PROCESS DESIGN
ENGINEERING

TRAINING MANUAL

Indus Global Academy of Technical Education

Branch of Indus USA Inc.

URL: www.indus-usa.com, URL: www.indusedu.com

PREFACE

The Post Graduate Diploma in Process Design Engineering aims at providing professional industrial training & exposure to various Process Engineering design principles for Chemical Engineers. The training programme provides complete knowledge to candidates starting from explaining the roles & responsibilities of Process Design Engineer to development of final process design engineering document i.e., Piping & Instrumentation Diagrams (P&IDs). This programme is designed to cater to the needs of fresher as well as experienced professionals.

This Training will enable Chemical Engineers to enter industry as Process Design Engineer. Process engineers are found in vast range of industries, such as the Oil & Gas, Refineries, Petrochemical, Chemical, Mineral Processing, Food, Pharmaceutical, Biotechnological industries etc., Process Engineering involves developing new process, project engineering and troubleshooting.

The purpose of the Training Manual is to introduce the basic concepts of the process Design Engineering. The Style and approach of the training manual is to provide insight view of the Process techniques to Chemical Engineers. Each lesson concentrates on a major topic and text attempts to explain technology step by step of the technology. Familiarity with the basic operation Process is assumed and material presented.

The materials covered in this training manual is an overview of what are felt to be commonly used and important aspect of Process Design engineering.

TABLE OF CONTENT

MODULE 1

PROCESS ENGINEERING

1.1 INTRODUCTION

PROCESS ENGINEERING is the application of Chemical, Mechanical, Petroleum, Gas and other engineering disciplines in the Development, Design, Construction, Efficient, Safe and economic operation of a plant / processing facility meeting customer's Specifications

- In a Consulting or Engineering contractor Organization, Process Design and / or Process Engineering is usually a Separate Group Responsible for Proposing / Developing / Designing a Process plant / facility for the customer.
- In an Operating or Production Company, Process Design and / or Process Engineering is involved in Research and Development, Technical Services or Engineering Department for developing new projects and processes.

1.2 DIFFERENT PHASES OF A PROJECT

There are five phases in a project, from a Process viewpoint. These are

- Study (Concept and feasibility)
- Engineering (Basic and Detail)
- Procurement
- Fabrication and Construction
- Commissioning and start-up

- **Concept study**

  A conceptual study is the development of an idea / concept for any proposed project.

- **Feasibility Study**

  A feasibility study is an analysis of the viability of an idea / concept through a disciplined and documented process of thinking through the project from its logical beginning to its logical end. It is an Investigating function and should be conducted to determine the viability of an idea / concept before proceeding with the development of the project.

  A feasibility study of a project is conducted at three levels

  - Operational Feasibility - “Will it work?”
  - Technical Feasibility - “Can it be built?”
  - Economic Feasibility (COST – BENEFIT ANALYSIS) - “Will it make economic sense if it works and is built? Will it generate PROFITS?”

- **Design and Engineering**

- Basic Engineering /Front End Engineering & Design (FEED) followed by Detailed Engineering

  FEED OR BASIC ENGINEERING is a common phrase used to define the project engineering activities involved in the first phase of engineering development for any production / processing facility.

  The objectives of FEED/BASIC engineering are to

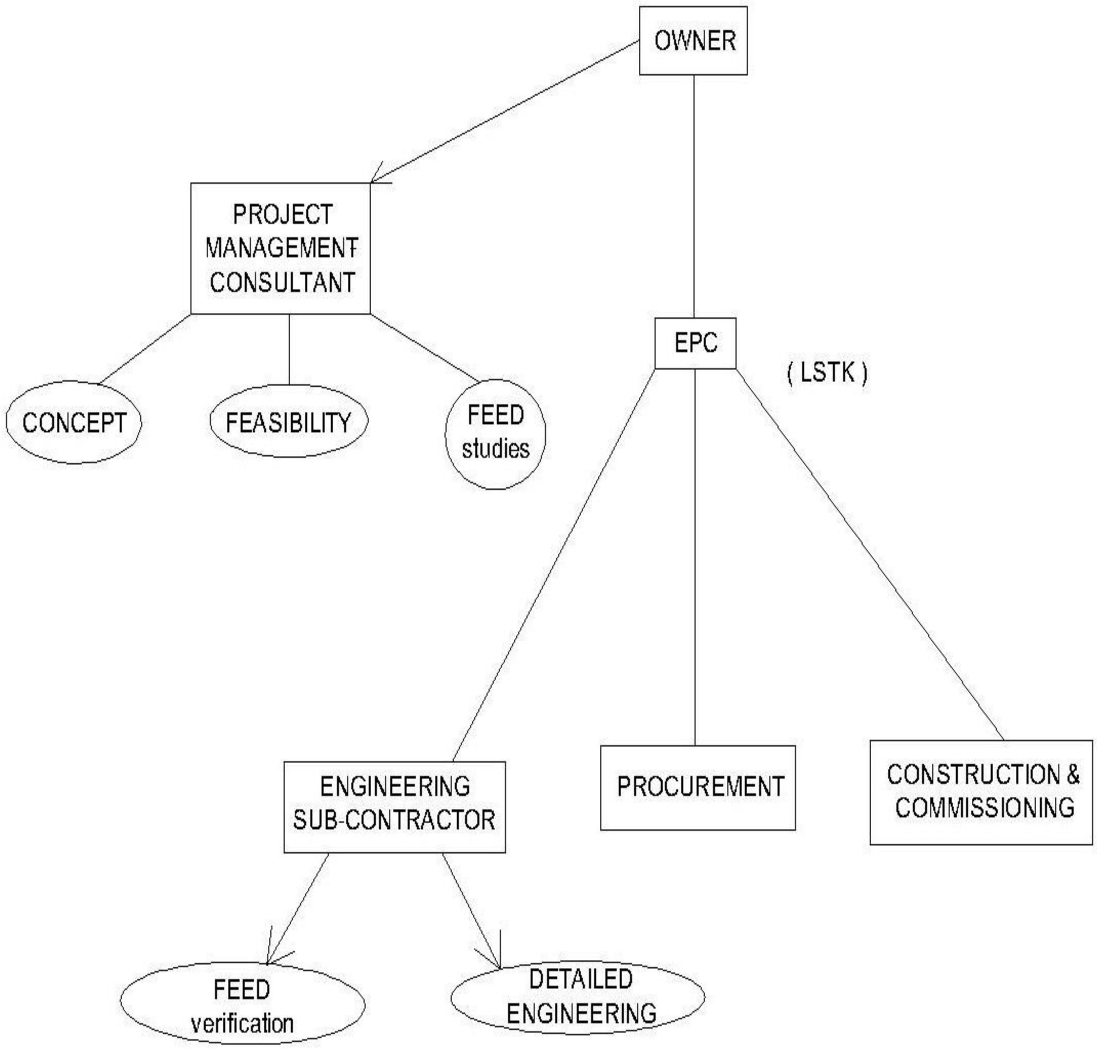
  - Develop project design basis for the facilities.
  - Select optimum process for achieving the required product specifications.
  - Develop project design philosophies as applicable to each engineering discipline.
  - Develop basic engineering documents (degree of detail can vary to suit project/client requirements).

- Develop cost estimate for the project (can be project/client specific).
- Make appropriate recommendations to owner/client.

The Detailed Engineering Phase involves engineering activities as follows

- Verification of FEED / Basic Design
- Carrying out Pre-engineering Survey, if required
- Updating / Finalization of FEED / Basic Design Deliverables
- Generation of engineering drawings / documents required for Construction
- Providing technical assistance for procurement
- Review and Incorporation of Vendor design / data into the design deliverables
- Providing technical support during the fabrication, construction and commissioning phases of the project
- Carrying out post engineering surveys, if required
- Preparation of as-built documentation and drawings

1.3 ELEMENTS IN PROJECT EXECUTION



In the execution of a project, various agencies are involved. They are:

- Owner – organization/company who wants to build and operate a processing plant.
- Project Management Consultancy (PMC) – they are hired by the owners to do the concept, feasibility studies, and carry out FEED / Basic Engineering Activities.
- Engineering Procurement Construction (EPC) / Lump Sum Turn Key (LSTK) Contractors – the FEED / Basic Engineering documents are given by owners to EPC to bid for the project. After the award of contract, EPC is responsible for:
    - FEED verification
    - Detailed Engineering
    - Procurement of various items from different vendors
    - Fabrication, Construction, and Commissioning.

