Department for Business, Energy & Industrial Strategy

SINTEF

C-Capture

drax

COVER NOTE to Key Knowledge Document

Report title: Baseline Test of Capture from Bio Flue Gas with MEA at Tiller Plant

This report is part of the work delivered under project CS359, “Negative CO_2 emissions from full scale BECCS utilising non-amine CCS chemistry”, which is part of BEIS CCUS Innovation call.

The project

The project is looking at implementing CCL’s technology onto existing infrastructure at Drax Power Station, applying it to BECCS (Bio-energy with Carbon Capture and Storage). Aspects of the project include scale-up, testing alternative gas-liquid contactors and feasibility studies to support the business case for full scale BECCS.

Summary of this KKD

A campaign on carbon capture from biomass flue gas was carried out at Tiller pilot plant from 30th September - 8th November 2019. Biomass was supplied by Drax power station. SRD of 3.57MJ/kgCO_2 was obtained for MEA, in agreement with typical values for MEA. The work confirmed the importance of keeping control of the particulate concentration in the flue gas to prevent high amine emissions due to aerosols. Increased levels of typical degradation products for MEA were found at the end of campaign. This can be explained by the high levels of ash dust in flue gas earlier in the campaign when the filter was not working properly. Flue gas was characterised using various set ups: FTIR, CPC, gravimetric and ELPI, for gaseous and particulate measurements at four different locations between the burner and the flue gas exit to the atmosphere. Zero emission of amine from the plant was achieved when the filter was working properly. Particulate effect on emissions was studied by partial bypass of the filter. Relationship is established between emissions, particle mass and particle number. Particle size distribution measurements identified the region of particle size responsible for emissions.

This campaign is one of three which were carried out simultaneously:

CLIME: Baseline Test of Capture from Bio Flue Gas with MEA at Tiller Plant
VOC: Volatile Organic Compounds abatement test at Tiller
TACT: Test of C-Capture solvent and process for CO_2 removal from bio flue gas at Tiller plant

Signed

Caspar Schoolderman (Project Director)

Other KKDs that are linked to this project are:

- FGD flue gas system repurposing study report
- Documents from FGD repurposing study
- Results from demo pilots
    - Baseline Test of Capture from Bio Flue Gas with MEA at Tiller Plant
    - Test of Capture from Bio Flue Gas with C-Capture solvent at Tiller Plant
    - VOC abatement trials at Tiller Plant
    - C-Capture solvent pilot plant results from Drax
- Results from Drax demonstrator evaluating the performance spray towers
- Results from lab column of plastic packed columns
- Results from TCM plant or similar scale plant
- Grant closure report
- CO_2 compression design report

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Report

Baseline test of capture from bio flue gas with MEA at Tiller plant

Tiller plant campaign CLIME 2019

Author(s)
Ugochukwu Edwin Aronu
Thor Mejdell, Kai Hjarbo, Actor Chikukwa, Andreas Grimstvedt, Are Lund

SINTEF Industry
Chemical and Environmental Process Engineering
2021-02-18

SINTEF Industri
SINTEF Industry
Address:
Postboks 4760 Torgarden
NO-7465 Trondheim
NORWAY
Switchboard: +47 40005100

info@sintef.no

Enterprise /VAT No:
NO 919 303 808 MVA

Report

Baseline test of capture from bio flue gas with MEA at Tiller plant

Tiller plant campaign CLIME 2019

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AUTHOR(S)
Ugochukwu Edwin Aronu
Thor Mejdell, Kai Hjarbo, Actor Chikukwa, Andreas Grimstvedt, Are Lund

CLIENT(S) C-Capture Limited DRAX Power Station	**CLIENT'S REF.** Caspar Schoolderman Carl Clayton
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ABSTRACT

A campaign on carbon capture from biomass flue gas was carried out at Tiller pilot plant during 30th September - 8th November 2019. Biomass was supplied by Drax power station. SRD of 3.57MJ/kgCO_2 was obtained for MEA, in agreement with typical values for MEA. The plant was down at various time during the campaign due to operational issues mostly linked to the accidental short circuit of one part of the flue gas filter elements. These incidents, although unwanted, revealed the importance of keeping control of the particulate concentration in the flue gas to prevent high amine emissions due to aerosols. Increased levels of typical degradation products for MEA were found at the end of campaign. This can be explained by the high levels of ash dust in flue gas earlier in the campaign when the filter was not working properly. Flue gas was characterised using various set ups: FTIR, CPC, gravimetric and ELPI, for gaseous and particulate measurements at four different locations between the burner and the flue gas exit to the atmosphere. Zero emission of amine from the plant was achieved when the filter was working properly. Particulate effect on emissions was studied by partial bypass of the filter. Relationship is established between emissions, particle mass and particle number. Particle size distribution measurements identified region of particles responsible for emissions.

PREPARED BY Ugochukwu Edwin Aronu	Ugochukwu Edwin Aronu (Feb 18, 2021 09:59 GMT+1)	SIGNATURE
CHECKED BY Aslak Einbu	Aslak Einbu (Feb 18, 2021 12:05 GMT+1)	SIGNATURE
APPROVED BY Duncan Akporiaye		SIGNATURE

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APPENDICES

1 Introduction

Carbon capture and storage from sustainably sourced biomass combustion flue gas results in negative CO_2 emissions. The present report describes the results from Bioenergy CO_2 capture; the CLIME project. This bioenergy with carbon capture and storage (BECCS) campaign is a benchmark campaign carried out at SINTEF's Tiller plant during the period September to November 2019. This work is the first of three projects undertaken jointly by Drax, C-Capture and SINTEF. The joint effort aims to further qualify C-Capture technology for CO_2 capture towards commercial scale. In earlier works for C-Capture's technology development, C-Capture Limited (C-CL) had earlier collaborations with SINTEF in the EEF project, a direct industry project, and CAPSIN project, a CLIMIT Demo project.

This campaign was preceded by a burner test campaign at Tiller during 26th August - 6th September 2019 where biopellets from Drax were used as fuel in Tiller multiphase burner. This activity gave a first-hand knowledge on operation of SINTEF's Tiller burner with Drax biopellets.

1.1 The CLIME project

Drax Power Station and C-Capture Limited have combined to understand how commercial bioenergy with carbon capture and storage (BECCS) using C-Capture's CO_2 capture technology, based on a water-lean, transformational non-amine solvent system could be achieved, whilst accelerating C-Capture’s technology development. Within this project, the CLIME (CO_2 removal from biomass burner flue gas using MEA at SINTEF Tiller plant) project, Drax desires to perform a benchmark campaign on CO_2 removal from biomass burner flue gas using a standard amine solvent, MEA. Results from this work form the basis for future development of BECCS for Drax and C-Capture. C-Capture is developing their proprietary technology for CO_2 capture in cooperation with Drax. Results from this campaign will be the baseline for comparison with the results from future tests with C-Capture's non-amine solvent system at Tiller. The CLIME project was extended with CLIME-ELPI where additional flue gas characterisation tests were carried out.

1.2 Objectives

The objectives of this work include:

- To perform a benchmark study on bioenergy with carbon capture and storage (BECCS) using a conventional amine, monoethanolamine (MEA), as the capture agent.
- To study the CO_2 removal performance of MEA from flue gas from a biomass burner.
- To perform this benchmark study using the SINTEF Tiller CO_2 pilot plant test rig.
- To use the biomass/biopellets provided by Drax Power Station to produce the flue gas in SINTEF's multifuel burner at Tiller.
- Characterise the flue gas from the burner at various locations before the absorber.
- Monitor emissions from the absorber effluent gas.
- Study solvent stability/ageing in the presence of flue gas from biomass burner during the campaign.

1.3 Biomass Pellets

The biomass pellets used in this project were supplied by Drax power station. Shipment was by land haulage from the producer in Sweden, and also directly from a shipping port in the UK, with some pellets delivered from Drax Biomass in the United States.

The biopellets are made from specific species of woody biomass, which falls under the Drax required specification for combustion at the Drax power station facility in North Yorkshire, UK.

1.4 Representative flue gas composition

A key aspect of the Tiller trials is to test under representative flue gas conditions so that the observed emissions and solvent degradation can be taken as representative for the Drax BECCS conditions.

The Table 1-1 below give the flue gas composition as measured in Tiller and the typical range from continuous flue gas analysis typical of biomass combustion at Drax.

Table 1-1: Flue gas compositions at Tiller and Drax

Species	Units	Tiller Value	Design	Min.	Max.	Representative Min<Tiller<Max
H_2O	Vol%	11.19	11.6	10	12.5	Yes
CO_2	Vol%	13.38	12.2	11	13	Yes
CO	ppm	17.30				
NO	ppm	43.57	84.8	50	114	Yes
NO_2	ppm	0.47				
SO_2	ppm	7.75	11 (SO_x)	0	30	Yes
NH_3	ppm	0.35				
HCl	ppm	0.72	1.2	0	3.0	Yes
HF	ppm	0.38				
HCHO	ppm	0.09				
TOC	ppm	0.16				
O_2	Vol%	5.95	5.8	4.5	8	Yes
Dust	mg/Nm^3	0 to 4.8	2.5	1	30	Yes
Dust	Million particles/Nm^3	2				

*[Fly ash composition comparison Tiller vs Drax – analysis of fly ash from Tiller not completed in UK due to COVID-19 at time of deliverable issue]

2 Description of the Tiller plant

A schematic process flow diagram of the total Tiller plant is shown in Figure 2.1. A propane burner (380 kW) provides heat to the buildings and flue gas to the plant. The plant is also equipped with additional 250 kW coal/biomass burner that may alternately provide flue gas to the plant. The diameters of the columns in the plant have been dimensioned according to the amount of flue gas available and are quite small. However, the design philosophy has been to otherwise design the plant as similar as possible to a full-scale post combustion plant. The gas rate (m/s), the liquid load ($m^3/h*m^2$), the packing material and the total packing heights are similar, such that the conditions for mass and heat transfer from gas to liquid and reaction rates will be very similar as in an industrial sized plant.

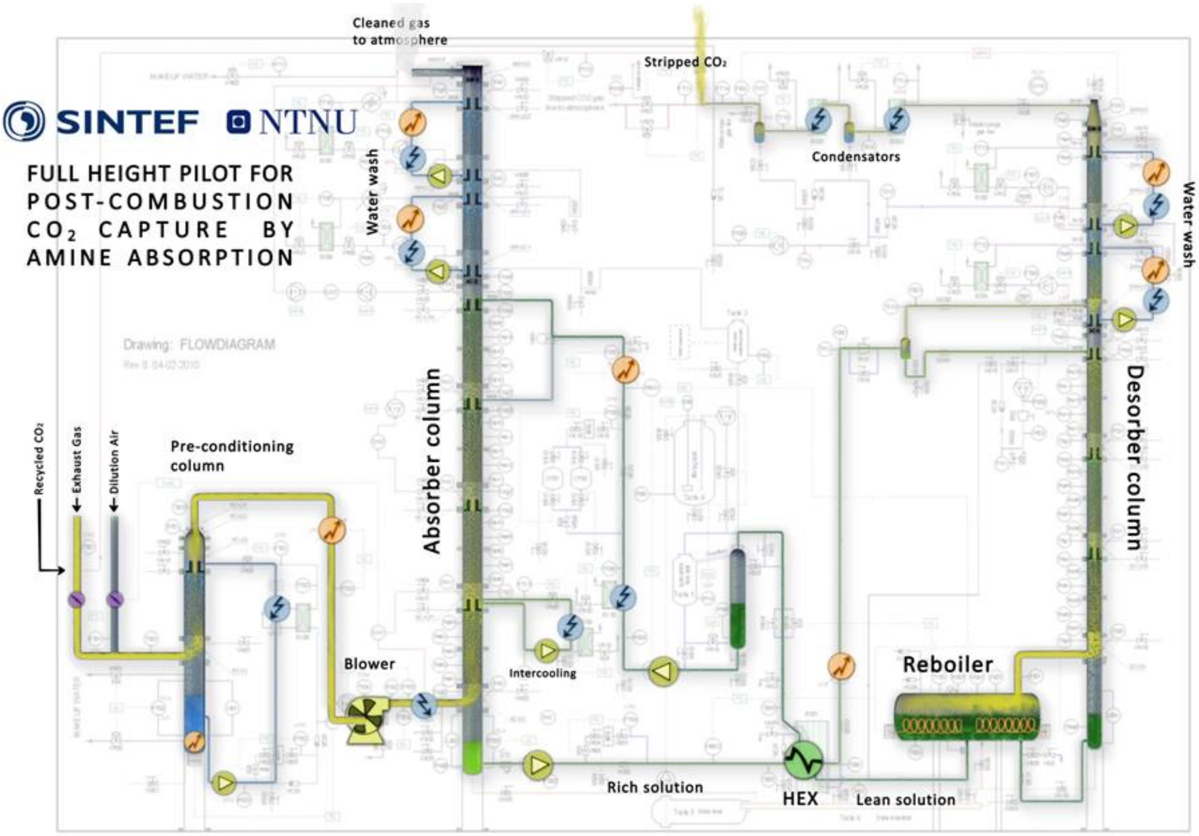


Figure 2.1 Schematic process flow diagram of Tiller pilot plant

Figure 2.2 Tiller pilot plant 250 kW multifuel (coal/biomass) burner

The pilot plant consists of three main parts: the flue gas pre-treatment, the CO_2 absorption part, and the solvent regeneration part. The pre-treatment part is used for setting the flow rate, the temperature, the humidity and the CO_2 concentration to desired values according to the experimental plan. The exhaust gas is first diluted with air and/or supplied with CO_2 from the stripper to produce the desired CO_2 concentration. It then goes through a direct contact cooler (DCC) to cool down the gas and get a well-defined humidity. The DCC is a 26 cm ID column with 2.5 m Mellapak 2X structured packing where cooled water is circulated.

Downstream from the DCC is a high capacity fan. A final adjustment of the gas temperature is obtained by a heat exchanger before the absorber.

The absorption column has 20 cm inner diameter and is equipped with 19.5 m structured Mellapak 2X packing divided into 4 sections. Liquid distributor and redistributors sections (in-house SINTEF design) are installed between each section, which facilitate sampling of both gas and liquid between each section. In the upper part of the column (above the 4th absorption section) 2 water-wash sections structured Mellapak 2X packing are used to remove amine vapour in the flue gas. Demisters are placed above the upper lean solvent distributor and above the upper water distributor to remove entrained droplets. Inter-cooling system has been installed to lower the solvent temperature in between all sections.

The column is instrumented with temperature sensors every metre, and pressure sensors below each packed column sections and above the upper water wash section. Each of these sections is designed for representative sampling of gas and liquid.

The solvent regeneration system consists of reboiler, desorption column and 2 condensers to separate stripped CO_2 and water/amine vapour. Recovered CO_2 will be discharged to the atmosphere, or recirculated to the feed gas system upstream of the DCC in order to increase the CO_2-concentration.

The stripper column has an inner diameter of 16.2 cm, and a total packing height of 13.6 m structured Mellapak 2X packing consisting of 3 sections with solvent distribution/redistribution between each of the sections. The liquid distributor and redistributor sections are of similar design to the absorber. The stripper column is equipped with temperature measurement every metre with pressure measurement below each section and above the upper section. The stripper column and the reboiler are equipped with a heat tracing system providing no heat loss to the surroundings.

The upper part of the stripper column has two water-wash sections similar to the water wash in the absorber. Demisters are placed above the upper (rich) solvent distributor and above the upper water distributor to remove entrained droplets. An interstage-heating system has been installed in between sections of the stripper column.

The whole plant is controlled by a process control system from Siemens (PCS 7). Around 100 temperatures and 70 other tags (pressures, analysers etc.) are handled by the system.

3 Campaign results

3.1 Campaign overview

The 30 wt % MEA was loaded into the plant in late August 2019. The plant started to operate on 30th September in Week 40. The campaign ended 6th November 2019 in week 45. Figure 3.1 shows the periods when the plant was up and running as a function of week number. It shows that the plant was shut down several times. This was because several incidents which will be described in the next section.

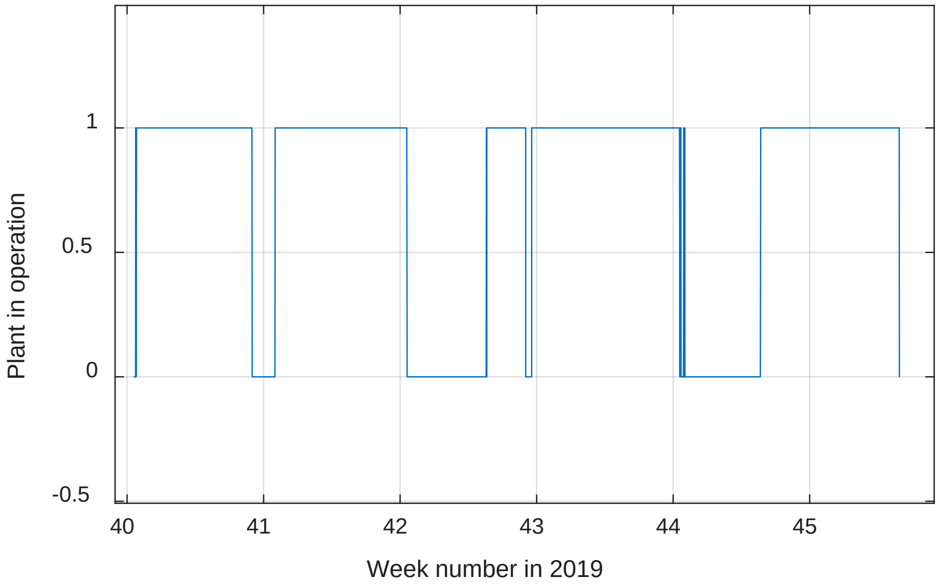


Figure 3.1: Time periods when the plant was running

For slow processes like corrosion and solvent degradation it is reasonable to disregard the periods when the plant did not run. In Figure 3.2 the time on stream (TOS), i.e. the accumulated time the plan was running, is shown as a function of time. A flat curve in this figure corresponds to a period when the plant did not run. Altogether the plant ran for 706 hours.

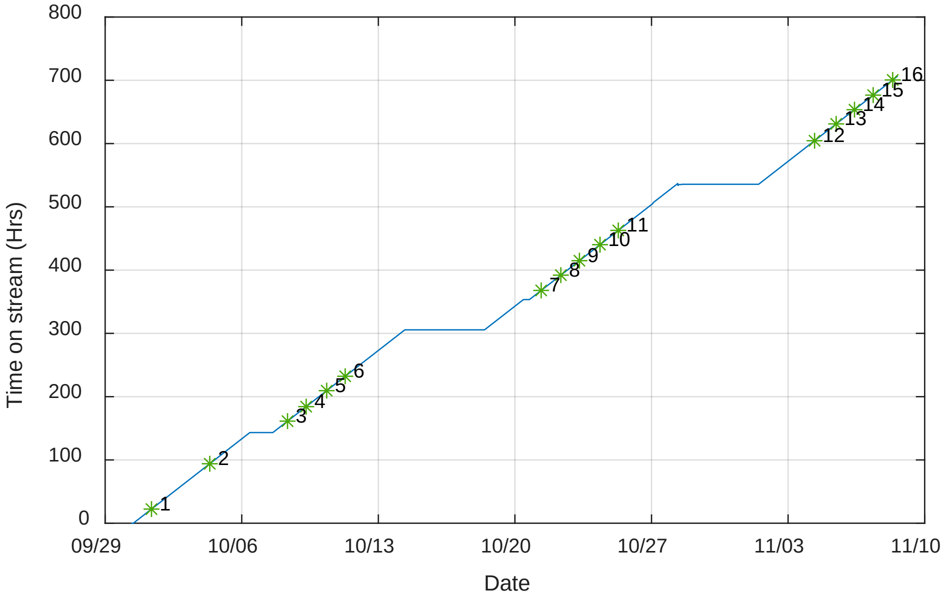


Figure 3.2 Time on stream (TOS) as a function of date. The TOS for the 12 runs is marked with a star

During the campaign 16 steady state runs were taken. The results of a run will typically consist of analysed liquid samples and the average of process variables over the last hour before the sampling.

3.2 Problems with equipment

Some practical problems encountered during the campaign that effected the campaign. These may be summarised as:

- Problems with the flue gas filter.
- Large variation of CO_2 from the bio burner
- Foaming and flooding in the stripper
- Break down of one of the Lean/Rich heat exchangers

3.2.1 Problems with the flue gas filter

Once the flue gas was introduced into the absorber very large emissions of MEA was seen in the FTIR instrument located at the gas outlet from the water wash. These emissions were due to aerosols in the gas. The aerosol mist could also be recorded by a fog sensor and be seen at the outlet from the building and in the inspection glasses between the upper sections of the absorber.

On 2nd October the flue gas into the absorber was switched from bio burner to the propane burner. The emissions shown in Figure 3.3 went down from several hundred ppm to almost nothing. The propane burner gas was used the rest of the week 40 until the plant was shut down due to pressure buildup in the desorber (see section 3.2.2). At the startup of the second week (week 41) the biofuel gas was introduced again until the plant went down due to trouble with the fan (see section 3.2.3).

During the third week (week 43), 16th October, the filter was opened, and it was disclosed that one filter element in the ceramic PALL filter was not implemented properly after a service last summer. The emissions of MEA were reduced to less than 1 ppm afterwards when the filter again was in order. This filter short circuit however resulted in the introduction of high dose of flue gas ash into the plant and to the solvent during the campaign until it was this was fixed.

It was not easy to quickly detect and correct the problem with the filter since this was the first time this biomass flue gas was passed into the absorber for capture with amine in this plant. It was not clear if the high emission was a character of the biomass flue gas. The resulting operational problems, high emissions and flue gas characterisation results measured by the condensation particle counter (see section 5.4.1) necessitated that the burner PALL filter must be opened for inspection.

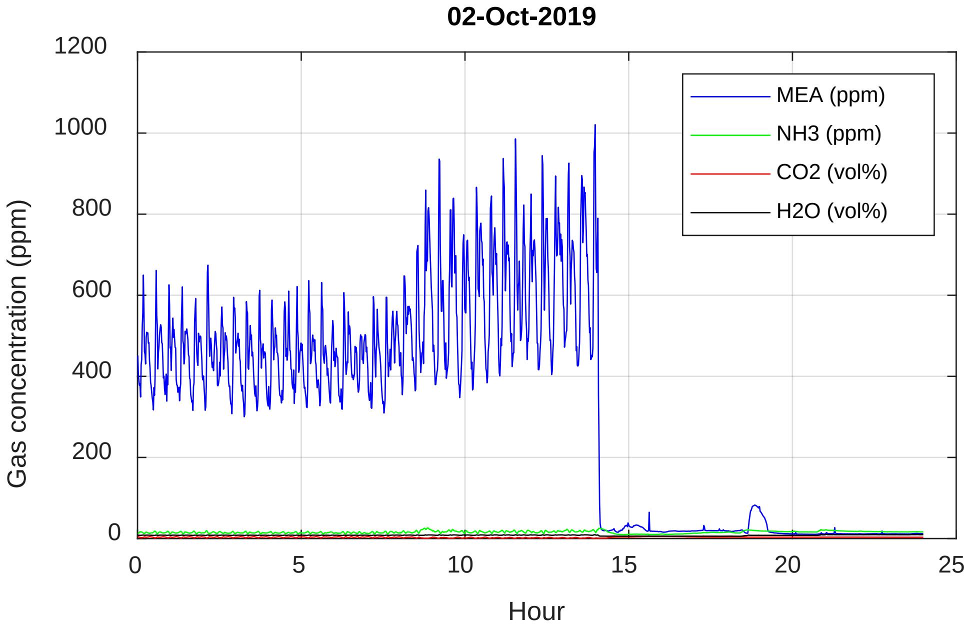


Figure 3.3 Emissions before and after the switch from bio fuel to propane exhaust

3.2.2 Pressure buildup in the desorber

The night between 5th and 6th October an incident with pressure buildup in the desorber occurred. The pressure measurements are shown in Figure 3.4. PT11 is the pressure in the desorber overhead system, which is controlled to 800 mbarg by a gas valve. PI03 is the pressure in the reboiler, while PD1, PD2, PD3 and PD4 are pressure sensors located between the sections in the desorber from the bottom and upwards.

PI03 in the reboiler started to increase slightly at time 19:20. Then it was quite constant from 20:30 to 23:30 when it started to increase again and after 01:15 very rapidly. At the same time the pressure PD1 which is located between the two lowest sections in the desorber started to increase. At about 03:00, PD2, located between section 2 and 3, also started to increase. Afterwards the pressures stabilise but have large oscillations and the plant was finally shut down at about ten o'clock in the morning.

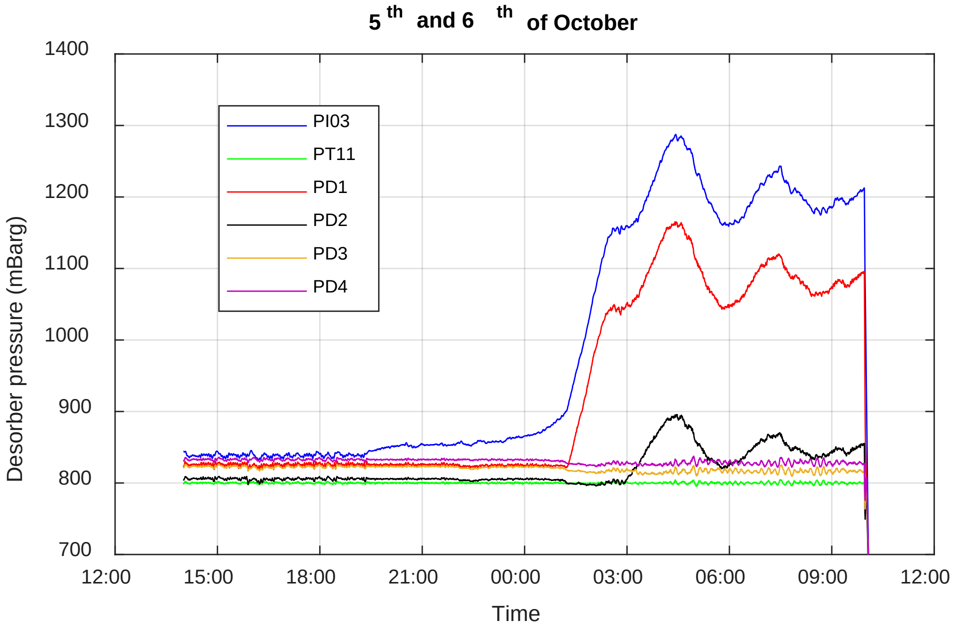


Figure 3.4 Pressure build up in the desorber

Increased pressures are typically due to liquid holdups in the column that restrict the vapor flow upwards in the column. It starts at the bottom of the column and builds upwards in the column. Since nothing was changed elsewhere in the process during the period, we might suspect that a phenomenon like foaming could be a reason.

A foaming test of the solvent (see Appendix) showed an increased solvent foaming compared to the initial solvent. A possible cause of the foaming is the increase of particulates in the solvent due to the filter malfunction. However, the pressure buildup was not experienced later in the campaign.

3.2.3 Problem with the gas fan

After the startup at Monday 7th of October the plant went continuously until the Monday morning 14th of October. The reason was that the gas fan did not work properly. In Figure 3.5 the actual flue gas rate is shown. The setpoint was 160 m^3/h, but the actual amount fluctuated at lot and especially towards the end of the period.

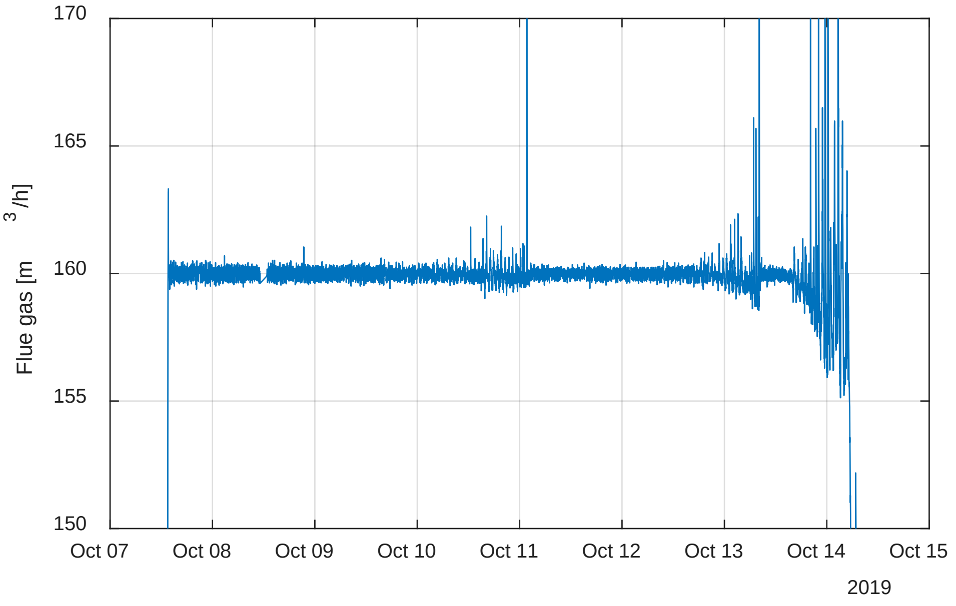


Figure 3.5 Flue gas rate during the second week of the campaign

In Figure 3.6 the temperature before and after the fan is shown. A very high temperature increase is correlated with the periods where the flow fluctuates. This corresponds with a high load on the fan and we had to look for restrictions in the gas pipeline.

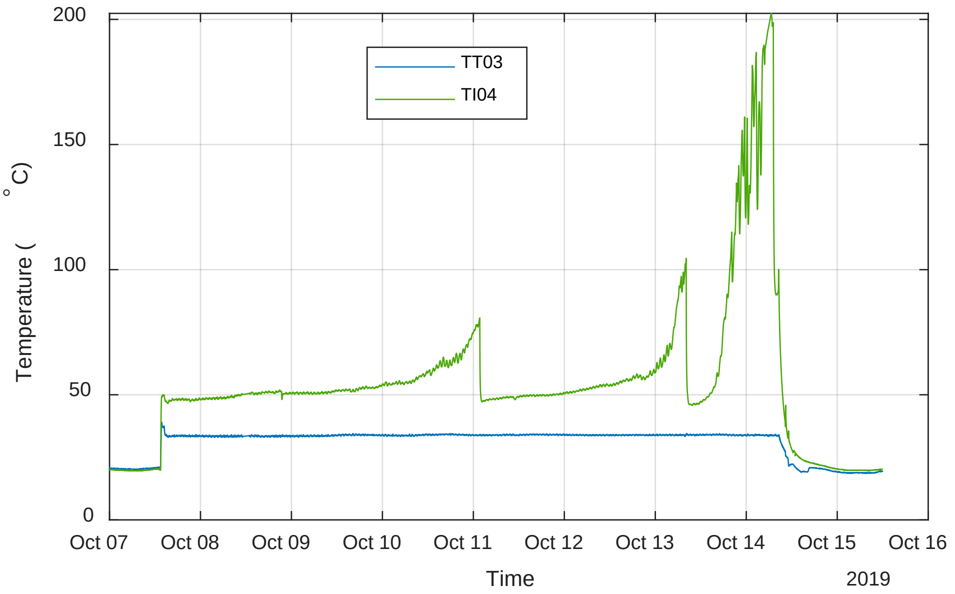


Figure 3.6 Temperature of the gas before (TT03) and after the fan (TI04)

After looking for restriction in the gas flow meter (FT03), the fan was opened and a filter wire in front of the fan was completely filled with particulates from the gas. The fan was then cleaned, and the wire removed.

3.2.4 Large variation of CO_2 from the bio burner

In the beginning of the campaign the bio-burner had large variations in O_2 and CO_2 concentration in the flue gas. This gave a persistent disturbance to the pilot plant and it was difficult to get good steady state data from the plant.

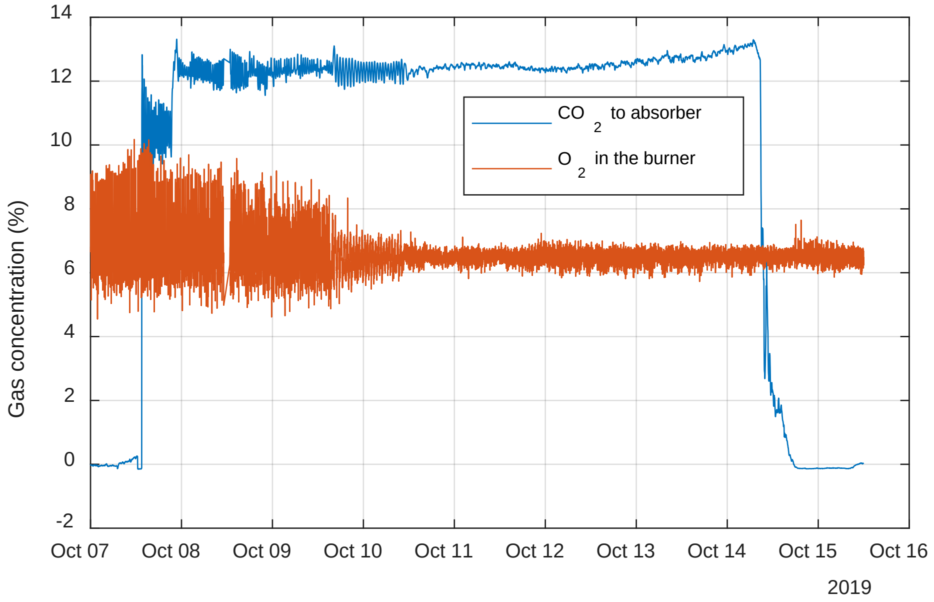


Figure 3.7 Oxygen in the burner and CO_2 to the absorber

An engineer from Polytechnik retuned the controller system for the burner during the days of 9th and 10th of October. In Figure 3.7 the concentrations of O_2 and CO_2 are shown before and after the re-tuning. As can be seen, both concentrations were much more constant afterwards. The retuning had also a large impact on the variations of the temperatures inside the burner as shown in Figure 3.8.

In Figure 3.9 one can observe that the CO_2 concentration, and to some extent also the O_2 concentration, started to increase again later in the campaign. The reason is not clear, but these variations were different. The variation later in the campaign had much higher frequency.

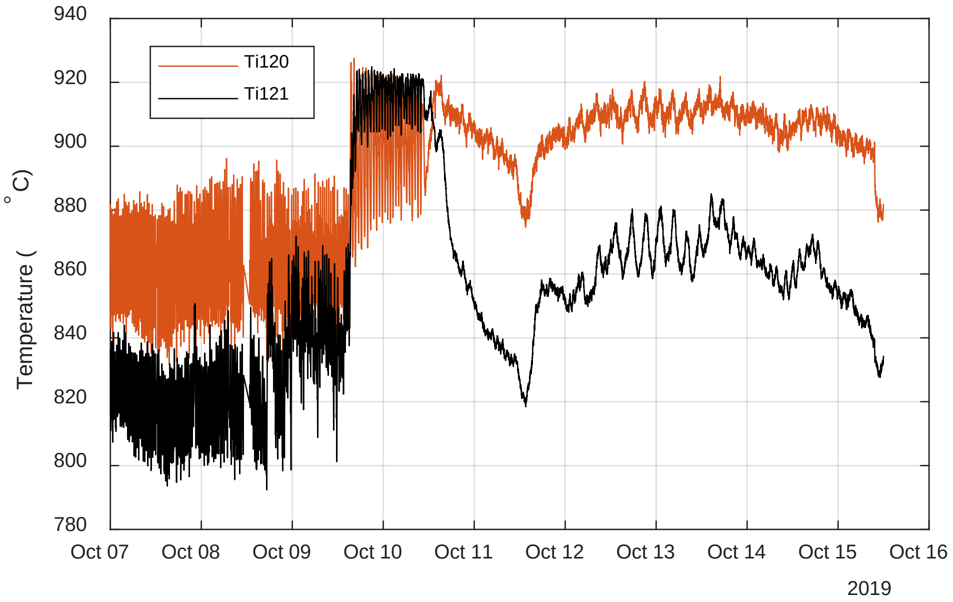


Figure 3.8 Temperature above the flames (Ti120) and the gas leaving the burner chamber (Ti121)

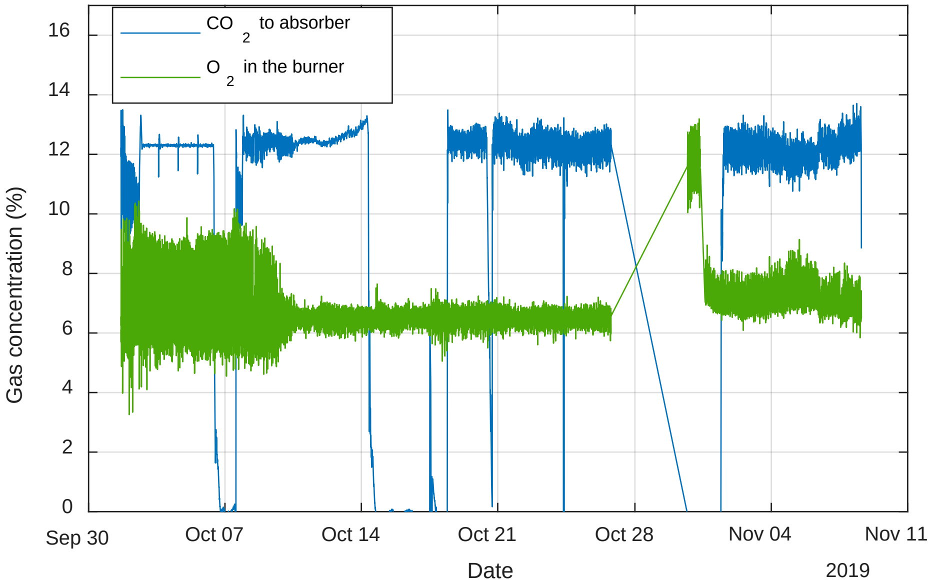


Figure 3.9 Oxygen in the burner and CO_2 to the absorber during the campaign

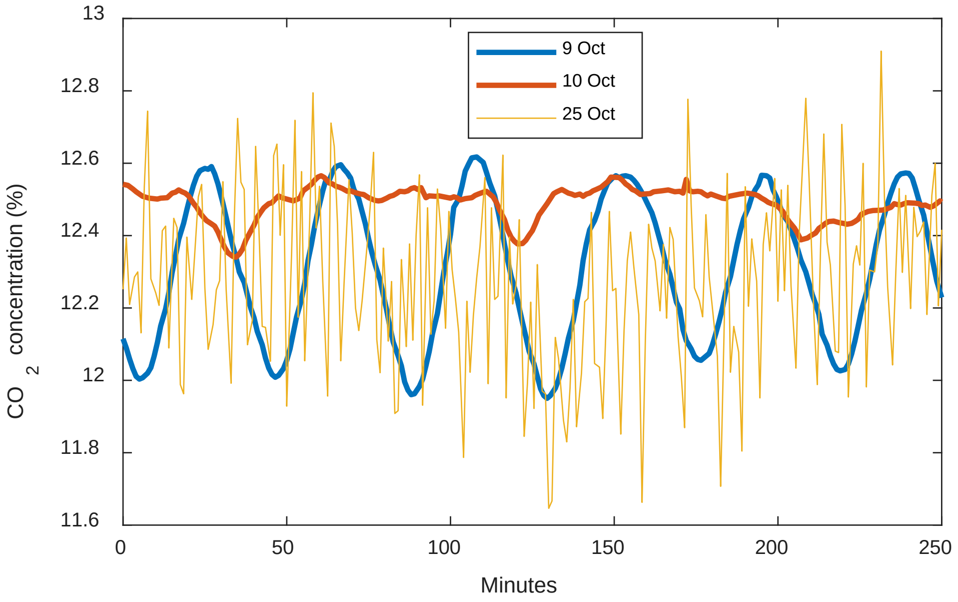


Figure 3.10 Variation of CO_2 into the absorber at 3 different dates

3.2.5 Computer crash and big problems with Lean/Rich heat exchanger

At 0:26 night to 28th of October we had a computer crash at Tiller with the result that no data was stored. The PLC system continued to work, but at some time in the morning also the plant stopped. With no data at hand it is difficult to figure out the exact reason but there was an alarm on low level in the reboiler.

The plant was started up in the morning, but it was difficult to get stable conditions for the plant. The liquid level and the flow from the reboiler was fluctuating all the time. It was also later observed that no absorption was taking place in the plant since CO_2 concentration in and out of the absorber were the same, as well as the rich and lean densities. A leak in the lean/rich exchanger was then suspected. The lean/rich exchanger was opened on 29th October. After a long investigation (including contact with the manufacturer) into the cause of the leakage across the heat exchanger it was found that the leakage occurred in the newer heat exchanger rather than the older heat exchanger as was earlier suspected. The newer heat exchanger was bought off the shelf, and this has an NBR gasket, rather than am EPDM gasket as is used in the older heat exchanger. The campaign then continued with one heat exchanger, this was not a problem since parametric tests had been completed.

3.3 Steady state runs

A total of 16 runs were taken during the campaign. A run was typically performed by adjusting and stabilising the process parameters during the end of one day and taking the liquid samples the next morning. All the sampled process variables were then averaged for about one hour.

In Table 3-1 and Table 3-2 the main results for each steady state run are given. All the variables sampled by the process control system are given in Appendix A.

Table 3-1 The main results for Run 1-8 in Tiller MEA campaign

		Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**	**Run 8**
		01.10.2019	**04.10.2019**	**08.10.2019**	**09.10.2019**	**10.10.2019**	**11.10.2019**	**21.10.2019**	**22.10.2019**
	Sampling time	**09:00**	**08:40**	**08:20**	**07:15**	**08:30**	**07:15**	**08:20**	**08:30**
Flue gas source		**Bio**	**Propane**	**Bio**	**Bio**	**Bio**	**Bio**	**Bio**	**Bio**
Gas inlet ABS	m^3/h	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
CO_2 inlet ABS	vol% dry	12.12	13.94	13.86	14.08	13.88	14.14	14.09	13.72
CO_2 outlet ABS	vol% dry	3.377	1.832	1.575	1.886	2.033	2.413	2.253	1.342
CO_2 recovery	%	74.7 %	88.5 %	90.1 %	88.3 %	87.1 %	85.0 %	85.9 %	91.4 %
Liquid inlet Absorber	kg/min	7.0	7.0	7.0	8.0	6.0	8.5	7.5	6.5
L/G ratio	kg/kg	2.35	2.29	2.32	2.67	2.02	2.82	2.38	2.12
Lean amine (tit)	mole/kg	4.873	4.876	5.068	5.015	5.359	5.405	5.461	5.591
Lean Loading	mole/mole	0.270	0.174	0.172	0.213	0.152	0.250	0.214	0.160
Rich Loading	mole/mole	0.514	0.511	0.501	0.506	0.518	0.491	0.496	0.506
Water Lean	weight %	31.8	32.5	31.8	31.4	30.5	29.8	29.4	29.7
Temp Liq Reboiler	°C	117.6	120.6	120.7	119.8	121.2	119.2	120.6	121.5
Desorber press top	kPa (g)	82.77	82.78	82.78	82.78	82.77	82.77	82.77	82.78
Reboiler pressure	kPa (g)	85.07	87.60	88.13	88.28	87.43	87.43	88.09	87.98
Reboiler duty	kW	22.97	30.03	31.04	31.05	31.55	29.83	31.24	31.75
SRD (based on FT14)	MJ/kg CO_2	3.89	3.74	3.70	3.71	3.87	3.67	3.76	3.64
Temp Gas outlet DCC	°C	21.5	39.7	20.9	21.4	21.7	21.9	21.7	22.9
Temp Lean amine inlet	°C	39.3	39.3	39.3	39.3	39.0	39.4	39.4	39.2
Intercooling TAp5	°C	49.3	50.9	50.1	53.4	46.9	55.3	51.4	48.9
Intercooling TAp10	°C	55.3	57.4	58.0	61.1	53.2	62.7	59.1	56.7
Intercooling TAp15	°C	64.1	68.5	69.5	71.4	65.6	72.0	69.5	69.3
T reboiler Liq	°C	117.6	120.6	120.7	119.8	121.2	119.2	120.6	121.5
T reboiler vap	°C	120.7	123.0	122.7	122.1	122.7	121.5	120.2	123.2
TDp3	°C	105.9	117.1	117.6	112.1	118.8	108.1	112.2	118.6
TDp7	°C	99.1	113.0	114.8	102.1	117.6	100.8	100.6	116.6
TDp13	°C	99.3	103.7	105.9	101.1	113.5	101.0	100.6	109.4
Cold rich TI05	°C	20.7	22.5	20.0	21.1	20.8	21.6	21.2	22.5
Cold leanTI08	°C	47.0	50.2	47.0	48.5	47.2	48.9	47.4	46.9
Hot rich TI06	°C	107.7	109.7	109.2	109.7	109.2	108.9	109.0	108.9
Hot lean TI07	°C	117.6	120.7	120.8	120.0	121.2	119.3	120.7	121.6
Gasout absorber	°C	61.9	67.4	67.1	66.8	68.4	66.4	67.1	68.6
Gas out wash	°C	30.7	27.5	25.0	35.0	29.0	29.0	37.0	37.0
Flow CO2 product	kg/h	21.4	29.1	30.3	30.3	29.5	29.4	30.1	31.5
CO2 FTIR	%		1.7	1.6	1.8	2.0	2.3	2.1	1.4
H2O FTIR	%		8.8	8.1	7.8	6.5	7.0	5.9	5.8
O2 FTIR	%		0.2	0.2	0.2	0.2	0.2	8.9	8.6
MEA FTIR	ppm		13.7	879.6	302.8	447.0	368.4	0.4	0.0
NH3 FTIR	ppm		16.9	10.5	20.4	5.1	31.2	32.9	16.4
CO FTIR	ppm		0.2	27.8	15.4	0.2	1.0	0.0	0.3
NO FTIR	ppm		41.5	88.1	86.0	128.1	87.4	124.3	122.5
NO2 FTIR	ppm		3.6	423.4	127.0	216.0	190.3	6.2	0.8
SO2 FTIR	ppm		0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO2 absorber gas	kg/h	22.3	30.7	31.3	30.9	29.7	30.1	31.7	31.9
CO2 absorber liquid	kg/h	21.9	29.5	29.8	29.5	30.7	29.3	29.7	31.9
CO2 desorber liquid	kg/h	21.5	29.9	29.7	29.4	30.8	29.1	29.4	32.4
CO2 desorber gas out	kg/h	21.3	28.9	30.2	30.1	29.4	29.2	29.9	31.4

Table 3-2 The main results for Run 9-16 in Tiller MEA campaign

		Run 9	**Run 10**	**Run 11**	**Run 12**	**Run 13**	**Run 14**	**Run 15**	**Run 16**
		23.10.2019	**24.10.2019**	**25.10.2019**	**04.11.2019**	**05.11.2019**	**06.11.2019**	**07.11.2019**	**08.11.2019**
	Sampling time	**07:20**	**08:40**	**07:10**	**08:35**	**11:10**	**09:40**	**08:40**	**08:40**
Flue gas source		**Bio**	**Bio**	**Bio**	**Bio**	**Bio**	**Bio**	**Bio**	**Bio**
Gas inlet ABS	m^3/h	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
CO_2 inlet ABS	vol% dry	14.07	13.90	13.69	13.51	13.04	13.25	13.40	13.94
CO_2 outlet ABS	vol% dry	1.580	1.424	1.902	2.547	1.580	1.699	1.833	2.280
CO_2 recovery	%	90.2 %	91.1 %	87.8 %	83.3 %	89.3 %	88.7 %	87.9 %	85.6 %
Liquid inlet Absorber	kg/min	8.0	7.0	6.0	7.5	7.5	7.5	7.5	7.5
L/G ratio	kg/kg	2.57	2.24	1.93	2.41	2.38	2.40	2.39	2.39
Lean amine (tit)	mole/kg	5.522	5.596	5.598	4.825	4.931	5.019	5.032	4.955
Lean Loading	mole/mole	0.215	0.175	0.149	0.199	0.184	0.191	0.189	0.185
Rich Loading	mole/mole	0.492	0.489	0.498	0.506	0.523	0.517	0.513	0.501
Water Lean	weight %	29.4	29.467	29.6	33.3	32.8	31.3	31.7	32.3
Temp Liq Reboiler	°C	120.8	121.366	121.7	124.2	120.5	120.5	120.6	120.6
Desorber press top	kPa (g)	82.77	82.78	82.76	82.77	82.78	82.78	82.78	82.77
Reboiler pressure	kPa (g)	89.58	88.22	87.84	115.20	87.72	88.00	88.02	88.00
Reboiler duty	kW	31.64	31.64	31.65	31.13	31.14	31.14	31.14	31.14
SRD (based on FT14)	MJ/kg CO_2	3.63	3.57	3.77	3.92	3.73	3.72	3.71	3.70
Temp Gas outlet DCC	°C	22.9	23.0	23.3	19.9	19.7	19.7	20.1	20.5
Temp Lean amine inlet	°C	39.3	39.4	38.4	39.4	39.3	39.4	39.4	39.3
Intercooling TAp5	°C	54.2	50.4	46.5	50.3	50.6	50.8	50.8	50.6
Intercooling TAp10	°C	62.6	58.5	53.4	57.1	58.2	58.5	58.4	57.6
Intercooling TAp15	°C	72.8	70.5	65.8	67.2	69.2	69.3	69.1	68.2
T reboiler Liq	°C	120.8	121.4	121.7	124.2	120.5	120.5	120.6	120.6
T reboiler vap	°C	123.0	123.3	123.3	126.7	122.9	122.9	122.9	123.0
TDp3	°C	111.0	117.3	119.0	116.0	115.7	115.2	115.0	115.5
TDp7	°C	102.0	112.1	117.7	103.1	106.0	104.4	104.0	105.0
TDp13	°C	101.6	102.9	113.1	101.8	100.3	100.2	100.2	100.3
Cold rich TI05	°C	22.7	22.8	22.9	40.8	40.5	40.7	41.0	41.1
Cold leanTI08	°C	48.6	46.5	45.4	47.1	46.9	47.0	47.3	47.4
Hot rich TI06	°C	109.6	109.0	108.3	110.3	108.4	108.4	108.4	108.4
Hot lean TI07	°C	120.9	121.4	121.7	124.3	120.6	120.7	120.7	120.8
Gasout absorber	°C	67.8	68.4	68.0	66.1	66.7	67.0	67.1	67.1
Gas out wash	°C	37.1	37.0	37.0	35.5	35.5	26.8	35.5	37.0
Flow CO2 product	kg/h	31.5	32.0	30.4	28.7	30.2	30.3	30.3	30.4
CO2 FTIR	%	1.5	1.5	1.9	2.5	1.7	1.7	1.8	2.2
H2O FTIR	%	6.1	5.9	6.0	5.5	5.8	6.4	5.5	6.0
O2 FTIR	%	8.6	8.7	8.6	9.8	10.2	10.0	10.0	9.6
MEA FTIR	ppm	0.0	0.0	0.0	0.0	37.8	0.0	0.0	0.0
NH3 FTIR	ppm	41.1	29.8	12.7	25.6	28.7	29.2	30.7	31.2
CO FTIR	ppm	0.5	0.0	0.0	83.6	58.6	19.2	178.4	15.6
NO FTIR	ppm	119.1	124.1	110.4	73.3	70.1	77.9	73.0	72.3
NO2 FTIR	ppm	1.5	1.3	0.5	1.7	20.1	2.0	2.7	2.3
SO2 FTIR	ppm	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
CO2 absorber gas	kg/h	32.8	32.9	31.0	29.1	30.48	30.55	30.65	31.17
CO2 absorber liquid	kg/h	31.7	31.0	30.4	28.8	31.4	31.5	31.6	30.5
CO2 desorber liquid	kg/h	32.0	31.1	30.3	29.2	31.5	31.5	31.0	30.6
CO2 desorber gas out	kg/h	31.4	31.9	30.3	28.6	30.1	30.2	30.2	30.3

3.4 Evaluation of experimental quality

3.4.1 Steady state stability

In order to compare different runs with each other it was important to do some qualification checks of the runs. The different runs should be at steady state conditions and data with serious oscillations should be detected.

