CAREER EPISODE 1

CE 1.1 Introduction

To explain my career episode, I have chosen to describe the details of an academic project that I completed during my bachelor degree program of Chemical Engineering which I undertook at the [redacted]". It was a group project and each group comprised of five members who worked together under the guidance and supervision of a Project Supervisor. I shall explain the details of mainly the work that I performed in this project while also shedding some light on the group effort & team work. I began the project work on ___________ and submitted its findings on __________. It allowed me approximately _____ months to complete the work.

CE 1.2 Background

CE 1.2.1

I undertook the challenges of this vast project by considering the worsening economic and energy shortfall situation in Pakistan. With the ever-growing population of Pakistan, its needs for energy is also growing, keeping in view the fact that the fossil fuels in Pakistan have depleted rapidly due to lack of proper management and lack of political will. Another important contributing factor was that the energy needs add to the largest part of import bill of the country, with foreign reserves alarmingly low causing economic crisis, it is the need of the hour to deal with these problems on an emergency basis.

CE 1.2.2

Pakistan has an advantage of being an agricultural country due to which we have a lot of crops throughout the year that produce tons of waste from agricultural crops which include bagasse, rice husk, molasses and so on. They are being discarded haphazardly which renders land and water pollution. Scientifically, they are sources of biomass and it can be converted to biomass for sustainable energy. Examining the sugarcane industry, we learn that molasses is by-product of the sugar production which is thrown to water bodies and cause water table contamination. It can be used to produce biofuels. It will not only help Pakistan but also the world at large as this is a carbon neutral process. Keeping all of these positive possibilities in view, we decided to use fermentation process to reduce the useless by-product to produce bio-ethanol which can be used as a motor fuel as well and it also happens to be more environment friendly as compared to the fossil fuels. Furthermore, the by-products produced from this process can be further used to make bio-gas which is suitable for domestic use. All of these factors acted as motivation for me to complete this project successfully and play my part in driving my country out of this crisis.

CE 1.2.3

The following objectives were undertaken for this project that were worked on in order to fulfil the larger aims:

- To complete market analysis so as to evaluate the project viability and comparison with other processes
- To complete process selection by comparison of different process and justify the selection criteria
- To describe the project thoroughly and create a project flow sheet using Aspen software
- To select the viable site for the project
- To create process flow diagram
- To calculate material and energy balance

- To design several equipment involved in the process including fermenter, shell & heat exchange, distillation column etc.
- To carry out HAZOP analysis
- To complete economic evaluation of the selected process

CE 1.2.4

As mentioned earlier, this project was a group task and the group comprised of five students, led by a group leader and working under the supervision of the project supervisor. I was selected as the group leader. The project also required regular reporting of the progress and for the sake of this the following organizational diagram was acted upon:

