

해저 공학

서유택

Lecture plan

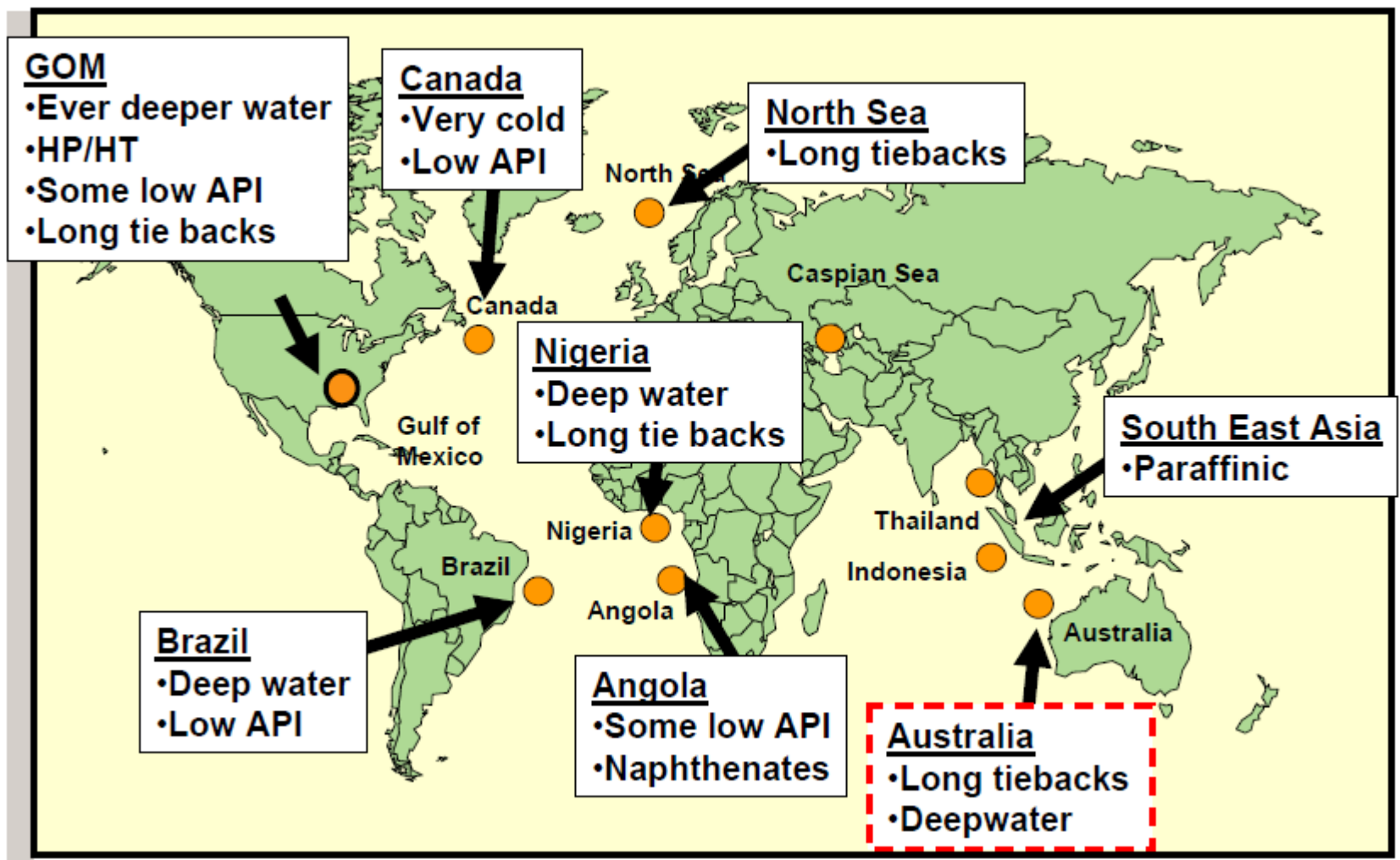
1	해양 유·가스전 개발 및 운전의 이해
2	해저 생산 시스템과 해양 플랫폼의 주요 구성 요소
3	해저 생산 시스템 설계 및 운전 특성
4	신규 해저 생산 시스템: subsea processing
5	해저 생산 유체의 열역학적 해석
6	해저 파이프라인의 설계 및 설치
7	다상 유동과 해저 파이프라인: 압력 강하 및 liquid holdup
8	다상 유동과 해저 파이프라인: 열전달과 U-value
9	해저 생산 시스템과 상부 공정 연결: Slug catcher design
10	고체 침적 현상과 저해 전략
Text book	Printed materials
Rating	Homework 20% Quiz (March, April, May) 30% Final exam 40 % Attendance 10%

Introduction

- The design and operation of offshore production facilities are becoming a critical component as the industry goes to deeper water, longer tiebacks, higher temperature and pressure reservoir.
- Safety and Environment considerations override all other items and should be considered in all design aspects.
- The design of the flow system and the operational procedures should maximize production and minimize down time and flow disruption
- Shutdown and start-up operations are the most critical in terms of implementation and personnel training



Emerging issues for offshore fields



Four major changes

1993

- Deepwater = 600 m
 - : 3 companies, few wells
- Hydrate/Wax apprehension
- Problem magnitude unknown
 - : Wax or Hydrate ?
 - : Time scale unknown
- Only steady state simulation
 - : Transient was uncertain

2003

- Deepwater > 2000 m
 - : Many companies & wells
- Hydrate/Wax avoidance
- Problem identified
 - : Hydrate > Wax > Napthenates
 - : Hydrate (min/hr) vs Wax (wks/mths)
- Steady state & Transient simulation

Flowline/Riser/Service line Design

- Reservoir fluid characteristics dominate design
 - : Pressure drop and cooling causes separation
 - multiphase regime causes irregular flow and vibration
 - slugging occurs as velocity decays
 - : Hydrate may form as P and T changes
 - : Waxes may precipitate on cooling
 - : Corrosion may occur as water condenses
 - : Sand may cause plugging
 - : Pigging may be required
- Emergence of “Flow Assurance” as an Engineering discipline

Typical Field Layout

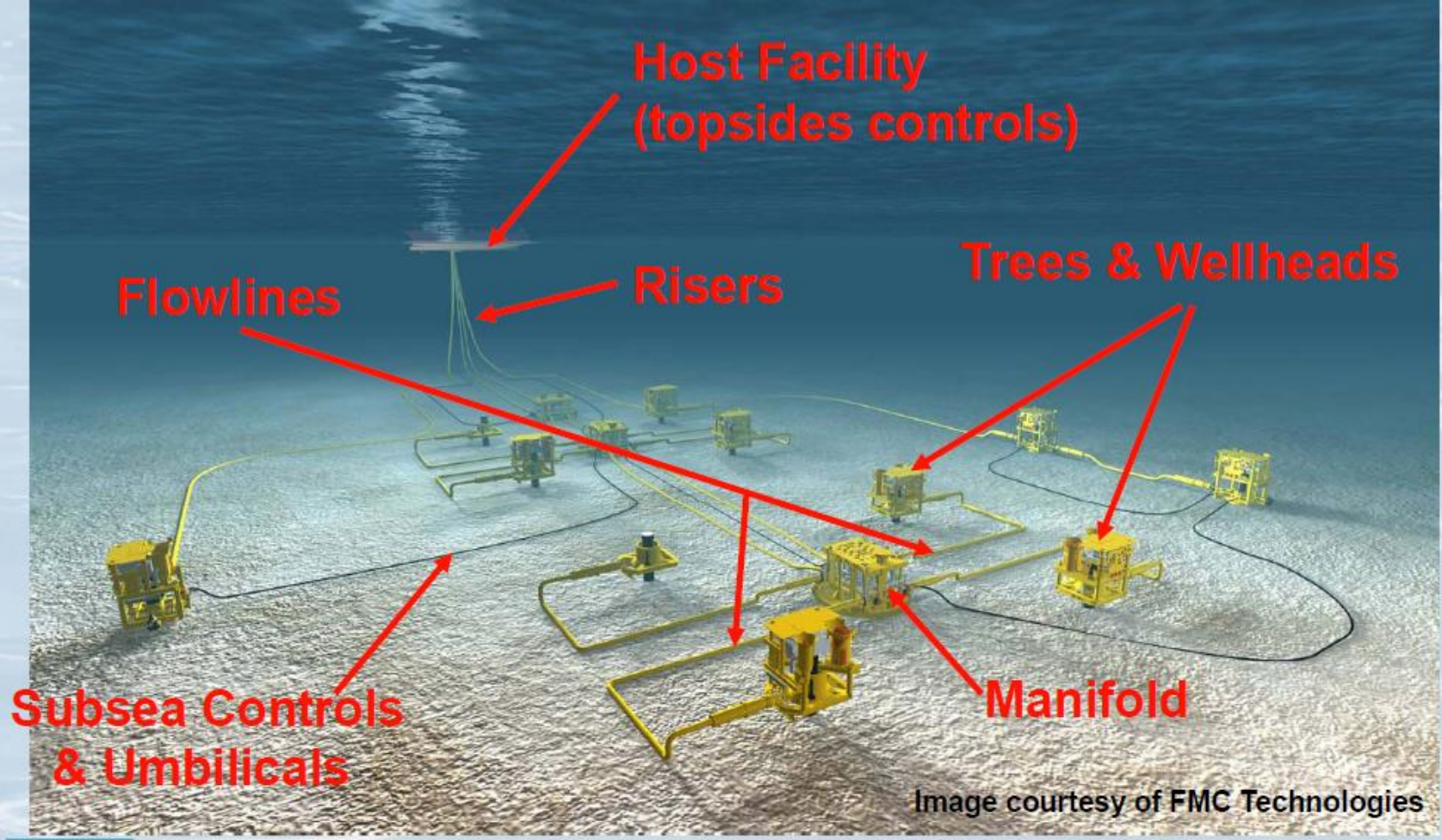
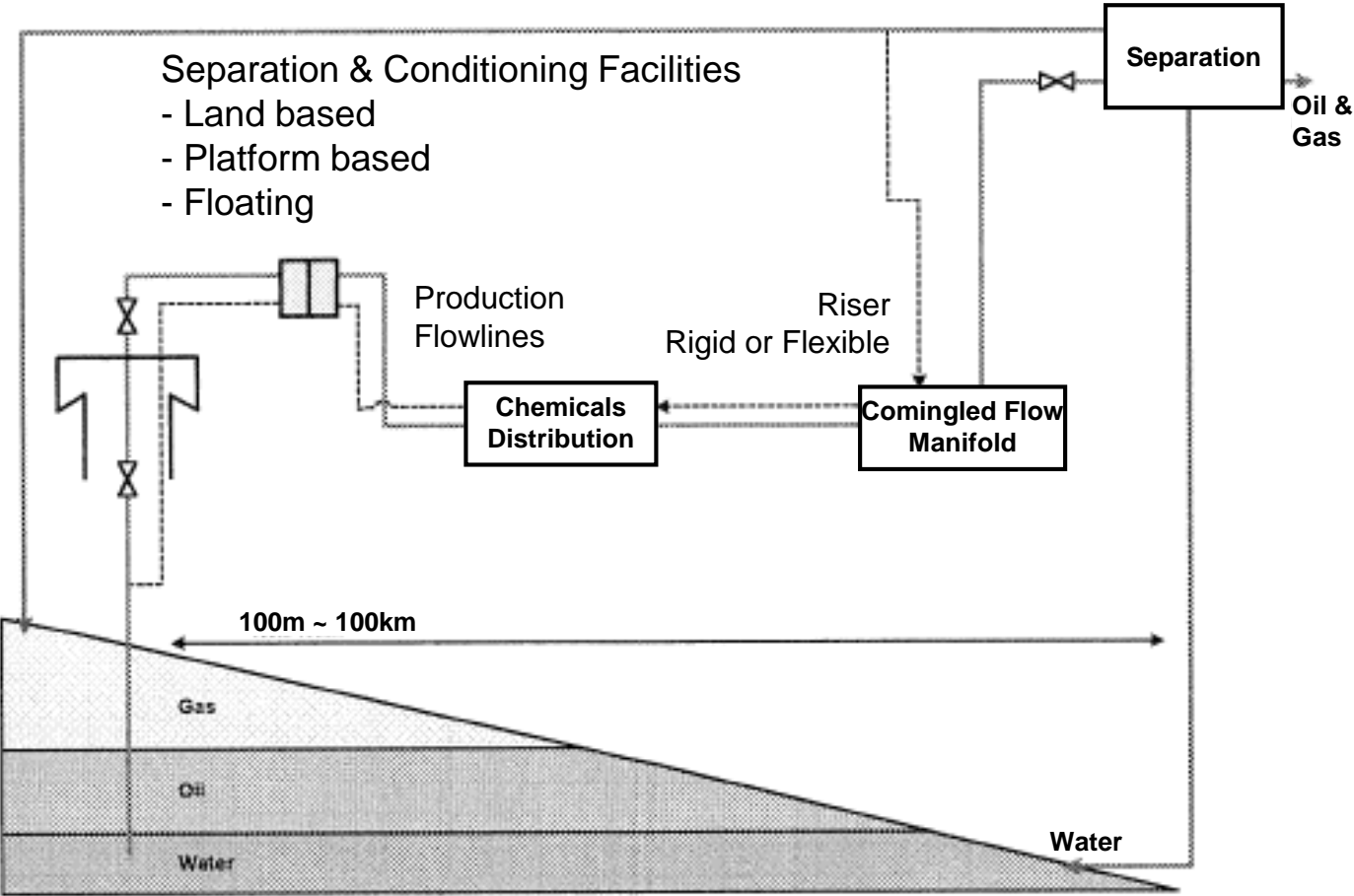


