TEKNOLOGI PEMROSESAN GAS (TKK 564)

GAS PROCESSING TECHNOLOGY (TKK 564)

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Instructor's Background

- BEng. (1995): Universitas Diponegoro
- Meng. (2000): Institut Teknologi Bandung
- PhD. (2006): Universiti Teknologi Malaysia

- Specialization:
  - Catalyst Design for Energy Conversion
  - Process Design for Energy Conversion
  - Combustion Engineering
  - Computational Fluid Dynamic (CFD)

Course Syllabus: (Part 1)

1. Definitions of Natural Gas, Gas Reservoir, Gas Drilling, and Gas production (*Pengertian gas alam, gas reservoir, gas drilling, dan produksi gas*)
2. Overview of Gas Plant Processing (*Overview Sistem Pemrosesan Gas*)
3. Gas Field Operations and Inlet Receiving (*Operasi Lapangan Gas dan Penerimaan Inlet*)
4. Gas Compression System (*Sistem Kompresi Gas*)
5. Gas Treating (*Pengolahan Gas*)
6. Gas Dehydration (*Dehidrasi Gas*)
7. First Assignment
8. *Ujian Tengah Semester*

Course Syllabus: (Part 2)

1. Hydrocarbon Recovery (*Pengambilan Kembali Hidrokarbon*)
2. Nitrogen Rejection and Trace Component Removal (*Penghilangan Nitrogen dan Komponen lainnya*)
3. Natural Gas Liquid Processing and Sulfur Recovery (*Pemrosesan Cairan Gas Alam dan Penghilangan Sulfur*)
4. Gas Transportation and Storage (*Transportasi dan Penyimpanan Gas*)
5. Liquified Natural Gas #1 (*Gas Alam Cair*)
6. Liquified Natural Gas #2 (*Gas Alam Cair*)
7. Second Assignment
8. *Ujian Akhir Semester*

LITERATURES

1. A. J. Kidnay, W.R. Parrish, (2006), ***Fundamentals of Natural Gas Processsing***, Taylor & Francis Group, Boca Raton

2. H.K. Abdel-Aal, M. Aggour, and M.A. Fahim, (2003). ***Petroleum and Gas Field Processing***. Marcel Dekker, Inc., New York.

Section 1

Definitions of Natural Gas, Gas Reservoir, Gas Drilling, and Gas production (*Pengertian gas alam, gas reservoir, gas drilling, dan produksi gas*)

Week #1

Definitions of Natural Gas, Gas Reservoir, Gas Drilling, and Gas Production

- **What is Natural Gas?**
  - The gas obtained from natural underground reservoirs either as free gas or gas associated with crude oil
  - Contains large amounts of methane (CH_4) along with decreasing amounts of other hydrocarbon
  - Impurities such as H_2S, N_2, and CO_2 are often found with the gas
  - generally comes saturated with water vapor.

Why are Oil and Gas so Useful?

- **Oil is liquid**. Meaning that oil may be transported and delivered through pipe
- The primary use of **natural gas is as a fuel**, it is also a source of hydrocarbons for petrochemical feedstocks and a major source of elemental sulfur
- Natural gas presents many **environmental advantages** over petroleum and coal
- **Carbon dioxide**, a greenhouse gas linked to global warming, is produced from oil and coal at a rate of about 1.4 to 1.75 times higher than from natural gas

Pollutants per Billion Btu of Energy

TABLE 1.1
Pounds of Air Pollutants Produced per Billion Btu of Energy

Pollutant	Natural Gas[a]	Oil[b]	Coal[c]
Carbon dioxide	117,000	164,000	208,000
Carbon monoxide	40	33	208
Nitrogen oxides	92	448	457
Sulfur dioxide	0.6	1,122	2,591
Particulates	7.0	84	2,744
Formaldehyde	0.750	0.220	0.221
Mercury	0.000	0.007	0.016

