Pre Feasibility Study of Integrated Paraxylene & Purified Terephthalic Acid Project of 1.2 MMTPA capacity at Paradip Refinery

1.0 INTRODUCTION:

The 15.0 MMTPA Paradip Refinery Project (PDRP) has been commissioned in Fuel-Refinery mode. The original configuration of PDRP included production of Petrochemical products, viz. Polypropylene (PP), Paraxylene (PX) and Styrene Monomer (SM) based on Refinery streams, in addition to fuel products. Considering the encouraging demand growth of Purified Terephthalic Acid (PTA), feasibility study was carried for Integrated PX and PTA Units of 1.2 MMTPA capacity each at Paradip. As per Market Report, there is a deficit of about 2.2 MMTPA PTA in India by 2024.

2.0 LOCATION OF THE PROJECT:

The PX & PTA plants along with new utility / offsite facilities, would be located in the vacant plot area situated on North side of creek of Paradip Refinery. Preliminary layout of the Project is given below:

PX-PTA Project at Paradip: Plot Plan
3.0  **PX-PTA PROJECT DESCRIPTION:**

Feed for the proposed PX-PTA plant will be Reformate, which is produced by processing Naphtha in CCRU. Reformate will be processed in the PX plant to produce PX, which will further be processed in the PTA plant for production of PTA.

Reformate is utilized for production of MS as well as PX. By-products of the PX plant viz. Toluene, Sulpholane Raffinate and Heavy Aromatics will be blended in MS/HSD pool. Benzene, the by-product from PX plant will be used for merchant sale.

3.1. **Major Facilities envisaged**

3.1.1. Paraxylene Unit having a capacity of 0.8 MMTPA. Brief description of the unit is given below:

**Paraxylene Unit consists of the following blocks:**
- Xylene Fractionation Unit
- Sulfolane Unit (Extractive Distillation)
- Benzene-Toluene Fractionation Unit
- Tatoray Unit
- Parex Unit
- Isomar Unit

**Block Flow Diagram of Paraxylene Unit**
Xylenes Fractionation Unit

Feed to the Xylenes Fractionation Unit emanates from three sources, coming in the form of Debutanizer bottoms from the CCR Platforming Unit, Toluene Column bottoms from the Benzene-Toluene Fractionation Unit, and Deheptanizer bottoms from the Isomar Unit.

The Platforming Unit’s Debutanizer bottoms is feed to the Reformate Splitter. The Light Reformate, i.e. the Reformate Splitter overhead liquid product, is pumped to the Feed Surge Drum in the ED Sulfolane Unit. The Reformate Splitter net bottoms, consisting of C8+ aromatics, are heated in the Clay Treater Feed Heater prior to entering the Clay Treaters. The Clay Treaters are responsible for removing olefinic material from the feed to the Xylene Columns. The effluent flow from the Clay Treaters is divided into two equally flowing streams; each acting as a feed to one of the two Xylene Columns. The flow rate of each of these two streams is reset by the level in the bottom of the Reformate Splitter.

In order to mitigate flare loads, this unit design employs the use of two identical Xylene Columns with identical overhead systems. In addition to receiving an equal amount of Reformate Splitter bottoms feed, each Xylene Column also receives an equal amount of Deheptanizer bottoms feed and an equal amount of Toluene Column bottoms feed, both of which consist primarily of mixed xylenes. The Deheptanizer bottoms are fed to the Xylene Column at the upper feed tray location. The Toluene Column bottoms combine with the Reformate Splitter bottoms prior to entering the Xylene Column at the lower feed tray location.

Overhead vapors from Xylene Column No 1 are condensed in the hot (shell) sides of Parex Raffinate Column Reboiler A, Parex Extract Column Reboiler A, and Isomar Deheptanizer Reboiler A. Similarly, overhead vapors from Xylene Column No 2 are condensed in the hot (shell) sides of Parex Raffinate Column Reboiler B, Parex Extract Column Reboiler B, and Isomar Deheptanizer Reboiler B. Condensed material from each train is pressured up to each system’s respective Xylene Column Receiver. From here, the net overhead liquid is pumped from each receiver to one of two Parex Feed Surge Drums. Each surge drum effluent stream is fed to the Parex Unit by two pumps operating in parallel. Prior to feeding the Parex Unit, however, the pump discharge streams combine into a single stream that is cooled by the Deheptanizer Feed-Parex Feed Exchanger in the Isomar Unit.

Each Xylene Column employs the use of two fired heaters operating in parallel to reboil the circulating bottoms material. There is a large degree of heat integration involved with the Xylene Column circulating bottoms systems. During normal operation, the circulating bottoms from Xylene Column No 1 are used as heat transfer media for the Parex Desorbent Rerun Column Reboiler, Clay Treater Feed Heater, Heavy Aromatics Column Reboiler, and Parex Raffinate Column Auxiliary Reboiler A. Meanwhile, the circulating bottoms from Xylene Column No 2 are used as heat transfer media for the Tatoray Stripper Reboiler and Parex Raffinate Column Auxiliary Reboiler B. Although
this describes the flow scheme during normal operation, the circulating bottoms systems were designed such that each train is capable of providing 100 percent of the duty required by any heat user, with the exception of the Parex Raffinate Column Auxiliary Reboilers. In the case of these heat users, Auxiliary Reboiler A will only accommodate flow from train one and Auxiliary Reboiler B will only accommodate flow from train two.

