

Natural gas processing



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Overview

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- Natural gas processing
- Natural gas liquefaction cycles
- LNG storage facilities
- Phase separation

Canada's first LNG export facility

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- Shell(40%)-Petronas-PetroChina-Korea Gas corp-Mitsubishi
- LNG plant to cost \$31bn (\$14bn Kitimat LNG)
- Capacity: 14mtpa (phase 1); 14mtpa (phase 2)
- Demand for LNG to double by 2035
- 293mtpa (2017) -> 445mtpa (2015)
- \$1.5/MMbtu

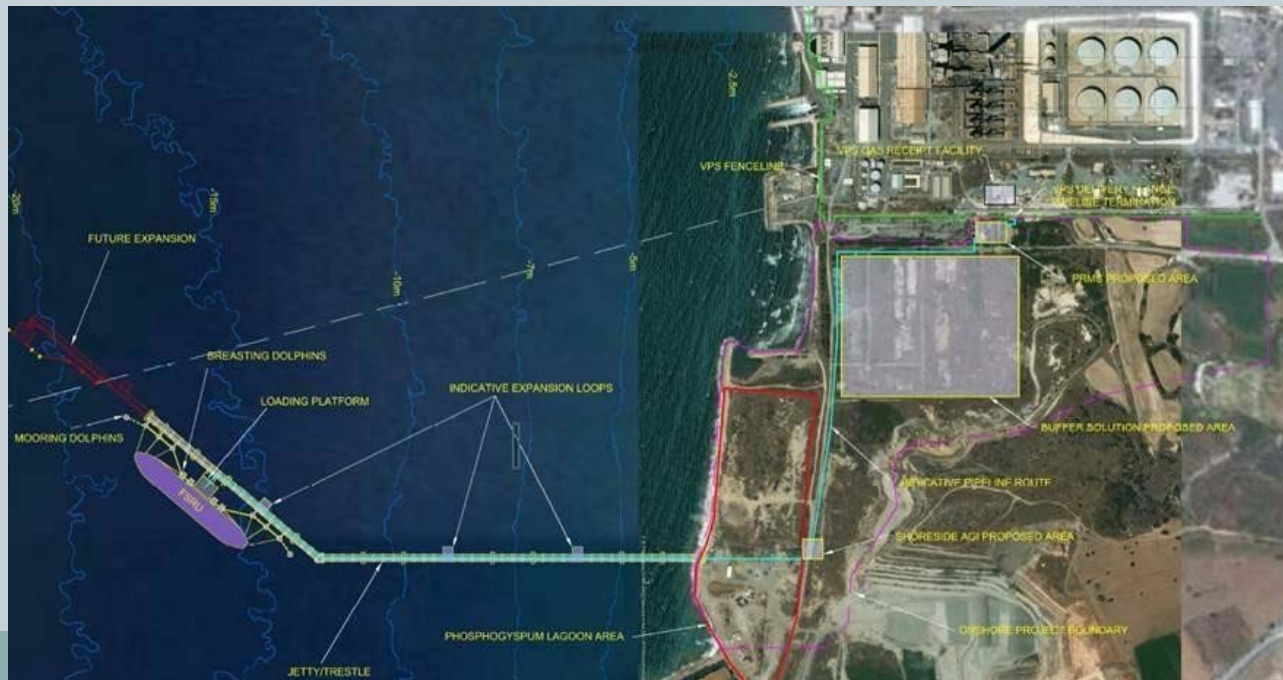
- [Video: LNG Canada](#)



Cyprus LNG receiving terminal

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- Cyprus FRSU to be built at Vasilikos
- €500m facility by Nov. 30, 2020
- €300m: design & construction + €200m LNG supply
- EU funding amounts to €100m
- Volume: 125,000 m³/yr



Natural gas processing

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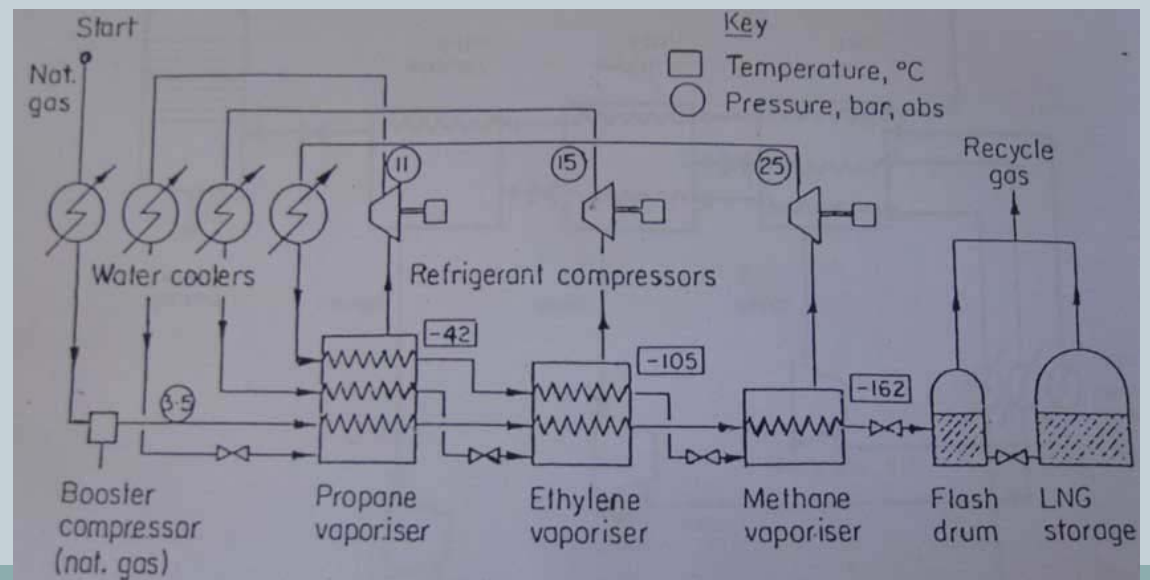
- Remove:
 - Liquids (H_2O)
 - Carbon dioxide (CO_2)
 - Acid gases (eg, H_2S)
 - Dry gas from water
- Pump sweet natural gas to shore via submarine pipeline
- If natural gas is dry (pure gas) minimal processing
- Compression station pumps gas to shore
- CO_2 and water usually re-injected in gas field



Natural gas liquefaction cycles

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- 1. Classical cascade
 - Refrigerants: a) propane, b) ethylene, c) methane in compression-refrigeration cycles
- 2. Modified cascades:
 - Mixed refrigerant
 - ✦ Fewer compressors & heat exchangers
 - ✦ Less space
 - ✦ Less costly to build
 - ✦ Costs less to operate
 - Precooled mixed refrigerant
 - ✦ Most popular cycle
 - ✦ Uses mixed refrigerants: N_2 , CH_4 , C_2H_6 ,
 - ✦ Known as C3 MR cycle

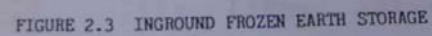
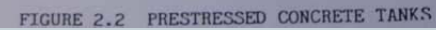
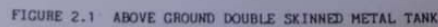


LNG storage facilities

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- Factors: cost, safety, reliability, efficiency, duty, aesthetics
- Aboveground double skinned metal tanks
 - ✦ Most reliable & predictable for heat inleak
 - ✦ Fire and explosion resistant, no geological constraints
 - ✦ Materials: Al, s. steel, 9% nickel steel
- Above/below ground prestressed concrete tanks
 - ✦ Reinforced pre- or post-stressed rods prevent cracks
- Inground frozen earth storage
 - ✦ A: Bigger tanks; D: costly excavation, structural stability, heat loss
- Mined caverns
 - ✦ Rarely present closed to demand

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Natural gas processing

Tackling the energy density question

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- What does the 1/610 volume reduction entail:

- Liquefaction: converting methane into liquid
- Storage of LNG
- Shipping LNG
- Export & import facilities

Natural gases' compositions

Component	Volume Percentage					
	Algerian LNG	Libyan LNG	Groningen	Lacq	St.Fergus	Bacton
Methane	86.5	70.0	81.2	69.2	93.23	92.61
Ethane	9.4	15.0	2.9	3.3	3.99	2.82
Propane	2.6	10.0	0.5	0.9	0.82	
iso-Butane	1.1	3.5	0.1	0.6	0.29	
n-Butane						
Pentanes & higher hcbns	0.1	0.6	<0.1	0.8	0.06	0.16
Carbon Dioxide	NIL	NIL	0.9	9.3	0.80	0.24
Nitrogen	0.3	0.9	14.4	0.6	0.89	3.40
Hydrogen Sulphide	-	-	-	15.3	-	-

Natural gas components' properties & other fuels

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Constituents	Molecular weight	Relative Density (Air = 1)	Gross Cal. Val. MJm ⁻³ (st)	Spontaneous Ignition Temperature °C	Flammability Limits (Percentage hydrocarbon in air)	Relative Percentage heat radiated from a burning pool
1	2	3	4	5	6	7
Methane	16	0.55	37.71	540	5.0 - 15.0	23
Ethane	30	1.04	66.35	515	2.9 - 13.0	-
Ethylene	28	0.97	59.72	425	2.7 - 34.0	38
Propane	44	1.53	93.94	450	2.1 - 9.5	-
Propylene	42	1.45	87.09	460	2.0 - 11.7	-
Butanes	58	2.00	n-121.80 iso-121.44	365-460	1.5 - 8.5	30
Butylene 1	56	1.94	114.98	385	1.6 - 10.0	-
Hydrogen	2	0.07	12.10	400	4.0 - 76.0	25
Petrol	80	3 to 4	174.5	280	1.4 - 7.6	30

- High diffusion; high buoyancy; high spontaneous ignition temp.

