

# Energy Conservation in Solvent Dewaxing Unit

## 1.0 Introduction

Virtually all industrial processes require both heating and cooling of the process streams. The key to maximise energy efficiency is to capture and reuse available waste heat within the process, reducing the need for additional heating and cooling and thereby eliminating some equipment as well. There are usually many options to recover waste heat like reconfiguring process equipment, heat pumping, process modifications, and integrating the process with the plant heat/power systems. However till recent time, finding the best solution has been more of an art than a science. Pinch Analysis, a systematic procedure based on fundamental thermo-dynamic principles, ensures finding an optimum heat recovery solution [1,2], Benefits include significantly lower energy cost, lower environmental emissions, and increased production capacity, all with highly favourable economics.

This paper deals with the application of Pinch Analysis for Solvent Dewaxing Unit (SDU) of an Indian Refinery. It was noted by the client that a large amount of medium pressure steam was being consumed in the solvent recovery section of the SDU. The basic objective of the present study was to establish the minimum amount of steam required in the solvent recovery section of the SDU and identify suitable cost effective energy reduction schemes. Pinch Analysis is essentially based on a set of data which are derived using heat and mass balance through rigorous simulation of the process system. Hence a good understanding of the -system as well as specific expertise in modelling and simulation is essential for making any suggestion for process modification. The paper reveals that appropriate process modification can generate high profit.

## 2.0 The Pinch Principle

He individual process heating and cooling duties as derived from process heat and material balance are combined to construct cold and hot composite curves respectively drawn on a Temperature Enthalpy (T-H) diagram. The curves represent the enthalpy availability and enthalpy demand in the process at various temperature levels as well as the minimum net heating and cooling requirements. The point of closest approach, where available temperature driving force between hot and cold composite curves is at a minimum, is called the process pinch. It separates the overall process into two distinct thermal domains: a heat sink above the pinch temperature, and a heat source below the pinch temperature. The temperature difference between hot and cold streams at the pinch is called the Minimum Temperature Presently not with KTIL Energy conservation in solvent dewaxing unit Approach (DT<sub>min</sub>). For each value of DT<sub>min</sub>, there are corresponding values of minimum heating and cooling requirements. These are the energy targets for maximum energy recovery.

In order to achieve the targets, the Heat Exchanger Network (HEN) design must satisfy the following three Pinch Principles:

- No hot utilities used below the pinch temperature
- No cold utilities used above the pinch temperature
- No heat transfer from hot streams above the pinch to cold streams below the pinch With the help of these fundamental rules, it is possible to design the process for maximum overall efficiency, achieving the optimum balance between capital costs, energy consumption, operating flexibility and environmental emissions.

## 3.0 Process Background

Three feedstocks namely Inter Neutral (IN), Heavy Neutral (HN) and Bright Neutral (BN) are processed intermittently in the SDU. A block flow diagram of die SDU is shown in Figure 1. The lube oil fraction from Vacuum Distillation Unit is processed in the Furfural Extraction Unit (FEU) to remove

aromatics from the lube oil. Raffinate from FEU enters the chilling section of SDU where it is mixed with the solvent containing Methyl Ethyl Ketone (MEK) and toluene (in almost equal volume ratio) and chilled to separate wax from the oil. In the filtration section the wax crystals, formed during chilling process, are separated in rotary drum vacuum filter.

Filtrate and slack wax mix from filtration section enter the solvent recovery section. This section consists of three subsections - Dewaxed Oil (DWO) recovery section and slack wax recovery section followed by a solvent drying section. Figure 2 shows the block flow diagram of these three sections. Filtrate containing DWO and solvent enters the DWO recovery section comprising of heat exchanger network (HEN1) and a series of three flash columns and a steam stripper in Flash Section 1. Slack wax and solvent mixture enters the slack wax recovery section comprising of heat exchanger network (HEN2) and a series of two flash columns and a steam stripper in Flash Section 2. Solvent drying section consists of a solvent drying column and a steam stripper. Pure solvent is collected from the bottom of the solvent drying column and hot water is pumped out from the bottom of the steam stripper. Since the solvent recovery section of the SDU is a large consumer of steam, pinch analysis was carried out only for this section as suggested by client.

