Byco: An Overwhelming Learning Experience

(A more like compte rendu of internship)

June – July 2016
At ORC - I

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Prologue

This report has been written with an intention to share my personal experience at Byco Petroleum Pakistan Limited as an engineering intern and to give exposure to the future interns as well as any individual who wants to know about it. Thus, I personally want to call it a review based write-up report. If anyone wants to know about the corporate profile, then the official website describes at its best that’s why I have not discussed about it separately. Similarly, being a forward vertically integrated company; knowledge about the organization, marketing and the other end-to-end business can also be dug online. As a Chemical & Process Engineering student, I have merely focused on the process and operations side during the internship period, covering all the possible downstream section. Though, I have also shared some words about the safety regulations and compliances as well as laboratory testing methodology being used at Byco. Thus, this report mainly incorporates major part of the above said discipline.

My location was at ORC-1 under Operations/OMS. The environment of safety over there is really sound which shows they are maintaining the safety compliances to the defined level. Tons of things available to learn over there which all cannot be fully understand during the limited internship period but I would like to advice the readers, whether one have studied the concerned subjects or not; try to gain some pre-requisite knowledge about the process as it would surely be fruitful for the future interns. I hope the readers can find this small contribution helpful in knowing the dynamics of the process side of the plant.

Acknowledgement

The Byco corporate office and HR department deserve the word of appraisal for providing the chance to the novice undergraduates to get the real-time exposure of industry and an unforgettable learning experience, also should be given huge applause for reaching the university and hiring the students as an intern as well as to the Directorate of Industrial Liaison, NED-UET for the timely management and support to the students. Every individual, from technicians to engineers, whoever played a role in my learning experience earns bunch of applause. I would also like to thank the non-technical staff of the admin office for the courage and support they have showed. Handling interns is not an easy task, the time it consumes of Shift Engineers costs much but they have provided us the maximum possible period for briefing about the plant while maintaining their own working responsibilities and for me, this is what actually matters in creating a foreground image of a company. Thanks a million, Byco!

Dated: 14th July 2016

1 all information cited here or whatever are as of July, 2016.
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General Overview

The whole plant is mainly divided into two main sections. The ORC is responsible for the processing of crude till the run-down of the final product while OMS handles the crude and final product shipment & storage. Remember that, the below hierarchy only incorporates the description of the operations side of the plant.

At Oil Movement and Storage, local crude comes from the interior oil depot in Pakistan through bowsers which have very low salt/Sulphur content present in it thus, it is termed as sweet crude. The imported crude comes via oil tankers and moored at Byco’s SPM through which all the crude comes directly to the storage area through long on and off shore pipelines system which reduces the transportation cost. It operates under Byco Terminals Pakistan Limited. Further, the oil can be blended with local crude according to the desired outcome. Usually, they don’t run the plant purely on local crude nor on the imported one. The storage section can also be classified into two sections, one is the product storage while the rest being crude storage tanks.

Apart from the process section, Utilities and Offsite are also present. The utilities department mainly work to meet the certain requirements of the plant. Steam generation, instrument air production, water treatment and supplying, production of chemical additives and look after of cooling tower, electricity distribution and maintenance all comes under utilities. Offsite are the departments that is situated outside the battery limits of process plant which includes the laboratory for testing, ERT (Emergency Response Team) which not only ensure safety measures but also responsible for taking quick actions when there’s any hazardous situation. A medical department is also present there for providing first aid treatment in any emergency case.

At Oil Refining Complex – I, there are total of five main process units which all are currently operational combining in total of handling about 35,000 barrel/day of crude. Customarily, the plant is also divided into two sections, termed as Black Section & White Section. The Black Section relates to the processing, separation, and handling of bottoms product usually furnace/lube oil, residues etc. while the White Section relates to the overhead product handling
like naphtha, gasoline, LPG etc. From their product catalogue, the main product is HSD (High Speed Diesel) also they have been making Winterized Diesel but now, not producing it for two years. They also do not produce HOBC due to less demand. They don’t market Kerosene as a commercial product rather than they inject it in diesel for high yield or make JP – I (Jet Fuel) as per demand rest, they produce PMG (Premier Motor Gasoline), furnace oil and LPG.

**ORC – I** is a hydro skimming type of refinery includes atmospheric distillation system along with necessary naphtha treatment. The main reason of calling it a hydro skimming refinery will be explained in the further process description section.

ORC – I operates under Byco Petroleum Pakistan Limited. ORC – II has been commissioned but not yet operational, its main outcome would be petroleum products and chemicals and is currently labelled under Byco Oil Pakistan Limited. Two major debottlenecking and revamps were done in 2008 and 2010 respectively which enhanced the capacity of production and overall payload on the plant was reduced. Byco was formerly known as Bosicor Petroleum. Currently, Byco co-owned by Abraaj Mauritius and Byco Business Incorporated.

This report has been divided into three main sections:

- Process Section at ORC – I
- Oil Movement & Storage alias Tank Farm
- Utilities
Process Section at ORC – I

From here, the process description begins. As I have already explained the main units that are working to produce the refined final product. So, here, I have broken down individual unit process as well as the pre-treatment part (if present) for better understanding.

Crude Distillation Unit (CDU)

CDU is the main and initial process unit of the plant. The main aim is not only to receive crude and convert it into valuable fractions but the pre – treatment also. It can be further divided into various small sections according to the type of further initial product treatment but here, it be treated as a one unit process.

Pre – Treatment of Crude

Blended Crude is pumped from the storage tank via four centrifugal charged pumps towards the CDU area where the stream of Caustic (3-5 °Be) is injected into the coming crude feed. This is a pre – requisite procedure to avoid any further contamination or scaling offered by salt present in the crude. Further, it goes towards the heat exchanger for pre – heating to the process temperature. The plant has two main trains of shell and tube heat exchangers, the new train was installed after the revamp in 2010 and the coming crude divides into two parallel streams and move towards the trains of heat exchangers. After that, the crude is fed to the desalter along with some quantity of water. Remember that, the local crude coming from different depots in Pakistan is sweet and has low salt content but the imported one has relatively a higher number of it. As previously explained, they blend the crude according to the product requirement and hence, they have also set a parameter on when to utilize desalter. Thus, the allowable limit is 10 ptb (pounds of salt per thousand gallons of crude) below that the desalter doesn’t function and only acts as a settler for crude. The function of desalter is to remove the maximum quantity of salt via hydrolysis. The main steps occurred in desalter are as under:

- Water Injection & dispersion
- Emulsification of water in oil
- Distribution in the electric field
- Coalescence & settling

After it, the brackish water runs down for further treatment or recycling while due to the density difference, the oil resides at the top part of the desalter and comes out of it. Till here, the pre – treatment of crude has been performed. In the next upcoming section, problems and parameters that should be monitored or given priority upon performing routine test and
Something about the desalter

The sole purpose of desalter is to remove salt content present in crude that can cause fouling, poisoning of catalysts and degradation of product. These salts are mainly chlorides and sulfates of Calcium and Magnesium like NaCl, MgCl₂, CaCl₂ and MgCl₂. The major hectic is with chlorides which hydrolyzes to hydrochloric acid cause severe corrosion.

\[ CaCl₂ + H₂O \rightarrow Ca(OH)₂ + HCl \]

There are mainly three types of desalters:

Natural Desalter: Settling time are given to salts, sediments which settle down under gravity and then drained out.

Chemical Desalter: Chemicals, mainly, surfactants are added to reduce the surface tension for making removal of salts and water easy.

Electrochemical Desalter: Where electric field is used to remove the salt content as what stated above. This desalter is currently in use at Byco.

