# Implementation of Mass & Energy Balance on PDE

## Internship Report

Submitted for the partial fulfillment of the degree of

**Bachelor of Technology**

**In**

**Chemical Engineering**

**Submitted By**

**Ayush Terak**

**0901CM201012**

**UNDER THE SUPERVISION AND GUIDANCE OF**

**Prof. Shivangi Sharma**

**Assistant Professor**

**Department of Chemical Engineering**

माधव प्रौद्योगिकी एवं विज्ञान संस्थान, ग्वालियर (म.प्र.), भारत
MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR (M.P.), INDIA
Deemed to be University
(Declared under Distinct Category by Ministry of Education, Government of India)
NAAC ACCREDITED WITH A++ GRADE

**January-May 2024**

## DECLARATION BY THE CANDIDATE

I hereby declare that the work entitled **"Implementation of Mass & Energy Balance"** is my work, conducted under the supervision of **Prof. Shivangi Sharma, Assistant Professor,** during the session Jan-May 2024. The report submitted by me is a record of bonafide work carried out by me.

I further declare that the work reported in this report has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Ayush

**Ayush Terak**

**0901CM201012**

**Date:** 24/05/2024
**Place: Gwalior**

---

This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief.

**Guided By:**

24/05/24

**Prof. Shivangi Sharma**
**Assistant professor**
Department of Chemical Engineering
MITS, Gwalior

**Departmental Project Coordinator**

24/05/24

**Prof. Shivangi Sharma**
**Assistant Professor**
Department of Chemical Engineering
MITS, Gwalior

**Approved by HoD**

Anish 24/05/24

**Prof. Anish P. Jacob**
**Assistant Professor & Coordinator**
Department of Chemical Engineering
MITS, Gwalior

COORDINATOR
Chemical Engineering
MITS, Gwalior

# PLAGIARISM CHECK CERTIFICATE

This is to certify that I/we, a student of B.Tech. in **Chemical Engineering** have checked my complete report entitled **"Implementation of Mass & Energy Balance"** for similarity/plagiarism using the "Turnitin" software available in the institute.

This is to certify that the similarity in my report is found to be 19% which is within the specified limit (20%).

The full plagiarism report along with the summary is enclosed.

**Ayush Terak**
**0901CM201012**

**Checked & Approved By:**

Anish
24/05/24

**Prof. Anish P. Jacob**
**Turnitin Coordinator**
Department of Chemical Engineering
MITS, Gwalior

# ACKNOWLEDGEMENT

The Internship Project has proved to be pivotal to my career. I am thankful to my institute, **Madhav Institute of technology & Science** to allow me to continue my diciplinary/interdisciplinary project as a curriculum requirement, under the provisions of the Flexible Curriculum Scheme (based on the AICTE Model Curriculum 2018), approved by the Academic Council of the institute. I extend my gratitude to the Director of the institute **Dr. R. K. Pandit** and Dean Academics, **Dr. Manjaree Pandit** for this.

I would sincerely like to thank my department, **Department of Chemical Engineering,** for allowing me to explore this project.

I am sincerely thankful to my faculty mentors. I am grateful to the guidance of **Prof. Shivangi Sharma,** Assistant Professor, Department of Chemical Engineering, for her continued support and guidance. I am also very thankful to the faculty and staff of the department.

Ayush.

------------------------------

**Ayush Terak**

**0901CM201012**

# INTERNSHIP CERTIFICATE

teva | api

**Ref – TEVA/HR/ MLR/ TRG.CER/05/24** **Date: 18th May 2024**

**<u>To whom so ever it may concern</u>**

This is to certify that **Mr. Ayush Terak** a student of Madhav Institute of Technology & Science, Gwalior (M.P.) has undergone a Training with us, on **"Mass and Energy Balance"** from **18.01.2024 to 18.05.2024**.

During the tenure of his training, he was found to be sincere and hard working.

We wish him all the best for his future endeavors.

For Teva API India Pvt. Ltd

18/05/2024

(Sachin Jain)
HR Generalist II – HR

**Teva API India Private Limited**
**Manufacturing Site:** Plot Nos. Q1 - Q4 Industrial Area, Ghirongi, District - Bhind, Malanpur - 477 117, Madhya Pradesh, INDIA.
**t:** +91 7539 283 942
**Regd. Office:** 12th Floor, Commerz II, International Business Park, Oberoi Garden City, Goregaon (E), Mumbai - 400 063
Maharashtra, INDIA | **t:** +91 22 6268 5555 | www.tava-api.com | **CIN No.:** U74899MH2002PTC326704

# ABSTRACT

The pharmaceutical business is an essential one that is involved in the worldwide development, production, and distribution of drugs for a range of medical diseases. The industry makes major contributions to the evolution of healthcare by extensively investing in research and development to create and enhance therapies. One of the many medications created by the pharmaceutical industry is Pyridine Dicarboxylate Ester (PDE). PDEs are crucial intermediates in the synthesis of statins, a class of drugs used to lower cholesterol levels. For example, they are used in the multi-step synthesis of atorvastatin, which involves complex transformations to build the final drug molecule, which are essential for managing hypercholesterolemia and preventing cardiovascular diseases. In addition to pharmaceuticals, PDEs are also valuable in the agrochemical sector for synthesizing herbicides and insecticides, contributing to improved agricultural productivity and sustainability. Recent advancements focus on improving the efficiency and selectivity of PDE synthesis through innovative catalysts and green chemistry approaches, aligning with the global shift towards environmentally sustainable chemical processes. The multifaceted applications and ongoing research underscore the importance of PDEs in modern organic synthesis, highlighting their potential to drive future innovations in chemical and pharmaceutical industries.

This report contains the study of various types of equipment’s and processes that are used in the manufacturing of PDE. So, this report consists of the mass and energy balance on the production of PDE which is an intermediate.

Keywords: Mass Balance, Energy Balance, Process Flow Diagram, Filtration.

# CONTENT

## Table of Contents

# ACRONYMS

| | |
|---|---|
| API | Active Pharmaceutical Ingredient |
| SRP | Solvent Recovery Plant |
| R | Reactor |
| V | Vessel |
| MSGL | Mild Steel Glass Lined |
| CF | Candle Filter |
| KRM | Key Raw Material |
| RPM | Revolutions Per Minute |

# NOMENCLATURE

| | |
|---|---|
| $\Delta p$ | Pressure drop |
| L | Length of bed |
| $\mu$ | Fluid viscosity |
| $\epsilon$ | Porosity |
| Dp | Particle diameter |
| v | Superficial velocity |
| $\rho$ | Density of Fluid |
| Q | Heat added to or removed from the system |
| m | Mass |
| $c_p$ | Specific heat capacity of substance |
| $\Delta t$ | temperature difference |

# LIST OF FIGURES

# CHAPTER 1: INTRODUCTION

Pyridine dicarboxylate esters (PDEs) are significant organic compounds in chemical synthesis, widely recognized for their versatility and utility as intermediates in the pharmaceutical and agrochemical industries. The presence of two ester functional groups on the pyridine ring provides numerous opportunities for chemical modifications, making PDEs valuable building blocks for the synthesis of various complex molecules.

## 1.1 Uses of Pyridine Dicarboxylate Esters

1. **Statins Production**: PDEs are crucial intermediates in the synthesis of statins, a class of drugs used to lower cholesterol levels. For example, they are used in the multi-step synthesis of atorvastatin, which involves complex transformations to build the final drug molecule.
2. **Other Pharmaceuticals**: PDEs are also used in the synthesis of other pharmaceutical agents, including antibiotics, antiviral drugs, and anti-inflammatory medications. Their versatile chemistry allows for the introduction of various functional groups needed in drug design.
3. **Agrochemicals:** PDEs serve as intermediates in the production of agrochemicals, such as herbicides and insecticides. Their ability to interact with biological systems makes them valuable in developing compounds that can protect crops from pests and diseases.

Mass balance and energy balance are foundational concepts in various scientific and engineering disciplines, serving as fundamental tools for analyzing and understanding the behavior of systems ranging from chemical reactors to environmental ecosystems. These balances are essential for ensuring the conservation of mass and energy within a system, providing valuable insights into processes, efficiencies, and environmental impacts. In this comprehensive exploration, we delve into the principles of mass balance and energy balance, elucidating their significance, applications, and interconnections.

The law of conservation of matter states that matter cannot be created or destroyed. This leads to the concept of mass, and the law can be expressed in the form that the mass of materials involved in any process is constant. It is now known that the law is too limited for matter moving at speeds close to the speed of light or for substances undergoing nuclear reactions. Under these circumstances, energy and mass are mutually convertible, and the sum of the two is constant, not just one. However, in most engineering this transformation is too small to detect, and mass and energy are assumed to be independent. Conservation of matter requires that materials entering any process must either accumulate or leave the process. There can be no loss or gain. Most of the processes we deal with involve neither accumulation nor depletion, and the law of conservation of mass takes the simple form that input equals output. The law is often applied in the form of material balances. A process is weighted by everything that enters it and credited with everything that leaves it. Material balances must be valid over the entire process or equipment and over any part of it. It must apply to all material entering and exiting the process and to each individual material passing through the process unchanged.

Mass balance, also known as material balance, revolves around the fundamental principle of conservation of mass, which states that mass is neither created nor destroyed in a closed system. It involves accounting for the mass of substances entering and leaving a system, ensuring that the total mass remains constant over time. Mass balance finds extensive applications in chemical engineering, environmental science, and industrial processes, where it is crucial for understanding material flows, reaction kinetics, and pollution control.

Energy balance, on the other hand, is rooted in the principle of conservation of energy, stating that energy cannot be created or destroyed but can only change forms within a closed system. Energy balance entails tracking the flow of energy into, out of, and within a system, ensuring that the total energy remains constant. This balance is vital for analyzing heat transfer, thermodynamic processes, and energy conversion systems, playing a pivotal role in fields such as thermodynamics, heat transfer, and power generation.

The interconnected nature of mass balance and energy balance is evident in many natural and engineered systems, where changes in mass often correspond to changes in energy and vice versa. For instance, in chemical reactions, mass balance dictates that the total mass of reactants equals the total mass of products, while energy balance ensures that the total energy input equals the total energy output, accounting for heat released or absorbed during the reaction.

In environmental systems, mass balance and energy balance are indispensable for assessing the fate and transport of pollutants, energy exchanges within ecosystems, and the impact of human activities on the environment. By applying these balances, scientists and engineers can model complex environmental processes, predict pollutant concentrations, and devise strategies for mitigating environmental pollution.

In industrial processes, mass and energy balances play a critical role in optimizing operations, reducing waste generation, and improving efficiency. By meticulously accounting for material and energy flows, engineers can identify inefficiencies, optimize process parameters, and minimize resource consumption, leading to cost savings and environmental benefits.

The principles of mass balance and energy balance extend beyond traditional engineering disciplines, finding applications in fields such as economics, ecology, and systems biology. In economics, for instance, mass balance principles are applied to analyze material flows in supply chains, while energy balance concepts are used to evaluate the energy efficiency of production processes.

# CHAPTER 2: LITERATURE SURVEY

The study on the topic “Mass and Energy Balances”. It covers the analysis based on fundamental conservation properties of mass and energy, also examines how the equations describing these conservation laws can be applied. “Application of Mass and Energy Balance Regularities in Fermentation”. It covers the Mass–energy balance equations are developed which relate the biomass energetic yield coefficient to sets of variables which may be determined experimentally.[1-3]

PDEs exhibit unique chemical properties due to the electron-withdrawing nature of the ester groups, which enhance the reactivity of the pyridine ring towards nucleophilic substitution reactions. This characteristic allows for the efficient introduction of different substituents, facilitating the synthesis of diverse chemical compounds. PDEs are typically synthesized through esterification reactions involving pyridine dicarboxylate acids and alcohols in the presence of acid catalysts. Additionally, various synthetic routes have been explored to enhance the yield and selectivity of PDE formation, including the use of novel catalysts and optimized reaction conditions.[2]

One of the most prominent applications of PDEs is in the pharmaceutical industry, particularly in the synthesis of statins. Statins, such as atorvastatin, are critical medications used to lower cholesterol levels and prevent cardiovascular diseases. The synthesis of atorvastatin involves several complex steps, with PDEs playing a crucial role as intermediates. The ester groups in PDEs facilitate subsequent reactions, such as hydrolysis, cyclization, and functional group modifications, which are essential for constructing the final drug molecule. The versatility of PDEs in drug synthesis highlights their importance in developing effective treatments for various health conditions.[5-6]

Recent advancements in the synthesis and application of PDEs have focused on improving the efficiency, selectivity, and sustainability of their production processes. Researchers have explored various catalysts, including biocatalysts and metal-organic frameworks, to enhance the yield and reduce the environmental impact of PDE synthesis. Additionally, innovations in green chemistry have led to the development of more sustainable methods for producing PDEs, aligning with the global shift towards environmentally friendly chemical processes.[7]

The study of "Assessing mass balance in pharmaceutical drug products". It covers the various methods by which mass balance can and should be measured, expressed, and evaluated in conjunction with degradation chemistry. "Analytical Aspects For Determination Of Mass Balances". It covers information around what is required to ensure that the data that are produced, be it by an analyst or engineer, is of the highest quality needed for a particular study. Details about what each analytical technique is tracking and what are its limitations, common mistakes that may confound analytical results, and coupling analytical methods to overcome these limitations are covered. The study of "Mass and Energy Balance Modelling of a Sugar Mill". It covers the integrated processes to identify the optimal set of products and the best route for producing them and the approach adopted at SMRI is a case study modelling of pre-selected plant configurations involving mass and energy balances of individual units constituting the bio-refinery.[8-10]

# CHAPTER 3: COMPANY PROFILE

Established in 1901 in Jerusalem, Teva has its global headquarters based in Israel. With a vast portfolio comprising over 3,500 medications, the company produces more than 85 billion pills and capsules across multiple production sites spanning over 30 countries. Initially, the company, originally named Salomon, Levin, and Elstein Ltd. after its chemist founders, relied on mule trains and camel caravans to distribute imported medications locally. Over time, Teva's growth was fueled by rising demand for regionally manufactured drugs. In 1976, the company rebranded as Teva Pharmaceutical Industries Ltd., reflecting its commitment to nature. Despite its expansion, Teva maintains a steadfast dedication to its origins, with its people and culture shaping its leadership position today. Throughout its history, Teva's leadership has been marked by resilience, entrepreneurialism, and a commitment to improving people's lives. Through strategic acquisitions, Teva has significantly expanded its global presence, broadening its expertise across various therapeutic areas, markets, and both patented and generic medicines. As a leading provider of specialty and generic drugs, Teva now ranks among the top 15 pharmaceutical companies worldwide.

