RELIANCE

**Reliance Industries Limited (RIL)** is an Indian conglomerate holding company headquartered in Mumbai, Maharashtra, India. Reliance owns businesses across India engaged in energy, petrochemicals, textiles, natural resources, retail and telecommunications. Reliance is the second most profitable company in India, the second-largest publicly traded company in India by market capitalizationand the second largest company in India as measured by revenue after the government-controlled Indian Oil Corporation. The company is ranked 114th on the [Fortune Global 500](https://en.wikipedia.org/wiki/Fortune_Global_500) list of the world's biggest corporations, as of 2014. RIL contributes approximately 20% of India's total exports. It is ranked 14th among the Top 250 Global Energy Companies by [Platts](https://en.wikipedia.org/wiki/Platts).

The company was co-founded by Dhirubhai Ambani and his brother Champaklal Damani in 1960s as Reliance Commercial Corporation. In 1965, the partnership ended and Dhirubhai continued the [polyester](https://en.wikipedia.org/wiki/Polyester) business of the firm. In 1966, Reliance Textiles Industries Pvt Ltd was incorporated in Maharashtra. It established a [synthetic fabrics](https://en.wikipedia.org/wiki/Synthetic_fiber) mill in the same year at [Naroda](https://en.wikipedia.org/wiki/Naroda) in [Gujarat](https://en.wikipedia.org/wiki/Gujarat). In 1975, the company expanded its business into textiles, with "Vimal" becoming its major brand in later years.

In 1985, the name of the company was changed from Reliance Textiles Industries Ltd. to Reliance Industries Ltd. During the years 1985 to 1992, the company expanded its installed capacity for producing [polyester](https://en.wikipedia.org/wiki/Polyester) [yarn](https://en.wikipedia.org/wiki/Yarn) by over 145,000 tonnes per annum.

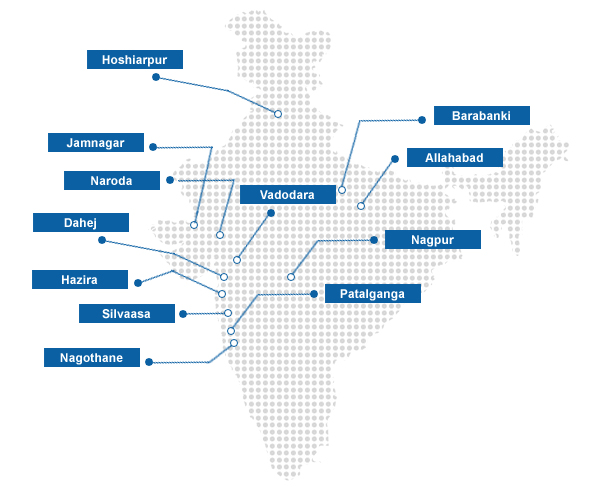
The Hazira petrochemical plant was commissioned in 1991–92.

In 1996, it became the first private sector company in India to be rated by international credit rating agencies

The years 1998–2000 saw the construction of the [integrated petrochemical complex at Jamnagar](https://en.wikipedia.org/wiki/Jamnagar_Refinery) in [Gujarat](https://en.wikipedia.org/wiki/Gujarat), the largest refinery in the world.

In 2002–03, RIL purchased a majority stake in Indian Petrochemicals Corporation Ltd. (IPCL), India's second largest petrochemicals company, from Government of India. IPCL was later merged with RIL in 2008. In the years 2005 and 2006, the company reorganized its business by demerging its investments in power generation and distribution, financial services and telecommunication services into four separate entities. In 2006, Reliance entered the organized retail market in India with the launch of its retail store format under the brand name of 'Reliance Fresh'. Major subsidiaries and associates:

* [Reliance Retail](https://en.wikipedia.org/wiki/Reliance_Retail)
* Reliance Life Sciences
* [Reliance Institute of Life Sciences](https://en.wikipedia.org/wiki/Reliance_Institute_of_Life_Sciences) (RILS)
* Reliance Logistics
* Reliance Clinical Research Services (RCRS)
* Reliance Solar
* [Relicord](https://en.wikipedia.org/wiki/Relicord)
* [Reliance Jio Infocomm Limited (RJIL)](https://en.wikipedia.org/wiki/Reliance_Jio_Infocomm_Limited_(RJIL))
* [Reliance Industrial Infrastructure Limited](https://en.wikipedia.org/wiki/Reliance_Industrial_Infrastructure) (RIIL)
* [LYF](https://en.wikipedia.org/wiki/LYF), a 4G-enabled VoLTE smartphone maker based in Mumbai.



***Various Locations of Reliance Industries***

**Reliance Industries Limited – Dahej Manufacturing Division**

Dahej Manufacturing Division (DMD), an integrated petrochemical complex located near Jageshwar Village, Bharuch District, Gujarat, 130 Kilometers southwest of Vadodara which earlier known as Indian Petrochemical Corporation Limited (IPCL) Dahej Manufacturing Division located near Bharuch, Gujarat, is spread over 1,778 acres. It comprises of an ethane / propane recovery unit, a gas cracker, a caustic chlorine plant and 4 downstream plants, which manufacture polymers and fibre intermediates.

The Dahej Manufacturing Division consists of the following existing plants & related utilities which are in operation.

* Vinyl Chloride Monomer (VCM)
* Poly Vinyl Chloride Unit (PVC)
* Chlor-Alkali Unit (CA)
* Gas Cracker Unit (GCU)
* Ethylene Oxide/ Ethylene Glycol Unit (EO/ EG)
* High Density Poly Ethylene Unit (HDPE)
* Ethylene Vinyl Acetate (EVA)
* Ethane Propane Recovery Unit (EPRU)
* Purified Terephthalic Acid Unit (PTA)
* Polyethylene Terephthalate (PET)
* Utilities including Captive Power Plant

The complex has its own facility for separating ethane/propane from rich gas containing recoverable amounts of ethane / propane purchased from GAIL. The lean gas from which the ethane / propane has been extracted is returned to GAIL. The ethane / propane mixture is then used as a feedstock for the gas cracker plant.

The complex was commissioned in two phases in order to rationalize cash flows and level of borrowings. The Caustic Chlorine, VCM and PVC pants in phase one was commissioned in 1997. After this, in phase two, HDPE plant, MEG plant, ethane / propane recovery plant and gas cracker unit were commissioned in 2000.

RIL-DMD produces main products namely Polyvinyl Chloride (PVC), High Density Poly Ethylene,(HDPE), Mono Ethylene Glycol (MEG), Caustic soda lye & Ethylene Vinyl Acetate (EVA),Polyethylene Terephthalate (PET) & Purified Terephthalic Acid (PTA) along with some valuable chemical by products like HCl, Wax, DEG, TEG, Mix Oil, RARFS etc., which are either consumed internally, exported to sister divisions or sold in the open market. Propylene produced in Gas Cracker Plant of DMD, which is a raw material for manufacture of PP Polymer, is exported to VMD where it has PP manufacturing Plant through connected piping network.

