

“Validation of Transformational CO₂ Capture Solvent Technology with Revolutionary Stability” (Apollo)

DE-FE0031727

August 19, 2022

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DE-FE0031727: Apollo Project

- Overall Project Objective:
 - Scaling up a novel amine-based solvent technology with revolutionary stability and excellent CO₂ capture performance to a 0.5 MWe scale using real flue gas
- Budget:
 - ION and partners: \$750,000
 - DOE-NETL: \$2,999,998
- Period of Performance:
 - June 1, 2019 to October 30, 2022



Pilot Solvent Test Unit (0.5 MWe)
National Carbon Capture Center (NCCC)
Wilsonville, AL (Courtesy of NCCC)

Project Scope and Key Milestones

- ✓ Laboratory scale work to fill critical knowledge gaps
- ✓ Run lab pilot for initial validation of ProTreat model
- ✓ Prepare for field-testing at NCCC
- ✓ Field-testing in the PSTU on:
 - ✓ 4.4 and 8% CO₂ from gas boiler
 - ✓ 11-13% from coal-derived flue gas
- Final data evaluation and extensive reporting

#	Milestone Title / Description	Originally Planned Completion Date	Revised Planned Completion Date	Actual Completion Date
M1	Kickoff Meeting	06/01/2019	11/15/2019	12/05/2019
M4	Functioning ProTreat® Module Delivered & Accepted	10/15/2019	07/31/2020	01/13/2021
M7	Host Site Modifications Installed & Commissioned by NCCC	1/2/2020	05/31/2020	03/26/2021
M8	Detailed Test Plan for PSTU Campaign Reviewed and Approved by ION & NCCC	12/16/2019	05/31/2020	01/19/2021
M10	PSTU Test Campaign Complete (per Test Plan)	7/13/2020	10/31/2021	09/30/2021
M11	Process Model Validation Complete	9/21/2020	10/31/2021	10/31/2021
M12	Solvent Degradation Studies Complete	5/5/2020	11/30/2021	10/31/2021
M13-M16	Appendices C, D, E, F of FOA	03/02/2021	10/31/2022	(Mar 2022)
M17	Final Report Delivered to DOE-NETL	05/31/2021	10/31/2022	

ION's CO₂ Capture Technology Development / ICE-21

Accelerated development path leveraging existing research facilities



2010

ION Lab-pilot
3 kWe
Boulder, CO, USA



2012

EERC
0.05 MWe
Grand Forks, ND, USA



2015

NCCC
0.5 MWe
Wilsonville, AL, USA



2016 - 2017

TCM
12 MWe
Mongstad, Norway



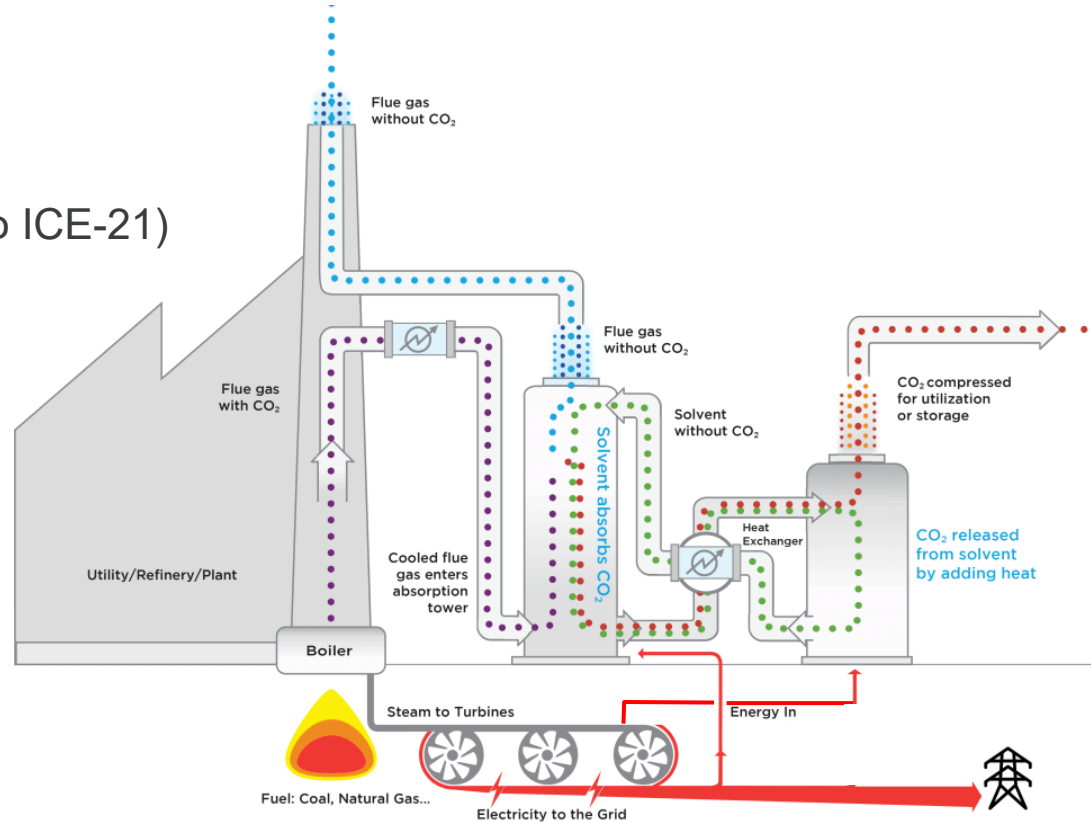
2018 - 2021

NPPD
300 & 700 MWe
Sutherland, NE, USA

Established Engineering Process

Basis of Performance (compared to ICE-21)

- Lower energy consumption
 - Similar fast kinetics
 - Higher working capacity
 - Similar low heat capacity
- Similar low corrosion
- **Revolutionary stability**



TESTING RESULTS AT NCCC

Campaign Operations Overview

Objective

- Run the PSTU with high up-time and high-quality data

Method

- Run parametric tests with NGCC flue gas to determine optimal operating condition
- Hold with NGCC flue gas for long-term testing
- Run coal parametric and Advanced Flash Stripper afterwards (runtime was dependent on coal gas availability)
- Test Advanced Flash Stripper with NGCC flue gas

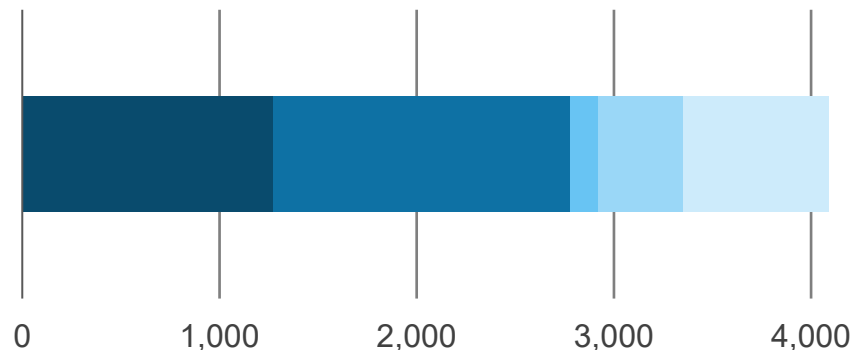
Results

- 6 Months of operation (March 29th – October 3rd)
- Over 4,000 hours of run-time
- 85% Run-time with NGCC
- 34% Run-time with Advanced Flash Stripper

Significance

- High uptime with **zero** solvent-related shutdowns increases confidence in reliability of large-scale projects