## 3.1 Products

Teva API produces approximately 400 active pharmaceutical ingredients, covering a wide range of therapeutic areas such as respiratory, cardiovascular, dermatological, hormonal, antiinflammatory, and oncology treatments, as well as muscle relaxants and immunosuppressants. The API portfolio includes over 1,200 patents and pending applications globally. Teva API operates in fifteen locations worldwide, including Israel, Hungary, Italy, the United States, and India. It specializes in various industrial technologies, including chemical synthesis, plant extract technologies, semi-synthetic fermentation, enzymatic synthesis, and high potency production. Additionally, Teva API ensures compliance with current Good Manufacturing Practices (cGMP) regulations and other quality standards. As a distinct business unit within Teva Pharmaceutical Industries, one of the world's largest generic drug manufacturers, Teva API has a rich history dating back to 1935. It has expanded its manufacturing and development capabilities globally, ensuring adherence to the company's stringent quality standards through comprehensive integration programs for each facility. 8 Currently, Teva API runs 15 production plants and 6 research and development centers worldwide. Each of these establishments plays a vital role in advancing their excellence in research, development, manufacturing, and customer service. In India, Teva operates three toptier manufacturing facilities located in Gajraula (Uttar Pradesh), Malanpur (Madhya Pradesh), and Ambernath (Maharashtra). In the district of Malanpur, Bhind, Madhya Pradesh, Teva operates a facility dedicated to manufacturing various types of active pharmaceutical ingredients (APIs), with products designed to target specific therapeutic needs:

1. Chronic Disease
2. Asthama
3. Hypertension/ Depression/Feeling Sadness
4. Bipolar disorder
5. Kidney
6. Lowering blood Cholesterol

**Vision**

In a field that always evolving, We want to be a leader and a symbol of quality.

**Mission**

The goal of Teva is to improve patients lives by being a world leader in biopharmaceuticals and generics. Everything we do has a purpose because of it, and it is what it is motivates us to go to work every morning.

# CHAPTER 4: PROBLEM FORMULATION

Mass and energy balance are fundamental principles in chemical engineering that play a critical role in the design, analysis, and optimization of chemical processes. mass and energy balances are essential tools in chemical engineering that support the efficient, safe, and sustainable design and operation of chemical processes. They are integral to achieving economic efficiency, regulatory compliance, and innovation within the industry.

**Problem:**

Perform an overall mass balance and energy balance on the PDE. Also mention every equipment and process involved in the process for the proper understanding of the mass and energy balance.

# CHAPTER 5: METHODOLOGY

The manufacturing typically employs batch processing, a method where a specific amount of raw materials undergoes processing in a single batch. The objective is to develop a thorough mass and energy balance for the batch production of ODES. This involves identifying inputs, outputs, and any accumulations that occur during the process, as well as assessing energy needs to enhance process efficiency.

## 5.1 Objectives

**Determine the Mass Balance:** Establish a detailed mass balance for the batch production of PDEs, considering all reactants, products, and by-products.

**Analyze the Energy Balance:** Calculate the energy inputs and outputs for each stage of the batch process, including heating, cooling.

## 5.2 Assumptions

1. Steady-state operation.
2. Ideal mixing in reactors.
3. Negligible heat losses to the environment.
4. Constant specific heat capacities for simplicity.
5. The reactor operates under isothermal.

## 5.3 Mass Balance Equation

For each component in the reactor, the mass balance equation can be written as:

Input – Output + Generation – Consumption = Accumulation

For steady state, Accumulation term = 0

No generation and consumption is taking place in the reaction so these terms are = 0

Now the final Balance is,

Input = Output

## 5.4 Energy Balance Equations

The general energy balance equation for the batch reactor system is:

$$Q = m^* C_p^* \Delta T$$

Performing a detailed mass and energy balance on the batch production of PDE is essential for optimizing the process. This formulation provides a systematic approach to analyze and optimize the batch production, ensuring high yield, energy efficiency, and minimal environmental impact.

## 5.5 Equipments for process reaction batch reactor

A batch reactor is a straightforward type of vessel used in chemical and industrial processes. It consists of a tank where chemical reactions take place, typically equipped with an agitator and internal heating or cooling systems. The sizes of batch reactors range from one liter to 15,000 liters. Batch reactors find applications in various industries, including steel, stainless steel, glass, and exotic alloy production. The liquids or solids involved in the process are introduced into the batch reactor through connections in the top cover. Any generated vapors or gases are released through similar connections. At the bottom of the reactor, there are discharge outlets for draining residual liquids after the completion of the chemical reactions. One of the primary advantages of a batch reactor is its versatility. Multiple operations can be performed in a single vessel without the need to break containment, which is particularly useful when handling toxic or highly potent compounds. Typically, a batch reactor employs a centrally mounted driveshaft with an overhead drive unit and impeller blades mounted on the shaft. The blade designs can vary, covering approximately two-thirds of the reactor's diameter. Baffles, which are stationary blades, are also commonly used to disrupt the flow caused by the rotating agitator. These baffles can be attached to the vessel cover or placed on the interior side walls.

Advantages of batch reactors include:

- Uniform composition throughout the reactor.
- Non steady state operation is common
- They are most cost effective in terms of instrumentation and construction compared to continuous reactors.

Disadvantages of batch reactors include :

- Tight temperature control is required for highly heat sensitive reactions.
- The quality of each batch may vary.

They consume significant resources.

## 5.6 Types of Agitators used in Process

- **i.** Paddle
- **ii.** Anchor
- **iii.** Propeller
- **iv.** Turbine

**i) Paddle Agitator** - It consists of two flat paddle-shaped impeller blades extending to reach the tank walls. It is used if no extensive axial and radial flow is required. These impellers can produce a laminar low shear flow and are used for low viscosity liquid mixing, crystallization, dissolution, and heat transfer. It is typically operated at low speeds and dominantly gives a tangential flow pattern.

Fig.1: Pictorial figure of Paddle Agitator

Source: Tradeindia

**ii) Anchor Agitator** - They have impellers having the shape of an anchor. They typically have a U-shape which matches the shape of the tank. They generate a dominant tangential flow pattern.

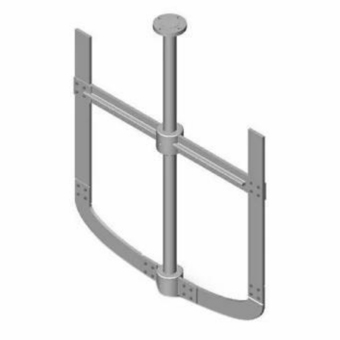


Fig.2: Pictorial figure of Anchor Agitator

Source: Indiamart

**iii) Propeller Agitator** - An axial-flow, high-speed impeller for low-viscosity liquids is called a propeller. Propellers of different sizes rotate at different motor speeds: 1150 r/min for small propellers and 400–800 r/min for bigger propellers. The liquid flow currents exiting the impeller follow a certain path until they are redirected by the vessel's wall or floor. Static liquid is entrained as it goes along by the extremely turbulent swirling column of liquid exiting the impeller, most likely much more than an identical column from a stationary nozzle would. The liquid is forcefully chopped or sheared by the propeller blades. Larger vessels might benefit from propeller agitators due to the continuous flow currents.

Fig.3: Pictorial figure of Propeller Agitator

Source: Agitec

**iv) Turbine Agitator** - Turbine agitators are used for mixing liquids in containers or tanks. They consist of a turbine instead of a propeller that rotates in the liquid at high speed and generates currents and turbulence thanks to nozzles that promote homogeneous mixing of the components.

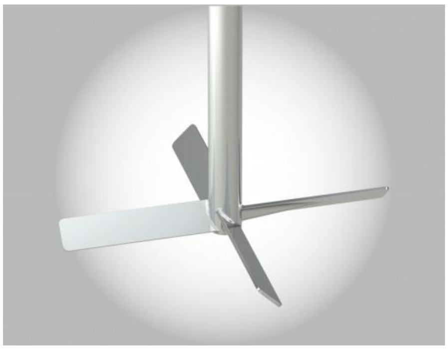


Fig.4: Pictorial figure of Turbine Agitator

Source: Agitec

**5.6.1 Purpose of Agitation:** Liquids are agitated for a number of purposes, depending on the objectives of the processing step. These purposes include

1. Suspending solid particles
2. Blending miscible liquids, e.g., methyl alcohol and water
3. Dispersing a gas through the liquid in the form of small bubbles
4. Dispersing a second liquid, immiscible with the first, to form an emulsion or suspension of fine drops
5. Promoting heat transfer between the liquid and a coil or jacket

### 5.6.2 Agitation Equipment

Liquids are oftenly agitated in a tank without sharp edges having a round bottom. The top of the tank is mostly closed. The proportions of the tank may vary accordingly. The liquid depth is genrally equals to the diameter of tank. Tank has no bottom sharp edges so that liquid current would not penetrate into the edges. An impeller is mounted on an overhung shaft, the shaft is connected to the motor, many times the shaft is connected to gearbox in order to alter the speed. Accessories such as inlet, outlet lines, coils, jackets, wells for thermometer or other temperature measuring device are usually included.

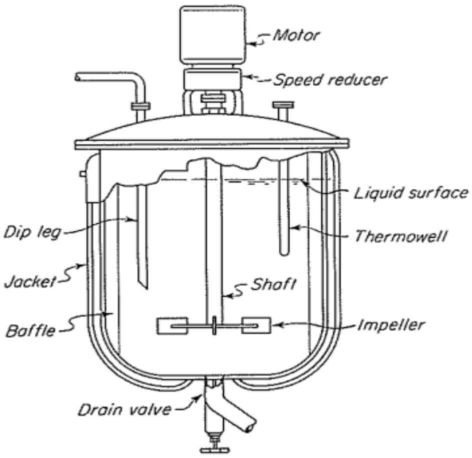


Fig.5: Pictorial figure of Agitation Process Vessel

Source : Unit Operations of Chemical Engineering McCabe and Smith

Agitators can handle various types of media, including liquids, gases, and solids (such as granules and powders). They are capable of working with slurries, suspensions, and highly viscous liquids. However, selecting the right agitator type, size, and design is critical, considering factors such as viscosity and sensitivity to shear stress. Agitators find widespread use in industries such as food and beverage, pharmaceutical, agricultural, biotechnology, paint, and water treatment.

### 5.7 Equipment for Filtration in this process

**Candle Filter –** The purpose of candle filters is to remove particles and contaminants from pharmaceutical preparations. These particles can include residues, microorganisms and other impurities that can compromise the quality and safety of the final product. The pore size of filter cartridges is measured in microns for effective removal of bacteria and other microorganisms from liquids. The smaller the micron rating, the finer the particles are removed. Candle filters provide thin cake pressure filtration, cake washing, drying, resuspension and automatic discharge as well as heel filtration in a closed pressure vessel.

**Working principle of candle filter** : The candles are covered with a porous filter media such as fabric or metal mesh that traps solid particles and allows the clear liquid or gas to escape through the hollow core of the candles. The filtered liquid or gas is then collected and discharged from the filter vessel.

Fig.6: Pictorial Figure of Candle Filter

Source : Sharplex.com

### 5.7.1 Filtration

Filtration is the removal of solids from a fluid by passing the fluid through a filter medium or septum on which the solids are deposited. The fluid is liquid and the valuable stream from the filter can be liquid or solid depending on the process requirement.

Liquid flows through the filter medium due to the pressure difference across the medium. Filters are therefore also divided into filters that operate with pressure above atmospheric pressure on the inlet side of the filter medium, and filters that operate with atmospheric pressure on the upstream side and negative pressure on the downstream side. Pressures greater than atmospheric can be developed by gravity acting on a column of liquid, by a pump or blower, or by centrifugal force. Most industrial filters are pressure filters, vacuum filters and centrifugal filters.

### 5.7.2 Principle of Filtration

Filtration is a special example of flow through a porous medium. In filtration, flow resistances increase with time as the filter media becomes clogged or a filter cake forms. The main quantities of interest are the flow through the filter and the pressure drop in the unit. Over time during filtration, either the flow rate decreases or the pressure drop increases. In what is called constant pressure filtration, the pressure drop is kept constant and the flow rate decreases with time; less commonly, the pressure loss is gradually increased, which is called constant rate filtration.

During cake filtration, the liquid passes through two resistances in series: the resistance of the cake and the resistance of the filter media. The resistance of the filter media, which is the only resistance in clarifying filters, is normally only important during the early stages of cake filtration. The resistance of the cake is zero at the beginning and increases as the filtration progresses. If the cake is washed after filtration, both resistances are constant during the wash period and the resistance of the filter medium is usually negligible.

The overall pressure drop at any time is the sum of the pressure drops over medium and cake. If $p_a$ the inlet pressure, $p_b$ the outlet pressure, and p' the pressure at the boundary between cake and medium,

$$\Delta p = p_a - p_b = (p_a - p') + (p' - p_b) = \Delta p_c + \Delta p_m$$

where $\Delta p$ = overall pressure drop

$\Delta p_c$ = pressure drop over cake

$\Delta p_m$ = pressure drop over medium

Pressure drop through filter cake:

A general equation named Ergun equation employed to calculate the pressure drop across the packed bed for all flow conditions, The Ergun equation combines both the laminar and turbulent components of the pressure loss across a packed bed.

