Dow Oil & Gas

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AIChE Netherlands / Belgium Section
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Dow Solvent Technologies for CO_2 Removal

Who We Are

Dow combines the power of science and technology to passionately innovate what is essential to human progress.

1897 Founded by Herbert H. Dow in Midland, Michigan

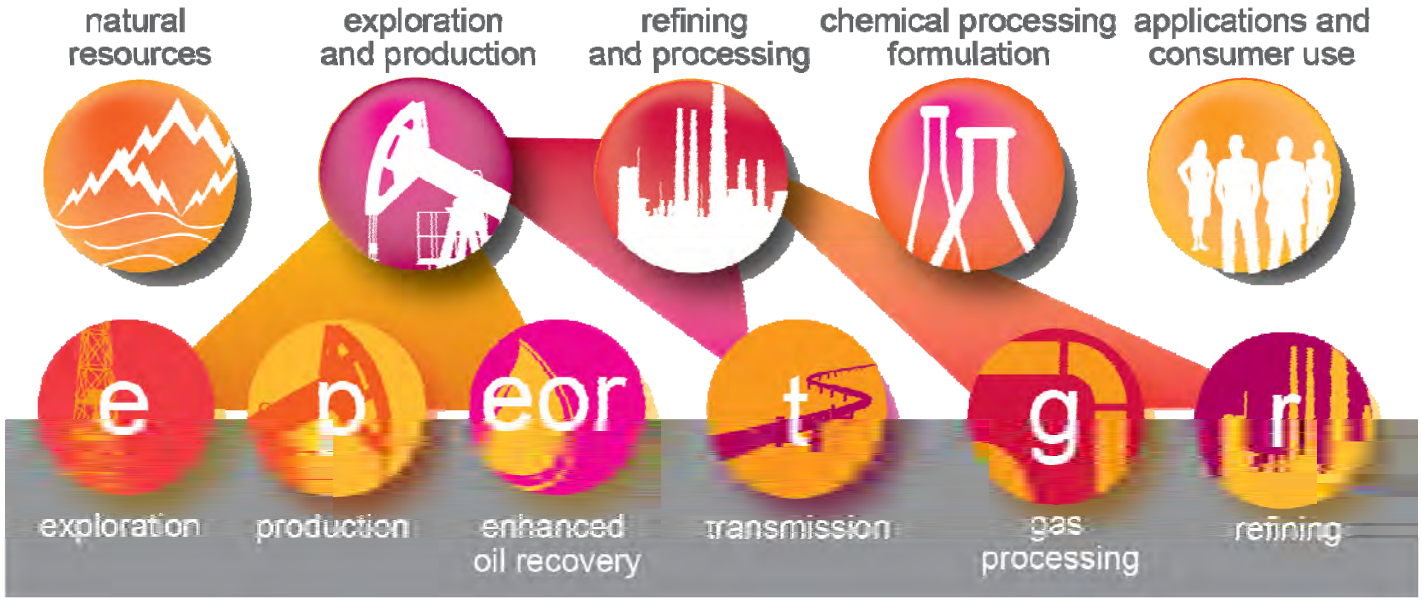
Serve customers in **160** countries

Manufacture more than **5000** products at **188** sites in **36** countries

Employ approximately **54000** people worldwide

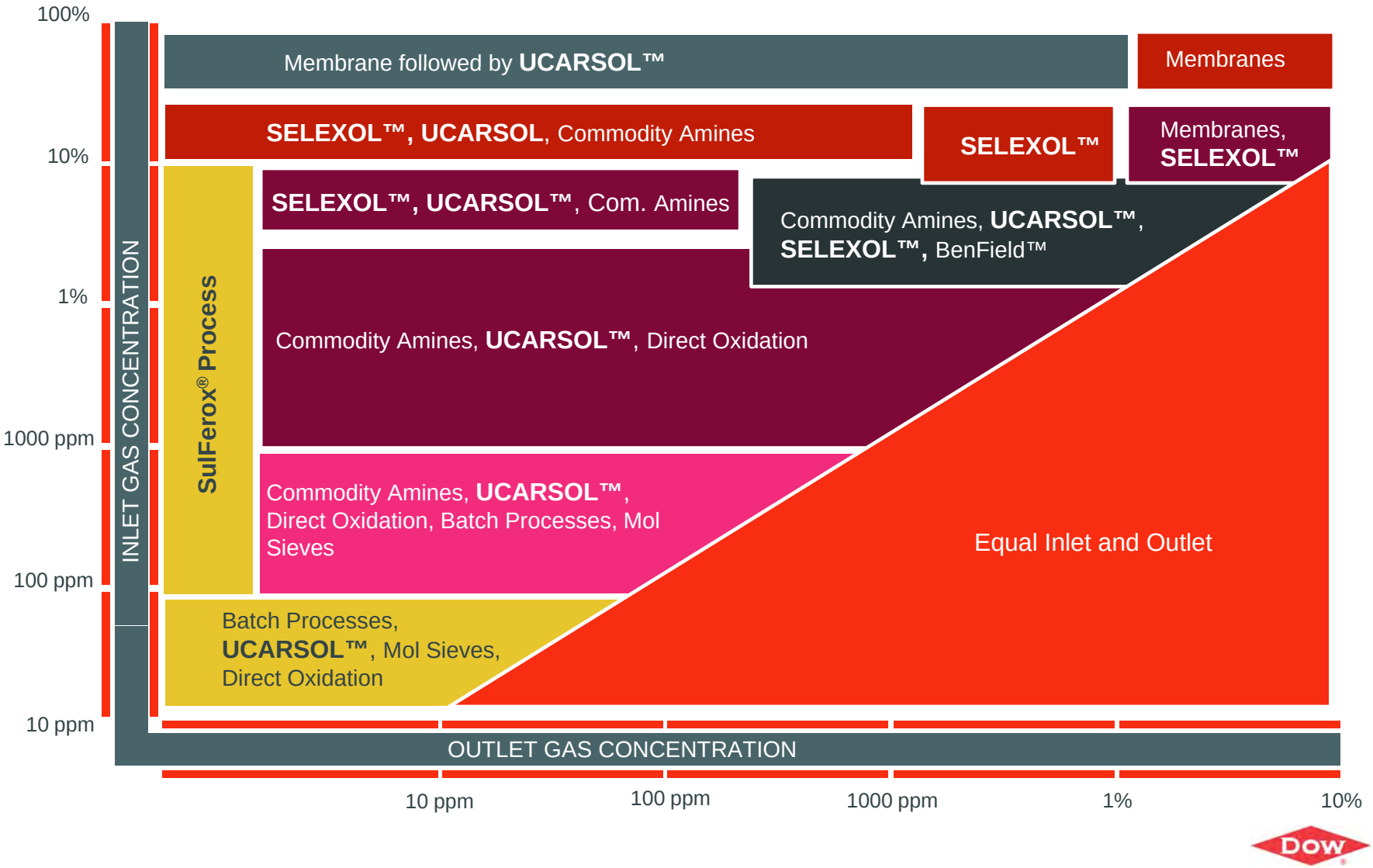
Dow Oil & Gas : Aligned to Industry Needs