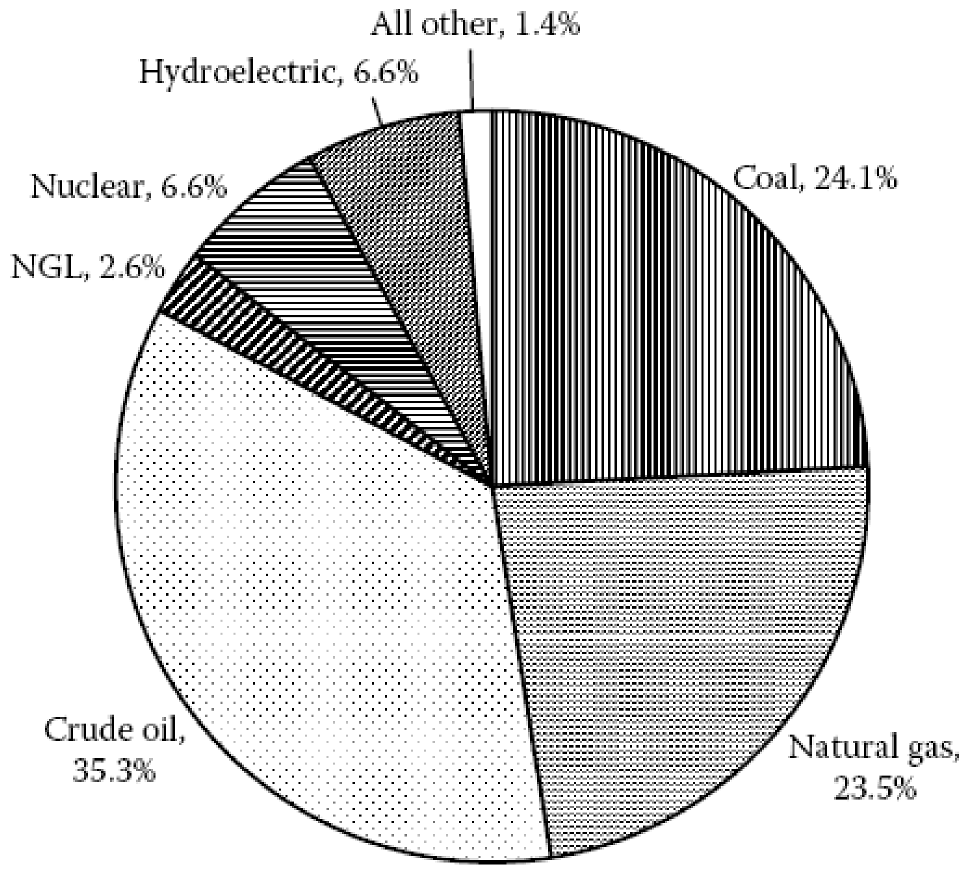
[a] Natural gas burned in uncontrolled residential gas burners.

[b] Oil is # 6 fuel oil at 6.287 million Btu per barrel and 1.03% sulfur with no postcombustion removal of pollutants.

