

INCREASE LNG PLANT PRODUCTION BY USING DUAL ENHANCED HEAT TRANSFER SOLUTIONS

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ABSTRACT

Dual enhanced tubes for LNG train pre-cooling circuit heat exchangers are now well known following their systematic use in all six AP-X trains in Qatar. Operational feedback since first startup in 2009 has been that the expected performance is met and even exceeded. For a given plant capacity, dual enhanced tubes provide a reduction in equipment size and associated cost savings. This technology has now been adopted for several grass root LNG plants as well as being considered for debottlenecking. The process design must be optimised to get maximum benefit from dual enhanced tubes. A balance is struck between reduction of the exchanger surface area and the reduction of the refrigerant compressor shaft power that results from using the reduced cold end temperature approach that is possible with this technology. This paper will describe the results of a study to assess the potential LNG production increase. Keeping the same liquefaction process (C3/MR) but using dual enhanced tubes, an increase in LNG capacity for constant refrigerant power and without any impact on the liquefaction unit CAPEX will be demonstrated. The paper will show that the use of dual enhanced tubes at an early stage of a project allows a significant increase in LNG plant capacity while minimizing the impact on :

• heat exchangers size, • plot plan • equipments costs • installation costs.

INTRODUCTION

Dual enhanced tubes for LNG train pre-cooling circuit heat exchangers are now well known following their systematic use in all six AP-X Mega-LNG trains in Qatar as well in the three first LNG trains after debottlenecking (all those trains being operated by QatarGas). Operational feedback from the six Mega-trains since first startup in 2009 has been that the expected performance is met and even exceeded. For a given plant capacity, dual enhanced tubes provide a reduction in equipment size and associated cost savings for a given targeted LNG production. This technology has now been adopted for several grass root LNG plants as well as being considered for debottlenecking.

Over the last 18 years, Technip and Wieland have collaborated to qualify dual enhanced tubes with the aim of becoming a hydrocarbon processing industry standard especially for large shell-and-tube heat exchangers for grassroots LNG and ethylene plants. This long experience allows the process scheme taking great advantage of the high efficiency tubes performances to minimize shell size and optimize fluid temperature approaches.

As LNG plant design is often based on utilizing the maximum power available from selected gas turbines driving the refrigerant compressors, one of the well-known possibilities for increasing the LNG plant throughput is by decreasing the temperature approaches on the refrigerant evaporators and condensers.

Shell and Tube heat exchangers are the conventional technology used for these services but limits are reached when temperature approach reduction is targeted:

- Onset of nucleate boiling

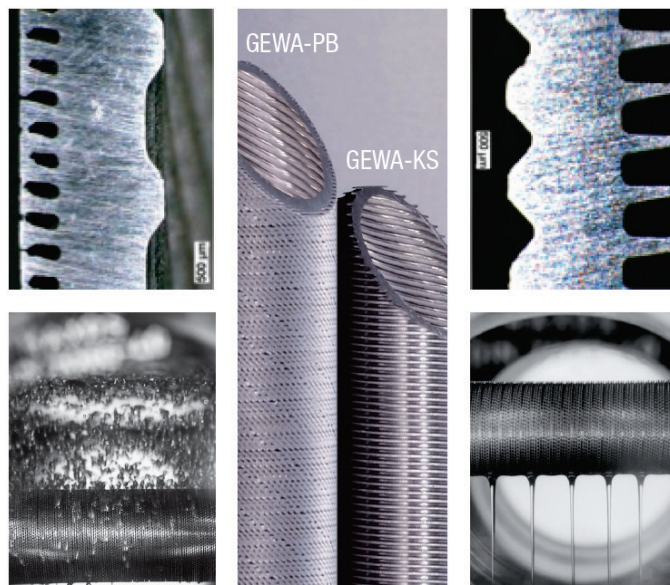
- Condensing coefficient
- By passes

Dual-enhanced tubes enable:

- High heat transfer coefficients at low temperature approaches
- Compact designs compared to plain tubes

The value of enhanced surface heat exchangers is illustrated in this paper through a comparative study of a complete LNG train with and without the improvement proposed.

Wieland GEWA-PB and GEWA-KS are used in the propane exchangers of LNG trains in Qatar, and soon in Papua New Guinea and Australia.



