Workshop on Future Large CO2 Compression Systems

Gaithersburg, MD
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Sponsored by EPRI / DOE / NIST

Large CO2 Sources & Capture Systems

Gas Processing Solutions LLC

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Workshop on Future Large CO2 Compression Systems
Large CO2 Source & Capture Systems
Agenda

- **CO2 Pipelines in USA for EOR**
- **3 Large CO2 Source/Capture/Compression Plants**
  - **ExxonMobil LaBarge-Shute Creek, WY *Natural Gas* Plant**
  - **CDT Inc / Lubbock, TX CO2-from-*CFPP-Flue Gas***
  - **Coffeyville Resources (KS) *Gasification*-based Fertilizer Plant**

CO2 Pipelines in USA for EOR (Enhanced Oil Recovery)

Major CO2 Pipelines in USA for EOR
Source: Melzer Consulting / 6th Annual Conference CC&S Conf-Pittsburgh / 10May2007

The Major* North American CO_2 Pipelines
Ref: Melzer Consulting '07

PIPELINE	Owner/Operator	Length (mi)	Length (km)	Diameter - in	Estimated Max Flow Capacity (mmcfpd)	Estimated Max Flow Capacity (million tons/yr	Location	PL Type
Adair	Apache	15	24	4	47	1.0	TX	II
Anadarko Powder River Basin CO2 PL	Anadarko	125	201	16	204	4.3	WY	II
Anton Irish	Oxy	40	64	8	77	1.6	TX	II
Bravo	Oxy Permian	218	351	20	331	7.0	NM,TX	II
Canyon Reef Carriers	Kinder Morgan	139	224	16	204	4.3	TX	II
Centerline	Kinder Morgan	113	182	16	204	4.3	TX	II
Central Basin	Kinder Morgan	143	230	16	204	4.3	TX	II
Chaparral	Chaparral Energy	23	37	6	60	1.3	OK	II
Choctaw	Denbury Resources	183	294	20	331	7.0	MS,LA	II
Comanche Creek (2007 reactivated)	PetroSource	100	161	6	60	1.3	TX	II
Cordona Lake	XTO	7	11	6	60	1.3	TX	II
Cortez	Kinder Morgan	502	808	30	1117	23.6	TX	II
Dollarhide	Chevron	23	37	8	77	1.6	TX	II
El Mar	Kinder Morgan	35	56	6	60	1.3	TX	II
Enid-Purdy (Central Oklahoma)	Anadarko	117	188	8	77	1.6	OK	II
Este I - to Welch, Tx	ExxonMobil, et al	40	64	14	160	3.4	TX	II
Este II - to Salt Crk Field	ExxonMobil	45	72	12	125	2.6	TX	II
Ford	Kinder Morgan	12	19	4	47	1.0	TX	II
Joffre Viking	Penn West Petroleum Ltd	8	13	6	60	1.3	Alberta	II
Llano	Trinity CO2	53	85	12-8	77	1.6	NM	II
Pecos County	Kinder Morgan	26	42	8	77	1.6	TX	II
Raven Ridge	Chevron	160	257	16	204	4.3	WY/Co	II
Sheep Mtn	British Petroleum	408	656	24	538	11.4	TX	II
Shute Creek	ExxonMobil	30	48	30	1117	23.6	WY	II
Slaughter	Oxy Permian	35	56	12	125	2.6	TX	II
Transpetco	TransPetco	110	177	8	77	1.6	TX,OK	II
W. Texas	Trinity CO2	60	97	12-8	77	1.6	TX,NM	II
Wellman	PetroSource	25	40	6	60	1.3	TX	II
White Frost	Core Energy, LLC	11	18	6	60	1.3	MI	II
Wyoming CO2	ExxonMobil	112	180	20-16	204	4.3	WY	II
Dakota Gasification (Souris Valley)	Dakota Gasification	204	328	16	204	4.3	ND/Sask	III
Pikes Peak	PetroSource	40	64	8	77	1.6	TX	III
Val Verde	PetroSource	83	134	10	98	2.1	TX	III
	Totals:	3,245	5,221					

* Tabulation does not include many shorter high pressure trunk lines to indiividual fields

600 MW- IGCC @ 90% CO2 Capture = 4.3 MM T/Y CO2

CO2 Pipelines in USA for EOR
Source: Polytec (Norway) / 08January2008
State-of-Art Overview / CO2 Pipeline Transport

Table 5-1: CO_2 composition transported in existing pipelines (given as vol% if not stated otherwise)

	Canyon Reef Carriers (4)	Central Basin Pipeline (5)	Sheep Mountain (6) (7; 8)	Bravo Dome Source (9)	Cortez Pipeline (10)	Weyburn (11)	Jackson Dome, NEJD
CO_2	85-98	98.5	96.8-97.4	99.7	95	96	98.7-99.4
CH_4	2-15 C6H14	0.2	1.7	-	1-5	0.7	Trace
N_2	<0.5	1.3	0.6-0.9	0.3	4	<300 ppm	Trace
H_2S	<200 ppm	< 20 ppm (spec)	--	-	0.002	0.9	Trace
C2+		-	0.3-0.6	-	Trace	2.3	-
CO	-	-	-	-	-	0.1	-
O_2	-	<10 ppm wt (spec)	-	-	-	<50 ppm wt	-
NOx	-	-	-	-	-		-
SOx	-	-	-	-	-		-
H_2	-	-	-	-	-	Trace?	-
Ar	-	-	-	-	-		-
H_2O	50 ppm wt	257 ppm wt	129 ppm wt	-	257 ppm wt	20 ppm vol	-

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Large CO2 Source & Capture Systems
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- 3 Large CO2 Source/Capture/Compression Plants
  - ExxonMobil LaBarge-Shute Creek, WY *Natural Gas* Plant
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  - Coffeyville Resources (KS) *Gasification*-based Fertilizer Plant

ExxonMobil Shute Creek NG Plant
CO2 Capture & Compression for EOR
Shute Creek, WY NG Treating Facility

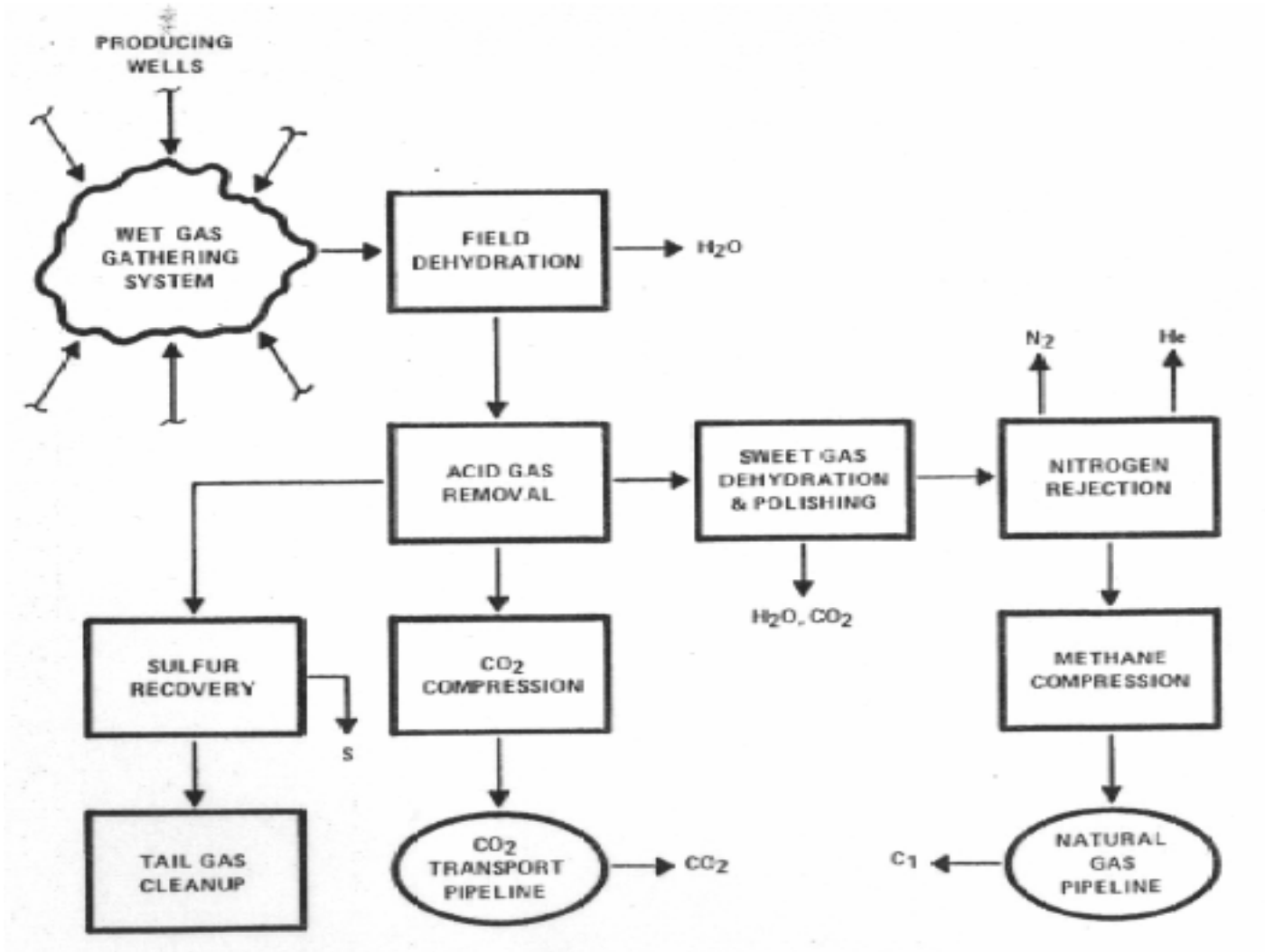
ExxonMobil -- Shute Creek, WY Gas Treating Facility

