ION Engineering Final Project Report
National Carbon Capture Center Pilot Testing

Project Award No. DE-FE0013303

“ION Advanced Solvent CO_2 Capture Project”

SUBMITTED BY

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Disclaimer:

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Executive Summary

ION Engineering, LLC (ION) is developing a proprietary advanced solvent and is one of the leading second-generation solvent developers for post-combustion CO_2 capture. Throughout small scale pilot testing with coal and natural gas-fired flue gas, bench scale pilot and laboratory testing, ION's advanced solvent has consistently demonstrated reductions in regeneration energy requirements by 15-30% in comparison to traditional aqueous mono-ethanolamine (Aq-MEA). These results demonstrate that ION's CO_2 capture technology has the potential to considerably reduce both capital and operating costs.

This report summarizes the results obtained during pilot testing at the National Carbon Capture Center (NCCC) located at Alabama Power's Plant Gaston in Wilsonville, Alabama. On-site work began approximately April 1, 2015, with four infrastructure modifications and additions, and pilot testing began in mid-June 2015. All testing was completed mid-August 2015. ION has published data for this campaign in Energy Procedia as part of the proceedings for the GHGT-13 Conference held in Lausanne, Switzerland.[1]

The NCCC's Pilot Solvent Test Unit (PSTU) utilizes a flue gas slipstream up to a maximum of 5,000 lb/hr from a commercially dispatched base-loaded 880-MW coal-fired boiler. The PSTU was used to validate the performance of ION's CO_2 capture technology against baseline Aq-MEA results.

The overall objectives of this project were to advance ION's solvent-based CO_2 capture process at the equivalent of approximately 0.6 Megawatts electrical (MW_e) scale pilot in order to meet the Department of Energy (DOE) goal for second generation solvents of ≥90% CO_2 capture rate, with 95% CO_2 purity at a cost of <$40 per tonne CO_2 captured by 2025. Additional objectives included: validation of ION's solvent specific simulation capabilities, completion of 1,000 hours of continuous testing, and an assessment of solvent lifetime.

ION successfully validated its solvent-specific ProTreat® simulation models with good convergence throughout numerous parametric and steady state testing conditions. This modeling capability was used to establish target test conditions and operational set points, while empirical PSTU results were used to evaluate simulation accuracy. Using ProTreat® simulations, ION was able to run a highly effective and efficient parametric test campaign. ION brought its solvent system online and operated continuously from the beginning of parametric work to the end of steady state testing, only coming down during commercial plant or PSTU outages, which were limited in occurrence and duration. Total test hours for the program exceeded 1,100 hrs.

ION utilized parametric testing to confirm process set points for optimal performance and primary/secondary control mechanisms. During parametric testing, ION maintained ≥95% CO_2 capture from the flue gas throughout a range of L/G conditions from L/G 2.0 to L/G 3.5. Under these conditions, regeneration energy ranged from 1,400 BTU/lbCO_2 to 1,800 BTU/lbCO_2. Steady state testing was conducted at an L/G of 3.0 with ≥95% CO_2 capture, with a regeneration energy requirement of about 1,600 BTU/lbCO_2. Based on ION's validated ProTreat® model and its

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[1] Brown, N.; Heller, G.; Staab, G.; Silverman, T.; Kupfer, R.; Brown, R.; Brown, A. Novel advanced solvent-based carbon capture pilot demonstration at the National Carbon Capture Center. Energy Procedia GHGT-13 (2017).

process design dedicated to the ION Advanced Solvent system, the regeneration energy can be as low as 1,090 BTU/lbCO_2.

ION demonstrated that it can successfully operate its advanced solvent in a pilot unit designed for traditional Aq-MEA solvent with minimal pilot modifications. Throughout pilot testing at NCCC, ION confirmed its understanding of process improvements and analytics that will enable successful operation of its solvent at significantly lower L/G circulation rates and regeneration energies.

ION is currently working with national and international partners to further demonstrate its carbon capture technology in real process environments and multiple commercial settings. The data gathered from this test campaign conducted at NCCC continues to strengthen ION's solvent technology and positive track record of executing off site test campaigns. ION anticipates that the recently completed pilot scale test at NCCC, along with future projects such as campaigning at Technology Centre Mongstad in Norway, will directly impact the state of the art of CO_2 solvent technologies and facilitate advancement of CO_2 capture towards commercialization and implementation of ION technology.

Introduction

The overall objectives of this project were to advance ION's solvent-based CO_2 capture process at the equivalent of approximately 0.6 Megawatts electrical (MW_e) scale pilot in order to meet the Department of Energy (DOE) goal for second generation solvents of ≥90% CO_2 capture rate, with 95% CO_2 purity at a cost of <$40 per tonne CO_2 captured by 2025. Additional objectives included: validation of ION's solvent specific simulation capabilities, completion of 1,000 hours of continuous testing, and an assessment of solvent lifetime.

ION applied an operational philosophy that concentrated on two key priorities throughout the spectrum of parametric and steady state test conditions to ensure the generation of high quality data that allow for successful execution of the project:

- 1st Priority – Maintain process & water balances
- 2nd Priority – Flue Gas treating to meet DOE goal of 90%+ removal of CO_2

To meet the project objectives, the project entailed of a full process simulation, evaluation of existing equipment of the PSTU and ultimately fitting of the capture process.

