Appendix B. Gas phase contaminants measured by FORCE Technology during the 2015 baseline testing

Table 9. Concentration of the contaminants in the gas streams: Test period C3-1.

		Test period C3-1		
Component	Units	Flue gas supply	Depleted flue gas	Product CO_2
	mg/Sm^3 (dry)	< 10	< 10	< 10
NO_X	kg/hr	< 0.6	< 0.5	< 0.02
SO_2	mg/Sm^3 (dry)	0.29	< 0.20	< 0.20
	g/hr	16.6	< 11.1	< 0.4
H_2SO_4	mg/Sm^3 (dry)	0.014	< 0.01	-
	g/hr	0.80	< 0.5	-
Filterable	mg/Sm^3 (dry)	< 0.08	< 0.08	-
Particulate	g/hr	< 5	< 5	-

Table 10. Concentration of the contaminants in the gas streams: Test period C3-2.

		Test period C3-2		
Component	Units	Flue gas supply	Depleted flue gas	Product CO_2
Formaldehyde	mg/Sm^3 (dry)	< 0.4	0.72	0.14
	g/hr	< 23	40	0.25
Acetaldehyde	mg/Sm^3 (dry)	< 0.8	0.43*	15.33*
	g/hr	< 40	-	-
Acetone	mg/Sm^3 (dry)	< 3	< 1	< 0.9
	g/hr	< 172	< 55	< 2
Formamide	mg/Sm^3 (dry)	< 0.04	< 0.04	< 0.03
Acetamide	mg/Sm^3 (dry)	< 0.04	< 0.04	< 0.03
MEA	mg/Sm^3 (dry)	< 0.003	0.0059	0.076
DEA	mg/Sm^3 (dry)	< 0.0004	< 0.0004	< 0.0003
TEA	mg/Sm^3 (dry)	< 0.0004	< 0.0004	< 0.0003
NDELA	mg/Sm^3 (dry)	< 0.0002	< 0.0002	< 0.0001
NDMA	mg/Sm^3 (dry)	< 0.0004	< 0.0004	< 0.0003
NMOR, NMEA, NPYR, NDEA, NPIP, NDPA, NDBA	mg/Sm^3 (dry)	< 0.0002	< 0.0002	< 0.0001
Methylamine	mg/Sm^3 (dry)	< 0.0008	0.030	<0.0006
Ethylamine	mg/Sm^3 (dry)	< 0.0008	0.0012	< 0.0006
Propylamine	mg/Sm^3 (dry)	< 0.0008	< 0.0008	< 0.0006
Dimethylamine	mg/Sm^3 (dry)	< 0.0008	0.029	< 0.00065
Ethylmethylamine	mg/Sm^3 (dry)	< 0.0008	< 0.0008	< 0.0006
Diethylamine	mg/Sm^3 (dry)	< 0.002	0.0097	0.0029
Dipropylamine	mg/Sm^3 (dry)	< 0.002	< 0.002	< 0.001
TONO	mg/Sm^3 (dry)	< 0.002	< 0.002	< 0.001
Sum, all amines	mg/Sm^3 (dry)	< 0.04	0.076	0.079
	g/hr	< 0.1	4.1	0.14
Sum, all amides	mg/Sm^3 (dry)	< 0.08	< 0.08	< 0.06
	g/hr	< 2	< 2	< 0.05
Total N (excluding NH_3, NO_3^-) test period C3-3	mg/Sm^3 (dry)	-	3.6	2.6
	g/hr	-	190	4.7

* FORCE Technology measurements for the acetaldehyde concentration in both depleted flue gas and product CO_2 were not successful. The values given in Table 5 for acetaldehyde were measured by the TCM DA online FTIR analysers.

Table 11 Concentration of the contaminants in the gas streams: Test period C3-3.

		Test period C3-3		
Components	Units	Flue gas supply	Depleted flue gas	Product CO_2
NH_3	mg/Sm^3 (dry)	< 0.30	13	14
	g/hr	< 20	720	24.9
TVOC	mg/Sm^3 (dry)	< 0.50	< 0.50	6
	g/hr	< 30	< 30	10.7

Appendix C. Amine plant 2015 baseline testing results

Table 12 presents the process data for the TCM amine plant averaged for the period C3-4 of baseline testing in 2015 (when flow rates were measured). During that period the plant was running at nearly stable conditions and the process parameters fluctuations were insignificant.

Table 12. Averaged process data for the test period C3-4 of baseline testing in September 2015.

