Process Improvement for Energy Saving

Case Study: a Methanol Plant

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Energy Management and Process Improvement of Methanol Production

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CO₂ Reduction and Energy Conservation in a Methanol Plant Using Pinch Technology with Pressure Drop Consideration

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Energy and economy savings in the process of methanol synthesis using Pinch technology

Dr. Nasr

We are pleased to announce that National Petrochemical Company (NPC) will host its 10th Iran Petrochemical Forum (IPF) on 13-14 May 2013, in Tehran. IPF’s decade history shows that it has managed to establish a reputation as a major networking event for prestigious Petrochemical industry decision makers, executives, scientists and business professionals. We, therefore, urge you to attend this international gathering.

The 10th IPF aims to focus on many urgent demands of our time such as: the impact of international economic crisis on the petrochemical industry worldwide, the likely shifts in market characteristics and supply chains & the impact of expected increase of feedstock prices.

In this forum, participants will also be briefed on NPC’s privatization and restructuring programs as well as its latest achievements and plans for increasing its output to top 100 million tons per year. Also, in this forum supply chain issues & opportunities will be addressed.

**Topics:**
- Value chain aspects of Iran’s petrochemical industry
- Introducing Iran’s petrochemical special zones and parks: venues of choice for investment
- Investment opportunities in Iranian petrochemical industry
- Advanced petrochemical technologies
- Petrochemical development trends (Iran & Asia)
- Worldwide trends & impacts of privatization in petrochemical industry
- Feedstock, production and marketing of petrochemicals
- Future of integrated petro-refinery, multipurpose and flexible plants
- Outlook of SMEs in petrochemical industry
- Innovation and optimization in petrochemical plants (Energy, Capacity)
- Products qualification & certification trends (REACH, …)
- Supply chain & logistics management in petrochemical industry
- World economic crisis, sanctions and petrochemical industry

All abstracts must be submitted by February 15-2013 for review.

An exhibition for displaying capabilities and technological potentials in Petrochemical industries will be held adjacent to the forum.
OUTLINES:

- Introduction to HTE
- Main Concepts in PDM Technology
- Methanol Process as a Case Study
- Procedure Demonstration on the Case Study
- Results and Interaction of Energy Saving & CDM
- Conclusion Remarks
MAIN OBJECTIVES:

The aim of this work is to perform a retrofit study of a methanol plant using Pinch Technology, in purpose of:

✓ Maximum Heat Recovery Between Process to Process HEN.

✓ Power Generation by utilizing a turbo expander after the methanol synthesis reactor to produce shaft work (electricity).
Pinch Analysis - Basics & Objectives:

- Retrieve the temperature profile of the whole process.
- Locate the level of the minimum allowable temperature difference between hot and cold streams (pinch point).
  - Predict, ahead of design, the minimum requirements of external energy, network area and number of units
  - Set the Energy & Capital “TARGET”
  - Maximize process-to-process heat recovery and minimize external utility loads and related costs
Intro:

Typical energy saving 15 – 45 %.

Very general – easily applicable in Power generation, Oil refining, Petrochemicals, Food and Drink Industry, Pulp & Paper, Hospitals etc.

Typical pay-back periods from a few weeks to 16 months (decision made by the client).

Considerably contributes to Emissions Reduction including $\text{CO}_2$
- Oil refining 10-25%
- Petrochemicals 15-25%
- Iron & steel 10-30%
- Chemicals 15-35%
- Food & drink 20-35%
- Pulp & paper 15-30%
Intro...:
Plant structure can be changed by use of compact heat exchangers through:

- DTMIN
- Capital cost

Compact heat exchangers

Heat transfer enhancement

Shell-and-tube

Pinch

Compact
Intro...:

- Most present applications are not grass-root but retrofits considerably more difficult constrained problem.

- Economy dictates the energy saving potential by pay-back period.
Heat Exchangers Types

- Shell & Tube
- Double pipe
- Air cooler
- Compact
Heat Transfer Enhancement Techniques

• Active Method (with power)
• Passive Method (without power)
• Compound Method
Passive Methods

Fouling heat exchanger tubes

- **Turbotal®:** reduction in fouling
  - Rotation about the axis
  - Microvibration

- **Spirelf®:** reduction in fouling
  - Radial vibration
  - Axial vibration

- **Fixotal®:** improvement in heat transfer
  - Increase in turbulence effect
NEW TECHNIQUE IS HTE BY TUBE INSERTS
Corrugated Tubes
ROD Baffle Heat Exchanger by Courtesy of Philips Co.
Expanded Metal Baffles

Bundle of an EMBaffle heat exchanger
Figure 9  Power plant application.
Fig. 1- Helical Baffle Heat Exchanger Installed in TPC Co.
Multistream Plate Fin Heat Exchanger
Twisted Tube Heat Exchangers
Advantages of Twisted Tube Heat Exchangers

