Career Episode 1:

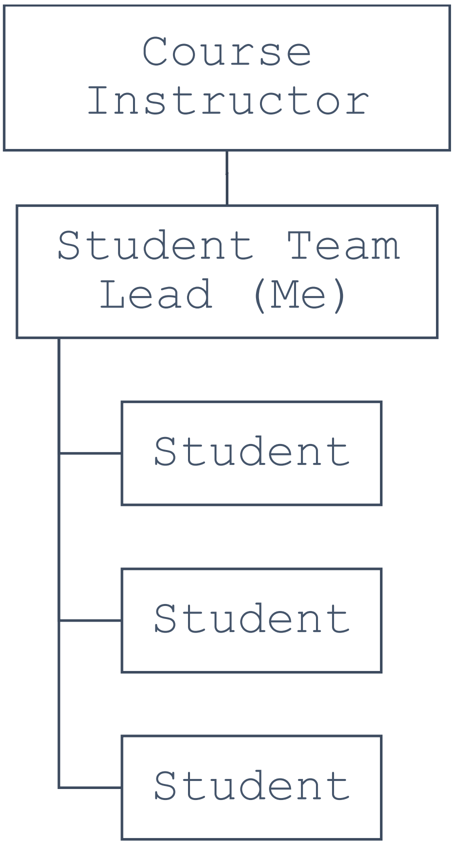
Introduction:

CE 1.1 I present my involvement in an assessment project in this career episode. I performed this project as a student. I was enrolled in Bachelor of Engineering (Petroleum) at the [redacted] University of Engineering and Technology in [redacted]. This project was related to a Complex Engineering Problem module for my Petroleum Refinery Engineering course. It was spring 2024 semester in which I performed this project.

Background:

CE 1.2 I knew that oil refineries process and transform crude oil into a wide range of products such as fuels, lubricants, and petrochemicals etc. and are fundamental to sustaining modern life and industrial operations. Refineries are dependent on complex engineering processes that involve separation, conversion, and treatment of hydrocarbons to produce high-quality, market-ready products. The intricate nature of refinery operations is a prerequisite for solving complex engineering issues, demonstrating technical and professional expertise.

CE 1.3 The project was conducted as part of the PE-406 curriculum and involved studying and improving key refinery processes, including separation, conversion, and finishing stages. The project was a collaborative effort undertaken by a team of engineering students under the guidance of the course instructor. The project provided a comprehensive overview of the processes involved in refinery operations, as well as identifying associated risks and hazards. I was the team lead for this assessment project.



CE 1.4 This project required us to utilize our theoretical knowledge by integrating it into realistic applications, accomplishing complex industrial tasks such as risk management and process optimization. My role as the team lead was to contribute to the design and evaluation of engineering solutions, focusing on maximizing process efficiency, ensuring safety, and complying with industry standards.

CE 1.5 The project involved performing an extensive literature review of separation, conversion, and finishing stages. Separation processes include both atmospheric and vacuum distillation, solvent deasphalting, extraction, and dewaxing, whereas, conversion processes include catalytic cracking, reforming, hydrocracking, and thermal conversion. Hydrotreating, blending, and sweetening are some of the Treatment and finishing techniques employed at the refineries.

CE 1.6 Additionally, the project emphasized risk and hazard identification across electrical, mechanical, chemical, and civil engineering domains. Mitigative strategies were devised for hazards such as equipment failure, chemical spills, and seismic vulnerabilities. This multifaceted approach underscored the necessity for robust engineering practices in refinery operations.

Personal Engineering Activity:

CE 1.7 I began the project by conducting a thorough literature review on all the processes performed in an oil refinery such as distillation, solvent extraction, hydrocracking, hydro treating, etc. I used online search engines such as Google Scholar and research rabbit to search recent review articles and relevant cited work. I also made use of available process flow diagrams to further improve my understanding of how various fragments of crude oil were distilled and converted into high grade products.

CE 1.8 I had knowledge that fractions or components of crude oil varied according to the hydrocarbon length and their properties, and that distillation was a fundamental process employed by every crude oil refinery to separate the crude oil fractions based on their boiling points. By reviewing literature, I did a comparative analysis between the two main types of this distillation, the atmospheric and the vacuum distillation. I learned that atmospheric distillation requires heating the crude oil to about 400°C followed by insertion into a distillation column to initiate separation, whereas vacuum distillation relies on insertion of crude oil into a vacuum distillation chamber to lower the boiling points and separate heavier fractions. I understood that vacuum distillation method relies on the Clausius-Clapeyron relation that I had studied in thermodynamics. The relation is denoted by the equation: $\ln(P2/P1) = \Delta Hv/R \times ({}^{1}/_{T1} - {}^{1}/_{T2})$ which explains that any liquid will boil when its vapor pressure equals or exceeds the atmospheric pressure that surrounds it.

