SUMMER TRAINING REPORT

Oil and Natural Gas Corporation

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Contents

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Last, not least, I express my deep sense of gratitude to all those persons and organizations who, directly or indirectly, helped me in bringing out this report.

About ONGC

Oil and Natural Gas Corporation Limited, commonly known as ONGC, is India's biggest multinational oil and gas company that is in the business of exploration and production of crude oil and natural gas. The headquarters is located in Dehradun, Uttarakhand, serving as a public sector undertaking (PSU) that comes directly under the administrative control of the Ministry of Petroleum and Natural Gas of the Government of India.

Historical Background and Establishment

Incorporated on August 14, 1956, ONGC was established with a vision of developing the country's hydrocarbon resources and reducing India's dependency on oil imports. The Corporation has since played a pivotal role in the growth and development of India's Oil and Gas sector, contributing considerably to the country's energy security.

Central Activities and OPERATIONS

1. Exploration and Production

The core business of ONGC relates to exploration, development, and production of indigenously and ex-indigenous crude oil and natural gas. It has a number of oil and gas fields spread over the various sedimentary basins of the country. Exploration targets the discovery of new reserves and optimization of production from already established fields with the aid of advanced technologies and efficient reservoir management practices.

2. Refining and Marketing

This includes, amongst others, subsidiaries in the area of refining crude oil and marketing petroleum products. The Mangalore Refinery and Petrochemicals Limited, which is the refining arm of ONGC, together with its JVC Hindustan Petroleum Corporation Limited, are the two major companies engaged in the activities of refining the crude oil to produce a broad variety of petroleum products for domestic consumption and export.

3. Global Presence

ONGC has also increased its geographical presence by its operations all over the world in countries like Russia, Vietnam, Iran, Kazakhstan, Brazil, and Sudan. In this regard, the international ventures are directly related to the strategic objective of ONGC for diversification of its asset base and geographical presence across the globe in the oil and gas sector.

4. Technical Advancements

ONGC has taken the lead in induction of new technologies and innovative work methodologies for oil and gas exploration and production. State-of-the-art seismic imaging techniques, advanced drilling technologies, and sophisticated reservoir management practices are some of the important initiatives taken by the company in optimizing production efficiency and recovering hydrocarbon resources from geologically challenging formations.

5. CORPORATE SOCIAL RESPONSIBILITY (CSR)

ONGC also pays much attention to CSR, which includes sustainable development, community welfare programs, and care for the environment. It undertakes a number of CSR Activities in the fields of education, health, infrastructure development, and environment care for improving societies that lie in the vicinity of the company.

Introduction to HYSYS

1.1 About HYSYS

Overview of Aspen HYSYS: HYSYS is an up-to-date, very powerful process simulation tool applied in the Oil and Gas, Refinery, and Chemical industries. The software allows engineers to model and optimize processes in order to ensure efficient and cost-effective operations.

History and Development: HYSYS is a product of Hyprotech, a Canadian Company formed in 1976. It was acquired by AspenTech in 2002 and further integrated its development as part of the suite in process engineering software.

Developers: AspenTech — Aspen Technology, Inc. today is the worldwide leading supplier of asset optimization software. It provides solutions to help customers optimize asset design, operations and maintenance across global process industries.

Key Features and Capabilities: These include rigorous thermodynamic models, detailed equipment modelling, dynamic simulation, and the interface of HYSYS with other products from AspenTech.

1.2 Why Use HYSYS?

Significance to Chemical Engineering: HYSYS is a critical tool in the design, analysis, and optimization of chemical processes. It can project what complex systems will do and help or advise the engineer to make appropriate decisions.

Industrial Applications: These range from industries related to oil and gas, petrochemical, and refining to pharmaceutical industries, specifically process design, safety analysis, and operational troubleshooting.

Benefits Over Other Simulation Software: HYSYS has a very user-friendly interface, huge libraries, accurate models, and integration capabilities that make it a go-for for many engineers**.**

1.3 HYSYS Advantages

User Friendly Interface: Its graphical user interface is designed in such a way that process modelling and analysis has become very easy to learn for beginners as well.

Component Libraries: HYSYS comes with large libraries of chemical components and thermodynamic models, so most processes can be simulated effectively.

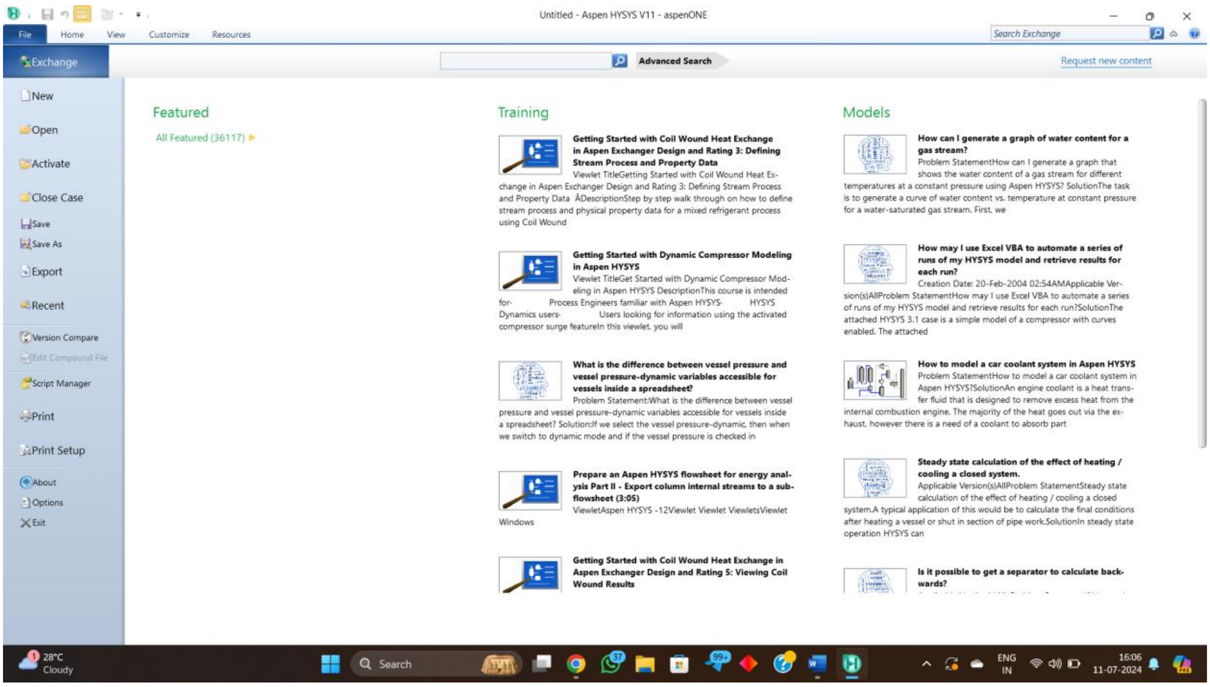
Accurate thermodynamic models: The product has rigorous thermodynamic models that guarantee accurate simulation results, hence process optimization and safety analysis. The tool is also well-integrated with other AspenTech products, thus promoting data exchange and the optimization of the whole process.

Starting with HYSYS

2.1 Starting with HYSYS

Opening the Software: To open HYSYS, open where you installed HYSYS to your computer. You should find it in your list of applications. Double-click to open the program. The program will open display the main interface.

Main Interface: The main places within the interface are the menu bar, toolbar, and the workspace. The workspace is where you will be creating/modifying your simulations.