Equipment and Process Evaluation

Using baseline MEA process data provided by NCCC, ION modeled MEA performance conditions in the PSTU using the ProTreat® simulation software. Completing this evaluation prior to the test campaign enabled ION to perform detailed analysis of the PSTU process and equipment. Given the characteristics of ION's advanced solvent, optimal test conditions were identified and results from the actual testing campaign were subsequently verified against the predicted model results.

NCCC TEST PLAN				
Steps	**Actions**			
1	**Coal Conditions Parametric Testing**			
	Flue Gas Flow Rate	**L/G**	**Reboiler Duty**	**CO2 Captured**
1.1	Fixed Condition # 1	High	Range: Low to High	>90%
		Medium	Range: Low to High	>90%
		Low	Range: Low to High	>90%
1.2	Fixed Condition # 2	High	Range: Low to High	>90%
		Medium	Range: Low to High	>90%
		Low	Range: Low to High	>90%
2	**Coal Conditions Steady State Testing**			
2.1	Steady state operation at optimum conditions obtained during parametric testing: up to 1,000 hrs			

Some minor changes to the PSTU equipment were requested after completing a thorough review of boundary conditions and existing equipment design, assisted by results from the ProTreat® simulations.

The NCCC, located in Wilsonville, Alabama, is a pre- and post-combustion carbon capture technology research, development, and testing facility. The Post-Combustion Carbon Capture Center (PC4) area at NCCC was completed in 2011 and was the focus of the ION solvent test campaign. Flue gas is supplied via slipstream to the PC4 facilities by Plant E.C. Gaston Unit 5, an 880 MW coal-fired boiler operated by Alabama Power, a subsidiary of Southern Company. The NCCC PC4 facilities includes multiple testing configurations, including the 0.5 MW PSTU that ION occupied during the 2015 test campaign. Upstream of PC4, flue gas pre-treatment includes particulate removal (hot ESP (electrostatic precipitation)), NO_x removal (SCR (selective catalytic reduction)), and flue gas desulphurization (wet-FGD).

PSTU Process Configuration

The PSTU was designed specifically for testing amine-based solvents for CO_2 removal from coal-fired flue gas. The general PSTU process configuration is illustrated in Figure 1. The PSTU contains a caustic scrubber (shared unit operation with other PC4 facilities), direct contact cooler, absorption column, followed by a conventional amine regenerator with thermosiphon reboiler for solvent regeneration and a single bed wash tower downstream of the absorber. The PSTU was designed and built as a robust MEA CO_2 scrubbing process. The flue gas entry point into the actual PSTU (since the pre-scrubber unit is shared with additional PC4 operations) is the Direct Contact Cooler (DCC). The PSTU column information is detailed in Table 1.

