A Summer Internship Project Report On

" Different Metallurgy Being Used In Petrochemical Industries "

for

Reliance

Industries Limited

DAHEJ MANUFACTURING DIVISION, GUJARAT

Submitted by:

AKASH NASKAR

Summer Internship, 2024

Under the guidance of:

Mr. Bhavesh Kumar Patel

For the partial fulfilment of the requirement for the award of the degree

of

BACHELOR OF TECHNOLOGY

in

METALLURGICAL AND MATERIALS ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, DURGAPUR

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BONAFIDE CERTIFICATE

This is to certify that the project report entitled **“Different Metallurgy Being Used in Petrochemical Industries”**, being submitted by **"Akash Naskar”** of NIT Durgapur who carried out the internship in the following industry:

SL. NO.	Company Details	Duration		No. of Days
		From	To	
1.	RELIANCE INDUSTRIES LIMITED, DMD, CES INSPECTION	21-05-2024	13-07-2024	54
			TOTAL	54 Days

Akash Naskar has undergone Internship for 54 days under the guidance of

Mr. Bhavesh Kumar Patel.

MR BHAVESH KUMAR PATEL

DEPUTY GENERAL MANAGER

CENTRAL ENGINEERING SERVICES

DAHEJ MANUFACTURING DIVISION

ACKNOWLEDGEMENT

I extend my heartfelt gratitude to all the distinguished individuals who played a pivotal role in the successful completion of my internship at Reliance Industries Limited.

First and foremost, I am deeply grateful to Reliance Industries Limited for providing me with the invaluable opportunity to undertake this internship. The enriching environment and support provided by the organization significantly broadened my understanding of industrial challenges and solutions.

I owe a special debt of gratitude to my mentor, **Mr. Bhavesh Kumar Patel**, Senior Manager CES Inspection Division. His unwavering support and guidance were instrumental throughout the entire period. **Mr. Deepak Roheda**'s dedication to mentoring and his valuable insightful advice were crucial to my learning and development.

My sincere appreciation goes to **Mr. Harish Krishna Moorthy**, my buddy, whose remarkable patience and exceptional guidance were a constant source of encouragement. His assistance and provision of essential resources were invaluable to the successful completion of my project.

I am also deeply indebted to all members of the CES-Inspection team. Their generous cooperation and willingness to share their expertise were indispensable to my training and the eventual fruition of this project.

Special thanks are due to **Mr. Jaideepsingh Mahra, Mr. Richpal Choudhury** and **Ms. Nayanika Kumawat** for their insightful knowledge about the industry. Their willingness to share vital materials was crucial to the thorough completion of my project. Their support was particularly appreciated whenever I encountered challenges.

Furthermore, I wish to acknowledge the consistent assistance and guidance from all the HR Managers throughout this internship. Their efforts ensured a seamless and enriching experience.

Lastly, I would like to express my gratitude to the **Head of the Department** and esteemed faculty members of the **Metallurgical and Materials Engineering Department** at the **National Institute of Technology, Durgapur**. Their encouragement and support to pursue this internship have been invaluable.

(AKASH NASKAR)

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ABSTRACT

This project investigates the diverse metallurgical materials utilized in the Dahej Manufacturing Division of Reliance Industries Limited, focusing on their application in petrochemical processes. The study examines various metals and alloys such as stainless steel, carbon steel, nickel-based alloys, and titanium, which are essential for components like reactors, heat exchangers, and piping systems. These materials are analyzed for their ability to withstand extreme operational conditions, including high temperatures, pressures, and corrosive environments. The study encompasses a thorough analysis of types of materials, their properties and their uses across different plants within the facility.

The methodology encompasses a comprehensive literature review, on-site inspection to assess the properties and performance of these materials. By evaluating resistance to corrosion, structural integrity, and overall efficiency, the project aims to identify the strengths and weaknesses of different metallurgical choices. Case studies of specific instances where particular materials led to significant performance improvements or failures are included to provide practical insights.

The findings from this project are expected to offer valuable recommendations for best practices in material selection, enhancing operational efficiency, reducing downtime, and improving safety in petrochemical processes. Ultimately, the project contributes to the advancement of metallurgical applications, ensuring the reliability and sustainability of petrochemical operations at the Dahej Manufacturing Division.

LIST OF ABBREVIATIONS

RIL- Reliance Industries Limited

DMD- Dahej Manufacturing Division

CS- Carbon Steel

SS- Stainless Steel

AS- Alloy Steel

ASS- Austenitic Stainless Steel

DSS- Duplex Stainless Steel

LAS- Low Alloy Steel

CI- Cast Iron

LTCS- Low Temperature Carbon Steel

CSRL- Carbon Steel Rubber Lined

FRP- Fibre-reinforced plastic

PP FRP- Polypropylene Fibreglass Reinforced Plastic

PVC- Poly Vinyl Chloride

GCU- Gas Cracker Unit

VCM- Vinyl Chloride Monomer

EDC- Ethylene dichloride

CA- Chlor-Alkali

PET- Polyethylene Terephthalate

PTA- Purified Terephthalic Acid

CCPP- Coal Based Captive Power Plant

EO-EG- Ethylene Oxide & Ethylene Glycol

HDPE- High Density Poly Ethylene

ABOUT RELIANCE

The Reliance Group, established by Dhirubhai H. Ambani in 1966, stands as India's foremost private sector conglomerate, with ventures spanning energy, materials, retail, entertainment and digital services. The group's annual revenue surpasses US$ 118.6billion. It's flagship company, Reliance Industries Limited, is a Fortune Global 500 enterprise and largest private sector entity in India.

Reliance's remarkable growth has been driven by its strategy of backward vertical integration, starting with textiles in the late 1970s. This approach has seen the company extend its reach into polyester, fiber intermediates, plastics, petrochemicals, petroleum refining and oil and gas exploration and production, achieving full integration along the materials and energy value chain.

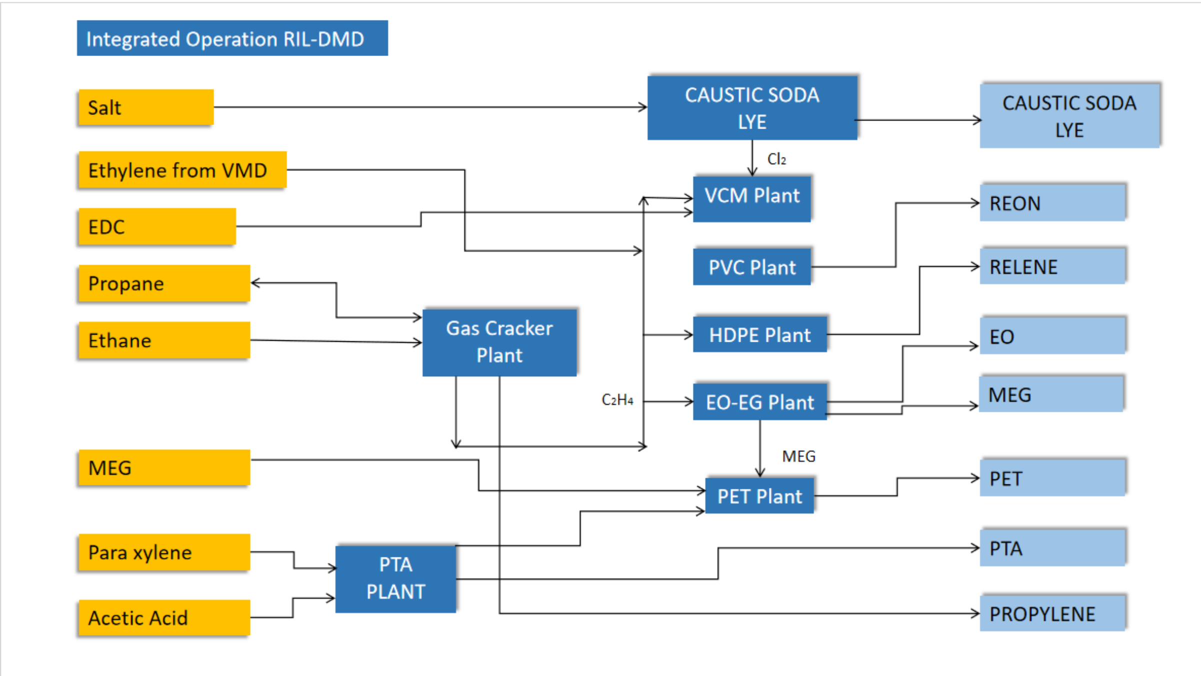
The Group's extensive portfolio includes exploration and production of oil and gas, petroleum refining and marketing, petrochemicals (such as polyester, fiber intermediates, plastics and chemicals), textiles, retail, infotel and special economic zones.

Reliance commands global leadership in its sectors, being world's largest producer of polyester yarn and fiber, and ranking among the top five to ten producers globally in major petrochemical products. Key Group companies include Reliance Industries Limited and its subsidiaries, as well as Reliance Industries Infrastructure Limited.

Reliance Industries Limited operates state-of-the-art manufacturing facilities across India, located in Allahabad, Barabanki, Dahej, Hazira, Hoshiarpur, Jamnagar, Nagothane, Nagpur, Naroda, Patalganga, Silvassa and Vadodara. In recent years, the company has expanded into green energy initiatives, aiming to lead in renewable energy production and sustainable practices.

Dahej Manufacturing Division

The Dahej Manufacturing Division, located near Bharuch, Gujarat, is pivotal component of Reliance Industries' petrochemical division and plays a vital role in the company's comprehensive operations. This extensive petrochemical manufacturing complex consists of several specialized units that produce a broad spectrum of chemicals and products. Strategically positioned near the Gulf of Khambat, the plant enjoys optimal access to essential raw materials and efficient transportation routes. The facility includes an ethane/propane recovery unit, a gas cracker, a caustic chlorine plant, and four downstream plants dedicated to the production of polymers and fiber intermediates.