- Baffle-Free Tube Support
- Tube to Tube Contact Points Eliminate Vibration
- More Efficient Heat Transfer
- Reduced Fouling
- Lower Pressure Drop
- Improved Tube side Flow
- Uniform Shell side Flow
- Twisted Tube Cleaning Efficiencies
- Higher Heat Transfer Area than S&T
Applications

- Chemical Industries
- Petroleum & Petrochemical Plants
- Pulp & Paper
- Power
- Steel
- Mining / Mineral Processing
- District Heating
الگوریتم طراحی سریع و بررسی
شاخه‌های کارکرد فناوری جدید
مبدل‌های حرارتی با لوله‌های پیچشی
در صنایع نفت (بخش اول)

تاریخ دریافت: 99/10/16
تاریخ پذیرش: 90/5/19

محمد رضا جعفری‌نصری، آباده همتی، امین سالم
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2- دانشگاه صنعت سهند، دانشکده مهندسی شیمی
افراش ظرفیت شبکه مبدل های حرارتی با به کارگیری مبدل هایی با لوله های پیچشی (بخش دوم)

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Extension of the Rapid Design Algorithm for Twisted-Tube Evaporative Fluid Coolers

The thermal analysis performance of evaporative fluid coolers (EFCs) is improved by replacing plain tubes by twisted oblong tubes. Results of the system are assessed by a rapid design algorithm (RDA) and compared to conventional plain-tube EFCs and other traditional algorithms including the effectiveness number of transfer units (ε-NTU). Based on the RDA, a relationship between heat transfer coefficients, pressure drops, heat transfer area, and mass transfer coefficient is derived. Using the maximum allowable pressure drops in this algorithm, the minimum required heat transfer area can be determined. The algorithm is validated by comparing the plain-tube EFC design with twisted-tube design. The RDA-designed EFCs with twisted tubes provide higher efficiency compared with the traditional designs with plain tubes in such that the new design needs a lower heat transfer area for a given heat load.

Keywords: Evaporative fluid coolers, Pressure drop, Rapid design algorithm, Twisted oblong tube

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1 Introduction

Evaporative fluid coolers (EFCs) are heat exchangers extensively applied in various industries. The use of heat transfer enhancement devices is necessary to meet the requirements of improved designs with both higher energy efficiency and saving. Nowadays, EFCs can be improved by various techniques. Applying twisted tubes is one of these approaches increasing the thermal efficiency of EFCs. The twisted-tube EFC is a type of heat exchanger which can augment the heat transfer coefficient of both tube and air sides. Fig. 1 illustrates a simple structure of a twisted-tube EFC.

In this setup, tubes play an important role in enhancing the heat transfer. Twisted tubes are formed into an oval section with a superimposed twist by some special techniques. Two ends of the tubes remain round to assemble them with the tube sheet. When the tubes are arrayed in the same direction, they can be supported by the tubes themselves, without the need of baffles or rods that are commonly used in conventional heat exchangers [10]. Fig. 2 displays the section of a twisted oblong tube.

Some basic assumptions are made to derive the fundamental modeling equations:
- The equipment and the cooling water passing through the circuit are insulated from the environment.
- Uniform and complete surface wetting of the tube bundle.
- Water loss by drift is insignificant.

Figure 1. Schematic diagram of a twisted-tube EFC.

- Radiation heat transfer can be neglected.
- The heat and mass transfer coefficients are constant inside the tube bundle [11].

Here, heat transfer analysis of twisted-tube EFCs is performed by an extended version of the RDA method developed by Jafari Nasr et al. [8, 9]. The results of heat transfer assess-
Process Integration Analysis
Optimization Method:

Three major approaches:

- Heuristics: not used separately any more.
- Algorithmic: not widely adapted in industries so far.
- Pinch technology: widely used at present.

✓ Pinch technology provides the optimization among heat recovery, external energy and exchanger area.
The diagram illustrates the concept of heat recovery in a process flow. The Hot Composite Curve and the Cold Composite Curve are shown, with the pinch point between them indicating the minimum temperature difference ($\Delta T_{\text{MIN}}$) required for heat exchange. The areas $Q_{\text{H,MIN}}$ and $Q_{\text{C,MIN}}$ represent the minimum heating and cooling utilities, respectively. The process to process heat recovery potential is indicated by the shaded area between the curves.
Pinch Technology

**TAC vs. $\Delta T_{\text{min}}$**

\[
TAC = \frac{CC}{n} + OC
\]

\[
OC = (C_{HU} + C_{CU})
\]

\[
CC = N_{\text{min}} \left[ a + \left( \frac{b \cdot A_{\text{retr}}}{N_{\text{min}}} \right)^c \right]
\]

- $N_{\text{min}} = [N_h + N_c + N_u - 1]_{\text{AP}} + [N_h + N_c + N_u - 1]_{\text{BP}}$

