Solvent De-asphalting Technology : Development & Performance (Conventional Vs Supercritical)

CSIR - INDIAN INSTITUTE OF PETROLEUM, DEHRADUN

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Presentation Outline

- About Solvent De-asphalting Technology (SDA)
- Development of Conventional De-asphalting Technology by CSIR-IIP and EIL
- Development of Supercritical De-asphalting Technology by CSIR-IIP and EIL
- Case Study - Application of Pinch Analysis on SDA unit to minimize steam and furnace duty requirements
- Summary





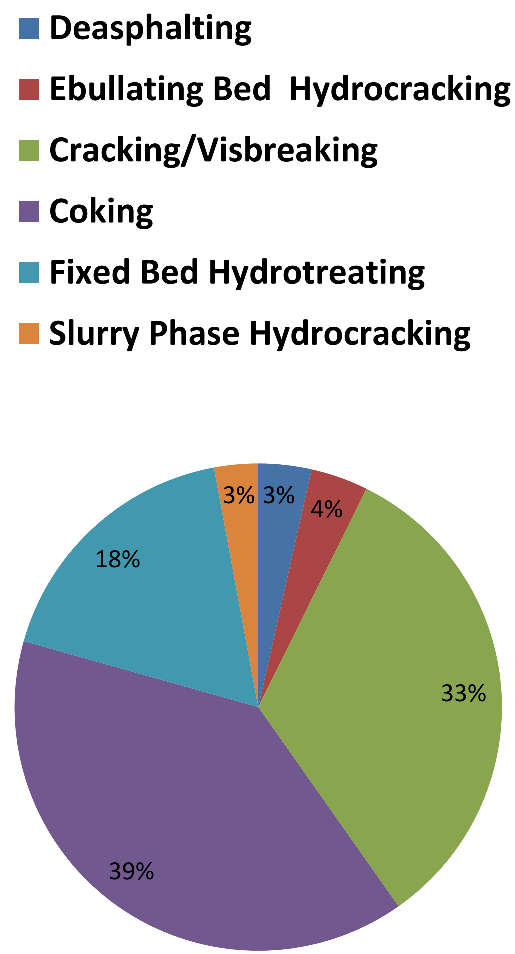
Introduction

- Several technologies are available for Resid Up-gradation :

  Non-catalytic
  - De-asphalting
  - Cracking/Visbreaking
  - Coking

  Catalytic
  - Ebullating Bed Hydrocracking
  - Fixed Bed Hydrotreating
  - Slurry Phase Hydrocracking

- De-asphalting is a low-cost option for processing of heavy crudes and production of high viscosity lube base oils
- CSIR-IIP has developed and commercialized Solvent De-asphalting Technology along with EIL







Drivers for Solvent De-asphalting (SDA)

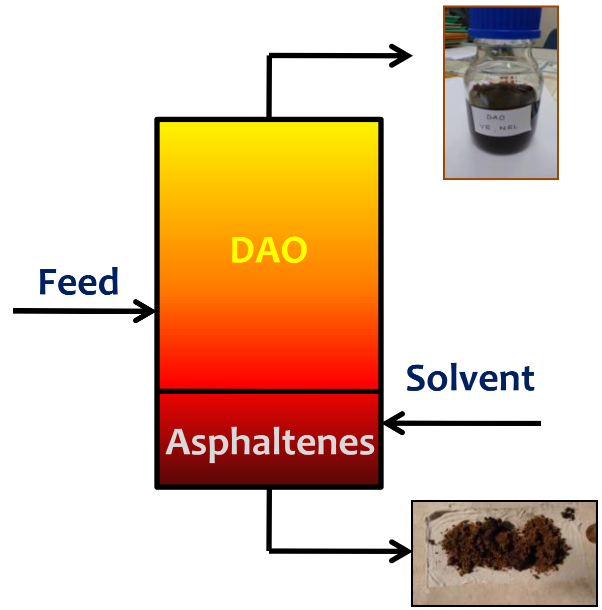
- Required to produce high viscosity lube base oils (Bright Stocks)
- Increased demand of feed stocks for FCC and Hydrocracking units to make more transportation fuels
- Challenge for processing of heavy crudes
- Declining residual fuel oil market
- To produce 'Asphalt' for use as a liquid feed for 'Gasifier' to make power, steam and hydrogen
- No solid handling - alternate to Delayed Coking
- To process un-conventional feed like Bitumen Tar Sands