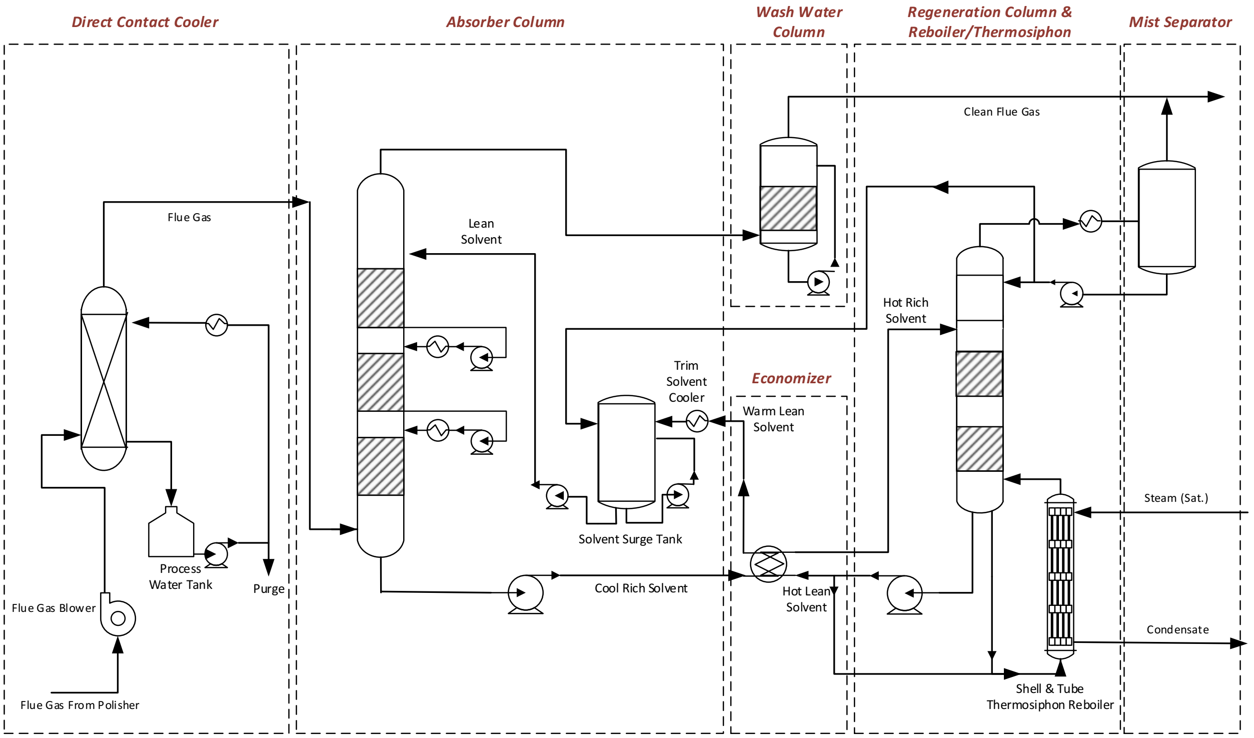

Figure 1 – Generalized process flow diagram of the PSTU at NCCC

Table 1. Column Properties

Property	Units	Pre-Treatment	DCC	Absorber	Regeneration
Column diameter	mm	743	597	641	591
Packing height (total)	mm		3,024	6,048	6,048
Number of sections		1	1	3	2
Packing type			Mellapak 252.Y	Mellapak 252.Y	Mellapak 252.Y
Material of construction		316 SS	316 SS	316 SS	316 SS

PSTU Detailed Process Configuration

The flue gas entering the PSTU is depicted on the lower left side of Figure 1, which occurs after passing through a polisher equipped with MellapakPlus™ M252Y structured packing and a Sulzer VMister™ that introduces aqueous caustic (recirculated) to further remove SO_x (not shown here). For the PSTU, the flue gas meters in at a flow rate of approximately 5,000 lb/hr (0.5 MW_e), and contains approximately 10-13 mol% CO_2 and SO_2 below 2 ppm-mol at approximately 160 ºF. The aqueous caustic will be used in a semi-batch mode. The caustic is expected to pick-up additional SO_2 along with NO_2 and a small amount of CO_2 during normal operation.

The second process step occurs in the PSTU using a dedicated DCC or Cooler/Condenser. This is the flue gas entry point into the actual PSTU (since the pre-scrubber unit is shared with additional PC4 operations). The DCC is equipped with MellapakPlus™ M252Y structured packing and a mist eliminator. This unit operation cools the inlet flue gas from approximately 160 ºF down to a normal operating temperature of approximately 110 ºF. ION required an additional amount of flue gas cooling for optimal technology operation and solvent efficiency, and specified a standalone chiller skid that would take the existing Cooling Tower Water (CTW) utility supplied at 90 ºF, and drop the temperature down to approximately 55 ºF. This 55 ºF chiller water will circulate to an existing heat exchanger that interfaces with the Process Water (PW). PW, now chilled to approximately 65 ºF, is sprayed into the DCC counter-currently to the flue gas stream, effectively cooling the flue gas down to the 85 ºF design temperature. The PW is mostly recycled, with a small volume PW make up stream available. This unit operation also mitigates entrainment of aqueous caustic carryover from the pre-scrubber, in order to protect solvent quality downstream in the Absorber Column.

The third unit operation occurs in the Absorber. The absorber column is equipped with three packed-bed absorber sections comprised of MellapakPlus™ M252Y structured packing. Each section is equipped with a VKR2 liquid solvent distributor plate and a mist eliminator installed at the top of the column. The absorber unit also includes solvent intercooler loops between the beds to optimize the solvent performance at lower operating temperatures. The bottoms of the top and middle beds are each equipped with a SKP draw chimney tray and 4" down pipe. The reaction between CO_2 and ION's advanced solvent is exothermic and there will be an increase in temperature for both the exiting solvent stream and the exiting flue gas stream.

From the absorber, CO_2 rich solvent leaves the bottoms and passes through a cross exchanger / economizer heat exchanger. ION requested, and had installed, insulation for this cross exchanger in order to minimize ambient heat loss and improve efficiency. The insulation minimizes ambient energy losses at the cross exchanger, to maximize heat recovery and further optimize the overall process gains.

The rich solvent travels from the cross exchanger to the next critical unit operation – the Regenerator unit. The regenerator column is equipped with two packed beds, 28 layers each, comprised of MellapakPlus™ M252Y structured packing with a VKR2 distributor and a mist eliminator installed. Upon entering the Regenerator Unit, the rich amine stream could possibly be phase-mixed and/or flashed depending on process conditions. The bottoms of the equipment utilizes either a forced or natural thermosiphon reboiler. Enthalpy from the reboiler will drive the ION Solvent to release CO_2 and thus regenerate lean solvent to be recycled back into the Absorber. Hot lean solvent cools through the cross-exchanger and passes back to the Absorber through particulate + carbon in-line filters.

The final process step takes the flue gas stream from the Absorber column and contacts it with wash water to remove and recover solvent vapor. This water wash column includes a single section of MellapakPlus™ M252Y structured packing with a single VKR2 distributor and mist eliminator.

Special Equipment Required for ION Test Campaign

ION Chiller

ION installed a portable chiller directly into the water pump-around loop on the direct contact cooler (DCC). Preliminary design indicated the need to increase the cooling capacity of this operation. ION took note of significant plant transients which increased the minimum achievable lean solvent delivery temperature to the absorber column by more than 13 °F (>7 °C).