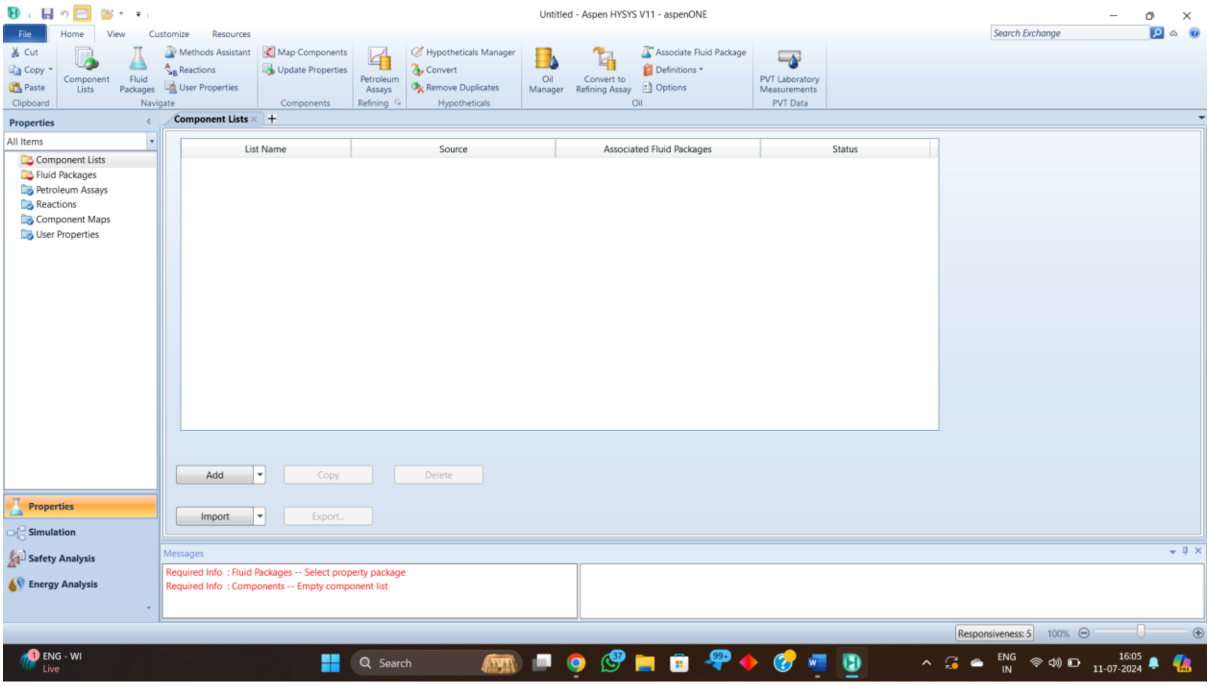
2.2 Simulation Basis Manager

Introduction and Purpose: The Simulation Basis Manager is where you define the chemical components, thermodynamic models and fluid packages for your simulation. This is the first step in creating a new simulation.

Setting up a new project: Open the Simulation Basis Manager from the main interface Type in a name for your project and specify the units of measurement.

2.3 Creating a New Simulation

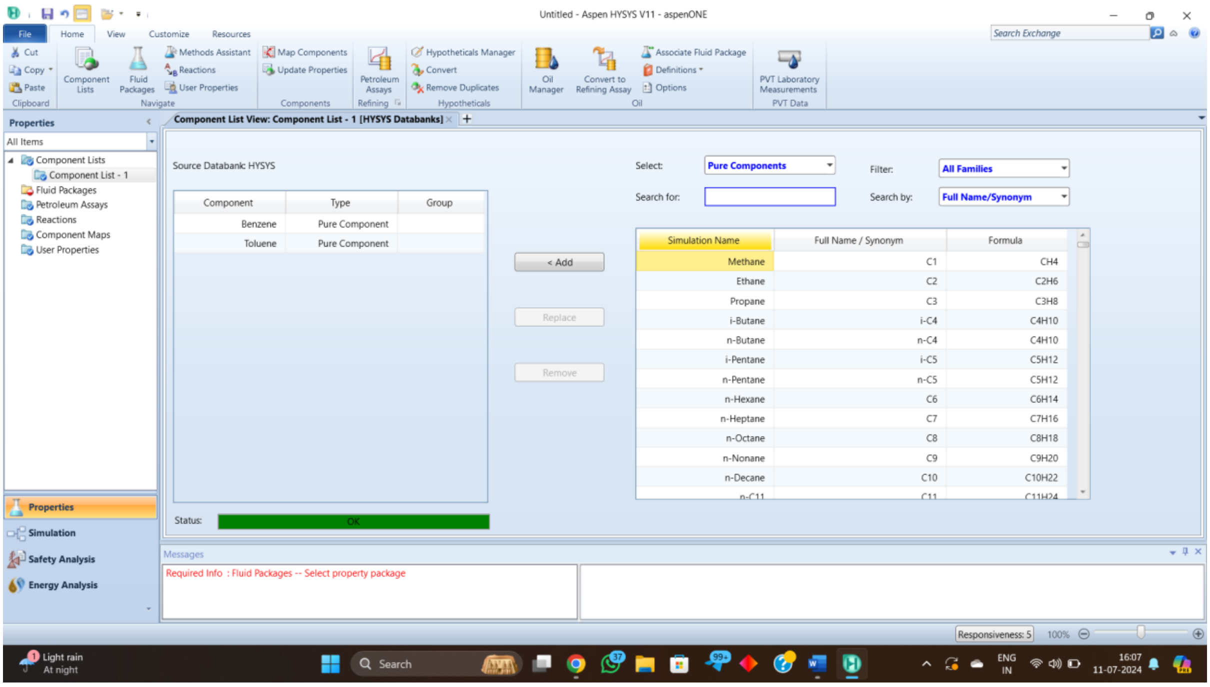
Step-by-Step Guide: Once the project has been set up, utilize the "New Simulation" option in the Simulation Basis Manager to generate a new simulation file.



2.4 Adding Components to the Simulation

Component Selection Process: Under the Simulation Basis Manager, click "Add Components" and select the relevant chemicals in the database. Add them to your project.

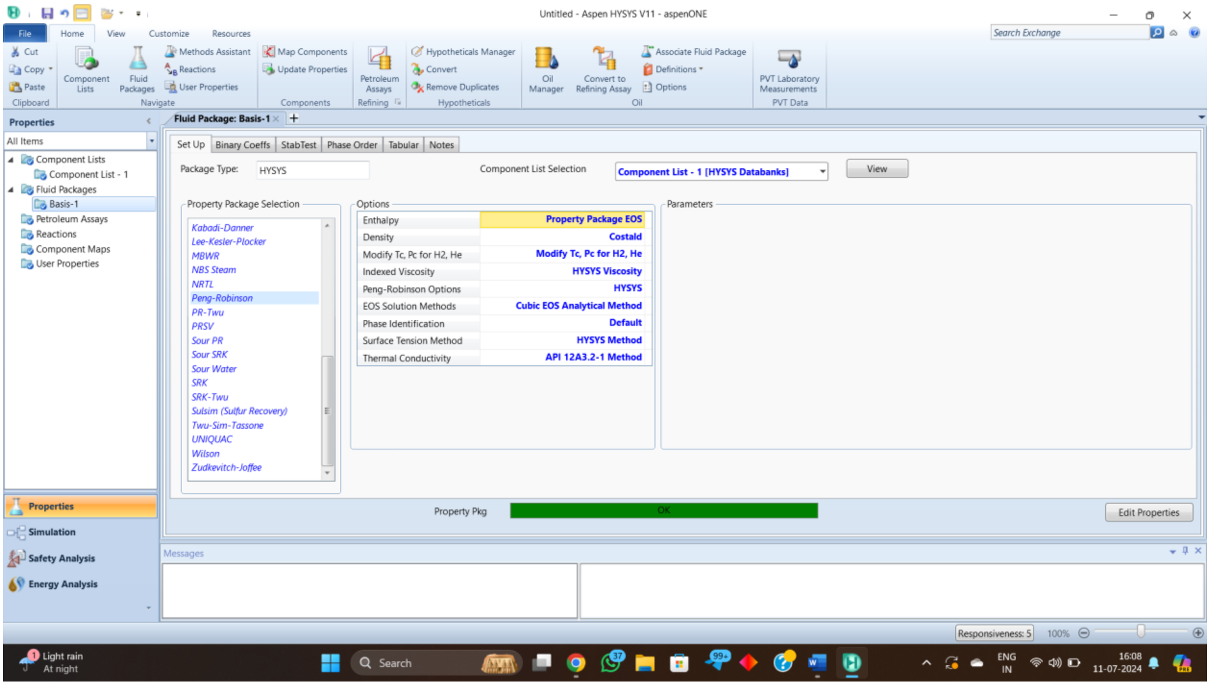
Adding and Managing Components: Ensure that all the necessary components are added. The added components can be managed by changing their properties or by removing them if need be.



