W1 Kiln HCl Abatement Trials – 2018/19

Introduction

During the production of Dolofrit®, the emission of HCl from kiln W1 is too high for the impending IED limit. On 1st of January 2020 this will be reduced to 10mg/m^3 from the current derogation of 200mg/m^3. As this represents a grave threat to the future operation of the kiln, since 2016, a number of abatement trials have been carried out involving, caustic soda, hydrated lime (Sorbacal® SP & SPS) and milk-of-lime (Neutralac® SLS45). This report details the recent trials involving Sorbacal® SPS.

Figure 1: W1 Rotary Kiln.

Table 1: Typical W1 Gas Emission Data, 2018.

	Average	IED Limit	Units
Gas Flow	307798	-	m^3/h
HCL	106	10	mg/m^3
SO_2	710	400	mg/m^3
HF	0.3	1	mg/m^3
Injection Temp.	375	-	^oC

Background

As previously mentioned trials of a similar nature were carried out; therefore prior to installation, advice from Lhoist's Business and Innovation Centre was sought and taken into consideration which consisted of:

- Injecting Sorbacal® SPS at rates of approx. 500 kg/h
- Adaptation of temperature to around 300°C, preferably by upstream water injection.
    - Avoid using air dampers
- Multiple injection points (minimum 4) to maximize natural in-duct dispersion
    - Position lances vertically at the ⅓ and ⅔ distances
    - Penetrate duct by a ¼ depth
- HCl cannot be removed selectively without abating a significant amount of SO_2 first

As well, a CFD analysis was carried out for optimized lime injection and dispersion within the duct. Multiple simulations of different injection configurations were executed; this can be viewed in the appendix. Ultimately, the configuration displayed in figure 2 was selected as it was the favoured arrangement in relation to equal sorbent distribution.

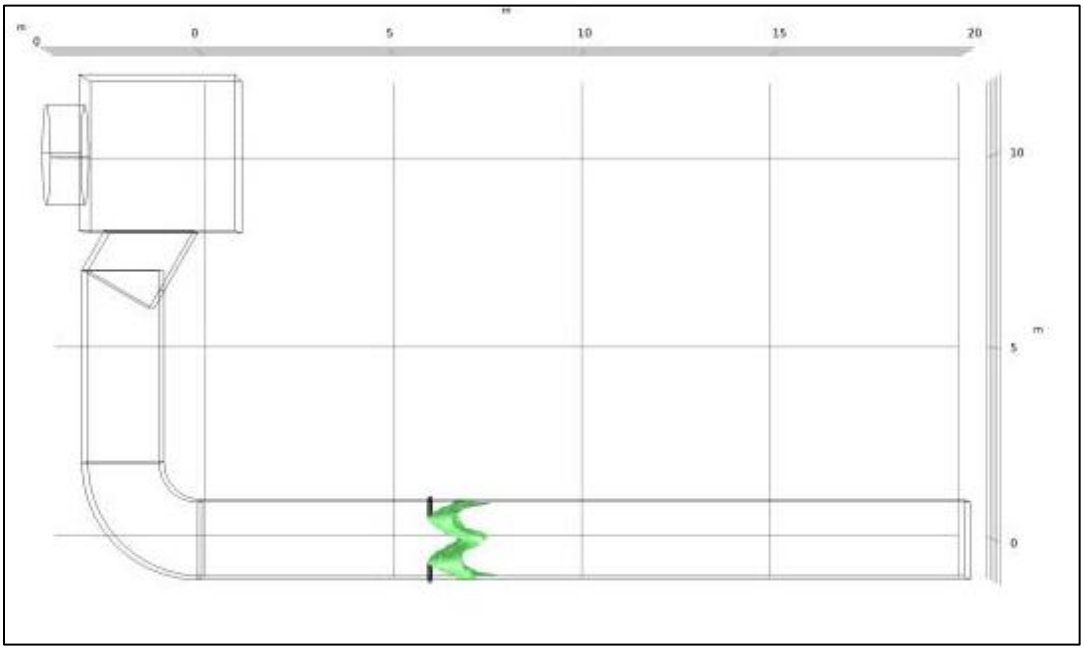

Figure 2: Injection downstream in the straight section.

It is important that the term "abatement" is defined to allow comparisons to be made and success to be quantified. Henceforward, it will be expressed as a percentage using the equation below:

$$\frac{initial\ level\ -\ abated\ level}{initial\ level} \times 100$$

E.g. initial level of 120mg/m^3 is reduced to 40mg/m^3, this is 67% abatement. Additionally, Initial level is expressed as the average HCl for the 2 hours prior to sorbent injection.

Method

HCl reduction is achieved by installing a dosing rig which is a device designed to inject FIBC Big Bags of Sorbacal® SPS into an existing flue gas duct. The Big Bags are attached securely on to the rig, where they are untied once positioned on the hopper. The addition-rate of the material is controlled with a variable-speed screw and pneumatically conveyed using positive pressure generated by a side channel blower. The blower transports the material to a splitter manifold, which conveys the reagent through 4 individual lines simultaneously from one source to the existing flue gas duct entry positions. As well as sorbent injection, phases of the trial involved adding atomised water to reduce the temperature profile of the duct.

Figure 3: Injection Assembly.

Trial Results

<u>30/11/2018</u>

Table 2: Fuel Ratio.

Fuel	Coke	Coal	Solvent
Percentage	33.3%	33.3%	33.3%

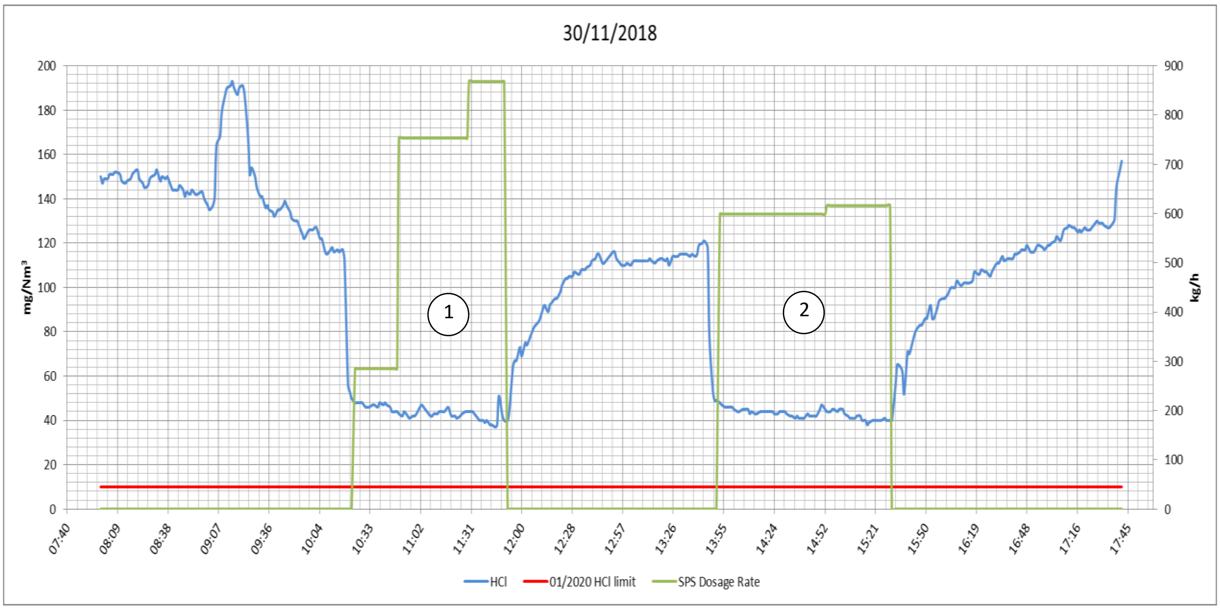

Figure 4: HCl v Dosage Rate.

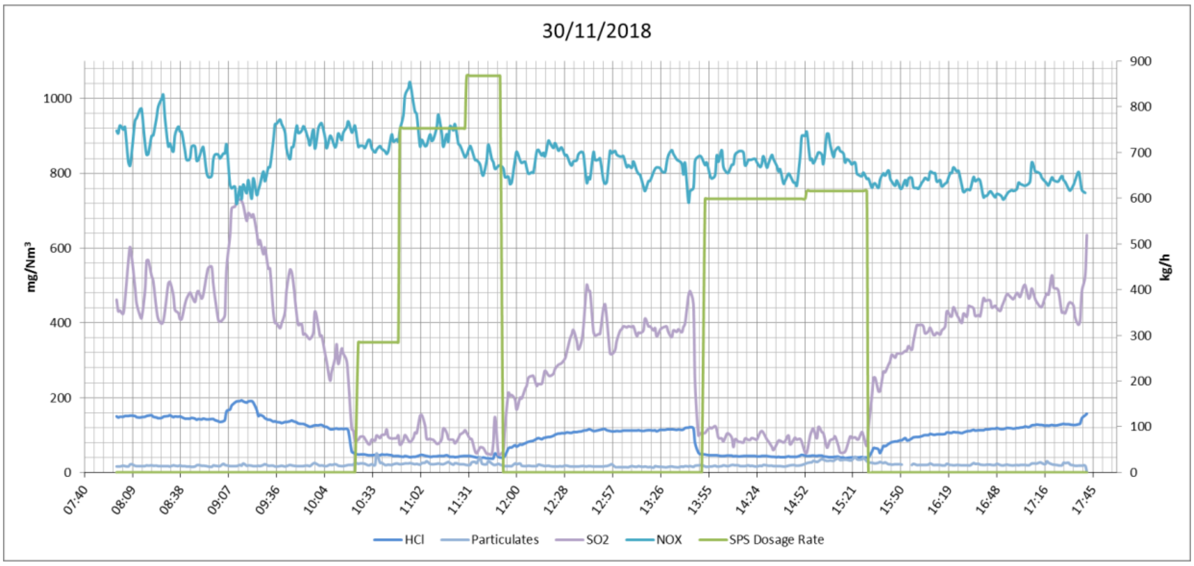

Figure 5: Emissions v Dosage Rate.