Following things should be accounted in terms of process parameters:

- Decrease in temperature increases the viscosity, making settling of salts difficult.
- High temperature increases water solubility and formation of emulsion with salt and water which causes carryover of it.

What’re the important parameters to consider in desalter?

This is a very important question to raise as there are many but some certain compulsory parameters to consider that can depict the conditions and predicts the hurdles in further processing means. Following are that important points to consider must:

**Water Quality:** Dilution water that’s mixed with the oil in the desalter should be salt free to maximum extent as well as has pH to the prescribed level, means neither acidic nor basic. As the dissolved salts ay contribute in fouling of heat exchangers and further cause corrosion problems. At Byco, they are using Boot Water* (overhead product) from accumulator which ensures maximum possible low salt content.

**Water Solubility in Crude:** This is the most important parameter to counter. At elevated temperature, as rule of thumb, around 0.4% of water dissolve in oil and as the problem of this solubility become more severe when the crude passes through a pre – heat train just before entering the pre – flash fractionating tower. As the temperature rises, water tends to leave the
residual salts in the oil which can cause severe damage to equipment. At Byco, they are maintaining the level of two phases inside the desalter in such a way to minimize this possibility.

*Boot Water: An important overhead component*

One important factor shall be discussed in the next part i.e. Crude Tower Overhead Corrosion and the parameter that relates to it, is the Overhead water content. At Byco, this water is tested frequently to check the amount of Iron or any traces of contaminated components as well as due to the hydrolysis in desalter HCl vapors are produced which comes out as an overhead side product from the crude tower and pre − flash tower causing severe corrosion to the upper section as well as to the condenser tubes. Thus, the importance of testing is significant to ensure safety as well as prevention from damages.

1Crude Tower Overhead Corrosion Problem, how can it be prevented?

This is one of the most common problem usually encountered in Petroleum Refineries. The problem originates from the desalter, the three-main salt content present in crude are NaCl, MgCl₂, CaCl₂ and out of these the heat stability is as under:

\[
NaCl > CaCl₂ > MgCl₂
\]

Hence, Sodium Chloride remains unaffected while Magnesium Chloride tends to hydrolyze at elevated temperature usually at crude tower’s flash zone releasing HCl vapors and the usual severe outcomes are in the form of:

- Loss of atmospheric distillation tower’s tray material/plugging
- Corrosion of condenser tubes and reflux drum

Since, at Byco, a single stage desalter is using currently which approximately removes around 90% of the salt content as compared to 99% removal from double stage removal. Here, the question arises, why don’t Byco utilize this to prevent corrosion? – The answer is – Magnesium Chloride is a troublesome salt and its removal is not that easy whether to use a single stage or multi stage. The HCl attack is continuously regenerated by reaction with H₂S because usually there’s an excess of H₂S inside the crude tower.

\[
HCl + Fe \text{ yields } FeCl₃ \text{ and then } FeCl₃ + H₂S \text{ yields } FeS₂ \text{ and } HCl
\]

This unfortunately leads to another factor to consider, HCl liberated out from the crude tower has usually a greater affinity for water and as long as no water is present the HCl vapors are non − corrosive in nature but as the overhead water droplets tend to condense, it dissolves all HCl.
and become highly corrosive in nature. The pH of HCl vapor without mixing with water condensate is about 2 while after dilution it increases to about 5.5 – 6.5. On the similar manner, naturally crude oil contains Naphthenic Acid which is highly corrosive in nature whether in vapor form or condense form hence, at Byco, they frequently observe the acid content present in crude and for this they perform TAN (Total Acid Number) testing.

**How Byco is taking Prevention Measures?**

The following actions are taken in Byco to overcome this issue:

- **Effective desalting to remove the maximum content of Magnesium Chloride.**
  As it has already been described there’s an allowable limit of 10 ptb of salt and usually local crude has less salt content as compared to the imported one so a balanced make up of crude is utilized.

- **Caustic injection to control Chlorides in the reflux drum boot water.**
  Caustic is injected at the feed section to the unit from storage section. It mixes along with the pumping crude thus suppressing any acid atmosphere.

- **Sufficient addition of neutralizing additives.**
  Ammonia is injected at the bottom of the pre – flash column to overcome any acidic content.

> Reference from Norman P. Lieberman’s article, published on Oil & Gas Journal, 1993

**Separation Process from Pre – Flash**

The crude coming from the desalter goes to the pre – heat section to attain some of the process temperature and then it is moved to the pre – flash column also known as pre – fractionating column which is equipped with a reflux system at the top and sieve trays inside. The column serves to separate lighter fractions present in the crude primarily Naphtha which is around 10% from the charged crude feed. Naphtha is obtained as an overhead product while the remaining crude is obtained from the bottom section of the column. The separation occurs due to sudden expansion and heat present in the column which draws lighter components to the top of the column. Off gases move towards 2knockout drum followed by the 3flare system.
Why Pre – Flash?
At Byco, it was installed after the major revamp that was done back in 2010. Pre – Flash column may be a new term to those readers who have never witnessed a real-time refinery as most of the text books don’t consider this term while explaining the concept of distillation. Anyhow, the main aim of its installation was:

✓ **Cost matters!**
As if the revamp was mainly focused on increasing the yield of valuable fractions by only considering changes in the main crude tower then eventually the vapor load at the rectifying section would increase causing serious disturbances and in the end, it could require changes in terms of process instruments that should have the ability to meet the pressure and condition requirements. Thus, to constraint the financial part, pre – flash was installed.

✓ **To reduce the naphtha load**
Naphtha load is distributed between the crude tower and pre – flash tower thus, increasing the yield. After its installation, the capacity boosted to 35k bbl/d.

Additives Used in Pre – Flash
To overcome the previously discussed corrosion effect, mainly as precaution measure, a Zinc based chemical additive called FilmPlus is mixed with fixed proportions of Kerosene and via P.D. Pump, it is injected to the top of the tower. It forms a protective coating inside and provides sustainable prevention. NH₃ is also injected in gaseous form from downward section to neutralize any acidic effect present in the crude.

Simplified Process Flow Diagram can be seen on the next page. Below is the table for guideline.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1</td>
<td>Single Point Mooring in Sea</td>
<td>E-1</td>
<td>Pre-Heat</td>
</tr>
<tr>
<td>E-10/E-9/E-13/E-12</td>
<td>Pre-heat trains</td>
<td>E-10</td>
<td>Diesel Stripper</td>
</tr>
<tr>
<td>E-14/E-15</td>
<td>Desalter</td>
<td>E-11</td>
<td>BPA Cooler</td>
</tr>
<tr>
<td>E-16</td>
<td>Pre-flash tower</td>
<td>E-13</td>
<td>Fin Fan Cooler</td>
</tr>
<tr>
<td>E-17</td>
<td>PD Pump</td>
<td>E-14</td>
<td>Trim Cooler</td>
</tr>
<tr>
<td>E-18</td>
<td>Reflux Drum</td>
<td>E-2</td>
<td>BORN Heater</td>
</tr>
<tr>
<td>E-19</td>
<td>Condenser</td>
<td>E-4</td>
<td>Distillation Column ADU</td>
</tr>
<tr>
<td>E-3</td>
<td>Crude Blending Tank</td>
<td>E-5</td>
<td>TPA Cooler</td>
</tr>
<tr>
<td>E-4/E-8/E-7/E-6</td>
<td>Charge/Booster Crude Pump</td>
<td>E-7</td>
<td>Kero Stripper</td>
</tr>
<tr>
<td>E-9</td>
<td>Reflux Drum</td>
<td>E-8</td>
<td>Condenser</td>
</tr>
</tbody>
</table>
Heating Section

The crude recovered from the bottom of Pre – Flash further moves to the pre – heating section to reduce the heat duty of the upcoming furnace that is used to heat the crude to nearby process temperature. First, let’s first describe the furnaces present in the CDU area; there are mainly three, two are box-type fuel oil furnaces while one is the main crude oil furnace. Among the two box-type fuel oil furnaces, one is currently operational and its main purpose is to fulfill the production of the heating fluid requirement by different heat exchangers present in the plant, though, many still utilizing the heat usually from the product or incoming crude as a continuous process.