2.5 Selecting a Fluids Package

Overview of Fluid Packages: Fluid packages are the thermodynamic models and methods used for estimating properties in simulations. For example, Peng-Robinson, Soave-Redlich-Kwong, or NRTL.

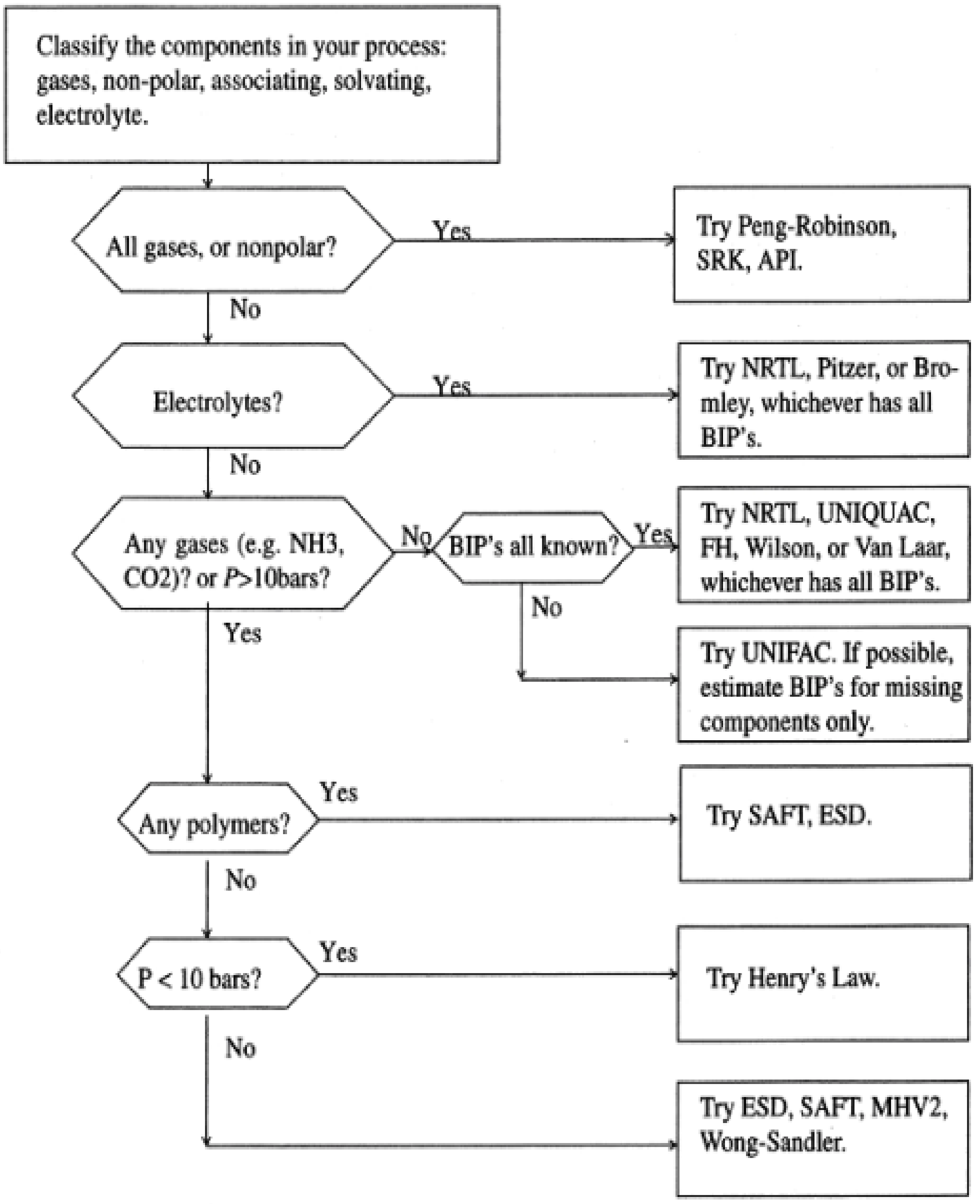
Selection Criteria: Choose fluid packages based on the components in your simulation and the process conditions. This will impact the accuracy in results from your simulation.



2.6 Thermodynamics Model Selection

Importance of Thermodynamics in Simulations: Thermodynamic models dictate what algorithms are used to calculate the different properties. Obviously, one needs as accurate a model as possible to get correct simulations.

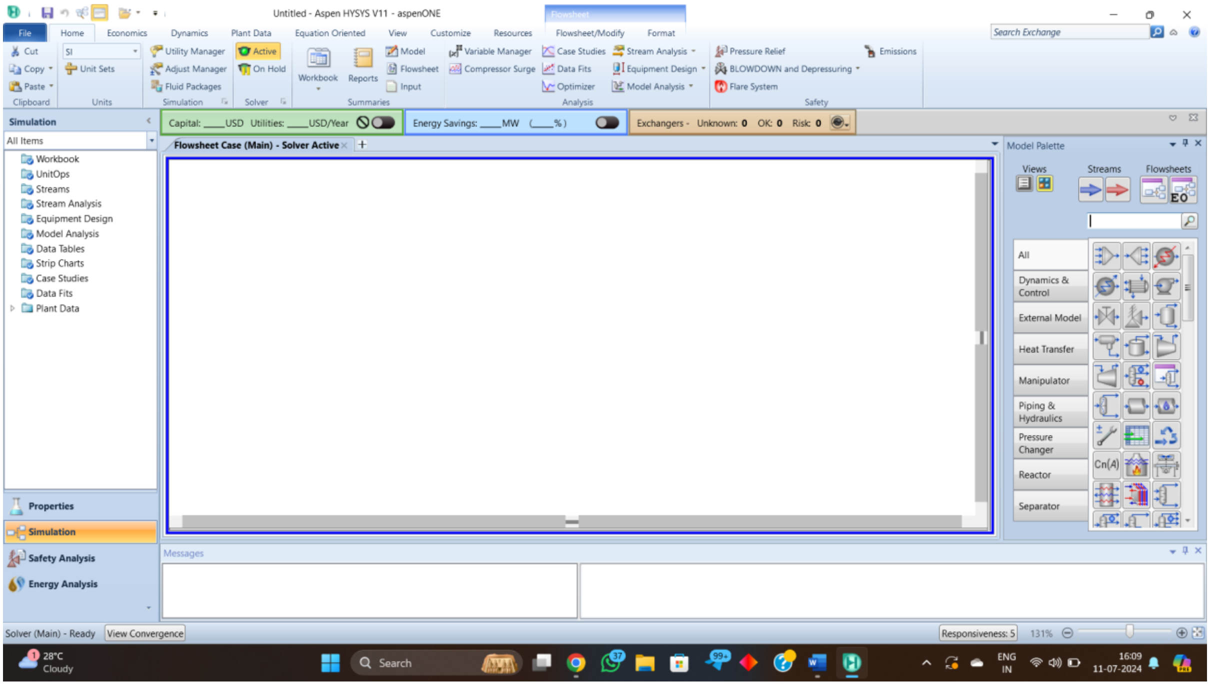
Selection of a Thermodynamic Model: Depending on the nature of the components, expected phase behaviour and process conditions, choose a suitable thermodynamic model.



