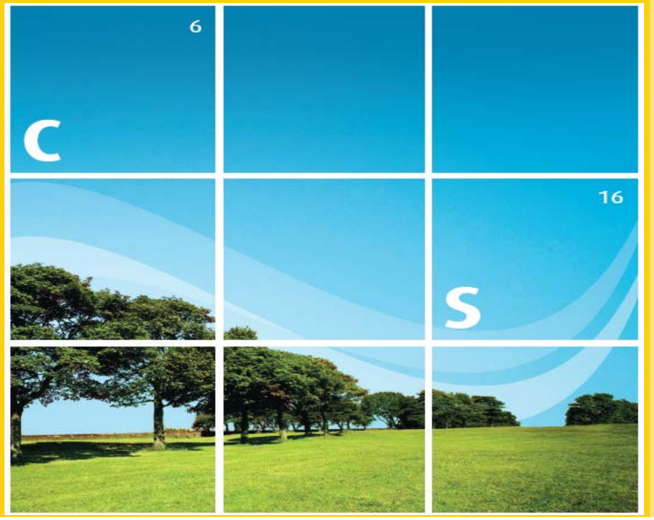
CANSOLV DC201 Carbon Capture System: Solvent Testing & Model Validation

Post-Combustion Capture Conference

Bergen, Norway

September 19, 2013



Shell Cansolv

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- Resources: Our use of the term “resources” in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

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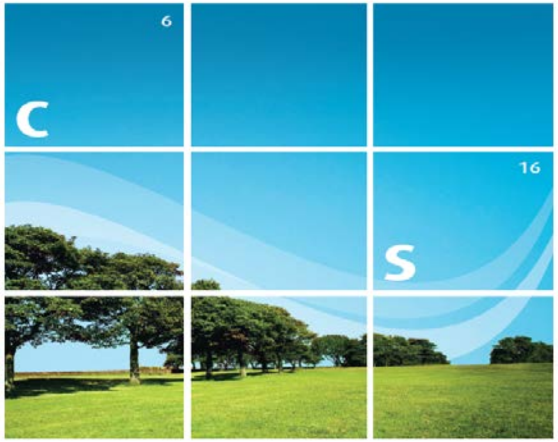
Presentation Agenda

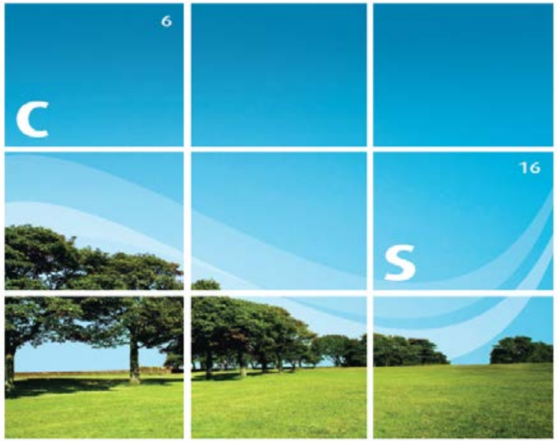
- Background of Cansolv Technologies
- Cansolv Modeling & Design Approach
- SO_2 Experience & Model/Design Validation
- CO_2 Experience Current/Future
- CANSOLV DC201 Model Development



Background of Cansolv Technologies

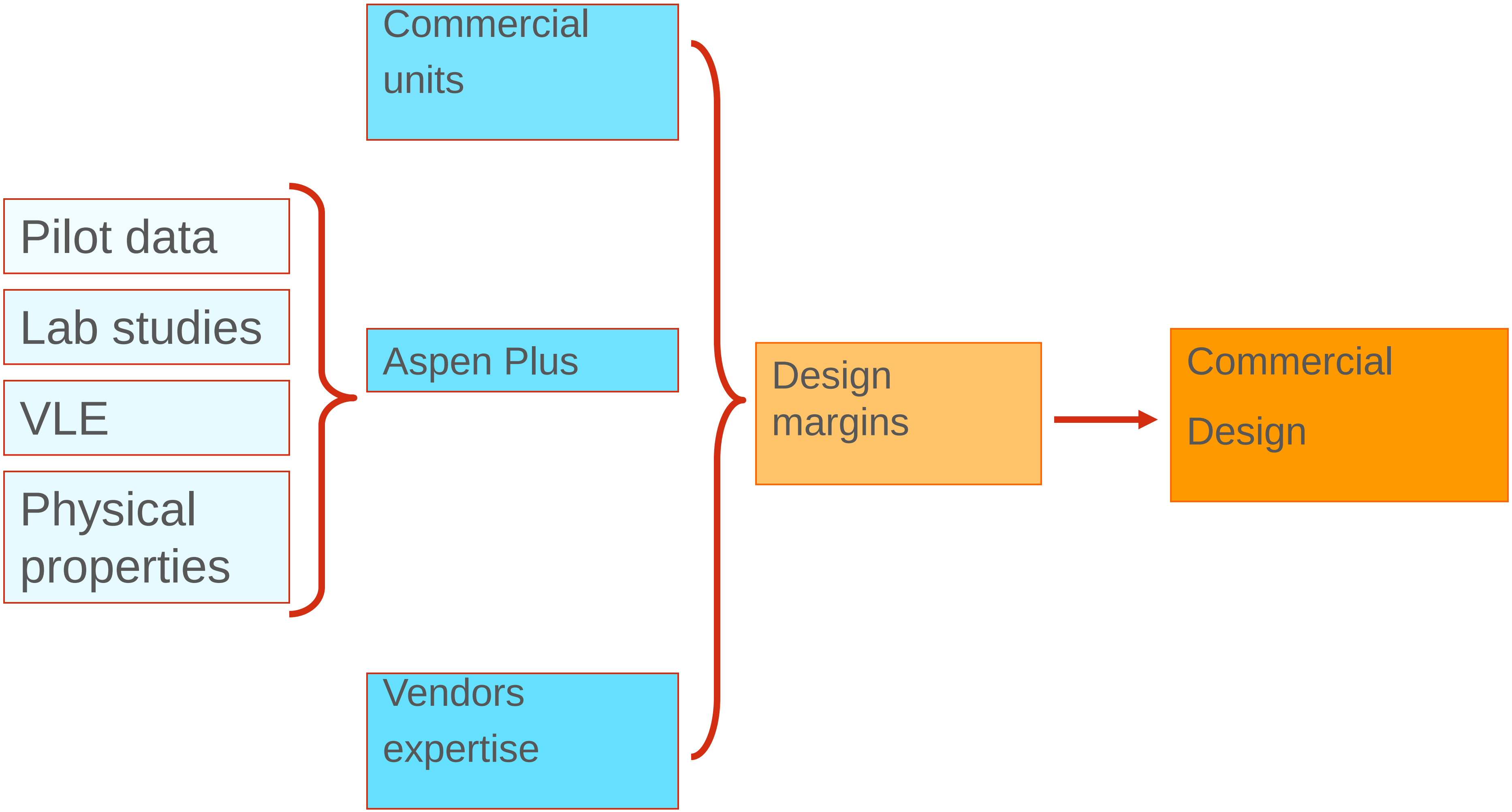
CANSOLV TECHNOLOGIES INC.