The crude after pre-heating moves toward the furnace commonly known as BORN® Furnace. This is a natural-draft fuel gas fired furnace. Some part of the flue gases utilizes here as a fuel and the source is from different overhead’s by-product. The furnace is equipped with serpentine coils through which crude circulates and has two main sections i.e. Radiation & Convection. The furnace provides necessary heating requirement for the crude before entering the crude distillation tower. According to the manufacturer, this is also termed as cylindrical heater and has heat duties typically in between 0.5 to 200 million BTU/hr. The breeching section provides an easy access to the exhaust gases to the damper where there’s a butterfly valve which operates accordingly to the pressure buildup.

Crude Tower or Distillation Column

The incoming crude from the furnace is fed to the distillation column, the heart of refinery and super-heated steam is injected from the downward section which acts as a driving force as well as heating medium to extract out the fractions from crude. The simultaneous Heat and Mass Transfer process ensures effective separation, as the lighter fraction move upward, it gets interacted with the down coming crude, the heavy constituents condense and releases heat which further evaporates the lighter component present in it and this process keeps on going continuously throughout the column. The main sections of crude tower are:

✓ **Stripping Section**
This is down most section just above the bottoms head level and this is termed stripping section because the steam strips out the vapors mainly from this section.

✓ **Feed or Flash Zone**
Where the feed/crude is fed. Some textbooks considered it as being a part of Stripping section.
**Rectifying Section**

The upper most section of the column where the vapor content is more and temperature is relatively low. This is termed as rectifying section due to reflux system, as some part of the product condensate recirculates here.

What are the main obtained products?

Depending on the temperature profile, different products are usually obtained but at Byco following are the main outcomes from the distillation column:

- **Naphtha** – It is separated as the topmost product from the column along with flue gases.  
- **Kerosene** – It is separated as the upper middle product.  
- **Diesel** – It is separated as the lower middle product.  
- **Furnace/Fuel Oil** – It is the heavier product obtained from the bottom most part.

The above-mentioned products are obviously not the final product. It further goes to treatment to yield further which shall be discussed shortly.

A look on the distillation column

The crude tower operates under atmospheric distillation category and equipped with 38 fixed-valve trays (*). Each tray has perforations that allows maximum contact area between vapor and liquid. The feed is fed at 34th tray and has an inlet temperature of about 370 °C. There’s no reboiler. Superheated steam coming from the utilities area is injected just below the 38th tray and above the bottom product level, here, it more or like acts as a stripping medium as well as providing necessary temperature requirement. The main aim is to provide the intimate contact between steam/vapor and liquid to strip out the content. The column has one reflux system at top and two pump arounds, one is called BPA (Bottom Pump Around) in between 28th and 33rd tray while the second one is installed just below the reflux system and termed as TPA (Top Pump Around) in between 8th and 10th Plate.

(*) Also known as floating cap plate, they are the modified version of sieve trays with relatively high perforations. It can be fixed or moveable. At Byco, there are fixed-valve trays as aforementioned. Moveable ones can prevent weeping as compared with the fixed one. A more detailed and comparative view of different and most commonly used plates/trays in the column is as under:
One thing should be noted from the above table is the turndown ratio which is simply the ratio of maximum to minimum throughput or design vapor throughput to minimum operable throughput. It should be considered as a major selection parameter before designing the column as it adds flexibility in terms of handling crude depending upon the nature of demand.

Above reference from Mas Transfer & Separation Processes by Binay K Dutta

What’s the purpose of injecting steam? What kind of refinery is this?
This is called “Hydroskimming” type of refinery, one of the most common in the world. There are certain reasons behind of calling it like that, some of them are:

✓ It has Hydro Treater Unit

The refinery is equipped with further processing of the naphtha and for this purpose Naphtha Hydro Treater is being used at Byco along with reformer. This type of refinery must yield Gasoline.

Main Refinery Types
For an ease of understanding, following are the main types of refineries:

1) Hydroskimming = Have Atmospheric Distillation Unit (ADU) and necessary treating processes, it produces gasoline.
2) Topping = It just separates crude into main constituents using ADU, produces naphtha but not gasoline.
3) Cracking = It has further treating units like Vacuum Distillation Unit (VDU), Catalytic Cracker etc.
4) Coking = It adds further level of complexity in crude handling by employing further processing of Vacuum Residue using Delayed Coking Process.
Atmospheric Distillation with Steam as a Heating source

This type of refinery usually uses no reboiler. Steam mainly using as a main source of breaking the feed into further fractions but it is debatable because it depends upon different parameters, in many refineries the furnace is the main source of leading crude to its main fractionating temperature. Since, steam generates from water alias ‘hydro’ and it also strips out the vapor to the top section thus ‘skimming’ it. Hence, Hydro-skimming is termed.

The main aims that are normally achieved by injecting steam are: Since, it’s superheated hence, acts as a heating source for the crude. Due to steam’s natural draft towards the top of column, it adds bulk flow and thus enhancing the mass transfer as well as heat transfer rate, in short transport phenomenon increases. It serves also as an equilibrium disturber, as the fuel oil begins to add up in the bottom part it comes under equilibrium with vapors just above it, eventually, decreasing the vapor flowrate hence, as the steam is carefully injected just above the bottom product, it disturbs the equilibrium, resulting no halt and smooth flowrate.

In a nutshell, we can elaborate the purpose of injecting steam as:

- Steam distillation is used primarily to avoid reaching the degradation temperature for thermally unstable materials.
- Steam lowers the partial pressure of the process fluid and so the boiling point, therefore, it boils at relatively low temperature.
- It acts as an equilibrium disturber because there is an equilibrium maintained at each stage in the fractionating tower it lowers the mass transfer rate, steam breaks this equilibrium as explained above.
- It is used for stripping reasons as it helps in removing light tails from residue and heavier products also it improves the quality of constituents – in side strippers, it improves the flash point of middle distillates i.e. Kerosene – similarly, it removes lighter fraction from the bottoms to facilitate Vacuum Distillation, if available.
- It helps in separating appreciable quantities of high boiling constituents.

What does reflux system do? What are pump arounds?

Reflux system is located at the top of the distillation column. It consists of a condenser, a reflux drum, and necessary fittings to control the reflux ratio. Simply, the condenser condenses the vapor and re-enter into column while some of them is taken as an overhead product. It improves the purity. It maintains the temperature and pressure profile.

A reflux system decreases the inside temperature while increasing the pressure.

Pump arounds are used for the same purpose as explained above. It takes the liquid from the tower and decreases its temperature by passing through exchangers and fin fans and thus helping in decreasing the temperature. This controls the temperature profile of the middle and downward section of the column.
Two widely used terms are Internal and External Reflux; after condensation, when the overhead product is reintroduced into the tower, the temperature at the top of the tower decreases causing heavier fractions to condense back and flow downward and this is called as Internal Reflux while the preceding being the External Reflux.