Source: EXOM – Midland CO2 Conference / 2005

ExxonMobil Shute Creek Natural Gas (NG) Plant
CO_2 Capture & Compression for EOR
Gas Processing Overview

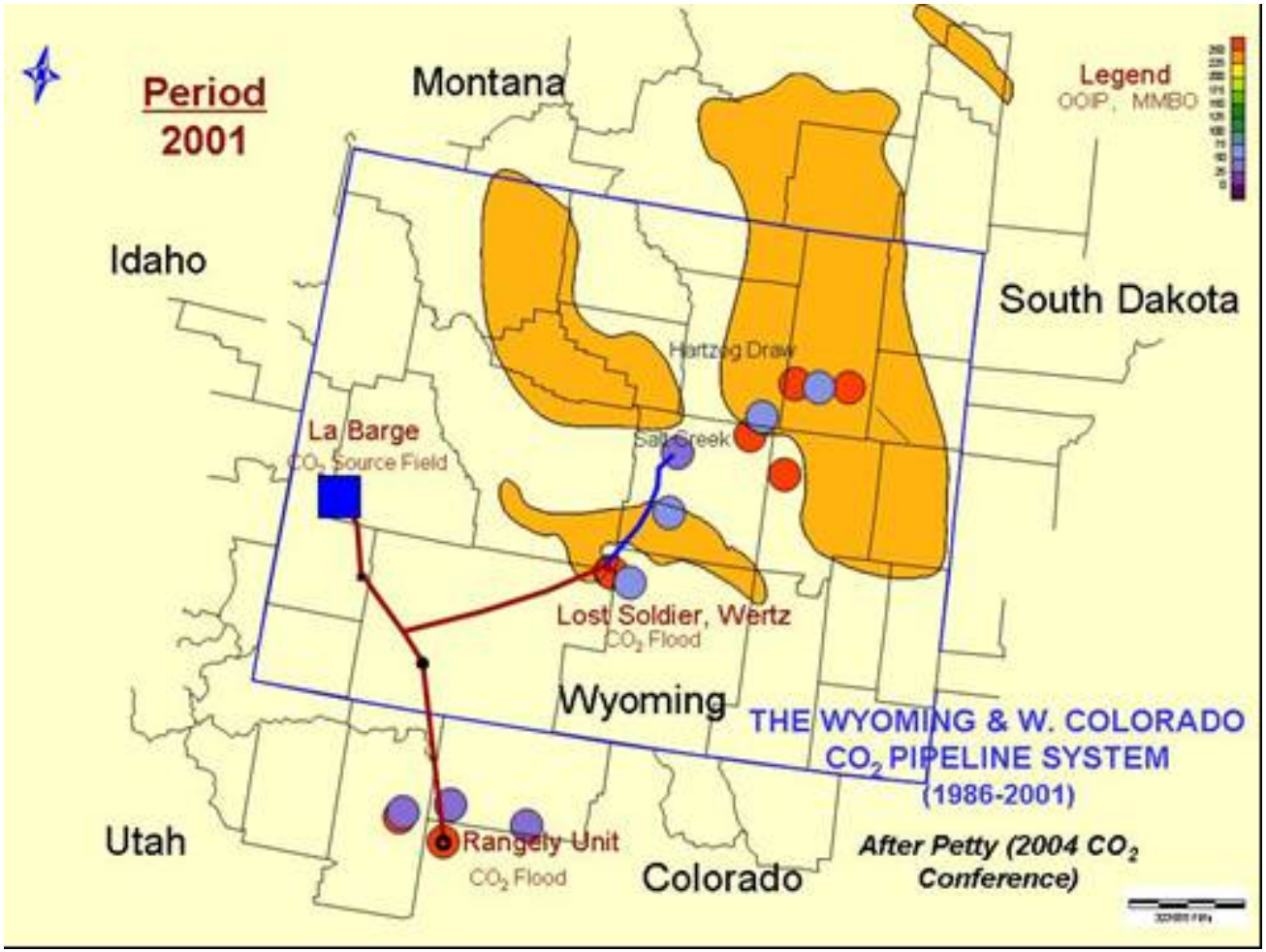
- LaBarge NG Field & Shute Creek Gas Treating Facility
- Commissioned in 1986 in SW-Wyoming
  - Initial Capacity of 480 MMSCFD of NG
  - Expanded in 2005 to 700 MMSCFD
- NG Feed: 5%V H_2S – 66%V CO_2 – 21%V CH_4 – 0.6%V He – 7%V N_2
- Marketable Products: CH_4, CO_2, He, & Sulfur
- Selexol Process (2-trains) used for Acid Gas Removal:
  - H_2S-Rich Acid Gas (65 MMSCFD H_2S & 25 MMSCFD CO_2)
    - Originally sent to Claus-SRU for Elemental Sulfur
    - Now Compressed, Liquified, and Pumped into Formation
    - Largest-known Facility for AG-Injection in Operation
  - CO_2 for Compression to Pipeline for EOR Fields

ExxonMobil LaBarge / Shute Creek Facilities
Overall Block Flow Diagram



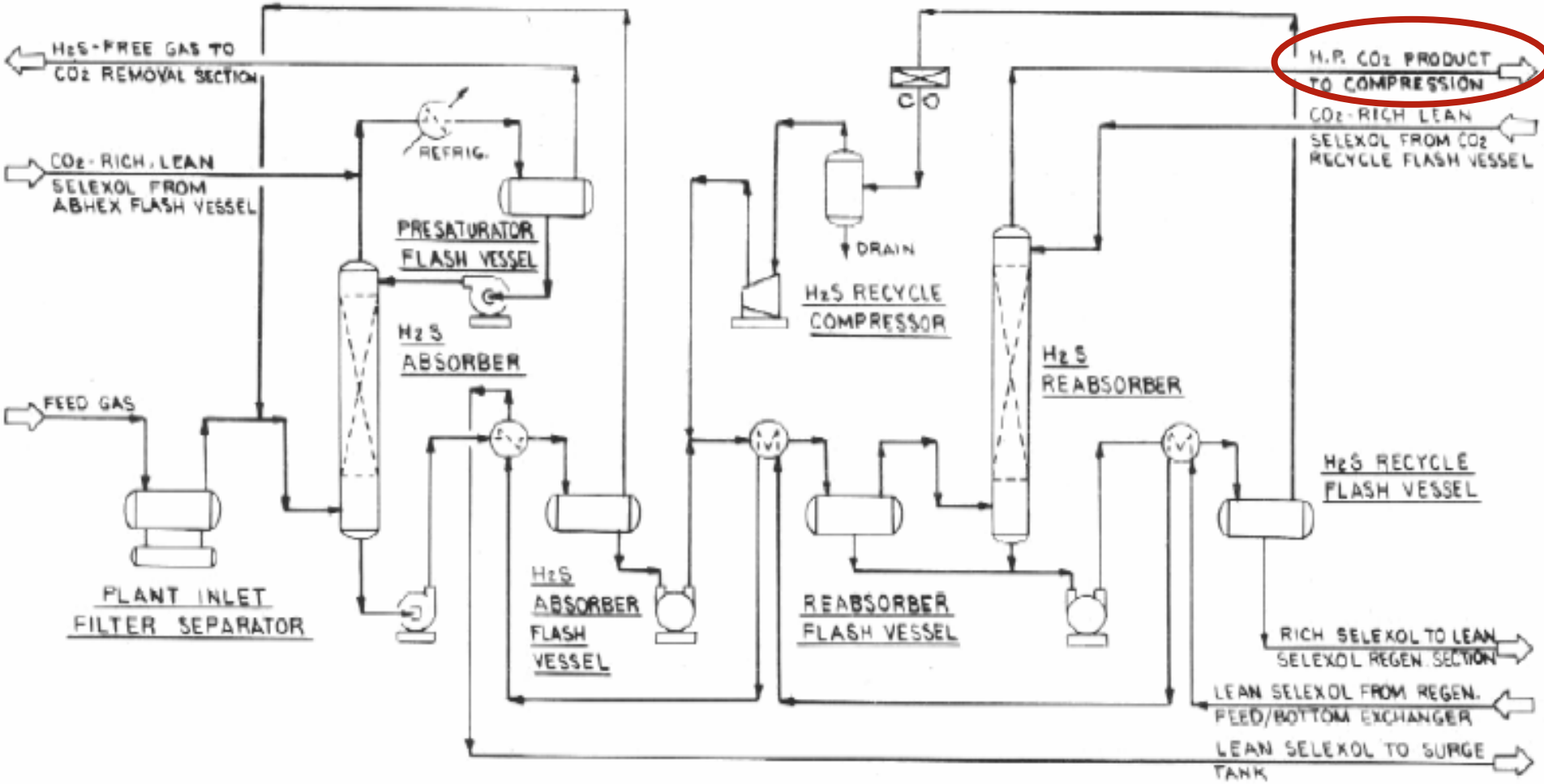
Source: EXOM / RM-GPA Mtg / Sept 1985

ExxonMobil LaBarge/Shute Creek Facilities
CO2 Capture & Compression for EOR
CO2 Source and CO2 Flood Locations