The Dahej Manufacturing Division (DMD) is India's only "**Salt to PVC**" integrated complex, spanning nearly 800 hectares. The unique feature of this complex is that, it is located in Petroleum, Chemicals, and Petrochemicals Project Investment Region (PCPPIR). Strategic location in Delhi-Mumbai Industrial Corridor (DMIC). It is located on a sea shoreline and is 60,000 DWT. The complex houses to the countries best Polyvinyl Chloride manufacturing facility. Captive Caustic Soda Plant, Captive Power Plant and Captive Ethylene manufacturing facility back the PVC facility. The main suppliers of Raw Materials are GAIL and ONGC.

The Dahej Plant is renowned for its significant production capacity, playing a crucial role in bolstering Reliance Industries' manufacturing prowess. Equipped with state-of-the-art infrastructure, it ensures efficient and safe operations through advanced production units, storage facilities, utilities, control systems, and a robust logistic network.

The plant produces a wide range of petrochemical products including Ethylene, Propylene, Reon, Relene, Ethylene oxide, Mono Ethylene Glycol, Polyethylene Terephthalate, Purified Terephthalic acid, and other high-value derivatives. These products are integral to various industries such as packaging, textiles, automotive, and agriculture.

PLANT	LICENSOR	CAPACITY (KTPA)
Chlor-Alkali	Thyssen Krupp, Germany	287
VCM	Ineos (EVC)	315
PVC	Oxy vinyls, USA	315
GCU	Stone & Webster (TECHNIP)	594
EOEG	Scientific Design, USA	172
HDPE	Lyondell Basell	160
PTA-5	Invista, UK	1120
PTA-6	Invista, UK	1120
PET-3	Camtex (USA) and Buhler (Switzerland)	648
CCPP	Thermax	

Introduction:

Metallurgy plays a crucial role in petrochemical industries due to the harsh operating conditions and corrosive environments involved in processing, transporting, and storing petrochemicals. Here are some reasons why different metallurgies are used in these industries:

- Corrosion Resistance: Petrochemical processes often involve exposure to corrosive substances such as acids, alkalis, and saltwater. Therefore, materials with high corrosion resistance, such as stainless steels, nickel alloys, and titanium, are preferred to ensure the integrity and longevity of equipment and infrastructure.
- Temperature and Pressure: Petrochemical processes frequently operate at high temperatures and pressures. Materials must be able to withstand these extreme conditions without deforming, weakening, or failing. Alloys like Incoloy, Hastelloy, and duplex stainless steels are commonly used for their high temperature and pressure resistance.
- Compatibility: The materials used in petrochemical equipment must be compatible with the specific chemicals and hydrocarbons being processed to avoid contamination or chemical reactions that could compromise product quality or safety.
- Mechanical Properties: Petrochemical equipment often undergoes mechanical stress and fatigue from factors like vibration, thermal cycling, and fluid flow. Materials with suitable mechanical properties, including strength, toughness, and fatigue resistance, are chosen to ensure reliable performance and safety.
- Cost Effectiveness: While high-performance alloys offer excellent corrosion resistance and mechanical properties, they can be expensive. Petrochemical companies often balance performance requirements with cost considerations to optimize material selection and overall project economics.
- Environmental Factors: Petrochemical facilities may be located in environments with specific challenges, such as high humidity, saline atmospheres, or exposure to harsh weather conditions. Materials are selected to withstand these environmental factors and minimize maintenance and replacement costs.
- Regulatory Compliance: Petrochemical industries are subject to stringent safety and environmental regulations. Materials used in equipment and infrastructure must meet regulatory standards for performance, durability, and environmental impact.

By carefully selecting the appropriate metallurgy for each application, petrochemical industries can ensure the reliability, safety, and efficiency of their operations while minimizing downtime and maintenance costs.

Material Selection Process:

The intended outcome of the material selection process is the identification of one or more materials with properties that satisfy the functional requirements of a product, such as strength or stiffness. Furthermore, it is desirable, although not mandatory, that the materials optimise performance objectives, for example the minimization of cost or environmental impact. Material selection is a multidisciplinary task which requires the interaction of numerous stakeholders, including product designers, material scientists, test engineers and end-users. Consequently, material selection problems are typically open-ended, with the preferred solution being subject to an ongoing trade-off between numerous constraints and objectives.

a) Considerations in Material Selection:

(i) Material Degradation: The first requirement is to set the design life of equipment, which is governed primarily by the extent of damage suffered by the environment. The important damage mechanisms are corrosion, oxidation, high temperature hydrogen attack and metallurgical degradation. Selection of material for resistance to different damage needs the following considerations:

- Operating conditions—Nature of environment, operating temperature and pressure.
- Type of corrosive constituents—
  (i) In presence of aqueous phase—acid, alkali, salts, etc.
  (ii) In absence of aqueous phase—H_2S, organic sulphur compounds, hydrogen, naphthenic acid, etc.
- Type of attack/damage—
  (i) Corrosion—Uniform, pitting, stress corrosion cracking, dealloying, hydrogen damage, etc.
  (ii) Metallurgical degradation— Spheroidization, sigma formation, carburization and temper embrittlement.
- Modification of environment—Corrosion control measures, e.g. neutralization, inhibitor addition, pH control, cathodic protection, cladding, coating, etc.
- Product purity—Specified limits of impurities in product.

Based on the above considerations, the first step is to identify the minimum required material for a particular service. The final selection is to be made after considering additional requirements discussed next.

(ii) Mechanical and Physical Properties: Mechanical and physical properties which need to be considered are:

- Strength—Higher the strength, lower is the thickness of material under a particular operating condition. This reduces the cost of material, cost of fabrication and in some cases the Post-Weld Heat Treatment (PWHT) requirement. On the other hand, too high a strength is not always preferred, because in certain environments cracking susceptibility increases with strength.

- Ductility/Fracture toughness—The material should be sufficiently ductile for processing and fabrication, and tough to avoid any brittle failures. This property is dependent on alloy composition, heat treatment, metallurgical degradation, etc.
- Creep property—In case of components operating at high temperatures in the creep regime, properties like creep strength and creep ductility become the dominant considerations. Higher the temperature and operating stresses, higher is the required creep resistance of material used.
- Thermal conductivity—This property is important in case of heat transfer services like heater tubes and exchangers.
- Thermal expansion/contraction—Where temperature changes are substantial or where two materials have substantially different coefficients of expansion, these properties are required to be considered in the design to avoid failures during service. Even for ambient temperatures, thermal expansion needs to be considered for long lengths of pipe.

(iii) Equipment Fabrication: In selecting any material of construction (MOC), the requirements related to design and fabrication also play an important role. The various factors are:

- Conformation to requirements of specification and codes being followed
- Good formability and adequate weldability of the material
- Post-weld heat treatment requirements
- Expertise available for shop and field welding

Type of Equipment: Type of equipment is considered for material selection primarily from the point of view of expected life, ease of replacement and safety considerations. Some important points are:

- Columns and vessels—When used at temperatures below creep range these are designed for longer life (20–30 years), which is ensured by providing
  (i) higher corrosion allowance or
  (ii) use of clad steel or
  (iii) use of more corrosion resistant alloys.
  For operation under creep range design life is normally 100,000 h.
- Piping—Pipes can be replaced with comparatively greater ease and, therefore, can be designed for an economic life using less corrosion resistant materials, considering service and risk.
- Exchanger tubes—Depending on operational conditions exchanger tubes can be attacked from both tube and shell side. Wall thickness that can be used is also limited and, therefore, economic considerations, i.e. life-cycle cost comaparison between

higher metallurgy with longer life and less corrosion resistant material having shorter life need to be made before final selection.

- Heater tubes—Conditions of operation here are more severe and the choice in many cases is for better material.
- Pumps—These are subjected to erosion/corrosion damage and, therefore, depending on service, use of corrosion resistant material may be preferred.
- Criticality—For critical equipment, generally better material is selected or a standby is provided. The decision is based on the cost.

(iv) Material Maintenance: Maintenance plays a vital role to get optimum performance from any equipment. With best of material selection, plant life will be affected if maintenance and operation are inadequate. On the other hand, with good maintenance and operation practices, an economic life can be obtained even if a less corrosion resistance material is used. Maintenance involves a multidisciplinary approach and a good maintenance practice requires the following important inputs:

(a) Mechanical inspection
(b) Preventive and predictive maintenance
(c) Regular turnaround
(d) Input of plant experience
(e) Input of expertise in various related fields
(f) Keeping abreast with the latest developments
(g) Failure and success analysis

Earlier, plants were designed considering maintenance shutdown once every year which was reflected in the popularly used word in industry as annual shut down. This approach has changed, and the present trend is to increase the period of continuous run to 2 or more years (depending on type of industry) in between shutdowns. This approach requires that no breakdown should occur during this period due to material failure. The emphasis has, therefore, shifted to specifying better material and improved corrosion control measures, better inspection and maintenance practices and close control on plant operation. As the length of run varies from industry to industry which is mainly decided by the plant management, this aspect is not always taken into consideration by the designer. In such cases, material upgradation becomes a part of plant maintenance activities.

(v) Design Philosophy: In material selection, the first step is to decide on materials having the minimum desired properties required on the basis of operating conditions, corrosion resistance, design life, criticality and product quality requirements. Once this is done, the other factors discussed earlier are considered along with economics (capital cost, interest on capital, labour cost, cost of corrosion control measures, cost of replacements, cost of inspection and maintenance, etc.) for the final material selection. Basically, three approaches to design are possible, namely:

(a) Minimum investment design, i.e. maximum maintenance or short life design.
(b) Minimum maintenance design, i.e. minimum maintenance or overdesign.
(c) Economic design, i.e. optimum cost and maintenance design.

Generally, economic design is used. In situations like offshore oil and gas production, not only the investment is high but also the cost of maintenance is many folds compared to an identical plant on shore because of constraints of space and logistics involved. The other approach is to consider life-cycle cost for optimization of final selection, especially where the reliability is of great importance.

