GPAC/PJVA Joint Conference

CO_2 Dehydration: Why? How Much? How?

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dexPro
INNOVATIVE DEHYDRATION TECHNOLOGY

Never take your eye off the target

Section 1

Who Are We?

Who ?

Acid Gas Injection

- Oil & gas EPCM company formed in 1987 – currently employ 250 people
- Started acid gas injection early – first project was in 1995
- Worked on acid gas projects or provided training in 12 countries outside of Canada, including 6 states in the US
- Involved in about 25% of the Alberta acid gas injection projects to date
- Published 7 books and over 50 articles and technical papers relevant to acid gas and CO_2 behavior, facility design, and injection operational issues
- Patented a novel cost effective acid gas dehydration process

Why ?

How Much ?

How ?

Section 2

Why Dehydrate?

Why ?

3 Reasons

Corrosion

Hydrate Formation

Imposed Specs

Why ?

Corrosion

+

= ACID !

Why ?

Corrosion

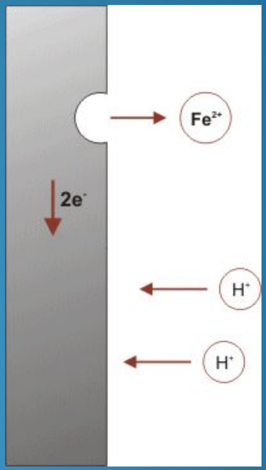
IT IS ALL ABOUT THE CONTAMINANTS

- carbonic, sulfuric, and nitric acids will form where CO_2, SO_2, and NO_X are present
- excess oxygen allows the corrosion to continue
- most likely cause of off-spec water content is carry over of water/glycol from the dehydration process
- stainless steel piping alternative is ~4-5 times more expensive than mild steel

Table 6-9
Corrosion of Mild Steel by Carbon Dioxide and Other Gases in Water*

Gas Concentration, ppm		Corrosion of Mild Steel, mils/year	
O_2	H_2S	A: CO_2 conc, 200 ppm	B: CO_2 conc, 600 ppm
8.8	0	28	60
4.3	0	18	44
1.6	0	12	34
0.4	0	17	27
<0.5	35	6	6
<0.5	150	15	16
<0.5	400	17	21

**Temperature 80°F, exposure time 72 hr.*
Source: Data of Watkins and Kincheloe (1958) and Watkins and Wright (1953)



Gas Purification, 5th edition

Why ?

Hydrates

- **Definition**

  A physical combination of water and small molecules producing a crystalline compound having “ice like” appearance but possessing different properties and structure than ice.

- **Problem**

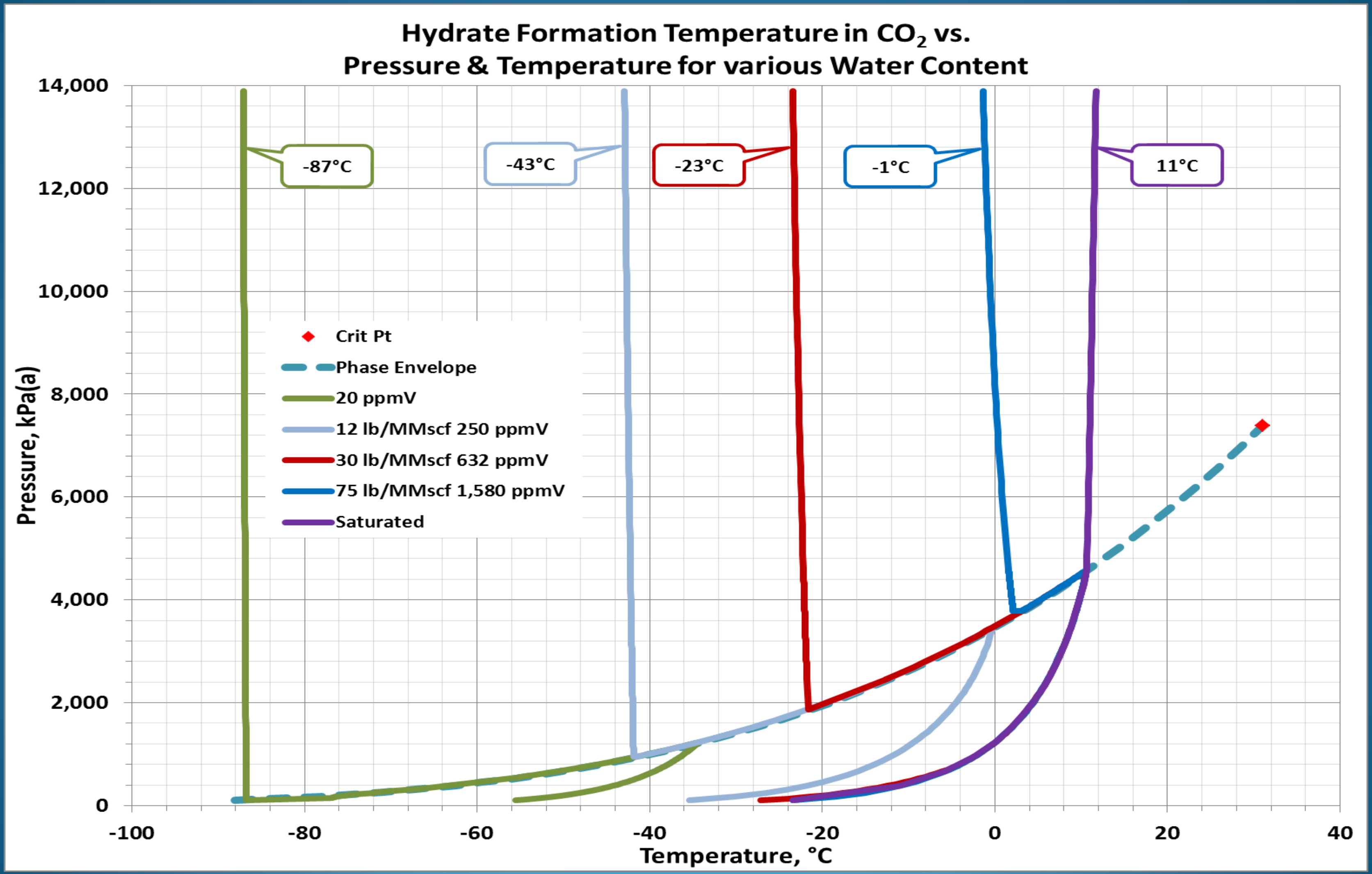
  At some temperature, above the freezing point of water, the water and acid gas will begin to form a solid called a hydrate.

  The Hydrate Formation Temperature and varies according to the pressure, gas composition, and water content of the vapour.

  Hydrates cause reduced heat transfer, excess pressure drops, blockages, and safety concerns.

Why ?

Hydrate Formation



Why ?

Pipeline Spec

- CO_2 pipeline operators impose minimum quality requirements for corrosion control and hydrate prevention

- Kinder Morgan CO_2 Pipeline Spec (June 5, 2008)

Component	Standard
Purity	**95% mole percent of Carbon Dioxide**
Water	**no free water, not more than thirty (30) pounds of water per MMscf in the vapor phase**
Oxygen	**not more than ten (10) parts per million, by weight, of oxygen**
Hydrogen Sulfide	**not more than twenty (20) parts per million, by weight, of hydrogen sulfide**
Total Sulfur	**not more than thirty-five (35) parts per million, by weight, of total sulfur**
Nitrogen	**not more than four mole percent (4%) of nitrogen**
Temperature	not exceed a temperature of 120°F
Hydrocarbons	not more than five mole percent (5%) of hydrocarbons; dew point not higher than -20°F
Other	**not contain more than 0.3 (three tenths) gallons of glycol per MMcf and at no time shall such glycol be present in a liquid state at the pressure and temperature conditions of the pipeline**

Why ?

Pipeline Spec

DNV-RP-J202 - "Design and Operation of CO_2 Pipelines" (April 2010)

- 4.8.3 Limitations on water content

  "… ensure that no free water may occur at any location in the pipeline within the operational and potential upset envelopes and modes, unless corrosion damage is avoided through material selection."

