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Emma Pierce
Senior Officer
Industry and Waste Regulation
Industry Regulation Team North-East
Natural Resources Wales

Date: 09/04/2020

Permit Reference: EPR/BK6483IU

Dear Emma,

Further to the Part A notification on 30/10/2019 concerning the fluoride emission from point ST2 (melt furnace baghouse stack), I attach the Schedule 1 Part B notification.

If you have any further questions, please do not hesitate to contact me.

Yours Sincerely,

Keith Martin

Keith Martin
Principal Engineer
Facilities and Environment

Enc: Schedule 1 Part B notification.

Part B Schedule 1 notification 26/03/2020

1.0 Part A Summary 30/10/2019

Emission point:	ST2
Process:	Melt furnace baghouse stack
Emission:	Fluoride
Permit limit:	1.0 mg/m3
TMUK result:	1.5 mg/m3
Uncertainty:	+/- 0.18 mg/m3
Date:	26/09/2019 14:00 – 15:00 hours.
Method:	BS ISO 15713 with MCERTS / UKAS accreditation

2.0 Background

The Casting process requires a supply of molten aluminium to produce parts. The aluminium is supplied from two melt furnaces – Low Pressure (LP) and High Pressure (HP) depending upon which metal grade is required for the part. The furnaces are charged primarily with aluminium ingots. Recovered scrap and swarf is also charged. The furnaces are natural gas fired and are served by a common exhaust gas emission point and associated baghouse for abatement. A third small Crucible furnace, which is used to recover small scrap parts, is also served by the exhaust gas system. Schematic diagrams of the melt furnaces and baghouse are shown below in Figure 1 and Figure 2 respectively.

The molten aluminium needs to be of sufficient purity to ensure a quality part is cast into the mould. This is achieved primarily through purchase of high specification ingots and scrap with a low impurity content. To remove the remaining impurities and also the aluminium oxides formed in the melt furnaces, a fluxing process is performed on the HP and LP furnaces.

Flux is added into the molten metal via a steel lance. The flux is a fine powder material and delivered by pressure from a compressed inert gas supply. The flux has a 5% potassium aluminium fluoride $KAlF_4$ content and aids removal of impurities both physically and chemically. Fluxing helps bind impurities as salt solids whilst at the same time allowing these salts to flow through the metal to the surface. Rafts of salt impurities float above the aluminium and here they can be skimmed off the surface with a steel rake as dross. The dross, which is a mixture of metal salts and oxides, is recovered for use off-site.

Fluxing gives rise to fluoride emissions as the fluorine combines with hydrogen to form hydrogen fluoride (HF). This acidic gas is neutralised through the lime dosing abatement process. The lime is 70% calcium hydroxide $Ca(OH)_2$ powder and this is delivered into the exhaust manifold before the bagfilters. The powder coats the bags and acts as an alkali layer which the acidic HF gas must pass through. Fluorine has a high affinity to calcium making lime the ideal abatement media. The abatement reaction is:

$$Ca(OH)_2 + 2HF = CaF_2 + 2H_2O$$

The calcium fluoride (CaF_2) salt is relatively insoluble and is removed from the baghouse as a dust during bagfilter cleaning. The bagfilters are periodically cleaned by a reverse flow of compressed air which momentarily increases pressure on the clean side of the bag knocking the dust off into waste drums under the baghouse. This is called the Clean-On-Demand system and it activates when the differential pressure across the bagfilters increases (I.E. when the filters start to block). Exhaust gases are emitted from a stack after the baghouse.

Fluxing is a periodic activity and is standardised across the shift pattern prior to dross removal. Therefore, HF emissions would be expected to peak during fluxing.