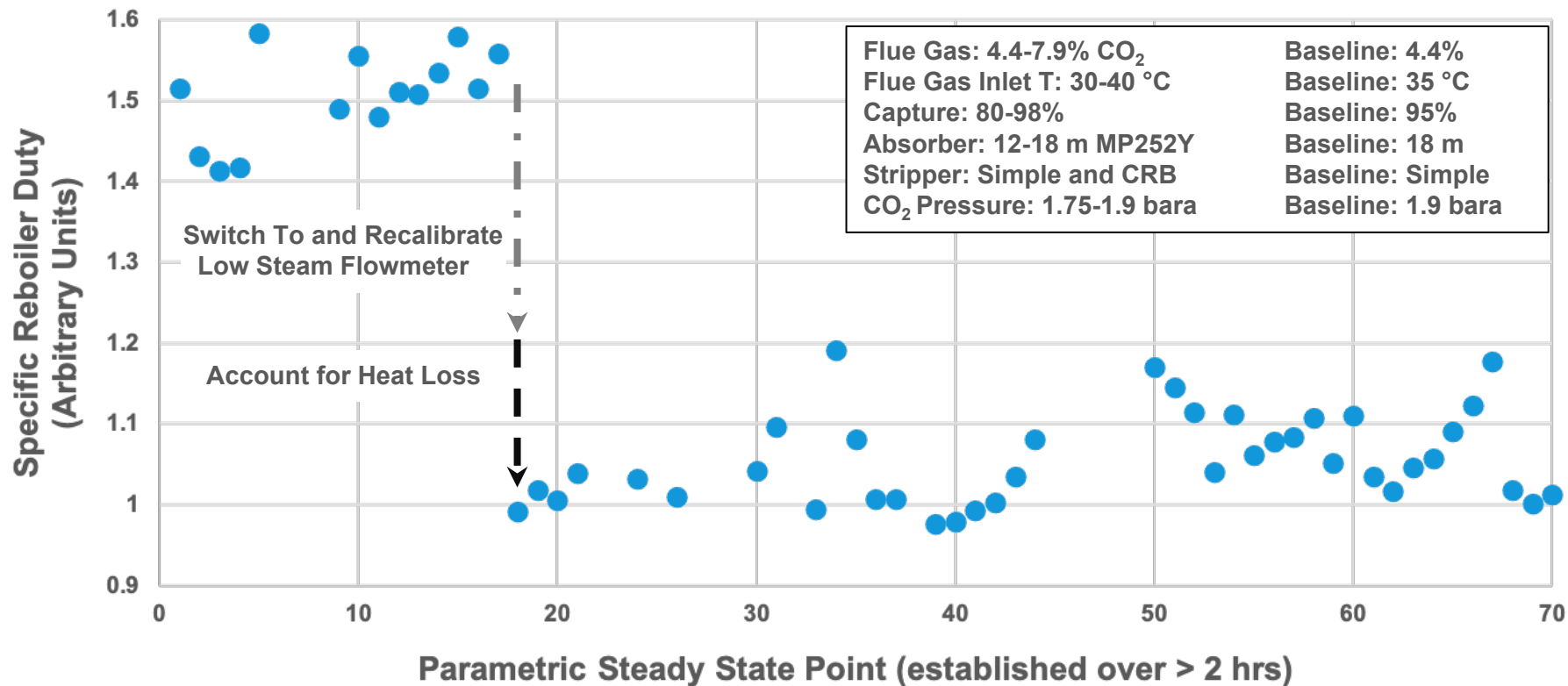
Operational Hours



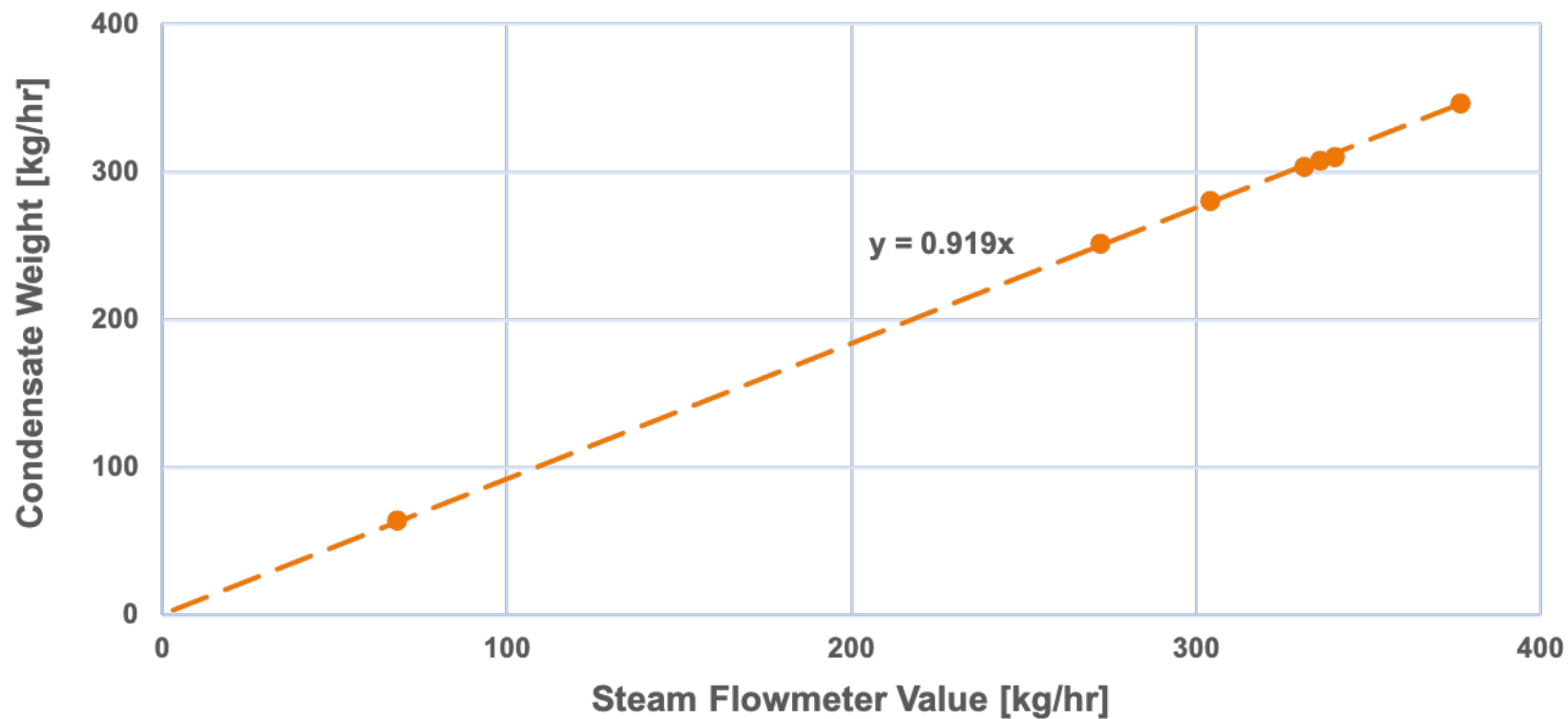
- Natural Gas Parametric (Simple Stripper)
- Natural Gas Long Term (Simple Stripper)
- Coal Parametric (Simple Stripper)
- Coal Long Term (Advanced Flash Stripper)
- NG Parametric (Advanced Flash Stripper)