Natural gas composition

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- Why liquefy natural gas?
 - LNG energy density: 2.4x CNG, 60% of diesel, 70% of gasoline
- Gas condensates:
 - H_2S , CO_2 , straight-chain alkanes, cyclohexane, naphthenes
 - Thiols (mercaptants), aromatics (benzene, toluene)
- Untreated natural gas consists predominantly of:
 - Nitrogen (N_2);
 - Carbon dioxide CO_2 ;
 - Traces of Sulphur;
 - Higher hydrocarbons
 - Impurities i.e., dust
 - Traces of Mercury (Hg) and occasionally
 - Helium (He)
 - Water vapour (H_2O)

Gas processing

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- Meets transport or final gas specs
- Processing objectives:
 - Generate a sales gas stream which meets specs (ie, Table 1). These specs are designed to meet pipeline requirements and needs of industrial & domestic consumers
 - Maximize NGLs share by producing lean gas stripped of most of the H/Cs other than methane.
 - Deliver a commercial gas (distinguished by a range of gross heating value).

Natural Gas Specifications in the Salable Gas Stream (Goar and Arrington, 1978)

Characteristic	Specification
Water content	4–7 lb/MMscf (max)
Hydrogen sulfide content	1/4 grain/100 scf (max)
Gross heating value	950 Btu/scf (min)
Hydrocarbon dew point	15°F at 800 psig (max)
Mercaptan content	0.2 grain/100 scf (max)
Total sulfur content	1–5 grain/100 scf (max)
Carbon dioxide content	1–3 mole percent (max)
Oxygen content	0–0.4 mole percent (max)
Sand, dust, gums, and free liquid	Commercially free.
Typical delivery temperature	120°F
Typical delivery pressure	714.7 psia

Initial gas processing

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- Min. purification at well-head
- Raw gas transmission
- Feed gas may contain: H_2O , CO_2 , H_2S , higher H/Cs, impurities
- Need to pig regularly due to two-phase flow
- First stage treatment:
 - Traps
 - Collect liquids
- Depending on temp., H_2O content, press. drop:
 - Glycol or methanol prevents hydrate formation
 - Glycol/methanol removed using fractionation in aqua/liquid separator
- Gas cooled close to freezing temp by heat exchanger
 - Removes more water
 - Heavy hydrocarbons in knock-out drum



Onshore initial H/C processing

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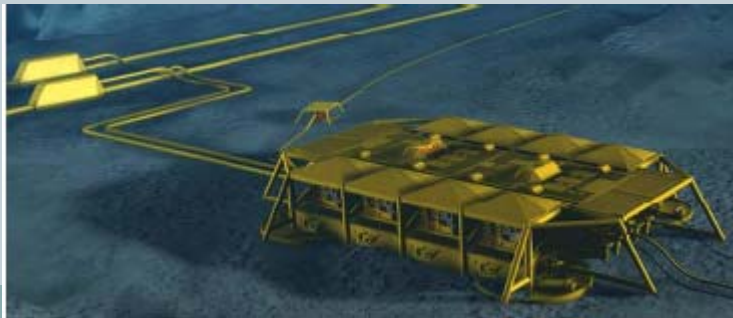
- Some purification at well-head
- Raw gas moved via pipeline(s)
- Feed gas may contain: H_2O , H_2S , CO_2 , heavier H/Cs, impurities
- Need to pig regularly due to two-phase flow
- First stage treatment:
 - Traps
 - Gather liquids
- Depending on temp, H_2O content, press drop:
 - Glycol or methanol prevents hydrate formation
 - Glycol/methanol removed using fractionation in H_2O /liquid separator
- Gas cooled close to freezing temp by heat exchanger
 - Separates more water
 - Heavy hydrocarbons in knock-out drum



Offshore gas processing

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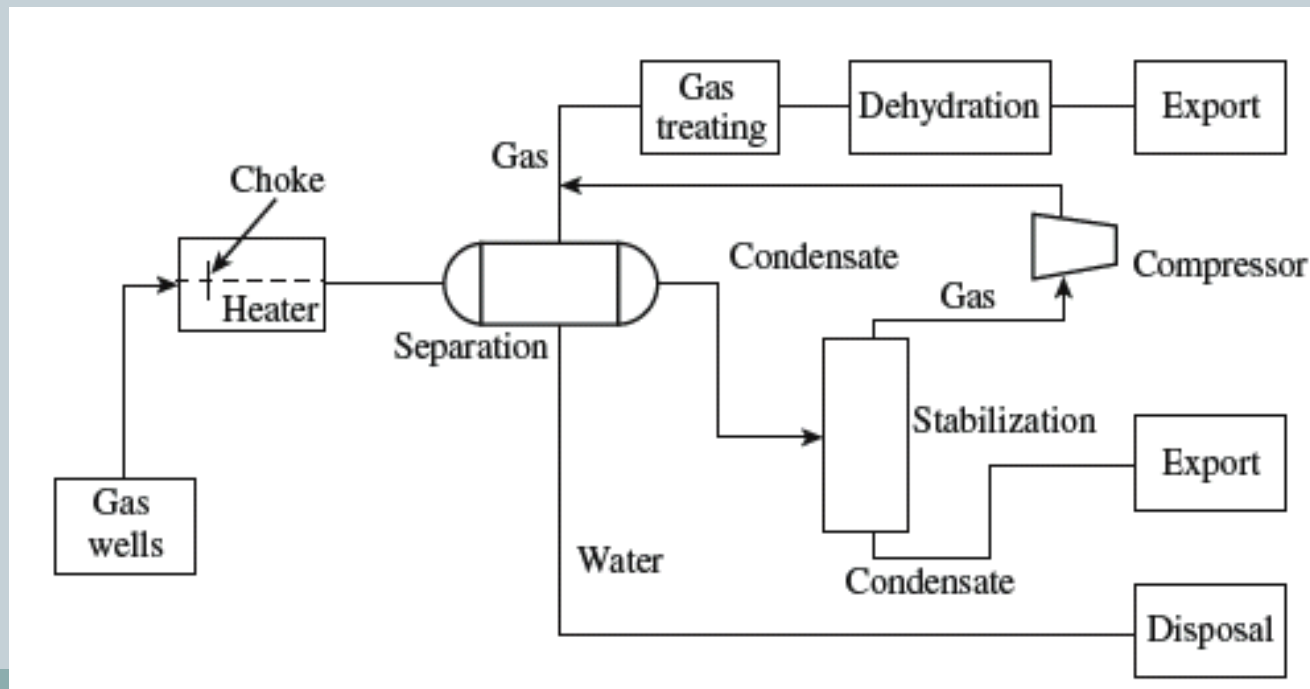
- Processing done onboard platform or subsea
- Separate:
 - Liquids (eg, H_2O , condensates, ...)
 - Carbon dioxide (CO_2)
 - Other acid gases (eg, H_2S)
 - Dehydrate gas
- Pump sweet natural gas to shore via submarine export pipeline
- If natural gas is dry (\approx pure CH_4) minimal processing
- Compression station pumps gas to shore
- CO_2 and water usually re-injected in gas field