Fig. 1. Schematic Diagram for Melt Furnaces

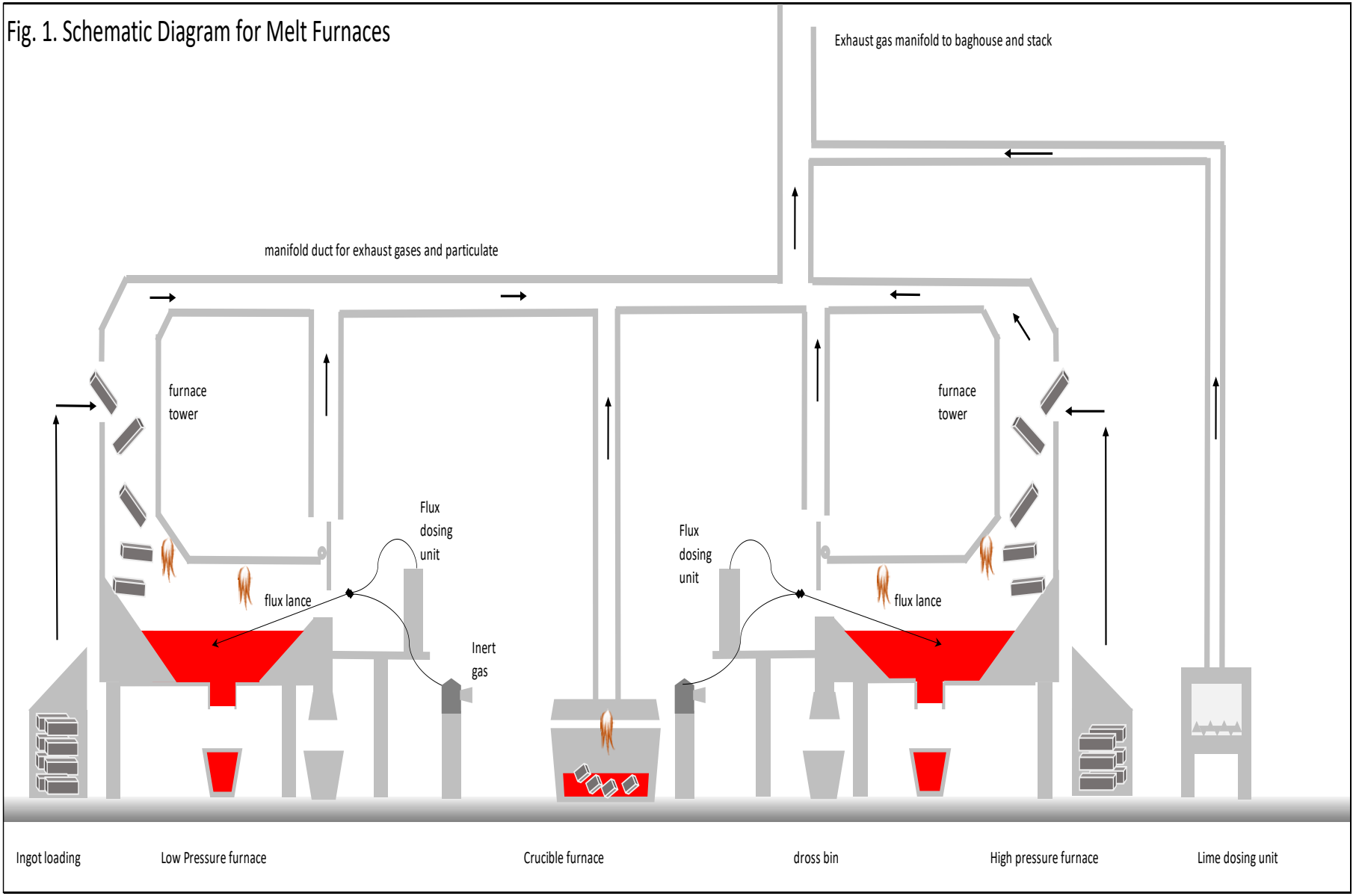
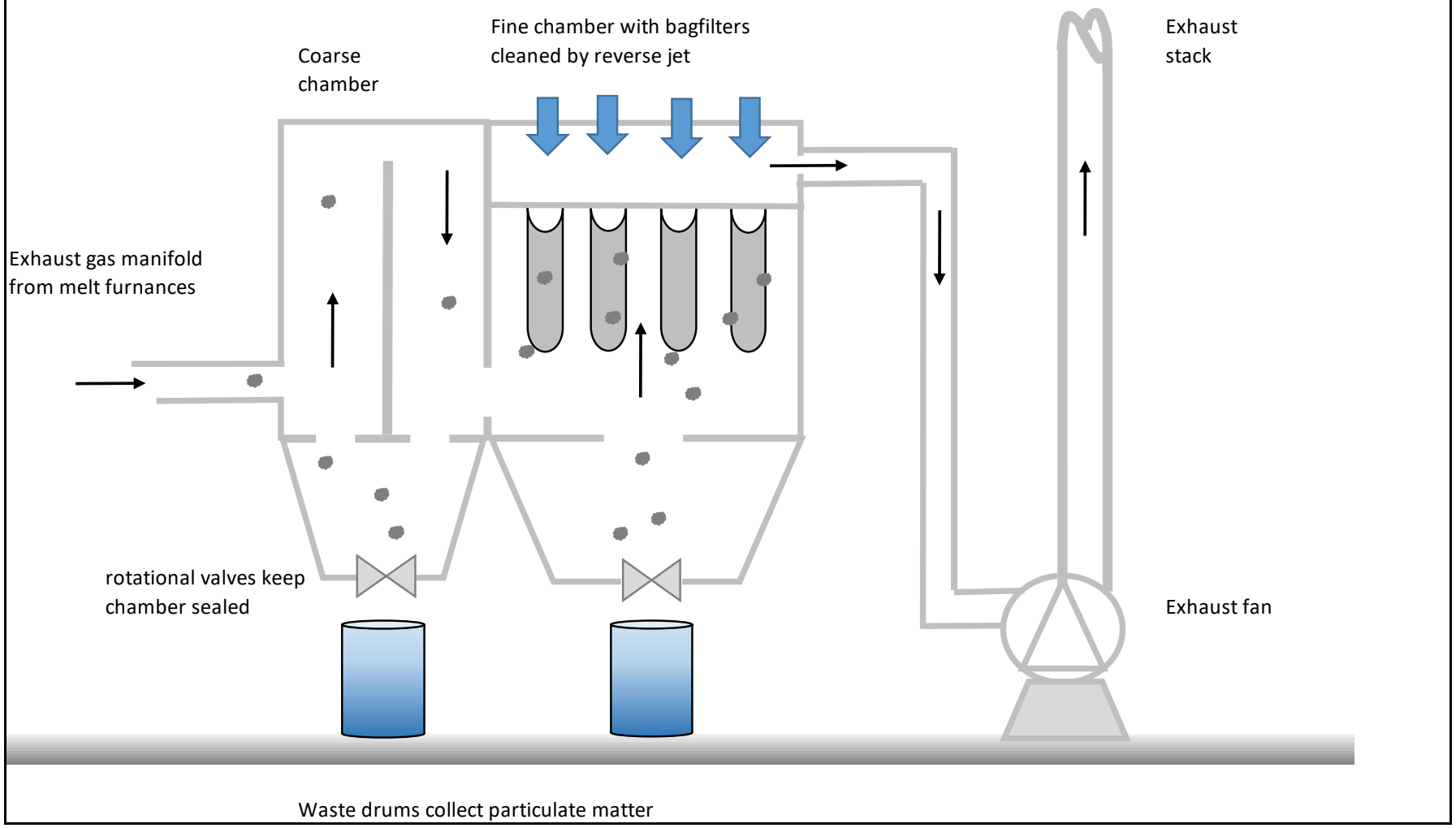
