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Operational Experience and Initial Results from the First Test Period at CO_2 Technology Centre Mongstad

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Abstract

The CO_2 Technology Centre Mongstad (TCM) is currently regarded as the largest CO_2 capture technology test center for testing and improving CO_2 capture. The aim of the TCM facility is to provide a platform for improving CO_2 capture processes by establishing the means for technology providers to further develop and verify their technologies on a larger scale, thereby promoting the application of CO_2 capture processes at full scale, worldwide.

The amine plant at TCM came on-line during the second quarter of 2012. This paper outlines the main functionalities of the amine plant and presents some operational experiences and initial results from the first operation period with MEA. Further testing in the plant over the next 15 months is dedicated to qualification programs aimed towards full third-party facilitated qualifications for large scale plants with ACC technology.

Keywords: CO_2 technology demonstration; MEA; post combustion carbon capture; amine plant operation experience

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Nomenclature

ACC	Aker Clean Carbon
CCM	CO_2 Capture Mongstad (full scale project)
CHP	Combined Heat and Power
EPC	Engineering, Procurement and Construction
MEA	Mono Ethanol Amine
MTU	Mobile Test Unit
RFCC	Residue Fluid Catalytic Cracker
SRD	Specific Reboiler Duty
TCM	Technology Centre Mongstad
TCMDA	Technology Centre Mongstad Joint Venture

1. Technology Centre Mongstad

The CO_2 Technology Centre Mongstad (TCM) is currently regarded as the largest CO_2 capture technology test center for testing and improving CO_2 capture processes. The facility is owned by TCMDA - a joint venture between Gassnova (the Norwegian state) (75%), Statoil (20%), Shell (2.4%) and Sasol (2.4%) [1]. The facility's total capacity is 100 000 tons of CO_2 captured per year, and the test results will be valid for direct scale-up to full scale CO_2 capture plants. The design and functionality is described in detail elsewhere [2].

The aim of the TCM facility is to provide a platform for improving CO_2 capture processes by establishing the means for technology providers to further develop and verify their technologies on a larger scale, thereby influencing the applicability of CO_2 capture processes worldwide.

There are two capture plants installed at TCM, one utilizing amine technology, designed and delivered by Aker Clean Carbon (ACC), and the second utilizing a chilled ammonia technology, designed and delivered by Alstom.

The two technologies will both be tested on two different flue gas sources. One of the sources is off-gas from the Residue Fluid Catalytic Cracker (RFCC) at the Mongstad Refinery. In addition to being a typical refinery emission gas this source exhibits similar characteristics and properties as flue gas from coal fired plants. The other source is exhaust gas originating from the Combined Heat and Power plant (CHP) at Mongstad.

As part of the EPC contract awarded by TCMDA to ACC, ACC was allocated the right - upon delivery of the plant to TCMDA - to lease the facility for the first period of operation. In essence, ACC being the user of the facility will specify the test program for the first 15 months of operation. TCM DA has the responsibility of operations of the facility including the obtaining of emission permit [3], as well as provision of operational support. Detailed results from testing with ACC proprietary solvents are owned by ACC.

2. Amine Plant

2.1. Absorber and Regeneration units

The purpose of the absorber tower and the associated water wash sections is to absorb a minimum of 85 % of the CO_2 in the flue gas, to maintain the water balance in the plant and to minimize amine and amine degradation products in the treated flue gas before exiting the tower.

The absorber tower in the amine plant is more flexible than commercial CCS plants, with three absorption sections - each with a separate lean amine inlet and a total of 60 temperature sensors, thus enabling thorough investigation of solvent reaction rates and distribution. Results to date have shown clear temperature profiles in the areas of reactions when feeding at all of the three inlets, both horizontally as well as vertically over the packing. This, in turn, provides a comprehensive understanding of the packing height requirements while confirming proper liquid distribution throughout the column.

In the sides of the rectangular-shaped absorber tower, four columns are installed through which gamma radiation sources are fitted (on an ad-hoc basis) to provide a scan of the column internals [4]. This scan has been performed twice; the first serving as a base-line scan and the second was performed shortly after full load of the plant was achieved (flue gas and solvent load). The scans showed no abnormalities, and good liquid distribution profile through the tower. A third scan is planned after a few months of operation to assess if any blockages or mal-distribution have occurred.

