W1 Kiln SLS45 HCl reduction trial – 22-23/1/18

W1 Kiln inlet

Introduction

W1 kiln emissions of HCl are too high for the impending IED limits. Eventually these limits will be set at 10mg/m3, but it is hoped to be set at 50mg/m3 for a transition period (Dolofrit). Typical levels are currently 120 ± 100mg/m3. This represents a grave threat to the future operation of the kiln. A trial is to be carried out using a Lhoist product called milk-of-lime (SLS45) to spray into the exhaust gas.

The kiln was producing Dolofrit, burning pet-coke and SDF (1050 litres/hr)

Trial Objective:-

To evaluate the abatement ability of milk-of-lime by modification of the following variables:-

1. Flow-rate of SLS45
2. Flow-rate of atomising air
3. Insertion depth of SLS45 lance
4. Additional water injection

Trial members

- Jim Bowman (author) Project Manager LWE (Northern Cluster)
- Xavier Mear Technical Sales Manager
- Ioannis Tsiknakis Process Team Leader and Kiln Burner

Methodology

A pump was used to pump from an IBC up to the kiln exhaust gas ducting about 12m above. The SLS45 was atomised with compressed air using a twin-stream injection lance, made with a standard SDF nozzle. The pump is a variable speed **Watson Marlow 720UN/ RE peristaltic pump.**

Injection pump

Injection point

The pump and lance were tested with water and compressed air. The spray pattern was not very wide, but the droplet size was very small if a lot of compressed air was used (120Nm$^3$/hr).

Water being atomised with compressed air

The fine spray was blown by the wind

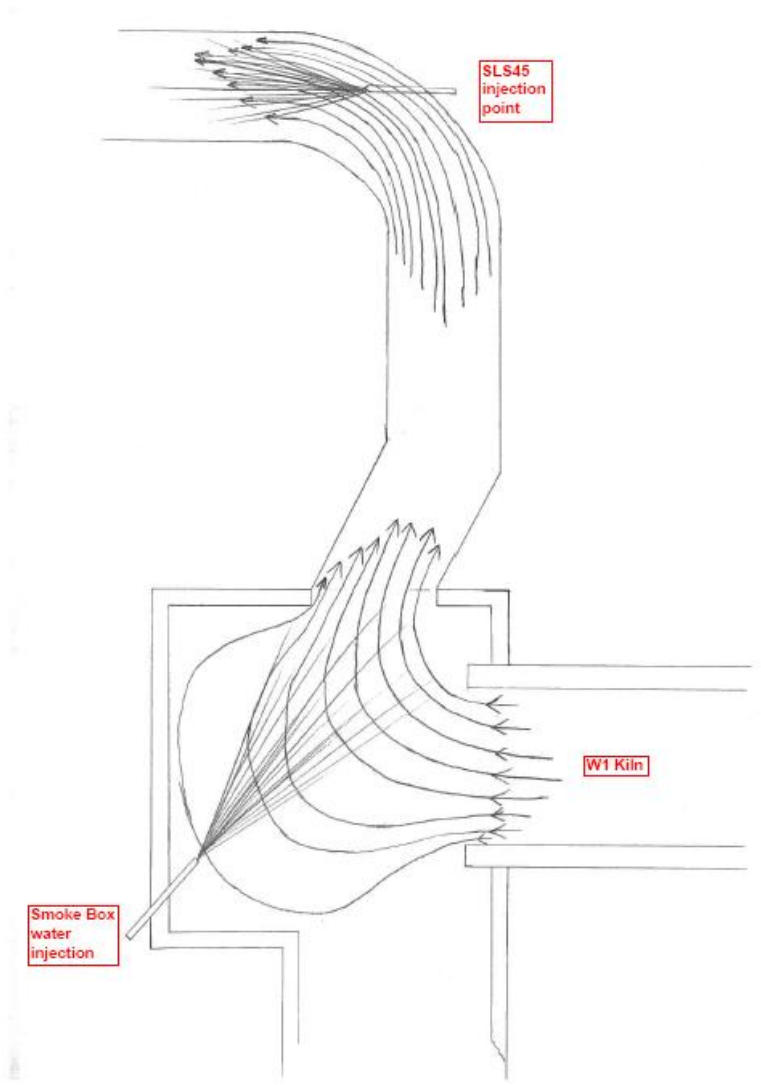



Diagram showing water injection point in the Smoke Box and SLS45 injection point in 90$^0$ bend in the ducting between Smoke Box and ESP