Design And Operational Considerations: Material selection alone does not ensure that the equipment will perform well in service. Design also plays an important role. Some of the design rules to minimize chances of material damage are:

(i)In service where stress corrosion cracking is a possibility

- Specify stress relief after fabrication where permitted.
- Avoid crevices or vapour space where corrosive chemicals can get concentrated.
- Do not use material, in cold worked condition,
- Use fabrication process which would minimize additional stresses, e.g. proper welding process, minimum mismatching of parts to be joined (specially for piping), free thermal movement,
- Ensure full bore flow. Keep in view the limitations, if any, for a particular material, e.g. PWHT of stainless steel.

(ii) Vessels and tanks should be designed with provision for full drainage. The drainage point should be at the lowest point and the drain pipe flushed with the bottom.

(iii) All parts should be approachable for inspection and maintenance.

(iv) Avoid as far as possible the use of dissimilar metals having a large potential difference.

(v) Where impingement/erosion-corrosion is likely to occur,

- provide corrosion resistance or replaceable impingement plate in tanks and columns,
- use ferrules in heat exchanger tubing inlet,
- use long radius bends, 3 or 4D bends in place of normal 1.5D for root pass of welds use TIG welding to have a good full penetration weld.

(vi) Provide injection facilities to reduce corrosivity of medium by neutralization, or inhibition, e.g. for boiler condensate, overhead corrosion and acidic water.

(vii) For lined vessels, both metallic and non-metallic, ensure that before lining

- the surface is without protrusions, weld splatters and burrs,
- the edges are rounded and not sharp.

(viii) For equipment and piping subjected to thermal stresses

- allow for free movement,
- eliminate sharp corners and edges,
- provide expansion bellows,
- provide expansion loops to pipes,
- provide angle and spring supports.

(ix) Operate the plant within design parameters and use recommended start up and shutdown procedures. If parameters, such as, temperature, pressure and throughput are required to be changed, ensure to get the effect of these changes checked on corrosion and mechanical behaviour of various equipment and make necessary modifications, where necessary.

b) Steps in Material Selection: The step-by-step approach to material selection by concerned persons/groups for design of the plant will be as follows:

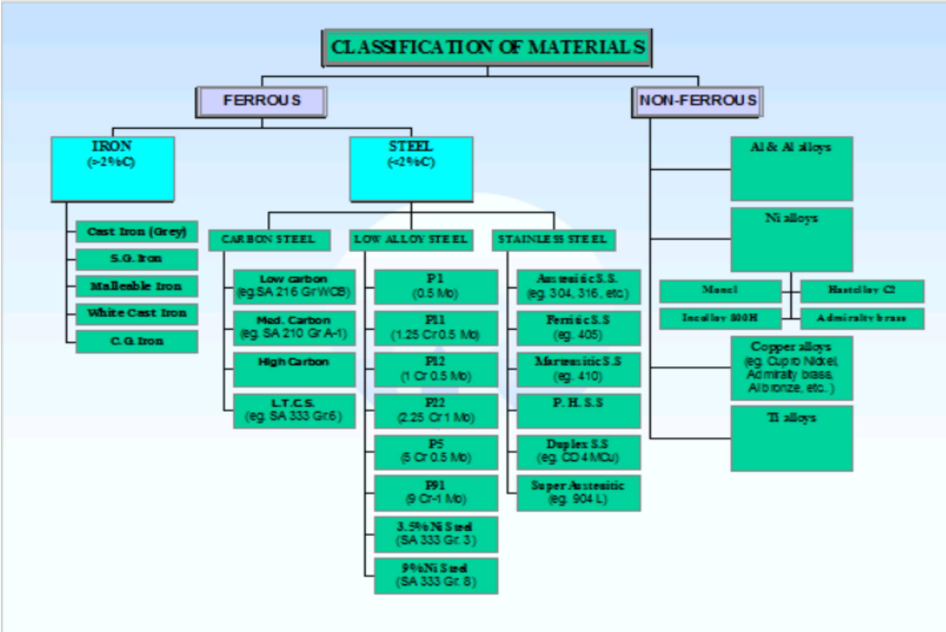
(i) Study the process flow diagram and identify temperature, pressure and composition of the streams. Here attention should be given even to the impurities or small amounts of constituents which might have not been considered by the process designer.

(ii) For selection of material in an operating plant, review the operation, inspection and maintenance history, conduct failure analysis and try to identify the causes of failure. Once the cause is established, the selection of material or corrosion control measure or design change becomes easier.

(iii) Identify the various alternatives available, including design and operational modifications. Grade these according to effectiveness and make the selection based on analysis of various factors, because the best is not always practical or economical. If necessary and if time permits, carry out simulated laboratory and field tests.

(iv) In many instances, plant throughput is increased or product pattern changed for which detailed study to set new process parameters is made, based on which de-bottlenecking is carried out. Increase throughput and changed operating parameters can in many cases adversely affect material performance leading to early failures. It is important that during such reviews, the impact on material performance should also be carried out and necessary action taken.

Different Types of Materials: Materials can be broadly classified into Metals, Non-Metals and the Composites. Metals are further divided into two subgroups viz. Ferrous and Non-Ferrous.



Classification Of Materials

- Ferrous:

  Carbon Steels:

  Plain carbon steels constitute the largest tonnage of ferrous material in use and cover alloys of iron and carbon, with small amounts of Mn, Si, S, P either added deliberately or present as impurities. As impurities, P and S are most deleterious and special care is needed to keep their contents at low levels. Sulphur (and also selenium) is, however, sometimes deliberately added to improve machinability of iron and its alloys. For structural plates, pressure vessels, sheets, rods and pipes, the carbon content varies from 0.1 to 0.35%. For higher strength and wear resistance and for components requiring heat treatment, higher carbon, normally up to 1.0%, are used for specific end uses, e.g. files, saws, cutting tools, rails, shafts etc.

  Carbon is the most important element to impart strength. Higher the carbon content higher is the strength. However, higher carbon adversely affects toughness and weldability. Thus, to retain the strength and also good weldability, carbon steels containing lower carbon (0.2–0.30%) are used for pressure vessels. The carbon steels generally have adequate impact strength at low temperatures (−29 °C), but for still lower temperature fine-grained impact tested steels are used up to a temperature of

−48 °C. For high temperature use (above creep limit), creep rupture strength and resistance to oxidation are the two important criteria. Almost all codes allow use of carbon steel up to 480 °C, though in earlier times it is used to be prescribed for temperatures as high as 520 °C. The present-day accepted practice is to limit its use to a maximum temperature of 450 °C.

- Carbon Steel is an iron-based alloy where carbon is the main strength giving element. Fe-C alloys with < 2% C fall under carbon steels.
- Types of carbon steel based on C content:
    - Low Carbon Steel: < 0.25% C
    - Medium Carbon Steel: 0.25-0.6% C
    - High Carbon Steel: 0.6-1.3% C
- Steels used in petrochemical industries have TS in the range of 345-485 Mpa
- 85% of the fabrication is from Carbon Steel because of very good mechanical properties, very good fabricability, weldability, low cost and easy availability.

Applications- Used in pipelines, storage tanks, pressure vessels, heat exchangers, valves etc.

Alloy Steels:

Innumerable grades of steels containing comparatively small amounts of alloying elements, e.g. chromium, molybdenum, nickel, vanadium, boron, etc., in different combinations are in commercial use. The total alloying content in these steels may vary from 0.5 to 9.0%. The alloying elements are added to increase strength; to lower UTS/YS ratio; improve ductility, fracture toughness, heat treatment and carburizing properties; corrosion resistance in specific environments; high temperature creep strength and resistance to oxidation. Excluding carbon, the alloys of iron containing <5% and 5 to <10% alloying elements are broadly classified as low and medium alloy steels, respectively.

- An iron-based alloy wherein the total alloying element is less than 10%. Made by addition of Cr, Ni, Mo, Cu, P, V in few percent to CS.
- Types:
    - Low Alloy Steel: <10% alloy
    - High Alloy Steel: >10% alloy
- Low alloy steels are pearlitic steels- similar to CS.
- High alloy steels are tool steels, corrosion and wear resistant steels with austenitic and ferritic structures.

(i) Low Alloy Steels – High Temperature:

- Typically used at RIL-DMD:
  - P1: 0.5% Mo steel
  - P5: 5% Cr + 0.5% Mo steel
  - P9: 9% Cr + 1% Mo steel
  - P11: 1.25% Cr + 0.5% Mo steel
  - P22: 2.25% Cr + 1% Mo steel
- Properties: High strength and creep resistance.
- Applications: For pressure vessels and boiler components operating at elevated temperatures.

(ii) Low Alloy Steels – Low Temperature:

- Typically used at RIL-DMD:
  - 3.5% Ni steel: Low temperature piping for ethylene and other cryo fluids in OSBL.
  - 9% Ni steel: Ethylene storage tanks at -103° C.
- Properties: Good ductility at low temperature.

High Alloy Steel: High alloy steels are mainly those which contain high amounts (>10%) of alloying elements. Stainless steels constitute the major material of construction among the high alloy steels in petrochemical industry.

Effect of Alloying Elements:

- Nickel – Improves Toughness, Ductility, TS, reduces DBTT, decreases critical cooling rate.
- Chromium– Improves hardenability, TS, creep resistance, corrosion and wear resistance.
- Molybdenum – Improves ductility, toughness, improves hardenability with Cr, improves creep resistance, improves pitting resistance.
- Vanadium – Improves fatigue resistance, enhances properties developed by other alloying elements.
- Tungsten – Forms hard, stable carbide, improves wear and abrasive resistance, increases hardenability, decreases rate of softening during tempering.
- Boron – Increases hardenability.
- Silicon – Increases grain size, enhances magnetic properties, increases electrical resistivity.

Stainless Steels:

Stainless steels are alloys with a minimum of 11.5% Cr. In addition, these can also have nickel, and comparatively smaller amounts of molybdenum, titanium, niobium and nitrogen. It is chromium which imparts the resistance to corrosion by forming a thin passive layer of chromium oxide on the surface. Many metals and alloys form a thin oxide film when exposed to air, but these are not stable and get easily destroyed when exposed to corrosive environments. However, for the film to impart protection it should form easily, be stable and most importantly re-form quickly once damaged. These requirements are fulfilled by chromium when added to iron as an alloying element. A number of commercial alloys are available, having high resistance to corrosion and oxidation and improved creep rupture properties. Some alloys, in addition, also possess much higher strength.