Figure 1 : Absorber and regeneration units in the amine plant

The two water wash systems each consist of a three meter packing section, a holding tank, a pump and a cooler. The top washing section may be utilized as an acid wash section. Two demisters are installed - one above the last absorption section and one above the upper water wash packing section. Both water wash systems have been operated at full load (50 t/h and 60 t/h respectively) without acid addition. Very low levels of amines have been detected from the absorber flue gas (below 1ppm) which verifies that the current water wash system was appropriately designed for the MEA specific runs.

To accommodate for the difference in CO_2 concentration in the two flue gas sources, two strippers (desorbers) are installed. The strippers are installed with different types of reboilers, one is a plate and frame reboiler and the other is a shell and tube reboiler. This enables validation of reboiler suitability in various operating scenarios. The welded plate and frame reboiler has proven to be sensitive towards steam/water hammer, subsequently leading to micro-cracking of the internals. While this was being attended to, the RFCC reboiler was put in operation with no further difficulties experienced. The CHP reboiler is expected to be back in service for testing with the ACC propriety solvent soon.

Figure 1 shows a picture from the 3D model of the amine plant, illustrating the absorption and desorption sections.

2.2. Data collection and laboratory

To be able to ensure good technology qualification, a vast amount of data is collected from more than 1000 online instruments in the amine plant and more than 1100 in the utility plant. In addition, there are multiple sampling points for liquid sampling throughout the amine plant. A laboratory has been established as part of the TCMDA infrastructure to analyze the liquid samples using state-of-the-art technologies. As the analytical procedures for many of the measurements required for particularly emissions related activities are in the development phase, extensive amount of time has been spent in establishing methods within the TCM laboratory. This process is on-going as improvements to existing methods are made by outside research organisations. In conjunction to analyses, methods for physical sampling also had to be established. This relates in particular to the isokinetic sampling at the absorber tower exhaust.

Properties such as conductivity, pH and density are measured online in the amine streams and these data can also be verified by lab analyses. Also, emissions monitoring is mainly done online and is regularly verified by isokinetic sampling and lab analyses.

To establish the mass balances and to monitor emissions to air, an FTIR analyzer is installed, measuring various components in the inlet flue gas stream, the treated flue gas stream out of the absorber and the CO_2 product stream out of the regenerator. The FTIR analyzer is the main piece of equipment used for emissions reporting to the authorities, especially for amine, ammonia and aldehyde components [2]. All data is logged and stored in an IP21 data management system.

3. Utilities

The TCM plant provides its own utilities and also receives some utilities from the adjacent Mongstad refinery and the CHP plant. Utilities such as cooling water (seawater), demineralised water, plant and instrument air and nitrogen are provided from the TCM facility directly. The imported utilities include process (raw) water, fire water, potable water and high-pressure steam, which is provided at 30 Barg and 335° C. Both the technology plants have their own steam let-down systems to medium- and low pressure steam. The plants also have their own steam condensate receiving system from where the condensate is returned directly to the Mongstad refinery.

The two flue gas sources are first run through a separate blower to obtain enough transport pressure to reach the TCM plant. The RFCC flue gas is also run through a sea water cyclone for particle removal. The flue gas from the CHP has a CO_2 concentration of ca. 3.5 mole%. There is a possibility to recycle CO_2 when the CHP flue gas source is in use, to boost the CO_2 content up to 9 mole%. It is a relatively clean flue gas with small amounts of NOx, SOx and ammonia, see Table 1.

Table 1: Typical flue gas compositions

	CHP		RFCC	
Component	Concentration (mole %)	Concentration (ppmv)	Concentration (mole %)	Concentration (ppmv)
N_2	78.6		79.5	
CO_2	3.6		12.9	
H_2O	2.5		2.5	
O_2	14.4		4.2	
Ar	0.9		0.9	
NO_x		5		75
CO		3		3
SO_x		0.3		25
NH_3		5		

The online FTIR is set to measure the quality of the flue gas entering the system, but difficulties were experienced in the calibration of the instrument at low levels of NOx. The estimated detection limit of NO (as NOx) is 5ppm at this stage as interferences with water peaks were observed. The result was that the instrument read 0ppm for levels below 5ppm during most of the MEA specific run.

4. General operational experience at TCM

Hot commissioning of the plant was carried out with MEA and flue gas from the CHP. A successful stability test conducted as part of commissioning marked the hand-over of the plant from Aker Clean Carbon to TCMDA and at the same time marked the start-up of the ACC test period at TCM. The initial tests in this test period was also carried out with MEA and flue gas from CHP.