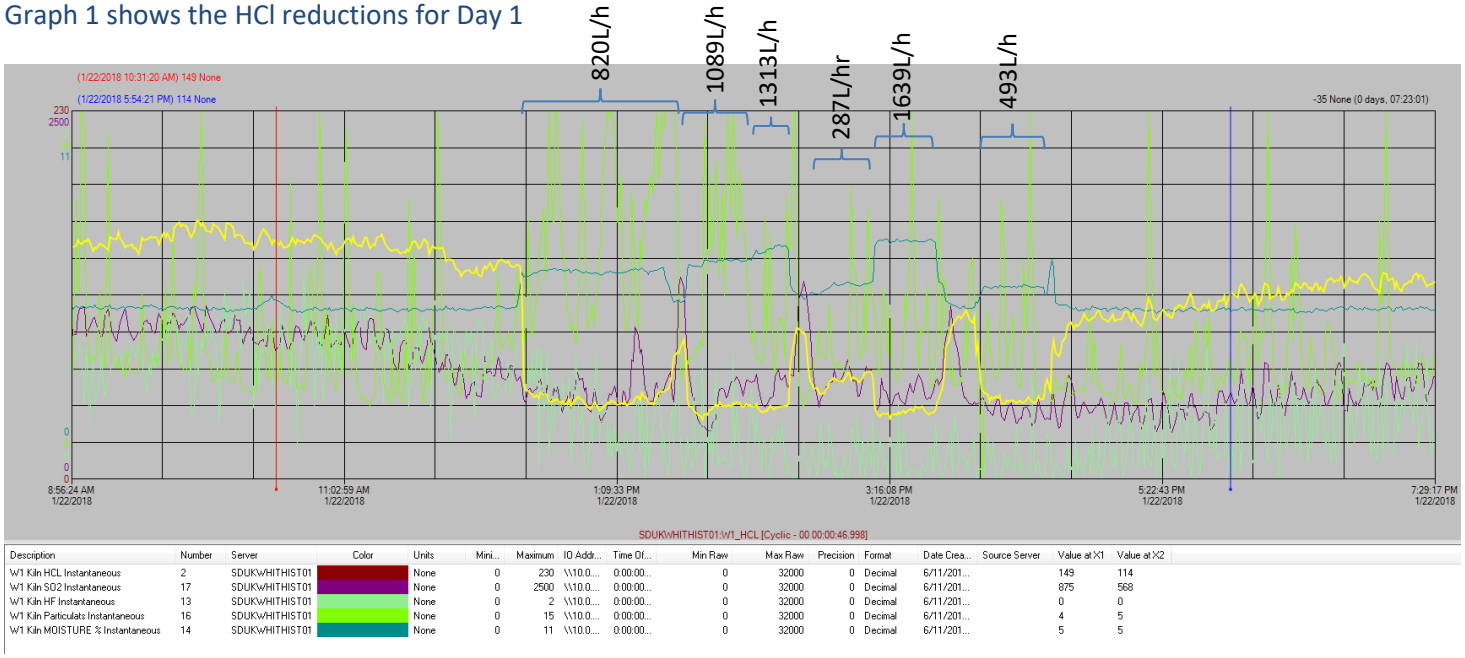
Dust samples were collected before, during and after the trial. These may be sent to a laboratory for materials testing to help to build up the picture about how much of the lime had reacted.