Image courtesy of FMC Technologies

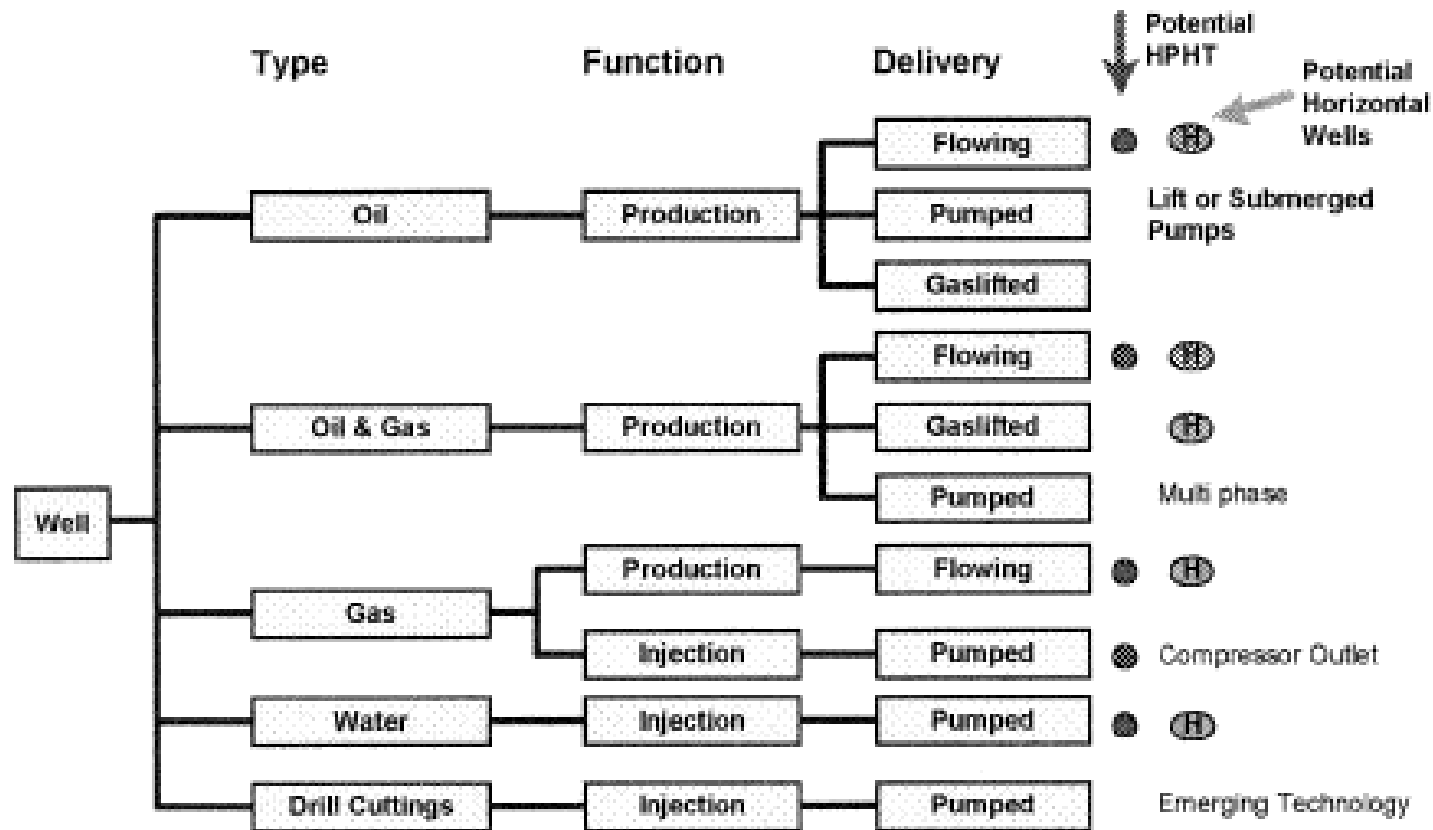
Field Development – The Building Blocks

- Reservoir Considerations
- Hydrocarbon Production Processing
- Subsea Production Options
- Health, Safety, and Environment

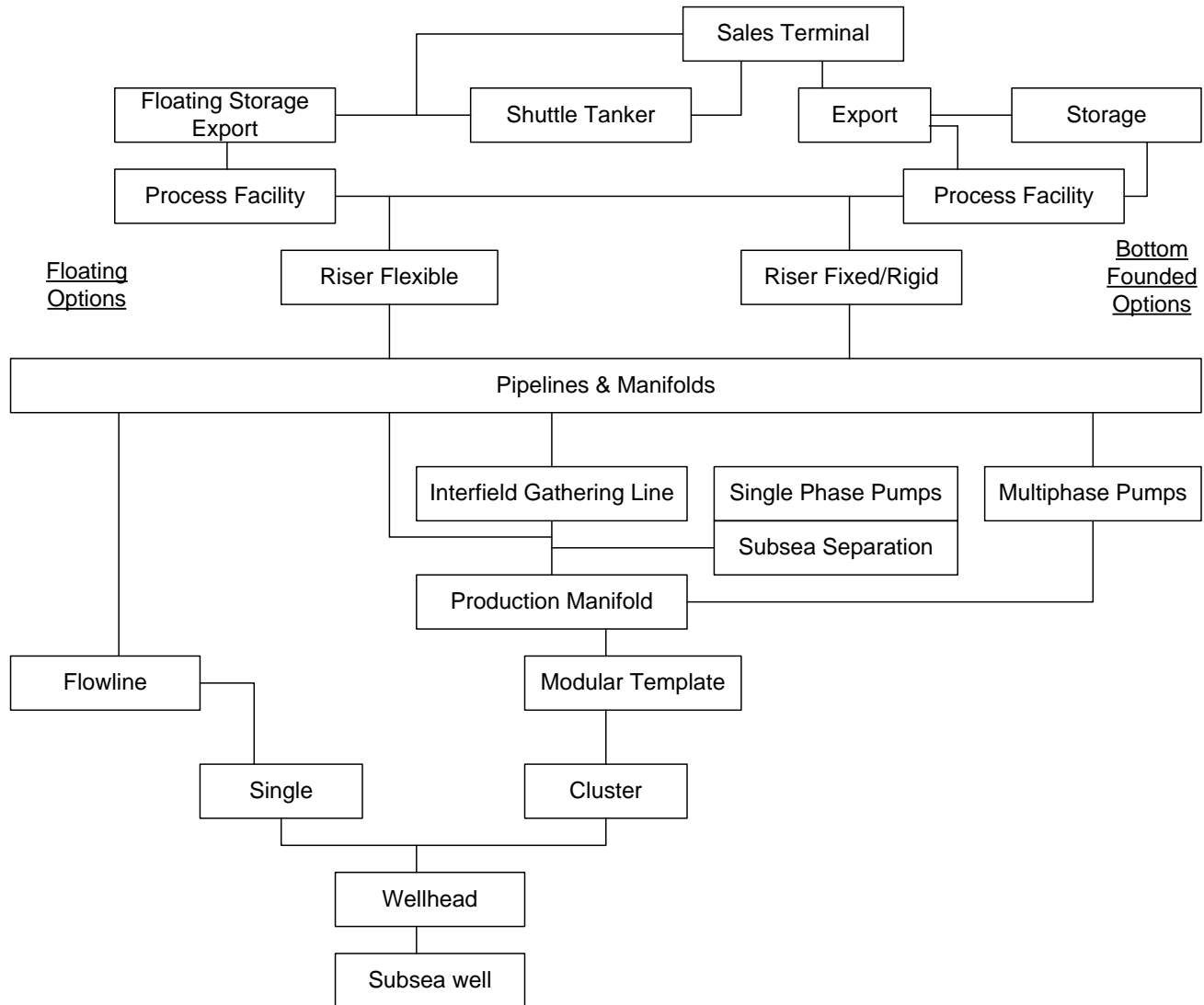
Hydrocarbon Production Processing



Subsea Production Options



Subsea Production Options



Reservoir

Fluid type	API gravity	GOR (scf/STB)	C1 mol%	Character
Black oil	< 30	< 2000	< 60	Liquid oil composed of various chemical species
Volatile oil	< 40	2000 ~ 3000	60 ~ 70	Fewer heavy molecules but more C2~C6; release of large amount of gas
Condensate	40 ~ 60	3300 ~ 50,000*	70 ~ 80	Gas at reservoir; Retrograde behavior yield light oil
Wet gas	40 ~ 60	> 50,000	80 ~ 90	Gas at reservoir; Two phase mixture in a flowline
Dry gas	NA	No liquid at STP	90 ~ 100	Primarily methane; solely gas under all conditions