- Founded in 1997 to commercialize post-combustion SO_2 Scrubbing
- Extensive experience with regenerable amine processes
- Track record of delivering commercial scale –flue gas treating amine plants worldwide
- 20+ Licenses, 15 in operation worldwide
- Part of the **Shell group** since Dec 2008 (100%)
- Based in Montreal, Canada and Beijing, PRC



Cansolv Modeling & Design Approach

Cansolv Modeling & Design Approach



SO_2 Experience & Model/Design Validation

Scale-Up of CANSOLV SO_2 Scrubbing

		Sulfur Recovery Unit, Belgium			Sulfuric Acid Plant, USA			FCCU, USA		
		Pilot (1999)	Design	**Commercial (2002)**	**Pilot (2000)**	Design	**Commercial (2002)**	**Pilot (2003)**	Design	**Commercial (2006)**
Gas Flow	**SCFM**	**35**	6,300	**6,000**	**70**	25,000	**25,000**	**50**	470,000	**430,000**
[SO2]in	**vol %**	**1.2%**	1.4%	**1.0%**	**0.4 %**	0.4 %	**0.4%**	**900 ppmv**	850 ppmv	**800 ppmv**
[SO2]out	**ppmv**	**<100**	75	**50**	**<20**	20	**15**	**20**	25	**15**
L/G	**gal/kscf**	**8.9**	10.7	**7.1**	**5.4**	3.2	**2.7**	**6.0**	4.2	**3.5**
Steam	**lb / gal**	**3.8**	3.6	**2.1**	**3.4**	2.9	**1.9**	**3.3**	2.8	**2.5**
absorber DxH	**ft x ft**	**0.5 x 14 ft**	4.6 x 30 ft	**4.6 x 30 ft**	**0.5 x 14 ft**	10 x 35 ft	**10 x 35 ft**	**0.5 x 14 ft**	32 x 120 ft	**32 x 120 ft**
stripper DxH	**ft x ft**	**0.3 x 16 ft**	4.3 x 50 ft	**4.3 x 50 ft**	**0.3 x 16 ft**	3 x 40 ft	**3 x 40 ft**	**0.3 x 16 ft**	12 x 64 ft	**12 x 64 ft**

x200 **x700** **X10,000**

From Pilot to Commercial Scale:

✓ **Confirmed lower steam consumption**

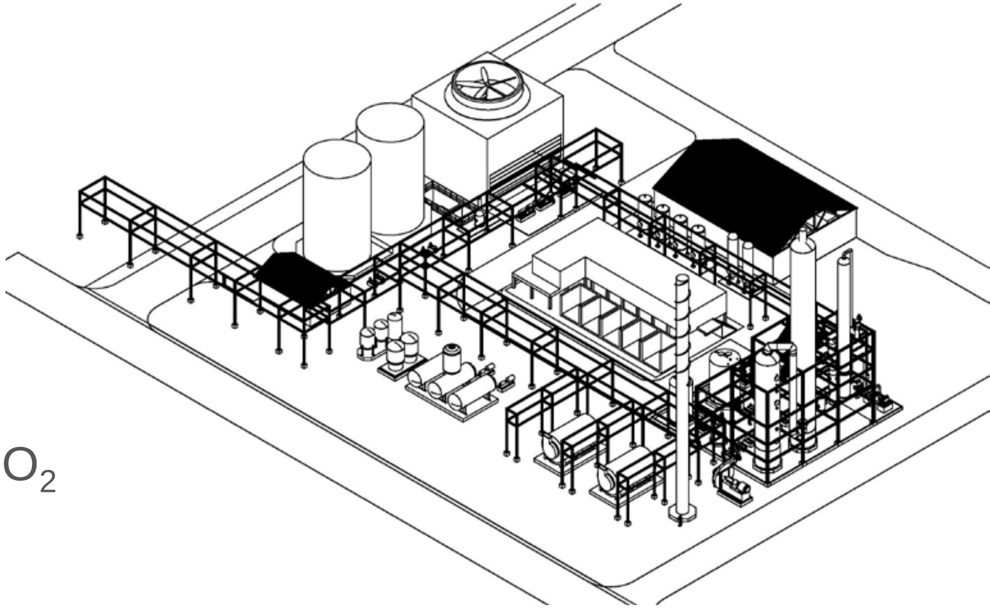
✓ **Confirmed improved hydraulics & mass transfer**