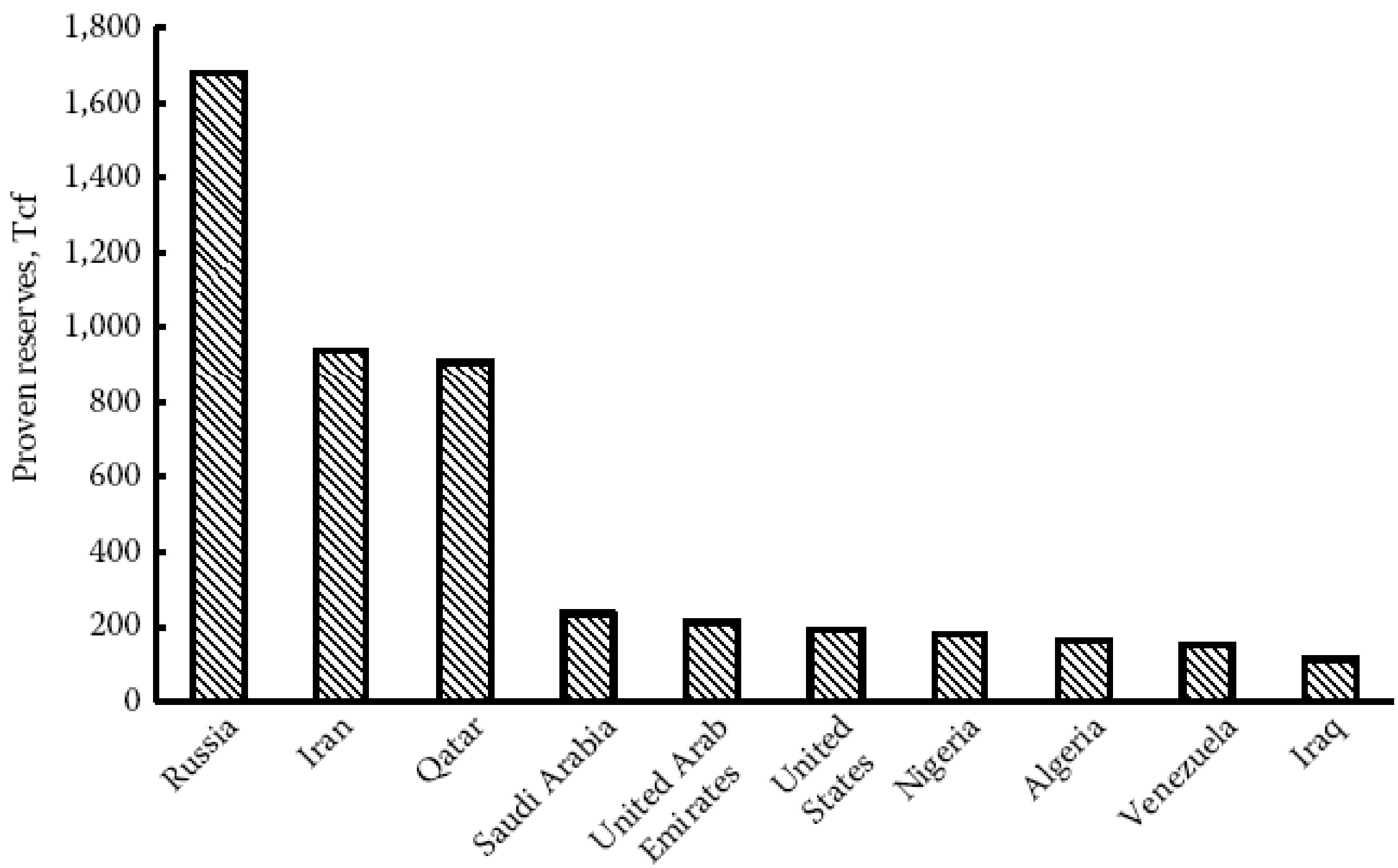
[c] Bituminous coal at 12,027 Btu per pound and 1.64% sulfur with no postcombustion removal of pollutants.

Source: Energy Information Administration (1998).