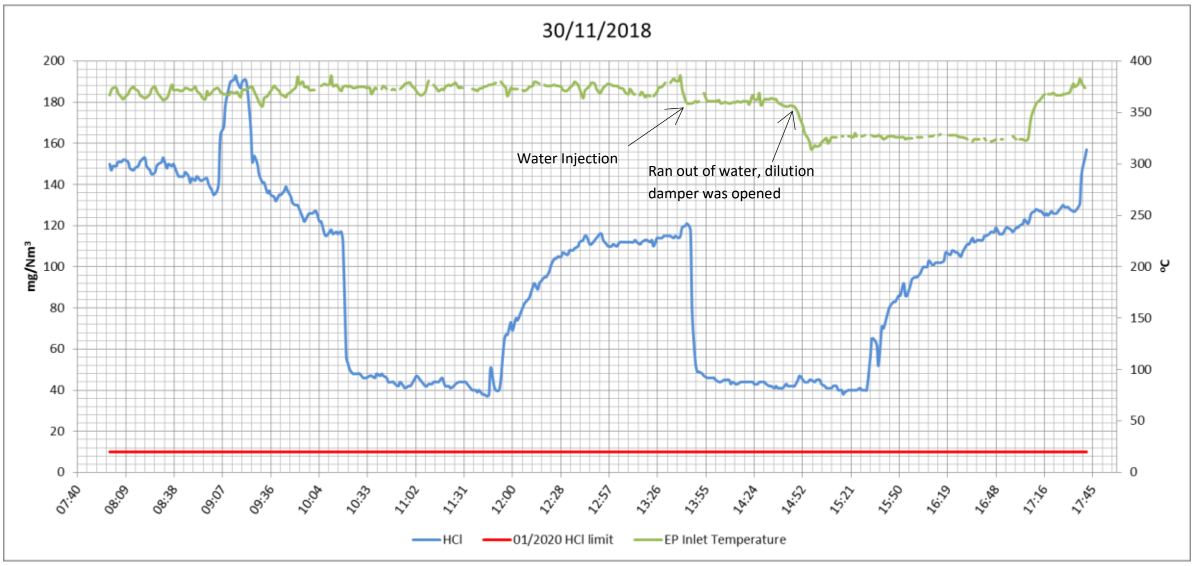

Figure 6: HCl v Temperature.

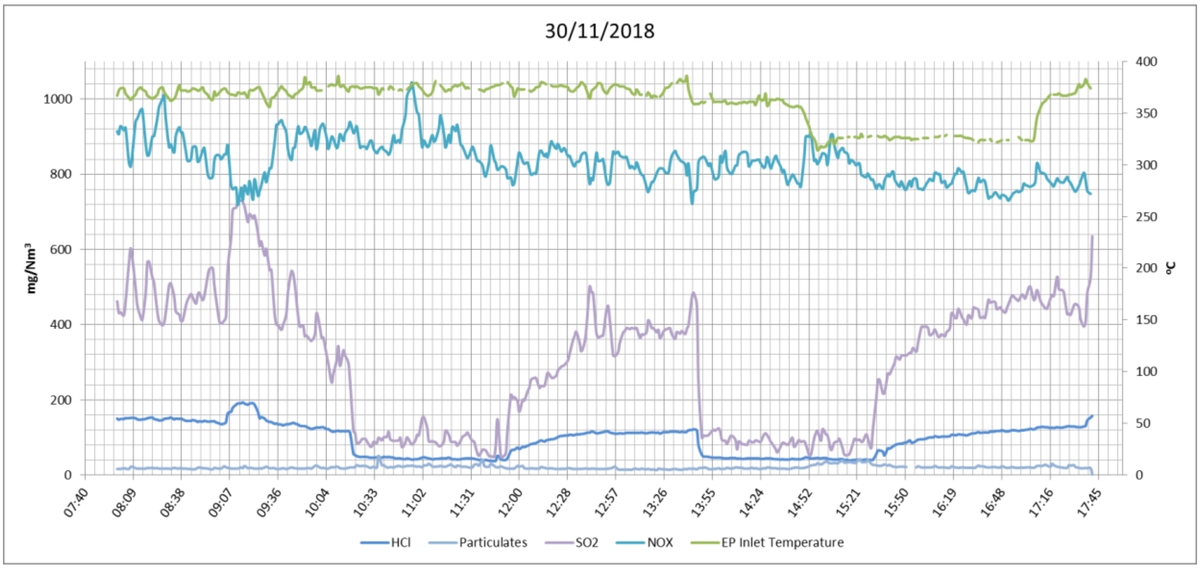

Figure 7: Emissions v Temperature.

Table 3: Average Abatement of HCl using Sorbacal SPS.

	Initial level of HCl	143.9	mg/Nm3
1st Phase	Avg. HCl with Sorbent	43.7	mg/Nm3
	Avg. Abatement	69.7	%
2nd Phase	Avg. HCl with Sorbent	43.0	mg/Nm3
	Avg. Abatement	70.1	%

11/03/2019

Table 4: Fuel Ratio.

Fuel	Coke	Coal	Solvent
Percentage	76.5%	-	23.5%

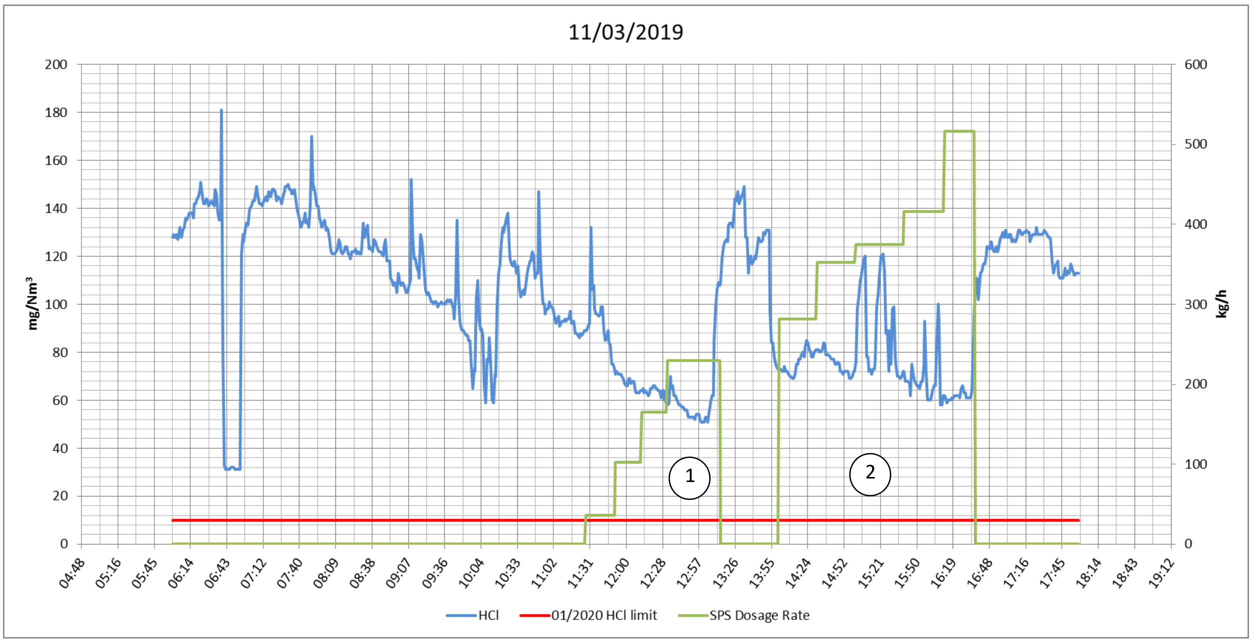

Figure 8: HCl v Dosage Rate.

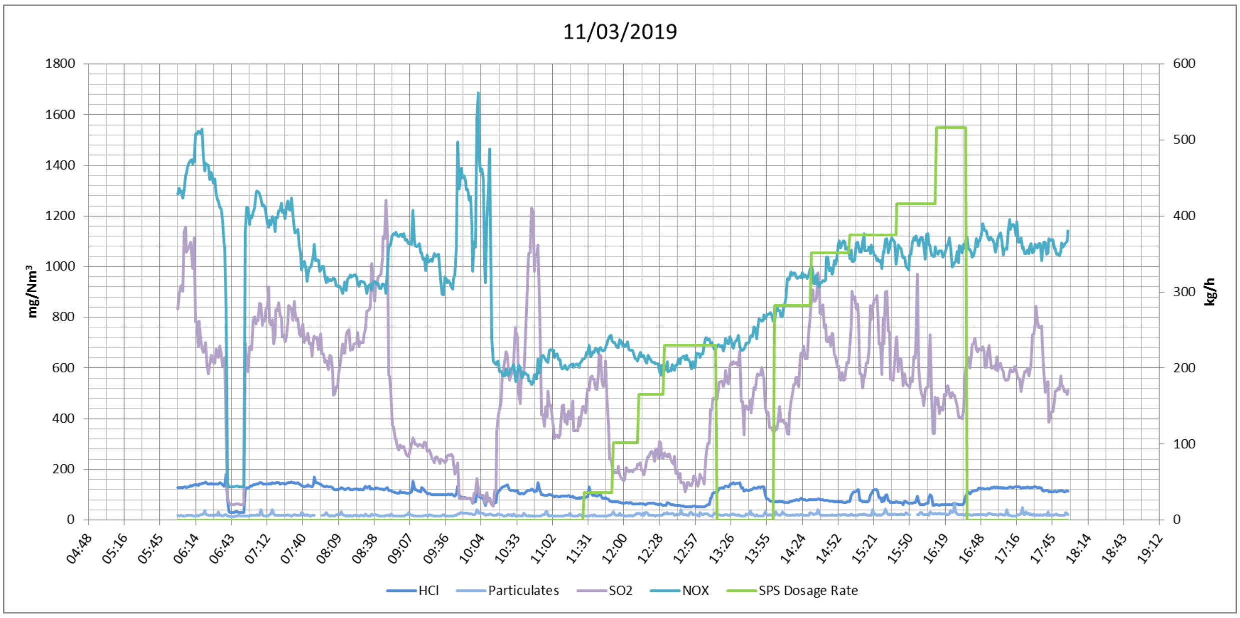

Figure 9: Emissions v Dosage Rate.

Table 5: Average Abatement of HCl using Sorbacal SPS.

	Initial level of HCl	99.1	mg/Nm3
1st Phase	Avg. HCl with Sorbent	70.1	mg/Nm3
	Avg. Abatement	29.3	%
2nd Phase	Avg. HCl with Sorbent	76.2	mg/Nm3
	Avg. Abatement	23.1	%

<u>12/03/2019</u>

Table 6: Fuel Ratio.