ASSUMPTIONS

As a basic case for the process study a 3.9 MTPA LNG train based on the Air Products (AP) Propane pre-cooled Mixed Refrigerant (C3/MR) liquefaction process has been considered.

- Cooling medium: cooling water, supply temperature: 28°C.
- Availability: 93%
- Feed gas from NGL Recovery unit

Table 1: Studied Cases

	Temperature approaches on propane evaporators	Temperature approaches on propane condenser
Base Case	3°C	14°C
Case1	2°C	14°C
Case 2	2°C	10°C
Case 3	2°C	7°C

This study shows the benefits of a reduction on the propane chillers and the propane condenser temperature approach on the LNG yearly production with a C3/MR unit based on the AP propane pre-cooled Mixed Refrigerant process.

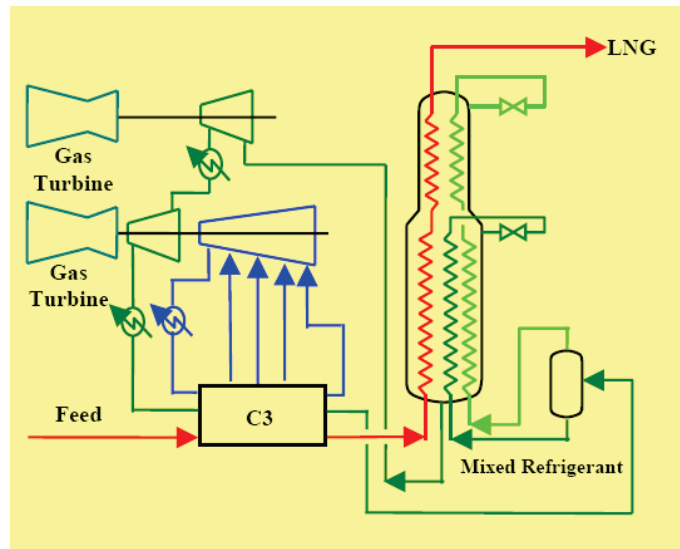


Figure 1: Air Product C3/MR process scheme (Split MR™)

A reduced temperature approach can be used to raise cold side temperatures or lower hot side temperatures.

In this first illustration, we consider fixed external temperatures (cooling water, Feed Gas and Mixed Refrigerant) and variation of the propane conditions.

The following diagram enables us to appreciate the gain in terms of compressor work when the condensing temperature and pressure decreases and the chillers operating temperature and pressure increases.

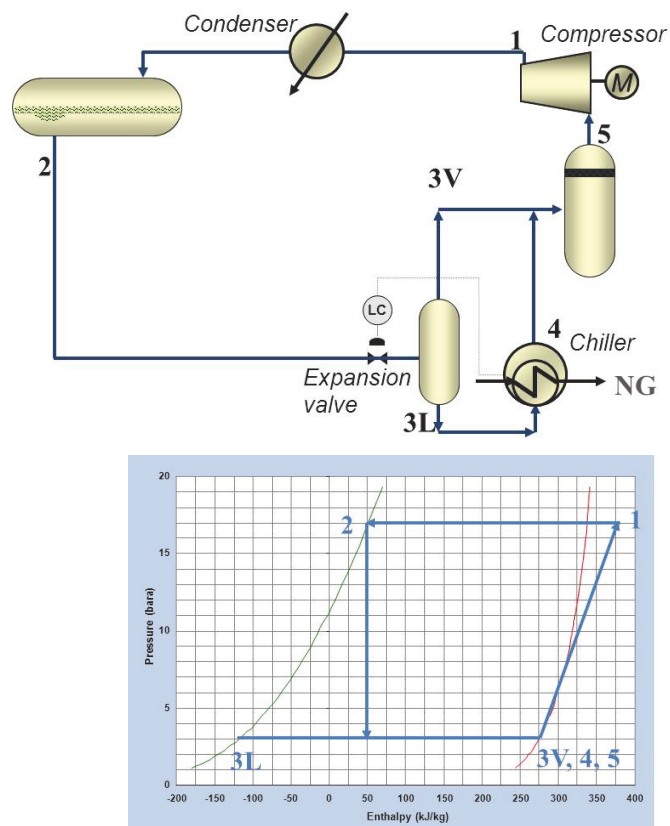


Figure 2: Enthalpy diagram

The 1-2 line goes down when the temperature approach is reduced on the condenser (lower condensing pressure) and the 3L-3V line goes up when the temperature approach is reduced on the chillers meaning that the chiller pressure is increased.