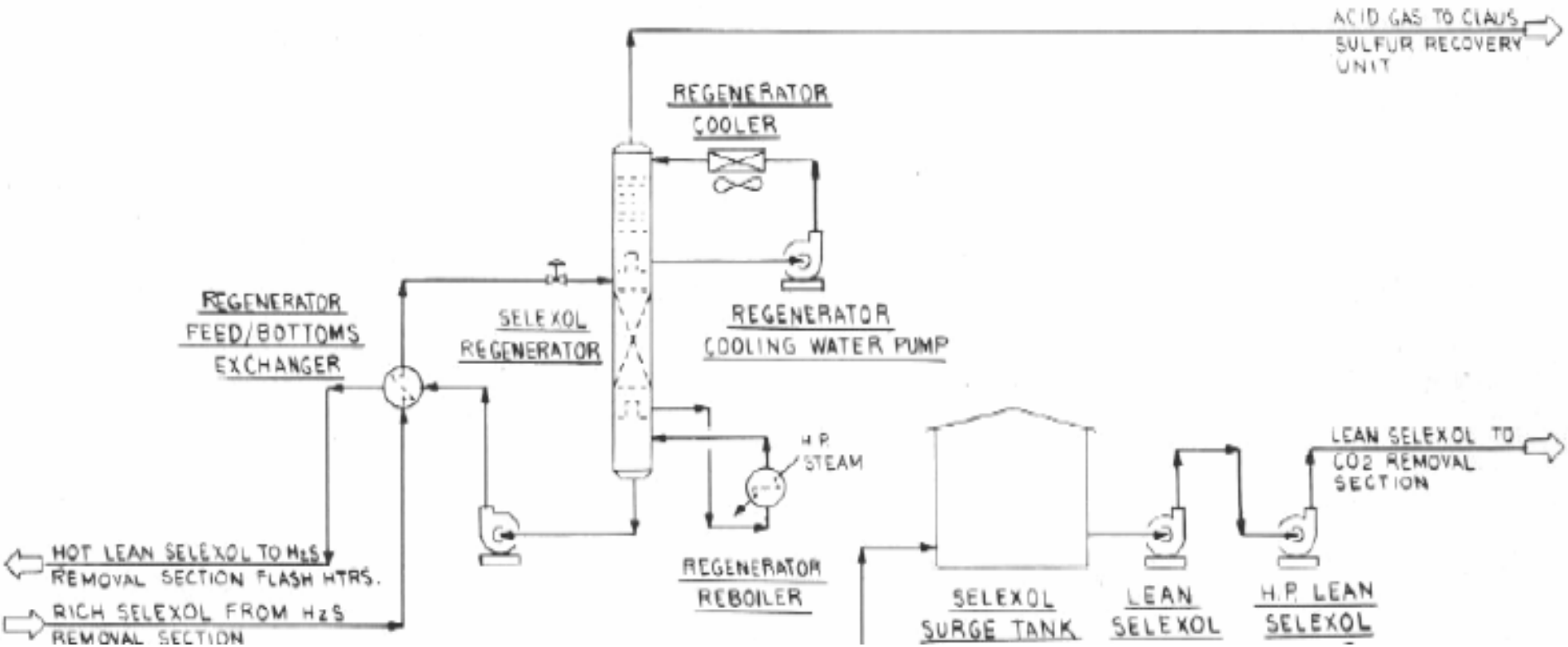
Source: Melzer Consulting / 6th Annual Conference on CC&S Conf-Pittsburgh / 10May2007

ExxonMobil Shute Creek NG Plant
Selexol Unit Process Flow Diagram
H2S Removal Section



Source: Stearns Rogers / AIChE Mtg / August 1983

ExxonMobil Shute Creek NG Plant
Selexol Unit Process Flow Diagram
H2S Removal Section



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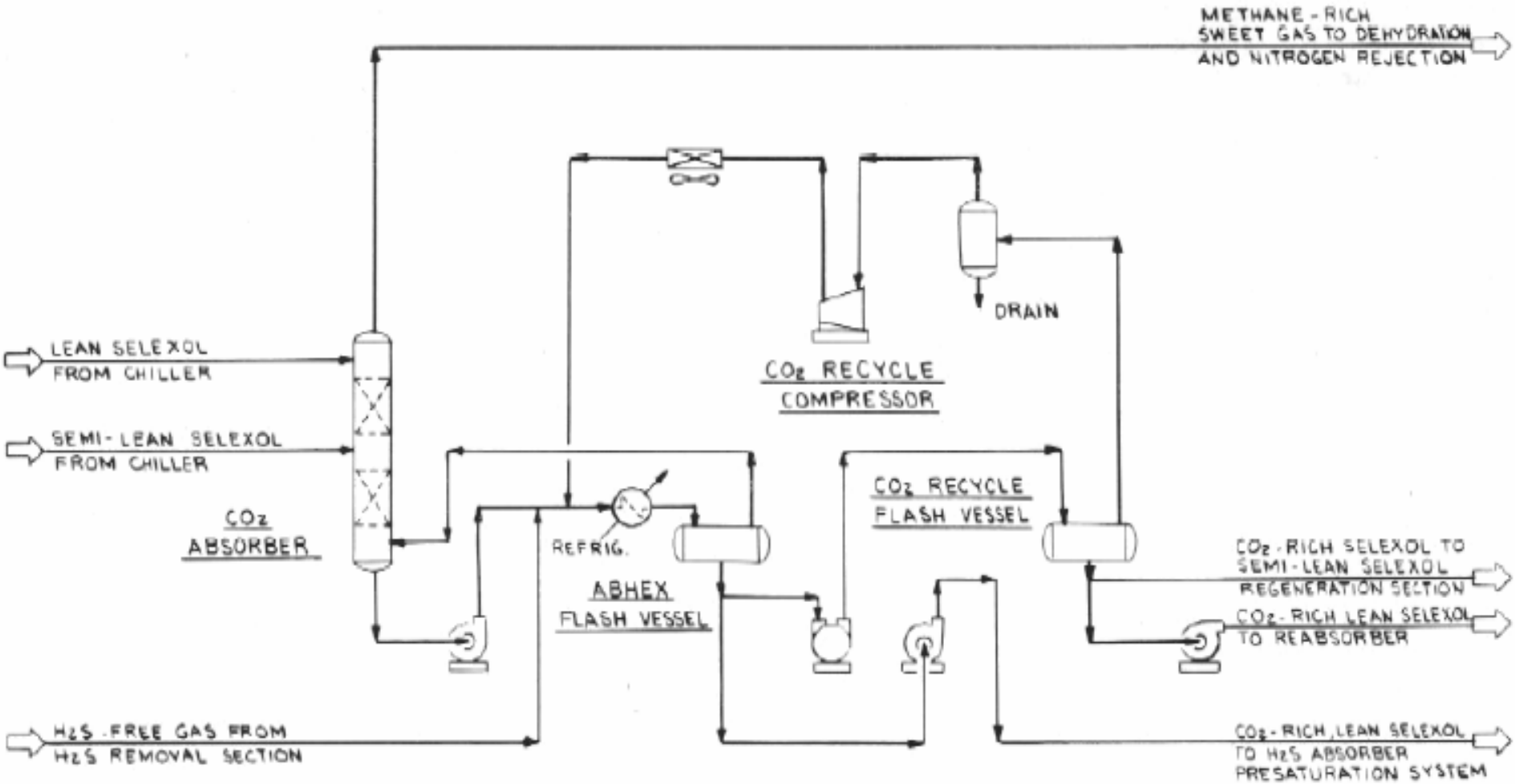
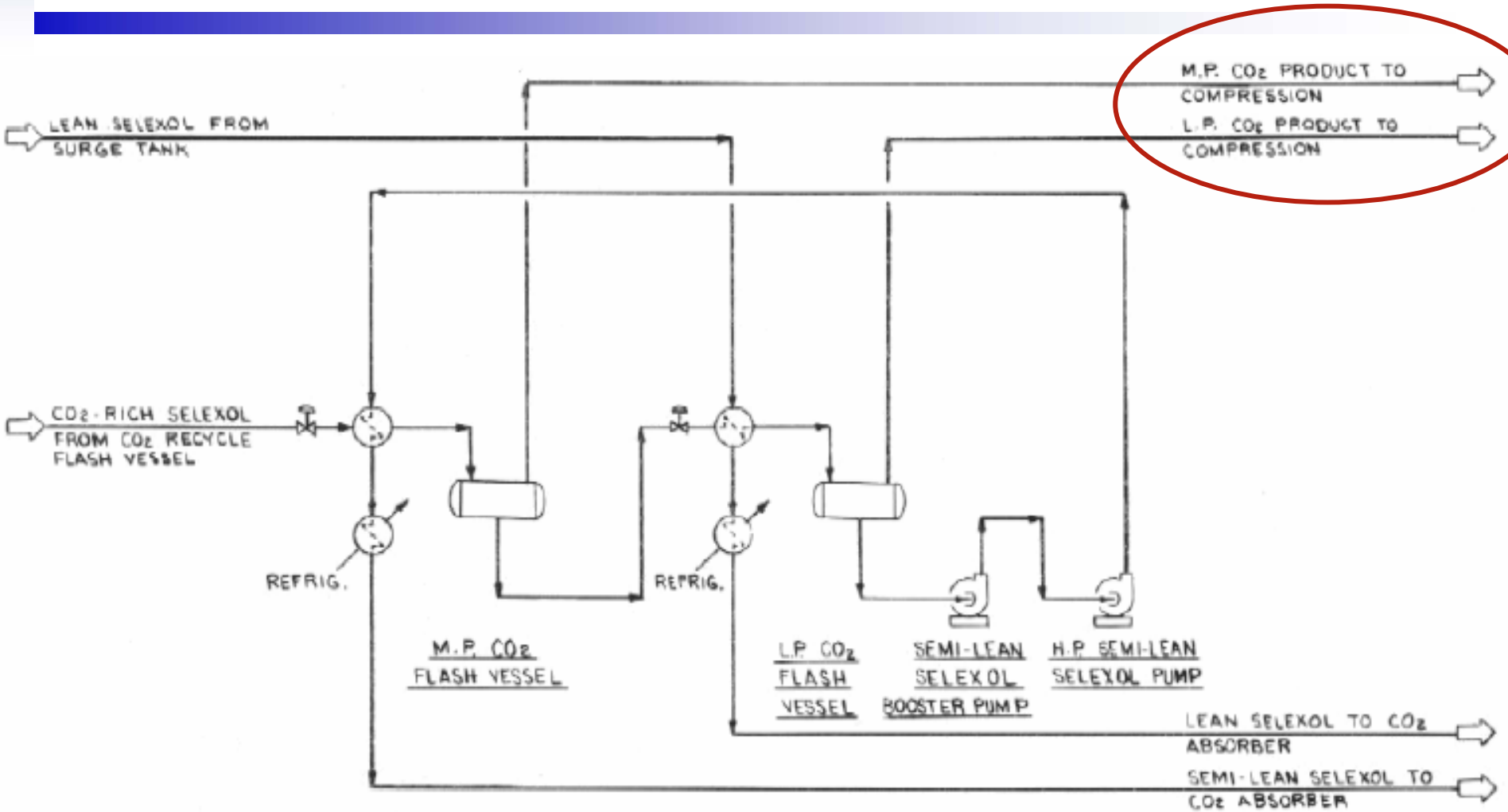
ExxonMobil Shute Creek NG Plant
Selexol Unit Process Flow Diagram
CO2 Removal Section