1.4 ROLE OF A PROCESS ENGINEER

In an engineering consultancy, process engineers are usually involved to varying degrees in different phases of a project. The involvement is high & challenging but not voluminous during study and first part of engineering (basic) as well as during commissioning (start-up). It is less challenging but more voluminous during second part of engineering (detail) and procurement; it is negligible during construction. Process engineers should try to adapt to the phase of the project, while doing their work.

- Study (Concept and Feasibility) – Generates Design Data / Information
- Engineering (Basic/FEED and Detail) – Validates and Disseminates the Design data / Information
- Procurement – Evaluation of Technical Bids / Discussion with vendors
- Construction – Response to Site Queries

- Commissioning / Start-up – Prepare procedures and assist in smooth / trouble –free commissioning

In a nut shell, the role of a process engineer is to provide services from concept to commissioning.

1.5 ADDITIONAL RESPONSIBILITIES OF A PROCESS ENGINEER

- Business Development

- Gathering knowledge on technologies (from Principals, Licensors, Vendors)

- Developing design capabilities in new areas

- Development of design tools, calculation procedures, technical database

- Training other engineering disciplines on general / specific process design aspects

- Site services - Data collection for revamping (brown field engineering), commissioning assistance

- Maintaining good customer relations and providing opportunities for repeat orders

1.6 CAPABILITIES OF A PROCESS ENGINEER

- Carrying out Simulation Study to develop Mass & Heat Balance and to establish fluid property databank.

- Performing Equipment (Vessels, Pumps, etc.) Sizing calculations

- Performing Line sizing and Hydraulic calculations

- Developing and updating Process Engineering deliverables

- Carrying out Effluent study to develop suitable Flare, Vent and Drain Systems for the facility
- Carrying out Utility System Design
- Participating in HSE (Health, Safety and Environment) studies like HAZOP (Hazard v/s Operability), SIL (Safety Integrity Levels) to record the design changes and to implement in Engineering
- Technical Assistance for Procurement
- Vendor offer review & clarifications
- Assistance in Technical Bid Evaluation
- Final Vendor data incorporation

1.7 PROCESS DESIGN ENGINEERING DELIVERABLES

Some of the major process design engineering deliverables are:

- Process Design Basis
- Process Simulation Study
- Process Flow Diagrams (PFDs)
- Equipment Design and specifications
- Line sizing and hydraulics
- Instrument sizing and specifications
- Piping and Instrumentation Diagrams (P&IDs)
- Utility consumption summary
- Cause and Effect Diagrams

Indus
Global Academy of Technical Education

ASSIGNMENT - MODULE 1

PROCESS ENGINEERING

1. Write briefly a general understanding, on Process Design Engineering?

   Note: Prepare in the form of presentations to illustrate the understanding.

MODULE 2

UPSTREAM OIL AND GAS OVERVIEW

2.1 RESERVOIR

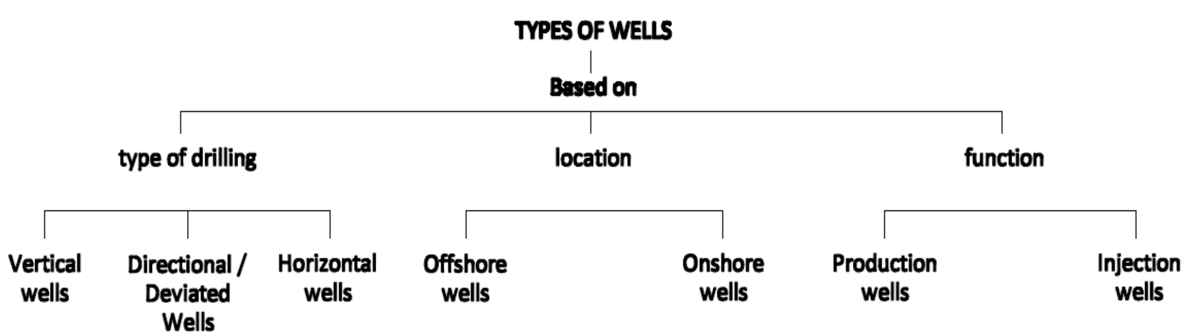
- Oil and gas deposits form an organic material (tiny plants and animals) deposited in the soil, around 100 to 200 million years ago, under, over or with the sand or silt, and is transformed by high temperature and pressure into hydrocarbons.

- For this reservoir to form, porous rocks need to be covered by non porous layers such as salt, and other such substances which can prevent the hydrocarbons from leaking out of the rocky area. As the rock structures begin to fold and uplift due to earthquakes and other tectonic movements, the hydrocarbons migrate out of the deposits and move upward in porous rocks and collects in crests under the non permeable rock, with gas at the top, then oil and fossil water at the bottom.

2.2 WELLS

Well is a term for any perforation through the earth's surface (reservoir) designed to find and release both petroleum oil and gas hydrocarbons. Wells are drilled using Jack up Rigs and Semi-submersibles.

TYPES OF WELLS



WELL COMPLETION

Well completion is a technique wherein the proper equipment is selected and installed to achieve the maximum production throughout the wells life economically. Well completion design varies from well to well and field to field.

2.3 OFFSHORE STRUCTURES

Type of offshore structure and production system depends on

- Water depth.
  - Water depths up to 200 m (typical)- **Shallow water**
  - Water depths 200 to 1000 m (typical)- **Deep water**
- Weather conditions
- Sea-bed conditions

Structures & Production Systems

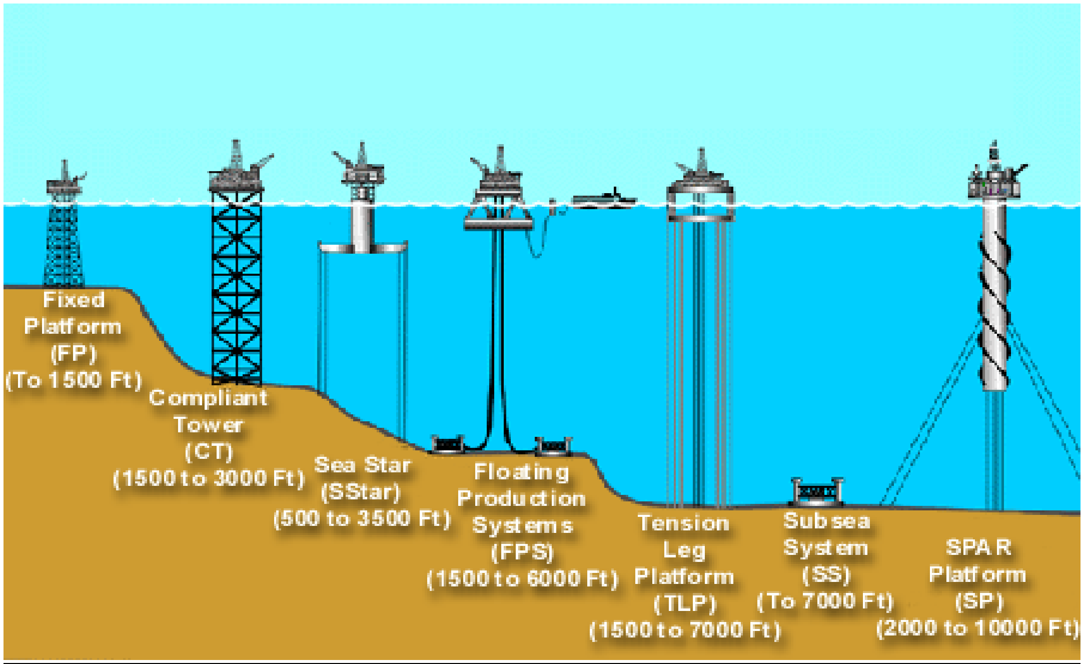
There are four types of concepts in structure, based on water depth:

- **Fixed Structure** → Steel Jacket Platform & Concrete Gravity Platform

- **Complaint Structure** → Guyed Tower, Complaint Piled Tower, Flexible Tower & Tension Leg Platform