* Retrograde gas can go as high as 150,000 scf/STB

Main Petroleum Components

Component	Formula	Boiling Temperature at 1 atm (°C)		Density at 1 atm and 15°C (g/cm ³)
		Paraffins	LNG	
Methane	CH ₄	-161.5		—
Ethane	C ₂ H ₆	-88.3		—
Propane	C ₃ H ₈	-42.2		—
<i>i</i> -Butane	C ₄ H ₁₀	-10.2		—
<i>n</i> -Butane	C ₄ H ₁₀	-0.6		—
<i>n</i> -Pentane	C ₅ H ₁₂	36.2		0.626
<i>n</i> -Hexane	C ₆ H ₁₄	69.0		0.659
<i>i</i> -Octane	C ₈ H ₁₈	99.3		0.692
<i>n</i> -Decane	C ₁₀ H ₂₂	174.0		0.730
Naphthenes				
Cyclopentane	C ₅ H ₁₀	49.5		0.745
Methyl cyclo-pentane	CH ₃ C ₅ H ₁₀	71.8		0.754
Cyclohexane	C ₆ H ₁₂	81.4		0.779
Aromatics				
Benzene	C ₆ H ₆	80.1		0.885
Toluene	C ₇ H ₈	110.6		0.867
<i>o</i> -Xylene	C ₈ H ₁₀	144.4		0.880
Naphthalene	C ₁₀ H ₈	217.9		0.971
Others				
Nitrogen	N ₂	-195.8		—
<u>Carbon dioxide</u>	CO ₂	-78.4		—
<u>Hydrogen sulfide</u>	H ₂ S	-60.3		—

Note:
Paraffin wax= 20<n<40

Paraffin
= Alkane
(C_nH_{2n+2})

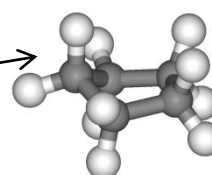
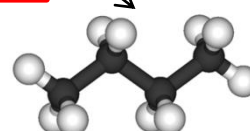
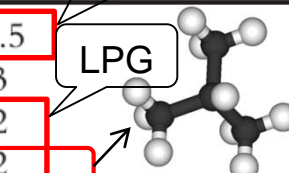
Naphthene
= Cycloalkane

Sweet corrosion

Sour corrosion

LNG

LPG



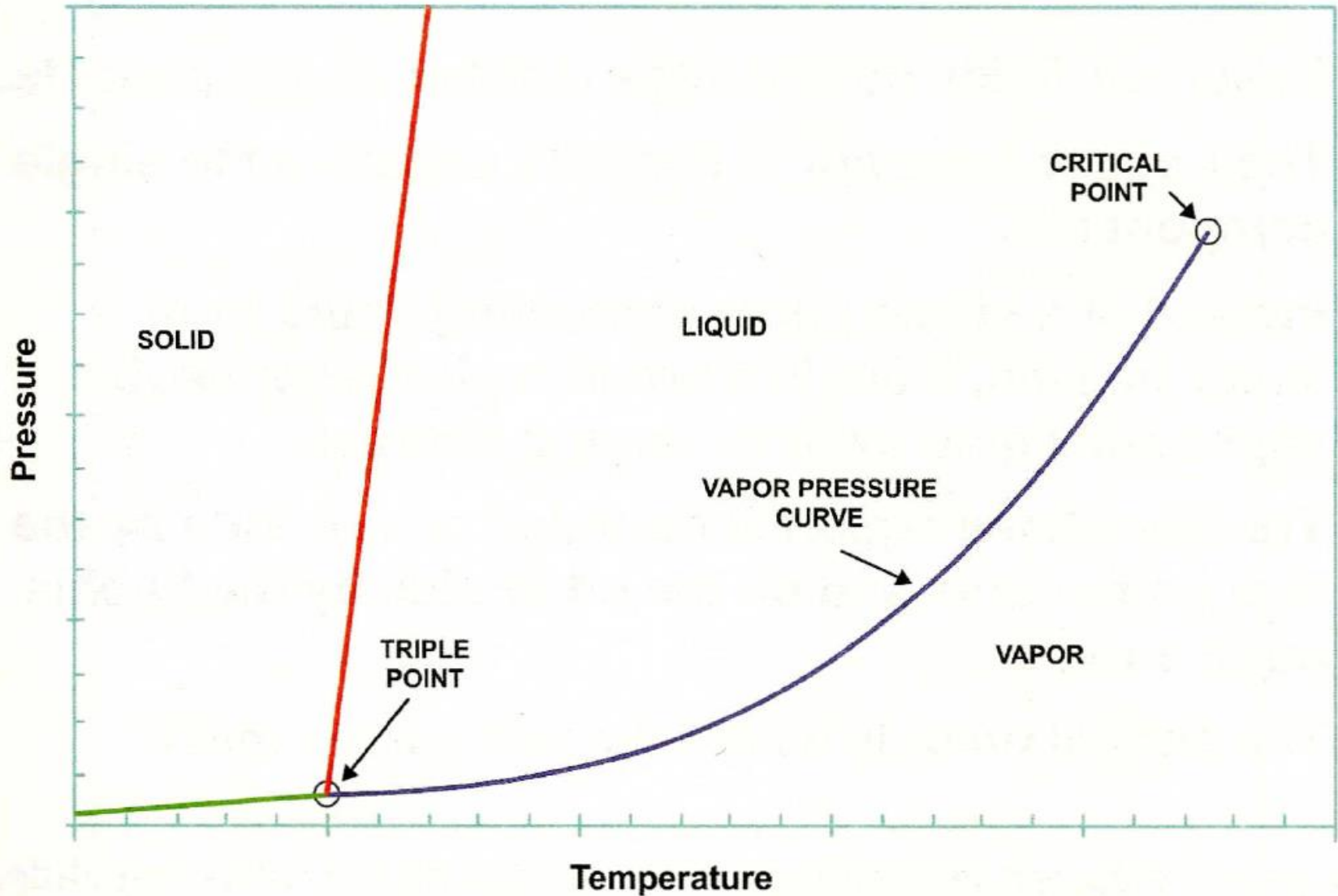
Natural Gas Compositions

Component	Pluto (mol %)	NWS (mol %)	Gorgon (vol. %)	Jansz (vol. %)	Browse (mol %)	Ichthys (mol %)
N ₂	8.1	0.8	2.0	2.3	0.5	0.4
CO ₂	1.9	3.0	14.0	0.3	9.8	8.5
CH ₄	83.0	85.3	76.7	91.5	79.3	70.0
C ₂ H ₆	3.9	5.8	3.2	3.8	5.6	10.3
C ₃ H ₈	1.4	2.2	0.9	1.1	2.1	4.2
C ₄ H ₁₀	0.7	1.0	0.3	0.4	0.9	1.9
C ₅ +	1.4	1.9	0.1	0.6	1.8	4.4

Reservoir fluids

- Oil and gas reservoirs formed in porous sedimentary rock many millions of years ago.
- Some reservoirs are close to the earth's surface whilst others are deep in the formation.
- Some have very high pressure and temperatures whilst other do not.
- The range of hydrocarbons varies, as does their concentration.
- Need to classify !!
 - Phase behavior: compositions
 - Fluid properties: API gravity
 - Reservoir flow characteristics: Productivity index