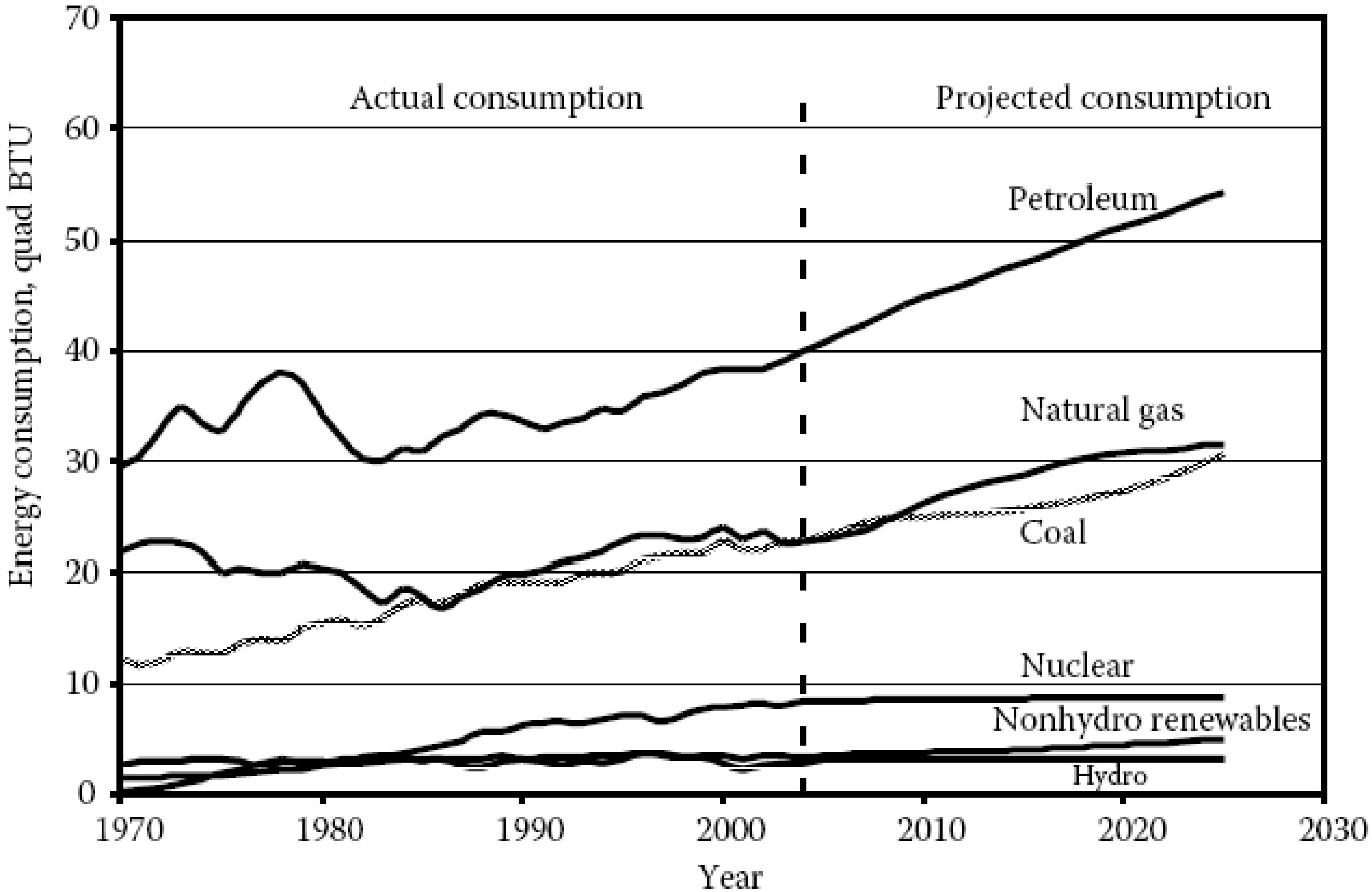
Primary Sources of Energy in the World in 2003



Major proven natural gas reserves by country



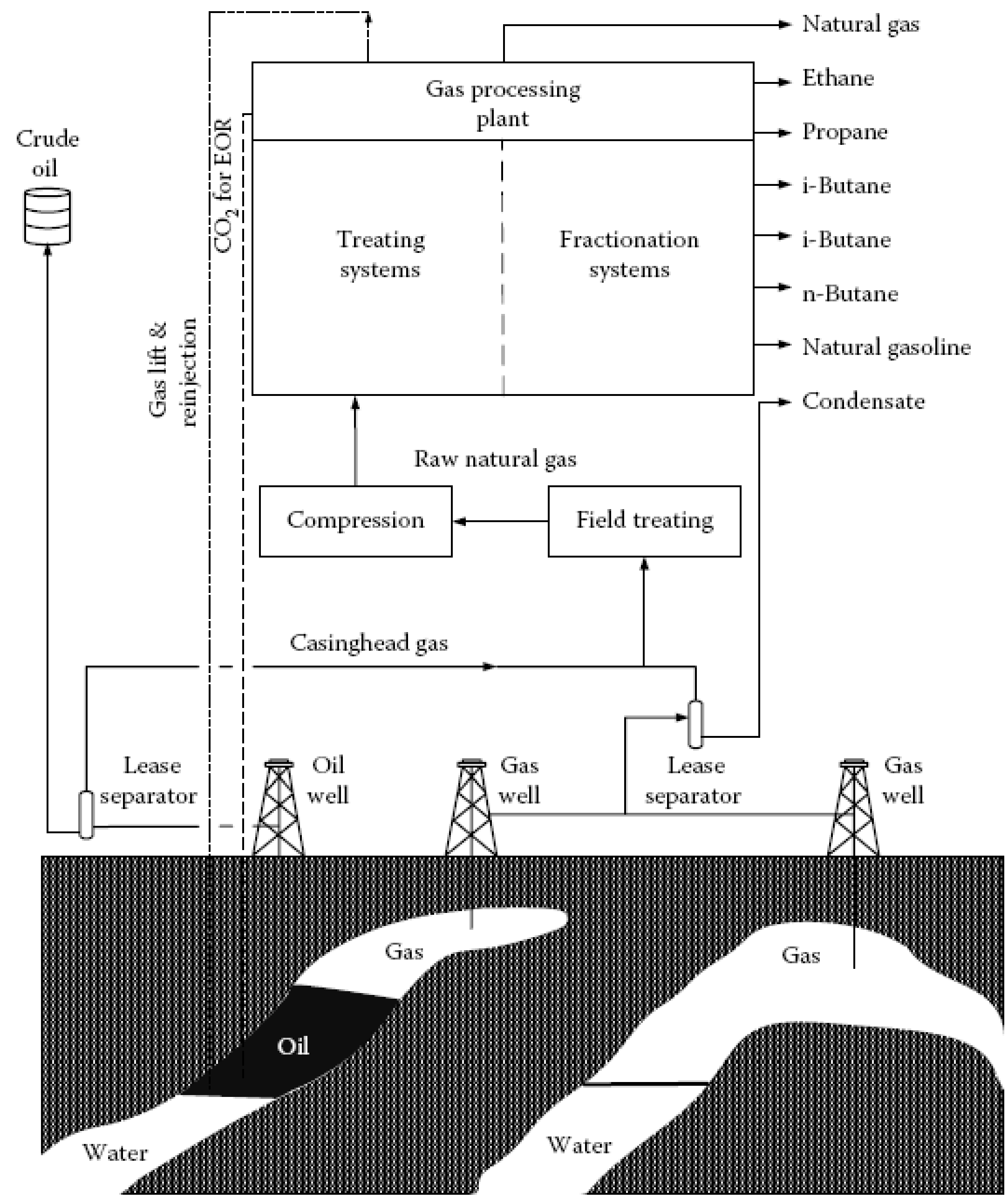
United States energy consumption by fuel



