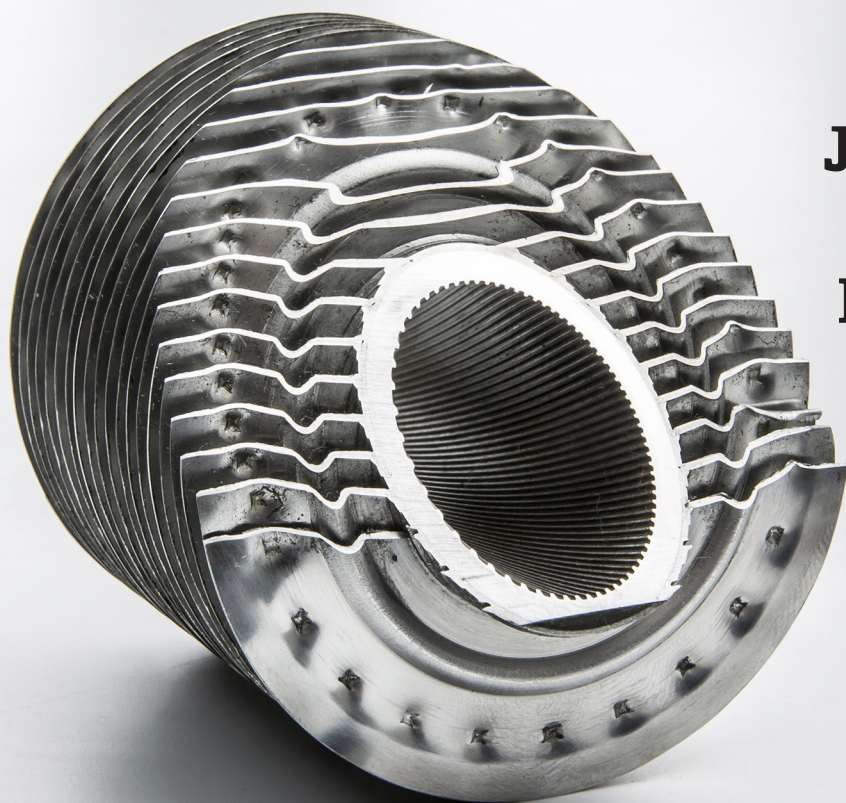
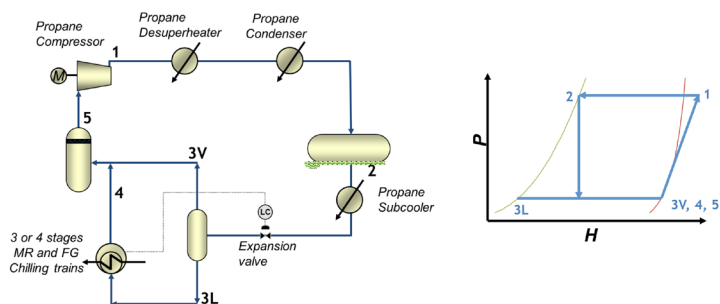


# ENHANCED HEAT transfer solutions

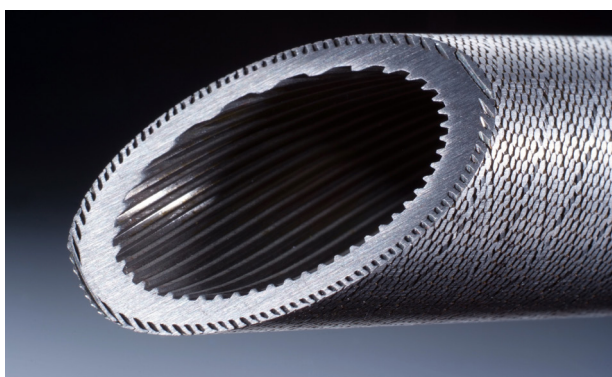


**Jeremy Provost,  
TechnipFMC,  
France,** outlines  
the benefits of  
dual enhanced  
heat transfer  
solutions for  
LNG plants.