Results

| Time | Pump speed in Hz | Nom. pump rate in l/hr | Calc. pump rate in l/hr | Atomis-ation air in Nm3/hr | HCl in mg/m3 ? | lance insertion depth in mm | Comment |
|---|---|---|---|---|---|---|---|
| **Day 1 - 22/1/18** | | | | | | | |
| 12:29 | 0 | 0 | 0 | 0 | 132 | 400 | 132 HCl 30 min av, SO2 650 |
| 12:30 | 14.3 | 1001 | 820 | 120 | | 400 | Start pump - IBC1 PXD08 |
| 12:40 | 14.3 | 1001 | 820 | 120 | 50 | 400 | |
| 13:10 | 14.3 | 1001 | 820 | 120 | | 400 | SO2 500 |
| 13:15 | 14.3 | 1001 | 820 | 120 | | 400 | 56 out of 93cm used |
| 13:41 | 0 | 0 | 0 | 120 | | | Stop pump |
| 13:42 | 19 | 1330 | 1089 | 120 | | | Start pump - IBC2 PXD14 |
| 14:17 | 22.9 | 1603 | 1313 | 120 | | | |
| 14:34 | 0 | 0 | 0 | 120 | | | Stop pump |
| 14:42 | 5 | 350 | 287 | 120 | | 400 | Start pump - IBC3 PXD15 |
| 15:12 | 28.6 | 2002 | 1639 | 120 | | 400 | |
| 15:44 | 28.6 | 2002 | 1639 | 120 | 45 | 400 | |
| 15:45 | 0 | 0 | 0 | 120 | | 400 | stop pump |
| 16:01 | 8.6 | 602 | 493 | 120 | | | Start pump - IBC3 PXD10 |
| 16:30 | 0 | 0 | 0 | 0 | | | Stop pump |
| | | | | | | | |
| **Day 2 - 23/1/18** | | | | | | | |
| 08:30 | 0 | 0 | 0 | 0 | | 400 | High HF during early morning so SDF turned off around 08:30. V high HCl (200) with SDF off. |
| 11:30 | 0 | 0 | 0 | 0 | | 400 | SDF back on |
| 11:53 | 0 | 0 | 0 | 0 | 180 | 400 | 0.8HF |
| 11:54 | 8.6 | 602 | 493 | 120 | | 400 | Start pump |
| 12:07 | 8.6 | 602 | 493 | 120 | 70 | 400 | |
| 12:14 | 8.6 | 602 | 493 | 120 | 65 | 400 | |
| 12:15 | 8.6 | 602 | 493 | 60 | | 400 | |
| 12:35 | 8.6 | 602 | 493 | 60 | 100 | 400 | |
| 12:36 | 8.6 | 602 | 493 | 120 | 75 | 400 | |
| 13:02 | 8.6 | 602 | 493 | 120 | 70 | 400 | |
| 13:08 | 0 | 0 | 0 | 120 | | 400 | pump off |
| 13:30 | 8.6 | 602 | 493 | 120 | | 150 | |
| 14:20 | 8.6 | 602 | 493 | 120 | 65 | 150 | |
| 14:25 | 8.6 | 602 | 493 | 120 | | 400 | |
| 15:15 | 0 | 0 | 0 | 120 | 130 | 400 | Noticed IBC empty. Pump stopped |
| 15:36 | 8.6 | 602 | 493 | 120 | | 400 | pump started |
| 15:49 | 8.6 | 602 | 493 | 120 | 66 | 400 | Air dilution damper open 80% |
| 15:51 | 8.6 | 602 | 493 | 115 | 55 | 400 | Start Smoke Box water injection, 2300l/hr, air 75Nm3/hr |
| 16:07 | 8.6 | 602 | 493 | 115 | 60 | 400 | Stack O2 9.2% - Air dilution damper fully closed |
| 16:21 | 8.6 | 602 | 493 | 115 | 70 | 400 | Air dilution damper fully closed |
| 16:24 | 14.3 | 1001 | 820 | 115 | | 400 | 2300l/hr, air 80Nm3/hr |
| 16:47 | 14.3 | 1001 | 820 | 115 | 65 | 400 | 8.5% stack O2, 370C EP inlet temp |
| 16:49 | 14.3 | 1505 | 820 | 115 | | 400 | 1900l/hr, air 80Nm3/hr |
| 17:00 | 0 | 0 | 0 | | | | IBC gone empty |
| 17:06 | | 0 | 0 | | | | Smoke Box water off |
| 17:07 | | 0 | 0 | | | | Rinse water through lime pump |
| | | | | | | | Everything off around 5:15 |