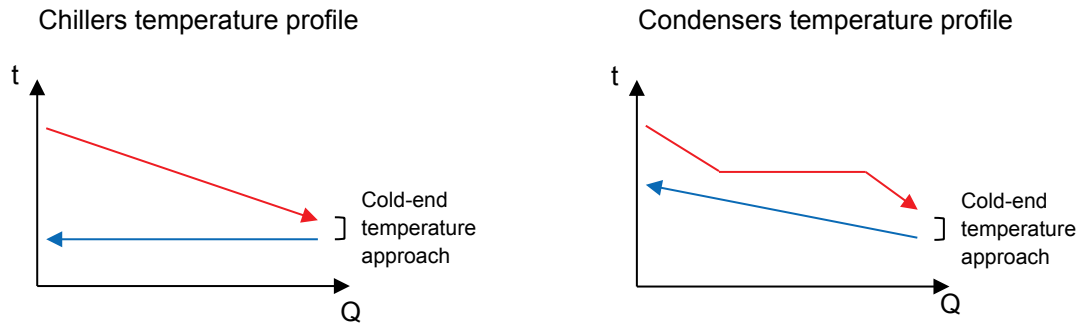


Figure 3: Temperature profiles

In practice it is of more interest to take advantage of smaller temperature approaches to increase LNG production.

This is furthermore the effect of retubing existing exchangers with Dual enhanced tubes.

It results directly on a reduced Propane Compressor consumed power which is in relation with the 5-1 line. The available power can be used to increase the Propane flowrate in order to increase both the Mixed Refrigerant flowrate and the Feed Gas flowrate.

SMALLER TEMPERATURE APPROACHES BRING INCREASED LNG PRODUCTION AT CONSTANT COMPRESSOR POWER

Table 2 summarizes the increased in LNG production considering constant total power for the Propane and the Mixed Refrigerant compressors for the studied cases in Table 1. The specific power reflects increased production thanks to better efficiency brought by the enhanced heat exchanger surfaces. The associated production gain is for a nominal plant design capacity of 7.8Mtpa (2 trains of 3.9Mtpa each) :

Table 2: Process impacts

	Base Case 3K on Chillers 14K on Condenser	Case 1 2K on Chillers 14K on Condenser	Case 2 2K on Chillers 10K on Condenser	Case 3 2K on Chillers 7K on Condenser
Total compressor power (MW)	268	268	268	268
Specific power ⁽¹⁾ (kWh/t)	0.34	0.34	0.33	0.33
Production increase (%)		~1	~2	~3.5

(1) Including Feed gas booster, BOG compressor, 5 MW other consumers....

In the base case the levels of propane pressure are respectively fixed at 1.25 bara, 2.5 bara and 4.75 bara for each propane compressor stage.

The MCHE is optimized for each case in terms of MR composition and flow rate, MR pressure at MR Compressor inlet, interstage temperature between hot and cold bundle. The pressure drop in the exchanger remains the same for all studied cases. As the optimization of the MCHE is subject to Licensors design and as Licensor has not been consulted for this study a temperature approach of approximately 3°C has been set for both bundles.

From a general point of view as the feed gas inlet temperature to MCHE decreases in all cases compare to base case it is easier to liquefy. More feed gas flow rate can be handled by MCHE and MR flow rate increases.

THERMAL DESIGN PHILOSOPHY

Figure 4 shows a typical scheme for a propane refrigerant loop with the following exchangers:

- The Propane Condenser,
- The Propane / Mixed Refrigerant chilling train (3 or 4 kettles),
- The Propane / Feed Gas chilling train (3 or 4 kettles).

And

- The Propane Desuperheater, for which the outlet temperature is controlled 5°C above dew point,
- The Propane subcooler.