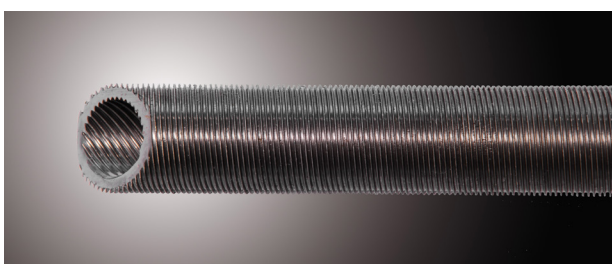
**T**oday, LNG accounts for approximately 2.5% of global energy demand. LNG trade as a share of global gas consumption is even predicted to increase from approximately 10% today to approximately 15% in 2035 within a dynamic natural gas market growing at a rate of 1.8% per year. This means that, despite the current lull, substantial investment in new plants will be required in the 2021 – 2035 period.<sup>1</sup> At the same time, the probability of lower prices exists. Following a fall from approximately US\$16/million Btu in 2014 to approximately US\$10/million Btu in 2015, the



**Figure 1.** Typical propane precooling cycle and the associated refrigeration cycle.



**Figure 2.** GEWA-PB.



**Figure 3.** GEWA-KS.



**Figure 4.** DIESTA.

revenues of the existing, under construction, as well as future LNG plants have been severely affected.<sup>2</sup> One way to enable LNG projects with better sustainability is to find technologies that boost production without impacting the construction and installation cost (CAPEX) and, if possible, the operating cost (OPEX).

## Optimisation of the process scheme

Heat transfer is at the core of any natural gas liquefaction process. On the warm side of the heat exchange path, natural gas, previously cleaned of CO<sub>2</sub>, heavy hydrocarbons and water, is cooled from ambient temperature down to -160°C and then stored in large tanks while waiting for LNG carriers for worldwide distribution. On the cold side of the heat exchange path, refrigerants, usually boiling liquids, at progressively lower temperatures remove heat from the natural gas. The vaporised refrigerants are compressed

and condensed, thereby rejecting the heat removed from the natural gas to the cooling medium through more heat exchangers. When several refrigerants are used, they act in cascade with a dedicated temperature range for each. Those refrigerants can be pure components or mixtures, hydrocarbons, as well as inert fluids, such as nitrogen. The AP-C3MR™ liquefaction process from Air Products combines a precooling section using propane (C3) as refrigerant with a mixed refrigerant (MR) for the liquefaction. Roughly speaking, the precooling cycle ensures natural gas cooling down to approximately -35°C while liquefaction operates from -35°C down to -160°C. The precooling cycle represents a significant 30 – 35% of the total refrigerant compressor shaft power and any reduction is of interest.

As shown in Figure 1, the main heat exchangers of a C3 precooling cycle are of two types:

- Propane evaporators, often referred to as the chilling train, remove heat from the natural gas (also named feed gas) and from the condensing MR that will be used in the liquefaction part. Each chilling train is composed of three to four kettle type heat exchangers installed in series, typically connected tubesheet to tubesheet.
- A propane condenser, which will transfer heat from the refrigerant, condensing at high pressure, to the cooling medium (either water or air).

For a typical 5 million tpy LNG train in a warm climate, these heat exchangers are large (approximately 250 MW rejected from the condenser), and ensuring good performance is essential to maintain production in combination with the massive rotating equipment (compressors and gas turbines). Efficiency to make them compact, and robustness to make them reliable, are the two keywords governing those technologies.

## Dual enhanced heat transfer technology

TechnipFMC has continuously worked to develop enhanced heat transfer technologies and propose innovative and sustainable solutions for LNG projects. The first success was met when the company partnered with Wieland Thermal Solutions. GEWA-PB (Figure 2) and GEWA-KS (Figure 3) are two tube technologies for shell and tube heat exchangers, which are now well accepted by operators. More recently, an advanced air cooling solution called DIESTA (Figure 4) has been

introduced by including Kelvion to the TechnipFMC and Wieland Thermal Solutions cooperation.

## GEWA-PB

GEWA-PB is the solution dedicated to external pure light hydrocarbon boiling. The use of dual enhanced GEWA-PB tubes started with the debottlenecking of three trains in Qatar followed by the six AP-X mega LNG trains (7.8 million tpy per train). Numerous projects have

selected and operated GEWA-PB equipped propane feed gas and MR chilling trains over the last 10 years and still do.

Using GEWA-PB dual enhanced tube in the design of the chillers, the chilling train length can be reduced in the range of 20 – 30% for a given temperature approach. Another benefit, however, is achieved by lowering the temperature approach to 2°C. This reduction results in an increase of 1% of LNG production.<sup>3,4</sup>

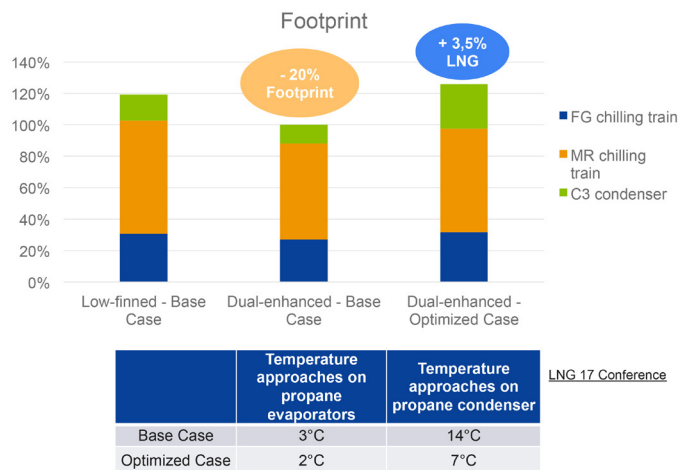


Figure 5. C3 precooling cycle optimised with GEWA-PB and GEWA-KS.