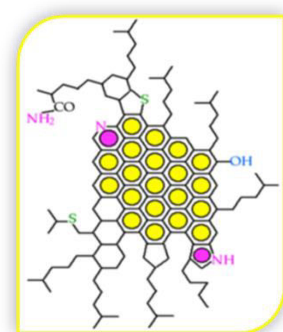




Solvent De-asphalting (SDA) Process

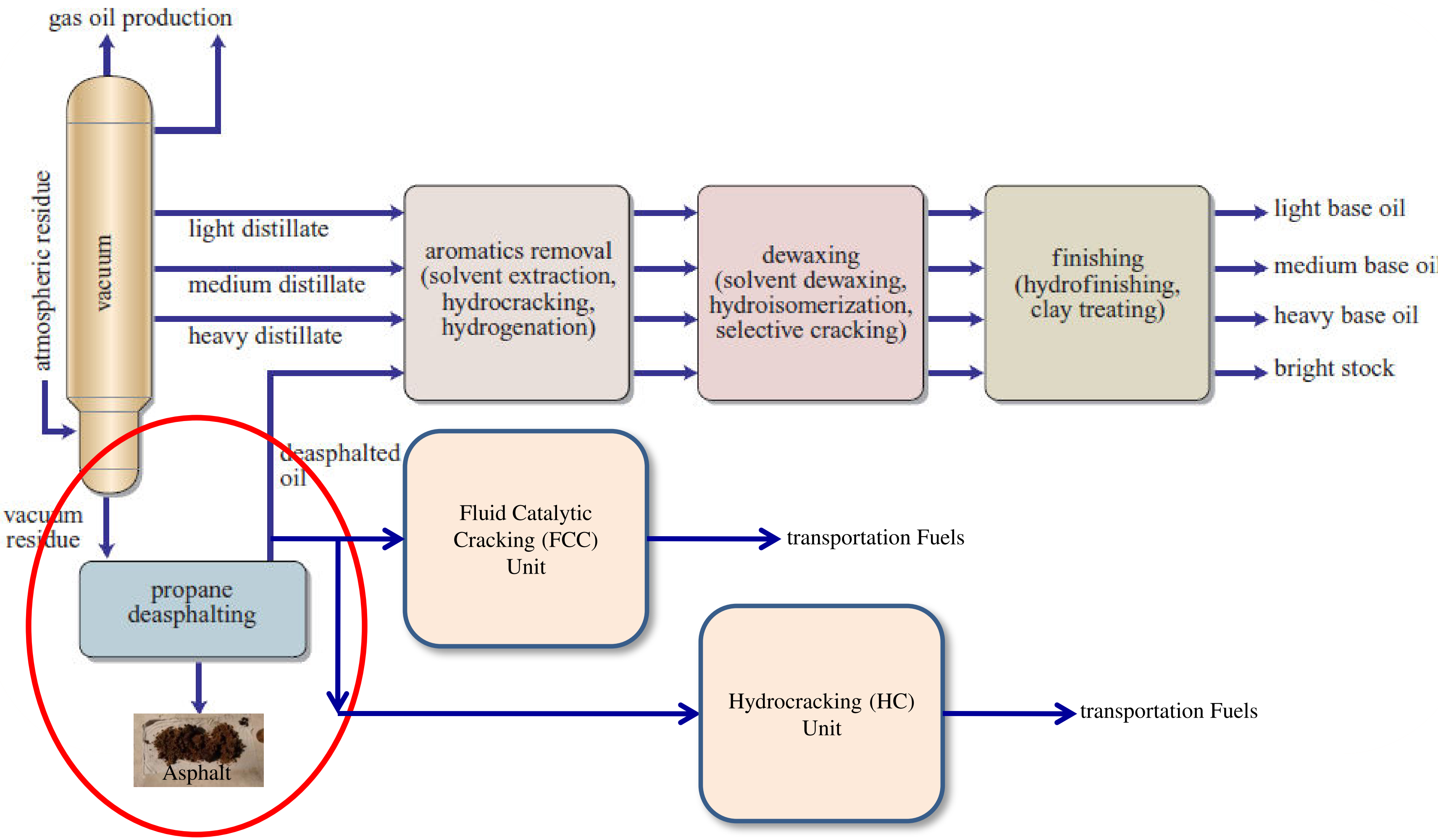
- A non-thermal, non-catalytic process
- Separates ‘ Asphaltenes ’ from crude or petroleum residues by selective precipitation
- Asphaltenes are coke precursor and deactivate catalyst sites, if feed is processed through Catalytic Processes
- Paraffinic solvents (C_3 to C_7) are used to separate asphaltenes
- Process removes asphaltenes, sulfur, nitrogen and metals from feed stocks
- Process is used to produce heavy lube base oils (Bright Stocks) and feed for FCC or Hydro cracking units





Asphaltene Core

Typical Location of De-asphalting Unit in Refinery



CSIR-IIP / EIL Conventional Solvent De-asphalting (SDA) Technology





Chronology of Developments……….

- Before 1980, indigenous technology for De-asphalting was not available
- CSIR-IIP started work on development of SDA Technology in late 70's
- Agreement was signed between CSIR-IIP and EIL to develop SDA technology jointly
- IIP generated lab data for design and construction of SDA pilot plant
- Scale up data generated for design of two commercial units: at HPCL, Mumbai and CPCL Chennai Refineries to produce Bright Stock
- Both units are running smoothly for the last 22 years





Work carried out at CSIR - IIP





Feed Stocks

- A large data bank on solvent Deasphalting was generated on a number of vacuum residues (VR) from various crudes :
  - North Rumaila crude
  - Darious crude
  - Bombay High crude
  - Basrah crude
  - Aghazari crude
  - Light Iranian crude
  - Kirkuk crude
  - Light Arab & Heavy Arab crudes
  - North Gujarat Crude
  - Assam Crude Mix





Typical Properties of Design Feed Stocks

- Typical physico-chemical properties of Light Arabian, Heavy Arabian residues and their Mix

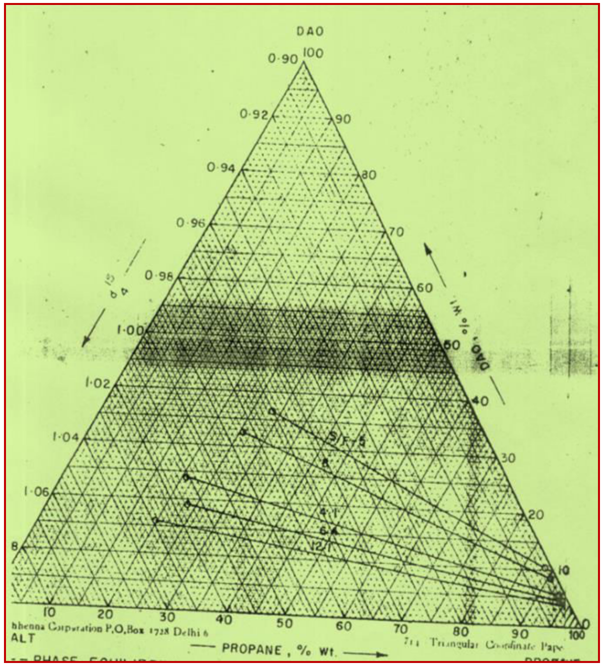
	VR-1	VR-2	VR 3
Specific Gravity	1.003	1.0246	1.0229
Viscosity @ 100^{o}C	345	1900	1099
CCR (Wt%)	16.4	21.1	20.7
Asphaltenes (Wt%)	4.2	7.5	6.3
Sulfur (Wt%)	4.05	4.45	4.29
Nickel (ppm)	19	70	46
Vanadium (ppm)	61	21	48
Nitrogen (ppm)	2875	1900	2080



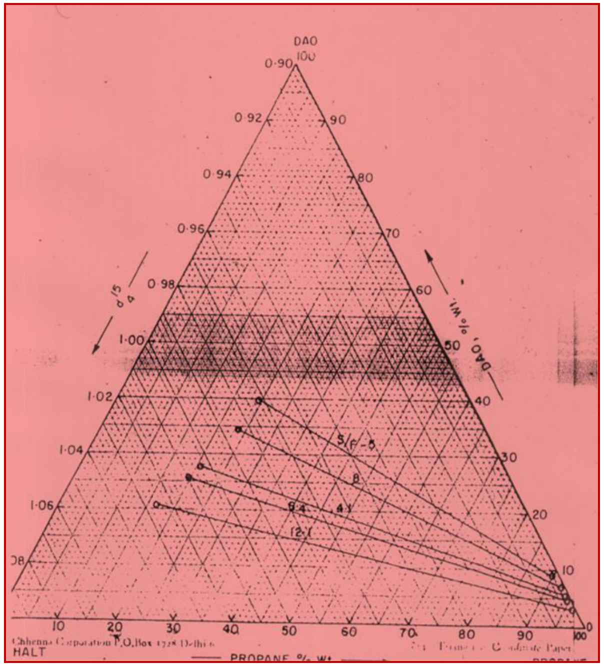


Liquid-Liquid Extraction Data

- Generation of Liquid-Liquid Equilibrium (LLE) data on feed stocks at IIP batch SDA unit (phase equilibrium data/tie line data)



LLE at Low Temperature



LLE at High Temperature





SDA Pilot Plant

- Design and Commissioning of SDA pilot plant at IIP

Extractor

Steps followed in design of commercial units….