Parametric Operations

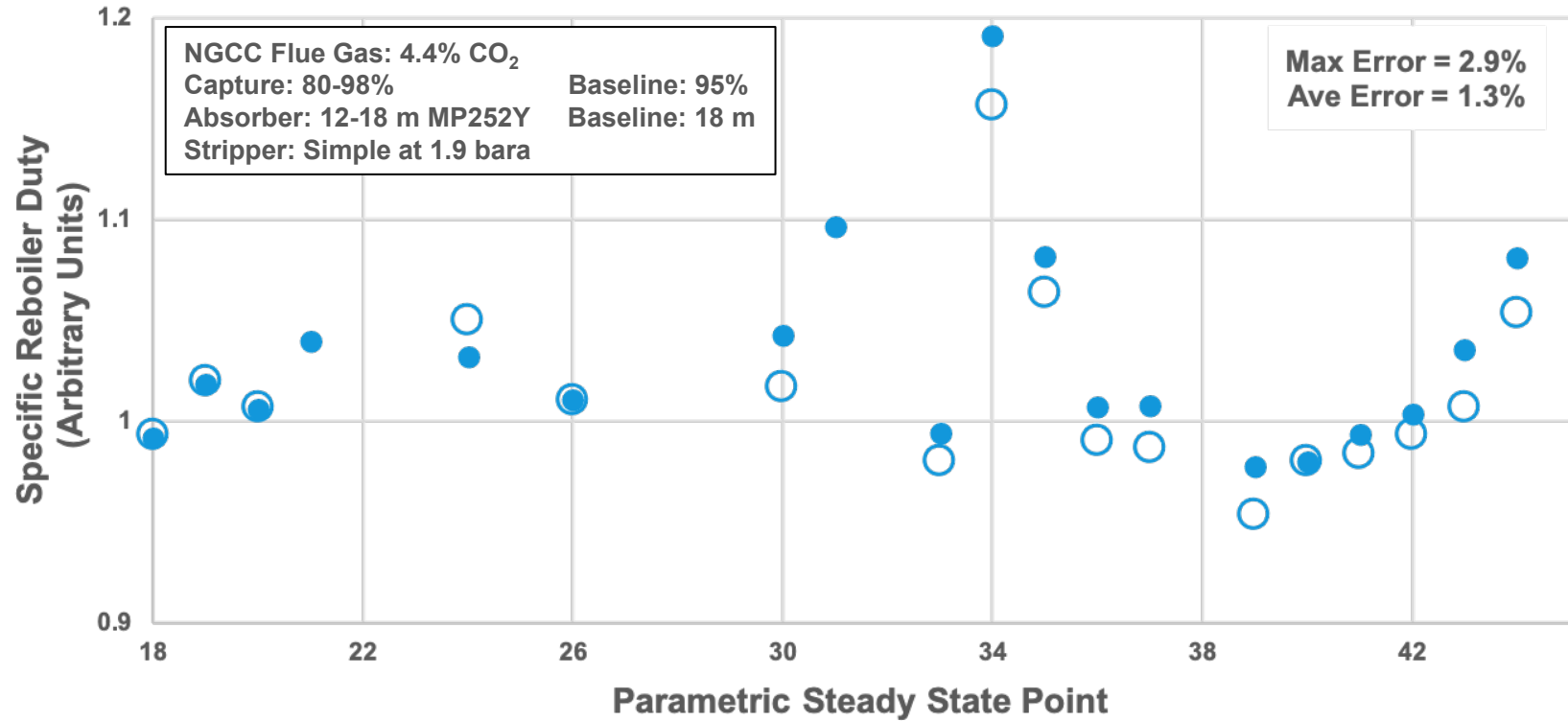
70 Different Parametric Settings



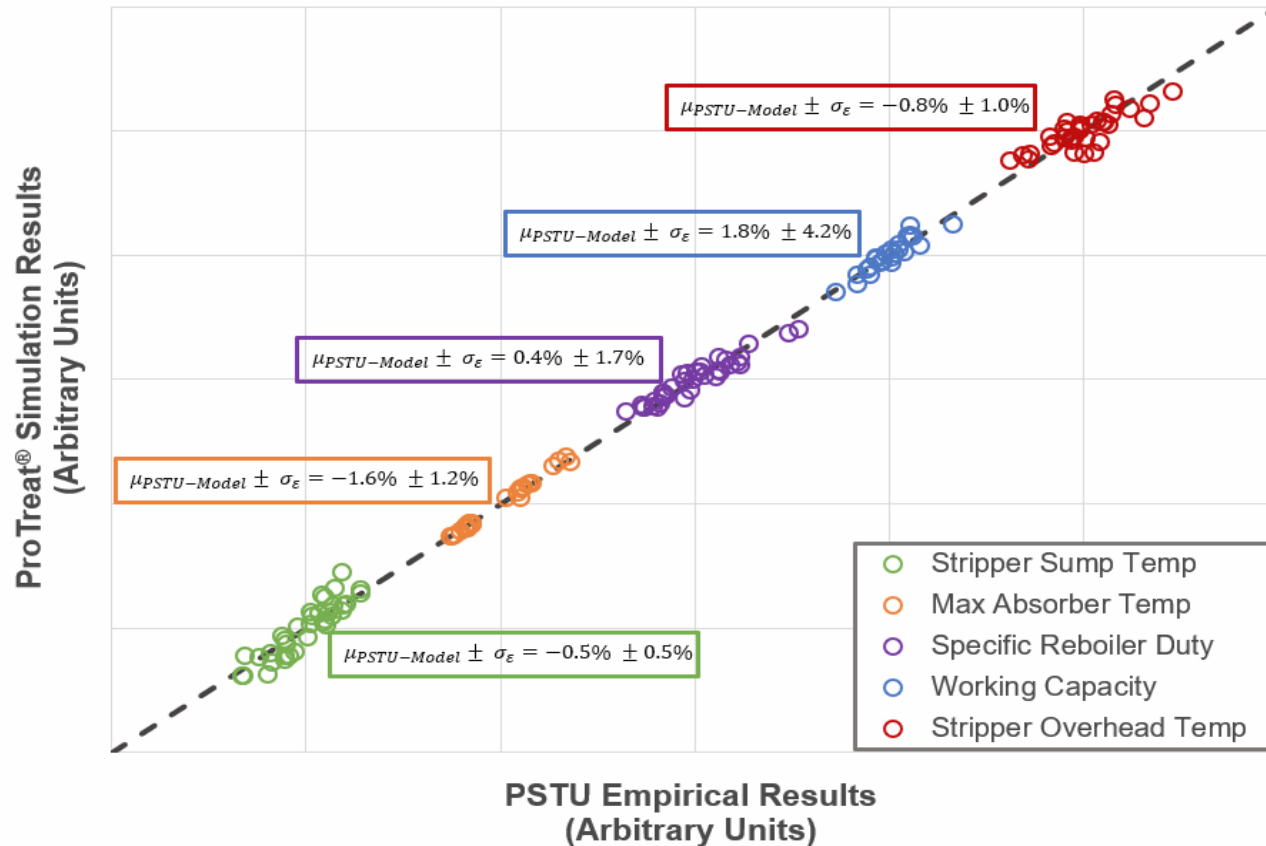
Recalibrating Steam Flowmeter