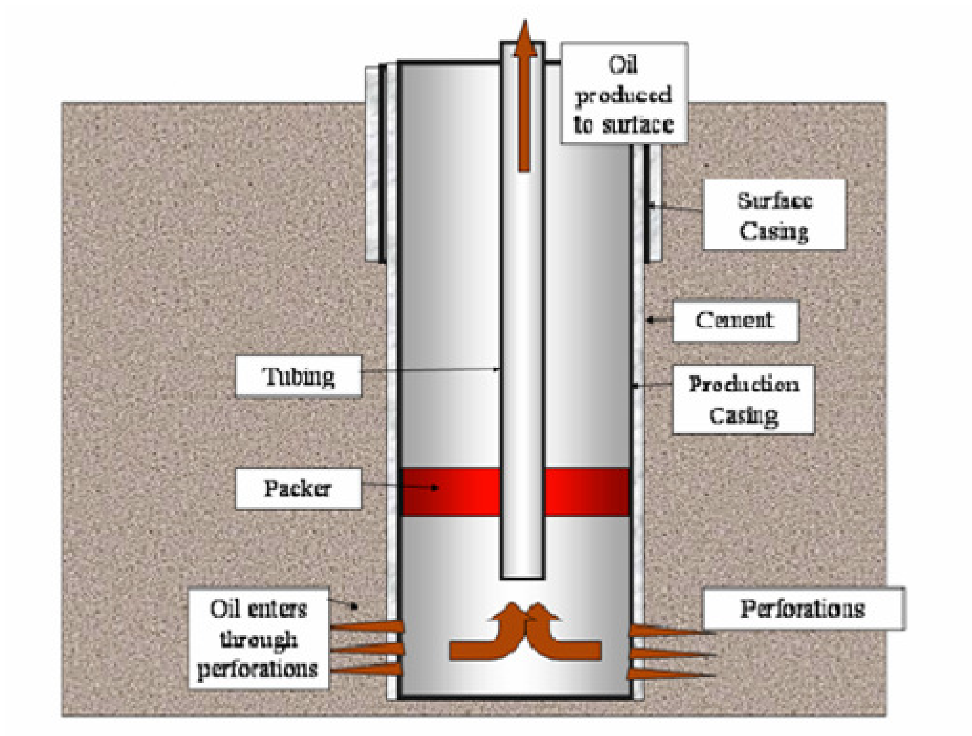
- **Floating Production System** → Tanker & Moorings and Semi-Submersible

- **Sub-sea System** → Sub-sea Templates and Sub-sea Separation unit



2.4 PRODUCTION TECHNIQUES

Self Flow:



- Self flow of well fluid happens when the Reservoir Pressure is greater than the Well Bore pressure or pressure of the Surface producing facilities.

- Reservoir pressure is created by Associated Gas and / or Formation water.

Artificial Lift:

- When there is a decrease in the reservoir pressure or the reservoir pressure is insufficient to overcome the pressure exerted by the fluid column, well fluid ceases to flow.

- To sustain production or to enhance recovery from these wells, the available energy is supplemented by external means and this is known as artificial lift.

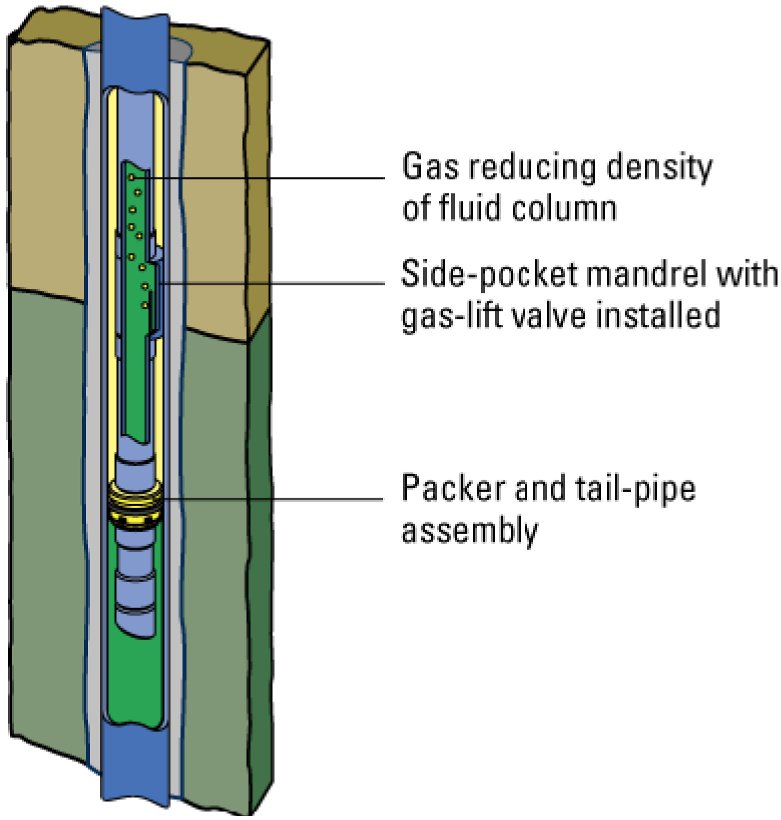
Methods of Artificial Lift:

The commonly used methods of Artificial Lift are:

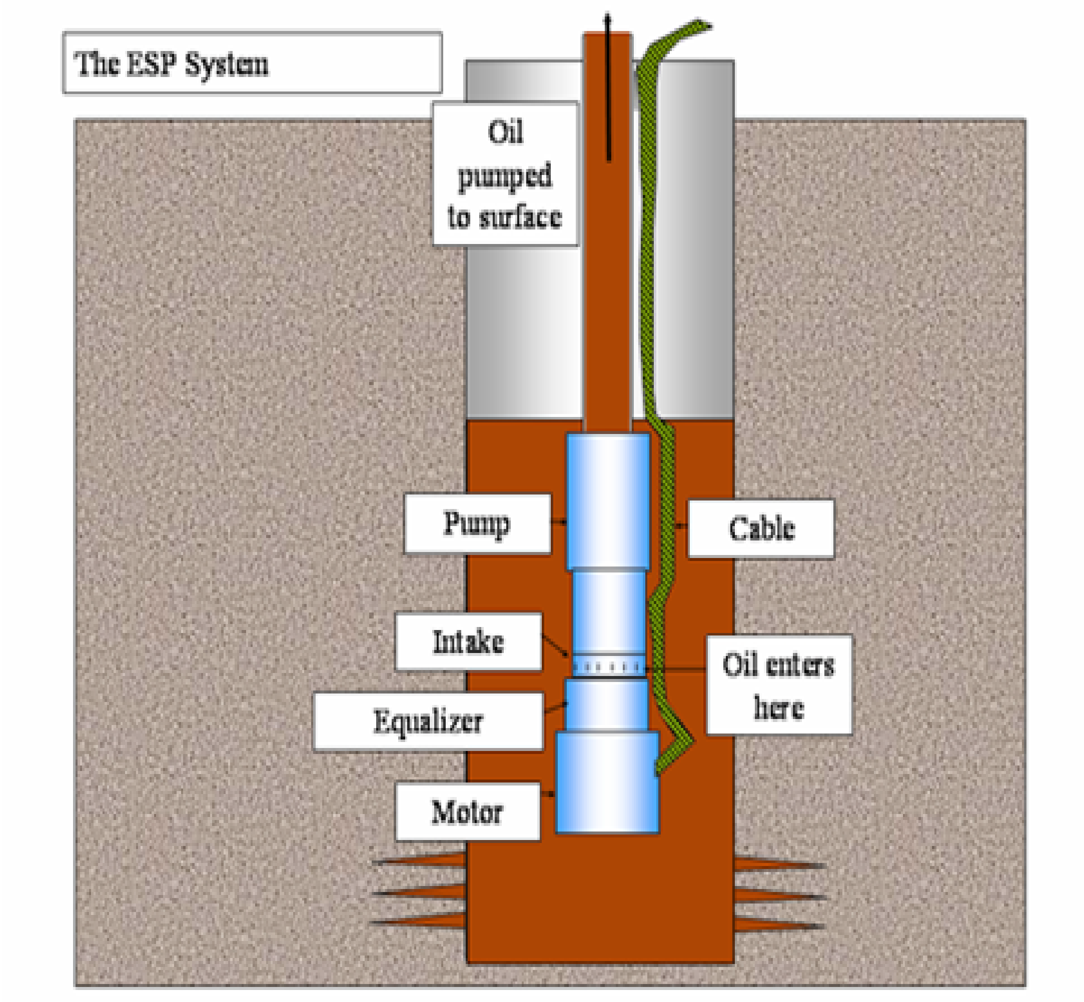
- Water injection – water at high pressure is directly injected into the reservoir to increase the reservoir pressure.