## 4.0 Data Analysis

Considering that a consistent set of mass and energy balance data is required for pinch analysis, it is necessary to reconcile and validate the raw plant data. Following steps were carried out for this purpose:

### 1. Modelling of Hydrocarbons:

Dewaxed oil and slack wax were modelled as separate single hypothetical hydrocarbon molecules for rigorous simulation.

Molecular weight, C/H ratio and Watson-K factor for DWO and slack wax were determined from specific gravity and ASTM data using API correlations. DWO was modelled as a condensed naphtheno-aromatic compound with a side paraffin chain whereas slack wax was modelled as a straight chain paraffin. API correlations to calculate density and specific heat for DWO and slack wax were incorporated into HYSYS (a steady state simulation software from Hyprotech, Canada) in order to calculate mass flow rate and enthalpy accurately.

### 2. Property package selection and parameter estimation:

Several property packages were tried for VLE calculation and it was found that NRTL model matched the operating data closely and it was chosen for simulation. HYCON (a conceptual modelling and design software from Hyprotech, Canada) was used to estimate NRTL parameters for MEK- Toluene-Water system using published experimental T-X-Y data. NRTL parameters for other combinations of DWO and slack wax were estimated using UNIFAC group contribution method in HYSYS.

### 3. Simulation of Solvent Dewaxing Unit:

Based on the above assumptions and specifications, rigorous simulation of the entire solvent recovery section was carried out on HYSYS.

The simulation values thus obtained were found to be closely matching the plant data and these were used for Pinch Analysis.

## 5.0 Pinch Analysis

Pinch Analysis of SDU was conducted following the steps described below.

### 5.1 Data Extraction

The first step in the Pinch study was to obtain the process stream data while ignoring any of the existing heat recovery designs. For each hot and cold stream in the system, the following data were established,

- The start or supply temperature of each stream
- The final target temperature for each stream
- The enthalpy change, from supply to target temperature for each stream.

The enthalpy curves were linearised within temperature intervals for the streams under going phase change.

## 5.2 Targeting

Using the stream data, the minimum heating and cooling requirements for a particular  $DT_{min}$  are predicted upfront of the Heat Exchanger Network (HEN) design by generating composite and grand composite curves. For the present study, a  $DT_{min}$  of 10 °C was selected to generate composite and grand composite curves for further analysis.

## 5.3 Analysis of Composite

Pand Grand Composite Curves and Process Modifications Pinch analysis was carried out for the total solvent recovery section as well as for DWO recovery section and slack wax recovery section separately.

A low hot utility target of 9.9 MMkcal/hr against actual consumption of 21.3 MMkcal/hr was found by heat integrating the two recovery sections (DWO recovery and slack wax recovery). However, it was not pursued since this was not acceptable to the client because of extensive piping modifications, large number of small sized new heat exchangers, space limitations and complexity in operation. Hence, pinch analysis of DWO recovery section and slack wax recovery section was carried out separately.

### 5.3.1 Dewaxed Oil Recovery section

The corresponding composite and grand composite curves for a  $DT_{min}$  of 10 °C are shown in Figure 3 and Figure 4 respectively.

The following major observations can be drawn from these Figures:

- The pinch occurs at a temperature of 132 °C and 122°C for the hot and cold streams respectively
- The hot and cold utility targets are 9.5 MMkcal/hr and 1.4 MMkcal/hr respectively

In comparison to the above targets, the present hot utility consumption is 11.9 MMkcal/ hr, higher than the minimum by 2.4 MMkcal/hr.

## Process Modifications

Process modifications were examined in the dewaxed oil recovery section by applying plus / minus principle. This principle states that shifting of hot streams from below the pinch to above or shifting of cold streams from above the pinch to below will result in reducing the utility target.

Bottom liquid from first flash stage in Flash Section 1 is a large cold stream above the pinch. Following the above principle, a part of this stream can be shifted below the pinch. This can be achieved by increasing vapourisation in first flash stage in Flash Section 1. The most appropriate means of increasing vaporisation in this flash stage is to increase the feed temperature to this stage.

With this process modification the hot and cold utility targets were reduced to 8.9 MMkcal/ hr and 0.8 MMkcal/hr respectively.