- Contains at least 11.5% Cr.
- Stainless property due to readily forming Cr_2O_3 film.
- Excellent corrosion resistance.
- High strength.
- Good oxidation resistance at high temperatures.
- Good creep resistance.

Types of Stainless Steels:

- Austenitic: SS 304, SS 316, SS 321, SS 347
- Ferritic: SS 405, SS 430
- Martensitic: SS 410, SS 403
- Duplex
- Precipitation Hardenable: 17-7 PH, 14-4 PH

I. Austenitic SS – 300 series:

- C < 0.08%- to minimise carbide formation.
- FCC structure; Non-magnetic; Easily weldable.
- Cannot be hardened by heat treatment.
- Not easy to machine, they work-harden.
- Stabilised grades (SS321, SS347) available to avoid carbide precipitation.
- Applications: Pipings and tubings, pressure vessels etc.

II. Ferritic SS – 400 series:

- BCC structure; magnetic.
- Cannot be hardened by heat-treatment.
- Relatively poor high temperature strength.

- Good ductility but limited toughness.
- Applications – Used in Piping systems, Heat exchangers, Storage Tanks, Flare systems etc.

III. Martensitic SS – 400 Series:

- Carbon ranges from 0.11 to 1.0%.
- BCC structure; magnetic.
- Lower corrosion resistance than ASS and FSS.
- Can be hardened by heat treatment.
- Also known as 12% Chrome steels.
- Applications: Used in Valves and fittings, pumps and shafts, heat exchangers etc.

IV. Duplex SS:

- Has the advantages of austenitic and ferritic stainless steels.
- Better resistance to Stress Corrosion Cracking.
- TS and YS- Generally twice as high as austenitic SS.
- Applications: Used in piping and tubing, heat exchangers and condensers, Pressure vessels and Tanks, valves etc.

Cast Irons:

Cast irons (CI) are Fe-alloys, with carbon varying from 2.5 to 4.5%. Depending on the composition and cooling rate from the molten state the carbon in CI is present as either Fe3C (cementite) or free carbon (graphite) or both. The various types of cast irons have basic variations in the form and morphology of carbon distribution. The strength and brittleness of cast irons depend on the form in which the carbon is present and increase with increase in the amount of Fe3C. The graphite in normal cast iron (grey cast iron) is distributed in flake form in a ferritic or pearlitic matrix. The poor workability or brittleness of graphitic cast iron is due to the presence of graphite in flake form. However, by suitable treatment (during melting and alternately by suitable heat treatment), the shape of graphite can be modified into nodular form. Nodular and malleable cast iron fall under this category

- Fe-C alloys containing > 2% C
  -Usually contain 2.5-4.5% C + silicon
- <u>Types:</u>
  - ✓ Grey Cast Iron
  - ✓ White Cast Iron
  - ✓ Malleable Cast Iron

- ✓ Ductile Cast Iron
- ✓ Alloy Cast Iron

I. Grey Cast Iron:

- Accounts for nearly 75 % of cast iron use.
- Contains graphite flakes, providing good wear resistance and damping capacity.
- TS: 150 – 400 Mpa (can be controlled by degree of graphitization).
- YS: 80-85% of TS.
- Application – Pump housings, valve bodies, and pipe fittings.

II. White Cast Iron:

- Carbon present in the form of cementite, contains carbide impurities, which make it hard and brittle and used where abrasion resistance is paramount.
- It is brittle and difficult to machine.
- It is used for making malleable and nodular CI.
- Applications: Abrasions & wear resistant liners, grinding balls, dies, pump impellers.

III. Malleable Cast Iron:

- Made by high temperature prolonged heat treatment of white cast iron.
- Carbides in WCI decomposes into ferrite and graphite in a compact aggregate form called *temper carbon*.
- TS: Varies from 300 – 600 Mpa.
- Applications: Used in valves, links, gears, Fittings, brackets, and other hardware subjected to moderate stress and wear.

IV. Ductile Cast Iron:

- Contains spherical graphite nodules, offering improved ductility and toughness compared to gray cast iron.
- Nodule forming elements like magnesium / cerium added.
- Suitable for components requiring higher strength and impact resistance.
- Application: Used in compressor parts, valves, pumps, crankshafts and flanges.

a. Alloy Cast Iron:

- Nickel Cast Iron-
  - ➢ Several Grades from 14-38% Ni.
  - ➢ Improved corrosion resistance e.g. Sea water applications.
- Silicon Cast Iron-
  - ➢ Several grades from 11-14% Si.
  - ➢ Good corrosion resistance e.g. HCL, chloride atmospheres etc.

- Non-ferrous:

i. Aluminium and Aluminium Alloys: Of the non-ferrous metals, tonnage-wise aluminium occupies the highest position. It is soft, has low strength and comparatively low melting point (about 660 °C). In spite of this, its lightness (about 1/3rd of that of iron), good resistance to corrosion, good electrical conductivity and comparatively lower cost makes these as attractive alternatives in many structural, decorative, electrical and corrosion resistance service. An important property of aluminium is its ability to develop considerable strength by suitable alloying and in some cases by subsequent heat treatment, known as age hardening. The aluminium and its alloys on cold working retain good ductility with increase in strength and therefore, are available in various degrees of cold working, known as tempers that are mentioned in alloys specifications.

ii. Nickel and Nickel Alloys: Compared to aluminium and copper, nickel is costlier but in spite of this it is extensively used both as pure nickel or mainly its alloy both for corrosion and high temperature services. Some of the important nickel base alloys are Monel (Ni-Cu), Inconel (Ni–Cr–Fe), Hastelloy (Ni–Cr–Mo). Use of nickel and its alloys is specially made where resistance to specific highly corrosive environment is needed as in strong caustic or hydrofluoric acid service.

iii. Titanium and Titanium Alloys: In process industry unalloyed titanium (also known as commercially pure or CP titanium) is commonly used. Titanium is selected for its excellent corrosion resistance properties in large varieties of environments, especially in applications where high strength is not required. However, because of high cost its use is limited to exchanger tubes using sea water as coolant and for some specific corrosive chemicals.

- Elastomers and Composites: Composites are materials made from two or more constituent materials with significantly different properties. When combined together in a composite, the constituent materials maintain their separate identities but contribute to the overall performance of the composite. Most oilfield composites have fiber reinforcements and polymer matrixes. Fiberglass and other fiber reinforced polymers (FRPs) are often used in low-pressure piping and similar applications.

  Elastomers are rubbery flexible polymers used for o-rings, gaskets, and seals of many types. They usually are made from thermosetting polymers with limited crosslinking. The limited crosslinking allows these materials to deform without breaking and, if the load is released, they recover their original shape.

METALLURGY IN USE AT RIL DMD:

- CS – General piping, vessels of all plants.
- Low alloy steels- P1, P11, P22, P91 in Boiler components in CPP, GCU. 3.5% Ni steel and 9% Ni steel in OSBL.
- LTCS- Low temperature piping in VCM, GCU.
- Cast Irons- Pump impellers, casings of motors and pumps.
- Austenitic SS - SS 304, 304L, 316, 316L, 321, 347, Alloy-20 in piping, equipment of all plants.
- Ferritic SS – SS 405, 430 in column, vessel lining in VCM.
- Martensitic SS – SS 410 in valve parts, shafts- all plants.
- Duplex SS – Pipelines, flowlines, heat exchangers, storage tanks and valves etc.
- PH SS – Valves, pump shafts and heat exchanger tubes etc.
- Nickel- Ni-200, Ni 210 in eqpt, piping in CA, VCM.
- Incoloy – Radiant coils in EDC furnace.
- Hastelloy C276 – Incinerator section and spargers in VCM.
- Inconel – Spraying basket in caustic prilling tower in CA.
- Monel – 70% Nickel & 30% Copper. Piping, tubesheet cladding in VCM.
- HP 40 Alloy – Radiant coils in GCU.
- Admiralty Brass – Heat exchanger tubes in lube oil coolers.
- Aluminium – Brazed fin exchangers in GCU, Silos in HDPE.
- Titanium – Equipment, piping in VCM.
- Tantalum – Instru components in VCM.
- Cupronickel –90% Copper and 10% Nickel. EDC vaporiser tubes in VCM.

Non- Metals in use at RIL DMD:

- FRP – Acid storage tanks, piping.
- Glass lined – V308 in VCM.
- PVDF lined – V625 in VCM.
- FEP lined – V111 in VCM.
- PTFE lined – EDC+HCL piping in VCM.

- Rubber lined – Acid tanks, hypo piping, piping etc.
- PP-FRP – H2SO4 storage tanks, piping in CA, caustic service.
- HDPE – Effluent water pipes from VCM to ETP.
- CPVC-FRP – Chlorine dying tower in CA.

Different Metallurgy being used in various plants of RIL-DMD:

i. CHLOR-ALKALI PLANT (CA):

- Description about Plant: Chlor-Alkali is the only inorganic plant of all sites of Reliance Industries. Saturated brine solution is purified in the purification section by means of precipitation, clarification and filtration process. The brine is sent to electrolysis cell element. Caustic soda and chlorine are produced commercially by means of electrolysis of brine using selective membrane process where membrane only allows Na+ ions to pass through it and rejects other ions. This results in Caustic Soda of very high purity.
- Input Raw Materials: Industrial grade common salt, high purity wash salt.
- Products: Caustic Soda Lye, Chlorine, Sodium Carbonate, Ammonia, Sodium bi-sulphite, Sulphuric acid, Alpha Cellulose, Flocculant.

