

Industrial Scale Carbon Capture Technology Testing at TCM: Results using CESAR 1

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Agenda

➤ Introduction

➤ Results

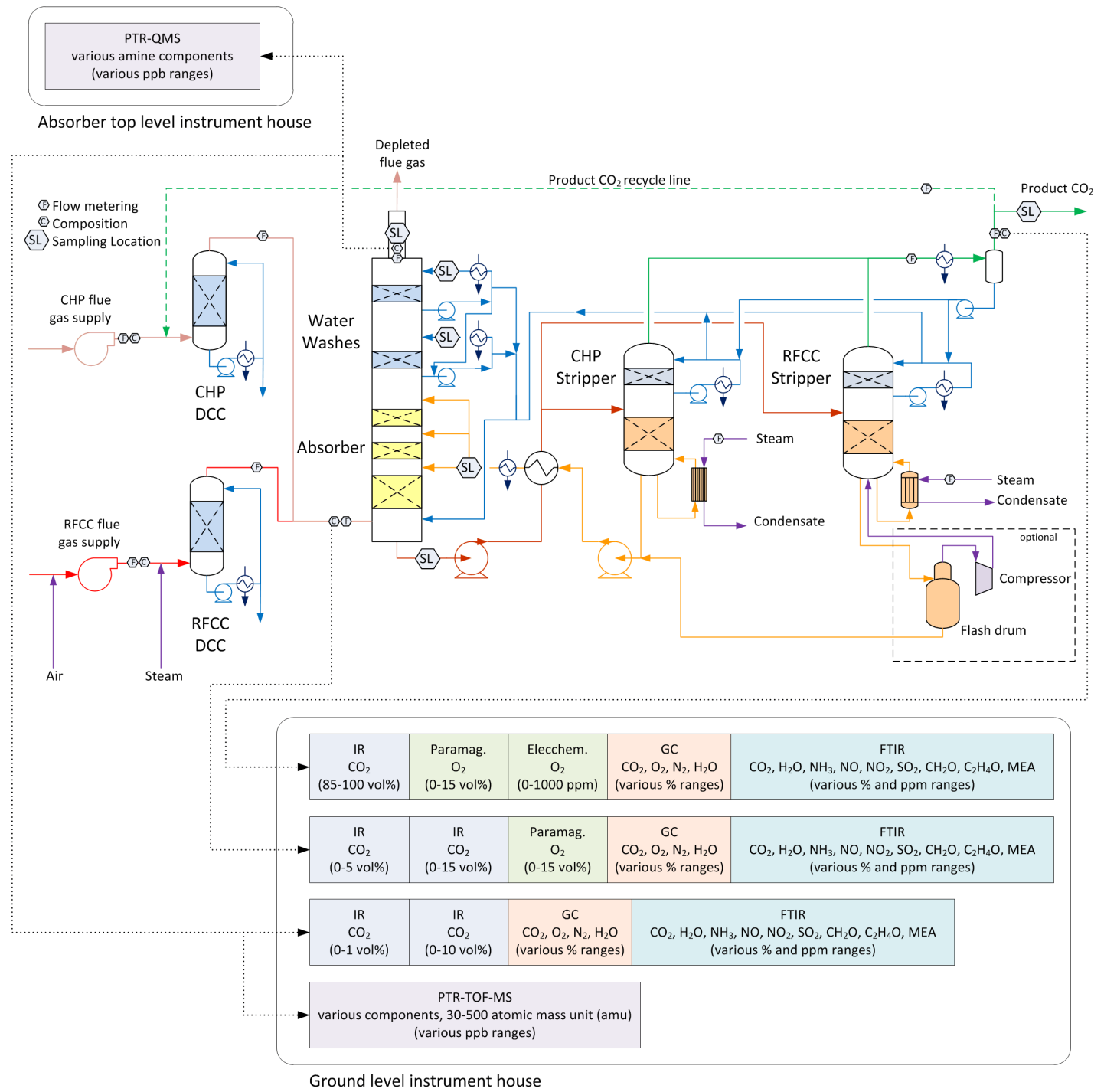
➤ Conclusions



Introduction



75,000 tons CO₂ per year

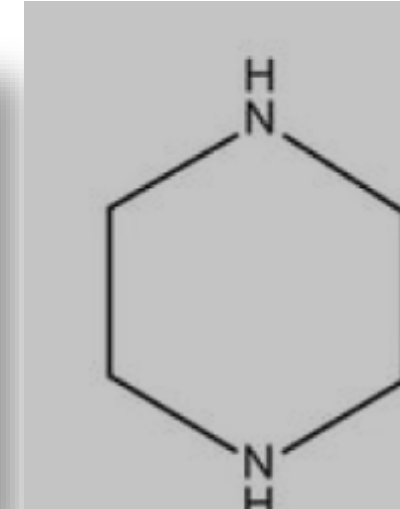
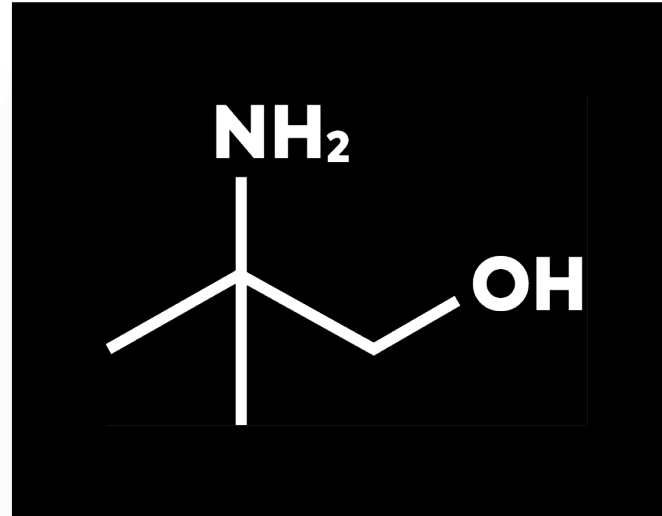


TCM flue gas

Component	RFCC	MHP
CO ₂ (%)	15.7	9.9
O ₂ (%)	2.5-3.5	3.8
H ₂ O (%)	5.5-7.5	6.2
NO ₂ (NO _x) (ppmv)	0.5-1.5	15 - 20
NH ₃ (ppmv)	0.2	0.2 (ppm(d))
Total particle no. (TN) (#/cm ³)	7.9 - 9.5 X 10⁴	-