Given as,

$$\frac{\Delta p}{L} = \frac{150\,\mu v(1-\varepsilon^2\ )}{\varphi^2 Dp^2 \epsilon^3} + \frac{1.75\rho v^2\,(1-\epsilon)}{\varphi \epsilon^3 Dp}$$

$\Delta p$ = Pressure drop

$L$ = Length of bed

$\mu$ = Fluid viscosity

$\epsilon$ = Porosity

$Dp$ = Particle diameter

$v$ = Superficial velocity

$\rho$ = Density of Fluid

## 5.8 Utilities

- Steam
- Chilled Water
- Chilled Brine
- Hot Water
- Hot oils
- Nitrogen
- Air

These utilities are used based on the process requirements.

## 5.9 Process Flow Diagram of PDE

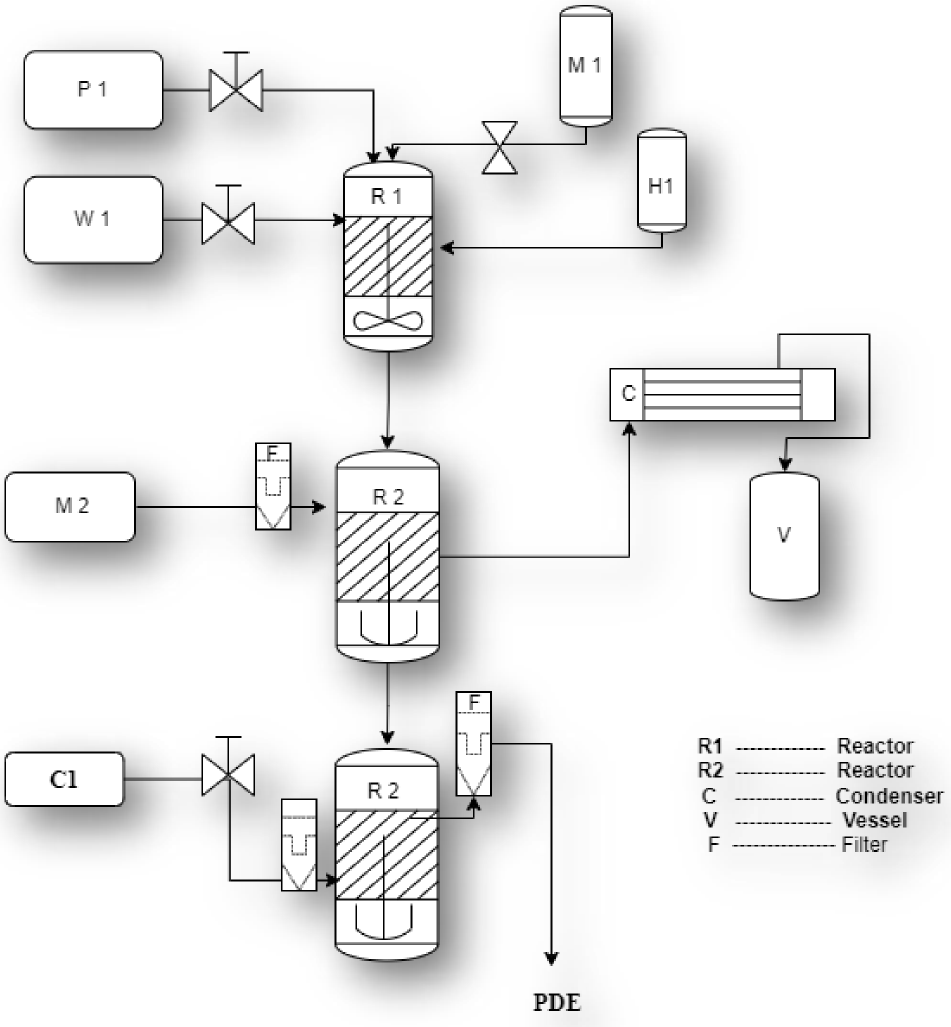


Fig.7: Pictorial figure of Process Flow Diagram

## 5.10 Manufacturing process of PDE

- Process starts with solution preparation.
- Key raw material P-1 charge through powder transfer system (PTS).
- Now, adding 1938 L M1 and 12.4 l HC in R-0208 with 372 L water in R-1.
- Agitate about 80-90 rpm.
- Temperature range 37°- 43°C with continuous mixing.
- Cool down the prepared solution.
- Transfer the solution to R-2 and 1008L M-1 is adding for distillation.
- Distillation process takes upto 9-12 hrs.
- Sample checking stage.
- Unreacted P-1 should not more than 1%.
- Now 19.375 kg of NH is added for PDE reaction at a temperature of 7-17°C.
- After PDE reaction again sample checking.
- P-1 should not more than 0.1 %.
- Intermediate formed for further Processes.
- Overall yield is 0.98

The total mass after the reaction was recorded as 2547.2 kg, which includes all reactants, solvents, and by-products. The initial 155 kg of raw material indicates the significant mass contribution from other components added during the process, such as solvents and reagents. We have the yield of PDE which is 0.9876 (0.99 approx.), by this yield we can find out the final PDE mass.

To calculate the amount of pyridine dicarboxylate ester (PDE) obtained from 155 kg of raw material (PAE) with a yield of 0.98 (98%), we use the formula:

**Mass of PDE obtained** = Yield × Mass of raw material

**Mass of PDE obtained** = 0.98 × 155 = 151.9 kg.

Thus, with a 98% yield, 151.9 kg of PDE is obtained from 155 kg of PAE. This high yield indicates an efficient production process, minimizing waste and ensuring that nearly all of the raw material is converted into the desired product. This efficiency is crucial for both economic and environmental reasons, as it maximizes the use of raw materials and reduces the need for additional resources and waste management.

Now, coming to the Energy balance, the energy balance calculation for the process indicates that the net energy required is 44763.844 J/kg $^{0}$C. This value represents the total energy input needed to drive the entire process, accounting for all energy sources, sinks, and losses.

# CHAPTER 7: CONCLUSION

In conclusion, the concepts of mass balance and energy balance play fundamental roles in various fields, including engineering, environmental science, and chemistry. Mass balance involves the accounting of mass entering and leaving a system, ensuring that what goes in equals what comes out. It's crucial for understanding processes like chemical reactions, pollution dispersion, and material flows in industrial operations. Similarly, energy balance focuses on tracking the energy entering and exiting a system, vital for evaluating efficiency, heat transfer, and overall system performance. Both balances serve as foundational tools for analyzing and optimizing processes, ensuring sustainability, and minimizing environmental impacts. Through diligent application of mass and energy balance principles, industries can improve resource utilization, reduce waste generation, and enhance overall efficiency. Moreover, these balances provide valuable insights into system behavior, aiding in the design of more efficient processes and the development of innovative technologies. The mass balance analysis of PDE API manufacturing has provided valuable insights into material flows, process efficiency, and areas for improvement. By addressing the identified inefficiencies and adopting advanced technologies, the production process can be optimized to achieve higher yields, reduced costs, and enhanced sustainability, ultimately contributing to better healthcare outcomes. A detailed mass and energy balance analysis for pyridine dicarboxylate ester production will provide insights into process efficiencies, areas for improvement, and potential cost savings. This comprehensive approach is essential for enhancing the overall sustainability and profitability of the pharmaceutical manufacturing process.

# CHAPTER 8: PROJECT OUTCOMES & SOCIETAL RELEVANCE

## 8.1 Achieved Outcomes

**1.** Methods and techniques for Safety measures used in the industry.

**2.** Identified the strategies to reduce the emissions and effluents from the process.

**3.** Conducting mass and energy balance, ensured that the production process met all relevant regulatory standards.

**4.** Identified key areas where energy consumption and material use could be reduced.

**5.** Overall mass balance yield enhancement of PDE.

**6.** By optimizing both mass and energy balances, the project achieved considerable cost savings.

**7.** Product yield calculation by mass balancing.

## 8.2 Societal relevance

**1.** The mass and energy balance optimization in the production of pyridine dicarboxylate esters (PDEs) has numerous benefits for society, significantly contributing to sustainability, economic efficiency, and environmental protection.

**2.** By maximizing yields and minimizing waste, the optimized mass balance ensures that raw materials are used more efficiently, reducing the consumption of non-renewable resources and lowering production costs.

**3.** The application of mass balance analysis in pharmaceutical production plays a crucial role in advancing healthcare outcomes, promoting patient safety, and fostering a sustainable society.

# REFERENCES

**1.** David Pritchard and Shaik Feroz, “Mass and Energy Balancing Calculations for Plant Design”, 2021; DOI:10.1201/9781003149200; ISBN: 9781003149200.

**2.** Feringa, B. L., et al. "Functionalized Pyridine Dicarboxylate Esters: Synthesis and Application in Complex Organic Molecules." Chemical Reviews, 2018. DOI: 10.1021/acs.chemrev.7b00567.

**3.** Nuggenhalli S. Nandagopal, “Mass and Energy Balances”, 2023; doi.org/10.1007/978-3-031-27879-2_1; ISBN 978-3-031-27879-2; pp 1–80.

**4.** Rizvi, S.S.H., “Mass and Energy Balances in Food Engineering Principles and Practices” 2024; doi.org/10.1007/978-3-031-34123-6_4; ISBN 978-3-031-34123-6; pp 153–180.

**5.** Klein, A., et al. "Pyridine-2,6-Dicarboxylate Acid Esters (pydicR2) as O,N,O-Pincer Ligands in CuII Complexes." Inorganics, 2019. DOI: 10.3390/inorganics7040053.

**6.** Yamada, T., et al. "Pyridine Dicarboxylate Esters as Building Blocks in the Design of Metal-Organic Frameworks." Journal of Materials Chemistry A, 2020. DOI: 10.1039/D0TA01536H.

**7.** Mukhopadhyay, S. "Pyridine-2,6-dicarboxylate esters in the synthesis of pharmaceutical intermediates." Journal of Organic Chemistry, 2015. DOI: 10.1021/acs.joc.5b01123.

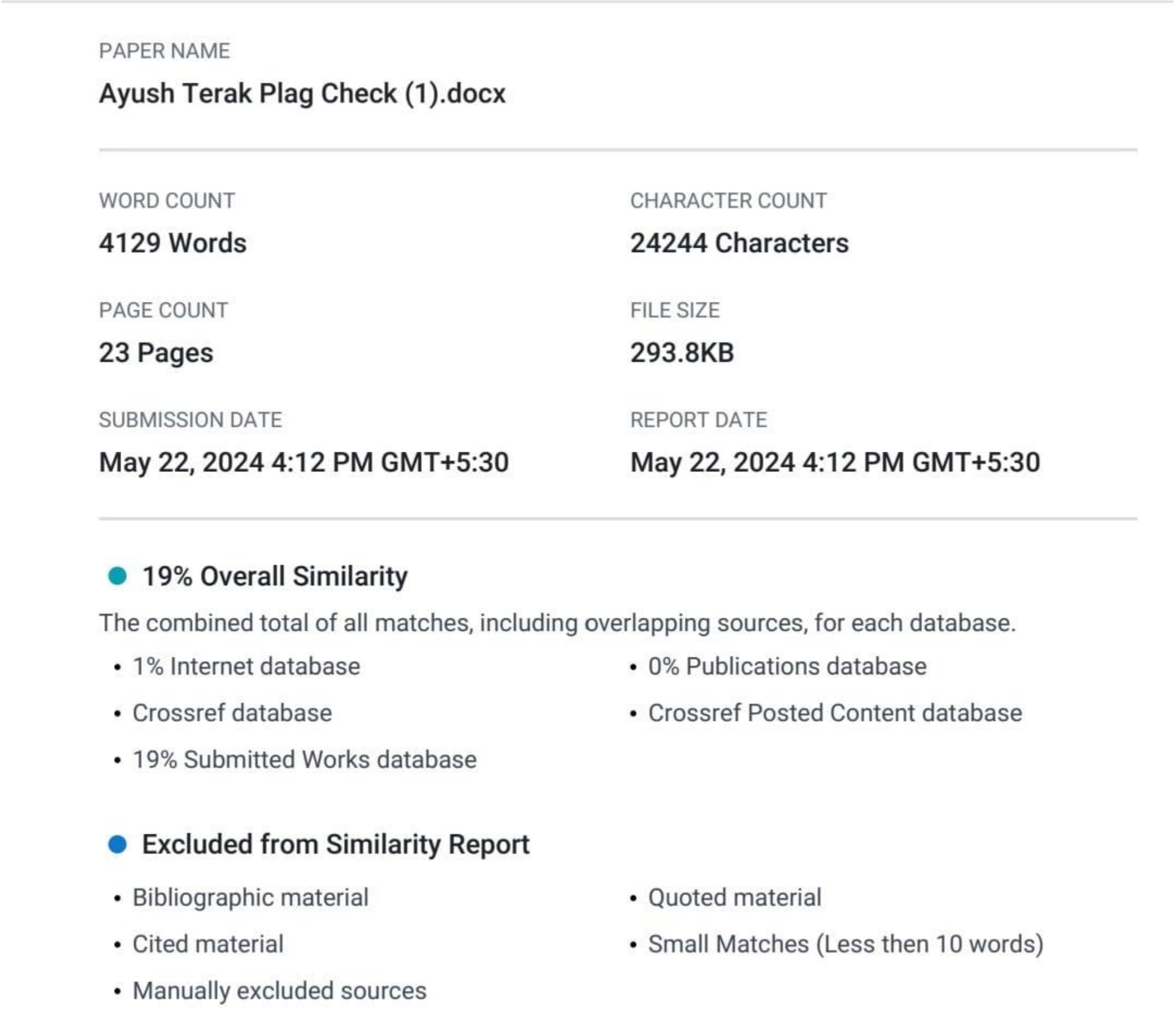
**8.** Yamada, T., et al. "Pyridine Dicarboxylate Esters as Building Blocks in the Design of Metal-Organic Frameworks." Journal of Materials Chemistry A, 2020. DOI: 10.1039/D0TA01536H.

**9.** "TEVA PHARMACEUTICAL INDUSTRIES LIMITED Reports Search Israeli Companies" www.israelbizreg.com. Retrieved October 19, 2016. Leading International API Supplier | Teva api (teva-api.com)

**10.** Tanaka, K., et al. "Green Chemistry Approaches for the Synthesis of Pyridine Dicarboxylate Esters." Green Chemistry, 2017. DOI: 10.1039/C7GC01527A.