We maximize value for our customers by providing comprehensive solutions across the oil, gas and mining value chains through chemistry expertise, industry knowledge and advanced innovation.



Recently aligned with our business to bring together Dow's industry-leading mineral extraction and processing technologies with our growing portfolio of technology offerings for oil and gas

Acid Gas Removal Technologies



Key Offerings for Amine Sweetening

UCARSOL™ Solvents
Multiple formulations used for gas treating; each provides key benefits, depending on customer specifications

Selective H_2S – preferentially absorbing H_2S while allowing CO_2 to slip

- UCARSOL™ HS-101 for gas treating
- UCARSOL™ HS-102 for acid gas enrichment
- UCARSOL™ HS-103 for tail gas treating
- UCARSOL™ HS-115 for liquid hydrocarbon treating

Tunable CO_2 removal – removal of CO_2 to a desired specification

- UCARSOL™ AP-802, AP-804, AP-806 – removal of CO_2 to pipeline specification
- UCARSOL™ AP-810, AP-814 – removal of CO_2 to cryogenic
- UCARSOL™ NH-608, for removal of CO_2 in ammonia applications
- CO_2 capture in coal based power plants using UCARSOL™ FGC-3000

Mercaptan and organic sulfur removal – capturing organic sulfur compounds requires unique solutions

- UCARSOL™ LE-701, LE-702 – removal of organic sulfur and meeting total sulfur specification

Refinery, low-energy solvents – where removal of bulk components is desired, but minimizing energy is key

- UCARSOL™ LE-713, LE-777, LE-801 – maximize energy savings

SELEXOL™ Solvent
Removal of acid gas, organic sulfur and hydrocarbons when there is a high partial pressure of target components

DOW

UCARSOL™ AP Solvents

- UCARSOL™ AP-800 Solvents are the latest generation of Dow solvents to remove carbon dioxide
- MDEA based solvents with different levels of activator, depending on the required sweet gas specification
- CO_2 removal applications include Natural Gas, LNG, Ammonia, IGCC, and Cryogenic Processing units.
- The AP-800 Solvents are advanced performance CO_2 removal products, outperforming other competitive solvents in the market place
- Technology can be offered on a non-licensed basis.
- For licensed approach, UOP can offer an Amine Guard™ FS license
- 15-Year Track Record
- More than 250 References