CESAR 1

Blended aqueous amine solution: **AMP** + **PZ**



Component	MW	Molarity (M)	Wt%
AMP	89.1	3	27
PZ	86.1	1.5	13
H ₂ O	18.0	33.3	60

Solvent Precipitation



Solvent Precipitation: History

- During Align-CCUS and two TCM internal testing campaigns (2019-2020), solvent precipitation was a significant operation challenge

CO ₂ conc. (vol%)	Flue gas temp., °C	Lean solvent temp., °C	Rich loading (mol/mol amine)
3 – 4	30	40	0.35- 0.45
10	37	40	0.4 - 0.43
13 – 15	40	40	0.35 -0.4
14.6	40	57	0.48

CESAR 1 Solvent Precipitation was seen over wide range of conditions

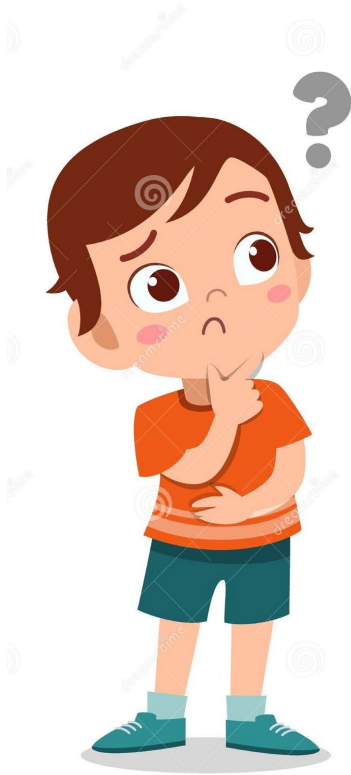
Solvent Precipitation: Present

CO ₂ conc. (vol%)	Flue gas temp., °C	Lean solvent temp., °C	Rich loading (mol/mol amine)
8 -10	30-35	40	0.59 - 0.635
13-15	30-35	35, 40, 45	0.59 - 0.69
18	35	35, 40	0.63 - 0.67

CESAR 1 Solvent Precipitation was **NOT** seen over wide range of conditions

Solvent Precipitation: Present

CESAR 1 Solvent Precipitation was **NOT** seen over wide range of conditions



Preliminary observation

Methyl-AMP	
Align-CCUS, TCM mg/kg	Aurora mg/kg
9000 - 12000	6000

- Detailed solvent analysis is undergoing
- Are there any other markers to facilitate/initiate Precipitation ?

Performance

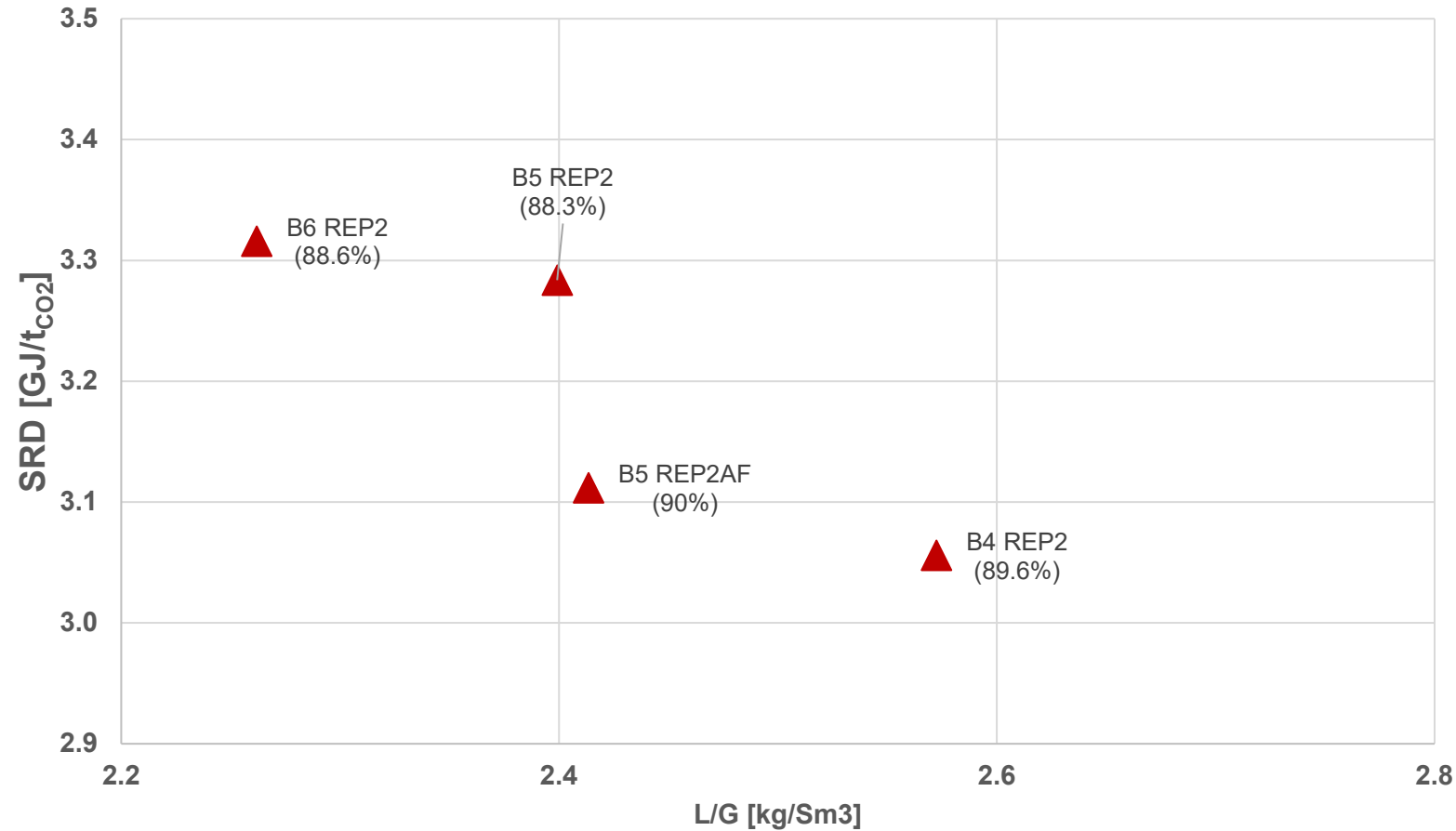


Key Terms

- ❑ CO₂ capture rate (%)
- ❑ CO₂ Loading, α : **moles of CO₂/mole of amine**
- ❑ Amine concentration : wt% or Molarity (**moles of amine /Litre solution**)
- ❑ SRD: Specific reboiler duty, **GJ/Ton CO₂**