## Analysis

### Graph 1 shows the HCl reductions for Day 1




### Assumptions:-

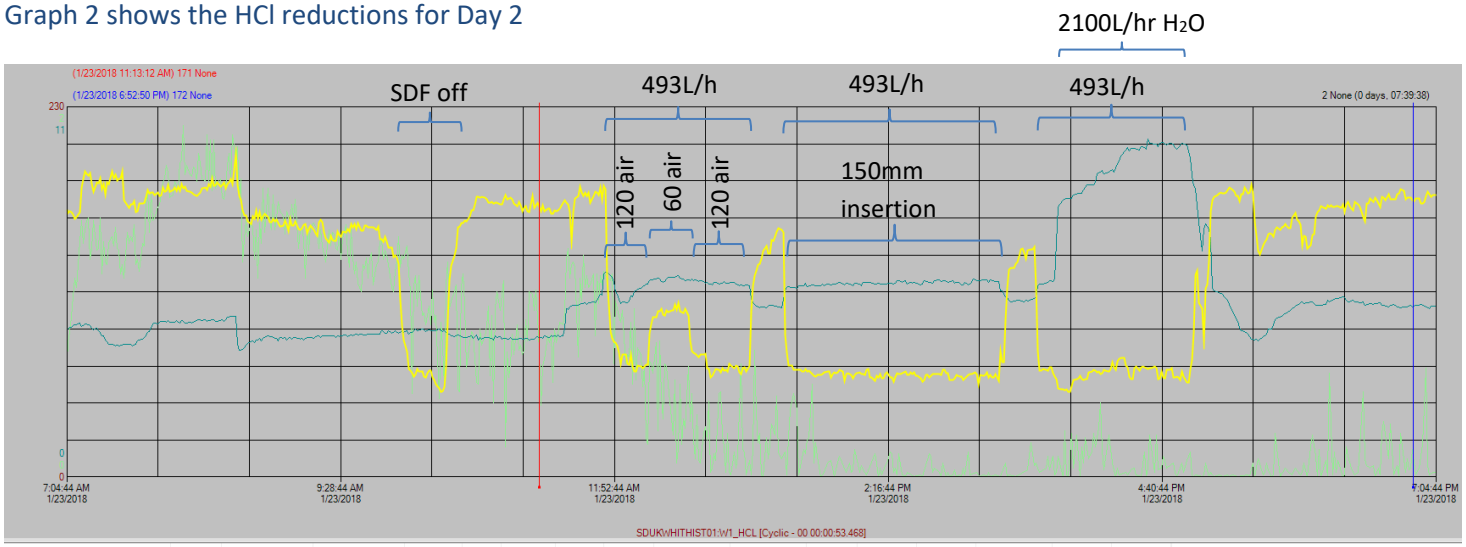
1. HCl before Day 1 trial – 135
2. HCl after Day 1 trial – 123
3. Assume a straight line increase between the above two levels