Insulated LRXC

ION insulated the solvent cross exchanger (economizer) to attempt to approach an adiabatic heat transfer operation. Prior to testing with ION, the existing solvent cross exchanger E-404 was uninsulated and a significant amount of ambient heat loss occurs at this unit operation. The advantage of insulating the cross exchanger was to mimic an ideal environment which would facilitate evaluation of optimal pressure drop across either side of the heat exchanger.

Flash Separation Bypass

ION installed a bypass solvent transfer line around the Inlet Separator flash tank which was unnecessary for operation of the ION solvent.

Mobile Laboratory

The ION Mobile Laboratory is a portable, self-contained analytical chemistry lab. A need to provide 24-hour support for near-real-time sampling and analysis of solvent and water conditions during the pilot solvent test campaign led to the fabrication of the lab. The following metrics were measured and tracked throughout testing: Solvent Water Content, Solvent Carrying Capacity, and Solvent Composition. Process control related directly to results obtained from the lab throughout the pilot test campaign. The lab was staffed 24 hours a day and results from the three main analytical techniques were uploaded into a master database for tracking, trending and process control decisions. A retrofitted intermodal container (also known as a Shipping Container, small size 20' x 8' x 8') was converted to include the following analysis: Karl Fischer titration (KF), Total Inorganic Carbon (TIC), and Gas Chromatography (GC).

Test Methodology

After completing modifications to the PSTU and identifying the optimal test conditions for parametric testing, two control strategies were prioritized to further define a successful test campaign.

1st Priority – Maintain process & water balances

The water in the wash tower basin is normally recycled into the process to maintain a reasonable water balance. ION Engineering maintained a water balance by operating at or around a prescribed temperature difference between the flue gas containing CO_2 entering the absorber, and the treated flue gas exiting the absorber. Water balance was achieved shortly after startup and maintained from then on until the end of testing. The water balance was confirmed with Karl Fischer titrations conducted over the entire testing campaign at NCCC.

2nd Priority – Flue Gas treating to meet DOE goal of 90%+ removal of CO_2

Limited control of lean solvent temperature and significant transients due to process constraints required ION to moderate upper absorber temperatures by variation of lean solvent loading and/or lean solvent flow rate if necessary. Both mechanisms where highly effective; however, higher steam flow rates and capture rates above 95% resulted from this method of operation.

Results of the Test Including Data Analysis

ProTreat® Model Validation

Partnering with OGT (Optimized Gas Treating), using the simulation engine ProTreat®, ION directed efforts into developing a solvent-specific simulation model prior to entering into the NCCC test campaign. Using data provided by NCCC obtained during benchmarking with a traditional MEA solvent, ION simulated the PSTU process and narrowed down the number of parametric test conditions prior to the steady state performance period.

OGT's ProTreat® is the best fit for modeling amine solvents because it is a true rate-based simulation, which sets it apart from other commercially available packages. By developing ProTreat® simulations prior to testing, ION was able to run a highly effective and efficient parametric test campaign.

The modeled design case was successfully validated at a variety of process conditions during operation at the PSTU – both parametric and steady state operating conditions. Convergence between the model and actual NCCC data is excellent and shown in Figure 2. The only two blue dot outliers were from initial parametric testing, when the system was not likely at steady state yet.

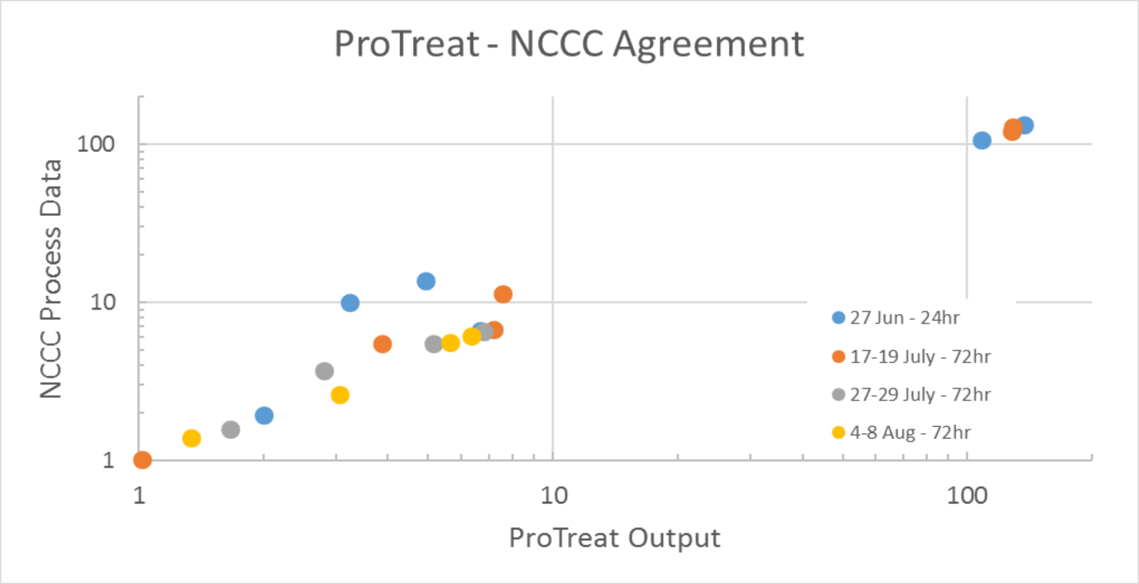

Figure 2 – ProTreat® – NCCC Agreement

Test Hours Accumulated

The official run time on the PSTU was 1,116 hours. The official start was June 24, 2015 at 8:42PM CST (when flue gas was first supplied to the absorber with the solvent flowing). Testing stopped August 10, 2015 at 9:03AM CST.

