Corporate Process Development & Innovation
/ A. Aubert

Confidential

NOTE: HCL ABATTEMENT TRIALS ON WHITWELL W1
9th-10th December 2015

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Sorbacal SP injection trials for HCl emission abatement have been performed from December the 9th to the 10th on Whitwell W1.

The objectives were to:

- Validate the suitability of Sorbacal SP dry injection to lower HCl emissions below 10mg/Nm³ when producing Dolofrit. Investigate the potential of this solution for SO2 abatement below 400mg/Nm³.
- Characterize Sorbacal SP abatement performance on W1 (stoichiometric factors) to forecast sorbent consumption.

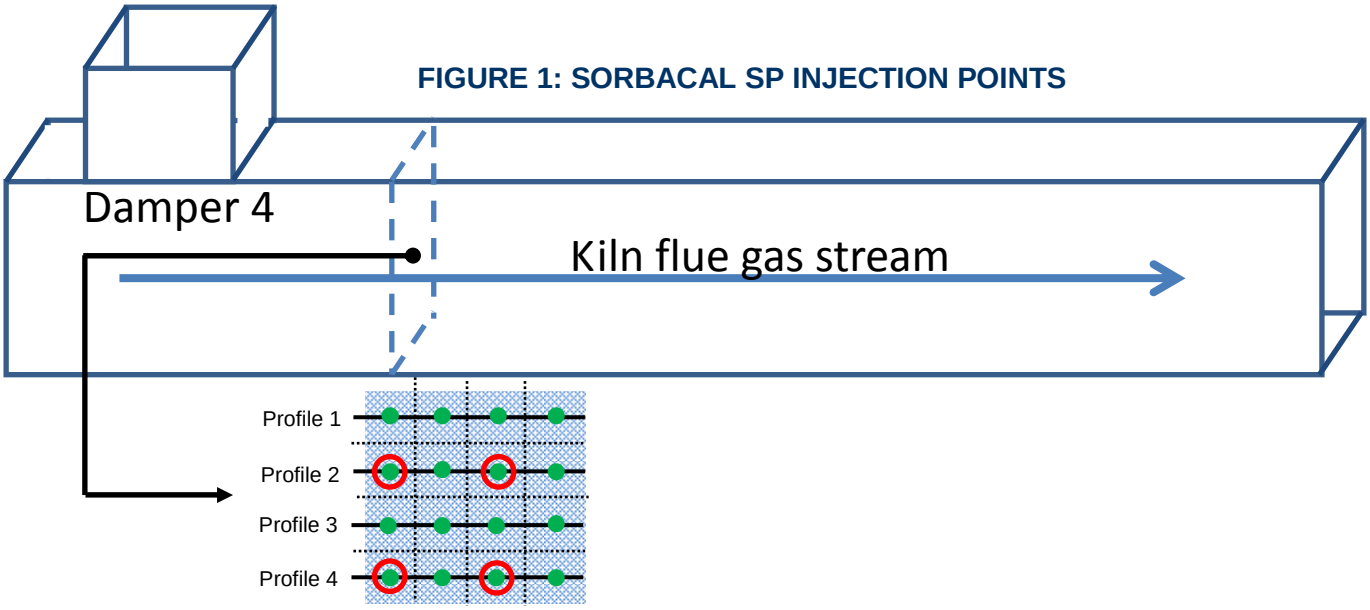
KILN OUTLET SORBACAL SP INJECTION CONDITIONS

Six Sorbacal injection trials have been performed on W1 with Sorbacal SP dosage ranging from 51 to 203kg/h. Maximum planned dosing rate of 500kg/h was not achievable with the received dosing rig.

In the figure below are presented the 4 injection points positions (red circles).

During the trials the kiln was producing Dolofrit between 320 to 360tph. The fuel mix was petcoke (3.4 to 4.1tph) + solvent (706 to 1241Lph).