- Still assuming that the total area of the network is distributed evenly among the exchangers
<table>
<thead>
<tr>
<th>No</th>
<th>Industrial Sector</th>
<th>Experience $DT_{\text{min}}$ Values</th>
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<tbody>
<tr>
<td>1</td>
<td>Oil Refining</td>
<td>20-40°C</td>
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<tr>
<td>2</td>
<td>Petrochemical</td>
<td>10-20°C</td>
</tr>
<tr>
<td>3</td>
<td>Chemical</td>
<td>10-20°C</td>
</tr>
<tr>
<td>4</td>
<td>Low Temperature Processes</td>
<td>3-5°C</td>
</tr>
</tbody>
</table>
Heat Integration

HEN

Grassroot

Retrofit Analysis

H1

100°C

60°C

50°C

40°C

C1
Retrofit Objectives

- Debottlenecking
- Energy Reduction
- Process/Feed/Process Modification
The HEN Retrofit Problem

Structural Changes

Additional Exchanger Area

RELOCATE: which units? where?
INSERT NEW MATCH: which streams? where?
STREAM SPLIT: which streams? where?

Energy

How much? What heat recovery?
Incentives for Retrofitting:

- Improve Efficiency
- Product Improvement
- Regulatory Compliance
- Safety Improvement
- Energy Efficiency Improvement
- Reduction of Maintenance costs
- Quality Improvement
- New Technology Implementation
Constraints in Retrofitting:

- Space & Layout (less freedom)
- Insufficient Information
- Harsh Environment

- Time (payback) & Investment Limitations
Tools for Retrofitting:

- Adding New Hxrs
- Adding More Shells (Parallel or Series ?!)
- Relocating
- Load Shifting
- Re-piping
- Stream Splitting
- Identifying XP Hxrs
For New Design

1. E = 100
   Area = 120

2. E = 120
   Area = 100

Target Curve for Stream Data

Area vs. Energy

120
100

Energy

100 120
\[ \alpha = \left[ \frac{A_{tx}}{A_x} \right]_{E_x} \]
α-Incremental
Saving = (existing - target) * [annual (hot + cold) utility cost]
The diagram illustrates the relationship between investment and saving, with a distinction between short payback and long payback periods.
Existing Network

Energy Usage

Exchanger Data

Phys. Properties

Stream Data

$\Delta P$'s, $h$'s, $R$'s

Project Limits

Cost Data

Theoretical Curve

Targeting Curve

Existing Network

Payback Line

Starting Point for

$\Delta T_{\text{min}}$

Research Institute of Petroleum Industry R.I.P.I.
Identify the Cross Pinch (XP) Heat Exchangers
Complete problem

Area target, $A_t$

$T$

Pinch

$\Delta T_{\text{min}}$

$H$

Placing a match (i)

Pinch

q

Remaining problem

Match (i) removed

Area target, $A_{tr}$

$T$

$\Delta T_{\text{min}}$

$H$

Maximum area efficiency ($\alpha_{\text{max}}(i)$) = $A_t / (A(i) + A_{tr}[i])$
\[ \alpha_{\text{max}}(j) = \frac{A_t}{(A(j) + A_{tr}(j))} \]
Complete problem

Area target, $A_t$

Placing a match (i)
Pinch

Remaining problem

Match (i) removed
Area target, $A_{tr}$

Driving force penalty = $(\Delta T_{\text{min}} - \Delta T_{\text{minr}})$
PROCESS DESCRIPTION OF METHANOL PRODUCTION:

Methanol is generated from the reaction between hydrogen carbon monoxide and carbon dioxide the ratio in feed mixture is determined:

\[
\text{Module} = \frac{\text{H}_2\% - \text{CO}_2\%}{\text{CO}\% + \text{CO}_2\%} = 2.09
\]

In addition to those mentioned other materials like methane and nitrogen exist in feed stock but do not participate in reaction these materials may enter into the system by feed or CO\(_2\) has been imported into plant.

\[
\text{CO} + 2\text{H}_2 \leftrightarrow \text{CH}_3\text{OH}
\]

\[
\text{CO}_2 + 3\text{H}_2 \leftrightarrow \text{H}_3\text{OH} + \text{H}_2\text{O}
\]

Coupled by:

\[
\text{CO} + \text{H}_2\text{O} \leftrightarrow \text{CO}_2 + \text{H}_2
\]
Methanol Process Box Diagram

CO₂ Compression

Desulfuration

Reforming

Process Gas Heat REC.