Fuel	Coke	Coal	Solvent
Percentage	84.7%	-	15.3%

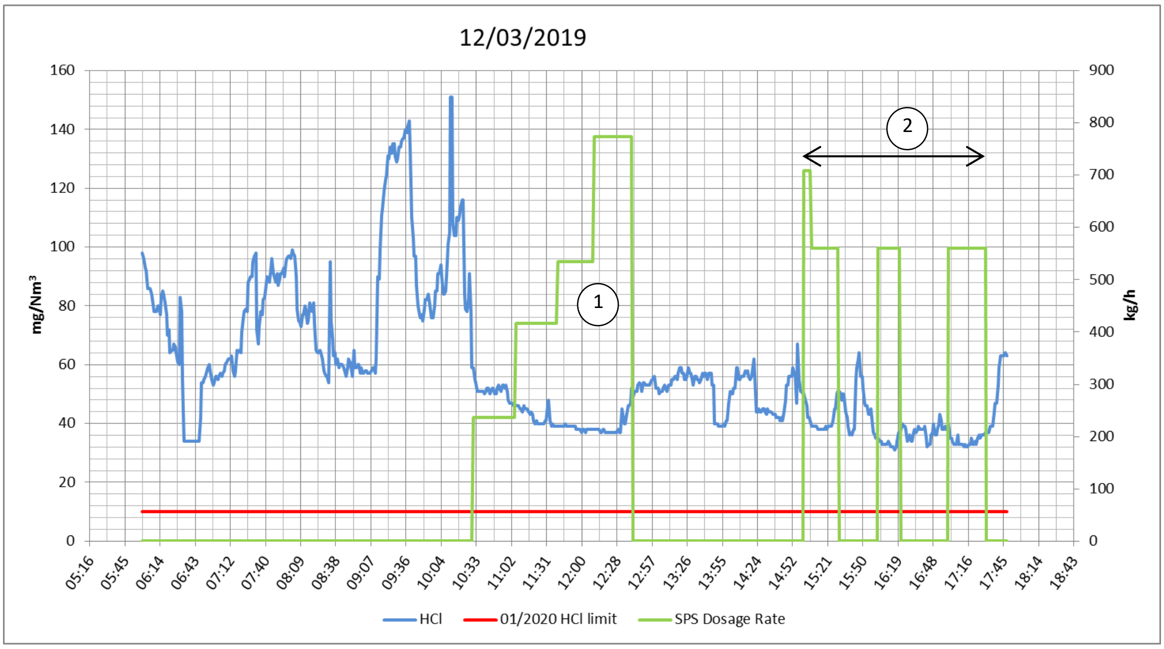

Figure 10: HCl v Dosage Rate.

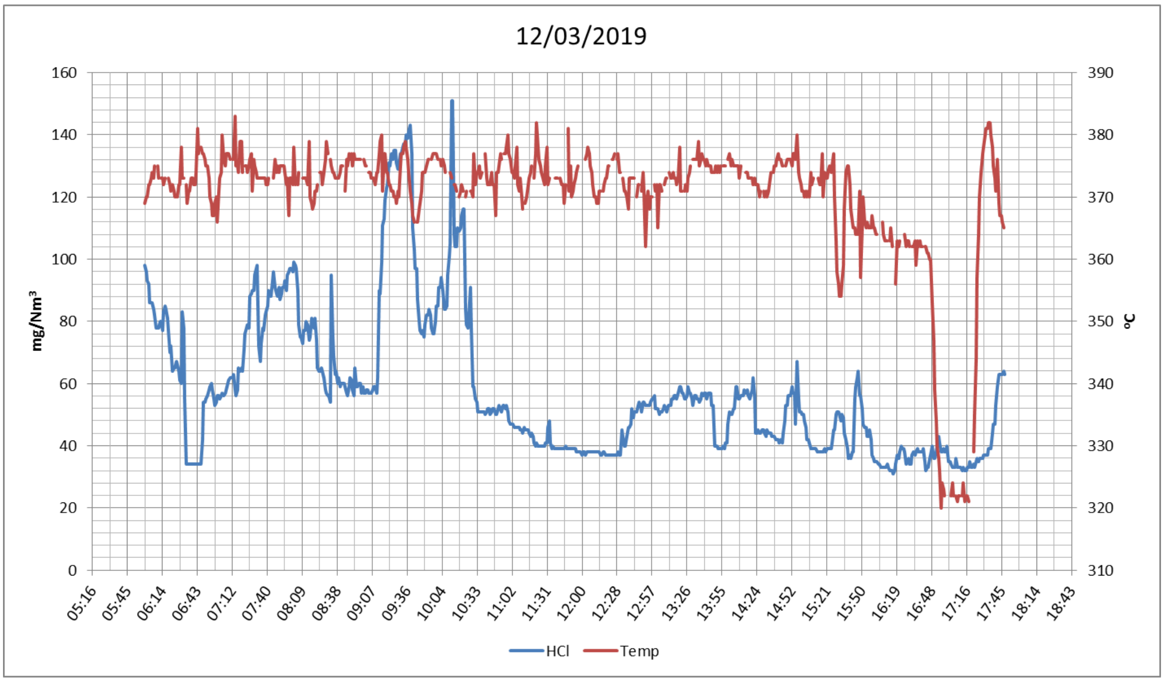

Figure 11: HCl v Temp.

Table 7: Average Abatement of HCl using Sorbacal SPS.

	Initial level of HCl	89.2	mg/Nm3
1st Phase	Avg. HCl with Sorbent	43.1	mg/Nm3
	Avg. Abatement	51.7	%
2nd Phase	Avg. HCl with Sorbent	36.6	mg/Nm3
	Avg. Abatement	58.9	%

25/03/2019

Table 8: Fuel Ratio.

Fuel	Coke	Coal	Solvent
Percentage	72.2%	-	27.8%

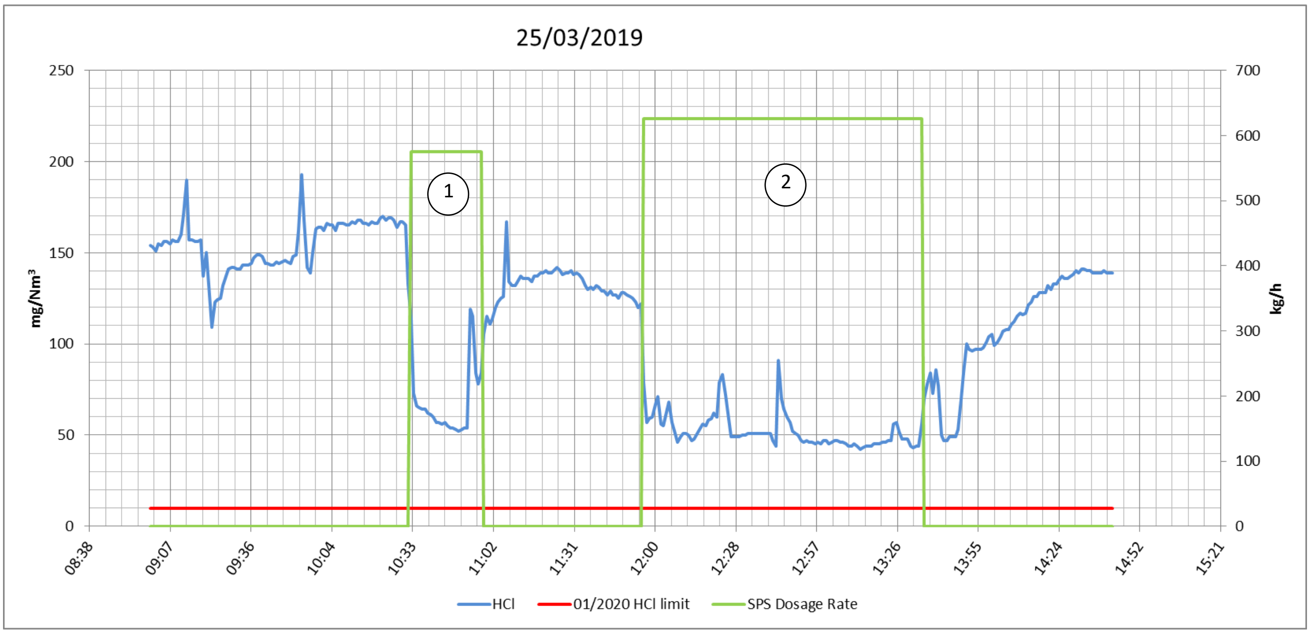

Figure 12: HCl v Dosage Rate.

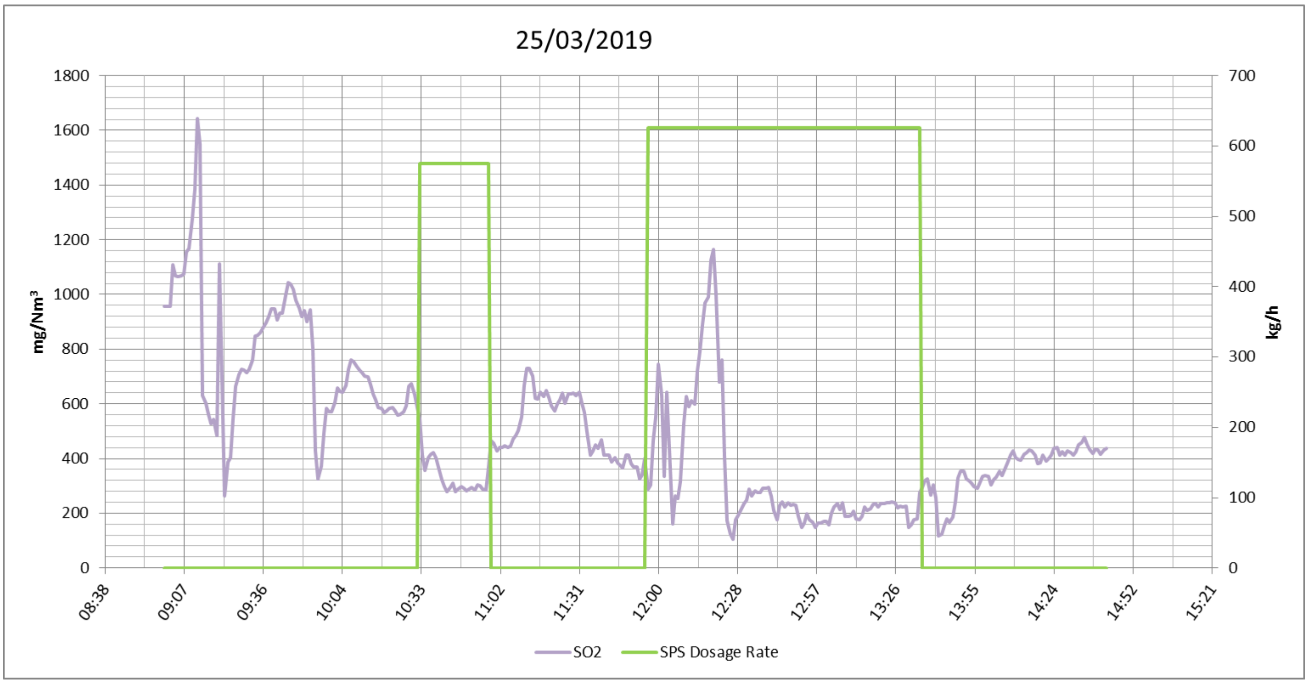

Figure 13: SO2 v Dosage Rate.

