Improvising Design & Performance of PHE
Scope

• Heat Transfer Theory

• Parameters defining Heat transfer performance

• Typical discussions

• Codes & standards
Law of Heat Transfer

Heat will flow from HOT ==> COOL medium

Temperature difference is necessary

Energy rejected from HOT side = Energy absorbed by COLD side
(.......minus losses to the surroundings)
Designing Heat Exchanger

\[ Q_{\text{fluid1}} = \dot{Q}_{\text{PHE}} = Q_{\text{fluid2}} \]

\[ Q_{\text{Fluid}} = m \cdot C_P \cdot DT \]

- \( m \) = Mass flow of fluid
- \( C_P \) = Specific heat capacity
- \( DT \) = Temp. diff. of fluid (IN/OUT)

\[ m_1 \cdot c_p_1 \cdot \Delta T_1 = U \cdot A \cdot \text{LMTD} = m_2 \cdot c_p_2 \cdot \Delta T_2 \]
Heat Load and Heat Balance

- The heat load of a heat exchanger is:

\[ Q_H = m_H \times C_{pH} \times \Delta T_H \] for hot side

\[ Q_C = m_C \times C_{pc} \times \Delta T_C \] for cold side

\[ Q = U \times A \times \text{LMTD} \]

The heat balance is:

\[ Q = Q_H = Q_C \]
Heat Transfer Coefficient

The overall heat transfer efficient is:

\[
\frac{1}{k} = \frac{1}{\alpha_H} + \frac{1}{\alpha_C} + \frac{d}{\lambda} + R_f
\]

d - the thickness of the heat transfer plate
l - the thermal conductivity of
    the heat transfer plate material (W/m², °C)
R_f - the fouling factor (m² °C/W)
Logarithmic Mean Temperature Difference

\[ \text{LMTD} = \frac{\Delta_1 - \Delta_2}{\ln(\Delta_1/\Delta_2)} \]
LMTD

- LMTD means Logarithmic Mean Temperature Difference

- LMTD is the driving force for heat transfer from the hot fluid to the cold fluid. (The average temperature difference between the two fluids)

- The smaller LMTD, the bigger heating surface required

- The smaller LMTD, the higher heat recovery
Thermal Length

\[ LMTD = \frac{(\Delta 1 - \Delta 2)}{\ln(\Delta 1/ \Delta 2)} \]

\[ \Theta 1 = \frac{\Delta T1}{LMTD} \quad \Theta 2 = \frac{\Delta T2}{LMTD} \]
Thermal Length, continued

High $\Theta$
- Tall plate or multi-pass.
- “Difficult” job, requires more area for fixed heatload and flow rates.

Low $\Theta$
- Short plate and single pass.
- “Easy” job, requires less area for fixed heatload and flow rates.
Thermal Length & Plate Length
Performance of heat exchanger

Heat Exchanger Performance

= Thermal Performance + Mechanical Performance
Performance of heat exchanger

Heat Exchanger Performance

= 

Thermal Performance (Thermodynamic)
(heat Transfer, Pressure drop)

+ 

Mechanical Performance
(Fouling, pressure retention, component life, serviceability..Etc)
Parameters affecting cost of heat exchanger

- **Design Pressures and temperatures:**
  - Higher the pressure & Temperatures, higher the cost.
  - May require thicker materials, thicker frames, larger bolts.

- **Allowable Pressure drops:**
  - Lower the allowable pressure drops, the higher the costs
  - Will have to balance this with operating costs.

- **Flow rates:**
  - Too high a cooling / heating flow rate, with limited pr. Drop
  - Makes unit pressure drop restricted, larger in size
  - Advantage in LMTD negated by Pr. Drop restriction
Parameters affecting cost of heat exchanger

- **Temperature approaches:**
  - The closer the temperature approach, the larger the unit and higher the cost.

- **Fouling factor:**
  - “Fouling factor” is a “self fulfilling prophecy” for PHE
  - Only adds costs while increasing the possibility of fouling.

- **Manufacturing to particular codes**
  - Special material may be needed, Adds costs, since
  - May increase lead time.
Relation Between Heat Transfer And Pressure Drop

\[ U \sim (\Delta p)^{1/3} \]

- Pressure drop, \( \Delta p \) = “price” you must pay for the heat transfer.
- High pressure drop \( \Rightarrow \) high velocity \( \Rightarrow \) high U-value \( \Rightarrow \) smaller unit
- ..........BUT higher pumping cost (for very high \( \Delta p \) )
- Tranter recommends \( \Delta p \) not less than 50 kPa
Relation Between Heat Transfer And Pressure Drop

\[ U \sim (\Delta p)^{1/3} \]