2.7 Enter Simulation Environment

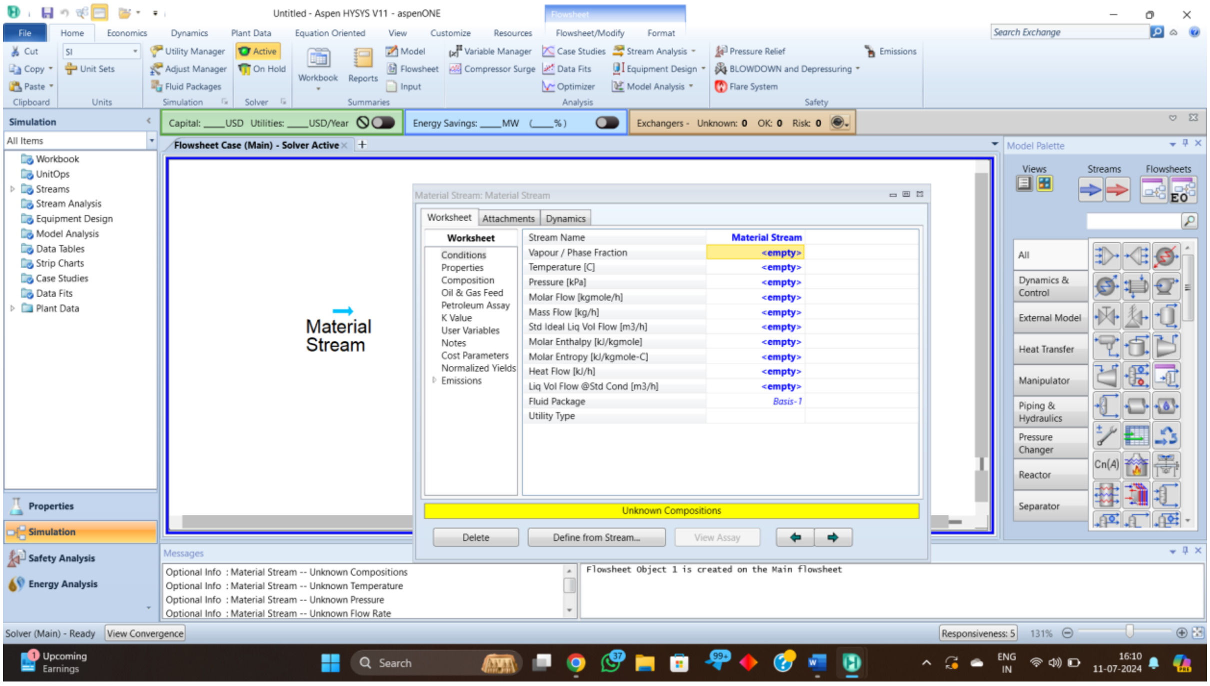
Simulation Environment: After defining a simulation basis, you can click "Enter Simulation Environment" to enter the main workspace where you will build and run your simulation.

Main Features and Buttons: The simulation environment includes buttons to add unit operations and streams, among others. You can also execute material balance calculations by running the computer application. You can spend a little time looking at the toolbar and menus.



2.8 Adding Material Streams

Define and Configure Material Streams: Material streams are used to represent the flow of substance in your process. The "Add Stream" button allows one to add streams by defining the properties of the stream.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Flowsheet Case (Main) - Solver Active
Material Stream
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User Variables
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Cost Parameters
Normalized Yields
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Material Stream
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Pressure [kPa]
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Fluid Package
Basis-1
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Delete
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Flowsheet Object 1 is created on the Main flowsheet
Solver (Main) - Ready
View Convergence

Equations of State – Mathematical Formulations

Equations of State are mathematical models in thermodynamics describing the relationships between P, V and T. These, in turn, are cardinal for any estimating approach about the behaviour of gases and liquids under various conditions, which is basic to process simulation and design in Aspen HYSYS.

3.1 Fundamental Principles and Terminologies

Equations of State:

An equation of state is a thermodynamic equation that links the state variables, among them pressure, volume, and temperature. The simplest, most well-known EOS is the ideal gas law given **PV=nRT**, where P is pressure, V is volume, n is the number of moles, R is the gas constant, and T is temperature.

Real Gas Behaviour: Real gases do not always obey the Ideal Gas Law, particularly at high pressures and low temperatures. Hence, more complex EOS have been developed to take into account interactions between gas molecules and volume occupied. The key parameters are:

Pressure: Force exerted by molecules of a gas or liquid per unit area on walls of its container.

V—Volume: It is the volume occupied by the gas or liquid.

T—Temperature: It is a measure of average kinetic energy of the molecules in the system.

Why EOS is important in Process Simulation:

Predicting Phase Behaviour: EOS helps in predicting the phase behaviour of mixtures, which is critically required in separation process design, notably distillation.

Property Calculations: EOS are used to calculate thermodynamic properties like enthalpy, entropy, and fugacity used in energy balance and process optimization.

3.2 Common Equations of State Used in HYSYS

1. Peng-Robinson EOS:

Introduction: The Peng-Robinson equation of state was developed by Ding-Yu Peng and Donald B. Robinson in 1976. It finds a very wide application in the oil and gas industry, particularly for hydrocarbon systems.

Mathematical Expression

$$P = \frac{RT}{V_m - b} - \frac{a\alpha(T)}{V_m(V_m + b) + b(V_m - b)}$$

Where P is the pressure, V_m is the molar volume, T is the temperature, R is the gas constant, a and b are substance-specific parameters, and $\alpha(T)$ is a temperature-dependent function.

Key Features:

- Suitable for non-polar and slightly polar substances.
- Accurately predicts the behaviour of both liquids and gases.

- Widely used for natural gas processing and petroleum refining.

2. Soave-Redlich-Kwong (SRK) EOS:

Introduction:

The SRK EOS is a mathematical alteration of the Redlich-Kwong EOS by Giorgio Soave in 1972 with the objective of improvement regarding reliance for the behaviour prediction of hydrocarbons and other compounds.

Mathematical Formulation

$$P = \frac{RT}{V_m - b} - \frac{a\alpha(T)}{V_m(V_m + b)}$$

Where a, b, and $\alpha(T)$ are parameters specific to each substance, with $\alpha(T)$ being a function of temperature.

Key Features:

- It is suited to use for both non-polar and weakly polar compounds.
- The improvement brought forth by SRK over its predecessor (Redlich-Kwong EOS) was in the introduction of a temperature correction factor.
- Commonly used in the petrochemical industry for VLE calculations.

3. Benedict-Webb-Rubin (BWR) EOS:

Introduction:

The BWR EOS was developed by M. Benedict, G. B. Webb, and L. C. Rubin in 1940. It is a rather complex equation, containing molecular interaction body terms, as well as the temperature dependency of such interactions.

There should be a remark here that is very complicated equation, which can promise good accuracy only for dense fluids and for liquid phases; therefore, the field of applications is likely to be for systems where distinct and accurate prediction of phase behaviour is desired. Also, it can be applied for both polar and non-polar compounds, including their complex mixtures.