✓ **Improved capture performance**

CO_2 Experience – Current & Future Projects

Cansolv CO_2 Capture Unit at Lanxess CISA

- Location: New Castle, South Africa
- Scale: 170 tpd CO_2 capture (90% capture)
- Natural Gas Boilers
- CO_2 for sodium dichromate production
- Plant to be self-sufficient on steam & CO_2



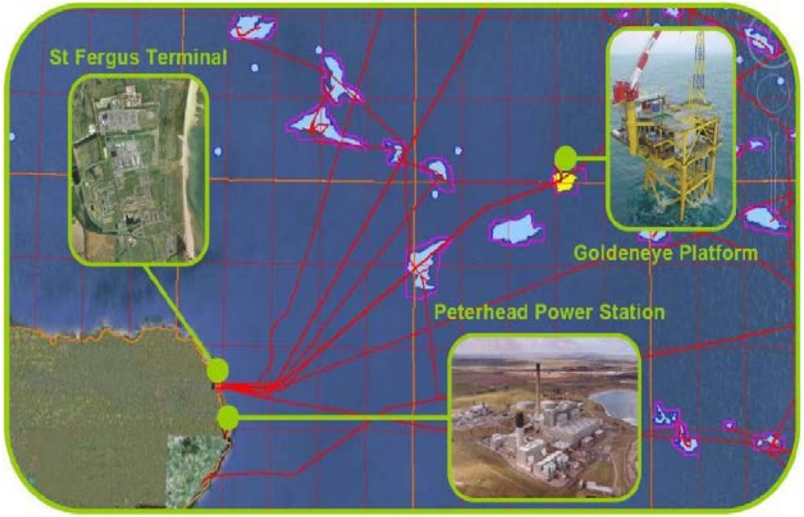
SaskPower BD3 (150 MW) Integrated CCS Demo Project

- Lignite coal fired power plant (150 MW Before CCS Project)
  - ~12% CO_2, ~ 1,000 ppmv SO_2
  - 90% Capture required
- ~ 1,200,000 tpy CO_2 captured
- CO_2 sold for EOR (Contract signed with Cenovus)
- SO_2 converted to H_2SO_4 (~60 tpd) & sold to fertilizer market

- Unique Cost savings features employed
  - Material of construction: lined concrete absorbers & amine tank
  - Rectangular absorbers to save on plot space and optimize packing design/installation
  - Integrated Heat Recovery between SO_2 and CO_2 systems

SSE Peterhead – CCGT CO_2 Capture Pre-FEED

- Completed Pre-FEED study for Scottish & Southern Energy
- Retrofit of a ~300MW CCGT to include CCS
- Sequestration of CO_2: Goldeneye (off-shore North Sea)



CANSOLV DC201 Model Development

Approach to Modeling Amine Processes

Model Development Roadmap

1- **Complete and acquire consistent set of data**

- ❑ Chemistry data
- ❑ VLE data (binary and ternary)
- ❑ Speciation data
- ❑ Heat of absorption data
- ❑ Heat capacity data
- ❑ Transport property data
- ❑ Kinetic data