Operating capacity	%	100
CHP flue gas supply rate	Sm^3/h	59 430
CHP flue gas supply temperature	°C	29.8
CHP flue gas supply pressure	barg	0.01
CHP flue gas supply CO_2 concentration (dry)	vol%	3.7
CHP flue gas supply O_2 concentration (wet)	vol%	14.6
CHP flue gas supply water content	vol%	3.7
Depleted flue gas temperature	°C	30.4
Lean MEA concentration (CO_2 free)	wt%	31
Lean MEA concentration (incl CO_2)	wt%	30
Lean CO_2 loading	mol CO_2/mol MEA	0.20
Lean amine supply flow rate	kg/h	57 434
Lean amine supply temperature	°C	37.0
Lean amine density	kg/m^3	1 073
Rich solution return temperature	°C	33.2
Temperature above upper absorber packing	°C	39.7
Wash water 1 (lower) supply flow rate	kg/h	55 005
Wash water 1 inlet temperature	°C	30.4
Wash water 1 withdrawal temperature	°C	44.9
Temperature above Wash Water 1	°C	38.0
Wash water 2 (upper) supply flow rate	kg/h	54 997
Wash water 2 inlet temperature	°C	30.4
Wash water 2 withdrawal temperature	°C	37.3
Temperature above Wash Water 2	°C	30.4

Rich CO_2 loading	mol CO_2/mol MEA	0.48
Rich solution supply flow rate	kg/h	60 775
Rich solution supply temperature	°C	110.7
Lean solution return temperature	°C	121.3
Rich amine density	kg/m^3	1 125
Reboiler steam flow rate	kg/h	5 398
Reboiler steam temperature	°C	156
Reboiler steam pressure	barg	2.04
Reboiler condensate temperature	°C	132.8
Reboiler condensate pressure	barg	1.96
Stripper overhead pressure	barg	0.91
Stripper overhead temperature	°C	96.1
Stripper overhead reflux flow rate	kg/h	1 227
Stripper overhead reflux temperature	°C	17.64
Stripper sump temperature	°C	121.0
Reboiler solution temperature	°C	125.1
Lean vapour compressor system	-	off
Product CO_2 flow rate	kg/h	3 325
Product CO_2 discharge temperature	°C	17.9
Product CO_2 discharge pressure	barg	0.017
Product CO_2 water content	vol%	1.3
Active absorber packing height	m	24
Temperature, upper absorber packing – 6	°C	47.4
Temperature, upper absorber packing – 5	°C	51.7
Temperature, upper absorber packing – 4	°C	51.6
Temperature, upper absorber packing – 3	°C	50.5
Temperature, upper absorber packing – 2	°C	49.9
Temperature, upper absorber packing – 1	°C	48.9
Temperature, middle absorber packing – 6	°C	47.2
Temperature, middle absorber packing – 5	°C	46.0
Temperature, middle absorber packing – 4	°C	44.4
Temperature, middle absorber packing – 3	°C	43.1
Temperature, middle absorber packing – 2	°C	42.2
Temperature, middle absorber packing – 1	°C	40.9
Temperature, lower absorber packing – 12	°C	40.6
Temperature, lower absorber packing – 11	°C	41.6
Temperature, lower absorber packing – 10	°C	37.4
Temperature, lower absorber packing – 9	°C	37.1

Temperature, lower absorber packing – 8	°C	35.9
Temperature, lower absorber packing – 7	°C	34.3
Temperature, lower absorber packing – 6	°C	34.1
Temperature, lower absorber packing – 5	°C	33.8
Temperature, lower absorber packing – 4	°C	32.9
Temperature, lower absorber packing – 3	°C	33.2
Temperature, lower absorber packing – 2	°C	32.5
Temperature, lower absorber packing – 1	°C	32.4
Stripping section packing height	m	8
Temperature, stripper packing – 7	°C	102.7
Temperature, stripper packing – 6	°C	103.1
Temperature, stripper packing – 5	°C	104.5
Temperature, stripper packing – 4	°C	107.7
Temperature, stripper packing – 3	°C	112.1
Temperature, stripper packing – 2	°C	114.7
Temperature, stripper packing – 1	°C	119.4

References

[1] Thimsen D, Maxson A, Smith V, Cents T, Falk-Pedersen O, Gorset O, Hamborg ES. Results from MEA testing at the CO_2 Technology Centre Mongstad. Part I: Post-Combustion CO_2 capture testing methodology Energy Procedia 63 5938-5958; 2014.

[2] Gjernes E, Pedersen S, Cents T, Watson G, Fostås BF, Shah MI, Lombardo G, Desvignes C, Flø NE, Morken AK, de Cazenove T, Faramarzi L, Hamborg ES. Results from 30 wt% MEA performance testing at the CO_2 Technology Centre Mongstad. Energy Procedia (GHGT-13), Forthcoming 2017.

[3] American Society of Mechanical Engineers, New York, NY. PTC-4, Fired Steam Generators, 2008.

[4] Hamborg ES, Smith V, Cents T, Brigman N, Falk-Pedersen O, de Cazanove T, Chhagnlal M, Feste JK, Ullestad Ø, Ulvatn H, Gorset O, Askestad I, Gram LK, Fostås BF, Shah MI, Maxson A, Thimsen D. Results from MEA testing at the CO_2 Technology Centre Mongstad. Part II: Verification of baseline results. Energy Procedia 63, 5994-6011; 2014.