Table 9: Average Abatement of HCl using Sorbacal SPS.

	Initial level of HCl	154.8	mg/Nm3
1st Phase	Avg. HCl with Sorbent	67.8	mg/Nm3
	Avg. Abatement	56.2	%
2nd Phase	Avg. HCl with Sorbent	52.1	mg/Nm3
	Avg. Abatement	66.4	%

Trial Analysis

30/11/2018 Figure 4-7

One of the recommendations from the Sorbacal SP trial in 2015 was to see if higher dosage rates can be achieved. The highest realised rate was 203 kg/h, which was not enough to decrease the level of HCl below 10mg/Nm³, hence the objective of this trial was to see if rates of up to 500kg/h and greater can be accomplished, with the calculated dosage rate in the appendix clarifying why a high rate is required. For this trial, a different calibre of dosing rig was selected and this piece of equipment achieved a maximum dosing rate of 868 kg/h.

Another recommendation from 2015 was to decrease the temperature profile with water injection to avoid re-carbonation, thus lowering the reagent consumption. This was implemented in the second phase of the trial from 13:43 to 14:38, where the average temperature was lowered from 375°C to 361°C. It was short lived as the water supply had ran out, consequently the air dilution damper was opened to reduce the temperature even further to 325 °C. Opening the dilution damper meant that the oxygen content increased significantly. This is measured by the CEMS and used to correct the gas-values to reference conditions. This has the effect of diminishing the apparent abatement performance.

It can be seen in both phases of the trial that significant abatement of HCl and SO_2 reached 70% and 80% respectively. During injection, the average SO_2 level was 89.2 mg/Nm³ which is well below the proposed limit of 400mg/Nm³. However the lowest level of HCl achieved was 37 mg/Nm³, which is still far off the desired target; consequently a further trial was carried out to investigate this issue.

11/03/2019 Figure 8 & 9

The objective of this trial was to determine whether HCl abatement is proportional to Sorbacal dosage rate (plateau – area of stability I.e. incrementally increase dosage rate every ~30 mins). It can be seen in figure 8 that it struggled which can be put down to a lack of sorbent being injected and a high level of SO_2 that was preferentially abated.

12/03/2019 – Figure 10 & 11

The first phase of the following day continued the same objective by incrementally increasing the dosage rate whilst monitoring its effect on the emissions. It became evident that the dosage rate had reached a point where little to no effect on HCl had occurred against a high consumption of reagent. It was clear to see that the dosage rate had reached an area of little variation around 420 – 534 kg/h, this range also corresponds to the calculated dosage rate in the appendix. The second phase of trial involved dosing whilst manipulating parameters such as gas volume and temperature:

A. *Sorbacal SPS at 375°C (with air dilution damper – normal conditions)*
    a. The first step was to alter the dosage level close to the determined range of 420 – 534 kg/hr. A decrease from 708 to 560 kg/hr is displayed.
B. *Sorbacal SPS at 375°C (close of air dilution damper using water injection)*
    a. This did not carry on for so long as a blockage in the reagent injection line had occurred.
C. *Sorbacal SPS at 300 - 350°C (water injection only)*
    a. Water injection was used to reduce the temperature to 325°C with the dilution damper closed. This was to check the effectiveness of Sorbacal SPS at the reduced temperature.

In general, over the two phases a good level of abatement (51 – 58%) was achieved however it is still far from the 90% abatement desired.

<u>25/03/2019 – Figure 12 & 13</u>

This trial run shows that a high level of abatement can be achieved without the need to alter gas temperature and volume.

Financial Considerations

Table 10: Cost of Sorbacal & Landfill Discharge if HCl Limit is 100mg/m³

Cost Dash Board 100 limit				Waste Fuel Cost / Hr	72.18	Doloflour t/hr	2.5	Tipping cost / t	150	
Month	Cost of Sorbacal	Tonnes produced	Dolofrit hours	Hours unable to abate	Cost of lost Solvent	Toal cost	Cost / T		Doloflour production	Hazardous waste tipping cost
Jan-18	7482.10	4024	351	0	0	7482.10	£ 1.86		877.5	131625
Feb-18	7302.09	3965	389	0	0	7302.09	£ 1.84		972.5	145875
Mar-18	3009.24	2884	151	0	0	3009.24	£ 1.04		377.5	56625
Apr-18	5650.36	4261	350	0	0	5650.36	£ 1.33		875	131250
May-18	5475.13	5778	443	0	0	5475.13	£ 0.95		1107.5	166125
Jun-18	9193.56	3192	615	6	433.08	9626.64	£ 3.02		1537.5	230625
Jul-18	9236.76	7275	560	9	649.62	9886.38	£ 1.36		1400	210000
Aug-18	3944.08	3417	385	1	72.18	4016.26	£ 1.18		962.5	144375
Sep-18	656.09	4658	413	0	0	656.09	£ 0.14		1032.5	154875
Oct-18	3441.86	5448	498	2	144.36	3586.22	£ 0.66		1245	186750
Nov-18	1642.56	4505	419	2	144.36	1786.92	£ 0.40		1047.5	157125
Dec-18	1653.83	3258	319	0	0	1653.83	£ 0.51		797.5	119625
									Hazardous waste tipping cost	
		Total Production	Total Hours	Total Lost SDF hrs		Total Cost	Cost / T		Total Cost	Cost / T
		52665	4893	20		£ 60,131.25	£ 1.14		£ 1,834,875.00	£ 34.84

Table 11: Cost of Sorbacal & Landfill Discharge if HCl Limit is 75mg/m³

Cost Dash Board 75 limit				Waste Fuel Cost / Hr	72.18	Doloflour t/hr	2.5	Tipping cost / t	150	
Month	Cost of Sorbacal	Tonnes produced	Dolofrit hours	Hours unable to abate	Cost of lost Solvent	Toal cost	Cost / T		Doloflour production	Hazardous waste tipping cost
Jan-18	12568.47	4024	351	2	144.36	12712.83	£ 3.16		877.5	131625
Feb-18	12904.45	3965	389	0	0	12904.45	£ 3.25		972.5	145875
Mar-18	5099.51	2884	151	0	0	5099.51	£ 1.77		377.5	56625
Apr-18	9604.64	4261	350	2	144.36	9749.00	£ 2.29		875	131250
May-18	10624.04	5778	443	0	0	10624.04	£ 1.84		1107.5	166125
Jun-18	16071.48	3192	615	15	1082.7	17154.18	£ 5.37		1537.5	230625
Jul-18	16327.88	7275	560	14	1010.52	17338.40	£ 2.38		1400	210000
Aug-18	7772.21	3417	385	5	360.9	8133.11	£ 2.38		962.5	144375
Sep-18	1987.35	4658	413	2	144.36	2131.71	£ 0.46		1032.5	154875
Oct-18	7303.46	5448	498	5	360.9	7664.36	£ 1.41		1245	186750
Nov-18	2963.04	4505	419	6	433.08	3396.12	£ 0.75		1047.5	157125
Dec-18	3473.79	3258	319	0	0	3473.79	£ 1.07		797.5	119625
									Hazardous waste tipping cost	
		Total Production	Total Hours	Total Lost SDF hrs		Total Cost	Cost / T		Total Cost	Cost / T
		52665	4893	51		£ 110,381.50	£ 2.10		£ 1,834,875.00	£ 34.84

Table 12: Cost of Sorbacal & Landfill Discharge if HCl Limit is 50mg/m³

Cost Dash Board 50 limit				Waste Fuel Cost / Hr	72.18	Doloflour t/hr	2.5	Tipping cost / t	150	
Month	Cost of Sorbacal	Tonnes produced	Dolofrit hours	Hours unable to abate	Cost of lost Solvent	Toal cost	Cost / T		Doloflour production	Hazardous waste tipping cost
Jan-18	6255.01	4024	351	218	15735.24	21990.25	£ 5.46		877.5	131625
Feb-18	8948.29	3965	389	202	14580.36	23528.65	£ 5.93		972.5	145875
Mar-18	2890.13	2884	151	83	5990.94	8881.07	£ 3.08		377.5	56625
Apr-18	8783.10	4261	350	119	8589.42	17372.52	£ 4.08		875	131250
May-18	14175.23	5778	443	93	6712.74	20887.97	£ 3.62		1107.5	166125
Jun-18	15115.69	3192	615	223	16096.14	31211.83	£ 9.78		1537.5	230625
Jul-18	17862.22	7275	560	193	13930.74	31792.96	£ 4.37		1400	210000
Aug-18	11770.01	3417	385	64	4619.52	16389.53	£ 4.80		962.5	144375
Sep-18	6462.51	4658	413	5	360.9	6823.41	£ 1.46		1032.5	154875
Oct-18	12795.67	5448	498	53	3825.54	16621.21	£ 3.05		1245	186750
Nov-18	6994.21	4505	419	36	2598.48	9592.69	£ 2.13		1047.5	157125
Dec-18	7809.56	3258	319	12	866.16	8675.72	£ 2.66		797.5	119625
									Hazardous waste tipping cost	
		Total Production	Total Hours	Total Lost SDF hrs		Total Cost	Cost / T		Total Cost	Cost / T
		52665	4893	1301		£ 213,767.82	£ 4.06		£ 1,834,875.00	£ 34.84