**PURIFIED TEREPTHALIC ACID PLANT**

1. **INTRODUCTION**

PTA has the form of a white, crystalline powder and looks like powdered sugar. It is quite inert, which means that, for example, it is difficult to dissolve in water or other liquids. PTA is an aromatic acid, primarily applied in the production of polyester. The main raw material for PTA is paraxylene (PX).

When Amoco Chemicals Belgium was established in 1967, the production of PTA (purified terephthalic acid) had already been planned. In 1969, the first PTA unit (PTA1) came on line and in 1991 the second one (PTA2) followed.

1. **RAW MATERIALS AND CHEMICALS**

* Paraxylene (raw material)
* Compressed air (raw material)
* Hydrobromic acid (promoter)
* Cobalt acetate (catalyst)
* Manganese acetate (catalyst)
* CMA catalyst solution
* Acetic acid (solvent)
* Normal propyl acetate (entrainer)
* Oxalic acid (catalyst recovery reagent)
* Sodium formate
* Platinum
* Hydrogen (for purification)
* Caustic soda 5% w/w (off gas scrubbing)

1. **PROCESS CHEMISTRY**
   1. **Oxidation chemistry**

Terephthalic acid (TA) is produced by the liquid-phase air oxidation of paraxylene in acetic acid solvent, and is catalyzed by soluble cobalt, manganese and bromine compounds

The water produced as a by-product of the reaction will slow down or inhibit the rate of reaction if allowed to build up in the liquid phase and is therefore continually withdrawn from the reactor. The overall reaction is extremely quick and typical reactor product only contains 0.2 to 0.3% of 4-carboxybenzaldehyde (4CBA), the major impurity.

*The reaction is highly exothermic, liberating close to 3,000 kcals or 12,500 kJ per kg of paraxylene consumed.* The reaction proceeds via a series of steps in which each methyl group is sequentially oxidized via the aldehyde to the acid.



The slowest step in the above series of reactions is the oxidation of paratoluic acid; hence this acid is the intermediate present in the largest quantity. Since paratoluic acid is soluble in acetic acid solvent it does not appear as the major impurity in the CTA product. 4CBA, although present in smaller amounts in the reactor is much less soluble in acetic acid: It co-precipitates with terephthalic acid and hence appears as the major impurity in CTA.

The process achieves a high yield of terephthalic acid from paraxylene - typically 96-97% of stoichiometry

Apart from some unreacted paraxylene escaping in the vapour stream leaving the reactor, there are other reactions forming by-products such as benzoic and trimellitic acids and some burning to CO/CO2. Impurities in the paraxylene feed, such as ortho and metaxylenes, toluene and ethylbenzene are respectively oxidised to ortho and isophthalic acids and benzoic acid.

Although Acetic acid does not appear in the main reaction sequence, acetic acid has an important role in the oxidation process. It serves as a solvent for both paraxylene and the cobalt/manganese/bromine catalyst in the reactor feed and it forms slurry with the precipitated CTA crystals, enabling the product to be easily removed from the reaction system. Acetic acid losses are a major economic consideration in the operation of the process hence, the process conditions must be optimized to give the desired level of 4CBA in the product whilst minimizing acetic losses. The overall reaction is as follows:



**3.2** **Purification Chemistry**

The function of the Purification Plant is to reduce the levels of intermediates and by-products. This is achieved by dissolving the CTA in water at high pressure / temperature and reacting the impurities with Hydrogen in the presence of a catalyst. This is called a Hydrogenation reaction. This reaction effectively converts the impurities into more soluble or non-coloured forms, which stay dissolved in the water phase in the subsequent crystallisation stage. Both CTA and 4CBA are very insoluble but p-TA is soluble. The p-TA and other non-coloured forms are purged from the plant in the mother liquor from the primary solid/liquid separation stage.

The main reactions that take place are: -

a) 4-CBA + Hydrogen p-TA + water (or to 4-carboxy benzyl alcohol).

Both products are soluble in water.

b) Colored impurities + Hydrogen Non -colored impurities or to soluble colored impurities.



**PTA – 5 & PTA – 6 (DMD)**

The PTA PLANT is designed for an annual capacity of 1,120,000 tonnes of Pure Terephthalic acid (PTA).

The PTA PLANT is designed to produce this output in an 8000 hour operating year, based on a flow sheet rate of 140 te/h of PTA, on a single stream basis. This rate is referred to as the normal capacity.

Design flexibility of the PTA PLANT is expected to allow operation in the range 70 – 110% of normal capacity.

**Raw Materials required for 100 % normal capacity**:

|  |  |
| --- | --- |
| Raw Materials | Specific Consumption  (Kg/TON of PTA) |
| Paraxylene | **656** |
| Acetic acid (as 100%) | **35.5** |
| Cobalt (as metal) | **0.03** |
| Manganese (as metal) | **0.06** |
| HBr (as 100%) | **0.55** |
| Entrainer (Normal Propyl Acetate) | **0.70** |
| Catalyst Recovery Reagent (Oxalic Acid) | **0.5** |
| Support Fuel (Methanol) | **2.62** |
| Caustic (100%) | **4.96** |
| Sodium Formate (as 100%) | **0.04** |
| Hydrogen (as 100%) | **0.12** |

**Utility Consumption for 100% normal capacity:**

|  |  |
| --- | --- |
| Item Description | Normal  (per TON of PTA) |
| Power | **25.56 KWh** |
| Superheated HP Steam | **0.69 Ton** |
| Demineralised Water | **1.87 m3** |
| Cooling water Circulation Flow | **330 m3** |
| Industrial Water | **0.25 m3** |
| Nitrogen | **1.5 Nm3** |

**OXIDATION SECTION:**

1. **GENERAL PROCESS:**

The Oxidation Plant is designed for continuous operation and consists of six main sections: Process Air Compression and Offgas Treatment, Reaction, CTA Crystallisation, Separation & Drying, Catalyst Recovery and Solvent Recovery.

In the Process Air Compression and Offgas Treatment Section atmospheric air is compressed and fed to the reactor. Cooled offgas from the reactor is heated and passed over a catalyst before passing through an expander, being scrubbed and discharged to atmosphere.

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.

In the CTA Crystallisation Section the reactor exit slurry is depressurised and cooled in a series of three crystallizing vessels. The precipitated terephthalic acid product is recovered in the Separation and Drying Section by continuous filtration incorporating a solvent wash stage. A proportion of the mother liquor generated in this stage is purged to Catalyst Recovery. Residual solvent acetic acid in the filter cake is removed in a continuous drier. The resultant product is conveyed to intermediate storage on the Purification Plant.

