	51.0	100%	100%	100%	100%	100%
DIESTA	40.0	47.2	110%	120%	100%	100%	86%

- +10% on duty and -14% on weight thanks to DIESTA