  - normal operation pressure and temperature envelope
    - safety factor of 2 is recommended
  - shut-in pressure combined with minimum ambient temperature
  - depressurization scenario
    - water dropout cannot be prevented without very stringent limits

Water content spec needs to be established according to the local transportation conditions

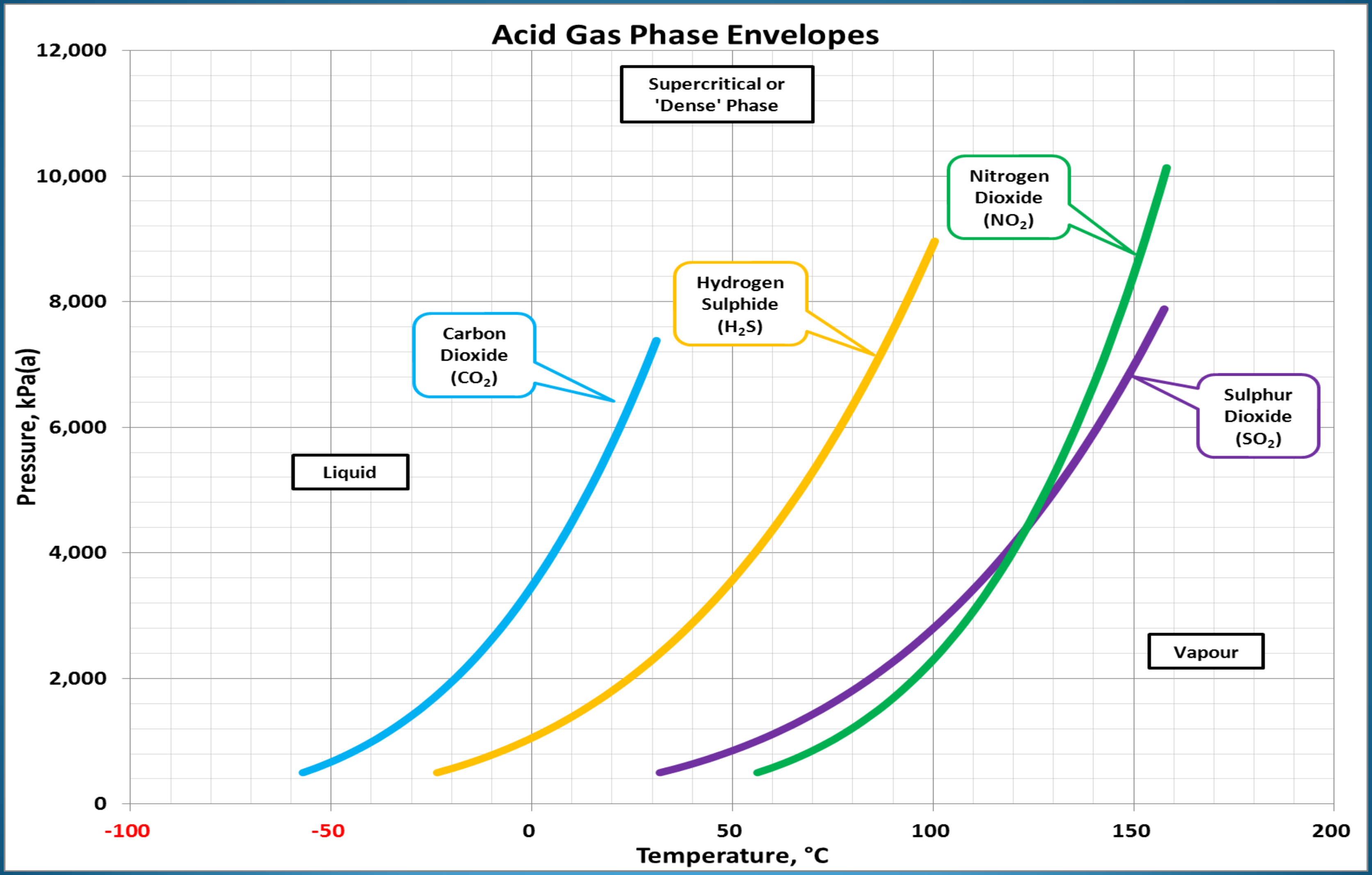
- Piping across the plant site might only require 75 lb/MMscf (1,580 ppm_V)
- Above ground piping in Arctic permafrost may require 12 lb/MMscf (252 ppm_V)

Section 3

How Much Dehydration ?

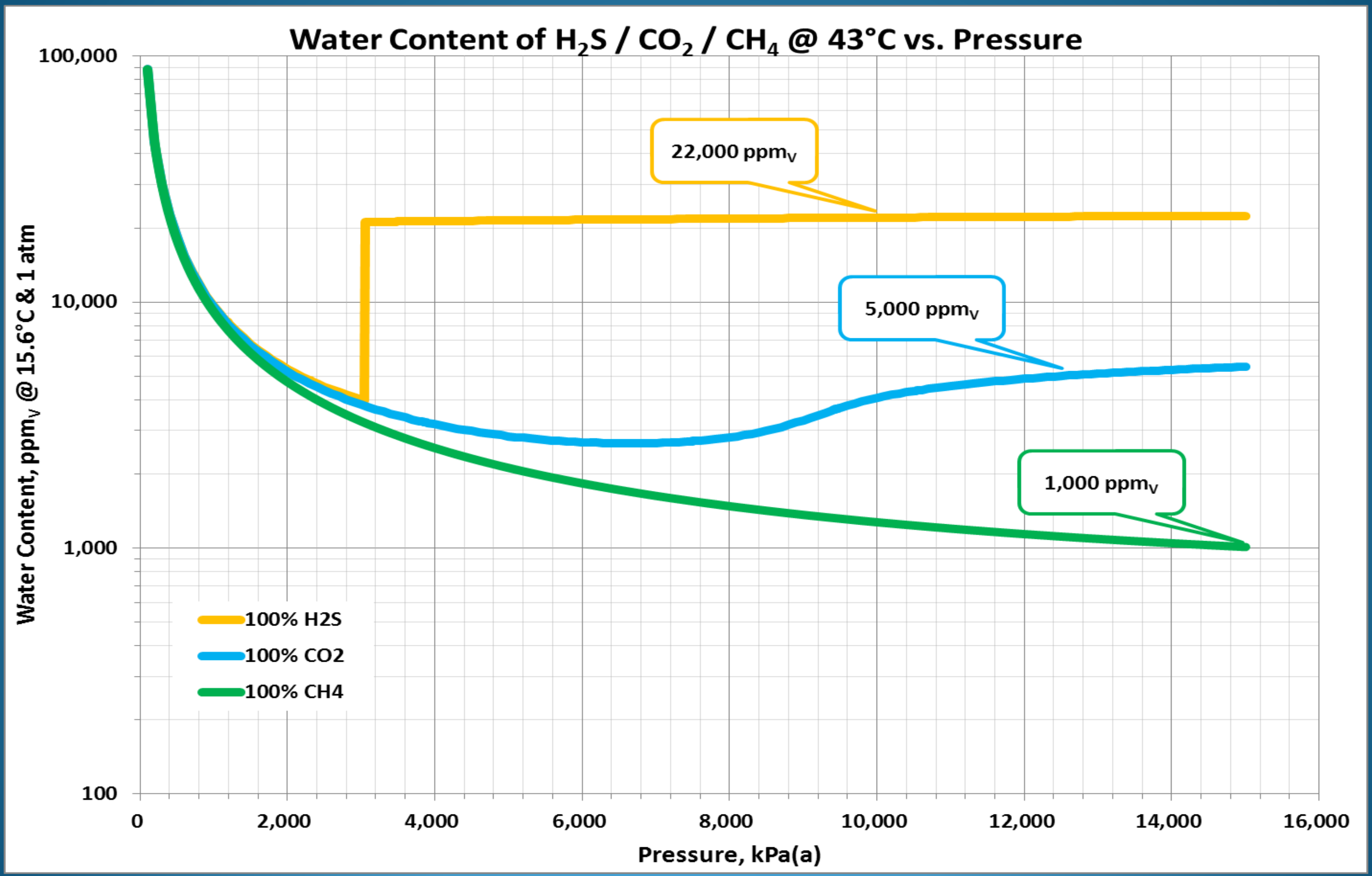
How Much ?