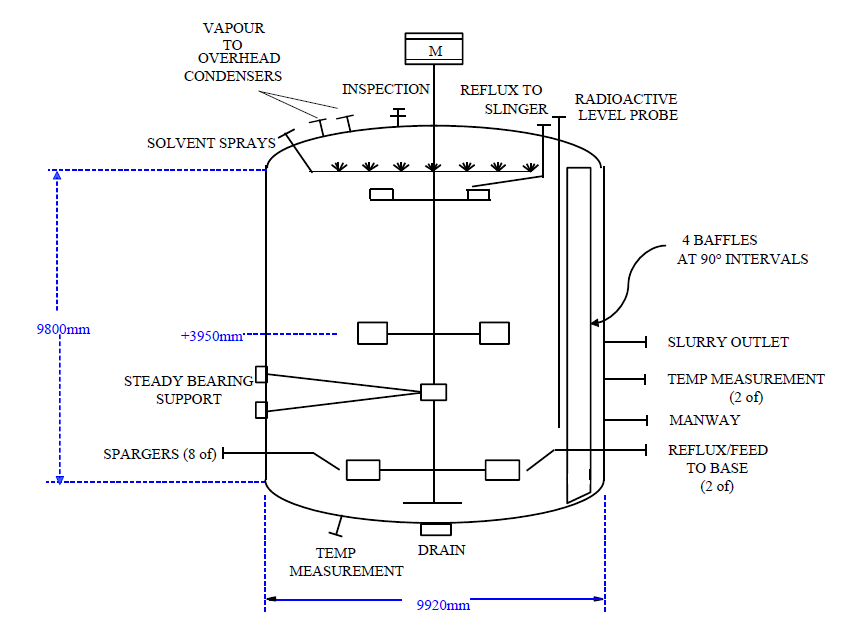
In the Catalyst Recovery Section, catalyst is recovered from the Oxidation Plant mother liquor purge. The composition of recovered catalyst is adjusted to produce a catalyst solution for feed to the Reaction Section.

In the Solvent Recovery Section, impure solvent recovered from the Reaction, Catalyst Recovery and CTA Recovery 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 the water of reaction, and produces purified acetic acid suitable for re-use in the Plant. The higher-boiling by-products are quench cooled in water and the resulting slurry disposed of in a Thermal Oxidizer or cooled and solidified in a Residues Flaker for subsequent processing OSBL.

1. **EQUIPMENT DESCRIPTION:**
   1. **OXIDATION REACTOR:**

The Oxidation Reactor is a vertical, agitated pressure vessel constructed from titanium-clad carbon steel. It has an internal diameter of 9920 mm and a tan-to-tan height of 9800 mm, providing a total volume of approximately 1013 m³. The vessel has an elliptical head and base and contains four equi-spaced baffles which extend from the bottom dished end to the top tangent line. The Reactor has a design pressure of 20.9 barg and a design temperature of 281°C. All vessel internals are **titanium**.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Design Conditions | | Operating Conditions | | Dimensions | |
| Pressure  (Barg) | Temperature  ( oC ) | Pressure  (Barg) | Temperature  ( oC ) | Diameter  (mm) | Height  (mm) |
| 20.9 | **281** | **15.3** | **197** | **9920** | **9800** |



Air is supplied to the Reactor through eight sparger pipes. These are located at 45° intervals near the base of the Reactor with the internal pipe outlets at the same elevation as the centreline of the curved radial blade impeller.

Each air line is equipped with a velocity averaging Pitot tube (“annubar”) flowmeter, a flow control valve, and a tight shut-off block valve. The line changes specification from stainless steel to titanium immediately downstream of the block valve. One of the spargers is provided with a bypass around its associated main flow control valve for start-up purposes. The bypass is equipped with its own flowmeter and flow control valve.

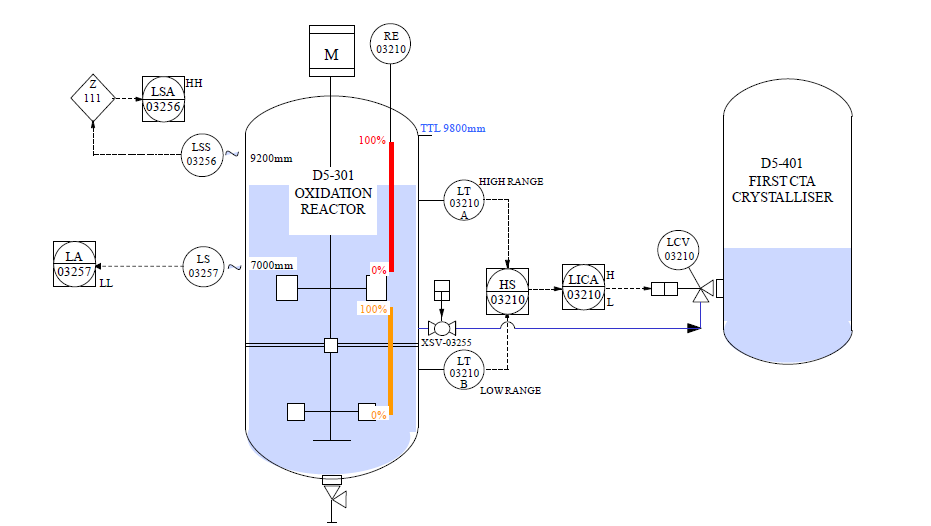
The Reactor is fitted with internal sprays in the head space. This serves three purposes:-

* Warming of vessel walls during start-up. Heated solvent or Mother Liquor is fed through the sprays from the Start-up Heater, E5-313.
* Cooling down of the vessel walls during shutdown. Solvent or Mother Liquor can be fed to the sprays via the Start-up Heater and the temperature of the solvent/Mother Liquor is reduced in a controlled manner.
* Cleaning of vessel walls during washout. Caustic solution (5% NaOH, 80°C) can be used to wash down the vessel and neutralize any remaining acetic acid vapour prior to vessel entry.

During normal operation a nominal flow of HP solvent is put through these sprays to prevent build-up of solids in the spray nozzles.

A Manway is provided for vessel inspection and this is located close to the vessel bottom tan line.

**Reactor Level Control:**



Level is measured using radioactivity. A set of radiation sources, RE-03210 is housed in an internal dip tube, which is sealed from the process. This radiation source can be lowered and raised within the dip tube and when in the lowered position, radiation is directed through the Reactor wall to detectors. Two fixed point detectors are located approx. 9200 mm and 7000 mm respectively from the vessel bottom tan line. Two tubular detectors cover two separate ranges at the top and bottom of the vessel rather than one continuous range over the whole height.