By the end of August 2012, the plant had been in operation capturing CO_2 for approx. 500 hours. Figure 2 below shows the time trend of the flue gas flow into the Absorber. The trend illustrates the operational period with CO_2 capture, during this time frame. It is worth noting that significant time during this period was dedicated to different commissioning-related activities, and several periods of down-time were necessary due to these activities, as evident from the figure. Figure 3 below shows both the accumulated operating hours of the amine plant and the accumulated CO_2 capture for this period.

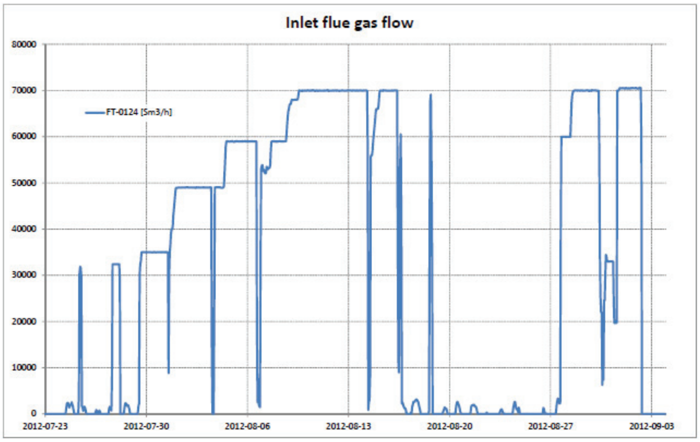

Figure 2: Inlet flue gas flow indicating operational periods, i.e.periods with CO_2 capture.

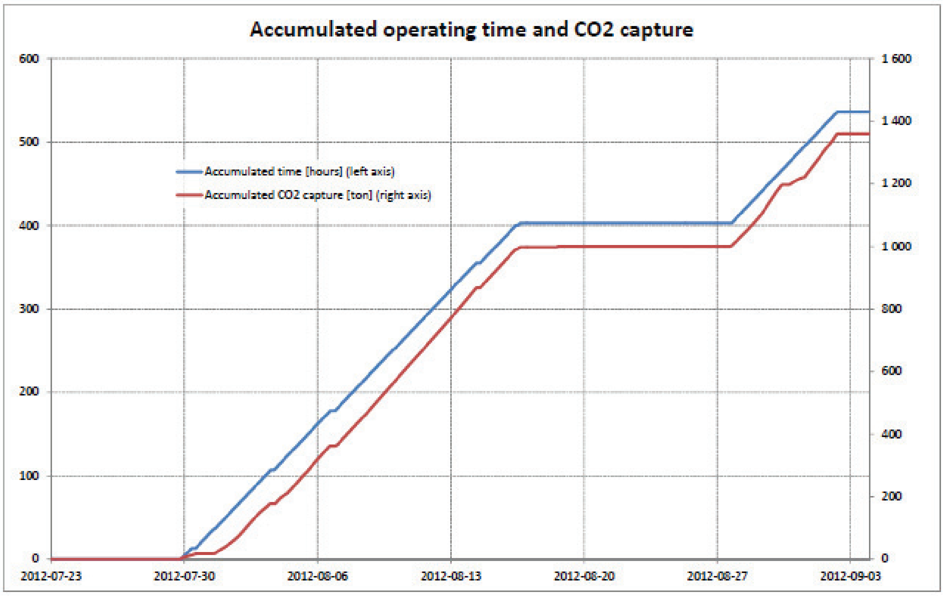

Figure 3: Accumulated hours of operation and CO_2 captured.

It *was* expected that a plant of such complexity in terms of amount of instrumentation would require substantial effort before normal operation was established. This has proven to be the case. The main operational focus this far has therefore been related to tuning of the plant, especially tuning of flow instruments and gas analyzers.