LNG and Large Middle East References

UOP Amine Guard™ FS, UCARSOL™ AP-800 Solvents

LNG

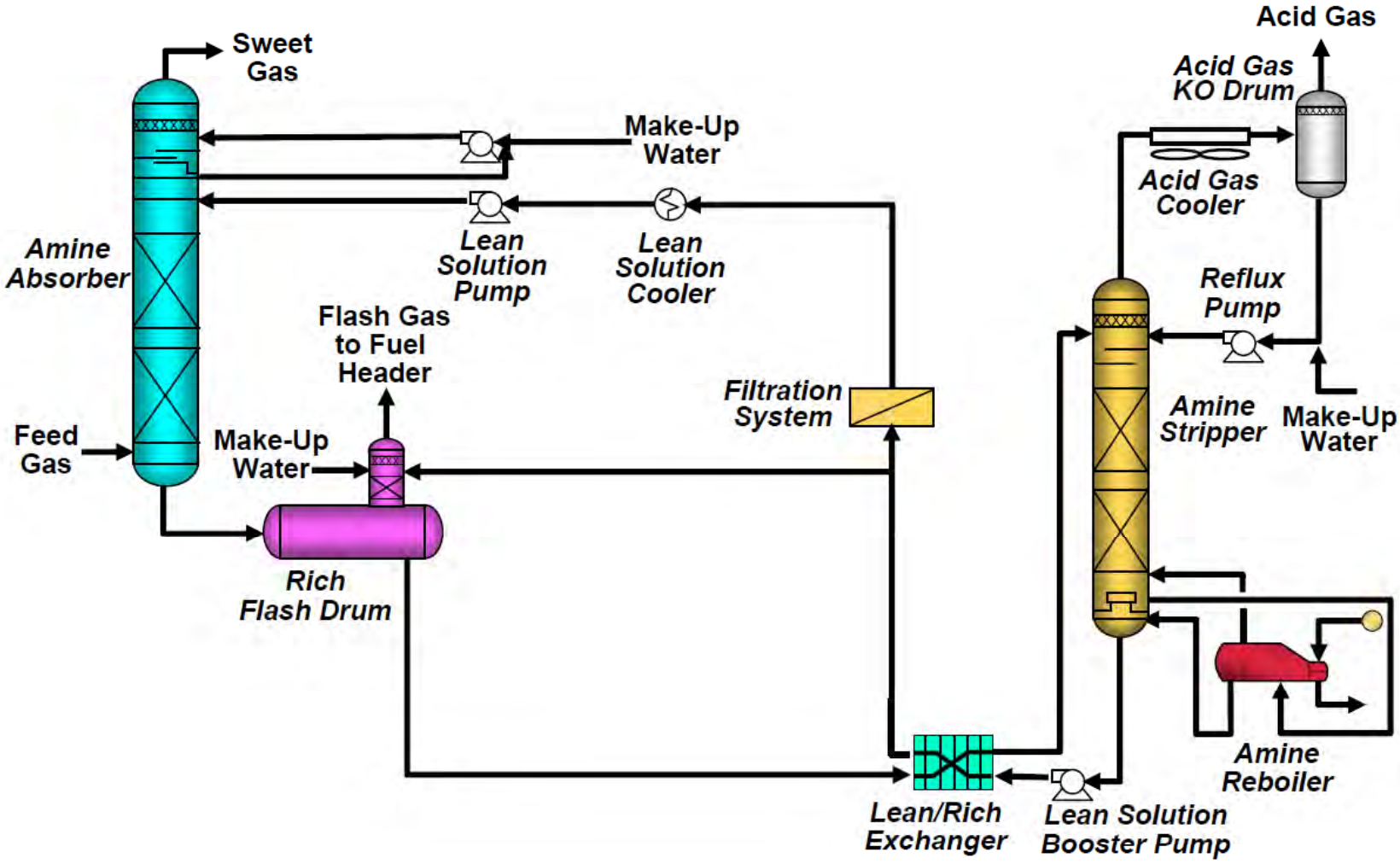
	Start-up	MMSCFD
RasGas Train 3 LNG	2004	750
RasGas Train 4 LNG	2005	750
RasGas Train 5 LNG	2006	750
RasGas Train 6 LNG	2008	1600
RasGas Train 7 LNG	2008	1600

Large Mid-East Gas Plants

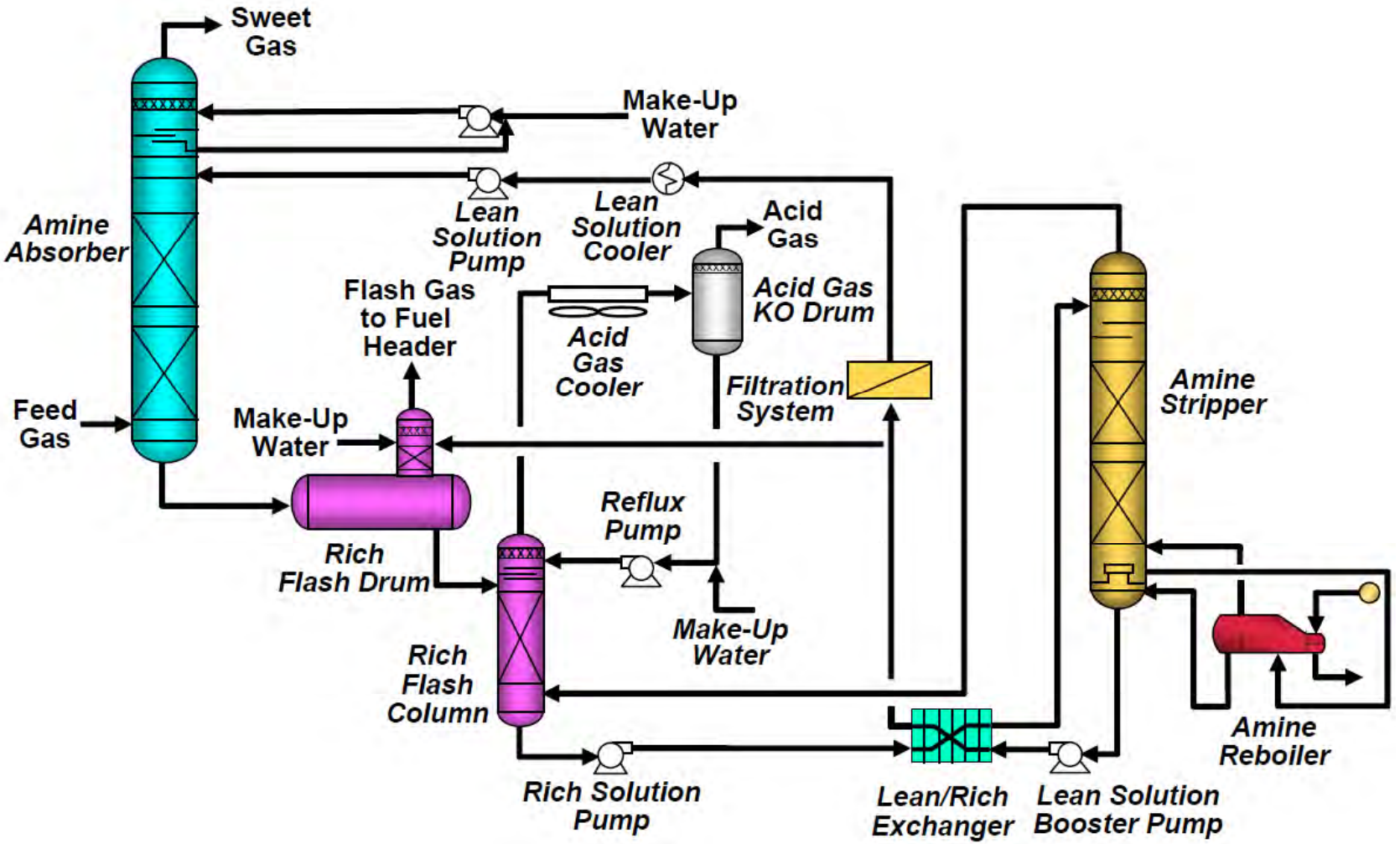
	Start-up	MMSCFD
RasGas Train AKG-1	2005	750
RasGas Train AKG-2	2008	1600
Dolphin, Train 1,2	2007	4 x 800
GASCO, OGD3, Train 1,2	2010	2 x 630
GASCO, ADG2, Train 1,2	2010	2 x 400