The Xylene Column net bottoms material is comprised of C9+ aromatics. Net bottoms streams from each Xylene Column combine into a single stream prior to feeding the Heavy Aromatics Column. Here, the C9 and C10 aromatics are taken overhead, condensed, and pumped to the Feed Surge Drum in the Tatoray Unit. Overhead vapors from the Heavy Aromatics Column are condensed both by an air cooler and by the Reformate Splitter Feed Heater, a shell and tube exchanger responsible for heating the Debutanizer bottoms feed from the Platforming Unit. Heavier C11+ aromatics are pumped from the bottom of the Heavy Aromatics Column to the Fuel Oil System.

- **Sulfolane Process Unit (Extractive Distillation)**

The Sulfolane process uses extractive distillation to recover high purity aromatics from a light reformates feedstock.

Feed to the unit is obtained from the overhead of the Reformate Splitter in the Xylenes Fractionation Unit, and from the bottoms stream of the Stripper in the Isomar Process unit. Extractive distillation is the method used to separate close-boiling components using a solvent that alters the volatility between the components. The solvent is generally a polar compound having a boiling point higher than the mixture. When applied to extractive distillation, the volatility of the aromatics is depressed relative to the other components in the mixture such that the non-aromatics can be distilled overhead in the Extractive Distillation Column.

There are two primary columns in the extractive distillation unit, they are the Extractive Distillation Column and the Recovery Column (or solvent stripper column). Aromatic feed, typically pre-fractionated, is directed to the Extractive Distillation Column.

It exchanges heat with the lean solvent and enters a central stage of the trayed column. The lean solvent is introduced near of top of the Extractive Distillation column.

Combining solvent and feed alters the relative volatilities of the components to be separated because of the non-ideal behavior of the mixture. This is the key to the process. The selectivity of the solvent renders aromatics relatively less volatile than the non-aromatics.

As the hydrocarbon vapor stream flows up the Extractive Distillation column, counter-current to the descending solvent, the aromatics are selectively absorbed.

The function of the upper section of the Extractive Distillation Column is to maximize aromatic recovery. The overhead vapor is non-aromatic and is referred to as the
raffinate. These vapors are condensed and sent to storage. A portion of the raffinate liquid is used as column reflux to rectify entrained solvent out of the overhead product. Overhead water is collected in the Extractive Distillation Column Receiver water boot and returned to the column. The Extractive Distillation Column is reboiled with steam. There is a reboiler preheater to recover heat from the lean solvent to reduce steam consumption in the reboiler.

In the lower section of the Extractive Distillation Column, the non-aromatics are preferentially stripped out of the liquid and enter the upper portion of the column as a vapor phase due to the solvent selectivity, which has made the saturates relatively more volatile than the aromatics. Again, because of finite selectivity, some aromatics, primarily benzene, are stripped into the upper section of the column where they must be re-absorbed. The lower section of the Extractive Distillation Column serves the function of aromatics purification.

The Extractive Distillation Column bottoms will contain solvent and highly purified aromatics. This material is sent to the Recovery Column (solvent stripper column). In this column, aromatics are separated from solvent under vacuum with steam stripping. The overhead aromatic product, depending on the composition (B or BT) is condensed and sent to storage or to clay treating prior to product fractionation. A portion of the extract liquid is used as reflux to remove residual solvent from the extract vapors. The Recovery Column is reboiled with steam. Water is collected in the Recovery Column Receiver water boot and is directed to the steam generator. This generator (heated by exchange with the Recovery Column bottoms) produces the stripping steam that is returned to the bottom of the Recovery Column via the Solvent Regenerator. Solvent is purified of residual hydrocarbons as it flows down the Recovery Column. At the bottom of the Recovery Column the solvent is essentially pure Sulfolane with a small amount of water. This is then returned to the Extractive Distillation Column as lean solvent. A slipstream of lean solvent is directed to a Solvent Regenerator to remove any degradation products.

- **Benzene-Toluene Fractionation Unit**

The Benzene-Toluene Fractionation Unit consists of two fractionation columns, the Benzene Column and the Toluene Column, and a set of two Clay Treaters. The purpose of this unit is to separate a purified benzene product from the C7+ aromatics, as well as separating toluene from C8+ aromatics so that the toluene can be sent to the Tatoray unit and to gasoline blending and the C8+ material can feed the Xylene Fractionation Unit. There are three separate feed streams that enter the Benzene Toluene Fractionation Unit. They consist of the overhead material from the ED Sulfolane Recovery Column, the overhead material from the Parex Finishing Column, and the bottoms material from the Tatoray Stripper.

Overhead material from the ED Sulfolane Recovery Column is preheated by the Clay Treater Charge Exchanger then heated to the Clay Treater process temperature by the
Clay Treater Charge Heater. Feed flows downward through the Clay Treaters where olefins are removed. The effluent from the Clay Treaters is cooled in the Clay Treater Charge Exchanger before mixing with overhead material from the Parex Finishing Column and the Stripper Bottoms product from the Tatoray Unit. The combined feed stream then enters the Benzene Column. The Benzene Column feed from the Clay Treater Charge Tank contains saturated water, which is removed in the Benzene Column Receiver.

The Benzene Column produces a side-draw benzene product, which is cooled and sent to storage. The toluene-rich Benzene Column bottoms product is heat exchanged with the Toluene liquid from the Toluene Column Receiver and fed the Toluene Column. The Toluene Column overhead vapor stream is condensed and the net product is sent to the Tatoray Unit and gasoline blending. The Toluene Column bottoms stream feeds the Xylene Column in the Xylenes Fractionation Unit.