Source of Natural Gas (Gas Reservoirs)

- Conventional natural gas generally occurs in **deep reservoirs**
- either **associated** with crude oil (associated gas) or in reservoirs that contain little or no crude oil (**non associated** gas)
- Associated gas is produced with the oil and separated at the **casinghead** or **wellhead**.
- Gas produced in this fashion is also referred to as **casinghead gas**, **oilwell gas**, or **dissolved gas**.
- Nonassociated gas is sometimes referred to as gas-well gas or dry gas. However, this dry gas can still contain significant amounts of NGL components.
- Roughly 93% of the gas produced in the United States is nonassociated

Schematic overview of natural gas industry



Natural Gas Compositions

- **Water** is almost always present at wellhead conditions but is typically not shown in the analysis
- Unless the gas has been **dehydrated** before it reaches the gas processing plant,
- the common practice is to assume the entering gas is **saturated with water** at the plant inlet conditions.

Typical gas Compositions

	Canada (Alberta)	Western Colorado	Southwest Kansas	Bach Ho Field[a] Vietnam	Miskar Field Tunisia	Rio Arriba County, New Mexico	Cliffside Field, Amarillo, Texas
Helium	0.0	0.0	0.45	0.00	0.00	0.0	1.8
Nitrogen	3.2	26.10	14.65	0.21	16.903	0.68	25.6
Carbon dioxide	1.7	42.66	0.0	0.06	13.588	0.82	0.0
Hydrogen sulfide	3.3	0.0	0.0	0.00	0.092	0.0	0.0
Methane	77.1	29.98	72.89	70.85	63.901	96.91	65.8
Ethane	6.6	0.55	6.27	13.41	3.349	1.33	3.8
Propane	3.1	0.28	3.74	7.5	0.960	0.19	1.7
Butanes	2.0	0.21	1.38	4.02	0.544	0.05	0.8
Pentanes and heavier	3.0	0.25	0.62	2.64	0.630	0.02	0.5

[a] Tabular mol% data is on a wet basis (1.3 mol% water)

Source: U.S. Bureau of Mines (1972) and Jones et al. (1999).