### 5.3.2 Slack Wax Recovery Section

The composite and grand composite curves for a  $DT_{min}$  of  $10^{\circ}C$  are shown in Figure 5 and Figure 6 respectively.

The following major observations can be drawn from these Figures:

- The pinch occurs at a temperature of  $110^{\circ}C$  and  $100^{\circ}C$  for the hot and cold streams respectively
- The hot and cold utility targets are  $6.8$  MMkcal/hr and  $3.2$  MMkcal/hr respectively
- In comparison to the above targets, the present hot utility consumption is  $9.4$  MMkcal/hr, higher than the minimum by  $2.6$  MMkcal/hr.

Process Modifications Here again, process modifications were carried out using pinch concepts such as plus/ minus principle to reduce the overall targets. Out of the many modifications attempted, two options proved to be beneficial. These are discussed below.

- **A. Vapourisation Duty of First Flash Stage in. Flash Section 2**

During analysis it was noted that the overhead vapour from first flash stage in Flash Section 2 was a hot stream below the pinch. Following the guidelines set by pinch analysis, it would be beneficial to minimise the duty of this stream. This could be achieved by decreasing vaporisation in first flash stage in Flash Section 2. The most appropriate means of decreasing vaporisation in first flash stage in Flash Section 2 was to decrease feed temperature to this flash stage. With this process modification, the hot and cold utility targets were reduced to  $6.5$  MMkcal/hr and  $2.9$  MMkcal/hr respectively. In comparison to the above targets, the present hot utility consumption is  $9.4$  MMkcal/hr, higher than the minimum by  $2.9$  MMkcal/hr.

- **B. Additional Flash Stage**

Further analysis of the GCC of Figure 6 revealed that a large enthalpy of first flash stage overhead vapour at a fairly higher temperature ( $100^{\circ}C$ ) below the pinch was unutilised and was being lost effectively to cooling water.

There was no cold stream below the pinch to accept this heat. Also a large amount of vapourisation was occurring in first flash stage in Flash Section 2 as indicated by the composite curves of Figure 5. These suggested that the vapourisation could be carried out in two stages. Besides, adding an additional flash stage in the slack wax recovery section would create a hot as well as a cold stream and thus providing more opportunities for process integration. This is clearly indicated in the grand composite curve with an additional flash stage as shown in Figure 7.

The additional flash stage was introduced between first and second flash stages of Flash Section 2. The minimum hot and cold utility targets further reduced to  $4.3$  MMkcal/hr and  $0.13$  MMkcal/hr respectively. Table 1 shows the different target values for dewaxed oil section and slack wax section.

## 6.0 Energy Conservation Schemes

The application of Pinch Analysis to the solvent recovery section of the SOU identified various possibilities, including modifications in the present operating conditions to attain increased energy conservation.

The final step as mentioned was to evaluate the identified possibilities to develop practical heat recovery alternatives. The heat recovery alternatives were developed for IN run (limiting capacity) and were subsequently checked for operability with HN and BN runs.

Two energy conservation schemes were developed and these are given below:

- Scheme 1 : Stand alone optimisation of Dewaxed Oil and Slack Wax Recovery Sections
- Scheme 2 : Additional

### **Flash Stage in Slack Wax Recovery Section**

Scheme 1: Stand alone optimisation of dewaxed oil and slack wax recovery sections In this scheme, the dewaxed oil and the slack wax recovery sections have been optimised individually.

### **Dewaxed Oil Recovery Section**

The modified heat exchanger network in this section requires two new heat exchangers. The areas of the two new heat exchangers were estimated as 180 m<sup>2</sup> and 600 m<sup>2</sup> respectively. This scheme resulted in steam savings of 2.8 MMkcal/hr in the dewaxed oil recovery section in comparison to the present steam consumption.

### **Slack Wax Recovery Section**

The modified heat exchanger network in this section requires one new heat exchanger. The area of the new heat exchanger was estimated as 220 m<sup>2</sup>. The above scheme resulted in steam savings of 2.7 MMkcal/ hr in the slack wax recovery section in comparison to the present steam consumption. Scheme 1 resulted in an overall steam savings of 5.5 MMkcal/hr and cooling water savings of 5.7 MMkcal/hr (in solvent drying section). This corresponds to a steam savings of 25 % compared to the present steam consumption with a payback of 0.6 years.