FIGURE 1: SORBACAL SP INJECTION POINTS



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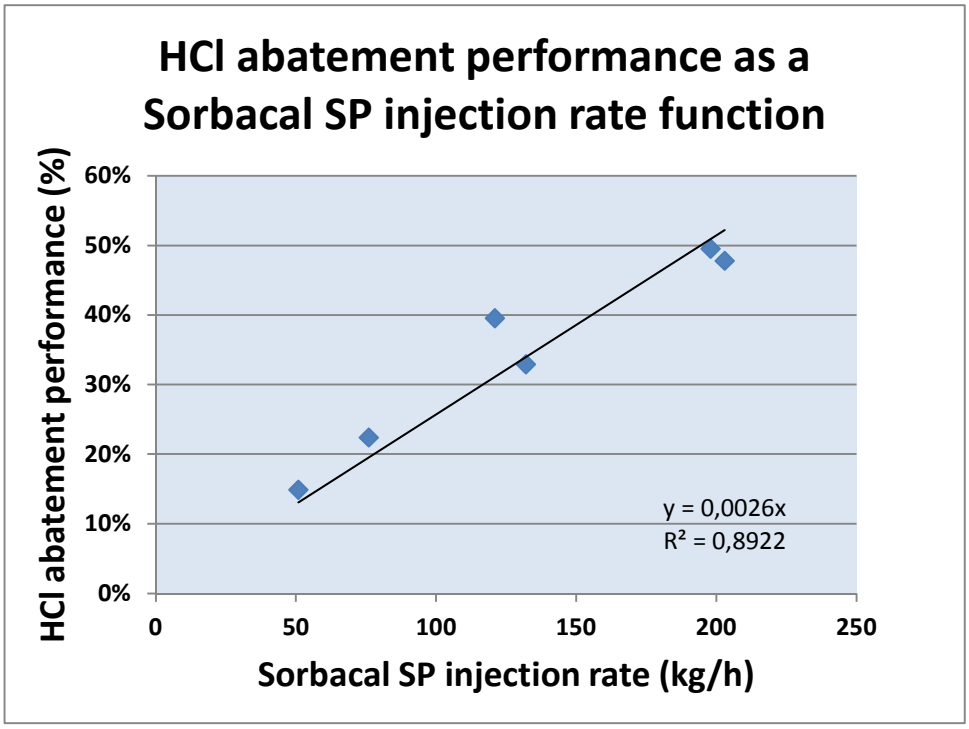
SORBACAL SP ABATTEMENT PERFORMANCE MONITORING

Sorbent abatement performances have been calculated based on plant CEM data. For each injection rates, the HCl and SOx average concentration during Sorbacal SP injection have been compared to a reference value being the average concentration 30min before and 30min after the sorbent injection (reference value). The abatement in % is defined as the fraction of the considered gas that have been captured relatively to the reference value: (1-[$gas_{with\ injection}$]/[$gas_{reference}$]).

SORBACAL SP ABATTEMENT PERFORMANCES

Based on the 6 injections trials, HCl and SOx abatement as a function of Sorbacal SP dosage have been plotted and are presented below.



Maximum HCl abatement of 50% was obtained for the maximum dosage (~200kg/h). We notice a clear linear correlation between the injection rate and the abatement performance without any threshold effect that would indicate a bad mixing of the sorbent with the flue gas.

However, stoichiometric factor being around 22 for 50% abatement, these performances are really poor compared to expectations (a stoichiometric factor close to 1 would have been expected). This could indicate a sorbent recarbonation due to high flue gas temperature and CO_2 concentration (~400°C, 13.5%)

50% abatement wasn't sufficient to lower HCl concentration below 10mg/Nm³. The lowest achieved HCl emission were around 39mg/Nm³. Based on a 100mg/Nm³ HCl concentration average and the trend presented in the figure above, **Sorbacal SP consumption to achieve a 90% abatement performance (i.e reducing HCl to ~10mg/Nm³) would be close to 350kg/h in these injection conditions**. **This represent ~47£/h for reagents based on a 140£ interco price for Sorbacal SP.**