Typical gas Composition in Indonesia

Component	Terengganu (Malaysia) [1)]	Natuna (Indonesia) [2)]	Terrell County (Texas USA) [3)]	Arun (Indonesia) [4)]
Methane (CH_4)	80.93	28.0[a]	45.7	75
Ethane (C_2H_6)	5.54	-	0.2	5.5
Propane (C_3H_8)	2.96	-	-	3.4[b]
Butane (C_4H_{10})	1.40	-	-	-
>=C_{5+}	-	-	-	0.8
Nitrogen (N_2)	0.10	0.5	0.2	0.3
Carbon dioxide (CO_2)	8.48	71.0	53.9	15
Hidrogen Sulfida (H_2S)	-	0.5	-	0.01

[a] CH_4 + low C_{2+} hydrocarbons
[b] C_3, C_4 hydrocarbons
[1)] Gordon et al. (2001)
[2)] Suhartanto *et al.* (2001)
[3)] Bitter (1997)
[4)] Centi *et al.* (2001)

Processing and Principal Products

- **Two primary uses of natural gas**:
  - As a fuel
  - As a petrochemical feedstock
- **Three reason of natural gas processing**:
  - **Purification**. Removal of materials, valuable or not, that inhibit the use of the gas as an industrial or residential fuel
  - **Separation**. Splitting out of components that have greater value as petrochemical feedstocks, stand alone fuels (e.g., propane), or industrial gases (e.g., ethane, helium)
  - **Liquefaction**. Increase of the energy density of the gas for storage or transportation
- What is different of Purification and Separation?