RFCC baseline 2020

- ❑ 14 mol% (dry) CO₂ in flue gas
- ❑ 18m packing height, 90% target capture rate
- ❑ Upper, lower and RFCC water wash in operation.
- ❑ Flue gas temperature 40°C
- ❑ SRD of 3.07 GJ/t_{CO2}



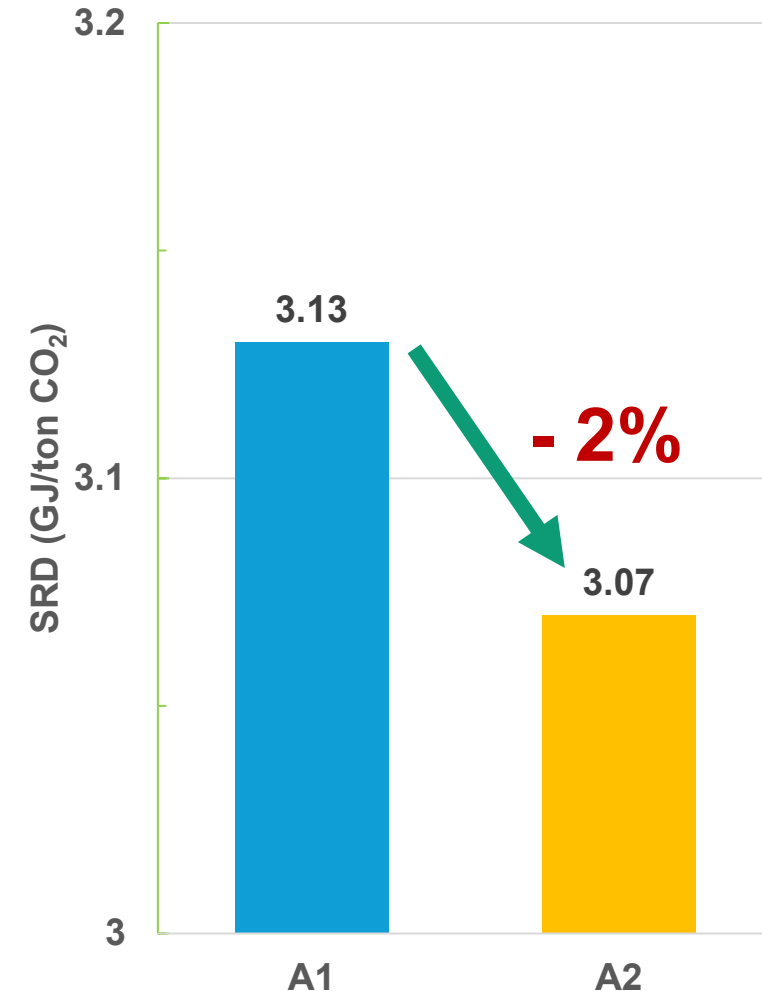
RFCC testing 2025 – Aurora

intercooling effect

☐ Good reproductivity of the EPRI Baseline (2020)