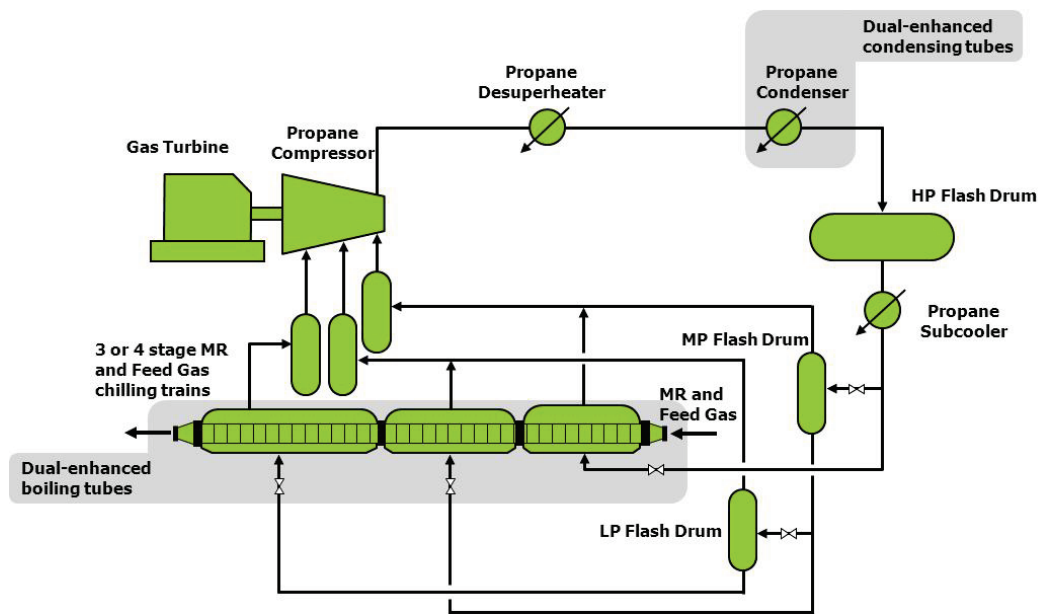


Figure 4: Simplified Refrigeration loop scheme

The key heat exchangers are the Propane/Mixed Refrigerant chillers, the Propane/Feed Gas chillers and the Propane Condenser. The reduction on the temperature approach on these particular exchangers enables an increase in LNG production. For all studied cases, the chilling trains and the propane condenser have been designed each with the suitable Dual-enhanced tubes.

For boiling services, the minimum temperature difference, for the onset of nucleate boiling, required between the tube wall and the bulk, for the GEWA PB structure is lower than for standard tubes. This allows a temperature approach reduction without any significant impact on overall heat exchanger dimensions.

For condensing applications, in contrast of boiling, there is no change in the heat transfer mechanism as temperature differences decrease. There nevertheless remains a large increase in the required surface area with plain tubes. The advantage of the GEWA KS is to balance the temperature approach reduction by the heat transfer coefficient increase, leading to a minimal increase in surface area.

The desuperheater and the subcooler have been included for completeness; the impact on the global results is negligible. Those two exchangers are not proposed with dual enhanced tubes. Their design is almost identical for all studied cases.

IMPACT OF SMALLER APPROACHES ON SURFACE AREA, FOOTPRINT AND COST

Figure 5 shows the relative surface area (expressed as “equivalent plain”) for the 4 studied cases:

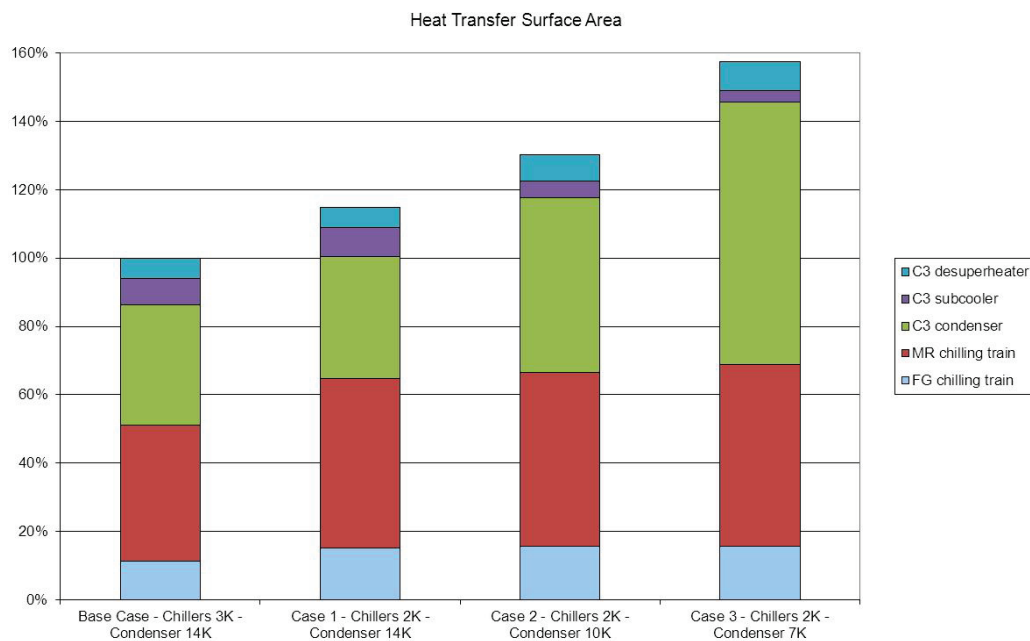


Figure 5: Effect on the Heat Transfer surface area

The chilling trains are both impacted (approximately +30%) by the temperature approach reduction from 3°C to 2°C.

Reducing the propane condenser approach is a key way to increase LNG production significantly with a substantial impact on the surface area of this equipment.

Figure 6 shows the relative foot print:

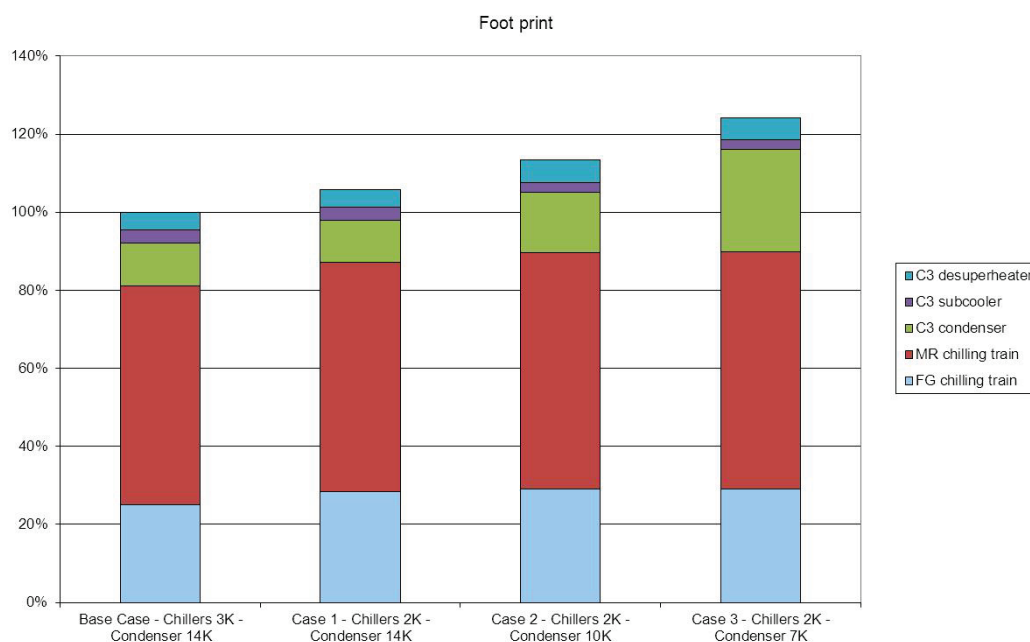


Figure 6: Effect on the foot print

The impact on the footprint is much less than for surface area.

The chilling trains are the most space consuming but plot space is driven by the kettle shells that change very little.