**11.** McCabe, W. L., Smith, J. C., & Harriott, P. (2005). Unit Operations of Chemical Engineering (7th ed.). McGraw-Hill Education.

# TURNITIN PLAGIARISM REPORT



PAPER NAME

**Ayush Terak Plag Check (1).docx**

| | |
|---|---|
| WORD COUNT<br>**4129 Words** | CHARACTER COUNT<br>**24244 Characters** |
| PAGE COUNT<br>**23 Pages** | FILE SIZE<br>**293.8KB** |
| SUBMISSION DATE<br>**May 22, 2024 4:12 PM GMT+5:30** | REPORT DATE<br>**May 22, 2024 4:12 PM GMT+5:30** |

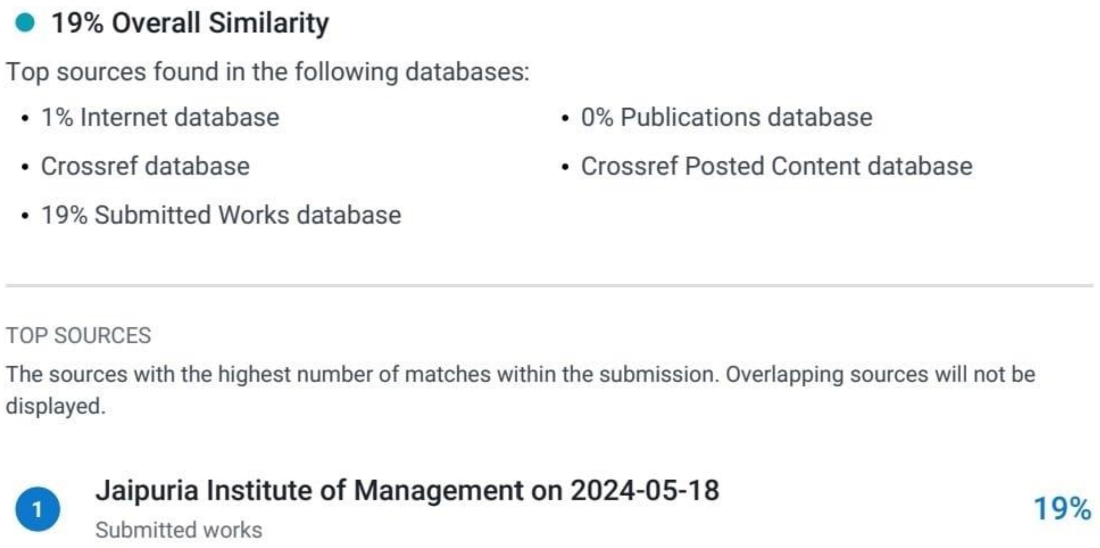
**19% Overall Similarity**

The combined total of all matches, including overlapping sources, for each database.

- 1% Internet database
- Crossref database
- 19% Submitted Works database
- 0% Publications database
- Crossref Posted Content database

**Excluded from Similarity Report**

- Bibliographic material
- Cited material
- Manually excluded sources
- Quoted material
- Small Matches (Less then 10 words)



● **19% Overall Similarity**

Top sources found in the following databases:

- 1% Internet database
- Crossref database
- 19% Submitted Works database
- 0% Publications database
- Crossref Posted Content database

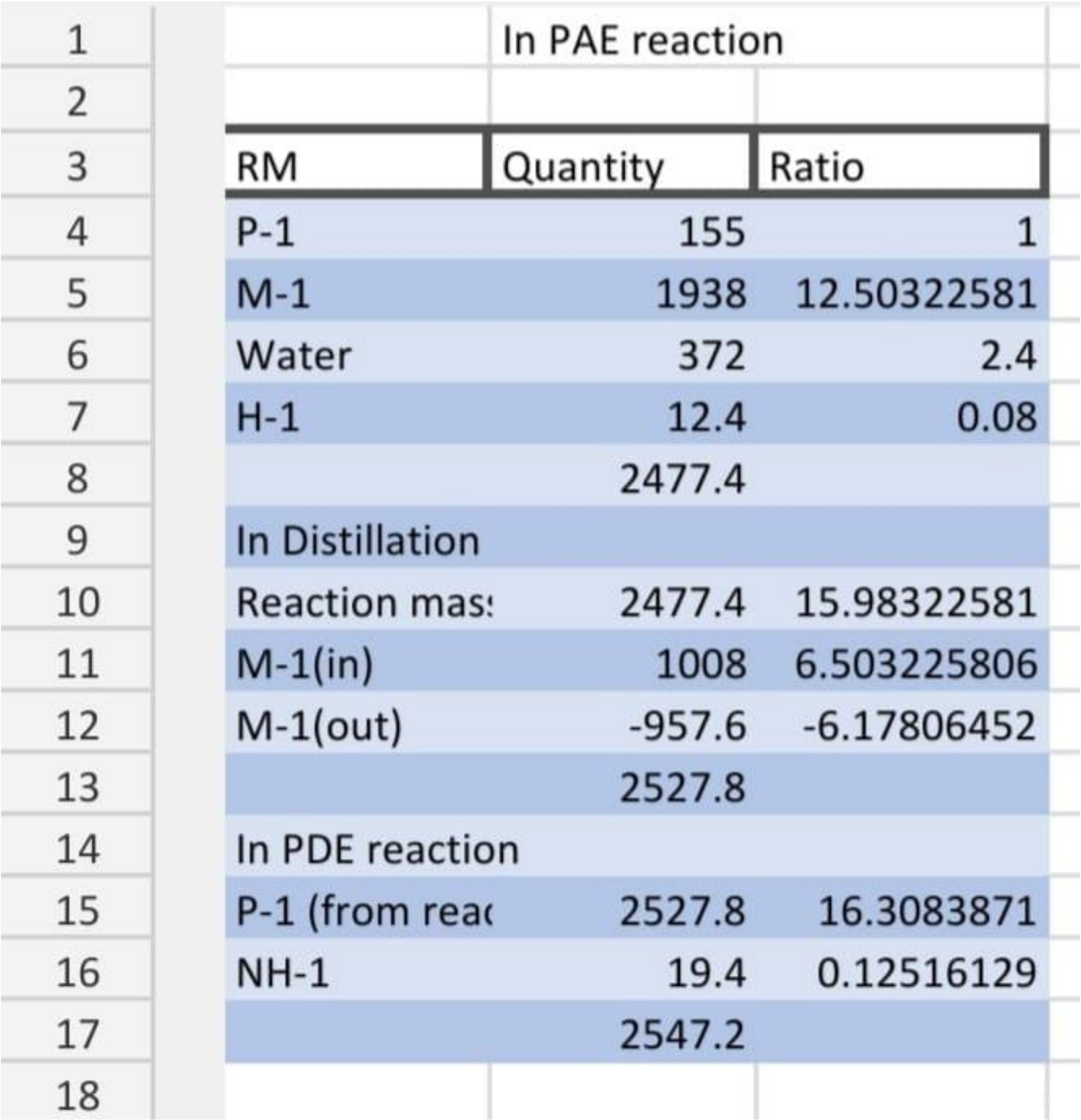
TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

| | | |
|---|---|---|
| 1 | **Jaipuria Institute of Management on 2024-05-18**<br>Submitted works | 19% |

# APPENDICES

## Appendix (A): Mass Balance Sheet



In PAE reaction

| RM | Quantity | Ratio |
|---|---|---|
| P-1 | 155 | 1 |
| M-1 | 1938 | 12.50322581 |
| Water | 372 | 2.4 |
| H-1 | 12.4 | 0.08 |
| | 2477.4 | |
| In Distillation | | |
| Reaction mass | 2477.4 | 15.98322581 |
| M-1(in) | 1008 | 6.503225806 |
| M-1(out) | -957.6 | -6.17806452 |
| | 2527.8 | |
| In PDE reaction | | |
| P-1 (from reac | 2527.8 | 16.3083871 |
| NH-1 | 19.4 | 0.12516129 |
| | 2547.2 | |

## Appendix (B): Energy Balance Sheet

ENERGY BALANCE:-

In PAE Reaction:-

| Componei | m | Cp | T | Energy |
|---|---|---|---|---|
| P-1 | 155 | 0.5 | 5.6 | 434 |
| M-1 | 372 | 1 | 5.6 | 2083.2 |
| Water | 1938 | 2.5 | 5.6 | 27132 |
| H-1 | 12.4 | 4.2 | 5.6 | 291.648 |
| | | | | 29940.848 J/kgC |

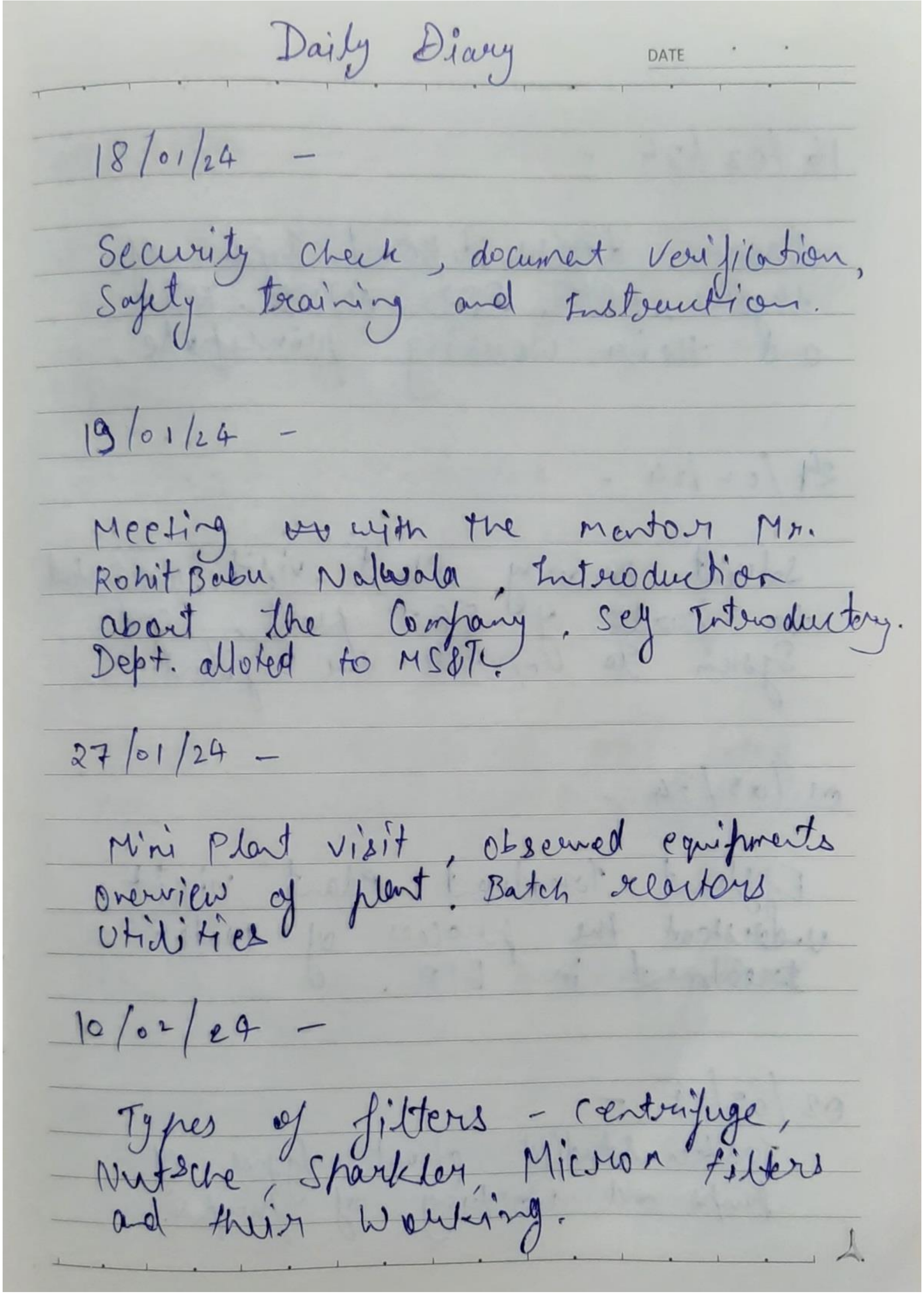
In  Distillation:-

| Componei | m | Cp | T | Energy |
|---|---|---|---|---|
| Reaction mas | 2477.4 | 0.5 | 3 | 3716.1 |
| M-1(in) | 1008 | 2.5 | 3 | 7560 |
| M-1(out) | -957.6 | 2.5 | 3 | -7182 |
| | | | | 4094.1 J/kgC |

In PDE reaction

| Componei | m | Cp | T | Energy |
|---|---|---|---|---|
| P-1(from reac | 2527.8 | 0.5 | 8 | 10111.2 |
| NH-1 | 19.4 | 3.98 | 8 | 617.696 |
| | | | | 10728.896 J/kgC |

**Appendix (C): Daily Diary**



Daily Diary

DATE

18/01/24 –

Security check, document verification, Safety training and Instruction.