The following process parameters were examined based on importance and sensitivity:

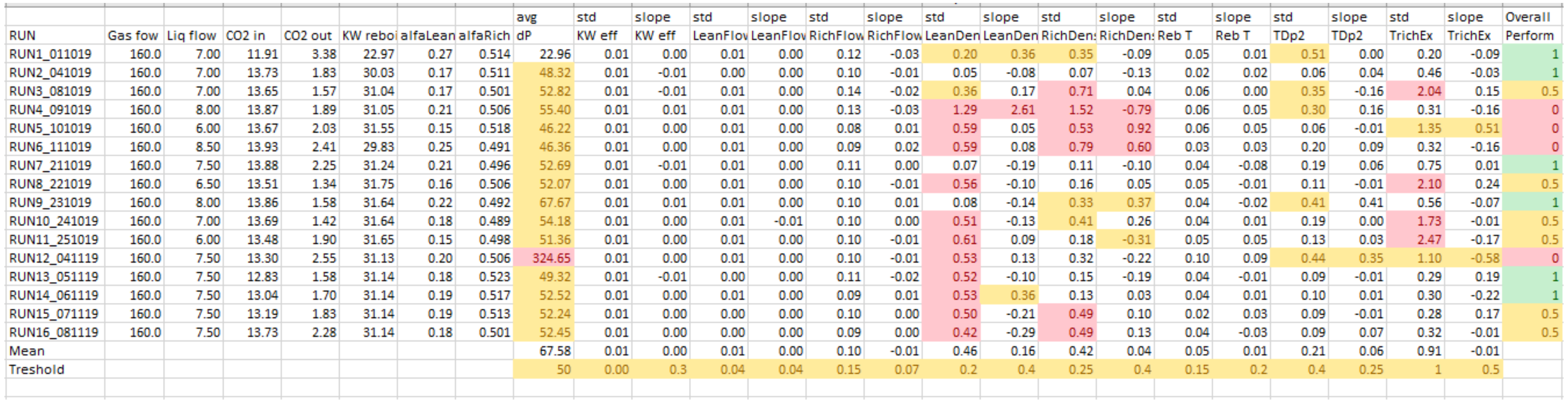
- Lean flow rate
- Rich flow rate
- Lean solvent density (lean loading)
- Rich solvent density (rich loading)
- Reboiler duty
- Reboiler temperature
- Temperature (TDp2) in the stripper
- Rich flow temperature from lean/rich heat exchanger
- Total pressure drop in the desorber

The standard deviation and the gradient during the averaging period were calculated for each of the variables and then compared with the other runs. The standard deviation reveals if the process has serious oscillations, and the gradient reveals if the process is drifting and not at steady state conditions. For example, a high positive or negative gradient means that the variable has increased or decreased significantly during the averaging period.

The result of the tests is shown in Table 3-3. For each variable, we have set a threshold based on experience from earlier campaigns. If a variable is close to this threshold it is marked yellow. If it is above it is marked red and dark red if it is far above the threshold. In the last column an overall assessment for each run is done. The runs are divided into three groups

- Good	marked with 1 and green colour	(6 runs)
- Medium	marked with 0.5 and yellow colour	(6 runs)
- Not so good	marked with 0 and red colour	(4 runs)

Table 3-3 Evaluation of steady state conditions



								avg	std	slope	std	slope	std	slope	std	slope	std	slope	std	slope	std	slope	std	slope	Overall
RUN	Gas fow	Liq flow	CO2 in	CO2 out	KW reboi	alfaLean	alfaRich	dP	KW eff	KW eff	LeanFlov	LeanFlov	RichFlow	RichFlow	LeanDen	LeanDen	RichDen:	RichDen:	Reb T	Reb T	TDp2	TDp2	TrichEx	TrichEx	Perform
RUN1_011019	160.0	7.00	11.91	3.38	22.97	0.27	0.514	22.96	0.01	0.00	0.01	0.00	0.12	-0.03	0.20	0.36	0.35	-0.09	0.05	0.01	0.51	0.00	0.20	-0.09	1
RUN2_041019	160.0	7.00	13.73	1.83	30.03	0.17	0.511	48.32	0.01	-0.01	0.00	0.00	0.10	-0.01	0.05	-0.08	0.07	-0.13	0.02	0.02	0.06	0.04	0.46	-0.03	1
RUN3_081019	160.0	7.00	13.65	1.57	31.04	0.17	0.501	52.82	0.01	-0.01	0.01	0.00	0.14	-0.02	0.36	0.17	0.71	0.04	0.06	0.00	0.35	-0.16	2.04	0.15	0.5
RUN4_091019	160.0	8.00	13.87	1.89	31.05	0.21	0.506	55.40	0.01	0.01	0.01	0.00	0.13	-0.03	1.29	2.61	1.52	-0.79	0.06	0.05	0.30	0.16	0.31	-0.16	0
RUN5_101019	160.0	6.00	13.67	2.03	31.55	0.15	0.518	46.22	0.01	0.00	0.01	0.00	0.08	0.01	0.59	0.05	0.53	0.92	0.06	0.05	0.06	-0.01	1.35	0.51	0
RUN6_111019	160.0	8.50	13.93	2.41	29.83	0.25	0.491	46.36	0.01	0.00	0.01	0.00	0.09	0.02	0.59	0.08	0.79	0.60	0.03	0.03	0.20	0.09	0.32	-0.16	0
RUN7_211019	160.0	7.50	13.88	2.25	31.24	0.21	0.496	52.69	0.01	-0.01	0.01	0.00	0.11	0.00	0.07	-0.19	0.11	-0.10	0.04	-0.08	0.19	0.06	0.75	0.01	1
RUN8_221019	160.0	6.50	13.51	1.34	31.75	0.16	0.506	52.07	0.01	0.00	0.01	0.00	0.10	-0.01	0.56	-0.10	0.16	0.05	0.05	-0.01	0.11	-0.01	2.10	0.24	0.5
RUN9_231019	160.0	8.00	13.86	1.58	31.64	0.22	0.492	67.67	0.01	0.01	0.01	0.00	0.10	0.01	0.08	-0.14	0.33	0.37	0.04	-0.02	0.41	0.41	0.56	-0.07	1
RUN10_241019	160.0	7.00	13.69	1.42	31.64	0.18	0.489	54.18	0.01	0.00	0.01	-0.01	0.10	0.00	0.51	-0.13	0.41	0.26	0.04	0.01	0.19	0.00	1.73	-0.01	0.5
RUN11_251019	160.0	6.00	13.48	1.90	31.65	0.15	0.498	51.36	0.01	0.00	0.01	0.00	0.10	-0.01	0.61	0.09	0.18	-0.31	0.05	0.05	0.13	0.03	2.47	-0.17	0.5
RUN12_041119	160.0	7.50	13.30	2.55	31.13	0.20	0.506	324.65	0.01	0.00	0.01	0.00	0.10	-0.01	0.53	0.13	0.32	-0.22	0.10	0.09	0.44	0.35	1.10	-0.58	0
RUN13_051119	160.0	7.50	12.83	1.58	31.14	0.18	0.523	49.32	0.01	-0.01	0.00	0.00	0.11	-0.02	0.52	-0.10	0.15	-0.19	0.04	-0.01	0.09	-0.01	0.29	0.19	1
RUN14_061119	160.0	7.50	13.04	1.70	31.14	0.19	0.517	52.52	0.01	0.00	0.01	0.00	0.09	0.01	0.53	0.36	0.13	0.03	0.04	0.01	0.10	0.01	0.30	-0.22	1
RUN15_071119	160.0	7.50	13.19	1.83	31.14	0.19	0.513	52.24	0.01	0.00	0.00	0.00	0.10	0.00	0.50	-0.21	0.49	0.10	0.02	0.03	0.09	-0.01	0.28	0.17	0.5
RUN16_081119	160.0	7.50	13.73	2.28	31.14	0.18	0.501	52.45	0.01	0.00	0.00	0.00	0.09	0.00	0.42	-0.29	0.49	0.13	0.04	-0.03	0.09	0.07	0.32	-0.01	0.5
Mean								67.58	0.01	0.00	0.01	0.00	0.10	-0.01	0.46	0.16	0.42	0.04	0.05	0.01	0.21	0.06	0.91	-0.01	
Treshold								50	0.00	0.3	0.04	0.04	0.15	0.07	0.2	0.4	0.25	0.4	0.15	0.2	0.4	0.25	1	0.5	

3.4.2 Obtained CO_2 recovery

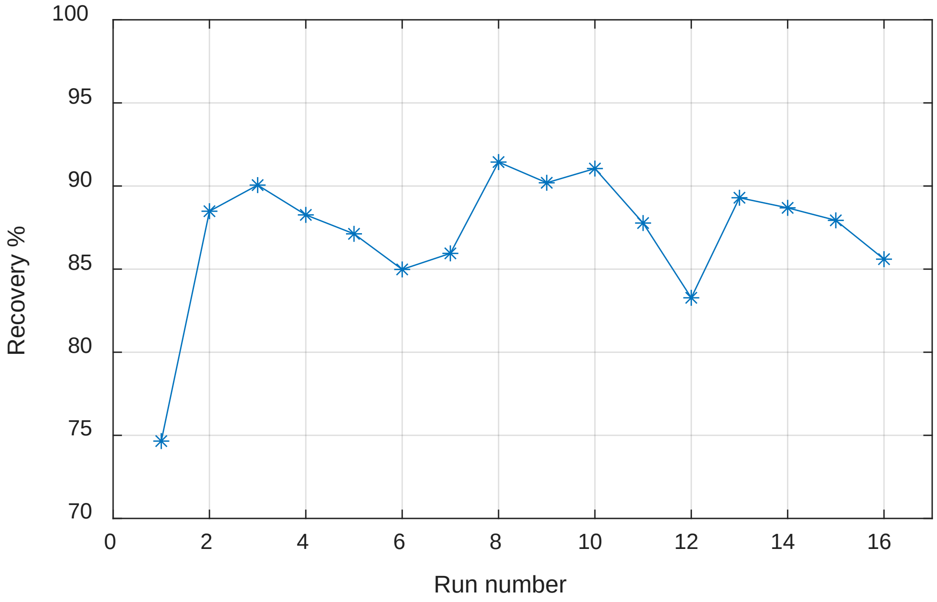


Figure 3.11 CO_2 recovery during the MEA campaign

Figure 3.11 shows the CO_2 recovery in the absorber of each run. Most of the time the recovery was between 85 and 90 %.

3.4.3 CO_2 mass balance

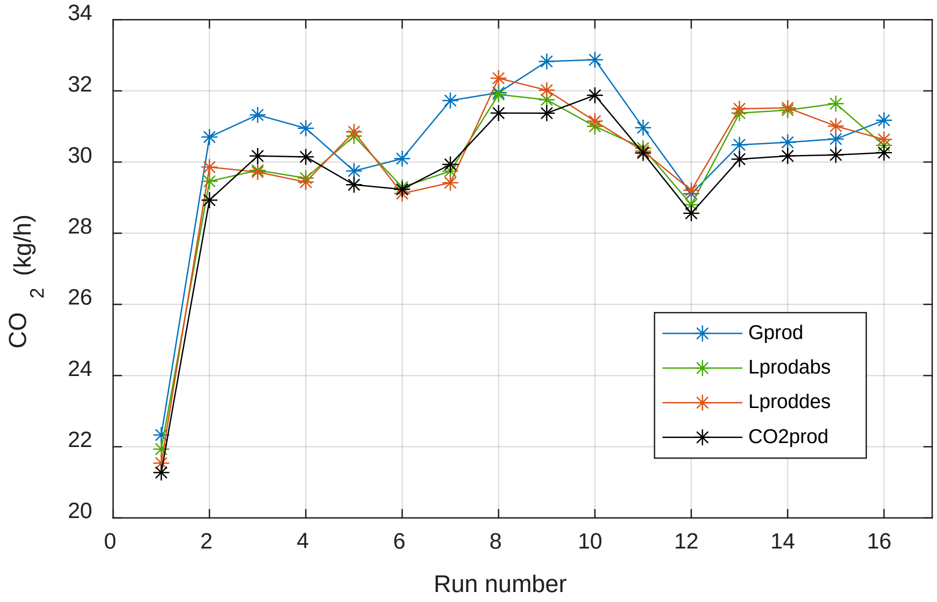


Figure 3.12 Mass transfer rates for CO_2

In Figure 3.12 the mass transfer of CO_2 in the plant is plotted. Four values are shown for each run:

1) Gas_{abs} : The amount of CO_2 taken from the exhaust gas, calculated from gas CO_2 analyses and temperatures in the gas.
2) Liq_{abs} : The amount of CO_2 absorbed in the liquid calculated from liquid measurements before and after the absorber.
3) Liq_{des} : The amount of CO_2 desorbed from the liquid calculated from liquid measurements before and after the desorber.
4) CO_2prod : The amount of CO_2 leaving the desorber, measured by the gas flow sensor FT14 and corrected for water content.

The figure shows very good accordance between the four independent measurements in each run. The standard deviation is on average 2.0%, or 0.6 kg/h.

One may calculate the specific reboiler duty (SRD) based on each of these four mass transfer values. This is shown in Figure 3.13.

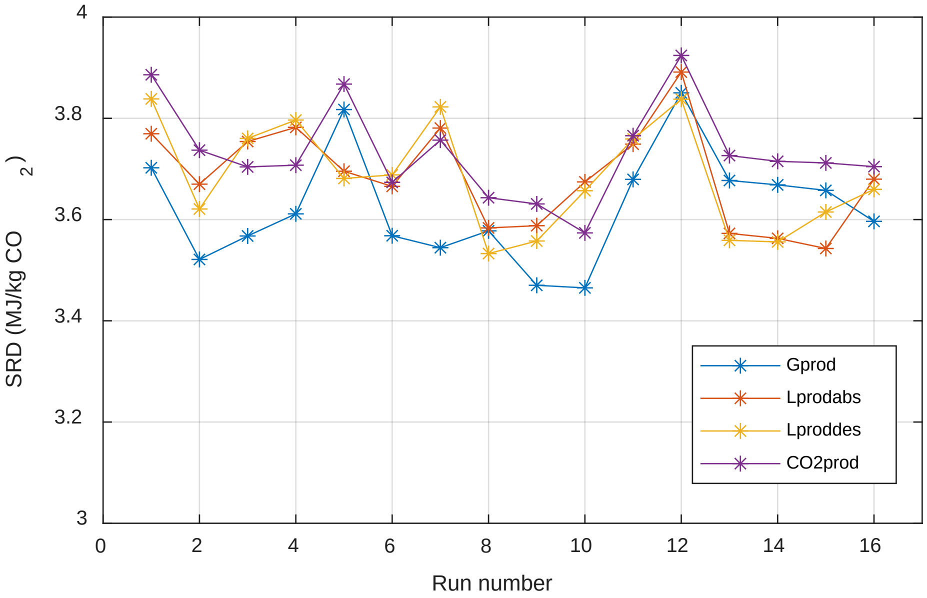


Figure 3.13 The specific reboiler duty (SRD) based on the individual mass transfer rates in Figure 3.12

The standard deviation is in average only 0.07 MJ/kg CO_2. The CO_2 production rate (CO_2 prod) is considered to be the most consistent measurement since it involves only the "FT14" sensor with a small correction for the water content (typically 1%). In the present report, we will use this value further on in tables and figures.

3.4.4 Total Amine balance

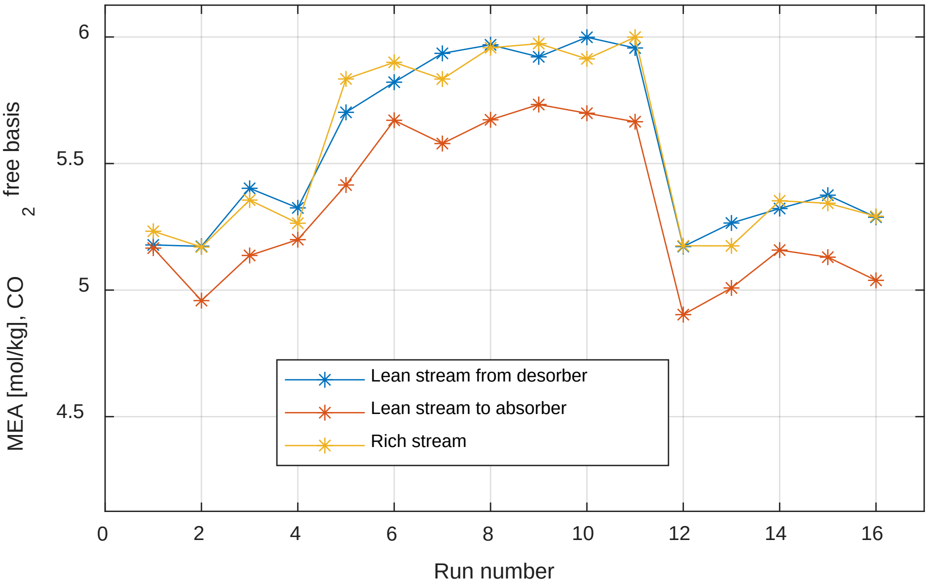


Figure 3.14 Amine concentration during the campaign in mol/kg CO_2 free solution

In Figure 3.14 the MEA concentration from titration is shown for the three sampling points VSL1 (lean stream from the desorber), VSL2 (lean stream to the absorber) and VSR1 (rich stream). In order to better compare the different values they are shown in a CO_2 free basis. This is done by using the following calculations:

$$\mathrm{Cam}_{\mathrm{CO_2free}} = \frac{\mathrm{Cam}}{1\text{-}\mathrm{w}_{\mathrm{CO_2}}}$$

$$\mathrm{w}_{\mathrm{CO_2}} = \frac{C_{CO_2} \cdot 44}{1000}$$

C_{am} and C_{CO2} are the analysed concentrations in mol/kg solution and w_{CO_2} is the weight fraction of CO_2

The CO_2 free amine concentration should be very similar for the sampling points VSL1 and VSLR1 since the mass of water going out with the CO_2 product is very small (~0.15-0.30 kg/h), which is less than 0.1% of overall liquid circulation flow. The measurements also show that this is the case (average standard deviation is only 0.036 mol/kg) and give confidence to the analysed results.

The difference between VSL1 and VSL2 is caused by the water coming from water wash sections into the buffer tank..

3.5 Optimal liquid circulation rate

The plan was to start the campaign by finding the optimal circulation rate. However, because of all of the problems with the equipment, many of the runs were not comparable. After considering the runs for quality, consistency and capture rate we choose the Runs 8 to 11 for comparison. In Figure 3.15, the specific reboiler duty (SRD) is shown as a function of liquid flow rates for these runs.

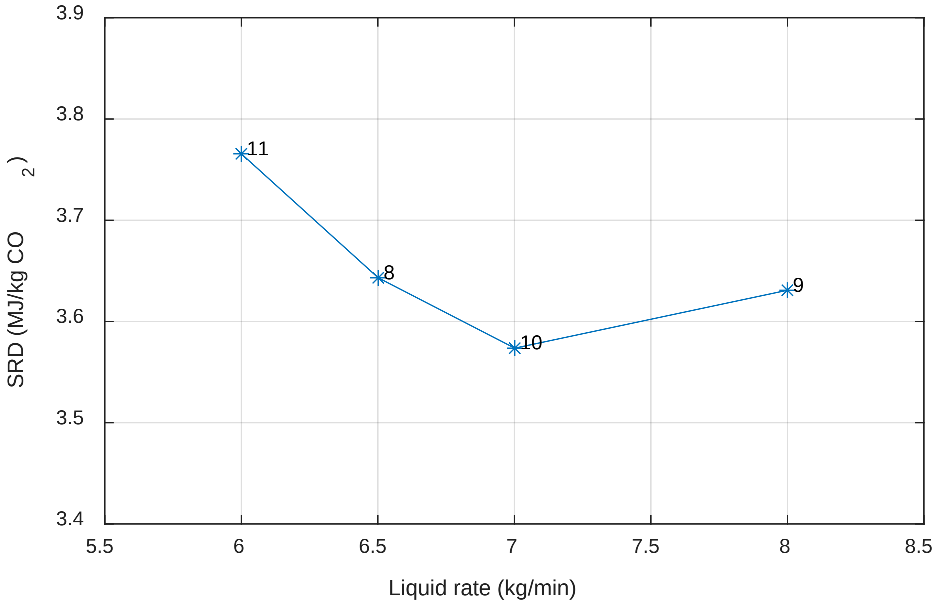


Figure 3.15 The specific reboiler duty (SRD) at various liquid circulation rates. The run numbers are marked at each point

The optimal circulation rate for the bio case is 7.0 kg/min, which corresponds to an L/G of 2.54. The SRD was then 3.57 MJ/kg CO_2. The SRD values are obtained with the heat tracing section implemented, but without taking into account the heat loss in the desorber feed line and overhead system. From earlier campaigns the remaining heat loss has an effect on the reboiler of about 1.5 kW. Subtracting this value from the reboiler duty the optimal SRD is then 3.40 MJ/kg CO_2.

In Figure 3.14 it is shown that the CO_2 free amine concentration was higher in the runs 8-11 than for a 30 wt% (4.91 mol/kg) solution. An average was 5.69 mol/kg for these runs and 16% higher than 30 wt%. Taking this into account the optimal liquid rate for a 30 wt% solution can be estimated to be 8.1 kg/min and an L/G of 2.94.

In Figure 3.16 and Figure 3.17 the temperature profiles for the absorber and the desorber columns are shown. In the absorber the runs with highest circulation rates are the ones with highest temperatures. The reason is that higher liquid flow rate for a given CO_2 recovery gives higher lean loading and lower rich loading and more of exothermic absorption occurs in the bottom of the column.

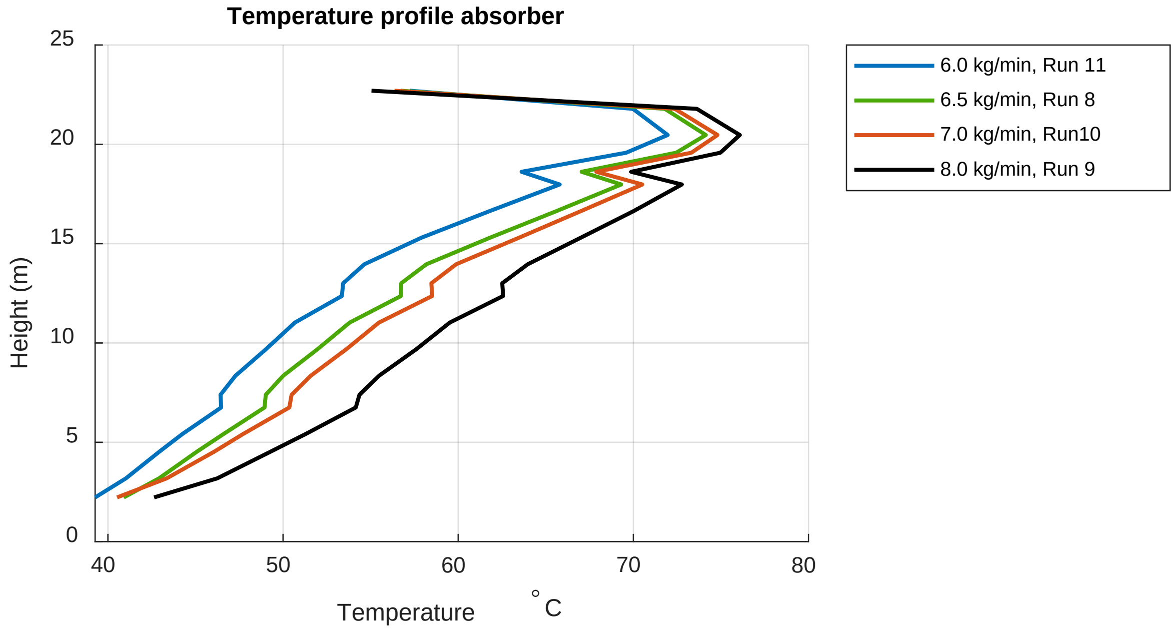


Figure 3.16 Temperatures in the absorber column for during liquid circulation rate optimisation

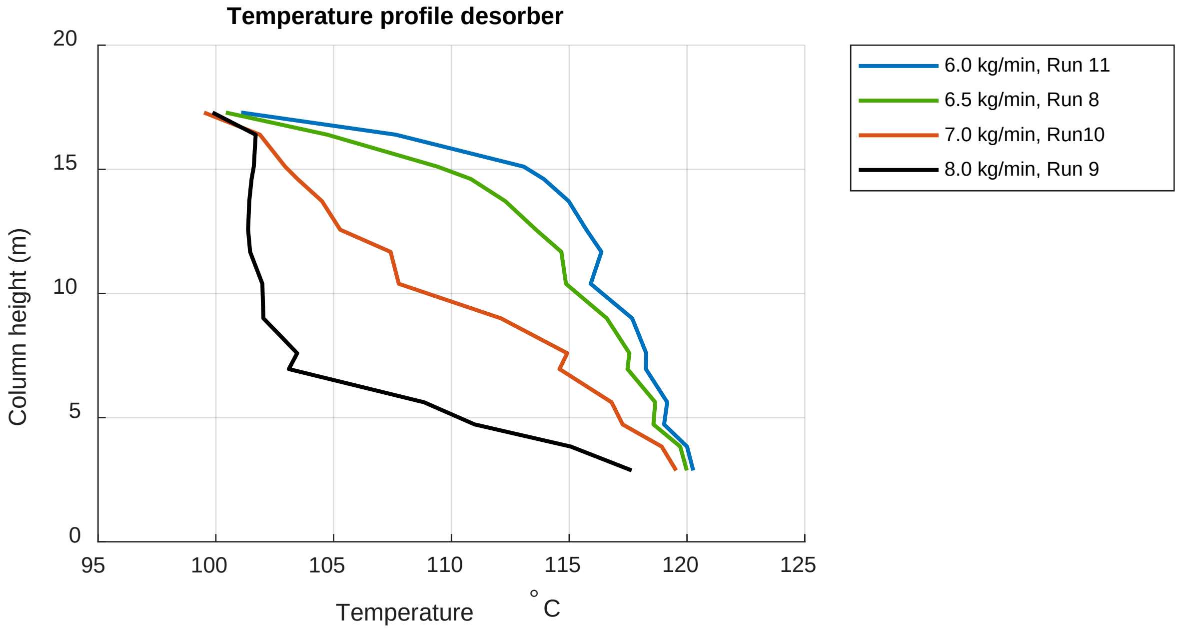


Figure 3.17 Temperature profiles in the desorber column as function of solvent circulation rate

In the desorber we see that Run 11 and 8 with liquid flow rates of 6.0 and 6.5 kg/min respectively are in the steam-limited regime with a temperature pinch in the bottom. Run 9 with the highest liquid flow rate (8.0 kg/min) is in the heat-limited regime with a temperature pinch in the top. The optimal Run 10 with 7 kg/min has a temperature profile in between these regimes. The pinch temperature in the top reflects the rich loading, with lower temperatures having higher loading. On the other hand, temperature in the bottom reflect the lean loading with high temperatures providing lower loading.

3.6 Wash section and emissions

The campaign started with only the internal wash sections AW1 and AW2, and wash water was circulated only in AW2. However, as the startup progressed and high emissions were observed from aerosol formation from ash dust, it became necessary to extend the wash sections by channeling the gas out of the absorber and AW2 through the external water wash sections (EWC1 and EWC2 as referred in this report). These however did not result in significant reduction in emissions. Furthermore, the wash sections were operated such that effluent gas was not cooled in the main column (wash section AW1 and AW2) but cooled gently in EWC1 and strongly in EWC2. The high emissions have been found to be mist induced, thus in this operating mode, due to humidity, particle size is expected to grow through the wash sections, which are then large enough to be taken out in the in last wash section, EWC2, where cooling is strong. With these operating modes, emissions remained high in the region of 300-400 ppm of MEA. This could potentially be explained by high level of particulates in the gas which depletes the gas phase amine to the extent that reduction in the number of particulates does not result in significant reduction in MEA emissions, because there is always sufficient particulates in the gas to continue gas phase MEA transport out of the wash section.

From 18th October, after the filter problem was identified and fixed, the filter and the plant operated at normal Tiller conditions. It can be observed that MEA emission dropped dramatically to below detection limit thus zero reading of the FTIR instrument (see Figure 3.18, Table 3-1 and Table 3-2). The MEA emission from this point onwards was zero until the end of the campaign. At Drax the particle concentration in the flue gas is higher, around 20 mg/m^3. In order to mimic similar conditions a by-pass valve was used.

“Normal operating conditions” is the mode in which the Tiller plant is usually operated with the multifuel burner, where the PALL filter is used to remove particulates in the flue gas from the burner. In this campaign, a by-pass valve was used to transport some of the particulates across the filter during tests. This operating mode is a special condition carried out as requested by Drax with the aim of having particulates in flue gas close to typical values obtained at Drax power station.

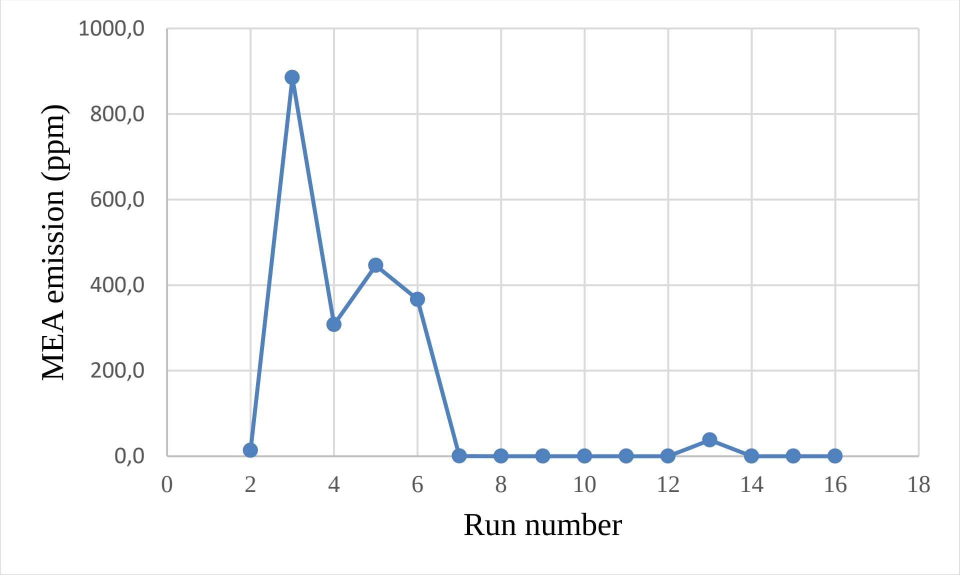


Figure 3.18 MEA emission as recorded at the FTIR during campaign

On 6th November, the plant was operated without the external wash to observe the effect on emissions, the result in Run 14, Table 3-2 also show that using only AW2 wash section without the external washes EWC1 and EWC2, zero emission of MEA was recorded. To enable a study of effect of particles on emissions, it was then necessary to bypass the PALL filter using the filter bypass valve, results on these are discussed in section 5.4. The plant was set for gravimetric filter measurement on 5th November, thus MEA emissions observed in Run 13 was due to filter bypass (see Figure 5.23).

It can be observed in Table 3-1 that MEA emissions under operating condition from the propane burner, Run 2, was 13.7 ppm. This is considered an effect from saturation of the water wash section with amine from previously very high emissions. This value would be expected to drop off had the campaign continued with propane burner in the subsequent days.

The DCC was operated with pH control for SO_2 removal, however, this was observed to use very little of the base at a time due to low levels of SO_2 in the biomass flue gas. SO_2 emissions Table 3-1 and Table 3-2 is seen to be mostly zero from the FTIR reading indicating emissions below detection limit.

During 30th October – 1st November, the pH control was not switched on after starting up. The pH dropped steadily from 8.8 to 6.5 during 1st - 7th November but SO_2 emission remained virtually zero, below detection limit.

4 Solvent analysis, degradation and corrosion

The MEA campaign ran for approximately 700 hrs (time on stream) over a period of around 1 ½ month. From the sample set collected during the campaign, 7 lean samples were selected for analyses of a range of compounds (see Table 4-1).

Table 4-1 Lean samples chosen for analysis of a range of compounds

Journal no	Sample id	RUN No	Time on Stream (TOS) [hrs]
P19735	Lean 1 1/10-19 09:00	1	22
P19745	Lean 1 8/10-19 08:20	3	161
P19765	Lean 1 11/10-19 07:15	6	232
P19803	Lean 1 21/10-19 08:20	7	368
P19821	Lean 1 24/10-19 08:40	10	440
P19843	Lean 1 4/11-19 08:35	12	604
P19865	Lean 1 8/11-19 08:40	16	701

4.1 Solvent amine, CO_2 and water

During the campaign, amine, CO_2 and H_2O were determined in LEAN for all runs. Amine (MEA) was determined by acid titration (i.e. alkalinity), water by Karl-Fischer titration and CO_2 by TIC/TOC analyser. For the selected samples these results are summarised in Table 4-2. In this table as the sum of MEA, CO_2 and water are given. The sum (mass balance) of these solvent compounds is between 98.4% and 101%.

Table 4-2 Analysis of solvent compounds in selected Lean samples. Mass balance is the sum if amine (MEA), CO_2 and H_2O

Journal no	Time on Stream (TOS) [hrs]	Amine [amine eq/kg]	CO_2 [mol CO_2/kg]	H_2O [wt%]	Mass Balance [%]
P19735	22	4.873	1.339	63.6	99.2 %
P19745	161	5.190	0.893	63.5	99.2 %
P19765	232	5.469	1.377	59.6	99.1 %
P19803	368	5.622	1.200	58.9	98.5 %
P19821	440	5.735	1.001	58.9	98.4 %
P19843	604	4.951	0.969	66.6	101 %
P19865	701	5.072	0.930	64.6	99.6 %

4.2 Solvent Degradation

Degradation of amine solvent in post combustion carbon capture is often divided into thermal degradation and oxidative degradation. Mechanism for thermal degradation of MEA is carbamate polymerisation and includes the formation of the main compounds OZD, HEEDA, HEIA and MEA-urea (da Silva *et al.*, 2012; Davis, 2009; Flø *et al.*, 2017). For oxidative degradation mechanisms there are still some knowledge gaps, but generally radical mechanisms are thought to play an important role in the initial steps (da Silva *et al.*, 2012). In the initial step, fragments of the MEA molecule or oxidised fragments of the MEA are expected products and as these are reactive, they will react with MEA or other degradation products. Example of such reactions are reaction of MEA with organic acids to form compounds as HEF, HEA, BHEOX (da Silva *et al.*, 2012). HeGly is another compound formed in the first step, but it is not clear what the precursor is. HeGly can further react with MEA to form HEPO via an intermediate compound (HEHEAA), see da Silva *et al.* for details. Metal ions such as Fe are known to catalyse oxidative degradation (Sexton *et al.*, 2009; Morken *et al.*, 2017). In the work by Morken and co-workers (Morken *et al.*, 2017) a degradation scheme for MEA is given, this paper also contain data on degradation products and measurements in solvent and emission from amine absorber.

4.2.1 Chemical analysis of degradation compounds

The selected samples were analysed for a wide range of degradation compounds and a list of abbreviation used in this report are given in Table 4-3

Table 4-3 Abbreviation degradation products

Abbreviation	CAS	Name
OZD	497-25-6	2-Oxazolidinone
BHEOX	1871-89-2	N1,N2-bis(2-hydroxyethyl)-Ethanediamide
HEA	142-26-7	N-(2-hydroxyethyl)-Acetamide
HeGly	5835-28-9	N-(2-hydroxyethyl)-Glycine
HEPO	23936-04-1	4-(2-hydroxyethyl)-2-Piperazinone
HEF	693-06-1	N-(2-hydroxyethyl)-Formamide
HEI	1615-14-1	1H-Imidazole-1-ethanol
HEIA	3699-54-5	1-(2-hydroxyethyl)-2-Imidazolidinone
MEA-urea	15438-70-7	N,N'-bis(2-hydroxyethyl)-Urea
N-HeGly	80556-89-4	Nitroso N-(2-hydroxyethyl)-Glycine

In Table 4-4 and Table 4-5 the obtained results using LC-MS for different degradation compounds are given. These results are also plotted versus time in Figure 4.1 (major degradation compounds) and Figure 4.2 (minor degradation product). Here we have chosen to classify compounds with concentration above 500 mg/l (at the end) as major products.

Table 4-4 Determined degradation products by LC-MS in Lean MEA

Journal no	Time on stream [hrs]	HEI [mg/L]	HEF [mg/L]	HEPO [mg/L]	HeGly [mg/L]	HEA [mg/L]	BHEOX [mg/L]	HEIA [mg/L]	OZD [mg/L]	MEA-Urea [mg/L]
P19735	22	34.8	122	126	200	9.3	6.1	0.5	14.0	304
P19745	161	75.7	133	2 220	942	40.3	3.2	11.4	23.0	1 478
P19765	232	110	143	3 630	1 212	62.3	4.9	19.4	36.1	1 857
P19803	368	224	231	6 386	2 279	184	9.6	30.0	42.4	2 299
P19821	440	272	225	8 738	2 661	238	9.9	38.9	39.0	2 606
P19843	604	320	260	12 591	3 042	338	11.2	59.6	64.9	2 338
P19865	701	347	315	15 392	3 328	395	12.6	74.2	60.7	2 375

Among the analysed compounds HEPO, HeGly and MEA-Urea are the most prevalent compounds. For both HEPO and HeGly there is a fairly linear increase during the campaign, while MEA-Urea seems to have a maximum between 400 and 500 hours followed by slight decrease. This behaviour is quite similar to what was observed in an earlier MEA campaign at Tiller, see Figure 4.1. This previous campaign was run with propane gas for approximately 500 hrs and then shifted to coal gas. Comparing the concentrations at 700 hrs, we see that HEPO is significantly higher in the current campaign (15 g/L versus 6 g/L), the same is also the case for HeGly (3 g/L versus 1 g/L) and MEA-Urea (2 g/L versus 1 g/L). Other studies also reported HEPO and HeGly as the major degradation products in MEA pilot campaigns (da Silva *et al.*, 2012), however in earlier studies MEA-Urea has not been analysed. Higher values of degradation products, HEPO, HeGly and MEA-Urea observed in this campaign can be explained by the high levels of ash dust in flue gas earlier in the campaign when the flue gas filter was not working properly and thus allowed full dust load in contact with the solvent.

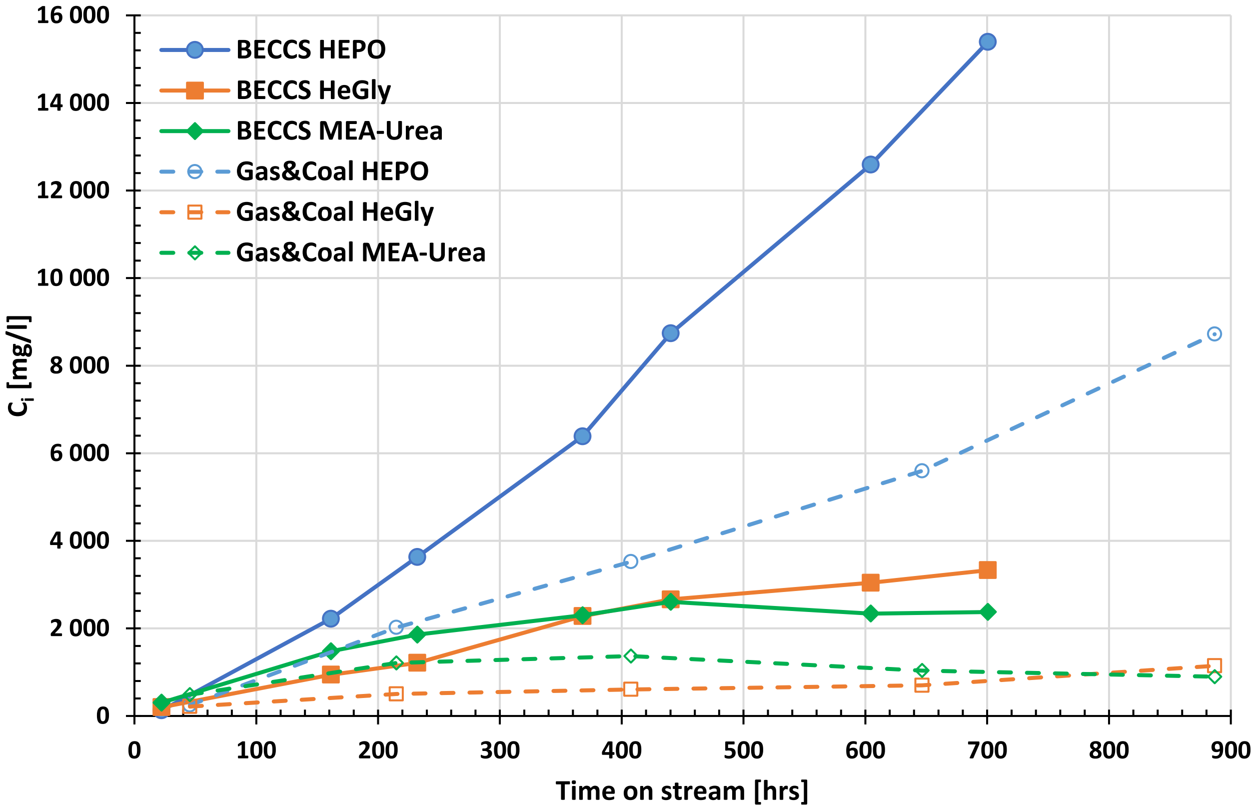


Figure 4.1 Development of major degradation products in LEAN solvent during the MEA campaign. Results from earlier MEA campaign indexed Gas&Coal and given with dotted lines

For the minor compounds (HEI, HEF, HEA, BHEOX, HEIA and OZD) analysed in this work, all of them show an increase during the campaign. This was also the case in the earlier MEA campaign at Tiller, see dotted lines in Figure 4.2 and Figure 4.3. The order of these compounds is different in the current campaign as HEA, HEI and HEF is the highest while HEIA was the highest in the previous campaign. The concentration at around 700 hrs is higher (around 2 times) in the current campaign for HEA, HEI and HEF while HEIA is lower.