2.1.1 ATMOSPHERIC DISTILLATION	2.1.2 VACUUM DISTILLATION
• Crude oil is first heated in a furnace to temperatures of around 350-400°C. It is then fed into a distillation column. It is also known as primary distillation. • The distillation column separates the crude oil into different fractions based on their boiling points. • Lighter fractions like gasoline and naphtha rise to the top, while heavier fractions like diesel and gas oils condense lower down. The heaviest residues, such as asphalt and lubricating oils, settle at the bottom.	• The residue from atmospheric distillation, which is still too heavy to vaporize at atmospheric pressure, is fed into a vacuum distillation unit. • This unit operates under reduced pressure (vacuum), which lowers the boiling points of the heavy components, allowing them to vaporize at lower temperatures without cracking. • This results in the extraction of heavy gas oils and lubricating oil base stocks, while leaving behind vacuum residue.

TABLE 1 COMPARISON OF ATMOSPHERIC AND VACUUM DISTILLATION

CE 1.9 I learned that refineries subject crude oil initially to atmospheric distillation and perform vacuum distillation on the residues.I further studied other separation techniques used in refineries such as solvent deasphalting, solvent extraction and dewaxing. I learned that deasphalting is required to isolate asphalt components after atmospheric distillation by heating and mixing with a short chain hydrocarbon until precipitation. This process enhanced the efficiency of the refineries and resulted in distillation of high value products. Solvent extraction is commonly used in refineries to improve quality and reduce impurities in end products. It uses aromatic hydrocarbons to perform a liquid phase extraction of desired fractions from crude oil based on densities and dissolution properties of the fractions.

CE 1.10 I studied in detail about solvent dewaxing as it is vital for producing lubricants with optimal properties in cold environments. I learned that dewaxing was performed by crystallization of wax components in crude oils by first treating crude oil or distillate with solvents specific for dissolving waxes and then cooling of the solution. Crystallization of waxes enables filtering of the dewaxed crude oil which has optimal flow properties at lower temperatures.

CE 1.11 I then researched the literature on the different types of conversion and finishing processes. I realized that some of the fractions obtained are not usable directly and are subjected to thermal or chemical conversion methods. I learned that there were different types of chemical and thermal conversions and made a comparison table for including in the project report.

Type	Sub-type	Process	End-product	Application
Chemical Conversion	Catalytic Cracking	Catalyst lowers the energy required for cracking	High-octane gasoline and other products	Gasoline, jet fuel, diesel, and petrochemicals
	Catalytic Reforming	Transformation of less valuable naphtha fractions over a catalyst bed	High-octane gasoline, aromatics and other valuable fractions	Gasoline blending and petrochemical production
	Hydrocracking	Uses hydrogen gas for cracking but to produce lighter, cleaner products	Diesel, jet fuel, and lighter hydrocarbons	Cleaner-burning fuels and petrochemicals
	Alkylation	Combining smaller hydrocarbon molecules such as olefins to create gasoline with higher octane ratings.	High-octane gasoline	High-performance gasoline blending
	Isomerization	Conversion of straight-chain fractions into their branched-chain isomers	Fractions with efficient combustion properties e.g. High-octane	Cleaner-burning gasoline fuels
Thermal Conversion	Delayed Coking	Converts residual oils and heavy fractions obtained into lighter products and solid coke using high temperatures	Petroleum coke, naphtha, gas oils	Coke production and feedstock
	Flexicoking	Converts heavy residual oils into lighter hydrocarbons through a combination of thermal cracking and gasification	Syngas, petroleum coke, light hydrocarbons	Energy production and refinery feedstock
	Visbreaking	Reduce the viscosity of heavy residual crude oils by thermal decomposition in the presence of steam	Reduced-viscosity residual oils, fuel oils	Fuel oil blending and refinery use

TABLE 2 COMPARISON BETWEEN TYPES OF CONVERSION TECHNIQUES

CE 1.12 At the end of the literature review, I focused on the various treatment and finishing processes and their importance in the refinery. I learned crude oil, being a fossil fuel has high amounts of metallic, sulphur and nitrogen-based impurities that render it unusable. Hydrotreating is a process that utilizes mixing the feedstock with hydrogen over a catalyst bed at high temperature and pressure to hydrogenate the mixture and convert impurities do hydrogen sulfide and ammonia and metallic hydrides.