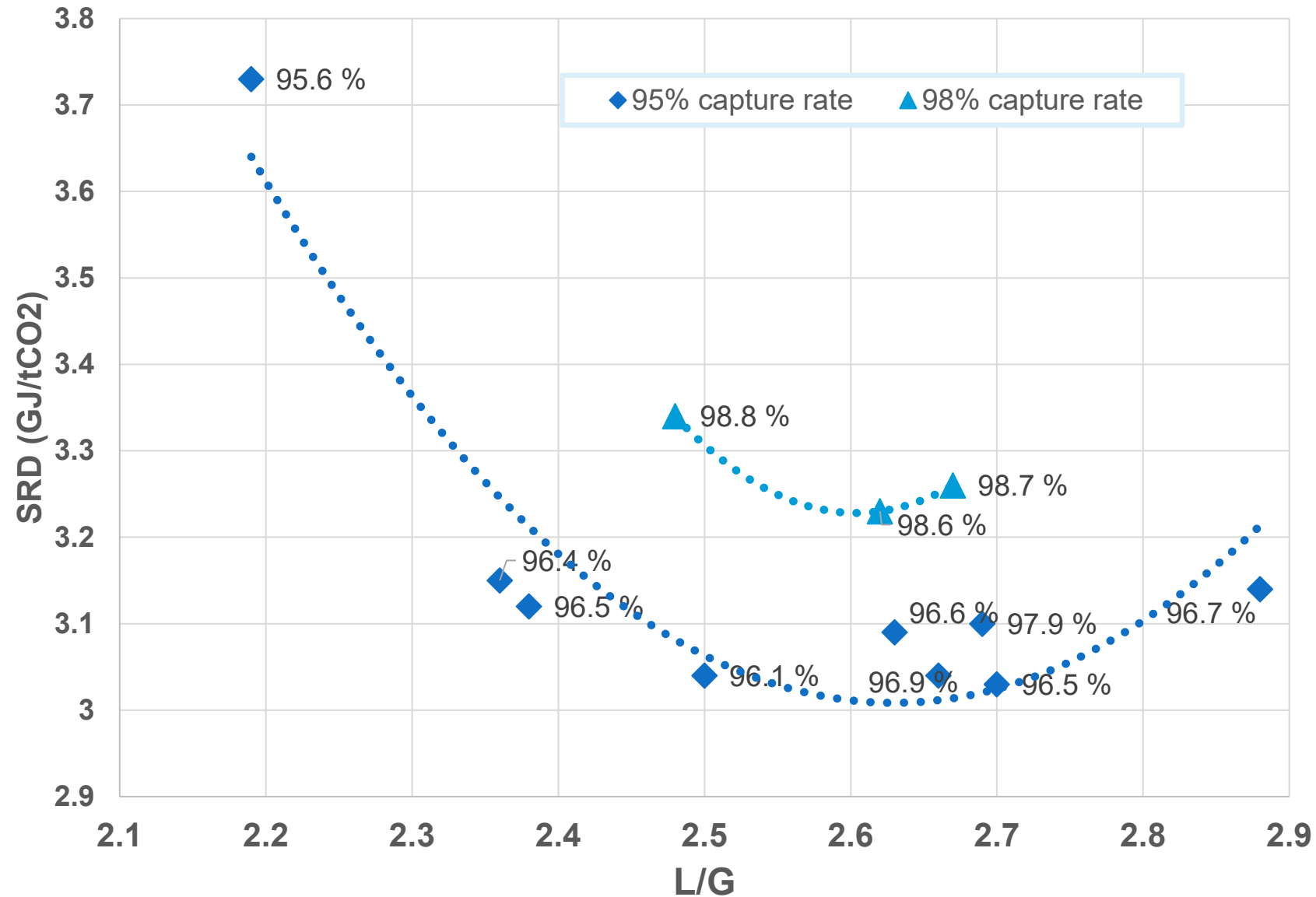
☐ 18m packing height

	2020	2025	
	EPRI Baseline	Test A1	Test A2
L/G	2,7	2,7	2,7
SRD(GJ/tCO ₂)	3,23	3,13	3,07
Capture rate (%)	91	92	92
Intercooling	NO	NO	YES

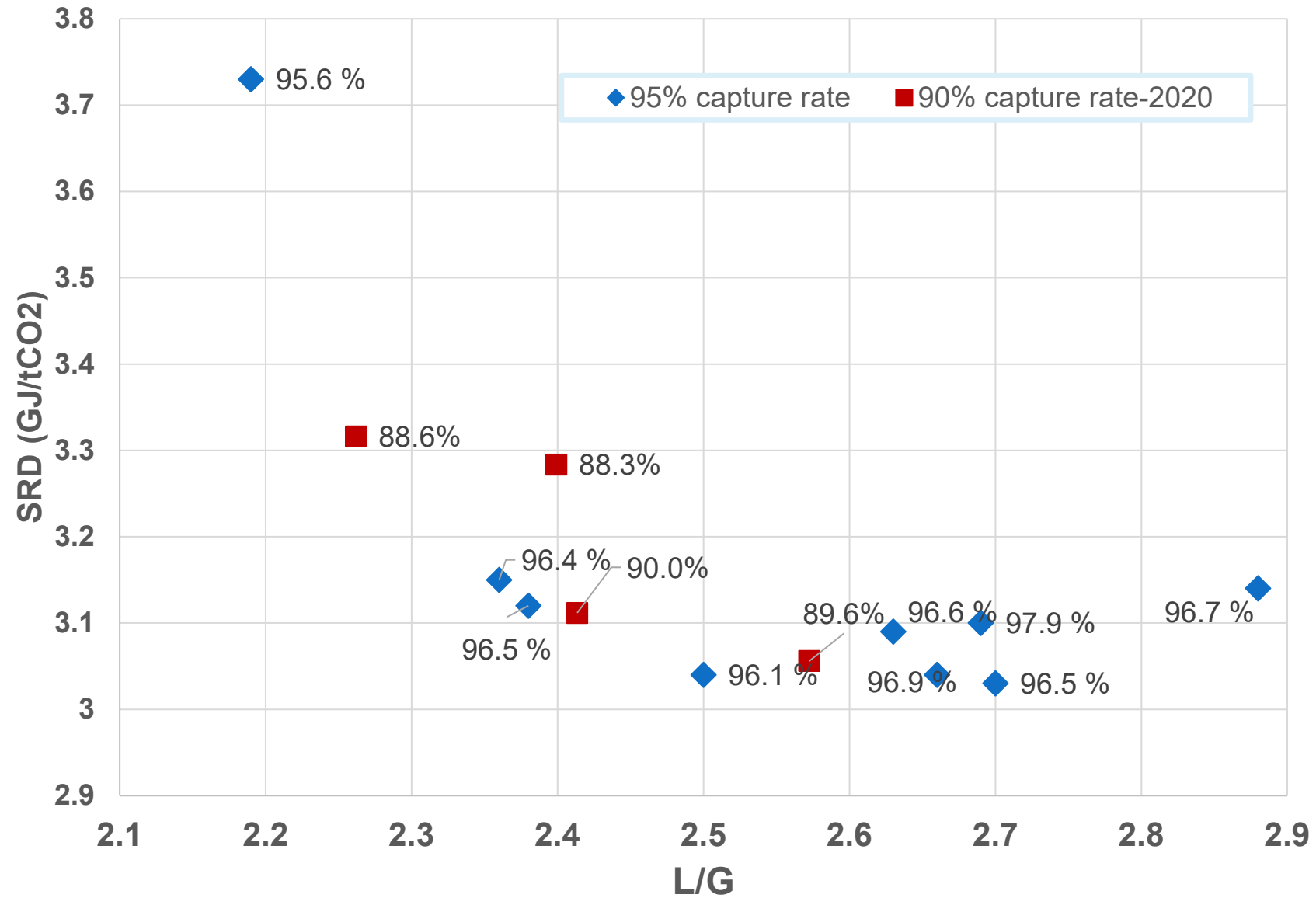


RFCC testing 2025 - Aurora

- 15 mol% (dry) CO₂ in flue gas
- 18m packing height
- Upper, lower and RFCC water wash in operation.
- Flue gas temperature 30°C