Acid Gas Phase Envelopes



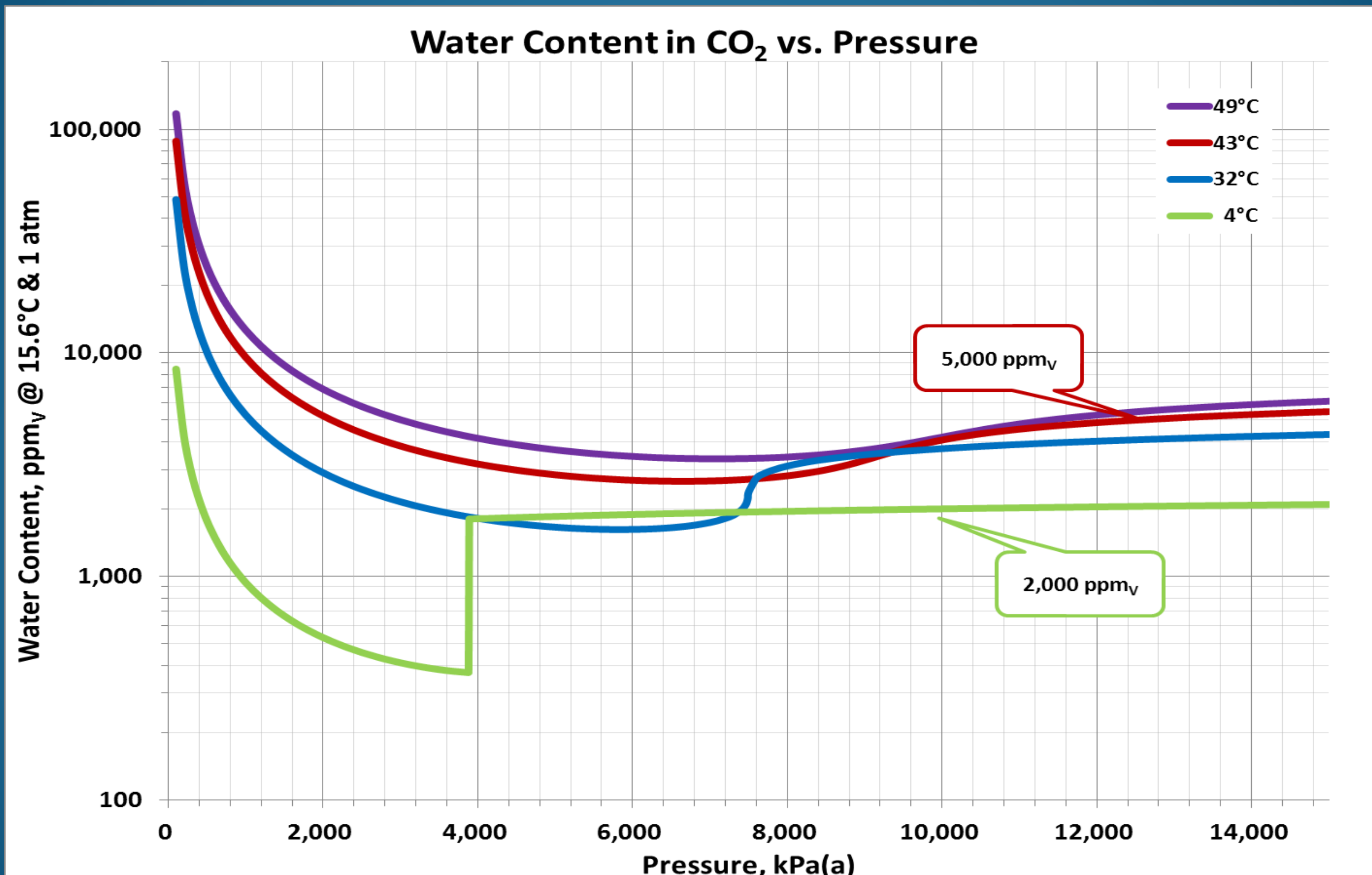
How Much ?

Water Content - AQUAlibrium



How Much ?

Water Content - AQUAlibrium



Section 4

How to Dehydrate ?

How ?

Methods

Compression

- **Water content in vapour is reduced as pressure is increased**

Desiccant

- **Absorption**
  - solid – calcium chloride
  - **liquid** – glycerin, **glycols (TEG)**
- **Adsorption –** gels, alumina**, molecular sieve**

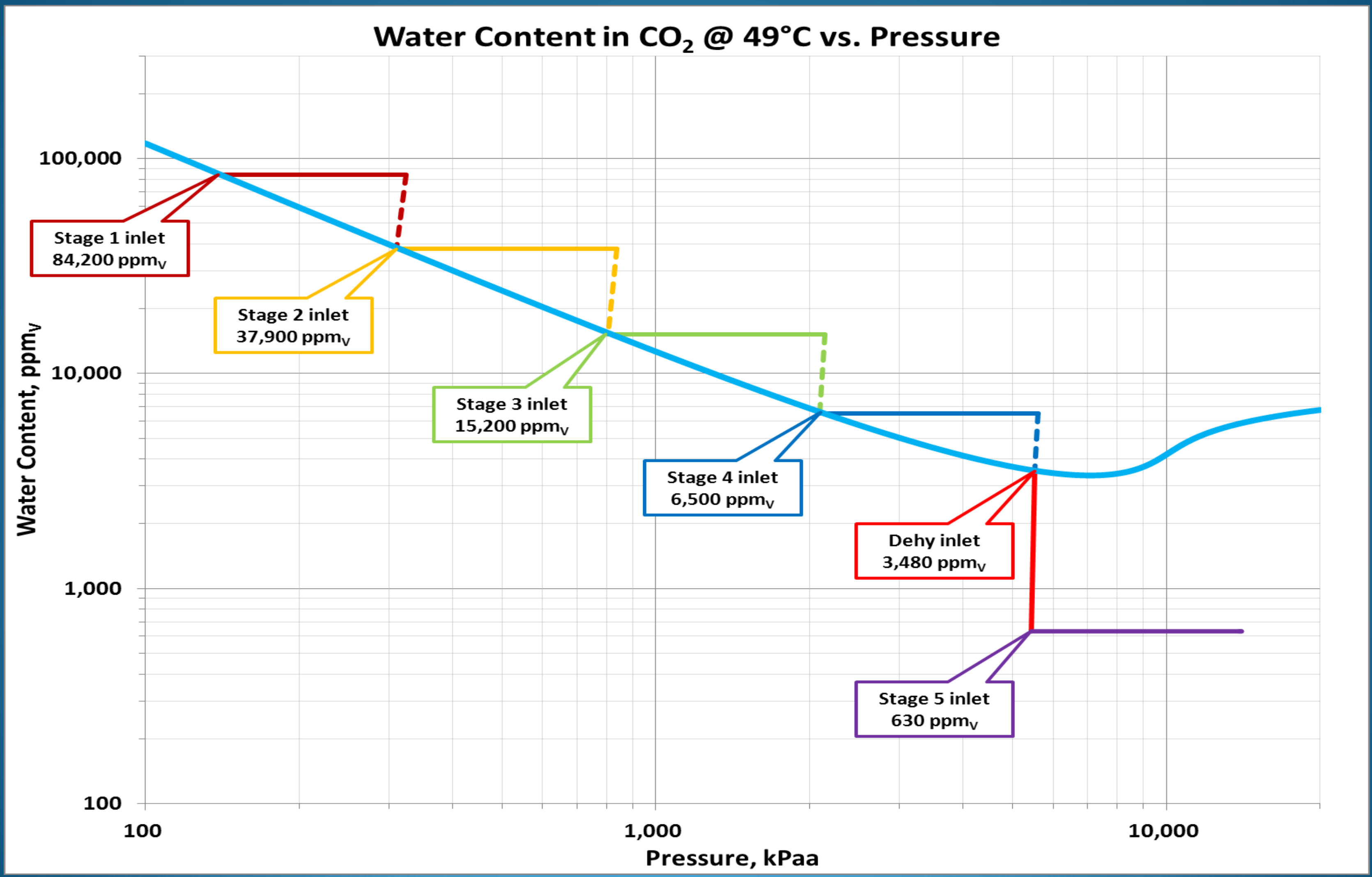
Refrigeration – thermodynamic phase separation

- **External (closed)**
  - **A/C, car, refrigerator, arena, gas plant liquids recovery**
- **Internal (auto-refrigeration)**
  - Choke plant dew point control
  - **DexPro™ (patented)**

Separation – 'mechanical' membrane permeation

How ?