- **Tatoray Process Unit**

The Tatoray Process Unit flow scheme consists of a fixed-bed reactor and a product separation section. The fresh feed to the Tatoray unit comes from the overhead of the Toluene Column in the Benzene-Toluene Fractionation Unit and the overhead of the Heavy Aromatics Column in the Xylenes Fractionation Unit. Feed is first combined with hydrogen-rich recycle gas in the Combined Feed Exchanger where it is preheated and vaporized by exchange with the hot reactor effluent. The feed is heated to reaction temperature in the Charge Heater before entering the Reactor. Feed flows down-flow over the catalyst bed. The reactor effluent is then cooled by exchange with the combined feed, condensed, and sent the Separator.

Hydrogen-rich recycle gas leaves the top of the Separator and is compressed in the Recycle Compressor. The recycle gas is mixed with makeup gas from the hydrogen central distribution system. The combined recycle gas joins the liquid feed upstream of the Combined Feed Exchanger.

A portion of the gas from the top of the Separator is vented to remove accumulated light ends from the recycle gas loop. This vent is sent to the fuel gas header.

Liquid from the bottom of the Separator is preheated in the Stripper Feed-Overhead Exchanger and Stripper Feed-Bottoms Exchanger before entering the Stripper. The light ends and a small portion of the benzene go overhead from the Stripper and are cooled and separated into gas and liquid products.

The Stripper Vent Condenser on the Stripper Receiver maximizes benzene recovery. The Stripper overhead vapor is sent to fuel gas.

The benzene and xylene products, together with the unreacted toluene and C9/C10 Aromatics, come from the bottom of the Stripper, are cooled in the Stripper Feed-Bottoms Exchanger, and finally go to the Benzene Column in the Benzene-Toluene
Fractionation Unit. The Stripper net overhead liquid is sent to the Isomar Stripper to remove the light ends.

**Parex Process Unit**

The purpose of the Parex unit is to separate Paraxylene from all other C8 Aromatics. The Parex process belongs to the UOP family of adsorption separation technologies based on the Sorbex separation concept.

The mixed Xylenes feed from the Xylene Fractionation Unit is first heated in the Deheptanizer Feed- Parex Feed exchanger located in the Isomar unit. A temperature controller adjusts the flow through the heat exchanger to hold the temperature of the Parex feed at the desired value of 147 °C.

This unit has two parallel adsorption trains and a common Fractionation Section.

The total feed enters the unit and then splits equally into two streams going to identical adsorbent trains. The feed then passes through the Feed Filter. The filter, remove any particulate matter that may damage the rotary valve or plug the adsorbent bed internals. The feed from the feed filter passes through the feed flow controller and into the Rotary valve. The Rotary Valves control the flow of feed, Desorbent, Extract and Raffinate streams to and from each set of Adsorbent Chambers.

The separation takes place in the adsorbent chambers. Each adsorbent chamber is divided into twelve adsorbent "beds". Each bed of adsorbent is supported from below by a specialized grid, which also contains highly engineered flow distributors to inject or withdraw liquid from the individual adsorbent beds, or redistribute the liquid over the cross-sectional area of the adsorbent chamber. Each flow distributor is connected to the Rotary valve by a bed line piping.

Each train has 24 adsorbent beds with grids and 24 bed lines connecting the grids to the Rotary Valve. Due to practical construction considerations, the 24 adsorbent beds are contained in two adsorption chambers in series with 12 beds in each chamber.

At any given time, only four of the bed lines are active, carrying the net streams into and out of the adsorbent chamber. The Rotary Valve is used to periodically switch the positions of the liquid feed and withdrawal points as the composition profile moves down the adsorbent chamber. Chamber Circulation pumps provide the liquid circulation from the bottom of one adsorbent chamber to the top of the other.

The dilute extract from the Rotary Valve is heated in the Extract Column Feed- Bottoms exchanger before feeding the Extract Column. The overhead vapor from the Extract Column is condensed in the Extract Column Condenser and collected in the Extract Column Receiver, which floats on the flare header through the Parex Vent Drum.
During normal operation the pressure drop through the Extract Column Condenser, the overhead vapor line, and the line from the condenser to the receiver will be stable enough that additional control of the extract column pressure is not required. A nitrogen purge is provided to the vent from the receiver to prevent material from returning from the vent to the receiver as the level in the receiver changes.

The Extract Column Overhead Pumps provide reflux to the top of the column and also the net overhead liquid, which is sent to the Finishing Column after getting preheated in the the Finish column Feed-Bottoms exchanger. The Extract Column is reboiled using heat from the Xylene Column overhead vapors in the Extract Column Reboiler. Desorbent from the Extract Column Bottoms Pumps is cooled in the Extract Column Feed-Bottoms Exchanger and the Desorbent Cooler.

A temperature differential transmitter is used between two of the Extract Column trays to monitor the temperature profile of the column. Adjusting the flow of the net extract stream enables the control of the composition for the extract.

An on-line analyzer monitors the overhead content of desorbent and helps in monitoring the desorbent loss with the extract.

The net overhead liquid from the Extract Column is heated in the Finishing Column Feed-Bottoms exchanger and passes to the Finishing Column. The column is reboiled using desuperheated MP steam in the Finishing Column Reboiler. The para-xylene product leaves the Finishing Column Bottoms Pumps under level control in finishing column and is cooled in the Finishing Column Feed-Bottoms Exchanger, the Paraxylene Cooler and the Paraxylene Trim Cooler and is stored in Paraxylene day tank.

It would then intermittently be pumped out to Paraxylene product storage tank in offsites through Paraxylene Transfer Pumps. The overhead vapor from the Finishing Column is condensed in the Finishing Column Condenser. From the Finishing Column condenser the liquid flows into the Finishing Column Receiver.

The Finishing Column Overhead Pumps provide the reflux to the top of the column and also the net overhead toluene, which is sent to the Benzene Column in the B-T Fractionation Unit.