Table 13: Cost of Sorbacal & Landfill Discharge if HCl Limit is 10mg/m³

Cost Dash Board 10 limit				Waste Fuel Cost / Hr	72.18	Doloflour t/hr	2.5	Tipping cost / t	0	
Month	Cost of Sorbacal	Tonnes produced	Dolofrit hours	Hours unable to abate	Cost of lost Solvent	Toal cost	Cost / T		Doloflour production	Hazardous waste tipping cost
Jan-18	0.00	4024	351	345	24902.1	24902.10	£ 6.19		877.5	0
Feb-18	112.83	3965	389	387	27933.66	28046.49	£ 7.07		972.5	0
Mar-18	102.15	2884	151	148	10682.64	10784.79	£ 3.74		377.5	0
Apr-18	0.00	4261	350	345	24902.1	24902.10	£ 5.84		875	0
May-18	0.00	5778	443	443	31975.74	31975.74	£ 5.53		1107.5	0
Jun-18	0.00	3192	615	615	44390.7	44390.70	£ 13.91		1537.5	0
Jul-18	0.00	7275	560	560	40420.8	40420.80	£ 5.56		1400	0
Aug-18	0.00	3417	385	384	27717.12	27717.12	£ 8.11		962.5	0
Sep-18	27.01	4658	413	412	29738.16	29765.17	£ 6.39		1032.5	0
Oct-18	0.00	5448	498	498	35945.64	35945.64	£ 6.60		1245	0
Nov-18	712.15	4505	419	387	27933.66	28645.81	£ 6.36		1047.5	0
Dec-18	0.00	3258	319	318	22953.24	22953.24	£ 7.05		797.5	0
									Hazardous waste tipping cost	
		Total Production	Total Hours	Total Lost SDF hrs		Total Cost	Cost / T		Total Cost	Cost / T
		52665	4893	4842		£ 350,449.70	£ 6.65		£ -	£ -

Tables 10-13, display the financial implications of dosing Sorbacal to comply with various HCl limits. In table 10, the limit value of 100mg/m³ is relatively high meaning SDF can be regular consumed as a fuel and less sorbent is required for abatement. However dosing Sorbacal has a high tipping cost as it will push the free lime content over the 10% limit the Whitwell quarry has for hazardous waste. A high tipping cost is still presented at the 75 and 50mg/m³ limit level as well as increasing sorbent output and less operating hours with SDF fuel, thus contributing to a higher cost (table 11 and 13). Table 13 shows that for a limit level of 10mg/m³ no SDF fuel can be used and more importantly, this level cannot be reached without significant financial investment for a FGT system.

Table 14: Assumed Process Parameters for an Estimated Cost of an FGT System at Lhoist Thrislington, 2016.

Assumptions		Description
650	C	Kiln exit temperature
180	C	Bag filter inlet temperature
362199	m3/hr	Stack gas volume @360C, 12.9% O2 as measured/calculated by Catalyst on testing 3-5th June 2015
62,798	Nm3/hr	Calculated kiln exit volume flow rate as calculated on separate tab
212,316	m3/hr	Calculated kiln exit volume @650C
104,203	m3/hr	Calculated Bag Filter inlet volume @ 180C
31,261	m3/hr	Assumed 20% air inleak
30,000	m3/hr	Volume of water vapour (guess)
2	Factor	Factor of safety for higher production scenario or loss of water cooling
330,927	**m3/hr**	**Total Bag Filter volume**

Table 15: Estimated Cost of an FGT System to Comply with Emission Standards at Lhoist Thrislington, 2016

Cost	Description
£ 1,288,490	Estimate of Conditioning Tower
£ 2,260,676	Bag Filter (328,000m3/hr), fan & ducting
£ 125,000	100T silo with Sorbacal dosing blower
£ 150,000	Engineering time to deliver project
£ 3,824,166	Sub total
£ 764,833	Contingency - 20%
£ 4,588,999	**Total**

Summary of Trials

Table 16: List of Completed HCl Reduction Trials

Date	Material	Dosage	HCl Base-level	Abated HCl	Abatement
10/12/2015	Sorbacal SP	198 kg/h	80	40	50%
18/10/2016	NaOH	165 l/h	21	17	19%
22/01/2018	SLS45	287 l/h	127	65	49%
22/01/2018	SLS45	1639 l/h	125	41	67%
30/11/2018	Sorbacal SPS	500 kg/l	144	43	70%

Recommendations for further work

- The following further tests are proposed which may lead to further abatement improvements
    - There is a theory that the SPS reacts preferentially with SO_2 before abating the HCl. This theory could be evaluated by repeating the trial with coal instead of petcoke to reduce the sulphur input to the kiln
    - Try injecting sorbents at the burner-pipe end of the kiln
    - Try injecting standard grade hydrated lime at the normal gas-duct temperature of 375^0C
- Temperature reduction didn't have any effect on HCl abatement using SPS
- It takes around 1 hour for the HCl to rebound to the underlying level. Thus when carrying out changes in future tests, time should be given to allow for this rebound (1 hour) and for a period of stability (1 hour). Hence a total of two hours between tests.

Conclusions

1. HCl emissions reduce with increased dosing of Sorbacal. There are, however, diminishing returns and there is little improvement for dosing rates above 534 kg/h
2. The best abatement performance was 70%. It is assumed that this could be achieved regularly with a permanent installation. However, given that the average HCl for 2018 was 106mg/m^3, it is assumed that it is possible to get this average down to 32mg/m^3.
3. The abatement performance was not improved by reducing the in-duct gas temperature with water injection
4. It is possible to reduce the reported HCl by just optimising the process parameters without sorbent injection. This can be done by using water injection into the exhaust gas ducting which causes the air-dilution damper to close. The water injection trial (August 2018) reached an apparent abatement of 48%.

Appendix

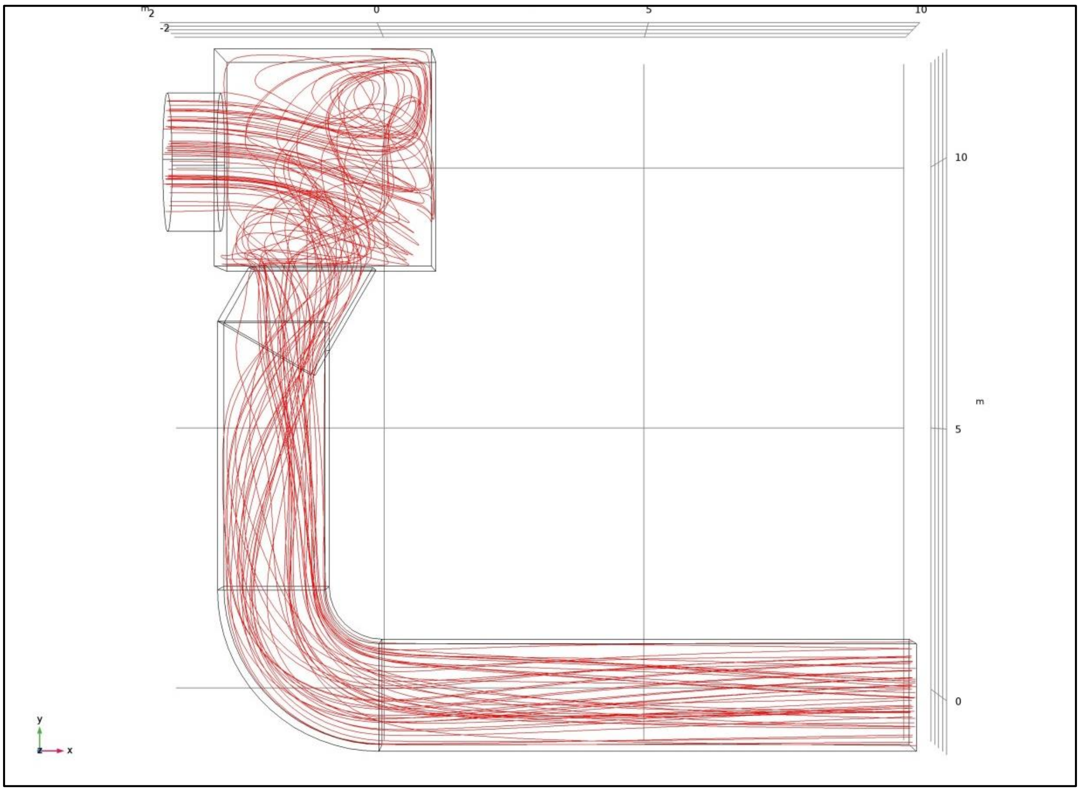

Figure 14: Streamlined Velocity Field of W1 Flue Gas (Z Direction).

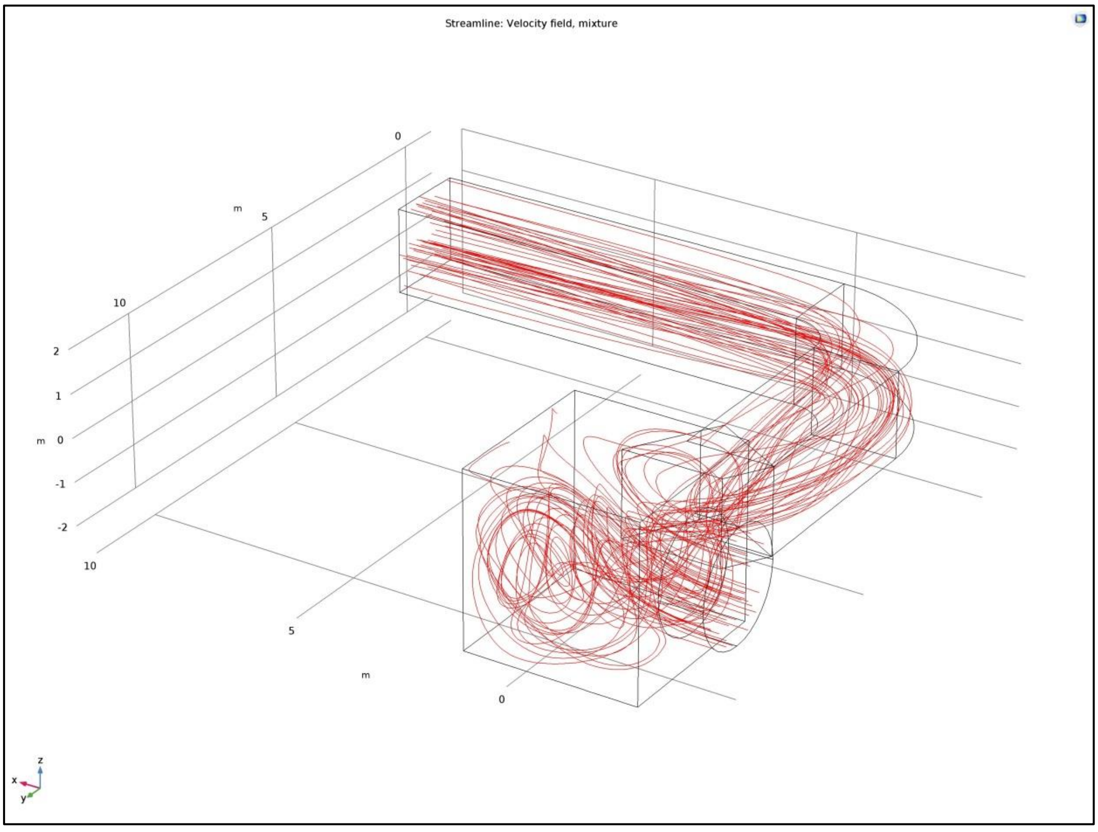

Figure 15: Streamlined Velocity Field of W1 Flue Gas.