Source: Stearns Rogers / AIChE Mtg / August 1983

ExxonMobil Shute Creek NG Plant
Selexol Unit Process Flow Diagram
CO2 Regeneration Section



Source: Stearns Rogers / AIChE Mtg / August 1983

ExxonMobil Shute Creek NG Plant
CO_2 Capture & Compression for EOR
Existing CO_2 Compression & Pipeline Steps

- Selexol Unit Supplies CO_2 at 200 & 60 (& LP?) psia
- 270 MMSCFD (15673 STD) CO_2 Compressed to 1750 psig
  - 49,000 HP in 4 Compressor Trains
  - Supplied by Dresser-Rand
- CO_2 is transported via 2 pipelines
  - 24-inch diameter / 48-mile long line
  - 20-inch diameter / 112-mile line

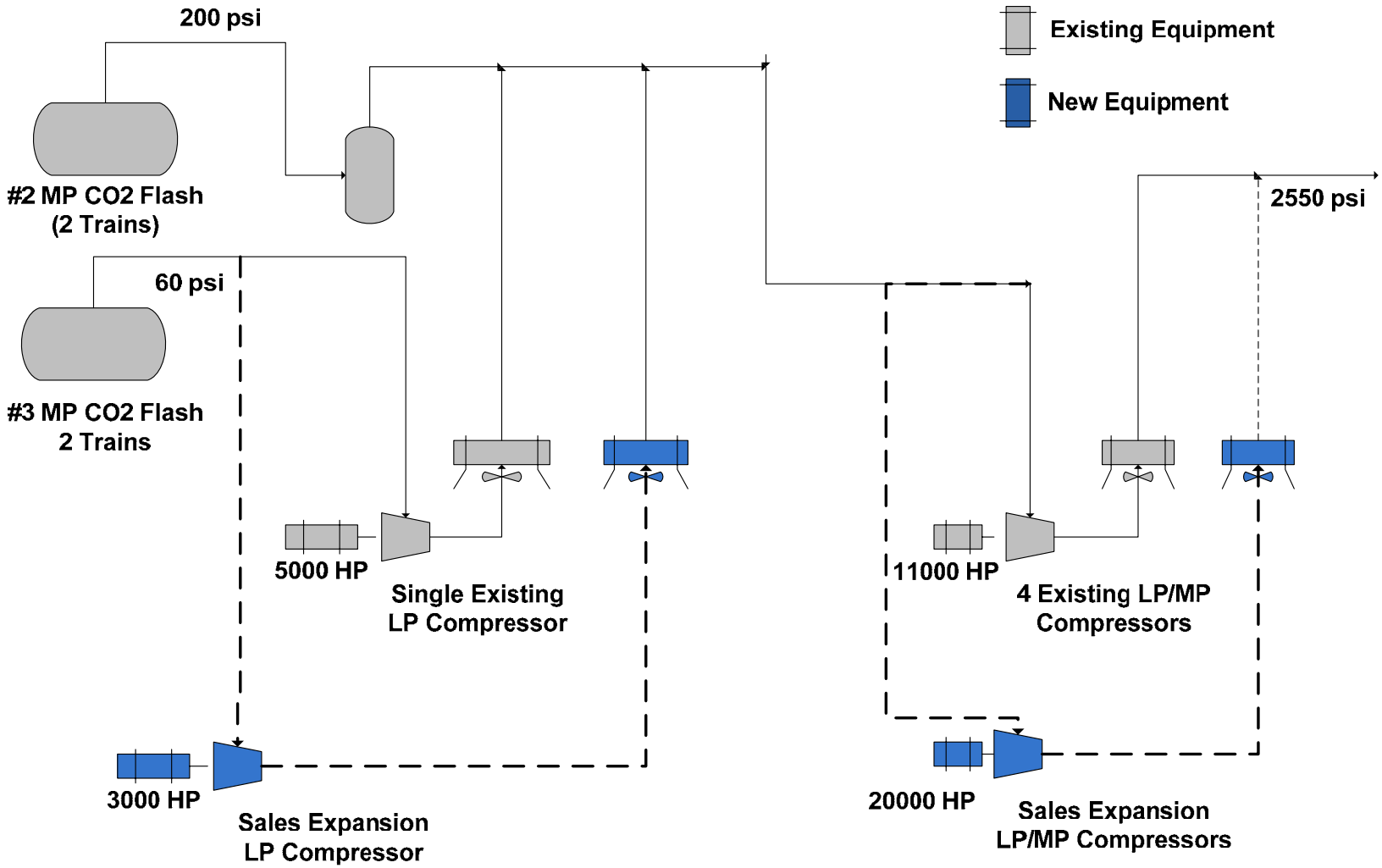
ExxonMobil Shute Creek NG Plant
CO_2 Capture & Compression for EOR
Expansion of CO_2 Compression & Pipeline

- Expansion of Facilities for Additional 110 MMSCFD (6385 STD) CO_2 for Pipeline EOR
- Fully-funded $72MM Project:
  - Detailed Design in November 2007
  - Long-lead Equipment Purchases Initiated in May 2008
  - Construction Initiated in late-2008
  - Commissioning Targeted by June 2010
  - Project Engineering Execution:
    - 25 EXOM Engineering Staff
    - 15 Washington Group Engineering Staff

ExxonMobil Shute Creek NG Plant
CO_2 Capture & Compression for EOR
Expansion of CO_2 Compression & Pipeline

- **Single 20,000-HP MP/HP compressor and a 3,000-HP LP compressor, both supplied by Dresser-Rand**
  - **LP Compressor is a Dresser-Rand DATUM Model D6R4S -- radial (barrel-type) design with 4 impellers with a straight-thru casing configuration**
  - **MP/HP Compressor is a Dresser-rand DATUM Model D10R8B -- radial (barrel-type) design with 8 impellers with a back-to-back casing configuration**
- **Will be the largest compressor unit in ExxonMobil USA Production Operations**

ExxonMobil Shute Creek NG Plant
CO2 Capture & Compression for EOR
CO2 Compression – Existing & Expansion