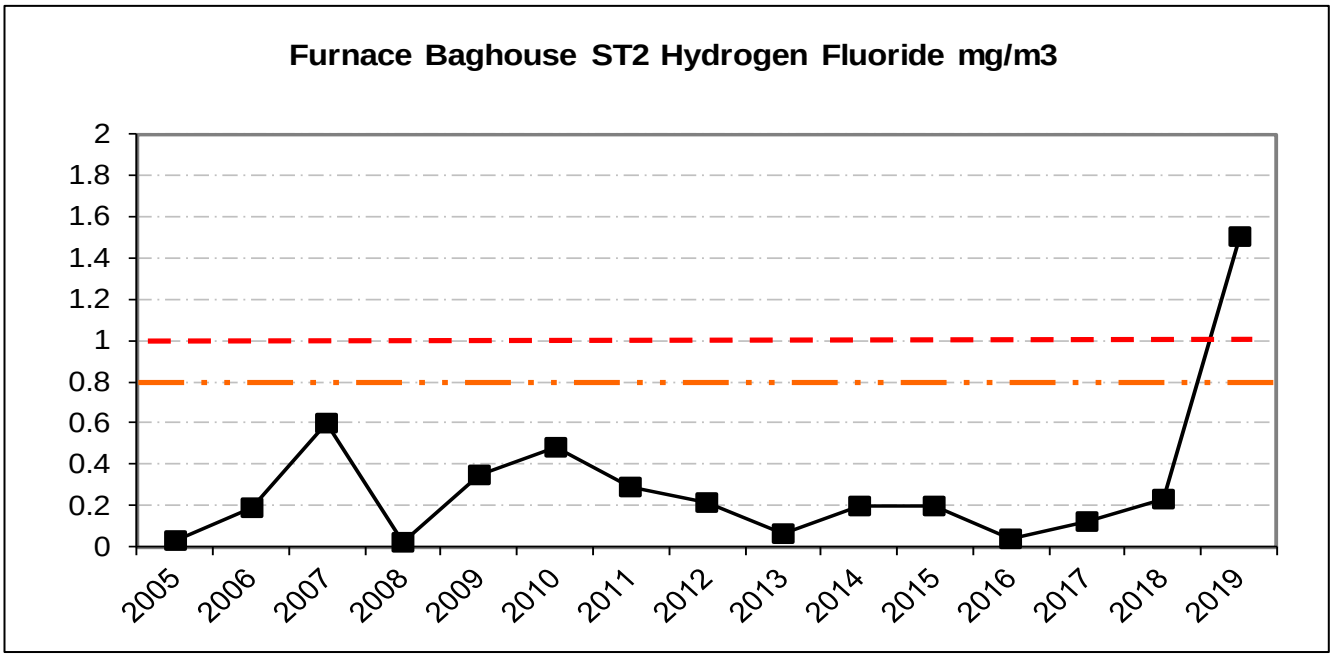