The normal operating level for the Reactor, with aerated slurry and with the agitator running is 8000 mm above the bottom tan line. This lies within the upper range of detection. The low measurement range is only utilised during abnormal operation such as start-up, shut-down and Reactor hold, when the Reactor contents are unaerated. In these circumstances the level falls to approx. 47% of the normal height which is outside the range of the upper detector.

The signal from LT-03210A or B is selected by HS-03210 and passes to LICA-03210 which is used to control the Reactor level by adjusting the slurry flow from the Reactor into the First CTA Crystalliser. The level control valve LCV-03210 is mounted on the First CTA Crystalliser vessel in order to minimise the distance between the valve and vessel. LICA-03210 has high and low alarms in the DCS set at 9000 mm and 7200 mm respectively above the bottom tan line. Note that these apply only to the top range of operation.

LSS-03256 provides the signal for the high level trip, LSA-03256, whilst LS-03257 provides the signal for extra low level alarm, LA-03257. These are set at 9200 mm and 7000 mm respectively above the bottom tan line.

* 1. **Crystallizers**

The purpose of the Crystallization Stage is to reduce the pressure and temperature of the Reactor products so that the TA crystals can be separated from the Mother Liquor by the Rotary Vacuum filters. The Crystallizers also provide buffer capacity between the Reaction and Product Recovery Sections.

The Product from the Reactor is let down in pressure under level control into the First CTA Crystalliser D5-401. Acetic Acid and water are flashed off and the vapour condensed by cooling in the First CTA Crystalliser Condenser E5-430. Further cooling of the vapour takes place in the First CTA Crystalliser Vent Condenser, E5-431, before being discharged into the HP Absorber D5-310.

The **First CTA Crystalliser** is a titanium clad carbon steel vessel fitted with bleed tubes or "Tell Tales" through the carbon shell to areas where the titanium sections are welded. If the welds fail then the bleed holes will pass liquid and warn of the leak before any serious damage to the carbon steel begins. The bleed holes must be kept clear of any vessel lagging and should be inspected daily.

The vessel is sized to provide adequate residence time for product quality control and to provide “buffer” capacity during plant upsets. Vessel diameter is designed to ensure minimal solids carryover in the vapour stream from the vessel. The maximum design pressure and temperature of the Crystalliser are 19.7 barg and 281 oC and it is also designed to withstand full vacuum.

The Crystalliser has diameter of 5800 mm and height of 8500 mm between upper and lower tangent lines. The vessel has an elliptical head and base and contains 4 equally spaced baffles, which extend from the bottom dished end to height 8075mm from the bottom tangent line. Vessel total capacity is 276 m3 with a normal operating volume of 168 m3, or approx. 55% of the level measurement range. All vessel internals are **Titanium.**

The offgas from the First CTA Crystalliser is analyzed continuously for oxygen and carbon dioxide downstream of the First CTA Crystalliser Vent Condenser. Three sampling conditioning systems are provided to further cool the gas and remove any volatiles to prevent contamination and flooding in the analyzers.

**For Crystallizer 1:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Design Conditions | | Operating Conditions | | Dimensions | |
| Pressure  (Barg) | Temperature  ( oC ) | Pressure  (Barg) | Temperature  ( oC ) | Diameter  (mm) | Height  (mm) |
| 19.7 | **281** | **13.8** | **190** | **5800** | **8500** |

The **Second CTA Crystalliser** is a titanium clad carbon steel vessel fitted with bleed tubes or through the carbon shell to areas where the titanium sections are welded. If the welds fail then the bleed holes will pass liquid and warn of the leak before any serious damage to the carbon steel begins. The bleed holes must be kept clear of any vessel lagging and should be inspected daily.

The slurry feed from the First CTA Crystalliser enters the Second CTA Crystalliser through the First CTA Crystalliser level control valve, which is pad mounted on the side of the Second Crystalliser. Slurry leaves the vessel and is fed to the Third CTA Crystalliser through a nozzle, located on the vessel side. Both the feed line and discharge line are provided with solvent flush, caustic flush and drain facilities.

**For Crystallizer 2:**

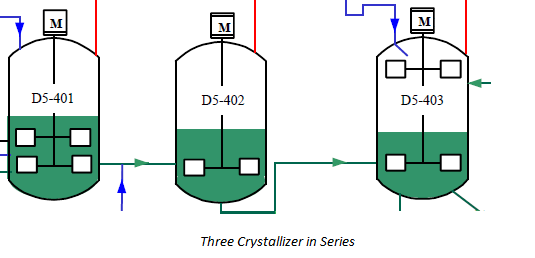
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Design Conditions | | Operating Conditions | | Dimensions | |
| Pressure  (Barg) | Temperature  ( oC ) | Pressure  (Barg) | Temperature  ( oC ) | Diameter  (mm) | Height  (mm) |
| 9.9 | **225** | **4.3** | **160** | **5800** | **8800** |

The **Third CTA Crystalliser** is constructed from duplex stainless steel and is sized to provide “buffer” capacity during plant upsets. The maximum design pressure and temperature of the Crystalliser are 4.1 barg and 170 oC. It is also designed to withstand full vacuum.

The slurry feed from the Second CTA Crystalliser enters the Third CTA Crystalliser through the Second CTA Crystalliser level control valve which is pad mounted on the side of the Third Crystalliser. Slurry leaves the vessel and is fed to the Third CTA Crystalliser Transfer Pumps, G5-407A/B through two pad mounted angle valves located on the vessel base dished end. Both the feed line and discharge/pump suction lines are provided with solvent flush, caustic flush and drain facilities.

**For Crystallizer 3:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Design Conditions | | Operating Conditions | | Dimensions | |
| Pressure  (Barg) | Temperature  ( oC ) | Pressure  (Barg) | Temperature  ( oC ) | Diameter  (mm) | Height  (mm) |
| 4.1 | **170** | **0.5** | **90** | **6000** | **8500** |



**2.3 Process Air Compressor:**

Air is drawn from the atmosphere through the Air Inlet Filter and Air Compressor Inlet Silencer to the suction side of each Process Air Compressor

The Process Air Compressor compresses up to ~ 490 t/h of ambient air to a pressure of up to 18.3 bara. The Compressor has five stages of compression with intercooling between the first four stages. During start up, air is discharged to atmosphere via the Blow-Off Silencer and during normal operation air is supplied to the Oxidation Reactor and First CTA Crystalliser via a common delivery line via the Air Compressor Discharge Silencer. The Oxidation Reactor can operate at pressures up to 16.25 barg. A much smaller air flow is supplied to the First CTA Crystalliser for the secondary oxidation process carried out in this vessel.

The degree of turndown of the Process Air Compressor is limited (70 - 80%) and for operation of the Oxidation Reactor at rates of 50% flowsheet or less, excess air from the delivery of the Compressor is sent to the Offgas Expander, via the air bypass route to the Catalytic Combustor, so that energy recovery can take place.