CO_2 Capture Performance

ION was able to capture ≥ 95% CO_2 at a range of L/G testing conditions, satisfying the project objective of ≥ 90% CO_2 capture.

Specific Heat Performance

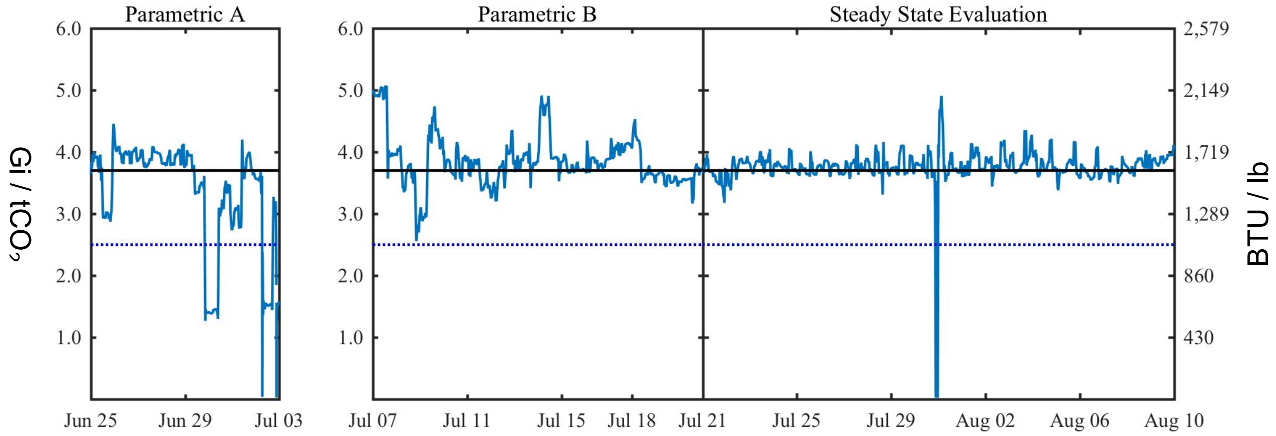

Figure 3 – ION's process performance at NCCC (blue line) and ION's design case performance predicted by ProTreat® (dotted line)

Figure 3 shows ION's process performance for the duration of the campaign. ION's specific energy result obtained while at NCCC was 1,600 BTU/lbCO_2 during steady state. ION captured almost 100% of the available CO_2 throughout this time frame. Running one bed of packing was likely the biggest energy penalty compounded by over-stripping and obtaining capture rates exceeding 97%, shown in Figure 4. There was an unforeseen outage from plant E.C. Gaston from July 3th to July 6th interrupting Parametric testing for a short duration. The design case using ION's solvent is 1,090 BTU/lbCO_2.

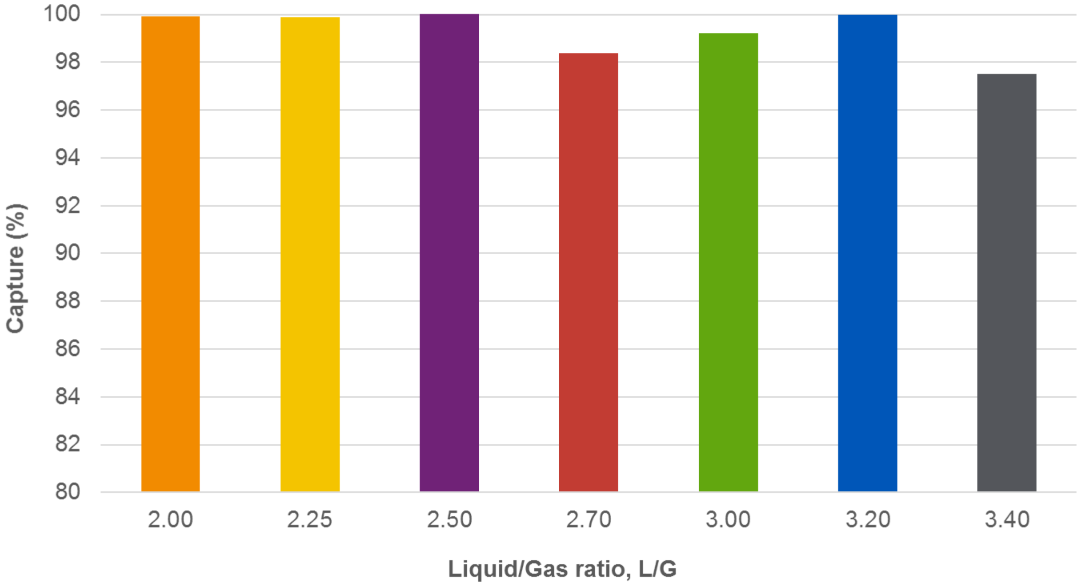

Figure 4 – ION's CO_2 capture rates at NCCC for varying L/G conditions

Solvent Lifetime

Amine-based solvents are known to undergo molecular degradation due to the standard process conditions of a carbon capture plant; this process transforms active solvent into less effective byproducts and is normally mitigated by implementing solvent replacement methodologies (and their associated costs). For coal-fired carbon capture, solvent degradation also includes irreversible reactions with flue gas contaminants.

