Overview of pinch analysis and its application in hydrocarbon Industries

- Save Water
- Reduce Waste
- Minimise Wastewater
- Increase Throughput
- Meet New Product Specifications
- Reduce and Plan Capital
- Reduce Emissions
- Reduce Operating Costs
- Improve Efficiency
- Introduce New Plant
- Improve Utility System Performance

19th January- 2015
SCOPE Conversion centre, Lodhi Road, New Delhi
Approaches to Optimize Thermal energy

- **Traditional Approach**
  - Largely based on Heuristics or Previous design experience
  - Several alternatives need to be generated and simulated to establish the best
  - Possibility of Sub-Optimal Design

- **Mathematical Method**
  - Formulate the design as a Mathematical Optimization Problem
  - Requires High Degree of Mathematical Skill and Programming Effort
  - Little OR no Physical Insight - Use of Brute Force

- **Thermodynamic Method-Pinch analysis**
  - User-Driven approach in the Development of Energy and Process System
  - Set Energy and Capital Targets before Design
  - Analysis with physical insight
Major Objective to achieve financial savings & green environment by better process heat integration (maximizing Process to Process heat recovery and reducing the External Utility Load)

Pinch analysis
Major Benefits

- Ability to set energy target for individual process or entire production site ahead of design
- Reduce energy consumption due to better process heat integration
- Reduce energy cost due to lower consumption and shifting load from higher to lower cost utilities
- Debottlenecking of boiler/cooling tower, and refrigeration system capacity
- Help to reduce local environmental emission
- Provide insight to Update or modify process flow diagrams
- Help in Identification of opportunities for combined heat and power (CHP) generation
Major Application Areas

- Oil refining
- Petrochemical
- Fertilizers and Pesticides
- Pulp and Paper
- Food Processing
- Distilleries and Breweries
Typical savings identified through energy pinch:

- Oil refining: 10-25%
- Petrochemicals: 15-25%
- Iron & steel: 10-30%
- Chemicals: 15-35%
- Food & drink: 20-35%
- Pulp & paper: 15-30%
Steps in Pinch Analysis

- Identification of Hot, Cold, and Utility Streams in the Process
- Thermal Data Extraction
- Selection of Initial DTmin Value
- Construction of Composite Curves and Grand Composite Curve
- Estimation of Minimum Energy Cost Targets
- Estimation of Heat Exchanger Network Capital Cost Targets
- Estimation of Optimum DTmin Value
  - Energy Cost and Capital Cost Trade-Off
- Design of Heat Exchanger Network (HEN)
Identification of Hot, Cold, and Utility Streams in the Process

**Thermal Data Extraction**

![Diagram showing temperature relationships T1 < T2 and T3 > T4 between heater and cooler](image)

<table>
<thead>
<tr>
<th>Stream</th>
<th>Stream type</th>
<th>Supply Temperature (°C)</th>
<th>Target Temperature (°C)</th>
<th>Duty (kW)</th>
<th>CP (kW/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hot</td>
<td>200</td>
<td>100</td>
<td>2000</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Hot</td>
<td>150</td>
<td>60</td>
<td>3600</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>Cold</td>
<td>80</td>
<td>120</td>
<td>3200</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>Cold</td>
<td>50</td>
<td>220</td>
<td>2550</td>
<td>15</td>
</tr>
</tbody>
</table>
Composite Curves
Composite Curves Observations

Pinch point is determined by the minimum temperature difference that will be accepted throughout the network.
Key Concepts in Pinch Technology

- No heat transfer across the Pinch
- No external heating below the Pinch
- No external cooling above the Pinch

Violation of any of the above rules results in higher energy requirements than the minimum requirements theoretically possible.
The grand composite curve is constructed by plotting the heat load difference between hot and cold composite curves, as a function of temperature.
Utility Placement

WE CAN SELECT APPROPRIATE UTILITY LEVELS
Estimation of Minimum Energy Cost Targets

TOTAL ENERGY COST = \sum_{U=1}^{U} Q_U \times C_U

Where \( Q_U \) = Duty of utility \( U \), kW
\( C_U \) = Unit cost of utility \( U \), $/kW, yr
\( U \) = Total number of utilities used
Estimation of Heat Exchanger Network (HEN) Capital Cost Targets

The capital cost depends upon:

- The number of exchangers
- The overall network area

\[
\text{C}($)_{\text{HEN}} = \left[ N_{\text{min}} \left\{ a + b \left( A_{\text{min}} / N_{\text{min}} \right)^c \right\} \right]_{\text{AP}} \\
+ \left[ N_{\text{min}} \left\{ a + b \left( A_{\text{min}} / N_{\text{min}} \right)^c \right\} \right]_{\text{BP}}
\]

where \(a\), \(b\), and \(c\) are constants in exchanger cost law

Exchanger cost ($)= a + b (Area)^c
**AREA TARGETING**

**NUMBER OF UNITS TARGETING:**

\[ N_{\text{minMER}} = (N_h + N_c + N_u - 1)_{\text{AP}} + (N_h + N_c + N_u - 1)_{\text{BP}} \]