19/01/24 –

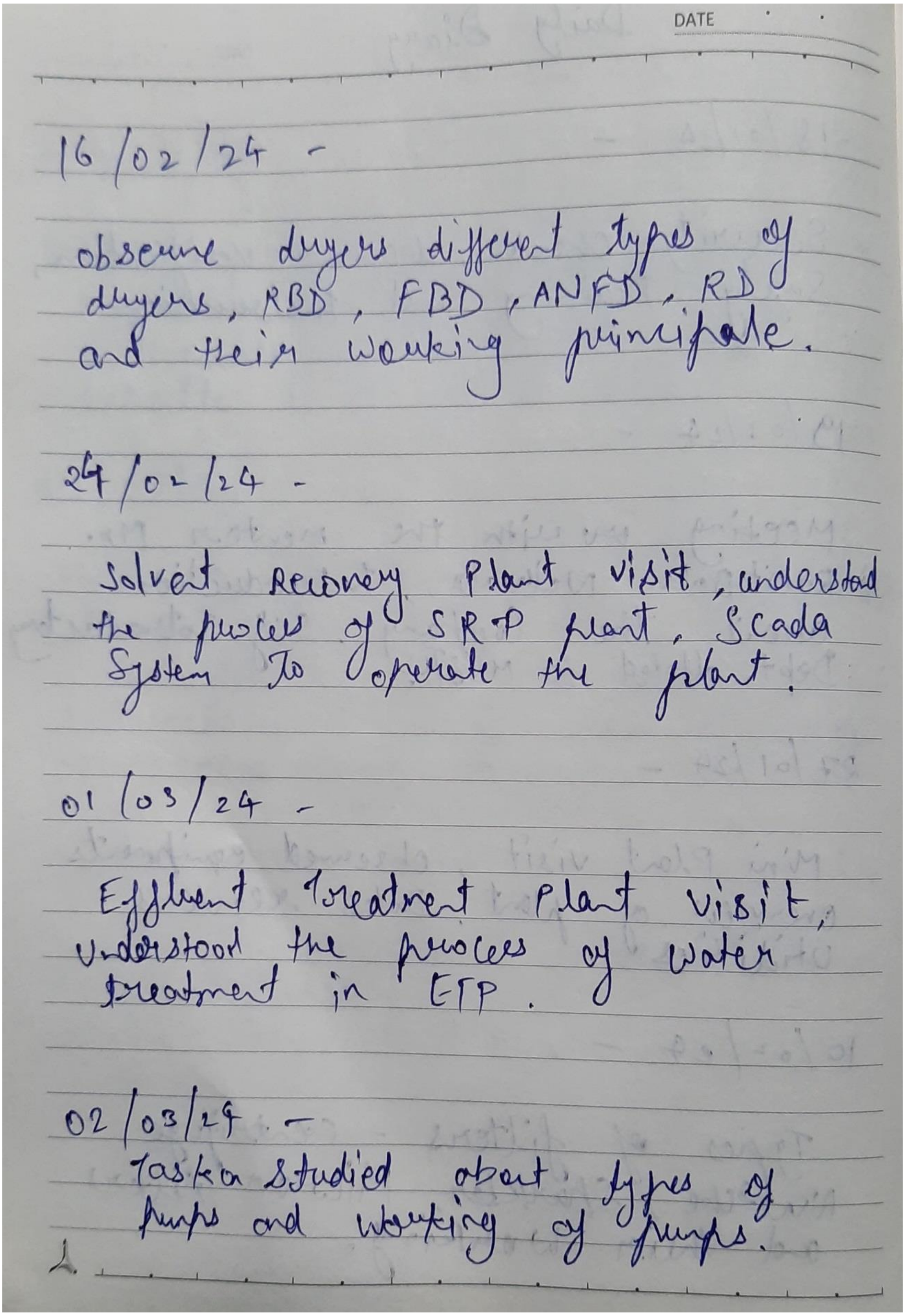
Meeting with the mentor Mr. Rohit Babu Nalawala, Introduction about the Company. self Introductory. Dept. alloted to MS&T.

27/01/24 –

Mini Plant visit, observed equipments overview of plant, Batch reactors Utilities

10/02/24 –

Types of filters - centrifuge, Nutsche, Sparkler, Micron filters and their working.



DATE

16/02/24 -

observe dryers different types of dryers, RBD, FBD, ANFD, RD and their working principale.

24/02/24 -

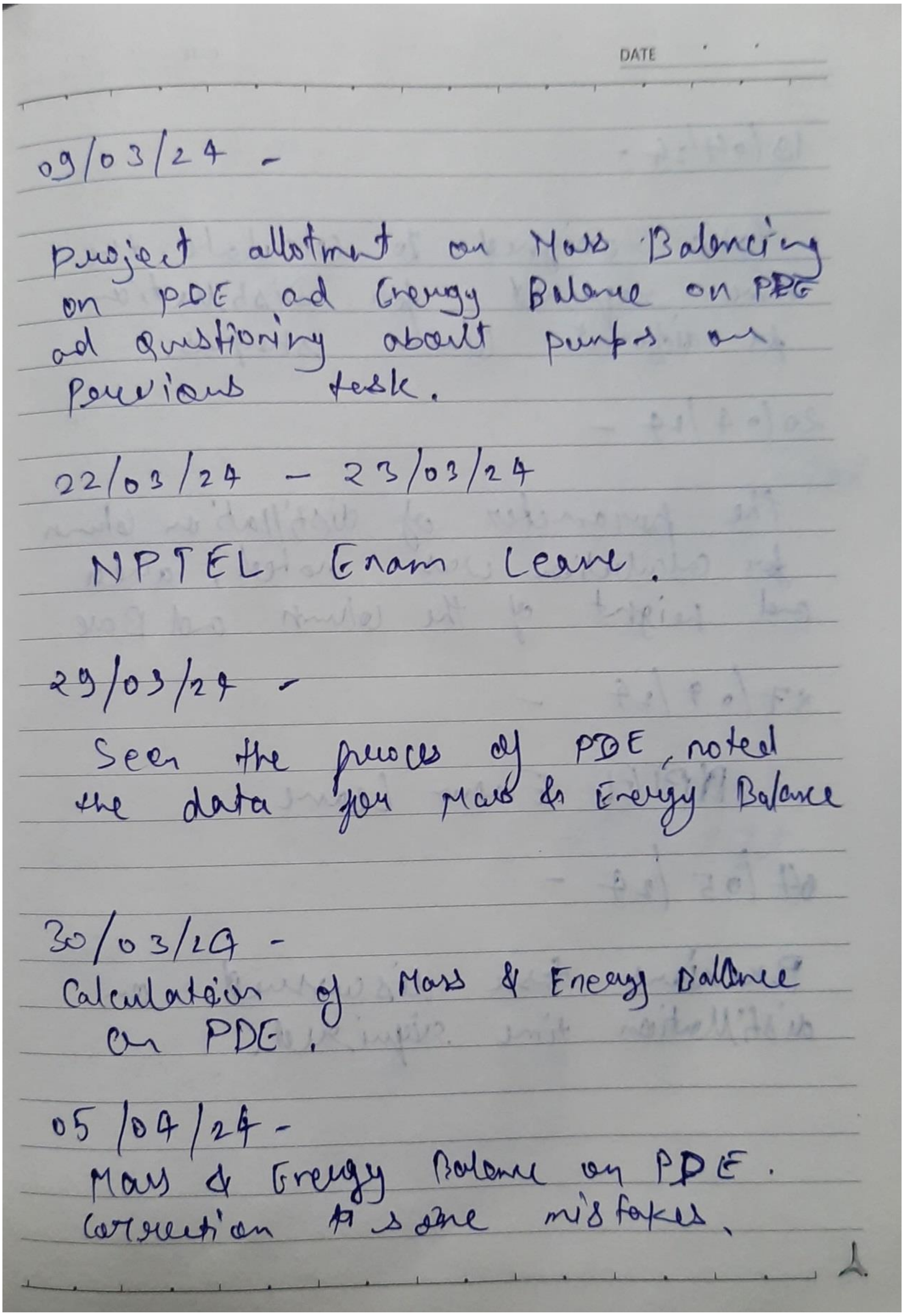
Solvent Recovery Plant visit, understand the process of SRP plant, Scada System To operate the plant.

01/03/24 -

Effluent Treatment Plant visit, understood the process of water treatment in ETP.

02/03/24 -

Task : Studied about types of pumps and working of pumps.



DATE

09/03/24 -

Project allotment on Mass Balancing on PDE and Energy Balance on PDE and questioning about pumps on previous task.

22/03/24 - 23/03/24

NPTEL Exam Leave.

29/03/24 -

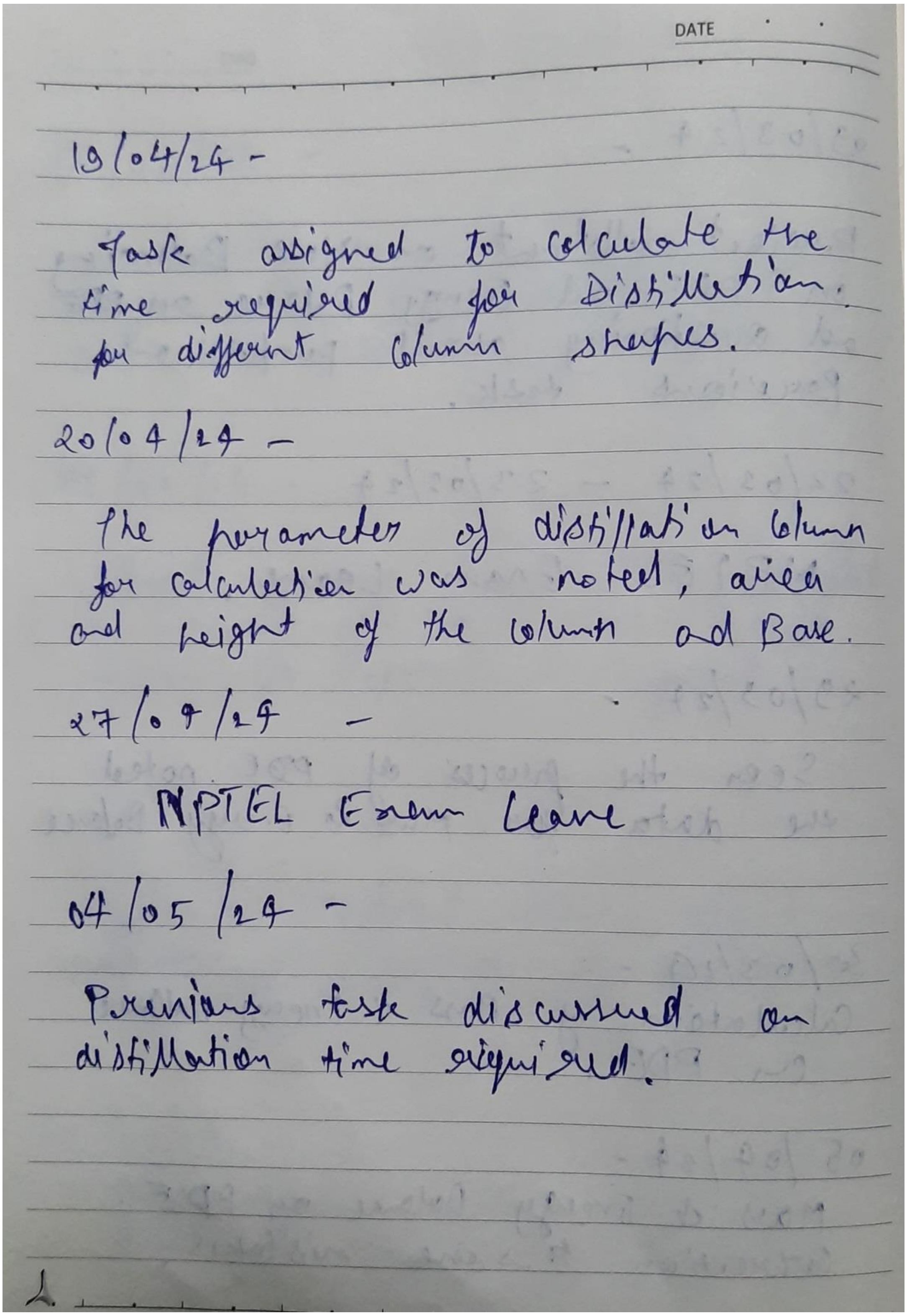
Seen the process of PDE, noted the data for Mass & Energy Balance

30/03/24 -

Calculation of Mass & Energy Balance on PDE.

05/04/24 -

Mass & Energy Balance on PDE. Correction to some mistakes.



DATE

19/04/24 -

Task assigned to calculate the time required for Distillation. for different column shapes.

20/04/24 -

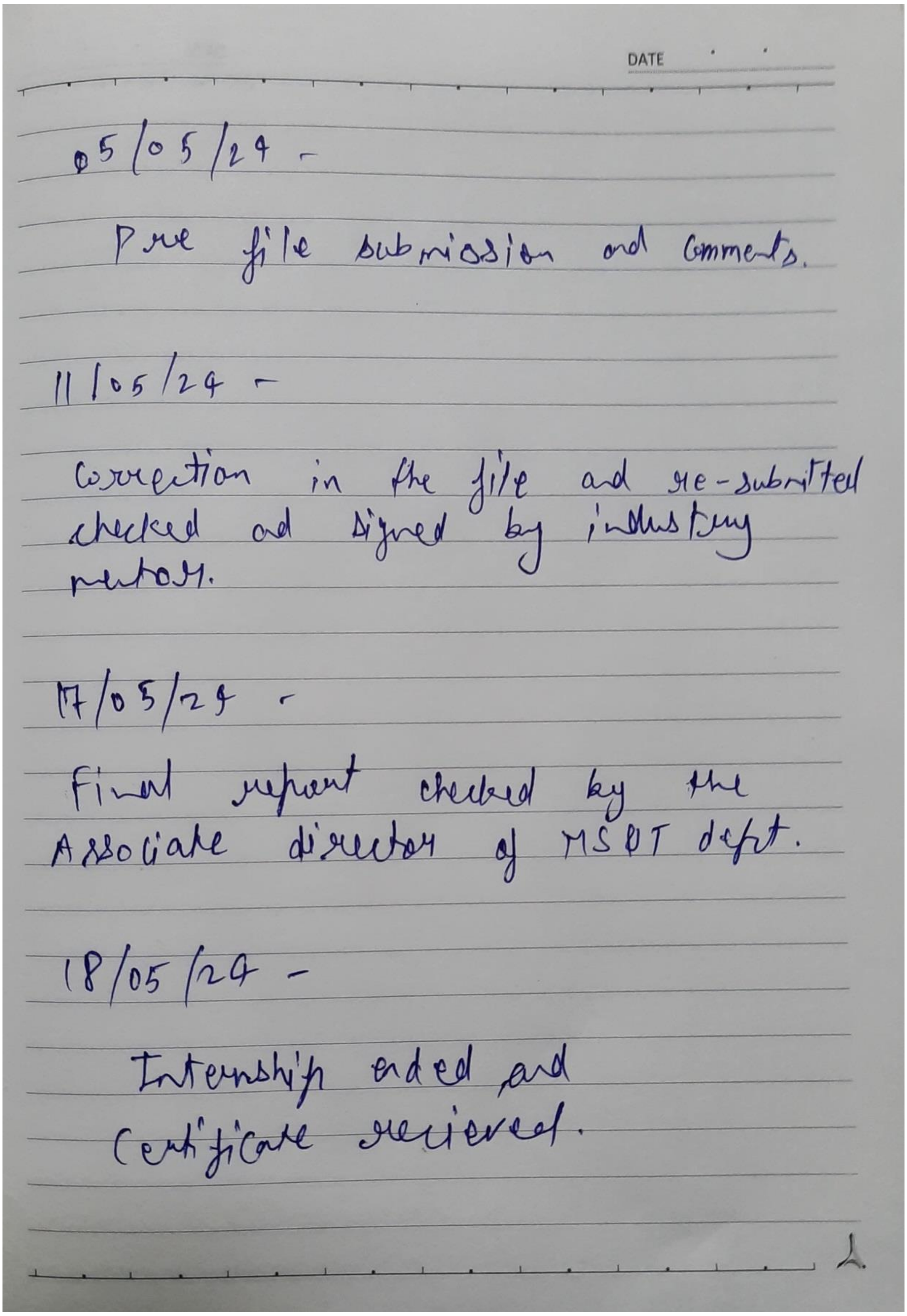
The parameter of distillation column for calculation was noted; area and height of the column and Base.