Required heat transfer area vs. pressure drop
## CASE STUDY

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Cold in °C</th>
<th>Cold out °C</th>
<th>Cold flow Lps</th>
<th>Hot In °C</th>
<th>Hot out °C</th>
<th>Hot flow Lps</th>
<th>PD Cold kpa</th>
<th>PD Hot Kpa</th>
<th>LMTD °C</th>
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Q = U * A * LMTD
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\[ U \sim (\Delta p)^{1/3} \]

\[ Q = U \times A \times \text{LMTD} \]
Typical Concerns / Discussions

- Fouling factor
- Flow direction
- Gaskets fixing means
- Weight of heat exchanger
- Codes / standards
FOULING FACTOR

7.4 Fouling margin

The purchaser shall specify a percentage fouling margin, $F$, calculated by

$$F = \left( \frac{U_{\text{clean}}}{U_{\text{service}}} - 1 \right) \times 100$$

where $U$ is the heat transfer coefficient (overall thermal transmittance).
Fouling Factor – A Self Fulfilling Prophecy

FIG. 8 Comparison of tubeside and PHE fouling
A.4 Design — Fouling margin RP 7.4

Conventional fouling-resistance values used with shell-and-tube heat exchangers should not be used in the thermal design of plate-and-frame heat exchangers. Actual fouling resistances, if known, should be given. In the absence of applicable data, a minimum of 10% fouling margin should be included. For crude oil service this may need to be increased to 25%. It is important to ensure that the addition of the extra margin is taken into account when checking the thermal design of the unit. Wall shear-stress provides a good indication of fouling tendency in a plate-and-frame heat exchanger. A minimum wall shear-stress of 50 Pa (0.007 psi) is recommended.
Parallel versus diagonal flow

- Simple piping for individual unit
- Simpler layout for hygienic service
- Standardisation.
Parallel versus diagonal flow

- True counter current
- Better distribution
- Better heat transfer
- Simple pipeline.
- Identical plates
- NO Crossover of pipes

It is only inside the heat exchanger that flow travels diagonally.
Diagonal / parallel flow

- Pipe connected to headers in case of diagonal / parallel flow.
- Overall pipeline layout in plantroom will be same.
- Pipeline DO NOT CROSS.
Flow arrangement for parallel flow
Flow arrangement for diagonal flow
Glued versus clip-on gaskets

• Clip-on gasket
  – Easy to fix on the plate
  – Extra glue not required.
  – Some fear of “reaction” with glue…!

• Glued gasket
  – Easy to assemble the heat exchanger
  – Easy to disassemble the heat exchanger
Glue / clip / button on the gasket plays NO role in performance of the heat exchanger.
GASKET FIXING MEANS

• PURPOSE
  - Ensure that the gasket fixed onto the plate will remain in its place ONLY until the unit is assembled.

• Glue / clips play **NO** role in an assembled unit

• Glue / clip **DOES NOT** take part in performance of PHE.
GASKET FIXING MEANS

- Clips / glue are useful ONLY at the time of unit assembly / maintenance.
- In assembled heat exchanger clips / glue is useless.
TYPICAL CLIP-ON GASKET
Weight of the heat exchanger

Weight of Heat Transfer plates
  +
Weight of gaskets
  +
Weight of frame

Weight of Fixed Cover
  +
Weight of Removable Cover
  +
Weight of support column
  +
weight of guide bars
  +
Weight of Tightening bolts
Weight of the heat exchanger
Weight of heat exchanger (1672 kg) = Frame (1257 kg) + HT plates & gaskets (415 kg)
Code compliance

• ASME / PED
  • Objective to ensure Strong / design.

• ASME involves AI
  • PED self governed

• Customisation possible in ASME
  • Only Pre-approved designs in PED

• Exclusions
  • HEAT TRANSFER
  • Pressure drop
  • Fouling
  • Ease of Maintenance / Service
Code compliance

• ASME / PED
  • Same heat transfer

• Same heat transfer plates

• Same gaskets

• Pre-approved MOC for frames only

• Pre-approved design / thickness for frame only

• Pre-approved ITP / QAP
Codes & standards

- TEMA
  - Tubular Exchanger Manufacturer’s Association
- API 662
  - General refinery services
- EN 1148
  - Water to water heat exchangers for district heating
- PTC 12.5
  - Power test code
ARI 400 versus AHRI certified

- ARI 400
  - Standard on performance rating & tests
- AHRI Liquid / Liquid Heat Exchangers Certification Program
  - Performance certified by AHRI

Is not same as

“in accordance with AHRI standard 400”
ARI 400 versus AHRI certified

• Units certified by AHRI displayed in the directory (AHRI homepage)

• Certified models must have a unique denomination.

• AHRI has got a version of all manufacturers selection software's
  - Customers can contact AHRI and verify specifications
  - The software is used to generate all duties for tests
  - Tests verify that the software within tolerances

• Changes in selection software and rerates published in directory

• AHRI certification limited to only thermal performance

• Has no connection to pressure vessel regulations
Questions are welcome
THANK YOU