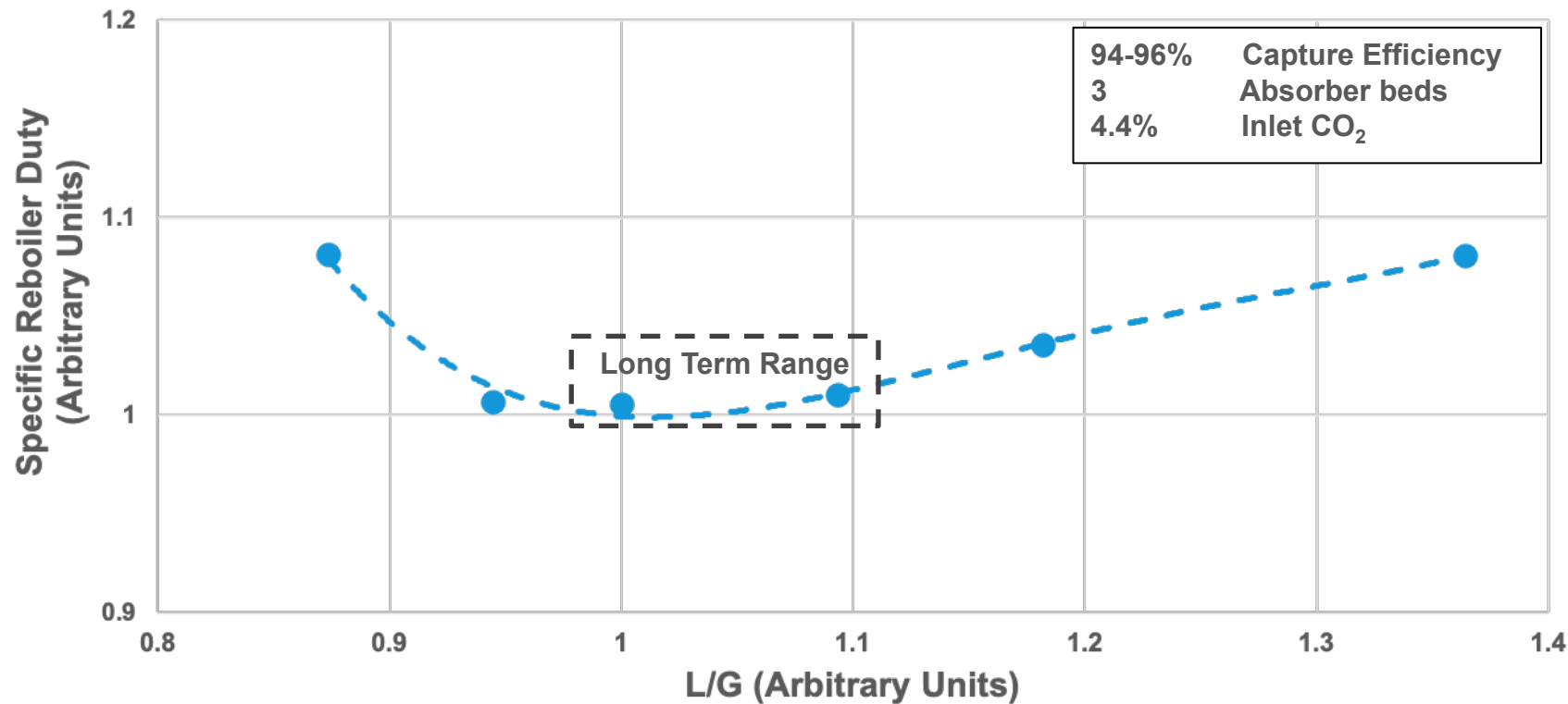
ProTreat® Model Validation



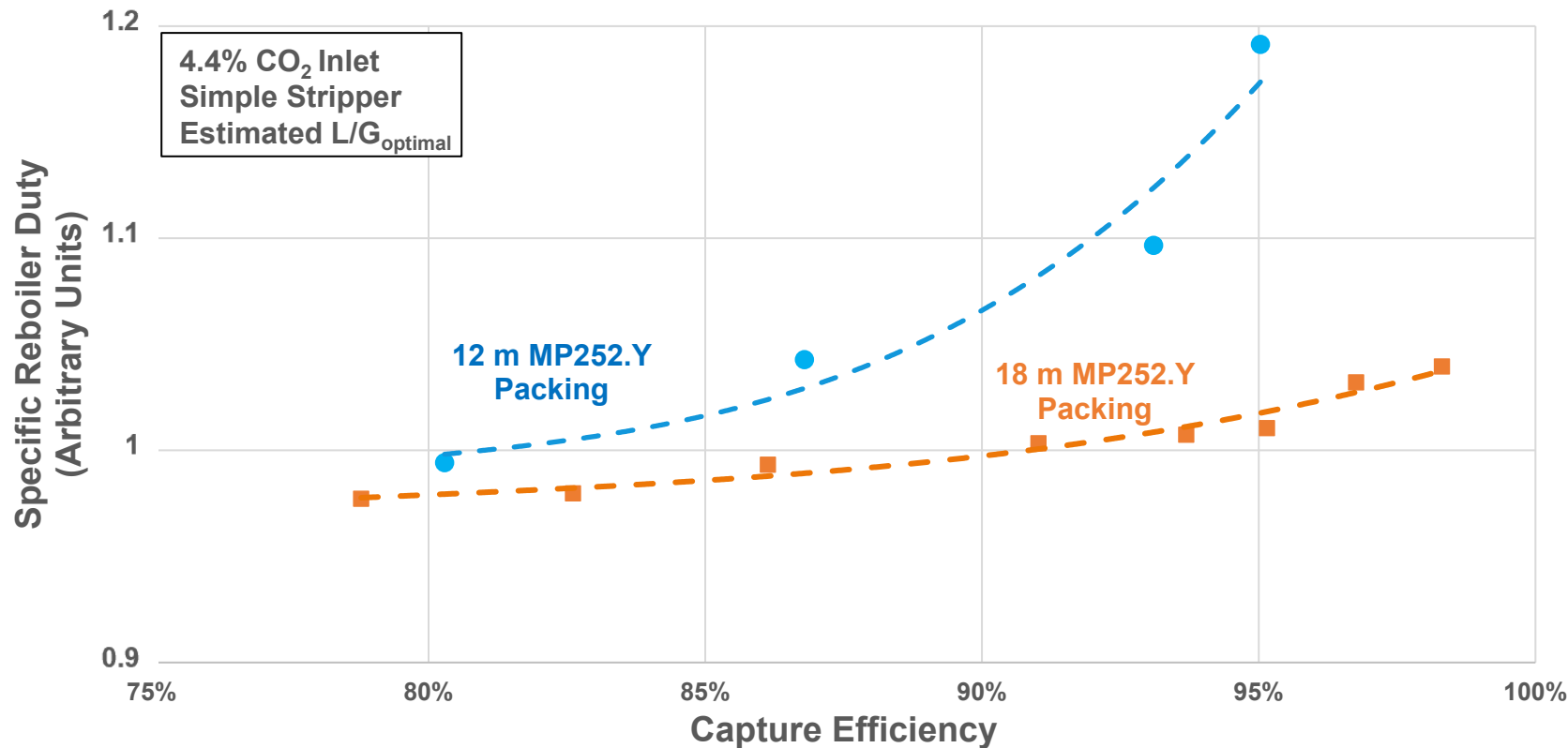
ProTreat® Model Validation