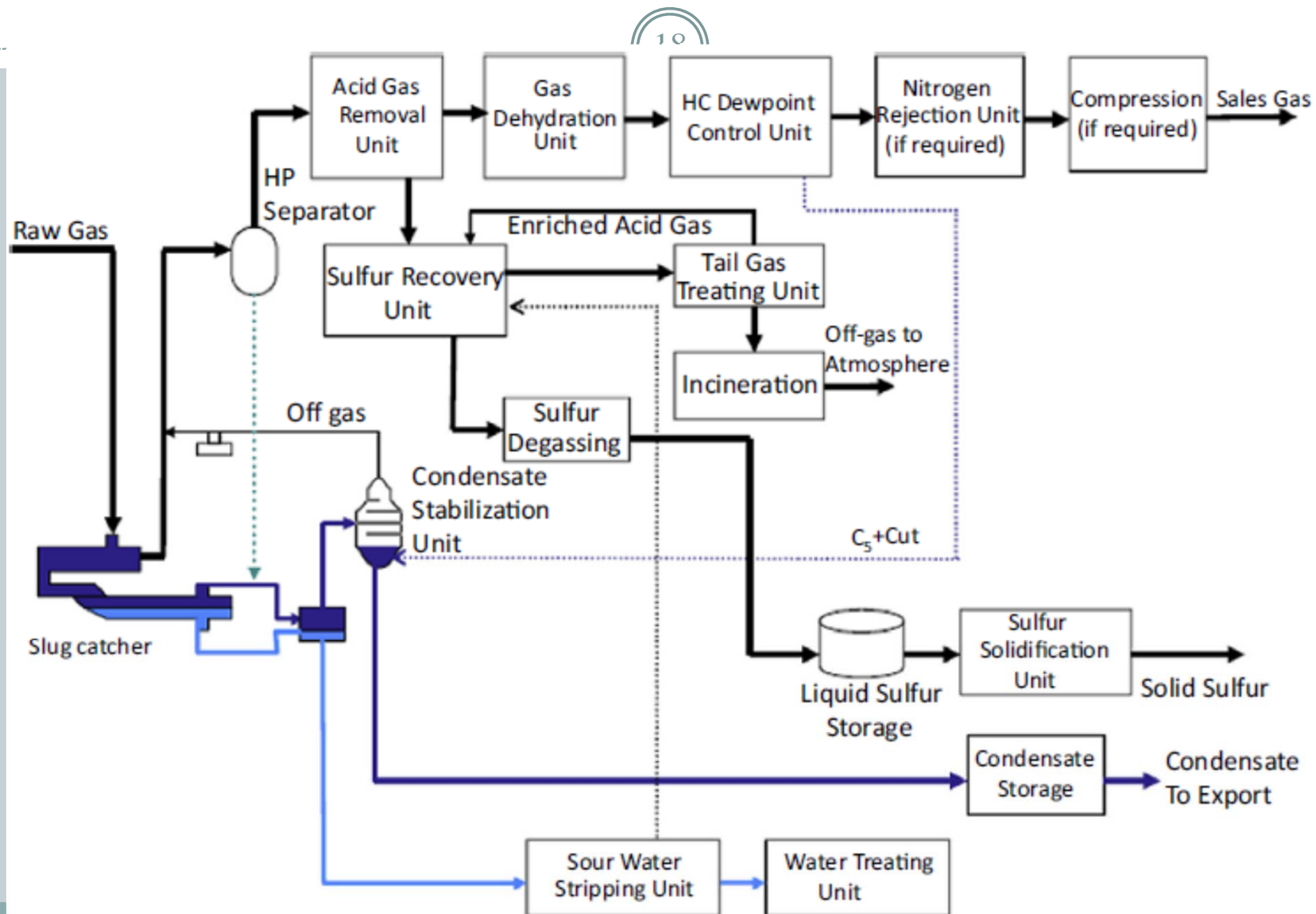
Offshore gas treatment

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- Flowline choke valve lowers gas pressure & temp.
- Choke & flowline section embedded in hot water to avoid hydrates
- Phase-separation removes condensates (natural gasoline, He, alkanes, ...) & water

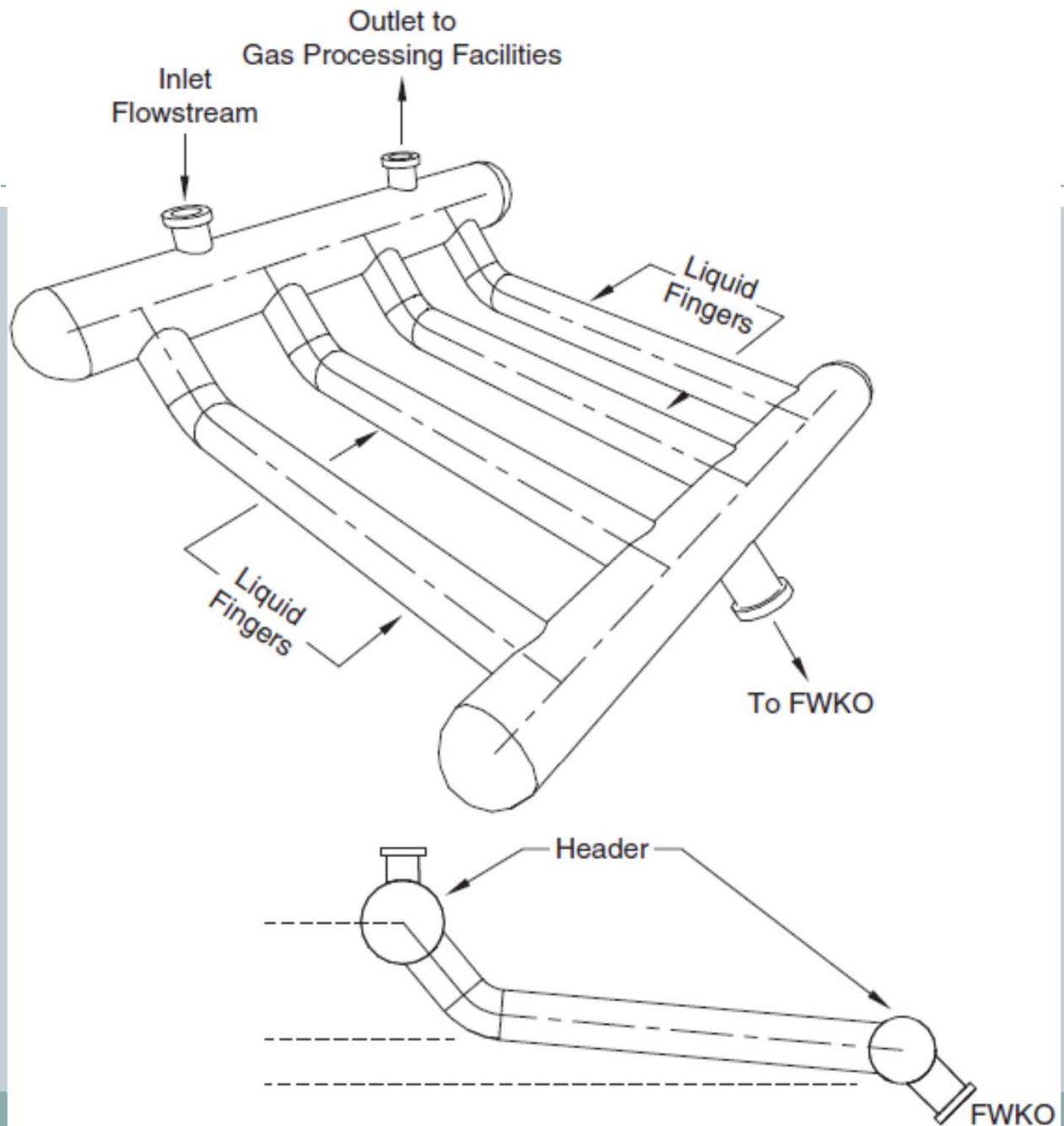
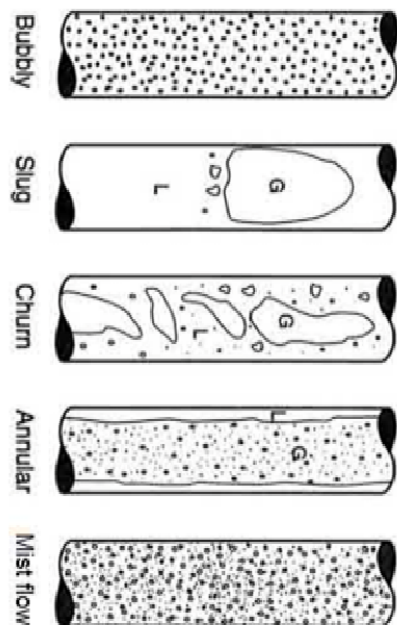


Natural gas plant unit



Slug catcher

- Used in gas gathering pipelines
- High gas-to-liquid ratio
- Less costly than vessel-type stms



Slug catcher (Ireland)