The power to drive the Compressor is provided by the Steam Turbine, which recovers energy by condensing excess plant steam and imported steam, and by the Offgas Expander which recovers energy from the Oxidation Reactor Offgas when the Reactor is on line.

The motor/generator package is used to start-up the machine and then exports excess power produced by the Steam Turbine and Offgas Expander at high plant rates.

Compressor C5-113 is a five-stage multi-shaft centrifugal compressor with three intercoolers, E5-116, E5- 117 and E5-118, in between the stages. E5-116 is the 1st stage intercooler between 1st and the 2ndstage. E5-117 is the 2nd stage intercooler between 2nd and the 3rd stage. E5-118 is the 3rd stage intercooler between the 3rd and the 4th stage. E5-118 is provided with a TCV in the bypass for temperature control. Intercoolers are provided for increasing the compressor Efficiency.

The normal rated flow through C5-113 is 379.23 m3/hr. (corresponding mass flow is 490 TPH). The flow to the compressor is controlled by the Inlet Guide Vane (IGV) opening. The nominal inlet and discharge (5th stage discharge) rated Pressure are 0.99 bara and 18.3 bara. The Inlet and Outlet (5th stage) temperatures are 45 oC (max) and 153 oC.

The Process Air Compressor is driven by an electric motor (which can also act as a generator), Steam Turbine and an Expander. The motor will act as the Drive for the compressor at the start-up when there is no steam and Offgas generation from the process respectively. Once the plant is in operation, there is steam and Process Offgas generation to run the Turbine and Expander and hence the Compressor will then be driven by the Steam Turbine and Expander. Also, at full capacity, there is excess generation of Power and the motor will act as a generator.

|  |  |  |  |
| --- | --- | --- | --- |
| Inlet Conditions | | Discharge Conditions | |
| Pressure  (Barg) | Temperature  ( oC ) | Pressure  (Barg) | Temperature  ( oC ) |
| 0.99 | **33** | **18.3** | **153** |

**2.4 Rotary Vacuum Filter:**

The CTA Rotary Vacuum Filters (ROVACs) separate the slurry fed from the Filter Feed Drum into a cake containing less than 15% w/w moisture, and Mother Liquor containing less than 1% w/w solids.

A partial vacuum is applied to the inside of a hollow rotating drum. Slurry is picked up by the drum and the Mother Liquor passes through the filtration cloth to the inside of the drum whilst the solids remain on the outer surface of the cloth forming the cake. The cake, still on the cloth, is washed with fresh solvent as the drum rotates and is then dried with gas drawn through the cake. The cake is blown off the cloth and transferred to the CTA Drier M5-423 by a series of screw conveyors. The vapour and liquid from the inside of the filter drum discharge to the CTA Mother Liquor Separator, F5-411A/B/C. The liquor passes to the Mother Liquor Drum, F5-506, and to Catalyst Recovery on level control. The vapour separates from the liquid and passes first to the CTA Vacuum Vapour Condenser E5-415A/B/C and then to the CTA Vacuum Pump G5-416A/B/C.

Three complete ROVAC systems are installed. All will normally operate together in order to improve quality and to increase operating flexibility. The systems are independent except for the CTA Vacuum Pump Knockout Drum F5-417 and the seal fluid system.

The Rotary Vacuum Filters M5-410A/B/C consist of a cylindrical, perforated filtration drum covered with compartmented filter media rotating on a horizontal axis and housed in a vapour tight casing. The machine is 2205 duplex stainless steel throughout, with the discharge chute having a polished surface. The design pressure of the casing is +0.3 and FoL /-0.3 barg and the design temperature is 125°C. Drum is designed for a higher vacuum (0.1 bara) as it is connected to the vacuum creation system.

Each ROVA filter has 60% of plant name plate capacity (84 TPH of dry PTA equivalent).

Filter medium is a porous cloth made of PEEK (Poly Ether Ether Ketone) with 155 micron pore size, monofilament and twill weaved having air permeability of 260 CFM/ft2 arranged in a single layer They come in two pieces and are caulked at the two edges and center of drum surface.

Slurry is pumped from the CTA Filter Feed Drum into a trough having a pool of slurry in which the filtration drum rotates in a partially submerged state. Degree of submergence of the drum in slurry pool can be varied between 11% and 18% of drum surface area and is used as one of the key parameter to adjust the throughput and ROVAC filter performance. Thus adjustment is done by varying the height of slurry pool which is done by varying the height of overflow weir. Speed of the drum can also be varied which is another key parameter to adjust the throughput and ROVAC filter performance. Speed can be varied using a VSD between 2-20 rpm. The feed compartment is inverted pyramid shaped to eliminate the need for auxiliary mechanical agitation devices. Solids are kept in suspension continuously by the upward flow of the feed to the filter. This gentle method of agitation keeps particle degradation to a minimum. The trough is 4.8 m long and for proper functioning of the filter it is important that slurry is distributed uniformly in the slurry pool along the length of the trough with minimum turbulence on the slurry pool surface. To ensure this, following are done – (a) multiple feed entry points, 3 entry points in this case, each with a pyramid structure (b) perforated distributor plate within each feed pyramid.

Five spray bars each with 26 spray nozzles (spray pattern: 90° full cone) are provided across the length of the ROVAC filter for cake washing after the first cake drying step (discussed below). The sprays are so laid out in an offset manner that the cake is washed along the entire length of the drum in the washing zone. Proper washing pattern and wash flow are very important for achieving the final quality of TA that comes out of Oxidation section of the plant.

 ***CTA Rotary Vacuum Filter***

**2.5 CTA/PTA Drier:**

The CTA Drier M5-423 dries wet CTA cake from the Rotary Vacuum Filters M5-410A/B/C reducing the solvent moisture content from 15% w/w to less than 0.1% w/w on a wet basis.

The wet cake from the Rotary Vacuum Filters is typically 70-90°C and the Drier exit CTA product is typically between 140-150 °C.

The CTA Drier is a rotary steam tube drier. It has a revolving cylindrical 2205 duplex stainless steel shell provided with four rows of 2205 duplex stainless steel steam tubes which extend along the length of the CTA Drier, designed for indirect heat-drying, using let down MP steam, normally at ~8.3 barg and 177°C.