- Gas injection – gas (treated) at high pressure is directly injected into the reservoir to increase the reservoir pressure.

- Gas Lift – the gas is injected into the well flow to lower the specific gravity of the oil to make the well flow.



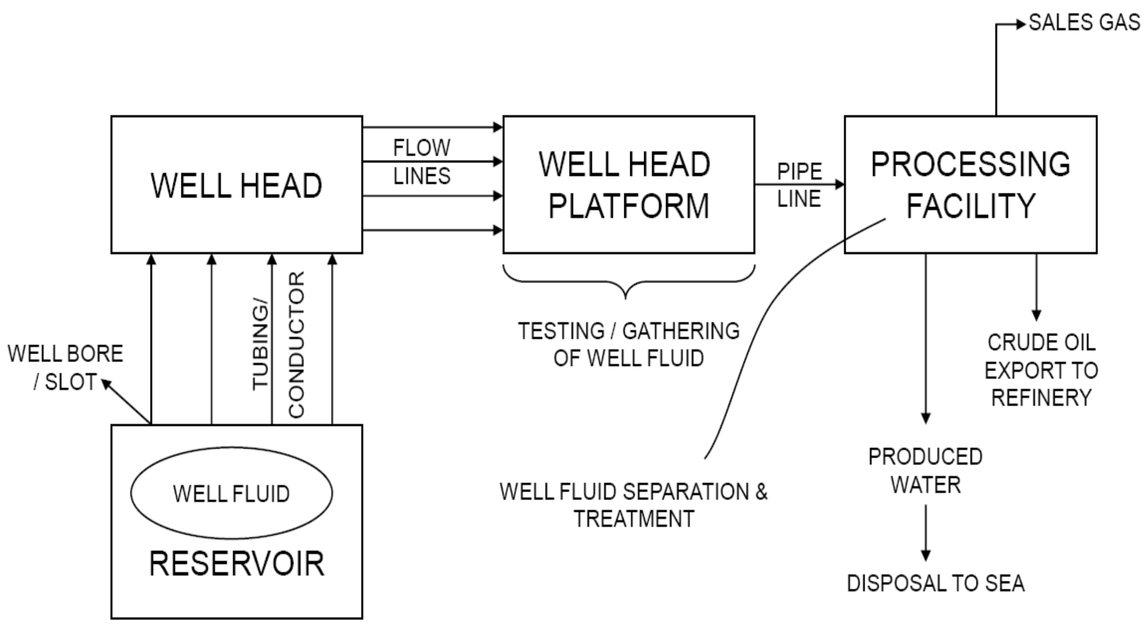
- Electrical Submersible pumping (ESP's) – these are inserted into wells to increase the pressure of the flowing fluid.



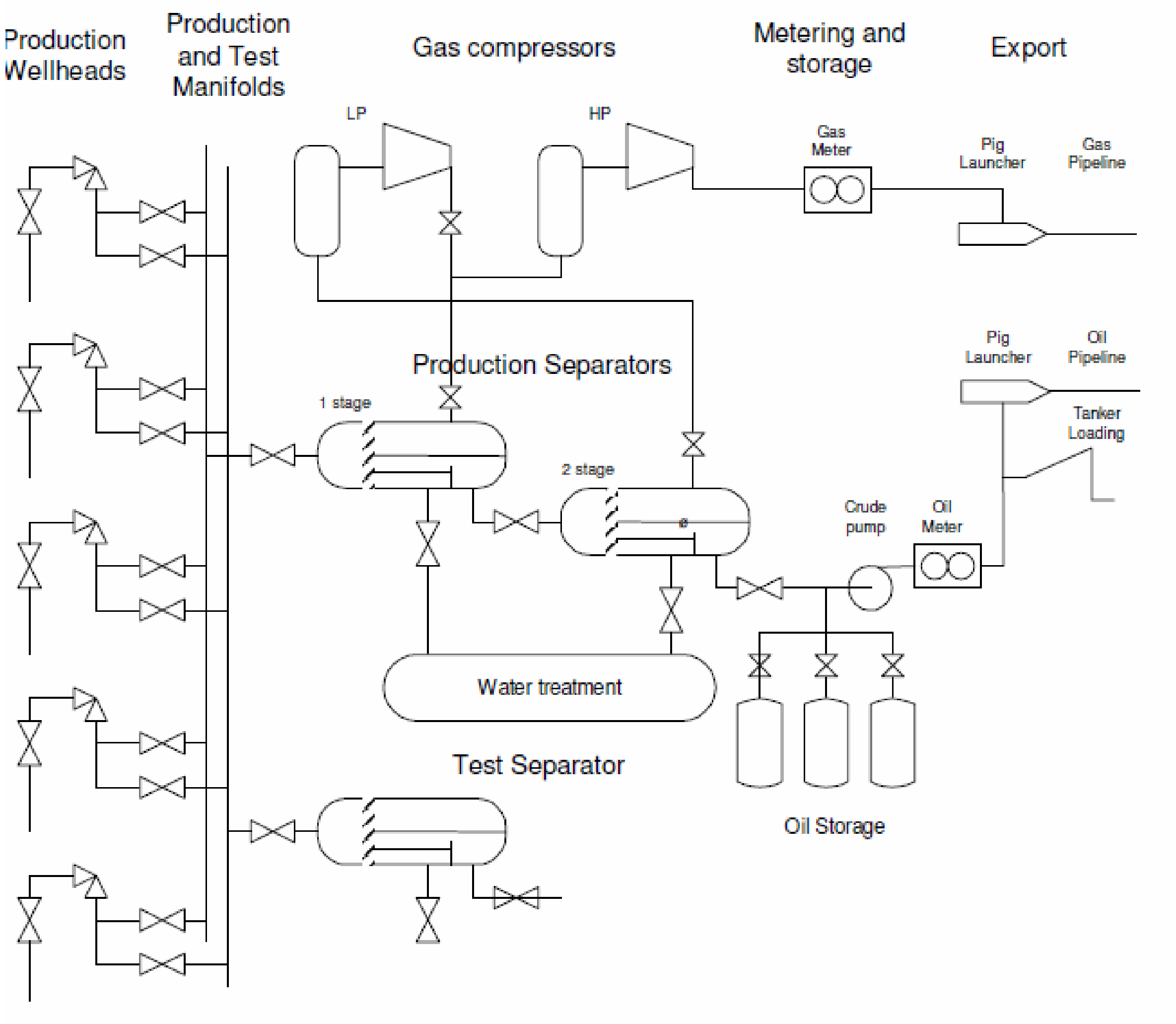
- Jet Pumps - these are placed below the fluid level in a wellbore to produce fluid from the reservoir by employment of a power fluid source.