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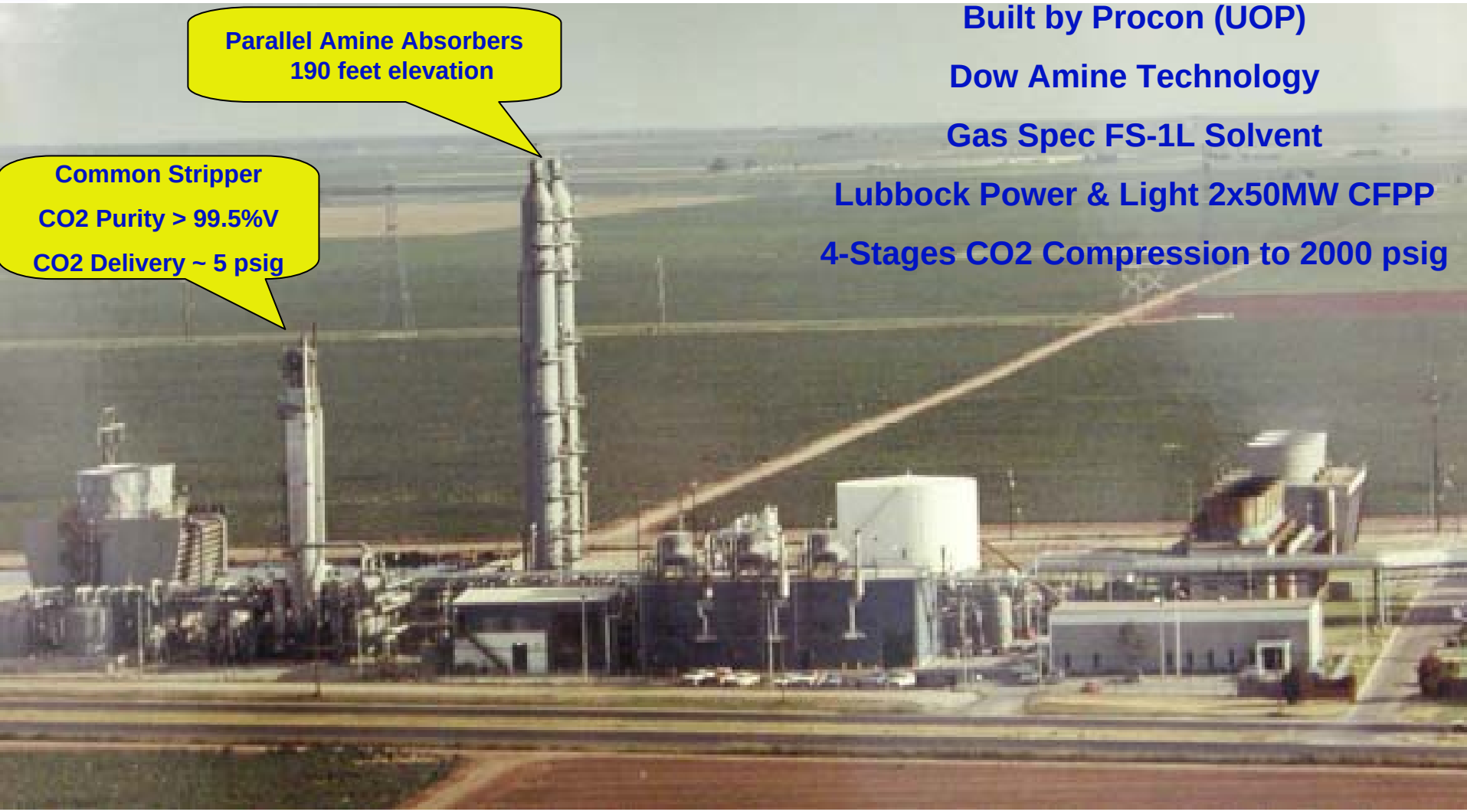
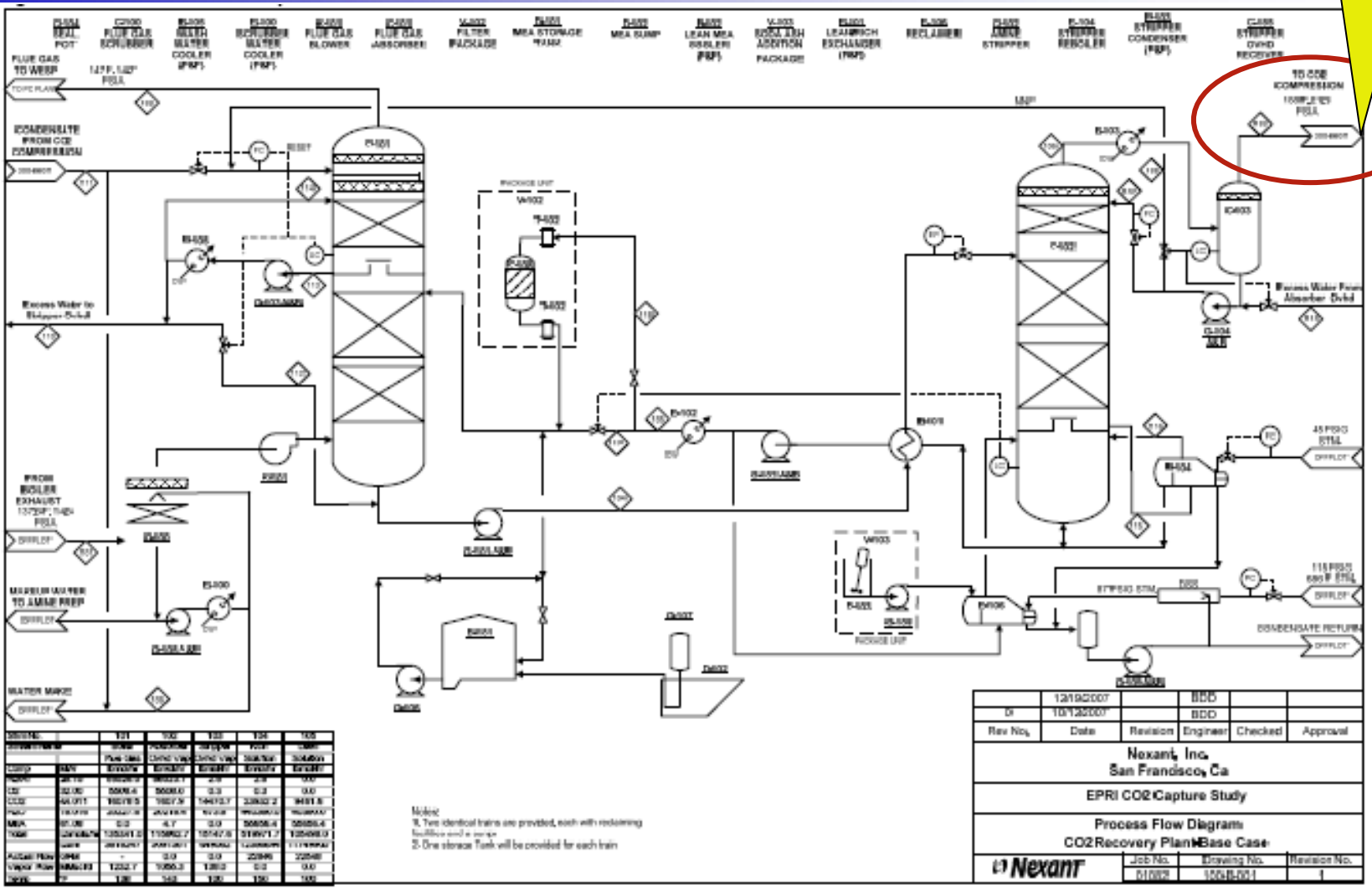
Carbon Dioxide Technology Corp
1150 STD CO2 from Coal-Fired PP in Lubbock, TX
Operational 1983-1984 for EOR Floods