Pump Around: Point to be noted
Pump around streams reduce the vapor flow rate throughout the column. Therefore, the required column is smaller than what would otherwise be required if pump around streams were not there. The drawback to using more pump around streams is that they tend to reduce the fractionation because a more fractionated liquid is mixed after cooling with a less fractionated liquid a few trays above.


Knock-Out Drums: purpose?
All the vent/flue gases coming out from different sections of the plant primarily, pre – flash and crude tower. Some of it utilizes as an energy requirement of some part of the plant like the flue gases are being used at Byco to fire the furnace and act as a super-heater in the boiler. The gases are not directly utilized for the above-mentioned purpose as they also contain some vapor fractions to which may be valuable. This, a knock-out drum is a final approach to collect any liquid content present in the gas stream and then the rest vapor-free gas may use as a fuel or vent out to the flare system.

Flare System: Purpose?
The flare system is probably the most commonly visible feature of any petroleum refinery. They safely burn excess hydrocarbon gases which cannot be recovered or recycled. The burning ensuring that the plant is operational and in running condition. Usually, all the columns that releases flue gases as a by-product have a pressure relieve system, upon high pressure, it diverts the gases to the knock drum followed by the flare system. By continuous burning and nature of flame, we can diagnose the sudden rise/fall of pressure. Also, if we simply vent out the off gases then the SOx, NOx and other hazardous gases can be released along with, creating a dangerous environment as some of the gases are heavier than...
air so it won’t disperse itself thus, it is better to burn them off. To ensure safety, pressure regulation and monitoring this part is very important. At Byco’s control room, a dedicated camera continuously monitors the flare system. Some part of steam is also injected with the flue gases to avoid any soot and ensures clean burning Steam is usually added to the gases to increase turbulence in the gas flow. This increases air intake that helps to achieve complete combustion and smokeless flaring. The flare system using at Byco commonly known as Elevated Flare System.


**Stripping Section**

There are mainly two strippers present along with the main crude tower. The two strippers are:

➢ **Kerosene Stripper**

Kerosene separated from the crude tower is injected from the top to the stripping column where it gets interacted with upcoming stream of steam which extracts out the lighter contents while Kerosene extracts out from the downward section. This further move towards heat exchanger followed by fin fan* and trim cooler** to cool the rundown product. This process enhances the purity of product as well as maintain several properties like flash point etc.

At Byco, almost all the Kerosene is injected to Diesel to increase its yield and they don’t market simple Kerosene as a commercial product.

**JP-I: Jet Fuel Production**

Depending upon the demand JP-I is prepared. When there’s a requirement then some part of this Kerosene goes further for the MerOx treatment (which will be discussed later) and then the sweet product with very low Sulphur content is obtained and the rundown is collected as a final product.

**Static Charge build up in JP – I: Hazard!**

Usually, as the crude refines increasingly all of its electrical conductivity decreases which cause a higher tendency to accumulate static charge which leads to explosion. This issue became more severe in the early use of automotive and aviation fuel when there was no source present to overcome this issue. Back in 1983, Stadis® was invented, it acts as a Static Dissipater Additive widely used in aviation and automotive fuels to increase the electrical conductivity of fuel. It is
based on Dinonylnaphthylsulfonic acid and chains of other organic compounds. At Byco, it is added in JP – I fuel as a chemical additive.

*Reference from innospec™ Stadis®*

➢ **Diesel Stripper**

For Diesel, the stripper utilizes when there is a deflection in the properties. It has the same function as per mentioned above. It also maintains the cloud point, flash point etc. of the fluid. Only HSD (High Speed Diesel) is obtained as there’s no demand to produce LSD (Low Speed Diesel). Byco used to produce ultra-winterized Diesel some two years ago, but due to less demand it is not producing anymore.

**Accumulator**

Previously, it has been explained that the Naphtha is mainly coming from two sections, one as a 10% recovered Naphtha from pre – flash and the rest from the crude tower. The both streams combine and further goes to the accumulator part where a 3 component, 2 phase mixtures is obtained. Water is drawn off continuously from the bottom which is further used in the desalter as a mixing medium and this is also tested frequently for any iron or contamination content. Off-gases vent out from the top while the naphtha recovers from the middle section.

**Naphtha Splitter**

It is a column with process very similar to the stripping and having sieve trays inside. As the name suggests, it splits the naphtha into lighter and heavier fractions. From accumulator, it moves to the pre-heat train to meet the process heating requirement and then comes here and split into two parts:

➢ **Light Naphtha**

Light Naphtha which ejects from the top while Heavy Naphtha separated from the downward section. Some part of these two streams are stored in the storage tanks for accidental usage especially when startup is required. Light Naphtha goes towards the LSU (LPG Separation Unit) (which shall be discussed) followed by MerOx treatment and then it stores in the LPG Bullets.

➢ **Heavy Naphtha**

Heavy Naphtha is considered as an export item. Hence, it moves to two sections depending upon the requirement and circumstances, one towards the MerOx treatment followed by storage while the other heavy naphtha stream goes to the Naphtha Hydrotreater (NHT) where it forms a feed for the reformer and finally reformate/MS or Gasoline is obtained from it.
Why *fin fan is placed before **trim cooler when cooling down the product?
This is due to the heat transfer rate. The forced convection from fin fan causes high change in temperature as compared to trim cooler. Although, it doesn’t produce high delta in temperature but still act as a better cooling medium. Secondly, ambient air is blowing which doesn’t require any cooling of itself and available in bulk quantity. It also reduces the heat load on the trim cooler as well as reduces the time cycle of cooling tower. Trim cooler is the cooler which only contains water in its tubes as a cooling medium. Also, fin fan is also highly favorable as it creates a forced draft for evaporation and cools down the product till it reaches wet bulb temperature.

Additives Used in Heavy Bottoms
Poly alkyl methacrylate (PMA) is used as a Pour Point Depressant. Viscosity of bottom’s product i.e. furnace/fuel oil and refined lube oils is of higher value and the quantity of wax in it results in higher value thus increasing the pour point of the oil. At low temperatures, the wax tends to separate, preventing oil flow, and hindering lubrication. PPDs are added to reduce the pour point of the oil while keeping the viscosity benefits of the wax. They alter the crystal growth size of the wax thus ensuring good flow ability. This is most commonly known as “Cutter-Stock”.

Reference from HiTEC® PPDs by Afton Chemicals™, U.S.A

Naphtha Splitter Simplified Diagram
MerOx Unit

The term MerOx is a portmanteau of Merceptans Oxidation. The unit was developed by UOP®, U.S.A. and the reactor uses the custom catalyst developed by them. The main aim of using this system is simply purification. Merceptans are Sulphur based compounds that are hazardous to the equipment as well as act as a contaminant for the fuel. They are Alkyl Sulfide Halides (RSH). More Sulphur content make the fuel sour which is undesirable. This system ensures effective treatment in this regard and removes all the disulfides and metallic compounds. The process of reducing sulfur content often termed as “Sweetening” and can be elaborated as:

### Why Sulphur/Mercaptan is injurious?
If it presents in the fuel, then upon combustion produces NOx and SOx along with other hazardous gases which is poisonous and injurious to both health and environment. Sulphur is a soft compound in general and upon high temperature it can cause dead spots in the reactor or in any column upon deposition which should be highly prevented. Mercaptans impart foul smell as well as can cause corrosion and can reduce octane number by reacting with octane inhibitor.