Table 1: Metallurgy of Major Loops of CA plant:

Sl. No.	Loop Name	MOC	Description
1	Brine Loop	CSRL, PP-FRP	NaCl solution is corrosive for most metals. Hence only non-metallics are resistant to it. RL and PP are resistant to brine.
2	Anolyte Loop	CSRL, FRP-HT, PVDF-FRP	Anolyte is NaCl solution with dissolved chlorine is corrosive for most metals. Hence only non-metallics are resistant to it.
3	32% Hot Caustic loop	Nickel, PP-FRP, CSRL	In Hot Caustic Ni, PP, and rubber are resistant.
4	32% Cold Caustic Loop	CS, FRP, PP-FRP	In Cold Caustic service CS works well. Non metallics are resistant to Caustic.
5	32% to 50% Hot Caustic Loop	SS 316L, Incoloy 825, Nickel 200, Nickel 201	Pure Nickel is very resistant to hot concentrated Caustic. However, Chlorates are detrimental for Nickel. Incoloy 825 works fine to 40% conc. Up to 150° C. Second effect evaporator connecting lines are of Incoloy 825.

6	Cold Caustic Loop	CS	CS is resistant to cold caustic with stress relieving of all joints.
7	Wet chlorine circuit	CSRL, FRP, Titanium	CSRL and Titanium is suitable for wet chlorine. However, Titanium shall not be used for dry chlorine as it is very exothermic reaction and may cause fire.
8	Dry chlorine circuit	CS	Carbon steel is suitable for Dry Chlorine. However slight ingress of moisture will make the stream corrosive.
9	Liquid chlorine	LTCS	For Chlorine at low temp. LTCS works fine in Liquid Chlorine service.
10	HCl loop	CSRL, PVC-FRP	HCl is corrosive for most metals. Hence non-metallics are resistant to it. CSRL or FRP works fine in HCl service.
11	Hypo loop	CSRL, FRP, PVC-FRP, Titanium	Hypo is a solution of Chlorine in Caustic. Most non-metallics and Titanium are resistant to it.
12	98% H2SO4 loop	CS	CS is resistant to 98% H2SO4 service at ambient. Conc. Acid forms a protective film of Ferrous sulphate when it comes in contact with CS. Hence preventing further corrosion of Carbon steel.
13	78% H2SO4 loop	PVC-FRP, Hastelloy-C 276	Dilute Sulphuric is corrosive to most metals. PVC-FRP is resistant to 78% H2SO4
14	Hydrogen loop	CS, SS 304	Hydrogen at ambient temperature is resistant to CS.
15	Ammonia Compressor loop	CS	Ammonia in absence of any moisture is resistant to Carbon steel.
16	EG loop	CS	EG at ambient temp. is resistant to CS.
17	Sulphate Remove System loop	FRP-HT, PVC	NaCl solution is corrosive for most metals. Hence only non-metallics are resistant to it.
18	Chilled water	CS	Chilled water in CA plant is inhibitor treated DM water. Its pH is about 6.5 and hence is resistant to carbon steel.

Figures:

Pump Impeller (MOC-Nickel)

PVC-FRP Tube (78% H_2SO_4 Service)

LTCS Pipe (Liquid Chlorine Service)

Fibre-Reinforced Plastic (FRP) Tubes

Exchanger (MOC- Nickel)

ii. VINYL CHLORIDE MONOMER (VCM):

Description About Plant: VCM plant is designed to produce 1,70,000 MT of VCM annually. Licensor is EVC (European Vinyl Corporation). It is a balanced process. The process of Vinyl Chloride Monomer (VCM) involves direct and Oxychlorination of Ethylene to form intermediate Ethylene dichloride (EDC) and thermal cracking of EDC to form VCM. The plant can be divided into four sections:

- Direct Chlorination Section
    a. High Temperature Chlorination (HTC)
    b. Low Temperature Chlorination (LTC)
- Pyrolysis and Quench Section – Recycle EDC.
- Oxy Chlorination and Oxy EDC Purification Section.
- Incinerator Section.
    - Raw Materials: Ethylene, Chlorine, Oxygen, EDC (Internal),
    - Products: Vinyl Chloride Monomer (VCM), EDC
    - By products: 22% HCl and light end.

Table 2: Metallurgy of Major Loops of VCM Plant:

Sl. No	Loop Name	MOC	Description
1.	EDC wash Loop EDC Purification Loop	CS+PTFE	EDC containing moisture (wet EDC) is known to show very high corrosion due to formation of acids in presence of water. PTFE lined carbon steel piping is used for sections that are operating around ambient temperatures.
2.	Direct Chlorination Loop, Pure EDC Loop, Recycle EDC Loop Recycle Column Reflux Loop Heavy Ends Loop & Purge EDC Loop	Carbon Steel	Carbon steel is used for service fluid having dry EDC, which is having lower corrosive tendencies in a wide range of temperatures. Fewer failures have been experienced in piping systems which have been attributed to ingress of moisture.
3.	Furnace Loop	Incoloy 800H/HT	This loop consists of coils of EDC cracking furnaces and temperature remains very high so Incoloy 800 is used.
4.	Cracked Gas Loop	Carbon Steel	Vapour and liquid steams containing HCl, EDC and VCM from quench column overheads, piping MOC is Carbon steel.

5.	Quench Column Bottoms Loop	Monel 400	Stream contains uncracked EDC, VCM, Dry HCl and coke particles. MOC for such service is Monel-400 to provide resistance to erosion-corrosion
6.	HCl Column Bottom to VCM Column VCM Product Loop VCM Purification Loop	Carbon Steel	Congealing service piping and equipment are provided with steam jackets/steam tracing. Damage to piping is caused due to presence of moist EDC. MOC used is Carbon steel
7.	Anhydrous HCl Loop	SS 304, Ni-200	Piping components carrying Vapour/ Liquid HCl(dry) have been provided with SS304 metallurgy and having cold insulation for low temperatures, failures have been experienced due to CUI and improper welding processes used during fabrication.
8.	Purge Gas Loop	Carbon Steel+ PTFE	It contains moist EDC vapours, moisture and ethylene, high corrosion is expected due to condensing acids in the vapour streams. PTFE lined carbon steel piping has been used for such streams in VCM unit
9.	Oxychlorination Loop	Nickel 200/ CS+PTFE	Reactor effluent streams contain ethylene and wet EDC at elevated temperatures show very aggressive corrosion behaviour for such conditions Nickel-200 has been selected as material of construction
10.	Ethylene Loop	Carbon Steel	Carbon steel is used due to its adequate resistance to ethylene under controlled conditions.
11.	Chlorine Loop	Carbon Steel	Carbon steel is used for its resistance to dry chlorine.
12.	Oxygen Loop	SS 304	SS 304 is used for its corrosion resistance in oxygen service.
13.	Propylene Loop	Carbon Steel	Carbon Steel works fine for propylene.
14.	Wet Vent Header Loop Wet Incinerator Header Loop	CS+PTFE	It contains moist EDC, HCl, moisture and high corrosion is expected. So, PTFE lined carbon steel piping has been used for such streams in VCM unit
15.	Fuel Gas Loop Nitrogen Loop Hydrogen Loop	CS	CS is suitable for Fuel Gas, Nitrogen and Hydrogen service.

16.	Azeo Drying Loop	Carbon Steel	Carbon steel is used but monitored for corrosion due to moist EDC.
17.	Caustic Loop	Carbon Steel	22% Caustic solution is used for wash / de-chocking equipment, piping with slurry, caustic injection points are provided, in all major slurry equipment.

Figures:

PTFE Lined Carbon Steel Pipe

Rupture Disc Holder (MOC- Monel)

Stainless Steel Pipe (SS 304)

MOC- Carbon Steel

Flange

MOC- Monel 400 (67% Ni – 23% Cu)

iii. GAS CRACKER UNIT (GCU):

Description About the Plant: GCU is known as the "Mother Plant" of RIL-DMD. The Gas Cracker Plant is designed to crack gaseous feedstock's, namely Ethane/Propane and LPG, to get Ethylene and Propylene as main products.

C_2/C_3 and propane are main feed for Gas Cracker plant. C_2C_3 is separated in EP fractionator and then ethane and propane are separately cracked in ultra selective cracking furnaces. There are total main five cracking furnaces and one demonstration-cracking furnace. The combined cracked effluent from all furnaces after heat recovery and quenching is compressed in cracker gas compressor.

The compressed gas after dehydration is separated in two sections mainly cryogenic fractionation and hot fractionation. Propylene and ethylene are used for refrigeration to get the cryogenic conditions. Expander compressor is provided to obtain the lowest temperature to minimise the loss of ethylene in residue gas. The total process blocks identified for Gas Cracker plant are as under: Feed handling, Furnace, Quench water system, CG compressor, Cold fractionation section, Acetylene conversion Unit & ethylene separation section, Hot fractionation, C2R/C3R refrigeration system, Utilities, Flare System

- Plant Inputs: Shale Ethane, Imported Propane, Jamnagar Propane.
- Finished Products: Ethylene and Propylene.
- Byproducts: Hydrogen, Methane, C4 mix, RARFS, Mix oil & Tar.

Table 3: Metallurgy of Major Loops of GCU:

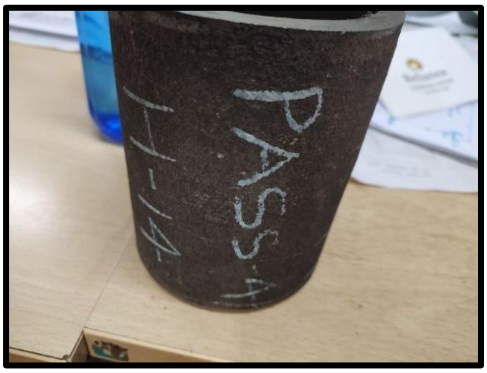
Sl. no	Loop Name	MOC	Description
1.	Ethane Header	CS, LTCS	LTCS is used for non-corrosive low temp. process.
2.	Propane Header	CS	CS is suitable for Propane service; operating temperature is 40-85° C.
3.	Depentaniser Section	CS	Temperature remains 40-85° C, CS is used.
4.	Furnace Convection & Radiant Section	CS, SS 304H, Incolloy 800H, A.S. (1.25% Cr, 0.5% Mo)	This loop includes convection and radiant tubes, ethane and propane cracking takes place. Due to very high temperature higher metallurgy is used. In Radiant Tubes Alloys of 25-35% Cr – 35-45% Ni are used because of the creep resistance.
5.	Ultra Selective Exchanger Inlet to Quench Tower Inlet	Incolloy 800H/P22, SS 304H, CS, P11	MOC is selected according to ambient temperature, for higher temperature pipings Incolloy 800H is used.
6.	Quench Tower and Quench Tower Closed Circuit	CS, SS	CS is used for structural components and non-corrosive areas where temperature remains from 50-200° C, while SS is used for corrosive environments and critical components like internals and piping in the quench tower and closed circuit.
7.	DSG & TAR Drum System	CS	CS is suitable for Dilution steam and Condensate service.
8.	Cracked Gas Compressor	CS	CS is suitable for Cracked Gas from Quench tower at ambient temp. (0.4 kg/cm2 & 40° C)
9.	Caustic Scrubbing System	CS	CS is suitable for caustic. (Up to 40° C)
10.	Residue Gas Loops	SS, LTCS, 3.5 Ni LAS, Aluminium Alloy, P11	Residue gas passing takes place. Low Alloy Steel is used for non-corrosive low temp. process; SS is used for corrosive process. Aluminium alloys may be used in heat exchanger tubing and structural components due to their light weight properties and resistance to corrosion in certain environments.