27/04/24 -

NPTEL Exam Leave

04/05/24 -

Previous task discussed on distillation time required.



DATE

05/05/24 -

Pre file submission and comments.

11/05/24 -

Correction in the file and re-submitted checked and signed by industry mentor.

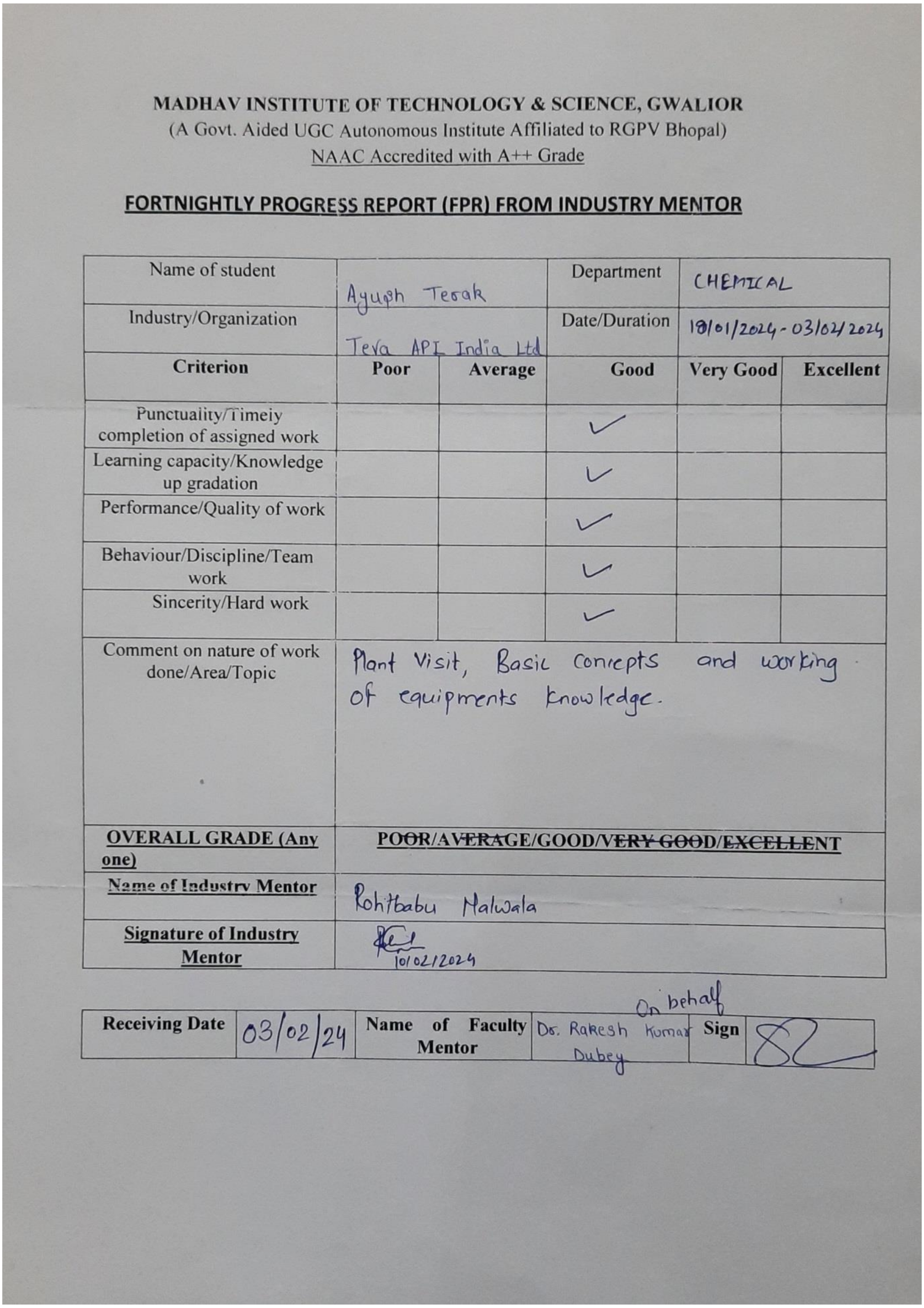
17/05/24 -

Final report checked by the Associate director of MSDT dept.

18/05/24 -

Internship ended and Certificate recieved.

## Appendix (D): FPRs

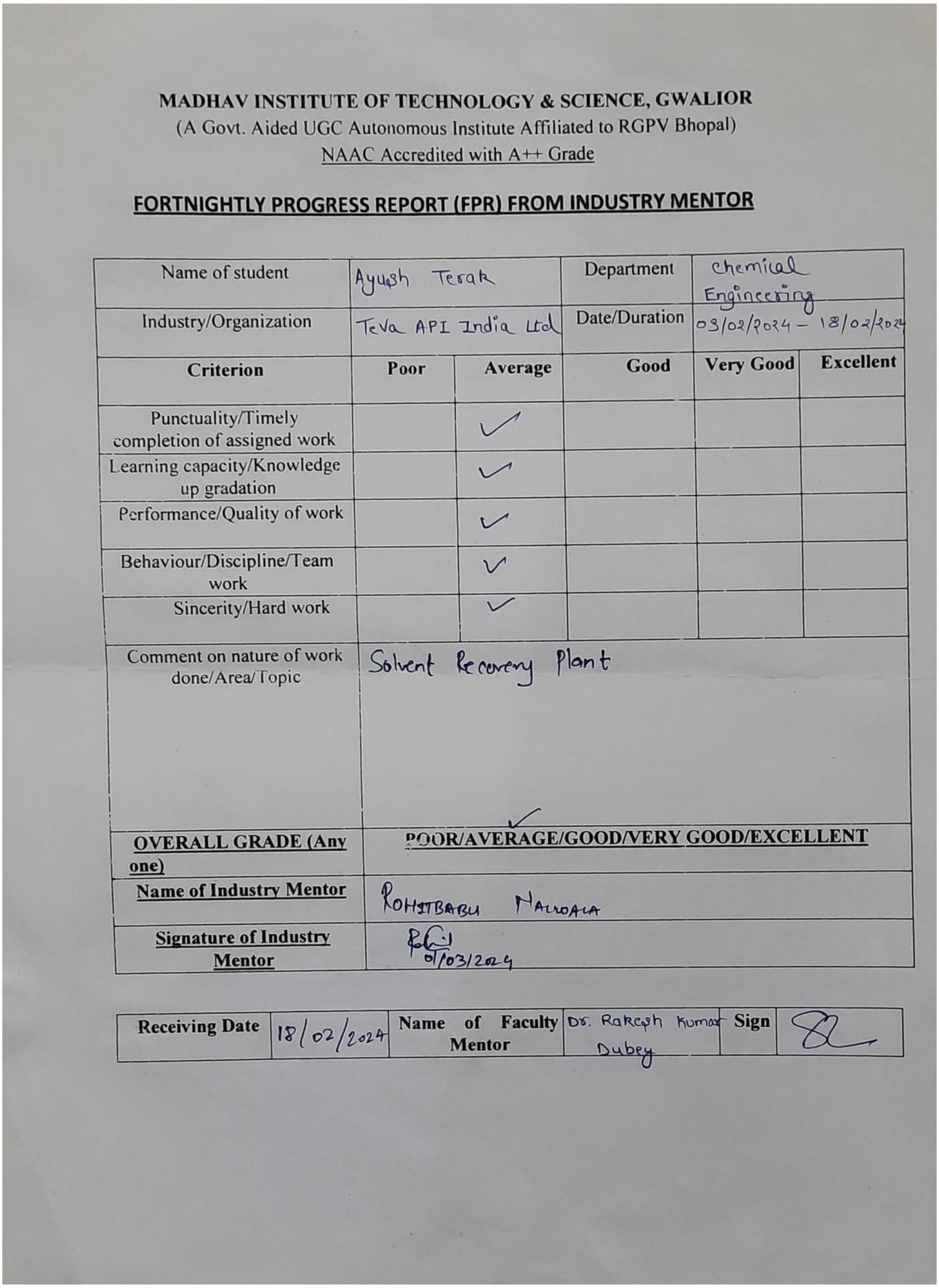


MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

**FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR**

| | | | | | |
|---|---|---|---|---|---|
| Name of student | Ayush Terak | | Department | CHEMICAL | |
| Industry/Organization | Teva API India Ltd | | Date/Duration | 18/01/2024 - 03/02/2024 | |
| **Criterion** | **Poor** | **Average** | **Good** | **Very Good** | **Excellent** |
| Punctuality/Timely completion of assigned work | | | ✓ | | |
| Learning capacity/Knowledge up gradation | | | ✓ | | |
| Performance/Quality of work | | | ✓ | | |
| Behaviour/Discipline/Team work | | | ✓ | | |
| Sincerity/Hard work | | | ✓ | | |
| Comment on nature of work done/Area/Topic | Plant Visit, Basic concepts and working of equipments knowledge. | | | | |
| **OVERALL GRADE (Any one)** | **~~POOR~~/~~AVERAGE~~/GOOD/~~VERY GOOD~~/~~EXCELLENT~~** | | | | |
| **Name of Industry Mentor** | Rohitbabu Malwala | | | | |
| **Signature of Industry Mentor** | 10/02/2024 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 03/02/24 | **Name of Faculty Mentor** | On behalf<br>Dr. Rakesh Kumar Dubey | **Sign** | |

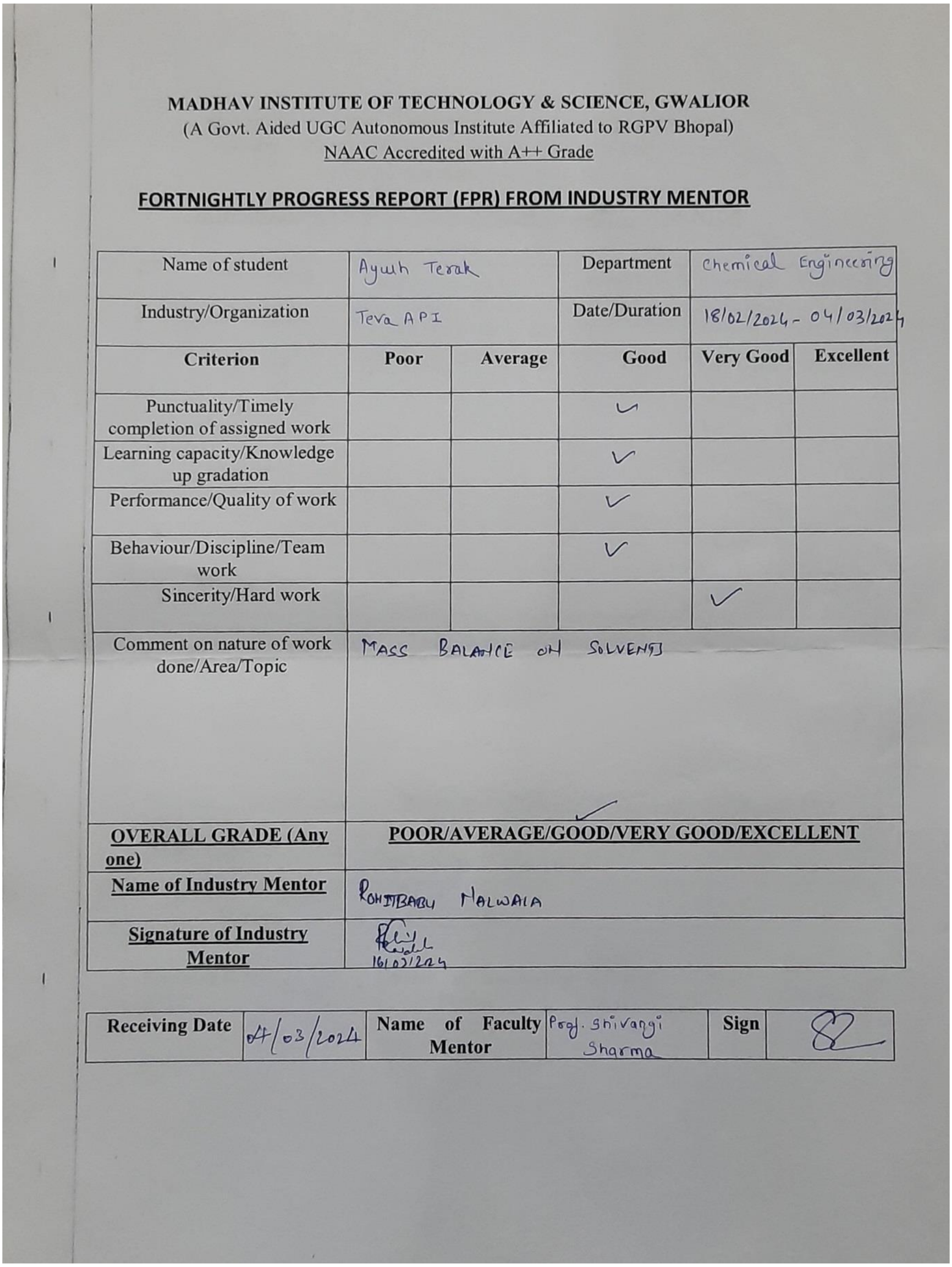


**MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR**
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

## FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR

| | | | | | |
|---|---|---|---|---|---|
| Name of student | Ayush Terak | | Department | Chemical Engineering | |
| Industry/Organization | Teva API India Ltd | | Date/Duration | 03/02/2024 – 18/02/2024 | |
| **Criterion** | **Poor** | **Average** | **Good** | **Very Good** | **Excellent** |
| Punctuality/Timely completion of assigned work | | ✓ | | | |
| Learning capacity/Knowledge up gradation | | ✓ | | | |
| Performance/Quality of work | | ✓ | | | |
| Behaviour/Discipline/Team work | | ✓ | | | |
| Sincerity/Hard work | | ✓ | | | |
| Comment on nature of work done/Area/Topic | Solvent Recovery Plant | | | | |
| **OVERALL GRADE (Any one)** | **POOR/[✓ AVERAGE]/GOOD/VERY GOOD/EXCELLENT** | | | | |
| **Name of Industry Mentor** | ROHITBABU MALWALA | | | | |
| **Signature of Industry Mentor** | 01/03/2024 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 18/02/2024 | **Name of Faculty Mentor** | Dr. Rakesh Kumar Dubey | **Sign** | |



**MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR**
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

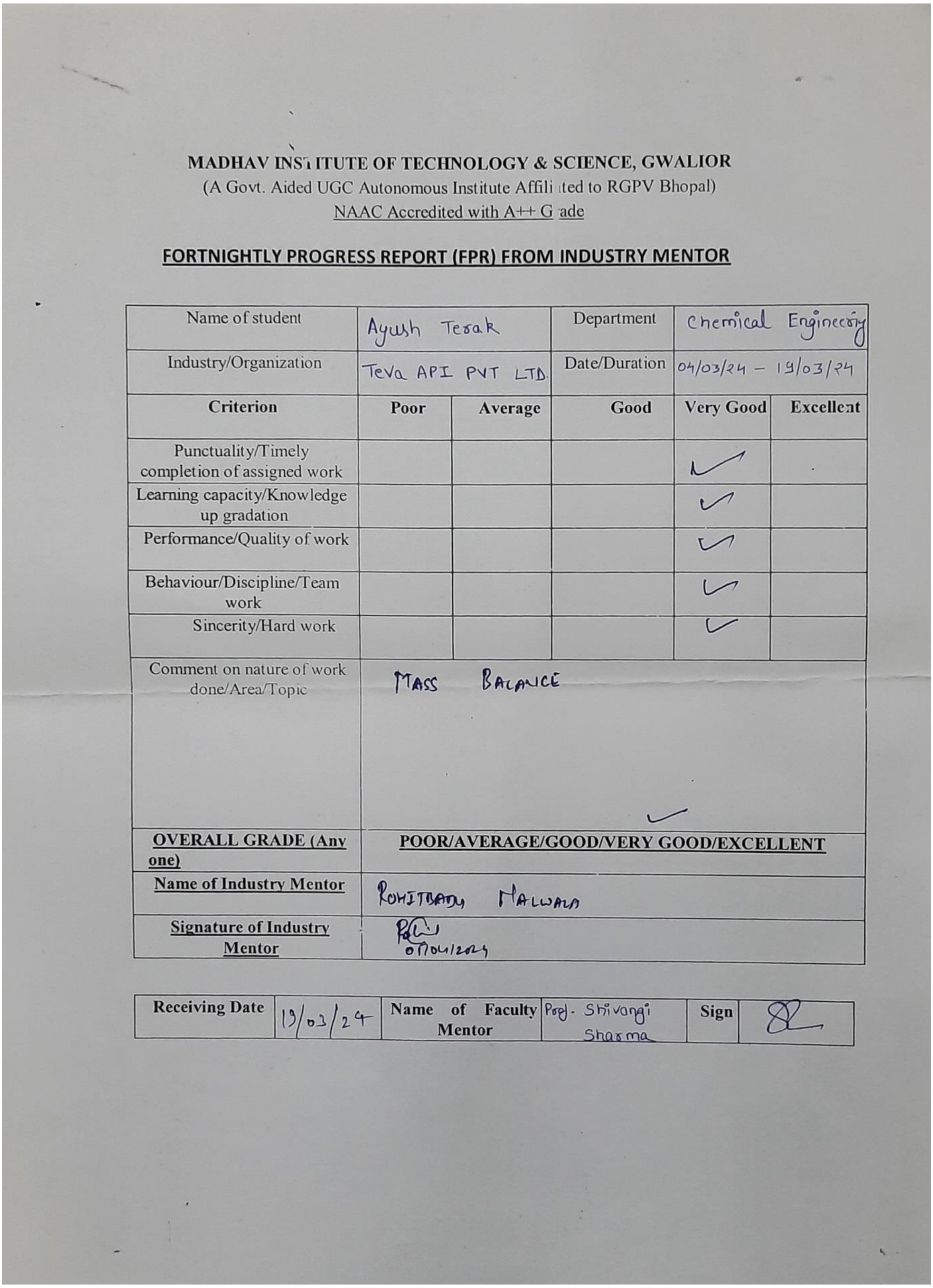
## FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR

| | | | |
|---|---|---|---|
| Name of student | Ayush Terak | Department | Chemical Engineering |
| Industry/Organization | Teva API | Date/Duration | 18/02/2024 - 04/03/2024 |

| Criterion | Poor | Average | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Punctuality/Timely completion of assigned work | | | ✓ | | |
| Learning capacity/Knowledge up gradation | | | ✓ | | |
| Performance/Quality of work | | | ✓ | | |
| Behaviour/Discipline/Team work | | | ✓ | | |
| Sincerity/Hard work | | | | ✓ | |

| | |
|---|---|
| Comment on nature of work done/Area/Topic | MASS BALANCE ON SOLVENTS |
| **OVERALL GRADE (Any one)** | **POOR/AVERAGE/[✓ GOOD]/VERY GOOD/EXCELLENT** |
| **Name of Industry Mentor** | ROHITBABU MALWALA |
| **Signature of Industry Mentor** | 16/03/2024 |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 04/03/2024 | **Name of Faculty Mentor** | Prof. Shivangi Sharma | **Sign** | |



MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

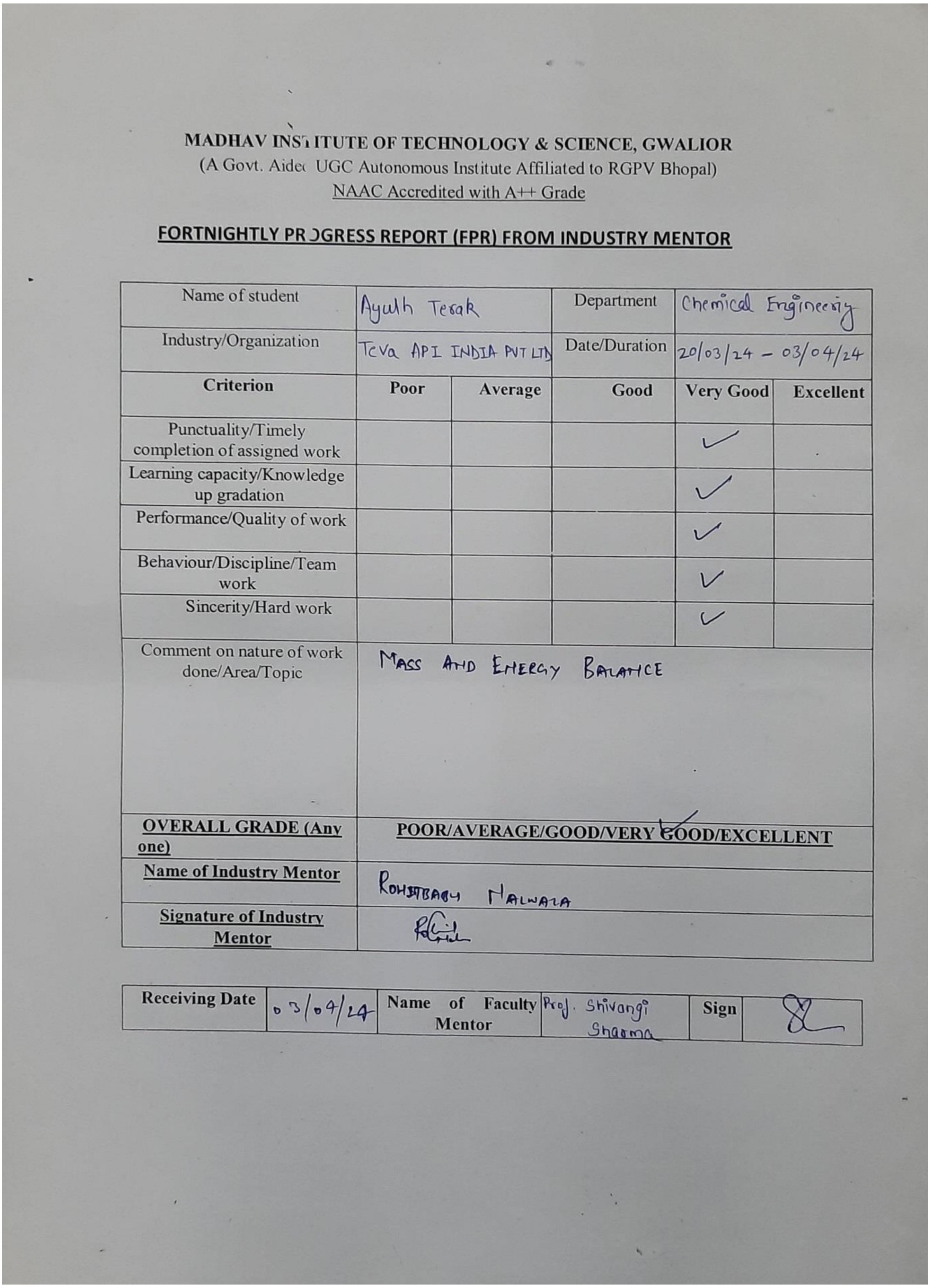
**FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR**

| | | | |
|---|---|---|---|
| Name of student | Ayush Terak | Department | Chemical Engineering |
| Industry/Organization | Teva API PVT LTD. | Date/Duration | 04/03/24 – 19/03/24 |

| **Criterion** | **Poor** | **Average** | **Good** | **Very Good** | **Excellent** |
|---|---|---|---|---|---|
| Punctuality/Timely completion of assigned work | | | | ✓ | |
| Learning capacity/Knowledge up gradation | | | | ✓ | |
| Performance/Quality of work | | | | ✓ | |
| Behaviour/Discipline/Team work | | | | ✓ | |
| Sincerity/Hard work | | | | ✓ | |

| | |
|---|---|
| Comment on nature of work done/Area/Topic | MASS BALANCE |
| **OVERALL GRADE (Any one)** | **POOR/AVERAGE/GOOD/[✓ VERY GOOD]/EXCELLENT** |
| **Name of Industry Mentor** | ROHITBADU MALWADA |
| **Signature of Industry Mentor** | 07/04/2024 |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 19/03/24 | **Name of Faculty Mentor** | Prof. Shivangi Sharma | **Sign** | |