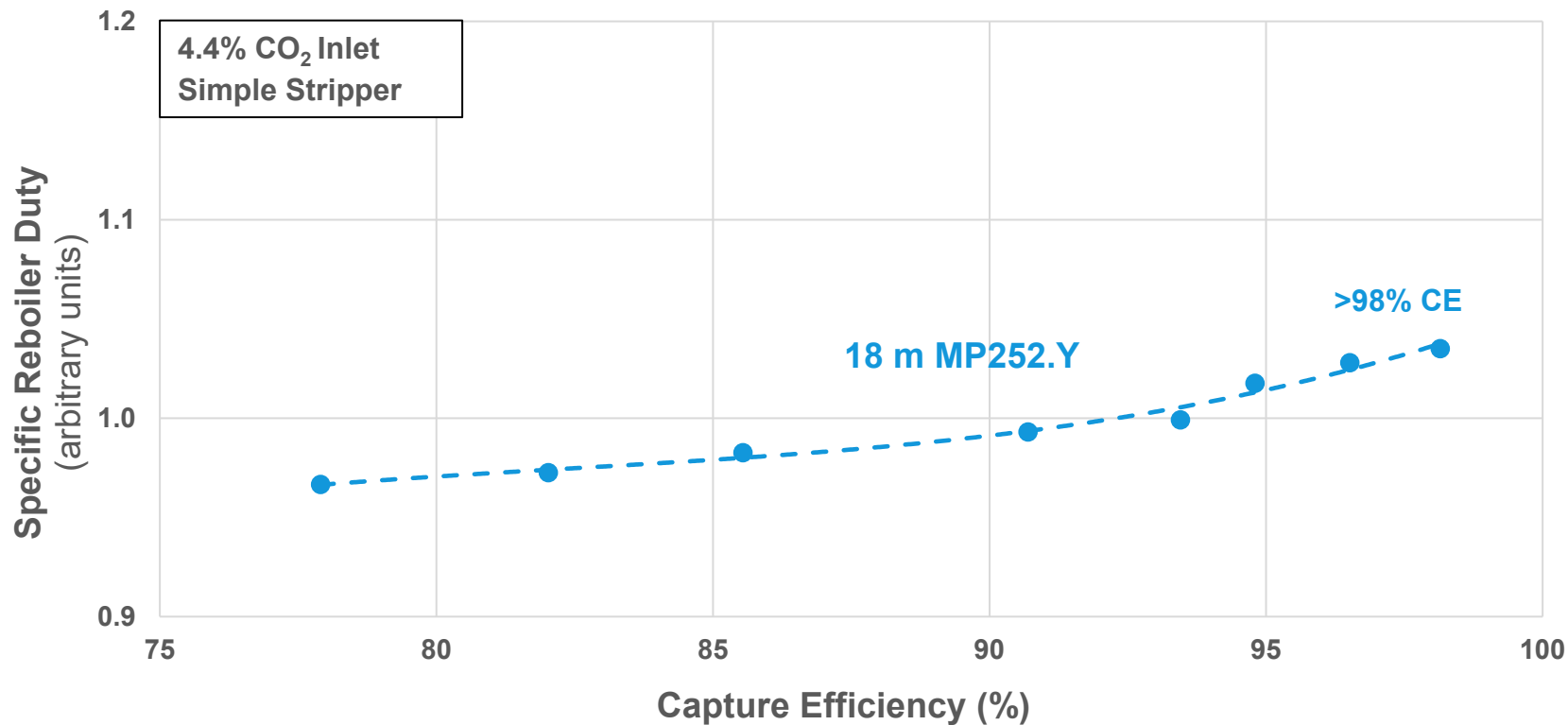
Simple Stripper SRD at 95% Capture



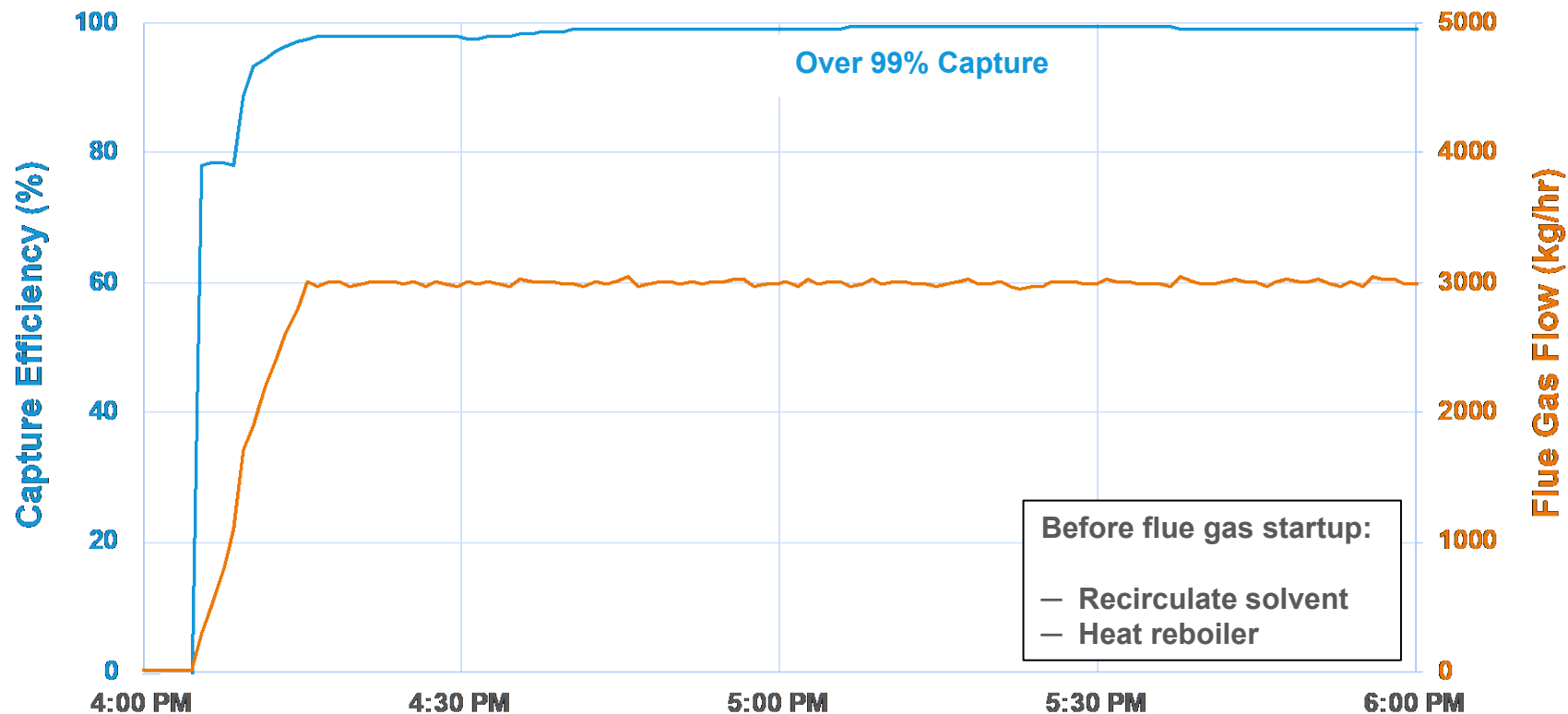
Variable Capture Efficiency with Simple Stripper