2- **High quality pilot data**

3- Data used to build the **Aspen Plus model** of the Cansolv process

4- **Commercial design**

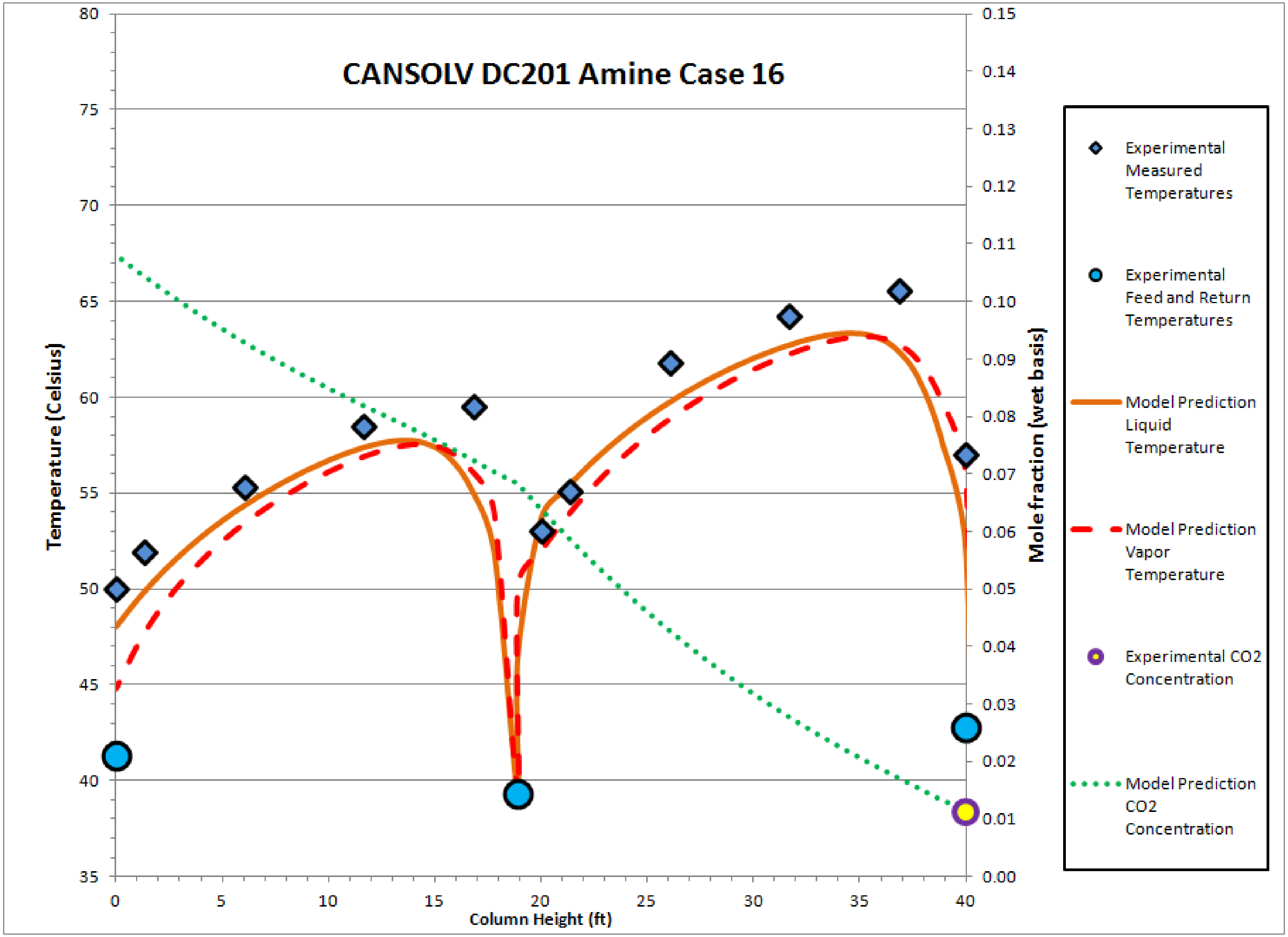
CANSOLV DC201 Absorber Model Validation & Design Margins

CANSOLV DC201 Model Validation Absorber Results

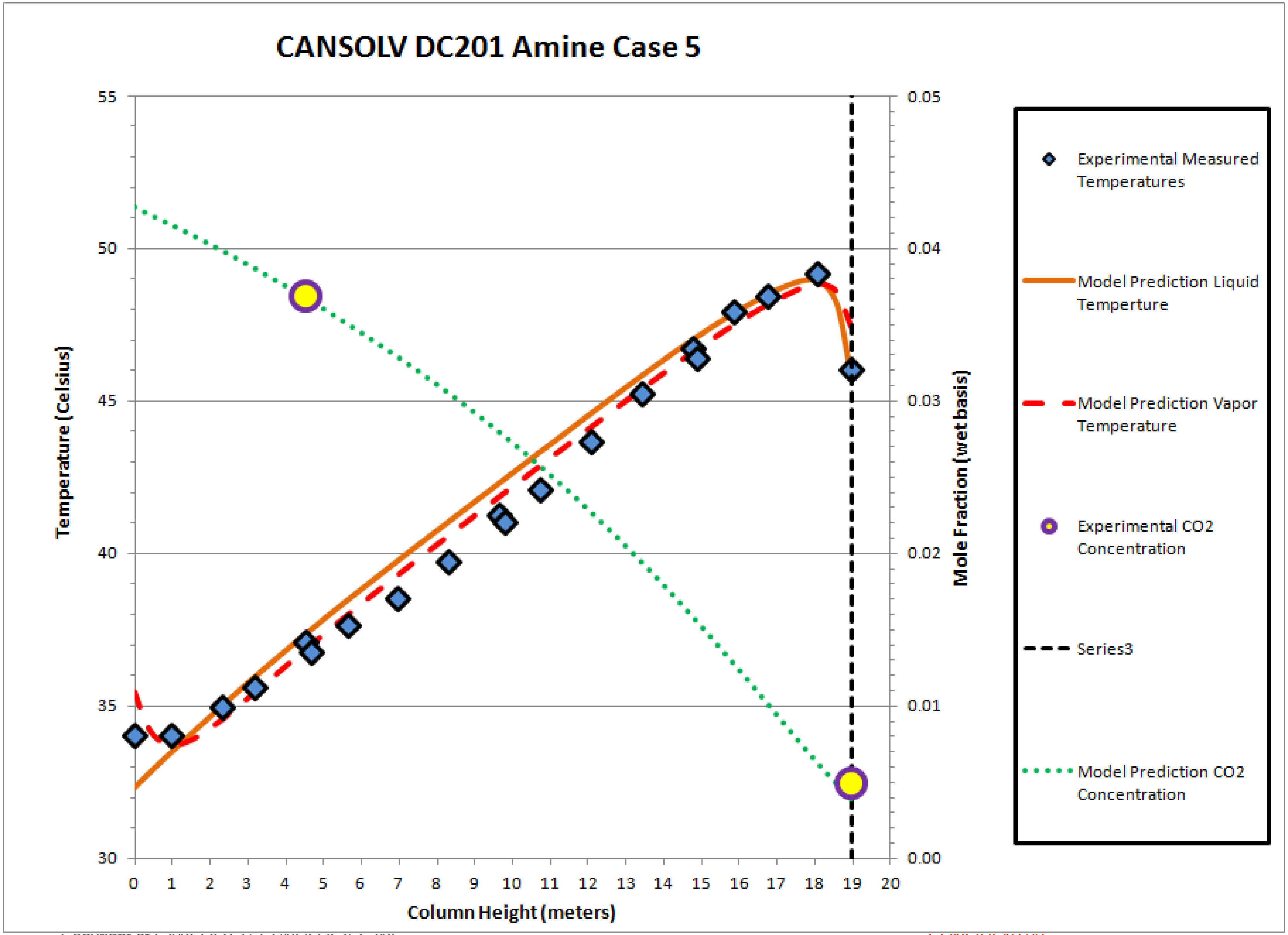
- 3 Independent Piloting Campaigns used for Validation of Model