UCARSOL™ and SELEXOL™ Solvents in 5 World Scale LNG Plants in Ras Laffan, Qatar

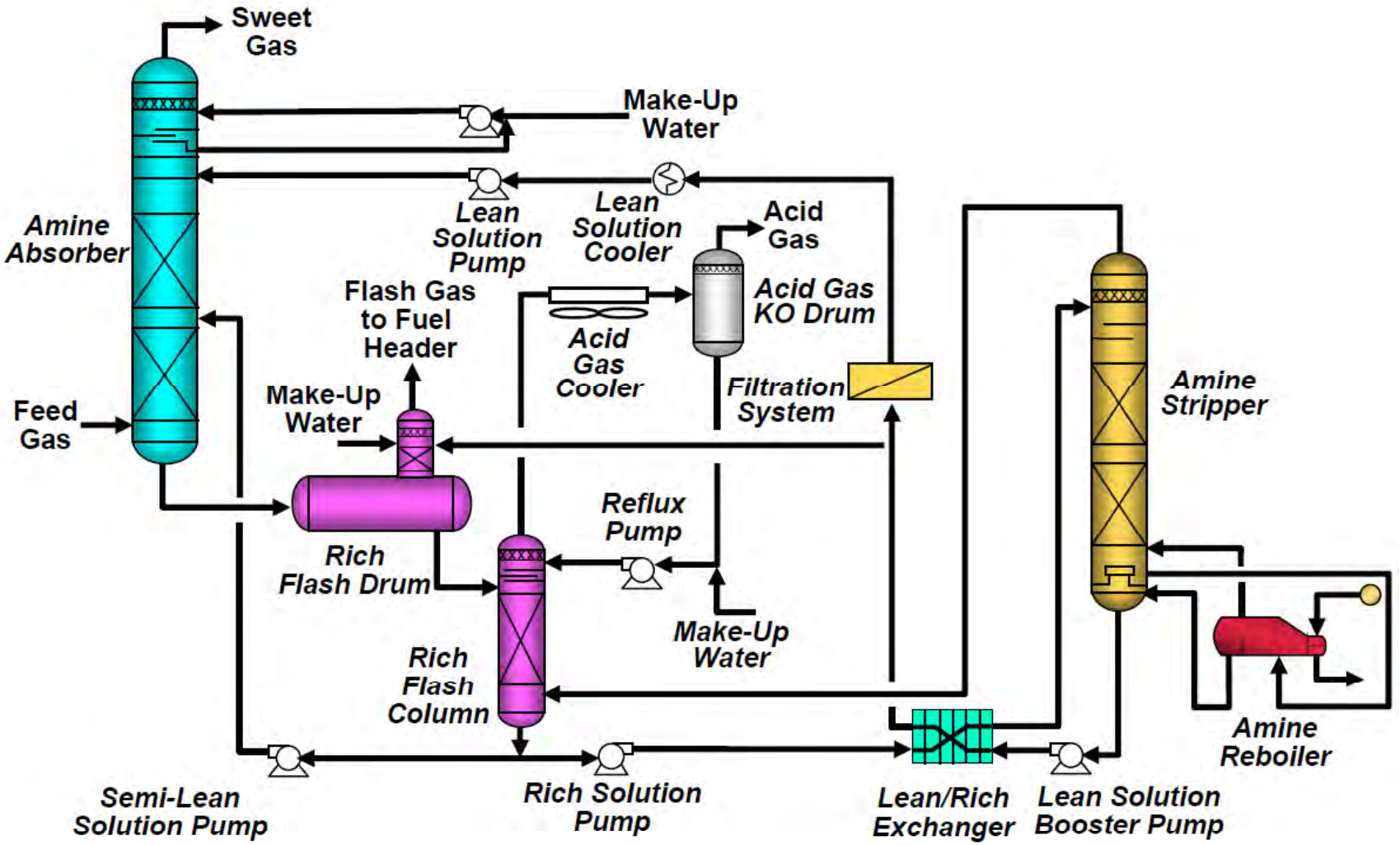
Conventional Process Scheme



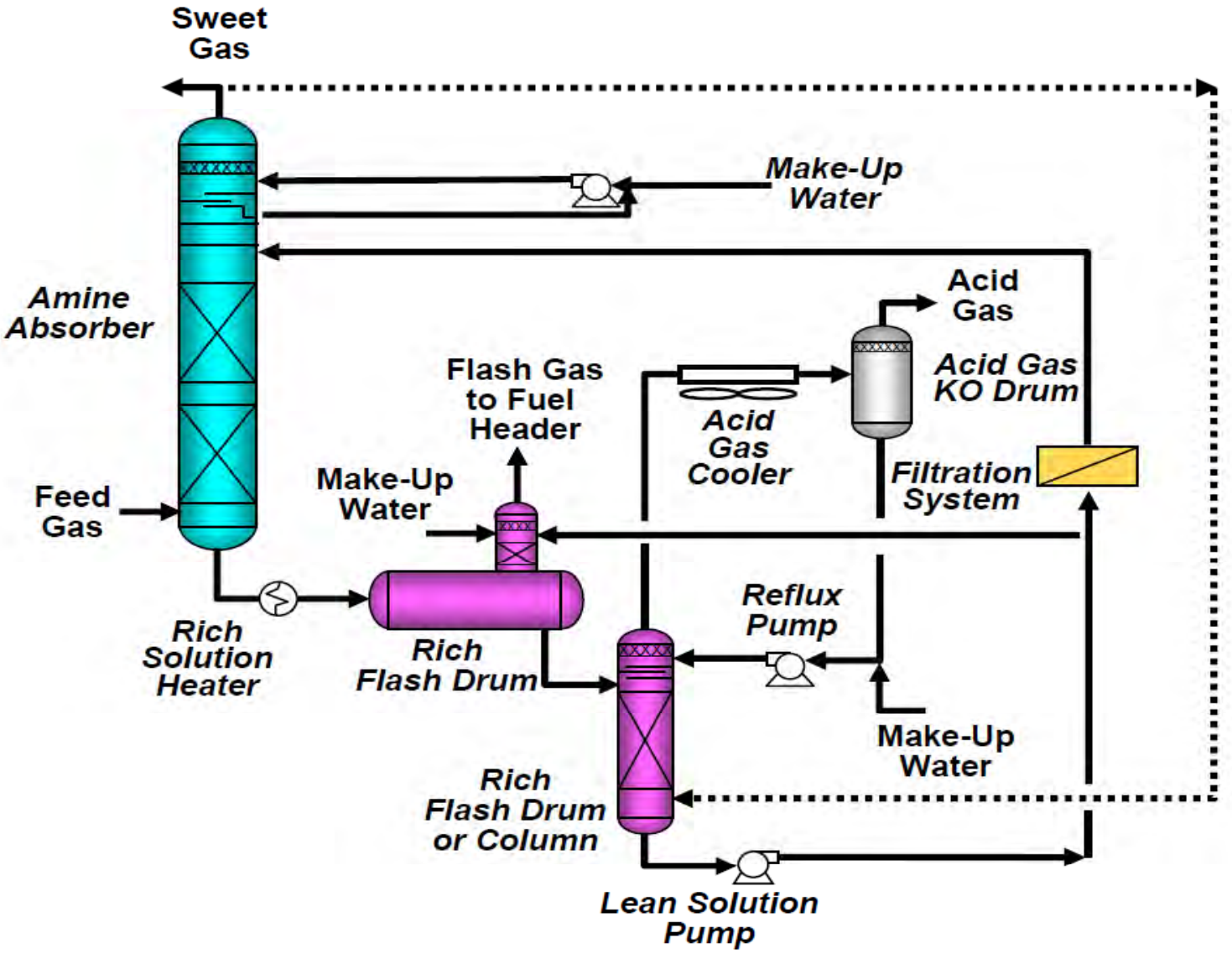
One Stage Process Scheme



Two Stage Process Scheme



Flash Regeneration Scheme



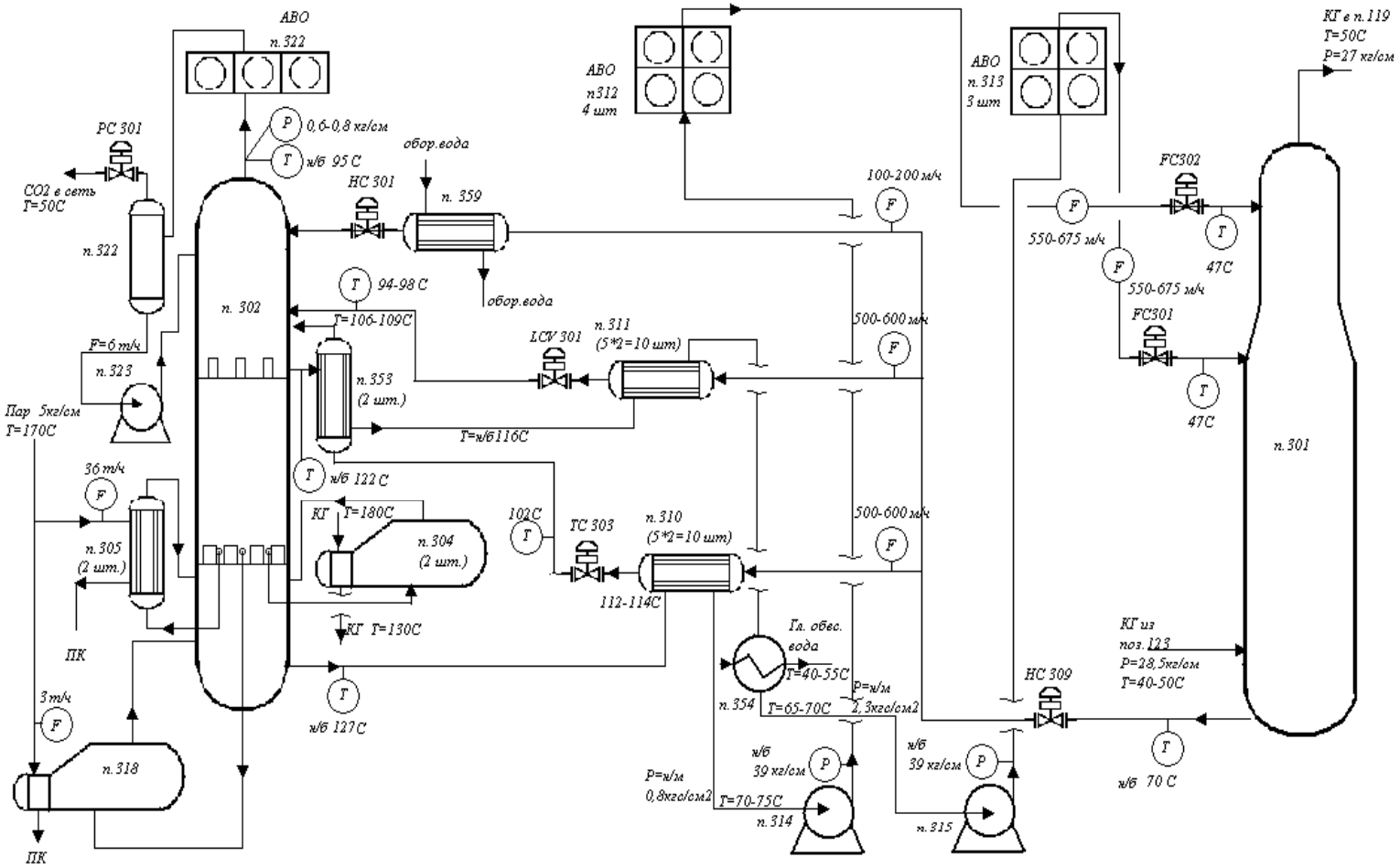
Comparing DEA and UCARSOL™ AP-814 Performance

Capacity Increase

	33% DEA	45 % AP-814
Processing capacity, kNm^3/hr	152	188
Circulation Rate, m^3/hr	217	230
Solvent CO_2 loading, mol/mol		
Lean	0.06	0.03
Rich	0.49	0.46
Reboiler Duty, Gcal/hr	12.6	12.6
Treated Gas CO_2		