Similar to the extract column the overhead receiver pressure floats with the relief header and a nitrogen purge line is provided to the vent line from the receiver to prevent material from returning from the vent to the receiver as the level in the receiver changes.

The Rotary Valves direct the raffinate from the Adsorbent Chambers to the Raffinate Column Feed-Bottoms Exchanger where it is heated upstream of the Raffinate Column (049-C-001).

Vapors from the Desorbent Rerun Column are also directed to the feed tray of the Raffinate column.
The column is reboiled using the Xylene Column overhead vapors in the Raffinate Column Reboiler and circulating bottoms from Xylene column in the Raffinate Column Auxiliary Reboiler. The desorbent leaves the Raffinate Column Bottoms Pumps and is cooled in the Raffinate Column Feed-Bottoms Exchanger and the Desorbent Cooler and is returned to the Adsorbent Chambers through the Rotary Valve after being filtered in the Desorbent Filter.

The overhead vapor from the Raffinate Column is condensed in the Raffinate Column Condenser and the liquid is collected in the Raffinate Column Receiver. Any uncondensed vapor leaves the receiver and is further cooled in the Raffinate Column Vent Condenser and the liquid is collected in the Raffinate Column Vent Drum, which floats on the Parex Vent Drum. Liquid from the vent drum runs back to the receiver and the total reflux is provided to the column using the Raffinate Column Reflux Pumps. Any water collected in the receiver is sent to the wastewater treatment plant (By others).

A Raffinate side cut is taken from near the top of the column and collected in the Raffinate Column Sidecut Surge Drum before going to the Isomar Unit.

During operation of the unit the heavy contaminants present in the feed will accumulate in the desorbent. To prevent this accumulation part of the desorbent leaving the Raffinate column is directed to Desorbent Rerun Column. The column is reboiled using Circulating bottoms from Xylene Column in the Desorbent Rerun Column Reboiler. The overhead vapors are directed to the Raffinate column. Heavy contaminants are removed from the bottom of the column.

Bottoms material from the Desorbent Rerun Column is removed on an intermittent basis. The heavy aromatics stream will be routed to the Heavy Aromatics Column Bottoms Cooler in the Xylene fractionation unit and then routed to the fuel oil system.

The Desorbent Rerun Column Bottoms Pumps, which are of proportioning type, withdraw a fixed quantity of heavy aromatics from the Desorbent rerun column. The Desorbent Rerun Column bottom level is maintained by regulating the duty of the Desorbent Rerun Column Reboiler through the LIC/FIC control.

The Desorbent Storage Tank provides the storage capacity for the desorbent makeup. The desorbent storage tank is an atmospheric tank which is nitrogen blanketed. The makeup desorbent is routed to the Desorbent Rerun column using the Desorbent Makeup Pump.

A Plant Inventory Storage Tank is provided to store the material in the unit in the event of a shutdown or a period of maintenance. Desorbent mixed with other process fluids are stored in the plant inventory tank. This tank is an atmospheric tank that is nitrogen blanketed.
The Parex Sump Tank is provided to collect the material vented and drained from the equipment during the normal operation and maintenance to conserve the valuable desorbent. The desorbent sump tank is a horizontal vessel located below grade to facilitate draining of process equipment. The Parex Sump Tank Pump provides the necessary hydraulic head to move the material in the sump tank to the plant inventory tank. The Parex Sump Tank Pumpout Cooler cools the material before being routed to the Plant Inventory Storage Tank.

The Desorbent Pumpout Cooler and Desorbent Pumpout Trim Cooler cools the material from the Parex Unit sufficiently for storage in an atmospheric tank. This is also used during startup and commissioning operations.

- **Isomar Process Unit**

An Isomar unit is always associated with the recovery of one or more xylene isomers. In this case the Isomar Unit is combined with the UOP Parex process for recovery of para-xylene. Fresh mixed xylene feed is first sent to a Xylene Column in the Xylene Fractionation Unit, which rejects C9+ aromatic components in order to meet feed specifications to the Parex unit. The Xylene Column overhead, containing less than 500 ppm C9+ aromatics, is then directed to the Parex unit where para-xylene is recovered. The raffinate from the Parex unit, containing less than 1 wt% para-xylene, is then sent to the Isomar unit which produces para-xylene from the other C8 aromatics. This C8 aromatics stream, Deheptanizer bottoms, is recycled back to the Xylene Column completing the loop.

The feed to the Isomar unit is first cooled by exchange with the Deheptanizer feed. By lowering the feed temperature, the duty on the Combined Feed Exchanger increases and the duty on the Product Condenser is decreased, thus reducing its size. The feed is then combined with hydrogen-rich recycle gas and make-up gas to replace the small amount of hydrogen consumed in the Isomar reactor. The combined feed is then vaporized by exchange with reactor effluent in the Combined Feed Exchanger and then heated to reactor operating temperature in the Charge Heater. The hot vapor feed is then sent to the Reactor where it is passed radially through a fixed bed of catalyst. The reactor effluent is cooled by exchange with the combined feed, condensed in the Product Condenser and then sent to the Separator. To maintain the correct catalyst hydration level required for optimum catalyst performance, water is injected into the reactor feed upstream of the Combined Feed Exchanger.

Hydrogen-rich gas is taken off the top of the Separator and recycled back to the Reactor using a motor driven Recycle Compressor. A small portion of the recycle gas is sometimes purged to remove accumulated light ends from the recycle gas loop. Liquid from the bottom of the Separator is heated on its way to the Deheptanizer by two exchangers: the Deheptanizer Feed-Isomar Feed Exchanger, and the Deheptanizer Feed-Parex Feed Exchanger.
The C7- overhead from the Deheptanizer is cooled and separated into gas and liquid products. The Deheptanizer overhead gas is chilled and separated with the chilled vapor exported to a low pressure fuel gas system while chilled liquid is returned to the column overhead receiver. The receiver liquid, along with Tatoray Stripper overhead liquid is sent to the Stripper to remove water and light hydrocarbons from the overhead product before it is sent to the ED Sulfolane Unit. The C8+ fraction from the bottom of the Deheptanizer is then recycled back to the Xylene Column.