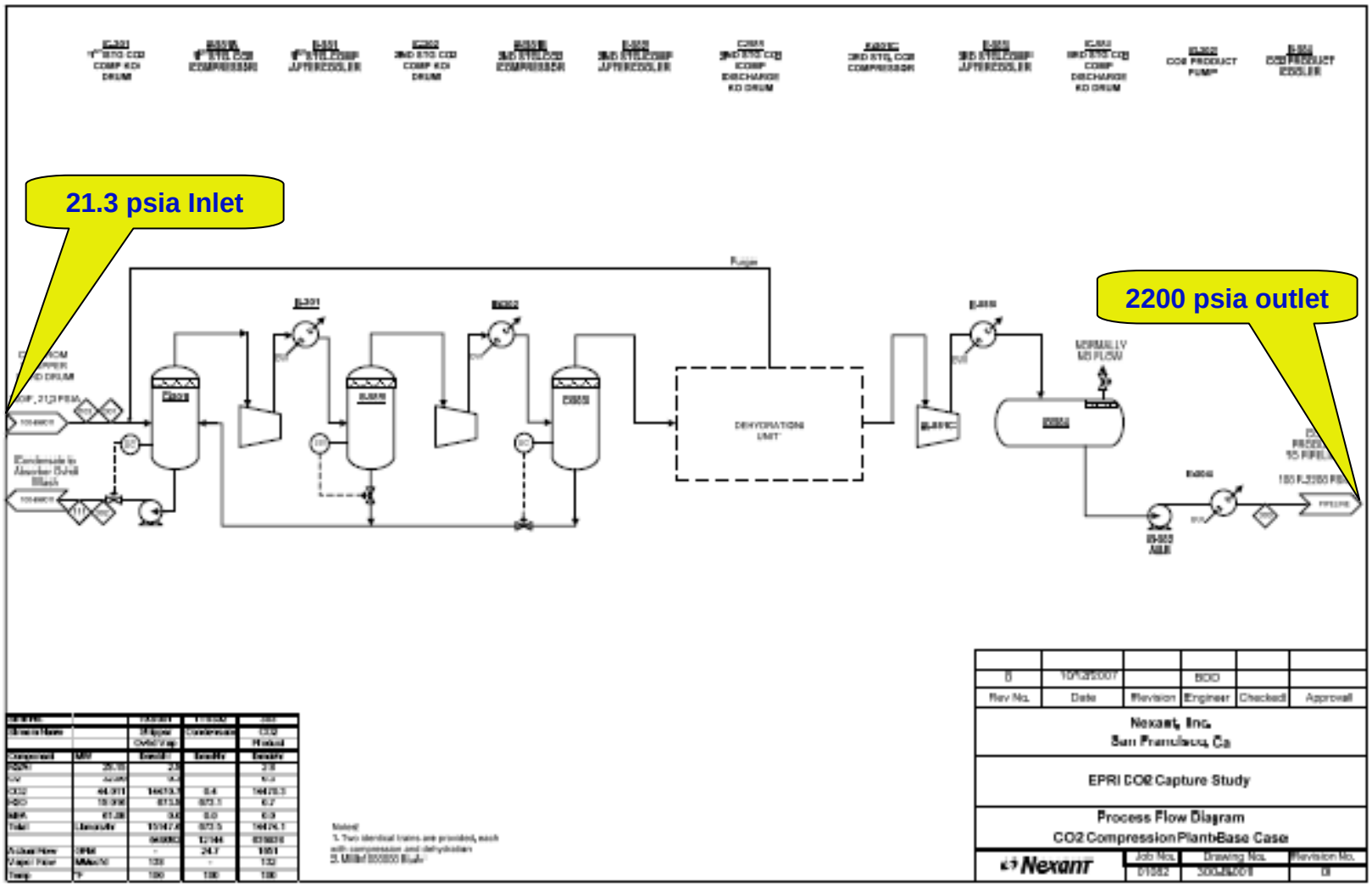
Source: NTNU - 2003

CO2 Capture from CFPP Flue Gas
EPRI-Nexant Report # 1014924
Amine Process Flow Diagram

CO2 @ B.L @ 21.3 psia



CO2 Capture from Flue Gas
EPRI-Nexant Report # 1014924
CO2 Compression Process Flow Diagram



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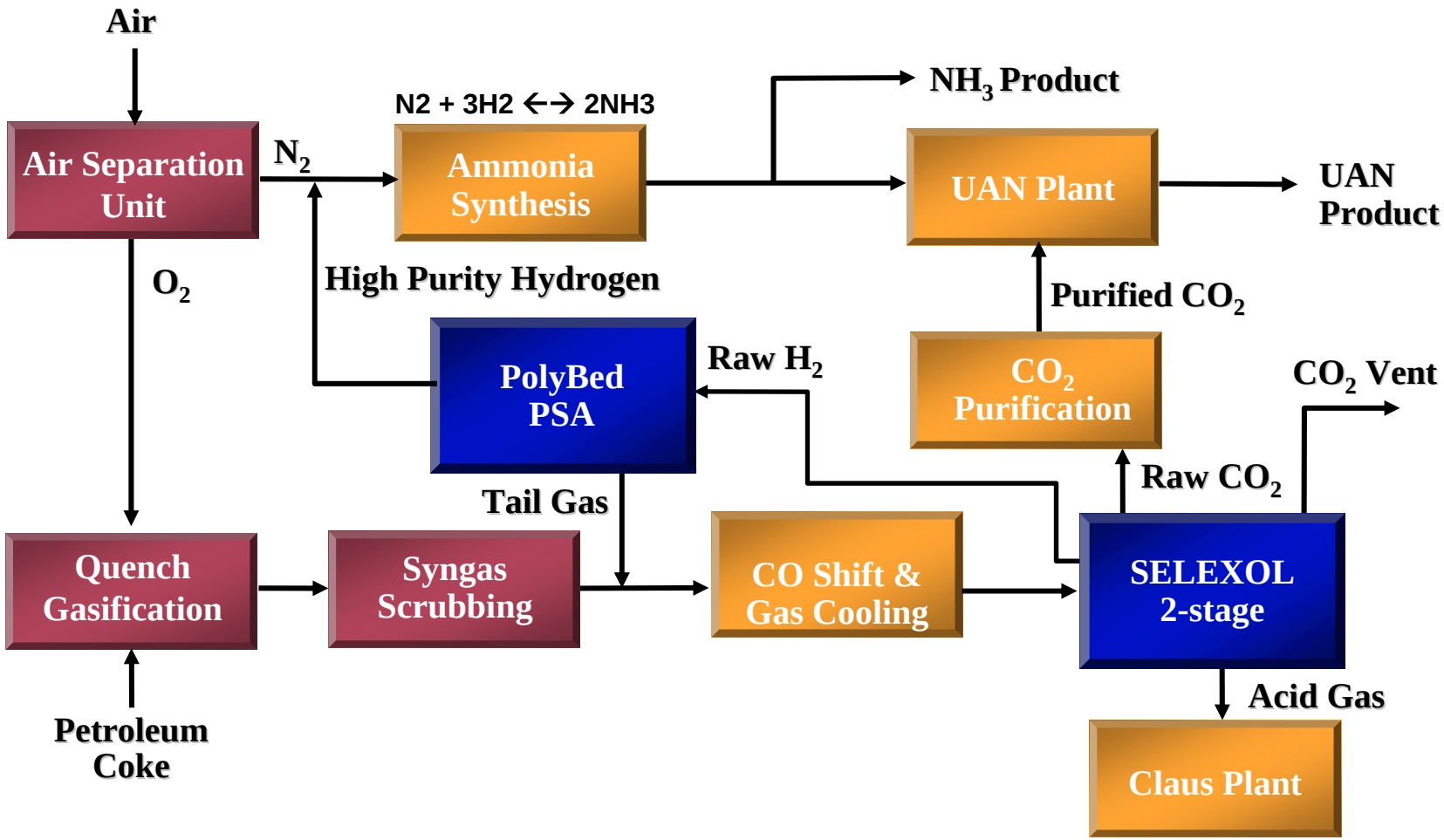
Coffeyville Resources / USA
Gasification-based NH3 Plant w Full CO2 Capture
Key Processing Design Features

- NH3 / UAN Fertilizer Complex (Commissioned July 2000):
  - 1140 MTD Ammonia Production
  - 1800 MTD Urea Ammonium Nitrate Solution Production
- Coffeyville Resources Refinery Pet Coke as Feedstock (1270 MTD)
- GE Quench Gasifiers (2 x 100%) @ ~42 barg pressure
- Linde (BOC) ASU Outside Battery Limits (1450 MTD O2)
  - High Purity N2 to NH3 Synthesis Loop
  - O2 to Gasifier
- 2-Stage Sour CO-Shift
- 2-Stage Selexol Unit AGRU (UOP) for separate H2S & CO2 Capture
- 10-bed PSA (UOP) for High-Purity H2 to NH3 Synthesis Loop
  - 101,900 NM3/Hr of 99.3%V H2 with <5 ppmv CO_X & <5 ppbv Sulfur

Coffeyville Resources / USA
Gasification-based NH3 Plant w Full CO2 Capture
Key Processing Design Features (cont)