| Trial # | Time | Calc. pump rate in l/hr | Atomis-ation air in Nm3/hr | HCl from Historian | Interpolated HCl baseline | Reduction ratio | % of baseline | lance insertion depth in mm | Comment |
|---|---|---|---|---|---|---|---|---|---|
| **Day 1 - 22/1/18** | | | | | | | | | |
| | 12:29 | 0 | 0 | 135 | 135 | | | 400 | 132 HCl 30 min av, SO2 650 |
| 1 | 12:30 | 820 | 120 | 49 | 135 | 2.8 | 36.3 | 400 | Start pump - IBC1 PXD08 |
| 1 | 12:40 | 820 | 120 | 49 | 135 | 2.8 | 36.3 | 400 | |
| 1 | 13:10 | 820 | 120 | 49 | 135 | 2.8 | 36.3 | 400 | SO2 500 |
| 1 | 13:15 | 820 | 120 | 49 | 135 | 2.8 | 36.3 | 400 | 56 out of 93cm used |
| 1 | 13:41 | 0 | 120 | 49 | 135 | 2.8 | 36.3 | | Stop pump |
| 2 | 13:42 | 1089 | 120 | 46 | 131 | 2.8 | 35.1 | | Start pump - IBC2 PXD14 |
| 3 | 14:17 | 1313 | 120 | 43 | 128 | 3.0 | 33.6 | | |
| 3 | 14:34 | 0 | 120 | | | | | | Stop pump |
| 4 | 14:42 | 287 | 120 | 65 | 127 | 2.0 | 51.2 | 400 | Start pump - IBC3 PXD15 |
| 5 | 15:12 | 1639 | 120 | 41 | 125 | 3.0 | 32.8 | 400 | |
| 5 | 15:44 | 1639 | 120 | 41 | 125 | 3.0 | 32.8 | 400 | |
| 5 | 15:45 | 0 | 120 | 41 | 125 | 3.0 | 32.8 | 400 | stop pump |
| 6 | 16:01 | 493 | 120 | 48 | 124 | 2.6 | 38.7 | | Start pump - IBC3 PXD10 |
| 6 | 16:30 | 0 | 0 | | | | | | Stop pump |

## Observations

1. Clearly diminishing returns in terms of dosing level
2. The dust levels appeared to be elevated during the Day 1 trial
3. The HF showed a clear reduction

## Graph 2 shows the HCl reductions for Day 2




| Description | Number | Server | Color | Units | Mini... | Maximum | IO Addr... | Time Of... | Min Raw | Max Raw | Precision | Format | Date Crea... | Source Server | Value at X1 | Value at X2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 Kiln HCL Instantaneous | 2 | SDUKWHITHIST01 | | None | 0 | 230 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 171 | 172 |
| W1 Kiln HF Instantaneous | 13 | SDUKWHITHIST01 | | None | 0 | 2 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 1 | 0 |
| W1 Kiln MOISTURE % Instantaneous | 14 | SDUKWHITHIST01 | | None | 0 | 11 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 4 | 5 |

## Assumptions:-

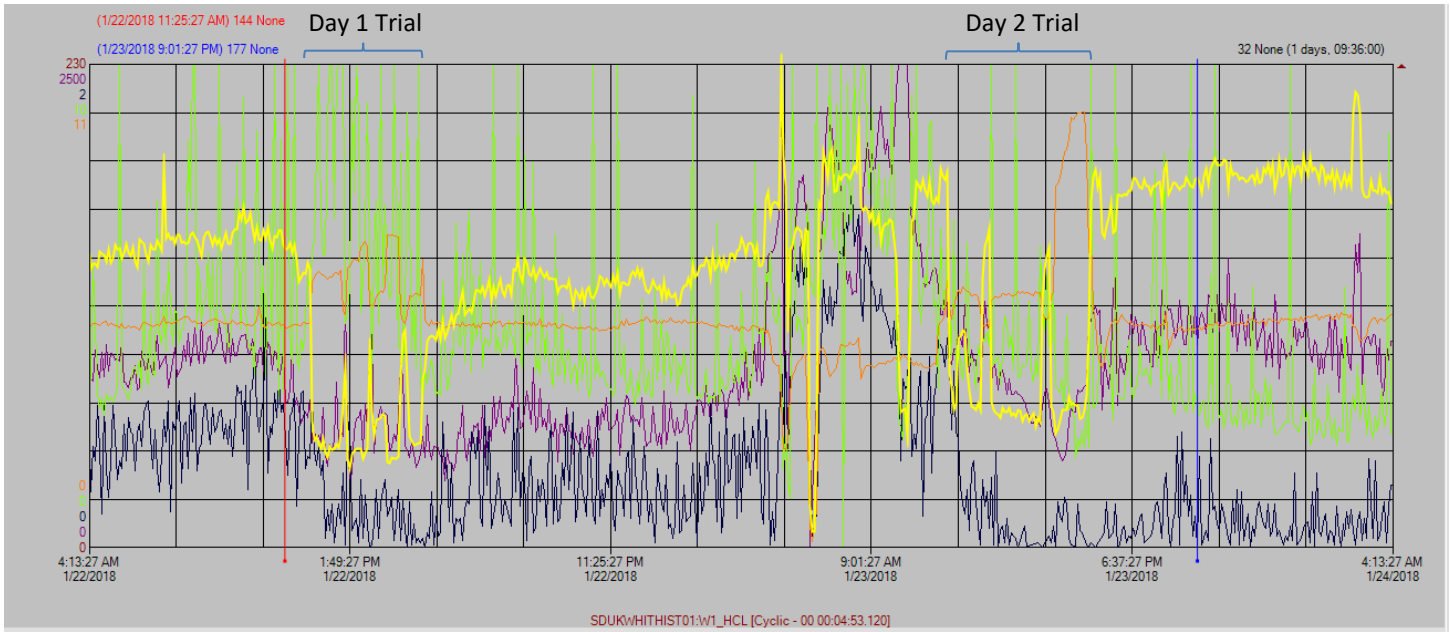
1. HCl before Day 2 trial – 170
2. HCl after Day 2 trial – 175
3. Assume a straight line increase between the above two levels