Synthesis Gas Compression

Methanol Synthesis

Methanol Compression

Methanol

Coupled by:

CO + 2H₂ ↔ CH₃OH

CO₂ + 3H₂ ↔ H₃OH + H₂O

CO + H₂O ↔ CO₂ + H₂
Conventional Process for Methanol Synthesis
PFD of MeOH Plant (Reformer Section of FPC)
PFD MeOH Plant (Reaction Section of FPC)
PFD of MeOH Plant (Separation section of FPC)
## Network Existing Conditions:

*Table 1- Network existing condition*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>$\Delta T_{\text{min}}$ (°C)</td>
<td>32.9</td>
</tr>
<tr>
<td>Cold Utility (MW)</td>
<td>93.42</td>
</tr>
<tr>
<td>Hot Utility (MW)</td>
<td>68.52</td>
</tr>
<tr>
<td>Process To Process Area (m²)</td>
<td>11063.8</td>
</tr>
<tr>
<td>Area Efficiency</td>
<td>%79</td>
</tr>
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</table>
Diagram of existing HEN in MeOH plant
CC. curve (fig. A) and GCC curve (fig. B) of existing network
### Table 2 - Result of physical properties calculation of heat exchanger streams at methanol plant in supply and target temperature

<table>
<thead>
<tr>
<th>$\Delta H$(kW)</th>
<th>$C_p$(kJ/kg)</th>
<th>$M$(kg/h)</th>
<th>$T_1$</th>
<th>$T_s$</th>
<th><strong>Stream</strong></th>
<th><strong>Stream ID</strong></th>
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<tr>
<td>176712</td>
<td>3.42</td>
<td>285393</td>
<td>140</td>
<td>915</td>
<td>Reformer outlet up to D-5005</td>
<td>1</td>
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<tr>
<td>31763</td>
<td>2.59</td>
<td>221452</td>
<td>103</td>
<td>140</td>
<td>D-5005 outlet up to D-2002</td>
<td>2</td>
</tr>
<tr>
<td>17979</td>
<td>289.98</td>
<td>179163</td>
<td>41</td>
<td>103</td>
<td>Separator outlet (D-5005)</td>
<td>3</td>
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<td>17979</td>
<td>2.67</td>
<td>212643</td>
<td>43</td>
<td>157</td>
<td>C-3001-E-1 interstage cooler</td>
<td>4</td>
</tr>
<tr>
<td>3068</td>
<td>3.59</td>
<td>36194.65</td>
<td>43</td>
<td>128</td>
<td>HP column product cooler</td>
<td>5</td>
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<tr>
<td>179989</td>
<td>3.55</td>
<td>664454</td>
<td>41</td>
<td>250</td>
<td>Reactor outlet</td>
<td>6</td>
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<tr>
<td>1383</td>
<td>1.54</td>
<td>309925</td>
<td>43</td>
<td>64.8</td>
<td>LP column oh condenser</td>
<td>7</td>
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<tr>
<td>45600</td>
<td>4.645</td>
<td>215104</td>
<td>270</td>
<td>133</td>
<td>Water preheater</td>
<td>8</td>
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<tr>
<td>102600</td>
<td>5.123</td>
<td>212952</td>
<td>324</td>
<td>270</td>
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<td>23940</td>
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<td>212952</td>
<td>389</td>
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<td>10</td>
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<tr>
<td>31763</td>
<td>1.63</td>
<td>244304</td>
<td>88</td>
<td>87</td>
<td>T-5001 reboiler</td>
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</tr>
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<td>4560</td>
<td>2.13</td>
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<td>Combustion air preheater</td>
<td>15</td>
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</table>
Existing HEN Analysis:

In Table (3) the result of the calculations in exiting HEN streams is determined by using a program which works with Bell-Delaware method.
Table 3 - Final data calculation of existing heat exchanger streams at methanol plant

<table>
<thead>
<tr>
<th>No.</th>
<th>∆P (Bar)</th>
<th>HTC (W/m²K°)</th>
<th>CP (KW/°C)</th>
<th>DH (KW)</th>
<th>Tt (°C)</th>
<th>Ts (°C)</th>
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<td>1278</td>
<td>57.3</td>
<td>48</td>
<td>Combustion air preheater</td>
</tr>
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</table>
Results of Existing of HEN:

- Net energy consumption of methanol plant is equal to 161.93MW. The amount of hot utility is 68.523MW provided by LP steam in 170 C°.

- The cold utility consumption is 93.415MW which provided by air (45.503MW) and cooling water (47.913MW).

- The Process to process area of existing situation is 11063m².