- Physico-chemical characterization of design/ reference feeds
- Generation of Liquid-Liquid Equilibrium (LLE) data at IIP batch SDA unit (phase equilibrium data/tie line data) with propane
- Data generation on IIP pilot plant
- Characterization of products (DAO & Asphalt) produced in pilot plant
- Process parameters were optimized for desired quality and yield (DAO) :
    - Temperature
    - Solvent-to-Feed ratio
    - Pressure
- Development of Process Flow Diagram
- Modeling and Simulation of entire flow sheet
- Design of the Extraction column

Factors Considered for Designing of SDA Unit.. contd

- **VR Feed Stocks :**

- 80 : 20 Vol mix of Light and Heavy Arabian Crude Mix
- Basrah Crude
- Light Iranian Crude

- **Product Rate :** 50,000 TPA of finished Bright Stock
- **Characteristics of DAO**

- CCR Wt % : 2.0 -3.0 (max)
- Viscosity @98.9° C : 42 -48 cSt
- Density gm/cc @ 15° C : 0.93 – 0.94

- **Yield of DAO :**

Crude Source	DAO Yield wt%	DAO Yield vol%
80 : 20 Vol LA and HA Mix	19.6	21.8
Basrah Crude	20.9	23.0
Light Iranian Crude	26.3	28.7

Factors Considered for Designing of SDA Unit.. contd

Creating Future Fuels

- Feed, Product & Solvent Specifications

Feed (VR)	Case – I (Light Iranian Crude)	Case – II (Arab Mix Crude)
Sp. Gravity	1.007	1.045
Molecular Weight (Dalton)	781	871
Conradson Carbon Residue (wt%)	18	25
Viscosity @ 98.9° C (cSt)	800	14050
De-Asphalted Oil	**Case – I (Light Iranian Crude)**	**Case – II (Arab Mix Crude)**
Sp. Gravity	0.935	0.950
Conradson Carbon Residue (wt%)	2.5	2.5
Viscosity @ 98.9° C (cSt)	35-45	35-45
Solvent Content (max ppm)	80	80
Asphalt	**Case – I (Light Iranian Crude)**	**Case – II (Arab Mix Crude)**
Sp. Gravity	1.045	1.075
Penetration (0.1 mm)	5-10	5.10
Solvent Content (max ppm)	30	30

Propane Solvent			
Sp. Gravity @15° C	0.51	Boiling Point	.42.0 ^{O}C
Viscosity@ 54° C (cSt)	0.20	Critical Temp.	96.7 ^{O}C
Propane/Ethane/Butane/Propylene (mol%)	95/1.6/3.3/0.1	Critical Pressure	42 Bar
Vapor pressure@ 40^{o}C Kg/cm^2	19.7	Molecular Formula	C_3H_8





Factors Considered for Designing of SDA Unit.. contd

- **Specifications of Extractor Operating Variables**

	50:50 LA HA mix	Iranian Light
Column Pressure (Kg/cm^2) abs	40.0	40.0
Solvent-to-Feed Ratio (v/v) @ 15° C	8.25	8.00
Column Top Temp. ° C	75 - 79	68 - 74
Column Bottom Temp. ° C	54 - 57	54
Pre-dilution Ratio %	10	10
Extractor t' put Capacity (m^3/hr)	69.4	72.0





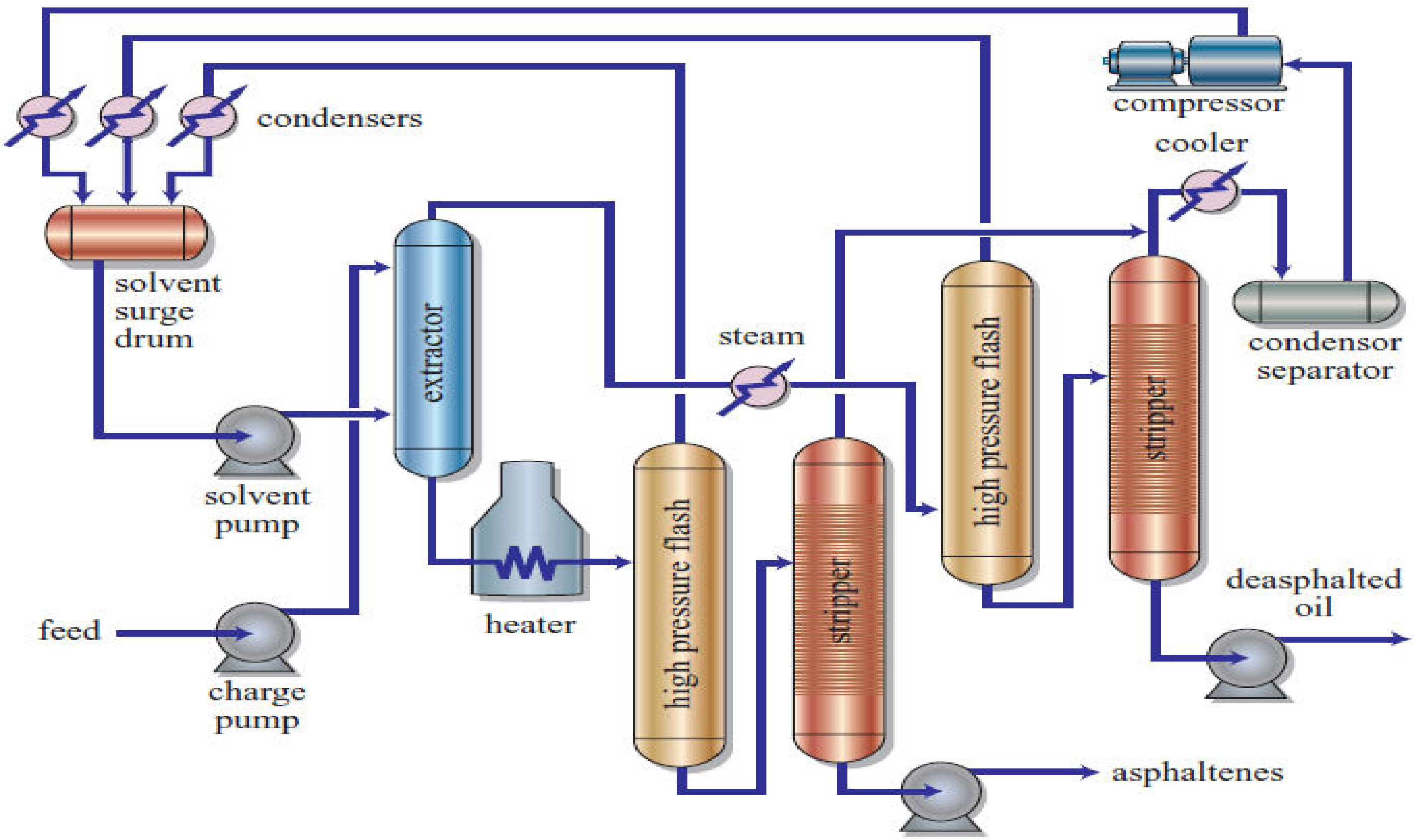
CSIR-IIP / EIL Supercritical De-asphalting Technology