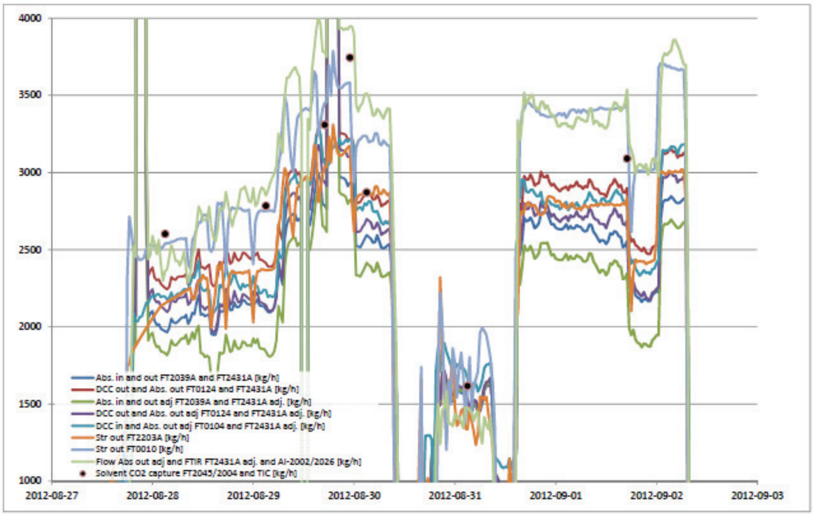

Figure 4: Illustration of mass-balance challenge

Figure 4 illustrates the challenge of mass balance closure, through different measured readings of the captured CO_2. A total of 8 online measurements as well as solvent analysis are available for calculating the CO_2 capture, and as seen, the readings had a discrepancy of ~40%. Through thorough investigations and testing of the flow meters set-up, we have now decreased the discrepancy and are able to close the balances to acceptable levels. Establishing and verification of the mass and heat balances, both in-house and by independent third party is still on-going at TCM.

5. Initial Results

5.1. CO_2 capture degree

During the initial start-up period, it was not our focus to maintain a constant CO_2 capture degree, or to maximize this. As seen from Figure 5, the capture degree has varied between 68% and close to 100% during operation. However, operational experience has now shown that the capture degree can be set at the required level and maintaining the capture at required 85-90% is achievable.

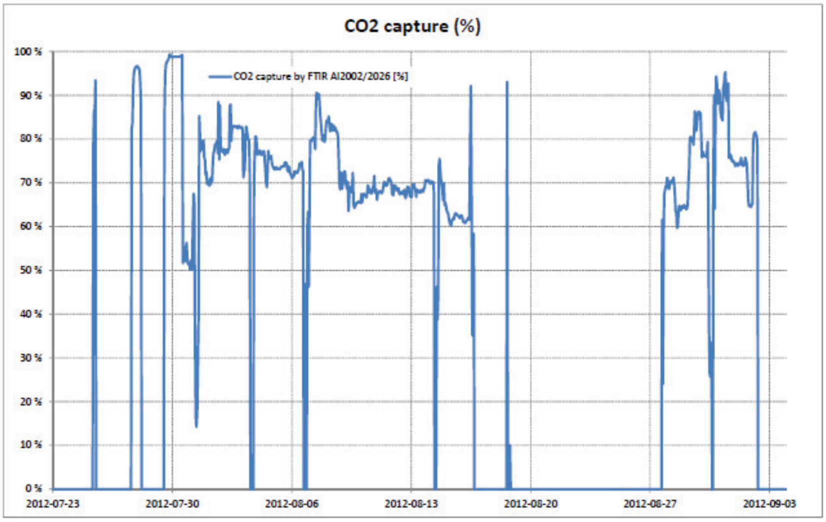

Figure 5: CO_2 capture degree throughout the period

5.2. Energy Consumption

The calculated Specific Reboiler Duty (SRD) in terms of MJ thermal/kg CO_2 captured is shown in Figure 6. Also in the figure, the measured steam consumption and the CO_2 capture is shown. The initially achieved SRD lies between 4.1 and 5 MJ/kg CO_2 and is within what we expected for MEA for these operational conditions, based on earlier experiences.