2.5 OVERALL OIL & GAS FACILITY – UPSTREAM

BLOCK DIAGRAM

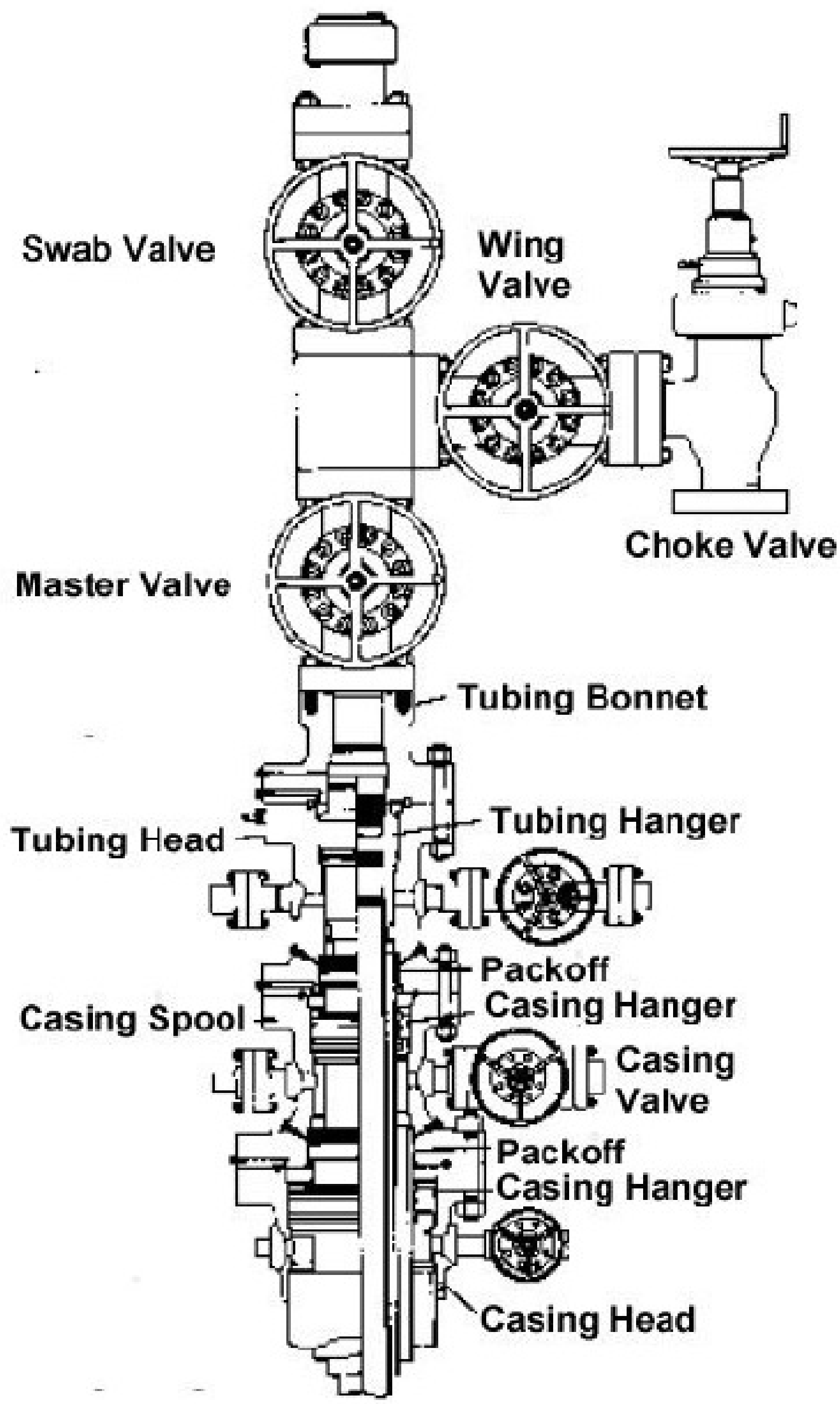


PROCESS OVERVIEW



2.6 WELL HEAD / CHRISTMAS TREE

The wellhead sits on top of the actual oil or gas well leading down to the reservoir. A wellhead may also be an injection well, used to inject water or gas back into the reservoir to maintain pressure and levels to maximize production. Once a natural gas or oil well is drilled, and it has been verified that commercially viable quantities of natural gas are present for extraction, the well must be 'completed' to allow for the flow of petroleum or natural gas out of the formation and up to the surface. This process includes strengthening the well hole with casing, evaluating the pressure and temperature of the formation, and then installing the proper equipment to ensure an efficient flow of natural gas out of the well. The wellhead structure, often called a Christmas tree, must allow for a number of operations relating to production and various technologies for maintaining the well and improving its production capacity.



Swab Valve
Wing Valve
Choke Valve
Master Valve
Tubing Bonnet
Tubing Head
Tubing Hanger
Packoff
Casing Hanger
Casing Spool
Casing Valve
Packoff
Casing Hanger
Casing Head

- A Wellhead / Christmas tree is an assembly of valves, spools and fittings, piping, gauges and flanges that exists atop an oil or gas well.

- The Christmas tree consists of hydraulically / pneumatically actuated valves viz.
    - Subsurface safety valve (SSSV),
    - Surface safety valves (SSVs) - Master valve and Wing valve

  These valves play an essential role by automatically isolating the individual wells during an Emergency Scenario.

- A choke valve is provided downstream of the wing valve to regulate the flow of well fluid from the well.

2.7 WELL HEAD PLATFORM

The function of a well platform is

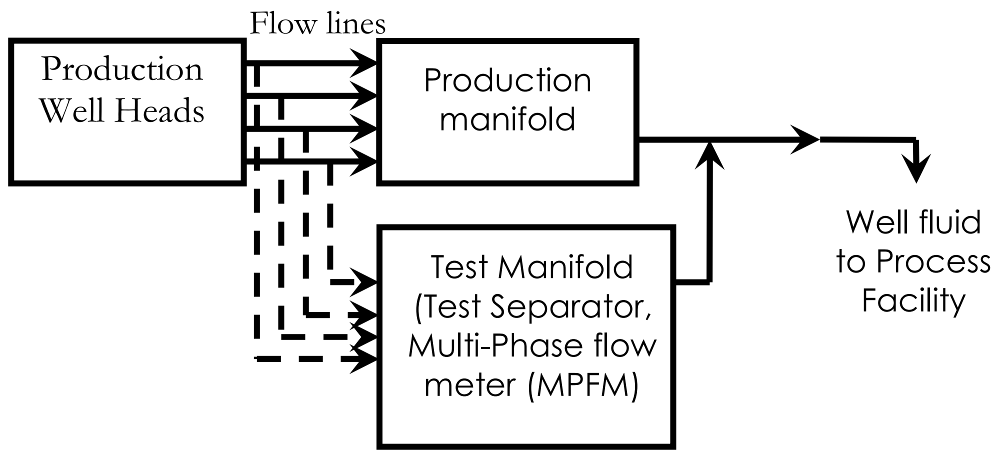
- To gather produced fluid from wells and transport to the processing platforms through sub-sea pipelines.
- To facilitate testing of wells.

A typical wellhead platform consists of

- Four legged jacket
- Super Structure with Main Deck, Cellar Deck, Stairways, Ladders, Railing and Heli-deck.
- Conductor Casing within the jacket framing, well head hook up piping system to connect wells to the manifold (production and test header).
- Boat Landing
- Pedestal Crane
- Test Separator
- Well fluid riser with Pig launcher
- Wellhead Control / Shutdown Panel
- Instrument Gas system
- Chemical Injection System
- Vent system
- Drain System
- Diesel System
- Water System
- Fire and Gas detection system (Gas detectors, Fusible loops)
- Fire Fighting system (portable extinguishers, DCP skid, etc)
- Solar Panels, Battery , Battery Charger, Telemetry unit, Navigational Aids

- Life Saving Equipment (Life Jackets, Life buoys, Life rafts, etc.)

BLOCK FLOW DIAGRAM – WELL HEAD PLATFORM (TYPICAL)



Process Description

The well fluid, from the reservoir flows via the well head, through the flow lines to the production and test manifolds. The produced well fluid from the production manifold is routed to a processing facility via pipelines.

The well fluid is routed to the test manifold from the flow line only during testing operations. Testing is carried out using test separators or multi-phase flow meters in the well head platform. In the test separator, the well fluid is separated from one or more wells for analysis and detailed flow measurement.