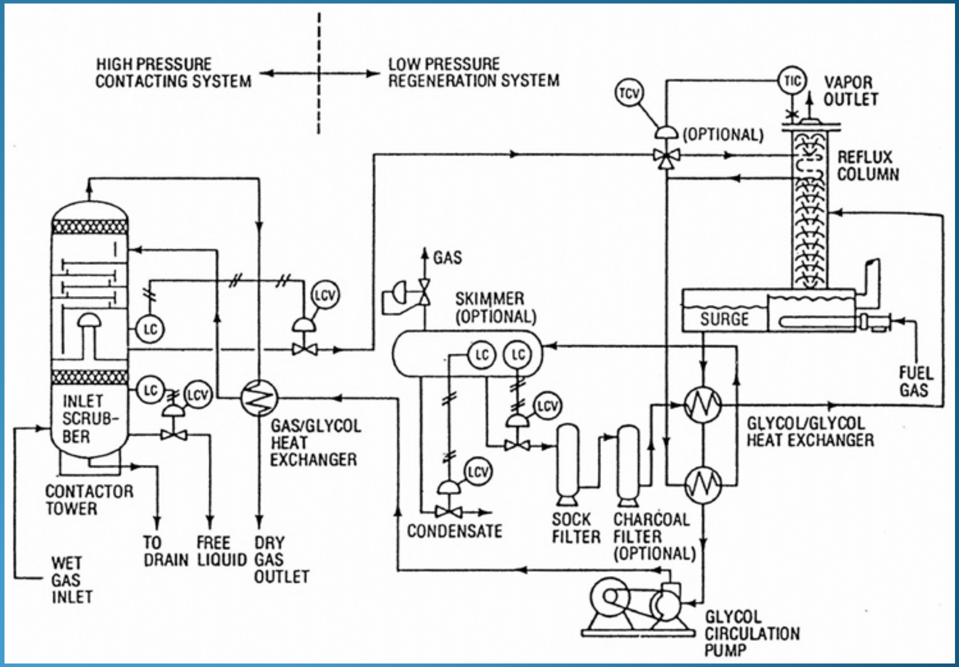
Compression



Absorption

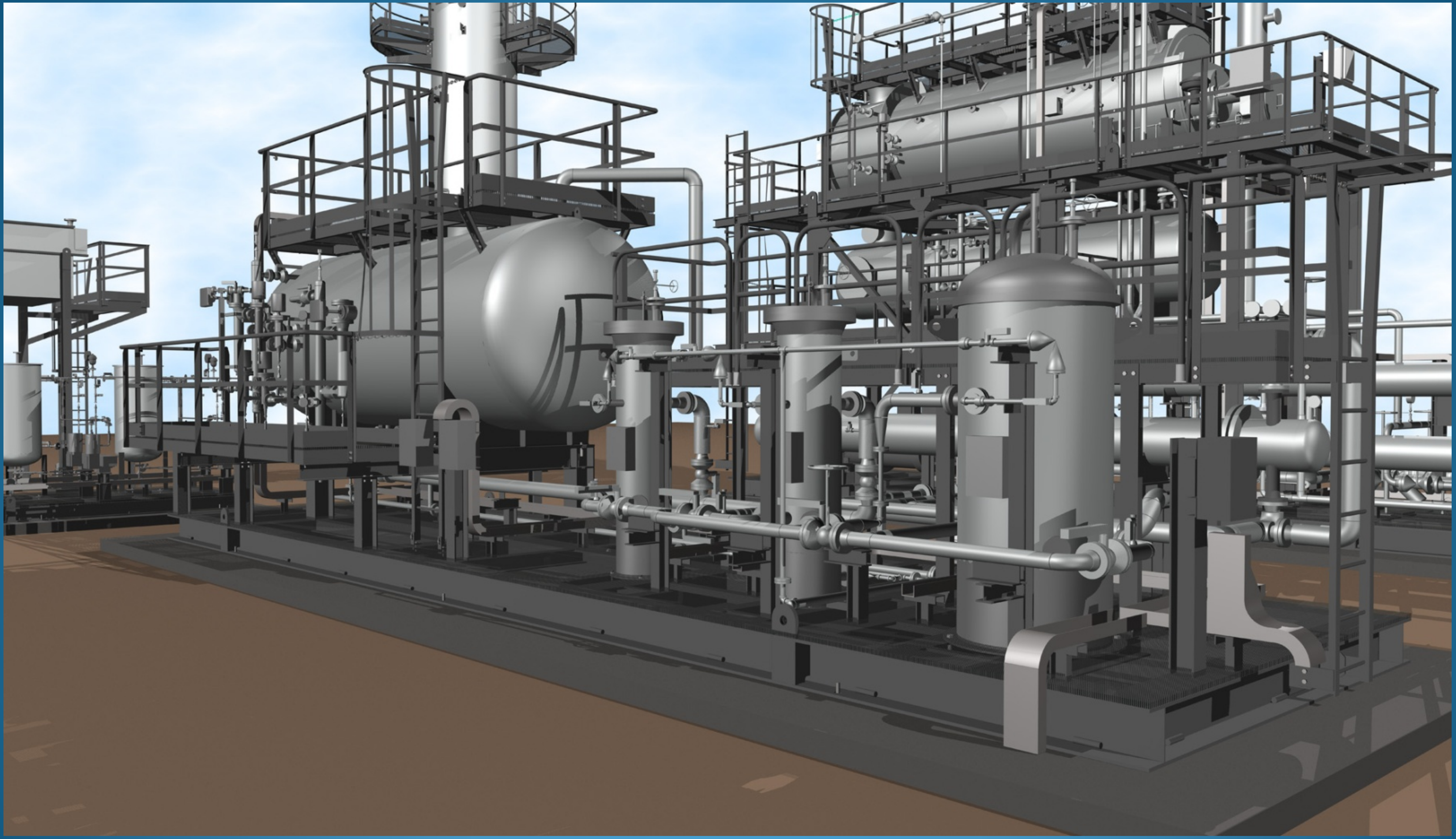
Simplified process overview - glycol

- CO_2 flows from the bottom up through a contactor
- 'dry' glycol flows from the top down through the contactor
- glycol absorbs water from the CO_2 as it flows through the glycol
- water, and other absorbed contaminants, are boiled out of the 'wet' glycol in a reboiler
- 'dry' glycol is recycled back to the contactor



How ?

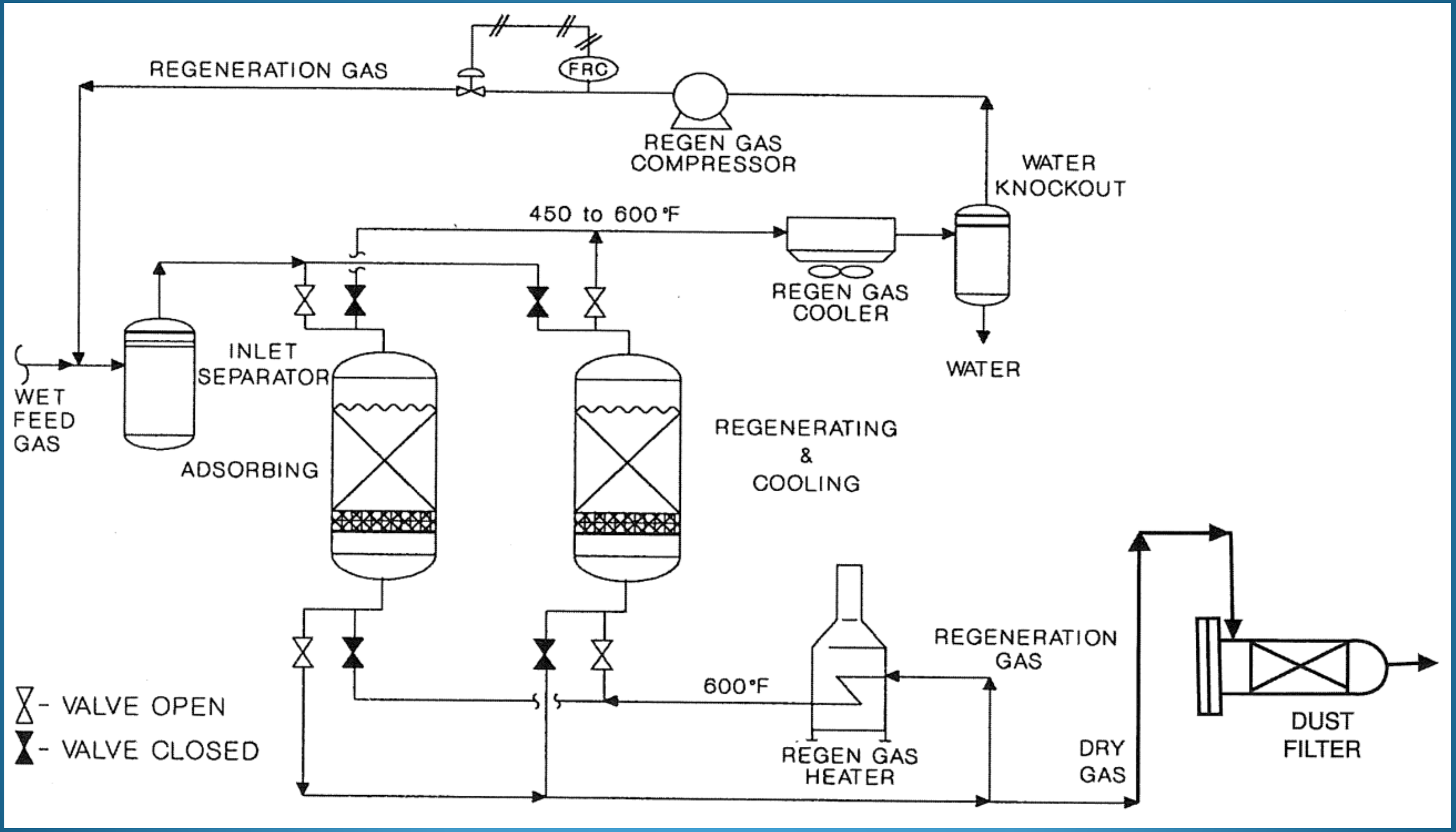
Absorption



Adsorption

Simplified process description - Molecular Sieve

- ‘wet’ CO_2 is dehydrated in one tower while the other tower is regenerating
- gas is heated up to 315 degC and reversed to regenerate the tower



How ?