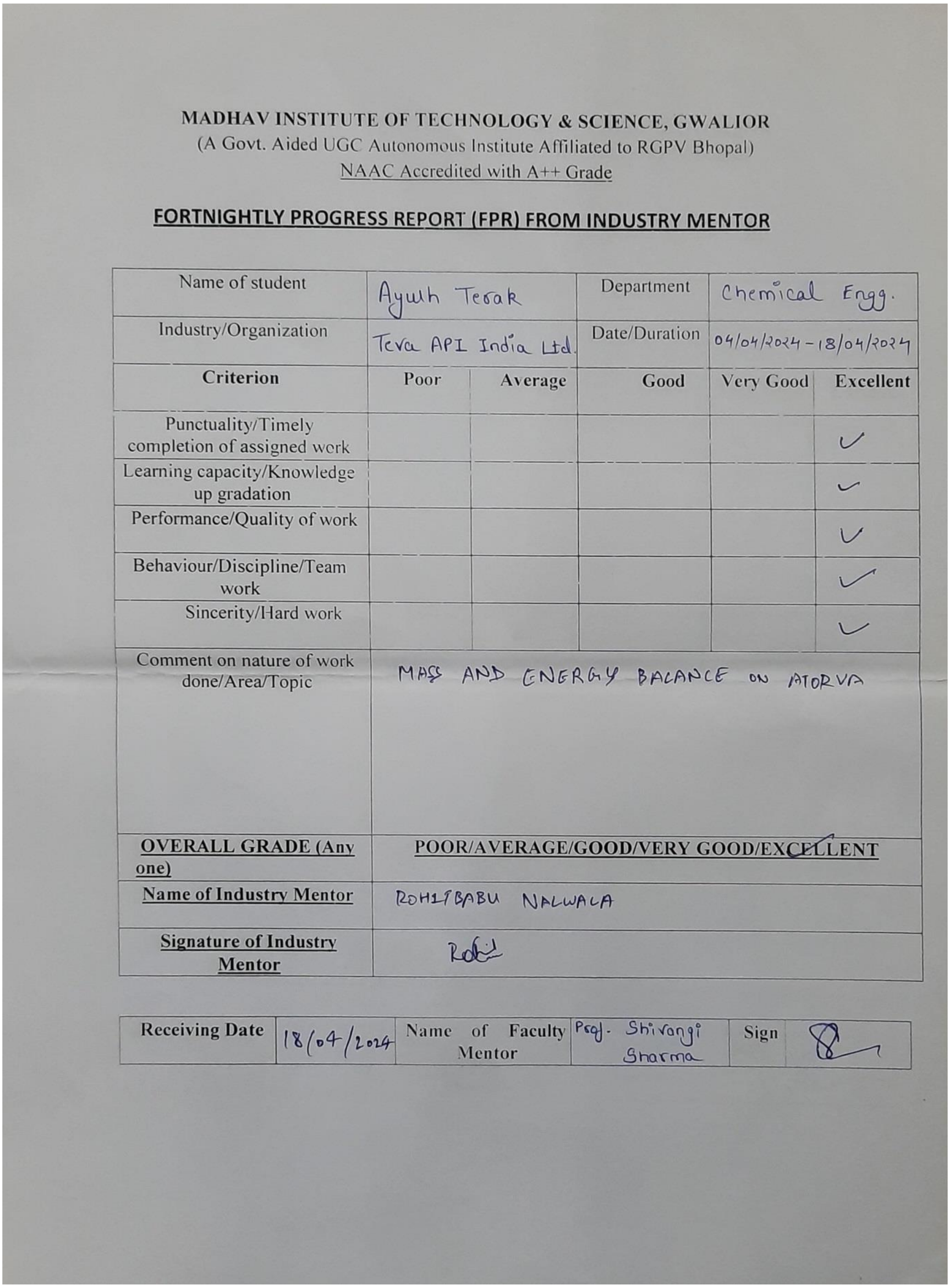


**MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR**
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

## FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR

| | | | | | |
|---|---|---|---|---|---|
| Name of student | Ayush Terak | | Department | Chemical Engineering | |
| Industry/Organization | Teva API INDIA PVT LTD | | Date/Duration | 20/03/24 – 03/04/24 | |
| **Criterion** | **Poor** | **Average** | **Good** | **Very Good** | **Excellent** |
| Punctuality/Timely completion of assigned work | | | | ✓ | |
| Learning capacity/Knowledge up gradation | | | | ✓ | |
| Performance/Quality of work | | | | ✓ | |
| Behaviour/Discipline/Team work | | | | ✓ | |
| Sincerity/Hard work | | | | ✓ | |
| Comment on nature of work done/Area/Topic | MASS AND ENERGY BALANCE | | | | |
| **OVERALL GRADE (Any one)** | **POOR/AVERAGE/GOOD/[✓ VERY GOOD]/EXCELLENT** | | | | |
| **Name of Industry Mentor** | ROHITBABU MALWALA | | | | |
| **Signature of Industry Mentor** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 03/04/24 | **Name of Faculty Mentor** | Prof. Shivangi Sharma | **Sign** | |

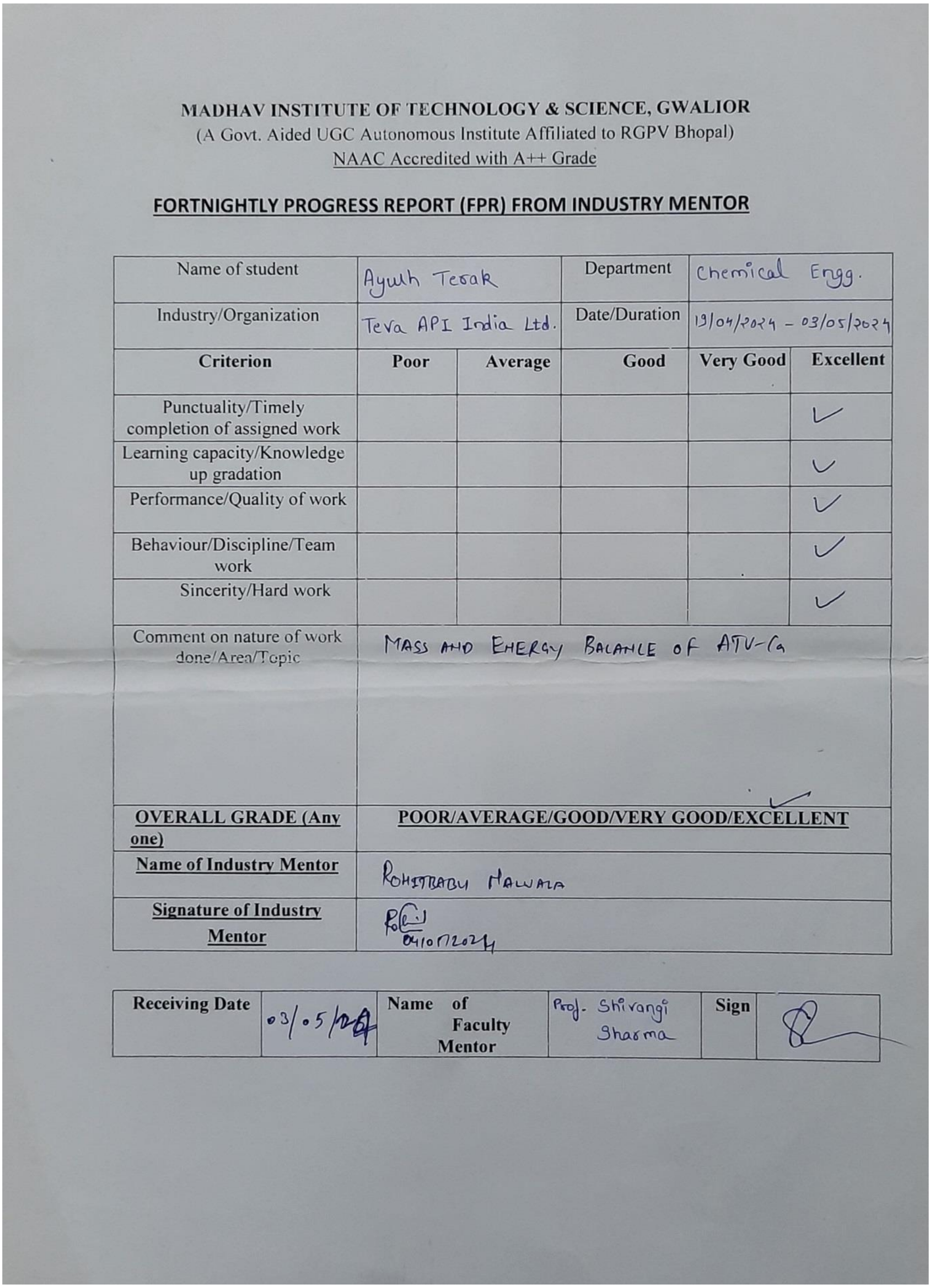


**MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR**
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

## FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR

| | | | | | |
|---|---|---|---|---|---|
| Name of student | Ayush Terak | | Department | Chemical Engg. | |
| Industry/Organization | Teva API India Ltd. | | Date/Duration | 04/04/2024 - 18/04/2024 | |
| **Criterion** | Poor | Average | Good | Very Good | **Excellent** |
| Punctuality/Timely completion of assigned work | | | | | ✓ |
| Learning capacity/Knowledge up gradation | | | | | ✓ |
| Performance/Quality of work | | | | | ✓ |
| Behaviour/Discipline/Team work | | | | | ✓ |
| Sincerity/Hard work | | | | | ✓ |
| Comment on nature of work done/Area/Topic | MASS AND ENERGY BALANCE ON ATORVA | | | | |
| **OVERALL GRADE (Any one)** | **POOR/AVERAGE/GOOD/VERY GOOD/[✓ EXCELLENT]** | | | | |
| **Name of Industry Mentor** | ROHITBABU NALWALA | | | | |
| **Signature of Industry Mentor** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 18/04/2024 | Name of Faculty Mentor | Prof. Shivangi Sharma | Sign | |



MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

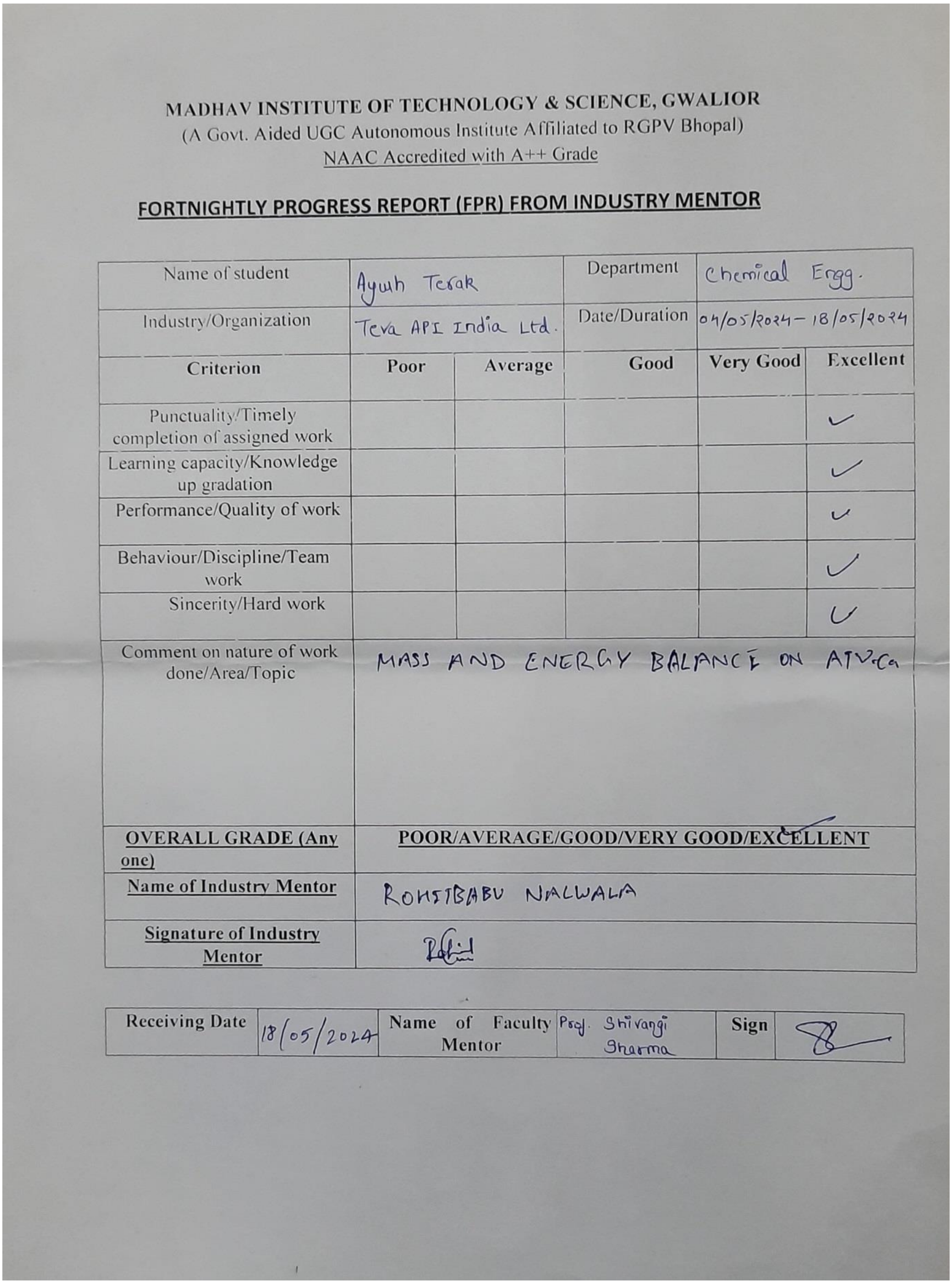
## FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR

| | | | |
|---|---|---|---|
| Name of student | Ayush Terak | Department | Chemical Engg. |
| Industry/Organization | Teva API India Ltd. | Date/Duration | 19/04/2024 – 03/05/2024 |

| Criterion | Poor | Average | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Punctuality/Timely completion of assigned work | | | | | ✓ |
| Learning capacity/Knowledge up gradation | | | | | ✓ |
| Performance/Quality of work | | | | | ✓ |
| Behaviour/Discipline/Team work | | | | | ✓ |
| Sincerity/Hard work | | | | | ✓ |

| | |
|---|---|
| Comment on nature of work done/Area/Topic | MASS AND ENERGY BALANCE OF ATV-Ca |
| **OVERALL GRADE (Any one)** | **POOR/AVERAGE/GOOD/VERY GOOD/[✓ EXCELLENT]** |
| **Name of Industry Mentor** | ROHITBABU MALWALA |
| **Signature of Industry Mentor** | 04/07/2024 |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 03/05/24 | **Name of Faculty Mentor** | Prof. Shivangi Sharma | **Sign** | |



MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR
(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV Bhopal)
NAAC Accredited with A++ Grade

## FORTNIGHTLY PROGRESS REPORT (FPR) FROM INDUSTRY MENTOR

| | | | |
|---|---|---|---|
| Name of student | Ayush Terak | Department | Chemical Engg. |
| Industry/Organization | Teva API India Ltd. | Date/Duration | 04/05/2024 – 18/05/2024 |

| Criterion | Poor | Average | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Punctuality/Timely completion of assigned work | | | | | ✓ |
| Learning capacity/Knowledge up gradation | | | | | ✓ |
| Performance/Quality of work | | | | | ✓ |
| Behaviour/Discipline/Team work | | | | | ✓ |
| Sincerity/Hard work | | | | | ✓ |

| | |
|---|---|
| Comment on nature of work done/Area/Topic | MASS AND ENERGY BALANCE ON ATV-Ca |
| **OVERALL GRADE (Any one)** | **POOR/AVERAGE/GOOD/VERY GOOD/[✓ EXCELLENT]** |
| **Name of Industry Mentor** | ROHITBABU NALWALA |
| **Signature of Industry Mentor** | |

| | | | | | |
|---|---|---|---|---|---|
| **Receiving Date** | 18/05/2024 | **Name of Faculty Mentor** | Prof. Shivangi Sharma | **Sign** | |