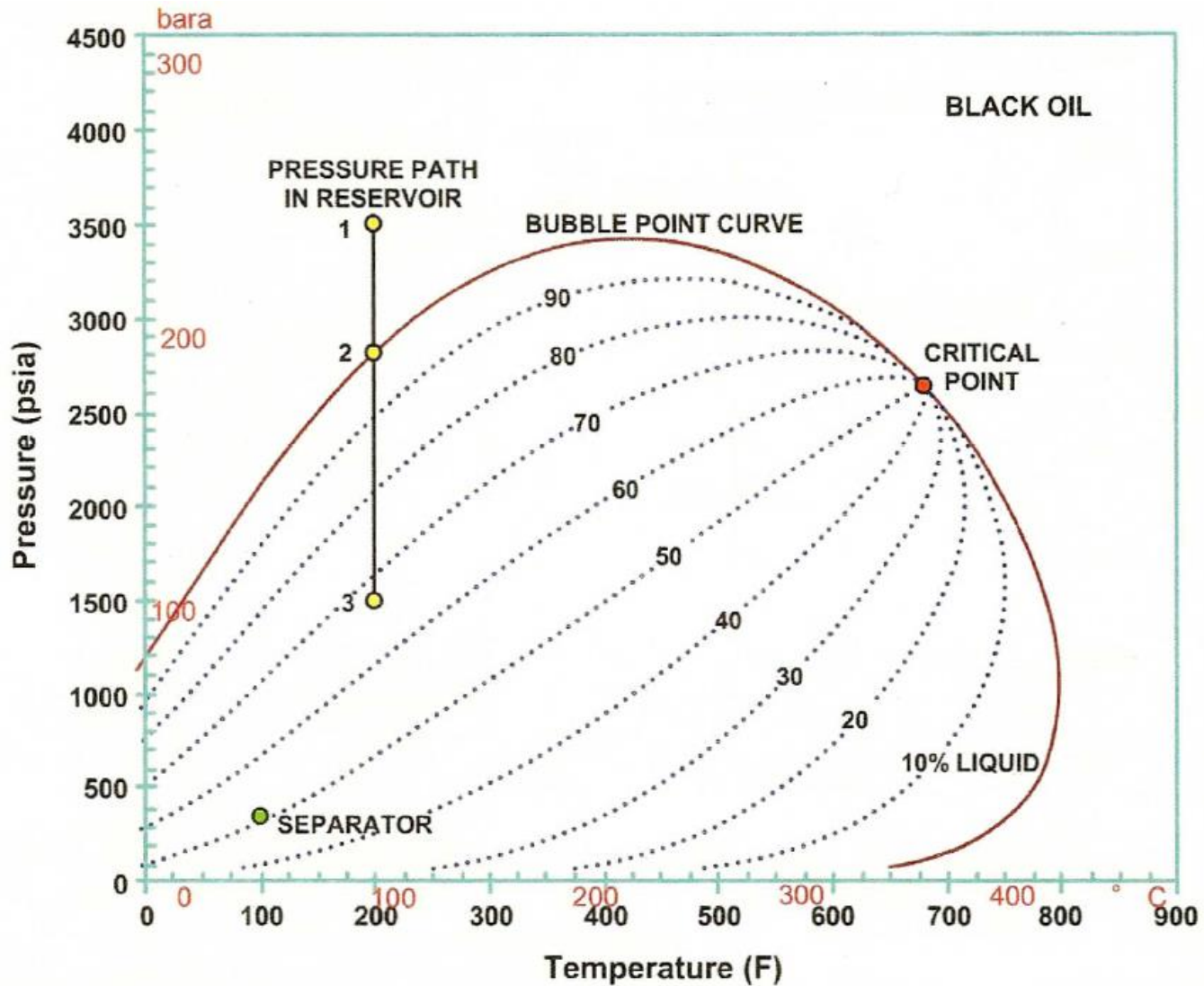
Phase behavior – Pure component



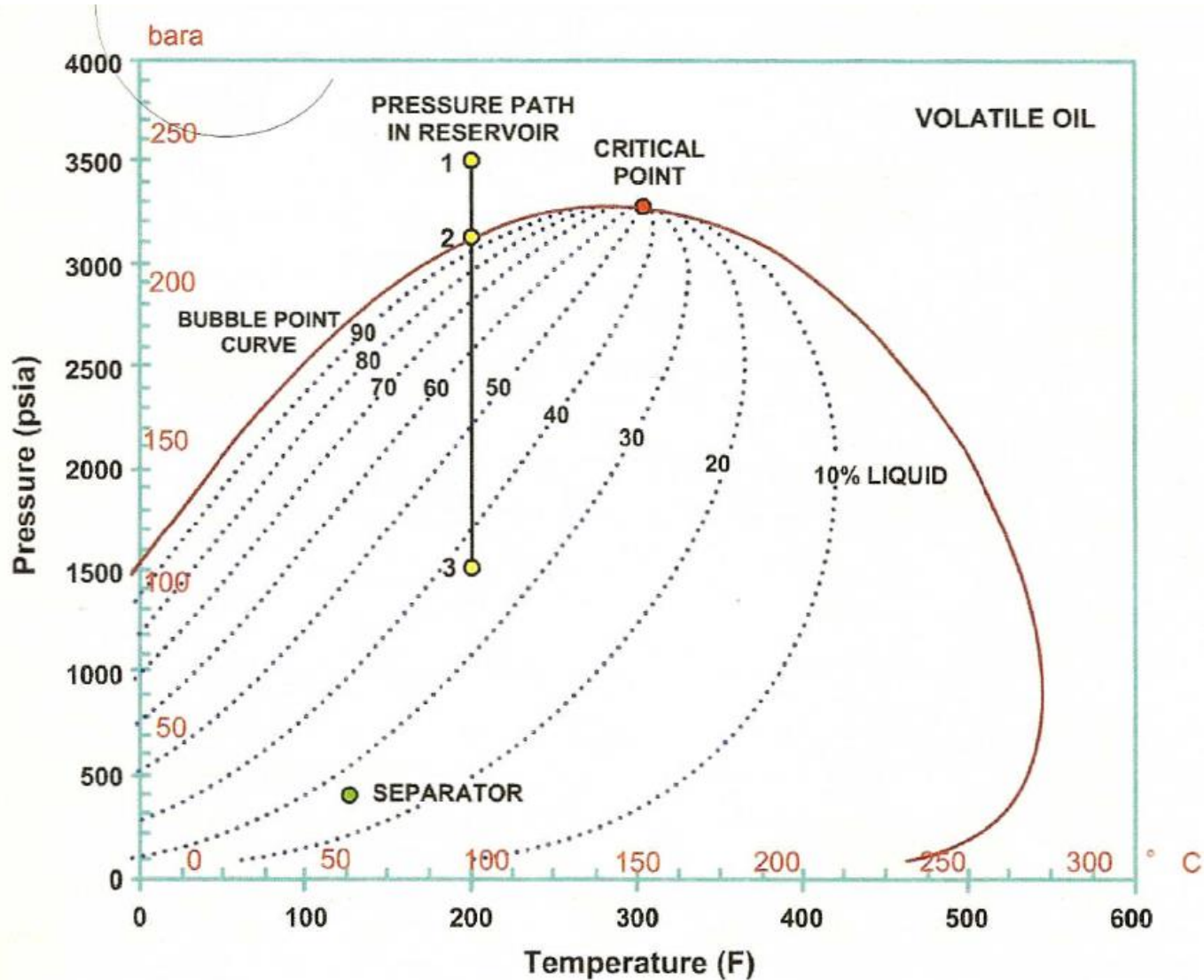
Phase behavior - Multicomponents

- Reservoir fluids have a huge number of components.
- Their phase behavior is complex compared to single components.
- Instead of a single curve separating liquid from vapor phases, there is a broad region where both vapor and liquid exist .
- The two-phase region is bounded on one side by the dew point curve and on the other side by the bubble point curve.
- The critical point is where the two curves meet