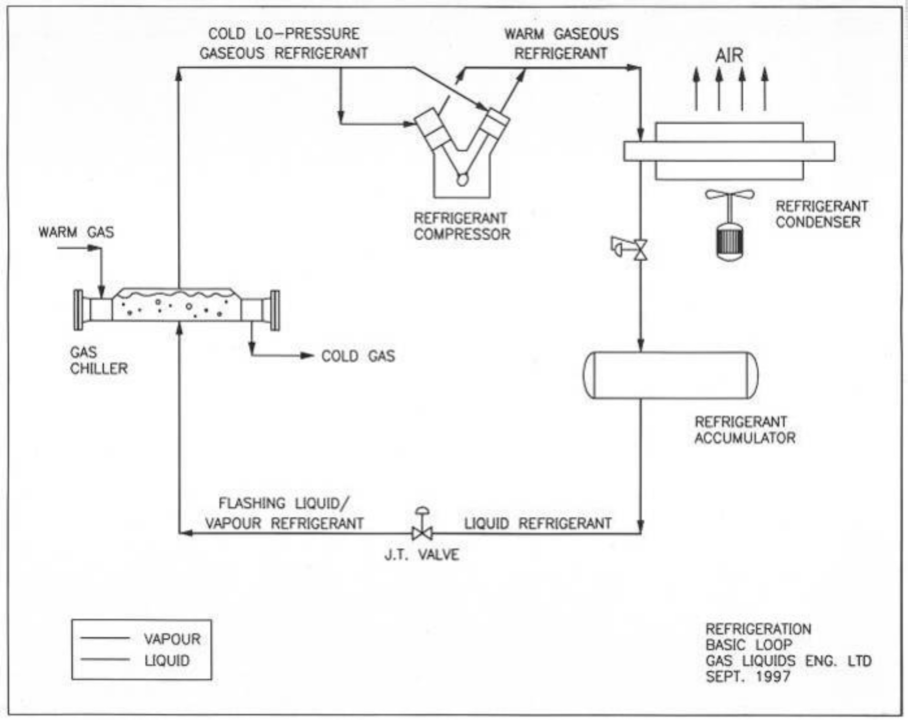
Adsorption

How ?

Refrigeration - external

Simplified process description

- **Condenser**
  - refrigerant is condensed to liquid
- **Expansion**
  - liquid refrigerant is expanded across a JT valve to desired temperature
- **Evaporator (chiller)**
  - cold refrigerant absorbs heat from CO_2 and evaporates refrigerant
- **Compressor**
  - refrigerant vapour is recompressed to desired cycle pressure and returned to condenser

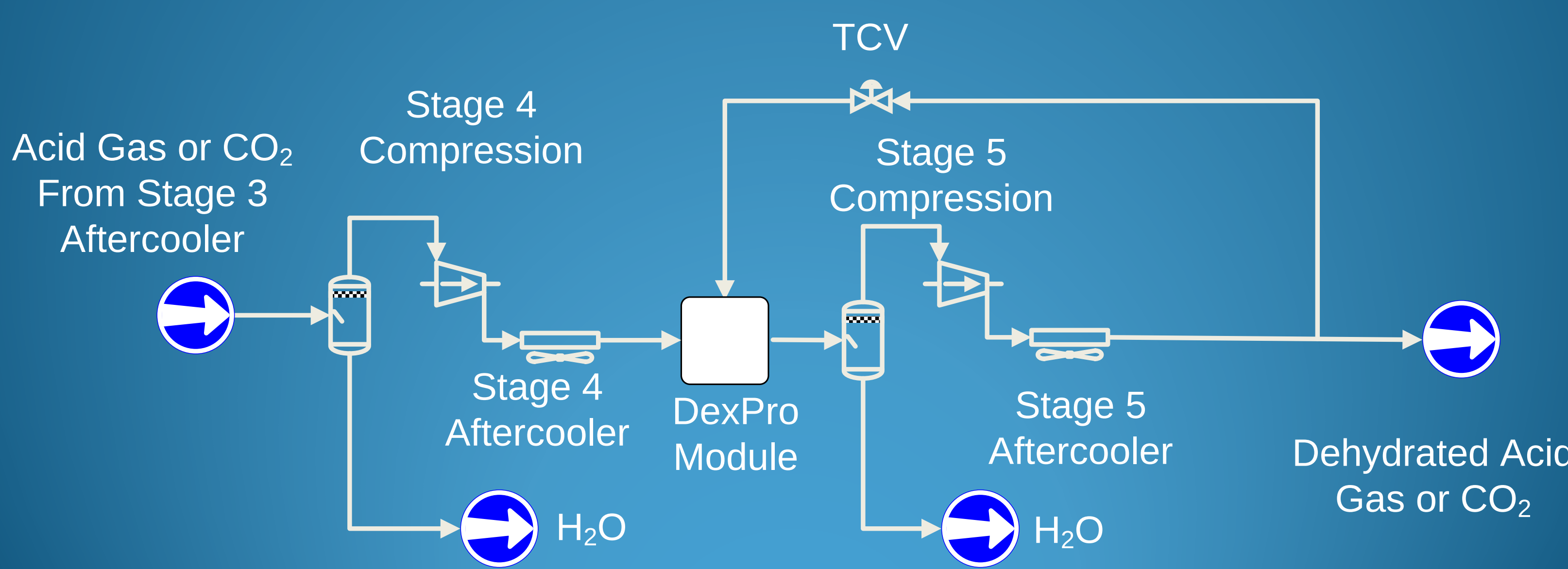


How ?

DexPro™

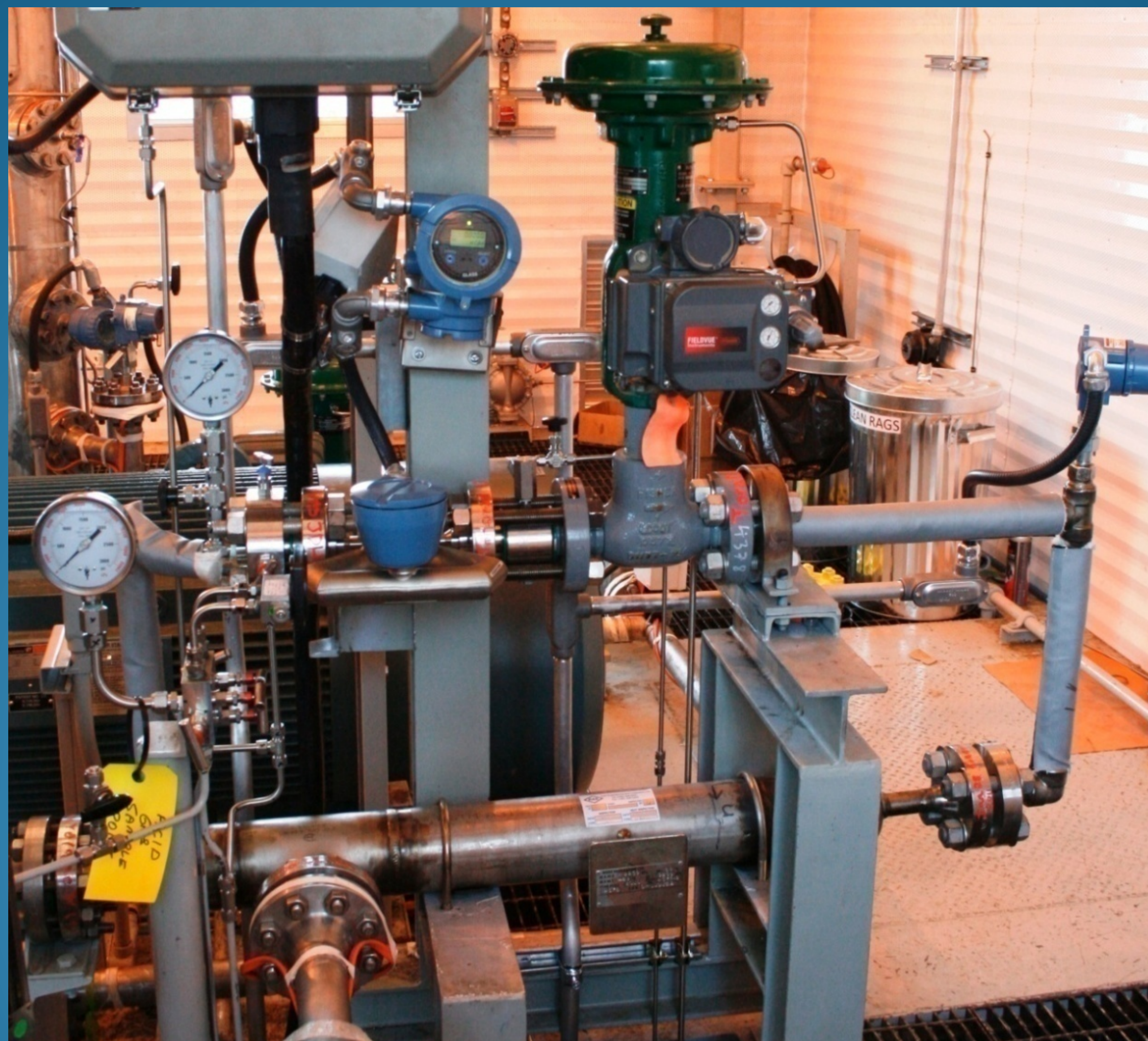
Simplified process description - DexPro™