Scheme 2: Additional flash stage in slack wax recovery section In this scheme, an additional flash stage was considered in the slack wax recovery section and the dewaxed oil recovery section was same as in scheme 1.

This scheme requires two new heat exchangers and one new flash column. The scheme resulted in steam savings of 4.8 MMkcal/hr in the slack wax recovery section compared to the present steam consumption.

Scheme 2 resulted in an overall steam savings of 7.6 MMkcal/hr and cooling water savings of 9.5 MMkcal/hr (in solvent drying section). This corresponds to a steam savings of 35 % compared to the present steam consumption with a payback of 0.4 years.

## **7.0 Benefits**

The cost benefit analysis was carried out for both the schemes. Table 2 shows the benefits obtained from these schemes,

## **8.0 Conclusions**

The present study has identified significant potential for additional energy recovery. Two process schemes have been identified for detailed evaluation. The scheme involving an additional flash stage in the slack wax recovery section results in the highest savings with the shortest payback period. The schemes involve minimal modifications and can be implemented in a normal plant turnaround. Schemes were developed for IN run and then checked for HN and BN run and were found operable.

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## References

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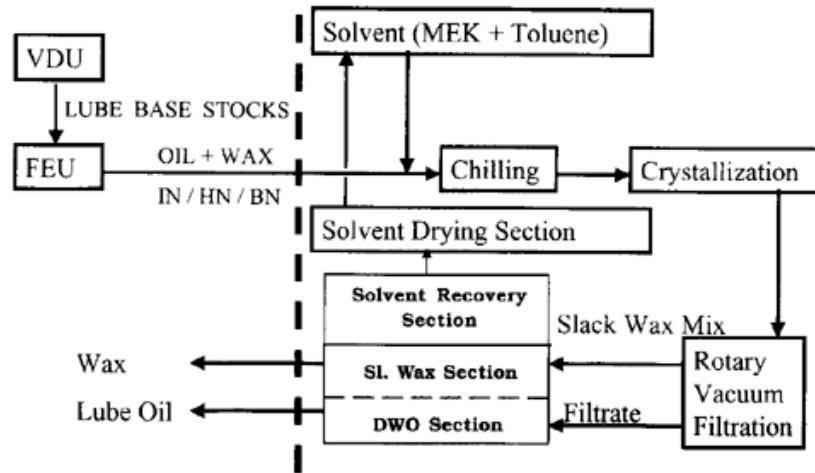