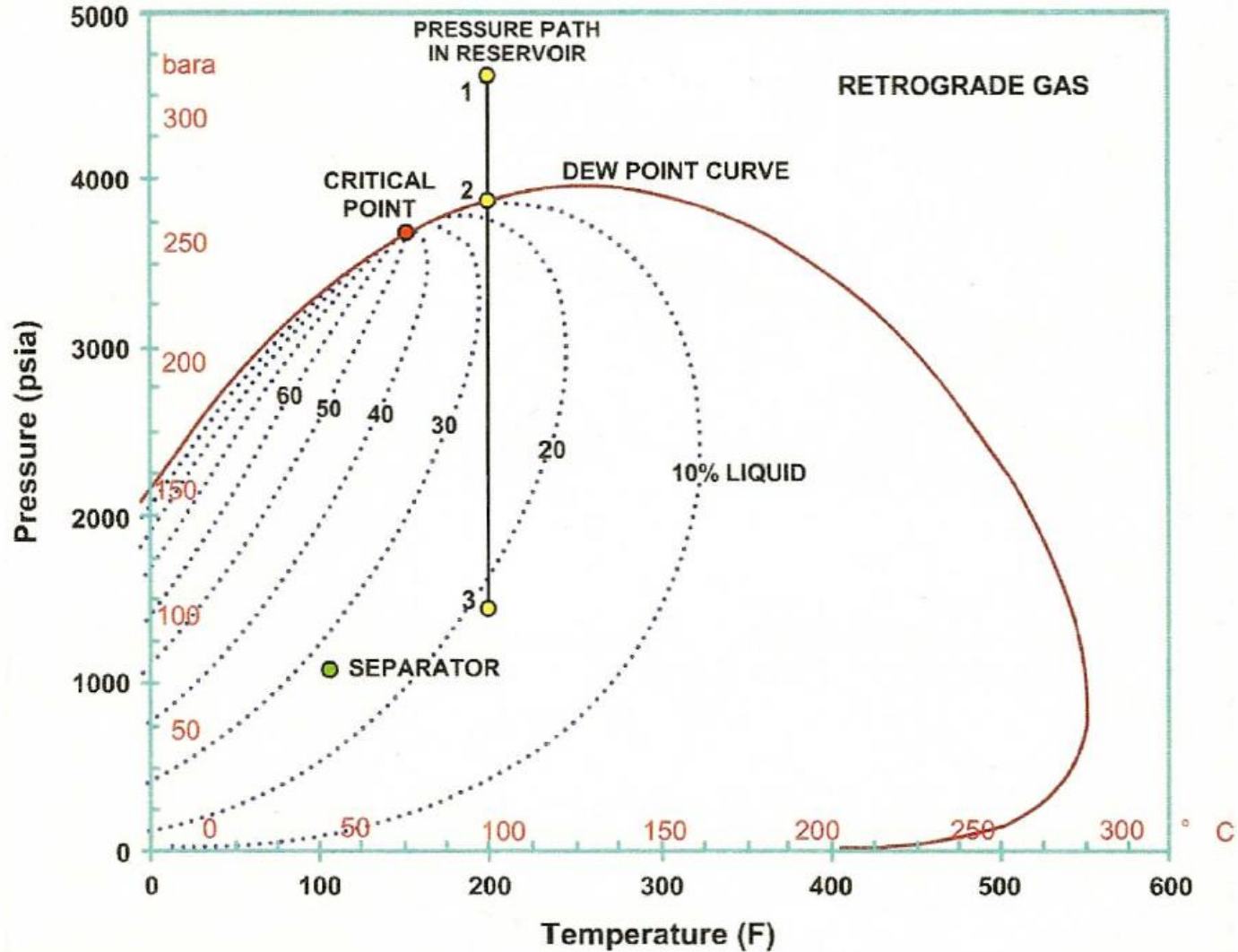
Black oil phase diagram



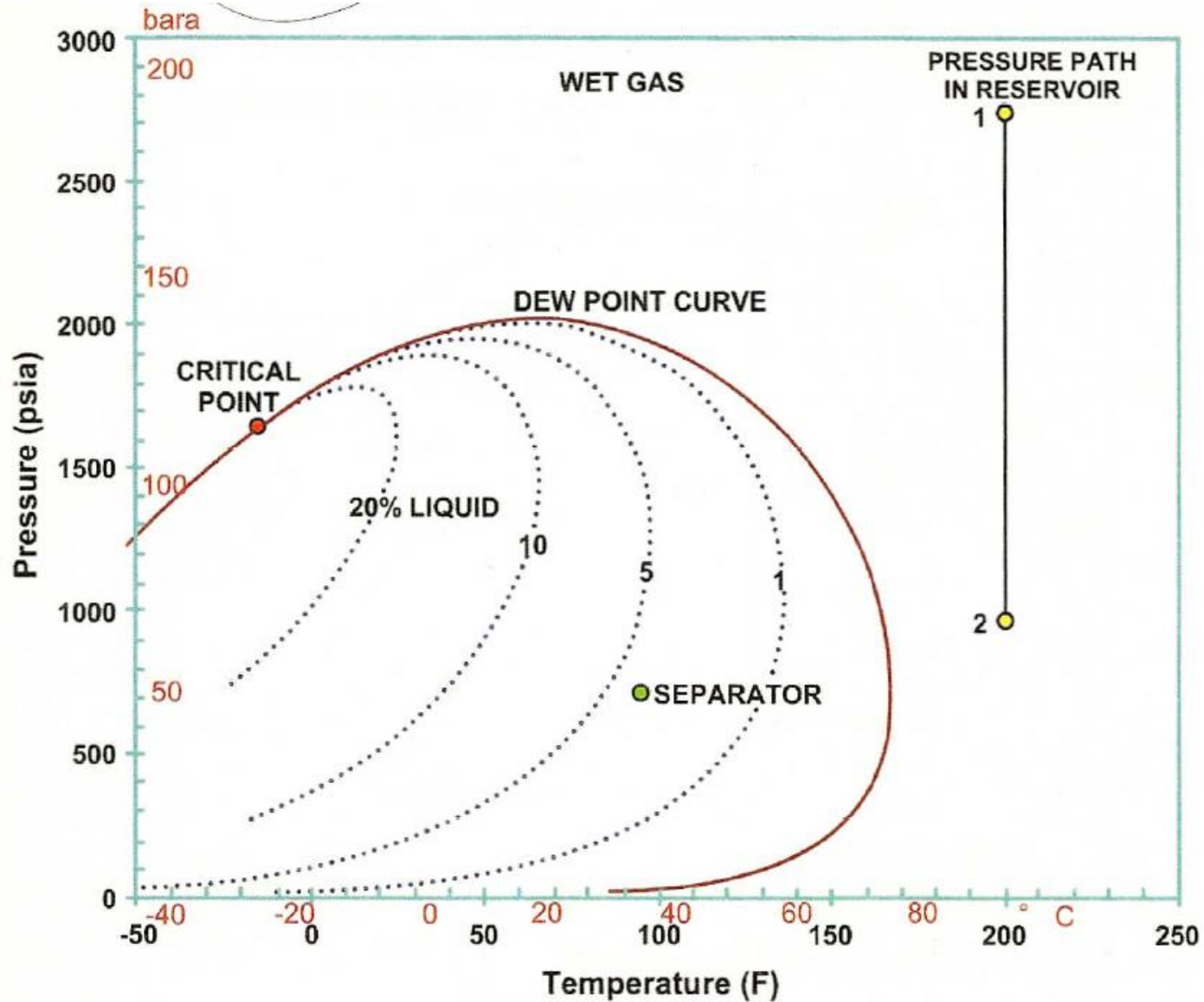
Volatile oil phase diagram



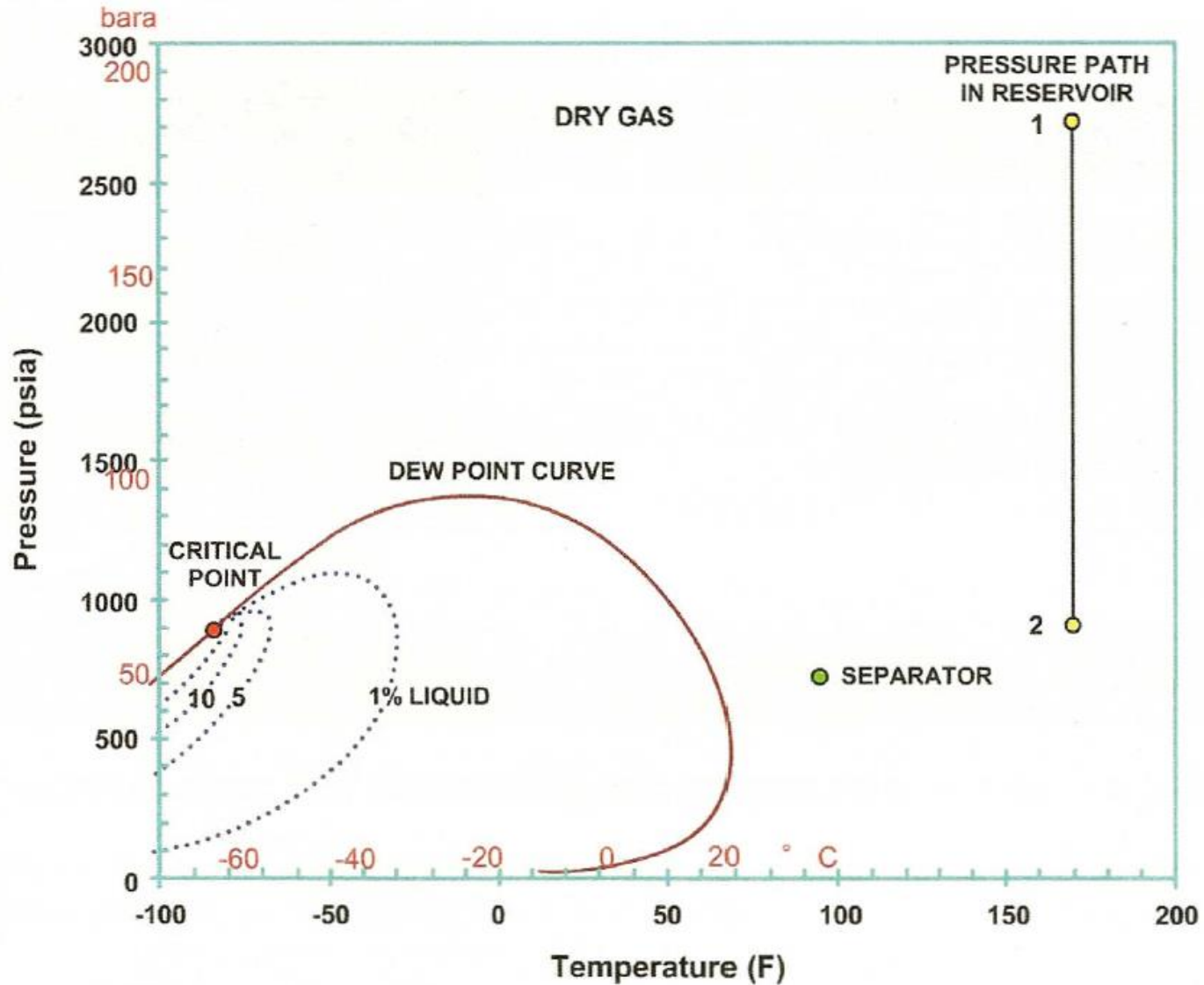
Condensate phase diagram



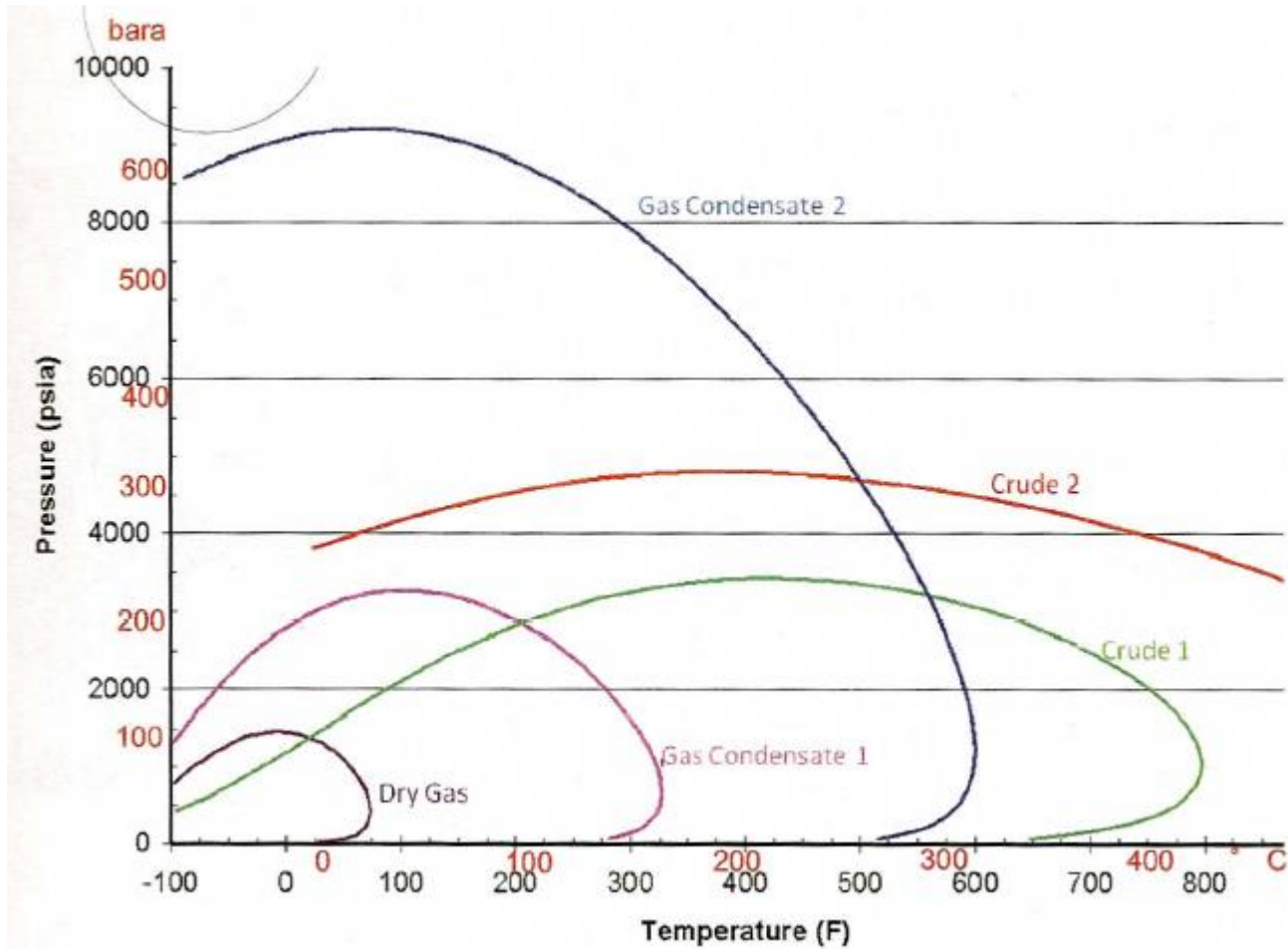
Wet gas phase diagram



Dry gas phase diagram



Two phase envelopes for various fluids

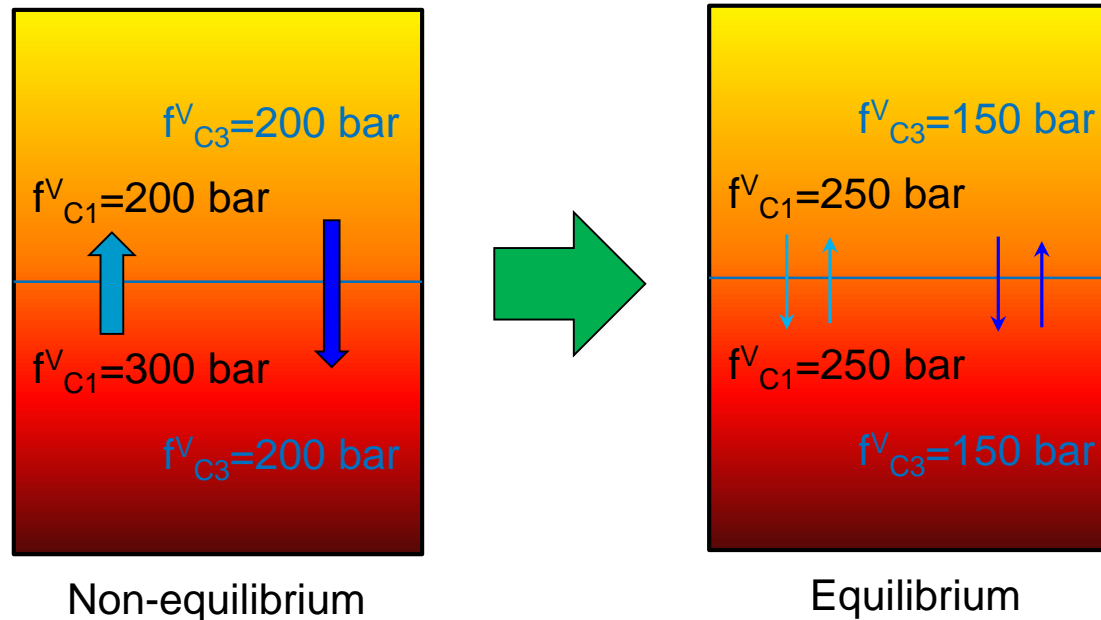


Reservoir flow characteristics

- Pressure is the main driving force for a reservoir and this will decay with time.
- The initial pressure and subsequent pressure profile of the reservoir will determine how reservoir flows and how it will produce.
- Above the bubble point pressure, all the gas is in solution and will remain in solution until the bubble point pressure is reached.
: The reservoir produces under “solution” drive.
(only 5~25% recovery of available reserves)
- At or below the bubble point pressure, the gas comes out of solution and forms a gas cap above the oil. The fluid is in the two-phase region and at equilibrium.
: The reservoir produces under “gas” drive. (20~40% recover)
- Once the well bottom pressure is equal to the reservoir pressure, the reservoir pressure can no longer support production.