- **TCV or JTV (Joule-Thomson Valve)**
  - Cools a small slip stream of Dry acid gas by reducing the pressure (expansion)
- **DexPro™ Module**
  - Cold Dry Acid Gas mixes with Wet acid gas in the DexPro Module
- **Stage 5 Suction Scrubber/Compressor/Cooler**
  - Condensed water from the DexPro Module is removed in suction scrubber
  - Cool Dry acid gas increases fluid compression efficiency



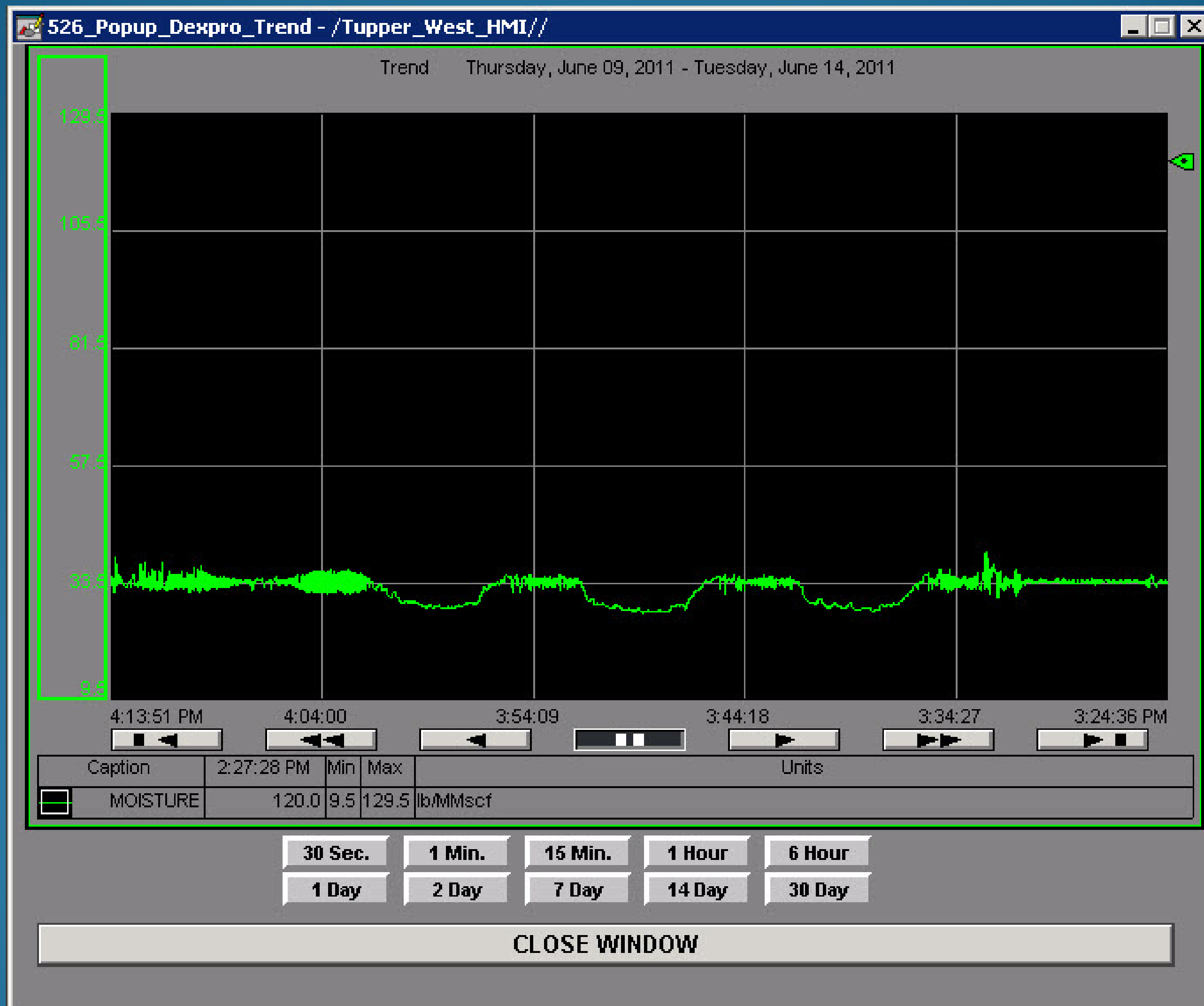
How ?

DexPro™



How ?

DexPro™


526_Popup_Dexpro_Trend - /Tupper_West_HMI//
Trend Thursday, June 09, 2011 - Tuesday, June 14, 2011
129.5
105.5
81.5
57.5
33.5
9.5
4:13:51 PM
4:04:00
3:54:09
3:44:18
3:34:27
3:24:36 PM
Caption
2:27:28 PM
Min
Max
Units
MOISTURE
120.0
9.5
129.5
lb/MMscf
30 Sec.
1 Min.
15 Min.
1 Hour
6 Hour
1 Day
2 Day
7 Day
14 Day
30 Day
CLOSE WINDOW

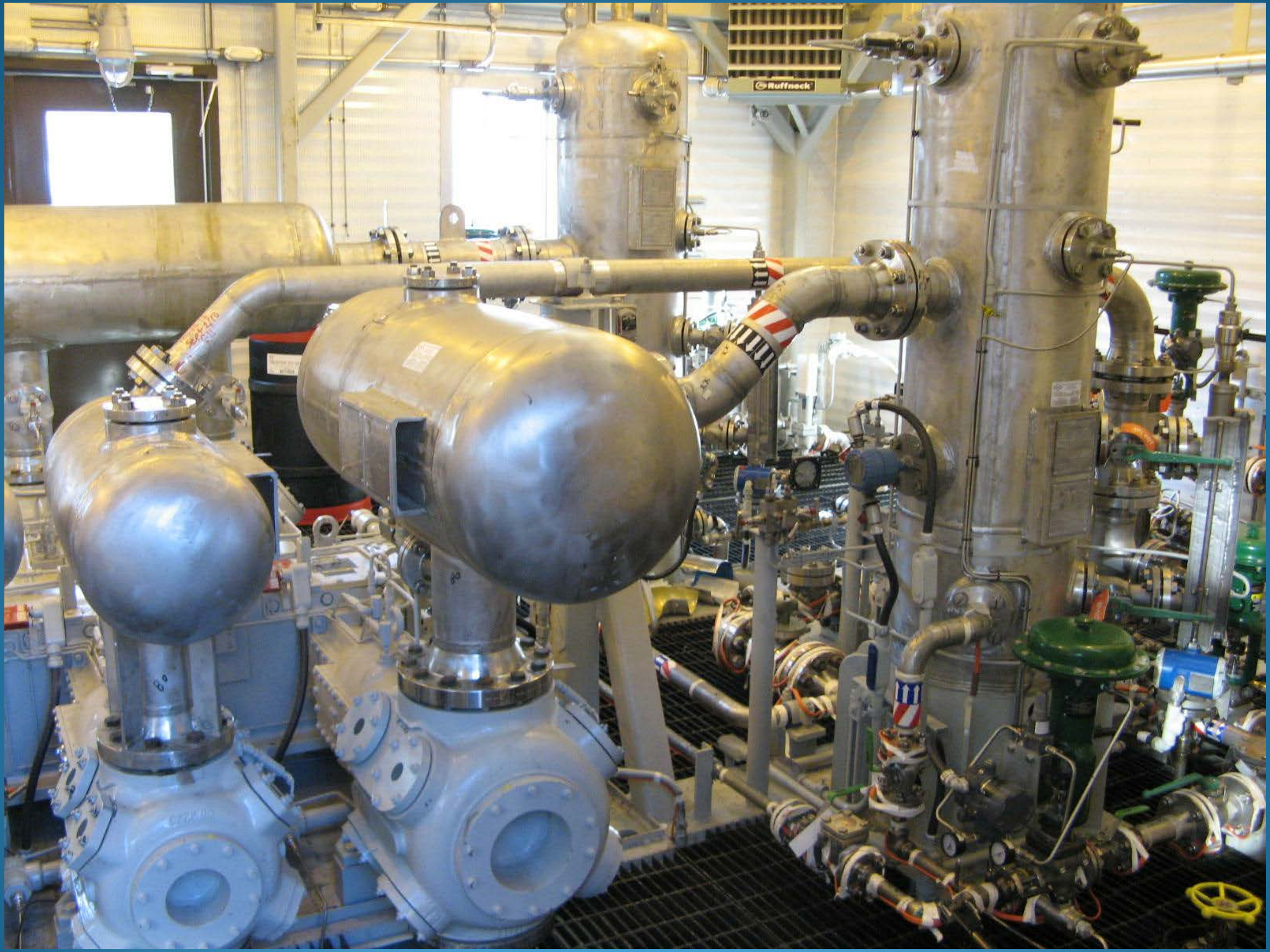
How ?