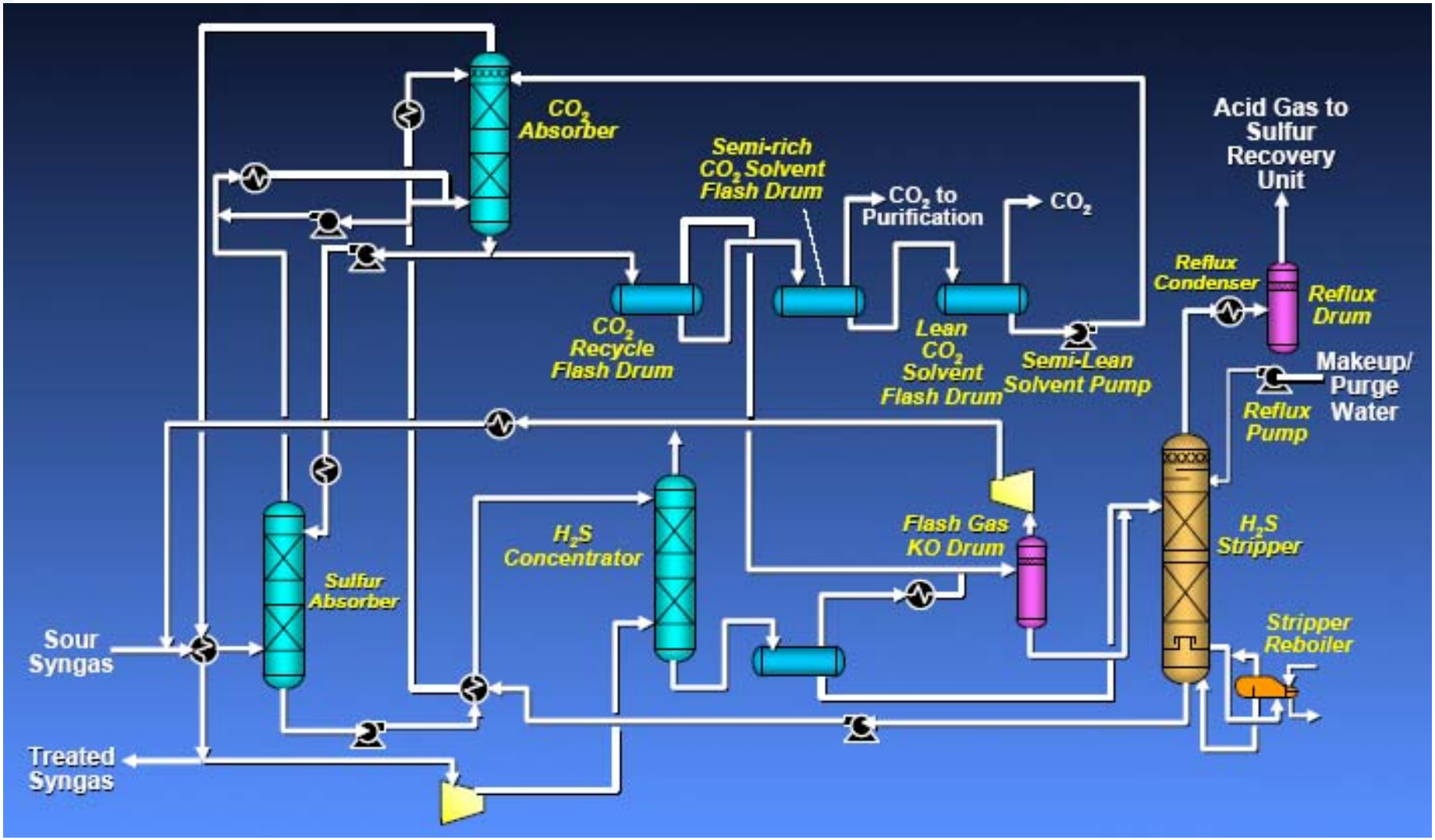
- Recycle of PSA Tail Gas to CO-Shift Unit (partial blow-down to fuel) for:
  - Maximum H2 Production
  - Maximum CO Conversion to CO2
- EPC – Black & Veatch Pritchard
- Sulfur Recovery – Tessenderlo Kerley
- NH3 / UAN – Ammonia Casale / Weatherly
- Well-Operated / Knowledgeable Staff / Many Lessons-Learned
- Profitable and Expanding Capacity
  - USA NH3 Industry Based on NG Virtually Eliminated in Past 5 Years

Coffeyville Resources
Plant Block Flow Diagram



Source: UOP – GTC Conf 2002

Coffeyville Resources
2-Stage SELEXOL Process Flow Diagram



Source: UOP – GTC Conf 2007

Coffeyville Resources
Syngas Composition
Post-CO-Shift & Cooling – Feed to Selexol

Feed Flowrate	**169,000 Nm^3/hr**	**(151 MM SCFD)**
Pressure	**36.9 bar-a**	**(535 psia)**
Temperature	**38 °C**	**(100 °F)**

Component	Mole %
H_2	> 56
CO	~ 1.2
CO_2	~ 41
H_2S and COS	~ 0.6
CH_4, Ar, & N_2	~ 1
H_2O	Saturated

2 Stages of CO-Shift

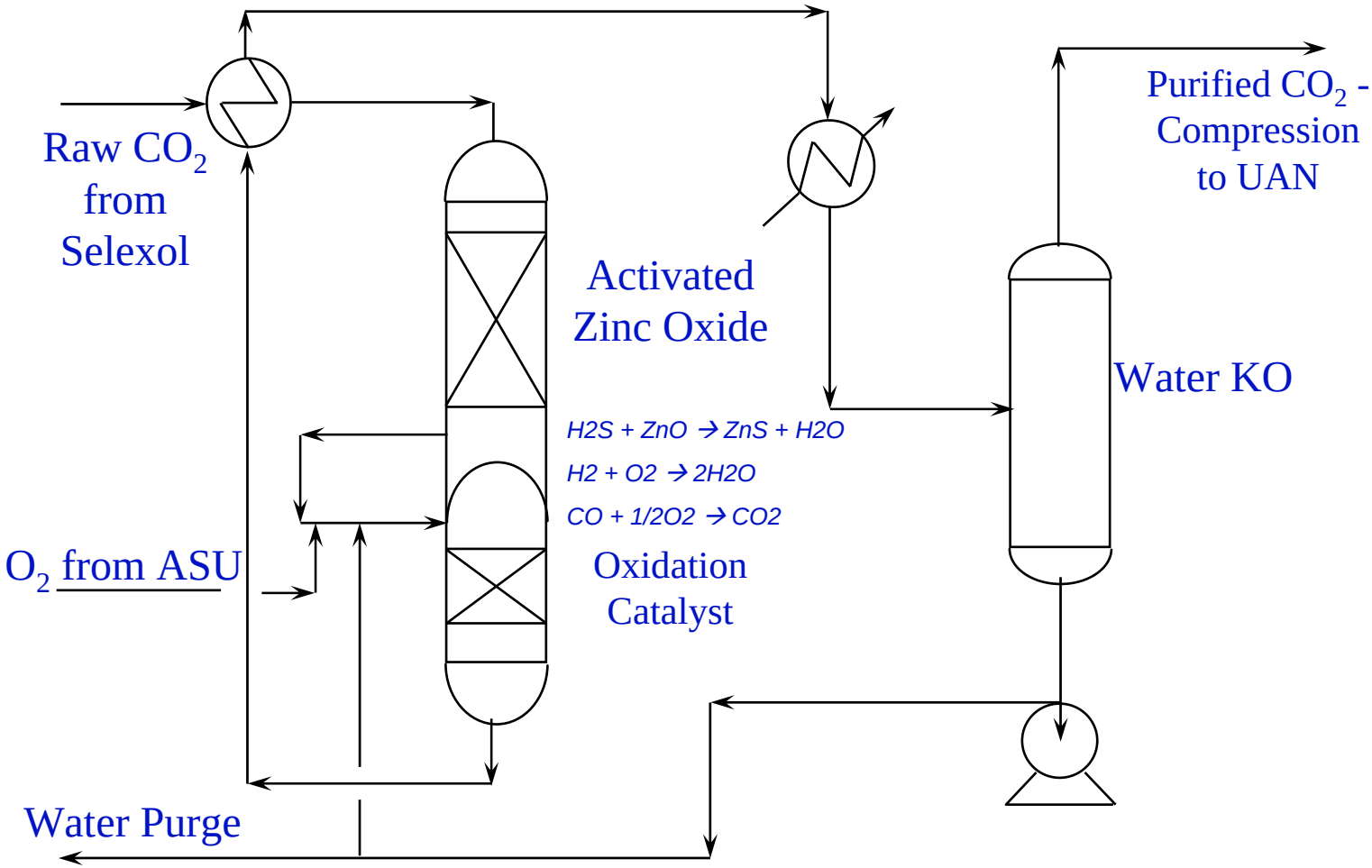
CO2/H2S Ratio ~ 70/1

Source: UOP – GTC Conf 2002

Coffeyville Resources / USA
Gasification-based NH3 Plant w Full CO2 Capture
CO2 Purification & Compression for UAN

- ~1/3 of the CO2 (~ 780 STSD) for the CO2 Compressors at ~150 psia for Urea Production
- ~2/3 of the CO2 is Presently Vented at ~5 psig
- HP CO2 for Urea goes through Pre-Purification Steps before Compression for Removal of Sulfur (H2S/COS) and H2/CO to Trace Levels
- CVR uses a Single Dresser-Rand Reciprocating Compressor to Compress the CO2 from about ~150 to 3800 psig in three stages using 2500 HP

Coffeyville Resources
CO_2 (for UAN) Trim Purification PFD



Source: BVP – LRGCC Conf 2000

Coffeyville Resources Ammonia-UAN Fertilizer Complex – Kansas, USA
CO2 Purity – Pre & Post CO2 Purification

Table 4
CO_2 Purification Feed Composition

Component	Mole %
Hydrogen	<5%
Carbon Dioxide	95%
Hydrogen Sulfide	< 1 ppm
Methane, CO & inerts	<0.5%
Carbonyl Sulfide	10 ppm
Feed Flowrate, MMSCFD	≤11
Pressure, psia	<150
Temperature, F	28

Raw CO2 from Selexol Unit to Pre-Purification Unit
Source: UOP LLC (a Honeywell Company) & BV Pritchard Presentation
Laurence Reid Gas Conditioning Conference / March 2000

Component	Mole %
CO2	99.32
H2	Nil
CH4 & CO	Nil
H2S & COS	Nil
H2O	0.68 (Saturated @ 140 psia and 100^0F)
Pressure	~140 psia
Temperature	~100^0F