	Units	Piloting Campaign 1	Piloting Campaign 2	Piloting Campaign 3
Absorber Packing Details				
Packing Type	type	Sulzer MellaPak Plus 252Y	Sulzer MellaPak 2X	Koch 1Y HC
Max Packing Height	m	18	19	11
Packing Diameter	m	0.64	0.20	0.20
# of Intercoolers	#	0,1 or 2	0 or1	0, 1, 2 or 3
Flue Gas Conditions				
Gas Flowrate	Nm^3/hr	1750	224	179
CO_2 Concentration	vol % (wet)	11 - 12	3 - 4	12 - 22
Temperature	^oC	40 – 50	30 – 40	30 – 40

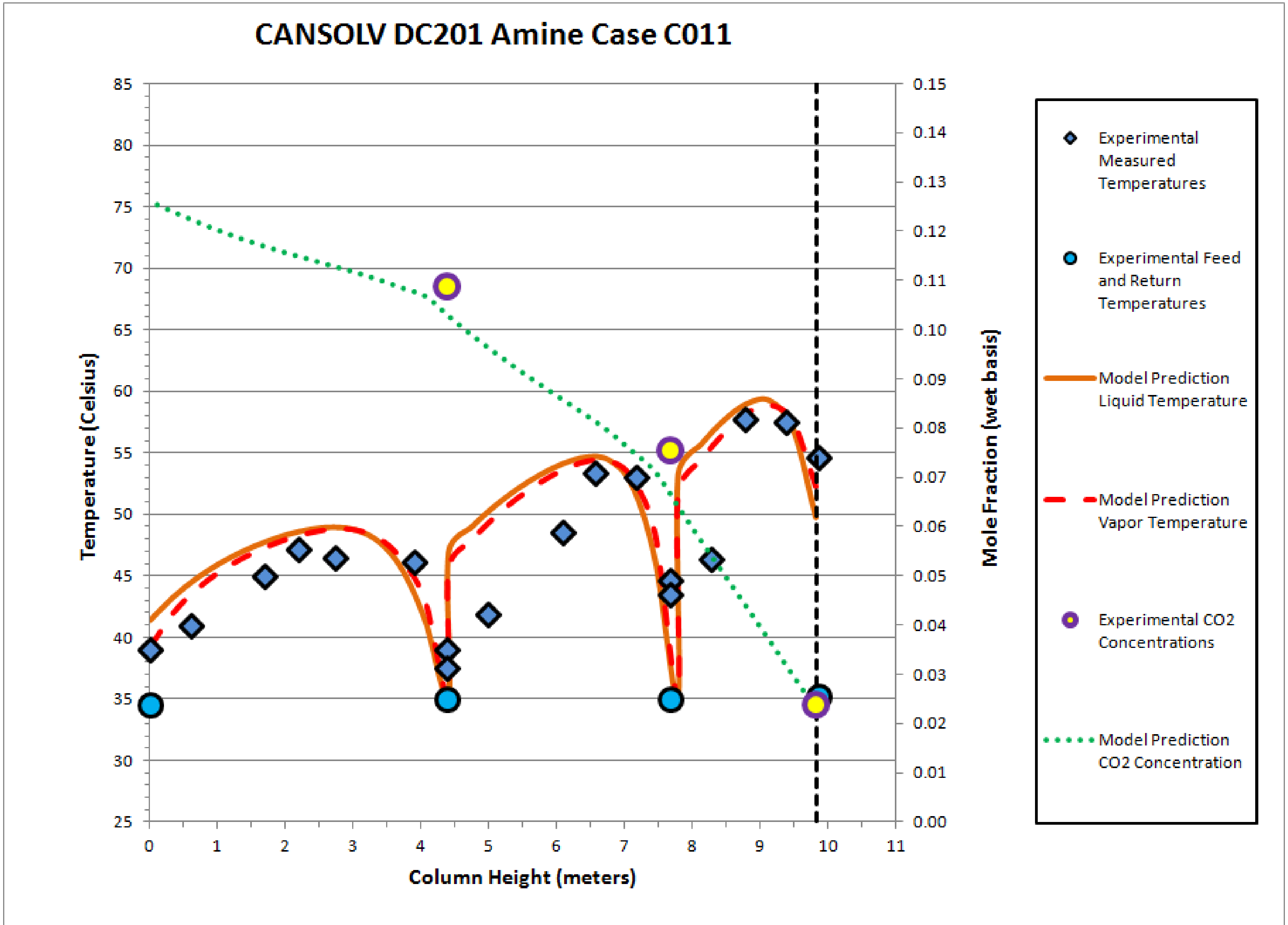
Absorber Profile Piloting Campaign 1



Absorber Profile Piloting Campaign 2



Absorber Profile Piloting Campaign 3



CANSOLV DC201 Model Validation Absorber Results

	Unit	Piloting Campaign # 1							
Case	#	4	12	16	17	18	29	30	31
Experimental CO2 Removal	%	91.1	91.9	89.4	95.0	90.7	83.2	91.7	91.2