Outlet from absorber	2%v	100 ppmv

Ammonia Applications

UCARSOL™ NH Solvents



Ammonia Plant Ukraine

Comparing MEA with UCARSOL™ NH-608 Performance

	MEA System Performance	UCARSOL NH-608 Performance
Recirculation Flow 1	650-670 m^3/hr	450-460 m^3/hr
Recirculation Flow 2	550-570 m^3/hr	430-450 m^3/hr
Regenerator Mid Column Temp	115-116 ºC	109 ºC
Regenerator Overhead Temp	91-93 ºC	82 ºC
CO2 in Treated Gas	50-80 ppm	18-27 ppm
Reboiler Steam	17+17+3 MT/hr Total = 37 MT/hr	3.5+3.5 + 0.0 MT/hr Total = 7 MT/hr

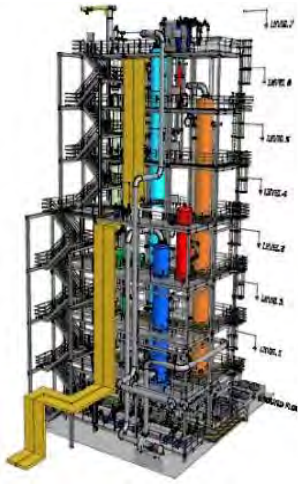
CO_2 Capture from Coal Based Power Plants

UCARSOL™ FGC Solvent 3000

- First Pilot Plant at Dow Chemical Site in Charleston, WV
  - Designed to capture 1,800 t CO_2/year using UCARSOL™ FGC-3000 solvent
  - Installation on commercial coal-fired boiler
  - Project progression
    - Operation began in September 2009
    - Validation of overall performance and unit operation
    - Implementation of 2nd generation improved flow scheme in February 2011
    - Focus on solvent management and emissions measurements, as well as proving concepts of the 3rd generation flow scheme
  - Completed more than 14,000 hrs of operation, 24/7, before pilot was shut down in October 2011