Phase equilibrium

- At equilibrium all components will have the same fugacity (f_i) in all phases.
- Fugacity may be understood as effective partial pressures taking into account non-ideal interactions with other molecules





Components of subsea and topside systems

Primary elements

- Tree & Wellheads
- Manifolds
- Flowlines & Risers
- Control systems →
- Umbilicals
- Subsea processing
- Surface facilities

Topside controls

- Master control station
- Electrical power unit
- Hydraulic power unit
- Topside umbilical junction boxes
- Chemical injection skid



Subsea Well head

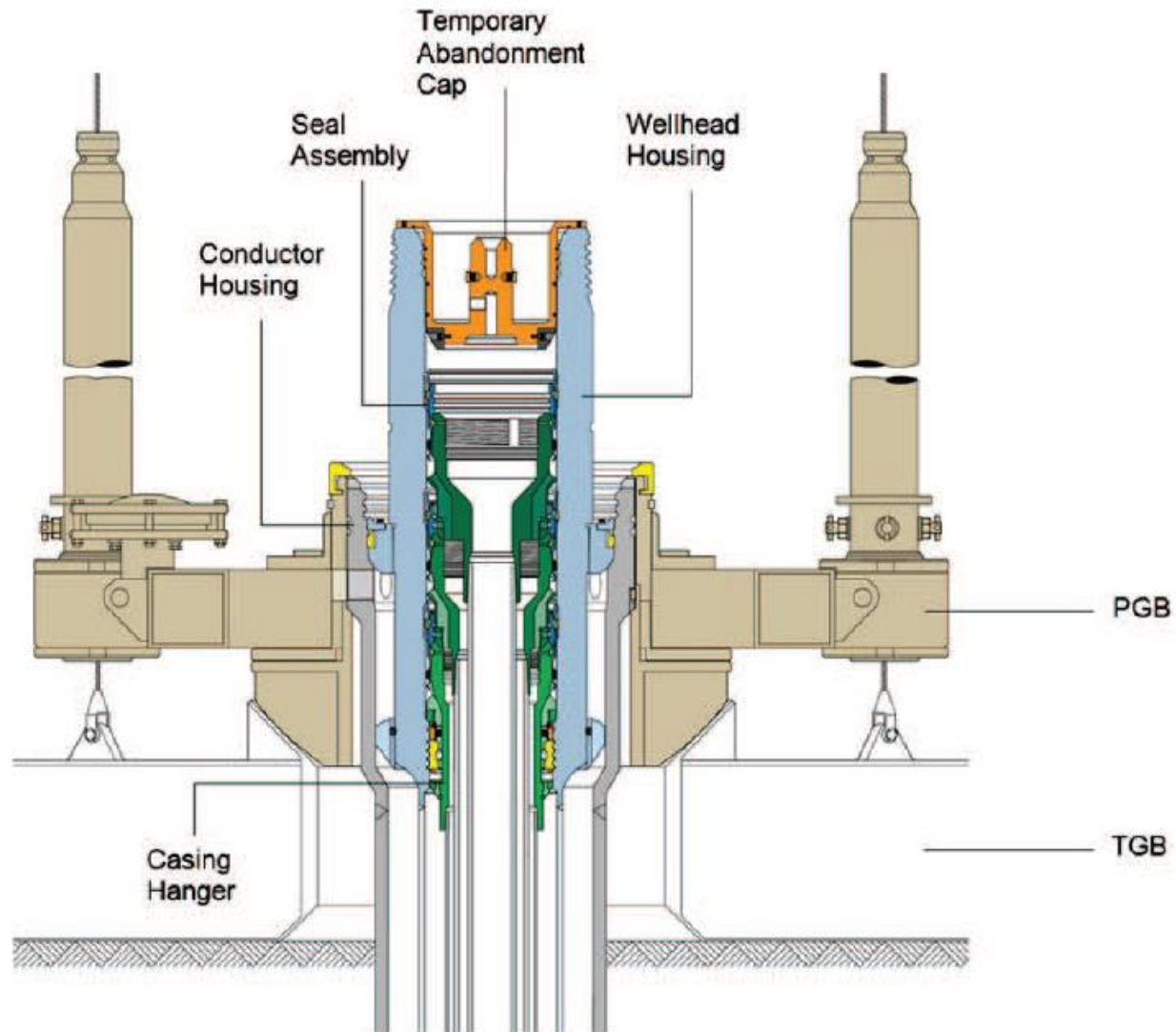
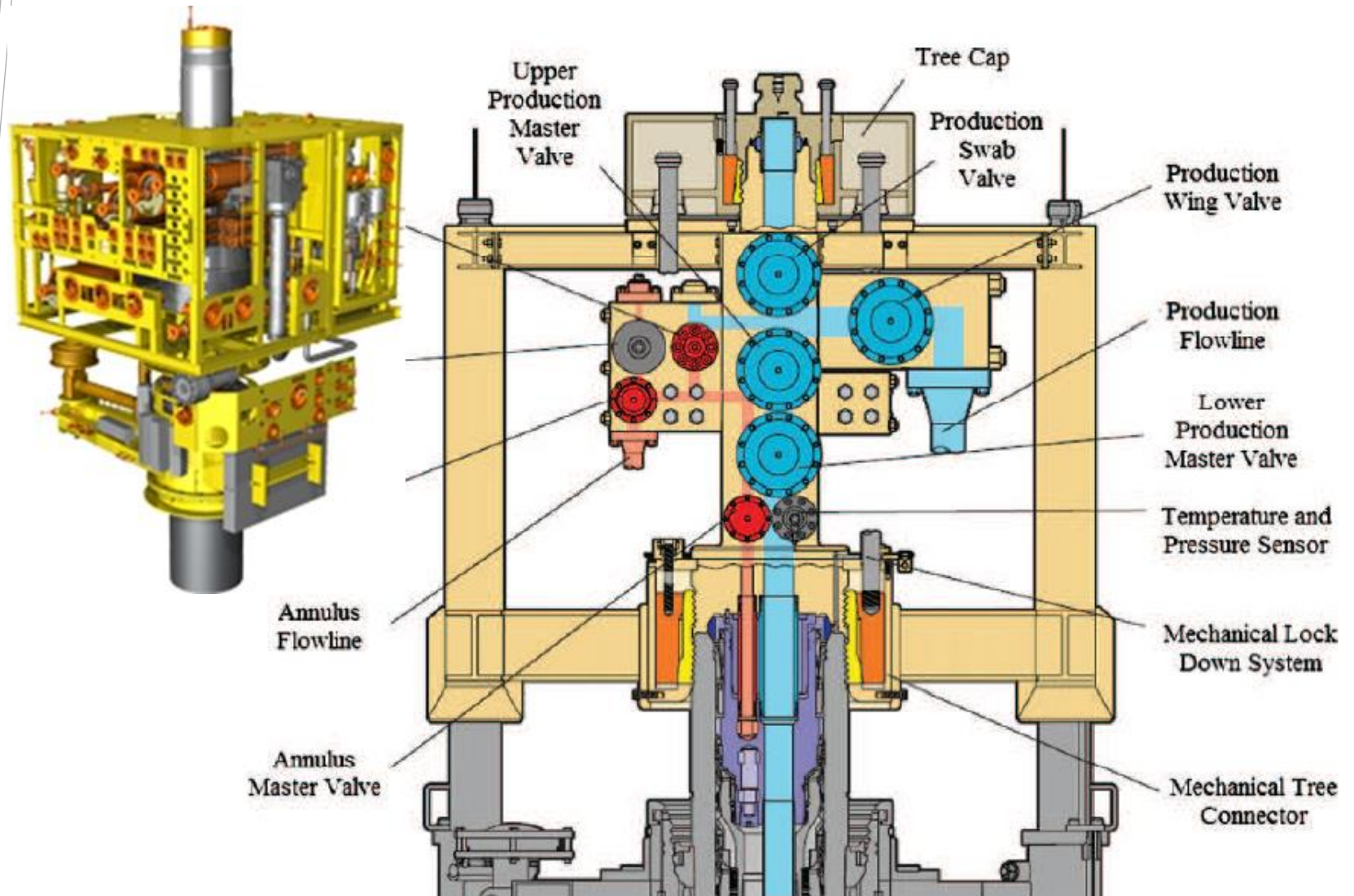
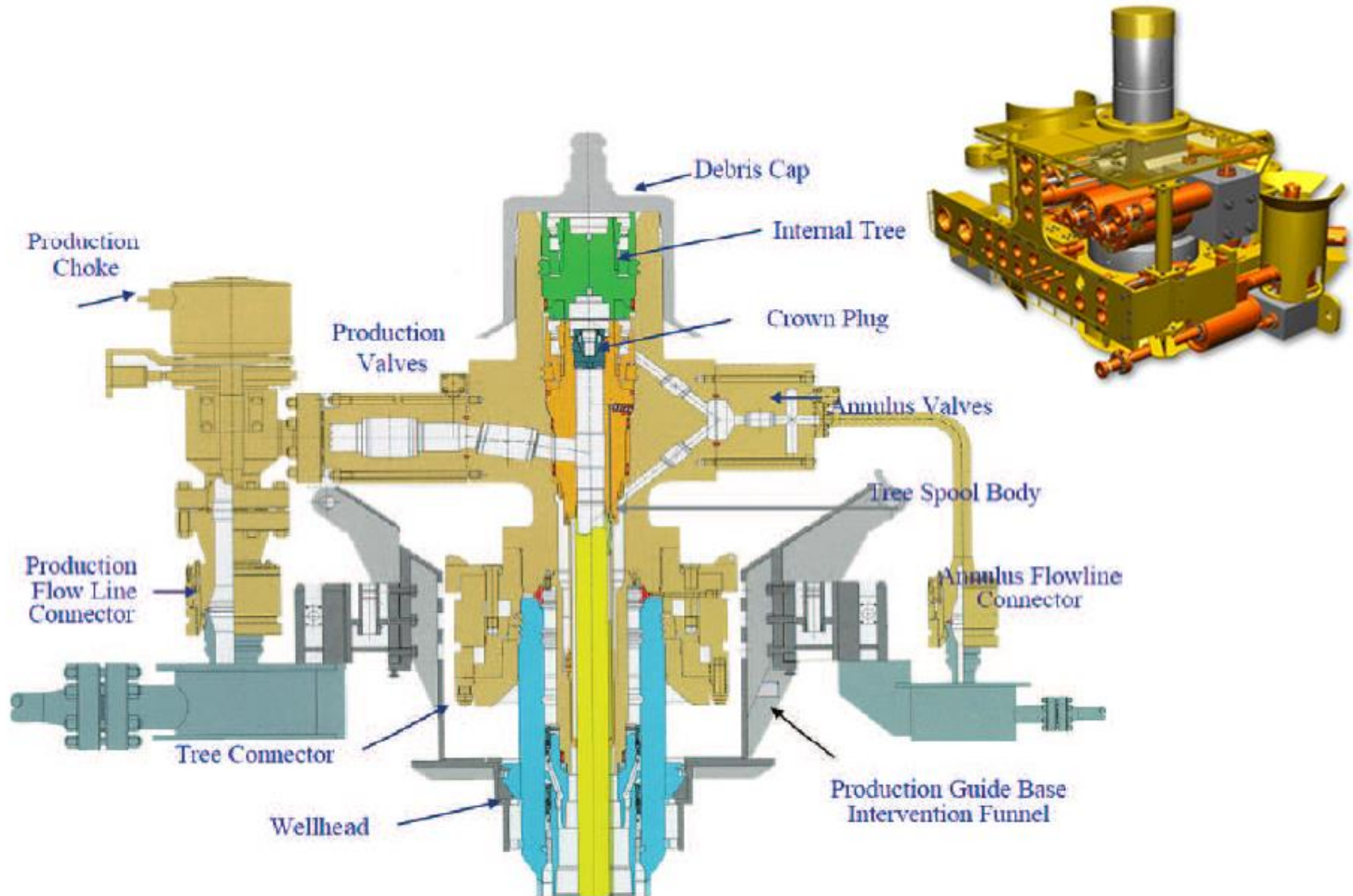