CE 1.13 In the next part of the project, I identified the various risks associated with refinery operations. I performed risk identification in collaboration with my team members. We divided risks into four categories, Electrical, Mechanical, Chemical and Civil. I led the risk identification in the mechanical domain. I recognized high temperatures could affect seals causing failure and cause leakage of feedstock from distillation and other process chambers causing fires and explosions. I realized that over-time, pump and compressor seals could also wear out presenting the same risks. I proposed in my report that refineries should install shutoff systems to prevent such events in case of a leak. I realized that during distillation and finishing processes, high pressures inside vessels can cause ruptures and bursts. These could also be contained with emergency shutoff systems. I proposed installation of guard rails around moving parts and preventive maintenance of all mechanical parts to mitigate associated risks and hazards.

CE 1.14 While identifying electrical risks, I communicated to my team that electrical sparks inside the refinery could interact with the vapours of various fractions being distilled and processed nearby. Sparks could be caused by arc flashes any direct or indirect contact with live electrical components. This could lead to fires or explosions. I proposed grounding of electrical systems and routine inspection and maintenance off electrical systems and circuit boards throughout the refinery as risk mitigation procedures.

CE 1.15 I along with my team then initiated identifying the civil risks associated with refinery operations. We segregated civil risk and hazards into three distinct categories, seismic, hydrological and structural. I deliberated with my team on the seismic effects on refineries situated in active or susceptible seismic zones either on land or water. I understood that seismic activity would pose a significant risk at cracking and rupturing essential structures such as pipelines, vacuum and high-pressure vessels. This would inadvertently lead to the release of flammable guesses causing further risk of fires and explosion. I proposed that this risk could also be mitigated through the emergency shutoff systems. Additionally, emergency shutoff valves could also be installed after every segment to ensure effective supply cutoff to minimize damage.

CE 1.16 At last, my team identified the chemical risks and hazards associated with processes and operations in a crude oil refinery. I had knowledge that refineries use many corrosives, toxic and highly reactive chemicals to process crude oil. I understood that spillage of such chemicals in events such as vessel ruptures and leakages can present a serious health and environmental safety hazard. I proposed industrial grade ventilation systems to avoid inhalation of such chemicals and personal protective equipment to avoid skin and eye contact. Additionally containment systems need to be installed to guarantee that such spills and leakages do not contaminate the soil and groundwater.

CE 1.17 Throughout the assessment project, I communicated with my course supervisor weekly for guidance and evaluation on the progress of the assessment project. I planned and divided the assessment tasks within team members and held meetings daily to track progress on the work. I used Google Scholar and Research Rabbit to find relevant literature and their cited work, evaluating how the knowledge on the subject matter evolved through the years. Through this assessment project I gained valuable knowledge on the subject matter and gained basic skills in risk assessment that would be vital for my career as an engineer. I also made a presentation on this project that me and my team presented to the students and faculty.

Summary:

CE 1.18 This assignment project seeked to understand in detail oil refinery operation with separation, conversions, and finishing processes. By reviewing the literature, I learned about the basic refinery procedures such as atmospheric and vacuum distillation, solvent deasphalting, solvent extraction, and dewaxing. Additionally, chemical and thermal conversion methods, their processes, outputs, and applications were learned in more detail. I also learned various crude oil treatment methods such as hydrotreating for the removal of impurities were studied for enhanced product quality.

CE 1.19 I lead risk assessments in refinery operations and identified hazards in mechanical, electrical, chemical, and civil domains, and proposed mitigation strategies that included emergency shutoff systems, preventive maintenance, electrical grounding, and installation of industrial-grade ventilation and containment. During the entire span of the project, I proved my competencies in teamwork, research, and communication by holding weekly discussions with my course supervisor and presenting outcomes to the other students and faculty. This project not only improved my technical knowledge of refinery operations but also prepared me with essential skills in risk assessment and problem-solving for my future engineering undertakings.

CE 1.20 This project consisted of carrying out teamwork, research, and communication skills whose fruits were weekly discussions with my course supervisor and presentation of the results to students and faculty. The project did not only add to my technical knowledge regarding operations in a refinery but also wielded my hands with some basics in risk assessment and problem-solving, which, in turn, prepared me for the future by way of engineering works.