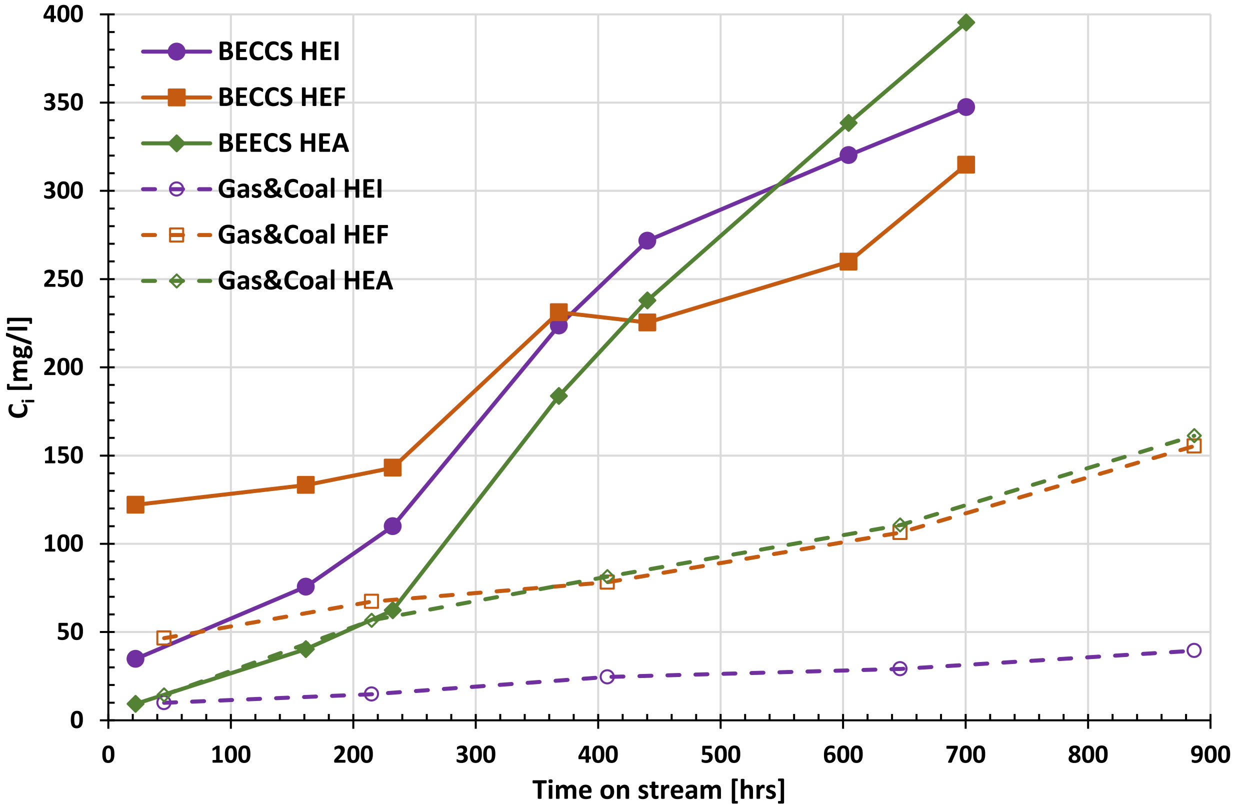


Figure 4.2 Development of some minor degradation products in LEAN solvent during the MEA campaign. Results from earlier MEA campaign indexed Gas&Coal and given with dotted lines

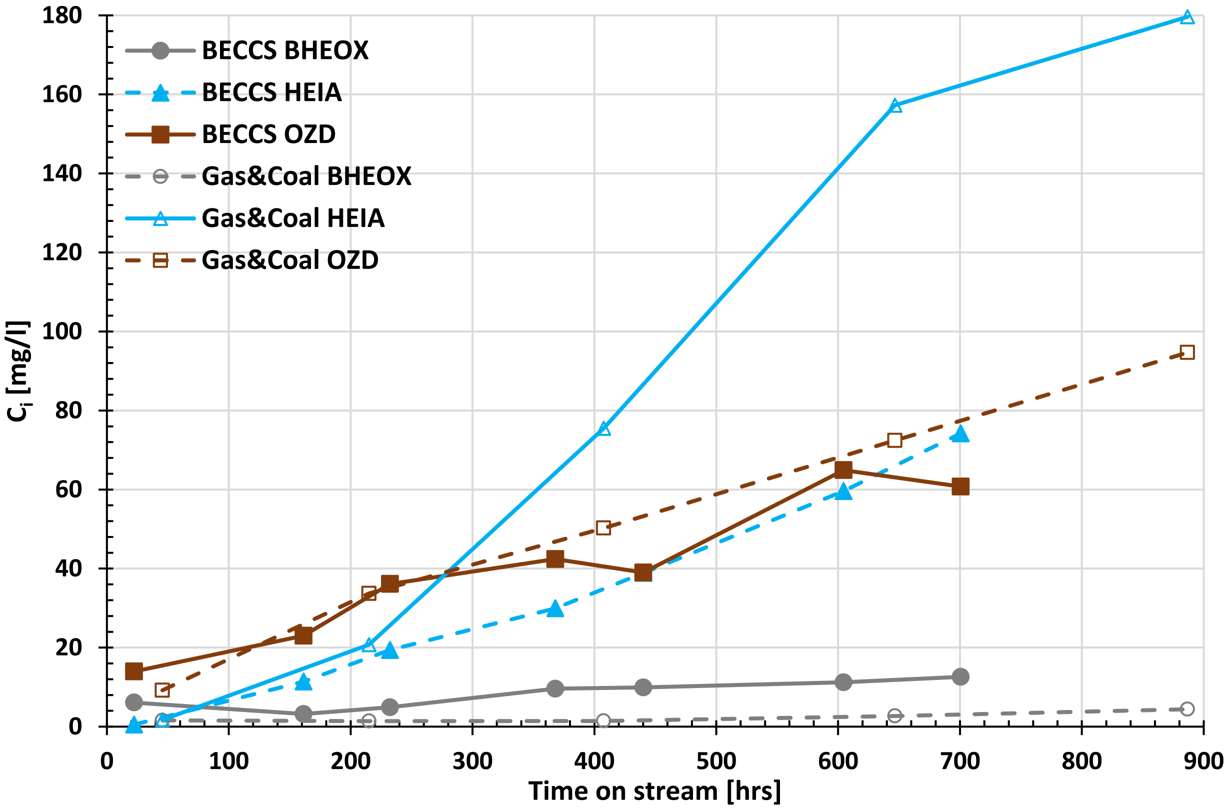


Figure 4.3 Development of some minor/trace degradation products in LEAN solvent during the MEA campaign. Results from earlier MEA campaign indexed Gas&Coal and given with dotted lines.

Ammonia is also a degradation compound from MEA solvents. As NH_3 is volatile, accumulation is somewhat limited. In Table 4-5 the analysis results for ammonia (NH_3) in the selected solvent samples are summarised. The results are also plotted against time in Figure 4.4. As can be seen the NH_3 level is between 150-200 mg/L in the lean solvent. This is quite similar to what was observed in the previous MEA campaign at Tiller, where concentration was between 110-190 mg/L.

Table 4-5 Determined ammonia by LC-MS in Lean MEA solvent

Journal no	Time on stream [hrs]	NH_3 [mg/L]
P19735	22	157
P19745	161	157
P19765	232	159
P19803	368	199
P19821	440	195
P19843	604	*na*
P19865	701	202

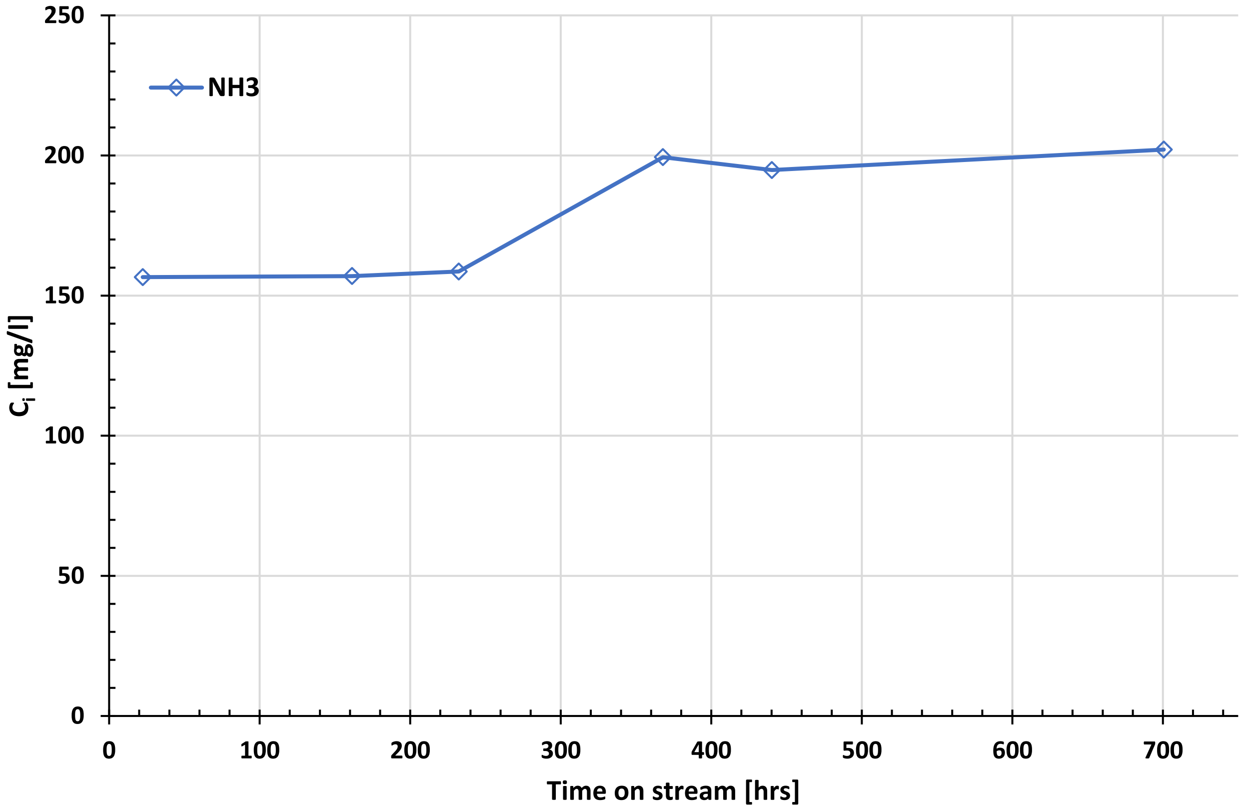


Figure 4.4 Ammonia in Lean MEA solvent (LC-MS)

Alkylamines is another group of volatile degradation compound from MEA. They are not analysed here, but they are usually at much lower concentration than NH_3 (e.g. <0.5 mg/L in previous MEA campaign).

So called heat stable salts (HSS) are another group of contaminants/degradation product in MEA solvent. For this campaign total HSS were determined in 3 samples by a wet chemistry method, and the results are summarized in Table 4-6. From Figure 4.5 we can observe a linear increase in HSS during the campaign. The HSS level at the end corresponds to around 0.7% of MEA. For comparison the HSS level at 650 hrs in the previous MEA campaign at Tiller was 0.02 eq/kg.

Table 4-6 Analysis of Heat stable salts (HSS) by wet chemistry in selected solvent samples

Journal no	Time on stream [hrs]	HSS [eq/kg]
P19735	22	0.013
P19803	368	0.023
P19865	701	0.036

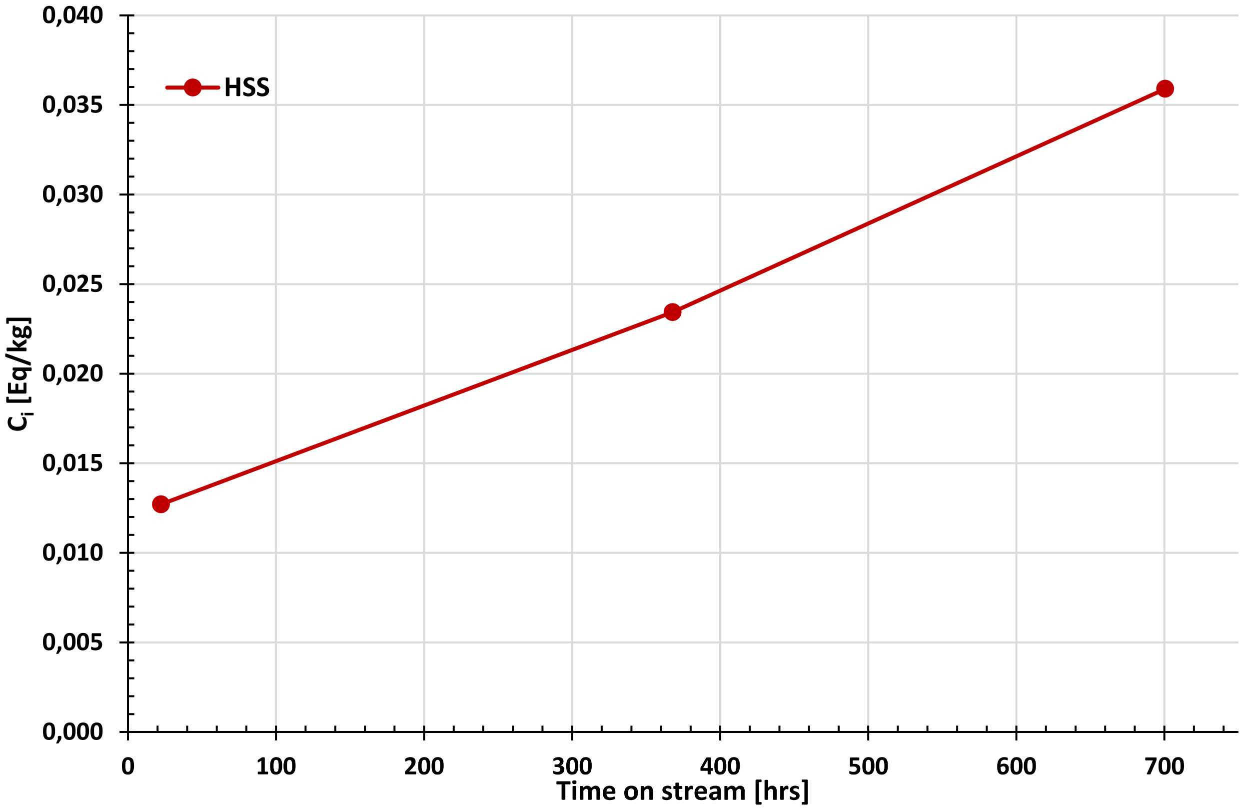


Figure 4.5 HSS levels during the MEA campaign

Total nitrosamine (TONO) were also determined in the selected lean samples, the obtained concentration are listed in Table 4-7 and they are also plotted versus time in Figure 4.6. In Figure 4.6, results from the earlier MEA campaign is also included for comparison (denoted as Gas&Coal). The results for the previous campaign show the specific nitrosamine N-HeGly is the major nitrosamine in MEA solvent (Einbu *et al.*, 2013; Fraboulet *et al.*, 2016). From the results we see that the start TONO level is not around zero for the current campaign (starts around 80 µmol/L) which is assumed to be due to some memory effect at the plant. However, if we compare the development (i.e. the slope) over time, the increase in nitrosamine with time is similar (0.036 versus 0.034) for the two campaigns.

Table 4-7 Determined total nitrosamine by GC-NCD in Lean MEA solvent

Journal no	Time on stream [hrs]	Total nitrosamine (TONO) [µmol/L]
P19735	22	84.9
P19745	161	79.4
P19765	232	95.4
P19803	368	101
P19821	440	101
P19843	604	109
P19865	701	102

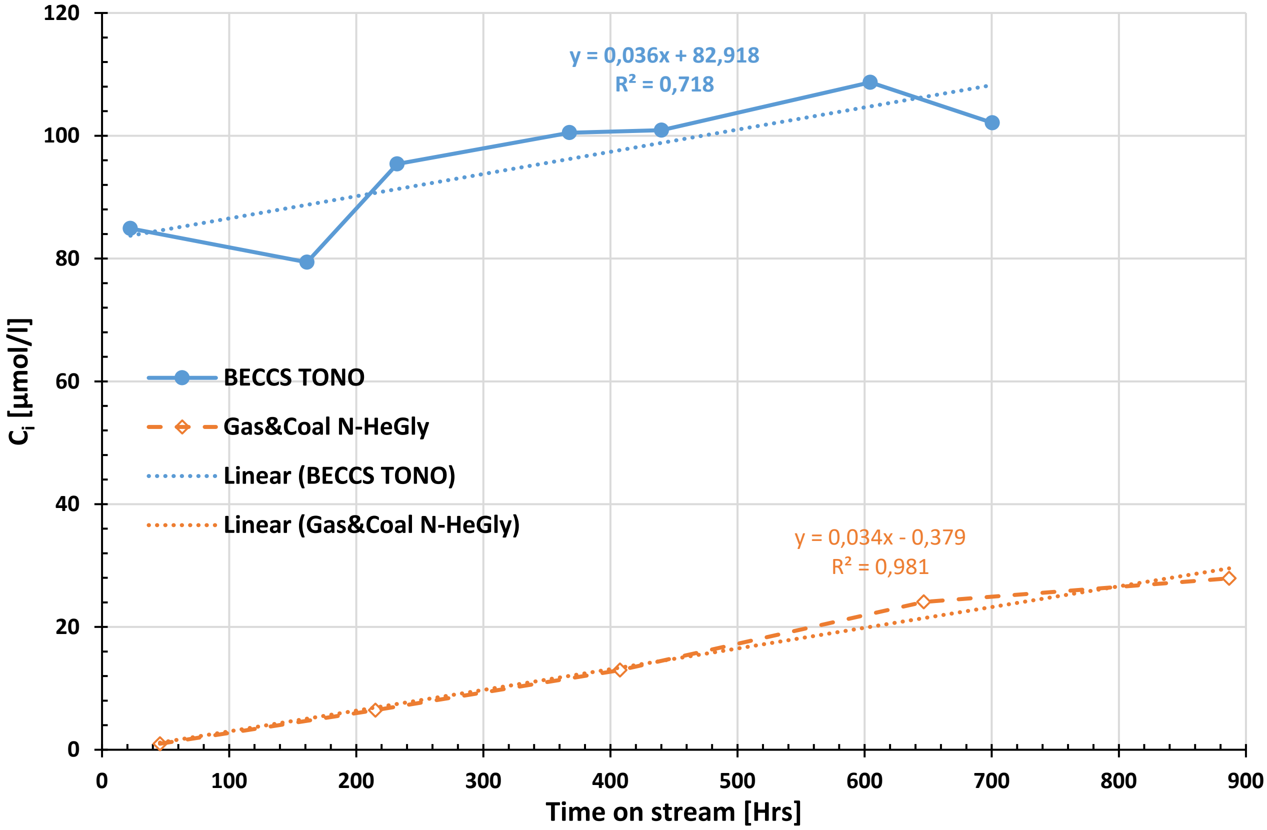


Figure 4.6 Determined total nitrosamine (TONO) in Lean solvent during the campaign. For comparison determined N-HeGly from earlier MEA campaign (Gas&Coal) is also shown

The relative degradation of MEA may be estimated as the sum of mole nitrogen per litre in the determined degradation product divided by the molar concentration of MEA at the start. In Figure 4.7 the estimated relative degradation is plotted versus time. As can be seen the estimated relative degradation seems to follow a linear increase with time. At the end of the campaign the estimated degradation is 6%, this somewhat higher than estimated in the previous MEA campaign (3% after 700 hrs). MEA degradation during the campaign is at the rate of 0.56 kg MEA/ton CO_2. Higher relative of degradation of MEA observed in this campaign can be explained by the high levels of ash dust in flue gas earlier in the campaign when the flue gas filter was not working properly and thus allowed full dust load in contact with the solvent.

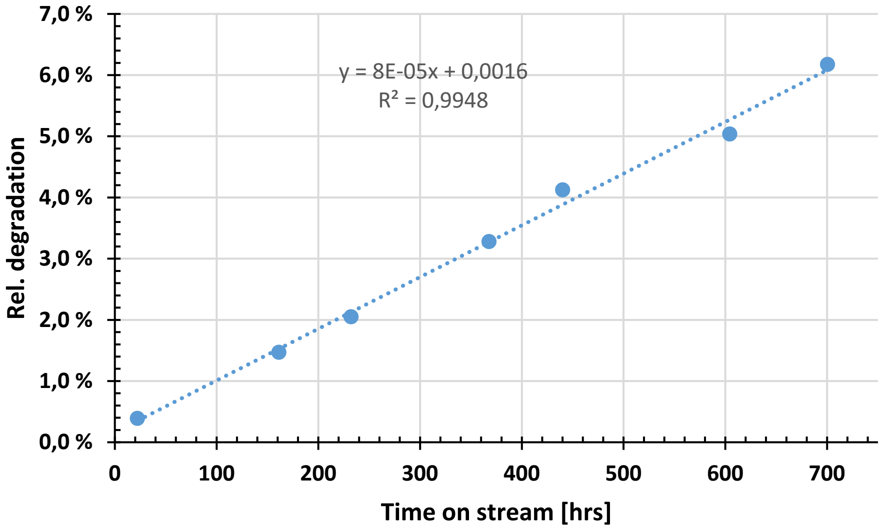


Figure 4.7 Estimated degradation

The mass balance in Table 4-2 may be updated with the determined degradation products, see Table 4-8. The mass balance including the degradation compounds is very close to 100% except for the two last samples. For those two samples the mass balance is 102-103 %, but overall, this acceptable.

Table 4-8 Mass balance, analysed compounds Lean samples

Journal no	Time on Stream (TOS) [hrs]	Solvent compounds [wt%]	Degradation compounds [wt%]	Total Mass Balance [wt%]
P19735	22	99.2 %	0.1 %	99.3 %
P19745	161	99.2 %	0.5 %	99.7 %
P19765	232	99.1 %	0.7 %	99.8 %
P19803	368	98.5 %	1.1 %	99.6 %
P19821	440	98.4 %	1.4 %	99.8 %
P19843	604	101 %	1.8 %	102.9 %
P19865	701	99.6 %	2.1 %	101.8 %

4.3 Analysis of Fe, Cr and Ni in lean solvent

Concentrations of metal ions may be an indicator of corrosion, selected samples were analysed by ICP-MS for dissolved metal ions (Fe, Cr and Ni). The results are given in Table 4-9 and also plotted versus time in Figure 4.8.

Table 4-9 Results for Fe, Cr and Ni determined by ICP-MS in Lean MEA solvent

Journal no	Time on stream [hrs]	Fe [mg/L]	Cr [mg/L]	Ni [mg/L]
P19735	22	4.74	0.41	0.41
P19745	161	4.74	0.87	1.85
P19765	232	7.90	1.08	2.57
P19803	368	9.27	1.36	3.84
P19821	440	10.2	1.56	4.66
P19843	604	11.6	1.96	6.90
P19865	701	12.4	2.53	9.07

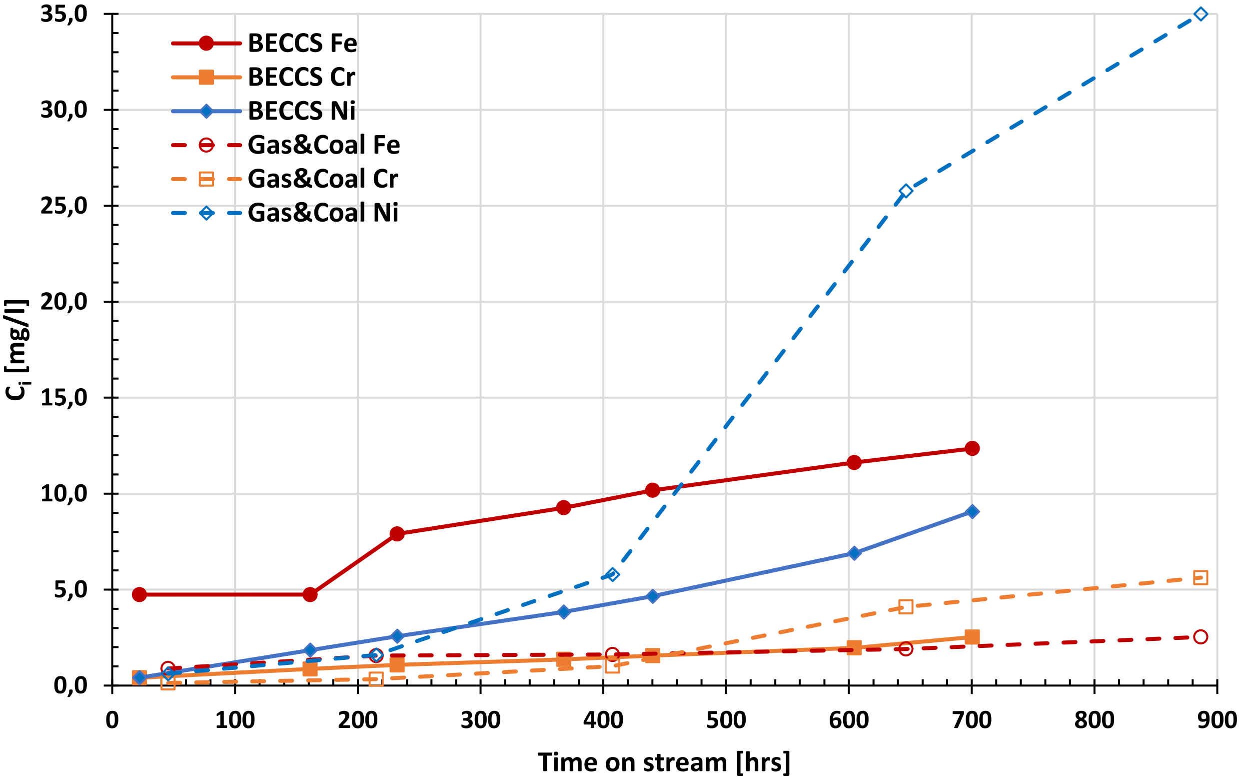


Figure 4.8 Metal ions in Lean MEA solvent. Results from earlier MEA campaign indexed Gas&Coal and given with dotted lines

As shown in Figure 4.8, concentration of Fe was the highest observed, followed by Ni concentration. Fe and Ni concentrations show a similar increase with time. For comparison, metal concentrations from the earlier MEA campaign are also shown in Figure 4.8 (as dotted lines). As can been seen, the Fe concentration is higher in the current campaign, while the Ni and Cr are lower.

5 Flue gas characterisation

The character of the flue gas from the combustion of the DRAX biopellets in the SINTEF multifuel burner was studied for the gas phase and particulate characteristics. FTIR was used for gas phase characteristics, while the particulate character was studied for particle number/cm^3, Np; particle mass, PM, mg/m^3 and particle size distribution, PSD. Different methods were deployed for the characterisation experiments. The set-up/method used, as well as other equipment relevant for the flue gas characterisation, are described below:

5.1 Characterisation set-up, method and relevant equipment

5.1.1 Condensation Particle Counter (CPC)

A condensation particle counter (CPC) was used to measure the total particle concentration of ultrafine and nanoparticles suspended in air or other carrier gases. In this technique, the particles are enlarged by a condensation process in order to enable the precise determination of their number with an optical light scattering detector. The working fluid, e.g. butanol or water, is vaporised as a condensation agent. The nanoparticles to be measured are directed through the vapor atmosphere, during which the vapor condenses on the nanoparticles in a cooling zone. The condensation process is influenced by the nanoparticles themselves, as well as the working fluid, the operating temperatures, and the volume flow.

Figure 5.1 shows the principle of operation for a condensation particle counter. The aerosol with nanoparticles enters the instrument at the bottom and reaches the heated evaporation chamber (the saturator).

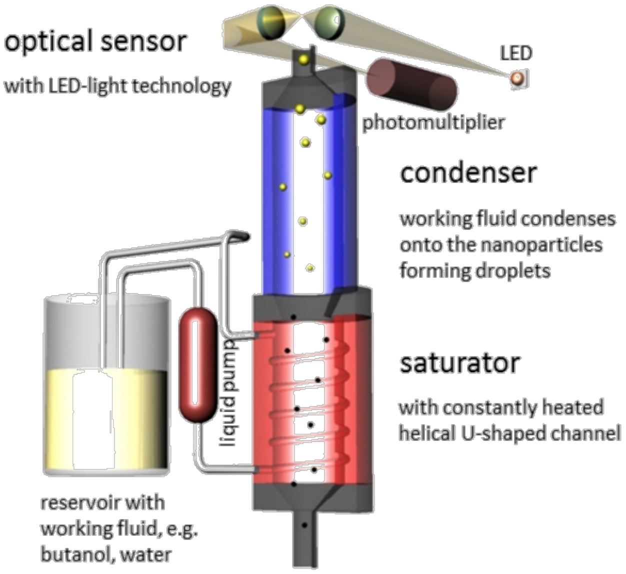


Figure 5.1 Schematics for theory of operation for a Condensation Particle Counter (CPC). Palas GmbH (Germany)

Downstream from the evaporation chamber, the aerosol/particles and the saturated carrier gas enter a cooled area, the condenser, in which the working fluid condenses onto the nanoparticles, forming droplets in the µm size range. Leaving the condenser, the droplets passes the optical sensor. Here, the size of the droplets is analysed, and their concentration is measured by counting them. The instrument enables real-time control of measurement data and parameters.

Temperatures of the condenser and saturator are controlled, the working fluid is circulated continuously from the reservoir to the constantly heated saturator and back to the reservoir at a flow rate that can be adjusted to accommodate different working fluids.

The CPC instrument applied in this work was a UF-CPC 200 from Palas shown in Figure 5.2.

Figure 5.2 Palas UF-CPC 200 condensation particle counter applied during the Tiller pilot test campaign

The CPC instrument is capable of measuring particle number densities up to 2×10^6 particles/cm^3 in single count mode without dilution of the sampled gas. SINTEF also has available a cascade diluter setup for representative dilution of the gas by a factor 1:10 or 1:100. No dilution of the gas was used for the measurements performed. The UF-CPC 200 has a 5% accuracy for the particle number density measurements when operated in single count mode with a measurement size range of 4 nm to 10 µm particle diameter according to the vendor. The particle diameter at which 50% particle counting efficiency is reached is defined as lower detection limit and referred to as the cut-off particle diameter. This cut-off particle diameter is dependent on factors like choice of working fluid and the temperature difference between saturator and condenser. Using butanol as working fluid and a temperature difference of 30 K, a rapid drop in counting efficiency for particle sizes below 12 nm was observed in a well-designed test.

The results reported in this work were performed with water as the working fluid due to the temperature of the flue gas. This gives less condensation growth of the particles, thus increasing the cut-off diameter.

In addition to their number, the UF-CPC 200 also measures the size of the grown droplets and provides the user with additional information concerning the condensation process.

5.1.2 The Gravimetric particle sampling equipment

For sampling dust particles and aerosols from gaseous streams micro-glass fiber thimbles are a convenient tool. Ahlstrom-Munksjö provides high purity extraction thimbles of considerable quality. The extraction thimbles are hollow cylinders with a round bottom, see Figure 5.3. These are understood to have exhibited an efficiency value of 99.98% for particles of 0.3 µm under test conditions and can withstand temperatures of up to 500 °C.

The gravimetric particle sampling train mainly consisted of a filter thimble, impinger bottle (for condensate collection), suction pump and the gas flowmeter, all connected as illustrated in Figure 5.4. Correct orientation/flow of the sampling equipment should be verified prior to sampling.

Figure 5.3: Picture of glass fiber thimble used for particle measurements

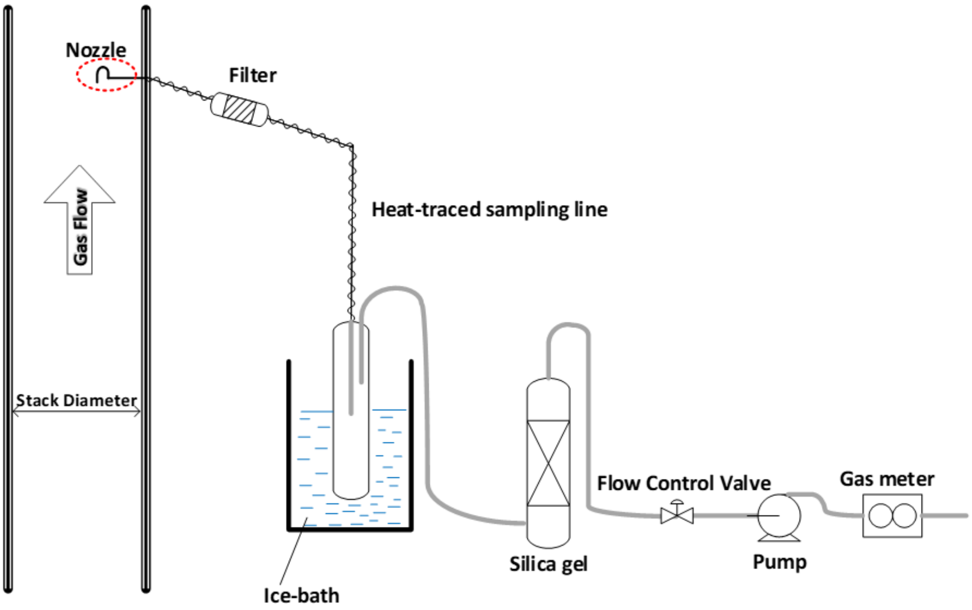


Figure 5.4: Schematic illustrating the setup used for particle sampling

Before sampling starts, an air leakage test must be performed in order to ensure that the sampling line and train are airtight. With the sampling-train system installed and tested for leakages, the gas pump can be started. If leakages cannot be eliminated completely, they should not exceed 2% of the sample gas volume. No leakages were detected for the measurements under discussion.

To facilitate numerical processing and analysis of results, data collection included sampling time, total gas volume flow, temperatures in the water bath and in the gas meter, weight of the flasks, filter thimble and silica gel before and after sampling.

5.1.3 Electrical Low Pressure Impactor (ELPI)

Dekati's Electrical Low Pressure Impactor, the ELPI, enables measurement of real-time particle size distribution and concentration in the size range of 6 nm - 10 µm with 10 Hz sampling rate. The ELPI's features include real-time stand-alone operation, wide sample concentration range, wide particle size range and robust structure for operation, even in harsh conditions. The use of impactor technology enables post-measurement chemical analysis of size classified particles. In addition, the ELPI can be used for real-time particle charge distribution and gravimetric impactor measurements (Dekati® ELPI$^+$, 2018).

The ELPI operating principle can be divided into three major parts: particle charging, size classification in a cascade impactor and electrical detection with sensitive electrometers. The particles are first charged into a known charge level in the corona charger. After charging, the particles enter a cascade low pressure impactor with 12-14 electrically insulated collection stages. The particles are collected in the different impactor stages according to their aerodynamic diameter, and the electric charge carried by particles into each impactor stage is measured in real-time by sensitive electrometers. This measured current signal is directly proportional to particle number concentration and size, thus the ELPI gives particle number concentration and size distribution in real-time. By switching the charger unit off, the ELPI can be used for particle charge distribution measurements.

An illustration of the working principle of the ELPI is given in Figure 5.5 while the ELPI instrument applied in this work was a Dekati's ELPIvi 4.0 shown in Figure 5.6.

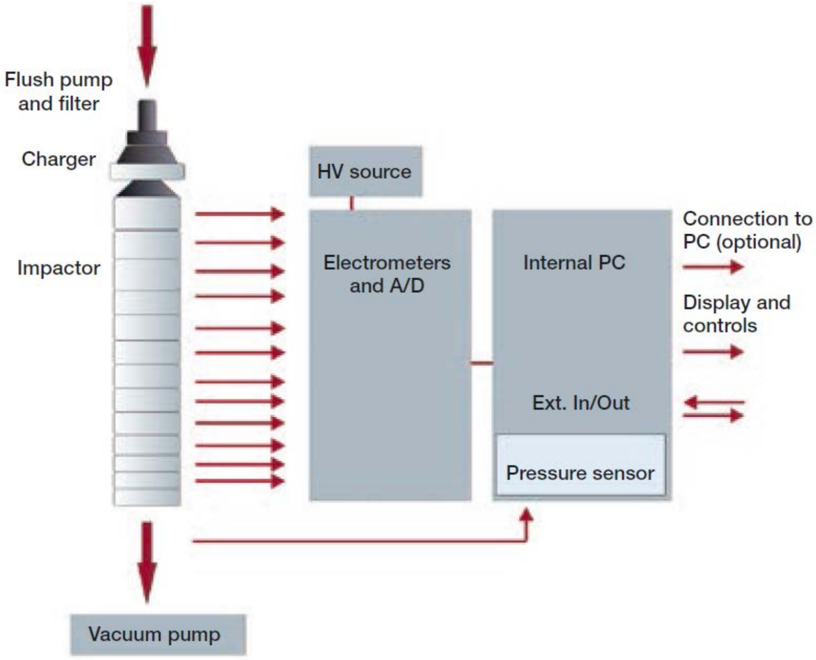
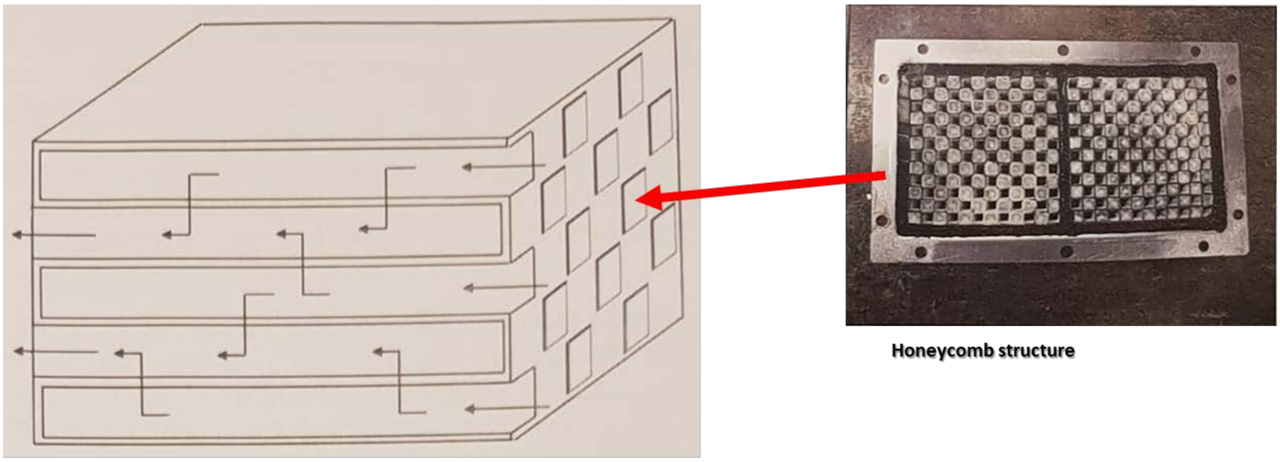


Figure 5.5 Illustration of working principle of the ELPI, Dekati® ELPI⁺, 2018

Figure 5.6 Dekati's ELPIvi 4.0 applied during the Tiller pilot test campaign

5.1.4 The PALL hot gas filter

PALL's Compact Blowback hot-gas filter system is based on ceramic filter elements with a honeycomb monolithic structure. The monoliths have a plurality of cells aligned in parallel. In order to get a wall flow, the cells are alternately plugged either at the upstream end or at the downstream side of the monoliths, see Figure 5.7. The gas flow enters in the cells open at the upstream side and flows through the walls and the cells open at the downstream side.



Honeycomb structure

Path flow through the monolith

Figure 5.7: Schematic to illustrate structure of the PALL filter

The particles are collected at the walls of the cells open at the upstream side. This results in the formation of a solid cake that is dislodged at a predetermined pressure drop or time by reverse blowback cleaning.

PALL blowback technology allows the filter modules to be sequentially regenerated on-line i.e. the regeneration is performed without interruption of the filtration. A specific volume of pressurised blowback gas flows through (in shock fashion) the filter honeycombs in reverse direction, thus detaching the cake from the cell walls. The residue is then blown out of the cells and subsequently settles (by gravity) in the dust-collecting vessel located at the bottom.

The honeycomb monolith structure is based on the well proven Pall Dia-Schumalith ceramic membrane hot gas filter elements which provide an excellent filtration performance. Filtration of particles with size down to less than 0.3 µm can be achieved yielding a clean gas concentration of typically less than 1 mg/Nm^3.

The performance of the filter does not depend on the retention efficiency, which is close to 100 %, but much more on its long-term pressure drop history. This history, in turn, depends on the various process parameters such as dust and gas properties, temperature and pressure and on blowback cleaning parameters such as blowback gas tank pressure, valve opening time, cycle time and the design of the entire cleaning device. The pressure drop will consequently have variations. During the tests it was typically 0.5 - 0.8 mbar.

5.1.5 FTIR instruments

Gas phase flue gas character was studied with FTIR and provisions were made for FTIR measurements; two instruments with a total of 3 channels were available:

- **FTIR (Gasmet DX4000 series):** equipped with one channel and located at the decarbonatedgas exit section, i.e. before the gas is emitted to the atmosphere. This DX4000 series is configured to measure H_2O, CO_2, CO, NO, NO_2, N_2O, SO_2, NH_3, CH_4, HCl, HF and different VOCs. Additional gases can be added without any hardware changes. Measurement ranges can be selected from sub-ppm up to vol% level. This system utilizes hot-and-wet measurement principle (no drying or dilution), which ensures that the analysis is done with a representative sample. The instrument consists of a two-stage particulate filtration: first one in sampling probe (2 µm) and the second one in sampling system (0.1 µm). The DX4000 used in this project is also equipped with a ZrO_2 sensor for accurate oxygen measurement.

- **FTIR (atmosFIR model from Protea):** equipped with multichannel capabilities. However, this instrument is only able to measure one channel at a time. For the measurements under study, two channels (Channel-1 and Channel-3) were active. The respective sampling locations are shown in Figure 5.8. The atmosFIR is essentially a multi-gas analyser suitable for combustion gas measurements offering a wide range of gas measurements, multiple analytical ranges, in-depth chemometric result diagnoses based on a dedicated on-board sampling system.

5.2 Sampling points

The location of the sampling points for flue gas characterisation was conveniently chosen in order to yield an overview of the potential changes that may occur along the gas phase path as the gas moves from the biomass burner until it exits the process as decarbonated gas. In normal operation, the flue passes through a series of components and sections which interfere and interact with particles, causing changes in particle content. The major ones in this case include:

- the cyclone
- the particle filter (PALL)
- the pre-conditioner column
- the absorber column
- water-wash sections

The sequential order of how these components/sections are connected as well as the respective locations of the sampling points are shown in Figure 5.8.

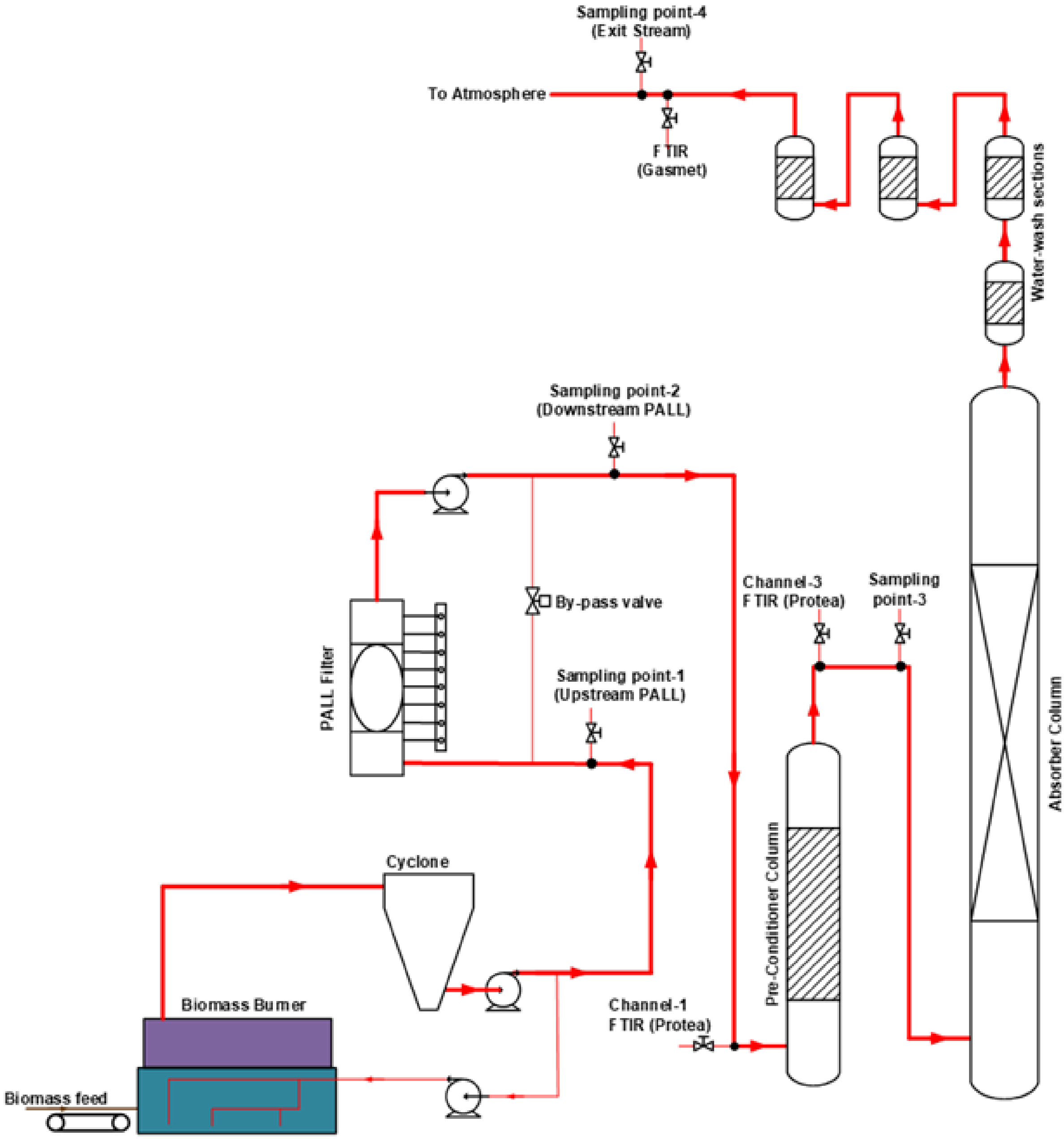


Figure 5.8: Schematic illustrating the sampling points for both particle and FTIR measurements

Sampling points are distributed as follows:

- Sampling point-1: located upstream the PALL filter i.e. to enable sampling raw flue gas from the biomass burner
- Sampling point-2: located downstream the PALL filter, to allow evaluation of the filter performance
- Sampling point-3: located downstream the pre-conditioner column i.e. also before the absorber gas inlet. This is intended to enable assessment of how much the pre-conditioner affects/modifies the particle content after the PALL filter before flues gas finally enters the absorber for CO_2 removal
- Sampling point-4: located downstream the water-wash sections, i.e. before the gas is emitted to the atmosphere

5.3 Experimental outline: Flue Gas Characterisation

The outline of experimental measurements carried out during flue gas characterisation is give in Table 5-1. The table shows range capability for each characterisation method used and the flue gas character measured by each method, as well as the sampling points. The table also includes extended activities carried out during the CLIME-ELPI project. In CLIME-ELPI additional flue gas characterisation using the ELPI for particle size distribution measurement, additional gravimetric filter measurement and additional characterisation at the absorber effluent gas.