Figure 22-5 Typical 18³/₄-in. Subsea Wellhead System (Courtesy of Drill-Quip)

Subsea tree - Vertical

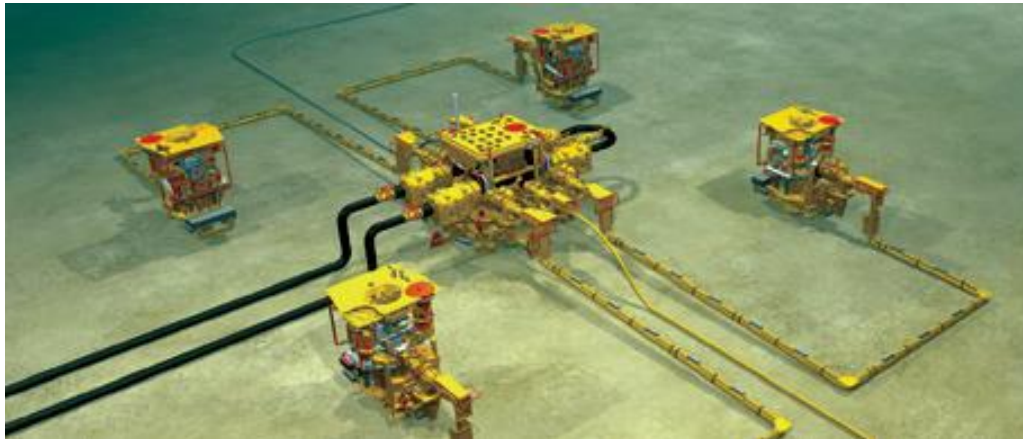


Subsea tree - Horizontal



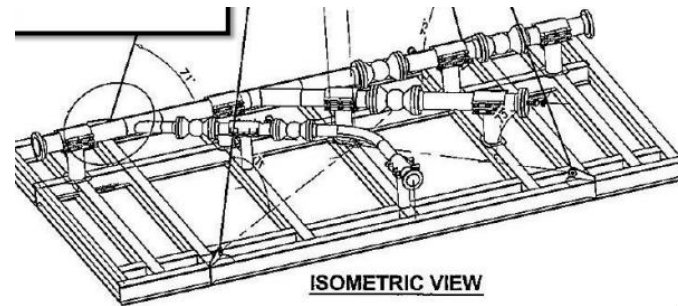
Subsea Manifolds

- Subsea manifolds have been used to simplify the subsea system, to minimize the use of subsea pipelines and risers, and to optimize the fluid flow of production in the system.
- The manifold is an arrangement of piping and/or valves designed to combine, distribute, control, and often monitor fluid flow.
- Subsea manifolds are installed on the seabed within an array of wells to gather produced fluids or to inject water or gas into wells.

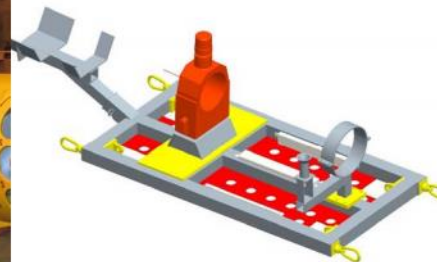


PLEM/PLET

- PLEM (Pipeline End Manifold)
 - : Used to comingle 2 or more pipelines together and eliminate the need for additional risers



- PLET (Pipeline End Termination)
 - : Used to link manifold to the production pipeline



Flowline

- Transport reservoir fluid to processing facilities
- Pipelines
 - : horizontal transfer from wellhead
 - : these may be very long
 - : may be rigid or flexible pipe
 - : commonly called flowlines

**Polypropylene
Insulation
Systems**

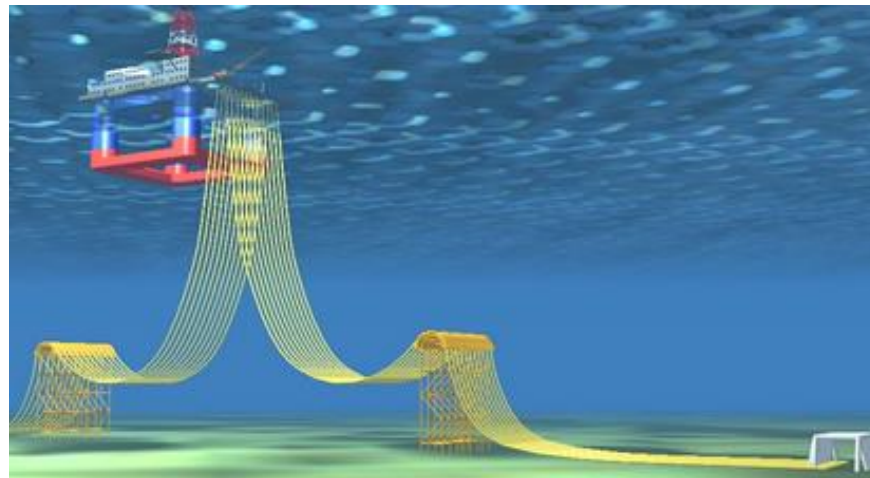


Concrete coated pipeline

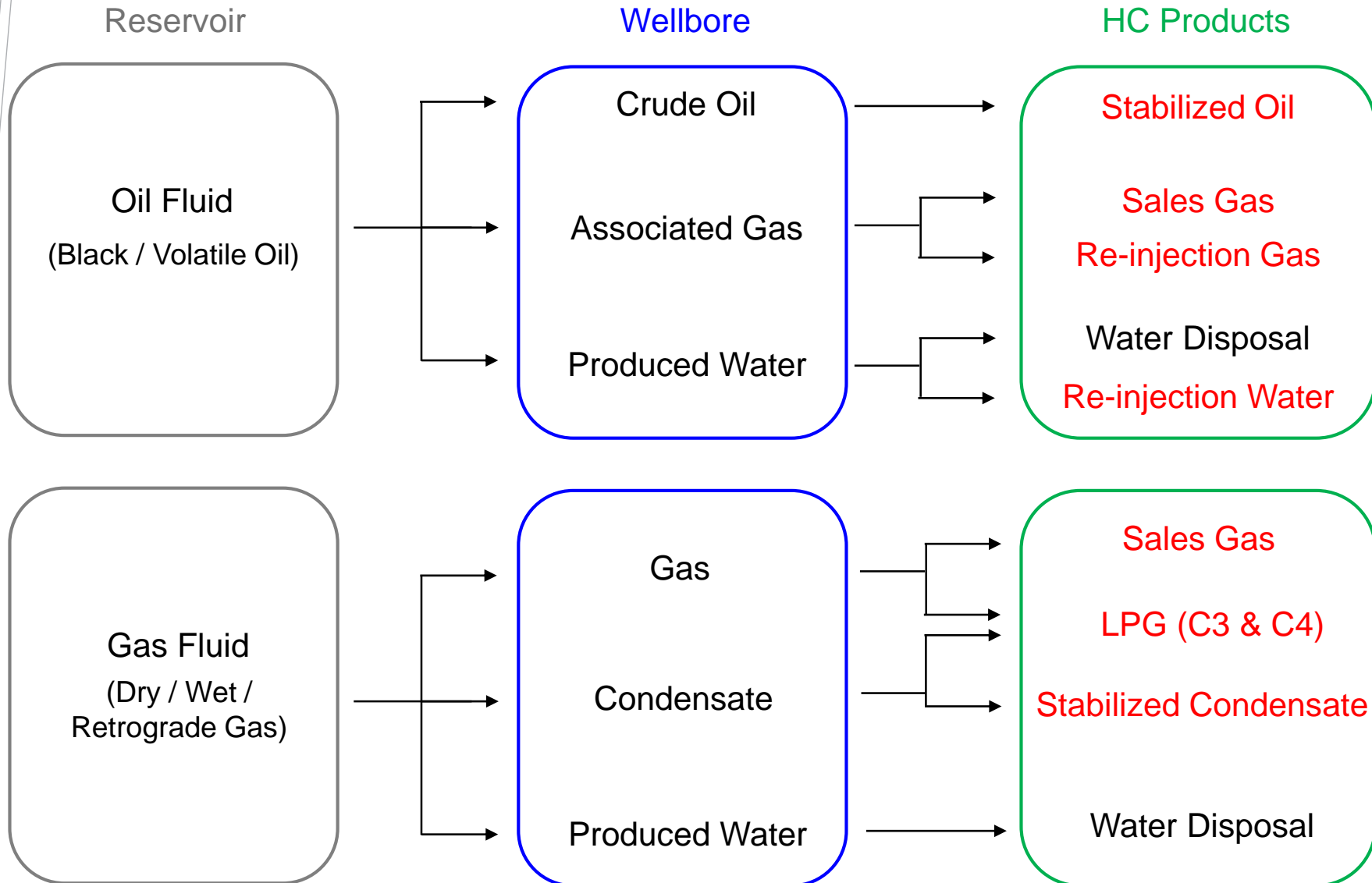


Riser

- Vertical transfer to above surface processing facilities
- Either Rigid or Flexible
- Rigid risers normally for fixed platforms
 - : pre-installed inside jacket frame
 - : cost effective and added riser protection
- Flexible risers mainly for floating production system
 - : Flexibility and reliability
 - : Easy and rapid installation