- The network energy consumption at $\Delta T_{\text{min}} = 33$ C° is equal to 161.93MW.
Table 4- Targeted Result on MeOH Plant

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>Targeted ( \Delta T_{\text{min}} ) (°C)</strong></td>
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<tr>
<td><strong>Existing ( \Delta T_{\text{min}} ) (°C)</strong></td>
<td>32.92</td>
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<tr>
<td><strong>Targeted Cold Utility (MW)</strong></td>
<td>70.62</td>
</tr>
<tr>
<td><strong>Targeted Hot Utility (MW)</strong></td>
<td>45.73</td>
</tr>
<tr>
<td><strong>Targeted Hot Utility Saving (MW)</strong></td>
<td>22.8</td>
</tr>
<tr>
<td><strong>Targeted Cold Utility Saving (MW)</strong></td>
<td>22.8</td>
</tr>
<tr>
<td><strong>Targeted Hot Utility Saving (%)</strong></td>
<td>33.27</td>
</tr>
<tr>
<td><strong>Targeted Cold Utility Saving (%)</strong></td>
<td>24.41</td>
</tr>
<tr>
<td><strong>Net Profit /Yr</strong></td>
<td>1803230</td>
</tr>
<tr>
<td><strong>Targeted Heat Surface (m(^2))</strong></td>
<td>6740</td>
</tr>
<tr>
<td><strong>Area Cost ($)</strong></td>
<td>643123</td>
</tr>
<tr>
<td><strong>Pump Displacement Cost ($)</strong></td>
<td>45600</td>
</tr>
<tr>
<td><strong>Total Cost ($)</strong></td>
<td>688723</td>
</tr>
<tr>
<td><strong>Payback Period (Yr)</strong></td>
<td>0.38</td>
</tr>
</tbody>
</table>
Identify the Cross Pinch Heat Exchangers

E-4001/1&2  E-2015  C-3001-E1  E-2010/11
DFP for MeOH Process
Retrofit Design of HEN in MeOH Plant

Grid diagram of HEN after modification
(The load of heat exchanger in terms of MW and temperature in °C)
Scenarios in Retrofit Targeting for:

Determination of Operating Point?

With consideration of:
Investment & Payback limits

- Max. Heat Recovery (HEN P-to-P Recovery)
  max. 700 k$

- Power Generation (GT Integration in Reactor)
  max. 3 Y
New Heat Exchanger Detail Design

As shown in previous figure the selected network is modified with 4 process to process new heat exchangers.

The total surface area has been added is equal to 7097.5 m² which are four new exchangers. Installed area in design procedure is 5% more than targeted procedure which is acceptable.
<table>
<thead>
<tr>
<th>New4</th>
<th>New3</th>
<th>New2</th>
<th>New1</th>
<th>Exchanger</th>
</tr>
</thead>
<tbody>
<tr>
<td>3629</td>
<td>2420</td>
<td>605</td>
<td>443.5</td>
<td>Area (Square meter)</td>
</tr>
<tr>
<td>1x3</td>
<td>1x4</td>
<td>1x1</td>
<td>1x1</td>
<td>Shells (ser. x par.)</td>
</tr>
<tr>
<td>2400</td>
<td>2158</td>
<td>2158</td>
<td>2139</td>
<td>Shell Diameter (mm)</td>
</tr>
<tr>
<td>2768</td>
<td>1384</td>
<td>1384</td>
<td>1360</td>
<td>Total No. of Tubes</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Tube Passes</td>
</tr>
<tr>
<td>25/4</td>
<td>25/4</td>
<td>25/4</td>
<td>19.05</td>
<td>Tube O.D. (mm)</td>
</tr>
<tr>
<td>2/11</td>
<td>2/11</td>
<td>2/11</td>
<td>2.11</td>
<td>Tube Thickness (mm)</td>
</tr>
<tr>
<td>40</td>
<td>50.8</td>
<td>50.8</td>
<td>50.8</td>
<td>Tube Pitch (mm)</td>
</tr>
<tr>
<td>5.486</td>
<td>5.486</td>
<td>5.486</td>
<td>5.486</td>
<td>Tube Length (m)</td>
</tr>
<tr>
<td>90</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>Tube Layout (DEG)</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>Baffle Cut (%)</td>
</tr>
<tr>
<td>800</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td>Baffle Spacing (mm)</td>
</tr>
<tr>
<td>AEL</td>
<td>AEL</td>
<td>AEL</td>
<td>AEL</td>
<td>Type</td>
</tr>
</tbody>
</table>
Power Integration:

A conventional power plant uses fuel energy to produce work and reject heat. Usually a gas turbine operates by internal combustion. Air and Fuel gas pass through a compressor into a combustion chamber. The combustion product are expanded into turbine which drives an electric generator. Many chemicals may be produced under high pressure at high temperature.

The high operating pressure of reactor outlet can be exploited to produce electricity using an open gas turbine. The open gas turbine is a basic gas turbine unit. The working fluid comes from a reactor and cycle through the following units.