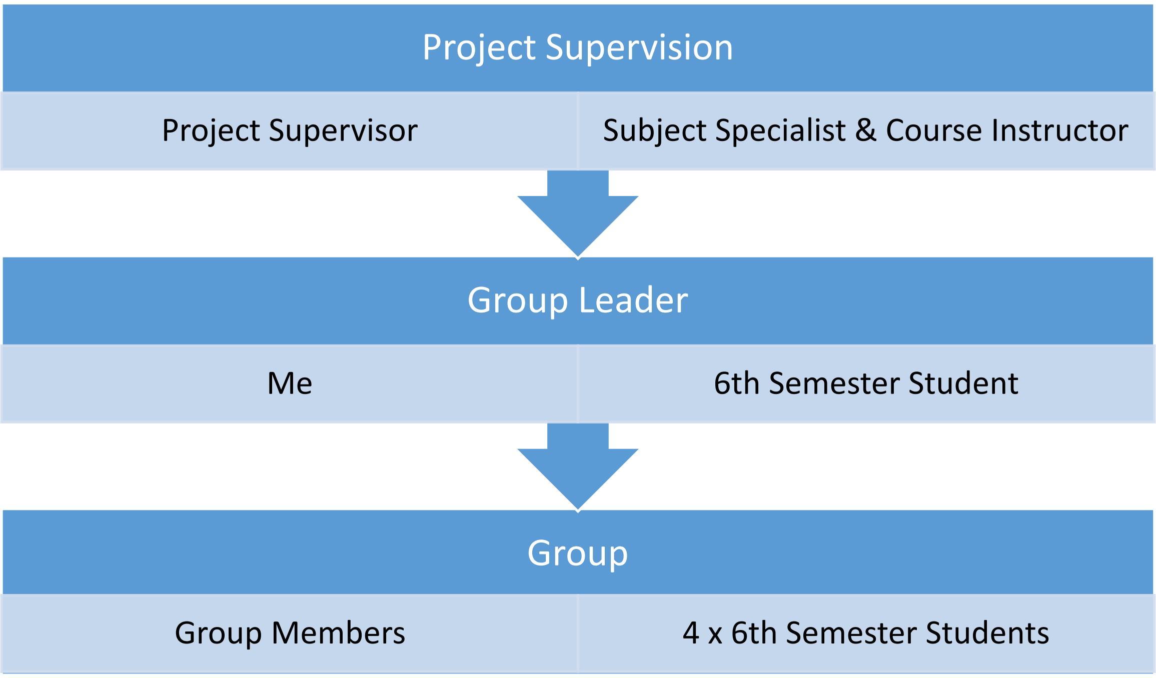

Fig. 1.1. Organizational Diagram for Project Reporting

CE 1.3 Personal Engineering Activity

CE 1.3.1

As for the first step of the project, we carried out a market analysis in order to evaluate the market share of ethanol production and its prospects. We gathered the relevant data from the statistics as well as agricultural departments in order to understand the availability and production of the sugarcane molasses. We also learned that there are many industries that are producing ethanol for domestic as well as export use. The export of ethanol from Pakistan is mainly to Europe and the export volumes are growing by every year. From the gathered data of exports from Trade Development Authority of Pakistan (TDAP), I prepared the following pie-chart using MS Excel in order to represent the data in the final project report.

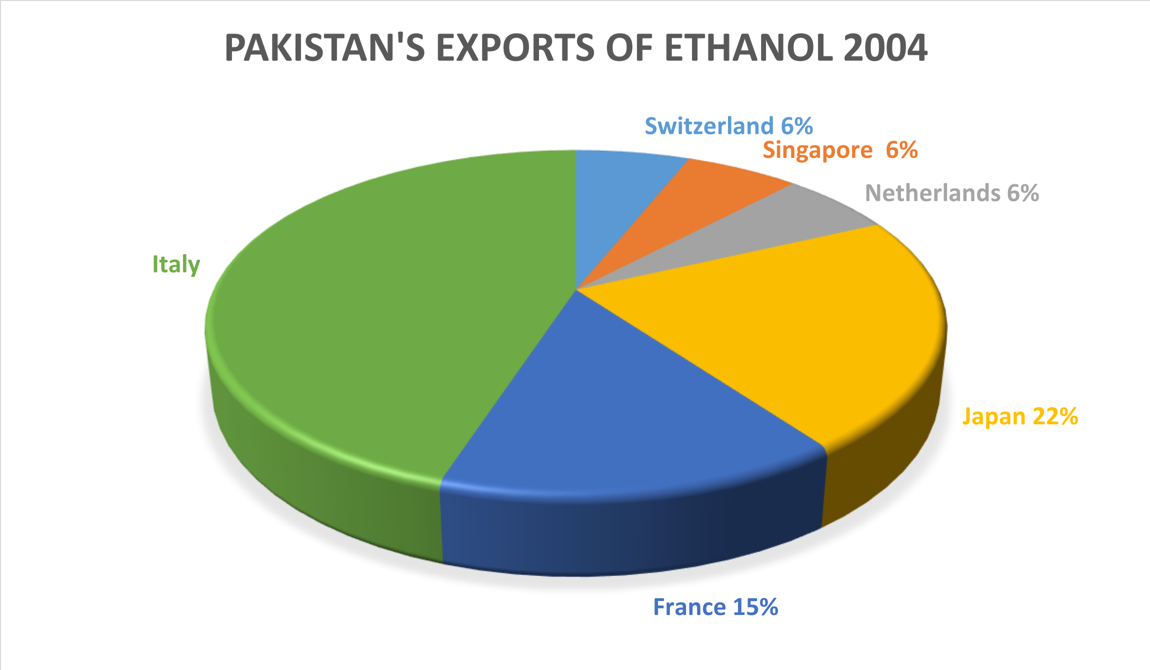

Fig. 1.2. Pakistan's Exports of Ethanol 2004

CE 1.3.2

In the next step, we evaluated different processes in order to select the more suitable process for this project. Usually ethanol is produced by the use of two different processes which are catalytic hydration of ethylene and biological processes such as fermentation of sugars by the use of yeast. From the process of hydration, I learned that the concentration of ethanol produced was 50 percent and there was less usage of steam in the distillation process as well as the purity of ethanol was greater than that from the fermentation process. I observed the downside of this process that in Pakistan where import is very expensive, ethylene would cost very high and it would in turn render the process unviable and inefficient. I also evaluated the process of fermentation with similar concerns and also with regards to the yield of ethanol and temperature as well as pH. I found out that the process of fermentation requires less energy to complete due to low temperature requirement. It also produces by products such as Bio Gas which can be used for domestic needs. I also concluded that the process is simpler and cheaper when compared to other processes.