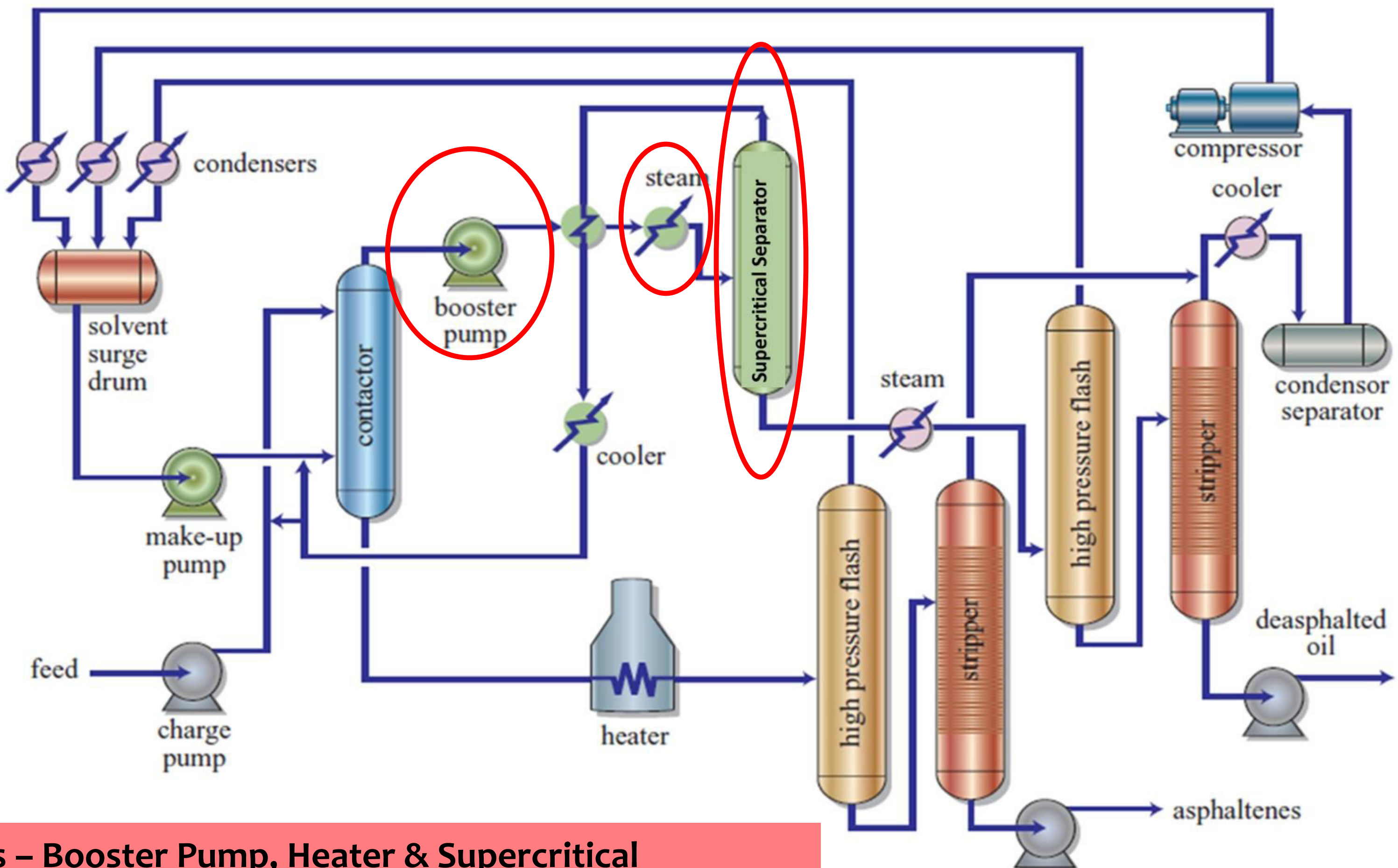
De-asphalting Process :

Conventional Solvent Recovery Block Flow Diagram



De-asphalting Process :

Supercritical Solvent Recovery for Converted Deasphalting Unit



Additions – Booster Pump, Heater & Supercritical Separator

Background

- IIP and EIL decided to upgrade the SDA to supercritical solvent recovery
- IIP along with EIL and HPCL submitted a proposal to CHT for funding . Scientific Advisory Committee of MoPNG approved the project

Supercritical SDA Technology Development Step-by-Step

- Physico-chemical characterization of various feeds
- Test Run at conventional PDA Plant at HPCL Mumbai
- Generation of Liquid-Liquid Equilibrium (LLE) data on feed stocks at IIP batch PDA unit (phase equilibrium data/tie line data)
- Design of an add-on pilot plant to process a slip stream of DAO - propane mix from extractor top for supercritical separation of propane and DAO
- Adequacy study of equipment of existing PDA plant at HPCL Mumbai Refinery
- Modeling and Simulation of Process
- Test Run at PDA Plant at HPCL Mumbai in supercritical mode
- Successfully demonstrated Supercritical PDA Technology at HPCL Mumbai Refinery





Operating Conditions (Conventional Vs Supercritical)