Model Prediction CO2 Removal	%	91.7	92.9	90.3	97.1	92.0	80.5	90.8	90.3
% Difference in CO2 Removal	% diff	0.7	1.1	1.1	**2.3**	1.5	-3.3	-1.0	-1.0

	Unit	Piloting Campaign # 2					
Case	#	RUN 3	RUN 4	RUN 5	RUN 8	RUN 12	RUN 15
Experimental CO2 Removal	%	90.1	90.2	89.0	89.9	93.3	92.9
Model Prediction CO2 Removal	%	92.0	90.3	90.6	92.5	94.7	90.4
% Difference in CO2 Removal	% diff	2.1	0.2	1.8	**2.8**	1.5	-2.7

CANSOLV DC201 Model Validation – Absorber Results

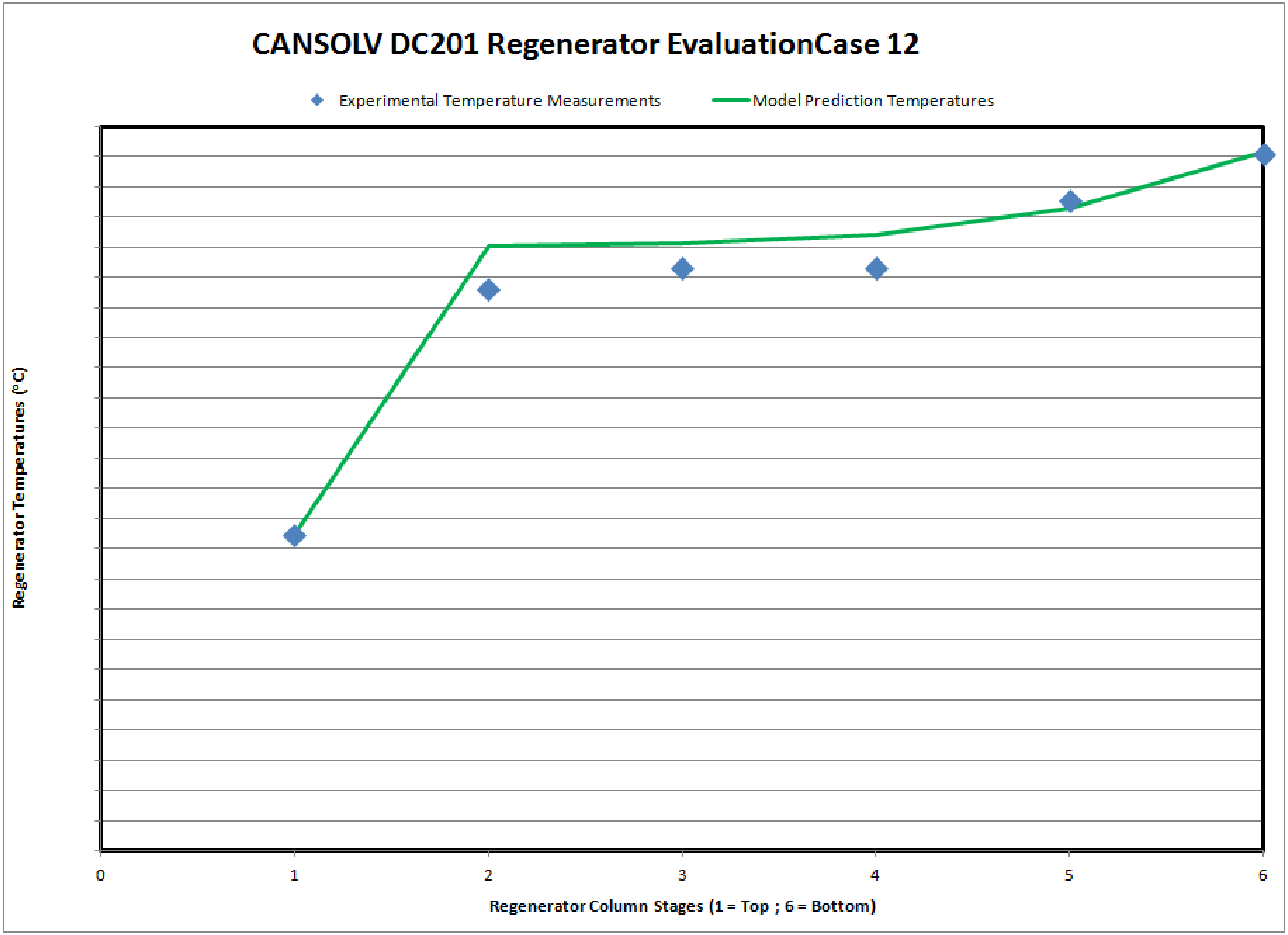
	Unit	Piloting Campaign # 3					
Case	#	C009	C010	C011	C015	C016	C017
Experimental CO2 Removal	%	89.5	93.7	83.4	90.3	88.2	91.3
Model Prediction CO2 Removal	%	89.6	94.9	83.1	92.1	91.2	95.6
% Difference in CO2 Removal	% diff	0.1	1.3	-0.4	1.9	3.5	**4.6**