Table 5-1 Outline of experimental activities for flue gas characterisation

Measurement Method/Device	Flue Gas Character Measured	Range of Particle Measured (µm)	Sampling Points	No. of measurements	FTIR measure
Condensate particle counter (CPC)	Number of particles, Np (1/cm^3)	≥ 0.7 (grown particles)	Before PALL filter	26	Yes
			After PALL filter		
			Mid absorber		
			Top absorber		
			After water wash (Outlet flue gas)		
Gravimetric filter measurement	Particle mass, PM (mg/Nm^3)	≥ 0.3	Before PALL filter	10	
			After PALL filter and before DCC		
			After DCC and Before absorber		
			After water wash (Outlet flue gas)		
Electrical low pressure impactor (ELPI)	Number of particles, Np (1/cm^3)	0.007 - 10	Before PALL filter	8	
	Particle Size Distribution, PSD		After PALL filter and before DCC		
Fourier-transform infrared spectroscopy (FTIR)	Gas phase component concentration (ppm or vol%)	N/A	After PALL filter and before DCC	Continuous	
			After DCC and Before absorber		
			After water wash (Outlet flue gas)		

5.4 Flue gas characterisation results and discussion

5.4.1 CPC measurement

A quick preliminary test of the flue gas from the bio burner was performed on 8th October 2019. Subsequent to this, the FTIR showed very high emission levels (Figure 5.9), fluctuating as the burner temperature was fluctuating, and it was decided to check the flue gas for particulates.

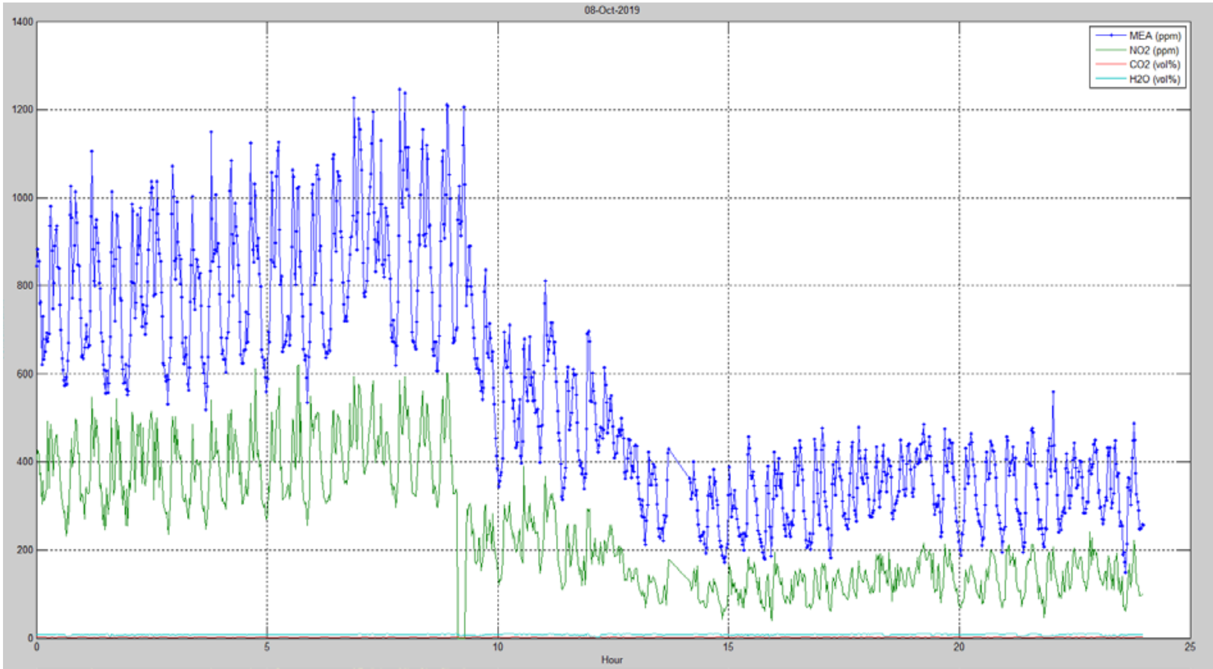


Figure 5.9 Emission measured by FTIR

The CPC was connected to the sample port on the flue gas line before the PALL filter unit. The number concentration of the CPC quickly went to the maximum value, indicating more than 2×10^6 particles/cm^3. The CPC was then connected to the sample port on the flue gas line after the PALL filter unit and before the DCC unit. The number concentration of the CPC quickly went to the maximum value, indicating more than 2×10^6 particles/cm^3. (Unfortunately, no photo was taken during these first trial measurements). This may have been an indication that the PALL filter unit was not operating efficiently, but since both readings were above the maximum, it was not possible to see the evidence.

The CPC was then moved to three different locations in order to measure the mist inside the Absorption column. On the 5th floor (mid absorber) the CPC still measured more than 2×10^6 particles/cm^3 (Figure 5.10). On the 7th floor (top absorber) the CPC still measured more than 2×10^6 particles/cm^3 (Figure 5.11). On the 11th floor (exit absorber) the CPC still measured more than 2×10^6 particles/cm^3 (Figure 5.12). These tests indicate a properly functioning CPC system.

It is important to note once more that the size distribution measured from CPC are grown particles thus are not the true particles sizes.

It can be seen from Figure 5.10 - Figure 5.12 is that particles of size 0.8-0.9 µm decreased at the top of the absorber, while particles of size 2-3 µm increased, indicating particle growth going from mid absorber to absorber top. At absorber exit, particles of size 0.8-0.9 µm increased again, indicating that larger particles had been removed at the demister and water wash sections.

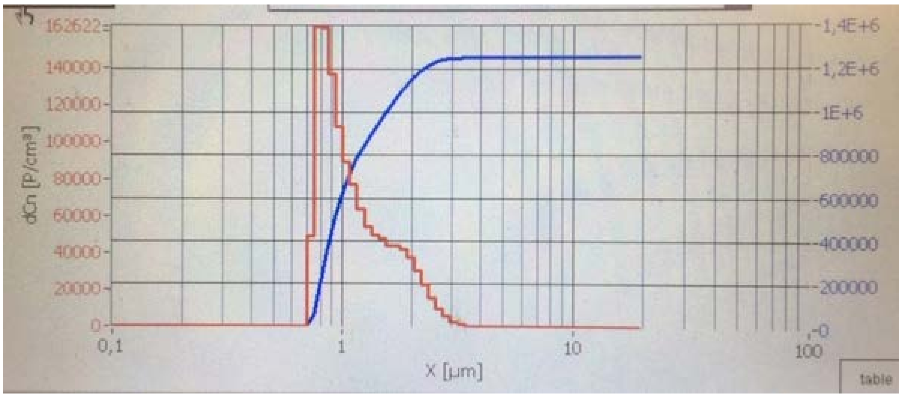


Figure 5.10 Mid absorber particle distribution; average particle size indicated 1.2 µm. The size distribution shows a slightly bimodal distribution with more grown particles in the 0.8-0.9 µm and less in 1-2 µm range

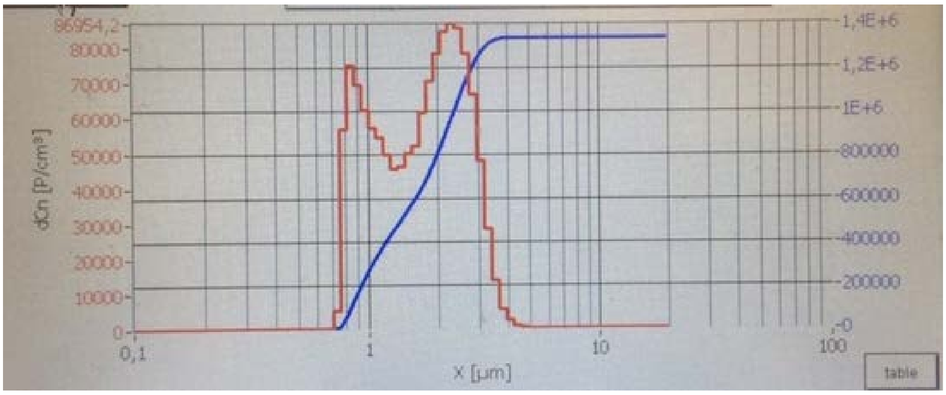


Figure 5.11 Top absorber particle distribution; average particle size indicated was 1.8 µm. The size distribution shows a bimodal distribution with grown particles in the 0.8-0.9 µm and 2-3 µm range

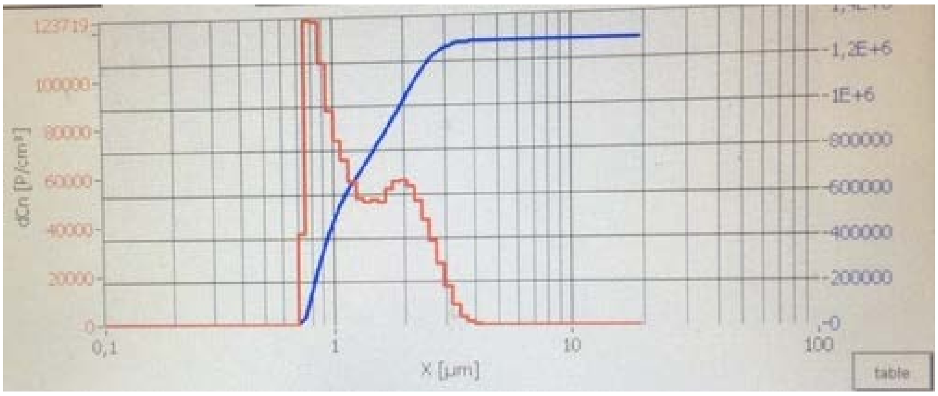


Figure 5.12 Exit absorber particle distribution; average particle size indicated was 1.4 µm. The size distribution shows a bimodal distribution with grown particles in the 0.8-0.9 µm and 2-3 µm range

A new test with CPC was carried out on the flue gas after the PALL filter was repaired on 9th October 2019. The FTIR log during the test is shown in Figure 5.13, while Figure 5.14 shows measured particle number density (particles/cm^3) and (b)

Figure 5.15 shows the grown particle size distributions and cumulative number density.

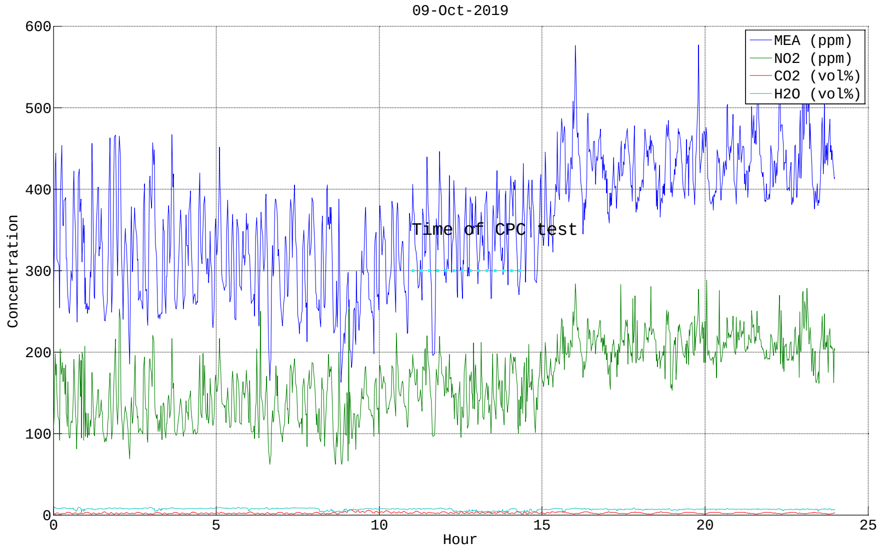


Figure 5.13 FTIR measurement and timespan of the CPC test

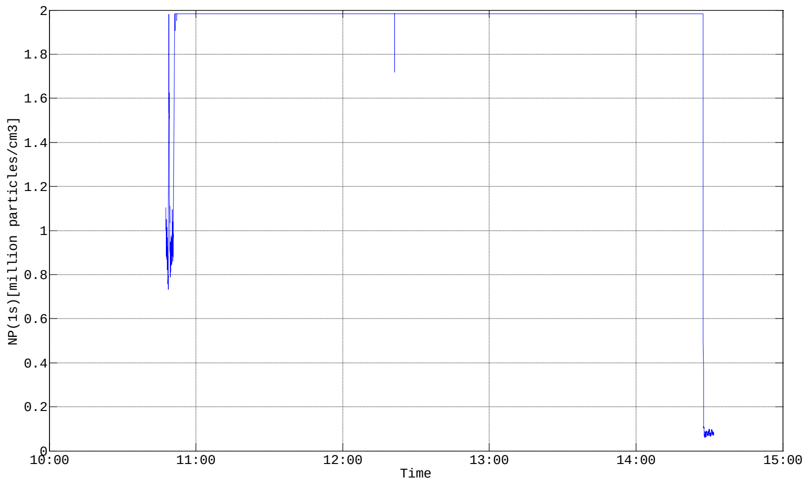
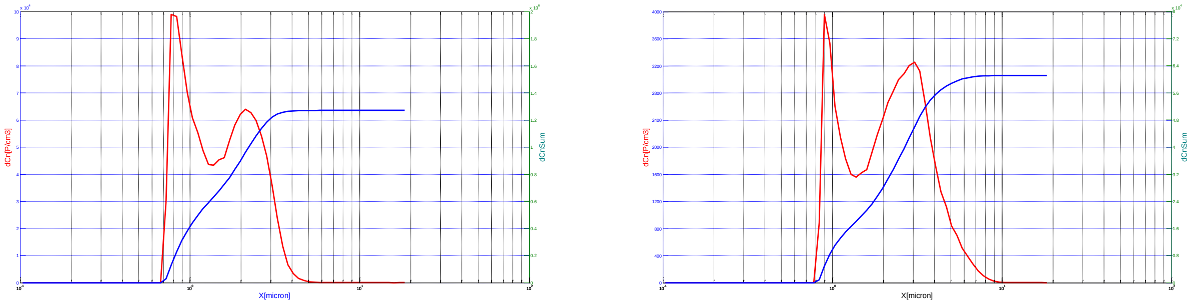


Figure 5.14 Number density measured by the CPC on the flue gas after the PALL filter



(a) **(b)**

Figure 5.15 Grown particle size distributions and cumulative number density, (a) after PALL filter; (b) inside air

The CPC clearly indicates a number density of 2×10^6 particles/cm^3 with average grown particle diameters of 1.5 µm measuring on the gas after the PALL filter unit. Switching to inside air showed around 60000 particles/cm^3 with average grown particle diameters of 2.4 µm. This indicated that the CPC was functioning as expected.

On the 10th October 2019 a combined test with CPC and gravimetric sampling of the flue gas was performed. FTIR log is shown in Figure 5.16.

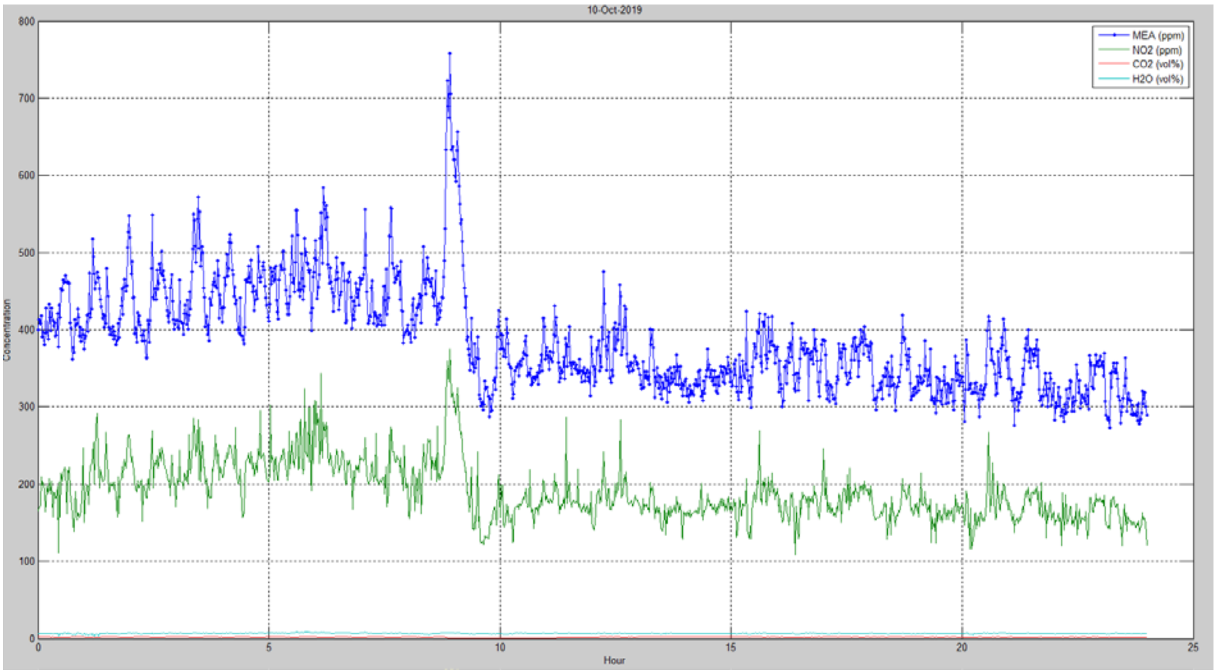


Figure 5.16 Emission measured by FTIR

When setting up for this test the CPC was accidentally exposed to under pressure from the sampling point. Under pressure in line caused backflow of liquid in the CPC. Under pressure was created by the suction from the main plant blower downstream. The CPC lines was drained, but the flow measurement seemed to be wrong, having a large offset value when turning the gas pump off. The measured number density of particles by the CPC is shown in Figure 5.17.

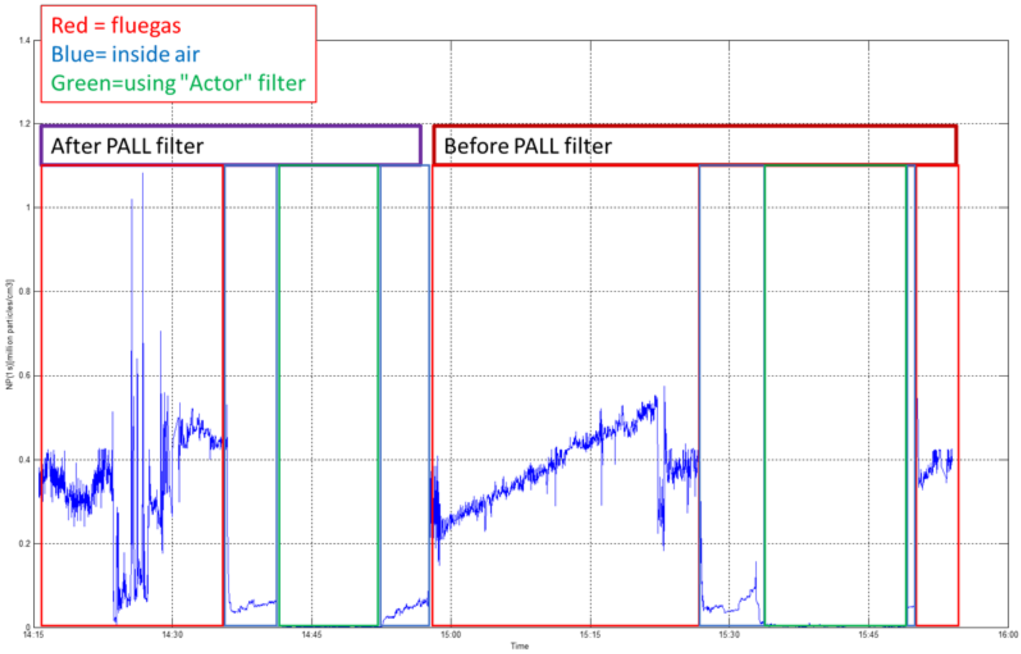
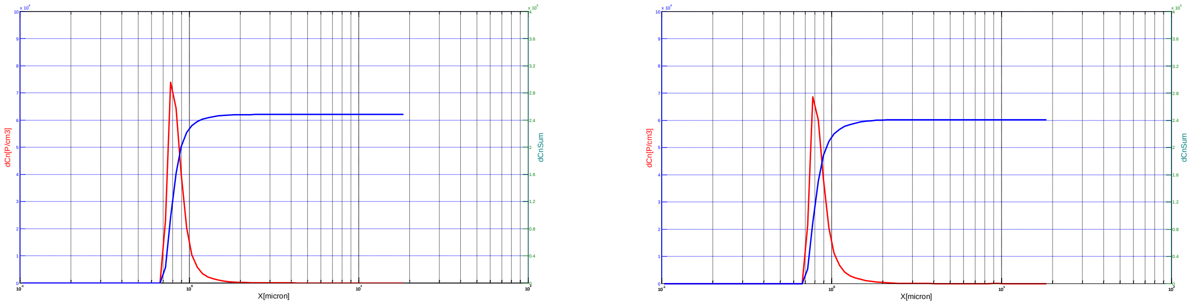


Figure 5.17 Measured number density of particles by the CPC on various locations as indicated by the colored areas in the figure

As shown in the Figure 5.17, around 0.4×10^6 particles/cm^3 are measured by the CPC before and after the PALL filter. Correcting for faulty flow measurement by a factor of 2.4 (based on measuring flow using an external MFC) gives an average particle density of about 1×10^6 particles/cm^3. This is half of the values obtained before, clearly indicating a problem with the CPC. Adjusting this number by a factor of 2 for other problems will then give readings around 2×10^6 particles/cm^3, similar to the measurements before the CPC was damaged. This approach was used for all data taken during the day. This indicates that a CPC measurement of around 2×10^6 particles/cm^3 leads to 350 ppm of MEA in the gas exiting the absorber.



a b

Figure 5.18 show the particle distributions measured by the CPC (a) before; (b) after the PALL filter unit

From the measured particle distribution shown in Figure 5.18, we clearly miss the fraction of grown particles seen the day before.

From these CPC measurements, similar readings were observed for both before and after the PALL filter. It can be concluded that the PALL filter does not remove small particles.

A new set of tests were performed on 24th October 2019 after the PALL filter unit had been checked and the internal leakage repaired (see section 3.2.1). In these tests, the filter bypass valve was adjusted at different levels of opening. CPC particulate measurement was carried out while the effect on emission were monitored via the FTIR. Results from these tests are shown in Figure 5.19.

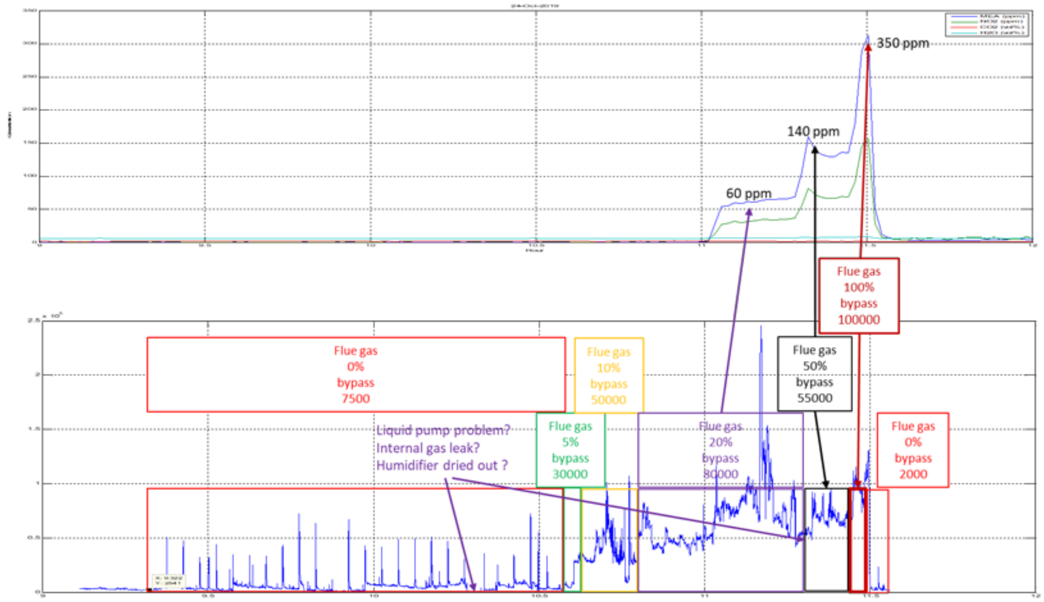
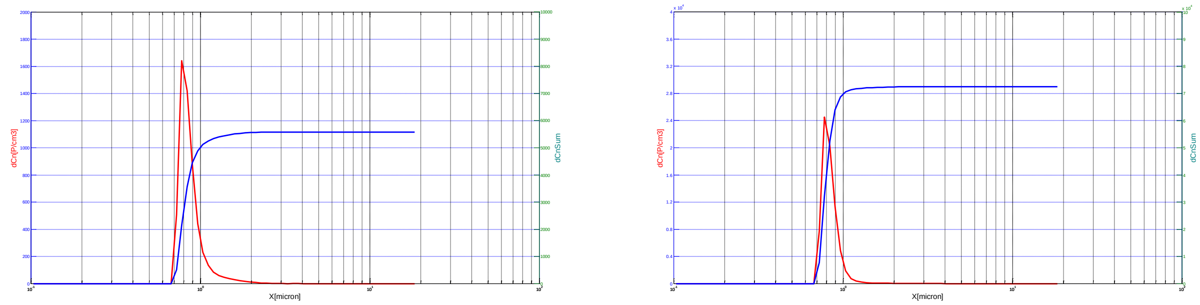


Figure 5.19 CPC results during the various tests conditions together with the measured emissions on 24.10.2019

The CPC performance was changing during the tests, clearly indicating more problems with gas and liquid pumps. It is however measuring an increased particle concentration every time the PALL filter cleaning is activated during the measurements with 0% bypass.



(a) (b)

Figure 5.20 Particle size distribution during (a) 0% open and (b) 100% open bypass valve

The number of particles measured increases, but the sizes decreases, and since growth is poor, a smaller fraction of the particles are actually measured. Thus, the data cannot be trusted.

Further test results from the continuation of tests on 24th October 2019 are shown in Figure 5.21.

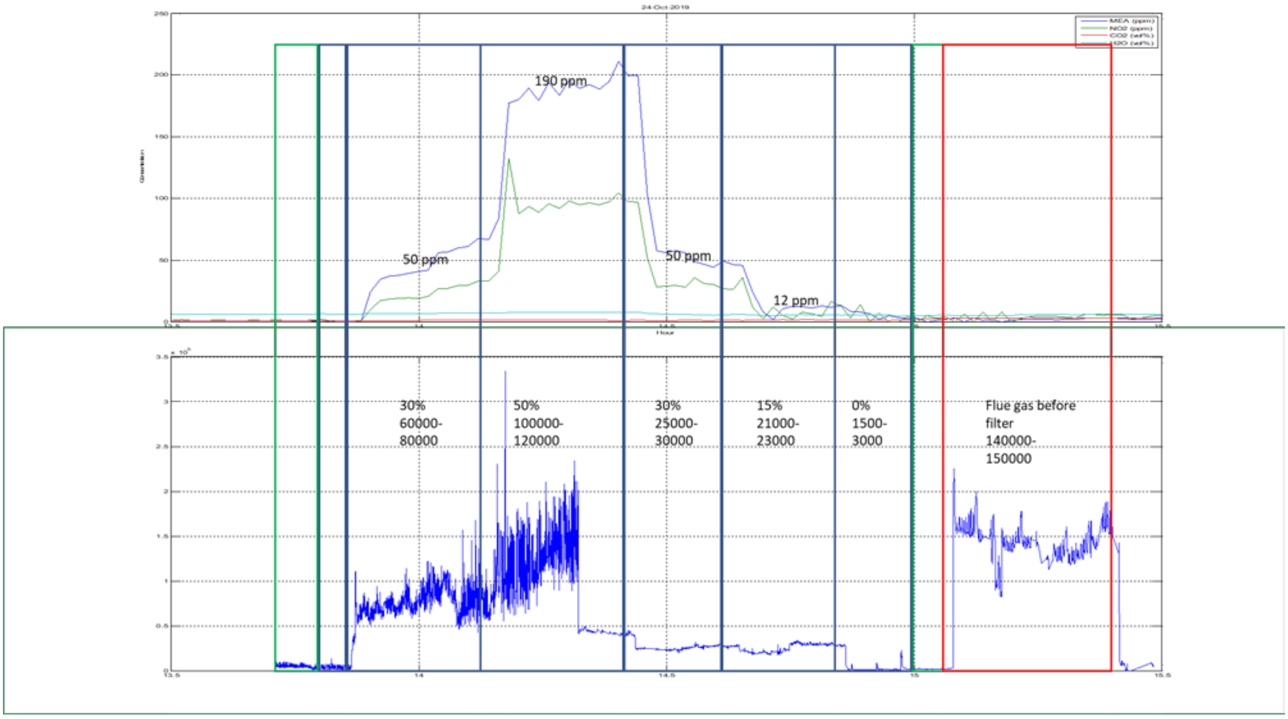


Figure 5.21 CPC results during the various tests conditions together with the measured emissions on 24.10.2019 during cont'd

A scaling of these results was done in a similar way as previously described, but this time flow factors and humidification factors are less consistent, thus the data cannot be trusted.

An indicative trend of MEA emissions as a function of CPC particle number density is shown in Figure 5.22. The level of emissions may not be dependent solely on numbers, but also the particle sizes. Small particles require higher supersaturation and longer residence time to grow big enough to noticeably add to the emissions.

Due to the problems experienced with the CPC, the reliability of the data measured is low, it will therefore not be used in further evaluation of the flue gas character in this report.

The summary of all flue gas character measured using the CPC is presented in Table 5-2.

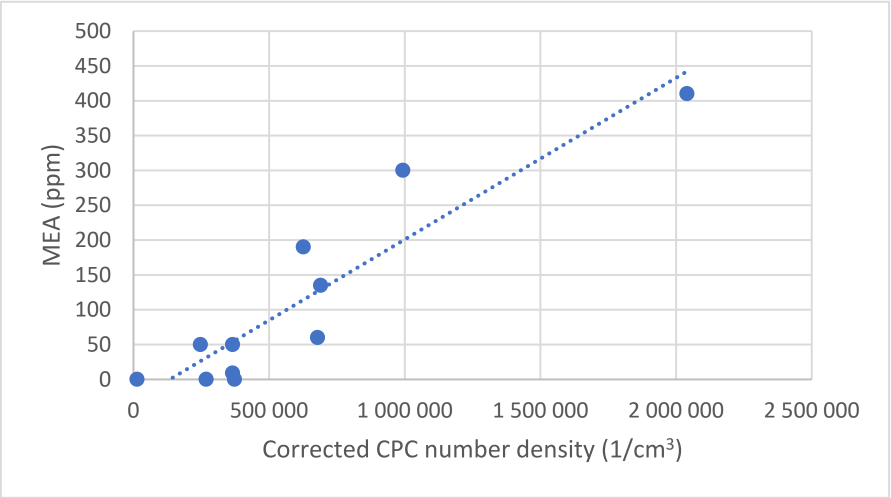


Figure 5.22 Measured MEA (ppm) by the FTIR as a function of "corrected" CPC number density (P/cm^3)

Table 5-2 Summary of flue gas characterization measurements using the CPC

Date	Sampling location	Burner/PALL filter/ CPC status	Est. percentage filter by-pass valve opening (%)	Est. Np (P/cm3)	FTIR amine (MEA ppm)	Comments
08.10.2019	Before PALL filter	Before burner tunning Filter NOT ok CPC ok	0	>1.98e6	410	Large number of particles measured at the filer section, along the absorber and at the gas outlet after water wash
	After PALL filter		0	>1.98e6	410	
	Mid absorber		0	>1.98e6	410	
	Top absorber		0	>1.98e6	410	
	After water wash		0	>1.98e6	410	
10.10.2019	After PALL filter	Same day as burner tunning Filter NOT ok Faulty CPC	0	2 040 691	355	CPC had earlier accidentally been exposed to under pressure from the sampling point. Underpressure in line caused backflow of liquid in CPC. Under pressure was created by the suction from the main plant blower, downstream. From these CPC measurements similar readings were observed for both before and after the PALL filter, it can be conclude that the PALL Filter does not remove small particles.
	Inside air		NA	299 394	NA	
	Before PALL filter		0	2 327 684	355	
	After PALL filter and after Gravimetric filter		0	9 298	355	
	Inside air		NA	344 598	NA	
	Before PALL filter and after Gravimetric filter		0	14 383	355	
24.10.2019	After PALL filter	After burner tunning Filter OK Faulty CPC	0	17 417	0.00	Generally low particulate/cm3 readings by the CPC is a strong indicator to problems with CPC. Insufficient humidication of very small particles makes them not to be counted. Liquid pump problem?, Internal gas leak? humidifier dried out? Gas flow increased 10:20 to see if higher particle count could be achieved
			5	268 530	0.00	
			10	372 830	0.00	
			20	678 589	60	
			50	689 896	135	
			100	993 156	300	
	Inside air	After burner tunning Filter OK Faulty CPC	NA	17 434	NA	
	After PALL Filter		0	13 313	0	
			30	246 932	50	
		After burner tunning Filter OK Faulty CPC confirmed	50	379 876	190	If humidifier dries out due to pump failure. It will reduce growth of particles, thus lowering number of particles detectable. An internal gas leak will reduce actual gas volume containing detectable particles
			30	221 890	50	
			15	221 890	9	
			0	18 639	0	
	Inside air		NA	17 751	NA	
	Before PALL filter		0	1 246 593	0	

5.4.2 Gravimetric particle measurement: results and discussion

During the CLIME-project campaign, some runs were dedicated for particle character measurement. These measurements were premised on the need to investigate and gain insight into how particle content in the flue gas affects amine emissions (MEA in this case). in conjunction with the role played by the PALL filter.

For this purpose, parametric variations were achieved by partially opening the bypass valve (to the PALL filter), thus facilitating some form of control on the particle concentration reaching the absorber column. When the bypass valve was fully closed, i.e. all the flue gas was passing through the PALL filter, no measurable emissions were observed. This suggests that the PALL filter was able to remove the size and / or amounts of the particles that caused emissions for this system.

It was noted that partial opening of the bypass valve yielded a certain amount of MEA emissions at the exit (Gasmet FTIR, see Figure 5.8), such that the FTIR readings (for MEA) were used to tune amount of by-pass opening. Gravimetric particle measurements were performed on the following days (2019):

- 10th October 2019 – the results for this run are considered invalid for the intended purpose as particle measurements on that day were inadvertently performed during a time frame when the process was in transient mode i.e. the burner had just been tuned from one set of conditions (characterised by significantly high particle content) to another (low particle content). The obtained results were too high (1073 and 361mg/Nm^3 for sampling point-1 and -2 respectively, refer to Figure 5.8) and seemed to confirm the suspected invalidity
- 5th November 2019 – the by-pass valve was partially opened yielding an average MEA emission of 37 ppm
- 8th November 2019 – the by-pass valve was partially opened yielding an average MEA emission of 170ppm

It is understood that the flue gas at Drax has a particulate content of around 1-30 mg/Nm^3 after the electrostatic precipitators. However, it should be noted that the burner at SINTEF is a different type. As such, it typically operates under different conditions and settings; implying that the respective product flue gas streams from the two biomass burners probably contain particles that may differ both in size and amount.

Particle measurements in this context were therefore aimed at establishing MEA emissions that would yield a particle content within the 1-30 mg/Nm^3 range when gravimetrically measured by thimble filters. Without a precedent, the 1st set of conditions (i.e. the tuning of the bypass valve on 5th November 2019) had to be an experience based 'guess' whilst the 2nd set of conditions (i.e. the tuning of the bypass valve on 8th November 2019) were guided by the results from the initial measurements.

Table 5-3: Summary of results for gravimetric particle measurements

	Sampling point-1	Sampling point-2	Sampling point-3	Sampling point-4
05/Nov-2019 (MEA Emission average ≈ 37 ppm)				
Particle Content (mg/Nm^3)	38.7	1.8	0.0	0.0
H_2O content in gas (vol%)	7.1	6.4	5.5	5.4
FTIR-H_2O average (vol%)	No FTIR sampling	-	5.7	6.3
08/Nov-2019 (MEA Emission average ≈ 170 ppm)				
Particle Content (mg/Nm^3)	36.0	4.8	0.0	0.0
H_2O content in gas (vol%)	7.36	6.7	4.0	6.9
FTIR-H_2O average (vol%)	No FTIR sampling	6.3	4.11	7.4

The results presented in Table 5-3 show that the numbers for the raw flue gas (i.e. sampling point-1) seem to be consistently close i.e. 38.7 mg/Nm^3 and 36 mg/Nm^3. Results from sampling point-2 correspond to what is obtained after the partial opening of the bypass valve; and these numbers are the ones linked to the resultant emissions. Measurements for sampling points 3 and 4 do not seem to yield interesting results for both cases.

As a general comment, the results in Table 5-3 suggest that for the type of flue gas produced by SINTEF's biomass burner (at those conditions + settings), a particle content of around ~2 mg/Nm^3 can cause MEA emissions close to ≈40ppm. Higher particle content will likewise yield even higher emissions as shown by 4.8 mg/Nm^3 corresponding to 170 ppm. The fact that no MEA emissions were observed when the bypass valve is fully closed; imply that the PALL filter was sufficiently effective in removing particle sizes that caused MEA emissions for this type of gas.

In order to have an impression of the quality of the data obtained for the gravimetric particle measurements, consistency between the water content (condensate collection) and corresponding FTIR readings is expected. Trends in the FTIR recordings also help to show stability of the process over time. The plots and trends shown in Figure 5.23 and Figure 5.24 suggest that these parameters exhibited a good degree of consistency within acceptable margins.

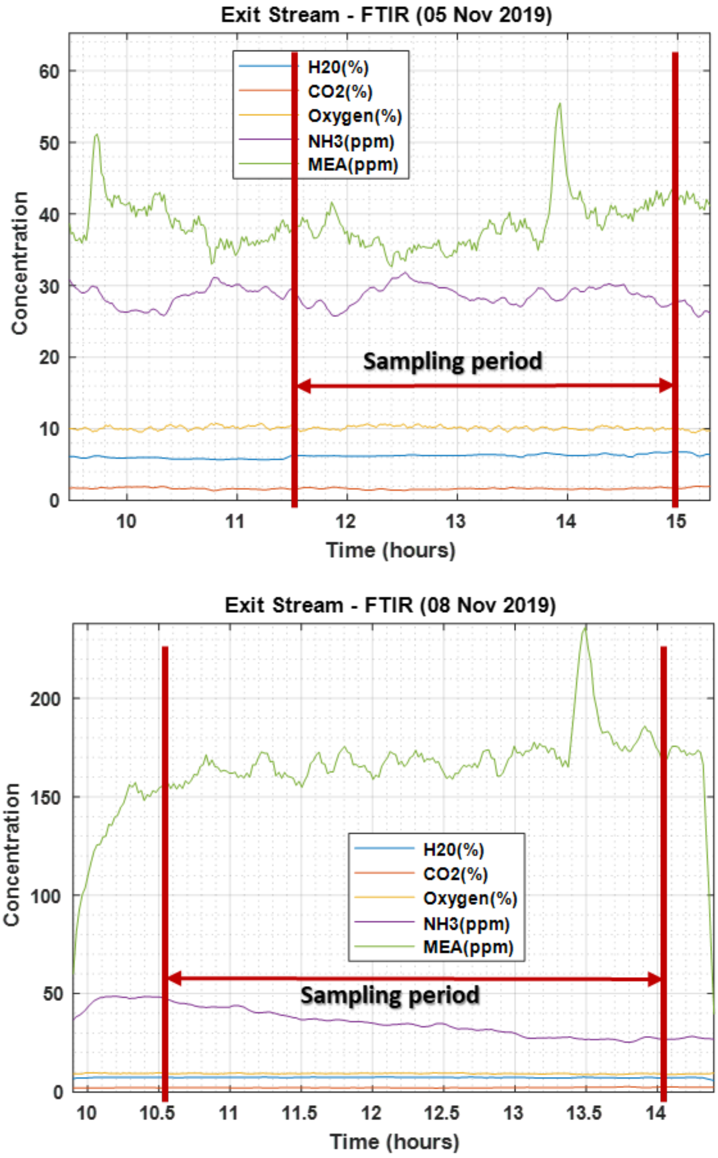


Figure 5.23: Gasmet FTIR (located at right at gas exit to the atmosphere) plots showing sampling periods and the corresponding process trends

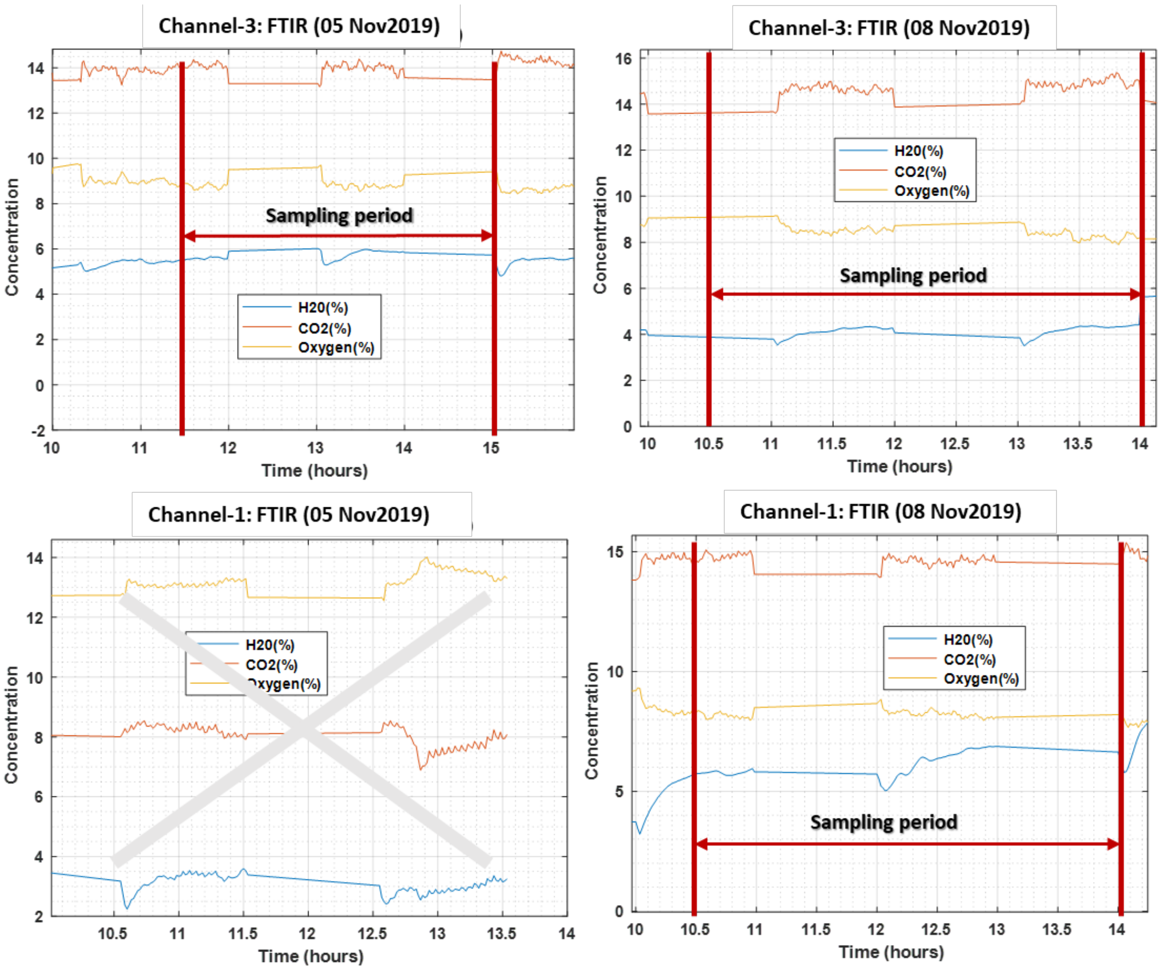


Figure 5.24: Protea FTIR plots showing sampling periods and the corresponding process trends. There was a leakage in the suction line for channel-1 on 05/Nov therefore the results are not valid. Channel-1 and channel-3 are located upstream and downstream the pre-conditioner column respectively

5.4.3 Electrical Low Pressure Impactor, ELPI

This activity was carried out as extension of the original plan of activities for flue gas characterisation. The need to have data on the distribution of particles was precipitated by the initial problems experienced in the project as described in section 3.2.1. It became necessary to acquire information on how the size distribution of the particles could affect the level of emissions experienced at the plant.

ELPI was therefore proposed and deployed for particle size distribution, this is because none of the initially proposed characterisation methods gives information on the particle size distribution (PSD) in the flue gas. CPC gives information on number of particles (Np) while gravimetric method gives information on particle mass (PM). The ELPI measurement carried out in this work was not designed for particle mass (PM), mg/m^3 measurement. ELPI measurement of PM requires the set-up operated in the gravimetric mode. This requires weighting each of the impactor stages and switching off the electric charge. The procedure used in this work measures PSD. All the data collected from the ELPI measurement are given in the Appendix. The data shown in the Appendix for PM, mg/m^3 are therefore not accurate in this case.

ELPI measurements were carried out on the flue gas before the PALL filter and after the PALL filter at sampling point-1 and sampling point-2 respectively, as shown in Figure 5.8. After measurement with a closed by-pass valve, the filter by-pass valve was opened at various degrees for measurement. FTIR reading was used as a measure for the level of filter by-pass valve opening. Summary of experiment measurements carried out using ELPI are shown in in Table 5-1 and summarised in Table 5-4. Sampling for the ELPI is typically measured for 20 min at steady state. However, to avoid carry over of particles from one saturated impactor stage to another, some of the measurements were concluded in less time when stable conditions were observed. Figure 5.25 shows a log of particle number measured at various PALL filter bypass valve set points. Dilution of the flue gas was necessary; the data is corrected for dilution. ELPI measurement assumes a round particle with density of 1.