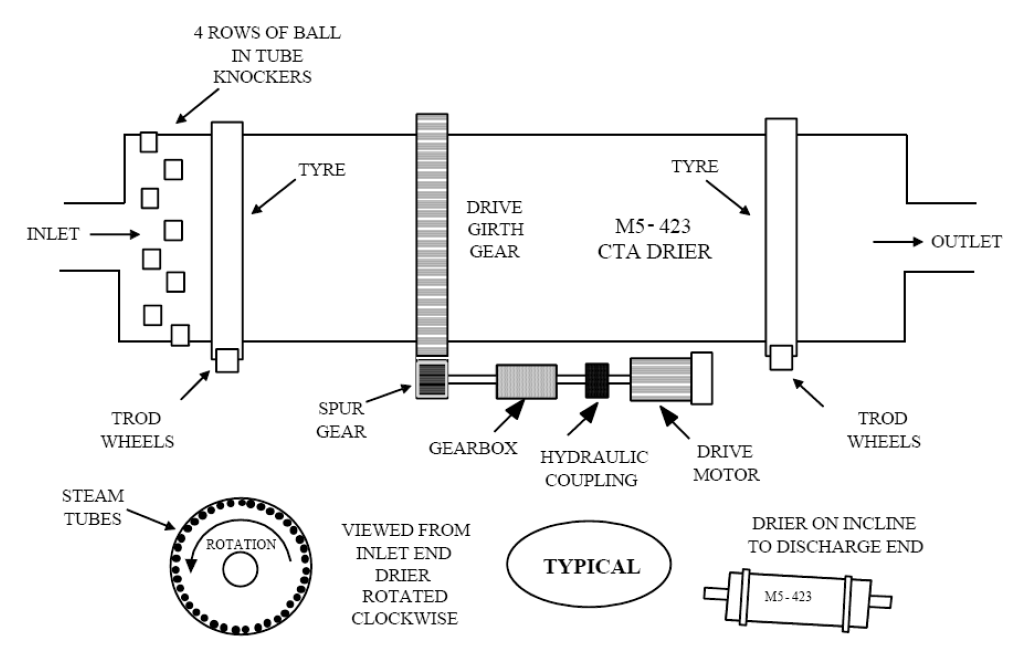
The design pressure of the shell is +0.3barg/-0.3 barg. The tubes have a design pressure of 15 barg/FV. The design temperature of the shell is 200°C and for the tubes is 230°C.

The CTA Drier has four rows of ball-in-tube knockers to reduce solid cake build-up at the inlet end. Ball knockers are “L” shaped pipes with steel balls inside. There are 4 rows of knockers with 12 knockers per row.

The CTA Drier is inclined toward the exit to help powder flow (inclination 3/100).

The temperature of the CTA powder exit the CTA Drier is important to ensure that drying is complete. The boiling point of Acetic Acid is 118 °C at atmospheric pressure and the powder must be heated above this to ensure adequate drying. Operational experience has shown that higher temperatures reduce fouling and build up on the CTA Drier tubes. The Drier should therefore be operated at a temperature of approx. 150°C. A combination of operating temperature and residence time provides the required drying. Residence time for a given plant throughput and inlet cake wetness is fixed as it is determined by the rotational speed, inclination of dryer which are both fixed. So operating temperature is the only variable that can be used to achieve the required drying performance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Design Conditions | | Operating Conditions | | Dimensions | |
| Pressure  (Barg) | Temperature  ( oC ) | Pressure  (Barg) | Temperature  ( oC ) | Diameter  (mm) | Height  (mm) |
| 0.3 | **200** | **0.01** | **150** | **4200** | **31000** |



***Typical CTA Drier Arrangement***

**2.6 Solvent Dehydration Column (DH Column):**

The Solvent Dehydration Column is designed to separate water from a number of water-rich liquid and vapor streams from the Oxidation plant, and produce acetic acid containing 5.0 ±0.5% w/w water from the base for redistribution as DH Solvent in addition to water containing 0.1% w/w acetic acid from the top of the Column. The Column is an azeotropic unit using normal propyl acetate (nPA) as an entrainer to reduce the energy required for the acetic acid/water separation by breaking the acetic acid/water azeotrope at high water concentration. The heat input to the Column is provided by the DH Column Reboiler which is a thermosiphon-type unit using LP steam.

DH Column D5-601 is a packed fractionating column constructed from 2205 Duplex Stainless Steel. It has an internal diameter of 6500mm (bottom) / 6900mm (top) and a tan/tan height of 38000mm. The column is separated into three sections: Zone A, Zone B and Zone C.

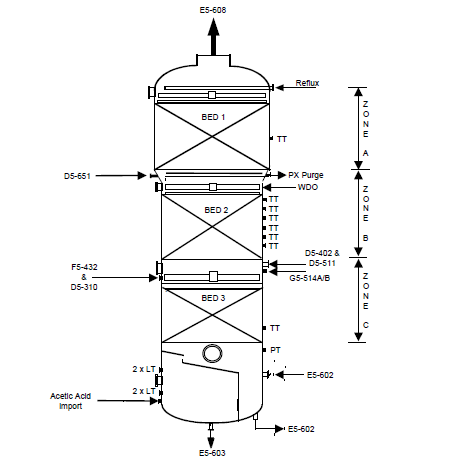
The top section, Zone A, is packed with one bed (Bed 1) of structured packing (INTALOX 2T or equivalent) constructed from 316L or 2205 Duplex stainless steel.

The middle section, Zone B is packed with one bed (Bed 2) of structured packing (INTALOX 2T or equivalent) constructed from 2205 Duplex stainless steel.

The bottom section, Zone C is packed with one bed (Bed 3) of structured packing (INTALOX 2T or equivalent) constructed from 2205 Duplex stainless steel.

An internal baffle is provided in the column bottom sump to partition the column base. Recovered acetic acid is collected first in the reboilers liquid feed sump below bed 3, this then overflows through the baffle weir to the second larger partition for storage, make up and supply of DH Solvent. An access panel is fitted on the partition baffle for inspection purposes and a drain hole is also provided at the baffle low point to ensure complete draining during shutdowns.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Design Pressure | | Design Temperature | | Dimensions | |
| Upper Section  (Barg) | Lower Section  (Barg) | Upper Section  (oC) | Lower Section  (oC) | Diameter  (mm) | Height  (mm) |
| 3.5 | **5.38** | **150** | **225** | **6500** | **38000** |



***DH COLUMN***

**2.7 HEAT EXCHANGERS:**

**2.7.1 SHELL AND TUBE TYPE:**

Shell and Tube Heat Exchangers are one of the most popular types of exchanger due to the flexibility the designer has to allow for a wide range of pressures and temperatures.

A shell and tube exchanger consists of a number of tubes mounted inside a cylindrical shell. Figure illustrates a typical unit that may be found in a petrochemical plant. Two fluids can exchange heat, one fluid flows over the outside of the tubes while the second fluid flows through the tubes. The fluids can be single or two phase and can flow in a parallel or a cross/counter flow arrangement.