3.1.2. Purified Terephthalic Acid (PTA) Unit having a capacity of 1.2 MMTPA. Brief description of the unit is given below

Purified Terephthalic acid is the organic compound with formula C6H4(COOH)2. This colorless solid is a commodity chemical, used principally as a precursor to the polyester PET, used to make clothing and plastic bottles.

Purified terephthalic acid (PTA) is also a raw material used in making high-performance multi-purpose plastics such as polybutyl terephthalate (PBT), polytrimethylene terephthalate (PTT).

Purified terephthalic acid (PTA) is made by causing a reaction between the secondary petroleum product paraxylene (PX) and acetic acid.

**Process Chemistry**

1. **1st Step : CTA Process**

   ![Chemical Reaction Diagram]

   \[
   \text{p-Xylene} + 3\text{O}_2 \rightarrow \text{HOOC-\text{-COOH} + 2H_2O}
   \]

   *Crude TPA(CTA)*

   *4-Carboxyl Benzaldehyde(4CBA)*

2. **2nd Step : PTA Process**
PTA Plant consists of the following two sections:

1. Crude Terephthalic Acid (CTA) Section
2. Purified Terephthalic Acid Section

1. Process Description of CTA Section

The Oxidation Plant is designed for continuous operation and consists of five main sections: Reaction, CTA Crystallisation, CTA Solvent Interchange, Catalyst Feed and Solvent Treatment.

In the Reaction section paraxylene feedstock is mixed with acetic acid solvent and catalyst solution and reacted with air. The major proportion of the terephthalic acid produced in the exothermic reaction is precipitated in the reactor to form slurry. The reactor vapours pass through a two-stage rectifier column which allows recovery of acetic acid, and excess reactor water is withdrawn from the overheads aqueous condensate.
In the CTA Crystallisation section the reactor exit slurry is depressurised and cooled in a series of three crystallising vessels. The precipitated terephthalic acid product is recovered and transferred directly to the Purification Plant by continuous filtration incorporating Solvent Interchange. A proportion of the mother liquor generated in this stage is purged to the Solvent Stripper via the TA Mother Liquor Filter.

In the Catalyst Feed section, fresh catalyst is imported and the flow adjusted to produce a catalyst solution for feed to the Reaction Section.

In the Solvent Treatment Section, impure solvent recovered from the Reaction and CTA Solvent Interchange Sections, is processed to remove acetic acid and water from the higher boiling reaction by-products. The recovered solvent is fractionated to remove low-boiling impurities, and produces clean acetic acid solvent for re-use in the Oxidation Plant. The higher-boiling by-products are quench cooled in water and the resulting slurry transferred to a CTA Residues Recovery Unit for recovery of catalyst, intermediates and by-products from the residues.

2. Process Description of Purification Plant (PTA Section)

Crude Terephthalic Acid (CTA) product from the Oxidation Plant contains a small quantity of impurities which must be removed before the material can be used in the manufacture of polyester products. This is achieved in the Purification Plant by selective catalytic hydrogenation of an aqueous solution of CTA at elevated temperature and pressure. Purified Terephthalic Acid (PTA) is subsequently crystallised and recovered by employing solid/liquid separation and drying steps.

The principal impurity, 4 Carboxy-Benzaldehyde (4CBA), is hydrogenated to para- Toluic Acid. The para-Toluic Acid, being more soluble in water than PTA, remains in aqueous solution during the subsequent crystallisation and product recovery stages.

3.1.3. Utilities & Offsite

Following new facilities have been considered, since capacity margin is not available in existing Paradip Refinery utility system after consumption in PP and Ethylene Glycol Project.

a) Offsite Facilities:

- For meeting the utilities' demand for the proposed PX & PTA plants, new facilities have been considered as per following details:

<table>
<thead>
<tr>
<th>Item</th>
<th>New Facilities Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power &amp; Steam</td>
<td>Steam and Power will be sourced from new CPP consisting of following facilities:</td>
</tr>
<tr>
<td></td>
<td>Gas Turbine (GT) : 1 x 102 MWh</td>
</tr>
<tr>
<td></td>
<td>Heat Recovery Steam Generator (HRSG) : 1 x 320 MT/hr</td>
</tr>
<tr>
<td>Cooling Water (m³/hr)</td>
<td>New Cooling Tower: 12 Cells x 4000 m³/hr (10 Working+2 Standby) with associated facilities.</td>
</tr>
</tbody>
</table>
### New Facilities Required