DexPro™


ISOLATE FROM VACUUM BEFORE SERVICING ANALYZER
AMETEK
5100
CO2
AMETEK
PROCESS INSTRUMENTS

How ?

DexPro™

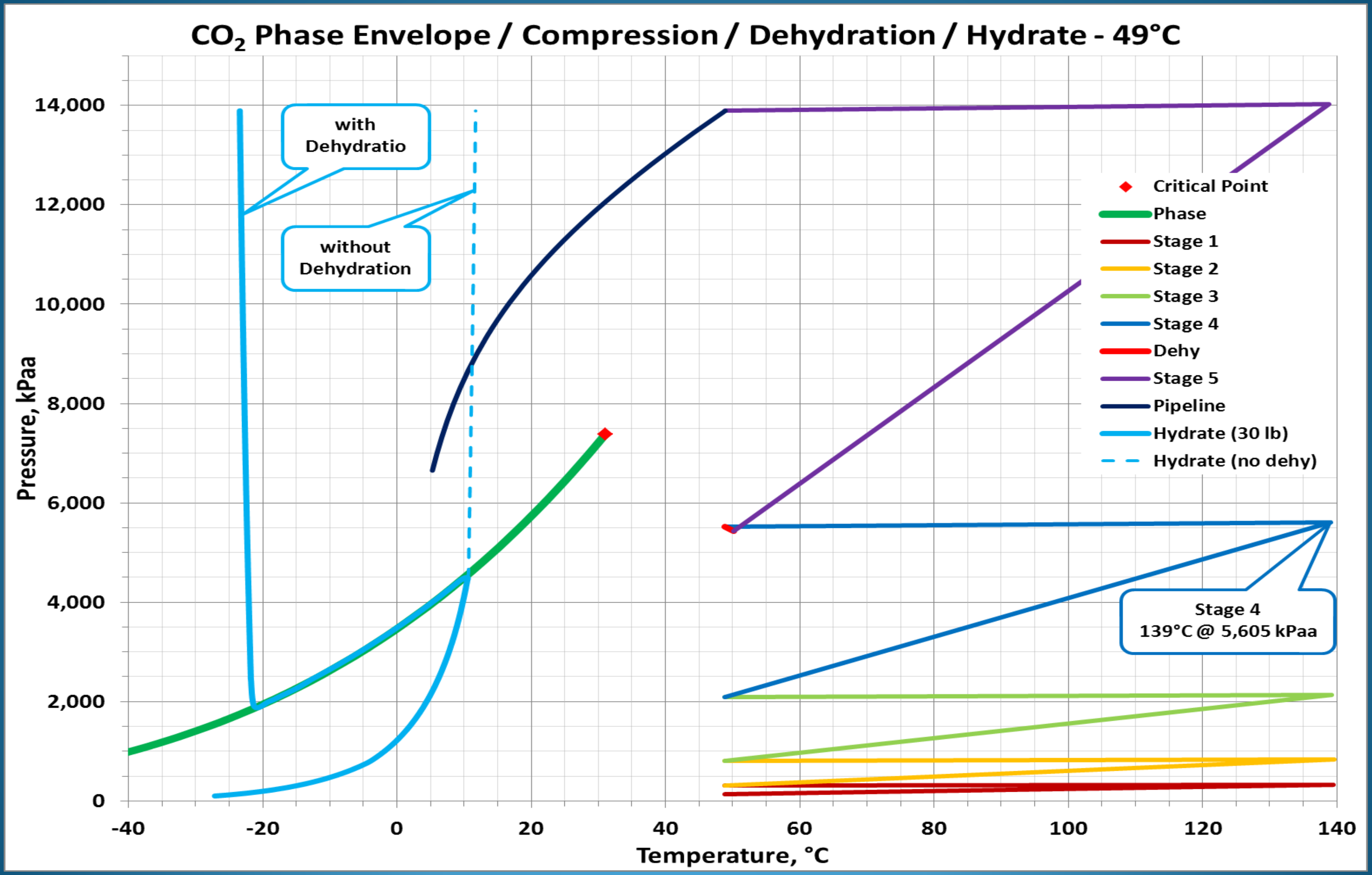


Section 5

How do they Compare ?

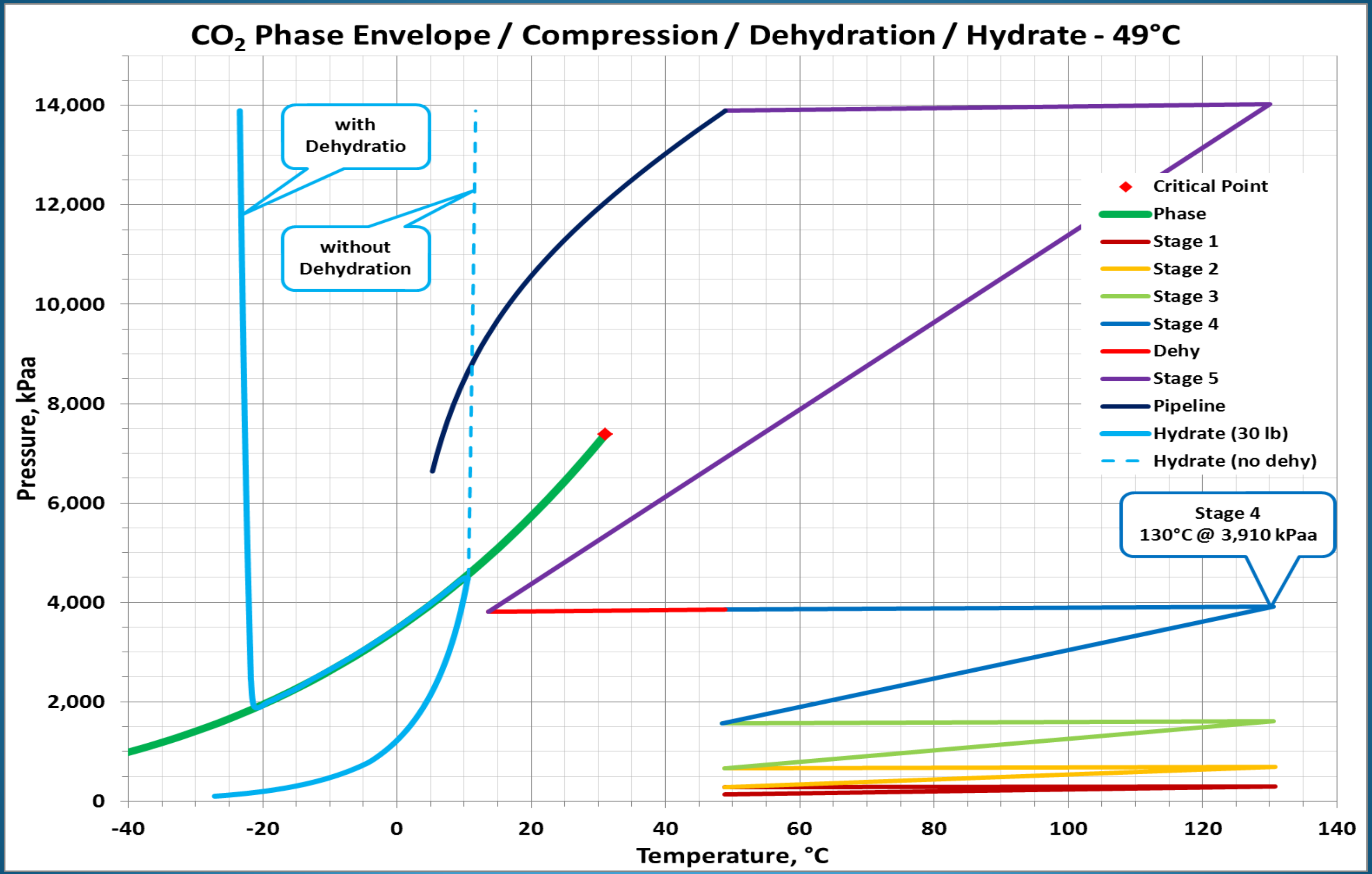
Compare ?