Variable Capture Efficiency with Simple Stripper

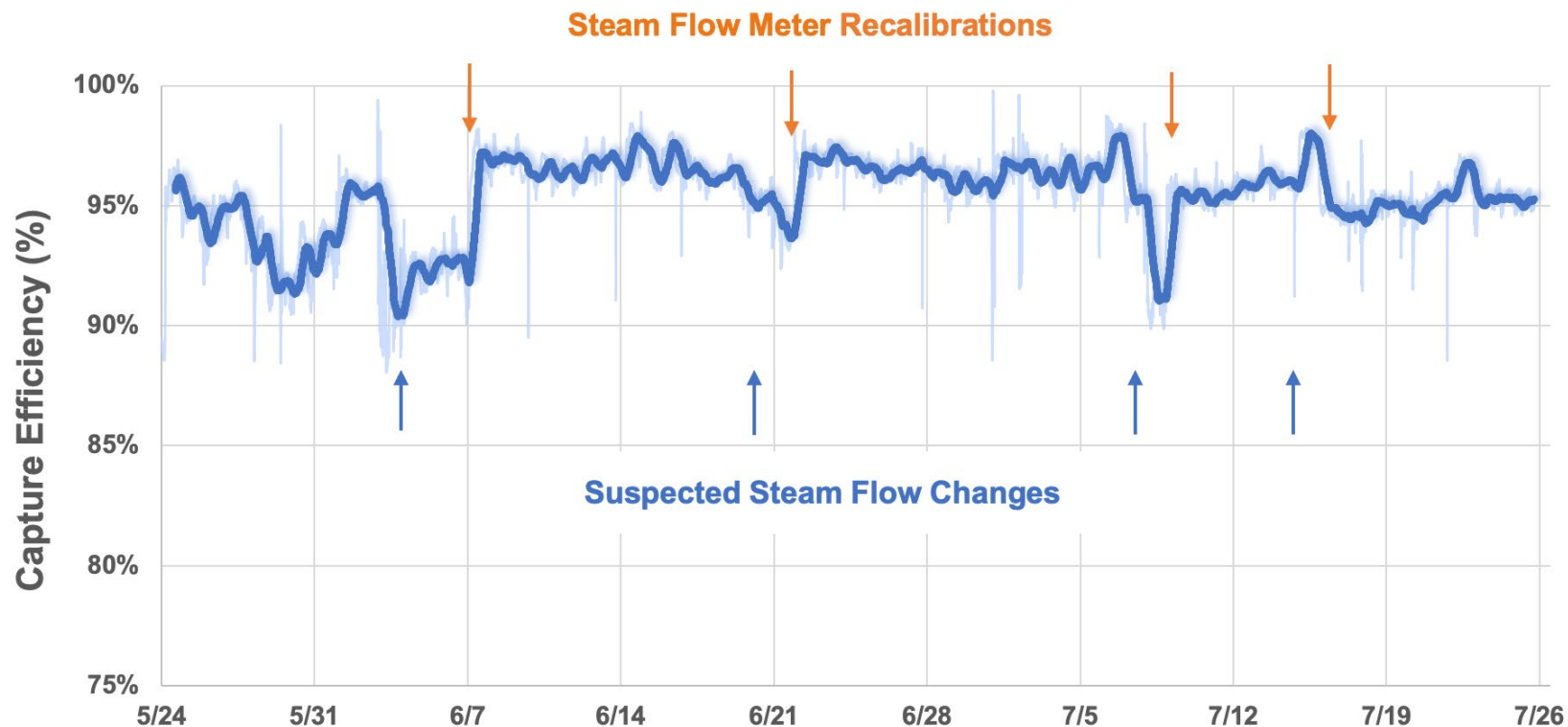


Capture-Ready Warm Start

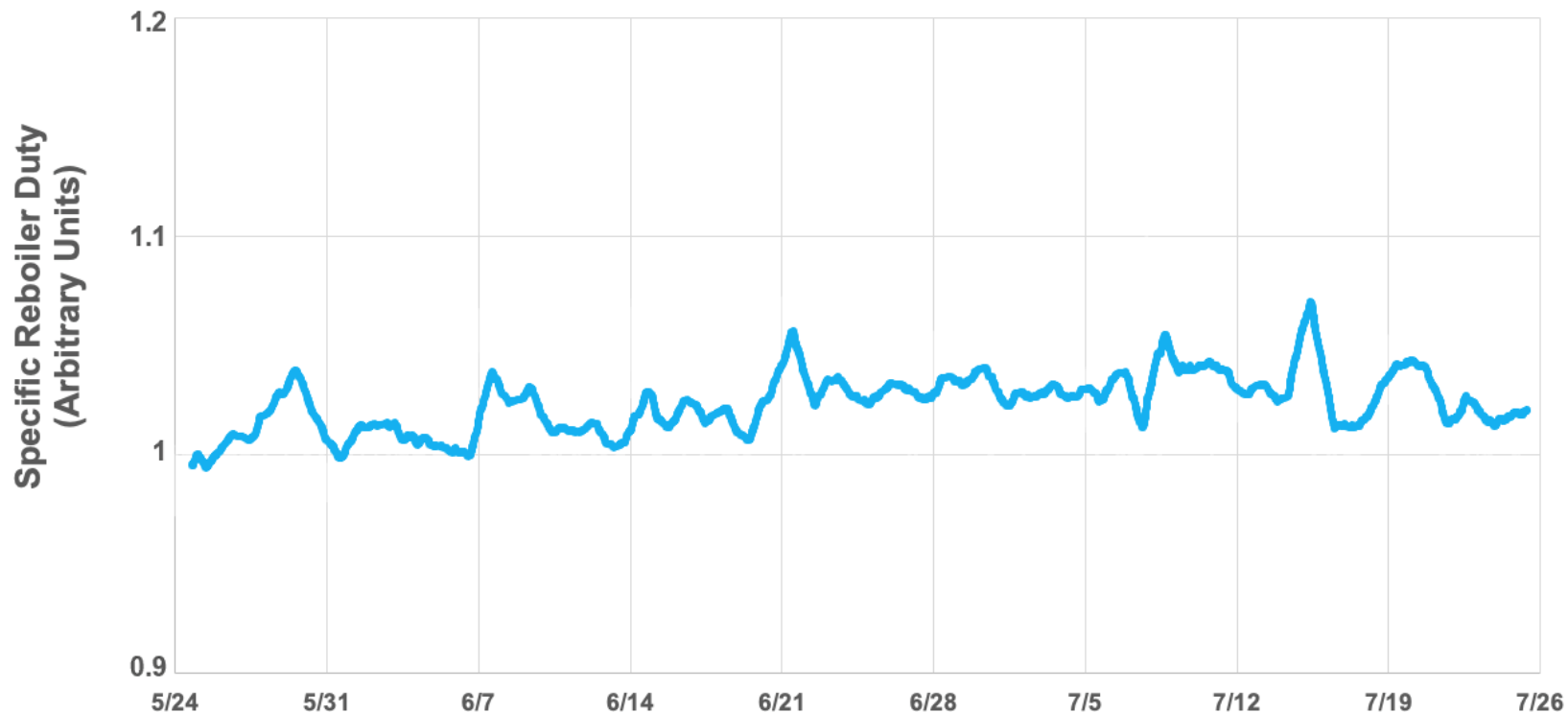