Figure 7 shows the variation in equipment cost:

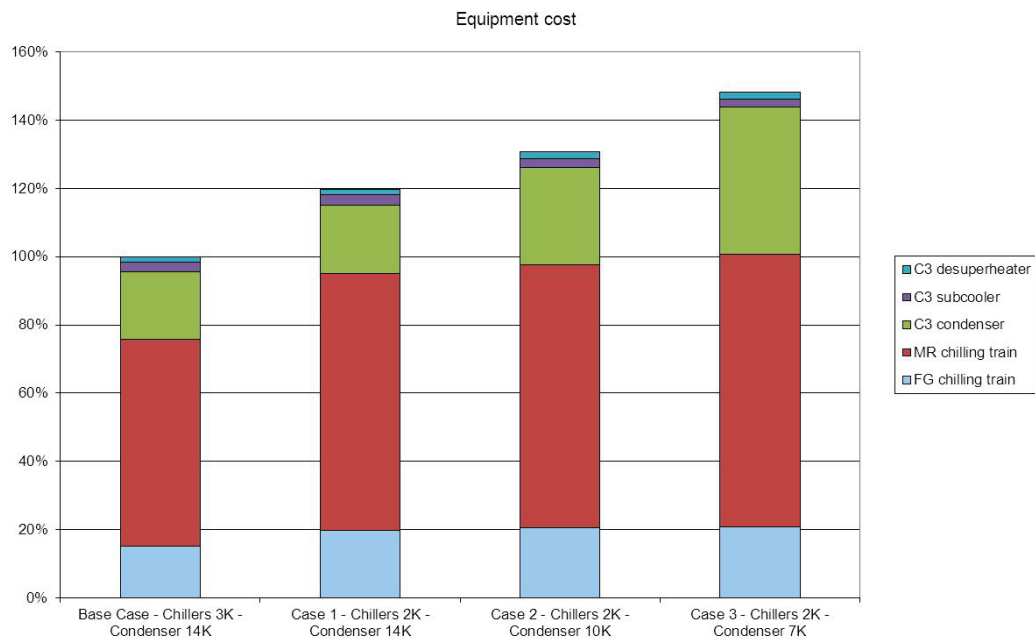


Figure 7: Effect on the equipment cost

The equipment cost study is based on the complete heat exchanger at the factory gate.

The total cost of heat exchangers in the refrigeration loop, is mainly driven by the chilling trains. Even if the major part of the cost impact for Case 3 (the most effective in view of the LNG production) comes from the increase in the condenser price, its share within the total stays below 30%.

LNG PRODUCTION INCREASE VS. DESIGN AND COST

The impact on the design and the benefits gained thanks to the temperature approach reductions on both the chilling trains and the condenser are detailed below for each case. The Base Case is the reference (3K approach on the chillers, 14K on the condenser).

Case 1 – 2K approach on the chillers, 14K on the condenser:

- +15% on the total installed surface area and +6% overall footprint
- 20% total equipment cost increase
- ~1 % LNG production increase

Case 2 – 2K approach on the chillers, 10K on the condenser:

- +30% on the total installed surface area and +13% overall footprint
- 31% total equipment cost increase
- ~2% LNG production increase

Case 3 – 2K approach on the chillers, 7K on the condenser:

- +57% on the total installed surface area and +24% overall footprint
- 48% total equipment cost increase
- ~3.5% LNG production increase

The overall cost of the heat exchangers in question is of the order of \$16MM for a 7.8Mtpa plant capacity (2 trains of 3.9Mtpa each), but this small amount, given the scale of the project, is offset by the large LNG production increase that can generate additional revenue every year.

In the case of debottlenecking an existing LNG train where LNG output is constrained by the propane refrigeration cycle only, additional LNG can be obtained for an investment of around 60\$/tpa.



Figure 8: Expected additional income for Case 3

Based on a current LNG price of 10 \$/MM Btu, the maximum extra cost of such a production increase is paid back in less than 1 month.

CONCLUSIONS

The use of dual enhanced tubes in the shell and tube exchangers of the propane cycle of LNG trains is a cost effective way of producing additional LNG.

Dual-enhanced tubes are a technological breakthrough with primary applications in clean processes such as in LNG plants for C2 and C3 refrigeration systems. The advantages are robust TEMA shell&tube exchangers with compactness, lightness and more heat exchange.

Dual-enhanced tubes promote very high thermal efficiency, and are suitable for boiling and condensing at small temperature differences where standard tubes are no longer applicable. Beyond this, system improvements can be achieved with savings regarding refrigerant and process fluid inventory as well as reduced pipe racks, support structures and foundations.

Propane condensation has been studied here only with cooling water within a Shell & Tube exchanger whereas the industry is leaning towards air cooling. Technip is willing to extend the approach to consider propane condensation in an air cooler.