3.3 Use and Benefits of Popular EOS in HYSYS

Peng-Robinson EOS

Application:

- Natural gas processing
- Petroleum refining
- Investigation of phase property of hydrocarbons

Benefits:

- High accuracy for hydrocarbon systems
- The liquid and vapor phases are considered identically.
- It is a well-validated model for the industry**.**

Soave-Redlich-Kwong (SRK) EOS

Application:

- Chemical and petrochemical industries
- Hydrocarbon processing

- Phase equilibrium calculations

Benefits:

- The use of advanced temperature correction factor provides an improved level of accuracy.
- Gives a detailed representation of molecular interactions.
- Higher accuracy for dense fluids.
- Applicable to a wide range of substances and conditions.

Comparison of EOS:

Peng-Robinson vs. SRK:

- Both expressions represent cubic equations of state and are of similar form. However, the Peng-Robinson EOS yields better for liquid densities and high-pressure systems;

Peng-Robinson and SRK vs. BWR:

- Of higher complexity and implementation is computationally expensive, BWR EOS give higher accuracy for dense phases and complex mixtures.

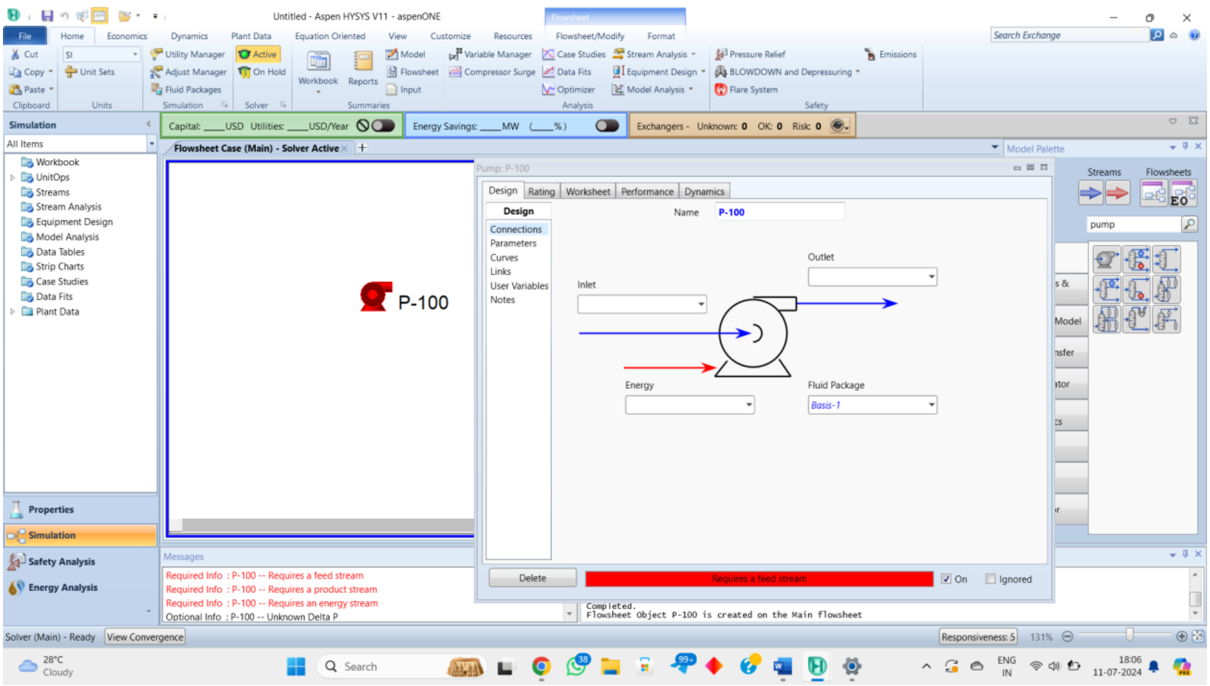
Pumps

4.1 Introduction to Pumps in HYSYS

- **Types of Pumps:** Centrifugal pumps, positive displacement pumps, and others. Each type has specific applications and characteristics.
- **Applications in Simulations:** Pumps are used to move fluids through the process. They are essential for maintaining flow rates and pressures.

4.2 Adding and Configuring Pumps

- **Step-by-Step Guide:** In the simulation environment, click "Add Unit Operation" and select a pump. Define the pump's properties, including inlet and outlet streams, flow rate, and head.



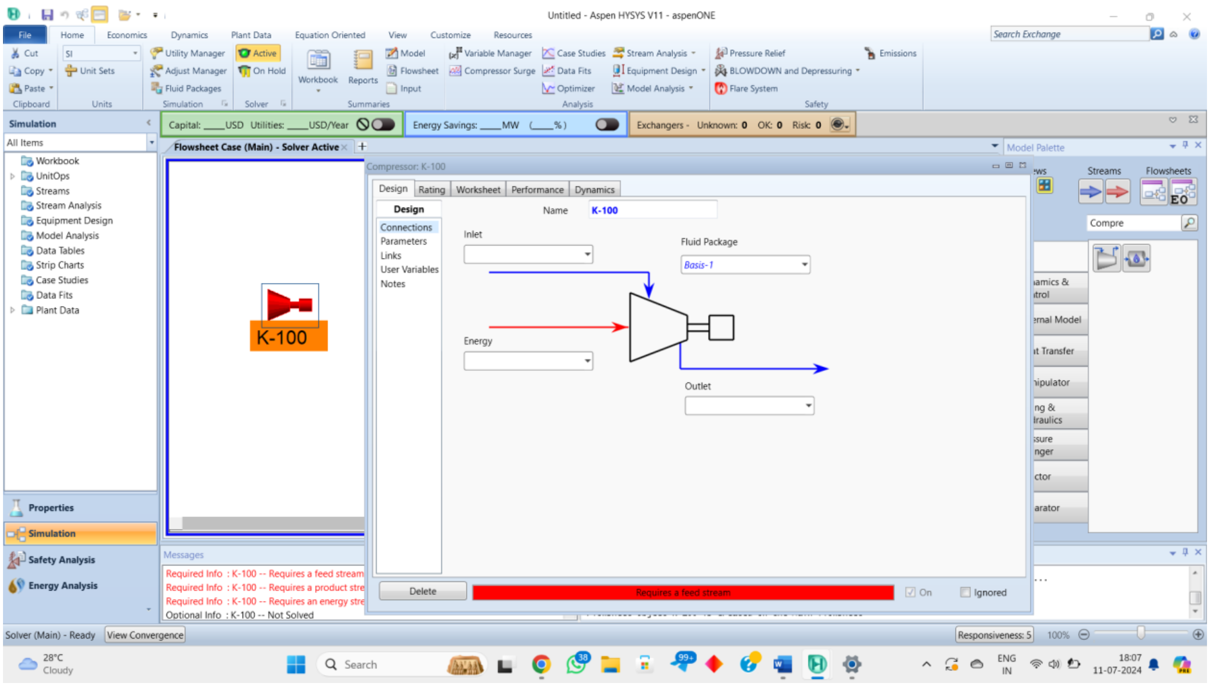
Compressors

5.1 Introduction to Compressors

- **Types and Applications:** Centrifugal compressors, reciprocating compressors, and screw compressors. Used for gas compression in various industrial processes.
- **Importance in Simulations:** Compressors are critical for maintaining gas flow rates and pressures. Accurate modelling is essential for process optimization and safety.

5.2 Adding and Configuring Compressors

- **Detailed Steps:** In the simulation environment, click "Add Unit Operation" and select a compressor. Define the compressor's properties, including inlet and outlet streams, compression ratio, and efficiency.