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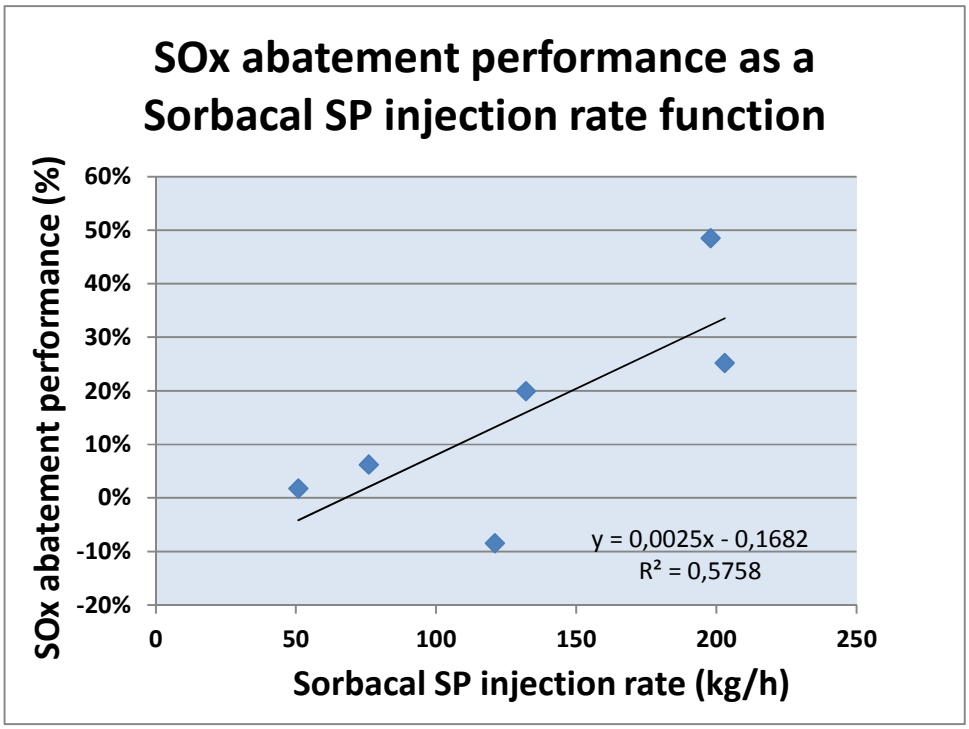

Due to high frequency of SOx concentration variation in fumes, the method for abatement performance calculation based on CEM data doesn't seems to be reliable, hence the negative performance point for the 132kg/h dosage.

However we notice the same global trend as for HCl abatement i.e a linear correlation between battement performance and sorbent dosage. A maximum abatement of 50% was obtained for the maximum dosage (~200kg/h).

Stoichiometric factor was around 3.75 for 50% abatement.

RECOMMENDATIONS

Few recommendations can be derived from these trials:

- Injection point temperature should be lowered with water injection to avoid recarbonation and thus lower the reagent consumption. However, impact on ESP performance of such a temperature lowering should be evaluated first.
- A CFD modeling of the injection configuration could be done by Nivelles for a better mixing assessment. An axial position for the Sorbacal injection could be considered ("burner" configuration, co-current, placed after the elbow) to ensure a better mixing with gases if necessary.
- In order to assess the Sorbacal SP direct sorbent injection solution suitability to decrease HCl emission below 10mg/Nm³ and SOx below 400mg/Nm³, higher dosages should be tested (at least up to 500kg/h as planned for these trials).

Alex Aubert

APPENDIX: TRIALS DATA

	Start	End	Sorbacal SP (kg/h)	kf3tonnes	W1_HCL	W1_SO2	W1_O2DRY	Pet Coke tph	Solvent l/h	Product tph	Fuel Consumption (MJ/t)
Reference -30min	9/12/2015 08:57	9/12/2015 09:26	0,0	29,4	97,1	556,6	11,4	3,6	1240,6	13,4	10937,8
Injection trial	9/12/2015 09:27	9/12/2015 09:47	76,1	29,5	77,4	509,4	11,4	3,6	1229,6	13,4	10780,1
Reference +30min	9/12/2015 09:48	9/12/2015 10:17	0,0	29,4	102,3	529,7	11,4	3,5	1218,9	13,4	10795,2
Abatement performance					22%	6%					