### What is happening in MerOx unit?
Simply, MerOx is the oxidation of mercaptans to alkyl disulfide. The reaction proceeds under caustic environment in the presence of catalyst which is a metal – preferably iron – based chelate, it diffuses on the surface of the activated carbon to increase the surface area. Air injected as an oxidation medium. The chain of reaction involves removal of Sulphur related compounds and caustic regeneration. The caustic used at Byco is of 50 °Be which further gets diluted according to the requirement. It converts mercaptans into Alkyl disulfides. The reactions are as under:

<table>
<thead>
<tr>
<th><strong>At Caustic Pre-Wash:</strong></th>
<th>NaOH + H₂S yield NaSH + H₂O, other reactions involve here are:</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSH + NaOH yield NaSR + H₂O &amp; H₂S + NaOH yield Na₂S + H₂O &amp; Na₂S + H₂S yield NaSH</td>
<td></td>
</tr>
</tbody>
</table>

**At Extraction:**

| 2RSH + 2NaOH yield 2NaSR + 2H₂O |

**Regeneration of Caustic:**

| 2NaSR + O₂ + 2H₂O yield 2RSSR + 4NaOH |

**Overall:**

| 4RSH + O₂ yield 2RSSR + 2H₂O |

**Formation of Sodium thiosulphate:**

| NaSH + O₂ yield Na₂S₂O₃ |
MerOx System at Byco

There are mainly four MerOx systems working currently under one unit based on the type of final product, all serve for the same purposes as explained above. They are as under:

➢ **Kerosene or JP – I MerOx**
If it is required to produce jet fuel, then Kerosene under goes with MerOx treatment. First, it goes to Pre-washer where caustic is showered against the upcoming stream of Kerosene. Further it moves to the sand filter where there is a bed of activated sand particles that can remove any contaminants and excess caustic. From here, air is injected to provide an Oxygen based medium in the reactor where, main treatment is performed. The product further goes to water wash to neutralize or remove the disulfides/metal compounds followed by a settler where separated caustic is separated and goes to caustic recirculation. The product then moves to the salt bed to remove any salts followed by sand filter and finished sweet product.

➢ **Heavy Naphtha MerOx**
The process for Heavy Naphtha MerOx is almost similar as depicted previously. The main difference is that, it doesn’t have to go through the sand filter. It goes to pre-wash followed by reactor and settler and finally run down.

➢ **Light Naphtha MerOx**
The process starts by introducing light naphtha to the batch caustic pre-wash from where, it bubbles out from the top. A demister/coalesce helps in restricting entrainment of caustic. It helps in removing any H₂S, if present followed by a Caustic settler, reactor which has an alkaline bed of catalyst along with charcoal bed and then the sand filter. After that, it runs down as a sweetened final product. In the batch, caustic is filled to around 70% limit with concentration of 12 to 15 °Be.
LPG MerOx
The process for LPG is slightly different as compared to the above-mentioned treatments. The LPG coming from LSU first goes to the pre-washer. The pre-washer is filled with 70% Caustic by volume and LPG is directed from the bottom and bubbled out from the top. At the top, there is a coalescer that traps caustic from moving along with LPG, this is also known as Batch Caustic Pre-wash. From here, it moves to the extractor unit which is equipped with trays with bubble caps, here, caustic is showered against the upcoming stream of LPG and caustic is separated out from the bottom. From here, LPG Stream moves to a settler to settle out any caustic/water content followed by a water wash to remove the disulfides and separated contaminants and salt bed to remove salt traces and then, sweetened LPG is taken out as a product and stored in bullets.

Why Use Caustic Pre-Wash?
It can dissolve low molecular weight mercaptans. It has the tendency to dissolve Hydrogen Sulfide gas. It also converts mercaptans into Sodium Mercaptide which is the intermediate product.
Spent Caustic Handling by Partial Oxidation of Sulfidic Caustic

The handling of contaminated sulfidic rich spent caustic can be a cumbersome process due to excessive Ph, High BOD (Biological Oxygen Demand) it is not feasible to dispose it easily. The process oxidizes the spent caustic causing a low pH effluent to generate which can be further treated at the waste water treatment system. The spent caustic is mainly the one which is used as a batch caustic prewash.

Caustic Recirculation & Re-generation

The utilized and diluted caustic coming out from different MerOx section combines altogether to form one stream and passes through a UOP® designed catalyst followed by a pre-heater which heats it to around 45°C. From here, it moves to the oxidizer column where a stream of air is injected to provide an Oxygen based environment. The oxidizer helps separating disulfides from the caustic then the caustic moves to the main unit equipped with coal bed at the bottom and Raschig Rings on the top. The caustic and disulfides forms a separate layer due to density difference and pass through the coal bed while the gases move upward through the rings and vent out. Disulfides is separated from the top while caustic is separated from the bottom. For extraction (MerOx WS™ catalyst) and for fixed-bed sweetening (MerOx FB™ catalyst) were developed. These catalysts are produced as liquid catalysts which enable easier handling. They are termed as WS and FB Reagent commonly. The above shown diagram depicts the combination process for effective treatment which can also be utilized.

All the above diagrams are taking as a reference from UOP MerOx™ treating process
UoP® based MerOx Treatment of Light Naphtha at Byco

Equipment List

<table>
<thead>
<tr>
<th>Displayed Text</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1</td>
<td>Batch Caustic Pre Wash</td>
</tr>
<tr>
<td>E-3</td>
<td>Sand Filter</td>
</tr>
<tr>
<td>E-4</td>
<td>Settler 2</td>
</tr>
<tr>
<td>E-6</td>
<td>Main Reactor w/ catalyst</td>
</tr>
<tr>
<td>E-7</td>
<td>Settler 1</td>
</tr>
</tbody>
</table>
UoP® based LPG MerOx Simplified Schematic at Byco

<table>
<thead>
<tr>
<th>Pipeline List</th>
<th>Equipment, Valve &amp; Instrument List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>P-10</td>
<td>Rich Water Outlet</td>
</tr>
<tr>
<td>P-11</td>
<td>Pure Water Inlet</td>
</tr>
<tr>
<td>P-12</td>
<td>LPG Stream</td>
</tr>
<tr>
<td>P-14</td>
<td>MerOx Treated LPG</td>
</tr>
<tr>
<td>P-15</td>
<td>Salt Content Drain</td>
</tr>
<tr>
<td>P-19</td>
<td>Caustic Level 1</td>
</tr>
<tr>
<td>P-2</td>
<td>Spent Caustic</td>
</tr>
<tr>
<td>P-20</td>
<td>Caustic Level 2</td>
</tr>
<tr>
<td>P-26</td>
<td>Water Inlet to Pump</td>
</tr>
<tr>
<td>P-28</td>
<td>LPG from LSU</td>
</tr>
<tr>
<td>P-3</td>
<td>Bubbled out LPG</td>
</tr>
<tr>
<td>P-4</td>
<td>Caustic Out</td>
</tr>
<tr>
<td>P-5</td>
<td>LPG to Settler</td>
</tr>
<tr>
<td>P-6</td>
<td>Drain</td>
</tr>
<tr>
<td>P-9</td>
<td>LPG to Water wash</td>
</tr>
</tbody>
</table>
UoP® based Kerosene & Heavy Naphtha MerOx at Byco

Equipment List

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<tr>
<th>Displayed Text</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1</td>
<td>Water Wash</td>
</tr>
<tr>
<td>E-2</td>
<td>Settler</td>
</tr>
<tr>
<td>E-3</td>
<td>Caustic Prewash</td>
</tr>
<tr>
<td>E-4</td>
<td>Reactor</td>
</tr>
<tr>
<td>E-6</td>
<td>Salt Bed</td>
</tr>
<tr>
<td>E-7/E-8</td>
<td>Sand/Clay Filter</td>
</tr>
<tr>
<td>E-11</td>
<td>Caustic Prewash</td>
</tr>
<tr>
<td>E-14</td>
<td>Settler</td>
</tr>
<tr>
<td>E-16</td>
<td>Reactor</td>
</tr>
</tbody>
</table>
Simplified PFD is developed using Microsoft Visio. Actual process components may vary.