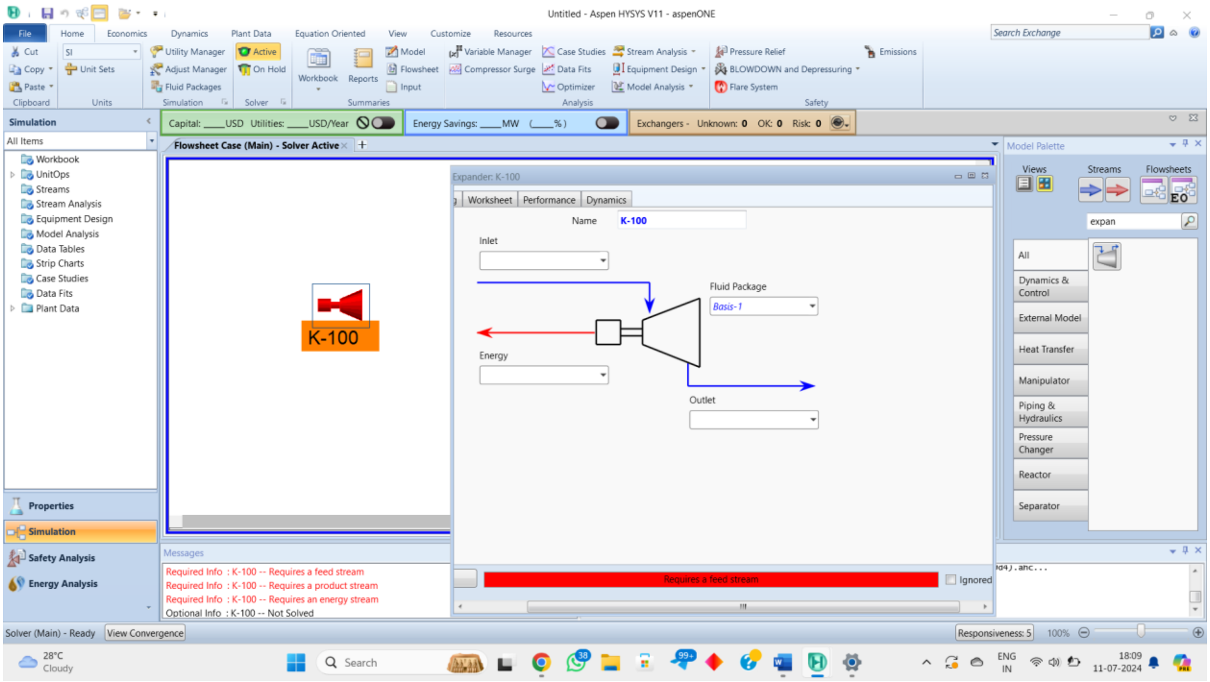
Expanders

6.1 Introduction to Expanders

- **Types and Uses:** Turbo-expanders and other types. Used for energy recovery and cooling in various industrial processes.
- **Role in Process Simulations:** Expanders are critical for maintaining gas flow rates and pressures. Accurate modelling is essential for process optimization and safety.

6.2 Adding and Configuring Expanders

- **Step-by-Step Instructions:** In the simulation environment, click "Add Unit Operation" and select an expander. Define the expander's properties, including inlet and outlet streams, expansion ratio, and efficiency.



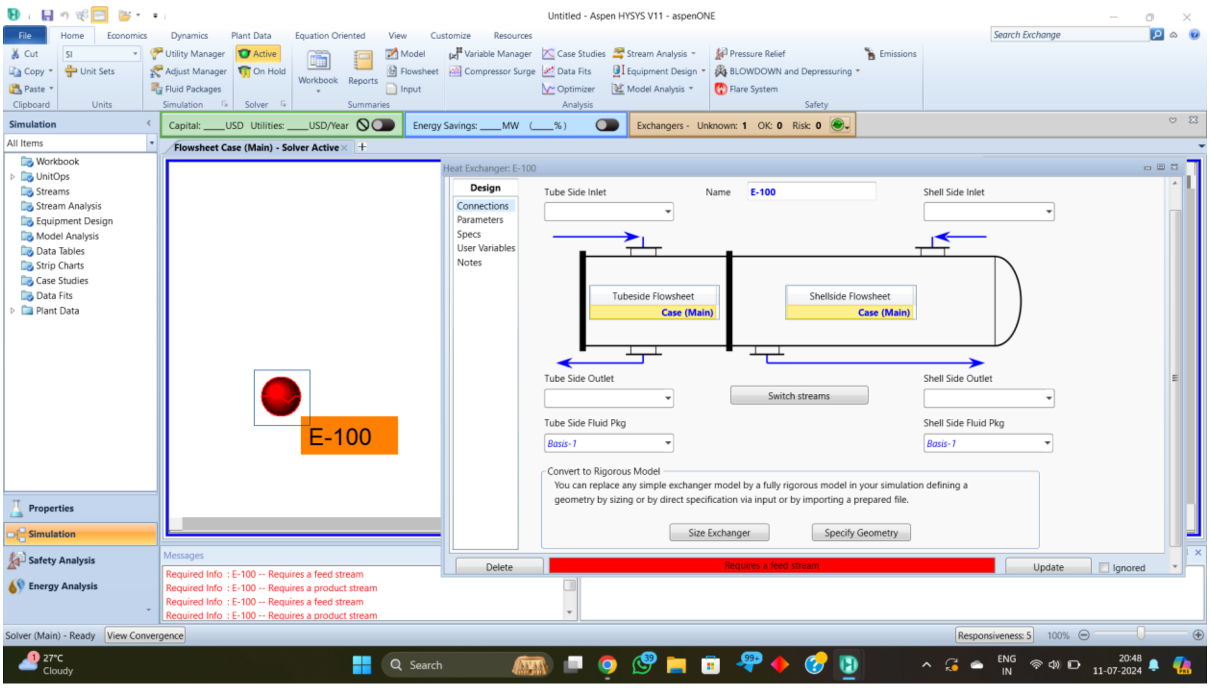
Heat Exchangers

7.1 Introduction to Heat Exchangers

- **Types and Applications:** Shell-and-tube heat exchangers, plate heat exchangers, and others. Used for transferring heat between fluids in various industrial processes.
- **Importance in Process Engineering:** Heat exchangers are critical for maintaining temperature control and energy efficiency. Accurate modelling is essential for process optimization and safety.

7.2 Adding and Configuring Heat Exchangers

- **Detailed Guide:** In the simulation environment, click "Add Unit Operation" and select a heat exchanger. Define the heat exchanger's properties, including inlet and outlet streams, heat duty, and temperature approach.