- Gas turbine
- Heat exchangers
- Separator
- Compressor
Open circuit gas turbine with separator
2-1: تراکم أدیاباتیک
3-2: واکنش
4-3: انبساط أدیاباتیک محصولات واکنش در توربین
5-4: خنک سازی و حرارت قابل حصول برای انتگراسیون
5-1: جداسازی و چگالش فاز بخار آن

شکل 8- نمودار ساده شده T-S در سیکل توربین گاز نشان داده شده در شکل (7)
In order to target the amount of electricity which can be produced from the reactor outlet, and also determine the new pressure and temperature of stream number six (table 3), it is necessary to simulate the mentioned power cycle at network. This has been performed with HYSYS software Ver. 3.2.

The simulation of turbine gas cycle with HYSYS software.
Modification of HEN to Power Generation

Grid diagram of HEN after modification
(The load of heat exchanger in terms of MW and temperature in °C)
New Hx Detail Design for Power Generation

- New heat exchangers were designed in detail with consideration of pressure drop using advance Bell-Delaware algorithm.

- This algorithm has an advantageous that design the surface and geometry of heat exchangers in order to meet the allowable pressure drops both in shell side and tube side. This results minimum surface area and maximum heat transfer coefficient.
Table 6- New Hx Detail Design for Power Generation

<table>
<thead>
<tr>
<th></th>
<th>New4</th>
<th>New3</th>
<th>New2</th>
<th>New1</th>
<th>Exchanger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (Square meter)</td>
<td>904.2</td>
<td>3629</td>
<td>1210</td>
<td>443.5</td>
<td></td>
</tr>
<tr>
<td>Shells (ser.xpar.)</td>
<td>1×1</td>
<td>1×3</td>
<td>1×2</td>
<td>1×1</td>
<td></td>
</tr>
<tr>
<td>Shell Diameter (mm)</td>
<td>1915</td>
<td>2400</td>
<td>2158</td>
<td>2139</td>
<td></td>
</tr>
<tr>
<td>Total No. of Tubes</td>
<td>2480</td>
<td>2768</td>
<td>1384</td>
<td>1360</td>
<td></td>
</tr>
<tr>
<td>Tube Passes</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Tube O.D. (mm)</td>
<td>25/4</td>
<td>25/4</td>
<td>25/4</td>
<td>19.05</td>
<td></td>
</tr>
<tr>
<td>Tube Thickness (mm)</td>
<td>2/11</td>
<td>2/11</td>
<td>2/11</td>
<td>2.11</td>
<td></td>
</tr>
<tr>
<td>Tube Pitch (mm)</td>
<td>40</td>
<td>40</td>
<td>50.8</td>
<td>50.8</td>
<td></td>
</tr>
<tr>
<td>Tube Length (m)</td>
<td>4.572</td>
<td>5.486</td>
<td>5.486</td>
<td>5.486</td>
<td></td>
</tr>
<tr>
<td>Tube Layout (DEG)</td>
<td>45</td>
<td>90</td>
<td>30</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Baffle Cut (%)</td>
<td>45</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Baffle Spacing (mm)</td>
<td>450</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>BEM</td>
<td>AEL</td>
<td>AEL</td>
<td>AEL</td>
<td></td>
</tr>
</tbody>
</table>
PFD of MeOH Plant after modification of HEN
Ref. (Fanavarar Petrochemical Co.)
PFD of MeOH Plant after modification of HEN
Ref.(Fanavaran Petrochemical Co.)
PFD of MeOH Plant after modification of HEN
Ref. (Fanavaran Petrochemical Co.)
EXISTING PROCESS

SIMULATION

DATA COLLECTION

PINCH ANALYSIS

RETROFIT ANALYSIS

SUGGESTED DESIGNS

- Network Pinch Method
- Diagnosis Stage
- Optimisation Stage

- 4 New HE
- Savings
  - Hot utility = 28+%
  - Cold utility = 20+%
  - Power Generation = 640,000MW
- Emissions reduction (30 MT/Y)
- Payback Time 11 months
Project Evaluating in Term of Clean Development Mechanism (CDM):

Incremental increase of greenhouse gas such as CO$_2$ which is the most important of them and its effect on global warming is forced developing country to decrease this harmful effect with help of several convention such as Kyoto protocol. Since industrialized country has low potential for reducing greenhouse gas emission because of their modern technology, instead of their commitment to reduce emission of CO$_2$ they prefer to meet the target with other countries. Since Iran has made no specific commitment on this issue hence by implementing such projects some credits can be obtained under the Kyoto Protocol and some revenue can be obtained too.
CDM Calculations:

Green house gas emission in (kg) for each Tera Joule (TJ) of fuel consumption according to net heat value:

1 Tera Joule = 56.100 (ton) CO$_2$

Energy saving in hot utility = 19.4714 MW

Thus:
19.4714(MJ/s) × 3600(s/hr) × 8000(hr/Year) = 560,776,320(MJ/Year) = 560.7(TJ/Year)

The amount reduction of CO$_2$ in year:

560.776 × 56.1 = 314,552.5(ton/year)