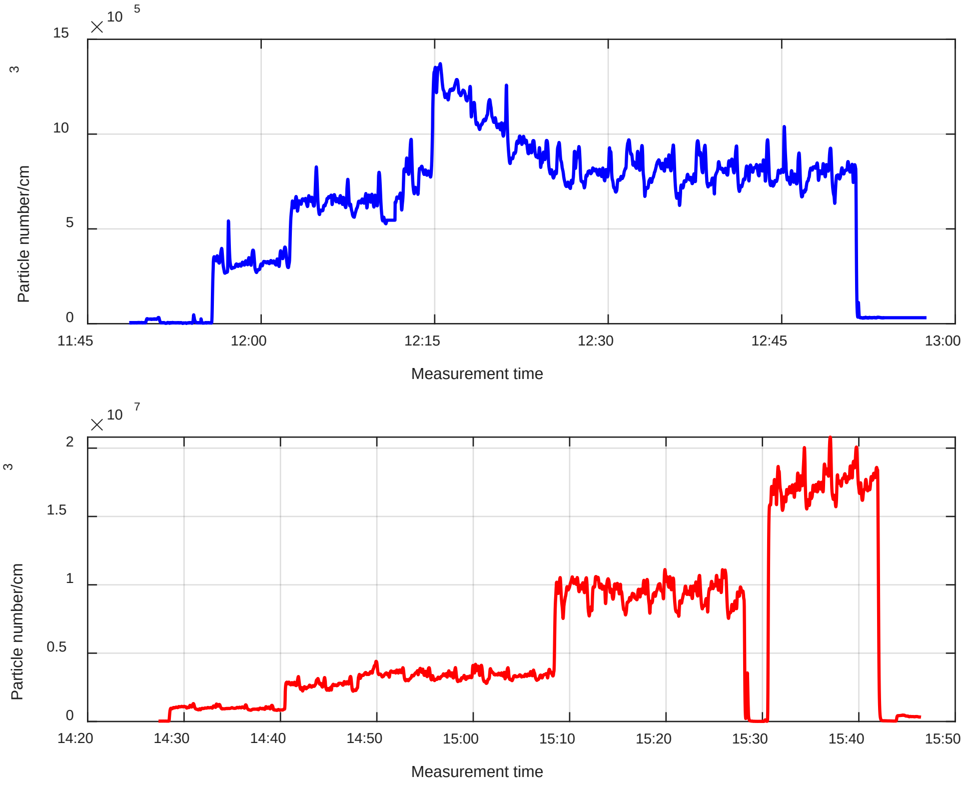


Figure 5.25 Particle number measurement log as measure by ELPI on 07.11.2019

The log of emission levels for MEA and NH_3 as well as CO_2 and H_2O concentrations during ELPI measurement is shown in Figure 5.26. The averaged FTIR result for all the relevant ELPI measurement period are presented in Table 5-4.

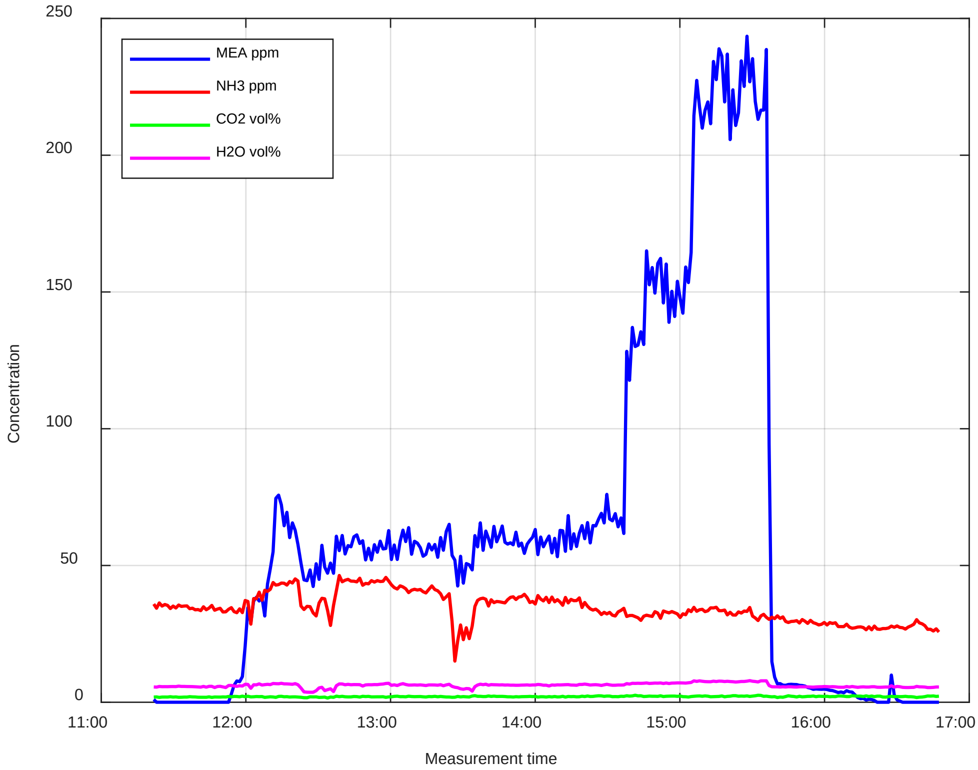


Figure 5.26 FTIR reading log during ELPI measurement on 07.11.2019

ELPI measurements results in Table 5-4 show number of particles, Np and particle size distribution.

When the PALL filter is operating normally, that is, without by-pass of the PALL filter, particle number from the burner is reduced from 1.74×10^7 to 7.29×10^3 particles and there is no detectable MEA emission. When the by-pass of the filter is opened, emission as recorded by the FTIR on the effluent flue gas is seen to increase according to the degree of opening up to 222 ppm. No detectable emission is seen when the filter is closed as shown by 0.00 ppm reading of MEA at the FTIR.

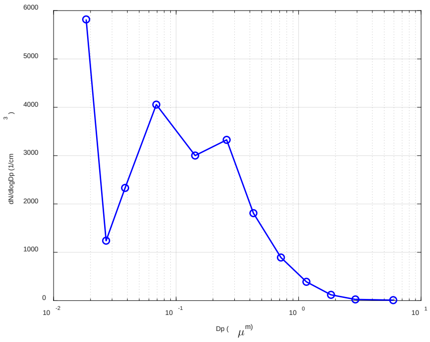
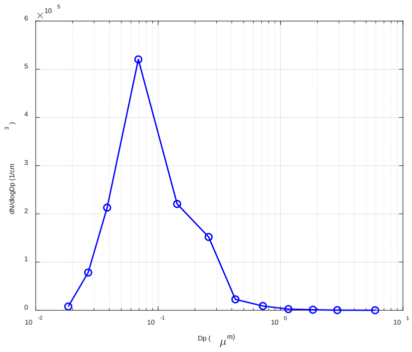
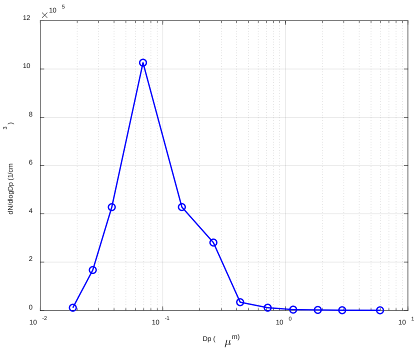
Furthermore, as shown in Table 5-4, it can be observed that the dominant particle size Dp, are in the range 0.038-0.143 µm when the filter by-pass is opened. And in all cases particles of size 0.0689 µm are most dominant. However, when the by-pass is closed the dominant size is more widely distributed with a maximum at 0.0184 µm.

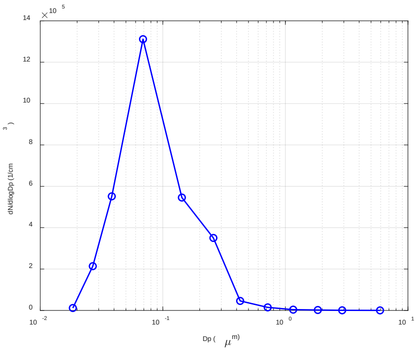
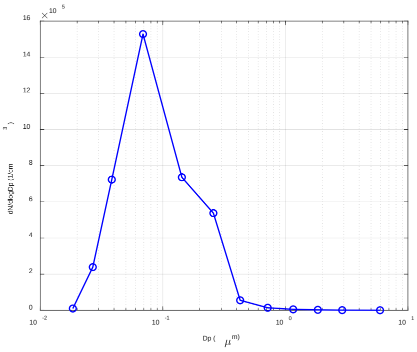
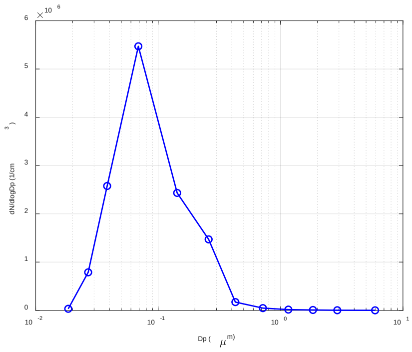
From this it can be deduced that under the burner operating conditions, particles of size 0.0689 µm are dominant. Particles of this size are also predominantly responsible for the emissions observed. Removal of this particle size by the PALL filter results to non-detectable emissions.

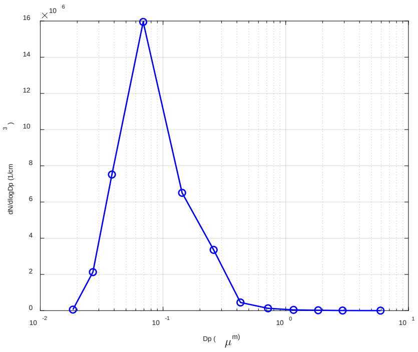
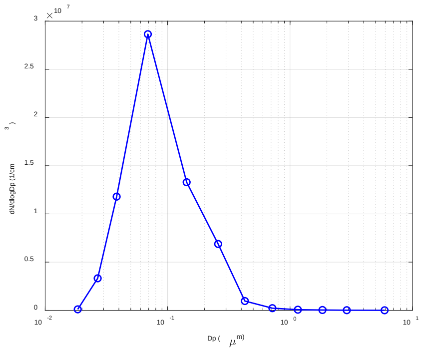
From the results in Table 5-4, a relationship between particle number (Np) and MEA emission is established and shown in

Figure 5.27.

Table 5-4 Summary of results from the ELPI measurement[*]

Sampling Point	Bypass Valve-FTIR set point (ppmMEA)	Estimate valve % opening[*]	Np (1/cm^3)	Particle Size distribution (PSD)	Dominant particle size, Dp (µm)
After Filter	0.00	0	7.293×10^3		0.0184
After Filter	6.78	5	3.214×10^5		0.0689
After Filter	35.86	10	6.235×10^5		0.0689

<table>
<tr><td>After Filter</td><td>54.81</td><td>20</td><td>7.956×10^5</td><td>
</td><td>0.0689</td></tr>
<tr><td>After Filter</td><td>67.05</td><td>25</td><td>9.978×10^5</td><td>
</td><td>0.0689</td></tr>
<tr><td>After Filter</td><td>152.59</td><td>40</td><td>3.405×10^6</td><td>
</td><td>0.0689</td></tr>
</table>

After Filter	222.43	50	9.514×10^6		0.0689
Before Filter			1.740×10^7		0.0689

* Valve opening was regulated such that similar emission level were obtained during other flue gas characterisation e.g. gravimetric filter measurement. This was done to enable data comparison from the different methods. Tracking of valve % opening here is therefore subjective and estimated.

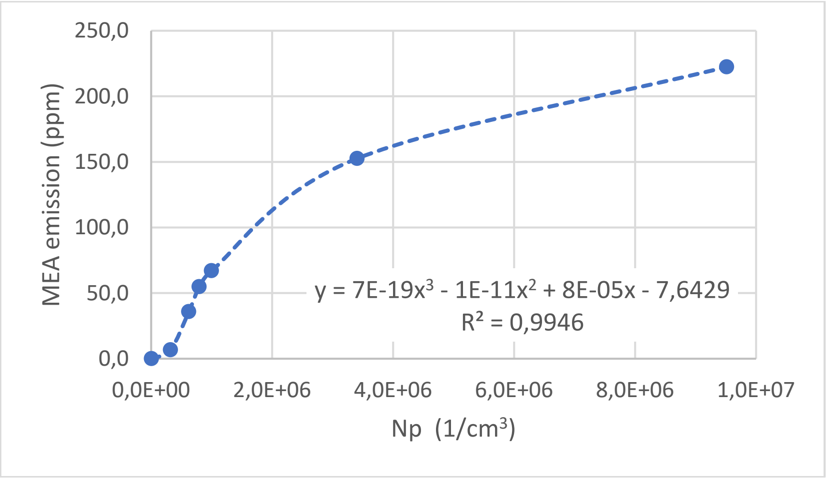


Figure 5.27 Relationship between number of particles and ppm MEA emission

Using the correlation relating number of particles, Np/cm^3 to emissions shown in Figure 5.27, combined with results from gravimetric filter measurement in Table 5-3, ELPI, FTIR and gravimetric measurement can be related in as given in Table 5-5 and shown in Figure 5.28. This relationship is not shown for CPC due to high uncertainty of data as discussed in section 5.4.1. It should be noted from Table 5-1 that the cut off point for ELPI is much lower than gravimetric filter. This implies that number of particles counted by the ELPI is much larger than the number of particles captured and weighed with the filter thimble in gravimetric measurement. Particle size distribution curves in Table 5-4 gives an indication of this.

Table 5-5 Relation between MEA emission, particle mass (PM) and particle number (Np)

FTIR	Gravimetric measurement	ELPI
MEA emission (ppm)	PM (mg/Nm^3)	Np (1/cm^3)
37	1,8	6,368E+05
170	4,8	4,456E+06

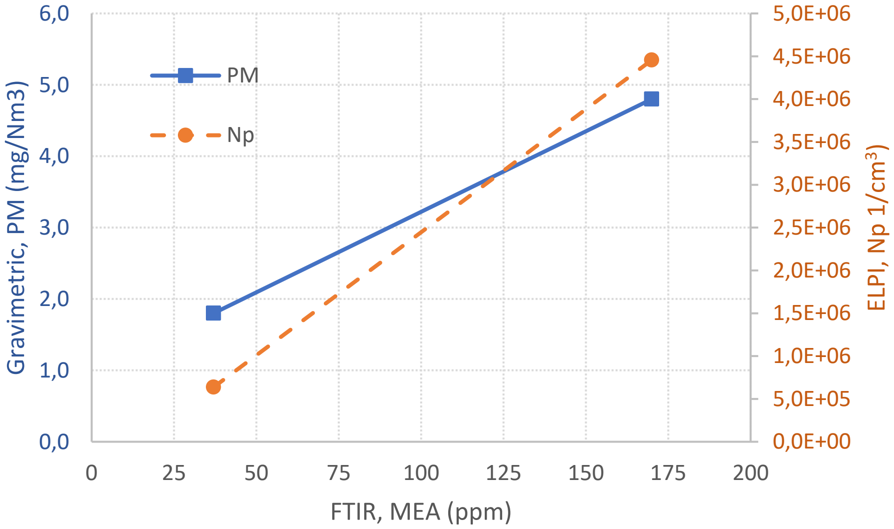


Figure 5.28 Relation between MEA emission, particle mass (PM) and particle number (Np)

6 Summary

A benchmarking pilot test campaign for bioenergy with carbon capture and storage (BECCS) has been carried out for Drax Power & C-Capture at the Tiller pilot plant using a conventional amine, MEA. Flue gas for the trial was produced by combustion of biopellets supplied by Drax power station in SINTEF's multifuel burner.

As expected, the SRD was determined for MEA in this campaign as 3.57 MJ/kgCO$_2$, similar to the established solvent regeneration energy requirement for MEA in other applications.

Under conditions of extremely low particle numbers in the flue gas, zero emissions of MEA were observed. However it should be noted that such conditions are unlikely to be representative of transient changes in conditions that can occur with any combustion process, the filter was bypassed to allow a small flow of particulates, to be representative of such circumstances and quantify the point at which emissions began to occur.It is regrettable that the PALL filter was accidentally not closed properly after service. This incident allowed a high dose of fly ash into the plant. This resulted in the operational problems experienced. Furthermore, this high level of fly ash in the plant is suspected to have accelerated solvent ageing observed in this campaign. Solvent ageing rate, represented by relative degradation rate, is seen to have increased to 6% in this campaign compared to 3% value in earlier campaign at Tiller when propane or coal burner flue gas were respectively used.

On the other hand, significant learnings were gained from this incident. The incident revealed an important consideration for the development of BECCS. It has shown that flue gas particulates must be adequately removed before the capture facility to avoid particulate related operational problems in a full-scale capture plant. The consequence of improper abatement of the particulates in a full scale BECCS capture plant may not have been fully appreciated without such incident. Behavior of other solvent systems in the presence such high dust dosage levels is unknown.

Flue gas characterisation results have shown that PALL filter at SINTEF facility effectively removes particles that are responsible for emissions. EPLI particle size distribution measurements show that ash particles of size 0.0689 µm are predominately responsible for the high emissions observed in the plant. A relationship between amine emission levels, number of particles/cm^3 and particle mass/Nm^3 has been established for the flue gas conditions for this campaign.

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			Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
			01.10.2019	**04.10.2019**	**08.10.2019**	**09.10.2019**	**10.10.2019**	**11.10.2019**
LOCATION	TAG	UNIT	08:00-09:00	07:40-08:40	07:20-08:20	06:15-07:15	07:30-08:30	06:15-07:15
T pack AC-1a	TAp1	(C)	41.3	44.5	41.2	42.7	41.2	44.0
T pack AC-1a	TAp2	(C)	43.4	45.9	43.5	46.0	42.5	48.0
T pack AC-1b	TAp3	(C)	45.6	47.5	45.9	49.0	44.0	51.0
T pack AC-1b	TAp4	(C)	47.1	48.7	47.5	50.7	45.2	53.0
T pack AC-1b	TAp5	(C)	49.3	50.9	50.1	53.4	46.9	55.3
T pack AC-2a	TAp6	(C)	49.4	50.9	50.2	53.5	46.8	55.5
T pack AC-2a	TAp7	(C)	50.3	51.8	51.2	54.6	47.7	56.6
T pack AC-2b	TAp8	(C)	51.8	53.4	53.2	56.5	49.3	58.5
T pack AC-2b	TAp9	(C)	53.1	54.8	54.9	58.3	50.9	60.2
T pack AC-2b	TAp10	(C)	55.3	57.4	58.0	61.1	53.2	62.7
T pack AC-3a	TAp11	(C)	55.3	57.4	57.9	61.1	53.3	62.7
T pack AC-3a	TAp12	(C)	56.3	58.7	59.5	62.4	54.6	63.9
T pack AC-3a	TAp13	(C)	58.6	61.5	62.7	65.4	57.8	66.5
T pack AC-3b	TAp14	(C)	61.0	65.0	66.1	68.4	61.4	69.1
T pack AC-3b	TAp15	(C)	64.1	68.5	69.5	71.4	65.6	72.0
T pack AC-4a	TAp16	(C)	62.4	66.1	66.8	69.2	62.1	69.5
T pack AC-4a	TAp17	(C)	66.7	71.8	72.4	73.9	69.6	74.2
T pack AC-4a	TAp18	(C)	68.5	73.7	73.9	75.3	72.2	75.5
T pack AC-4b	TAp19	(C)	66.4	71.7	72.0	73.1	70.4	73.2
T pack AC-4b	TAp20	(C)	50.2	51.8	54.6	54.4	58.7	53.9
T gas AC-GI	TAg0	(C)	41.6	44.3	40.6	41.2	42.6	40.6
T gas AC-LD1	TAg1	(C)	49.5	51.0	50.2	53.4	46.9	55.4
T gas AC-LD2	TAg2	(C)	55.1	57.2	57.7	60.9	53.0	62.4
T gas AC-LD3	TAg3	(C)	64.3	68.8	69.8	71.7	65.9	72.2
T gas AC-LD4	TAg4	(C)	61.9	67.4	67.1	66.8	68.4	66.4
T gas AW-LD1	TAg5	(C)	57.6	63.1	63.4	63.1	63.9	62.2
T gas AW-LD2	TAg6	(C)	34.8	41.9	33.8	57.6	59.4	57.8
T liq AC-S	TAlq0	(C)	41.3	44.8	41.4	42.7	41.1	43.4
T liq AC-LD2	TAlq2	(C)	55.8	58.1	58.7	61.8	53.6	63.1
T liq AC-LD3	TAlq3	(C)	64.9	69.6	70.3	72.1	66.4	72.5
T liq AC-LD4	TAlq4	(C)	42.2	49.3	50.6	51.8	42.2	50.2
T liq AW-LC1	TAlq5	(C)	58.4	63.7	64.3	64.2	64.8	63.3
T pack DC-1a	TDp1	(C)	113.6	119.1	119.3	117.3	120.0	115.2
T pack DC-1a	TDp2	(C)	111.2	118.7	118.8	116.1	119.7	113.4
T pack DC-1a	TDp3	(C)	105.9	117.1	117.6	112.1	118.8	108.1
T pack DC-1b	TDp4	(C)	101.8	116.9	117.6	109.6	118.9	105.7
T pack DC-1b	TDp5	(C)	99.0	115.1	116.2	103.8	118.1	101.1
T pack DC-2a	TDp6	(C)	99.0	115.5	116.4	104.4	118.1	101.1
T pack DC-2a	TDp7	(C)	99.1	113.0	114.8	102.1	117.6	100.8
T pack DC-2b	TDp8	(C)	99.5	109.6	113.1	101.6	116.3	101.2
T pack DC-2b	TDp9	(C)	99.1	108.7	111.9	101.0	116.4	100.7
T pack DC-2b	TDp10	(C)	99.1	106.5	110.1	100.9	115.9	100.7
T pack DC-3a	TDp11	(C)	99.1	105.6	108.7	100.9	115.2	100.8
T pack DC-3a	TDp12	(C)	99.2	104.3	106.9	101.0	114.3	100.9
T pack DC-3b	TDp13	(C)	99.3	103.7	105.9	101.1	113.5	101.0
T pack DC-3b	TDp14	(C)	99.4	102.4	103.0	101.2	107.9	101.1
T pack DC-3b	TDp15	(C)	97.4	99.9	99.7	99.2	102.2	99.2
T vap DC-GI	TDg0	(C)	117.3	120.5	120.5	119.6	121.0	118.9
T vap DC-LD1	TDg1	(C)	99.4	115.7	116.7	105.1	118.4	101.7
T vap DC-LD2	TDg2	(C)	99.7	107.3	111.0	101.6	116.2	101.4
T vap DC-LD3	TDg3	(C)	97.9	99.3	99.1	98.9	100.8	97.7
T vap DW-LD1	TDg4	(C)	91.7	95.3	94.9	94.6	97.4	93.7
T vap DW-LD2	TDg5	(C)	86.4	92.2	91.7	91.4	94.5	90.3
T vap DW-GO	TDg6	(C)	86.2	91.9	91.4	91.1	94.1	90.1
T liq DC-S	TDlq0	(C)	112.6	118.3	118.3	116.7	118.9	114.6
T liq DC-LD1	TDlq1	(C)	99.5	115.2	116.3	104.3	118.4	101.6
T liq DC-LD2	TDlq2	(C)	99.1	105.7	109.2	101.0	115.3	100.8
T liq DC-LD3	TDlq3	(C)	99.0	101.5	100.9	101.0	100.1	101.0
T liq DW-LC1	TDlq4	(C)	94.6	97.3	96.8	96.5	98.9	95.7
T liq DW-LD1	TDlq5	(C)	84.2	86.4	88.1	86.9	90.7	87.1
T liq DW-LD2	TDlq6	(C)	86.0	90.9	90.3	90.0	92.7	89.2
T gas Exhaust	TI01	(C)	30.9	117.2	31.3	30.3	31.1	30.4
T gas In PC-GI	TI02	(C)	20.3	83.7	19.9	20.2	20.7	20.9
T gas Out PC-GO	TI03	(C)	21.5	39.7	20.9	21.4	21.7	21.9

			Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
			01.10.2019	**04.10.2019**	**08.10.2019**	**09.10.2019**	**10.10.2019**	**11.10.2019**
LOCATION	TAG	UNIT	08:00-09:00	07:40-08:40	07:20-08:20	06:15-07:15	07:30-08:30	06:15-07:15
T gas Out FAN	TI04	(C)	51.5	52.3	49.1	50.6	55.3	48.5
T liq Rich In EX01	TI05	(C)	20.7	22.5	20.0	21.1	20.8	21.6
T liq Rich Out EX01	TI06	(C)	107.7	109.7	109.2	109.7	109.2	108.9
T liq Lean In EX01	TI07	(C)	117.6	120.7	120.8	120.0	121.2	119.3
T liq Lean Out EX01	TI08	(C)	47.0	50.2	47.0	48.5	47.2	48.9
T liq Boiler	TI09	(C)	117.6	120.6	120.7	119.8	121.2	119.2
T vap Boiler	TI10	(C)	120.7	123.0	122.7	122.1	122.7	121.5
T liq Cond Out DW-LC1	TI11	(C)	24.3	26.5	24.9	25.2	25.8	25.9
T liq Rich In RV1	TI12	(C)	99.2	101.8	101.0	101.7	100.0	101.3
T vap Out Flush GLS1	TI13	(C)	23.2	25.5	23.7	24.0	24.6	24.6
T liq Cond M-up to AW-LD2	TI14	(C)	21.5	23.7	22.2	22.5	22.9	23.2
T liq Cond feed to DW-2	TI15	(C)	18.7	17.1	15.8	15.9	16.0	16.4
T vap Out EX02	TI16	(C)	13.7	11.2	10.6	10.6	11.0	10.4
T vap Out EX03	TI17	(C)	19.0	18.9	17.8	17.7	18.3	18.3
T liq recirc PC-C In EX08	TT01	(C)	18.5	44.3	18.1	18.8	19.0	19.4
T liq recirc PC-C Out EX08	TT02	(C)	18.9	39.8	18.5	19.1	19.3	19.6
T gas In FAN	TT03	(C)	33.6	38.3	33.4	33.5	33.7	33.9
T gas Out EX11	TT04	(C)	47.7	48.6	45.6	47.0	51.0	45.4
T liq in Intercooler 1	TT05	(C)	33.1	34.7	32.9	34.5	30.0	36.3
T liq Lean Out EX10	TT06	(C)	39.9	40.0	39.9	39.9	39.7	40.0
T liq Lean Out HE03	TT07	(C)	39.3	39.3	39.3	39.3	39.0	39.4
T liq recirc AW-1 Out EX06	TT08	(C)	57.7	23.7	22.6	22.9	23.5	23.6
T liq recirc AW-1 Out HE05	TT09	(C)	57.0	31.0	22.4	22.5	23.1	23.2
T liq recirc AW-2 Out EX07	TT10	(C)	29.1	36.1	31.8	55.9	58.0	57.0
T liq recirc AW-2 Out HE06	TT11	(C)	27.6	34.8	30.3	54.5	56.7	55.6
T liq recirc DW-1 Out EX04	TT12	(C)	31.0	32.9	31.5	31.6	32.3	32.1
T liq recirc DW-2 Out EX05	TT13	(C)	87.1	91.9	91.3	91.0	93.7	90.3
T liq coolwater Out EX02	TT14	(C)	20.0	15.0	15.0	15.0	15.0	15.0
T gas Out EX03	TT15	(C)	18.4	17.9	16.9	16.7	17.3	17.3
T HeatS DC-S	TDs01	(C)	112.6	118.4	118.3	116.7	118.9	114.7
T HeatS DC-1a	TDs02	(C)	110.2	118.3	118.6	115.2	119.5	112.2
T HeatS DC-1b	TDs03	(C)	100.2	115.7	116.6	106.5	118.2	103.1
T HeatS DC-2a	TDs04	(C)	98.2	111.7	113.7	101.7	116.2	100.1
T HeatS DC-2b	TDs05	(C)	98.8	107.3	110.7	100.7	115.8	100.4
T HeatS DC-3a	TDs06	(C)	99.3	104.6	107.2	101.1	114.3	100.9
T HeatS DC-3b	TDs07	(C)	98.8	101.8	102.4	100.6	107.3	100.4
T HeatS Boiler	TDs08	(C)	117.6	120.6	120.7	119.8	121.2	119.2
T HeatS Rich	TDs09	(C)	40.9	44.3	40.9	42.3	40.7	43.0
T HeatS Gas Pipe	TDs10	(C)	21.6	23.7	22.5	23.0	23.5	23.6
T HeatS Abs top	TDs11	(C)	20.8	23.1	22.0	22.8	22.8	23.0
Heated gas out	TI20	(C)	0.0	0.0	0.0	0.0	0.0	0.0
Tgas after SCR	TI21	(C)	0.0	0.0	0.0	0.0	0.0	0.0
Tgas after cooler	TI22	(C)	0.0	0.0	0.0	0.0	0.0	0.0
T cooling water in AW1	TW1	(C)	22.5	9.3	21.7	22.5	22.9	23.1
T cooling water out AW1	TW2	(C)	21.2	8.6	21.4	21.8	22.4	22.5
T cooling water in AW2	TW3	(C)	9.9	9.6	8.9	9.3	9.2	9.3
T cooling water out AW2	TW4	(C)	24.8	30.8	19.9	57.0	58.7	57.4
T pack AW-1	TAT1	(C)	57.9	63.7	64.0	63.6	64.6	62.8
T pack AW-1	TAT2	(C)	59.0	64.6	65.1	64.7	65.5	63.8
T pack AW-2	TAT3	(C)	56.2	62.1	59.7	62.4	63.3	61.6
T pack AW-2	TAT4	(C)	35.0	41.6	33.5	57.9	59.7	58.1
Temp AW3 gas out	TT16	(C)	30.7	27.5	25.0	35.0	29.0	29.0
Temp Liquid AW3	TT17	(C)	21.4	23.7	22.1	33.3	27.9	27.8
Temp AW-3 gas in	TT18	(C)	21.3	23.3	22.0	22.7	23.4	23.3
Temp. AW-4 Low	TI26	(C)	20.3	22.8	21.5	50.1	44.4	44.5
Temp AW3 top	TI27	(C)	21.5	23.8	22.3	35.8	29.5	29.5
T light phase	TI28	(C)	0.0	0.0	0.0	0.0	0.0	0.0
T after static mixer	TI29	(C)	38.0	38.0	37.7	37.7	37.4	37.8
T from coal burner	TI101	(C)	98.4	95.4	93.4	89.2	107.5	98.1
T out of deNOx	TI102	(C)	95.8	94.3	92.0	92.3	92.2	92.3
T bypass filter	TI103	(C)	113.1	110.6	109.8	102.9	132.5	115.6
Tafter filter	TI104	(C)	51.5	52.3	49.1	50.6	55.3	48.5
T before CO2 recirc	TI105	(C)	16.4	16.7	16.4	15.6	15.7	16.1
T before FAN101	TI106	(C)	16.2	16.5	16.2	15.3	15.5	16.0

			Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
			01.10.2019	**04.10.2019**	**08.10.2019**	**09.10.2019**	**10.10.2019**	**11.10.2019**
LOCATION	TAG	UNIT	08:00-09:00	07:40-08:40	07:20-08:20	06:15-07:15	07:30-08:30	06:15-07:15
T after Fan 101	TI107	(C)	16.2	16.5	16.2	15.4	15.5	16.0
T liq after pump caustic	TI108	(C)	42.6	19.8	41.6	42.1	42.6	42.6
T liq after heater caustic	TI109	(C)	43.2	20.5	42.2	42.8	43.2	43.3
T liq after caustic cooler	TI110	(C)	34.6	19.7	34.6	34.6	34.7	34.6
Not in use	TI30	(C)	0.0	0.0	0.0	0.0	0.0	0.0
T water out intercooler 1	TI31	(C)	21.0	22.4	20.3	20.8	21.0	21.5
T water to intercooler 1	TI32	(C)	21.0	22.6	20.4	21.1	21.3	21.7
T liq out Intercooler 1	TI33	(C)	21.0	22.7	20.3	21.0	21.4	21.7
T liq in Intercooler 2	TI34	(C)	20.2	22.4	21.0	21.1	21.8	21.8
T water out intercooler 2	TI35	(C)	20.4	22.6	21.1	21.3	21.9	22.0
T water to intercooler 2	TI36	(C)	20.1	22.2	20.8	20.8	21.5	21.6
T liq to Intercooler 3	TI37	(C)	20.7	22.9	21.5	21.8	22.3	22.4
T water out Intercooler 3	TI38	(C)	20.5	22.7	21.2	21.5	22.0	22.2
T water to intercooler 3	TI39	(C)	21.6	23.8	22.2	22.4	23.0	23.1
Temp. AW-3 Low	TI40	(C)	20.8	23.4	21.9	56.9	58.0	56.8
Temp. AW-3 High	TI41	(C)	21.2	23.8	22.3	56.6	55.4	55.3
T liq recirc AW- Out EX13	TI42	(C)	21.4	24.0	22.4	56.7	55.0	55.1
Not in use	TI43	(C)	0.0	0.0	0.0	0.0	0.0	0.0
T liq out Intercooler 2	TT20	(C)	20.2	22.3	20.8	21.0	21.5	21.7
T liq out Intercooler 3	TT21	(C)	21.1	23.3	21.8	22.1	22.5	22.7
Not in use	TT22	(C)	0.0	0.0	0.0	0.0	0.0	0.0
T gas out AW3	TT23	(C)	21.0	23.5	21.8	56.4	55.0	55.0
T in HE30	TT24	(C)	98.3	114.8	115.8	103.5	117.4	100.7
T in HE31	TT25	(C)	97.7	104.7	108.5	99.7	114.3	99.6
T gas Out PC2	TT26	(C)	35.0	22.5	35.0	35.0	35.0	35.0
T HeatS HE30	TDE01	(C)	98.3	114.8	115.7	103.6	117.4	100.7
T HeatS HE31	TDE02	(C)	97.7	104.7	108.5	99.7	114.3	99.6
T above burner flames	TI120	(C)	890.6	862.1	863.9	861.8	898.4	898.0
T leaving burner chamber	TI121	(C)	845.6	820.4	819.9	835.5	915.4	837.3
Tgas after boiler	TI122	(C)	156.6	157.8	155.4	146.7	181.7	163.4
Tgas return chamber	TI123	(C)	125.2	125.6	123.5	115.0	150.8	130.9
T hot water	TI124	(C)	89.5	89.5	89.0	87.2	94.6	89.4
T water return	TI125	(C)	74.0	74.0	74.0	74.0	73.9	72.0
Pabs AC-GI	PA0	(mbara)	988.8	1017.3	998.1	995.0	995.6	995.5
Pabs AC-LD1	PA1	(mbara)	989.0	1016.6	998.1	995.3	995.6	996.1
Pabs AC-LD2	PA2	(mbara)	990.0	1018.3	998.3	995.2	996.1	996.0
Pabs AC-LD3	PA3	(mbara)	989.3	1017.6	997.6	994.5	995.4	995.2
Pabs AC-LD4	PA4	(mbara)	986.0	1013.5	994.4	991.0	992.7	991.8
Pabs AW-LD1	PA5	(mbara)	979.6	1007.0	987.4	984.1	985.6	985.2
Pabs AW-LD2	PA6	(mbara)	973.0	1000.1	981.0	974.7	976.1	975.3
Pabs Atmospheric Pressure	PA7	(mbara)	984.3	1012.5	992.9	986.8	988.6	987.8
Pgauge DC-GI	PD0	(mbarg)	27.8	27.8	27.8	27.8	27.8	27.8
Pgauge DC-LD1	PD1	(mbarg)	849.1	864.3	868.6	872.2	864.2	871.9
Pgauge DC-LD2	PD2	(mbarg)	822.2	843.9	848.8	849.0	848.3	847.3
Pgauge DC-LD3	PD3	(mbarg)	840.7	861.7	866.0	866.0	864.5	864.5
Pgauge DW-LD1	PD4	(mbarg)	850.8	869.0	873.6	873.9	871.2	870.2
Pgauge DW-LD2	PD5	(mbarg)	843.9	859.8	865.1	865.4	861.9	861.6
Pgauge DW-GO	PD6	(mbarg)	854.4	872.4	877.2	877.4	875.0	873.3
Pgauge Diluent air	PT01	(mbarg)	-0.07	-19.96	0.08	0.08	0.22	0.25
Pdiff Level PC-S	PT02	(mbar)	26.00	25.34	25.74	23.53	26.04	24.99
Pdiff Level AC-S	PT03	(mbar)	24.99	25.01	25.00	24.99	25.00	25.00
Pdiff Level Lean Out boiler	PT04	(mbar)	42.98	42.99	43.00	43.02	42.98	43.00
Pgauge Level Tank 2	PT05	(mbar)	30.44	56.10	26.67	28.62	23.24	23.35
Pgauge Level Tank 3	PT06	(mbar)	3.12	3.24	3.14	3.15	3.18	3.18
Pdiff Level DW-LC1	PT07	(mbar)	-1.24	-1.24	-1.24	-1.24	-1.24	-1.24
Pdiff Level DW-LC2	PT08	(mbar)	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
Pdiff Level AW-LC1	PT09	(mbar)	34.00	34.00	33.96	34.15	33.97	34.06
Pdiff Level AW-LC2	PT10	(mbar)	25.98	26.01	25.95	26.10	25.98	26.15
Pgauge CO2-line US VR27	PT11	(mbarg)	827.7	827.8	827.8	827.8	827.7	827.7
Pgauge Level Tank 1	PT12	(mbar)	23.85	10.61	2.10	20.27	6.01	21.43
Pabs PC-GO	PI01	(mbara)	984.6	991.2	993.0	987.0	988.9	988.0
Pabs In AC-GI DS EX11	PI02	(mbara)	991.9	1020.4	1001.4	998.5	998.8	999.1
Pgauge Vapour boiler	PI03	(mbarg)	850.7	876.0	881.3	882.8	874.3	874.3
Pgauge CO2-line DS EX03	PI04	(mbarg)	837.8	845.5	847.5	847.5	846.4	846.2

			Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
			01.10.2019	**04.10.2019**	**08.10.2019**	**09.10.2019**	**10.10.2019**	**11.10.2019**
LOCATION	TAG	UNIT	08:00-09:00	07:40-08:40	07:20-08:20	06:15-07:15	07:30-08:30	06:15-07:15
Pgauge Rich US RV1	PI05	(mbarg)	1813.3	1816.9	1816.1	1964.1	2010.6	1769.6
Pgauge Level Tank 4	PI06	(mbar)	3.6	3.6	3.6	3.7	3.7	3.7
Water vol recirc PC	FT01	(l/min)	0.01	16.00	0.01	0.01	0.01	0.01
Water vol filter PC	FT02	(l/min)	1.2	1.2	1.2	1.2	1.2	1.2
Gas vol In AC-GI	FT03	(m3/h)	160.0	160.0	160.0	160.0	160.0	160.0
Rich vol filter Out AC-S	FT04	(l/min)	0	0	0	0	0	0
Lean vol filter In AC-LD4/3	FT05	(l/min)	0.00	0.00	0.06	0.01	0.00	0.00
Cond vol recirc DW-1	FT06	(l/min)	3.30	3.30	3.30	3.30	3.30	3.30
Cond vol recirc DW-2	FT07	(l/min)	3.30	3.30	3.30	3.30	3.30	3.30
Cond vol M-up to AW-LD2	FT08	(l/min)	-67.33	-67.33	-67.33	-67.33	-67.33	-67.33
Water vol recirc AW-1	FT09	(l/min)	1.99	1.99	1.99	1.99	1.99	1.99
Water vol recirc AW-2	FT10	(l/min)	5.83	6.82	8.78	8.78	8.78	8.78
Water mass M-up to AW-LD2	FT11	(kg/h)	0.00	0.00	0.00	0.00	0.00	0.00
CO2 vol recirc In VG01	FT12	(m3/h)	0.01	4.00	2.00	2.00	2.00	2.00
Liq vol recirc Intercooler	FT13	(l/min)	0.00	0.00	0.00	0.00	0.00	0.00
CO2 mass Out EX03	FT14	(kg CO2/h)	21.38	29.07	30.31	30.28	29.50	29.37
Vap mass In DC-GI	FI01	(kg vap/h)	0.28	40.50	42.12	41.68	47.67	36.07
Cond vol Out DW-LD1	FI02	(l/h)	0.00	0.00	0.00	0.00	0.00	0.00
Vap vol In DC-LC1	FI03	(m3/h)	0.00	0.00	0.00	0.00	0.00	0.00
Lean mass In AC-LD4/3	FMD1_1	(kg/min)	7.00	7.00	7.00	8.00	6.00	8.50
Lean dens In AC-LD4/3	FMD1_2	(kg/m3)	1059.7	1039.8	1041.3	1050.2	1040.5	1064.5
Rich mass Out AC-S	FMD2_1	(kg/min)	7.21	7.21	7.16	8.18	6.15	8.69
Rich dens Out AC-S	FMD2_2	(kg/m3)	1108.36	1105.05	1112.64	1111.36	1121.10	1119.14
CO2-1 ch2 % In AC-1a	GA1_1	(%dry)	11.91	13.73	13.65	13.87	13.67	13.93
CO2-1 ch1 % In AC-2a	GA1_2	(%dry)	11.31	13.66	13.34	13.57	3.80	1.16
CO2-2 ch2 % In AC-3a	GA2_1	(%dry)	0.00	0.00	0.00	0.00	0.00	0.00
CO2-2 ch1 % In AC-4a	GA2_2	(%dry)	0.00	0.00	0.00	0.00	0.00	0.00
CO2-3 ch2 % Out AC-4b	GA3_1	(%dry)	3.73	2.03	1.74	2.04	2.20	2.60
CO2-3 ch1 % Out AW-OP	GA3_2	(%dry)	3.38	1.83	1.57	1.89	2.03	2.41
Boiler	HE01	(kW)	22.97	30.03	31.04	31.05	31.55	29.83
Sump PC	HE02	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Lean solvent feed to AC	HE03	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Rich solvent feed to DC	HE04	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Water recirculation AW-1	HE05	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Water recirculation AW-2	HE06	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Gas inlet absorber, US FAN	HE07	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Diff P Level Tank2	PT05	(L/h)	30.44	56.10	26.67	28.62	23.24	23.35
FogS inlet Abs	FS01	(%)	64.79	59.83	65.93	65.93	63.91	62.19
FogS outlet WW	FS02	(%)	26.25	83.57	26.36	23.93	22.68	23.48
Pdiff level tank FDF	PT13	(mbar)	10.00	10.00	10.00	10.00	10.00	10.00
Pgauge tank FDF	PT14	(barg)	1.10	1.10	1.10	1.30	1.40	1.00
Wash water bleed	FT15	(L/h)	-0.08	-0.01	0.00	0.00	0.00	0.00
Pgauge Rich DS EX01	PI07	(barg)	2.78	2.66	2.67	2.95	2.93	2.67
Flow cooling water AW-1	FT16	(l/min)	3.32	3.32	3.32	3.32	3.32	3.32
Flow cooling water AW-2	FT17	(l/min)	3.32	3.32	3.32	3.31	3.31	3.31
Pressure AW3 bottom	PA08	(mbar)	978.39	1006.26	986.97	981.19	983.18	982.47
Pressure AW3 top	PA09	(mbar)	972.60	1000.14	981.14	975.70	977.61	976.78
Level sump AW3	PT15	(mbar)	-0.19	0.06	-0.10	22.29	22.66	22.65
Water vol recirc AW-3	FT18	(l/min)	-1.64	-1.64	-1.64	9.04	8.14	8.22
pH Level	PH01	(-)	9.28	9.36	9.48	8.87	8.82	8.76
Lean massflow from desorber	FMD3_1	(l/min)	6.80	6.69	6.62	7.65	5.63	8.17
Lean density from desorber	FMD3_2	(kg/m3)	1055.4	1034.4	1038.1	1046.1	1037.1	1060.0
Level sump AW-4	PT16	(mbar)	0.00	32.98	32.91	26.25	25.84	26.26
Pdiff after coal filter	PI101	(mbar)	-22.53	-21.26	-22.84	-21.72	-25.32	-24.45
P after Fan101	PI102	(mbar)	10.80	-12.83	10.73	12.12	7.19	10.15
P top caustic column	PI103	(mbar)	506.72	506.93	504.59	502.50	501.78	502.60
Pdiff soot filter	PT101	(mbar)	0.44	0.29	0.75	0.76	0.81	0.80
Level caustic sump	PT102	(mbar)	59.72	59.19	59.94	59.82	59.83	59.80
pH caustic sump	PH101	(pH)	9.00	9.29	9.00	9.00	9.00	9.00
Gas volume rate after Fan 101	FT101	(m3/h)	188.26	132.44	193.62	191.89	197.72	194.77
Water volum rate caustic column	FT102	(l/min)	12.23	0.00	13.12	12.95	12.88	12.84
Desorber interheater low	HE30	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Desorber interheater high	HE31	(kW)	0.00	0.00	0.00	0.00	0.00	0.00
Flow water intercooler 1	FI05	(l/min)	0.01	0.01	0.01	0.01	0.01	0.01

			Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
			01.10.2019	**04.10.2019**	**08.10.2019**	**09.10.2019**	**10.10.2019**	**11.10.2019**
LOCATION	TAG	UNIT	08:00-09:00	07:40-08:40	07:20-08:20	06:15-07:15	07:30-08:30	06:15-07:15
Flow water intercooler 2	FI06	(l/min)	0.00	0.00	0.00	0.00	0.00	0.00
Flow water intercooler 3	FI07	(l/min)	0.00	0.00	0.00	0.00	0.00	0.00
Recirc flow intercooler 2	FT20	(l/min)	0.00	0.00	0.00	0.00	0.00	0.00
Recirc flow interooler 3	FT21	(l/min)	0.00	0.00	0.00	0.00	0.00	0.00
Recirc flow AW3	FT19	(l/min)	0.00	0.00	5.70	18.00	18.00	18.00
P AW3 bottom	PA10	(mbar)	31.25	33.76	33.07	36.78	36.62	36.69
P AW3 top	PA11	(mbar)	134.00	0.00	134.39	134.33	134.31	134.29
Furnace underpressure	PI100	(Pa)	58.09	57.22	57.52	57.19	58.57	60.48
O2 in flue gas	O100	%	6.73	6.86	6.98	6.62	6.54	6.50