Advanced Amine Field Pilot

Demonstration Unit at EDF Power Plant Le Havre



- Designed to capture 25 t CO_2/ day, 90% CO2 capture
- Advanced flow scheme & operation validation
- Flue gas: slipstream from 600 MWe coal plant (EDF host facility)
- French funding by ADEME (French Environment and Energy Management Agency)
- Project schedule
  - Overall 2010-2013 program
  - Test from Q2 2013 to Q2 2014

ALSTOM edf DOW

SELEXOL™ Solvent

- Polyalkylene Glycol Dimethyl Ether

  $R – O – (CH_2 - CH_2 - O)_n – R$

- Invented by Allied Signal in 1950's
- Purchased by Norton in 1982, then by Union Carbide in 1990
- Became a Dow solvent after the merger in 2001
- About 115 units were built of which still many in operation

SELEXOL™ Solvent : Applications

- Purification of lean natural gas
- Low-energy ammonia/urea production
- Gasification
- Heavy oil partial oxidation
- Landfill gas purification
- Light hydrocarbon dew point control

DOW and UOP SELEXOL™ Solvent Relationship

- UOP is the exclusive licensor of SELEXOL™ in Gasification and Ammonia applications
- UOP provides license/warranty, Dow provides solvent
- If no license involved, Dow can work directly with customers
- Dow and UOP cooperatively develop solvent and design improvements

SELEXOL™ is a Physical Solvent

How is Physical Absorption Affected ?

Pressure

- High Pressure Increases the Driving Force for Absorption

Temperature

- Low Temperature Increases the Solubility of the Acid Gases in the Liquid Phase

Capacity

- For Physical Solvents, the Higher the Pressure, the Greater the Capacity

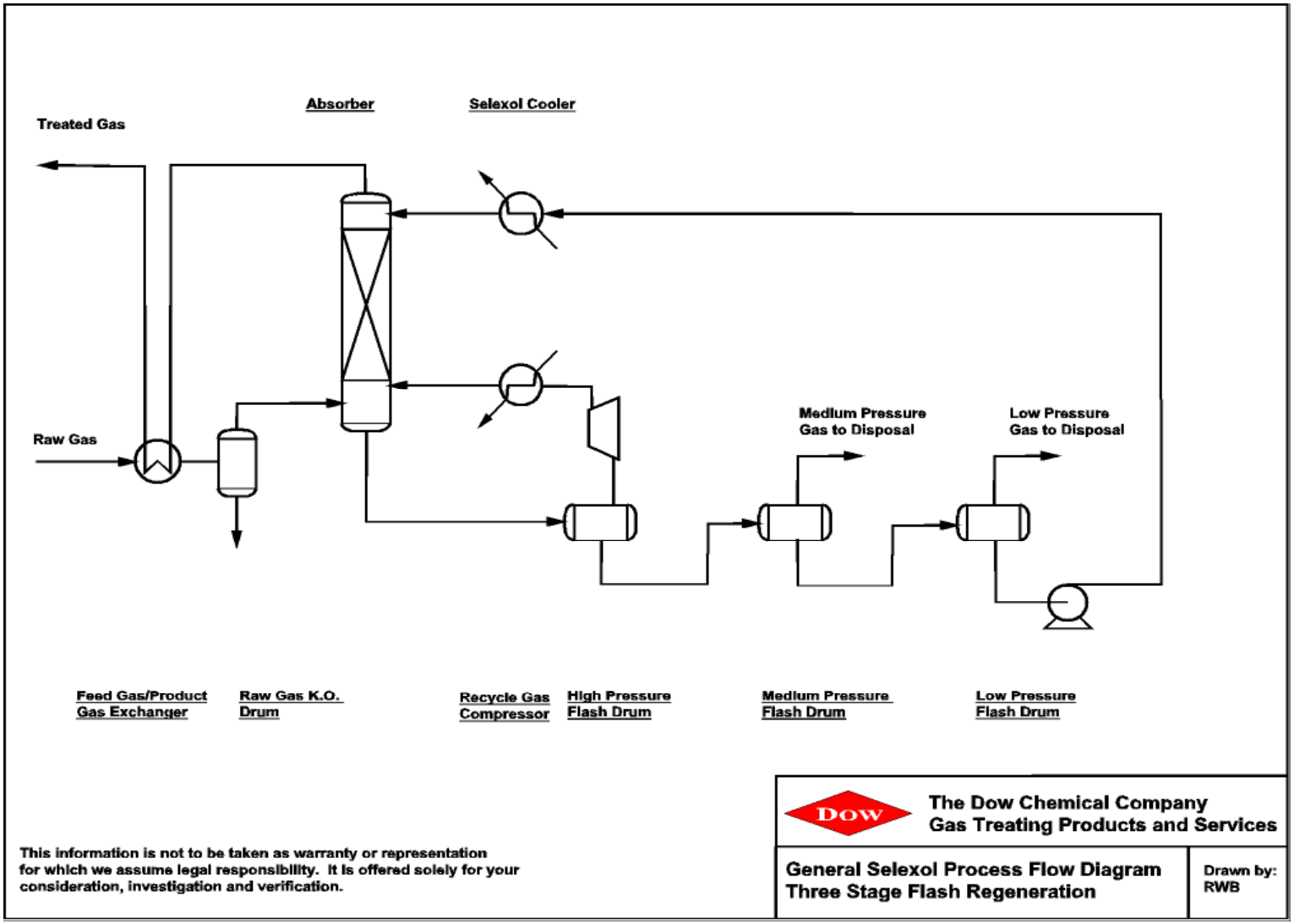
Mass Transfer

- Packing Height or Number of Trays has an Effect, but it is Smaller Than the Effect of Temperature, Pressure or Solvent Flow