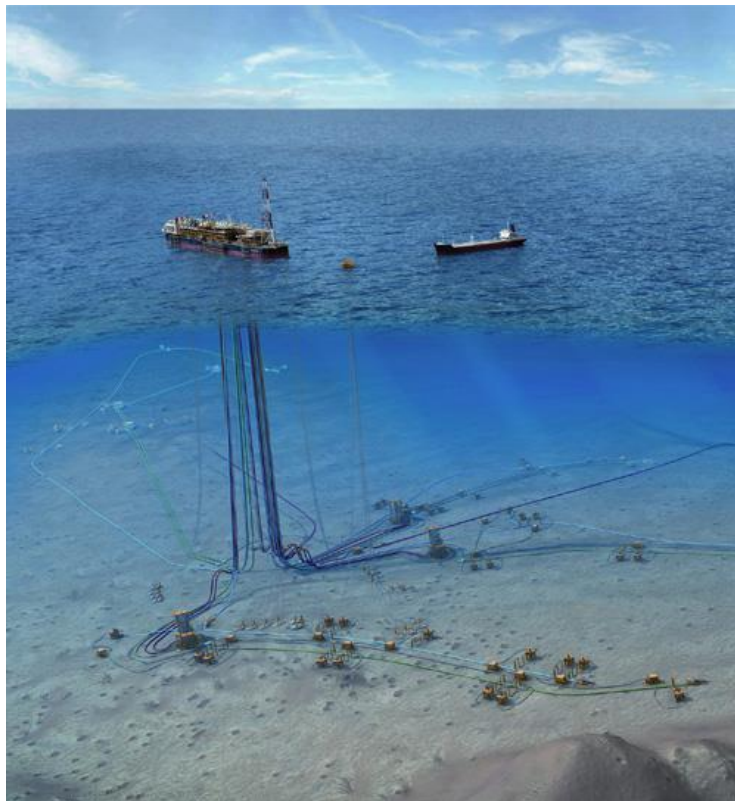


Value chain from reservoir



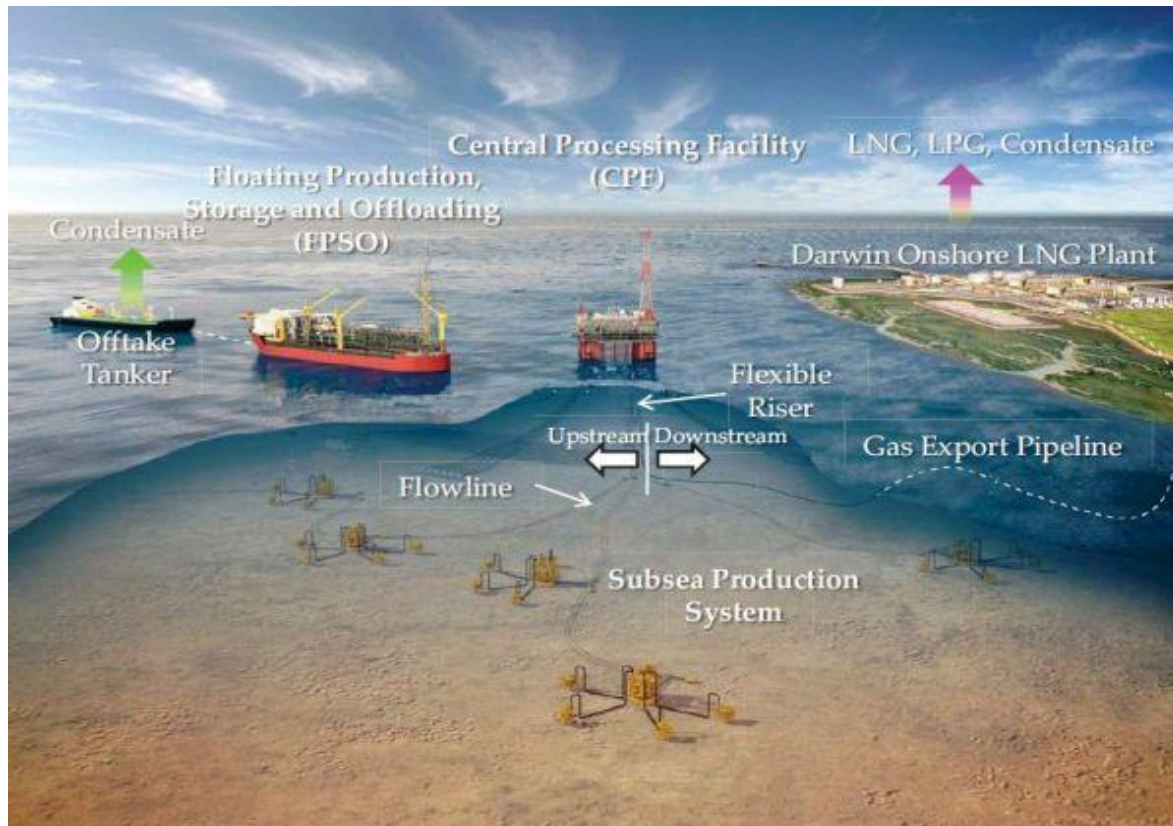
Oil field development

- Processing hydrocarbons received from local production wells i.e. from a platform or subsea template
- Well stream is processed & stored on the vessel, offloaded to a shuttle tanker or exported via a pipeline

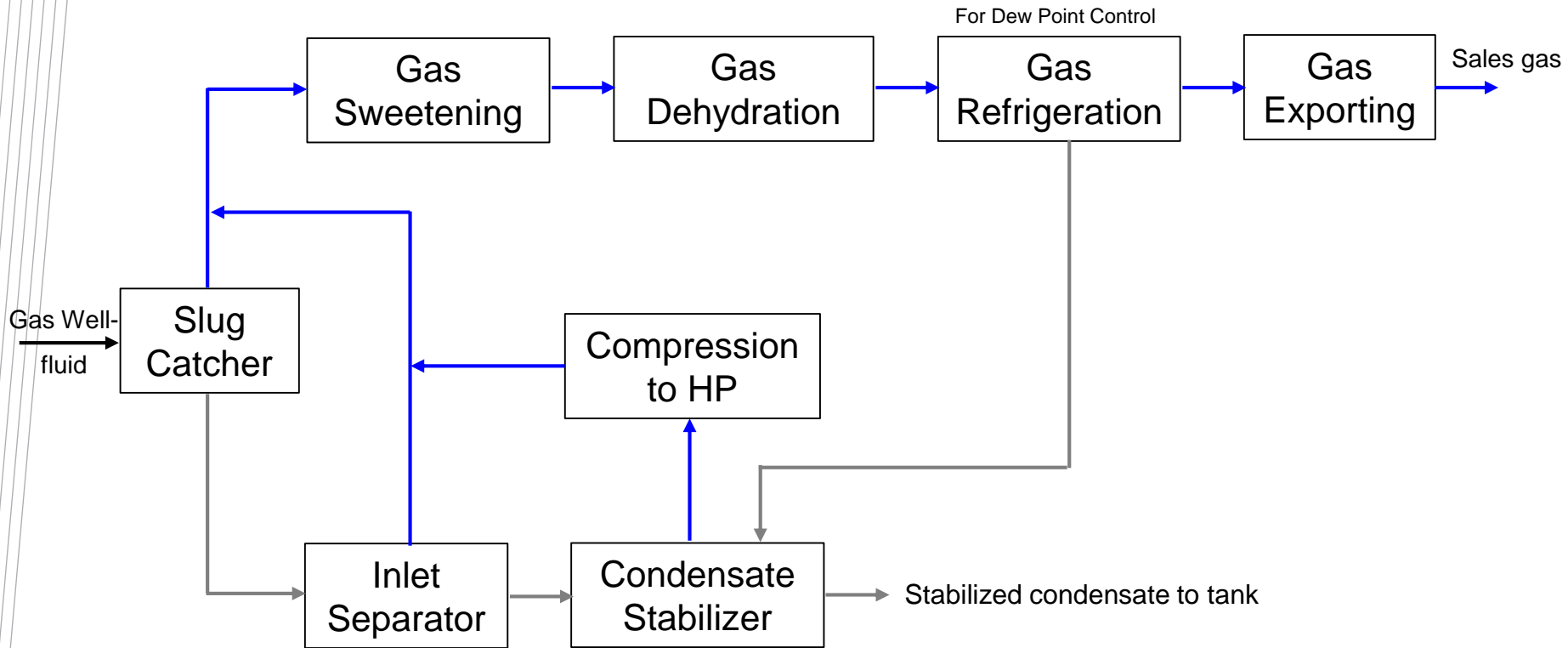


Gas field development

- Processing hydrocarbons received from local production wells i.e. from a platform or subsea template
- Well stream is processed & stored on the vessel, offloaded to a shuttle tanker or exported via a pipeline / or producing LNG

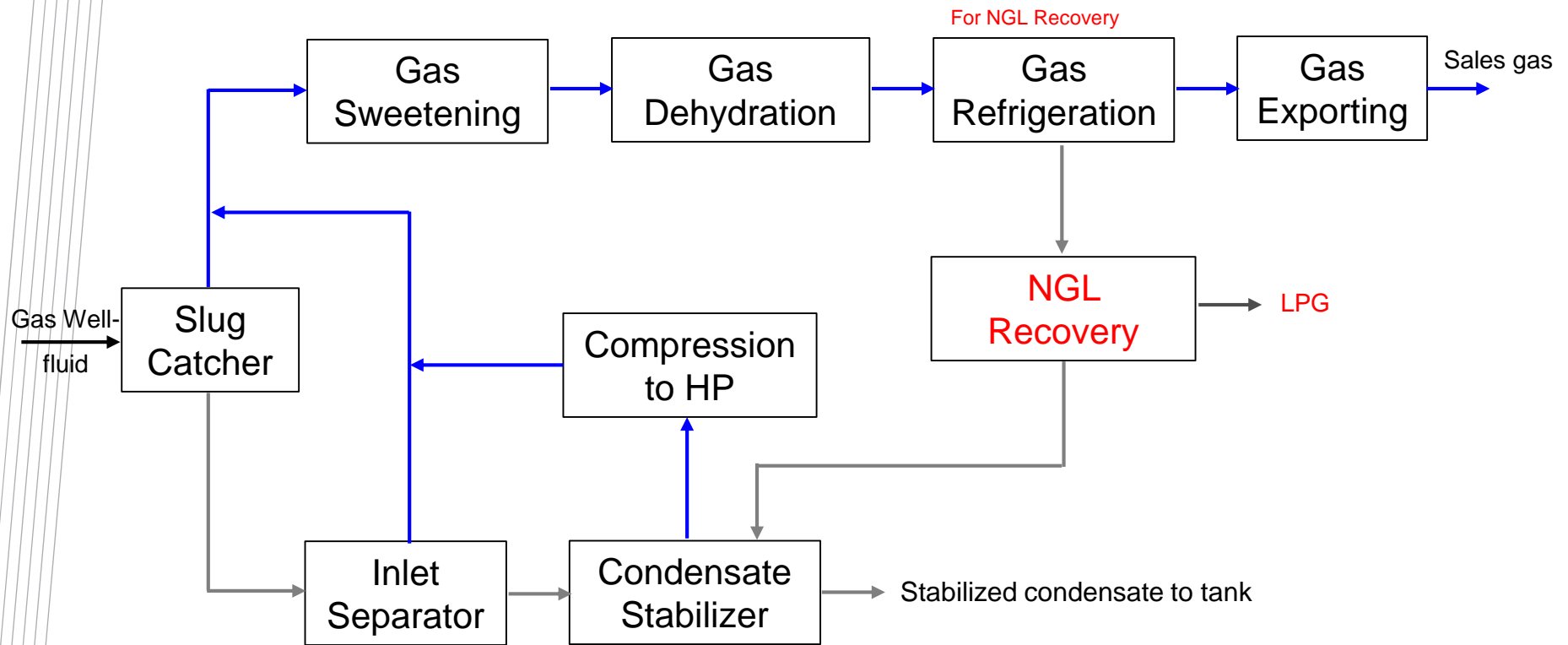


CPF for gas field (1)



- Well Fluid Stream
- Gas Stream
- Liquid HC stream

CPF for gas field (2)



- Well Fluid Stream
- Gas Stream
- Liquid HC stream

What happens if something goes wrong



Flowline failure
(Operated below min. pressure limit)



Tree failure
(Sand erosion damage)

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Thank you