Figure 1 : Process Block Flow Diagram

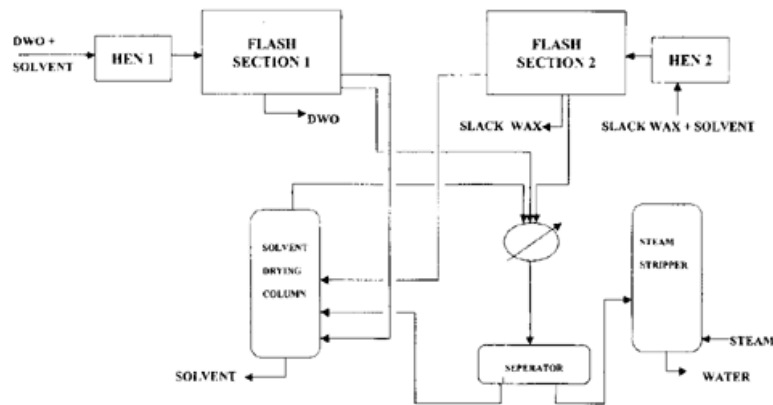


Figure 2 : Block Flow Diagram of Solvent Recovery Section

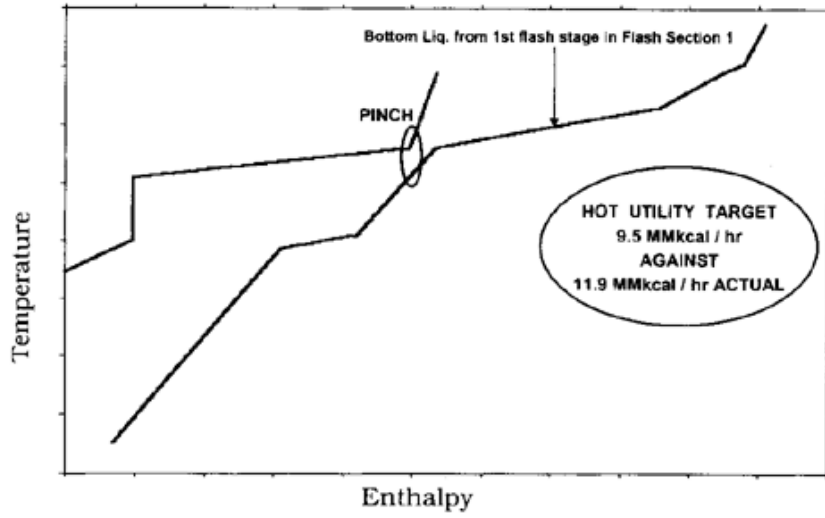


Figure 3 : Composite Curves for DWO Section

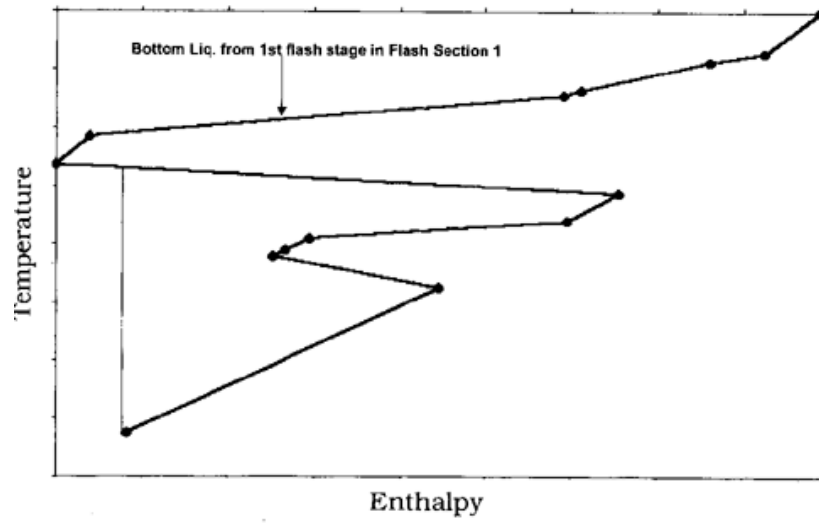


Figure 4 : Grand Composite Curve for DWO Section

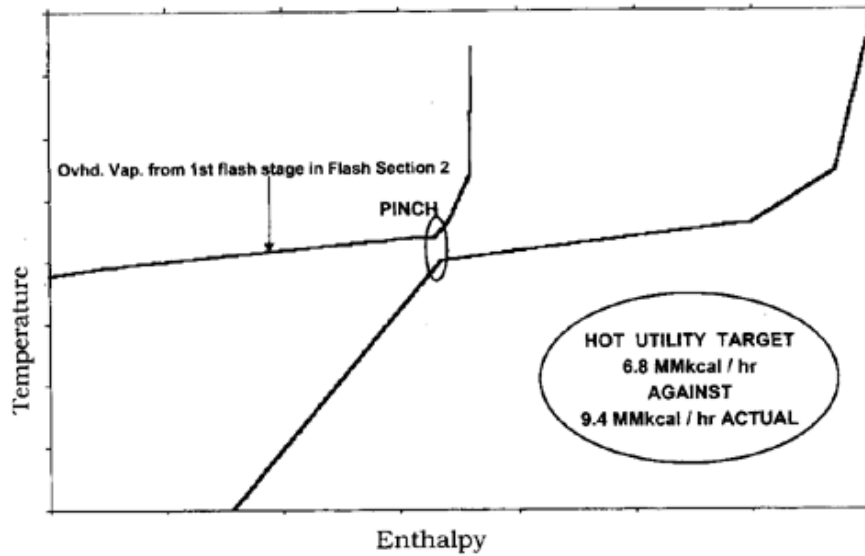


Figure 5 : Composite Curves for Slack Wax Section

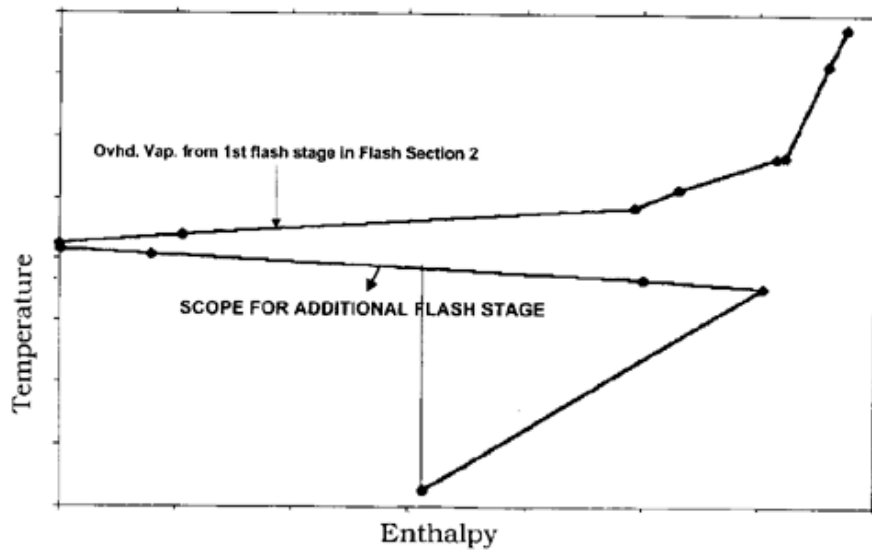


Figure 6 : Grand Composite Curves for Slack Wax Section

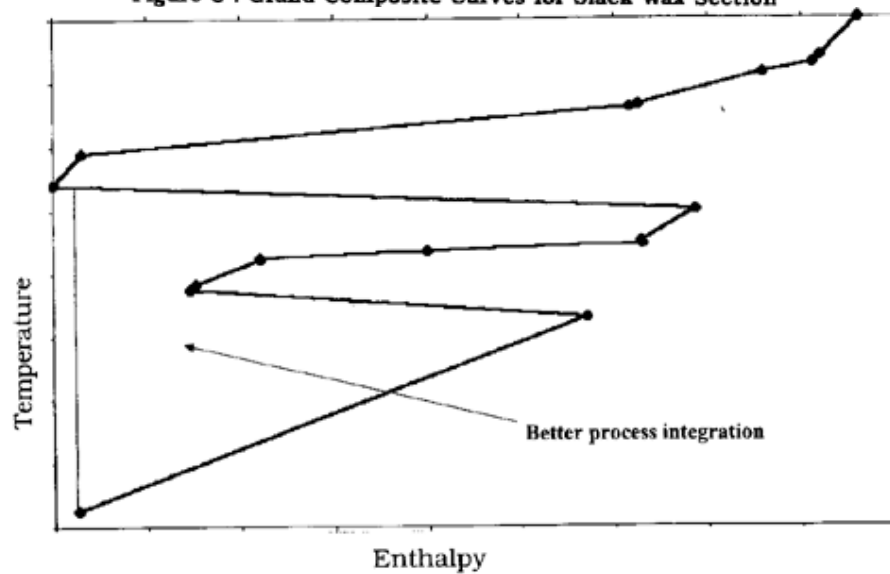


Figure 7 : Grand Composite Curve with Additional Flash Stage

Table 1 : Hot Utility Target Reduction by various Process Modifications				
Section	Process Modification	Energy Consumption, MMkcal/hr		
		Present Operation	Target Without Process Modification	Target After Process Modification
Dewaxed Oil	Feed Temp. to first stage flash of Flash Section 1 increased	11.9	9.5	8.9
Slack Wax	Feed Temp. to First stage flash of Flash Section 2 decreased	9.4	6.8	6.5
	Additional flash stage in Flash Section 2	9.4	6.8	4.3

Table 2 : Calculated Benefits of Proposed Schemes			
Process Scheme	Steam Savings, T/hr	Additin Heat Exchange Area, m2	Payback Years
Stand Alone Optimization of DWO and Slack Wax sections	11	1000	0.6
Additional Flash Stage in Slack Wax section	15.	950	0.4

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**Reference:**

<http://www.centreforhightechnology.com/>