Since each ton of CO$_2$ cost ten dollars $:
Income due to reduction of CO$_2$ = 31455.2 × 10 = 314,552.5($/Year)
### Table 7- Project Comparison Due to Payback Period Time (for two Scenarios)

<table>
<thead>
<tr>
<th></th>
<th>Project evaluating without considering CDM</th>
<th>Project evaluating with considering CDM</th>
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<tbody>
<tr>
<td><strong>International price cost($)</strong></td>
<td>711,561</td>
<td>711,561</td>
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<tr>
<td><strong>Domestic price cost($)</strong></td>
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<td>711,561</td>
</tr>
<tr>
<td><strong>Investment($)</strong></td>
<td>711,561</td>
<td>711,561</td>
</tr>
<tr>
<td><strong>Income due to saving($)</strong></td>
<td>1539,472</td>
<td>1,854,024</td>
</tr>
<tr>
<td><strong>Pay back period time(year)</strong></td>
<td>0.46</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>1.38</td>
<td>0.85</td>
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<tr>
<td>Tolerance (%)</td>
<td>Design</td>
<td>Targeting</td>
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<tr>
<td>--------------</td>
<td>-------------</td>
<td>-----------</td>
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<tr>
<td>4.71</td>
<td>73.9445</td>
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<td>7.26</td>
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<td>19.4714</td>
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<tr>
<td>14.60</td>
<td>19.4714</td>
<td>22.8</td>
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<tr>
<td>14.58</td>
<td>28.42</td>
<td>33.27</td>
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<tr>
<td>14.63</td>
<td>20.84</td>
<td>24.41</td>
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<tr>
<td>14.60</td>
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<td>1,803,230</td>
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<tr>
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<td>91</td>
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<tr>
<td>5.30</td>
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<td>643,123</td>
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<td>45600</td>
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<td>3.32</td>
<td>711,561</td>
<td>688,723</td>
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<td>21.05</td>
<td>0.46</td>
<td>0.38</td>
</tr>
<tr>
<td>Tolerance(%)</td>
<td>Design</td>
<td>Targeting</td>
</tr>
<tr>
<td>-------------</td>
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<tr>
<td>1.05</td>
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<td>-139.9</td>
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<td>1.98</td>
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<td>34.92</td>
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<td>640×10^6</td>
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<td>2.15</td>
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<td>5.22</td>
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<td>3.54</td>
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<td>25,000,000</td>
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<tr>
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<tr>
<td>0.76</td>
<td>2.267</td>
<td>2.25</td>
</tr>
</tbody>
</table>
Conclusions:

- Because of energy saving in this project the amount of emission of flue gas in atmosphere decreases so environmental pollution such as greenhouse effect will be controlled.

- Because of increasing heat transfer between hot and cold stream in network the load of furnace and demand for hot utility will be reduced.

- The result of targeting procedure is due to the pressure drop consideration.

- It reduces the consumption of exhaustible fossil fuels.
Now

Process Improvement by New Generation of Exchangers
Twisted Tube Heat Exchangers
Gambit Geometry Simulation
A comparison of plain and twisted tube by Fluent software
A comparison of plain and twisted tube by Fluent software
## Hot and Cold Utilities for Retrofit of HEN with Plain Tubes

<table>
<thead>
<tr>
<th>Utility</th>
<th>Inlet Temp. (°C)</th>
<th>Outlet Temp. (°C)</th>
<th>M.CP (kW/°C)</th>
<th>Energy Consumption (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-2013</td>
<td>98.59</td>
<td>41</td>
<td>0.289984</td>
<td>16.7</td>
</tr>
<tr>
<td>C-3001</td>
<td>79.2</td>
<td>43.1</td>
<td>0.101439</td>
<td>3.7</td>
</tr>
<tr>
<td>E-4002</td>
<td>98.04</td>
<td>41</td>
<td>0.861196</td>
<td>49.1</td>
</tr>
<tr>
<td>E-5006</td>
<td>135.8</td>
<td>138</td>
<td>22.415</td>
<td>49.3</td>
</tr>
</tbody>
</table>
Cost Function of Twisted Tube HXrs

- Capital (construction) cost function of Twisted tube HEX

\[ \text{Cost}($) = 43.74A^{1.27} + 15180 \]

- Tube replacement cost function of twisted tube HEX

\[ \text{Cost}($) = 267.64A_{\text{shell}} + 468.47 \]
# Temps. Input & Output of Twisted Tube HXrs