The shell and tube exchanger consists of four major parts:

* Front Header—this is where the fluid enters the tubeside of the exchanger. It is sometimes referred to as the Stationary Header.
* Rear Header—this is where the tubeside fluid leaves the exchanger or where it is returned to the front header in exchangers with multiple tubeside passes.
* Tube bundle—this comprises of the tubes, *tube sheets*, *baffles* and tie rods etc. to hold the bundle together.
* Shell—this contains the *tube bundle*.

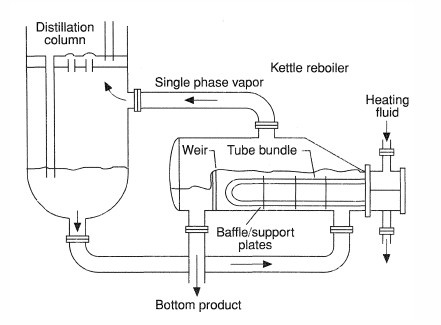
**2.7.2 REBOILER**

**Reboilers** are heat exchangers typically used to provide heat to the bottom of industrial distillation columns. They boil the liquid from the bottom of a distillation column to generate vapors which are returned to the column to drive the distillation separation. The heat supplied to the column by the reboiler at the bottom of the column is removed by the condenser at the top of the column.

Proper reboiler operation is vital to effective distillation. In a typical classical distillation column, the entire vapor driving the separation comes from the reboiler. The reboiler receives a liquid stream from the column bottom and may partially or completely vaporize that stream. Steam usually provides the heat required for the vaporization.

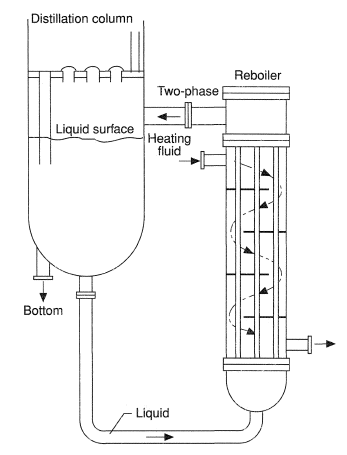
**Kettle Reboilers**

The layout of the kettle reboiler is illustrated schematically in figure below. Liquid flows from the column into a shell in which there is a horizontal tube bundle, boiling taking place from the outside this bundle. The vapor passes back to the column as shown. Kettle reboilers are widely used in the petroleum and chemical industries; their main problems are that of ensuring proper disentrainment of liquid from the outgoing vapor and the problem of the collection of scale and other solid materials in the tube bundle region over long periods of operation.



**Vertical Thermosyphon Reboiler**

This type is illustrated in figure below. The liquid passes from the bottom of the tower into the reboiler, with the evaporation taking place inside the tubes. The two-phase mixture is discharged back into the tower, where the liquid settles back to the liquid pool and the vapor passes up the tower as shown. The heating fluid (typically condensing steam) is on the outside of the tubes. The *vertical thermosyphon* reboiler is less susceptible to fouling problems and in general has higher heat transfer coefficients than does the kettle reboiler. However, additional height is required in order to mount the reboiler.



**2.8 PUMPS, COMPRESSORS AND EVAPORATOR**

**2.8.1 PUMPS:**

A **pump** is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action

**CENTRIFUGAL PUMPS:**

A centrifugal pump converts input power to kinetic energy by accelerating liquid in a revolving device - an impeller.

The most common is the volute pump - where fluid enters the pump through the eye of the impeller which rotates at high speed. The fluid accelerates radially outward from the pump chasing and a vacuum is created at the impellers eye that continuously draws more fluid into the pump.

Common uses include water, sewage, petroleum and petrochemical pumping. The reverse function of the centrifugal pump is a water turbine converting potential energy of water pressure into mechanical rotational energy.

**RECIPROCATING PUMPS:**

Reciprocating pump is a positive displacement pump. The given pump is single acting single cylinder pump with air vessel. It can be used for less discharge at higher heads. Priming is not required because it is a positive displacement pump. Reciprocating pumps are used in pumping water in hilly areas. Reciprocating pumps has lower efficiency compared to centrifugal pumps.

**2.8.2 COMPRESSORS:**

An **air compressor** is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). Compressor C5-113 is a five-stage multi-shaft centrifugal compressor with three intercoolers, E5-116, E5-117 and E5-118, in between the stages. E5-116 is the 1st stage intercooler between 1st and the 2ndstage. E5-117 is the 2nd stage intercooler between 2nd and the 3rd stage. E5-118 is the 3rd stage intercooler between the 3rd and the 4th stage. E5-118 is provided with a TCV in the bypass for temperature control. Intercoolers are provided for increasing the compressor Efficiency.