			Run 7	**Run 8**	**Run 9**	**Run 10**	**Run 11**
			21.10.2019	**22.10.2019**	**23.10.2019**	**24.10.2019**	**25.10.2019**
LOCATION	TAG	UNIT	07:20-08:20	07:30-08:30	06:20-07:20	07:40-08:40	06:10-07:10
T pack AC-1a	TAp1	(C)	41.4	40.9	42.6	40.5	39.3
T pack AC-1a	TAp2	(C)	44.3	42.9	46.2	43.4	41.0
T pack AC-1b	TAp3	(C)	47.0	45.1	49.3	46.1	42.9
T pack AC-1b	TAp4	(C)	48.7	46.6	51.3	47.7	44.2
T pack AC-1b	TAp5	(C)	51.4	48.9	54.2	50.4	46.5
T pack AC-2a	TAp6	(C)	51.6	49.0	54.4	50.5	46.4
T pack AC-2a	TAp7	(C)	52.6	50.0	55.5	51.6	47.3
T pack AC-2b	TAp8	(C)	54.5	52.0	57.6	53.6	49.0
T pack AC-2b	TAp9	(C)	56.2	53.8	59.5	55.5	50.7
T pack AC-2b	TAp10	(C)	59.1	56.7	62.6	58.5	53.4
T pack AC-3a	TAp11	(C)	59.0	56.7	62.5	58.5	53.4
T pack AC-3a	TAp12	(C)	60.3	58.2	64.0	59.9	54.6
T pack AC-3a	TAp13	(C)	63.2	61.8	67.0	63.5	57.9
T pack AC-3b	TAp14	(C)	66.3	65.6	70.0	67.0	61.8
T pack AC-3b	TAp15	(C)	69.5	69.3	72.8	70.5	65.8
T pack AC-4a	TAp16	(C)	66.8	67.0	69.9	67.9	63.6
T pack AC-4a	TAp17	(C)	72.3	72.4	75.0	73.3	69.6
T pack AC-4a	TAp18	(C)	73.9	74.1	76.1	74.8	72.0
T pack AC-4b	TAp19	(C)	71.4	71.8	73.6	72.4	70.0
T pack AC-4b	TAp20	(C)	55.4	56.7	55.0	56.4	57.2
T gas AC-GI	TAg0	(C)	38.8	39.3	39.3	37.6	37.5
T gas AC-LD1	TAg1	(C)	51.5	49.0	54.2	50.4	46.4
T gas AC-LD2	TAg2	(C)	58.8	56.5	62.2	58.2	53.2
T gas AC-LD3	TAg3	(C)	69.7	69.6	73.0	70.8	66.1
T gas AC-LD4	TAg4	(C)	67.1	68.6	67.8	68.4	68.0
T gas AW-LD1	TAg5	(C)	62.2	63.5	62.8	63.4	62.8
T gas AW-LD2	TAg6	(C)	58.8	60.4	59.6	60.4	59.7
T liq AC-S	TAlq0	(C)	41.9	41.1	42.9	40.8	39.5
T liq AC-LD2	TAlq2	(C)	59.7	57.3	63.2	59.1	54.0
T liq AC-LD3	TAlq3	(C)	70.3	70.2	73.4	71.2	66.7
T liq AC-LD4	TAlq4	(C)	47.0	41.9	50.6	46.8	41.3
T liq AW-LC1	TAlq5	(C)	63.3	64.7	64.3	64.8	64.4
T pack DC-1a	TDp1	(C)	117.8	120.0	117.6	119.5	120.3
T pack DC-1a	TDp2	(C)	116.3	119.7	115.1	118.9	120.0
T pack DC-1a	TDp3	(C)	112.2	118.6	111.0	117.3	119.0
T pack DC-1b	TDp4	(C)	108.7	118.7	108.8	116.8	119.2
T pack DC-1b	TDp5	(C)	101.8	117.5	103.1	114.6	118.3
T pack DC-2a	TDp6	(C)	102.0	117.6	103.5	114.9	118.3
T pack DC-2a	TDp7	(C)	100.6	116.6	102.0	112.1	117.7
T pack DC-2b	TDp8	(C)	99.4	114.9	102.0	107.8	115.9
T pack DC-2b	TDp9	(C)	100.0	114.7	101.5	107.4	116.4
T pack DC-2b	TDp10	(C)	99.9	113.6	101.4	105.3	115.7
T pack DC-3a	TDp11	(C)	100.2	112.3	101.4	104.5	115.0
T pack DC-3a	TDp12	(C)	100.5	110.8	101.5	103.5	113.9
T pack DC-3b	TDp13	(C)	100.6	109.4	101.6	102.9	113.1
T pack DC-3b	TDp14	(C)	100.9	104.7	101.7	101.9	107.6
T pack DC-3b	TDp15	(C)	99.1	100.4	99.9	99.5	101.1
T vap DC-GI	TDg0	(C)	120.1	121.2	120.5	121.1	121.4
T vap DC-LD1	TDg1	(C)	102.8	117.9	104.1	115.3	118.6
T vap DC-LD2	TDg2	(C)	100.6	114.3	102.0	106.1	116.2
T vap DC-LD3	TDg3	(C)	98.6	99.6	99.4	98.6	100.7
T vap DW-LD1	TDg4	(C)	93.5	94.9	94.3	93.8	96.5
T vap DW-LD2	TDg5	(C)	90.1	91.8	91.2	90.8	93.6
T vap DW-GO	TDg6	(C)	89.8	91.6	90.8	90.4	93.3
T liq DC-S	TDlq0	(C)	117.0	119.0	117.1	118.6	119.2
T liq DC-LD1	TDlq1	(C)	102.2	117.6	103.6	114.6	118.4
T liq DC-LD2	TDlq2	(C)	100.2	113.0	101.5	104.7	115.2
T liq DC-LD3	TDlq3	(C)	100.9	100.8	101.6	101.0	100.4
T liq DW-LC1	TDlq4	(C)	95.6	96.9	96.3	95.9	98.1
T liq DW-LD1	TDlq5	(C)	83.9	87.5	85.6	84.7	87.5
T liq DW-LD2	TDlq6	(C)	89.0	90.5	89.8	89.5	92.0
T gas Exhaust	TI01	(C)	32.0	30.2	31.4	31.7	31.0
T gas In PC-GI	TI02	(C)	20.8	22.3	22.1	22.3	22.8
T gas Out PC-GO	TI03	(C)	21.7	22.9	22.9	23.0	23.3

			Run 7	**Run 8**	**Run 9**	**Run 10**	**Run 11**
			21.10.2019	**22.10.2019**	**23.10.2019**	**24.10.2019**	**25.10.2019**
LOCATION	TAG	UNIT	07:20-08:20	07:30-08:30	06:20-07:20	07:40-08:40	06:10-07:10
T gas Out FAN	TI04	(C)	41.4	42.4	43.0	38.0	38.0
T liq Rich In EX01	TI05	(C)	21.2	22.5	22.7	22.8	22.9
T liq Rich Out EX01	TI06	(C)	109.0	108.9	109.6	109.0	108.3
T liq Lean In EX01	TI07	(C)	120.7	121.6	120.9	121.4	121.7
T liq Lean Out EX01	TI08	(C)	47.4	46.9	48.6	46.5	45.4
T liq Boiler	TI09	(C)	120.6	121.5	120.8	121.4	121.7
T vap Boiler	TI10	(C)	120.2	123.2	123.0	123.3	123.3
T liq Cond Out DW-LC1	TI11	(C)	25.4	26.5	26.6	26.9	27.3
T liq Rich In RV1	TI12	(C)	101.0	100.5	101.7	100.9	99.9
T vap Out Flush GLS1	TI13	(C)	24.0	25.1	25.2	25.6	25.9
T liq Cond M-up to AW-LD2	TI14	(C)	22.7	23.4	23.7	24.0	24.4
T liq Cond feed to DW-2	TI15	(C)	16.4	16.2	16.2	16.4	16.5
T vap Out EX02	TI16	(C)	10.2	10.4	10.3	10.2	10.8
T vap Out EX03	TI17	(C)	17.8	18.0	18.3	18.4	19.0
T liq recirc PC-C In EX08	TT01	(C)	19.6	21.7	20.5	21.1	21.1
T liq recirc PC-C Out EX08	TT02	(C)	19.9	21.9	20.8	21.4	21.5
T gas In FAN	TT03	(C)	33.9	34.1	33.7	34.1	34.1
T gas Out EX11	TT04	(C)	39.3	40.3	40.4	36.2	36.1
T liq in Intercooler 1	TT05	(C)	35.3	33.7	36.2	34.4	32.6
T liq Lean Out EX10	TT06	(C)	40.0	39.9	39.9	40.0	39.0
T liq Lean Out HE03	TT07	(C)	39.4	39.2	39.3	39.4	38.4
T liq recirc AW-1 Out EX06	TT08	(C)	22.9	23.8	24.1	24.4	24.8
T liq recirc AW-1 Out HE05	TT09	(C)	22.5	23.5	23.8	24.1	24.5
T liq recirc AW-2 Out EX07	TT10	(C)	58.3	59.8	59.2	60.0	59.4
T liq recirc AW-2 Out HE06	TT11	(C)	57.0	58.5	57.9	58.7	58.0
T liq recirc DW-1 Out EX04	TT12	(C)	32.3	32.4	32.8	32.9	33.6
T liq recirc DW-2 Out EX05	TT13	(C)	90.1	91.5	90.8	90.5	93.0
T liq coolwater Out EX02	TT14	(C)	15.0	15.0	15.0	15.0	15.0
T gas Out EX03	TT15	(C)	16.8	16.8	17.2	17.3	17.8
T HeatS DC-S	TDs01	(C)	58.5	119.0	117.1	118.6	119.2
T HeatS DC-1a	TDs02	(C)	67.8	119.5	114.6	118.6	119.8
T HeatS DC-1b	TDs03	(C)	70.5	117.8	105.7	115.4	118.5
T HeatS DC-2a	TDs04	(C)	56.4	115.3	101.4	110.6	116.2
T HeatS DC-2b	TDs05	(C)	58.6	113.8	101.1	106.0	115.7
T HeatS DC-3a	TDs06	(C)	65.6	110.9	101.5	103.7	114.0
T HeatS DC-3b	TDs07	(C)	62.3	104.1	101.1	101.3	107.0
T HeatS Boiler	TDs08	(C)	50.9	121.5	120.8	121.5	121.7
T HeatS Rich	TDs09	(C)	41.3	40.5	42.4	40.2	38.9
T HeatS Gas Pipe	TDs10	(C)	23.2	23.9	24.2	24.5	24.9
T HeatS Abs top	TDs11	(C)	22.6	23.6	23.6	24.0	24.3
Heated gas out	TI20	(C)	0.0	0.0	0.0	0.0	0.0
Tgas after SCR	TI21	(C)	0.0	0.0	0.0	0.0	0.0
Tgas after cooler	TI22	(C)	0.0	0.0	0.0	0.0	0.0
T cooling water in AW1	TW1	(C)	25.8	27.4	28.0	27.1	28.5
T cooling water out AW1	TW2	(C)	22.1	22.9	23.1	23.5	23.8
T cooling water in AW2	TW3	(C)	8.8	9.0	9.1	9.1	9.1
T cooling water out AW2	TW4	(C)	57.0	57.0	57.2	57.1	56.7
T pack AW-1	TAT1	(C)	62.9	64.5	63.7	64.5	63.9
T pack AW-1	TAT2	(C)	63.7	65.0	64.3	64.9	64.3
T pack AW-2	TAT3	(C)	61.9	63.3	62.6	63.3	62.5
T pack AW-2	TAT4	(C)	59.5	61.0	60.2	61.0	60.3
Temp AW3 gas out	TT16	(C)	37.0	37.0	37.1	37.0	37.0
Temp Liquid AW3	TT17	(C)	34.9	34.9	35.5	35.5	35.5
Temp AW-3 gas in	TT18	(C)	23.0	23.6	24.0	24.4	24.8
Temp. AW-4 Low	TI26	(C)	51.3	51.1	50.0	49.6	49.4
Temp AW3 top	TI27	(C)	37.9	37.9	37.8	37.8	37.7
T light phase	TI28	(C)	0.0	0.0	0.0	0.0	0.0
T after static mixer	TI29	(C)	37.8	37.7	37.8	37.8	36.7
T from coal burner	TI101	(C)	93.5	95.0	93.1	97.8	95.0
T out of deNOx	TI102	(C)	93.1	95.5	94.9	94.6	95.5
T bypass filter	TI103	(C)	116.7	117.9	115.2	118.2	117.3
Tafter filter	TI104	(C)	41.4	42.4	43.0	38.0	38.0
T before CO2 recirc	TI105	(C)	16.5	20.7	18.1	19.7	19.7
T before FAN101	TI106	(C)	16.5	20.8	18.0	19.7	19.7

			Run 7	**Run 8**	**Run 9**	**Run 10**	**Run 11**
			21.10.2019	**22.10.2019**	**23.10.2019**	**24.10.2019**	**25.10.2019**
LOCATION	TAG	UNIT	07:20-08:20	07:30-08:30	06:20-07:20	07:40-08:40	06:10-07:10
T after Fan 101	TI107	(C)	16.5	20.8	18.1	19.6	19.7
T liq after pump caustic	TI108	(C)	44.8	44.5	44.5	45.2	45.2
T liq after heater caustic	TI109	(C)	45.4	45.1	45.2	45.9	45.9
T liq after caustic cooler	TI110	(C)	34.5	34.4	33.8	34.5	34.4
Not in use	TI30	(C)	0.0	0.0	0.0	0.0	0.0
T water out intercooler 1	TI31	(C)	21.5	22.9	22.6	23.0	23.0
T water to intercooler 1	TI32	(C)	21.6	23.0	22.7	22.9	23.1
T liq out Intercooler 1	TI33	(C)	21.6	22.9	22.6	22.9	23.0
T liq in Intercooler 2	TI34	(C)	21.2	21.9	22.2	22.3	22.7
T water out intercooler 2	TI35	(C)	21.5	22.2	22.4	22.7	23.0
T water to intercooler 2	TI36	(C)	21.2	21.9	22.3	22.5	22.8
T liq to Intercooler 3	TI37	(C)	21.8	22.6	22.8	23.0	23.3
T water out Intercooler 3	TI38	(C)	21.6	22.4	22.7	22.9	23.3
T water to intercooler 3	TI39	(C)	22.8	23.6	23.7	24.1	24.3
Temp. AW-3 Low	TI40	(C)	57.7	59.1	58.5	59.2	58.6
Temp. AW-3 High	TI41	(C)	55.4	55.6	55.6	55.6	55.6
T liq recirc AW- Out EX13	TI42	(C)	55.1	55.0	55.1	54.9	55.0
Not in use	TI43	(C)	0.0	0.0	0.0	0.0	0.0
T liq out Intercooler 2	TT20	(C)	21.2	22.0	22.3	22.5	22.9
T liq out Intercooler 3	TT21	(C)	22.3	23.1	23.4	23.6	24.0
Not in use	TT22	(C)	0.0	0.0	0.0	0.0	0.0
T gas out AW3	TT23	(C)	55.0	55.0	55.1	55.0	55.0
T in HE30	TT24	(C)	60.9	117.0	102.9	114.0	117.7
T in HE31	TT25	(C)	65.1	112.0	100.2	103.6	114.2
T gas Out PC2	TT26	(C)	35.1	34.9	34.4	35.1	35.0
T HeatS HE30	TDE01	(C)	101.4	117.0	102.9	114.0	117.7
T HeatS HE31	TDE02	(C)	98.6	112.0	100.2	103.7	114.2
T above burner flames	TI120	(C)	892.8	883.9	887.6	897.4	890.5
T leaving burner chamber	TI121	(C)	902.4	856.2	886.0	915.8	873.1
Tgas after boiler	TI122	(C)	160.8	159.8	158.5	161.6	159.8
Tgas return chamber	TI123	(C)	130.8	131.3	128.6	131.9	130.2
T hot water	TI124	(C)	89.0	88.9	88.6	89.4	89.1
T water return	TI125	(C)	71.9	72.0	72.0	72.1	71.9
Pabs AC-GI	PA0	(mbara)	1020.2	995.9	1009.0	1002.6	994.7
Pabs AC-LD1	PA1	(mbara)	1019.5	995.5	1008.3	1001.9	994.0
Pabs AC-LD2	PA2	(mbara)	1020.7	996.8	1008.9	1002.5	995.1
Pabs AC-LD3	PA3	(mbara)	1019.9	996.1	1008.2	1001.8	994.4
Pabs AC-LD4	PA4	(mbara)	1015.5	991.8	1004.1	998.1	990.8
Pabs AW-LD1	PA5	(mbara)	1008.5	984.8	996.7	990.7	983.7
Pabs AW-LD2	PA6	(mbara)	998.7	974.8	987.0	980.8	973.7
Pabs Atmospheric Pressure	PA7	(mbara)	1011.4	987.3	999.8	993.6	986.3
Pgauge DC-GI	PD0	(mbarg)	27.8	27.8	27.8	27.8	27.8
Pgauge DC-LD1	PD1	(mbarg)	868.9	870.3	875.4	871.5	867.8
Pgauge DC-LD2	PD2	(mbarg)	845.5	854.8	852.3	853.8	852.7
Pgauge DC-LD3	PD3	(mbarg)	863.5	869.8	869.2	871.7	865.2
Pgauge DW-LD1	PD4	(mbarg)	871.7	876.9	876.8	878.4	873.8
Pgauge DW-LD2	PD5	(mbarg)	863.1	867.6	867.7	869.1	863.9
Pgauge DW-GO	PD6	(mbarg)	874.8	880.1	879.9	881.2	876.9
Pgauge Diluent air	PT01	(mbarg)	0.33	0.48	0.52	0.52	0.54
Pdiff Level PC-S	PT02	(mbar)	25.55	24.17	25.00	24.67	24.69
Pdiff Level AC-S	PT03	(mbar)	24.99	25.00	24.99	25.00	25.00
Pdiff Level Lean Out boiler	PT04	(mbar)	43.00	43.00	43.00	43.01	43.03
Pgauge Level Tank 2	PT05	(mbar)	103.13	88.06	79.90	74.84	75.85
Pgauge Level Tank 3	PT06	(mbar)	3.16	3.21	3.21	3.23	3.23
Pdiff Level DW-LC1	PT07	(mbar)	-1.24	-1.24	-1.24	-1.24	-1.24
Pdiff Level DW-LC2	PT08	(mbar)	-1.18	-1.18	-1.18	-1.18	-1.18
Pdiff Level AW-LC1	PT09	(mbar)	34.00	34.00	34.00	34.01	34.00
Pdiff Level AW-LC2	PT10	(mbar)	25.96	25.97	25.97	25.97	26.03
Pgauge CO2-line US VR27	PT11	(mbarg)	827.7	827.8	827.7	827.8	827.6
Pgauge Level Tank 1	PT12	(mbar)	8.11	8.36	8.27	8.52	8.90
Pabs PC-GO	PI01	(mbara)	1011.8	987.9	1000.3	994.1	987.0
Pabs In AC-GI DS EX11	PI02	(mbara)	1023.8	999.5	1012.8	1006.1	998.4
Pgauge Vapour boiler	PI03	(mbarg)	880.9	879.8	895.8	882.2	878.4
Pgauge CO2-line DS EX03	PI04	(mbarg)	847.0	848.9	848.9	849.6	847.6

			Run 7	**Run 8**	**Run 9**	**Run 10**	**Run 11**
			21.10.2019	**22.10.2019**	**23.10.2019**	**24.10.2019**	**25.10.2019**
LOCATION	TAG	UNIT	07:20-08:20	07:30-08:30	06:20-07:20	07:40-08:40	06:10-07:10
Pgauge Rich US RV1	PI05	(mbarg)	1752.1	1740.8	1764.2	1748.5	1735.1
Pgauge Level Tank 4	PI06	(mbar)	3.6	3.7	3.7	3.7	3.7
Water vol recirc PC	FT01	(l/min)	0.01	0.01	0.01	0.01	0.01
Water vol filter PC	FT02	(l/min)	1.2	1.2	1.2	1.2	1.2
Gas vol In AC-GI	FT03	(m3/h)	160.0	160.0	160.0	160.0	160.0
Rich vol filter Out AC-S	FT04	(l/min)	0	0	0	0	0
Lean vol filter In AC-LD4/3	FT05	(l/min)	0.00	0.00	0.00	0.00	0.00
Cond vol recirc DW-1	FT06	(l/min)	3.30	3.30	3.30	3.30	3.30
Cond vol recirc DW-2	FT07	(l/min)	3.30	3.30	3.30	3.30	3.30
Cond vol M-up to AW-LD2	FT08	(l/min)	-67.33	-67.33	-67.33	-67.33	-67.33
Water vol recirc AW-1	FT09	(l/min)	1.99	1.99	1.99	1.99	1.99
Water vol recirc AW-2	FT10	(l/min)	8.78	8.78	8.78	8.78	8.78
Water mass M-up to AW-LD2	FT11	(kg/h)	0.00	0.00	0.00	0.00	0.00
CO2 vol recirc In VG01	FT12	(m3/h)	2.00	2.00	2.00	2.00	2.00
Liq vol recirc Intercooler	FT13	(l/min)	0.00	0.00	0.00	0.00	0.00
CO2 mass Out EX03	FT14	(kg CO2/h)	30.07	31.52	31.52	32.03	30.41
Vap mass In DC-GI	FI01	(kg vap/h)	45.97	48.46	43.06	45.53	47.41
Cond vol Out DW-LD1	FI02	(l/h)	0.00	0.00	0.00	0.00	0.00
Vap vol In DC-LC1	FI03	(m3/h)	0.00	0.00	0.00	0.00	0.00
Lean mass In AC-LD4/3	FMD1_1	(kg/min)	7.50	6.50	8.00	7.00	6.00
Lean dens In AC-LD4/3	FMD1_2	(kg/m3)	1057.2	1046.3	1058.8	1050.8	1044.8
Rich mass Out AC-S	FMD2_1	(kg/min)	7.70	6.70	8.22	7.20	6.19
Rich dens Out AC-S	FMD2_2	(kg/m3)	1122.16	1125.51	1121.81	1125.71	1128.07
CO2-1 ch2 % In AC-1a	GA1_1	(%dry)	13.88	13.51	13.86	13.69	13.48
CO2-1 ch1 % In AC-2a	GA1_2	(%dry)	13.56	11.76	1.37	13.10	13.35
CO2-2 ch2 % In AC-3a	GA2_1	(%dry)	0.00	0.00	0.00	0.00	0.00
CO2-2 ch1 % In AC-4a	GA2_2	(%dry)	0.00	0.00	0.00	0.00	0.00
CO2-3 ch2 % Out AC-4b	GA3_1	(%dry)	2.37	1.43	1.56	10.06	0.23
CO2-3 ch1 % Out AW-OP	GA3_2	(%dry)	2.25	1.34	1.58	1.42	1.90
Boiler	HE01	(kW)	31.24	31.75	31.64	31.64	31.65
Sump PC	HE02	(kW)	0.00	0.00	0.00	0.00	0.00
Lean solvent feed to AC	HE03	(kW)	0.00	0.00	0.00	0.00	0.00
Rich solvent feed to DC	HE04	(kW)	0.00	0.00	0.00	0.00	0.00
Water recirculation AW-1	HE05	(kW)	0.00	0.00	0.00	0.00	0.00
Water recirculation AW-2	HE06	(kW)	0.00	0.00	0.00	0.00	0.00
Gas inlet absorber, US FAN	HE07	(kW)	0.00	0.00	0.00	0.00	0.00
Diff P Level Tank2	PT05	(L/h)	103.13	88.06	79.90	74.84	75.85
FogS inlet Abs	FS01	(%)	61.93	58.31	58.31	57.57	58.30
FogS outlet WW	FS02	(%)	97.33	97.30	97.33	97.33	97.33
Pdiff level tank FDF	PT13	(mbar)	10.00	10.00	10.00	10.00	10.00
Pgauge tank FDF	PT14	(barg)	1.00	1.00	1.00	1.00	1.00
Wash water bleed	FT15	(L/h)	0.00	0.00	0.00	0.00	0.00
Pgauge Rich DS EX01	PI07	(barg)	2.58	2.53	2.61	2.55	2.51
Flow cooling water AW-1	FT16	(l/min)	3.32	3.32	3.32	3.32	3.32
Flow cooling water AW-2	FT17	(l/min)	3.34	3.43	3.36	3.34	3.38
Pressure AW3 bottom	PA08	(mbar)	1005.79	981.82	994.42	988.41	981.11
Pressure AW3 top	PA09	(mbar)	999.72	976.38	988.43	982.63	975.40
Level sump AW3	PT15	(mbar)	22.63	22.64	22.65	22.65	22.62
Water vol recirc AW-3	FT18	(l/min)	8.69	8.60	9.02	9.05	9.01
pH Level	PH01	(-)	8.26	8.16	8.35	8.27	7.99
Lean massflow from desorber	FMD3_1	(l/min)	7.17	6.14	7.68	6.65	5.67
Lean density from desorber	FMD3_2	(kg/m3)	1054.1	1043.4	1054.8	1048.2	1042.2
Level sump AW-4	PT16	(mbar)	25.72	25.76	25.68	25.79	25.72
Pdiff after coal filter	PI101	(mbar)	-20.14	-21.15	-20.34	-20.93	-21.28
P after Fan101	PI102	(mbar)	-37.30	-41.84	-47.42	0.95	-2.46
P top caustic column	PI103	(mbar)	492.20	478.87	482.57	504.08	498.67
Pdiff soot filter	PT101	(mbar)	4.61	5.49	7.16	9.37	7.98
Level caustic sump	PT102	(mbar)	59.88	59.94	59.94	59.93	59.99
pH caustic sump	PH101	(pH)	9.00	9.00	9.00	9.00	9.00
Gas volume rate after Fan 101	FT101	(m3/h)	210.40	210.99	211.65	205.32	204.89
Water volum rate caustic column	FT102	(l/min)	9.50	9.49	9.50	9.49	9.46
Desorber interheater low	HE30	(kW)	0.00	0.00	0.00	0.00	0.00
Desorber interheater high	HE31	(kW)	0.00	0.00	0.00	0.00	0.00
Flow water intercooler 1	FI05	(l/min)	0.01	0.01	0.01	0.01	0.01

LOCATION	TAG	UNIT	**Run 7** **21.10.2019** 07:20-08:20	**Run 8** **22.10.2019** 07:30-08:30	**Run 9** **23.10.2019** 06:20-07:20	**Run 10** **24.10.2019** 07:40-08:40	**Run 11** **25.10.2019** 06:10-07:10
Flow water intercooler 2	FI06	(l/min)	0.00	0.00	0.00	0.00	0.00
Flow water intercooler 3	FI07	(l/min)	0.00	0.00	0.00	0.00	0.00
Recirc flow intercooler 2	FT20	(l/min)	0.00	0.00	0.00	0.00	0.00
Recirc flow interooler 3	FT21	(l/min)	0.00	0.00	0.00	0.00	0.00
Recirc flow AW3	FT19	(l/min)	18.00	18.00	18.00	18.00	18.00
P AW3 bottom	PA10	(mbar)	0.00	0.00	0.00	0.00	0.00
P AW3 top	PA11	(mbar)	137.76	134.15	135.67	134.45	134.09
Furnace underpressure	PI100	(Pa)	60.49	60.25	59.71	60.02	60.54
O2 in flue gas	O100	%	6.60	6.53	6.47	6.49	6.54

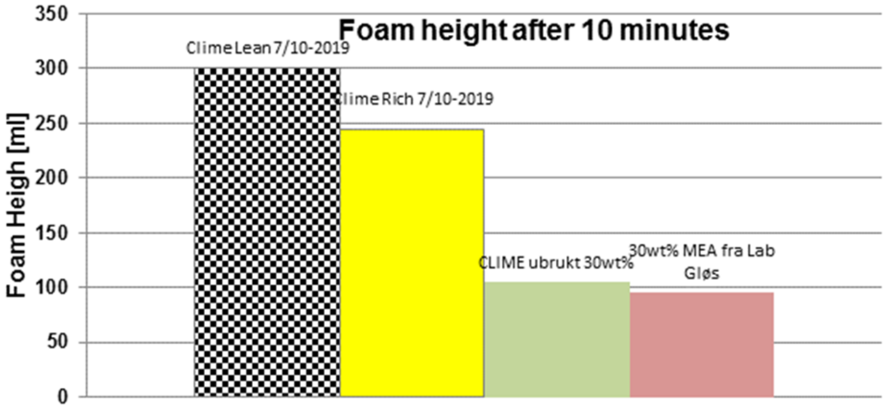
			Run 12	**Run 13**	**Run 14**	**Run 15**	**Run 16**
			04.11.2019	**05.11.2019**	**06.11.2019**	**07.11.2019**	**08.11.2019**
LOCATION	TAG	UNIT	07:35-08:35	10:10-11:10	08:40-09:40	07:40-08:40	07:40-08:40
T pack AC-1a	TAp1	(C)	40.9	40.7	40.7	41.0	41.2
T pack AC-1a	TAp2	(C)	43.6	43.8	43.8	44.0	44.0
T pack AC-1b	TAp3	(C)	46.2	46.4	46.4	46.5	46.5
T pack AC-1b	TAp4	(C)	47.7	48.2	48.2	48.3	48.1
T pack AC-1b	TAp5	(C)	50.3	50.6	50.8	50.8	50.6
T pack AC-2a	TAp6	(C)	50.4	50.7	51.0	51.0	50.7
T pack AC-2a	TAp7	(C)	51.3	51.7	52.0	52.0	51.6
T pack AC-2b	TAp8	(C)	53.0	53.6	53.9	53.9	53.4
T pack AC-2b	TAp9	(C)	54.5	55.4	55.7	55.6	55.0
T pack AC-2b	TAp10	(C)	57.1	58.2	58.5	58.4	57.6
T pack AC-3a	TAp11	(C)	57.0	58.2	58.5	58.3	57.5
T pack AC-3a	TAp12	(C)	58.3	59.6	59.8	59.7	58.8
T pack AC-3a	TAp13	(C)	60.9	62.7	62.9	62.8	61.7
T pack AC-3b	TAp14	(C)	64.0	65.9	66.0	65.8	64.8
T pack AC-3b	TAp15	(C)	67.2	69.2	69.3	69.1	68.2
T pack AC-4a	TAp16	(C)	65.2	66.4	66.3	66.4	65.6
T pack AC-4a	TAp17	(C)	70.3	72.2	72.3	72.1	71.5
T pack AC-4a	TAp18	(C)	72.4	73.8	73.8	73.8	73.5
T pack AC-4b	TAp19	(C)	70.3	71.8	71.7	71.6	71.4
T pack AC-4b	TAp20	(C)	54.5	54.9	55.1	55.1	55.3
T gas AC-GI	TAg0	(C)	38.4	37.6	37.6	38.2	38.6
T gas AC-LD1	TAg1	(C)	50.3	50.6	50.8	50.9	50.6
T gas AC-LD2	TAg2	(C)	56.8	57.9	58.2	58.1	57.3
T gas AC-LD3	TAg3	(C)	67.5	69.5	69.6	69.4	68.4
T gas AC-LD4	TAg4	(C)	66.1	66.7	67.0	67.1	67.1
T gas AW-LD1	TAg5	(C)	61.7	62.6	62.4	62.4	62.6
T gas AW-LD2	TAg6	(C)	58.5	59.4	37.9	57.3	58.3
T liq AC-S	TAlq0	(C)	41.3	40.9	41.1	41.4	41.5
T liq AC-LD2	TAlq2	(C)	57.6	58.8	59.1	59.0	58.2
T liq AC-LD3	TAlq3	(C)	68.1	70.1	70.2	70.0	69.1
T liq AC-LD4	TAlq4	(C)	52.0	52.1	52.2	52.2	52.4
T liq AW-LC1	TAlq5	(C)	62.7	63.3	63.5	63.5	63.4
T pack DC-1a	TDp1	(C)	121.6	118.6	118.5	118.5	118.7
T pack DC-1a	TDp2	(C)	119.2	117.9	117.7	117.6	117.9
T pack DC-1a	TDp3	(C)	116.0	115.7	115.2	115.0	115.5
T pack DC-1b	TDp4	(C)	113.5	114.5	113.5	113.3	114.0
T pack DC-1b	TDp5	(C)	108.7	109.7	107.9	107.5	108.6
T pack DC-2a	TDp6	(C)	107.6	110.3	108.7	108.3	109.3
T pack DC-2a	TDp7	(C)	103.1	106.0	104.4	104.0	105.0
T pack DC-2b	TDp8	(C)	101.9	100.9	100.1	100.0	100.5
T pack DC-2b	TDp9	(C)	101.3	101.5	100.8	100.7	101.1
T pack DC-2b	TDp10	(C)	101.3	100.5	100.2	100.2	100.4
T pack DC-3a	TDp11	(C)	101.4	100.4	100.2	100.1	100.3
T pack DC-3a	TDp12	(C)	101.6	100.3	100.1	100.1	100.3
T pack DC-3b	TDp13	(C)	101.8	100.3	100.2	100.2	100.3
T pack DC-3b	TDp14	(C)	101.9	100.3	100.2	100.2	100.3
T pack DC-3b	TDp15	(C)	100.0	98.3	98.3	98.3	98.4
T vap DC-GI	TDg0	(C)	124.0	120.3	120.3	120.3	120.4
T vap DC-LD1	TDg1	(C)	109.3	111.2	109.6	109.3	110.2
T vap DC-LD2	TDg2	(C)	101.9	101.2	100.9	100.8	101.1
T vap DC-LD3	TDg3	(C)	99.8	98.8	99.2	99.0	99.0
T vap DW-LD1	TDg4	(C)	95.3	93.4	93.2	93.2	93.4
T vap DW-LD2	TDg5	(C)	92.2	90.0	89.8	89.8	90.0
T vap DW-GO	TDg6	(C)	91.9	89.8	89.5	89.5	89.7
T liq DC-S	TDlq0	(C)	120.6	117.8	117.7	117.7	117.9
T liq DC-LD1	TDlq1	(C)	109.2	110.0	108.3	108.0	108.9
T liq DC-LD2	TDlq2	(C)	101.4	100.5	100.2	100.2	100.4
T liq DC-LD3	TDlq3	(C)	101.8	100.0	100.0	100.0	100.1
T liq DW-LC1	TDlq4	(C)	97.2	95.5	95.3	95.3	95.5
T liq DW-LD1	TDlq5	(C)	88.7	86.8	86.6	86.7	86.9
T liq DW-LD2	TDlq6	(C)	90.9	89.0	88.8	88.8	89.0
T gas Exhaust	TI01	(C)	32.3	32.0	31.6	31.9	32.0
T gas In PC-GI	TI02	(C)	18.7	18.2	17.9	18.7	19.1
T gas Out PC-GO	TI03	(C)	19.9	19.7	19.7	20.1	20.5

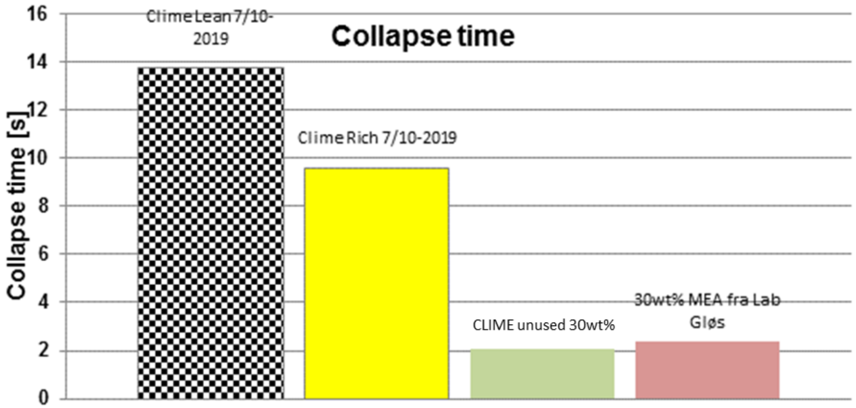
			Run 12	**Run 13**	**Run 14**	**Run 15**	**Run 16**
			04.11.2019	**05.11.2019**	**06.11.2019**	**07.11.2019**	**08.11.2019**
LOCATION	TAG	UNIT	07:35-08:35	10:10-11:10	08:40-09:40	07:40-08:40	07:40-08:40
T gas Out FAN	TI04	(C)	41.7	39.6	39.6	41.0	42.2
T liq Rich In EX01	TI05	(C)	40.8	40.5	40.7	41.0	41.1
T liq Rich Out EX01	TI06	(C)	110.3	108.4	108.4	108.4	108.4
T liq Lean In EX01	TI07	(C)	124.3	120.6	120.7	120.7	120.8
T liq Lean Out EX01	TI08	(C)	47.1	46.9	47.0	47.3	47.4
T liq Boiler	TI09	(C)	124.2	120.5	120.5	120.6	120.6
T vap Boiler	TI10	(C)	126.7	122.9	122.9	122.9	123.0
T liq Cond Out DW-LC1	TI11	(C)	24.5	24.5	24.2	24.3	24.6
T liq Rich In RV1	TI12	(C)	102.7	99.8	99.7	99.8	100.1
T vap Out Flush GLS1	TI13	(C)	23.0	23.4	22.7	23.1	23.5
T liq Cond M-up to AW-LD2	TI14	(C)	21.7	22.0	21.5	21.7	22.0
T liq Cond feed to DW-2	TI15	(C)	16.5	16.7	16.6	16.7	16.8
T vap Out EX02	TI16	(C)	12.2	11.8	11.9	12.0	11.9
T vap Out EX03	TI17	(C)	16.3	15.8	16.0	16.3	16.2
T liq recirc PC-C In EX08	TT01	(C)	15.8	16.0	15.5	16.4	17.6
T liq recirc PC-C Out EX08	TT02	(C)	16.3	16.4	16.0	16.9	18.0
T gas In FAN	TT03	(C)	33.7	33.5	33.5	33.5	33.5
T gas Out EX11	TT04	(C)	38.7	36.9	37.0	38.0	39.0
T liq in Intercooler 1	TT05	(C)	33.0	32.9	33.1	32.9	33.1
T liq Lean Out EX10	TT06	(C)	40.0	40.0	40.0	40.0	40.0
T liq Lean Out HE03	TT07	(C)	39.4	39.3	39.4	39.4	39.3
T liq recirc AW-1 Out EX06	TT08	(C)	22.2	22.4	21.9	22.1	22.3
T liq recirc AW-1 Out HE05	TT09	(C)	21.8	21.9	21.6	21.7	21.8
T liq recirc AW-2 Out EX07	TT10	(C)	58.3	59.0	36.3	55.8	57.2
T liq recirc AW-2 Out HE06	TT11	(C)	57.0	57.7	34.8	54.5	55.9
T liq recirc DW-1 Out EX04	TT12	(C)	31.1	31.1	30.8	30.7	31.1
T liq recirc DW-2 Out EX05	TT13	(C)	91.9	90.1	89.9	89.9	90.1
T liq coolwater Out EX02	TT14	(C)	20.0	20.0	20.0	20.0	20.0
T gas Out EX03	TT15	(C)	15.3	14.6	15.0	15.3	15.1
T HeatS DC-S	TDs01	(C)	120.6	117.8	117.7	117.7	117.9
T HeatS DC-1a	TDs02	(C)	118.9	117.4	117.1	117.1	117.4
T HeatS DC-1b	TDs03	(C)	110.9	111.9	110.5	110.1	111.0
T HeatS DC-2a	TDs04	(C)	103.3	104.7	103.4	103.1	103.9
T HeatS DC-2b	TDs05	(C)	101.1	100.7	100.2	100.1	100.4
T HeatS DC-3a	TDs06	(C)	101.7	100.4	100.2	100.2	100.4
T HeatS DC-3b	TDs07	(C)	101.4	99.7	99.6	99.6	99.8
T HeatS Boiler	TDs08	(C)	124.1	120.5	120.5	120.6	120.7
T HeatS Rich	TDs09	(C)	40.6	40.3	40.4	40.7	40.9
T HeatS Gas Pipe	TDs10	(C)	22.2	22.5	21.7	21.9	22.3
T HeatS Abs top	TDs11	(C)	21.5	21.8	20.8	21.3	21.8
Heated gas out	TI20	(C)	0.0	0.0	0.0	0.0	0.0
Tgas after SCR	TI21	(C)	0.0	0.0	0.0	0.0	0.0
Tgas after cooler	TI22	(C)	0.0	0.0	0.0	0.0	0.0
T cooling water in AW1	TW1	(C)	21.5	21.8	21.3	21.5	21.8
T cooling water out AW1	TW2	(C)	21.0	21.4	20.8	20.9	21.2
T cooling water in AW2	TW3	(C)	6.5	6.4	5.8	6.4	6.4
T cooling water out AW2	TW4	(C)	55.6	55.8	28.2	57.6	58.1
T pack AW-1	TAT1	(C)	62.4	63.5	63.3	63.2	63.4
T pack AW-1	TAT2	(C)	63.2	64.2	63.9	63.9	64.1
T pack AW-2	TAT3	(C)	61.4	62.1	59.9	62.1	62.3
T pack AW-2	TAT4	(C)	59.1	59.8	38.0	57.8	58.9
Temp AW3 gas out	TT16	(C)	35.5	35.5	26.8	35.5	37.0
Temp Liquid AW3	TT17	(C)	33.7	33.7	21.7	33.6	34.9
Temp AW-3 gas in	TT18	(C)	22.0	22.3	21.2	21.7	22.1
Temp. AW-4 Low	TI26	(C)	49.4	49.3	24.2	50.9	52.5
Temp AW3 top	TI27	(C)	36.2	36.2	24.9	36.5	37.9
T light phase	TI28	(C)	0.0	0.0	0.0	0.0	0.0
T after static mixer	TI29	(C)	37.7	37.7	37.7	37.7	37.8
T from coal burner	TI101	(C)	87.8	93.6	91.8	92.1	92.3
T out of deNOx	TI102	(C)	89.5	93.5	90.0	93.2	93.6
T bypass filter	TI103	(C)	114.9	116.4	118.8	19.7	110.9
Tafter filter	TI104	(C)	41.7	39.6	39.6	41.0	42.2
T before CO2 recirc	TI105	(C)	15.0	20.8	17.5	19.1	19.5
T before FAN101	TI106	(C)	15.4	20.8	17.7	18.8	19.4

			Run 12	Run 13	Run 14	Run 15	Run 16
			04.11.2019	**05.11.2019**	**06.11.2019**	**07.11.2019**	**08.11.2019**
LOCATION	TAG	UNIT	07:35-08:35	10:10-11:10	08:40-09:40	07:40-08:40	07:40-08:40
T after Fan 101	TI107	(C)	15.3	20.8	17.6	18.9	19.5
T liq after pump caustic	TI108	(C)	42.2	42.2	42.6	42.9	43.7
T liq after heater caustic	TI109	(C)	42.9	42.9	43.3	43.5	44.4
T liq after caustic cooler	TI110	(C)	34.6	34.6	34.6	34.5	34.7
Not in use	TI30	(C)	0.0	0.0	0.0	0.0	0.0
T water out intercooler 1	TI31	(C)	20.0	20.5	19.8	20.6	20.6
T water to intercooler 1	TI32	(C)	19.6	19.9	19.5	19.9	20.5
T liq out Intercooler 1	TI33	(C)	19.6	19.9	19.3	19.8	20.2
T liq in Intercooler 2	TI34	(C)	20.6	20.6	20.3	20.4	20.2
T water out intercooler 2	TI35	(C)	20.6	20.8	20.5	20.6	20.4
T water to intercooler 2	TI36	(C)	20.2	20.3	20.0	20.1	20.2
T liq to Intercooler 3	TI37	(C)	21.1	21.1	20.9	21.0	21.1
T water out Intercooler 3	TI38	(C)	20.8	20.8	20.6	20.7	20.8
T water to intercooler 3	TI39	(C)	21.7	22.0	21.6	21.7	22.0
Temp. AW-3 Low	TI40	(C)	57.6	58.2	28.5	56.9	57.9
Temp. AW-3 High	TI41	(C)	55.4	55.4	27.9	56.6	57.7
T liq recirc AW- Out EX13	TI42	(C)	55.0	55.0	28.2	56.7	57.7
Not in use	TI43	(C)	0.0	0.0	0.0	0.0	0.0
T liq out Intercooler 2	TT20	(C)	20.4	20.4	20.1	20.2	20.2
T liq out Intercooler 3	TT21	(C)	21.3	21.5	21.2	21.3	21.5
Not in use	TT22	(C)	0.0	0.0	0.0	0.0	0.0
T gas out AW3	TT23	(C)	54.9	55.0	27.8	56.4	57.4
T in HE30	TT24	(C)	108.1	109.5	107.8	107.5	108.4
T in HE31	TT25	(C)	100.2	99.2	99.0	98.9	99.1
T gas Out PC2	TT26	(C)	35.0	35.0	35.0	35.0	35.0
T HeatS HE30	TDE01	(C)	108.3	109.4	107.8	107.4	108.4
T HeatS HE31	TDE02	(C)	100.3	99.2	99.0	98.9	99.1
T above burner flames	TI120	(C)	810.8	799.9	814.3	809.6	818.3
T leaving burner chamber	TI121	(C)	790.5	794.4	802.0	799.7	791.1
Tgas after boiler	TI122	(C)	160.8	159.9	159.6	159.1	158.3
Tgas return chamber	TI123	(C)	128.7	128.8	134.4	127.1	126.8
T hot water	TI124	(C)	88.6	88.1	88.1	88.0	88.1
T water return	TI125	(C)	72.1	72.0	72.0	72.0	72.0
Pabs AC-GI	PA0	(mbara)	1006.0	1011.5	1005.1	1008.1	1015.5
Pabs AC-LD1	PA1	(mbara)	1005.3	1011.0	1004.6	1008.1	1015.4
Pabs AC-LD2	PA2	(mbara)	1006.4	1011.7	1005.6	1009.5	1016.6
Pabs AC-LD3	PA3	(mbara)	1005.7	1011.0	1004.9	1008.8	1015.9
Pabs AC-LD4	PA4	(mbara)	1002.1	1006.3	1000.5	1004.6	1011.9
Pabs AW-LD1	PA5	(mbara)	994.7	999.0	993.4	997.5	1004.7
Pabs AW-LD2	PA6	(mbara)	984.8	988.9	986.1	987.4	994.7
Pabs Atmospheric Pressure	PA7	(mbara)	998.1	1002.2	999.1	1000.3	1007.7
Pgauge DC-GI	PD0	(mbarg)	27.8	27.8	27.8	27.8	27.8
Pgauge DC-LD1	PD1	(mbarg)	1042.5	866.7	869.4	869.1	868.6
Pgauge DC-LD2	PD2	(mbarg)	847.2	849.7	850.1	850.3	850.2
Pgauge DC-LD3	PD3	(mbarg)	862.1	866.5	867.0	867.2	867.1
Pgauge DW-LD1	PD4	(mbarg)	868.5	872.5	873.0	873.1	872.9
Pgauge DW-LD2	PD5	(mbarg)	859.6	864.2	864.8	865.0	864.6
Pgauge DW-GO	PD6	(mbarg)	871.7	875.7	876.1	876.2	876.2
Pgauge Diluent air	PT01	(mbarg)	0.31	0.34	0.43	0.42	0.53
Pdiff Level PC-S	PT02	(mbar)	24.66	25.56	26.19	25.62	24.91
Pdiff Level AC-S	PT03	(mbar)	25.00	25.00	25.00	25.00	25.00
Pdiff Level Lean Out boiler	PT04	(mbar)	43.00	42.99	43.00	43.00	43.01
Pgauge Level Tank 2	PT05	(mbar)	36.95	84.73	64.69	62.49	70.58
Pgauge Level Tank 3	PT06	(mbar)	3.09	3.10	3.08	3.08	3.09
Pdiff Level DW-LC1	PT07	(mbar)	-1.24	-1.24	-1.24	-1.24	-1.24
Pdiff Level DW-LC2	PT08	(mbar)	-1.18	-1.18	-1.18	-1.18	-1.18
Pdiff Level AW-LC1	PT09	(mbar)	33.97	34.01	33.99	34.06	34.05
Pdiff Level AW-LC2	PT10	(mbar)	26.00	25.99	25.98	26.06	25.85
Pgauge CO2-line US VR27	PT11	(mbarg)	827.7	827.8	827.8	827.8	827.7
Pgauge Level Tank 1	PT12	(mbar)	11.63	12.22	12.43	12.67	12.94
Pabs PC-GO	PI01	(mbara)	998.4	1002.6	999.5	1000.8	1008.3
Pabs In AC-GI DS EX11	PI02	(mbara)	1009.7	1015.2	1009.0	1012.8	1020.2
Pgauge Vapour boiler	PI03	(mbarg)	1152.0	877.2	880.0	880.2	880.0
Pgauge CO2-line DS EX03	PI04	(mbarg)	845.5	847.4	847.6	847.7	847.6