To be corrected with
Packing Height
Design Margins

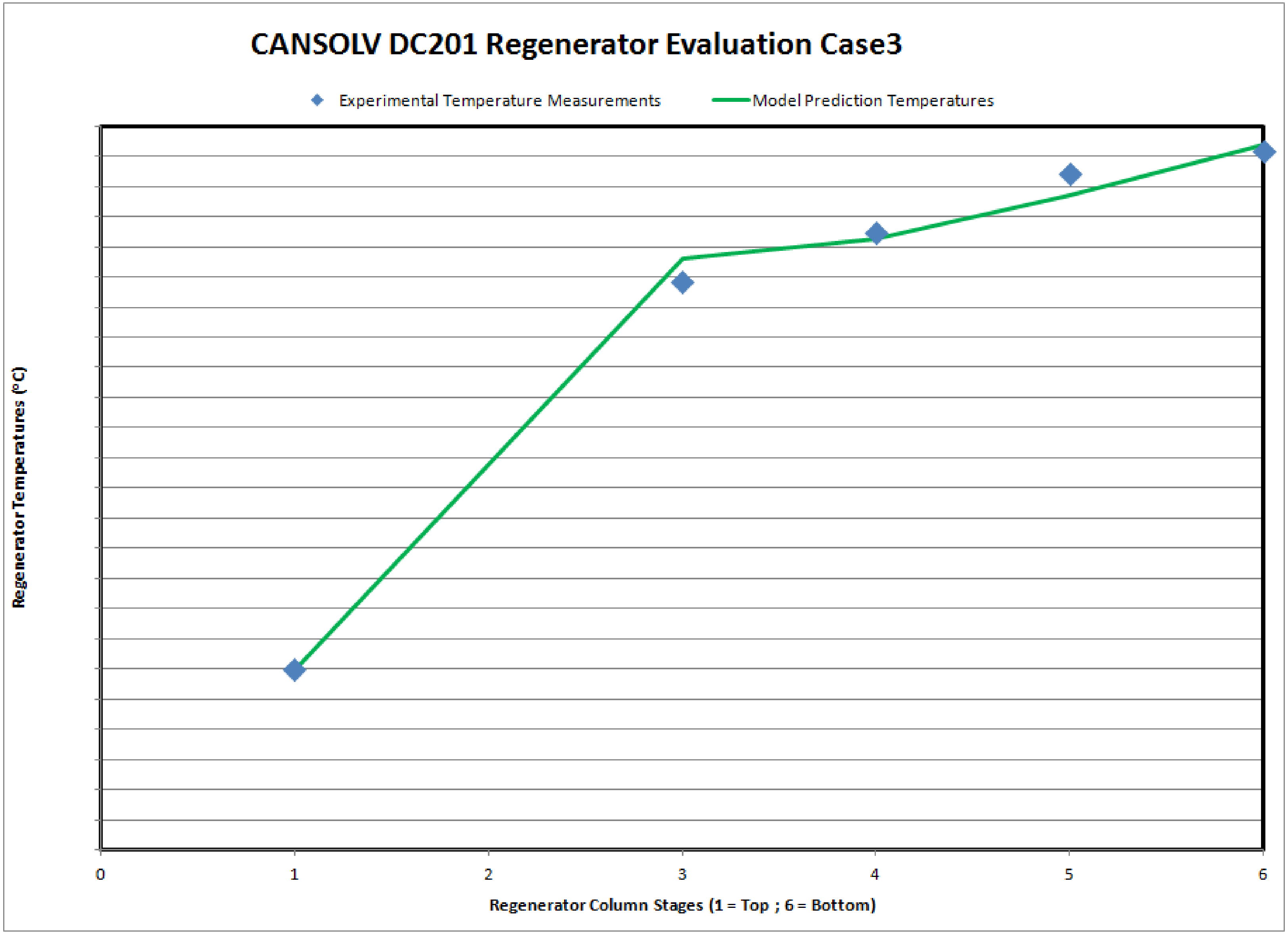
Total Packing Margin =
Model Uncertainly + Operational Uncertainty + Scale up Margin