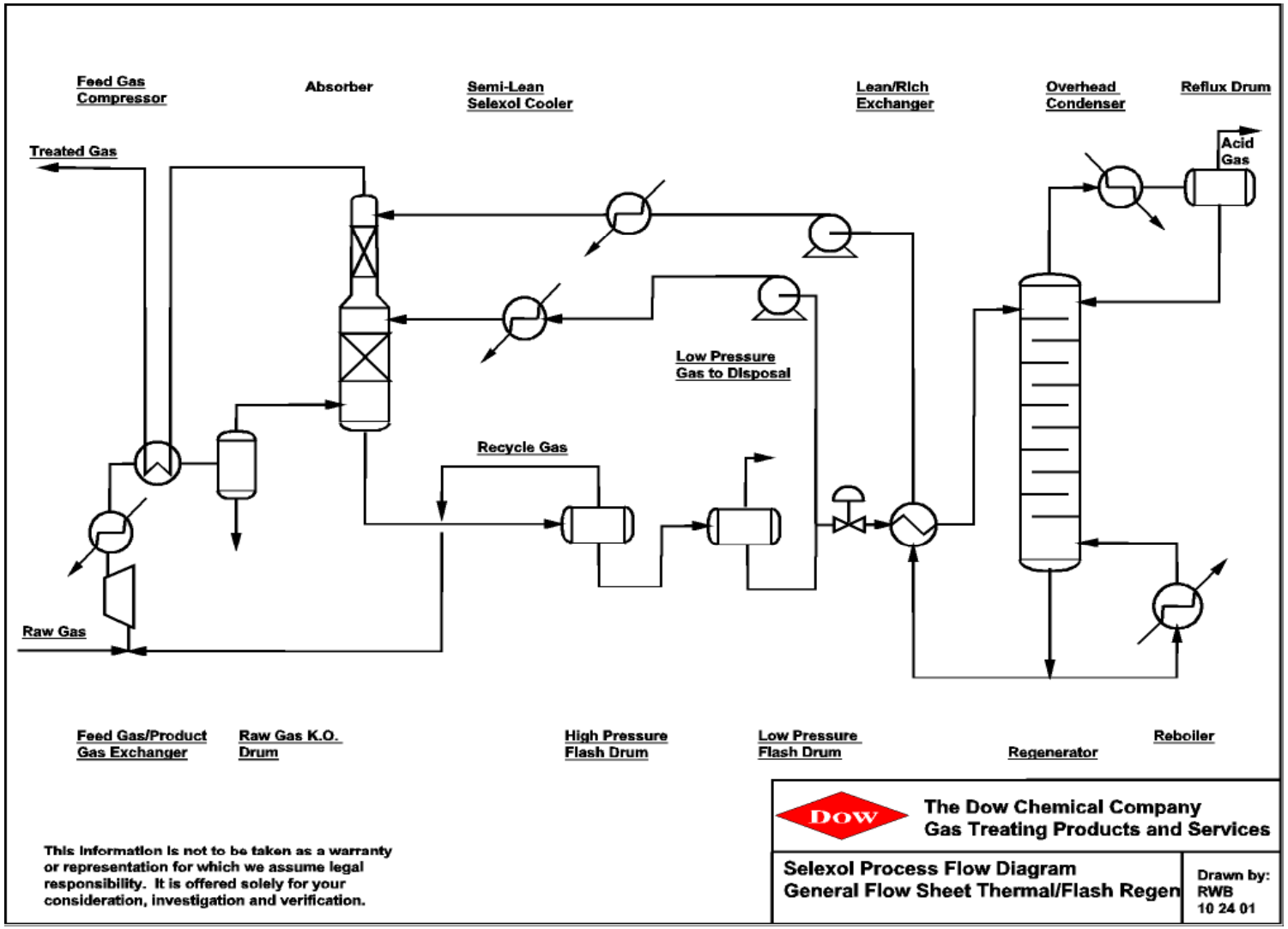
Relative Solubility of Various Gases in SELEXOL

Component	R = K'CH4 / K' Component	Component	R = K'CH4 / K' Component
H_2	0.20	H_2S	134
N_2	0.30	C_6H_{14}	167
CO	0.43	CH_3SH	340
CH_4	1.00	C_7H_{16}	360
C_2H_6	7.20	CS_2	360
CO_2	15.2	C_2H_3Cl	400
C_3H_8	15.4	SO_2	1,400
i-C_4H_{10}	28	C_6H_6	3,800
n-C_4H_{10}	36	C_2H_5OH	3,900
COS	35	CH_2Cl_2	5,000
i-C_5H_{12}	68	CH_2Cl_3	5,000
C_2H_2	68	C_4H_4S	8,200
NH_3	73	H_2O	11,000
n-C_5H_{12}	83	HCN	19,000

SELEXOL™ Solvent Design for CO_2 Removal



SELEXOL™ Solvent Design for H_2S Removal



Regeneration Methods for SELEXOL

Regeneration Method	Treated Gas Specification
Flash Only - No Heat	3 - 4% CO_2
Vacuum Flash or Heated Flash	1 - 2% CO_2
Inert Gas Stripping	< 1% CO_2 < 4 ppm H_2S
Steam Stripping	< 500 ppm CO_2 < 4 ppm H_2S

Thank You

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