Glycol & Molecular Sieve Dehydration – 49°C



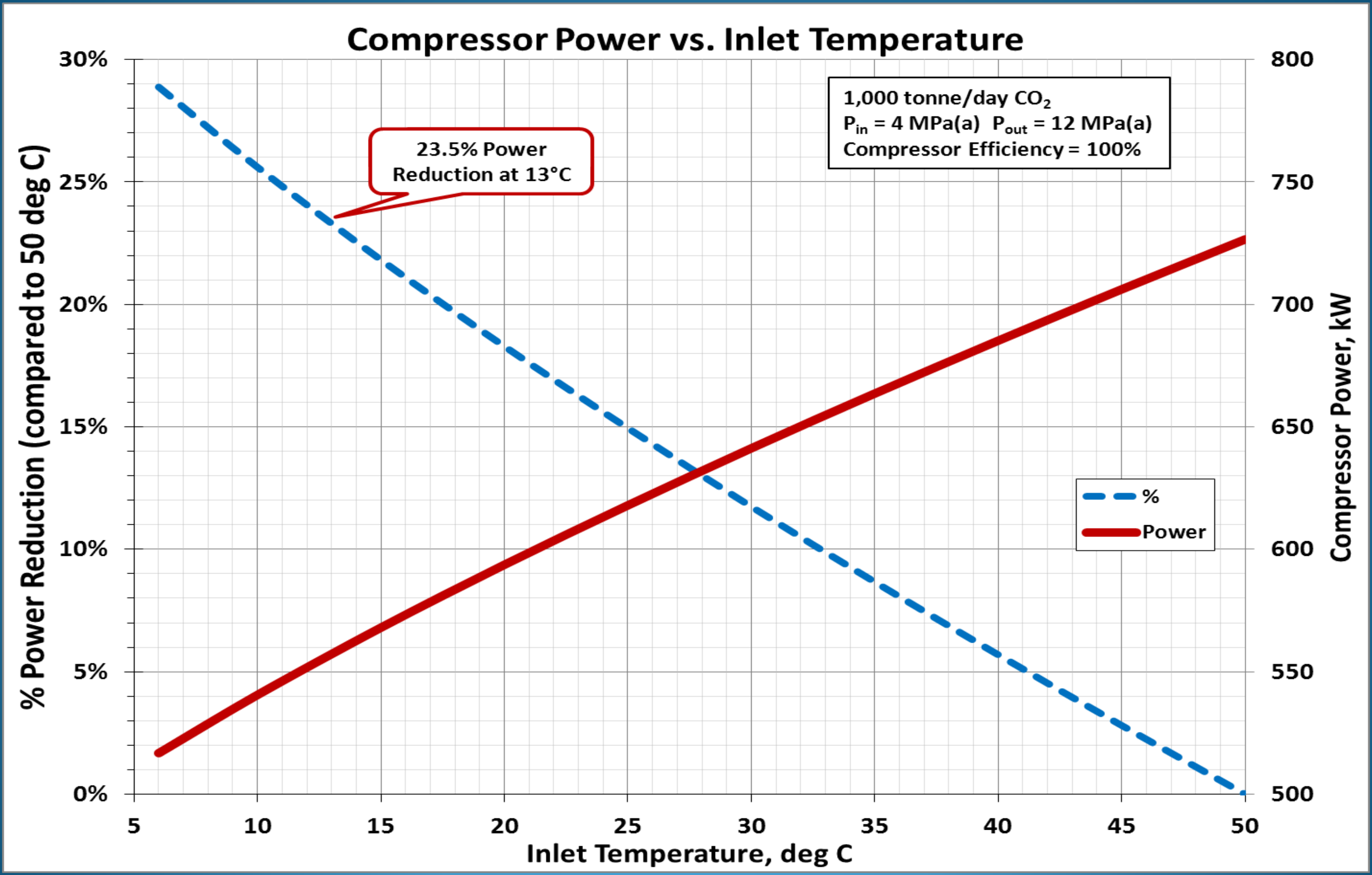
Compare ?

Refrigeration & DexPro™ – 49°C



Compare ?

Compressor Performance vs. Inlet Temperature



Compare ?

Example Case

- 1,000 tonne/day → 538,300 Sm^3/d of dry CO_2
- water saturated at 48°C @ 40 kPa(g)
- pipeline inlet design pressure → 13,800 kPa(g)
- 4 compression (centrifugal) stages
- inter-stage / after-cooling between compressor stages
  - 40°C process (CO_2)
- 632 ppm_V dehydration requirement (30 lb/MMscf)
  - ~-20°C hydrate formation temperature

Compare ?

Process

			No Dehydration	Triethylene Glycol	External Refrigeration	DexPro™
Compression	main	hp_{gas}	*5,469.9*	5,494.0	5,256.8	5,539.0
	refrigeration	hp_{gas}			163.3	
		total	***5,469.9***	**5,494.0**	**5,420.1**	**5,539.0**
				0.44%	***-0.91%***	***1.26%***
Cooling Water	main	gpm_{US}	*1,441*	1,446	1,340	1,447
	condenser	gpm_{US}			94	
		total	***1,441.0***	**1,446.0**	**1,434.0**	**1,447.0**
				0.35%	***-0.49%***	***0.42%***
Heat	regenerator	btu/hr		**80,257**		
Regenerator Vent	CO_2	t/yr		135.2		
	Water	t/yr		280.6		
	Glycol	lb/yr		41.0		
Glycol losses	pipeline	lb/yr		17,788.9		
	vent	lb/yr		41.0		
Methanol losses	pipeline	lb/hr			23.2	
		bbl/d			2.0	

Horsepower

Cooling

Regeneration

Still Vent

TEG losses

MeOH losses

Compare ?

Size

TEG Dehy	Weight
30" Contactor	6,500
Still Column	200
Vent	200
Flash Tank	500
Reboiler/Surge	1,000
Piping	1,450
Skid	1,700
Wiring	200
Glycol	3,000
miscellaneous	250
Total (kg.)	**15,000**
tonne	**15.0**
	Size
Height	9.2 m.
Length	4.3 m.
Width	2.4 m.
Footprint (m^2)	**10.3**

DexPro™	Weight
DexPro™ Module	350
Regulators	10
Analyzer	75
Control Panel	65
Pump/motor	50
Frame	75
Instruments	50
Wiring	200
miscellaneous	125
Total (kg.)	**1,000**
tonne	**1.0**
	Size
Height	1.8 m.
Length	1.8 m.
Width	0.6 m.
Footprint (m^2)	**1.1**

Lowest Weight

Lowest Area

Compare ?

Economics

		No Dehydration	Triethylene Glycol	External Refrigeration	DexPro™
Dehydration Capital Cost	**installed**	$ -	**$ 2,100,000**	**$ 1,350,000**	**$ 600,000**
Annual Operating Cost					
Compression	$70/MWhr	$ 2,502,206	$ 2,513,218	$ 2,479,409	$ 2,533,788
Triethylene Glycol	$1.00/lb	$ -	$ 843	$ -	$ -
Methanol	$0.25/lb	$ -	$ -	$ 50,812	$ -
Annual Maintenance Cost			$ 210,000	$ 135,000	$ 6,000
Total Annual Cost		$ 2,502,206	**$ 2,724,061**	**$ 2,665,221**	**$ 2,539,788**
Present Value of Operating Cost		$ 26,508,403	**$28,858,740**	**$28,235,388**	**$26,906,550**
discount rate	*7%*				
term (years)	*20*				
	TOTAL NPV	$ 26,508,403	**$30,958,740**	**$29,585,388**	**$27,506,550**
	difference	$ -	**$ 4,450,337**	**$ 3,076,986**	**$ 998,147**

Lowest CAPEX

Lowest OPEX

Best NPV

- DexPro™ capital cost does not reflect one time license fee

How ?

DexPro™

DexPro™ has a number of key advantages

- Lowest capital cost (CAPEX)
- Lowest operating cost (OPEX)
- Best economics (NPV)
- No rotating equipment
- Simplicity of process and equipment
- Extreme turndown
- No fugitive emissions or off-gas handling requirement
- Very small environmental footprint
- Very small physical footprint

QUESTIONS ?

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