CE 1.3.3

In the next phase of the project, I laid down the process selection criteria so as to facilitate the feasibility as well as the implementation of this project as well as any such projects in the future. I concluded the criteria to be as; the raw material has to be present readily near the plant site, the process has to be energy efficient and there must not be any energy requirements in terms of pressure or temperature, the entire process must be completed within normal operational conditions, the process has to be economically viable so as to be reasonably comparable with the other processes, also the process has to be well within the limits detailed by the relevant Environmental Protection Agency.

CE 1.3.4

The next step included the process of selection of microbes in which I evaluated the different microbes which were deemed fit for the process of fermentation. I also formulated a table mentioning the pros and cons of all the probable microbes by using MS-Word and added it to the project report.

CE 1.3.5

The following capacity was chosen by me by keeping in view the capacity of other ethanol manufacturing industries from sugarcane molasses in the table below:

Ethanol	1,50,000 (litres/day)
Bio-Gas	5.650 (tons/day)

Tab. 1.1. Capacity chosen of plant

CE 1.3.6

In the next step, I selected the plant site as well on the basis of the factors that include availability of raw material which should be readily available at the site so as to decrease the cost of transportation, availability of water resources as the process as well as the plant require water, availability of road network for the need of transportation of the produced product also there should be availability of adequate area and space for storage of raw materials and products. Considering all of the aforementioned factors, I selected [redacted] for the proposed site of our plant, which is a major district in the Southern Punjab of Pakistan.

CE 1.3.7

I developed a process flow diagram using the Aspen Plus V11 which is a vastly used process simulation software used in the field of chemical engineering. The following figure shows the developed process flow diagram:

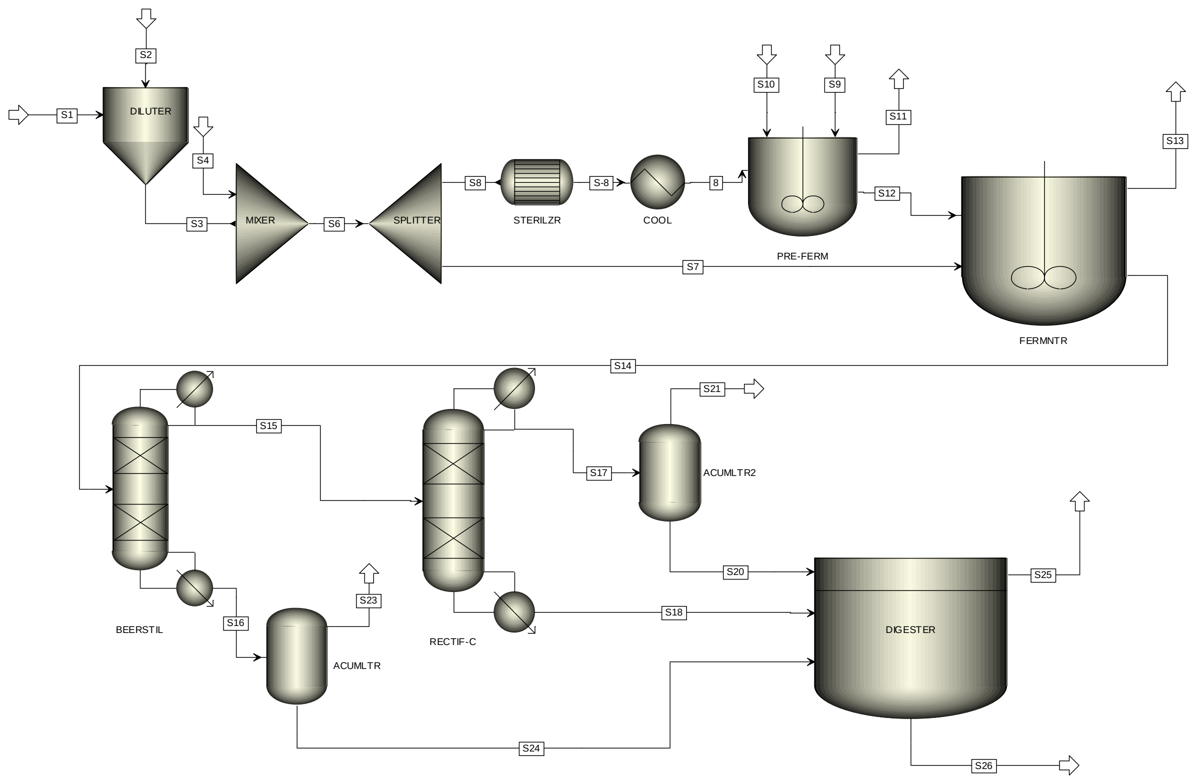

Fig. 1.2. Process flow diagram developed using ASPEN PLUS V11

CE 1.3.8

I carried out the detailed calculations for the purpose of material balance in the next step of the project by using the following mathematical expressions respectively:

$$Capacity = 150{,}000\,\frac{liter}{day}$$

$$Density = 0.79\,\frac{Kg}{liter}$$

$$Capacity = 118{,}500\,\frac{Kg}{day}$$

$$Capacity = 118.5\,\frac{ton}{day}$$

Furthermore, I used the following chemical reaction for the selected process:

$$\underset{(180)}{C_6H_{12}O_6(aq)} \xrightarrow{zymase\ (32^\circ C)} \underset{(92)}{2C_2H_5OH(aq)} + \underset{(88)}{2CO_2(g)}$$

From this chemical reaction, I concluded that on weight for weight basis, 180 units of hexose sugar must yield 92 respective units of ethanol. This conclusion was based on the following mathematical calculations:

Calculations:

$$92kg\ of\ ethanol = sugar\ required\ 180\ kg$$

$$1kg\ of\ ethanol = sugar\ required\ \frac{180}{92}kg$$

$$118.5\ \frac{tons}{day}\ of\ ethanol = sugar\ required\ 231.84\ tons/day$$

Purity of ethanol = 95%

Amount of convertible sugar = 231.84 × 0.954

Amount of convertible sugar = 221.17 tons/day

CE 1.3.9

Moreover, I calculated the weight yield to be 51% basing it on glucose conversion although 5 percent of sugar was used for the growth of cell as well as to uphold the energy requirement for synthesizing the compounds which were organic in nature including acetic acid, acetaldehyde, glycerol and fuel oil and they were all mainly higher alcohols. So the minimum yield is approximately 48% of the feed sugar.

CE 1.3.10

In the next step I computed the material balance around different process components. I started from the diluter which was used in the process to dilute the molasses by the adding 2-fold of water into the raw molasses. Then by utilizing what I learned from the study of literature, I calculated the amount of sulfuric acid which was to be added and then well mixed with the diluted feed of molasses. Also, in the splitter, the feed stream was divided into two streams. Then the appropriate and measured amount of nutrients were added by me so as to partially convert the glucose into ethanol along with the growth of yeast in pre-fermenter unit. The main chemical reaction used for this purpose by me was:

$$C_6H_{12}O_6(aq) \quad zymase\ (32°C) \quad 2C_2H_5OH(aq) + 2CO_2(g)$$

I observed that in the pre-fermenter trivial quantity of ethanol was formed which also entered in the fermenter. By reviewing the validated literature and personal knowledge, I concluded that 8% of ethanol was present at the outlet of fermenter. Furthermore, the product stream of fermenter entered into a column which is beer still. In this unit, I observed that the overhead vapors were rich and concentrated in ethanol whereas the bottom product stream contained non-fermentable sugars, different metals, un-reacted nutrients, un-reacted yeast, different metals, different ash and fusel oils etc. In the next product phase, the rectifying column was utilized by me to distinct aldehydes along with ethanol due to the fact that aldehyde was a lighter key as compare to key components. Thus, I concluded that these two components leave the column from top. I also ensured that the water which was heavy key component, was removed as the bottom product of this column. Similarly, material balancing was carried out in accumulator 1, accumulator 2 and aerobic digester. I also tabulated the findings of each step using MS-Excel. The following table shows the summary of material balance around accumulator:

Summary of Material Balance			
Components	Input (tons/day)	Output (tons/day)	
	M 17	M 23	M 24
Fermentable sugars	14.149	-	14.149
Non-fermentable sugars	14.501	-	14.501
Non-sugar Components	50.003	-	50.003
Inorganic Components	95.008	-	95.008
Water	938.900	-	938.900
Fusil oil	0.367	0.367	-
H_2SO_4	0.250	-	0.250
Yeast	1.250	-	1.250
Nutrients	0.217	-	0.217
Ethanol	0.113	-	0.113

Tab. 1.2. Summary Of Material Balance Around Accumulator

CE 1.3.11

In the consequent step, I calculated the energy balances across sterilizer, cooler, pre-fermenter, fermenter, beer still as well as rectifying column using the well-established processes and mathematical calculations within the domain of the chemical and process engineering.