**2.8.3 EVAPORATORS:**

The Residue Evaporator is a wiped film type unit. It is in principle a vertical, externally-heated tube over whose inner surface a rotor spreads the product that is to be evaporated as a thin film.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **MASS AND ENTHALPY BALANCES** | | | | | | | | | | |
|  |  | |  | |  | |  | |  | |
|  |  | |  | |  | |  | |  | |
| **First Crystallizer** | | | | | | | | | | |
|  |  | |  | |  | |  | |  | |
| **INLET** | | | | | **OUTLET** | | | | | |
| **Stream no.** | **Mass** | | **Enthalpy** | | **Stream no.** | | **Mass** | | **Enthalpy** | |
| 3 | 12148.5 | | 19 | | 47 | | 486069 | | -957560 | |
| 8 | 464625 | | -904490 | | 46 | | 53704.9 | | -94169 | |
| 118 | 37071.4 | | -85798 | | Total | | **539773.9** | | **-1051729** | |
| 98 | 17928.6 | | 17928.6 | |  | |  | |  | |
| 119 | 4000 | | -9258 | |  | |  | |  | |
| 120 | 4000 | | -9258 | |  | |  | |  | |
| Total | **539773.5** | | **-990856.4** | |  | |  | |  | |
| Error | **-0.4** | | **60872.6** | |  | |  | |  | |
|  |  | |  | |  | |  | |  | |
| **HP Absorber** | | | | | | | | | | |
|  |  | |  | |  | |  | |  | |
| **INLET** | | | | | **OUTLET** | | | | | |
| **Stream no.** | **Mass** | | **Enthalpy** | | **Stream no.** | | **Mass** | | **Enthalpy** | |
| 49 | 12137.2 | | -1846 | | 20 | | 365111 | | -24789 | |
| 17b | 362309 | | -36457 | | 21 | | 141460 | | -397730 | |
| 19 | 130850 | | -363720 | | 22a | | 86425.2 | | -197820 | |
| 26 | 6000 | | -26356 | | Total | | **592996.2** | | **-620339** | |
| 114b | 81699.4 | | -191980 | |  | |  | |  | |
| Total | **592995.6** | | **-620359** | |  | |  | |  | |
| Error | **-0.6** | | **-20** | |  | |  | |  | |
|  |  | |  | |  | |  | |  | |
| **Dehydration Column** | | | | | | | | | | |
|  |  | |  | |  | |  | |  | |
| **INLET** | | | | | **OUTLET** | | | | | |
| **Stream no.** | **Mass** | | **Enthalpy** | | **Stream no.** | | **Mass** | | **Enthalpy** | |
| 53 | 41567.7 | | -102140 | | 122 | | 6100 | | -13302 | |
| 54 | 54987.1 | | -119910 | | 125-122-139+124 | | 6000.4 | | -5456.8 | |
| 21 | 141460 | | -9258 | | 108 | | 487226 | | -795520 | |
| 99 | 60762 | | -140350 | | 109a | | 231359 | | -531080 | |
| 107 | 4461.6 | | -10054 | | Total | | **730685.4** | | **-1345358.8** | |
| 124 | 5881.8 | | -8387 | |  | |  | |  | |
| 128 | 421614 | | -635190 | |  | |  | |  | |
| Total | **730734.2** | | **-1025289** | |  | |  | |  | |
| Error | **48.8** | | **320069.8** | |  | |  | |  | |
| **Mother Liqour Drum** | | | | | | | | | | |
|  | |  | |  | |  | |  | |  |
| **INLET** | | | | | | **OUTLET** | | | | |
| **Stream no.** | | **Mass** | | **Enthalpy** | | **Stream no.** | | **Mass** | | **Enthalpy** |
| 155 | | 15603.9 | | -36724 | | x | | 0 | |  |
| 80 | | 239726 | | -551980 | |  | |  | |  |
| 78 | | 13252 | | -32181 | |  | |  | |  |
| 90 | | 11947.6 | | -26581 | |  | |  | |  |
| 125 | | 8012.6 | | -20651 | |  | |  | |  |
| 95+x+133+159-88 | | -288554.1 | | 667963 | |  | |  | |  |
| Error | | **-12** | | **-154** | |  | |  | |  |
|  | |  | |  | |  | |  | |  |
| **Solvent Stripper** | | | | | | | | | | |
|  | |  | |  | |  | |  | |  |
| **INLET** | | | | | | **OUTLET** | | | | |
| **Stream no.** | | **Mass** | | **Enthalpy** | | **Stream no.** | | **Mass** | | **Enthalpy** |
| 110 | | 10000 | | -23144 | | 99 | | 60762 | | -140350 |
| 154 | | 46960 | | -111350 | | 100 | | 240000 | | -452260 |
| 63 | | 566.1 | | -2445 | | 101 | | 963116 | | -1801200 |
| 96 | | 4485.4 | | -18598 | | 102 | | 4030.4 | | -7594 |
| 100 | | 240000 | | -452260 | | Total | | **1267908.4** | | **-2401404** |
| 101 | | 963116 | | -1801200 | |  | |  | |  |
| 103 | | 2693.1 | | -5472 | |  | |  | |  |
| 106 | | 87.8 | | -317 | |  | |  | |  |
| Total | | **1267908.4** | | **-2414786** | |  | |  | |  |
| Error | | **0** | | **-13382** | |  | |  | |  |
|  | |  | |  | |  | |  | |  |
| **Offgas Scrubber** | | | | | | | | | | |
|  | |  | |  | |  | |  | |  |
| **INLET** | | | | | | **OUTLET** | | | | |
| **Stream no.** | | **Mass** | | **Enthalpy** | | **Stream no.** | | **Mass** | | **Enthalpy** |
| 44 | | 19139.9 | |  | | 38 | | 334877 | |  |
| 37 + 94 | | 4617.2 | |  | | 39 | | 193096 | |  |
| 36 | | 314522 | |  | | Total | | **527973** | |  |
| 143 | | 4568.3 | |  | |  | |  | |  |
| 43 | | 179687 | |  | |  | |  | |  |
| x | | 5500 | |  | |  | |  | |  |
| Total | | **528034.4** | |  | |  | |  | |  |
| Error | | **61.4** | |  | |  | |  | |  |

**Effluent Treatment Plant**

The Effluent Treatment Plant has been designed to handle liquid and slurry waste streams from the PTA plant. A drainage philosophy has been developed to collect various liquid effluent streams from the site and these liquid streams are fed into the ETP at one of three entry points;

* Effluent from the Buffer Tanks, plus PET plant effluent and laboratory waste is fed into the effluent pre-treatment section,
* Raw sewage is expected to be fed to the aerobic treatment section,
* Clean water discharges (e.g. cooling tower and demin water plant blowdowns) are fed to the Treated Effluent Tank.

The ETP produces a treated liquid effluent stream, a solid effluent stream and a biogas stream. The liquid stream passes to the site liquid outfall, the solid stream is discharged for offsite disposal, and the biogas is collected and compressed for use as a fuel supplement. As an alternative, the biogas may be directed to flare stack for disposal.

The Effluent Treatment Plant is expected to comprise the following elements:

1. Effluent pre-treatment, consisting of pH control, nutrient addition and effluent temperature control.

2. Anaerobic treatment, with biogas collection and compression.

3. Aerobic treatment combined with tertiary treatment (to remove suspended solids) in a membrane bioreactor

4. Sludge dewatering and drying system.

5. Treated Effluent Tank.

6. Reverse osmosis unit.

1. 7. Filtration unit for ‘clean’ process feeds to the RO unit (e.g. cooling water blowdown).

8. Pre-treatment unit for raw sewage.

9. Final Effluent Pit.

The Effluent Treatment Plant is designed to meet the following emission levels for waste water prior to discharge:

* pH 5.5 to 9
* Biological Oxygen Demand (BOD5) less than 60 mg/l
* Suspended solids less than 100 mg/l
* Mineral Oil less than 20 mg/litre
* Temperature less than 45°C
* Manganese less than 5.0 mg/l (\*)
* Cobalt less than 3.0 mg/l (\*)

(\*) *Depending on the economics of the operation, these limits may both be reduced to 2.0 mg/l*.

Several recycle streams are included in the Effluent Treatment Plant design for returning out of specification material for further treatment. These are expected to be:

* Recycle from Treated Effluent Tank to Buffer Tanks,
* Recycle from Anaerobic Feed Tanks to Buffer Tanks, and
* Recycle from Anaerobic Collection Pit to Buffer Tanks

Under certain conditions (e.g. plant overhaul) there will be little or no flow entering the Buffer Tanks. If this condition is expected to persist for a significant period of time the ETP rate will need to be reduced in order to maintain adequate operation of the anaerobic system until main flow to the Buffer Tanks can be reestablished. It is expected that the anaerobic system will be capable of turning down to 10% of normal design rate for a minimum of a fortnight and be capable of prompt resumption of higher rate operation.