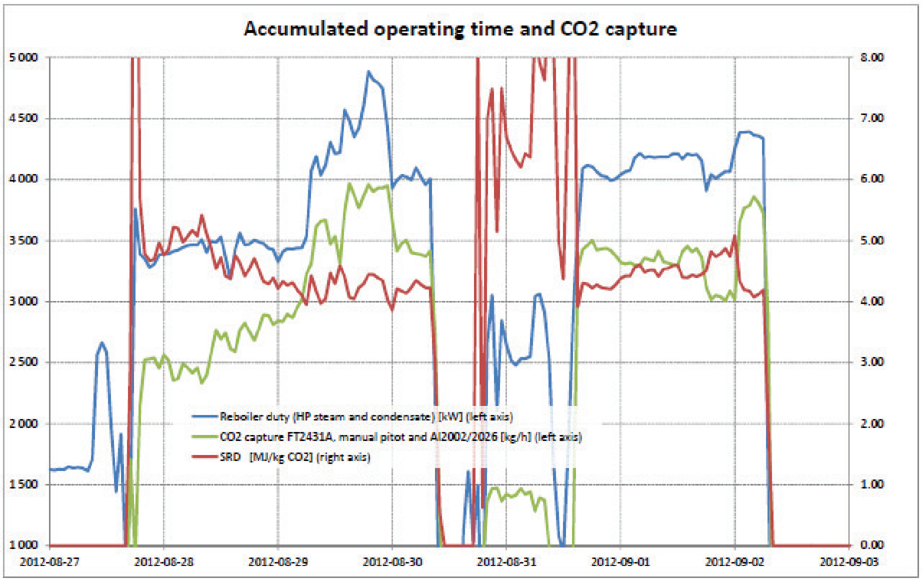

Figure 6: Measured energy consumption

5.3. Emissions

The surveillance and minimization of emission from the TCM plant was and remains top priority [2,3]. The emission from the amine plant is closely monitored through online measurements, isokinetic sampling and lab analysis. In Figure 7, the emission of MEA throughout the period as measured by the online FTIR instrument is shown. It is seen that during this first operational period, low levels of MEA emissions were detected with the online measurements, well within the expectation level and emission permit [2]. Superimposed on the graph are points representing the results from isokinetic sampling and laboratory analysis of MEA. As seen from the figure, these manual measurements have confirmed the readings from the online instrumentation.

6. Future Testing

ACC is responsible for developing a test program at TCM during the Test Period and will utilize the plant for their proprietary solvent development and technology qualification.

Recently, the MEA has been replaced with one of ACC's proprietary amines and for the next months, operation of the plant will be dedicated to a qualification program for the full-scale Mongstad project (CCM) using one of ACC's proprietary amine developed to minimize environmental impact and steam consumption The amine plant at TCM, ACC's Mobile Test Unit (MTU), testing at supplier and laboratory testing are all inputs to this program.

Following completion of the ongoing qualification program, a reference run with MEA (Baseline Reference Case) will be conducted, providing more details and confidence to the data presented as the first initial results. Subsequent to the reference case, ACC will continue to utilize the TCM plant for further testing of their proprietary solvent using both the CHP and RFCC flue gas source.

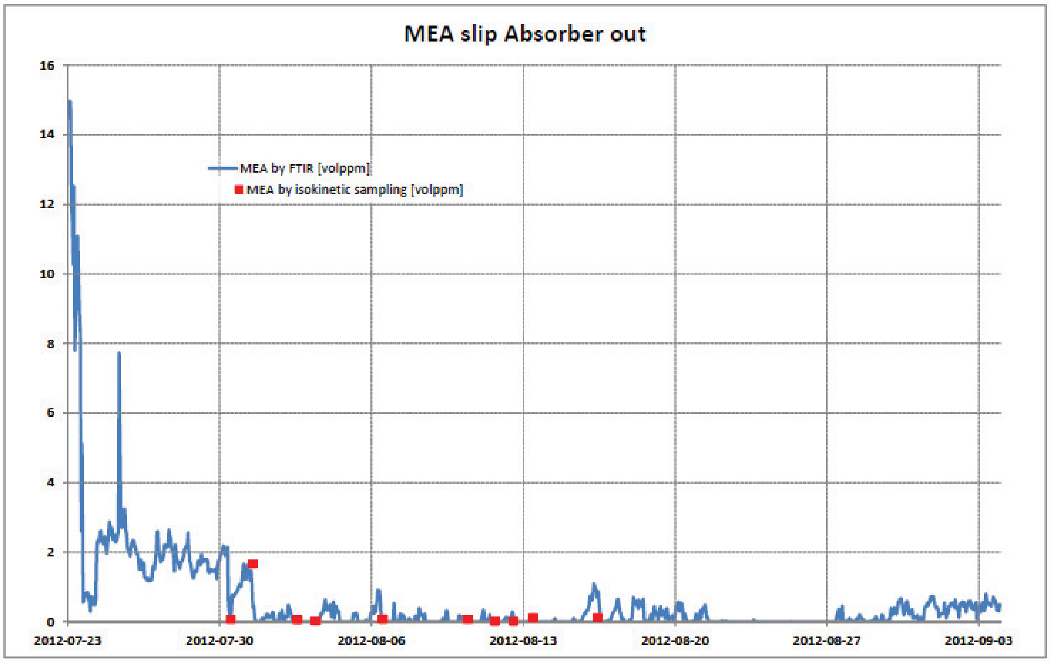

Figure 7: Emission profile as measured by online instrumentation as well as isokinetic sampling.

7. References

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