Doctor Sweetening Process/Test

One of the first and earliest effort in the field of sweetening was made by Mathew L. Kalinowski in 1954. The process involves around the chemistry of removing mercaptans as follows:

Litharge (Lead oxide) dissolves in 5-30 weight% concentrated caustic forming Sodium Plumbite or Doctor’s Solution as:

\[
PbO + 2NaOH \rightarrow Na_2PbO_2 + H_2O
\]

Doctor’s solution is then mixed with petroleum product, the two remain immiscible but mercaptans mixed with it forming lead mercaptide, as:

\[
2RSH + Na_2PbO_2 \rightarrow (RS)2Pb + 2NaOH
\]

The product is then treated with powdered sulfur which reacts with lead to form blackish lead sulfide commonly known as disulfide, as:

\[
(RS)2Pb + S \rightarrow RS-SR + PbS
\]
If no Sulfur is introduced, it oxidizes as:

\[
2(\text{RS})_2\text{Pb} + 2\text{NaOH} + \text{O}_2 \rightarrow 2\text{RS}^- + 2\text{Na}_2\text{PbO}_2 + 2\text{H}_2\text{O}
\]

This disulfide forms a layer which can then be separated but this process doesn’t remove Sulfur completely and may increase the sulfur and lead content. It is a laborious process which needs frequent checking of the sulfur and lead content because both are now considered as illegal to be present in the petroleum product above certain level as well as a threat to human life. UOP MerOX Process was introduced to overcome this issue which has already been described above. The process now uses widely as a testing methodology to describe the sourness/sweetness of petroleum product.

**Test for Sweetened Product**

The procedure for testing involves the following steps:
- Take some amount of sweetened product.
- Add approximately equal amount of doctor solution that is Sodium plumbite.
- Add suitable amount of powdered sulfur.
- If there is brownish color or somewhat black precipitate of PbS then the doctor test is positive and the product is sweetened. If the color of sulfur crystal remains unchanged then the test is negative and vice versa.

*Reference from Doctor Sweetening Process Using Sulfur Mathew L. Kalinowski, Chicago, Ill., assignor to Standard Oil Company, Chicago, a corporation of Indiana, March 11, 1954*

**Naphtha Hydro Treater Unit (NHT)**

This unit is designed for hydrogenation process or mainly to saturate olefins and double-bonded hydrocarbons into single bonded compounds. Heavy Naphtha coming from the splitter is stored as a product and some excess part comes for hydro treating to make final product like gasoline. Secondly, it removes the undesired compounds as well that may lower the properties of final product like its RON* and RVP**. It prepares the inlet feed for the reformer as the reformer has precious catalytic reactors and the catalyst are very sensitive to Sulphur and other compounds which leads to catalytic poisoning hence, hydro treating is very necessary.

Following important reaction takes place here:
Main Reactions

*Hydrodeoxygenation:* Converts organic oxygen content into water.

*Hydrodesulphurization:* Removal of Sulphur and its compounds.

*Hydrodenitrogenation:* Removal of Nitrogen and its organic compounds by conversion into Ammonia which utilizes in the pre-flash as well.

*Hydrocracking:* Breakdown of large hydrocarbon chains into smaller chains. The last important factor is, it also removes aromatic compounds especially Benzene and its isomers as we already know that Benzene is carcinogenic and the emission cause cancer so any traces of it should not be present in gasoline.

*Hydrodemetallization:* Conversion of hazardous metals and organometallic compounds into metal sulfides.

Main Process

Hydrogen is mixed with the incoming stream of Heavy Naphtha followed by pre-heating the stream to reduce the heat load and then it moves to the cylindrical furnace where it reaches to its process temperature of around 300°C followed by a reactor. The reactor Co-Mo catalyst inside which provides necessary process conditions from here, it goes to air coolers to cool down the product followed by a product separator where off-gases vent out. The reactor has a demister bed inside to form coalesce. The liquid separated from the separator further moves to the desulphurization tower where a temperature profile is maintained and as the name suggests, Sulphur and its related compounds separated out easily. The final product appears to be the feed for reformer. Streams in desulfurizer can be traced from the diagram shown on the next page. For reference, there’s a recirculation of product stream from main furnace, the product stream exchanges heat with the incoming stream, some part of product stream passes through a boiler or a Waste Heat Recovery system to generate steam.

What’s RON & RVP?

RON stands for Research Octane Number, a necessary parameter that explains the quality of gasoline as an anti-knocking inhibitor. N-hexane has an octane rating of zero while branched octane has an octane rating of 100. They blend together to form the standard RON based gasoline for the market that is 87. RVP stands for Reid Vapor Pressure, this is indeed an important parameter of gasoline to understand as well. Vapor Blockage is a problem that used to be occur in automobiles fuel line that runs on gasoline due to its high vapor pressure it forms a cloud inside the pipeline causing the fuel pump to cease. RVP is the test carried out in a confined space including air and moisture in the closed environment at slightly elevated temperature to depict the quality of gasoline of forming vapor blanket.
The reformer section aims to covert the straight chain compounds into branched chains and convert the feed from naphtha hydro treater into high value of RON to meet the specs requirement of gasoline. The process involves the reactors designed by UOP® and they are using their own Pt-Rh catalysts. These catalysts are sensitive as explained above hence, before giving feed to the reformer, it must have already been treated before with NHT. These catalysts can be regenerated but after 3-4 times, new installation is mandatory.

Main Process
The product obtained from the NHT section is fed to a pre-heater and then it moves towards a main furnace and series of reactors. There are three individual reactors. The furnace provides the necessary process temperature requirement and in reactors, reforming and platforming of naphtha is performed, linear chains converted into branched chains of more valuable components. From the reactor, it goes to the product separator where off-gases and primarily hydrogen is obtained followed by a stabilizer section where a reboiler ensures the continuous circulation and thus providing the stabilizing conditions as well. The product obtained is termed as reformate/motor spirit or premier motor gasoline. No further additional blending is required as the gasoline obtained has already standard octane number.

Where the Hydrogen comes for NHT?
During platforming, hydrogen is generated as a byproduct. The good thing is, it is recoverable and it is recovered from the reformer section and stored in storage tanks from where, it circulates continuously to the NHT for hydrogenation. There’s a compressor section located along with reformer at Byco. There are two of them called as: Recycle Compressor and Booster Compressor. The recycle one, takes the Hydrogen from the reformer and with the help of booster compressor it injects it to the NHT section.

Chemical Additives Used
Tetrachloroethylene commonly known as Perc is injected to the reformer reactor. There are two main purpose of it:

- It provides chlorine enriched environment that is necessary to drive the reactions.

  The nature of reaction needs Chlorine as a reaction medium but excess chlorine can cause disruptions in the reactions and will favor more of the hydrocracking and eventually less yield of reformate. To overcome this issue, sometimes water based ethanol is injected in the reactor to suppress the chlorine content.

- It controls the moisture content inside.

  Moisture content is not favorable for the reaction as it extracts out chlorine from the catalyst. When there is an excess of moisture content, more Perc is injected.
Apart from the reformer section, Methyl cyclopentadienyl manganese tricarbonyl commonly known as MMT is added as an anti-knock inhibitor at the tank farm area, this is acted as an Octane booster. The Gasoline extracted from the reformer is colorless usually and dye is added to give a distinguished color in it.