<table>
<thead>
<tr>
<th>Twisted Tube</th>
<th>Inlet Temp. (Tube) (°C)</th>
<th>Outlet Temp. (Tube) (°C)</th>
<th>Inlet Temp. (Shell) (°C)</th>
<th>Outlet Temp. (Shell) (°C)</th>
<th>Heat Transfer Area (m²)</th>
<th>Cost of Tube Replacement ($)</th>
<th>Heat Recovery (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEX.1</td>
<td>103</td>
<td>95.75</td>
<td>48</td>
<td>63.28</td>
<td>620</td>
<td>10,330</td>
<td>2.1</td>
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<tr>
<td>HEX.2</td>
<td>157</td>
<td>72.61</td>
<td>63.2</td>
<td>74.68</td>
<td>847</td>
<td>10,417</td>
<td>8.56</td>
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<tr>
<td>HEX.3</td>
<td>172.1</td>
<td>146.07</td>
<td>135</td>
<td>136</td>
<td>3,388</td>
<td>10,417</td>
<td>25.6</td>
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<tr>
<td>HEX.4</td>
<td>146.07</td>
<td>92.94</td>
<td>73.8</td>
<td>136.24</td>
<td>5,080</td>
<td>11,533</td>
<td>46.53</td>
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</table>
# Hot and Cold Utilities for Retrofit of HEN with Twisted Tubes

<table>
<thead>
<tr>
<th>Utility</th>
<th>Inlet Temp. (°C)</th>
<th>Outlet Temp. (°C)</th>
<th>M.CP (kW/°C)</th>
<th>Energy Consumption (MW)</th>
<th>Energy Saving (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-2013</td>
<td>95.75</td>
<td>41</td>
<td>0.289</td>
<td>15.88</td>
<td>0.82</td>
</tr>
<tr>
<td>C-3001</td>
<td>72.61</td>
<td>43.1</td>
<td>0.101</td>
<td>2.99</td>
<td>0.7</td>
</tr>
<tr>
<td>E-4002</td>
<td>92.04</td>
<td>41</td>
<td>0.861</td>
<td>43.96</td>
<td>5.14</td>
</tr>
<tr>
<td>E-5006</td>
<td>136.2</td>
<td>138</td>
<td>22.415</td>
<td>40.35</td>
<td>8.95</td>
</tr>
</tbody>
</table>
## Project Economic Comparison for Two Scenarios (Twisted Tube)

<table>
<thead>
<tr>
<th></th>
<th>Project evaluation Without considering CDM</th>
<th>Project evaluation with considering CDM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment($)</strong></td>
<td>754,249</td>
<td>754,249</td>
</tr>
<tr>
<td><strong>Income due to saving($/Yr)</strong></td>
<td>625,282</td>
<td>769,300</td>
</tr>
<tr>
<td><strong>Payback period time(Yr)</strong></td>
<td>1.21</td>
<td>0.98</td>
</tr>
</tbody>
</table>
## Comparison of Utilities HXrs Modifications

<table>
<thead>
<tr>
<th>Utility</th>
<th>Existing Plain Tube Units (MW)</th>
<th>Targeting Plain Tube Units (MW)</th>
<th>Targeting Twisted Tube Units (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-2013</td>
<td>17.9</td>
<td>16.7</td>
<td>15.8</td>
</tr>
<tr>
<td>C-3001</td>
<td>11.5</td>
<td>3.7</td>
<td>2.9</td>
</tr>
<tr>
<td>E-4002</td>
<td>59.4</td>
<td>49.1</td>
<td>43.9</td>
</tr>
<tr>
<td>E-5006</td>
<td>87.2</td>
<td>49.3</td>
<td>40.3</td>
</tr>
</tbody>
</table>

**E-2013:**
- $Q_H=68.5\text{ MW}$
- $Q_C=93.4\text{ MW}$
- $\Delta T_{\text{min}}=33^\circ C$

**C-3001:**
- $Q_H=45.7\text{ MW}$
- $Q_C=70.6\text{ MW}$
- $\Delta T_{\text{min}}=16^\circ C$
PINCH ANALYSIS

EXISTING PROCESS

SUGGESTED DESIGNS

SIMULATION

DATA COLLECTION

RETROFIT ANALYSIS

• Network PDM
• Application of Twisted Tube Units
• RDA Algorithm Developed

• 4 New TW-HX
• Savings
  • Hot utility = 18%
  • Cold utility = 35%
  • Area Added = 41%
  \[ \Delta T_{\text{min, Existing}} = 33^\circ \text{C} \quad \Delta T_{\text{min, Ret.}} = 16^\circ \text{C} \]
• Emissions Reduction (30 MT/Y)
• Payback Time 11 months
Conclusions:
A Realistic Retrofit Analysis have to consider:

- Pressure drop optimization
- Fouling effect
- New heat exchanger technologies

- A new extension of RDA for twisted tube heat exchangers
- Significant energy saving by application of twisted tube heat exchanger
- Adding 4 new process to process heat exchangers Shell and Twisted Tube (41% Heat Transfer Area more than Plain Tube) to the selected network, results up to 35% for Cold utility and 18% for Hot utility recovery
- Application of this technology results a significant reduction in CO$_2$
Thanks for Your Attention