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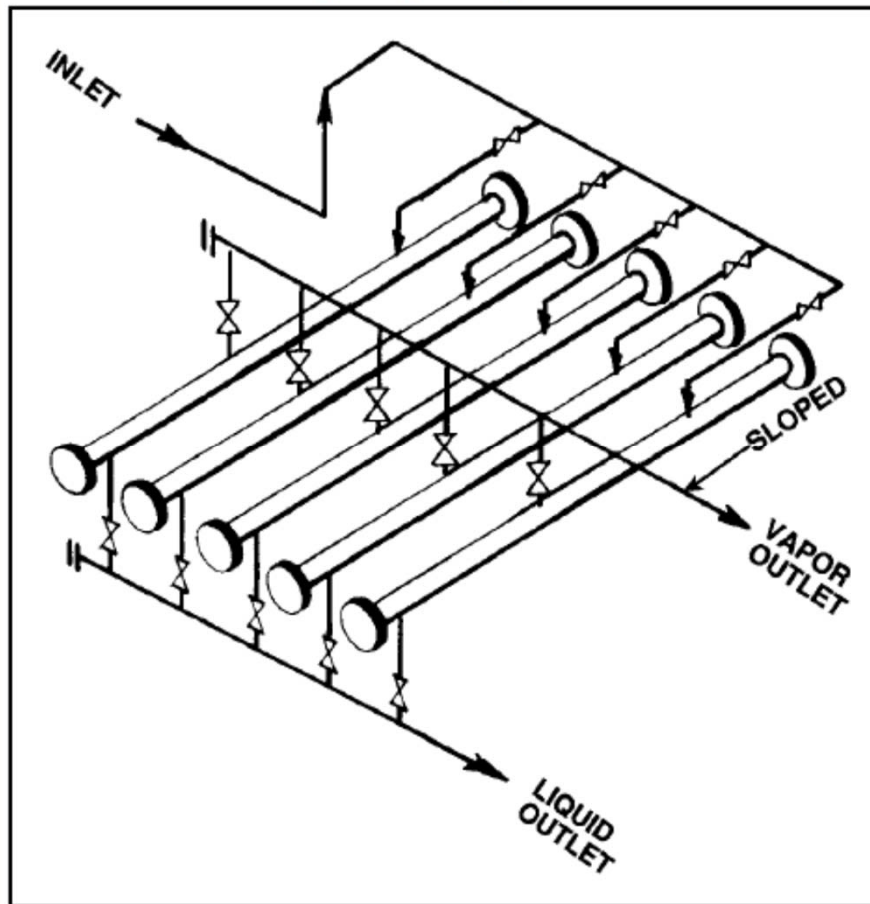
- Serves as gas & liquid separation (de-gas) device
- Surge vessel for fluctuating liquid flow rates
- Prevents overloading
- Dampener for periodic forces



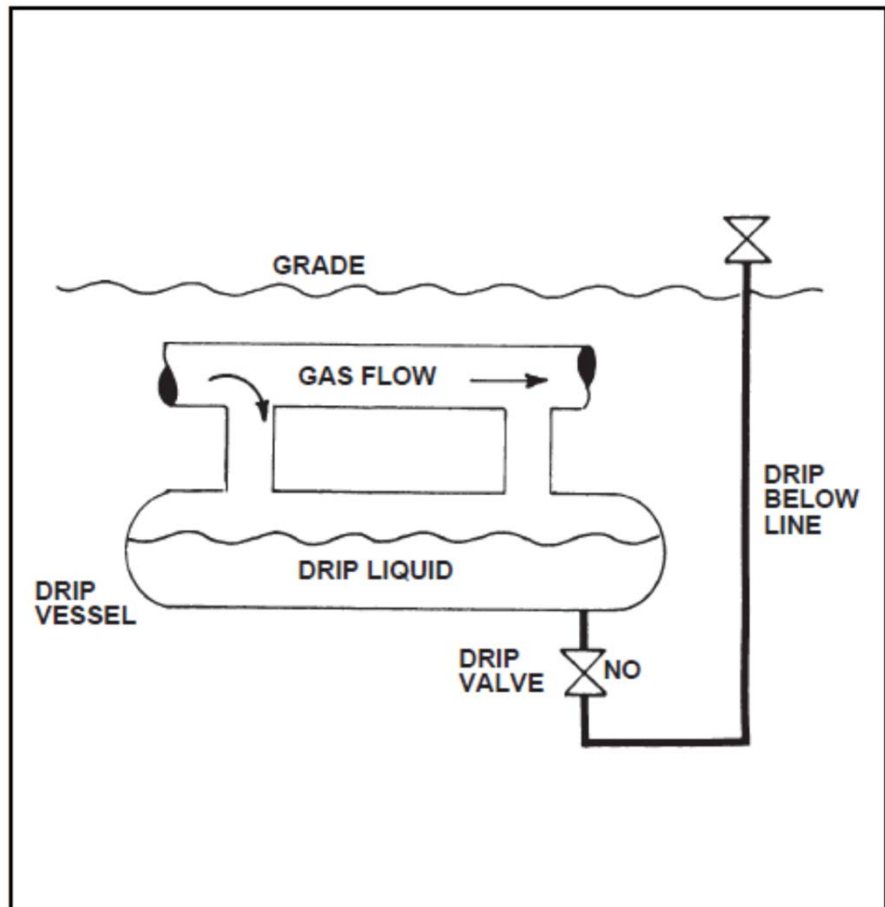
Plug catchers

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Multiple Pipe Slug Catcher



Example Line Drip

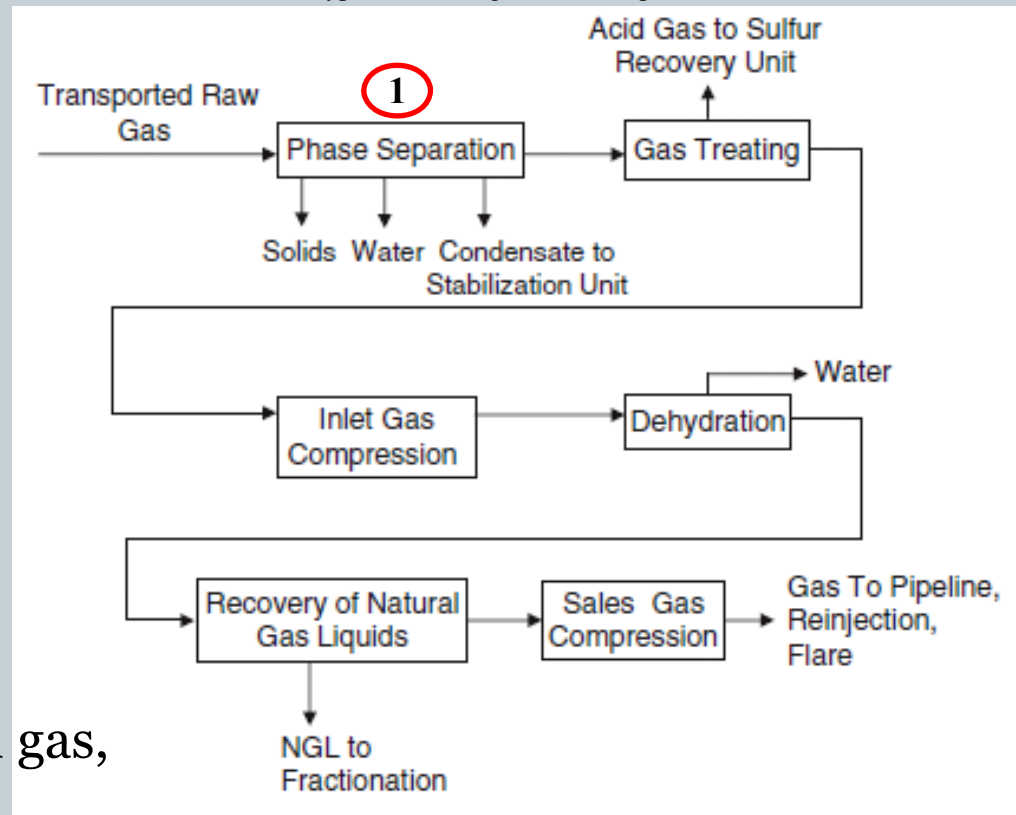


Gas processing

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- Separate NG from:
 - Condensates
 - Non-condensable
 - Acid gases (H_2S , CO_2)
 - H_2O
- Gas treatment customized to gas composition
- Varying loads & compatibility i.e. inlet composition
- Optimization of treatment process necessary
- Depends on volume of natural gas, NG output, plant recoveries
- Depends of remoteness & ambient temperature