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Cooling Tower:</td>
<td>2 Cells X 1000 m³/hr (1 Working + 1 Standby) with associated facilities.</td>
</tr>
<tr>
<td>De-mineralized (DM) Water (MT/hr)</td>
<td>New DM water : 2 Trains X 300 m³/hr (1 Working + 1 Standby) with associated facilities</td>
</tr>
<tr>
<td>Treated Raw Water (m³/hr)</td>
<td>Desalination Plant of 2000 m³/hr capacity along with water intake and reject discharge facilities.</td>
</tr>
<tr>
<td>Instrument Air (Nm³/hr): Plant Air: (Nm³/hr)</td>
<td>Air Compressors : 2 x 6500 Nm³/hr (1 Working + 1 Standby) with associated facilities</td>
</tr>
<tr>
<td>Low Pressure (LP) Nitrogen (Nm³/hr)</td>
<td>Cryogenic Nitrogen Plant : Capacity</td>
</tr>
<tr>
<td>High Pressure (HP) Nitrogen (Nm³/hr)</td>
<td>• Gaseous - 3100 Nm³/hr</td>
</tr>
<tr>
<td>Fuel Gas/ Natural Gas (MT/hr)</td>
<td>New Natural Gas system</td>
</tr>
<tr>
<td>Effluent (m³/hr)</td>
<td>There is no continuous effluent from PX Complex. Effluent emanating from PX plant shall be routed to new Effluent Treatment Plant (ETP) of Paradip Refinery. New ETP for PTA plant : Capacity 300 m³/hr consisting of anaerobic and aerobic system.</td>
</tr>
<tr>
<td>Flare System (MT/hr)</td>
<td>72” flare header, new Knock Out Drum (KOD), new flare stack (Diameter : 66”, Height:131 m) in existing PP flare stack derrick in North side of creek.</td>
</tr>
</tbody>
</table>

### b) Storage and Dispatch Facilities:

- Following storage facilities have been considered:

<table>
<thead>
<tr>
<th>Service</th>
<th>Destination</th>
<th>Type</th>
<th>Working Capacity (No. x m³)</th>
<th>Storage time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>Merchant Sale</td>
<td>Internal floating</td>
<td>4 x 1840</td>
<td>7</td>
</tr>
<tr>
<td>Toluene</td>
<td>MS Blend / Merchant Sale</td>
<td>Internal floating</td>
<td>2 x 4974</td>
<td>7</td>
</tr>
<tr>
<td>Reformate*</td>
<td>PX plant</td>
<td>Internal floating</td>
<td>1 x 16177</td>
<td>3</td>
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<tr>
<td>Raffinate</td>
<td>MS Blend</td>
<td>Fixed roof (Dome)</td>
<td>2 x 3091</td>
<td>7</td>
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<tr>
<td>C9 / C10 Aromatics</td>
<td>MS Blend</td>
<td>Internal floating</td>
<td>1 x 166</td>
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<tr>
<td>Heavy Aromatics</td>
<td>HSD Blend</td>
<td>Internal floating</td>
<td>1 x 143</td>
<td>1</td>
</tr>
<tr>
<td>Acetic Acid</td>
<td>PTA plant</td>
<td>Fixed Roof (Cone)</td>
<td>2 x 374</td>
<td>-</td>
</tr>
<tr>
<td>PTA Product Silo</td>
<td>Merchant Sale</td>
<td>Silo</td>
<td>4 x 3023</td>
<td>-</td>
</tr>
<tr>
<td>PTA Warehouse</td>
<td>To store PTA, Flexible Intermediate Bulk Container (FiBC),</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
considering inventory for 15 days.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Mode of Dispatch</th>
<th>Facilities Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PX-PTA Project feasibility study undertaken considering Paradip Refinery and CPCL Naphtha. Currently, Paradip Refinery is having 2 x 15000 KL NHTU feed tanks and 4 x 10000 KL Naphtha product tanks. Requirement of additional Naphtha tank for PX-PTA Project will be studied during DFR stage.</td>
<td></td>
</tr>
</tbody>
</table>

- Following dispatch facilities have been considered:

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Mode of Dispatch</th>
<th>Facilities Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA</td>
<td>Truck (Domestic)</td>
<td>Dock Levelers + EOT Cranes + bulk loading points</td>
</tr>
<tr>
<td></td>
<td>Railway (Domestic)</td>
<td>Existing Petcoke Rapid Rail Loading System (RRLS) track is proposed to be utilized for PTA Rail dispatch. Container loading by Reach Stacker on Rail Rack has been considered. For creating Rail loading facility, existing Green Belt area adjacent to eastern boundary wall (near Petcoke Silos) need to be relocated by procuring about 16 acres private land (non-agricultural) at north side of said Green Belt area.</td>
</tr>
<tr>
<td></td>
<td>Ship (Export)*</td>
<td>Container transfer to Paradip Port by truck.</td>
</tr>
<tr>
<td>Benzene</td>
<td>Truck (Domestic)</td>
<td>New gantry with loading arms</td>
</tr>
<tr>
<td></td>
<td>Ship (Export)</td>
<td>8” pipeline to jetty with loading arms</td>
</tr>
<tr>
<td>Toluene</td>
<td>Truck (Domestic)</td>
<td>New gantry with loading arms (Toluene is to be blended in MS. However, facilities for merchant sale have also been considered).</td>
</tr>
</tbody>
</table>

c) Fire Water System

The governing fire water requirement for the proposed integrated PX-PTA Complex is 4633 m³/hr and corresponding fire water storage requirement is 27798 m³. The fire water demand is calculated based on two major fires occurring simultaneously anywhere in the Complex as per OISD 116 (July 2012 edition) standards.

The existing fire water pumping capacity is 7155 m³/hr and existing firewater storage capacity is 34252 m³. Therefore, fire water requirement for integrated PX-PTA Complex
will be met from existing fire water facilities at Paradip Refinery. Necessary piping and related facilities will be provided as per statutory norms.

4.0 PROJECT SCHEDULE:

The project is scheduled to be commissioned in 2022-23.

5.0 PROJECT COST: Rs. 9137 crore

6.0 EFFLUENT HANDLING SYSTEM:

- Gaseous Effluent Management

The main pollutant will be the sulphur dioxide emitted from the furnaces along with the flue gases. As the emission of sulphur dioxide is due to fuel burning only, the quantity emitted will depend on the sulphur present in the fuel and the quantity of the fuel burnt off gas generated during normal operation is routed to Fuel Gas system.