Generic Raw Gas and Product Slate

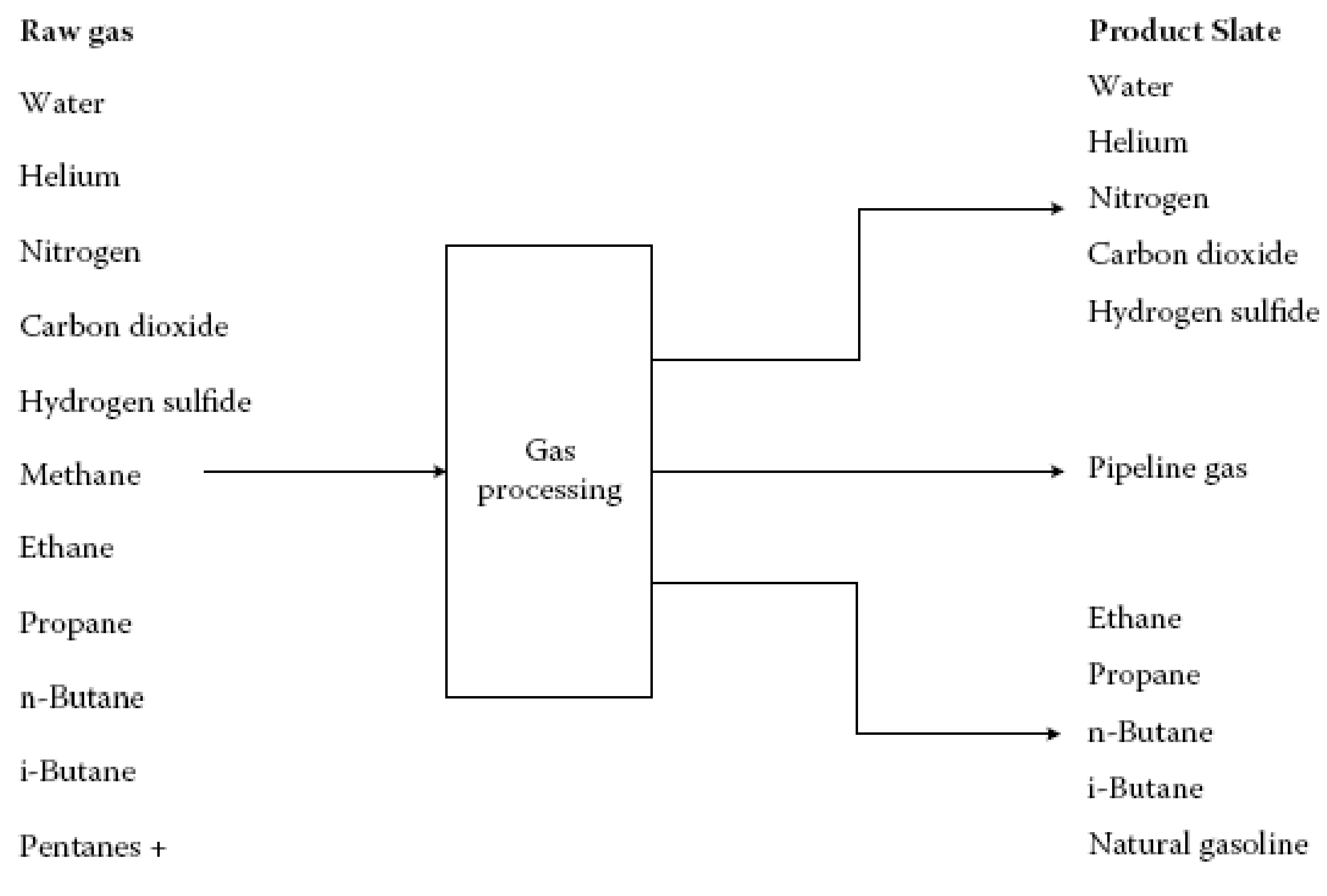


FIGURE 1.6 Generic raw gas and product slate.

Product Specifications

- **Natural Gas**:
  - The composition of natural gas varies considerably from location to location, and
  - as with petroleum products in general, the specifications for salable products from gas processing are generally in terms of both composition and performance criteria
  - For natural gas these criteria include: Wobbe number, heating value, total inerts, water, oxygen, and sulfur content.
  - The first two criteria relate to combustion characteristics.
  - The latter three provide protection from pipeline plugging and corrosion.

Specifications for Pipeline Quality Gas

Major Components	Minimum Mol%	Maximum Mol%
Methane	75	None
Ethane	None	10
Propane	None	5
Butanes	None	2
Pentanes and heavier	None	0.5
Nitrogen and other inerts	None	3
Carbon dioxide	None	2–3
Total diluent gases	None	4–5
	Trace components	
Hydrogen sulfide	0.25–0.3 g/100 scf (6–7 mg/m³)	
Total sulfur	5–20 g/100 scf (115–460 mg/m³)	
Water vapor	4.0–7.0 lb/MM scf (60–110 mg/m³)	
Oxygen	1.0%	
	Other characteristics	
Heating value (gross, saturated)	950–1,150 Btu/scf (35,400–42,800 kJ/m³)	
Liquids	Free of liquid water and hydrocarbons at delivery temperature and pressure	
Solids	Free of particulates in amounts deleterious to transmission and utilization equipment	

Source: Engineering Data Book (2004).

Liquid product Specification

- As with gases, specifications for liquid products are based upon both composition and performance criteria.
- For liquid products, the performance specifications include: Reid vapor pressure, water, oxygen, H_2S, and total sulfur content.
- Safety considerations make vapor pressure especially important for the liquid products because of regulations for shipping and storage containers.

TABLE 1.8
Major Components and Vapor Pressures of Common Liquid Products

Liquid Product	Composition[a]		Vapor Pressure[b] at 100°F, psig, max(at 37.8°C, kPa, max)
High-ethane raw streams	C_1	1–5 wt%	—
	C_2–C_5	balance	
Ethane–propane mixes	C_1	0.6–1 wt%	—
	C_2	22.5–40.5	
	C_3	59.5–77.5	
	C_4+	0.2–4.5	
High-purity ethane	C_1	1.5–2.5 wt%	—
	C_2	90–96	
	C_3	6–5	
	C_4+	0.5–3.0	
Commercial propane	Predominantly C_3 and C_3=		208 (1,434)
Commercial butane	Predominantly C_4 and C_4=		70 (483)
Commercial butane–propane mixes	Predominantly C_4 and C_3		208 (1,434)
Propane HD-5	C_3	> 90 liq vol%	208
	C_3=	< 5	(1,434)
	C_4+	< 2.5	

[a] Throughout the book C_1, C_2 etc, refer to methane, ethane, etc. The "=" denotes an olefin. The term C_4+ denotes propane and heavier compounds.

[b] Vapor pressure as defined by D1267-02 Standard Test Method for Gage Vapor Pressure of Liquefied Petroleum (LP) Gases (LP-Gas Method).

TABLE 1.9

Maximum Levels of Major Contaminants of Common Liquefied Products Concentrations are in ppmw unless specified otherwise.