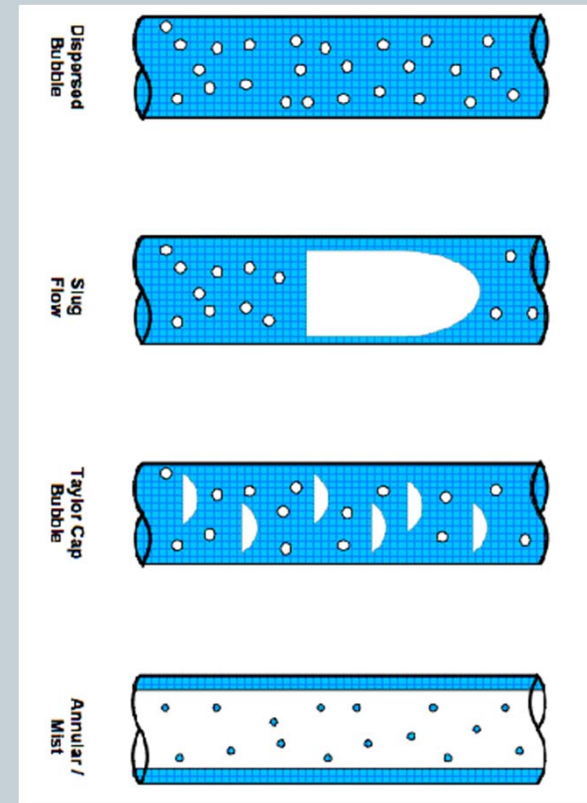
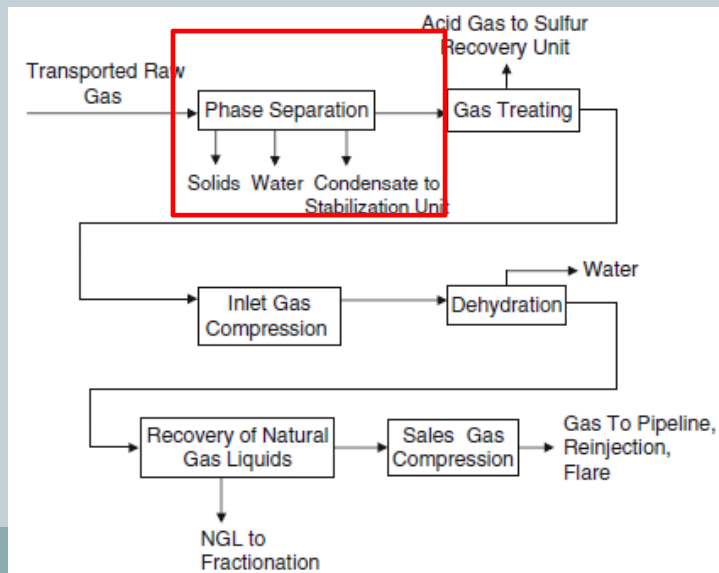
Typical onshore gas treatment process



Phase separation

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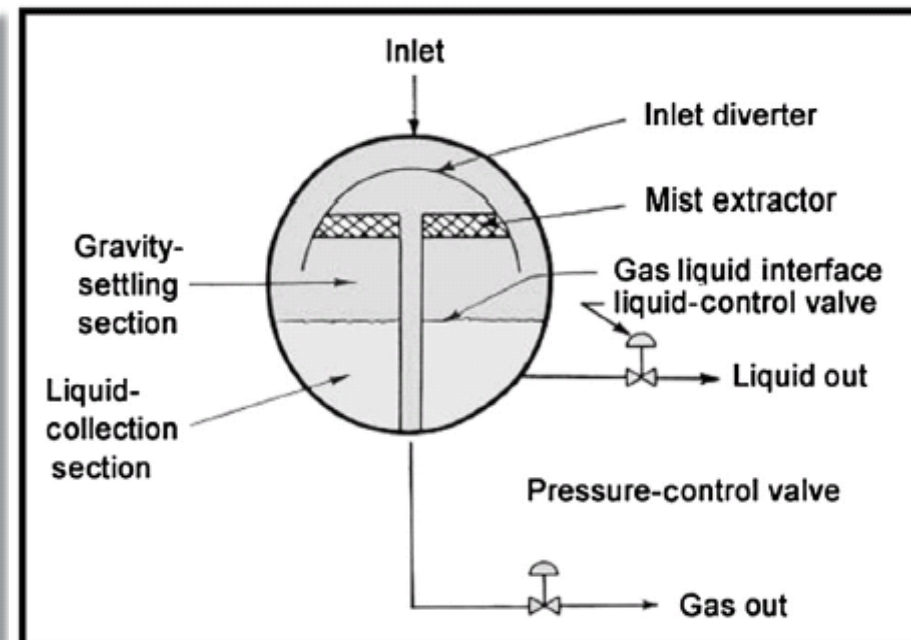
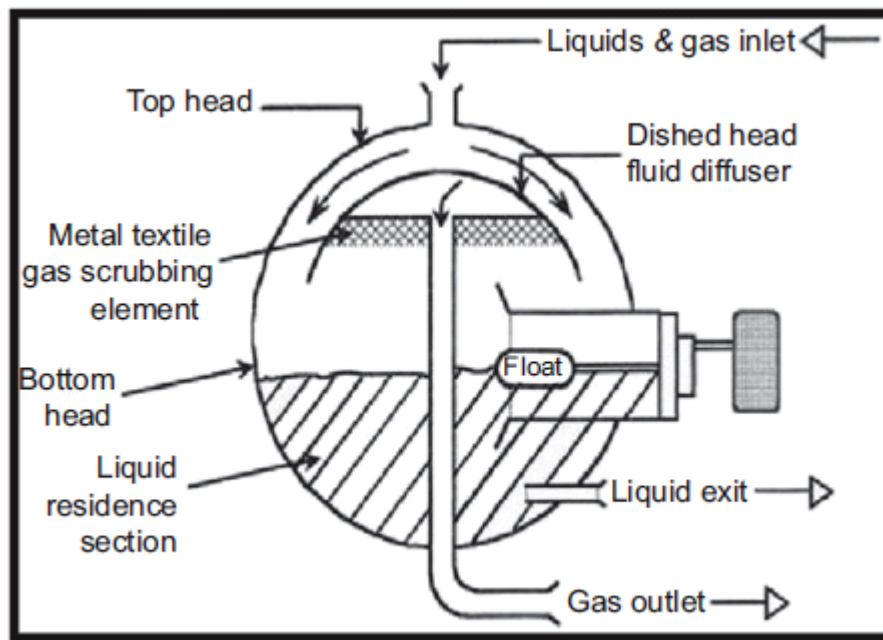
- Performed via a phase separator
- Complicated by two- or three-phase flow (gas-liquid-solid states)
- Liquid slug-flow; eliminated by slug catchers
- Filters remove particulates
- Outputs: hydrocarbon condensate & H₂O/methanol or H₂O/glycol phases



Spherical separators

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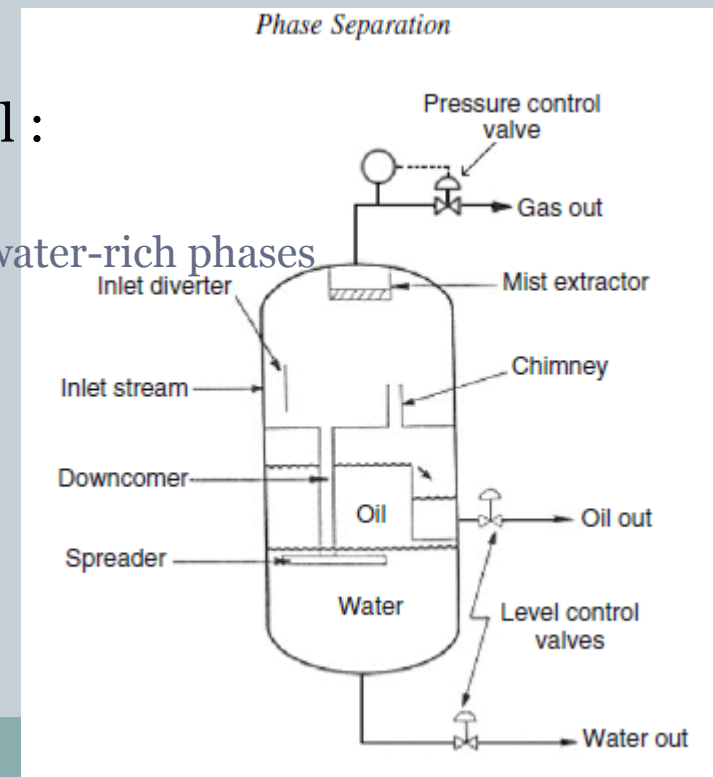
- Preferred for high pressure operation
- Compact size
- Small liquid volumes