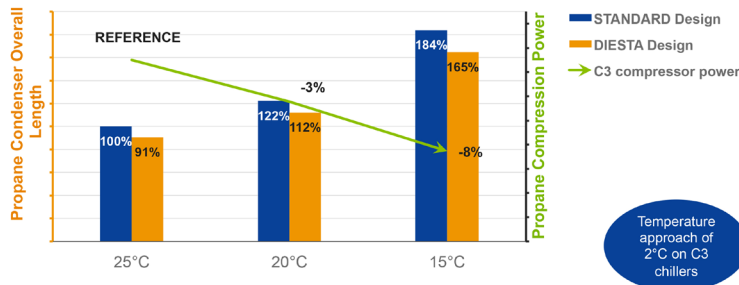


Figure 6. Optimised GEWA-PB and DIESTA combination.

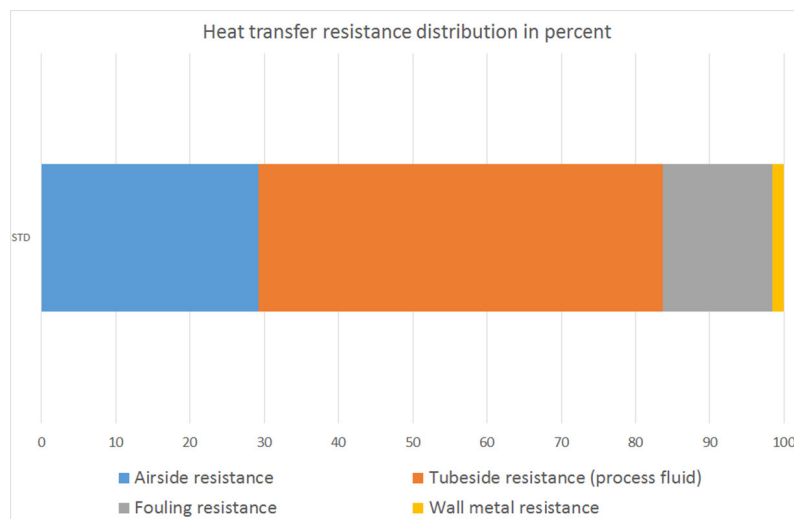


Figure 7. Vacuum gas oil (VGO) cooler heat transfer resistance distribution.

## GEWA-KS

GEWA-KS is the solution dedicated to light hydrocarbons condensing externally with cooling water flowing on the tube side. The GEWA-KS tube allows an increase in the shell side condensing heat transfer coefficient, leading to a more compact design in identical operating conditions. Several projects, such as the six AP-X mega LNG trains, are equipped with this technology. GEWA-KS allows the temperature approach of the propane condenser to be reduced, while keeping the same layout. Today, up to 5720 km of GEWA-PB and GEWA-KS have been manufactured and installed.

## DIESTA

Dedicated to air coolers and optimised for propane condensation, DIESTA is a dual enhanced finned tube jointly developed by TechnipFMC, Wieland Thermal Solutions and Kelvion with the support of the French Agency for Energy (ADEME) and Total.

This technology combines and improves the legacy of two technologies: the enhanced finned tube, so called Groovy fins, developed by Kelvion, and the GEWA-PB inner geometry, developed by TechnipFMC and Wieland.

By proposing an optimised combination of dimples and grooves, DIESTA delivers a higher air side heat transfer coefficient, while limiting the impact on the pressure drop. For a propane air cooled condenser, the air side thermal resistance represents approximately 60% of the total, but the tube side still represents 30% and when the size of the air cooler is 200 m long by 16 m wide, it is valuable to improve the tube side heat transfer coefficient. DIESTA allows this due to an inner groove dedicated to propane condensation.

The development programme included a rigorous test campaign. Tube to tubesheet connections, a fin pull test, fouling and cleaning behaviour, etc., were all successfully checked and validated

during this development<sup>5</sup> following the step wise approach of API 17N, Technology Readiness Levels in the oil and gas industry.