| Trial # | Time | Calc. pump rate in l/hr | Atomis-ation air in Nm3/hr | HCl from Historian | Interpolated HCl baseline | Reduction ratio | % of baseline | lance insertion depth in mm | Comment |
|---|---|---|---|---|---|---|---|---|---|
| **Day 2 - 23/1/18** | | | | | | | | | |
| | 08:30 | 0 | 0 | | | | | 400 | High HF during early morning so SDF turned off around 08:30. V high HCl |
| | 11:30 | 0 | 0 | | | | | 400 | SDF back on |
| | 11:53 | 0 | 0 | 175 | | | | 400 | 0.8HF |
| 7 | 11:54 | 493 | 120 | 69 | 175 | 2.5 | 39.4 | 400 | Start pump |
| 7 | 12:07 | 493 | 120 | 69 | 175 | 2.5 | 39.4 | 400 | |
| 7 | 12:14 | 493 | 120 | 69 | 175 | 2.5 | 39.4 | 400 | |
| 8 | 12:15 | 493 | 60 | 104 | 175 | 1.7 | 59.4 | 400 | |
| 8 | 12:35 | 493 | 60 | 104 | 175 | 1.7 | 59.4 | 400 | |
| 9 | 12:36 | 493 | 120 | 66 | 175 | 2.7 | 37.7 | 400 | |
| 9 | 13:02 | 493 | 120 | 66 | 175 | 2.7 | 37.7 | 400 | |
| 9 | 13:08 | 0 | 120 | 147 | 175 | | | 400 | pump off |
| 10 | 13:30 | 493 | 120 | 64 | 175 | 2.7 | 36.6 | 150 | |
| 10 | 14:20 | 493 | 120 | 64 | 175 | 2.7 | 36.6 | 150 | |
| 11 | 14:25 | 493 | 120 | 64 | 175 | 2.7 | 36.6 | 400 | |
| 11 | 15:15 | 0 | 120 | 137 | 175 | | | 400 | Noticed IBC empty. Pump stopped |
| 12 | 15:36 | 493 | 120 | 67 | 175 | 2.6 | 38.3 | 400 | pump started |
| 12 | 15:49 | 493 | 120 | 67 | 175 | 2.6 | 38.3 | 400 | Air dilution damper open 80% |
| 13 | 15:51 | 493 | 115 | 66 | 175 | 2.7 | 37.7 | 400 | Start Smoke Box water injection, 2300l/hr, air 75Nm3/hr |
| 13 | 16:07 | 493 | 115 | 66 | 175 | 2.7 | 37.7 | 400 | Stack O2 9.2% - Air dilution damper fully |
| 13 | 16:21 | 493 | 115 | 66 | 175 | 2.7 | 37.7 | 400 | Air dilution damper fully closed |
| 14 | 16:24 | 820 | 115 | 64 | 175 | 2.7 | 36.6 | 400 | 2300l/hr, air 80Nm3/hr |
| 14 | 16:47 | 820 | 115 | 64 | 175 | 2.7 | 36.6 | 400 | 8.5% stack O2, 370C EP inlet temp |
| 14 | 16:49 | 820 | 115 | 64 | 175 | 2.7 | 36.6 | 400 | 1900l/hr, air 80Nm3/hr |
| 14 | 17:00 | 0 | | 126 | 175 | | | | IBC gone empty |
| | 17:06 | 0 | | | 175 | | | | Smoke Box water off |
| | 17:07 | 0 | | | 175 | | | | Rinse water through lime pump |
| | | | | 176 | 175 | | | | Everything off around 5:15 |
| | | | | 175 | | | | | Baseline state of HCl after tests |