Phase separation (2)

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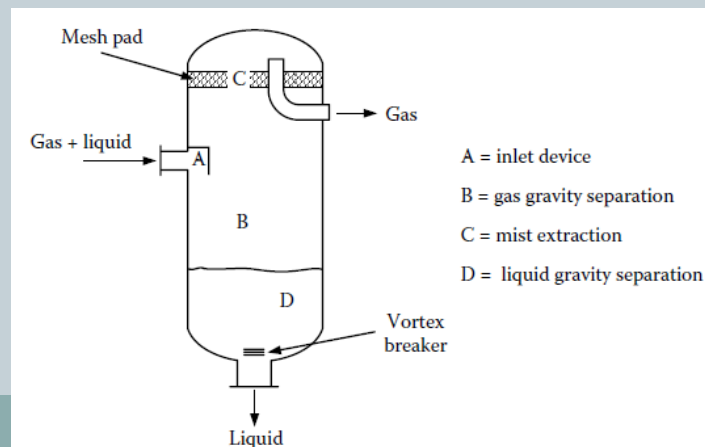
- **Gravity separation** requirements: fluids immiscible & different ρ
- **Momentum change**: used for bulk fluid volumes
- **Mist** cannot be separated by gravity
- Gravity separators are pressure vessels
- Separate mixed stream into gas & liquids
- Gravity separators: a) vertical & b) horizontal :
 - a) 2-phase: separate gas from liquids
 - b) 3- phase: separate in addition to (a) crude oil & water-rich phases
- **Operational pressures**:
 - 1) Low pres.: 10-180psi
 - 2) Medium pres.: 230-700psi
 - 3) High-press.: 975-1,500psi



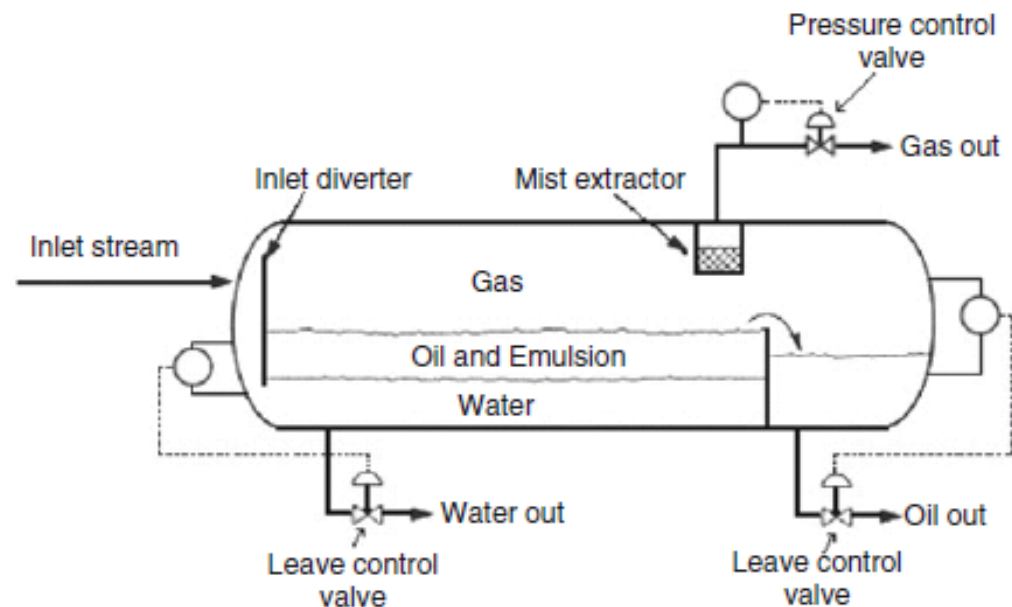
Phase separation (3)

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- The 3 mechanisms for removing gases & liquids or solids from NG:
 - Momentum; by changing the direction of the flow; for bulk separation
 - Gravity settling; Lower velocity causes droplets to settle
 - Coalescing; small become large droplets & are collected by gravity
- Gas/liquid separation
- Gravity settling section
- Mist extractor
- Proper pressure & liquid level control



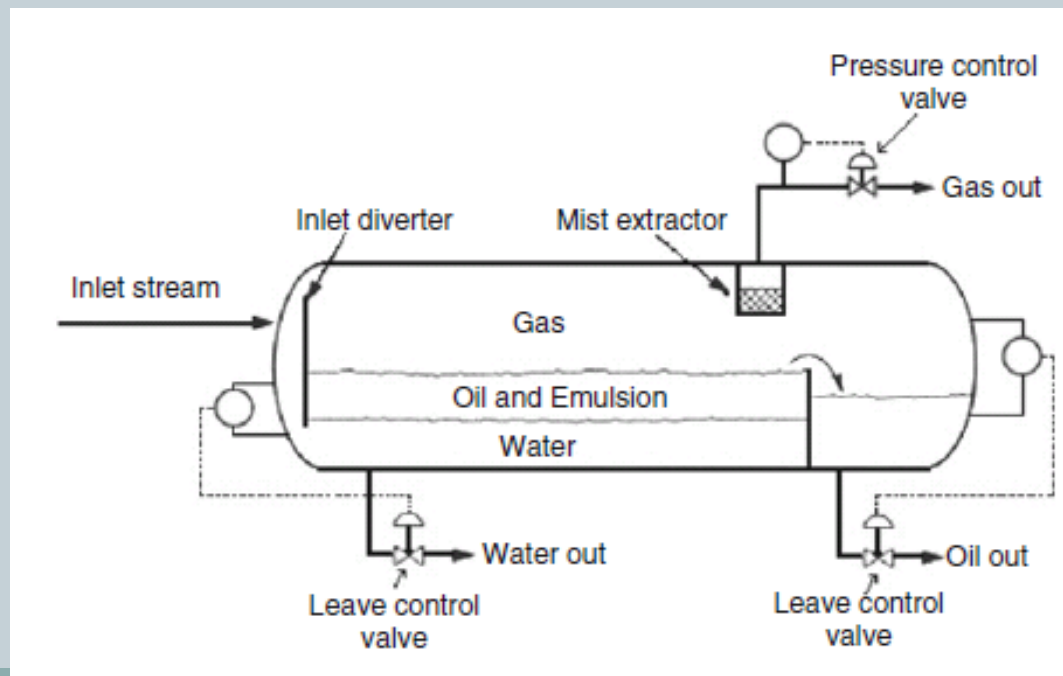
Horizontal 3-phase gravity separator.



Phase separation (4)

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- Gas-liquid separators despite not being super-effective do not clog
- Small d liquid droplets ($d < 3\mu\text{m}$) removed using *filter separators*
- Coalescing filters are used to eliminate small liquid droplets
- Liquid collection also removes solids such as iron sulfide (corrosion)



Liquid-liquid separators

- Configuration depends on # of phases (2 or 3)
- Liquids present 2 challenges:
 - Small differences in ρ make separation difficult
 - Presence of emulsions complicates things