			Run 12	**Run 13**	**Run 14**	**Run 15**	**Run 16**
			04.11.2019	**05.11.2019**	**06.11.2019**	**07.11.2019**	**08.11.2019**
LOCATION	TAG	UNIT	07:35-08:35	10:10-11:10	08:40-09:40	07:40-08:40	07:40-08:40
Pgauge Rich US RV1	PI05	(mbarg)	1892.1	1890.1	1890.1	1890.7	1889.4
Pgauge Level Tank 4	PI06	(mbar)	3.6	3.6	3.6	3.6	3.6
Water vol recirc PC	FT01	(l/min)	0.01	0.01	0.01	0.01	0.01
Water vol filter PC	FT02	(l/min)	1.2	1.2	1.2	1.2	1.2
Gas vol In AC-GI	FT03	(m3/h)	160.0	160.0	160.0	160.0	160.0
Rich vol filter Out AC-S	FT04	(l/min)	0	0	0	0	0
Lean vol filter In AC-LD4/3	FT05	(l/min)	0.00	0.00	0.00	0.00	0.00
Cond vol recirc DW-1	FT06	(l/min)	3.30	3.30	3.43	3.30	3.30
Cond vol recirc DW-2	FT07	(l/min)	3.30	3.30	3.30	3.30	3.30
Cond vol M-up to AW-LD2	FT08	(l/min)	-67.33	-67.33	-67.33	-67.33	-67.33
Water vol recirc AW-1	FT09	(l/min)	1.99	1.99	1.99	1.99	1.99
Water vol recirc AW-2	FT10	(l/min)	8.78	8.78	8.78	8.78	8.78
Water mass M-up to AW-LD2	FT11	(kg/h)	0.00	0.00	0.00	0.00	0.00
CO2 vol recirc In VG01	FT12	(m3/h)	3.00	3.00	3.00	3.00	3.00
Liq vol recirc Intercooler	FT13	(l/min)	0.00	0.00	0.00	0.00	0.00
CO2 mass Out EX03	FT14	(kg CO2/h)	28.68	30.20	30.29	30.33	30.39
Vap mass In DC-GI	FI01	(kg vap/h)	41.99	43.70	42.75	42.35	42.71
Cond vol Out DW-LD1	FI02	(l/h)	0.00	0.00	0.00	0.00	0.00
Vap vol In DC-LC1	FI03	(m3/h)	0.00	0.00	0.00	0.00	0.00
Lean mass In AC-LD4/3	FMD1_1	(kg/min)	7.50	7.50	7.50	7.50	7.50
Lean dens In AC-LD4/3	FMD1_2	(kg/m3)	1048.6	1047.4	1049.6	1049.6	1048.2
Rich mass Out AC-S	FMD2_1	(kg/min)	7.69	7.69	7.70	7.71	7.71
Rich dens Out AC-S	FMD2_2	(kg/m3)	1111.88	1114.05	1116.40	1116.13	1114.46
CO2-1 ch2 % In AC-1a	GA1_1	(%dry)	13.30	12.83	13.04	13.19	13.73
CO2-1 ch1 % In AC-2a	GA1_2	(%dry)	0.50	0.41	0.17	0.17	0.17
CO2-2 ch2 % In AC-3a	GA2_1	(%dry)	0.00	0.00	0.00	0.00	0.00
CO2-2 ch1 % In AC-4a	GA2_2	(%dry)	0.00	0.00	0.00	0.00	0.00
CO2-3 ch2 % Out AC-4b	GA3_1	(%dry)					
CO2-3 ch1 % Out AW-OP	GA3_2	(%dry)	2.55	1.58	1.70	1.83	2.28
Boiler	HE01	(kW)	31.13	31.14	31.14	31.14	31.14
Sump PC	HE02	(kW)	0.00	0.00	0.00	0.00	0.00
Lean solvent feed to AC	HE03	(kW)	0.00	0.00	0.00	0.00	0.00
Rich solvent feed to DC	HE04	(kW)	0.00	0.00	0.00	0.00	0.00
Water recirculation AW-1	HE05	(kW)	0.00	0.00	0.00	0.00	0.00
Water recirculation AW-2	HE06	(kW)	0.00	0.00	0.00	0.00	0.00
Gas inlet absorber, US FAN	HE07	(kW)	0.00	0.00	0.00	0.00	0.00
Diff P Level Tank2	PT05	(L/h)	36.95	84.73	64.69	62.49	70.58
FogS inlet Abs	FS01	(%)	62.88	63.64	62.12	62.88	63.64
FogS outlet WW	FS02	(%)	97.33	41.07	97.34	97.34	97.34
Pdiff level tank FDF	PT13	(mbar)	10.00	10.00	10.00	10.00	10.00
Pgauge tank FDF	PT14	(barg)	1.20	1.20	1.20	1.20	1.20
Wash water bleed	FT15	(L/h)	0.00	0.00	0.00	0.00	0.00
Pgauge Rich DS EX01	PI07	(barg)	2.75	2.87	2.87	2.86	2.85
Flow cooling water AW-1	FT16	(l/min)	3.32	3.32	3.32	3.32	3.32
Flow cooling water AW-2	FT17	(l/min)	3.34	3.33	3.32	3.32	3.32
Pressure AW3 bottom	PA08	(mbar)	992.40	996.51	993.07	994.97	1002.32
Pressure AW3 top	PA09	(mbar)	986.04	990.33	986.84	988.64	996.21
Level sump AW3	PT15	(mbar)	22.67	22.67	32.09	22.66	22.66
Water vol recirc AW-3	FT18	(l/min)	8.89	9.00	-0.97	8.84	8.99
pH Level	PH01	(-)	8.17	8.58	8.78	8.25	8.14
Lean massflow from desorber	FMD3_1	(l/min)	7.13	7.14	7.15	7.17	7.16
Lean density from desorber	FMD3_2	(kg/m3)	1046.1	1044.6	1047.2	1047.1	1045.2
Level sump AW-4	PT16	(mbar)	25.81	25.71	29.85	26.51	26.51
Pdiff after coal filter	PI101	(mbar)	-20.76	-21.98	-21.46	-21.60	-21.67
P after Fan101	PI102	(mbar)	-34.26	-19.42	-25.00	-33.99	-45.00
P top caustic column	PI103	(mbar)	483.47	496.72	492.39	489.48	487.98
Pdiff soot filter	PT101	(mbar)	19.82	16.36	18.00	20.01	22.45
Level caustic sump	PT102	(mbar)	59.92	60.03	59.80	59.91	59.94
pH caustic sump	PH101	(pH)	7.14	6.96	6.76	6.59	9.00
Gas volume rate after Fan 101	FT101	(m3/h)	204.64	203.38	203.17	203.98	204.86
Water volum rate caustic column	FT102	(l/min)	10.80	10.73	10.38	10.10	9.89
Desorber interheater low	HE30	(kW)	0.00	0.00	0.00	0.00	0.00
Desorber interheater high	HE31	(kW)	0.00	0.00	0.00	0.00	0.00
Flow water intercooler 1	FI05	(l/min)	0.01	0.01	0.01	0.01	0.01

			Run 12	**Run 13**	**Run 14**	**Run 15**	**Run 16**
			04.11.2019	**05.11.2019**	**06.11.2019**	**07.11.2019**	**08.11.2019**
LOCATION	TAG	UNIT	07:35-08:35	10:10-11:10	08:40-09:40	07:40-08:40	07:40-08:40
Flow water intercooler 2	FI06	(l/min)	0.00	0.00	0.00	0.00	0.00
Flow water intercooler 3	FI07	(l/min)	0.00	0.00	0.00	0.00	0.00
Recirc flow intercooler 2	FT20	(l/min)	0.00	0.00	0.00	0.00	0.00
Recirc flow interooler 3	FT21	(l/min)	0.00	0.00	0.00	0.00	0.00
Recirc flow AW3	FT19	(l/min)	18.00	18.00	-0.25	18.00	18.00
P AW3 bottom	PA10	(mbar)	36.00	36.15	32.70	35.94	36.85
P AW3 top	PA11	(mbar)	135.28	135.58	135.40	135.41	137.61
Furnace underpressure	PI100	(Pa)	59.97	60.24	60.24	59.88	60.06
O2 in flue gas	O100	%	7.05	7.51	7.24	7.11	6.85

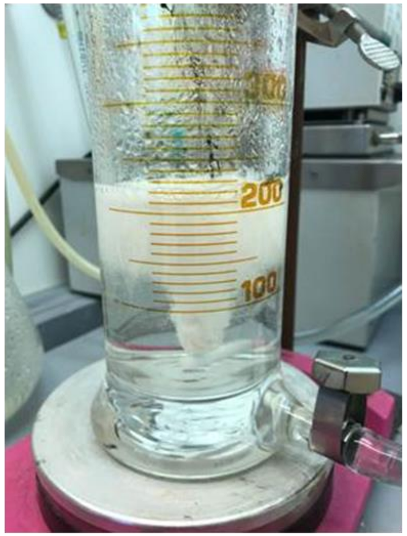




Lean 30% MEA

Rich 30% MEA

Unused 30% MEA



Lean 30% MEA foam did not collapse completely

					Titration	analyzator	Karl Fischer				ICP-MS	ICP-MS	ICP-MS	LC-MS degraderingsprod									NH3	GC-NCD
Jornalnr	Sample name	Rekv. nr.	RUN Nr	TOS [hrs]	Amine [amine eq/kg]	CO_2 [mol CO_2/kg]	H2O [wt%]	Amine CO2 free basis	Korr factor	Amine $_{corrected}$ [amine eq/kg]	Fe [mg/l]	Cr [mg/l]	Ni [mg/l]	HEI [mg/l]	HEF [mg/l]	HEPO [mg/l]	HeGly [mg/l]	HEA [mg/l]	BHEOX [mg/l]	HEIA [mg/l]	OZD [mg/l]	MEA-Urea [mg/l]	NH3 [mg/l]	Total nitrosamine µmol/l
P19732	30% MEA 26/9-19 12:45	20190099	0		4,641																			
P19733	30% MEA 26/9-19 14:00	20190099	0		4,677		71,0																	
P19734	Lean før tilsatt CO2 30/9-19 09:30	20190099	0	0	4,699		70,6	*4,70*	*1,239*	*5,822*														
P19735	Lean 1 1/10-19 09:00	20190099	1	22	4,873	1,339	63,6	5,18	*1,000*	*5,178*	4,74	0,41	0,41	34,8	122	126	200	9,3	6,1	0,5	14,0	304	157	84,9
P19736	Lean 2 1/10-19 09:00	20190099	1	22	4,873	1,289																		
P19737	Rich 1/10-19 09:00	20190099	1	22	4,679	2,404																		
P19738	WW 9etg. 1/10-19 09:00	20190099	1	22	0,181	0,103																		
P19739	WW 10etg. 1/10-19 09:00	20190099	1	22	0,109	0,071																		
P19740	Lean 1 4/10-19 08:40	20190099	2	94	4,978	0,855	65,0	5,17	*1,042*	*5,390*														
P19741	Lean 2 4/10-19 08:40	20190099	2	94	4,774	0,844																		
P19742	Rich 4/10-19 08:40	20190099	2	94	4,632	2,365																		
P19743	WW 9etg. 4/10-19 08:40	20190099	2	94	0,061	0,033																		
P19744	WW 10etg. 4/10-19 08:40	20190099	2	94	0,020	<0.015																		
P19745	Lean 1 8/10-19 08:20	20190100	3	161	5,190	0,893	63,5	5,40	*1,000*	*5,400*	4,74	0,87	1,85	75,7	133	2 220	942	40,3	3,2	11,4	23,0	1478	157	79,4
P19746	Lean 2 8/10-19 08:20	20190100	3	161	4,945	0,847																		
P19747	Rich 8/10-19 08:20	20190100	3	161	4,790	2,402																		
P19748	WW 9etg. 8/10-19 08:20	20190100	3	161	0,241	0,099																		
P19749	WW 10etg. 8/10-19 08:20	20190100	3	161	0,078	0,046																		
P19750	ACEMS 7/10 16:30-8/10 08:30	20190100	0		0,584																			
P19751	Lean 1 9/10-19 07:15	20190100	4	184	5,069	1,091	62,7	5,32	*0,978*	*5,208*														
P19752	Lean 2 9/10-19 07:15	20190100	4	184	4,961	1,041																		
P19753	Rich 9/10-19 07:15	20190100	4	184	4,712	2,386																		
P19754	WW 9etg. 9/10-19 07:15	20190100	4	184	0,304	0,129																		
P19755	WW 10etg. 9/10-19 07:15	20190100	4	184	0,161	0,078																		
P19756	ACEMS 8/10 15:45-9/10 08:55	20190100	0		0,309																			
P19757	Lean 9/10-19 13:30	20190100	0		5,382	0,803																		
P19758	Lean 1 10/10-19 08:30	20190101	5	209	5,493	0,834	61,0	5,70	*0,935*	*5,330*														
P19759	Lean 2 10/10-19 08:30	20190101	5	209	5,226	0,795																		
P19760	Rich 10/10-19 08:30	20190101	5	209	5,150	2,666																		
P19761	WW 9etg. 10/10-19 08:30	20190101	5	209	0,352	0,146																		
P19762	WW 10etg. 10/10-19 08:30	20190101	5	209	0,188	0,082																		
P19763	Syrevask 1 10/10-19 08:30	20190101	5	209	0,105	0,051																		
P19764	Syrevask 2 10/10-19 08:30	20190101	5	209	0,051	0,032																		
P19765	Lean 1 11/10-19 07:15	20190101	6	232	5,469	1,377	59,6	5,821	*0,902*	*5,251*	7,90	1,08	2,57	110	143	3 630	1 212	62,3	4,9	19,4	36,1	1857	159	95,4
P19766	Lean 2 11/10-19 07:15	20190101	6	232	5,341	1,320																		
P19767	Rich 11/10-19 07:15	20190101	6	232	5,233	2,569																		
P19768	WW 9etg. 11/10-19 07:15	20190101	6	232	0,275	0,129																		
P19769	WW 10etg. 11/10-19 07:15	20190101	6	232	0,142	0,075																		
P19770	Syrevask 1 11/10-19 07:15	20190101	6	232	0,086	0,053																		
P19771	Syrevask 2 11/10-19 07:15	20190101	6	232	0,050	0,036																		
P19803	Lean 1 21/10-19 08:20	20190106	7	368	5,622	1,200	58,9	5,935	*0,886*	*5,260*	9,27	1,36	3,84	224	231	6 386	2 279	184	9,6	30,0	42,4	2299	199	101
P19804	Lean 2 21/10-19 08:20	20190106	7	368	5,300	1,136																		
P19805	Rich 21/10-19 08:20	20190106	7	368	5,175	2,568																		
P19806	WW 10etg. 21/10-19 08:20	20190106	7	368	0,0089	<0.015																		
P19807	Syrevask 1 21/10-19 08:20	20190106	7	368	0,010	<0.015																		
P19808	Syrevask 2 21/10-19 08:20	20190106	7	368	0,016	<0.015																		
P19809	Lean 1 22/10-19 08:30	20190106	8	392	5,731	0,905	59,3	5,969	*0,896*	*5,348*														
P19810	Lean 2 22/10-19 08:30	20190106	8	392	5,452	0,886																		
P19811	Rich 22/10-19 08:30	20190106	8	392	5,259	2,663																		
P19812	WW 10etg. 22/10-19 08:30	20190106	8	392	0,0068	<0.015																		
P19813	Syrevask 1 22/10-19 08:30	20190106	8	392	0,0069	<0.015																		
P19814	Syrevask 2 22/10-19 08:30	20190106	8	392	0,010	<0.015																		
P19815	Lean 1 23/10-19 07:20	20190107	9	415	5,607	1,206	58,9	5,922	*0,886*	*5,248*														
P19816	Lean 2 23/10-19 07:20	20190107	9	415	5,437	1,173																		
P19817	Rich 23/10-19 07:20	20190107	9	415	5,289	2,604																		
P19818	WW 10etg. 23/10-19 07:20	20190107	9	415	0,0081	<0.015																		
P19819	Syrevask 1 23/10-19 07:20	20190107	9	415	0,010	<0.015																		
P19820	Syrevask 2 23/10-19 07:20	20190107	9	415	0,016	<0.015																		
P19821	Lean 1 24/10-19 08:40	20190107	10	440	5,735	1,001	58,9	5,999	*0,887*	*5,323*	10,2	1,56	4,66	272	225	8 738	2 661	238	9,9	38,9	39,0	2606	195	101
P19822	Lean 2 24/10-19 08:40	20190107	10	440	5,458	0,961																		
P19823	Rich 24/10-19 08:40	20190107	10	440	5,246	2,564																		
P19824	WW 10etg. 24/10-19 08:40	20190107	10	440	0,0070	<0.015																		
P19825	Syrevask 1 24/10-19 08:40	20190107	10	440	0,0077	<0.015																		
P19826	Syrevask 2 24/10-19 08:40	20190107	10	440	0,013	<0.015																		
P19827	Lean 1 25/10-19 07:10	20190108	11	463	5,732	0,858	59,3	5,957	*0,895*	*5,330*														
P19828	Lean 2 25/10-19 07:10	20190108	11	463	5,464	0,808																		
P19829	Rich 25/10-19 07:10	20190108	11	463	5,302	2,642																		
P19830	WW 10etg. 25/10-19 07:10	20190108	11	463	0,0060	<0.015																		
P19831	Syrevask 1 25/10-19 07:10	20190108	11	463	0,0060	<0.015																		
P19832	Syrevask 2 25/10-19 07:10	20190108	11	463	0,010	<0.015																		
P19841	Tiller 21/10-19 08:20	20190111	0		5,546	1,211																		
P19842	Tiller Lean 4/11-19 08:50	20190111	0		4,928	0,959																		
P19843	Lean 1 4/11-19 08:35	20190111	12	604	4,951	0,969	66,6	5,172	*1,090*	*5,638*	11,6	1,96	6,90	320	260	12 591	3 042	338	11,2	59,6	64,9	2338		109
P19844	Lean 2 4/11-19 08:35	20190111	12	604	4,698	0,952																		
P19845	Rich 4/11-19 08:35	20190111	12	604	4,641	2,347																		
P19846	WW 10etg. 4/11-19 08:35	20190111	12	604	0,0093	<0.015																		
P19847	Syrevask 1 4/11-19 08:35	20190111	12	604	0,010	<0.015																		
P19848	Syrevask 2 4/11-19 08:35	20190111	12	604	0,017	<0.015																		

					Titration	analyzator	Karl Fischer				ICP-MS	ICP-MS	ICP-MS	LC-MS degraderingsprod									NH3	GC-NCD
Jornalnr	**Sample name**	**Rekv. nr.**	RUN **Nr**	TOS **[hrs]**	**Amine** **[amine eq/kg]**	**CO_2** **[mol CO_2/kg]**	**H2O** **[wt%]**	**Amine** **CO2 free basis**	***Korr factor***	***Amine** corrected* ***[amine eq/kg]***	**Fe** **[mg/l]**	**Cr** **[mg/l]**	**Ni** **[mg/l]**	**HEI** [mg/l]	**HEF** [mg/l]	**HEPO** [mg/l]	**HeGly** [mg/l]	**HEA** [mg/l]	**BHEOX** [mg/l]	**HEIA** [mg/l]	**OZD** [mg/l]	**MEA-Urea** [mg/l]	NH3 [mg/l]	**Total nitrosamine** **µmol/l**
P19849	Lean 1 5/11-19 11:10	20190112	13	631	5,051	0,925	65,6	5,265	*1,058*	*5,571*														
P19850	Lean 2 5/11-19 11:10	20190112	13	631	4,812	0,893																		
P19851	Rich 5/11-19 11:10	20190112	13	631	4,624	2,416																		
P19852	WW 10 etg 5/11-19 11:10	20190112	13	631	0,108	0,056																		
P19853	Syrevask 1 5/11-19 11:10	20190112	13	631	0,039	0,025																		
P19854	Syrevask 2 5/11-19 11:10	20190112	13	631	0,0266	0,019																		
P19855	Lean 1 6/11-19 09:40	20190112	14	654	5,093	0,979	62,7	5,322	*0,976*	*5,196*														
P19856	Lean 2 6/11-19 09:40	20190112	14	654	4,944	0,942																		
P19857	Rich 6/11-19 09:40	20190112	14	654	4,772	2,466																		
P19858	WW 10 etg 6/11-19 09:40	20190112	14	654	0,012	<0.015																		
P19859	Lean 1 7/11-19 08:40	20190113	15	677	5,141	0,989	63,4	5,375	*0,996*	*5,354*														
P19860	Lean 2 7/11-19 08:40	20190113	15	677	4,923	0,917																		
P19861	Rich 7/11-19 08:40	20190113	15	677	4,768	2,448																		
P19862	WW 10 etg 7/11-19 08:40	20190113	15	677	0,0075	<0.015																		
P19863	Syrevask 1 7/11-19 08:40	20190113	15	677	0,0085	<0.015																		
P19864	Syrevask 2 7/11-19 08:40	20190113	15	677	0,015	<0.015																		
P19865	Lean 1 8/11-19 08:40	20190113	16	701	5,072	0,930	64,6	5,288	*1,029*	*5,439*	12,4	2,53	9,07	347	315	15 392	3 328	395	12,6	74,2	60,7	2375	202	102
P19866	Lean 2 8/11-19 08:40	20190113	16	701	4,839	0,902																		
P19867	Rich 8/11-19 08:40	20190113	16	701	4,739	2,375																		
P19868	WW 1 10 etg 8/11-19 08:40	20190113	16	701	0,0084	<0.015																		
P19869	WW AW2 10 etg 8/11-19 08:40	20190113	16	701	0,0076	<0.015																		
P19870	Syrevask 10 etg 8/11-19 08:40	20190113	16	701	0,015	<0.015																		
P19871	VSL1 Lean 8/11-19 08:50	20190113	0		5,053	0,932																		

DEKATI

ALL DISTRIBUTIONS

Date	#######	Filename	ELPi_Tiller_BIO-Mass_dowr
Time	11:48:36	Note	sintered metal

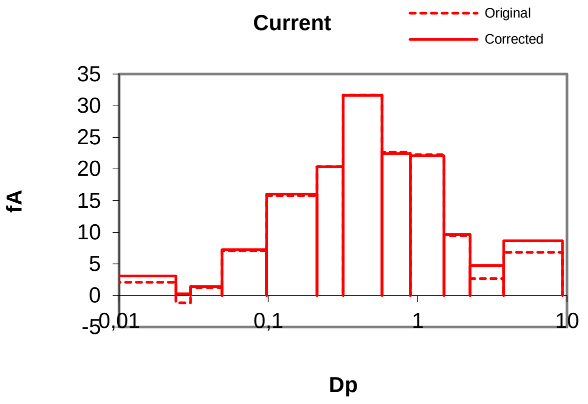
		Sample	Time
Distribution average	From	145	11:51:00
	To	385	11:55:00

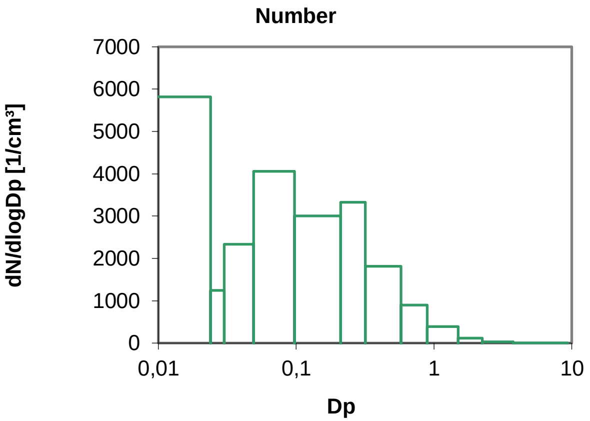
Dilution	8,86
Density	1

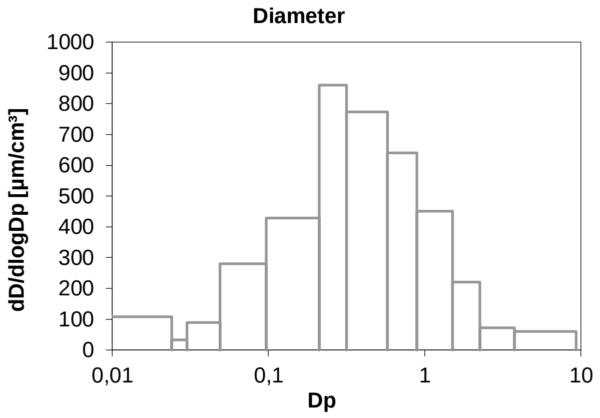
☑ Correction

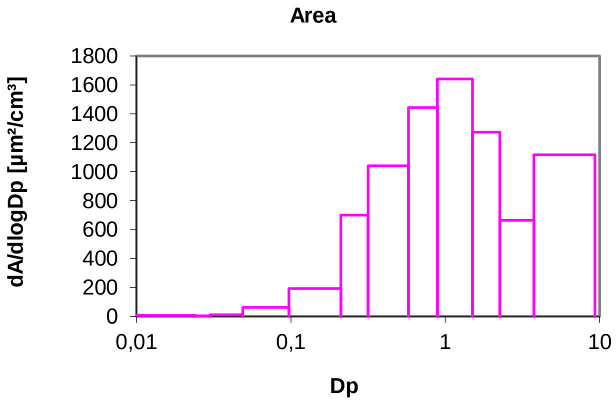
☐ Stokes Dp

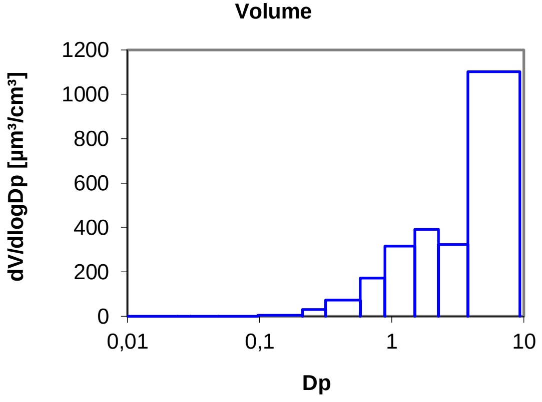
Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

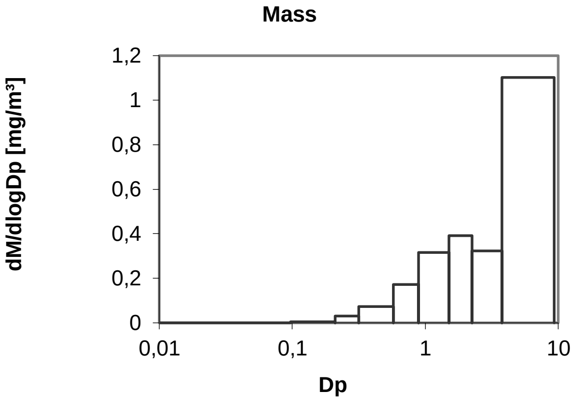






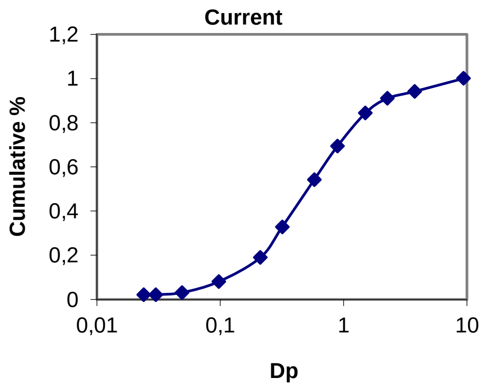


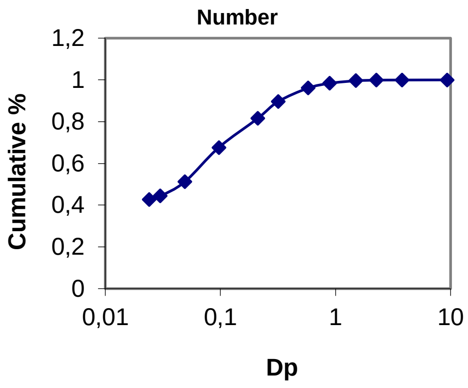


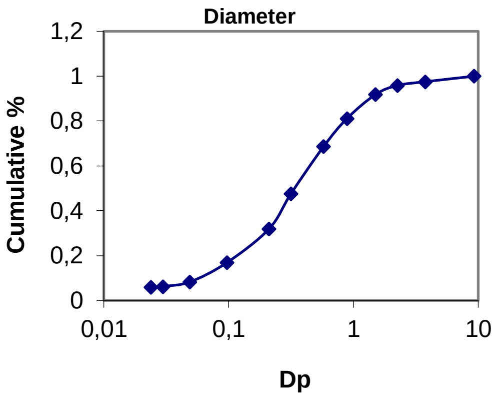


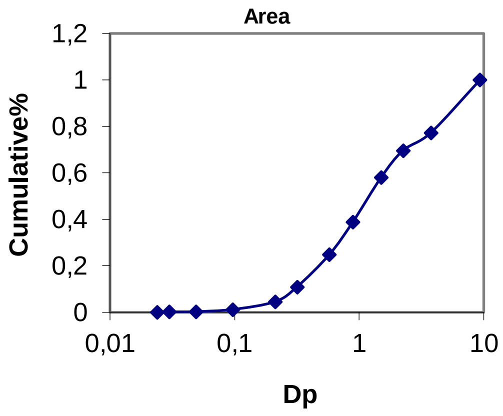
c	1	2	3	4	5	6	7	8	9	10	11	12	Total	From Ch	1	
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**		To	12	Median
Current	3	0	1	7	16	20	32	22	22	10	5	9	**147,4307944**	fA	0,50652	µm
Number	3113	120	497	1203	1013	588	471	169	88	21	6	4	**7293**	1/cm³	0,05704	µm
Diameter	57	3	19	83	145	152	201	121	102	39	16	24	**962,8842779**	µm/cm³	0,31071	µm
Area	3	0	2	18	65	124	271	273	372	223	148	441	**1940,343985**	µm²/cm³	1,26029	µm
Volume	0	0	0	0	2	5	19	33	72	68	72	435	**706,1566497**	µm³/cm³	3,40217	µm
Mass	0	0	0	0	0	0	0	0	0	0	0	0	**0,70615665**	mg/m³	3,40217	µm
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0				
Current dI/dlogDp	6	2	6	24	48	115	122	119	97	55	21	22				
Number dN/dlogDp	5818	1240	2332	4055	3002	3326	1810	892	389	120	25	10				
Diameter dD/dlogDp	107	33	89	280	429	860	774	640	451	221	73	60				
Area dA/dlogDp	6	3	11	61	193	699	1040	1443	1641	1275	665	1117				
Volume dV/dlogDp	0	0	0	1	5	30	74	172	317	391	322	1102				
Mass dM/dlogDp	0	0	0	0	0	0	0	0	0	0	0	1				

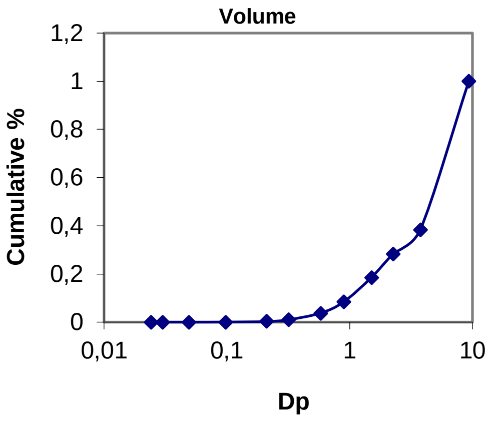
Cumulative distributions

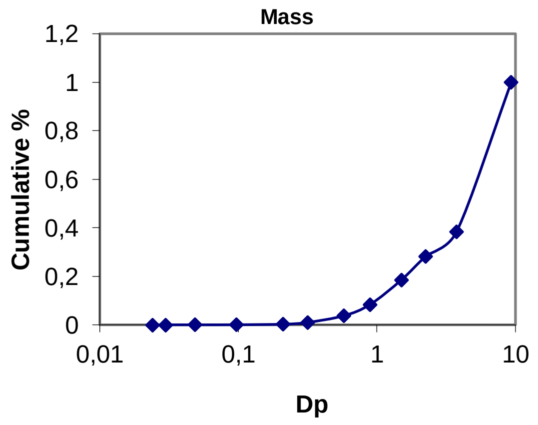












DEKATI

ALL DISTRIBUTIONS

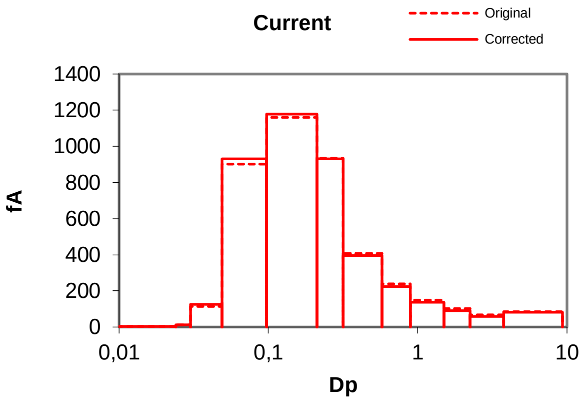
Date	#######	Filename	ELPi_Tiller_BIO-Mass_dowr
Time	11:48:36	Note	sintered metal

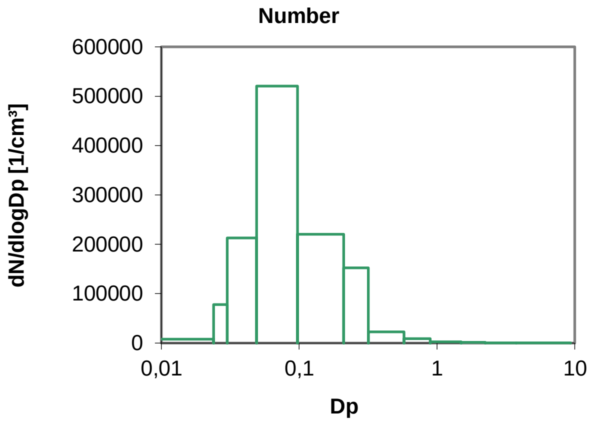
		Sample	Time
Distribution average	From	445	11:56:00
	To	745	12:01:00

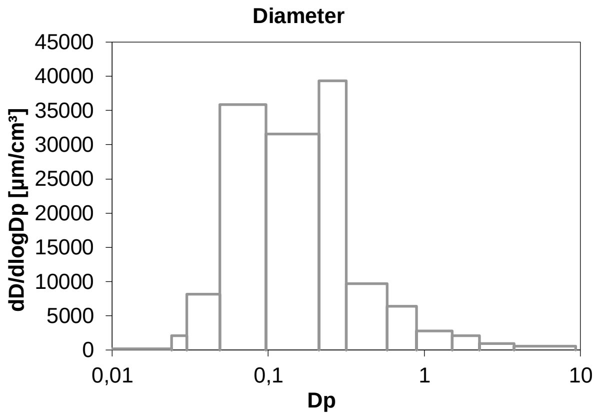
Dilution	8,86
Density	1

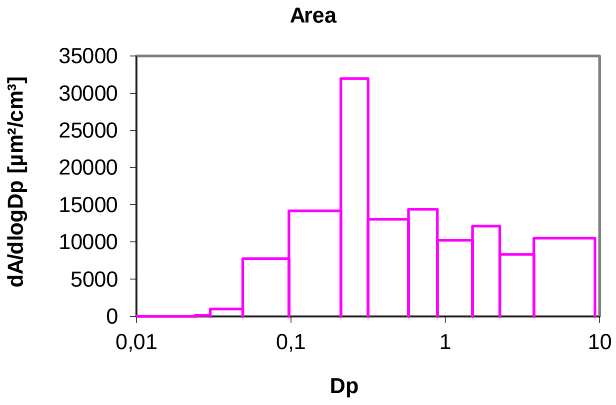
☑ Correction ☐ Stokes Dp

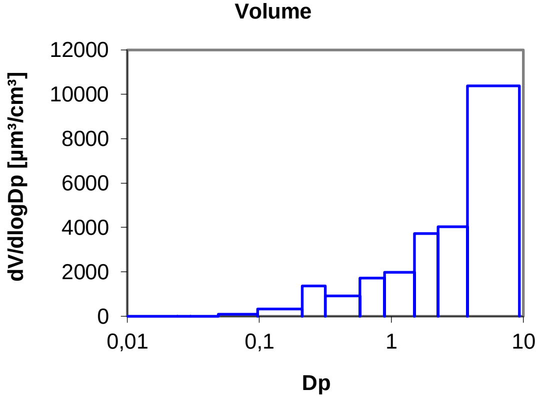
Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

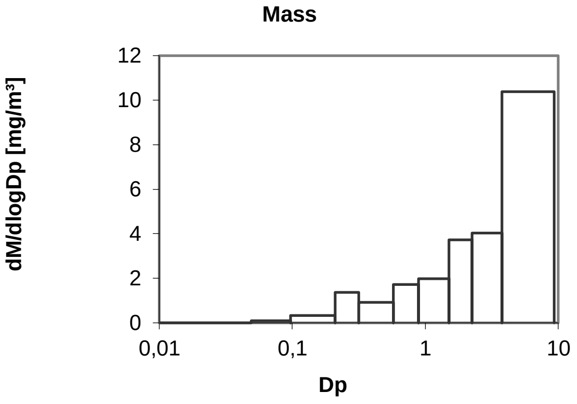






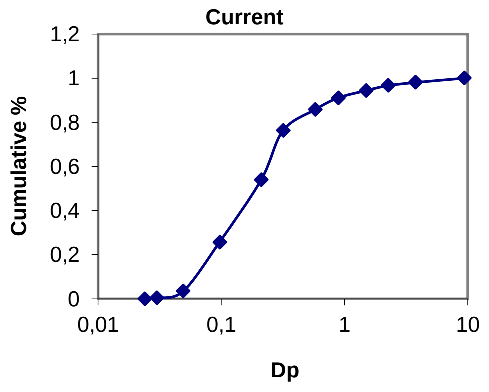


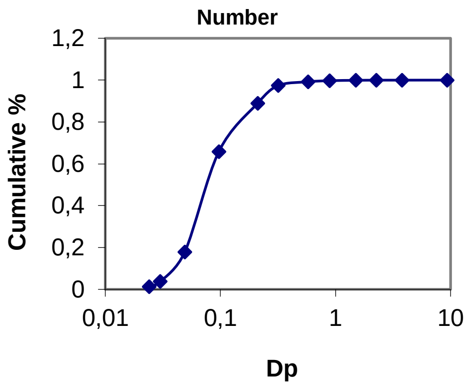


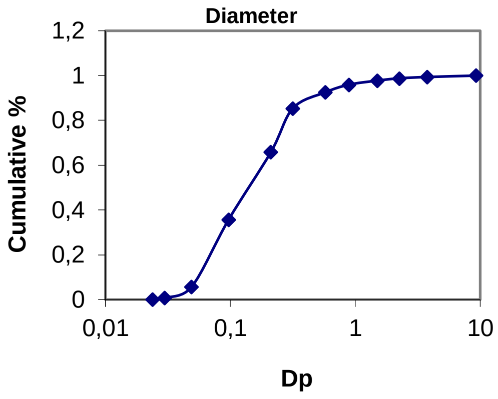


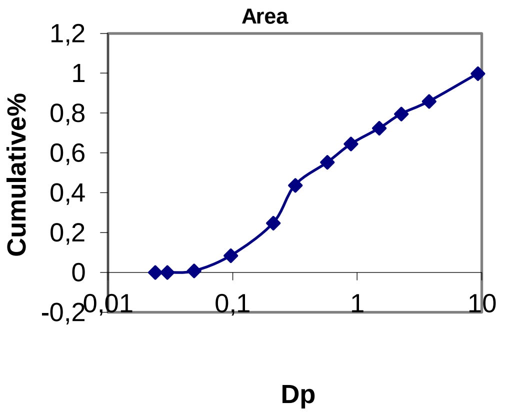
c	1	2	3	4	5	6	7	8	9	10	11	12	Total	From Ch	1	
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**		To	12	Median
Current	4	13	126	932	1178	930	396	223	138	92	59	81	**4173,726035**	fA	0,20356	µm
Number	4221	7591	45396	154360	74451	26893	5900	1680	552	200	70	38	**321351**	1/cm³	0,08516	µm
Diameter	78	204	1741	10642	10651	6955	2523	1205	639	368	203	223	**35432,13345**	µm/cm³	0,1513	µm
Area	5	17	210	2305	4787	5651	3390	2717	2325	2125	1858	4153	**29542,16404**	µm²/cm³	0,56907	µm
Volume	0	0	1	26	114	244	242	325	449	651	900	4099	**7051,7427**	µm³/cm³	3,0117	µm
Mass	0	0	0	0	0	0	0	0	0	1	1	4	**7,0517427**	mg/m³	3,0117	µm
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0				
Current dI/dlogDp	8	136	593	3142	3491	5260	1523	1181	609	527	265	206				
Number dN/dlogDp	7888	78334	213052	520473	220589	152129	22681	8881	2432	1142	314	95				
Diameter dD/dlogDp	145	2102	8169	35882	31558	39344	9700	6372	2817	2102	912	565				
Area dA/dlogDp	8	177	984	7772	14184	31967	13033	14361	10250	12145	8335	10520				
Volume dV/dlogDp	0	1	6	89	338	1378	929	1717	1979	3724	4040	10383				
Mass dM/dlogDp	0	0	0	0	0	1	1	2	2	4	4	10				

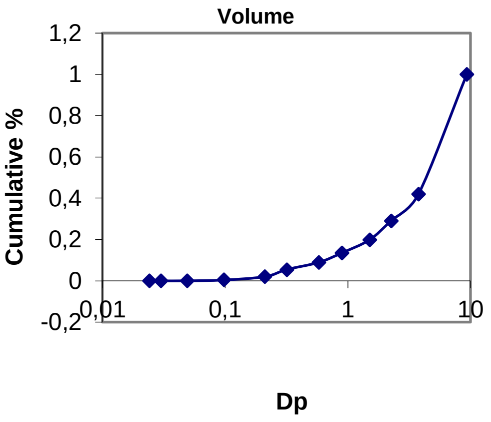
Cumulative distributions

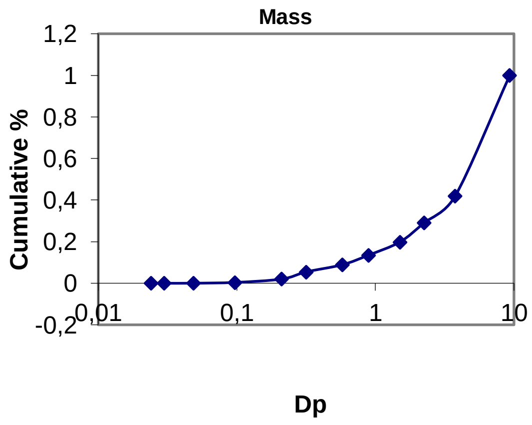












DEKATI

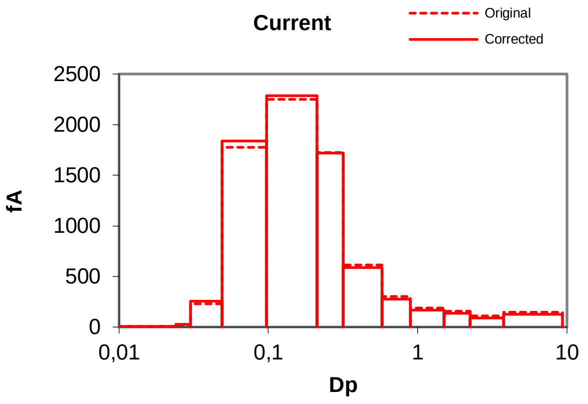
ALL DISTRIBUTIONS

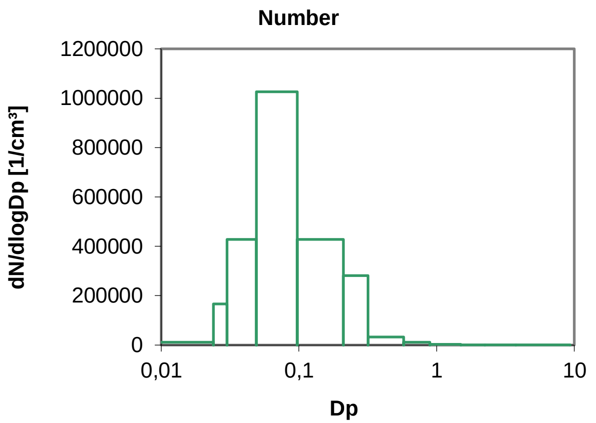
Date	#######	Filename	ELPi_Tiller_BIO-Mass_dowr
Time	11:48:36	Note	sintered metal

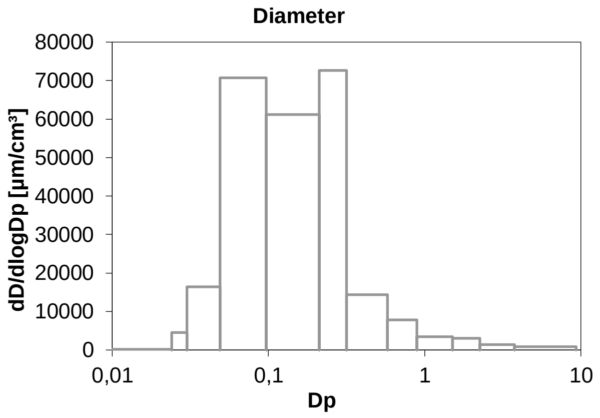
		Sample	Time			
Distribution average	From	805	12:02:00		Dilution	8,86
	To	1374	12:12:00		Density	1