CANSOLV DC201 Regenerator Model Validation & Design Margins

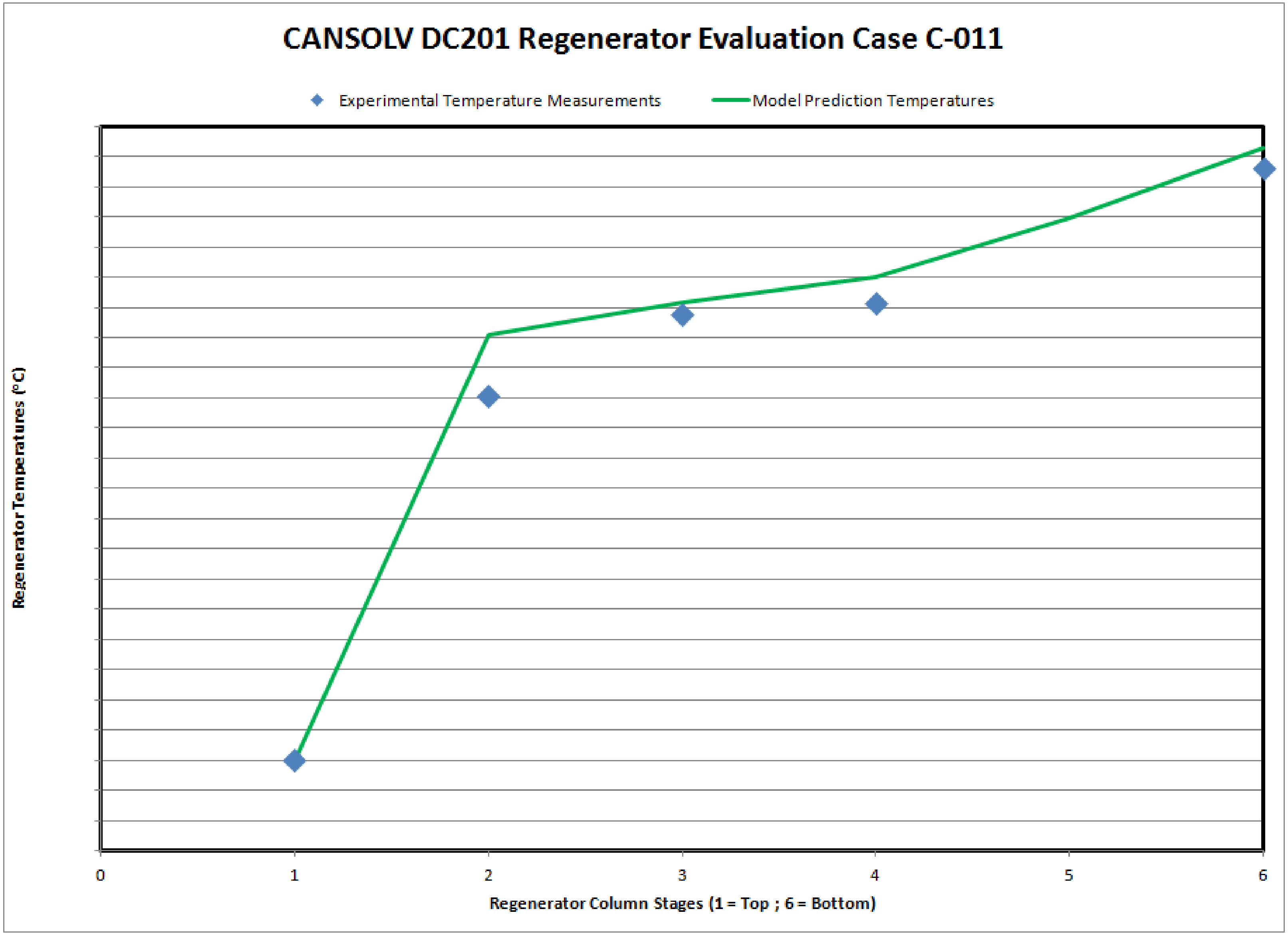
Regenerator Profile Piloting Campaign 1



Regenerator Profile Piloting Campaign 2



Regenerator Profile Piloting Campaign 3



CANSOLV DC201 Model Validation Regenerator Results

	Unit	Piloting Campaign # 1						
Case	#	12	16	17	18	27	29	30
Experimental Stripping Factor	GJ/TonCO_2	2.35	2.41	2.55	2.41	2.54	2.62	2.82
Model Stripping Factor	GJ/TonCO_2	2.23	2.56	2.73	2.50	2.72	2.62	3.00
% Difference	%	**5.1**	-6.2	-7.1	-3.7	-7.1	0.0	-6.4

	Unit	Piloting Campaign # 2			
Case	#	3	4	5	8
Experimental Stripping Factor	GJ/TonCO_2	3.22	3.28	3.22	3.19
Experimental Stripping Factor corrected for heat loss	GJ/TonCO_2	3.06	3.12	3.06	3.03
Model Stripping Factor	GJ/TonCO_2	3.08	3.07	3.10	3.01
% Difference	%	-0.7	**1.5**	-1.3	0.7

	Unit	Piloting Campaign # 3		
Experimental Stripping Factor	GJ/TonCO_2	2.78	2.51	2.63
Model Stripping Factor	GJ/TonCO_2	2.75	2.65	2.80
% Difference	%	**1.1**	**-5.6**	**-6.5**

CANSOLV DC201 Model Validation – Regenerator Results

Maximum under prediction of Stripping Factor:

Piloting Campaign 1 = 5.1 %

Piloting Campaign 2 = -4.0 %

Piloting Campaign 3 = 1.1 %

→ To be corrected with Energy Consumption Design Margins

Thank you!

Questions…?