- **Main Operating Conditions for Conventional and Supercritical SDA**

	Conventional	Supercritical
Feed (m^3/hr)	36 - 50	36
Extractor Top/Bottom Temp. (° C)	72/50	72/50
LP Separator Pressure (Kg/cm^2)	23.5	26.0
LP Separator Temp. (° C)	67	67
HP Separator Pressure (Kg/cm^2)	36.5	42.0
HP Separator Top/Bottom Temp. (° C)	110/160	103/103





Application of Pinch Analysis on Propane De-asphalting (PDA) Unit to Minimize Steam and Furnace Duty Requirements





Background

1. PDA Unit

- Generally, PDA units are designed for high solvent-to-feed ratios; values of 16 to 18 are not uncommon.
- Huge quantity of solvent is recovered from DAO and pitch stream by evaporation through multiple flashes for its reuse – a highly energy intensive process
- Historically, 'Pinch Analysis' tool was not available during initial development of supercritical solvent recovery system

2. PDA unit operations

PDA unit has a general configuration :

- Feed and Extraction section
- De-asphalted oil Recovery Section
- Pitch (Asphalt) Recovery Section





Background….. contd

3. Problems

- One of the Indian Refinery was facing problem in PDA unit i.e. Choking and fouling problems in asphalt mix/asphalt run down heat exchanger
- This was leading to significant increase in furnace duty and asphalt cooler duty
- Also adversely affecting the unit throughput

4. Observations

There was a huge delta T difference at the entrance of asphalt mix which causes asphalt deposition





IIP's Solutions

IIP proposed to carry out 'Pinch Analysis' on PDA unit for energy and process optimization

1. Pinch analysis of PDA solvent recovery section was carried out using enthalpy data derived from converged simulation files validated with plant operation data for optimized operation conditions
2. The sensitivity analysis of overall energy consumption for change in pressure and extent of propane recovery in flash drums was carried out to select best operating conditions.
3. Operating conditions were optimized by a sensitivity analysis for hot utility requirement for:
   - Change in feed temperature to HP Flash
   - HP flash pressure and % vaporization in HP Flash

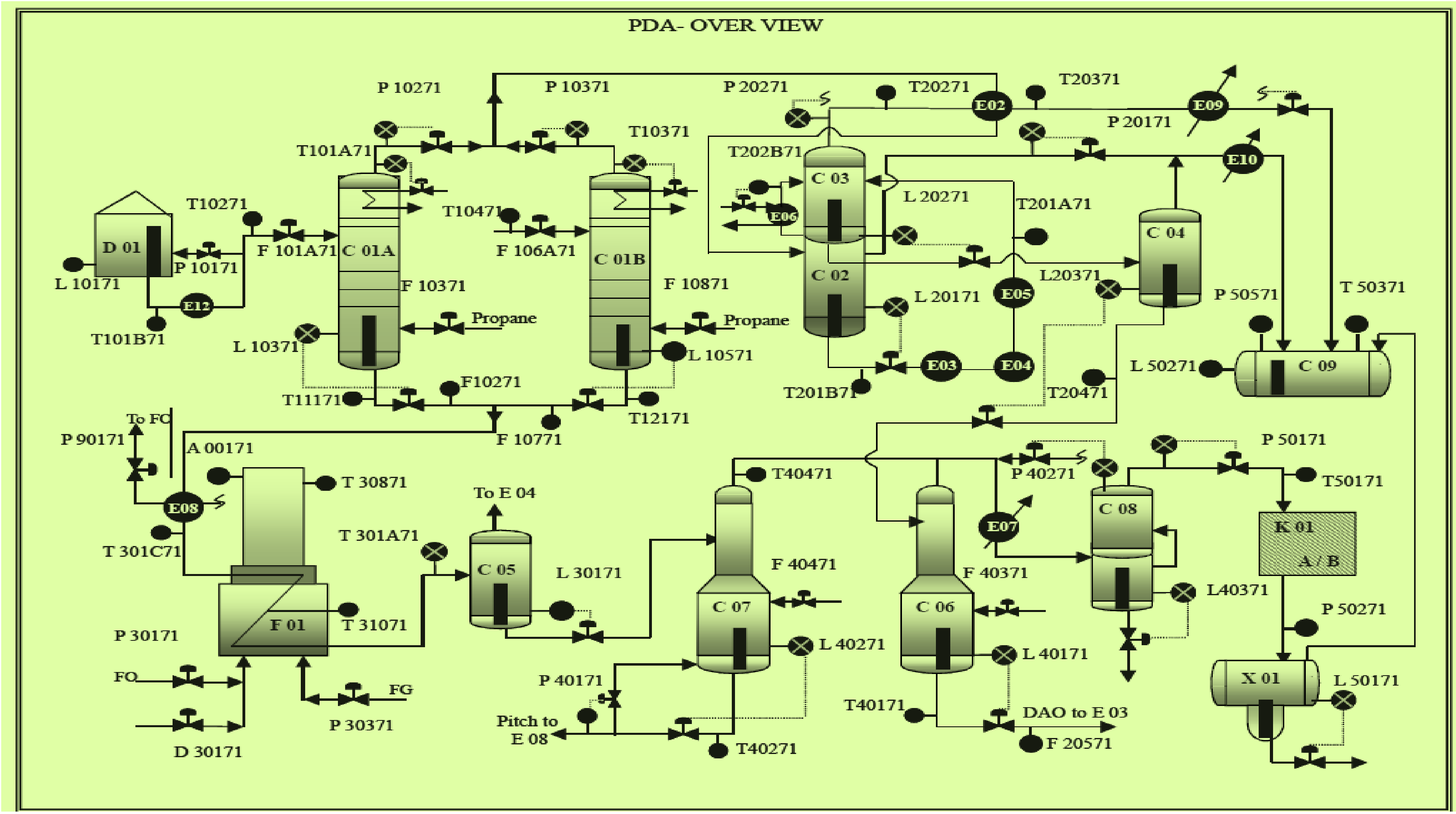




IIP's Solutions…. contd

4. Energy of Hot streams which was not utilized properly in the process was also identified.
5. Based on above findings a new heat exchanger network was designed.
6. New integrated process suggests not only significant saving in LP steam and furnace duty but also troubleshoots the choking and fouling of asphalt based heat exchanger.