RFCC testing 2020 VS 2025



Take away message

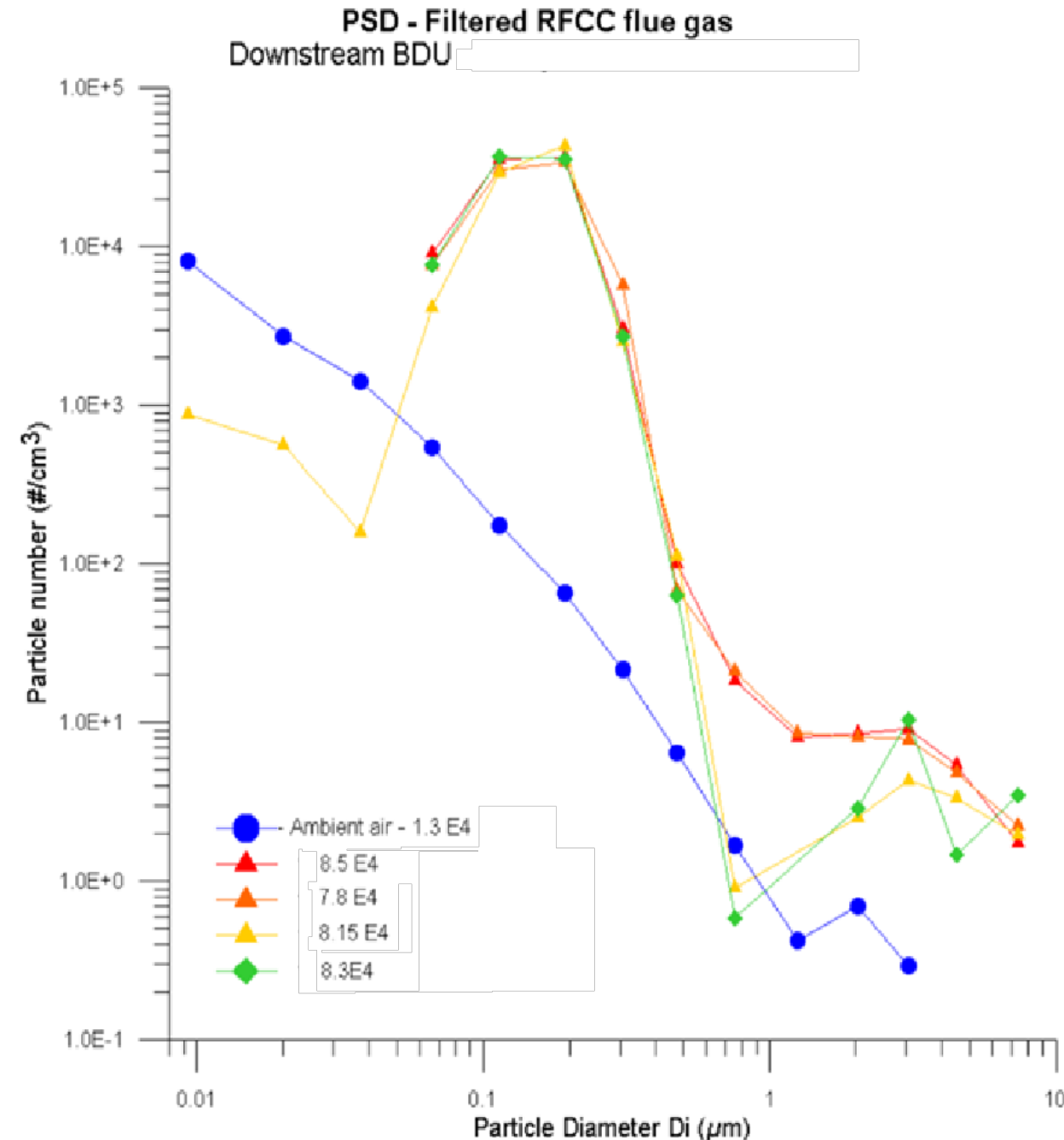
**CESAR 1 without precipitation performs
much better than previous experience**