	H_2S	Total Sulfur[a]	CO_2	O_2	H_2O
High-ethane raw streams	50	200	3,500		No free[b]
Ethane–propane mixes	#1[a]	143	3,000	1,000	No free[b]
High–Purity ethane	10	70	5,000	5	No free[b]
Commercial propane	#1	185	—	—	Pass test[c]
Commercial butane	#1	140	—	—	—
Commercial butane–propane mixes	#1	140	—	—	—
Propane HD-5	#1	123	—	—	Pass test[c]

[a] Concentration acceptable provided the copper strip test, which detects all corrosive compounds, is passed. The #1 represents the passing score on the copper-strip test, D1838-05 Standard Test Method for Copper Strip Corrosion by Liquefied Petroleum (LP) Gases. Eckersley and Kane (2004) discuss sample handling problems related to the test.

[b] Limit is no free water present in product.

[c] Moisture level must be sufficiently low to pass the D2713-91(2001) Standard Test Method for Dryness of Propane (valve freeze method), which corresponds to roughly 10 ppmw.

Source: Engineering Data Book (2004).

Combustion Characteristics

- **Natural gas is as a fuel** ➔ pipeline gas is normally bought on the basis of its **heating value**
- **Determination of the heating value** of a fuel involves two arbitrary but conventional standard states for the water formed in the reaction:
  - All the water formed is a liquid (gross heating value, frequently called higher heating value [HHV])
  - All the water formed is a gas (net heating value, frequently called lower heating value [LHV])
- The heating value is normally calculated at 60°F and 1 atm (15.6°C and 1.01 atm), standard conditions for the gas industry, and, thus at equilibrium, the water would be partially liquid and partially vapor.

Heating Value ….

- Heating values for custody transfer are determined either by direct measurement, in which bomb calorimetry is used, or by computation of the value on the basis of gas analysis.
- The formulas for the calculation of **ideal gas gross heating values**, on a volumetric basis are (Gas Processors Association, 1996):

$$H_v^{id}(dry) = \sum_{i=1}^{n} x_i H_{vi}^{id}$$

$$H_v^{id}(sat) = (1 - x_w) \sum_{i=1}^{n} x_i H_{vi}^{id}$$

- The equations assume that the gas analysis is given on a dry basis, that water is x_W when the gas is saturated at the specified conditions.

- The mole fraction can be calculated from:

$$x_w = \frac{P_w^{Sat}}{P_b}$$

- The vapor pressure of water at 60°F (15.6°C), the common base temperature, is 0.25636 psia (1.76754 kPa).
- The most commonly used base pressures, P_b, and the values of $(1 - x_W)$ are listed below.

P_b(psia)	$1 - x_W$
14.50	0.9823
14.65	0.9825
14.696	0.9826
14.73	0.9826
15.025	0.9829

Contoh Perhitungan HV

- **Example 1.2** Calculate the heating value of the Alberta gas given in Table 1.4. Assume the heating value for the butanes to be that of isobutene, and for the C5+ fraction, use pure hexane.
- Table 1.10 shows the calculations with heating values obtained from Appendix B. This mixture has a gross heating value of 1,202.2 Btu/scf (44,886 kJ/Sm3). Note that credit is not given for the heating value associated with H2S in contractual situations. It is unlikely that a gas stream with 3.3% H2S would be burned.

$$H_v^{id}(dry) = \sum_{i=1}^{n} x_i H_{vi}^{id}$$

$$H_v^{id}(sat) = (1 - x_w) \sum_{i=1}^{n} x_i H_{vi}^{id}$$

TABLE 1.10
Calculations with Heating Values Obtained from Appendix B

	Mole %	H_{vi}^{id} Btu/scf	$x_i H_{vi}^{id}$
Helium	0	0.0	0
Nitrogen	3.2	0.0	0
Carbon dioxide	1.7	0.0	0
Hydrogen sulfide	3.3	637.1	21.0
Methane	77.1	1010.0	778.7
Ethane	6.6	1769.7	116.8
Propane	3.1	2516.2	78.0
Butanes as isobutane	2.0	3252.0	65.0
Pentanes and heavier as hexane	3.0	4756.0	142.7
Totals	100.0		1202.2