Process Flow Diagram of Existing PDA Unit



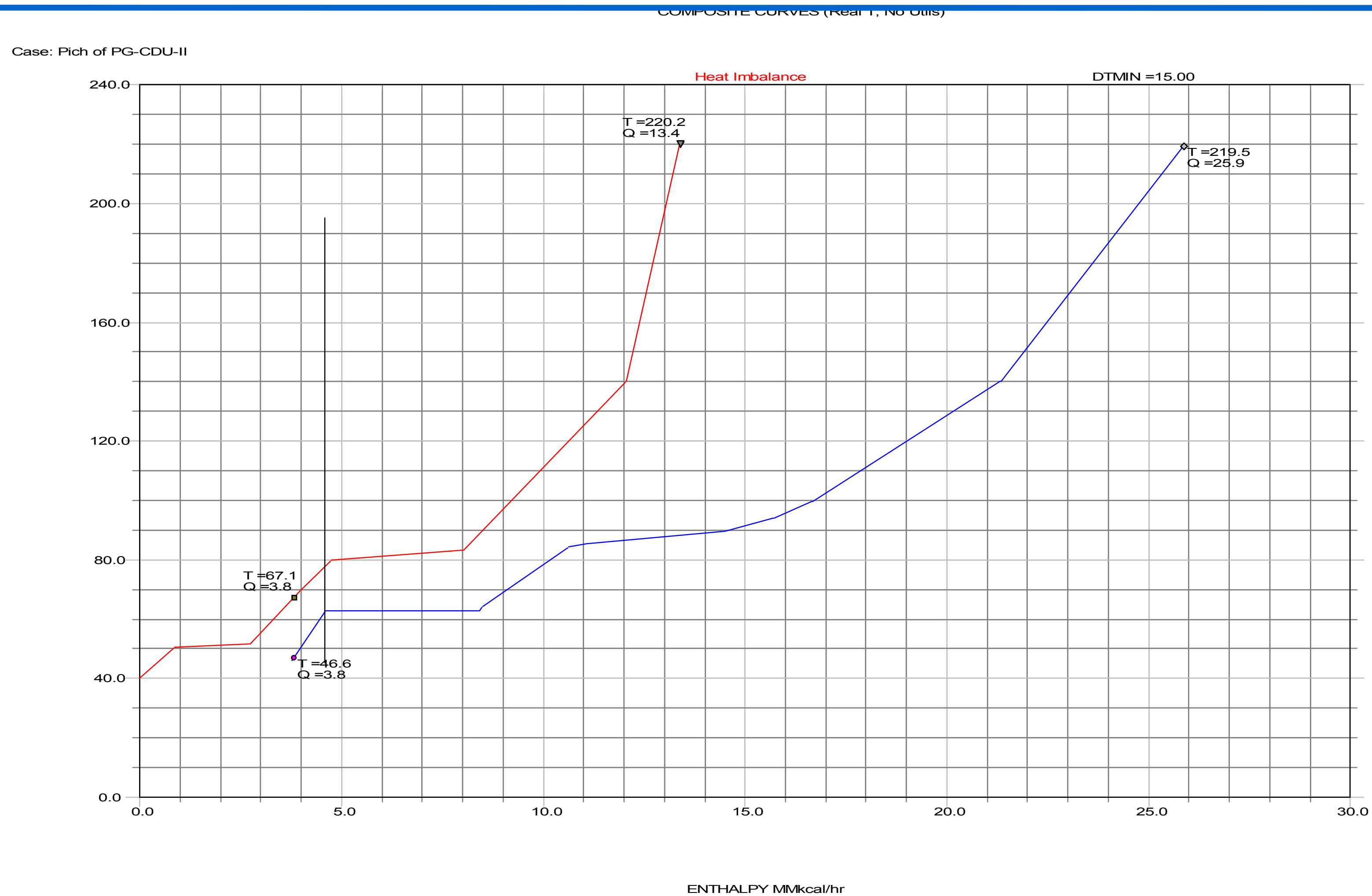
Stream Data for Overall System

Stream	nomenclature	Supply Temp ° C	Target Temp° C	FLOW (KG/HR)	Duty MMkcal/hr
DAO mix to LP FD	DAO LP	62.80	62.84	159574	3.840
DAO mix to HP FD	DAO HP	64.3	84.5	81974	1.135
DAO mix to HP FD	DAO HP1	84.5	89.6	81974	3.099
DAO mix to HP FD	DAO HP2	89.6	99.6	81974	1.136
DAO mix to HP FD	DAOHP3	99.6	140	81974	2.384
HP FD overhead vapor	HPOVH	140.0	83.3	66209	2.577
HP FD overhead vapor	HPOVH1	83.3	80.0	66209	3.179
HP FD overhead vapor	HPOVH2	80.0	40	66209	2.052
Asphalt FD OVHD vapor	ASPOVH	220	51.5	28767	2.798
Asphalt FD OVHD vapor	ASPOVH1	51.5	50.6	28767	1.810
Asphalt FD OVHD vapor	ASPOVH2	50.6	40.0	28767	0.329
DAO to storage	DAO	140	70	15101	0.627
VR+prpane mix to extractor	VR+propane-1	139.6	129.8	89056	0.723
VR+prpane mix to extractor	VR+propane-2	129.8	110	89056	1.101
Asphalt to storage	Asphalt	220	170	62339	1.840
ASPHALT mix	ASmix1	46.18	85.29		1.91
ASPHALT mix	ASmix2	85.29	93.98		1.47
ASPHALT mix	ASmix3	93.98	220.00		7.15