2.8 PROCESS PLATFORM

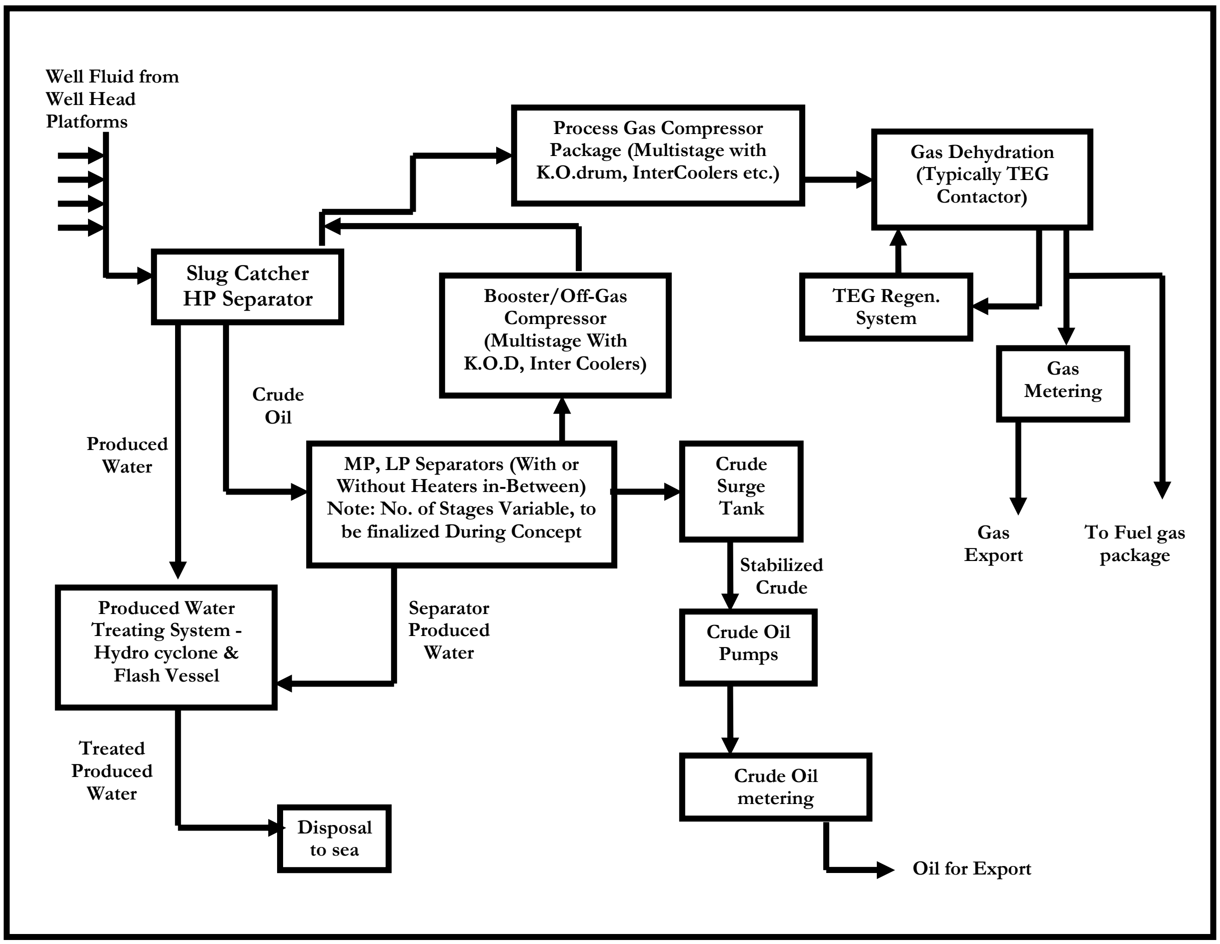
These are normally eight legged platforms and do not have any well. The produced fluid from well platforms is received in a process Platform for processing and transportation.

The main processing facilities on a Process Platform include:

- Separation system (Separate oil, gas and water)
- Crude Oil / Condensate Stabilization and Export system (Treat and pump oil to a subsea off-take pipeline)

- Produced Water handling system (Treat and dispose off produced water)
- Gas Compression and dehydration system (Treat and compress gas to a subsea off-take pipe line)

BLOCK FLOW DIAGRAM – OIL & GAS PROCESS FACILITIES (TYPICAL)



Process Description

In the PROCESS PLATFORM, the well fluid obtained from the WELL HEAD PLATFORMs, is primarily separated into gas, crude oil & produced water and further processed to meet the product specifications of the end users / customers.

- **High pressure separation** involves separation of well fluid to oil, gas and water using high pressure separators.

- **Crude Oil stabilization** involves removal of lighter hydrocarbons (C_2- C_6), sulfur-bearing compounds, salts and water to meet the customer requirements. Optimum number of separation stages varies with:
    - Flowing well head pressure at the process complex
    - Reservoir composition
    - Gas compression requirements, and
    - Vapour pressure specification, for export crude.

- **Process Gas Compression** involves increasing the pressure of natural gas to meet the sales gas pressure requirement by the customer. **Gas dehydration** process involves the removal of water from gas to meet Dew point specification of the sales gas.

- **Produced Water treatment** involves removal of hydrocarbon traces from produced water before the water is discharged overboard. Skim Vessels, Corrugated plate interceptors (CPI), Induced gas floatation (IGF) are some treatment systems used to separate oil from produced water.

2.11 UTILITY & AUXILIARY SYSTEMS

Some of the typical utility and auxiliary systems in a processing facility are

- Fuel gas system
- Glycol Regeneration system
- Flare System
- Power Generation
- Closed Drain System

- Open Drain System
- Instrument and utility air package
- Hypochlorite generation package
- Diesel storage and supply system
- Heating medium system (Hot Oil, Water)
- Potable water generation and supply system
- Sewage treatment package
- Chemical injection package (storage and supply)
- Fire water system (Fire water pumps, jockey pumps, deluge valve etc)
- Sea water / cooling water system (sea water lift pumps, filters etc.)
- HVAC (Heating, Ventilating & Air Conditioning)
- Material Handling – Deck Cranes, Monorails
- Fire detection and Fighting system
- Safety Equipment
- Control and Shutdown system

OFFSHORE PLATFORM – WELL HEAD

OFFSHORE PLATFORM – PROCESS

ASSIGNMENT - MODULE 2

UPSTREAM OIL AND GAS OVERVIEW

1. Write process description for the following:

    i) Overall upstream oil & gas process

    ii) Well Head Platform (WHP)

    iii) Processing Facility

FLUID PHASE BEHAVIOR

3.1 COMPOSITION OF WELL FLUID

- Well fluid is a mixture of one or more of the following
  - Hydrocarbon liquids
  - Hydrocarbon gases
  - Non-hydrocarbon gases (N_2, CO_2, H_2S, H_2O etc)
  - Produced water (with dissolved salts)
  - Solids (sand)

- Hydrocarbon components in the mixture range from the lightest Methane (CH_4) to high molecular weight components with up to 40+ Carbon atoms.

- Four primary types of hydrocarbons are found
  - Paraffinic (Saturated straight or branched chains)
  - Naphthenic (Saturated cyclo-paraffin)
  - Olefinic (Unsaturated chains)
  - Aromatic (Unsaturated cyclo-paraffin)

- Lighter components (C_1 to C_6) are predominantly Paraffinic

- Heavier components are predominantly Naphthenic, Olefinic and Aromatic

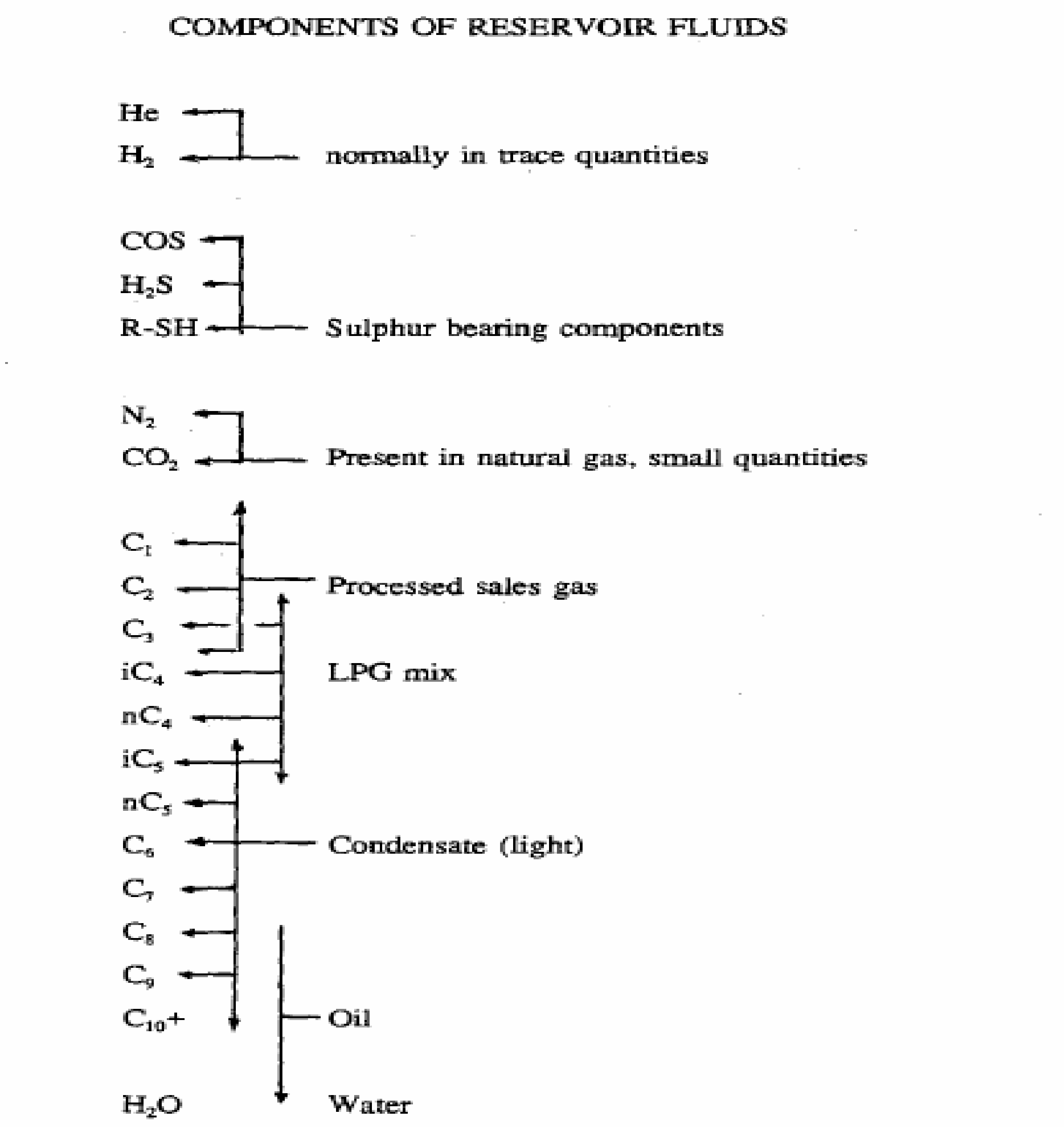
3.2 DETERMINATON OF WELL FLUID COMPOSITION