Coffeyville Resources Ammonia-UAN Fertilizer Complex – Kansas, USA Aerial View of Plant

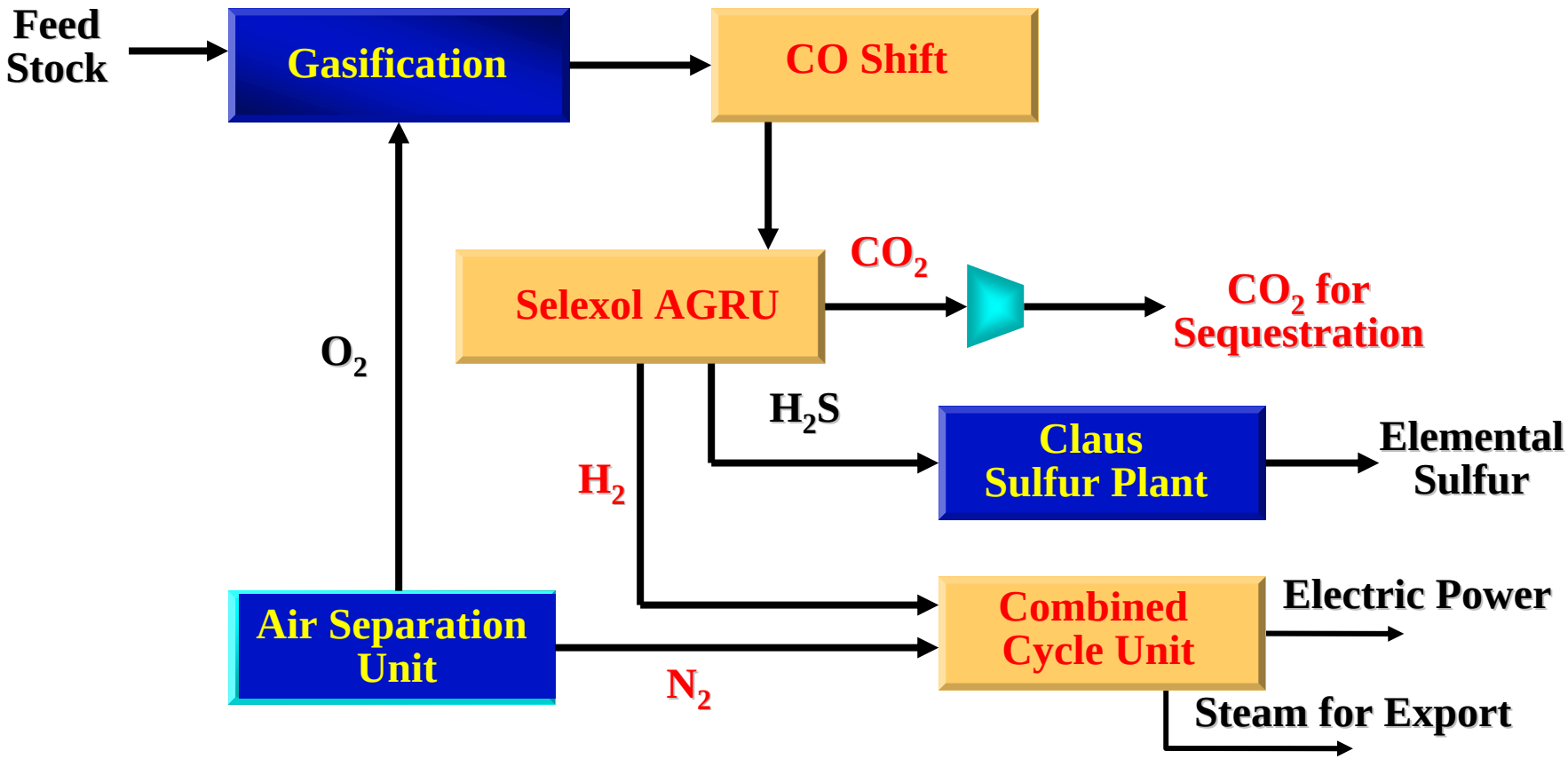
Source: UOP – GTC Conf 2002

Coffeyville Resources (UOP) SELEXOL and PSA Units

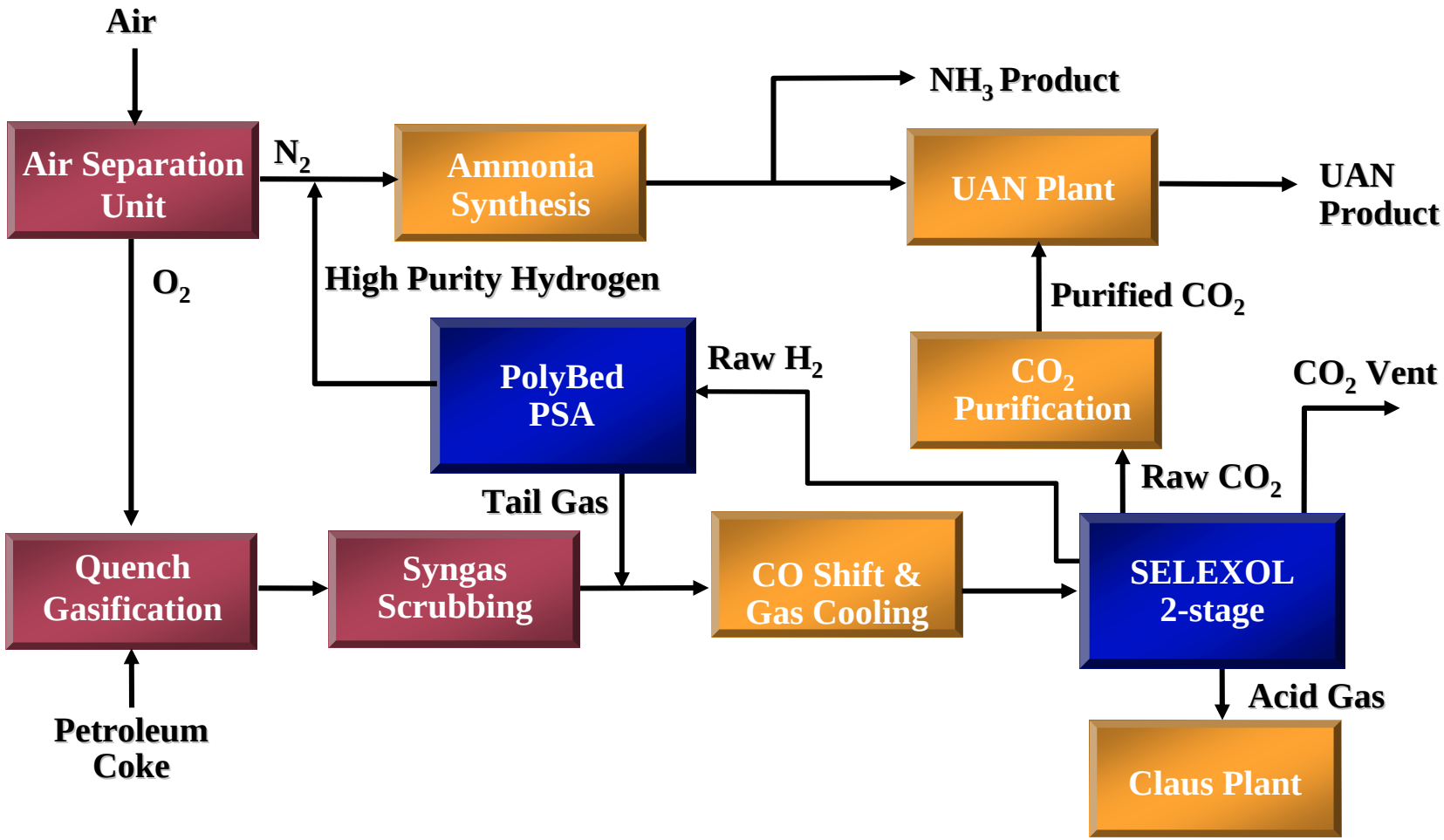
Source: UOP – GTC Conf 2002

CVR Fertilizer Complex
Blueprint for IGCC w CO_2 Capture

IGCC with CO_2 Capture Block Flow Diagram



Coffeyville Resources
Plant Block Flow Diagram



Source: UOP – GTC Conf 2002

Coffeyville Resources Fertilizer Plant Path Forward to IGCC w CO2 Capture

- Solid (Pet Coke) Feedstock
- Quench Gasifier for CO-Shift-Ready Syngas
- 2-Stage Sour CO-Shift for High CO Conversion
- 2-Stage Selexol for Separate H2S and CO2 Capture
  - CO2 Capture > 90%
  - Portion of CO2 Delivered at Elevated Pressure for Compression
  - Portion of CO2 "Sequestered" via N2-Fixation (Fertilizer)
- Combination of H2 and N2 for NH3 Synthesis
  - (For IGCC – combination to Gas Turbine)
- CO2 Trim Purification (dependent upon specifications)
- Production of High-Purity H2 by PSA
  - (Potential for Fuel Cell Usage)

Coffeyville Resources Fertilizer Plant – foreground
Coffeyville Resources Refinery – background
Thank You & Questions!

Source: UOP – GTC Conf 2007