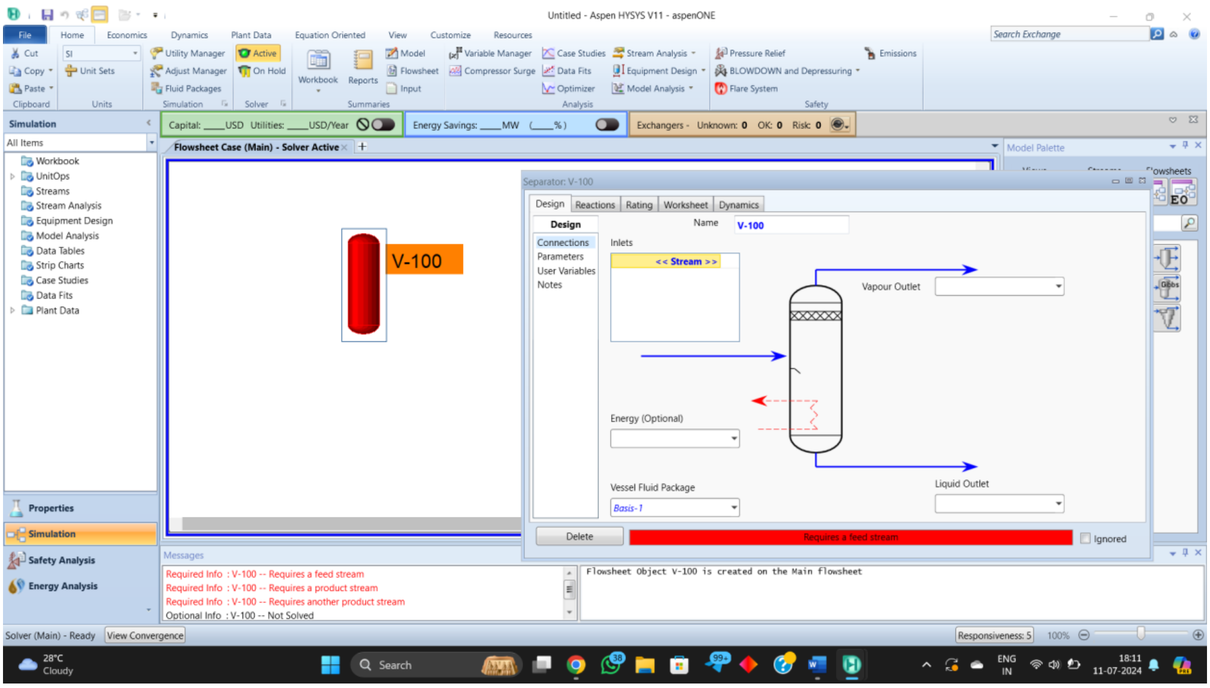
Flash Separators

8.1 Introduction to Flash Separators

- **Types and Uses:** Single-stage and multi-stage flash separators. Used for separating vapor and liquid phases in various industrial processes.
- **Role in Process Simulations:** Flash separators are critical for phase separation and purification. Accurate modelling is essential for process optimization and safety.

8.2 Adding and Configuring Flash Separators

- **Step-by-Step Instructions:** In the simulation environment, click "Add Unit Operation" and select a flash separator. Define the separator's properties, including inlet and outlet streams, pressure, and temperature.



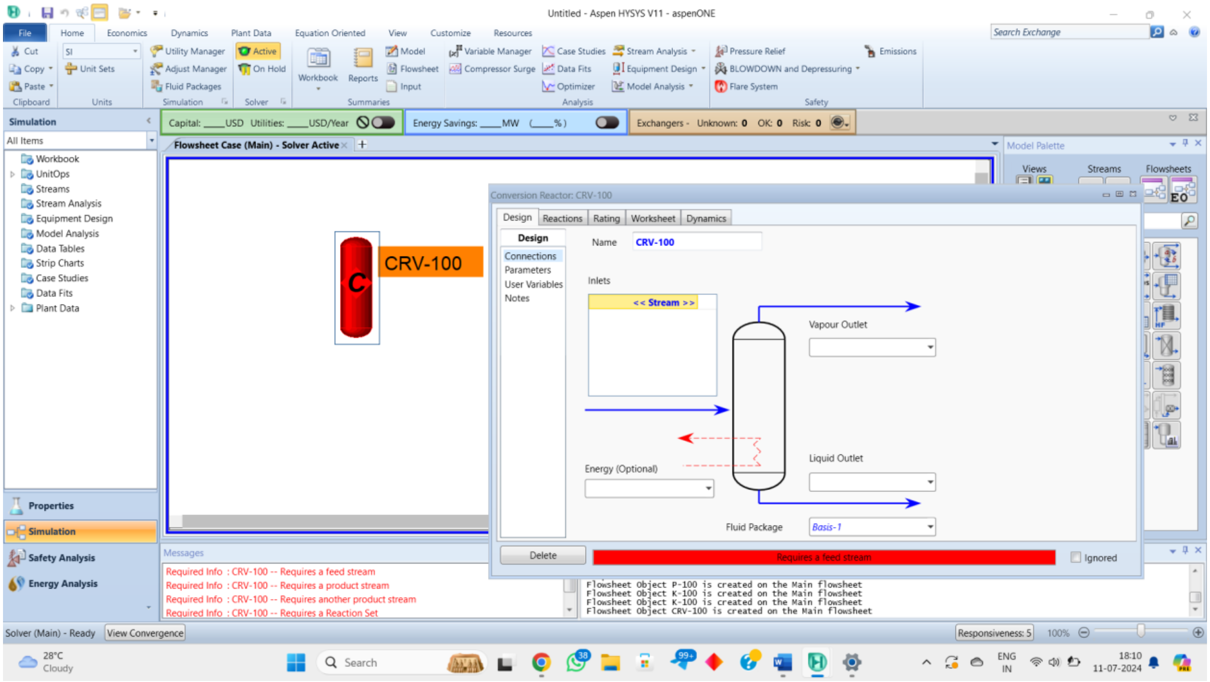
Conversion Reactions

9.1 Introduction to Conversion Reactions

- **Types and Applications:** Catalytic and non-catalytic conversion reactions. Used for transforming reactants into products in various industrial processes.
- **Importance in Simulations:** Conversion reactions are critical for chemical production and process optimization. Accurate modelling is essential for achieving desired product yields and quality.

9.2 Adding and Configuring Conversion Reactions

- **Detailed Guide:** In the simulation environment, click "Add Unit Operation" and select a reactor. Define the reactor's properties, including reactants, products, conversion rate, and operating conditions.



Examples

Example 1: Process Involving Reaction and Separation Toluene is produced from n-heptane by dehydrogenation over a Cr2O3 catalyst: CH3CH2CH2CH2CH2CH2CH3 → C6H5CH3 + 4H2 The toluene production process is started by heating n-heptane from 65 to 800 o F in a heater. It is fed to a catalytic reactor, which operates isothermally and converts 15 mol% of the n- heptane to toluene. Its effluent is cooled to 65 o F and fed to a separator (flash). Assuming that all of the units operated at atmospheric pressure, determine the species flow rates in every stream.

Solution:

1. Start HYSYS and File/New/Case.

2. Simulation Basis Manager will pop up. Click Add. Fluid Package window will be opened. Choose Peng Robinson as Base Property Package.

3. Open Component page of Fluid Package window and add components (toluene, n- heptane, and hydrogen) and close the Fluid Package.

4. Click Enter Simulation Environment at the bottom of Simulation Basis Manager.

5. Click Heater in the Object Palette and click it on Process Flow Diagram (PFD). Click General Reactor, three different reactors will pop up, click conversion reactor and click it on PFD. Do the same for the Cooler and Separator.

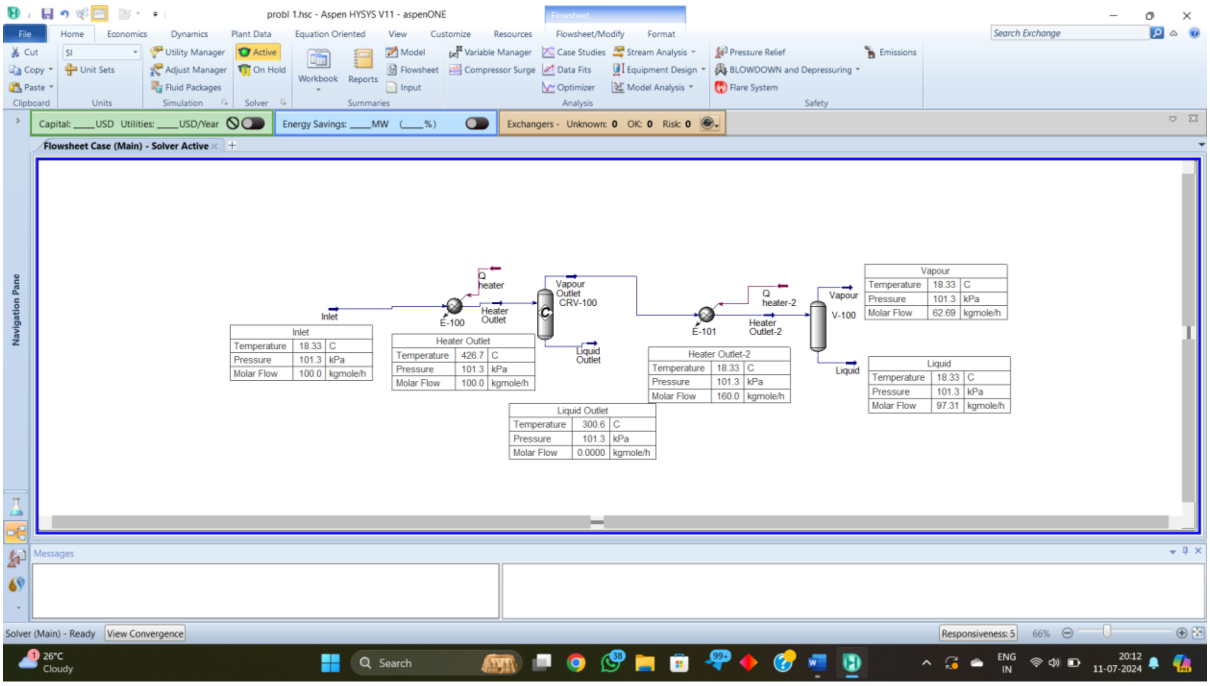
6. Name inlets and outlets of all process units.