- Reservoir fluid samples are collected via test wells. Laboratory analysis of the collected sample enables establishing well fluid composition.

- Chromatographic analysis is typically used for determination of composition of light components (up to C_6 or C_7).

- True boiling point or ASTM distillation technique can be used to determine the composition of heavier fractions. The composition is reported in terms of distillation cuts with associated properties (boiling point, mol. Wt., and density).

- Properties like wax content & pour point are also determined.
- The analysis of liquid & vapour portions can be combined mathematically to determine the overall reservoir composition.



3.3 WELL FLUID PHASE BEHAVIOUR

P-T Phase Diagram – Well Fluid (Typical)

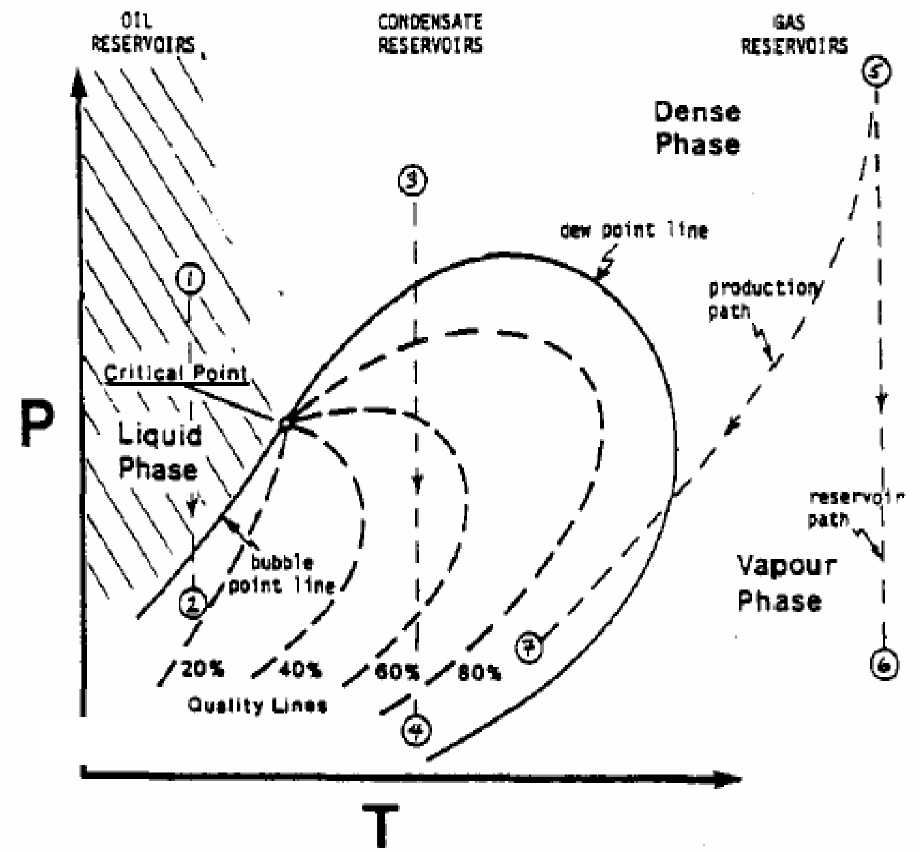


Figure 2.1. Pressure-Temperature Phase Diagram of Reservoir Fluid

- **PHASE:** Is a homogeneous system i.e. a system in which the properties in a gross sense are either same from point to point or change in a continuous manner.

- **CRITICAL POINT:** For a multi-component system, this refers to the temperature & pressure conditions at which the liquid & vapour phases are identical.

- **CRICONDENBAR:** The maximum pressure at which the vapour & liquid phases can co-exist at equilibrium in a multi-component system.

- **CRICONDENTHERM:** The maximum temperature at which the vapour & liquid phases can co-exist at equilibrium in a multi-component system.

- **DEW POINT:** The temperature at any given pressure or the pressure at any given temperature, at which liquid initially condenses from a gas or a vapour.
  - Water Dew point: Temperature at which water vapour starts to condense from a gas mixture.
  - Hydrocarbon Dew point: Temperature at which hydrocarbons start to condense from a gas mixture.
  - Dew point curve represents 100% vapour
  - Vapour Fraction : 1

- **BUBBLE POINT:** The temperature at a specified pressure at which the first stable vapour forms above a liquid.
  - Bubble point curve represents 0 % vapour
  - Vapour Fraction : 0

- **GAS HYDRATES:** Ice – like structures formed due to the presence of water component along with lighter hydrocarbons at
  - Low temperatures or
  - High Pressures
- **GOR (Gas to Oil Ratio):** The ratio of gas to liquid hydrocarbon produced from a well.

  Normally reported in standard volume units of gas per standard volume units of oil/liquid

  E.g. standard cubic feet of gas per stock tank barrel (SCF/STB)

  Based on the GOR the reservoirs are typically classified as follows
  - GOR > 100,000 SCF/STB –GAS RESERVOIR
  - GOR > 5000 - 100,000 SCF/STB –GAS-CONDENSATE RESERVOIR
  - GOR < 5000 SCF/STB –OIL RESERVOIR

3.4 EQUATIONS OF STATE

Equation of State is an equation that relates the P-V-T behaviour of the fluid.

Following are some of the EOSs

- VIRIAL EQUATION
- BENEDICT-WEBB-RUBIN (BWR) EQUATION
- VAN DER WAAL EQUATION and its variations such as
  - REDLICH KWONG (RK) EQUATION
  - SOAVE REDLICH KWONG (SRK) EQUATION
  - PENG ROBINSON (PR) EQUATION

Note: *PENG ROBINSON is the most commonly used EOS for hydrocarbon mixtures.*

ASSIGNMENT - MODULE 3

FLUID PHASE BEHAVIOR

1. Prepare a UNIT CONVERSION TABLE specifying units (SI & FPS systems) with conversion factors, for various operating and physical property parameters.

   Format:

Sl. No.	Parameter	SI	FPS	Conversion factor

2. Convert 25MMSCFD (Metric Million [10^6] Standard Cubic Feet per Day) of gas with molecular weight, MW = 26 into Mass Flow Rate (kg/h).

   Hint:
   i) Standard conditions (STP) – 15.5°C, I atm
   ii) Normal conditions (NTP) – 0°C, 1 atm
   iii) 1kgmol of any gas occupies 22.414 m^3 at NTP

MODULE 4

PROCESS SIMULATION

4.1 INTRODUCTION

Process Simulation is

- A model-based representation of chemical, physical and other technical processes and unit operations in software.
- Used for the design, development, analysis and optimization of technical processes and is mainly applied to chemical plants and processes.

4.2 PURPOSE

For the design of various components in any plant/facility, Process Simulations are performed to

- Solve Mass and Energy balances using in-built mathematical models.
- Obtain the Flow rates, Compositions and Thermo Physical Properties of process streams at its various operating conditions.
- Predict Phase behavior of Fluids.