LONG-TERM TESTING

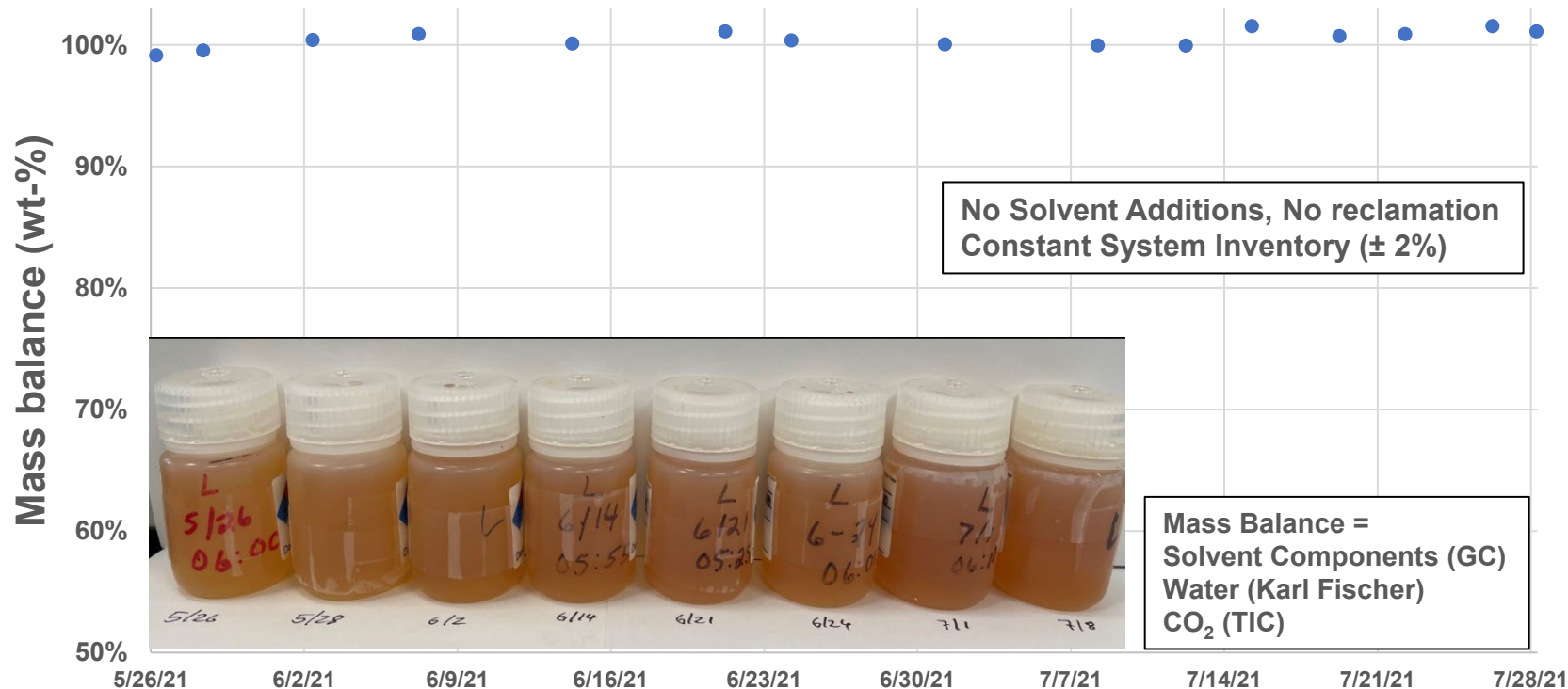
95% Capture for 1500 Hours



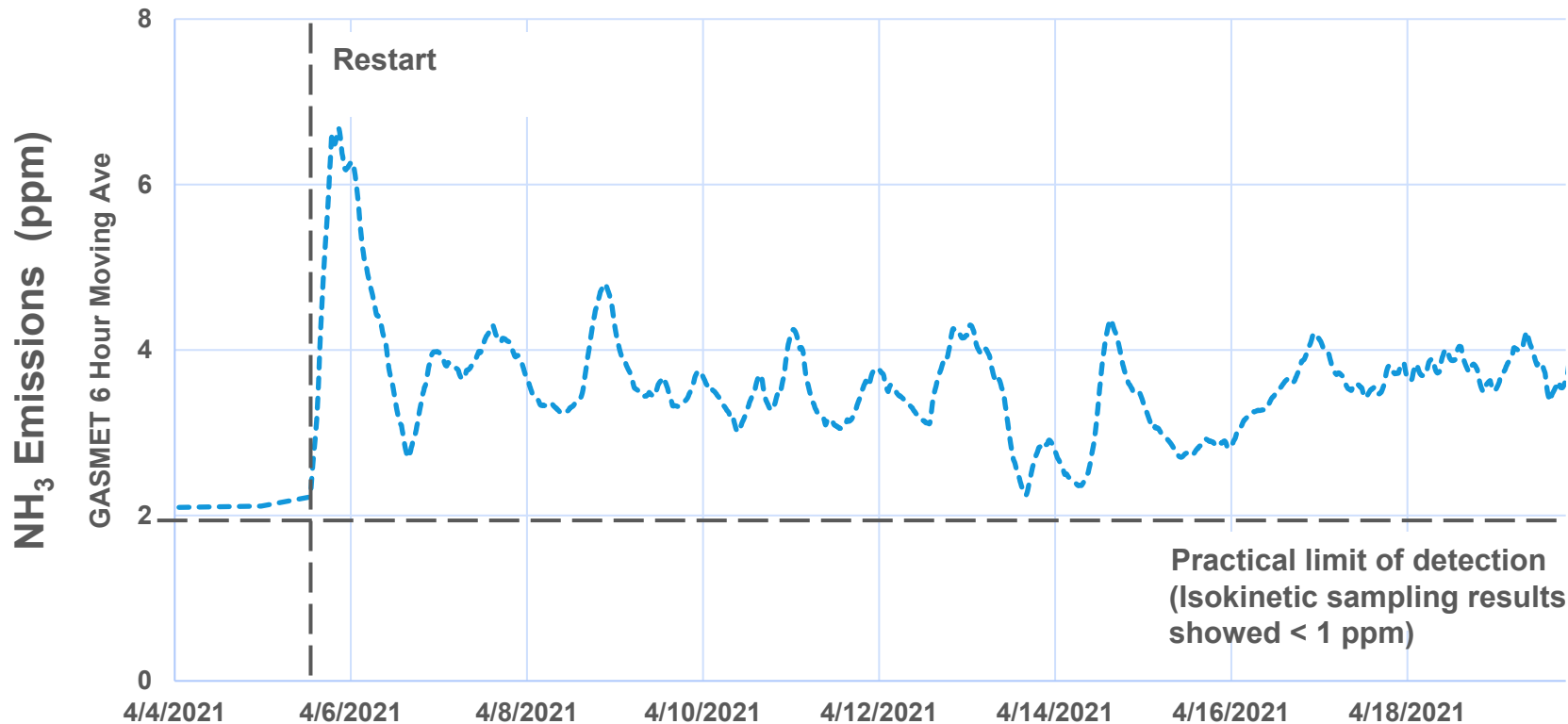
Stable SRD and Operations for 1500 Hours