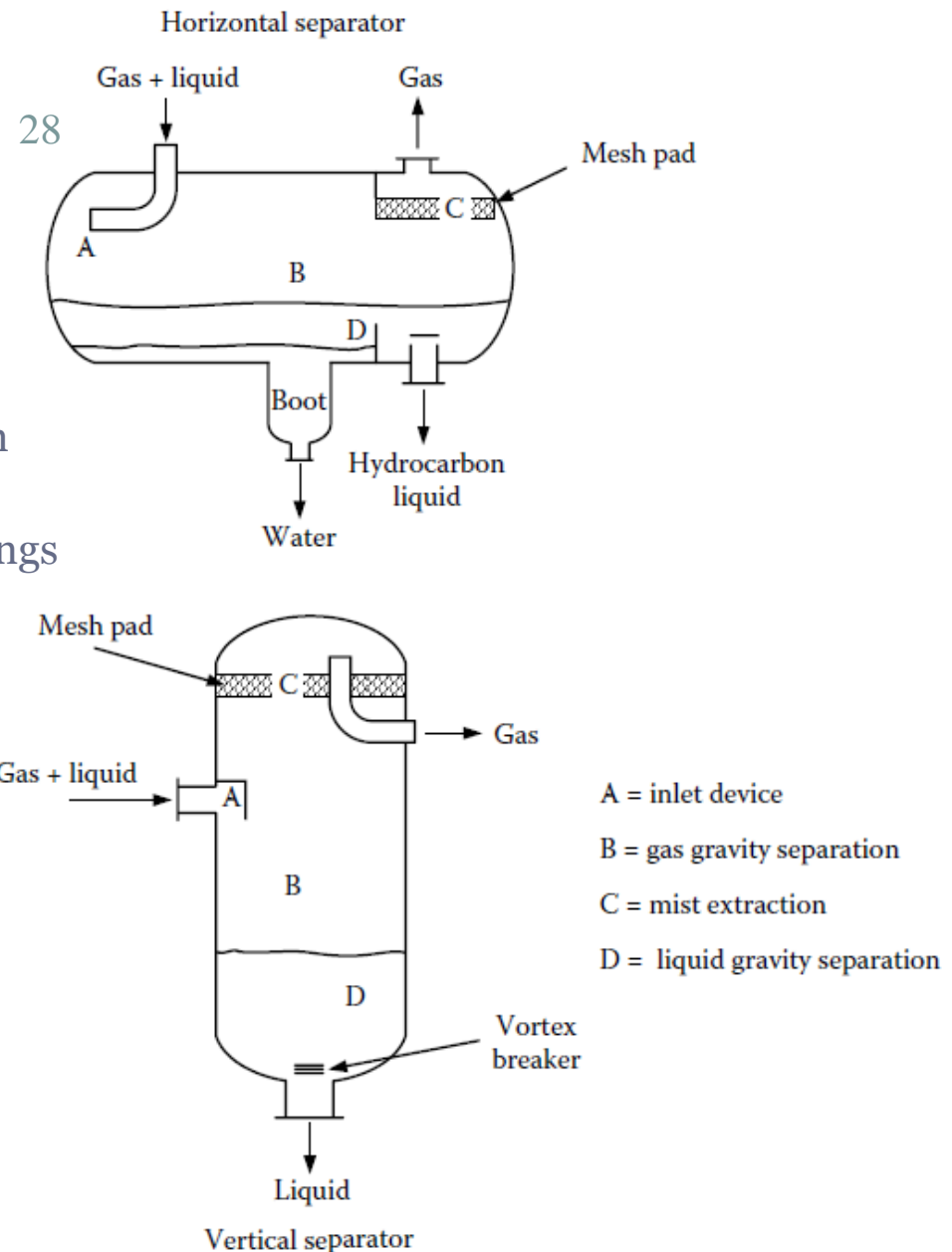
TABLE 3.3
Typical Retention Times for Gas-Liquid Separations

Type of Separation	Retention Time (Minutes)
Natural gas condensate separation	2 – 4
Fractionator feed tank	10 – 15
Reflux accumulator	5 – 10
Fractionation column sump	2 ^a
Amine flash tank	5 – 10
Refrigeration surge tank	5
Refrigeration economizer	3
Heat medium oil surge tank	5 – 10 ^b

^a If the fractionator column sump is feeding a downstream fractionator column, it should be sized as a feed tank (McCartney, 2005).

^b This vessel must have adequate space to allow for expansion of the heat medium from ambient to operating temperature (McCartney, 2005).

Source: Engineering Data Book (2004b).



Gas dehydration

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- Export gas must meet min. water content: 3-4 lb/MMscf
- Water hazards:
 - Condense in submarine pipeline low spots;
 - Form gas hydrates;
 - Combine with acid gases to foster corrosion;
 - Slug flow formation promotes erosion.
- H₂O often removed via glycol dehydration:
 - Triethylene Glycol (TEG)
- Or desiccant or absorbent like silica or alumina gel

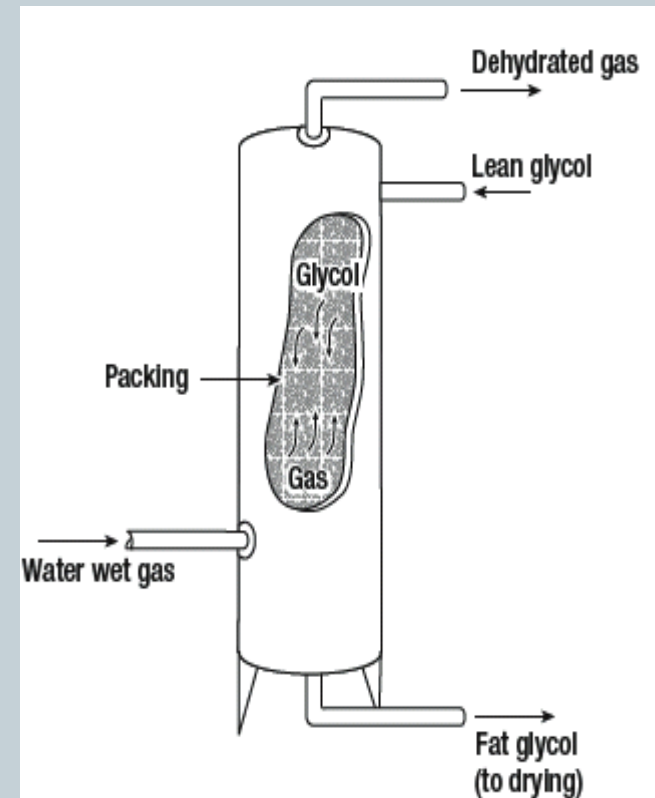
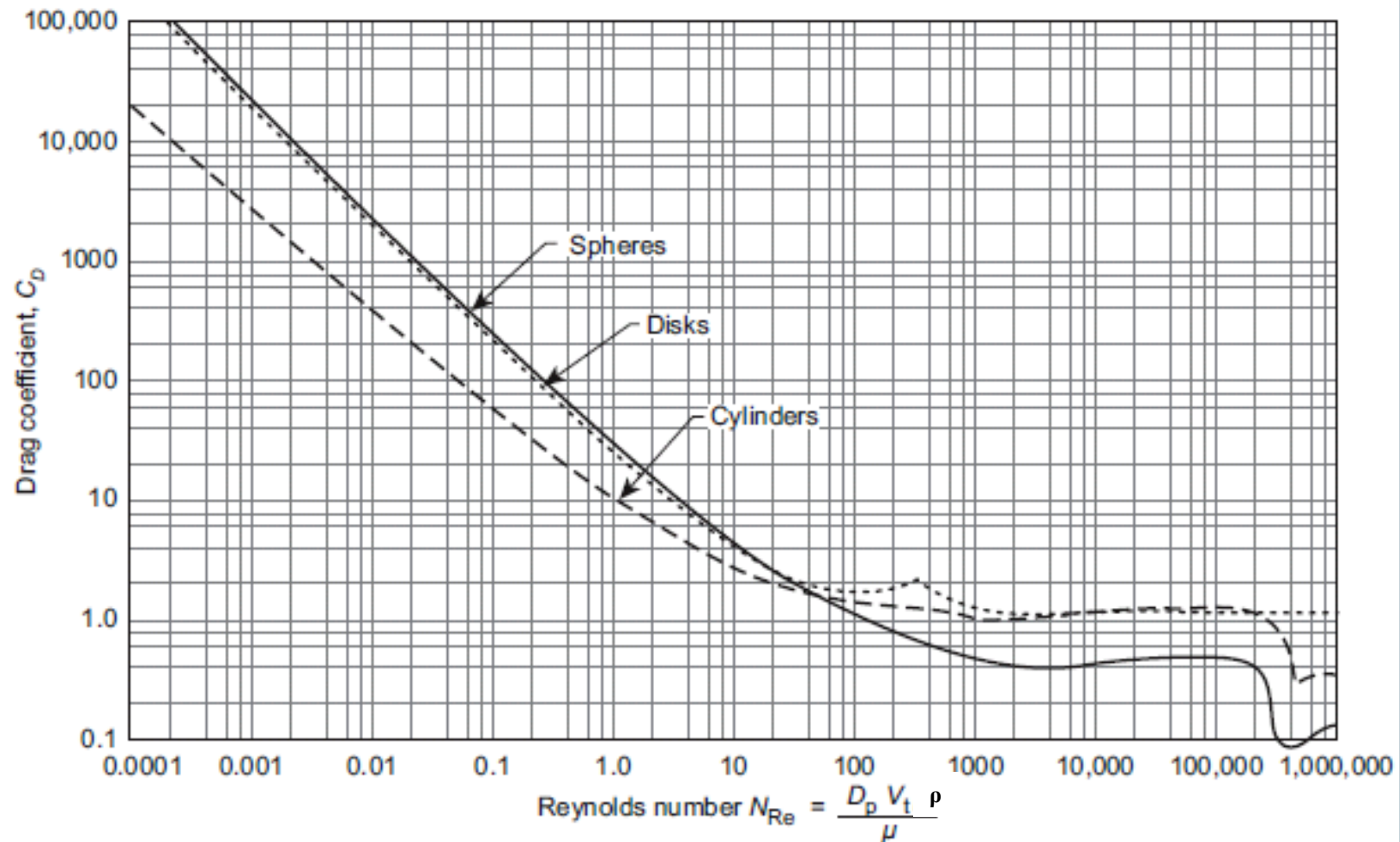


