LNG heat exchangers

TEP-10

2008
MFC - LNG process temperature profile

Temperature profile

Temperature

Duty

Duty

Temperature

Warm

Cold
Idle work in refrigeration
The Carnot process

Combined 1st and 2nd law

Heat release to environment

Supplied energy – Ideal work

Heat release to process fluid

Reference temperature

Temperature for refrigeration

$Q_{\text{ref}} = T_{\text{ref}} \Delta S$

$W = Q_{\text{ref}} - Q_0 = (T_{\text{ref}} - T_0) \Delta S$

$Q_0 = T_0 \Delta S$
Ideal work – mixed refrigerant
Sum of small Carnot processes
Lowest possible compressor work for natural gas liquefaction

Isentropic compressor with integrated cooling

Isentropic expansion turbine

LNG Cooling curve

Minimal temperature difference in heat exchanger

Net ideal work

StatoilHydro
Process impacts

• Relation between process efficiency and heat exchanger efficiency

\[
\frac{EXERGY_{loss}}{DUTY} \approx T_{ref} \cdot \frac{T_{hot} - T_{cold}}{T_{hot} \cdot T_{cold}}
\]
Swhe – Spiral Wound Heat Exchanger

**Principal construction**

- Headers and nozzles
- Tube plates
- Tube bundle
- Spacers
- Shell
- Shroud
LNG-SWHE

Principal construction
Vendors

Linde

Air Products
Manufacturing Procedure for Spiral Wound Heat Exchangers

1.1 Mandrel

2.1 Tube Bundle Winding

2.2 (First Tube Layer) (Second Tube Layer)
SWHE – Fabrication – The mandrel
SWHE – Fabrication – tube winding

Tube winding with 4 tubes in parallel
Tube inclination

One single tube straighten out

All single tubes connected to the same stream need to have the same length in order to obtain same pressure drop and equal fluid distribution.

This is obtained by equal inclination angle.

Different layers may have different angles → Not mixed layers.
Tube configuration

Radial tube distance
kept constant by spacers

Longitudinal tube distance
kept constant by spacers
Manufacturing Procedure for Spiral Wound Heat Exchangers

2.3 Tubing Completed

2.4 Shroud to Bundle

2.5 Bundle Completed
SWHE – Fabrication – tube winding layer by layer
SWHE – Fabrication – Tube winding complete
Avoiding by-pass flow ...

The shroud
Manufacturing Procedure
for Spiral Wound Heat Exchangers

3.1 Shell Fabrication

3.2 Insertion of Bundle

3.3 SWHE Completed
SWHE – Fabrication – Complete
Manufacturing Procedure for Spiral Wound Heat Exchangers

4. SWHE in Operating Position
SNØHVIT SWHE characteristics

• Liquefier
  – Surface = 11330 m²
  – Dshell = 3.4 m
  – Lbundle = 10.4 m

• Sub-cooler
  – Surface = 16740 m²
  – Dshell = 3.7 m
  – Lbundle = 12.7 m
SWHE starting its journey to Melkøya
The two Snøhvit LNG spiral wound heat exchangers, in transport from Schalchen to Bremen to be installed in the cold box prior to shipment to Hammerfest.
Shell side hydraulic characteristics

- Two-phase distribution
- Gravity drained liquid
- Increased shear flow
- Complete evaporated

EVAPORATING FLUID - FROM LIQUID TO GAS
Tube side hydraulic characteristics

- Gas feed
- Liquid leaving nozzle
- Complete condensation
- Increased liquid amount transported by gas shear
- Gas entering nozzle
PFHE
Plate-fin heat exchanger
Plate-fin heat exchanger
Principal function

1. Block or Core
2. Header
3. Nozzle
4. Width
5. Stacking height
6. Length
7. Passage outlet
8. Cover sheet
9. Parting sheet
10. Heat transfer fin
11. Distribution fin
12. Side bar
13. End bar
Fin patterns

The range comprises four basic fin pattern types:

**PLAIN** • A sheet of metal with corrugated fins at right angles to the plates.

**PERFORATED** • A plain fin constructed from perforated material.

**HERRINGBONE** • Made by displacing the fins sideways at regular intervals to produce a zig-zag effect.

**SERRATED** • Made by simultaneously folding and cutting alternative sections of fins. These fins are also known as the lanced or multi-entry pattern.
Manufacturing process

Plate by plate ...

In a stacking platform
Vacuum brazing of block
Welding headers and leak testing
Cold-box
Cold-box
Hammerfest
Shell-tube
Helixchanger – Main sea water cooler
Helifin – Helixchanger with low-fin tubing
Helifin during manufacturing

HELIFIN Heat Exchanger Tube Bundle in Fabrication