Studies of heat stable salts (HSS) showed that the highest detected compound was sulfate at about 0.2 wt.% of the entire system after the 1,116-hour exposure (Figure 5). Sulfate is not thought to be a degradation byproduct of ION's solvent; rather, it is hypothesized to originate in carried-over sulfur from E.C. Gaston, or the polisher unit supplying flue gas to the PSTU and reacting with excess oxygen in the flue gas. It is important to note that the ION solvent was never purged. Nonetheless, ION never drained or reclaimed solvent during the test campaign. No impact on solvent performance was observed with respect to specific heat requirement (i.e. steam flow) or capture efficiency, even as degradation products and heat stable salts increased.

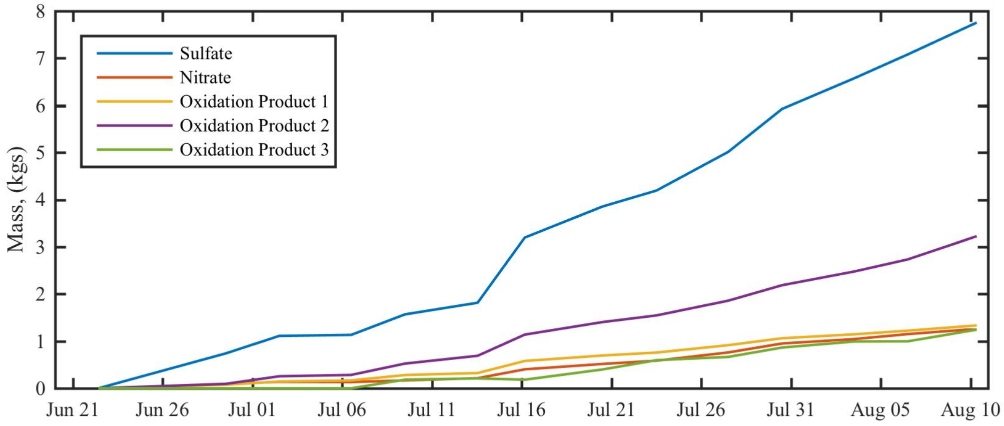

Figure 5 - Accumulation of heat stable salts

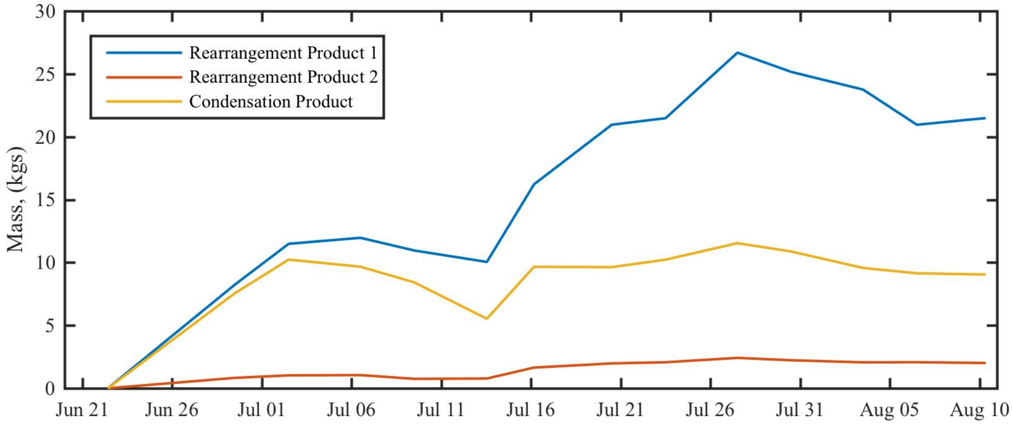

Figure 6 - Solvent degradation

ION solvent from the PSTU was sampled and analyzed for degradation products using GC/MS. Of the degradation products identified, the largest suspected degradation product accumulated to 0.4 wt.% at the completion of the test campaign (Figure 6).

Operational considerations were rectified to best suit the stable operation during the testing campaign. ION did not observe large accumulations of HSS or solvent degradation over the 1,116-hour period, suggesting solvent longevity, although longer testing periods would be needed to confirm solvent durability sufficient for commercial operation.

Metal and Corrosion

Transformational technologies for carbon capture using amines can, and have in the past, presented process conditions that call for expensive, corrosion-resistant materials for the construction of gas treating facilities. ION demonstrated the morphological and chemical tenacity of one carbon steel and three stainless steels at the surface level. The steel samples, in the form of disk coupons, were exposed throughout the testing campaign using ION's solvent.

Scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS), and weight-loss analysis as per ASTM G1-G4 standard methodologies were used to determine acceptable and non-acceptable steel materials for ION's solvent.

Based on the results, ION's solvent indicates a less corrosive potential than MEA. Published pilot scale corrosion studies of MEA in carbon and mild steels showed unacceptably high corrosion rates (> 7 mils per year)[2]. However, carbon steel coupons in the absorber column at NCCC using ION's solvent showed much lower corrosion rates (< 0.05 mils per year). When taking into consideration the substantial process equipment costs associated with constructing a CO_2 capture facility, low corrosion rates is a very important factor to define materials of construction. Carbon steel was less resolute in the regeneration column; lower grade stainless steels were found to be adequate there. Of the metals tested under flue gas conditions, the 304 stainless steel was the most compatible material for ION's solvent system, including the harsh operating conditions associated with regeneration. For future projects with ION's solvent, a lesser grade steel, such as 304 grade stainless steel, will significantly reduce the capital investment required for commercial-sized gas treating facilities.

[2] Cousins, A.; Ilyushichkin, A.; Pearson, P.; Cottrell, A.; Huang, S.; Feron, P. Corrosion coupon evaluation under pilot-scale CO_2 capture conditions at an Australian coal-fired power station. Greenhouse Gas Sci Technol. **3** (2013) 169-184.

General Observations or Process Deviations

Lean Solvent Absorber Inlet Temperature

Temperature control of the lean solvent entering the absorber was greatly hindered by two factors; (1) location of the trim cooler before the solvent surge tank, (2) insufficient heat removal capacity of the heat exchanger. The location of the trim cooler heat exchanger led to sluggish control of the lean solvent temperature, due to both the large thermal mass of the solvent in the surge tank and the solvent heating from the lean solvent pump. Temperature control was ultimately affected by the lack of heat exchanger capacity. In operation, this exchanger was typically running at 100% duty with a stable temperature differential which never achieved the process temperature set point.

One of the most challenging and limiting aspects of the test campaign was controlling the lean solvent temperature entering the absorber. CO_2 capture rate, water balance and solvent inventory are all directly impacted by any fluctuation of the inlet lean solvent temperatures.

DCC/Contact Cooler

The direct contact cooler (DCC) was equipped with a commercial chiller unit to cool the gas contact water loop rather than using the existing cooling tower water. The addition of the chiller unit was chosen to mitigate the risk of excess water intake to the absorber in the inlet flue gas leaving the DCC by enabling lower flue gas temperatures than possible with existing cooling tower water. In operation, there were several issues with the chiller and control of inlet flue gas temperature (Figure 7).

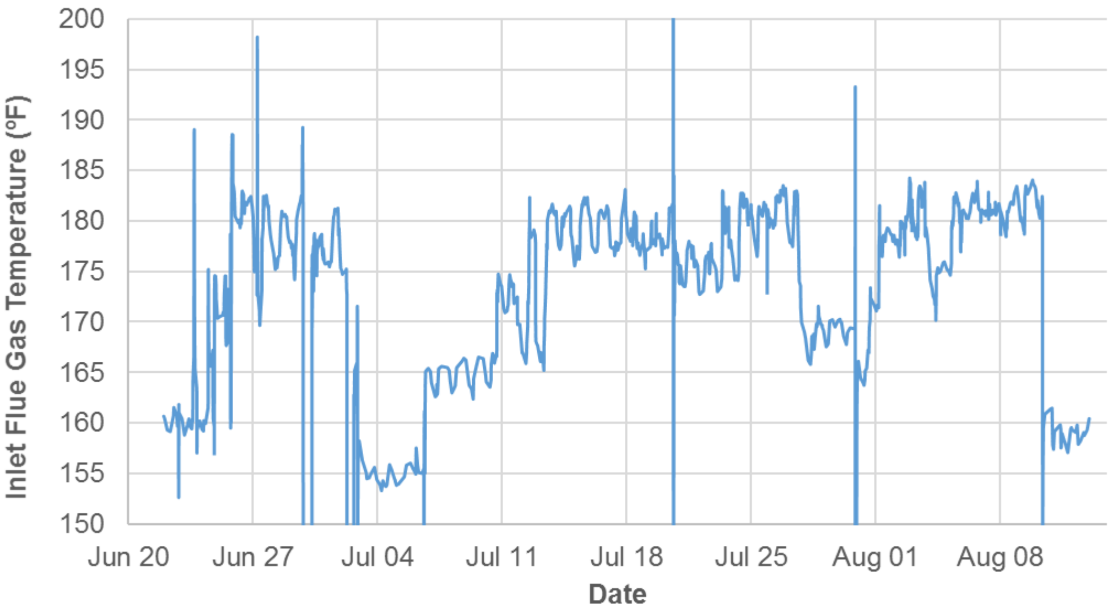

Figure 7: Plot of direct contact cooler (DCC) inlet flue gas temperature vs time

The first unexpected issue was that the chiller unit was equipped with a flow switch that would shut down the chiller when the process control valve would close below 25% open. This would lead to large flue gas temperature swings until the chiller could be restarted. From that point the chill loop process control valve had to be left to manual control to avoid chiller shutdown. The chiller would have been better designed with a full flow idle loop with branching to the DCC heat exchanger such that the low flow would never be activated.