**Main Reactions**

The reactions in reformer mainly occur in the acidic and metallic side of the Pt-Rh catalyst. To develop the acidic nature in the catalyst usually Chlorine and Fluorine based additives are used. Thus, Perc is used to serve for this purpose. As I have mentioned in the above section about the use of Perc, here, another purpose has also been explained.

Following reactions are occurring in the reformer unit:

**Reactions at Active Sites**

![Reaction Network Diagram](image)

Predominant Active Sites: A = Acid, M = Metal, I = Hydrocracking and Demethylation(M); II = Paraffin Isomerization; III = Dehydrocyclization.

**FIGURE 4.1.5** Generalized Platforming reaction network.

- **Dehydrogenation of Naphthenes**

The important Aromatic reaction from Naphthenes is the dehydrogenation of alkyl cyclohexane. This reaction proceeds rapidly and is favored by high reaction temperature and low pressure. The metallic side of the catalyst promotes this reaction. This reaction is highly desirable as it produces Hydrogen as a side-product which is an essential feed requirement of NHT. The reaction is endothermic in nature and takes place rapidly, essentially lead to completion.

- **Hydrocracking of Paraffin and dealkylation**

The acidic function of the catalyst favors this reaction under high pressure and temperature. The paraffin cracks and disappear from the gasoline boiling range, the
remaining aromatics concentrate the gasoline resulting in higher octane number. Usually, Hydrogen is consumed during this reaction and the net liquid content is reduced, making this reaction undesirable to some extent. Dealkylation reaction has the same properties as explained above, the sole purpose is to remove the alkyl group.

- **Isomerization (mainly of n-paraffin)**

This reaction is favored by acidic part of the catalyst and its main function is to form branched chains from straight run chains or to form ring arrangements of certain aromatics. The isomerization of alkylcyclepentane to alkylcyclehexane must take place before it gets converted to aromatics. Reaction occurs rapidly at optimum temperature.

- **Dehydrocyclization of Paraffin**

This reaction is favored by low pressure and high temperature and both acidic and metallic part of the catalyst plays role in the promoting the reaction. Its main purpose is to perform molecular rearrangement of paraffin to Naphthenes. This is considered as the most difficult reaction to proceed. Paraffin cyclization increases as the molecular weight of the paraffin increases.

What does SOR & EOR mean?

SOR/EOR is the condition mainly associated with the reactors/vessels equipped with catalyst bed. Start of Run condition means the temperature and main process parameters that obtain when the catalyst is working at its maximum efficiency or particularly when it is new as there’s less purge and more desired product under standard operating conditions. When it gets deactivated after certain time, the purge increases and the process parameters tend to deviate from the actual condition, the results obtained at that time is called End of Run condition.
Why the series of reactor is smaller at feed but larger on the product side?

There are three reactors placed in ascending order in terms of their size. Since, the reactant (feed) has obviously, no product content at the beginning hence, less surface area of catalyst is required to yield the maximum outcome. As it enters the next reactor, some conversion of reactant has already been done & product content is increased so, the remaining reactant requires more surface area to yield and vice versa.

Some additional details about Reformer

There are two major reforming processes developed by UOP® - commonly known as UOP® Platforming Process – are as under:

- **Semi Regenerative Catalyst based Reformer**: These were developed earlier and now has become obsolete. These are fixed bed reactors employing non-metallic catalyst. They are needed to shut down in order to regenerate the catalyst by burning off the coke deposition. To maximize the cycle time, they are needed to operate at high pressure ranges. The process involves mixing of feed with hydrogen and heating up to the requirement followed by the series of reactors and run down towards a separator where gases are removed and the liquid is sent to the stabilizer whose purpose is to fractionate the volatile constituents from high octane gasoline. The process diagram shown below depicts most of this Reforming process.
Continuous Catalyst Regeneration (CCR) based Reformer:
This is an improved version of the SR based reactors where the catalysts regenerate continuously without shutting down the process. The catalysts generally withdrawn from the last reactor. The catalysts regenerate in a controlled environment and then transfers back to the first reactor. It favors low pressure operation and produced more refined high-octane product. Aromatics passes through it relatively unchanged, Naphthenes react easily ad paraffin are most difficult to convert. Naphthas are classified as:

**Lean**
Low Naphthene & Aromatic content which yields less reformate

**Rich**
Contains high proportions of Naphthene content which yields more reformate

---

**FIGURE 4.1.2** UOP CCR Platforming process.
Nature of Catalysts
Heterogenous, composed of base support (usually Al₂O₃) on which active metal is placed, bimetallic (normally Pt-Rh), to develop acid functionality a promoter based on Cl or F is added as explained above.

Reactor Pressure and Temperature
For practical purposes, a close approximate for pressure is the last reactors’ inlet pressure, if pressure decreases it causes to yield more hydrogen and reformate dropping the temperature which affects the quality as well as it causes to increase the coking rate of the catalyst as well. The reactors’ temperature can be classified as:

- **Weight Average Inlet Temperature (WAIT)**  
  Can be obtained by multiplying the product fractions with the inlet temperature

- **Weight Average Bed Temperature (WABT)**  
  Can be obtained by multiplying the product fractions with the average of inlet & outlet temperature

*Diagram and literature reference from UOP® Platforming™ Process by Lipinski, Baird & James, Des Plaines Illinois. Simplified PFD can be seen on the next page.*

Rough Description showing how the reformer reactor looks from inside
**Equipment List**

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LPG Separation Unit (LSU)

Commonly, LPG is produced by separating out the main gaseous components from the light naphtha stream and then mixed it accordingly to give a composition of LPG. But, at Byco, the usual composition of 60-40 ratio of butane propane is not practiced, they only consider the main properties of LPG that should meet the standard requirement. One of which is called Weathering, an evaporation test of LPG liquid content which depicts the result.

Here, the LPG unit mainly consists of: 1) Depropanizer  2) Debutanizer  3) Deethanizer
Out of which deethanizer is not operational as it doesn’t capable to operate under defined process parameters so they are using it as a bypass.

Main Process

Light naphtha moves through the above three mentioned columns to remove the gaseous components but ethane is not removed while on Depropanizer, propane is removed to some extent with traces left same for the debutanizer. All the columns are equipped with reboiler inside that ensures continuous circulation. The final LPG product is taken from the top of Depropanizer and forward it to the reformer unit followed by storage in LPG bullets. The final product has major part of ethane with traces of butane and propane.

In a simplified and general manner, light naphtha first goes to Deethanizer, from top ethane gets removed, the bottoms go to Depropanizer, from top propane gets removed, the bottoms go to the final Debutanizer where butane gets removed while the light naphtha obtains from the bottoms which further goes to MerOx Treatment.

Sources

LPG is obtained from two sources one from the top of the stabilizer in the NHT and second from the LSU unit. Customarily, the top product of stabilizer is termed as butane while the product separated from LSU is called propane. This should not be confused with the actual products. Both are termed as LPG in reality.