### Optimised precooling cycle

The precooling cycle is often designed with temperature approaches that do not reflect the potential of dual enhanced heat transfer technologies.

A 3°C temperature approach is often applied in the chilling train while a 25°C temperature approach is considered for the propane air cooled condenser. Today, such approaches are achievable using standard technologies, such as low fin tubes in the chillers and extruded or wrapped under tension finned tubes in the air cooled condenser. Using dual enhanced heat transfer technologies allows a significant saving in terms of the size of this equipment, but whereas the CAPEX may be improved a little, in operations, revenue (Figures 5 and 6) will remained unchanged.

Reduced temperature approaches with dual enhanced tubes offer a more sustainable solution by increasing the production and thus the revenue.

Based on site data collected on heat exchangers equipped with GEWA-PB, a temperature approach of 2°C in the chilling trains is achievable. For the air cooler, a 20°C temperature approach is also achievable within a standard layout.

To evaluate the benefit in reducing the temperature approaches, a case study was conducted<sup>6</sup> based on the following:

- A 5 million tpy LNG train.
- 70 – 87 MW gas turbines.
- An ambient air temperature of 29°C.

The selected combination (2°C temperature approach in the chilling train and 20°C temperature approach for the air cooled condenser) frees up 3% extra power on the C3 compressor that can be redistributed between the high pressure, medium pressure and low pressure MR compressors, directly increasing the LNG production by 3%. The 15°C temperature approach results in an excessively long air cooler bank.

As shown in the last row of the Table 1, an added benefit is no increase of the CO<sub>2</sub> footprint as the power is not increased. CO<sub>2</sub> production per tonne of LNG is even decreased by the same figure of 3%.<sup>7</sup>

### From study to reality

When starting the marketing of DIESTA two years ago,<sup>5</sup> the solution was available only for LNG applications. Since that time, the addition of new surface structures has opened up opportunities in non-LNG projects, either for grassroot facilities or for



**Figure 8.** Bottom structure and fan ring and plenum assembly at ground.



**Figure 9.** Erection of the lower part on the pipe rack.

**Table 1.** Summary table of the optimised combination of GEWA-PB and DIESTA

|                                               | Reference case | Case 1 |
|-----------------------------------------------|----------------|--------|
| Propane evaporators temperature approach (°C) | 3              | 2      |
| Propane condenser approach (°C)               | 25             | 20     |
| Propane condenser length (m)                  | 224            | 252    |
| Propane compression power (MW)                | 75.9           | 72.1   |
| Total compression power (MW)                  | 190.1          | 190.1  |
| LNG production increase (%)                   | Reference      | +3     |
| Emissions reduction (%):                      | Reference      | -3%    |
| Tonnes CO <sub>2</sub> /tonne LNG             |                |        |

revamping/debottlenecking. Some examples of these new services include the following:

- Quench water coolers for naphtha cracking ethylene plants.
- Vacuum gas oil (VGO) distillation coolers for refineries.

As one example, a special tube side enhanced structure for low fouling and viscous liquids was developed and successfully installed. On the air side, the same enhanced finned structure is manufactured. The

**Table 2. DIESTA benefits for the VGO cooler**

| Same power consumption       | DIESTA/standard |
|------------------------------|-----------------|
| Footprint                    | Identical       |
| Finned area                  | -20%            |
| Weight                       | -4%             |
| Tonne of product/electric kW | +14%            |



**Figure 10.** DIESTA bundle installation with typical plywood protection plates.



**Figure 11.** VGO cooler equipped with DIESTA tubes.

analysis of the heat transfer resistance distribution for a VGO cooler (Figure 7) helps determining the gains shown in Table 2.

As shown in Figures 8, 9, 10 and 11, there is no difference between installing and erecting a DIESTA air cooler versus a standard one. Firstly, the lower part of the steel structure, the plenum chambers and fan rings are assembled at ground for this forced draft air cooler (Figure 8). Then, the prepared structured is lifted and bolted to the main pipe rack (Figure 9). DIESTA bundles are installed on the top the structure (Figure 10) to be put finally in operation (Figure 11).

## Conclusion

Dual enhanced tubes are now well established technologies that can be used to reduce space requirements or more profitably to increase production and associated revenues. This is particularly true for the propane precooling cycle of LNG plants based on the leading AP-C3 MR process for which the combination of GEWA-PB and DIESTA can provide an increase in LNG production up to 3% without impacting power consumption and with a limited impact on layout.

DIESTA has spread its benefits in other areas and has been successfully installed in a refinery confirming the great potential of the technology for a wide range of applications. [LNG](#)

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