The second issue with the chiller unit was that the maximum temperature set point was too low (68 °F), preventing higher flue gas temperatures to be specified for water balance control.

The largest issue with the chiller unit was that it was undersized for the process conditions experienced at the NCCC. Flue gas temperatures observed typically were 175-180 °F and frequently exceeded 180 °F. The DCC was designed for a maximum inlet flue gas temperature of 160°F, but during the test period unique operating conditions resulted in elevated temperatures. These conditions were a result of the following:

- Flue gas demand: The PSTU pre-scrubber simultaneously provides flue gas to several developer projects which may at times require different pressure profiles. During the ION test, the flue gas blower was required to be operated at its maximum capacity. The compression energy added by the blower to the flue gas providing the inlet pressure requirements to fulfill all developer needs on this common system was higher than anticipated.
- Ambient conditions: The test occurred during the months of June – August, which are typically the hottest months of the year in an area where 100 °F is not uncommon for an afternoon high. This, compounded with the blower demand, contributed to the high inlet flue gas temperature.

- Cooling capacity: The cooling water systems at the NCCC were also close to their upper limit, due to the simultaneous operation of other developer equipment and the ambient conditions experienced. However, the cooling water temperatures were still below the stated maximum design temperature for the duration of the test.

Regardless of the above stated contributing factors to the elevated flue gas temperatures experienced during the test, a sufficiently-sized heat exchanger would be adequate for a commercial platform to meet the requirement for temperature-controlled inlet flue gas.

Discussion and Conclusion

Throughout the majority of the ION testing campaign at NCCC, the ION solvent was considerably and purposefully over-stripped and also operated at a higher L/G than would be designed for a commercial operation. Successfully managing the temperature profile in the absorber column, as well as preventing excess solvent loss to the wash water tower, were the two main reasons for over-stripping and operating at higher liquid flow rate. This operating philosophy deviated from ION's design case. There was considerable difficulty managing the real-time process limitations of more than 13 °F (> 7 °C) observed on the inlet lean solvent feed into the absorber column. Upstream plant transients, combined with the position and limited capacity of the trim cooler compounded this process constraint. The insufficient control of the lean solvent temperature entering the absorber column prevented ION from operating the solvent at preferred conditions.

An additional complication to the management of the absorber temperature profile was found to be characteristics of the solvent itself. The beneficial characteristics of the ION solvent are identified as a high working capacity (and thus, low L/G), and fast kinetics which are preserved to near completion of the CO_2 absorption reaction. Detailed process design is a path to dealing with the claimed benefits of low L/G solvents. Fitting a process to existing equipment is a challenge; designing equipment to fit a technology is a much better approach for commercialization. With less solvent needed to capture a set target amount of CO_2, there is inherently less overall system mass to absorb the thermal energy produced when the CO_2 capture reaction occurs. This higher absorber temperature condition required mitigation steps for this campaign and now becomes a consideration during future process design activities.

The discrepancy in specific heat of CO_2 processing between ION's design case (2.5 GJ/tonne (1,090 BTU/lbCO_2)) and what was observed during NCCC operation (3.6 GJ/tonne (1,600 BTU/lbCO_2)) can partly be attributed to three factors. ION solvent required operation at a 50% higher L/G than the design case, which consequently resulted in capturing 95-100% CO_2 throughout the majority of testing. The energy penalty was further compounded due to the fact that the solvent was still being stripped down to the design case lean CO_2 loading.

ION's testing at NCCC is supportive of the fundamental ION process model. A direct 1:1 validation, was not possible due to process limitations combined with characteristics of the ION solvent. Despite some limitations encountered, important information about the ION solvent was gained during this test campaign. Some key takeaways include: stable operational performance at multiple conditions, low corrosion rates, no observed foaming, and a quickly responding system lending to an ease of operation. All of these benefits support claims made by ION regarding the performance of its leading solvent. ION has published data for this campaign in Energy Procedia as part of the proceedings for the GHGT-13 Conference held in Lausanne, Switzerland.[1]

The ION Engineering Roadmap for Commercialization

ION Engineering first tested their solvent to capture CO_2 in-house on a bench scale setup of approximately 0.01 MWe power plant. Then, ION scaled up to a 0.1 MWe equivalent pilot system at a partner site. In 2015, ION tested at NCCC using their PSTU, which is a plant that delivers CO_2-containing flue gas equivalent to a 0.5 MWe coal-fired power generating platform. The knowledge gained, hands-on experience, and data obtained from testing at NCCC has enabled ION Engineering to continue with new and larger projects using their patented solvent at other facilities. Moving forward, ION is currently (Sep 2016 – Apr 2017) testing at a power plant at the Technology Centre Mongstad in Norway that supplies flue gas equivalent at a scale approximately 25X larger than the capacity of the PSTU.

[1] Brown, N.; Heller, G.; Staab, G.; Silverman, T.; Kupfer, R.; Brown, R.; Brown, A. Novel advanced solvent-based carbon capture pilot demonstration at the National Carbon Capture Center. Energy Procedia GHGT-13 (2017).