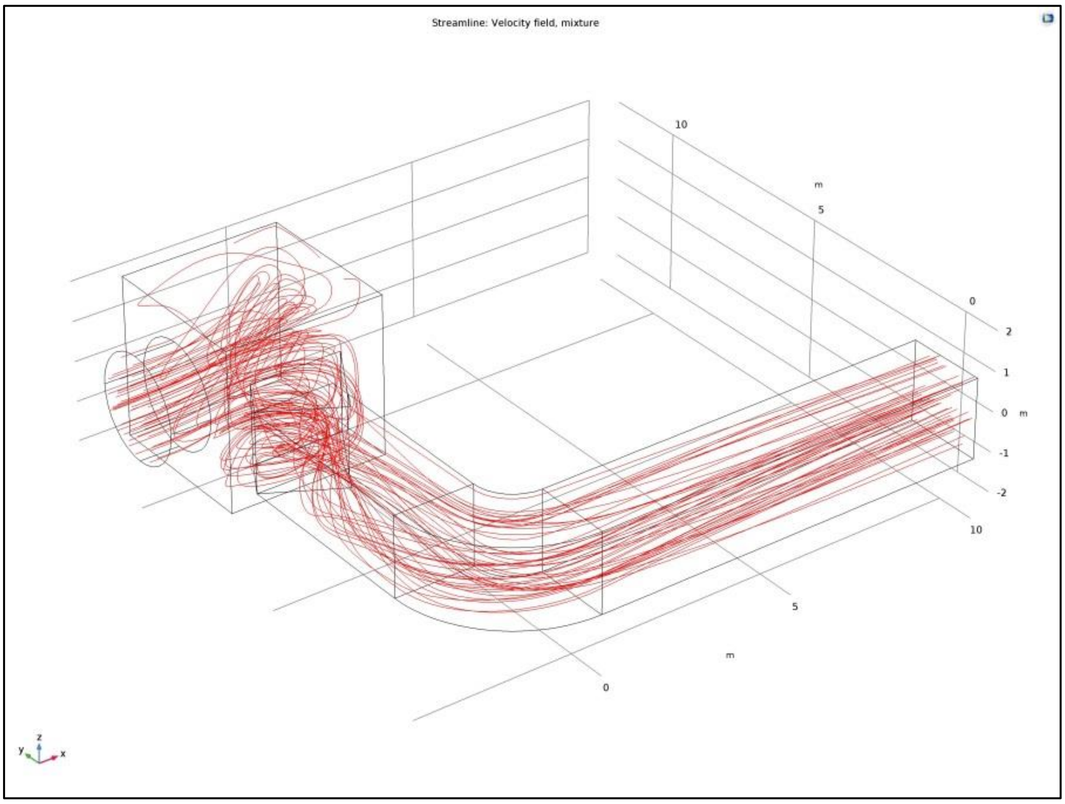

Figure 16: Streamlined Velocity Field of W1 Flue Gas.

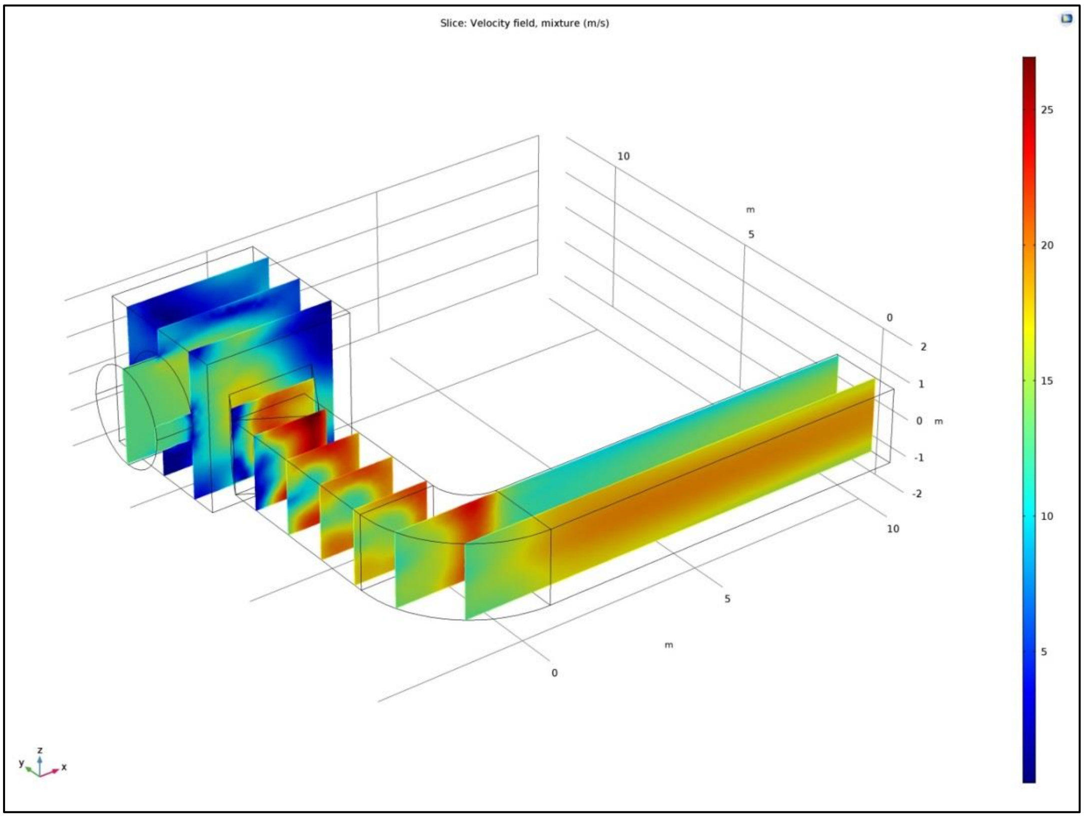

Figure 17: Sliced Velocity Field of W1 Flue Gas.

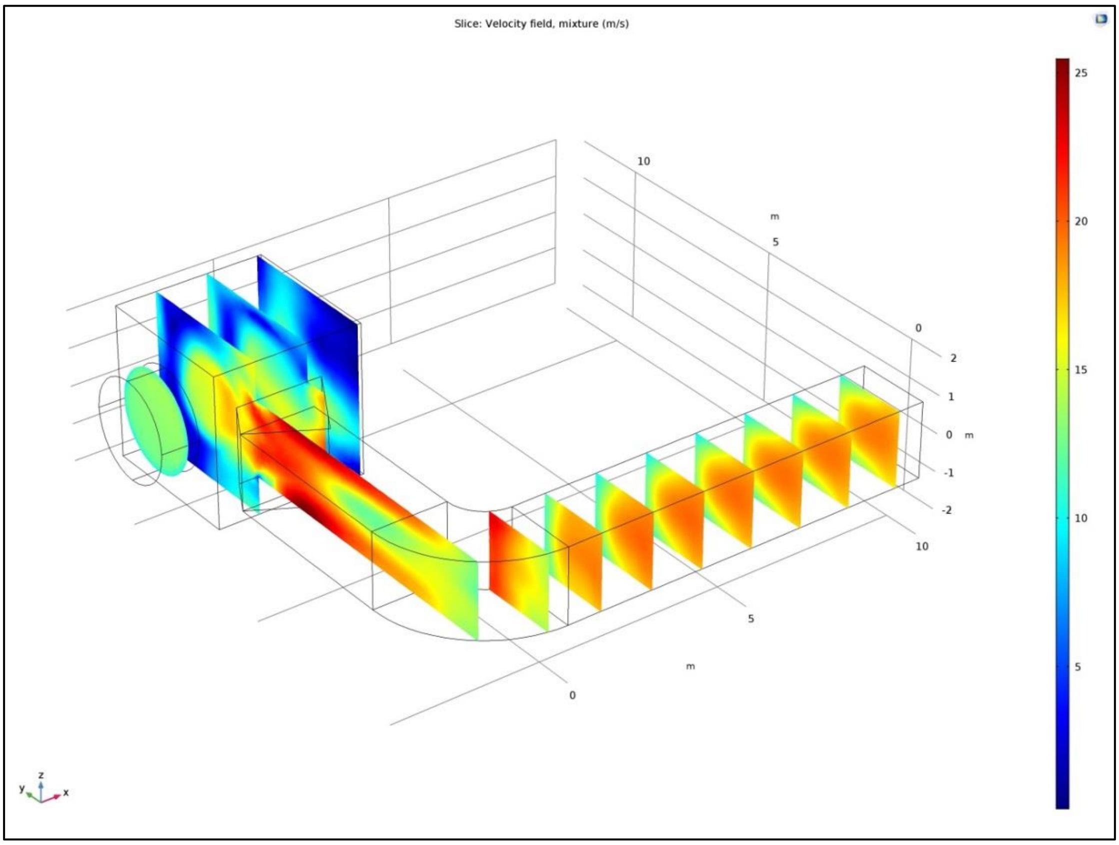

Figure 18: Sliced Velocity Field of W1 Flue Gas.