Heavy Naphtha

Light Naphtha

From MerOx treatment, one stream goes towards storage section while the latter goes to NHT unit. It is a major constituent of Gasoline as it contains $C_7>$. From LSU, it goes to the MerOx treatment followed by storage. Light Naphtha mainly constitutes $C_7<$.
LPG Separation Unit Simplified Schematic (Commonly known as LSU) at Byco

The PFD is developed using Microsoft Visio. It is a simplified diagram and actual process components may vary.
(OMS) Oil Movement & Storage alias Tank Farm

The OMS section at Byco is mainly responsible for safe and effective handling of crude as well as final product. Storage, Chemical dosing, pumping, logistics, transportation and various other responsibilities are on their shoulders. Skimming of oil is also done here. At main process area, there are underground tanks which serves as a rejected form of oil which may contain other chemicals or water content as well. The oil moves with its own head to the OMS area where oil and water are separated and the water after certain treatments flash out to the sea. The separated mixture of oil is called Slop Oil which stores in a separately dedicated tank. There is testing system of various product present at the tank form which is called TMB test (Top Middle Bottom), this test provides the composition analysis of either raw crude or the finished product.

Following two types of tank are present at Byco:

Fixed Roof Internal Floating Disc
For all the product storage needs, this type of tank is mainly used. It consists of a fixed roof at the top and an internally floating disc which rises or falls depending upon the level of fluid inside. As the vapor pressure of refined product is usually very high and at elevated temperature, this can cause serious vapor build up inside the tank hence, to overcome this, internal floating disc is mainly used. As the liquid stays below the disc while its accumulated vapor stays out from the rims and remains at top under fixed roof which ensures safe storage and lower the evaporative loss.

External Floating Roof
For crude storage, this type of roof is used mainly used, mainly to overcome evaporative losses. It keeps pressurized the crude all the time and usually has a very little vapor build up inside due to lesser or no space. The roof floats over the liquid as the liquid rises and has nothing to cover at the top. It prevents losses of valuable components from the crude, as there are thousands of contents present in it all having different boiling point as well as different vapor pressure and if it vents out. It can cause to build up vapor cloud which can explode as well as losses can lower the yield of valuable products.

Piping System & Safety
There are mainly five pipes that are connected to an individual tank the system of operation is almost the same:
RUNDOWN: From where, the product comes to store in the tank.
SUCTION: From where, the product ships to the bowsers.
CIRCULATION: Internal circulation mechanism, to maintain the level.
FIRE WATER LINE AT TOP w/ FOAM LINE: It only operates when there might be a fire.
DRAIN/TESTING LINE: To drain or take any sample.

There are breather systems situated at the top that has perforations inside which permits ventilation and ensures a safe pressure inside the tank.

Level Measuring
The control room has annunciators inside which displays the parameters associated with each tank and beeps alarm when there’s an over filling of head. FWL (Free Water Level) and TOV (Total Overhead Volume) are two main parameters that is checked frequently inside the tank. There are three methods widely practiced at Byco:

BOB GAUGE: It has a bob corresponding to the inside free height of the tank. The needle present outside moves down when the liquid level rises to give the free height value and vice versa.

DIP TAPE: This is considered as the most efficient and accurate level measuring method which consumes time as well as energy. The tape has a metal cylinder at the bottom and the operator has to dip it till it reaches the datum, the final height can be visible once it is taken outside. A special marking is used on the tape which upon meeting with liquid turns pink and final height can be depicted. For free water level, a special water finding paste is used.

ATG SYSTEM:
Automatic Tank Gauging System is an electronically measuring instrument. It is a multifunctional device and can measure:

- Density
- Temperature
- Flowrate
- Head
- Volume

LPG Bullets
LPG is a liquefied gas and hence stored in a liquid-gas state in a pressurized vessel called as LPG Bullets. The vapor can be liquefied upon increasing the pressure or lowering down the temperature. As the LPG is commercially available in gaseous form, it doesn’t store fully in the tank but in variable percentage with liquid. As the vapor extract out from the top, the liquid tends to boil and generates more vapor and thus, this cycle continues. Water showering from outside the tank is usually done to maintain temperature gradient.
Utilities Section

The utilities section at Byco deals with the operation of cooling towers, handling of raw water and its treatment as well as the operation of boiler to generate the steam.

Boiler Operation
The boiler present at ORC – I is a D-type low pressure water tube boiler. It utilizes the treated sea water from the RO and softener plant to generate superheated steam. The water after treatment comes to the treated water tank where it moves to the boiler section. Amine is injected in the water stream to nullify Oxygen content followed by de-aerator* where steam is injected from the bottom which strips out Oxygen from the water then it moves to the economizer where it is pre-heated to minimize the further heat load then it moves to the steam drum where saturated steam is generated followed by a super-heater which further forms superheated steam to be utilized in distillation area.

How can we recognize a water-tube boiler?
Usually, water tube boiler has two separate drums which can be identified easily one is called the steam drum and the second one is called the mud drum.

Types of Blowdown and how can scaling be prevented?
Scaling is a cancer to the boiler. It can cause massive distortion upon exploding the boiler due to different pressure and temperature failure conditions. While, it is recommended to use zero TDS and zero hardness water in the boiler but there is some hardness present in it which cannot be fully removed hence a blowdown is very necessary at the bottom which takes out all the excess water and contaminants along with. There are mainly two types:
Continuous Blowdown: Usually some of the water accumulates at the bottom of the steam drum which should be taken out and for this purpose continuous blowdown is used.
Intermittent Blowdown: It is a high-pressure blowdown, can be performed periodically to extract out any scale present inside along with extra water.

*Corrosion Issue: Prevention method
As I have mentioned about the de-aerator, this serves as a corrosion inhibitor. Steam is injected in the water to perform kind of stripping as it takes out the Oxygen as well as the dissolved Carbon dioxide. Since, CO_2 can cause sweet corrosion in the form of acid attack. Carbon dioxide has the tendency to form Carbonic Acid which corrodes the transmission lines and the boiler itself.
ORC – II, RO Plant Operation & Water Treatment

There is a water channel constructed at Byco which serves as an open basin to store raw sea water. The pH of raw water is acidic in nature around 6 – 6.5. Most of the chemical dosing is performed outside the main RO plant. The water first treated with caustic which boosts the pH then to overcome the biological growth HOCl is added which is a main source of oxidizing agent and suppresses the amount of Oxygen present in it followed by the addition of a polymer-based chemical which serves the purpose to form chains and brings the flocs or coagulates to the top. From here, it goes to the DAF tank (Dissolve Air Floatation) where air is injected inside and the floating contaminants skim out from the top from here it goes to a vessel where it gets saturated with air and the run down in the tank and then it goes to two main RO sections. Sodium met bisulfide and anti-scalant is added before RO treatment which reduces chlorine content. Till here, all the visible particles have been removed.

Sea – Water Reverse Osmosis (SWRO)
The water is pumped from the tank to a cartridge filter followed by a multimedia filter (MMF) which has a layer of silica and gravels. After washing out, it moves to the RO filters via high pressure pumps. The membranes are of circular type water injects from the outer circular are and travels to the center from the tiny pores of 0.01 Angstrom and termed as permeate which is taken out from the center the rest being outside is called reject which drains out in the sea.

Energy Recovery Turbine: recovery of energy from water
The permeate coming out has a high pressure and lot of energy present in it. To minimize the pump, load some part of it is recirculated back to a turbine which adds energy to the moving impeller of the pump resulting in high pressure recovery.

Brackish Water Reverse Osmosis (BWRO)
The water coming from the previous RO reaches here and on the similar manner with two additional passes the water further purifies and we finally get a product from 100000 TDS to around 100 TDS.

Electro Deionizer (EDI)
This is a latest technology bases equipment and has a bed of resins that further treats the water and lower the TDS to around zero value. Brine is circulated inside to make the resin working effectively. It has electrodes and via electrolysis the ions separated and move towards their respective electrodes. The have selective resins present inside. The working principle is like electro dialysis. The final treated water from here then pump out to the Boiler area at ORC – I for the necessary use.