- \( N_h \) = Number of hot streams
- \( N_c \) = Number of cold streams
- \( N_u \) = Number of utility streams

\( \text{AP} / \text{BP} : \text{Above} / \text{Below Pinch} \)

\[ \text{Area} = \frac{Q}{[U \times T_{LM}]} \]
Estimation of Optimum DTmin Value by Energy-Capital Trade Off
Some example of pinch analysis in Hydrocarbon Industries
## Revamp of CDU for enhancement of pre heat recovery or preheat temperature

<table>
<thead>
<tr>
<th>Case</th>
<th>Arab mix (70:30) (4.5 MMTPA)</th>
<th>Bonny Light (4.5MMTPA)</th>
<th>Arab mix (50:50) (5.0 MMTPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base (Existing heat exchanger network)</td>
<td>290 °C</td>
<td>280.9 °C</td>
<td>---</td>
</tr>
<tr>
<td>Proposed Heat exchanger network</td>
<td>302.4 °C</td>
<td>285.9 °C</td>
<td>294.6 °C</td>
</tr>
<tr>
<td>Preheat increase</td>
<td>12.4 °C</td>
<td>5.0 °C</td>
<td>4.6 °C (290 °C as base)</td>
</tr>
</tbody>
</table>
## Understanding of CDU OVHD vapor heat recovery

<table>
<thead>
<tr>
<th></th>
<th>Case without OVHD vapor</th>
<th>Case with OVHD vapor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinch Temp, °C</td>
<td>292</td>
<td>292</td>
</tr>
<tr>
<td>Hot utility (furnace duty), MMKcal/hr</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Cold utility, MMkcal/hr</td>
<td>36.8</td>
<td>57.6 (36.8+20.8)</td>
</tr>
</tbody>
</table>

- **Heat recovery from overhead vapor compel us to take a note-**
  - Since hot utility requirement is not reducing, products run down temperature will increase
  - Possibility of crude leak in the column overhead product in overhead condense due to very high pressure difference between tube and shell side.
  - Crude needs to be lifted up to CDU condenser location
Cost effective design of Solvent recovery section of dewaxing/De-oiling unit

- Used plus minus principle of pinch analysis for process modification to change the hot utility temperature without affecting the quality of products

- A furnace of 3.95 MMkcal/hr replaced by MP steam heat exchanger in the proposed configuration
### List of major pinch analysis projects carried out at CSIR-IIP

<table>
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<tr>
<th>Projects</th>
<th>Benefits achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Distillation Unit's preheat train, IOCL, Guwahati</td>
<td>For same hot utility consumption CDU's throughput could be increased from 1 MMTPA to 1.3 MMTPA</td>
</tr>
<tr>
<td>Delayed Coker Unit's preheat train, IOCL, Guwahati</td>
<td>4715 MMkcal energy savings per annum</td>
</tr>
<tr>
<td>Crude Distillation Unit's preheat train, Reliance Jamnagar</td>
<td>For same hot utility consumption CDU's throughput could be increased by 30M³/hr</td>
</tr>
<tr>
<td>Solvent recovery section of Lube Extraction Unit, HPCL, Mumbai</td>
<td>Hydrodynamic debottlenecking of Solvent Recovery Circuit (SRC) furnace for proposed unit capacity of 48M³/hr from 36 M³/hr using flash drum and 7% energy savings by relocation of heat exchanger.</td>
</tr>
<tr>
<td>FCC Unit at IOC Panipat Refinery</td>
<td>Furnace duty saved by 1.26 MMKcal/hr</td>
</tr>
<tr>
<td>Design of heat exchanger network for the solvent recovery section of dewaxing unit, NRL</td>
<td>Furnace of 4.0 MMkcal/hr was replaced by MP steam heater</td>
</tr>
<tr>
<td>Crude Distillation &amp; Delayed Coker Units, IOCL, Digboi Refinery</td>
<td>Feed preheat was increased by 10 ºC in CDU and by 7 ºC in DCU</td>
</tr>
<tr>
<td>Pinch Analysis of Propane Deasphalting (PDA) Unit, CPCL, chennai</td>
<td>Energy requirement of the unit reduced by 7.6 MMkcal/hr which was ~ 50% of energy consumption in the existing operation</td>
</tr>
<tr>
<td>Pinch analysis of solvent recovery section of wax Solvent Deoiling Unit (SDU)</td>
<td>10% saving in furnace fuel</td>
</tr>
<tr>
<td>Crude preheat maximization study for CDU-I &amp;II, HPCL, Vizag</td>
<td>10 - 16% energy saving based on the extent of revamp/ addition of new heat exchanger allowed</td>
</tr>
<tr>
<td>Study and Pinch analysis of for enhancement of Pre Heat recovery in CDU-2 and to process 0.5 MMTPA ARAB Mix Crude post IREP</td>
<td>Capacity enhancement from 4.5 MMTPA to 5.0 MMTPA with 4.5 ºC increase in preheat</td>
</tr>
</tbody>
</table>