Fig. 1: Drag coefficient vs Re # on spherical bodies










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Theory & example

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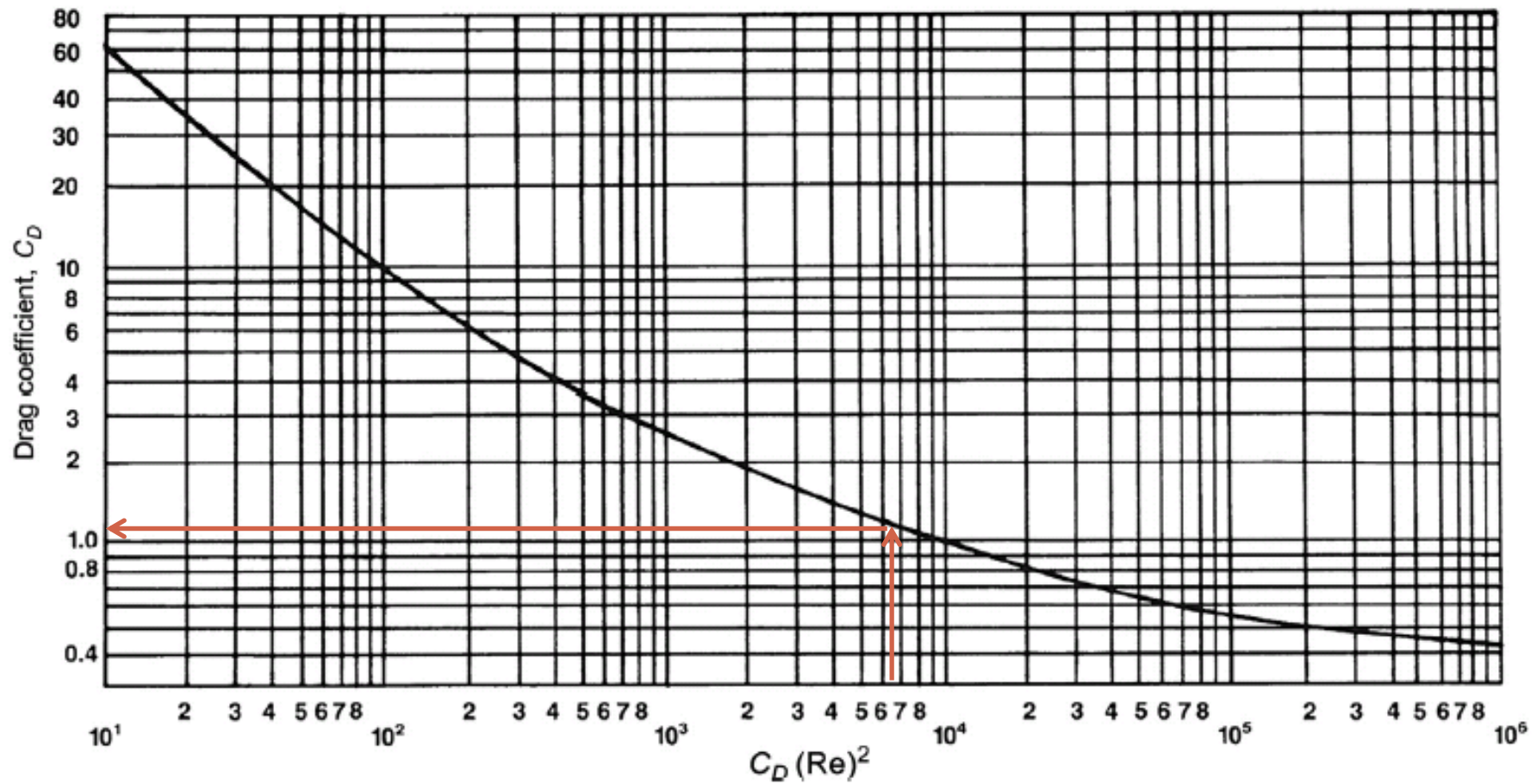
- Theory #1: Gas (vapour)-Liquid separation
- Example #1

Shape		Drag Coefficient
Sphere	→ 	0.47
Half-sphere	→ 	0.42
Cone	→ 	0.50
Cube	→ 	1.05
Angled Cube	→ 	0.80
Long Cylinder	→ 	0.82
Short Cylinder	→ 	1.15
Streamlined Body	→ 	0.04
Streamlined Half-body	→ 	0.09

Measured Drag Coefficients

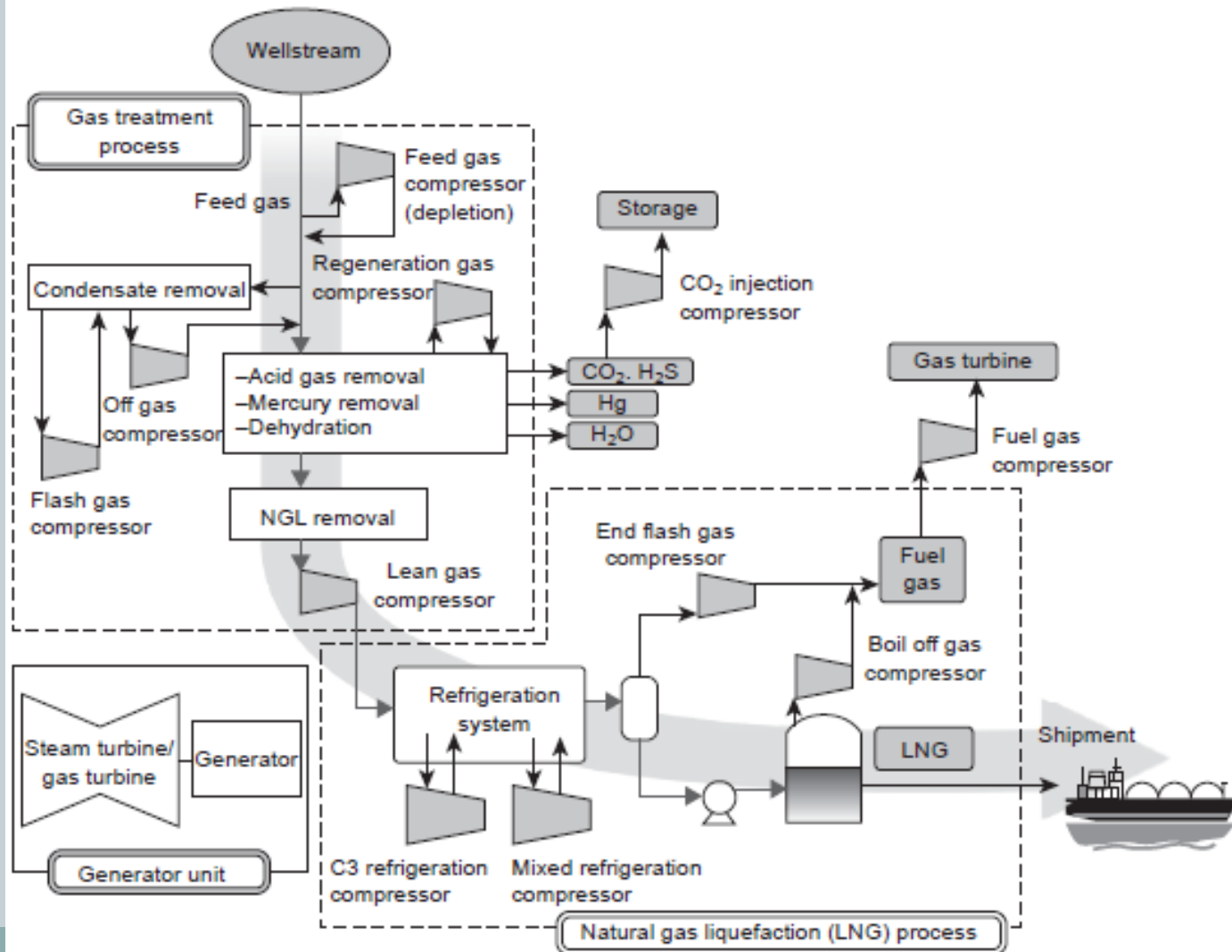
Fig. 2: Drag coefficient for rigid spheres

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LNG block diagram

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Next...

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- Phase separation
- Acid gas treatment
- Natural gas dehydration
- Natural gas liquid recovery

Thanks for your attention!