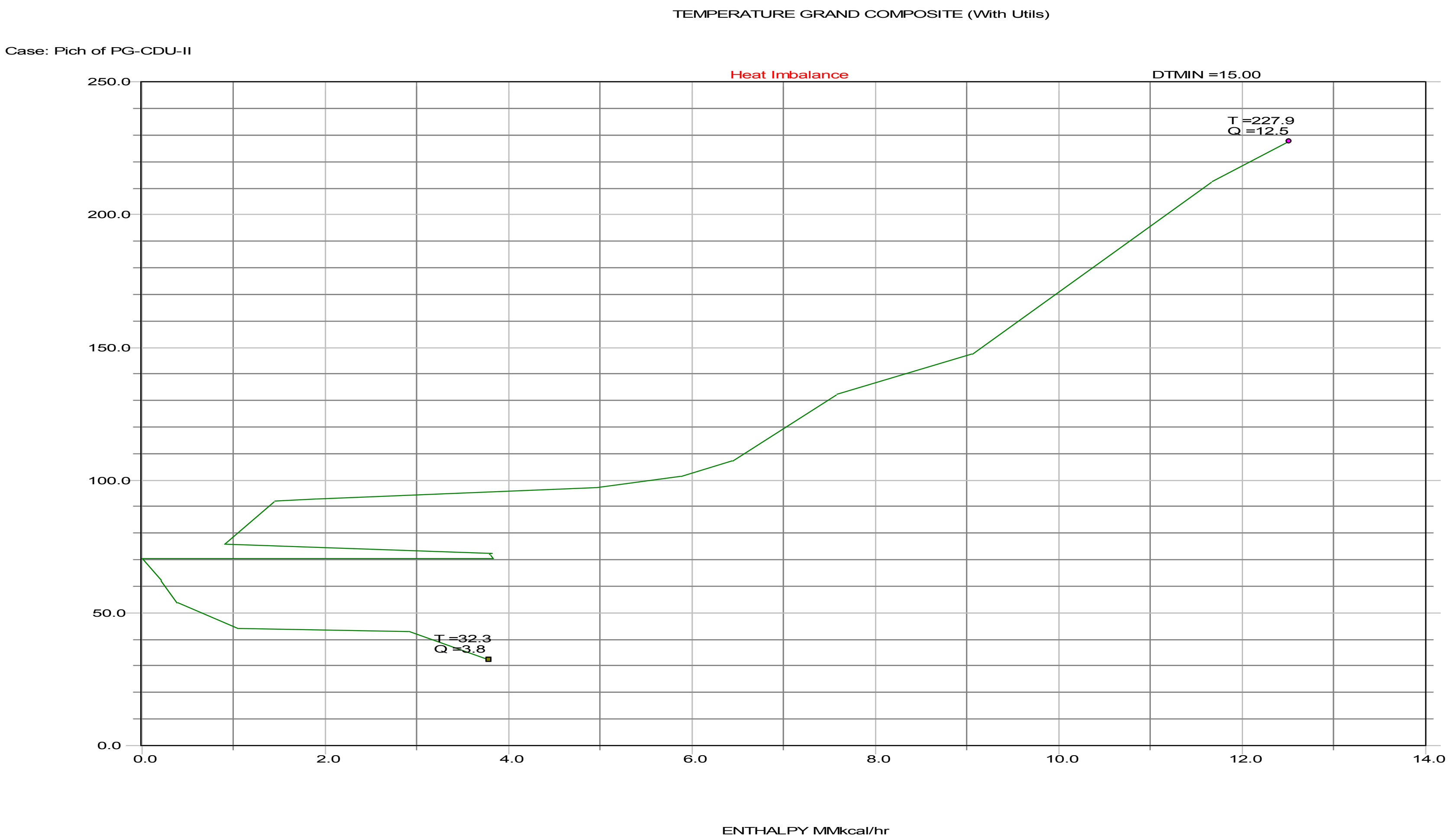




Composite Curve : Excluding Asphalt R/D



Grand Composite Curve for Combined Scenario



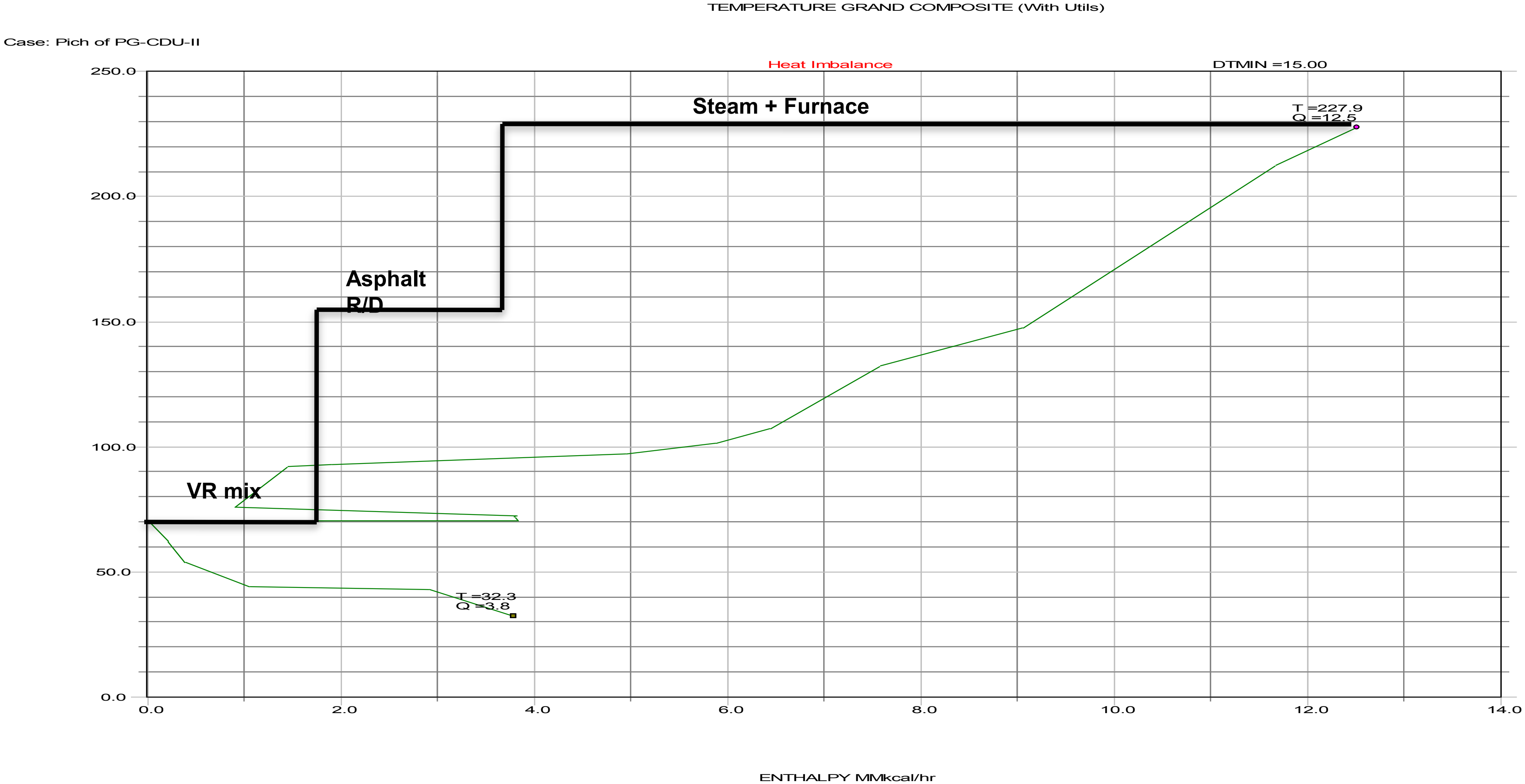
Observations from Pinch Analysis

- Pinch Temperatures : 70.3 °C
- Process to Process Heat Exchange: 22.8 MMKcal/Hr
- Pinch Utility Targets
  - Hot : 12.5 MMKcal/Hr
  - Cold : 3.8 MMKcal/Hr
  - Does not include Cold utility requirement to condense vapour from strippers and after flash