			Aluminium is used for connection to Aluminium Plate Fin Exchangers.
11.	Methane Polishing Unit	SS 304	SS 304 is used for liquid Methane service.
12.	Demethaniser Section	SS, 3.5 Ni LAS, Al, LTCS, CS	Feed is composed of H2, CH4, C2s, C3s etc. CS is suitable for 20-30° C, LTCS is used for -36 to -30° C, and SS or LAS is used at -130 to -90° C; Aluminium alloys may be used in heat exchanger tubing and structural components due to their light weight properties and resistance to corrosion in certain environments
13.	Deethaniser Section	CS, LTCS, SS, Al	Ethylene rich steam passing takes place, CS is suitable for -21 to 65° C, LTCS is used for -33 to -12° C and SS/Al is used for further lower temperature.
14.	Acetylene Converter Unit	CS, P11, SS	SS is used at critical areas exposed to corrosive substances.
15.	C2R System	SS 304, LTCS, LAS (3.5% Ni)	Ethylene refrigerant is supplies at extremely low temperature. Metallurgy changes according to temperature.
16.	C3R System	CS, LTCS	Propylene Refrigeration takes place so LTCS is suitable.
17.	Instrument Air, Service Air & Plant air & Nitrogen System	CS	CS is suitable for these services.
18.	Chemical Injection Dosing System	CS, SS	Several chemical dosing takes place to maintain ambient environment, so according to the service metallurgy is used.

Figures:

Low-temperature Carbon Steel Pipes

Gasket (MOC- SS 304L)



Radiant Tubes

(25-35% Cr – 35-45% Ni)

Valve (MOC- Carbon Steel)

Flange (MOC- SS 304H)

iv. POLY VINYL CHLORIDE PLANT (PVC):

Description About the Plant: At RIL-DMD, the production of Polyvinyl Chloride (PVC) employs the suspension polymerization method, where Vinyl Chloride Monomer (VCM) is combined with water and pigments acting as suspension agents in a stirred reactor to create a stable suspension. To control the molecular weight of PVC, chain transfer or cross-linking agents are added, while varying concentrations of polyvinyl alcohol serve as emulsifiers. The polymerisation is initiated by Di (2-ethylhexyl) peroxidecarbonate (EHP) and t-Butyl peroxy pivalate (TBP), with sodium bicarbonate used to buffer the reaction's pH. Polystat is included to prevent PVC build-up on the reactor walls. Fresh VCM is supplied via pipeline from an adjacent plant and stored in horizontal carbon steel tanks before processing.

Vinyl Chloride Supply: Fresh Vinyl Chloride supply is piped directly from the adjacent VCM plant.

Storage: Vinyl Chloride is stored in horizontal carbon steel tanks.

Output: The process outputs a slurry of PVC fines; wastewater is generated as a byproduct.

Table 4: Metallurgy of Major Loops of PVC Plant:

Sl. No.	Loop Name	MOC	Description
1	Fresh VCM Circuit	CS, SS 304, SS 316	Corrosion may take place due to high acidity so SS is used.
2	Recovered VCM Circuit	CS, SS 304, SS 316	SS 304 and SS 316 are used due to their excellent corrosion resistance against chlorine-containing compounds.
3.	PVC Slurry Circuit	SS 304, SS 316, CS SS 304 Clad, Alloy 20	This loop mainly handles PVC Slurry and SS is suitable for PVC Slurry service. Alloy 20 is used for its exceptional resistance to corrosion in both oxidizing and reducing environments. Nickel based alloys are mainly used to resist SCC and used in corrosive process liquid vapour and gas, Hot Bottom Piping for Hot PVC slurry, SS 316L is used for RVCM Slurry.
4	Ammonia Circuit	CS	Ammonia acts as refrigerant and ammonia is handled by CS.
5.	Glycol Circuit	CS, SS 316	Glycol at low temp is resistant to CS and at high temp is resistant to SS 304.

6.	Catalyst and Pigment Dosing Circuit	CS, SS 304	SS is used for Corrosion Resistance.
7.	Steam Network	CS	The steam is clean with pH normally neutral so CS is suitable.
8.	Nitrogen Circuit	CS	CS is used for Nitrogen Service.
9.	Instrument Air Circuit	CS, SS 304	SS 304 is used in corrosion prone areas.
10.	Cooling Water Circuit	CS	CS is suitable for cooling water service.
11.	Antifoam Circuit	CS, SS 304, SS 316	Tanks/Columns are of CS, Pumps are of SS 316, Exchangers are of SS 316L and SS 304 and Pipings are of CS. Pits are of concrete mainly.
12.	Nonyl Phenol Circuit	CS, SS 316, SS 304	Nonyl Phenol acts as an inhibitor, SS is used in corrosion prone areas.
13.	Nitric Oxide Circuit	SS 304	Corrosive process liquid, vapour and gas, Lube Oil, Nitrogen, Ammonia.
14	Demineralized Water Circuit	SS 304, SS 316	DM water is used as suspension media and SS is used as MOC as SS provides corrosion resistance for DM Water.
15	Condensate Circuit	CS	CS is used for condensate service.

Figures:

Elbow (MOC- SS 316)

Carbon Steel Pipes

Stainless Steel 304 Pipes

v. High Density Poly Ethylene (HDPE):

Description About Plant: The HDPE plant is able to produce the full product range for injection Moulding, blow Moulding and extrusion applications. The product state covers the melt index range of 0.05-60.0 g/10 min. The product densities vary between 0.94-0.96 g/cm3 dependent on co-monomer concentration and melt flow index. The plant is designed for 1,60,000 MT PE-HD annual capacity with on stream time to be 8000 hrs/calendar year. The plant is divided into 8 areas, named Area 100, Area 200, Area 300, Area 400, Area 500, Area 600, Area 700, Area 800. The main utilities used in HDPE plant are VHP Steam, MP Steam, LP Steam, DM Water, Raw Water, Fire Water, Cooling Water, Nitrogen, Service air, Plant air and Instrument air.

- Raw Materials: Ethylene, Titanium tetrachloride, Butene, Triethyl Aluminium, Hydrogen, Hexane, Magnesium Ethylate.
- Catalyst used is Ziegler Catalyst.
- Product: Relene

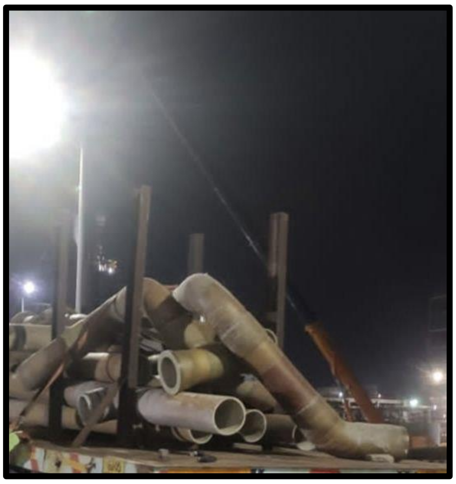
Table 5: Metallurgy of Major Loops of HDPE Plant:

Sl. No.	Loop Name	MOC	Description
1.	Ethylene Loop	CS, SS	Operating temperature is 7-50° C, Ethylene at ambient temp and low pressure can be handled in CS. SS is also resistant to ethylene.
2.	Fresh Hexane Loop	CS	CS is suitable for cold Hexane, Hexane Vapour and distilled Hexane return supply, operated at 30-40° C temp.
3.	Hexane Mother Liquor Loop	CS	Mother liquor consists of Hexane butene and dissolved wax, CS is compatible.
4.	Butene Loop	CS	The butene loop may not encounter highly corrosive conditions compared to other parts of the plant. Carbon steel provides adequate corrosion resistance in these less aggressive environments.
5.	Hydrogen Loop	CS, AS	Hydrogen at ambient temperature is resistant to CS. AS is used for better corrosion resistance and longevity in critical areas prone to hydrogen embrittlement.
6.	Catalyst Loop	SS & CS	Ziegler catalyst is used in HDPE production and loop is operated at 30-120° C, SS is chosen for corrosion resistance in areas exposed to catalysts and chemical.
7.	Hot Nitrogen Loop	SS	SS is suitable for N2 supply.
8.	Chilled Hexane Loop	CS, CSLT, SS	Operated at low temperature so CSLT is used.
9.	Propylene Loop	CS, CSLT	Propylene is used as a refrigerant in plant, CSLT works fine in Propylene service.
10.	Caustic Loop	CS, CS (Rubber Lining), SS	NaOH of concentration 30% is used in plant processing areas. CS is suitable for Caustic at low temp without stress relief. However, at high temp and higher conc. Stress relieving is to be done. Stainless Steel is suitable for usage at higher temp Caustic.