	Start	End	Sorbacal SP (kg/h)	kf3tonnes	W1_HCL	W1_SO2	W1_O2DRY	Pet Coke tph	Solvent l/h	Product tph	Fuel Consumption (MJ/t)
Reference -30min	9/12/2015 09:48	9/12/2015 10:17	0,0	29,4	102,3	529,7	11,4	3,5	1218,9	13,4	10795,2
Injection trial	9/12/2015 10:18	9/12/2015 10:48	50,9	29,9	90,9	459,4	11,4	3,5	1231,8	13,6	10633,3
Reference +30min	9/12/2015 10:49	9/12/2015 11:18	0,0	29,4	111,1	405,0	11,6	3,5	1234,4	13,4	10811,6
Abatement performance					15%	2%					

	Start	End	Sorbacal SP (kg/h)	kf3tonnes	W1_HCL	W1_SO2	W1_O2DRY	Pet Coke tph	Solvent l/h	Product tph	Fuel Consumption (MJ/t)
Reference -30min	9/12/2015 13:16	9/12/2015 13:45	0,0	29,1	143,5	761,7	11,9	3,4	858,3	13,2	10044,7
Injection trial	9/12/2015 13:46	9/12/2015 14:46	121,0	29,2	84,4	794,4	11,6	3,7	1027,8	13,3	10931,3
Reference +30min	9/12/2015 14:47	9/12/2015 15:42	0,0	29,3	135,4	702,6	11,6	3,5	1191,8	13,3	10659,3
Abatement performance					39%	-9%					

	Start	End	Sorbacal SP (kg/h)	kf3tonnes	W1_HCL	W1_SO2	W1_O2DRY	Pet Coke tph	Solvent l/h	Product tph	Fuel Consumption (MJ/t)
Reference -30min	9/12/2015 14:47	9/12/2015 15:42	0,0	29,3	135,4	702,6	11,6	3,5	1191,8	13,3	10659,3
Injection trial	9/12/2015 15:43	9/12/2015 16:58	132,2	29,4	69,6	421,9	11,7	3,5	1196,7	13,4	10646,3
Reference +30min	9/12/2015 16:59	9/12/2015 17:28	0,0	29,4	72,1	351,2	11,8	3,5	1183,6	13,3	10643,9
Abatement performance					33%	20%					

	Start	End	Sorbacal SP (kg/h)	kf3tonnes	W1_HCL	W1_SO2	W1_O2DRY	Pet Coke tph	Solvent l/h	Product tph	Fuel Consumption (MJ/t)
Reference -30min	10/12/2015 08:43	10/12/2015 09:13	0,0	32,6	88,8	334,3	11,7	4,1	1074,5	14,8	10809,5
Injection trial	10/12/2015 09:13	10/12/2015 10:14	198,0	31,5	39,9	203,9	11,5	4,1	1059,5	14,3	11158,1
Reference +30min	10/12/2015 10:14	10/12/2015 11:13	0,0	33,0	69,2	457,4	11,3	4,0	764,8	15,0	10015,0
Abatement performance					50%	49%					

	Start	End	Sorbacal SP (kg/h)	kf3tonnes	W1_HCL	W1_SO2	W1_O2DRY	Pet Coke tph	Solvent l/h	Product tph	Fuel Consumption (MJ/t)
Reference -30min	10/12/2015 10:14	10/12/2015 11:13	0,0	33,0	69,2	457,4	11,3	4,0	764,8	15,0	10015,0
Injection trial	10/12/2015 11:13	10/12/2015 12:14	203,0	32,4	38,7	289,5	11,4	3,9	706,0	14,7	9997,6
Reference +30min	10/12/2015 12:14	10/12/2015 12:44	0,0	32,8	78,8	316,3	11,4	3,7	978,0	14,9	9653,1
Abatement performance					48%	25%					