Simulations are also performed to detect abnormal conditions like

- Formation of hydrates by hydrocarbons due to fall in pressure (& temperature).
- Fall in temperature below hydrocarbon and / or water- dew point.
- Flashing of liquids across control valves or drain valves, etc.
- Condensation of vapors due to cooling.
- Latent heat data required at relieving conditions (temperature and pressure) for safety valve sizing calculations.
- Time behavior of inventory streams during depressurization.
- Minimum temperatures during venting from high pressure to atmosphere, which may affect material selection upstream and/or downstream of vent valve (inclusive).

4.3 STEADY STATE SIMULATION

- Steady-state models perform a mass and energy balance of a stationary process (a process in an equilibrium state).

- Steady state simulators are used for

    - **Process design** (to determine the process conditions required to produce the desired product)

    - **Process equipment design** (to size the equipment required to produce the desired product)

    - **Process design optimization** (to determine the optimum configuration of equipment and maximize energy recovery)

    - **Process Optimization** (to determine changes to the current operating conditions that can either reduce operating costs or increase production).

4.4 DYNAMIC SIMULATION

- It is an extension of steady-state process simulation whereby time-dependence is built into the model.

- It requires increased calculation time and is mathematically more complex than a steady state simulation.

- For process design, it is used for operator training and optimum process control.

- It is used to study the response of the process to sudden changes in operating conditions.

In dynamic process design simulators, the key operating conditions are maintained using simple PID (Proportional, Integral and Derivative) controllers.

4.5 SIMULATION SOFTWARE

- Process simulation software describes processes in flow diagrams where unit operations are positioned and connected by product streams or educts.
- The software solves the mass and energy balance to find a stable operating point.

Some simulators:

- **HYSYS** – UPSTREAM OIL & GAS APPLICATIONS
  PROPERTY PACKAGE – PENG ROBINSON

- **PRO II & ASPEN PLUS** – REFINERY APPLICATIONS

4.6 INPUTS FOR SIMULATION

Typical inputs required for simulating upstream oil and gas process are

- Well fluid composition
    - Gas (dry or saturated)
    - Oil (hypothetical data / ASTM or TBP Distillation data)

- Production profile indicating flow rates for gas, oil and water or GOR or water cut data at stock tank conditions

- Operating flows, pressure & temperature at various points in the process

- Product specifications

4.7 USES OF SIMULATION FOR PROCESS DESIGN

- Generate heat and material balance tables for the facility
- Generate process flow diagrams
- Perform equipment sizing calculations
- Perform line sizing calculations
- Perform instrument sizing calculations
- Generate process datasheets / specification for equipment and instruments

4.8 HYSYS – THE SOFTWARE & ITS USAGE

HYSYS is a commercially available integrated simulation environment designed for complete user customization. This enables the seamless integration of proprietary unit operations, reactions and property packages and interaction with other application to create powerful hybrid programs, allowing companies to fully leverage engineering software investments. With HYSYS, engineers need to develop only a single process model that can be used from the conceptual design through on-line application to improve designs, optimize production and enhance decision making.

A feature of the PFD described in the simulation, allows us to trace the calculation status of the objects in the flow sheets. There lies a status indicator at the bottom of the property view for a stream or operation.

BRIEF INSTRUCTIONS FOR THE USE OF HYSYS

Use of this simulation software for chemical processing involves the following steps:

1. Selection of components
2. Selection of a thermodynamic properties package
3. Construction of a flow sheet
4. Specification of known stream and unit compositions and conditions
5. Running the simulation program
6. Interpretation of the results

1. Selection of Components

Obtain the HYSYS window and select the blank sheet **(New Case**) on the toolbar. This will open the **Simulation Basis Manager** window under the tab Components. There should be no listing under Master Component List. Press the **View** button, which should result in a Component List View window appearing. Select components and press the **Add Pure** bar to add them to the components list, until it contains all components present in the desired simulation. For the example problem, select methane and then ethane. Close this window to return to the Simulation Basis Manager window.

2. Selection of the Thermodynamic Properties Package

Select the **Fluid Pkgs** tab at the bottom. Press the **Add** bar to open the Fluid Package selection window. Select a fluid properties package by highlighting it. Close this window to return again to the Simulation Basis Manager window. It should read Basis-1, NC: 2, PP: Peng-Robinson.

Press the **Enter Simulation Environment** bar to go to the process flow diagram window PFD – Case (Main). If you want to change the components or thermodynamics package at a later time, you must re-enter the Basis Environment, by clicking on the appropriate icon (**conical flask**) on the toolbar above the flow sheet workspace.

3. Construction of Flow sheet

Expand the PFD (process flow diagram) worksheet to fill the screen. Now, you must place the unit operations on the PFD workspace. This is accomplished by selecting operations from the Case (Main) side toolbar called the **Object Palette**, and left clicking again at the desired location on the flow sheet. If you need to move units at any time, they can be dragged across the workspace by clicking and holding the left mouse button.

4 Specification of known stream and unit compositions and conditions

Add the material stream on the PFD by clicking on the **blue stream** on the object palette or press **F4**. Double click on the stream to bring up the property view. Enter the composition of the stream and two of either temperature, pressure or vapor fraction. Also input the molar/mass/std ideal liquid volume flow. Providing this defines the stream and the stream now becomes *dark blue* in color. Similarly add the **unit operations** from the object palette as per the requirement of the problem. Double click on the unit operation and select the inlet streams and provide the outlet streams

Running the simulation program

To run a simulation, all that you need to do is press the Green Light (Solver Active) icon on the toolbar just above the flow sheet. In fact this should not be needed, as the simulation will run automatically, if all the specifications have been made correctly, and the Green Light was on.
A feature of the PFD described in the simulation, allows us to trace the calculation status of the objects in the flow sheets. There lies a status indicator at the bottom of the property view for a stream or operation. This indicator displays three different states for the object:

Interpretation of the results

The results of the simulation can be viewed by clicking on the Workbook icon on the toolbar above the flow sheet

Notice that you can see some properties of streams and units by running the arrow over each item on the PFD. You can toggle between stream names, temperatures, pressures and flow rates by using Shift N, Shift T,

Status	**Description**
Red Status	A major piece of defining information is missing from the object. For example, a feed or product stream is not attached to a separator. The status indicator is red and an appropriate warning message appears.
Yellow Status	All major defining information is present but the stream or operation has not been solved because one or more degrees of freedom are present. For example a cooler whose outlet stream temperature is unknown. The status indicator is yellow and appropriate warning message appears
Green Status	The stream or operation is completely defined and solved. The status indicator is green and an OK message appears.

Shift P and Shift F combined keystrokes.

You can print the PFD by right clicking on it and choosing Print PFD. Or, you can open the Workbook and right click on the banner, choosing Print Datasheet. Be sure and save the PFD as when you add the unit operation, by choosing Save As under the File menu.

4.9 TYPICAL OPERATIONS IN SIMULATION SCHEMES

- Mixer to join streams
- Tee to separate streams
- Valve to reduce pressure and study Joule-Thomson effect (cooling)
- Pumps/compressors to increase stream pressure
- Heaters and coolers for adjusting stream temperature
- Heat exchangers for exchange of heat between two streams in the same scheme
- Separators, 2-phase to separate gas and liquid, 3-phase to separate gas, oil & water
- Saturator to saturate any given stream with water vapor
- Splitter to split components hypothetically
- Columns with/without re-boiler and condenser for unit operation like dehydration, absorption and/or distillation.
- Control operations like "SET", "ADJUST", "BALANCE" AND "RECYCLE" for automatic iteration and cross-relation between streams.

ASSIGNMENT - MODULE 4

1. Calculate mole fraction, weight fraction, and weight % for the following components, based on their corresponding mole %:

Component	*Mole %*
N_2	0.45
H_2S	0.62
CO_2	5.94
CH_4	81.61
C_2H_6	6.74
C_3H_8	2.37
$i\text{-}C_4H_{10}$	0.49
$n\text{-}C_4H_{10}$	0.7
$i\text{-}C_5H_{12}$	0.24
$n\text{-}C_5H_{12}$	0.23
C_6H_{14}	0.21
C_7H_{16}	0.41

2. Calculate Gas, Oil and Water flow rate in MMSCFD, BOPD (Barrels Of Oil per Day, and BWPD (Barrels Of Water per Day) respectively, from the following data:

GOR = 315 SCF/STB
Water cut = 20%
Gas flow rate = 40MMSCFD