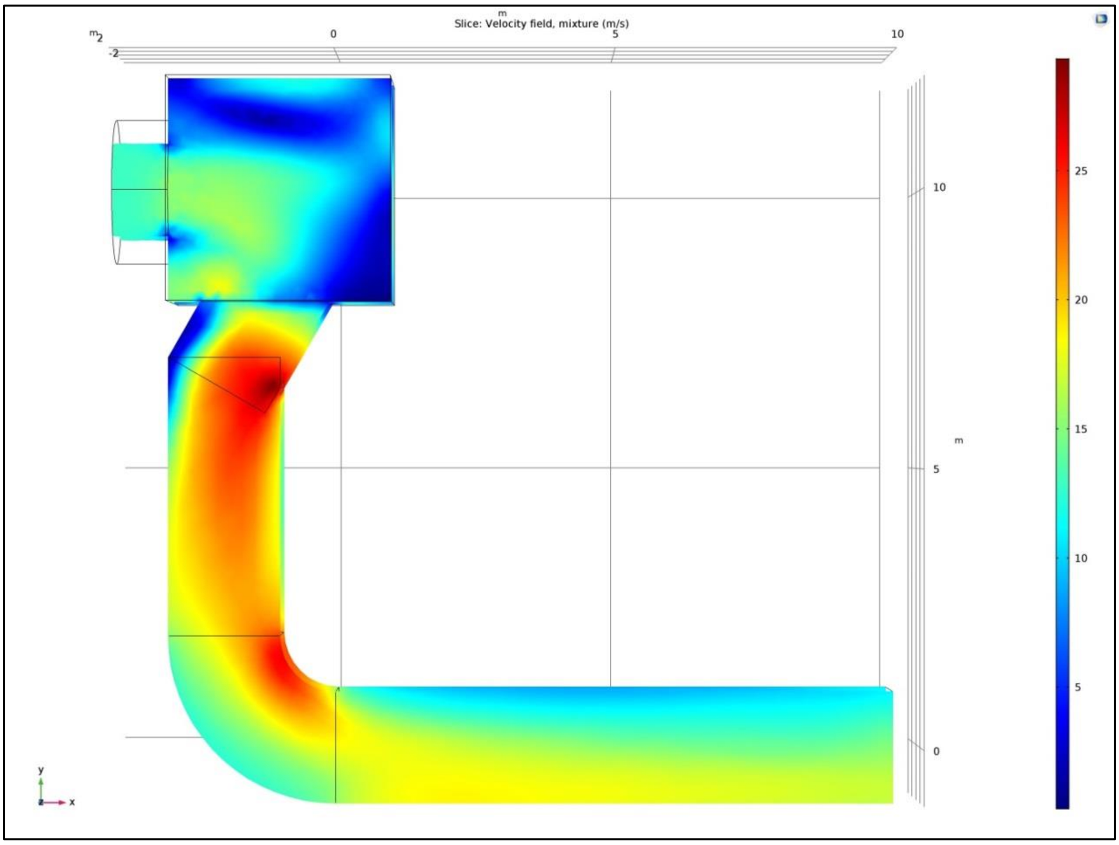

Figure 19: Sliced Velocity Field of W1 Flue Gas (Z Direction).

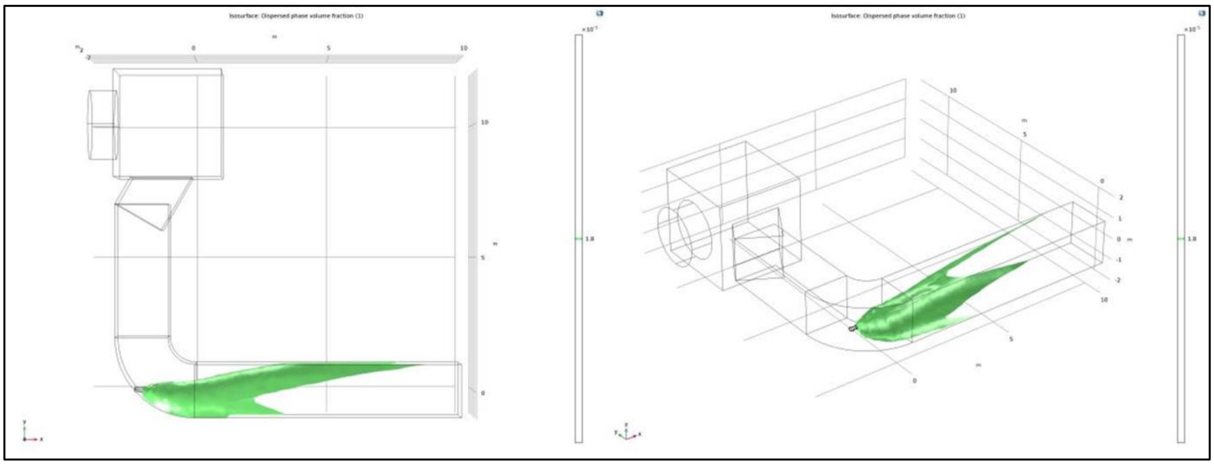

Figure 20: Case 1 - Injection at the elbow with a single injection point. Small penetration positioned at H1/2.

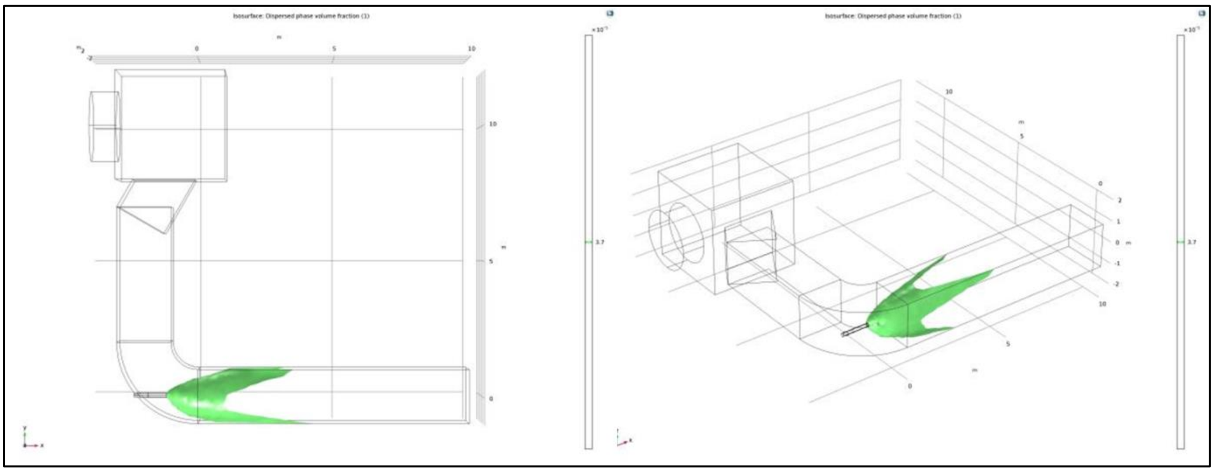

Figure 21: Case 2 - Injection at the elbow with a single injection point. Long penetration positioned at H1/2.

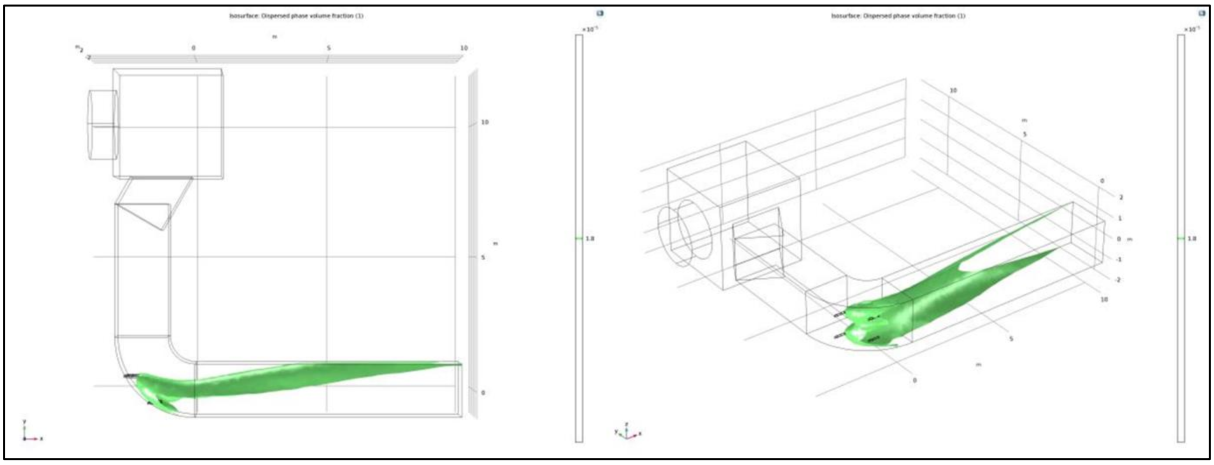

Figure 22: Case 3 - Injection at the elbow with four injection points. Medium penetration positioned at H1/3 & H2/3.

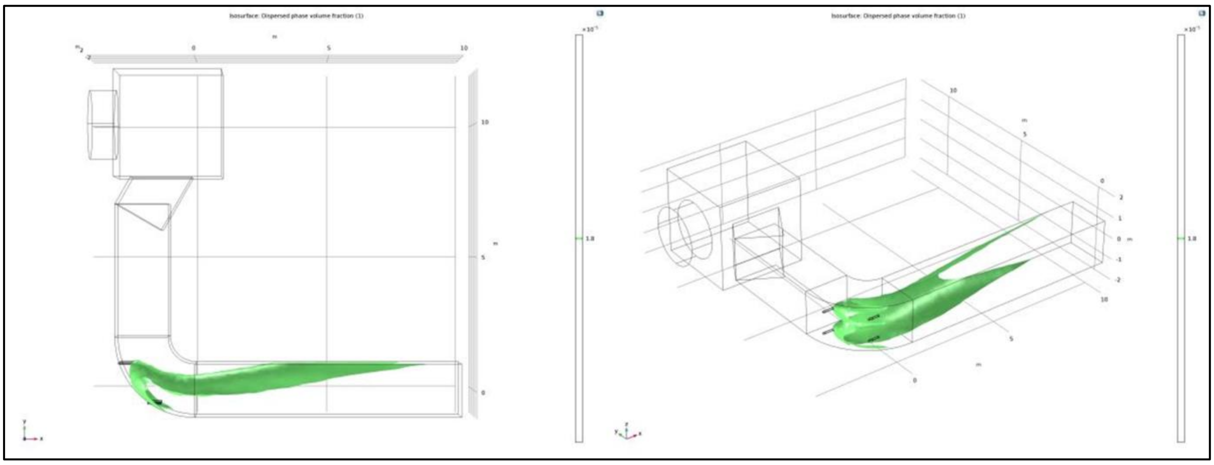

Figure 23: Case 4 - Injection at the elbow with four injection points. Medium penetration positioned at H0 & H2/3.