CE 1.3.12

In the next major step of the project, I calculated the detailed process design calculations and concluded that the following were the optimum conditions to achieve the maximum yield of ethanol during fermentation. I recommended that these conditions must be maintained during the whole batch of fermentation.

Temperature = 32°C

Pressure = 101.325 kPa

pH = 6.5

I used the following equation in order to calculate the entire batch time:

$$t_b = t_f + t_R + t_c + t_E$$

V_R = Volume of Reactor

t_b = batch time

t_f = filling time/loading time = 2hrs

t_R = Reaction time = 32hrs

t_c = cooling time = 1.5hrs

t_E = Emptying time/unloading time = 0.5hrs

Then;

t_b =2+32+1.5+0.5

=36hrs

I also calculated the volume of the reactor by using the following mathematical equation:

$$V_R = \frac{m * t_b}{\rho}$$

CE 1.3.13

I also completed the computations for the mechanical design of the project. At first, I calculated the wall thickness by using the following mathematical equation:

$$t_w = \frac{P * r_i}{(S * E_J) - 0.6P} + C_C$$

I concluded that the maximum allowable pressure is almost 30 to 40% more than existing pressure at base. We further used the tori spherical head as the pressure of our system and it was considered to be less than 150 psia. So, the thickness of tori spherical head was calculated by me using the equation below;

$$t_H = \frac{P*R_C*W}{2*f*j} + C_C$$

Another important aspect of the process design was the design of power requirement for the entire process. I calculated this by using the following formula:

$$P = N_P * N^3 * {D_a}^5 * \rho$$

My team completed the design of the cooling jacket as well as the agitator which were to be used in the process. I cross-checked all the calculations in order to ensure accuracy and precision.

CE 1.3.14

Distillation was to be used widely in this process in order to separate relatively volatile compounds from those that were non-volatile so as to achieve highest quality of the product. For this purpose a distillation column was designed by me for our plant. Usually, in such processes, two types of distil columns are used known as namely tray columns and packed bed columns. I made the choice for the type of distillation column based on a detailed analysis of cost for them as well as considering other impacting factors. By considering all the relevant parameters and comparing it with my system, I came to a conclusion that the system was non-foam and non-fouling, the column diameter was expected to be larger than 1.5m, average temperature calculated in my system was around 360~370 K and column height was high. So I selected tray column based on all the aforementioned reasons. With the help of my team members, I also calculated the various design specifications of the distillation column which included minimum reflux ratio, operating reflux ratio, number of plates at total reflux (minimum number of plates), theoretical number of plates, tray efficiency, actual number of trays, feed location point, column diameter calculations, physical properties, column pressure drop, residence time and height of the column by making use of the relevant mathematical equations and steps.

CE 1.3.15

Additionally, I also performed a detailed analysis of the designed distillation column by using ASPEN PLUS V11. For this purpose, I initially developed the simulation of the respected process member in the software. I started this by adding components and respective property method within the software. In the next step, I had to select the method to be used for simulation. For ethanol water systems, the suitable property methods were NRTL or SRK. For this trial, we selected NRTL (NRTL (reon) Ideal Gas and Henry Law). After that we ran the property analysis to evaluate all the variables and constants for the selected equation of state. Then we moved towards simulation environment. Initially we began with Distillation Using Winn-Underwood-Gilliland Method (DSTWU) which was a shortcut method. Feed data was added by me in the software which was derived earlier from the mass and energy balance calculations. Then I clicked on the DSTWU in the software dialogue box and entered its requirements and ran it to see the relevant results of the analysis which can be seen in the screen image below showing that the mass balance was also satisfied:

Summary | Balance | Reflux Ratio Profile | Status

Minimum reflux ratio	2.23854	
Actual reflux ratio	2.40039	
Minimum number of stages	9.34395	
Number of actual stages	28	
Feed stage	25.557	
Number of actual stages above feed	24.557	
Reboiler heating required	2025.77	kW
Condenser cooling required	5340.2	kW
Distillate temperature	351.63	K
Bottom temperature	377.003	K
Distillate to feed fraction	0.290794	

Fig. 1.3. Summary of DSTWU on ASPEN PLUS V11

I also used the RADFRAC in the next phase of software analysis. RADFRAC is rigorous method which stands for Rigorous 2 or 3-Phase Fractionation for Single Columns.

CE 1.4 Summary

I completed all the work assigned to me within the allocated time by working in coordination with not only my team mates but also with my project supervisor to whom I submitted regular progress reports regarding the project. This academic project enhanced my abilities to understand the complex engineering projects and the various factors impacting them in different ways.