Fig. 2. Schematic Diagram for Baghouse



3.0 Investigation

The fluoride emission exceedance was monitored during normal mass production. All other emission parameters were compliant. The melt process has a good history of compliance with the fluoride emission limit value – no exceedances have occurred previously and results have always been below TMUK's internal limit of 0.8 mg/m3. The graph below shows TMUK's fluoride compliance history including the 2019 exceedance on 26th September.



TMUK discussed the emission result with the monitoring contractor to ensure it was representative and not erroneous. The monitoring contractor confirmed the sampling, analysis and reporting were all completed to standard.

The production records were matched against the emission monitoring sampling times and it was evident that fluxing had occurred at 14:00 hours on the 26/09/2019 – coinciding exactly with the start of the emissions test. Therefore, peak HF emissions could be expected at this point. No other sources of fluoride are known.

The table below shows when the emission test occurred in relation to the fluxing.

Time	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Emission Test																								
HP Flux																								
LP Flux																								
Lime Dosing																								
Clean-On-Demand	Activated by differential pressure monitoring																							

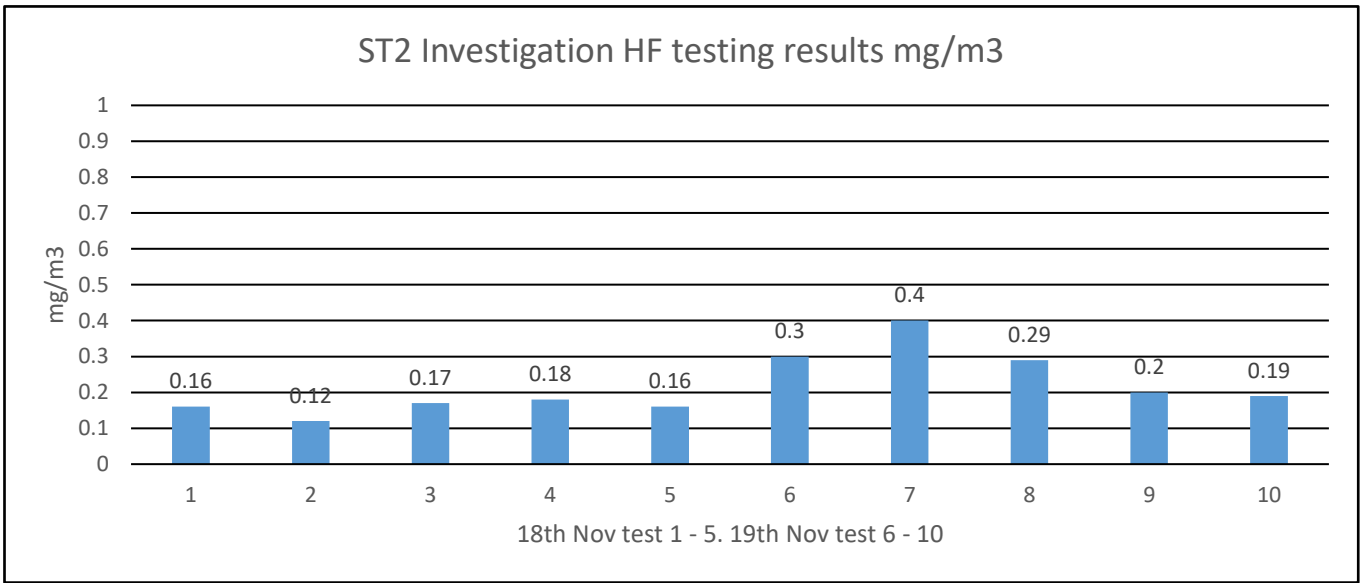
The table also shows that lime dosing occurred at the start of testing according to design standards. However, the lime addition system does not have a recording function and therefore no corroboration of the standard lime dosing and actual dosing could be made. The efficacy of the lime abatement during the test could not be determined.

As the emissions exceedance was a singular test and to progress the investigation a series of 10 further HF emissions tests were undertaken. Each test would again be BS ISO 15713 with MCERTS / UKAS accreditation

over 1 hour. The 10 tests were split over 2 days with 5 tests each day. The first day, would be used to make a trial process change – the bagfilter "Clean-on-Demand" mechanism would be switched off. This would allow any dosed lime to remain on the bagfilters, providing the maximum HF abatement potential. The process was returned to standard on the second day with no process changes. Test 9 on the second day coincided with fluxing on the HP furnace and attempted to replicate the process conditions during the emissions exceedance on 26th September. Test 10 on the second day would be an assumed worst case scenario – standard process conditions but with non-standard sequential fluxing of both melt furnaces.

Test	Date	Time	Fluxing scenario	Process set-up	HF Result mg/m3
1	First day 18/11	09:05 – 10:05	No fluxing	Bagfilter Clean-On-Demand off during fluxing	0.16
2		10:25 – 11:25	No fluxing		0.12
3		12:14 – 13:14	No fluxing		0.17
4		13:20 – 14:30	HP furnace fluxing		0.18
5		15:45 – 16:45	HP and LP fluxing sequentially		0.16
6	Second day 19/11	08:55 – 09:55	No fluxing	Standard	0.30
7		10:20 – 11:20	No fluxing		0.40
8		11:47 – 12:47	No fluxing		0.29
9		13:10 – 14:10	HP furnace fluxing		0.20
10		15:30 – 16:30	HP and LP fluxing sequentially		0.19

The average result of the 10 tests is 0.22 mg/m3. It can be seen that there is no significant difference either between Clean-On-Demand activation or between fluxing conditions. The 3 highest results were all obtained when fluxing was off. Test 9 which attempted to replicate the initial emissions exceedance and Test 10 which was the assumed worst case scenario did not show elevated levels of HF emission.



The investigation testing did not highlight either significantly beneficial or detrimental process conditions for HF emissions. However, it did confirm the process is compliant with the permit emission limit value. Whilst it is possible, the initial exceedance was a spurious result, the investigation continued to assess a number of process variables that could influence the HF emission.

3.1 Fluxing Quantity

The actual fluxing quantity being dosed was checked against the process standard and found to be correct. The standard was then benchmarked with a similar Toyota casting plant in Japan and the TMUK fluxing amounts were found to be higher on HP and lower on LP. No historical records could be found to explain the difference, however it is possibly linked to the original quality of metal grades was the UK plant was first manufactured.