7. You will notice that the reactor is coloured red with the error message, “Need a reaction set.” Now we need to input what the reaction is. Click Flowsheet/Reaction Package. Add Global Reaction Set. Then, click Add Reaction at the lower right side of the window and choose Conversion.

Add three components (n-Heptane, Toluene, Hydrogen) and Stoichiometric Coeff (-1, 1, 4). Click Basis page, and type 15 for Co (this is the conversion). Close windows until you see PFD.

8. Double click reactor. Choose Global Reaction Set as Reaction set and close the window.

9. Now, open worksheet, and type in all the known conditions for the streams. Note that only blue coloured fonts are the values that you specified. If you more information than the degree of freedom allows, it will give you error messages.



Example 2: Modification of Process for the Improvement

Inspection of the calculation results of Example 1 shows that the cooling duty is comparable to the heating duty, suggesting that the utility load can be reduced by preheating the feed stream with hot reactor product. Modify the process by adding a heat exchanger.

<u>Solution:</u>

This can be accomplished in the PFD using the following steps:

1. Click Heater of PFD and change the name of the feed stream to E-102. Close the window.

2. Click the Vapour Outlet stream of PFD. Worksheet of the outlet stream will pop up. Change the name of the Reactor effluent stream to Vapour Outlet.

3. Click Cooler of PFD and change the name of the feed stream to Exc. Outlet.

4. Install the Pre-Heater unit, using the Heat-exchanger model, with Feed and Pre-Heat as the tube-side inlet and outlet streams, and with Vapour outlet and Exc. Outlet as the shell side inlet and outlet streams. Click Parameter at the left side of the window. Specify Delta p as 0 for both tube side and shell side. Choose Weighted Exchanger as Model. Close the window.

5. You still need to specify one more condition. Open the Worksheet and specify the temperature of Pre-Heat stream to 600 F. You may change this temperature to see how it affects the Heat-duty.

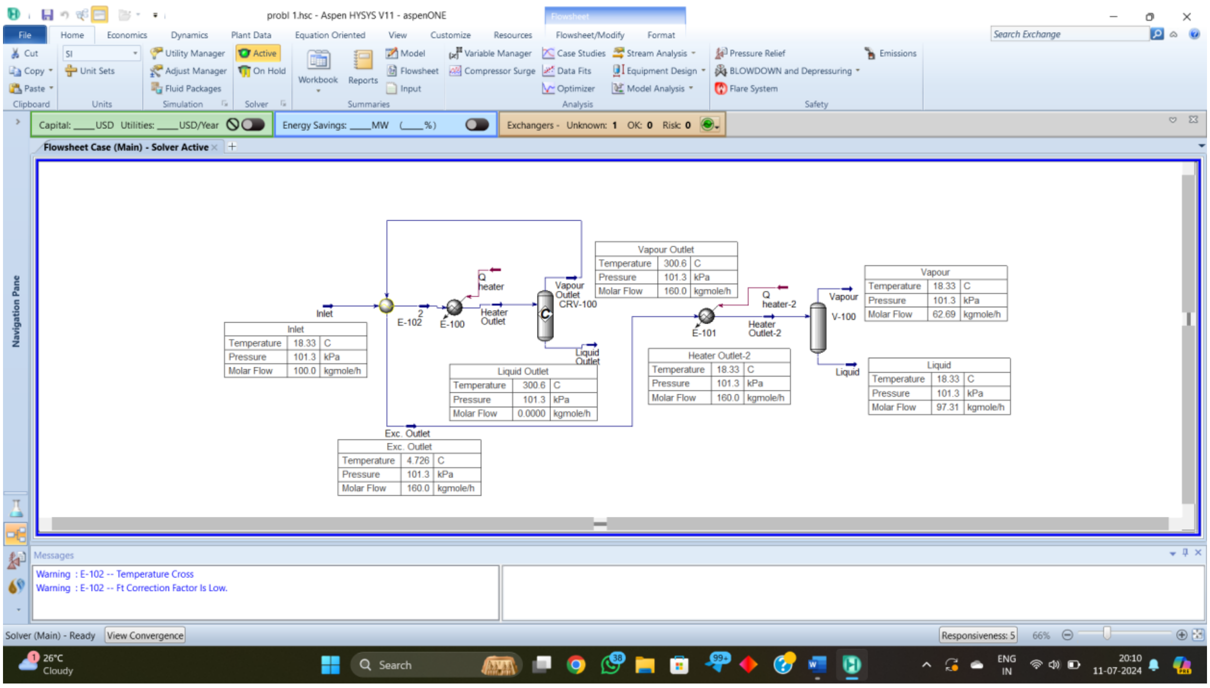
6. You can change the Pre-Heat stream temperature and see how it affects the H-Duty and UA (heat transfer coefficient x interfacial area). Increasing Pre-Heat temperature can reduce the H-Duty, but it will increase UA, which means that you need a heat exchanger with more interfacial area (bigger and with more inner pipes). Obviously, there will be upper limit of Pre-Heat temperature no matter how good your heat exchanger is. You can see this effect by changing the temperature and

recording the change of other values. This can be done by using Databook function (under the Tools pull down menu.). The process can be described as follows:

a. Open Tools/Databook. Click Insert button and choose Pre-Heat as object, Temperature as Variable and click Add button. Do the same for Heat-Duty as object, Heat Flow as Variable and Heat Exch as object, UA as Variable. Close the window.

b. Go to the Case Studies page and click Add. Check Ind (Independent variable) for Pre-Heat and check Dep (Dependant variable) for Heat-Duty and Heat Exch. Click View. Type in 500 for Low Bound, 620 for High Bound, and 10 for Step Size.

c. Click Start. After a few seconds, click Results.



Conclusion

The internship experience in ONGC has exposed us to a great extent to practical applications regarding Aspen HYSYS in the oil and gas industry. We have covered, in our report, right from setting up a simulation in Aspen HYSYS to fundamentals of equations of state and functioning of equipment such as pumps, compressors, expanders, heat exchangers, and flash separators. The detailed study of conversion and equilibrium reactions, along with their operation examples, helped do justice to the wide capabilities of HYSYS with regard to process simulation and optimization.

The internship provided hands-on experience whereby theoretical knowledge was applied directly into practical working scenarios, developing problem-solving skills with a strong base of technical expertise. Mentor Mr. Kaustubh Tripathi and facilitator Ms. Shuna Sharma were critical in making this an all-rounded learning experience.

This report shows the amount of knowledge and skills learned through this internship, which was very pivotal in expanding my personal and professional horizons. The deep dive into Aspen HYSYS will, without a doubt, create a firm base for all future pursuits within chemical engineering and process simulation.

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