			CSRL is suitable for usage in equipment.
11.	Waste Water Loop	CS, FRP	The pH of waste water remains approx. 6.5 and hence CS is suitable at ambient temp. FRP is used for its corrosion resistance.
12.	Condensate Water Loop	P11 Alloy Steel, CS, SS	MOC is selected according to ambient condition.
13.	VHP Steam Loop	P11 Alloy Steel	Temperature is above 70° C and pressure remains 105kg/cm2, P11 Alloy steel is used.
14.	MP Steam Loop	CS	CS works fine for MP Steam service.
15.	LP Steam Loop	CS	CS is suitable for LP steam service.

Figures:

Carbon Steel Tubes



Fibre-Reinforced Plastic Tubes

Mild Steel Sheets

P11 Alloy Steel Tubes

vi. ETHYLENE OXIDE & ETHYLENE GLYCOL (EO-EG):

Description About Plant: The Ethylene Oxide (EO) and Ethylene Glycol (EG) plant, integral to the DMD, exemplifies cutting-edge chemical processing.

- Raw materials used: Ethylene, Oxygen and Methane.
- Catalyst used is Silver Catalyst (Syndox catalyst).
- Products are Ethylene Oxide (EO), Monoethylene Glycol (MEG).
- By Products: Diethylene Glycol (DEG), Triethylene Glycol (TEG), TEG bottom.

Ethylene Oxide: Ethylene Oxide (EO) or oxirane (C_2H_4O), is a cyclic ether with three-membered ring structure composed of two carbon and an oxygen. Its unique molecular shape makes it highly reactive, readily participating in addition reactions and polymerizing by opening its ring. EO is isomeric with acetaldehyde but differs significantly in reactivity and applications.

Table 6: Metallurgy of Major Loops of EO-EG Plant:

SL NO.	Loop Name	MOC	Description
1.	Ethylene Loop	CS & SS 304	Ethylene at ambient temp and low pressure can be handled in CS. SS is also resistant to ethylene.
2.	Oxygen Loop	SS 304	In ISBL piping oxygen is handled in clean material such as SS. The pipe shall be degreased and cleaned prior to put in service.
3.	Methane Loop	CS & SS 304	Methane is a clean fluid and CS is compatible. In critical area few pipe lines are of SS also.

4.	Caustic Loop	CS, SS 304 & CSRL	CS is suitable for Caustic at low temp without stress relief. However, at high temp and higher conc. Stress relieving is to be done. St. steel is suitable for usage at higher temp Caustic. CSRL is suitable for usage in equipment.
5.	HCL Loop	CSRL	Dil. HCL is very corrosive fluid. It cannot be handled by normal metals. However, it is resistant to non-metals. CSRL is suitable for HCL.
6.	10% EO Solution Loop	CS & SS 304	SS 304 is suitable for dil. EO service.
7.	Dilute Glycol Loop	CS & SS 304	Initially the evaporator section in EO-EG plant was of CS. Frequent leakages were observed in CS lines and equipment due to erosion-corrosion. Metallurgy of all equipment is upgraded to SS 304/304L. But SS 304/304L also facing similar issue. This may be due to SCC. Hence Duplex SS 2205 is suitable for dil. Glycol at higher temp.
8.	Evaporator Process Steam/Condensate Loop	CS & SS 304	Metallurgy of all equipment is upgraded to SS 304/304L also from CS. But SS 304/304L also facing the similar issue. This may be due to SCC. Hence Duplex SS 2205 is suitable for dil. Glycol at higher temperature.
9.	Glycol Loop	CS & SS 304	Glycol at low temp is resistant to CS and at high temp is resistant to SS 304.
10.	Cycle Water Loop	SS 304	Cycle water contains 2-3 mole % of EO and hence SS 304 is required as CS might get corroded.
11.	Waste Water Loop	CS	The pH of waste water remains approx. 6.5 and hence CS is suitable at ambient temp.
12.	Utilities Loop	CS	All lines to be painted for any external corrosion. Cooling water flow to be maintained to avoid Stagnancy.
13.	Cycle Gas Loop	SS 304	Cycle gas contains ethylene and oxygen hence CS may be prone to iron pick up hence SS is required.
14.	Carbonate Loop	SS 304	SS 304 is suitable for Carbonate Loop.
15.	NALCO Loop	SS 304	Sodium Nitrate is resistant to Stainless Steel.

			The Cr present in SS provides corrosion resistant to pipeline.
16.	Ethylene Oxide Loop	SS 304	For pure EO service SS is required as in CS iron pick up may occur. Also, there may be issue of erosion-corrosion.
17.	Steam and Condensate Loop	CS	The steam is clean with pH normally neutral. However few failures were observed at elbows mainly due to two phase flow. Overall CS had worked fine in condensate.
18.	Off gas loop	CS	Periodic inspection of piping after condenser.

Figures:

CSRL Pipes

Carbon Steel Pipes

SS 304 Seamless Pipes

vii. PURIFIED TEREPTHALIC ACID (PTA):

Description About Plant:

- Largest PTA plant in India integrated with PET, Tank farm & Warehouse.
- Maximization of Raw Material and minimize energy utilization through process design.
- Largest Process Air Compressor in the country supplies by Man Diesel Turbo.
- Integrated with Process, Steam generated from Waste heat and energy from Reactor off gas are utilized to generate Power.
- Terephthalic acid is produced by oxidation of p- Xylene.
- Waste water from Oxidation Reaction is used as Process water in Purification i.e. reduction in DM Water Consumption.
- Rotary Pressure filter (Low Speed), Old generation plants use high speed two centrifuges.
- PTA plant is divided into two major parts Oxidation and Purification.
- Raw Materials: Para- Xylene, Air, Hydrogen.
- Chemicals: Acetic Acid, Caustic, Sodium Formate, Oxalic Acid.
- Catalyst: Cobalt Acetate, Manganese Acetate, Hydrobromic Acid etc.
- Utilities: Power, Steam, Instrument Air, Plant Air, Nitrogen, Cooling Water, Service Water, DM water, Fire Water
- Byproduct: CBAM

Table 7: Description of Major Loops of PTA Plant:

SL NO.	LOOP NAME	MATERIALS USED	DESCRIPTION
1.	Process Air (from Block Valve to Oxidation Reactor)	Ti, SS 316L, CS	Titanium piping is used in oxidation section of PTA unit.
2.	Cooling Water Loop	CS	CS is used in cooling water service.
3.	Oxidation Reactor and Overhead Condensers	Ti, SS 2205, SS 316L	Oxidation reactor is typically clad construction. Reactor feed mixer is of SS 2205. Titanium piping is used in oxidation section of PTA unit.
4.	Paraxylene to Feed Mixer Loop	Ti, SS 316L, CS, SS 316L	Paraxylene is the raw material for this plant. Carbon Steel is used in Para-Xylene service. P-Xylene lines freezing temp of 13° C, these lines are insulated and have heat tracing.
5.	Startup Heater Loop	SS 316L, SS 2205, Ti	Higher metallurgy is used for corrosion prone areas.

6.	Oxy Reactor to RoVac Loop	SS 2205, SS 316L, Ti	Oxidation reactor and CTA Crystallizers are typically clad construction. Titanium Piping and heat exchangers are used in oxidation section of PTA unit.
7.	Overhead Loop	Ti, CS, SS 2205, SS 316L	For pressure vessels, columns, heat exchanger and piping duplex stainless steel grade 2205 is used. CTA Crystallizers are typically clad construction of Ti.
8.	Mother Liquor Loop	SS 316L, SS 304L	Austenitic stainless steel remains the major MOC for the PTA plants. SS in suitable for Mother Liquor Circuit
9.	Solvent Scrubber Loop	SS 316L	DSS is mostly used in hot acetic acid circuits containing halides at intermediate temperatures. SS 316L is used in Solvent Scrubber Loop.
10.	Solvent Loop	SS 2205, SS 316L, SS 2205, Ti	Acetic Acid storage is of SS. DSS is mostly used in hot acetic acid circuits containing halides at intermediate temperatures
11.	Feed Slurry Drum	SS 304L, Hastelloy C276	Austenitic SS in used in PTA Slurry Circuit, Hot Slurry piping from Purification Reactor to first crystallizer prone to high temperature erosion-corrosion has C276 as material of construction.
12.	Catalyst Loop	SS 316L, Ti, SS 2205, SS 304L	HBr is the catalyst. PTFE lined SS 316L piping is used for catalyst Hydrogen bromide (HBr) at ambient conditions.
13.	Flaker Loop	SS 304L	The feed tough is constructed from 2205 Duplex SS and it is provided with a heating coil arrangement constructed from SS304.
14.	First PTA Crystallizer to Rotary Pressure Filter Loop	C276, SS 304L	Hot slurry piping from Purification Reactor to first crystallizer prone to high temperature erosion-corrosion has C 276 as material of construction. Super Austenitic Stainless steel (2RK65 / 904L) is used for tubes in 1st and 2nd Purification Crystallizer pre-heater, and hydrogen recovery preheater / cooler condensers. Purification reactor has lining of SS347 by weld overlay on Low alloy steel. CTA impurities are removed by hydrogenation with catalyst.

15.	Hydrogen Loop	SS 304L, SS 316L, CS	Reactor materials are in line with API 941 for high temperature hydrogen service
16.	Steam Loop Condensate Loop	CS	CS is suitable for Steam, Condensate, Air (PAC circuit) Caustic and Cooling water service.
17.	Caustic Loop	CS	Caustic service has additional requirement for PWHT.
18.	Purif Mother Liquor Loop	SS 304L	Austenitic Stainless Steel is used in Mother Liquor Circuit.
19.	Paraxylene Storage to Plant Loop	CS	P-Xylene lines freezing temp of 13° C, these lines are insulated and have heat tracing. CS is used in Para Xylene Service.