Emission mitigation

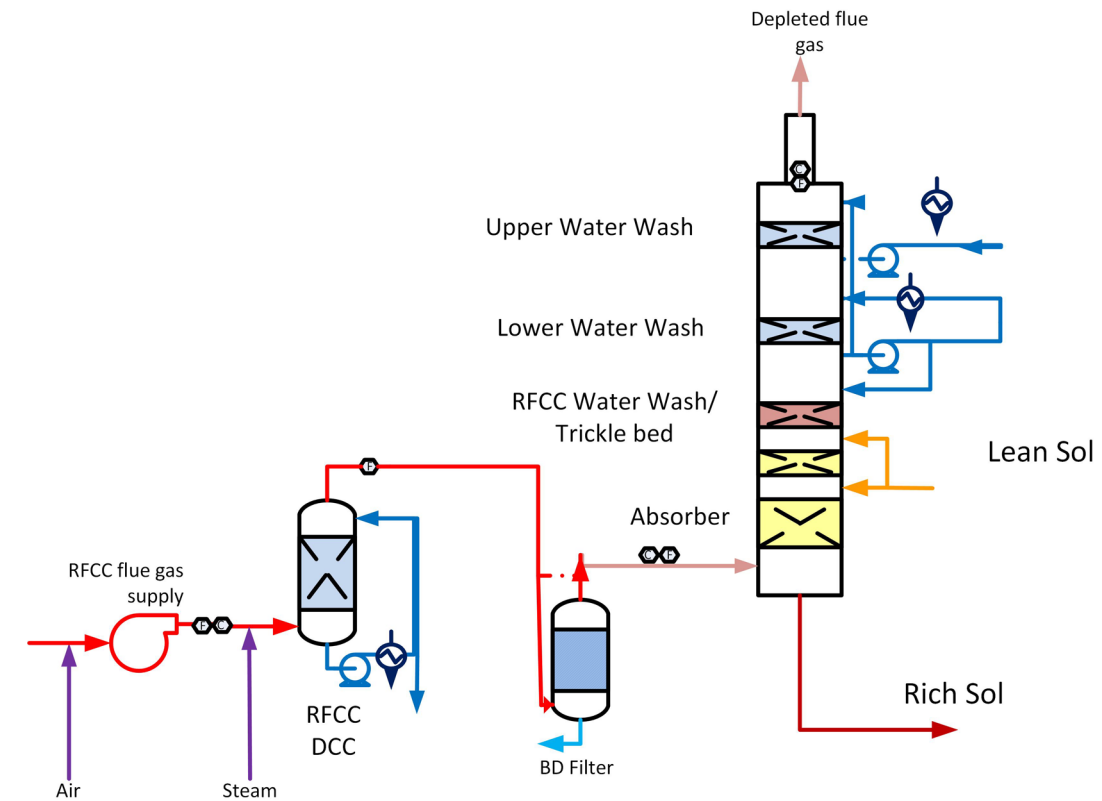
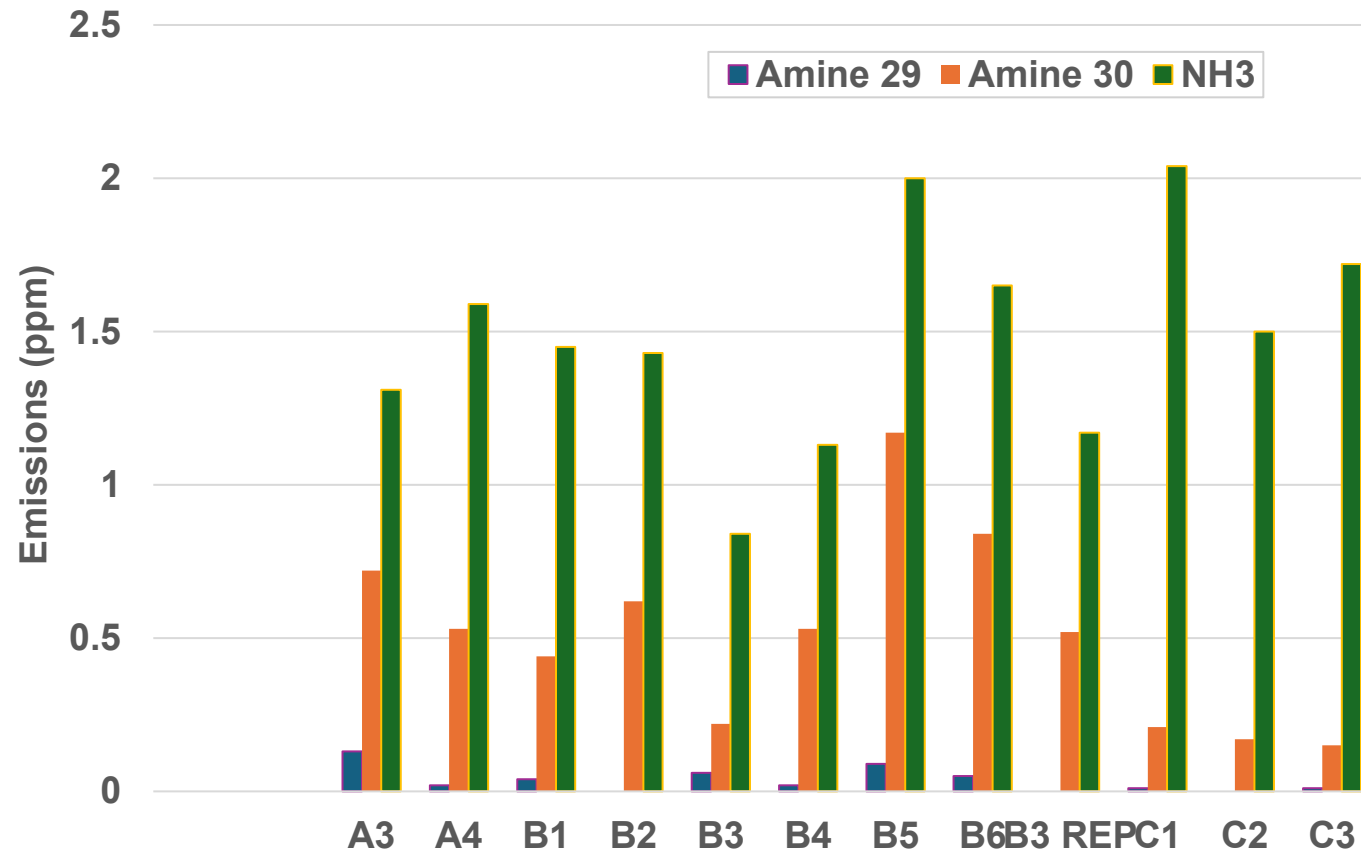


RFCC flue gas

Component	RFCC
CO ₂ (%)	15
NO ₂ (NOx) (ppmv)	0.5-1.5
Total particle no. (TN) (#/cm ³)	7.9 - 9.5 X 10 ⁴