ICE-31 Transformational Stability



Low Emissions



ICE-31 DEVELOPMENT PATH FOR NGCC AND COAL GAS RESULTS

ION's CO₂ Capture Technology Development – ICE-31

Development Path



2016

Lab Development

Simulated Flue Gas



2017 - 2018

**Bench-scale
Pilot**

>3,000 hrs Coal

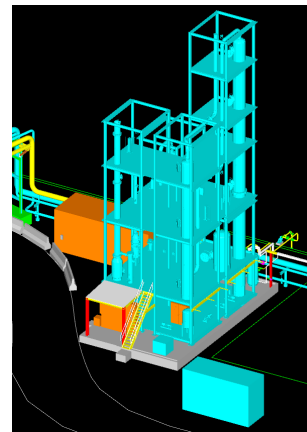


2019 - 2021

**National Carbon
Capture Center**

0.5 MWe

Coal & Natural Gas



2020 - 2023

**Project Enterprise
~10,000 hours
10 tpd (~1 MWe)**

Natural Gas



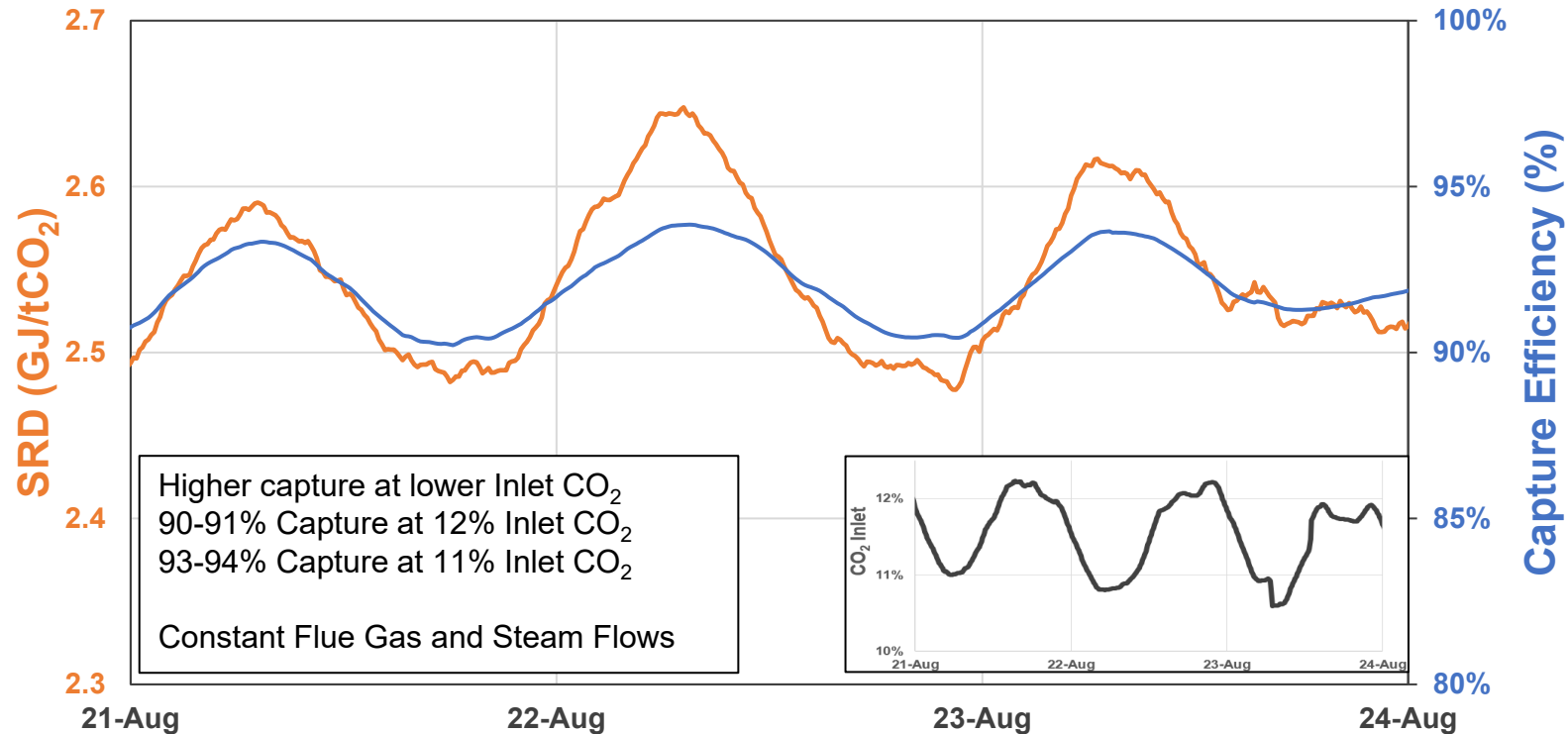
2022 →

**Commercial
Scale**

Commercial
operations
FE&P
FEED
Feasibility

Coal gas: Effect of load-following on SRD and CE

Steady state operation with Advanced Flash Stripper



NCCC Team

DOE Office of Fossil Energy & Carbon Management

ION Team

THANKS



Acknowledgement

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Appendix

Organization Chart

ION Engineering

(Lead Institution)

- Management of scope, schedule and budget of overall project
- Laboratory work to support solvent property information development
- Develop test plan for 0.6 MWe demonstration
- Supervise NCCC in daily execution of test plan
- Analysis of all campaign and laboratory data
- Complete DOE Deliverables: TEA, Technology Gap Analysis, EH&S Risk Assessment, Technology Maturation Plan, and all other required reporting

Commonwealth Scientific & Industrial Research Organisation (CSIRO)

Subawardee

- Laboratory work complementary to ION in support of solvent property information development
- Support for ION's test plan development through testing with simulated gas
- Lab analysis support during test campaign & breakdown product analysis at conclusion of campaign

Optimized Gas Treating (OGT)

Subcontractor

- Module development for ProTreat® simulation software

National Carbon Capture Center (NCCC)

Host Site

- Host site of 0.6 MWe PCC test facility
- Preparation of PSTU for test campaign
- Support for test plan development & execution
- Daily execution of test plan

Sargent & Lundy (S&L)

Subcontractor

- Techno-economic Analysis Development

Hellman & Associates

Subcontractor

- EH&S Support for test campaign
- EH&S Risk Assessment

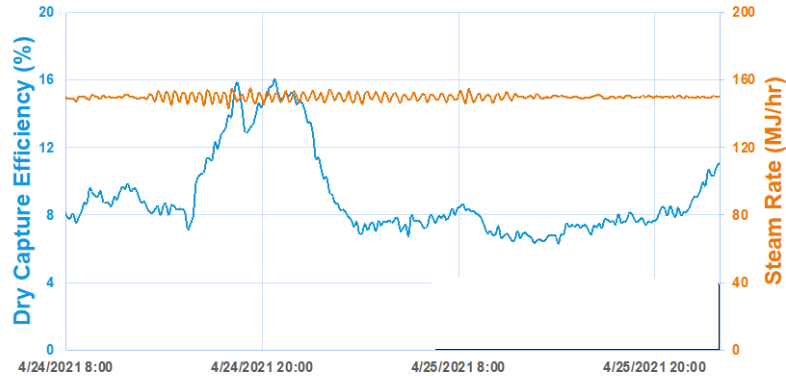
Project Schedule – April 2021 update

To be confirmed with DOE (NCE)

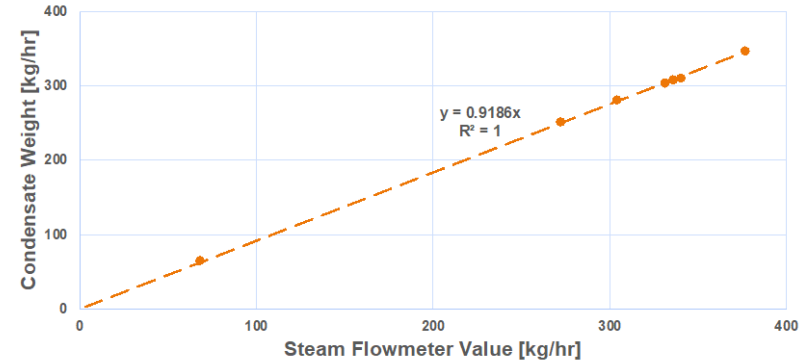
Apollo Project Schedule		Budget Period 1																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Oct-20 -> Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22
Task 1	Project Management	M2				M3		M1		M5		M4	M6-8, 12											M9-11	M13-17
Task 2	Laboratory Scale Evaluations																								
	2.1 Lab-work for ICE-31 Properties																								
	2.2 Develop ICE-31 Process Model in ProTreat®																								
	2.3 Thermal and Oxidative Stability Study																								
	2.4 Process Development Facility (PDF) Operation																								
Task 3	Host Site Preparation and Test Plan Development																								
	3.1 Develop Campaign Test Plan																								
	3.2 Campaign related Environment, Health, and Safety (EH&S)																								
	3.3 Host Site Preparation																								
Task 4	Field Testing at 0.6 MWe PCC Plant																								
	4.1 0.6 MWe PCC Operation Phase I																								
	4.2 Analysis and Phase I Data Evaluation																								
	4.3 0.6 MWe PCC Operation Phase II																								
	4.4 Data Evaluation																								
	4.4 Decommissioning																								
Task 5	Analytical Reporting for DOE Metrics																								
	5.1 Process Model Validation																								
	5.2 Techno-economic Analysis (TEA)																								
	5.3 State Point Data Table																								
	5.4 Technology Gap Analysis																								
	5.5 Environmental Health and Safety Risk Assessment																								
	5.6 Technology Maturation Plan																								
	5.7 Final Reporting																								
Overall Task		Schedule due to COVID-19 Delay																							
Subtask		Subtask at Beginning & end of Project																							

Back-up slide

Determining System Heat Loss *Preliminary*



Recalibrating Steam Flowmeter *Preliminary*



Overall Mass Balance