Melt furnace	Actual Flux	Standard Flux	Benchmark Flux (Japan)
High Pressure	15 kg / dose	15 kg / dose	10 kg / dose
Low Pressure	5 kg / dose	5 kg / dose	10 kg / dose

3.2 Lime Dosing System

The lime dosing system was inspected and a partial blockage was discovered on the screw feed mechanism. The blockage of compacted powder was immediately removed and the system returned to standard. It is not possible to state how much the blockage impacted on the lime dosing quantity, although some obstruction to powder delivery could have occurred. This malfunction was not evident because the lime dosing system uses a 30 minute run timer when dosing. Whilst this timer was working, the system has no check of the quantity of lime being dosed. The standard dose of 7 kg/day was checked by theoretical calculation and found to be sufficient for the levels of flux being added.

3.3 Clean-On-Demand System

The Clean-on-Demand system responds to increasing pressure differential across the bagfilters and ensures process efficiency and abatement protection. However, it is now recognised that cleaning will also remove some of the lime powder coating the bags. There is the potential that if a Clean-On-Demand was triggered simultaneously with fluxing, then the lime abatement could be ineffective as the powder is removed from the bags. As the Clean-On-Demand system does not record actual cleans, the potential impact on the emissions exceedance cannot be determined.

4.0 Countermeasures

Whilst no definitive root cause can be attributed to the emissions exceedance, the investigation identified a number of process improvements that TMUK have implemented to reduce HF emissions.

4.1 Fluxing Quantity

The fluxing quantity standard has been modified to reflect the benchmarked Japanese plant. A 10 kg flux for each furnace has been implemented. This reduces the total amount of flux consumed by 10kg per day and will reduce associated HF emissions from the furnace. There has been no impact to metal casting quality.

Melt furnace	No. Fluxes /day	Old Flux standard	Total amount of flux (old)	New Flux standard	Total amount of flux (new)
High Pressure	4	15 kg	60 kg	10 kg	40 kg
Low Pressure	2	5 kg	10 kg	10 kg	20 kg
Total	6	-	70 kg	-	60 kg

4.2 Lime Dosing System

The partial blockage on the lime dosing system screw feed was removed and full lime dosing restored. In addition, the dosing system no longer uses a 30-minute timer but instead uses a weight-based system to ensure the correct amount of lime is added. This is tracked by a member daily to confirm abatement efficiency and identify malfunctions. Any deviation from the correct amount of lime dosing will prompt a clean of the screw feed to ensure there are no blockages and confirmation the dosing is correct. The cleaning process has been standardised.

4.3 Clean-On-Demand System

The Clean-On-Demand system has been modified to inhibit cleaning during fluxing. This will prevent any lime powder removal from the bagfilters during peak fluoride emissions. Once fluxing is complete the Clean-On-Demand system is returned to normal operation. This is controlled by the member operating the melt furnaces and is standardised work. This was trialled during the investigation alongside HF testing, as reported above, and whilst no significant impact was demonstrated, it is still thought to be a positive improvement to the abatement system.

5.0 Conclusion

The HF emissions exceedance is difficult to quantify as a mass as a definitive change point could not be identified and test result could not be replicated. Based on the compliance history and subsequent compliant re-test results, it is unlikely a significant long-term emissions breach occurred.

A single malfunction was identified – this being the partial blockage of lime dosing screw feed that was immediately rectified. Tracking of the lime dosing system has been changed to highlight and correct malfunctions.

Significant process improvements were identified and implemented to minimise HF emissions. An overall reduction in the amount of flux dosed into the furnaces and inhibition of the bagfilter Clean-On-Demand system during fluxing have been implemented and standardised. These improvements are designed to minimise the HF loading into the abatement and maximise the lime abatement efficacy during peak HF emissions (fluxing).

To avoid future speculation on singular test results, subsequent emissions monitoring for HF will use triplicate sampling (3 separate tests) with the average result being reported. This will also apply to hydrogen chloride (HCl) sampling.

Signed: *Keith Martin*

Name: Keith Martin

Position: Principal Engineer

Date: 09 / 04 /0 2020

I am authorised to sign on behalf of Toyota Motor Manufacturing (UK) Ltd.