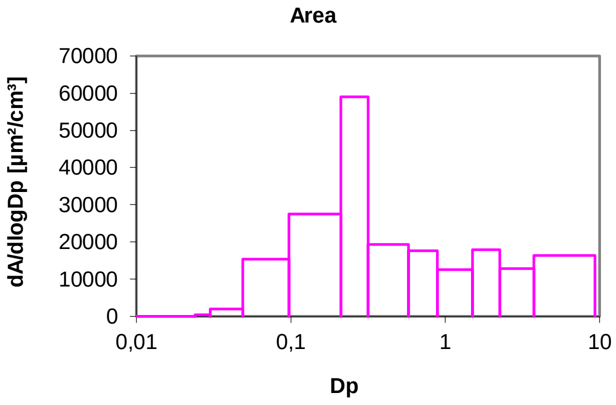
☑ Correction ☐ Stokes Dp

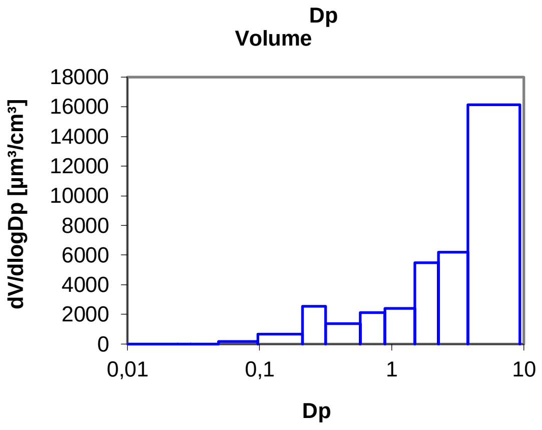
Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

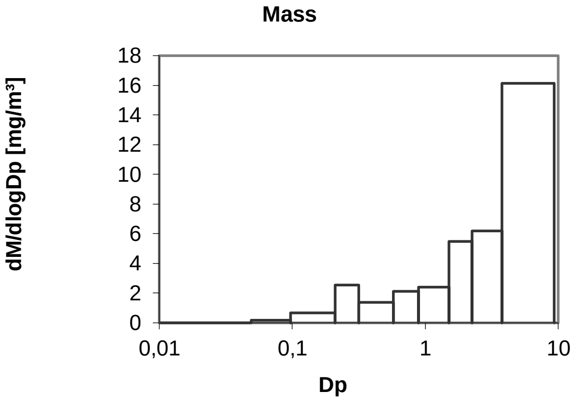






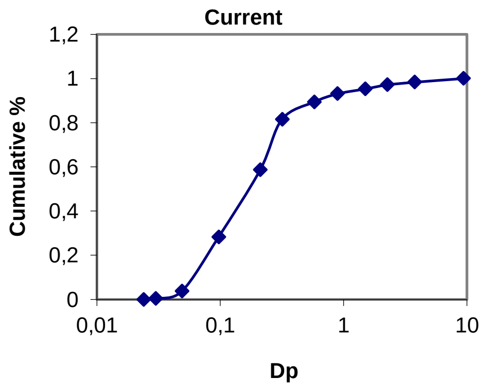


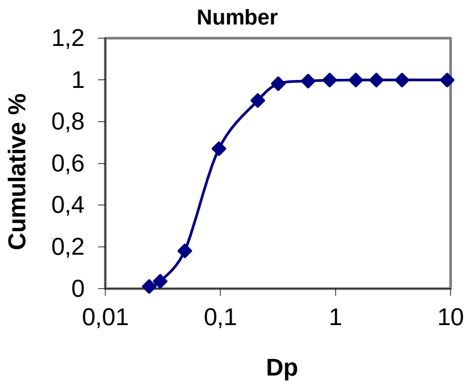


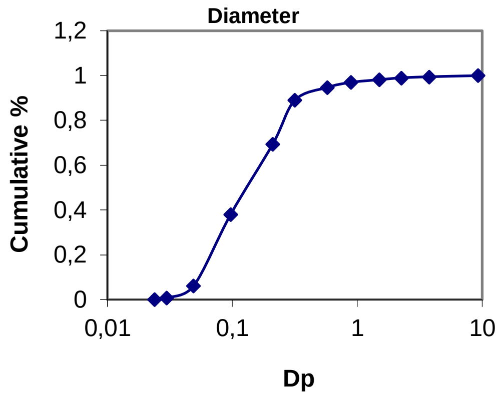


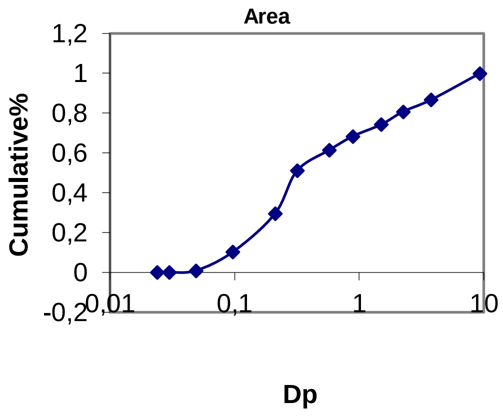
c	1	2	3	4	5	6	7	8	9	10	11	12	Total	From Ch	1	
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**		To	12	Median
Current	6	28	253	1837	2286	1717	590	275	168	136	91	126	**7512,533172**	fA	0,18214	µm
Number	5787	16195	91104	304313	144428	49649	8776	2070	673	294	107	59	**623457**	1/cm³	0,08345	µm
Diameter	107	435	3493	20980	20662	12841	3753	1485	780	541	312	347	**65736,02246**	µm/cm³	0,13982	µm
Area	6	37	421	4544	9287	10433	5043	3348	2837	3129	2853	6454	**48390,34665**	µm²/cm³	0,49126	µm
Volume	0	0	3	52	221	450	359	400	548	959	1383	6370	**10745,63753**	µm³/cm³	3,01116	µm
Mass	0	0	0	0	0	0	0	0	1	1	1	6	**10,74563753**	mg/m³	3,01116	µm
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0				
Current dI/dlogDp	11	290	1190	6194	6772	9712	2266	1455	742	775	406	320				
Number dN/dlogDp	10815	167119	427566	1026088	427922	280858	33740	10943	2966	1683	482	148				
Diameter dD/dlogDp	199	4484	16393	70741	61220	72637	14430	7851	3436	3095	1401	879				
Area dA/dlogDp	12	378	1975	15322	27515	59017	19388	17694	12502	17887	12799	16349				
Volume dV/dlogDp	0	2	13	176	656	2544	1382	2116	2413	5484	6204	16136				
Mass dM/dlogDp	0	0	0	0	1	3	1	2	2	5	6	16				

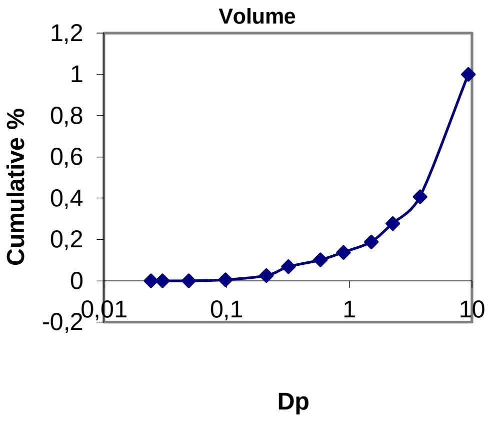
Cumulative distributions

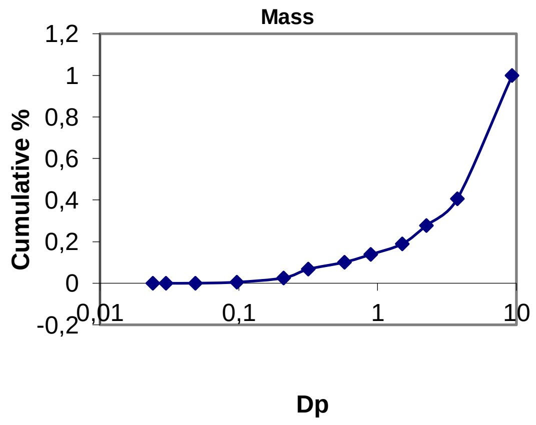












DEKATI

ALL DISTRIBUTIONS

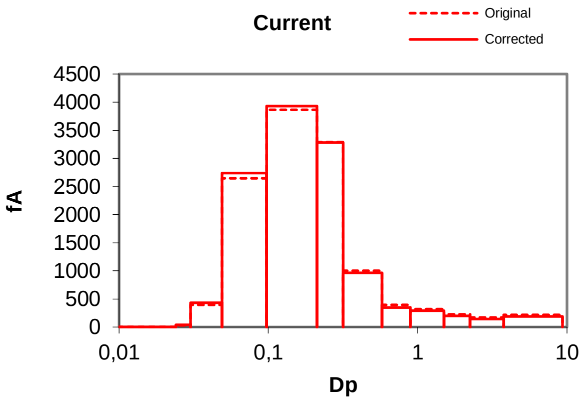
Date	#######	Filename	Clime-Thiller Biomass burne
Time	14:27:21	Note	sintered metal

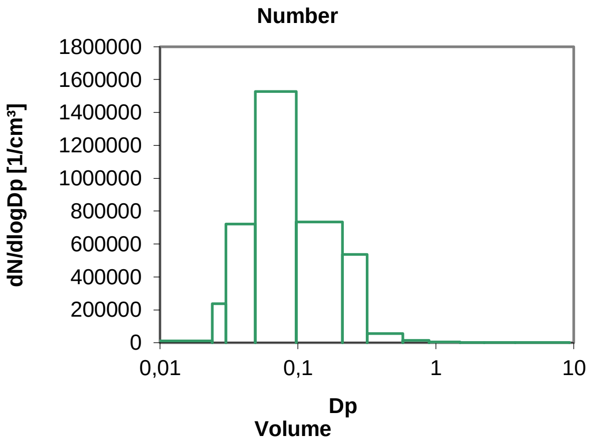
		Sample	Time
Distribution average	From	80	14:28:40
	To	740	14:39:40

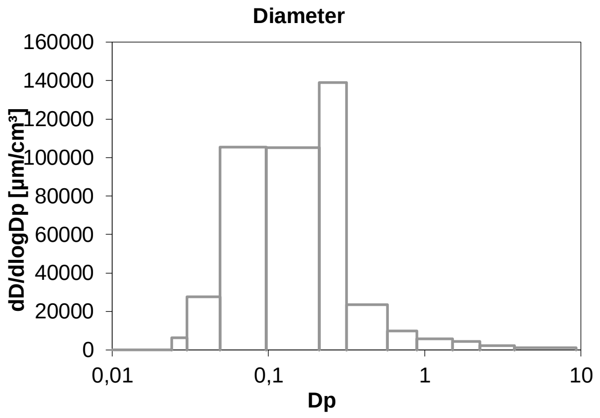
Dilution	8,86
Density	1

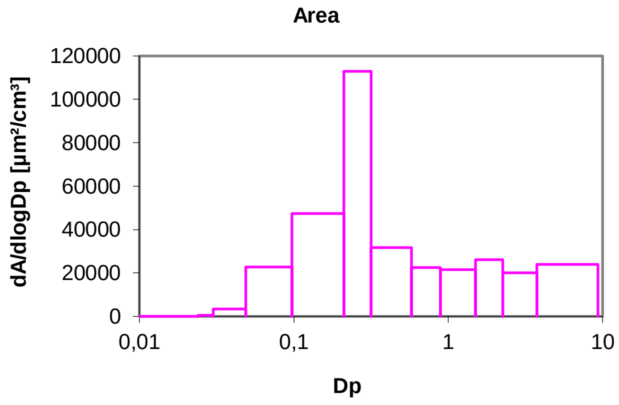
☑ Correction ☐ Stokes Dp

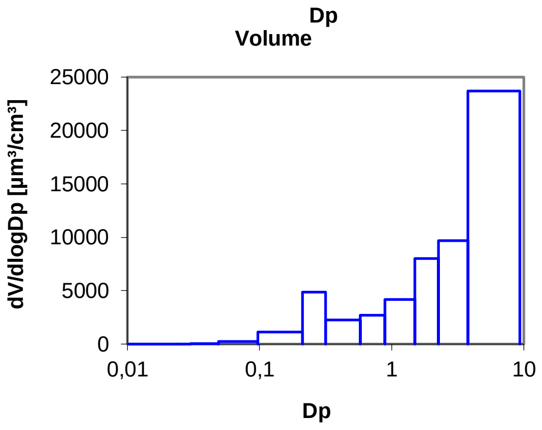
Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

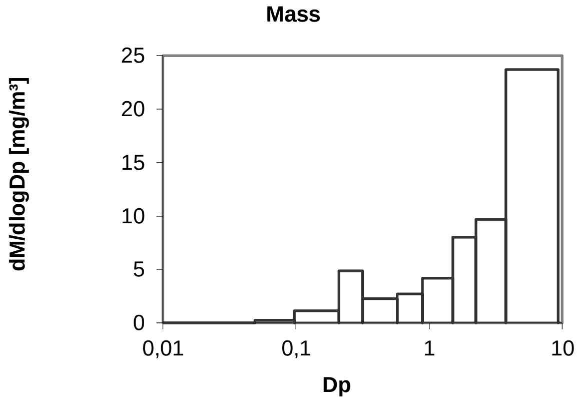






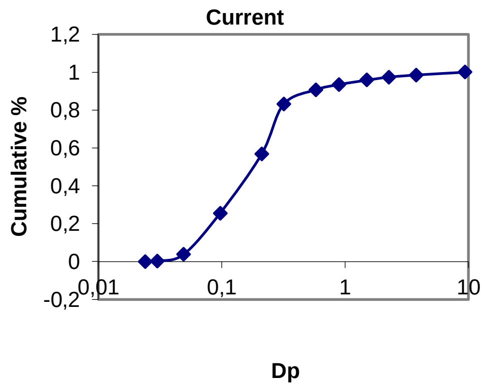


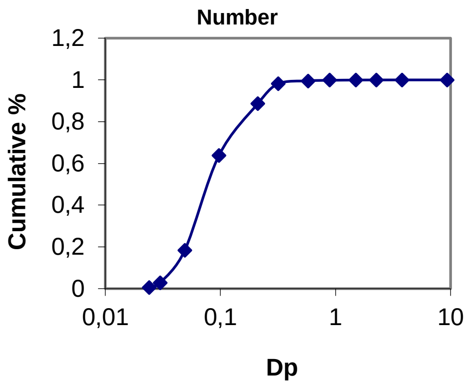


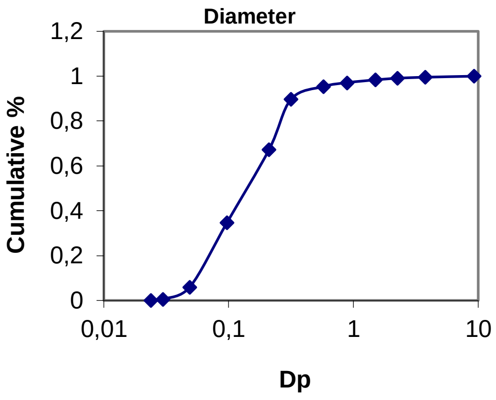


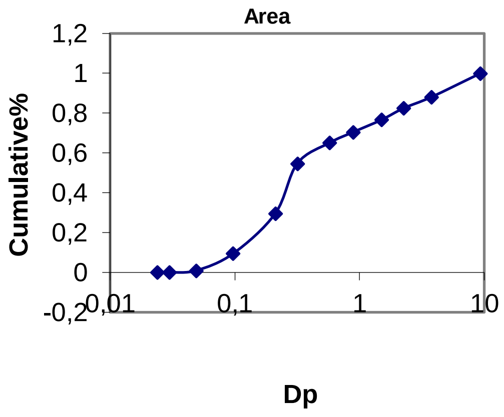
c	1	2	3	4	5	6	7	8	9	10	11	12	Total	From Ch	1		
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**		To	12	Median	
Current	5	40	429	2736	3930	3285	965	349	291	198	141	186	**12555,05957**	fA	0,18397	µm	
Number	5252	23136	154061	453145	248338	95003	14367	2628	1161	431	168	86	**997775**	1/cm³	0,08645	µm	
Diameter	97	621	5907	31241	35528	24570	6144	1886	1345	792	488	510	**109127,3663**	µm/cm³	0,14398	µm	
Area	6	52	711	6766	15968	19963	8255	4250	4894	4577	4455	9479	**79377,22614**	µm²/cm³	0,45806	µm	
Volume	0	0	5	78	381	860	588	508	945	1403	2159	9356	**16283,47192**	µm³/cm³	2,86573	µm	
Mass	0	0	0	0	0	1	1	1	1	1	2	9	**16,28347192**	mg/m³	2,86573	µm	
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0					
Current dI/dlogDp	10	415	2012	9224	11644	18583	3710	1847	1281	1134	635	470					
Number dN/dlogDp	9815	238735	723037	1527923	735794	537420	55231	13893	5118	2461	752	218					
Diameter dD/dlogDp	181	6406	27722	105338	105265	138990	23621	9967	5928	4527	2188	1291					
Area dA/dlogDp	10	540	3339	22815	47311	112929	31737	22464	21570	26163	19986	24013					
Volume dV/dlogDp	0	2	21	262	1128	4868	2262	2686	4164	8021	9687	23700					
Mass dM/dlogDp	0	0	0	0	1	5	2	3	4	8	10	24					

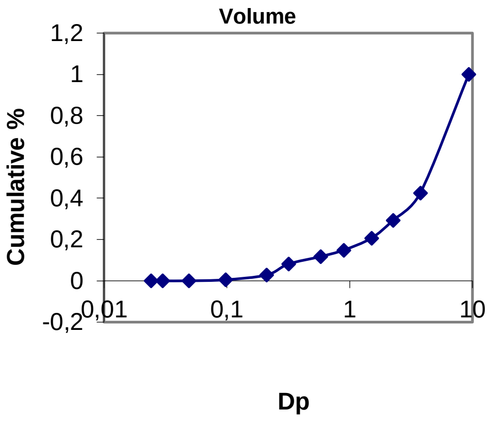
Cumulative distributions

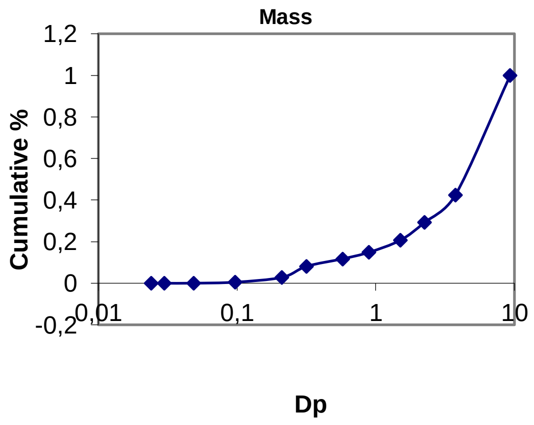












ALL DISTRIBUTIONS

Date	#######	Filename	ELPi_Tiller_BIO-Mass_dowr
Time	11:48:36	Note	sintered metal

		Sample	Time
Distribution average	From	2634	12:33:00
	To	3714	12:51:00

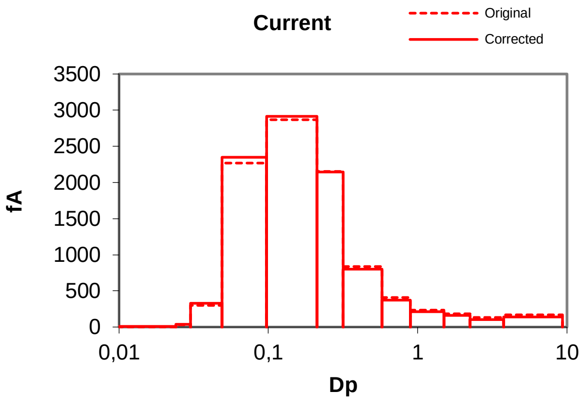
Dilution	8,86
Density	1

☑ Correction

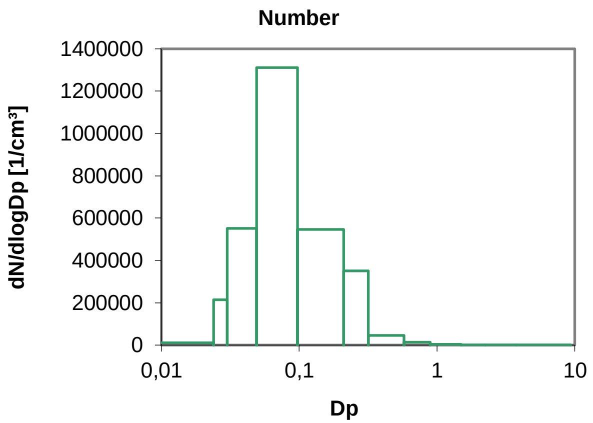
☐ Stokes Dp

Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

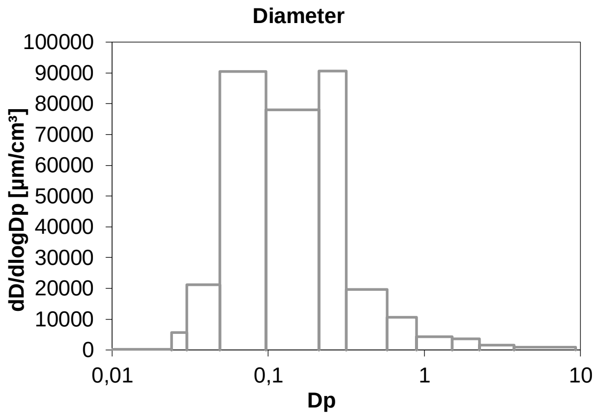
Current



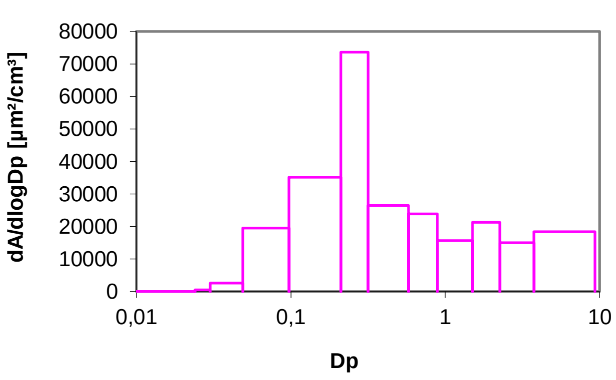
Number



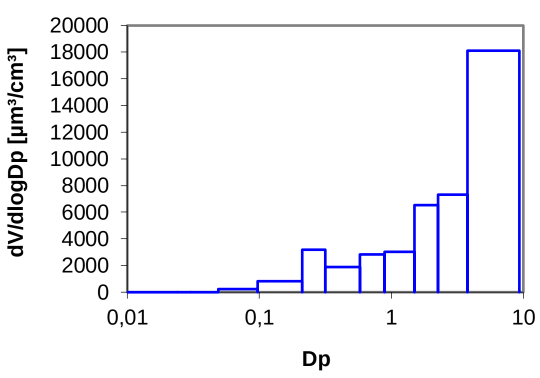
Diameter



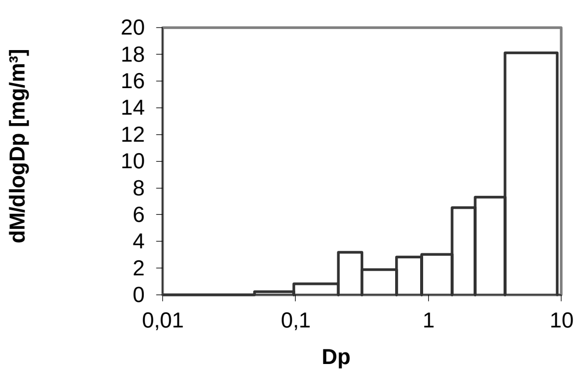
Area



Volume



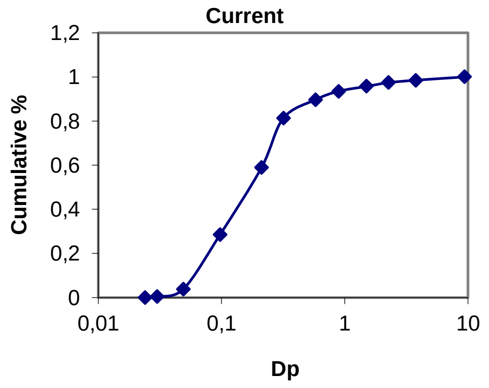
Mass



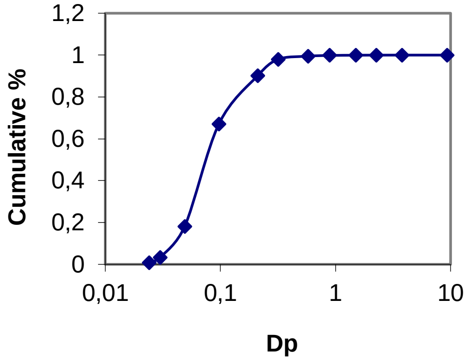
c	1	2	3	4	5	6	7	8	9	10	11	12	Total	From Ch	1	
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**		To	12	Median
Current	6	36	327	2348	2914	2141	803	371	210	161	107	142	**9565,200894**	fA	0,18057	µm
Number	6249	20732	117508	388878	184158	61931	11949	2787	839	350	126	66	**795573**	1/cm³	0,08348	µm
Diameter	115	556	4505	26810	26346	16017	5110	1999	972	643	368	389	**83831,69463**	µm/cm³	0,13946	µm
Area	7	47	543	5807	11841	13014	6866	4506	3538	3717	3358	7245	**60487,39685**	µm²/cm³	0,46596	µm
Volume	0	0	3	67	282	561	489	539	683	1140	1628	7151	**12542,81967**	µm³/cm³	2,85503	µm
Mass	0	0	0	0	0	1	0	1	1	1	2	7	**12,54281967**	mg/m³	2,85503	µm
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0				
Current dI/dlogDp	11	372	1534	7916	8635	12114	3085	1959	926	921	478	359				
Number dN/dlogDp	11679	213934	551486	1311226	545636	350335	45935	14730	3700	1999	567	167				
Diameter dD/dlogDp	215	5740	21144	90399	78060	90605	19646	10567	4285	3677	1649	987				
Area dA/dlogDp	12	484	2547	19579	35084	73616	26396	23817	15592	21247	15066	18353				
Volume dV/dlogDp	0	2	16	225	837	3173	1881	2848	3010	6514	7302	18114				
Mass dM/dlogDp	0	0	0	0	1	3	2	3	3	7	7	18				

Cumulative distributions

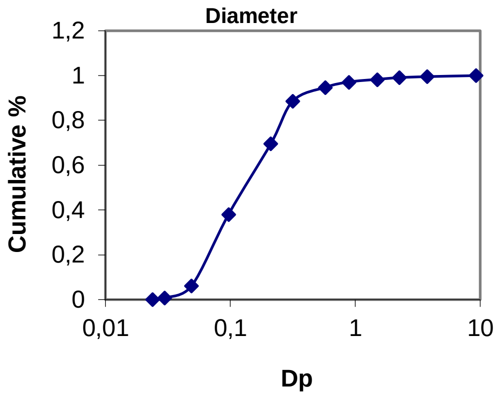
Current



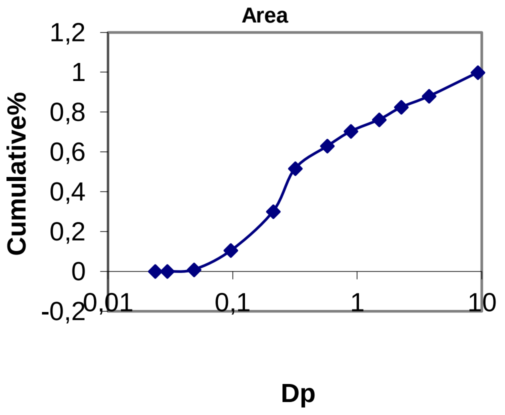
Number



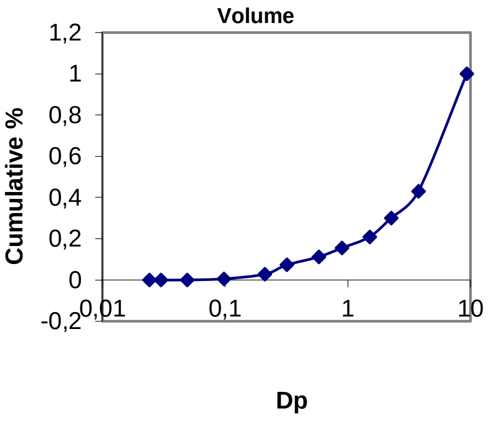
Diameter



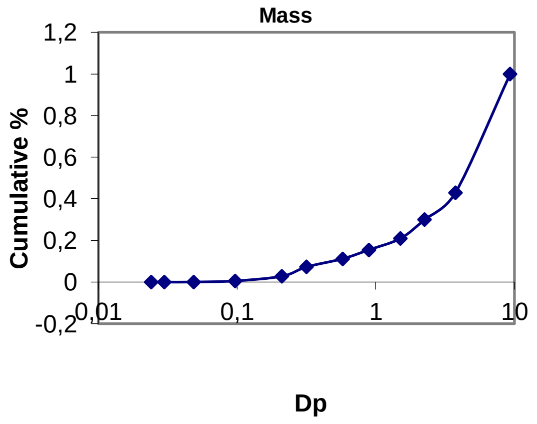
Area



Volume



Mass



DEKATI

ALL DISTRIBUTIONS

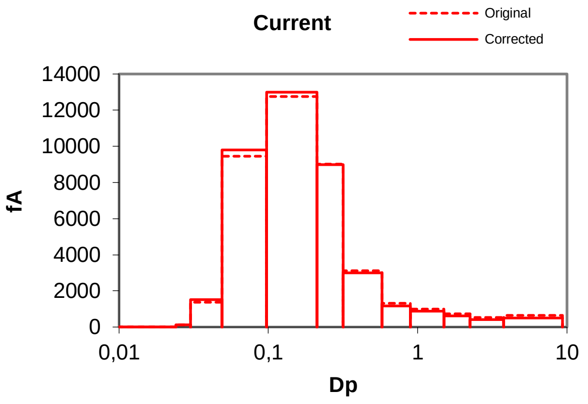
Date	#######	Filename	Clime-Thiller Biomass burne
Time	14:27:21	Note	sintered metal

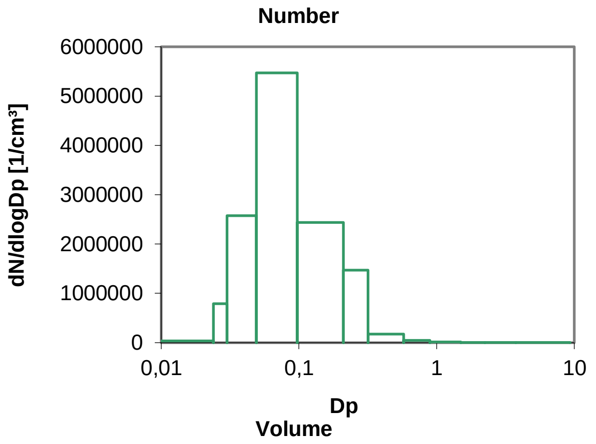
		Sample	Time
Distribution average	From	1400	14:50:40
	To	2360	15:06:40

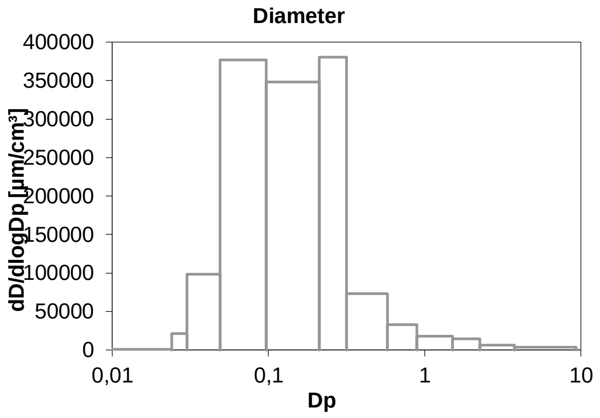
Dilution	8,86
Density	1

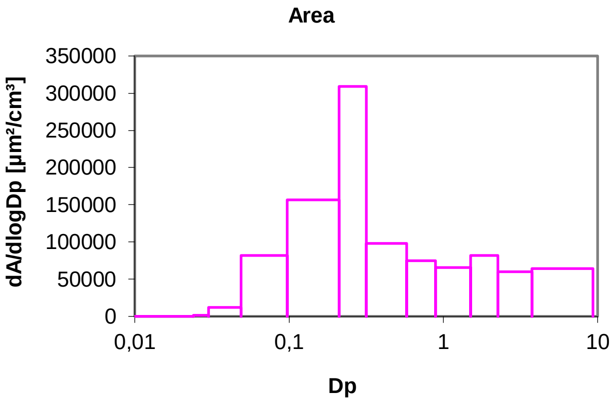
☑ Correction ☐ Stokes Dp

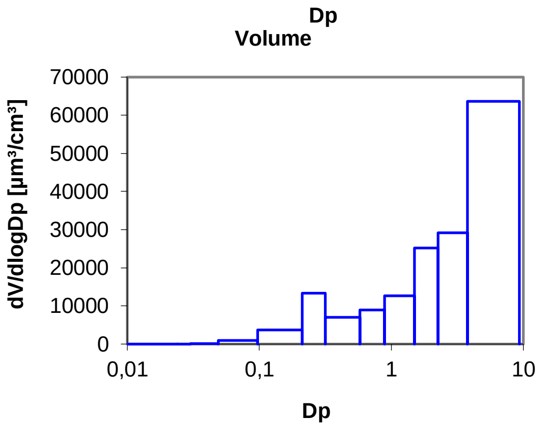
Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

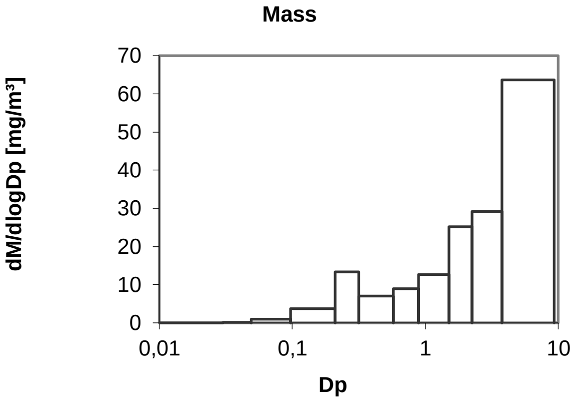






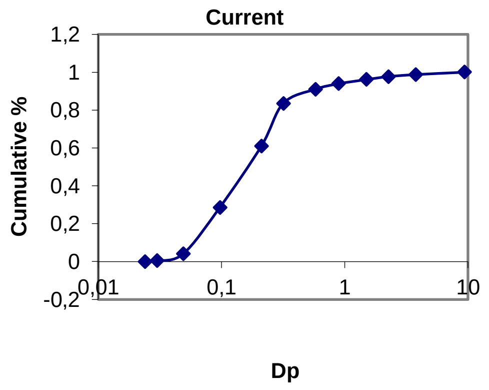


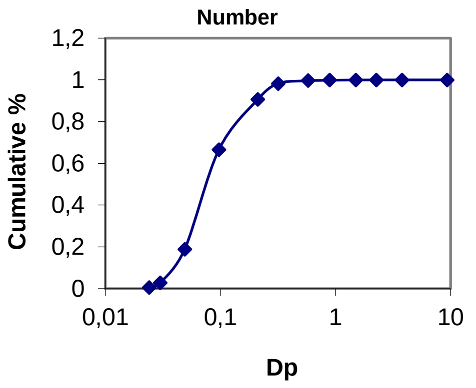


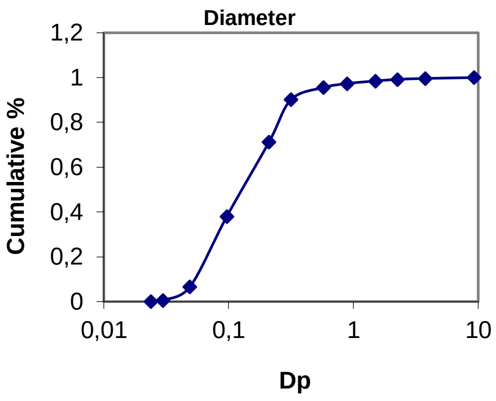


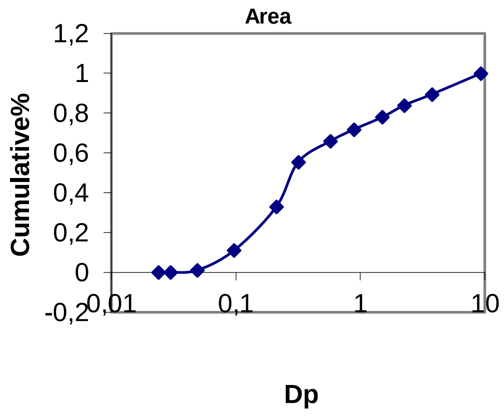
c	1	2	3	4	5	6	7	8	9	10	11	12	Total	From Ch	1	
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**		To	12	Median
Current	17	133	1527	9795	12993	8991	2988	1167	884	622	427	498	**40042,07341**	fA	0,17313	µm
Number	17193	76341	548968	1622474	821060	260020	44487	8776	3531	1351	506	231	**3404938**	1/cm³	0,08333	µm
Diameter	317	2048	21048	111857	117463	67248	19026	6296	4090	2484	1471	1369	**354716,5572**	µm/cm³	0,1359	µm
Area	18	173	2535	24227	52793	54638	25563	14190	14882	14358	13438	25460	**242276,0769**	µm²/cm³	0,42701	µm
Volume	0	1	16	278	1259	2355	1822	1697	2873	4402	6513	25128	**46344,78886**	µm³/cm³	2,7103	µm
Mass	0	0	0	0	1	2	2	2	3	4	7	25	**46,34478886**	mg/m³	2,7103	µm
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0				
Current dI/dlogDp	31	1368	7169	33026	38497	50861	11488	6168	3895	3558	1914	1263				
Number dN/dlogDp	32130	787747	2576409	5470693	2432694	1470895	171027	46386	15563	7720	2269	585				
Diameter dD/dlogDp	593	21137	98781	377161	348028	380410	73145	33278	18027	14202	6599	3467				
Area dA/dlogDp	34	1782	11898	81688	156420	309082	98277	75003	65595	82077	60288	64495				
Volume dV/dlogDp	0	8	76	939	3730	13323	7005	8968	12663	25164	29222	63654				
Mass dM/dlogDp	0	0	0	1	4	13	7	9	13	25	29	64				

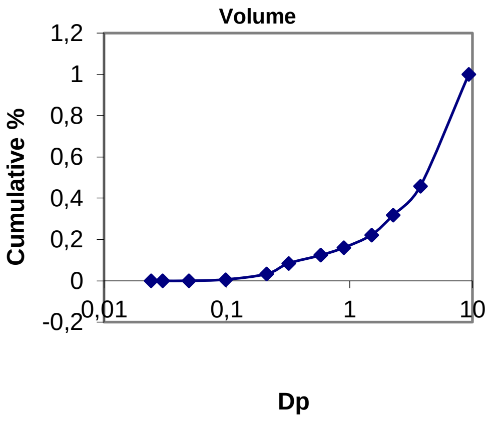
Cumulative distributions

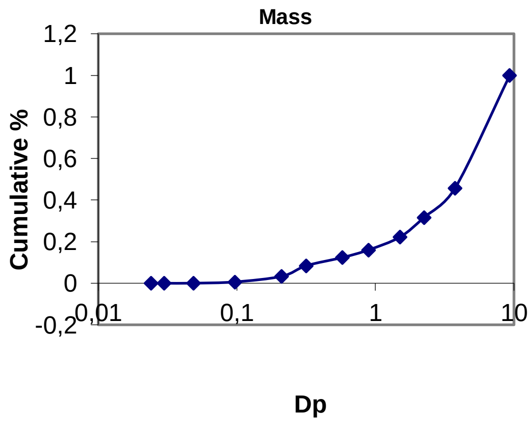












DEKATI

ALL DISTRIBUTIONS

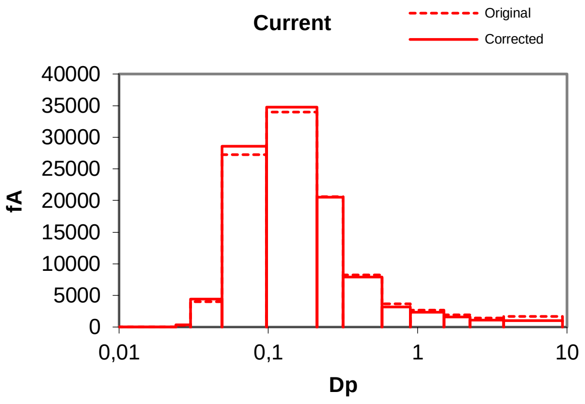
Date	#######	Filename	Clime-Thiller Biomass burne
Time	14:27:21	Note	sintered metal

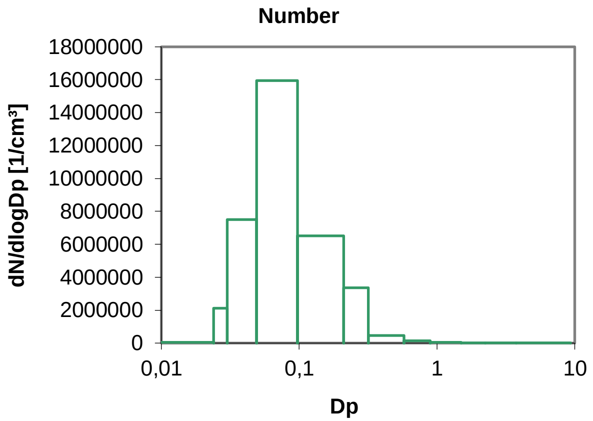
		Sample	Time
Distribution average	From	2540	15:09:40
	To	3560	15:26:40

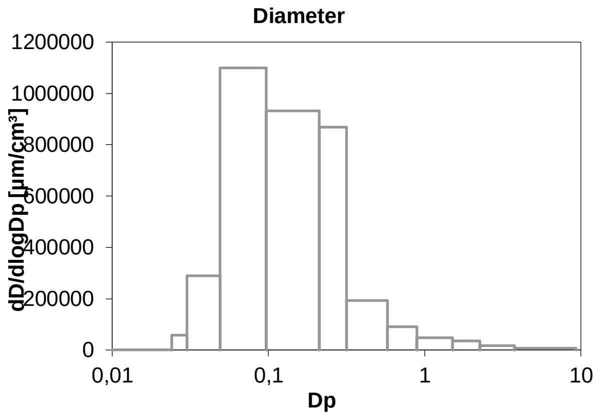
Dilution	8,86
Density	1

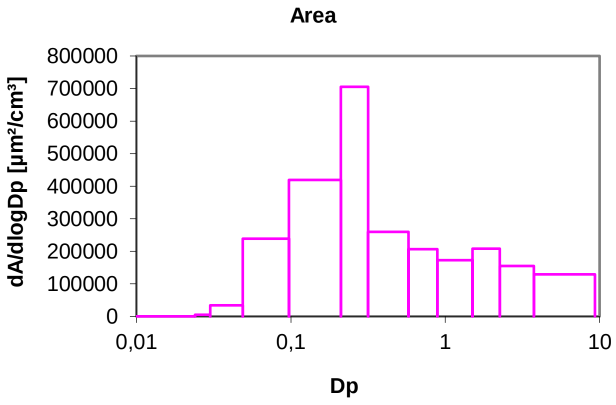
☑ Correction ☐ Stokes Dp

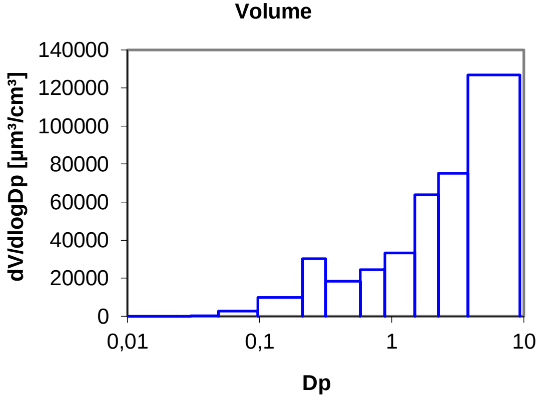
Stage n:o	1	2	3	4	5	6	7	8	9	10	11	12	13
Dp	0,007	0,024	0,030	0,049	0,097	0,211	0,317	0,577	0,892	1,504	2,250	3,759	9,329

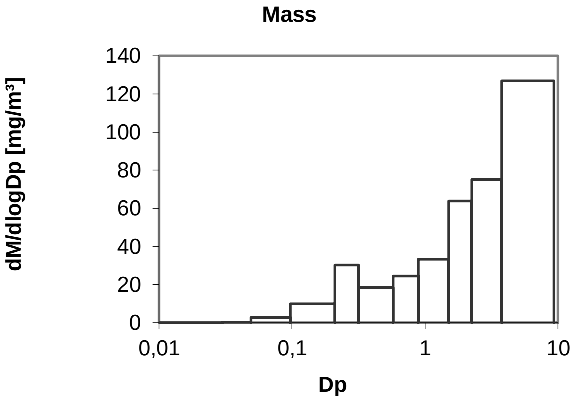












c	1	2	3	4	5	6	7	8	9	10	11	12	**Total** From Ch	1	
Di	**0,0184416**	**0,02683**	**0,03834**	**0,06894**	**0,14306**	**0,25863**	**0,42768**	**0,71741**	**1,15826**	**1,83957**	**2,90822**	**5,9218**	To	12	Median
Current	29	358	4458	28555	34760	20516	7876	3201	2318	1580	1096	994	**105742,1282** fA	0,164	µm
Number	30190	206063	1602054	4730141	2196547	593331	117260	24074	9264	3429	1299	461	**9514112** 1/cm³	0,08096	µm
Diameter	557	5529	61424	326105	314244	153450	50149	17271	10730	6307	3778	2728	**952273,0599** µm/cm³	0,12939	µm
Area	32	466	7399	70630	141236	124678	67380	38926	39044	36450	34517	50747	**611504,5259** µm²/cm³	0,39167	µm
Volume	0	2	47	812	3368	5374	4803	4654	7537	11175	16730	50085	**104588,3788** µm³/cm³	2,43527	µm
Mass	0	0	0	1	3	5	5	5	8	11	17	50	**104,5883788** mg/m³	2,43527	µm
dlogdp	1	0	0	0	0	0	0	0	0	0	0	0			
Current dI/dlogDp	55	3694	20920	96284	102990	116057	30280	16919	10218	9033	4917	2517			
Number dN/dlogDp	56418	2126333	7518739	#######	6508081	3356382	450797	127248	40831	19599	5828	1167			
Diameter dD/dlogDp	1040	57056	288273	1099569	931065	868045	192796	91290	47292	36055	16950	6910			
Area dA/dlogDp	60	4810	34723	238153	418463	705282	259039	205751	172087	208365	154861	128550			
Volume dV/dlogDp	0	22	222	2736	9978	30401	18464	24602	33220	63884	75062	126875			
Mass dM/dlogDp	0	0	0	3	10	30	18	25	33	64	75	127			

Cumulative distributions