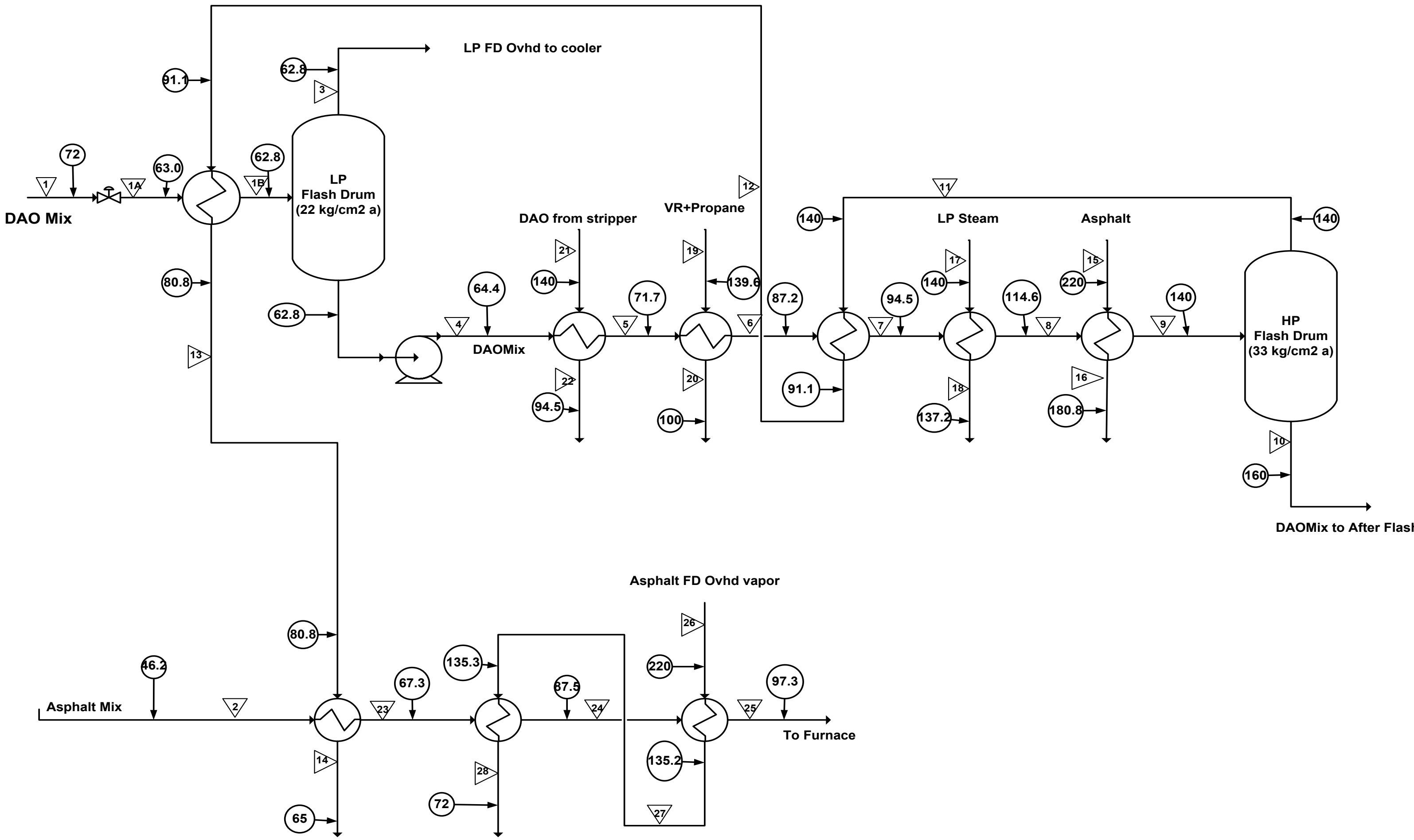




Utility Placement



Proposed Heat Exchanger Network







Major differences in the Flow Sheets before and after Heat Integration

- Use of excess heat available in VR-propane mix stream going to extractor
- Use of HP flash drum vapor heat to preheat the LP flash bottom stream and pitch mix stream
- Troubleshooting of problem of congealing of the pitch and pitch mix stream heat exchanger by exchanging the heat of pitch stream with hot DAO stream with controlled outlet temperature.
- Exchanging the heat from Pitch flash drum vapor stream in pitch recovery section instead of DAO recovery section.
- New PDA configuration includes addition of 4 new heat exchangers





Energy Consumption Comparison

The utility and financial savings summary for existing and after IIP' s solution is given in Table. There is drastic reduction in utility consumption.

Utility Name	Existing case	IIP' s Solution	Savings	
	Energy (MMkcal/hr)		Energy	*Financial
Furnace duty	10.53	7.07	3.46	9.23
LP steam, MMkcal/hr	5.752	1.6	4.15	9.86
Cooling utility	17.94	10.39	7.55	N.E

*Fuel oil price: 30000 Rs/ton, LP steam price -1500 Rs/ton, furnace efficiency-90%; Fuel oil and hating value-10000; LP steam heating value=507 kcal/kg.

- Proposed configuration implementation provides savings :
  - LP steam by 72% in DAO recovery Section
  - Furnace duty by 33% in Asphalt recovery section





Conclusions of Pinch Study

- Existing SDA units can be optimized using pinch analysis and process simulation for reducing energy consumption by ~ 50%.
- Proposed energy efficient configuration for propane de-ashphlting of vacuum residue fetches Rs 19.07 crores financial savings.
- This will result in pay back period of few months for additional heat exchangers cost.

Considering the benefits of above study, It seems that a proper thought should be given to optimize the existing PDA units before shifting to super critical process.





Summary

1. SDA is emerging as a technology for up-gradation of petroleum residues and non-conventional feeds
2. CSIR-IIP along with EIL has developed a SDA Technology. Successfully running in two Indian refineries.
3. CSIR-IIP and EIL have also developed a supercritical SDA Technology. Trial run successfully given at HPCL Mumbai Refinery.
4. IIP also provides technical supports to Refineries
5. IIP offers Pinch Analysis for existing SDA units for their optimization. In one study, the redesigning of HEN led to significant energy saving and reduce carbon footprint.






Thank You