Under normal circumstances there shall be no continuous/intermittent point releases of volatile hydrocarbon streams. However, during start up/shut down or any emergency operation, popping up of any pressure safety relief valves, the hydrocarbon streams released shall be directed to an elevated flare for complete combustion. This will eliminate the possibility of forming an explosive mixture due to sudden release of unburnt hydrocarbons to the atmosphere.

Pressure Relief valves are provided to discharge hydrocarbons safely to flare during abnormal operations. The flare elevation shall be such so that there will be no impact of thermal radiation on the operating personnel in the plant. To ensure complete combustion of released hydrocarbons through flare, a pilot burner shall always be burning with the aid of fuel gas.

In order to reduce the emission of Nitrogen oxides all the heater furnaces shall be provided with well-proven low NOₓ burners.

The gaseous emissions from various process units shall confirm to the standards prescribed by the concerned authorities. In the event of failure of any pollution control system(s) adopted by the unit, the respective unit shall be shut down immediately and shall not be restarted until the control measure(s) are rectified to achieve the desired efficiency.

Ambient air quality around the premises shall be limited as per National Ambient Air Quality Standards (NAAQS).
• **Fugitive Emissions**

The fugitive emissions as the title suggests are primarily due to intermittent / continuous leakage or evaporation of volatile organic carbons (VOCs) from processing/storage area of the plant handling hydrocarbons.

The likely sources of such fugitive emissions of VOCs in plant are the main processing area, the tank farm area having storage tanks for feed and lighter products and the loading/unloading gantry area. These fugitive emissions originate from the static and dynamic compressors joints and seals used in flanges, pumps, mixers, valve packing and connection joints to the atmosphere like sampling and relief valves etc. in order to minimize the fugitive emissions of VOCs.

In order to minimize the Fugitive emissions, the following measures will be taken during design stage:

a) Minimizing the number of valves, control valves and flanges to reduce potential leak sources consistent with plant safe operability and maintenance needs. High-grade gasket materials for packing.

b) Provision of Floating Roof Storage tanks for volatile products storage.

c) Provision of better sealing arrangement for Floating Roof in such storage Tanks.

d) All vents and drains that are not operated on a regular basis to be blinded, capped or plugged.

e) Fugitive emissions from rotary equipment will be minimized by the use of high performance seal systems / double seal systems as applicable.

f) Due to the carcinogenic nature of benzene, all streams containing 0.5 % weight or more of benzene and 25 % weight or more of C7 through C9 aromatics, the following provisions to be made to reduce the emissions.

• Closed sampling

• Usages of “State-of-the-art” low leakage valves preferably bellow seals.

• Closed aromatics collection system with a below grade drum in an open pit receiving all drains of the corresponding process part

• Dual mechanical seals for pumps

• Valves, flanges and joints shall satisfy the requirements of TWA (Time- Weighted Average) exposure limit of 1 ppm for an 8 hour workday (OSHA’s requirement)

g) All water streams saturated with aromatics to be sent to a suitable processing or treating facility in order to minimize aromatic emissions to the environment.
• **Waste Water Management.**

In PX Complex, waste water streams are generally generated from the Raffinate and
Finishing column receivers of Parex unit and Deheptanizer column receiver of Isomar
unit. The waste water streams are typically drained on an intermittent basis and are
normally disposed off by sending to waste water treatment facilities.

In PTA Complex, waster water streams are generally generated from PTA Mother liquor
and off gas scrubber purge. Dedicated ETP plant has been consider to handle PTA
effluent.

At the design stage, there are several measures proposed to be incorporated in the
process to minimize the impact the generation of waste water. Some of these measures
are described below:

- The closed blow down system for all hydrocarbon liquid discharges from the process
  units, which in turn reduces the net wastewater both in terms of quantum load and quality,
  shall be incorporated.
- Provision of appropriate segregation and collection philosophy for various effluent
depending on individual streams’ characteristics.
- Paving the process area to avoid contamination of soil/sub-soil/ground water in case of
  accidental spills/leakage of hydrocarbon liquids.
- Following different sewers or headers have been proposed to handle the effluent
generated from the plant:
  - Oily Water Sewer (OWS), its collection and pumping to OCS (Oil Collection System)
  - Contaminated Rain Water Sewer (CRWS)
  - Sanitary Sewer
  - Storm Sewer (SS)

• **Effluent Treatment Plant**

Effluent Treatment Plant (ETP) including WWT plant and effluent treatment & disposal
facilities is required for the proposed PX-PTA integrated complex at Paradip Refinery
to treat wastewater effluents and other effluents from PTA complex.

One new ETP including WWT plant and effluent treatment & disposal facilities is
considered for PTA complex as the existing ETP at Paradip Refinery cannot be
utilized for the same.