Observations

1. Trial 8 performed far worse due to the much reduced atomising air
2. Trial 10 showed no impact of reducing the insertion depth of the SLS45 lance. This suggest the mixing is already good in the duct, and that "streaming" does not occur
3. Trial 13 shows no reduction in HCl from the additional water injection
4. Trial 14 shows a slight further reduction in HCl to 37% by increasing the SLS45 pump rate

## Graph 3 – Showing 45 hours and both trials




| Description | Number | Server | Color | Units | Mini... | Maximum | IO Addr... | Time Of... | Min Raw | Max Raw | Precision | Format | Date Crea... | Source Server | Value at XT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 Kiln HCL Instantaneous | 2 | SDUKWHITHIST01 | | None | 0 | 230 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 144 |
| W1 Kiln SO2 Instantaneous | 17 | SDUKWHITHIST01 | | None | 0 | 2500 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 1011 |
| W1 Kiln HF Instantaneous | 13 | SDUKWHITHIST01 | | None | 0 | 2 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 1 |
| W1 Kiln Particulats Instantaneous | 16 | SDUKWHITHIST01 | | None | 0 | 10 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 3 |
| W1 Kiln MOISTURE % Instantaneous | 14 | SDUKWHITHIST01 | | None | 0 | 11 | \\10.0.... | 0:00:00... | 0 | 32000 | 0 | Decimal | 6/11/201... | | 5 |

## Observations from 45 hour graph

1. The dosing of SLS45 has had an adverse effect on particulates on the Day 1 trial, but no noticeable effect on the Day 2 trial
2. The injection of water has reduced the particulates by around 20%
3. The SO2 is reduced from around 1200 to 700 during the Day 2 trial
4. The HF varies a lot, but shows a clear reduction during the Day 1 and Day 2 trials to perhaps 50%

## Financial implications

The bulk delivered cost of SLS45 would probably be about £60/T. The typical SDF burn rate is 15% for Dolofrit. This saves around £37/hr. The breakeven point for pumping SLS45 would therefore be around 617kg/hr. The aim would be to make the lime effective at much lower input rates.

## Next steps (for discussion)

1. Try to dampen the pulsating nature of the pump (approx. 5:1 ratio of pumping to not pumping)
2. Increase the number of injection points
3. Test the ESP dust to understand how much of the lime had reacted (Xavier Mear)
4. Analyse the gas volume/concentration to calculate a theoretical stoichiometric dosing rate
5. Estimate what the annual cost of SLS45 would be to keep the kiln below the limits. At the time of writing, the HCl daily limits for 2018-9 are expected to be as follows:-
    - 200mg/m3 Dolofrit with SDF
    - 180mg/m3 Dolomet with SDF

## Conclusion

The equipment used for the trial was very basic, and there is plenty of scope to improve this set-up. However, the results were very encouraging. It was demonstrated that the HCl could be reduced to 33% (from 125 to 41mg/m3) with a dosing rate of 1600 litres/hr. The results indicated that increasing pump rate gave diminishing returns. Even at a pump rate of 493 litres/hr, the HCl was reduced to 37%. The SO2 was reduced to 58% from 1200 to 700mg/m3. The HF was also reduced to around 50%.