RFCC flue gas



**40% cooling in Lower WW and
60% cooling in Upper WW**

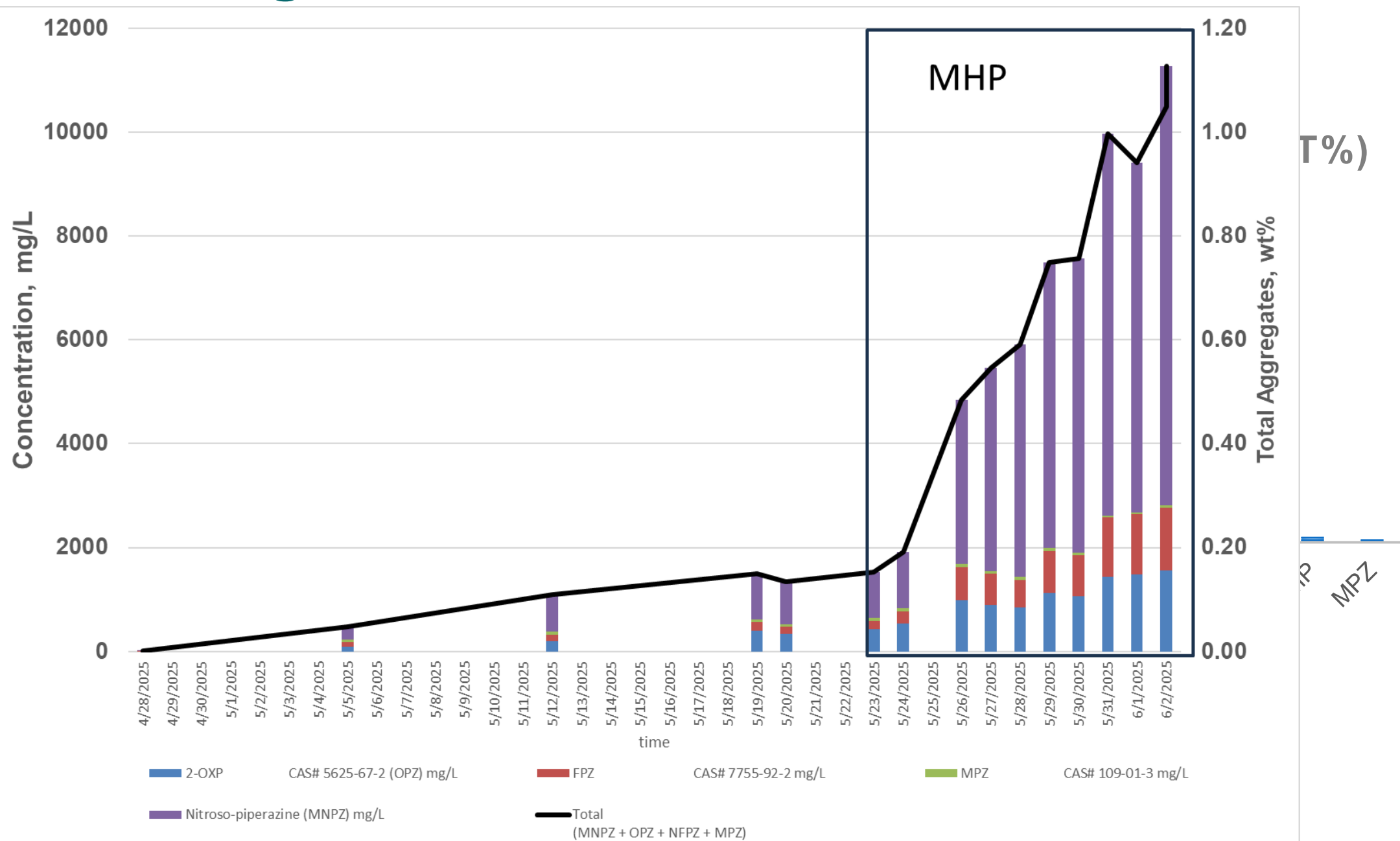
Take away message

**Emission of AMP was less than 0.1-0.2 ppm
and PZ was less than 1 ppm mostly**

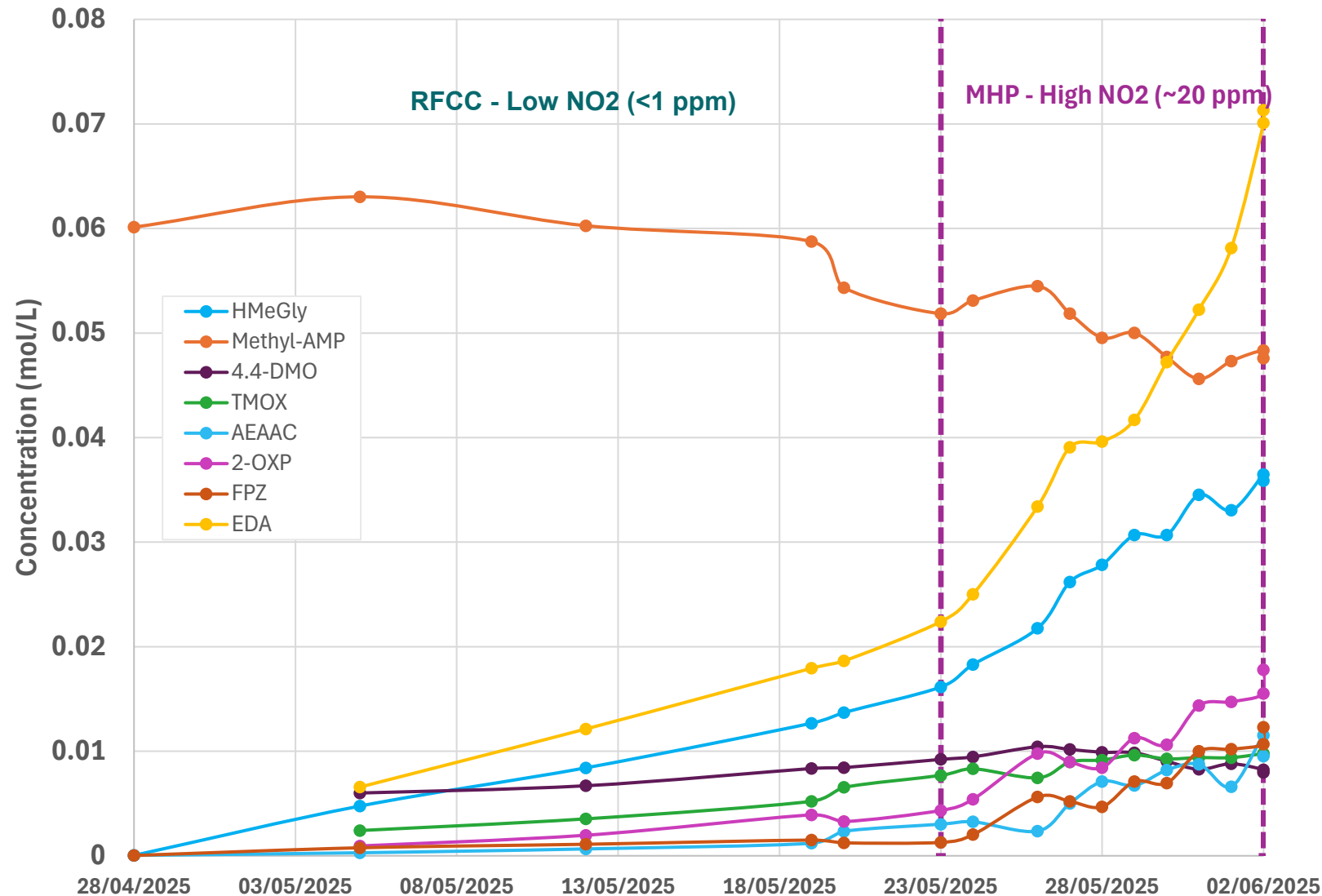
Degradation



degradation



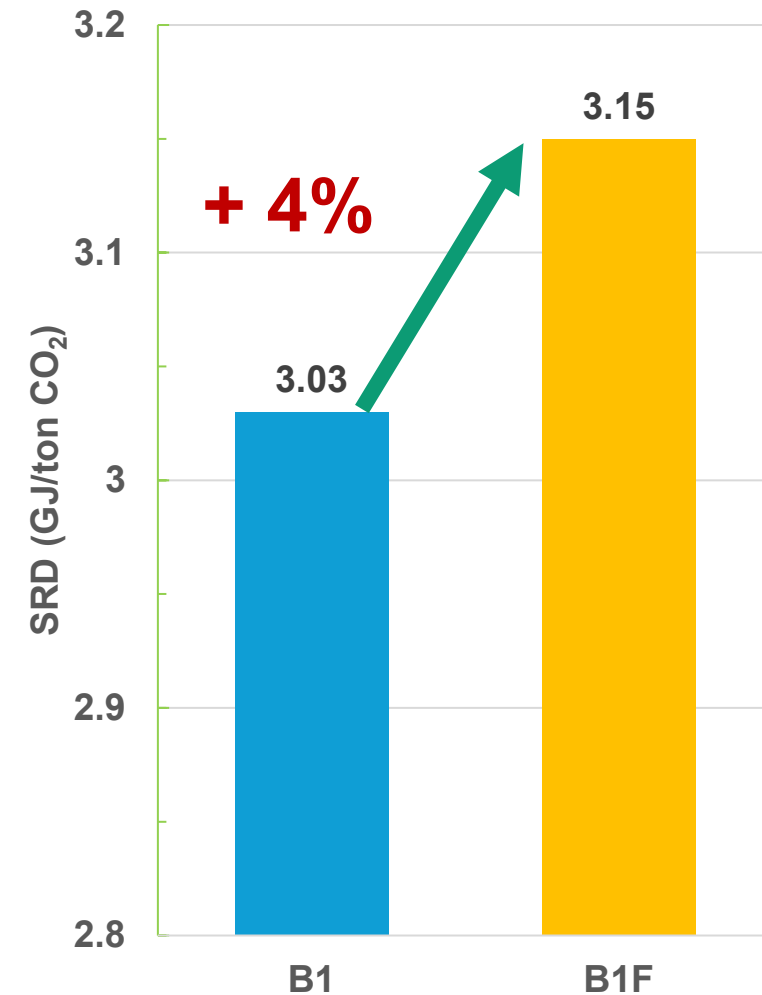
NO₂ impact on degradation



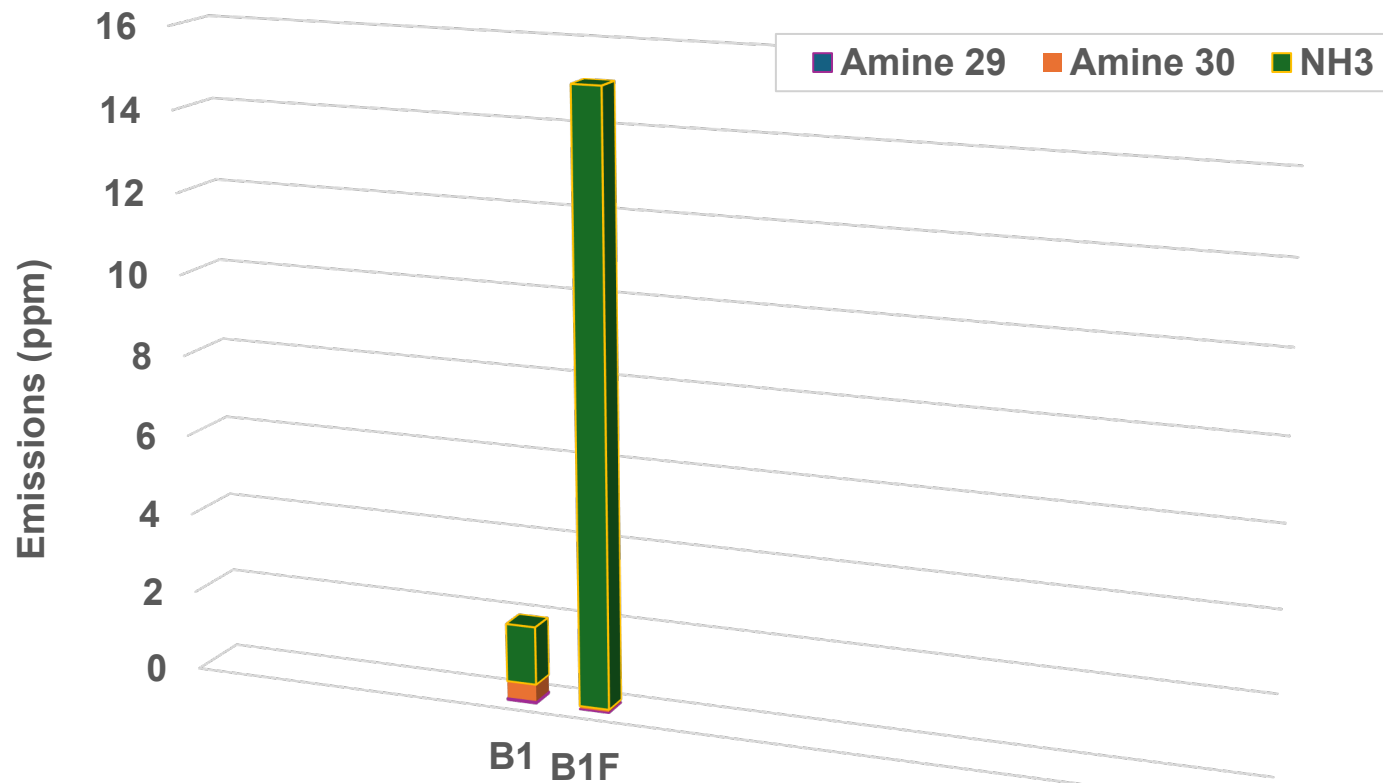
- NO₂, increases formation rate of several degradation compounds significantly (EDA, HMEGly, 2-OXP, FPZ)

solvent degradation effect

	Fresh	Degraded
	B1	B1F
L/G	2,7	2,7
SRD(GJ/tCO ₂)	3,03	3,15
Capture rate (%)	96.5	95.8
Intercooling	YES	YES



Emissions



Increased NH₃ emission

Take away message

- **NO₂ increased degradation rapidly**
- **due to degradation SRD increased by 4-5%**
- **With Effective water wash operation, AMP, PZ emissions were below 0.1-0.2 ppm**
- **NH₃ emissions increased to almost 15 ppm from 2 ppm**



Connect with TCM

Partnering for CCS Deployment

Why TCM?

- ❖ +60,000 operational hours → proven, bankable performance
- ❖ 17 post-combustion capture technologies tested and derisked for commercial deployment → unmatched track record
- ❖ Neutral, independent test center → trusted by industry, investors & policy makers

What We Offer:

- ❖ **Advisory services:** technology screening, selection & scale-up
- ❖ **Project support:** from feasibility through FID
- ❖ **CO₂ quality expertise:** Characterization, specifications & impurity impacts on compression, Liquefaction, transport & storage
- ❖ Open for new test campaigns, Tailored **advisory services**, Strategic **partnerships & joint projects**

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High Pressure Stripping



High Pressure stripping