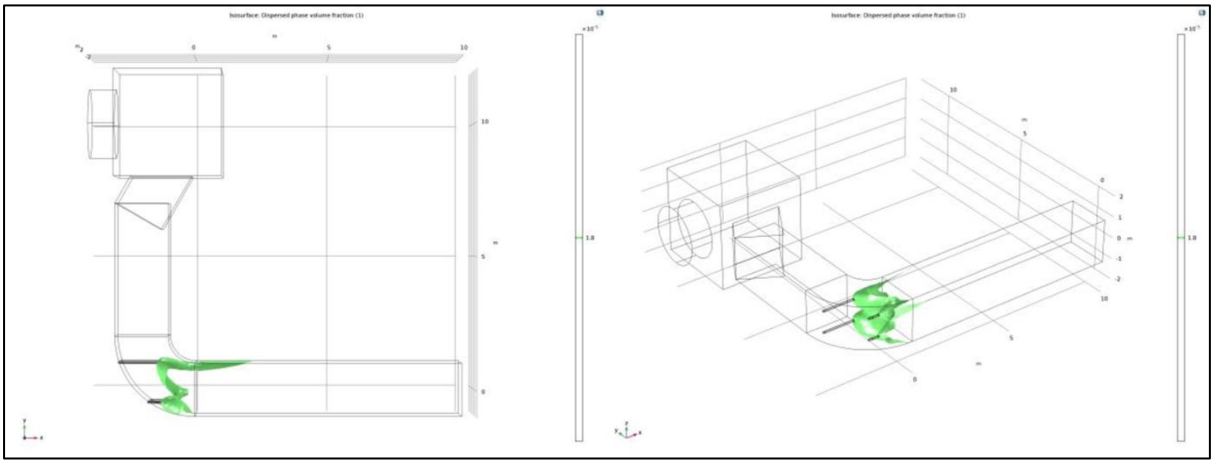

Figure 24: Case 5 - Injection at the elbow with four injection points. Long penetration positioned at H0, medium penetration positioned H2/3.

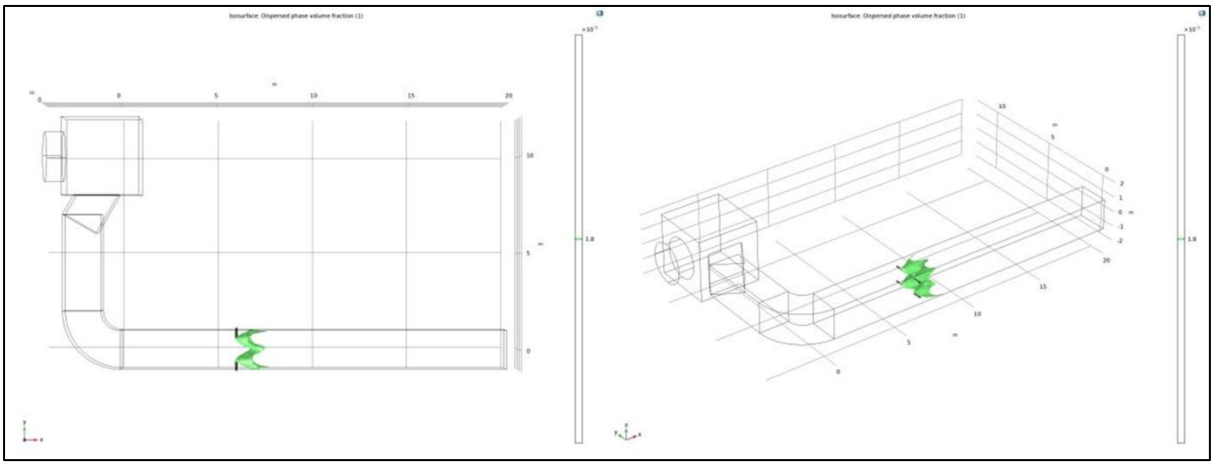

Figure 25: Case 6 - Injection downstream in the straight section with four injection points. ¼ duct penetration at position V1/3 & V2/3.

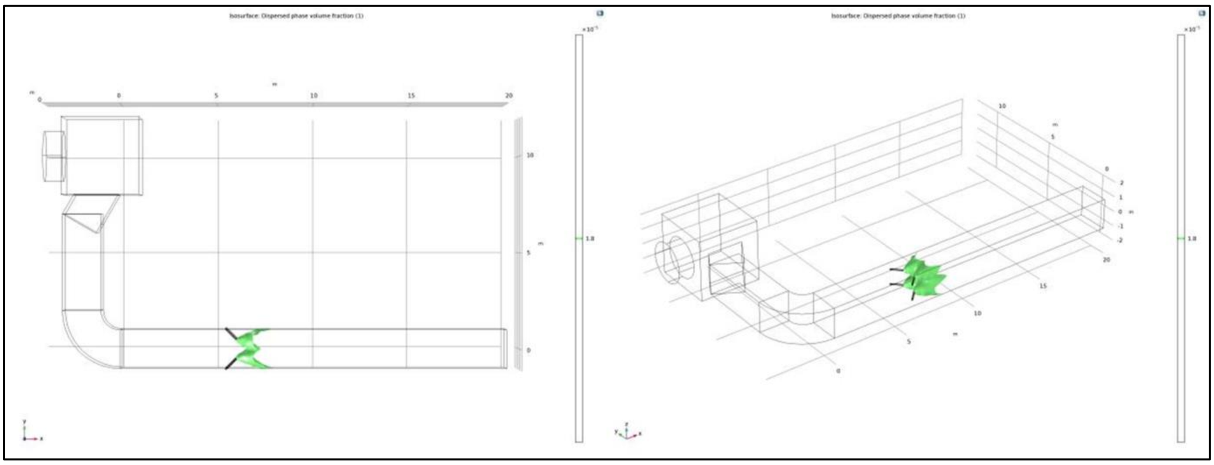

Figure 26: Case 7 - Injection downstream in the straight section with four injection points. ¼ duct penetration at position V1/3 & V2/3 at a 45° angle.

Lime Dosage Rate Estimate

1) Dry corrections for O_2 and Flow Rate

O_2 Dry = O_2 x $\left(\frac{1}{1-H_2O}\right)$ = 12.3% x $\left(\frac{1}{1-7.5\%}\right)$ = 13.3 %

Flow Rate Dry Q = $Flow\ Rate \times (1 - H_2O)$ = 307798 x (1-7.5%) = 284713.15 Nm^3

Flow Rate, O_2 ref = $Flow\ Rate\ Dry\ Q \times \left(\frac{O_{2\,atm} - O_{2\,dry}}{O_{2\,atm} - O_{2\,ref}}\right)$ = 296000 x $\left(\frac{20.9\% - 13.3\%}{20.9\% - 11\%}\right)$ = 218645.4 Nm^3

2) Dry corrections for HCl & SO_2

HCl $_{(wet)}$ x $\left(\frac{1}{1-H20}\right)$ / ($\frac{O_{2\,atm} - O_{2\,dry}}{O_{2\,atm} - O_{2\,ref}}$) = 106 x $\left(\frac{1}{1-7.5\%}\right)$ / $\left(\frac{20.9\% - 13.3\%}{20.9\% - 11\%}\right)$ = 149.22 mg/m^3

SO_2 $_{(wet)}$ x $\left(\frac{1}{1-H20}\right)$ / ($\frac{O_{2\,atm} - O_{2\,dry}}{O_{2\,atm} - O_{2\,ref}}$) = 710 x $\left(\frac{1}{1-7.5\%}\right)$ / $\left(\frac{20.9\% - 13.3\%}{20.9\% - 11\%}\right)$ = 999.5 mg/m^3

HF $_{(wet)}$ x $\left(\frac{1}{1-H20}\right)$ / ($\frac{O_{2\,atm} - O_{2\,dry}}{O_{2\,atm} - O_{2\,ref}}$) = 0.3 x $\left(\frac{1}{1-7.5\%}\right)$ / $\left(\frac{20.9\% - 13.3\%}{20.9\% - 11\%}\right)$ = 0.42 mg/m^3

3) Pollutants to Remove

HCl Dry – HCl Limit = 149.22 - 10 = 139.22

$\left(\frac{139.22}{149.22}\right)$ x 100 = 93.3%

SO_2 Dry – SO_2 Limit = 999.5 - 200 = 799.5

$\left(\frac{799.5}{999.5}\right)$ x 100 = 79.99%

4) Convert to kg

HCl = $\left(\frac{139.22 \times 227232.3}{10^6}\right)$ = 30.44 kg/h

SO_2 = $\left(\frac{799.5 \times 227232.3}{10^6}\right)$ = 174.81 kg/h

5) Lime Required

$$\underset{Ca(OH)_2}{74} + \underset{2HCL}{73} \rightarrow CaCL_2 + 2H_2O$$

Stoichiometric Factor = (74/73) = 1.013

HCl = 30.44 x 1.013 = 30.84 kg/h

$$\underset{Ca(OH)_2}{74} + \underset{SO_2}{64} \rightarrow CaSO_3 + H_2O$$

Stoichiometric Factor = (74/64) = 1.156

SO_2 = 174.81 x 1.156 = 202.08 kg/h

Total HCl & SO_2 = 232.91 kg/h

Standard Hydrate = 3 (SF) x 232.91 = 698.74 kg/h

Sorbacal SP = 2.1 (SF) x 232.91 = 489.12 kg/h

Sorbacal SPS = 2 (SF) x 232.91 = 465.83 kg/h