Different effluent streams emanating from PTA complex are to be collected,
segregated and treated in a new Effluent Treatment Plant (ETP), to meet
applicable regulatory requirements before final disposal.
- Effluent Treatment Plant Configuration for PX-PTA integrated Complex as per feasibility study

The complete Effluent Treatment Plant including WWT plant and effluent & disposal facilities includes the following sections:

a) Surge & Equalization System
b) Anaerobic Treatment System
c) Aerobic Treatment Section
d) Water Filtration Section
e) Sludge Handling & Separation System

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a) Surge & Equalization System:

PTA plant process wastewater streams are piped to the Surge Tank or to Equalization Tank. The surge tank collects the relatively high and periodic flows from the sources. The holding / storage provided by the surge tank allows for controlled, reduced flow transfer to the equalization tank. The surge tank is above grade, circular tank. ISBL waste acids may enter the tank during unit upsets. The surge tank is equipped with in-tank jet mixing system.

b) Anaerobic Treatment System:

The equalized effluent is pumped to a conditioning tank. Chemicals are added into the conditioning tank (mostly neutralized chemicals and nutrients etc.).
From the conditioning tank the neutralized effluent is then fed to the proposed Anaerobic Reactor, UASB (Upflow Anaerobic Sludge Blanket Digester) by use of reactor feed pumps. Target COD reduction in anaerobic reactor is >85% (After complete stabilization). The anaerobically treated wastewater with reduced COD load from the reactor top is allowed to flow by gravity to the aerobic waste water treatment system. Methane rich biogas collected in reactor top is conveyed to Biogas Handling System. Condensate traps to be provided at the inlet line of Biogas Handling System to remove condensate from biogas. From the biogas zone of the anaerobic reactor, the biogas is drawn through biogas compressors/ liquid ring pump, pressurized and then sent to the boiler heater to use as a fuel. If the biogas is not used in the boiler, the same shall be sent to flare system for flaring.

c) Aerobic Treatment Section:
After treatment in WWT, the process waste water will be routed to effluent treatment & disposal facilities for final treatment. Treated wastewater from WWT is combined with boiler; cooling tower and demineralized water blow down streams and are routed to effluent treatment & disposal facilities for final treatment. Along with process water effluent streams, the other liquid effluents streams like spent caustic stream, catalyst regeneration effluents & contaminated rain water streams shall also be separately routed to effluent treatment and disposal facilities for final treatment. The effluents pass through aeration tank and clarifier before moving to water filtration section.

d) Water Filtration Section – Tertiary Treatment by DMF and ACF:
Water filtration section is located in downstream the Aerobic Treatment Units. The aerobic effluent coming from aeration & clarification systems contains a significant amount of suspended solids that need to be removed by means of a tertiary treatment.

Tertiary treatment section includes:
1. Filtration system through pressure sand filter
2. Activated carbon Filters

The clarified water is feed into pressure sand filter for filtration of suspended particles if present in water. Filtered water is further fed to Activated Carbon Filter to remove color, odour, organic & COD present in water.

e) Sludge Handling & Dewatering System:
Sludge Handling & dewatering System include:

1. Sludge Sump:
Sludge generated in the ETP will be collected in the sludge sump. Aeration will be employed in the sludge sump either through blowers and aeration grids or mechanical aeration system
2. **Belt filter or Sludge Dewatering:**

Dewatering system for sludge generated from plant will be done by using belt press, which will be a common facility for all streams. Hopper and sludge loading facilities will also be provided. The sludge will be dewatered from inlet consistency of 3-4% solids to ~22% solids in the belt press. The filtrate from belt press will be sent to distribution box of aeration tank.

### Different Effluents Flow Rates

a) **Wastewater Effluents:**

<table>
<thead>
<tr>
<th>Stream</th>
<th>Temp (°C)</th>
<th>Flow rate (m³/hr)</th>
<th>Duration</th>
<th>COD (t/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA Unit Water Treatment Column Bottoms</td>
<td>40</td>
<td>33.8</td>
<td>Continuous</td>
<td>11.6</td>
</tr>
<tr>
<td>PTA Unit Off-gas Scrubber Effluent</td>
<td>34</td>
<td>34.8</td>
<td>Continuous</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>PTA Unit R²R Effluent</td>
<td>40 - 100</td>
<td>8.5</td>
<td>Continuous</td>
<td>13.2</td>
</tr>
<tr>
<td>PTA Unit Drier Gas Scrubber &amp; Fifth Crystalliser Preheater Condensate Pot Effluent</td>
<td>50</td>
<td>17.6</td>
<td>Continuous</td>
<td>0.6</td>
</tr>
<tr>
<td>Routine washings / draining to ISBL effluent pits</td>
<td>80</td>
<td>20</td>
<td>Intermittent</td>
<td>3.0</td>
</tr>
<tr>
<td>PX Unit</td>
<td>40</td>
<td>1</td>
<td>Continuous</td>
<td>-</td>
</tr>
<tr>
<td>Cooling Tower blowdown</td>
<td>Ambient</td>
<td>184</td>
<td>Intermittent</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>300</td>
<td>-</td>
<td>28.6</td>
</tr>
</tbody>
</table>

- **Solid Waste Management**

During the design stage itself due care shall be taken to select the process technologies generating minimum solid wastes so that their handling, treatment and disposal does not cause any serious impact on the existing land environment.

The brief solid wastes management plan proposed is given below.

Solid Wastes Handling, Treatment and Disposal
There are primarily three type of solid wastes generated in a plant namely:

- Spent Catalysts
- General Solid Wastes
- Sludge

a) Spent Catalysts

Spent clay is generated from the Xylene Unit, Isomar unit and B-T Unit. The expected clay life is one to two years and it is normally disposed of locally in an environmentally acceptable manner (like landfill). Similarly the ultimate life of adsorbent of the Parex unit is ten years and it is also disposed of locally in an environmentally acceptable manner (like landfill). Spent catalyst from the Tatoray, Isomar and PTA Units has an ultimate life of about ten years. The spent catalyst may be sent for metal recovery, but it typically is disposed locally in an environmentally acceptable manner (e.g. Cement Kiln).

b) General Solids Wastes

It is estimated that small quantities or non-hazardous, non-recyclable, solid waste consisting of waste refractory, spent insulation, used filter cartridges shall be generated. These wastes shall be disposed off as landfill.

c) Sludge

In PTA plant, Solid waste produce by the process are transferred to the Thermal Oxidiser for disposal.