Figures:

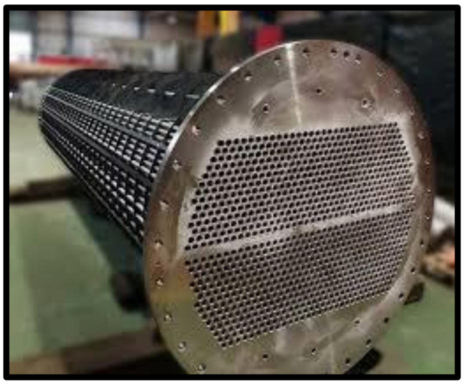
Pipe Fittings (MOC- SS 304L)

Flanges (MOC- Carbon Steel)

Valve (MOC- SS 316L)

Duplex SS Pipes

Hastelloy C276 (Ni–Cr–Mo) Tubes



Heat Exchanger (MOC- Titanium)

Ball Valve (MOC- SS 316, Seal- High Density Graphite)

viii. COAL BASED CAPTIVE POWER PLANT (CCPP):

Description About the Plant:

- DMD complex steam and Power requirement completely swapped from gas-based power plant to Coal Based Power Plant from 16 Jan 2018.
- Raw Materials used are Coal, Lime Stone, Bed Material, Natural Gas and Nitrogen.
- Output are Power, VHP Steam and by product is ash.
- The entire process of generation of power from coal has three main stages. In first stage, the raw material (coal) is stored, crushed and conveyed to boilers and the ash generated is conveyed to silos.
- The second stage involves release of heat energy stored in coal to convert water into superheated steam in the coal fired boilers.

- In third stage, the high-pressure steam from boilers is passed through steam turbines which in turn drives an AC generator, thereby generating electricity.

Table 8: Metallurgy of Major Loops of CCPP:

Sl. No.	Loop Name	MOC	Service
1	VHP Steam	CS, P11, P22, P91	This Loop comprises of High Pressure and High Temp Steam.MOC changes according to service. CS is suitable for steam temp below 400° C, P11 is used for steam of temperature between 400 to 500° C and for above 500° C steam P22 is used.
2	Auxiliary Steam	CS, P11	This Loop comprises of Medium Pressure Auxiliary Steam. P11 is used for steam of temperature between 400 to 500° C Mainly CS is used.
3	Pegging Steam	CS, P11	This Loop comprises of Medium Pressure Pegging Steam. P11 is used for steam of temperature between 400 to 500° C
4	Extraction Steam	CS	This Loop comprises of Medium/Low Pressure extracted Steam. CS is suitable for Extracted Steam Service.
5	Boiler Feed Water	CS	CS is suitable for pressurised feed Water service.
6	Condensate	CS	CS is used for Condensate service.
7	LP Dosing	Austenitic Stainless Steel	This comprises of Chemical Dosing of Carbohydrazide Solution. Austenitic SS is suitable for that.
8	Amine Dosing	Austenitic Stainless Steel	Austenitic SS is suitable for Chemical Dosing system of Morpholine and Cyclohexylamine.
9	Acid Dosing	SS 316L	This loop comprises of receipt storage transfer and dosing of H2SO4 and SS 316L is used as MOC.
10	Chlorine Dosing	CS (PTFE Lined)	PTFE lined CS is used for Chlorine dosing system as corrosion may be take place.
11	Instrument Air	Austenitic Stainless Steel	Austenitic SS is used for Instrument Air System.
12	Potable Water	CS	Galvanised CS is used for Potable Water System.

13	DM Water	SS	SS is suitable for Demineralized Water System.

Figures:

Gasket (MOC- SS)

Valve (MOC- Carbon Steel)

Low Alloy Steel (P11) Tubes

O- Rings (MOC- Rubber)

ix. POLYETHYLENE TEREPHTHALATE (PET):

Description About the Plant:

- Polyethylene Terephthalate (PET) is made industrially by reacting TPA/IPA with ethylene glycol (EG) to form dihydroxethyl-terephthalate (DHET) which is the monomer of PET. Excess glycol in the DHET which is the monomer of PET. Excess glycol in the DHET is subsequently removed in a poly-condensation reaction to form PET. The PET manufacturing process can be expressed in two steps, Esterification and Polymerisation.
- Capacity: 1800 TPD (648 KTA)
- Product: Poly Ethylene Terephthalate.

- Brand Name: RELPET

Table 9: Metallurgy of Major Loops of PET Plant:

Sl. No.	Loop Name	MOC	Remarks
1.	Raw Material Powder Loop	SS 304	Austenitic stainless steel is used in the Raw Material Powder Loop of PET plants due to its excellent corrosion resistance, chemical compatibility, temperature resilience.
2.	Oligomer Circuit	SS 304, SS 316	Austenitic stainless steels remaining the major MOC for PET plants. These grades have good compatibility to Oligomer Circuit, Oligomer circuit.
3.	Air Loop	CS	CS is suitable for process air and plant air service.
4.	Caustic Loop	CS	CS is suitable for Caustic at low temp without stress relief. However, at high temp and higher conc. Stress relieving is to be done.
5.	Dowtherm Area	CS	Dowtherm fluids, which are heat transfer fluids, are typically not highly corrosive to carbon steel under controlled conditions, allowing carbon steel to perform adequately without the need for more expensive materials.
6.	Steam Loop	CS	The steam is clean with pH normally neutral so CS works fine for steam loop.
7.	Condensate Loop	CS	CS had worked fine in condensate services.

Figures:

Valve (MOC- Carbon Steel)

Stainless Steel Tubes

Case Study: Gasket Seat in a Shell and Tube Condenser in a Petrochemical Plant.

Service: Shell and tube assembly to condense organic product vapor flowing on the tube side, with cooling water, fresh land source water, on the shell side.

Problem: Leak has occurred on the cooling water side on the floating tube-sheet end. Gasket groove on the tubesheet face had corroded resulting in a rough surface and hence leak.

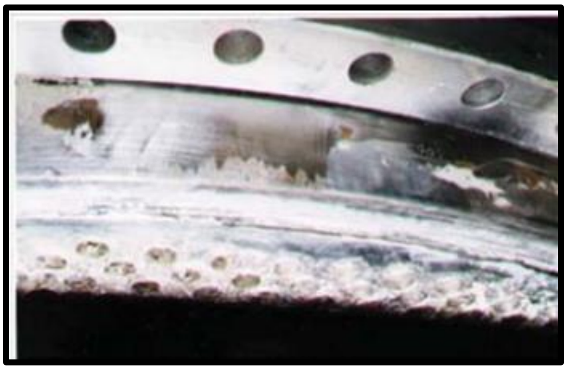
Material: Type 304SS for tube-sheet and gasket.

Observations:

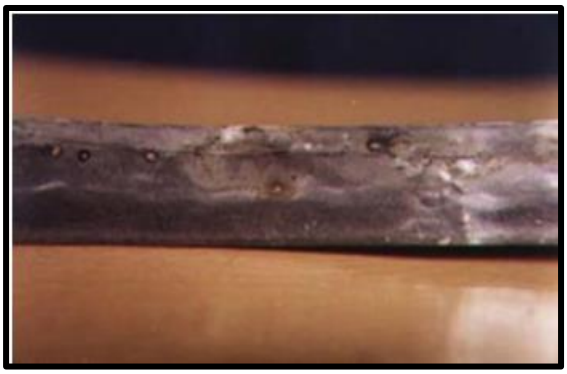
- Rough corrosion on the gasket seat groove.
- Gasket was specified as "Type 316 SS spiral wound PTFE filled." But the actual gasket used was "Type 304 SS asbestos enveloped".
- The asbestos was in a highly damaged condition and the 304 SS envelope was in a highly pitted condition with several leaky holes.

Diagnosis: Pitting corrosion by the chlorides in the cooling water (~150 ppm) at about 40∘C on the 304 SS envelope. This makes the asbestos wet. Wet asbestos with stagnant water leads to Crevice Corrosion of both 304 SS envelope and 304 SS gasket groove.

Remedy: Use only corrosion-resistant non absorbing gaskets like "SS 316 Spiral Wound PTFE filled gasket" and not any lower quality absorbing type gaskets.



(a)



(b)

Fig. (a) Gasket groove surface showing localized corrosion marks. (b) 304SS asbestos gasket envelope showing through and through corrosion pits.

Conclusions:

The project on "Different Metallurgy Being Used in Petrochemical Industries" underscores the critical importance of material selection in ensuring the efficiency, safety, and durability of petrochemical processes at the Dahej Manufacturing Division (DMD) of Reliance Industries Limited.

- Material Selection Based on Corrosion Resistance: In the petrochemical industry, materials are meticulously chosen for their ability to withstand specific corrosive environments. Stainless steels (such as SS304 and SS316L) and nickel-based alloys (like Nickel 200 and Monel 400) are preferred for their superior resistance to corrosive chemicals, including chlorides and acids.
- Cost and Efficiency Considerations: Carbon steel (CS) is widely utilized for non-corrosive processes due to its cost-effectiveness and adequate performance in less aggressive environments. Achieving a balance between material cost and service requirements is essential for efficient petrochemical operations.
- Specialized Applications: Specific conditions necessitate specialized materials like Incoloy 800H and rubber-lined CS, LTCS, PVC, and FRP, which provide high-temperature stability and chemical resistance. These materials are crucial for applications such as furnace outlets and the handling of wet HCl.
- Regulatory and Safety Compliance: Material selection at DMD also ensures adherence to industry regulations and safety standards. For instance, stress-relieved carbon steel is used for caustic solutions to prevent stress corrosion cracking, ensuring compliance with safety norms.
- Maintenance and Longevity: Appropriate metallurgy enhances the longevity and reliability of equipment, thereby reducing maintenance costs and downtime. Stainless steels and nickel alloys are particularly noted for their durability in challenging environments.
- Adaptability to Process Changes: The versatility of materials used in the petrochemical industry allows for adaptation to varying process conditions. For example, SS316 can handle both low and high-temperature glycol solutions, demonstrating the flexibility required in petrochemical operations.
- Environmental Impact: Selecting the right materials minimizes the risk of leaks and spills, mitigating environmental hazards. The use of corrosion-resistant alloys significantly contributes to protecting the environment from potentially harmful chemical releases.

Overall, the meticulous approach to material selection at RIL-DMD ensures operational efficiency, safety, cost-effectiveness, and environmental protection, highlighting the critical importance of metallurgy in the petrochemical sector.

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