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PFC Survey in Some Smelters of China

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Abstract

PFC survey was performed by Zhengzhou Research Institute of CHALCO (ZRI). Results of the first PFC survey from several different Chinese smelters are discussed in this paper. This survey included normally-operated, newly-started, power-limitation and new control-mode potlines. The measurement equipment used in the survey is MG2030 FTIR which comes from America MKS Instruments. Gas sampling was directly pumped out of main exhaust duct before stack and transmitted into FTIR by Teflon tube. Fugitive PFC emission was not measured. The calculation of PFC amount was based on accepted IPCC Tier 3 method. Total PFC emission was calculated from duct PFC emission divided by collection efficiency. Newly-started, new control-mode and power-limitation potlines emitted much more PFC than normally-operated ones. PFC emission from power-limitation potline was the highest among seven potlines. Three of the seven potlines have PFC emission lower than original IAI 2010 target. Two potlines have PFC emission close to Australia 2006 average level. The lowest amount of PFC emission is 0.21 tCO_2-e/t-Al.

Introduction

Reduction of PFC emissions has been a priority for the global aluminum industry since the industry became aware of the climate change impact of the two PFC compounds, tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) emitted during anode effects. Primary aluminum production in China has increased more than four times over the past 10 years. The fast-expanding of Chinese aluminum production is largely due to investment in new capacity, employing PFPB technology with the lowest PFC emission. Now China is the single largest primary aluminum producer and PFPB technology has been spread to all of its smelters along with extinguish of Soderberg technology cells.

The International Aluminum Institute (IAI) conducts annual survey of global primary aluminum producers on anode effect (AE) performance from which PFC emissions are calculated according to Intergovernmental Panel on Climate Change (IPCC) Good Practices methodology (1). The participation of IAI AE survey has for a number of years remained around the 90% mark except China. Since China continues to make a larger share of global Al production, the total survey participation rate falls annually (2). IAI is making efforts to seek cooperation with the Chinese aluminum industry in order to improve the accuracy of the emissions projection. At the same time, as part of the APP (Asia Pacific Partnership for Clean Development and Climate), Chinese government began to pay more attention on PFC emission from aluminum industry. Thus, Zhengzhou Research Institute of Chalco (ZRI)/National Engineering and Technology Research Center for Aluminum decided to investigate PFC emission from Chinese smelters. A FTIR was bought from MKS Instruments in 2008, at the same time a research team was set up in ZRI.

Measurement Strategy

MG2030 FTIR The measurement equipment is MG2030 which comes from America MKS Instruments. Preparation and training of the FTIR were finished in early 2008. The FTIR and its pump were assembled separately. Sampling pump is assembled together with gas filters and gas temperature controllers (see Figure 1). They are placed into wooden boxes and suitcases for shipment.

Figure 1 - MG2030 FTIR

Sampling

First survey included seven potlines which belong to several different smelters of China. PFC measurements were finished by ZRI team from June to September in 2008. During measurement, gas samples were directly pumped out of main exhaust duct and transmitted into the FTIR through Teflon tube while fugitive gas emission was not measured. Sampling location was usually chosen on the horizontal duct between dry scrubber and chimney stack (see Figure 2).

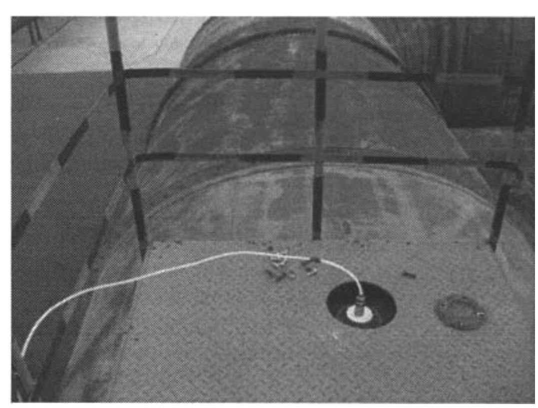

Figure 2 - Sampling Location

Data Collection

The MG2030 was monitored with a laptop. Sampling gas was heated to 150℃ and passed continuously through FTIR gas cell. PFC spectra are collected, transformed into digital signals and plotted vs time by special software in the monitoring laptop. PFC concentration was recorded by the laptop at intervals of 1~60 seconds (see Figure 3). There would be a PFC peak when an anode effect occurred. Some gases such as HF, SO_2 and H_2O may bring some negative effect on PFC measurement. But in this survey these gases were not removed from gas sample in order to learn their concentration fluctuation.

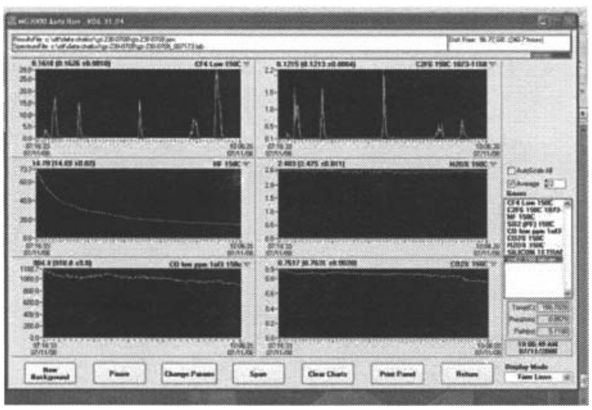

Figure 3 - PFC Time Lines

Calculation Methodology

The survey requests AE performance data from the measured potline, usually reported by smelters directly to ZRI research team. The key data, required to estimate potline or facility performance including anode effect performance and related data for calculating total PFC emissions, are as follows:

- Primary aluminum production (MP) during measurement, in tonnes of molten metal tapped from cells;
- Anode effect frequency (AEF), the average number of anode effects occurring per cell day;
- Anode effect duration (AED), the average time in minutes of each anode effect;
- Collection efficiency, percentage of exhaust gas collected in main duct.

The anode effect performance data above allows for the calculation, by IPCC Tier 3 methodologies, to obtain facilities' total CF_4 and C_2F_6 emissions, and then tonnes of CO_2 equivalent emitted per tonne of aluminum produced through applying each PFC's GWP (Global Warming Potential).

PFC Survey

In this survey, in order to get information as much as possible, smelters in different region were chosen. They locate in North-western China, South-western China and Central China, respectively. Seven potlines were selected including different situations such as normally-operated, newly-started, new control-mode and power-limitaion potlines (see Table I). Newly-started potlines were those which suffered heavy ice-rain in the beginning of 2008. PFC survey was performed according to the Protocol for PFC Measurement published by IAI/USEPA in 2008. PFC emissions were calculated according to accepted IPCC Tier 3.

Table I - Status of Potlines in the Survey

Code	Line current, kA	Total cells including	Annual aluminum production, kilotons
A	182	261	124.830
B	335	30	25.345
C	239	286	180.325
D	202	204	107.610
E	295	276	209.923
F	215	263	150.015
G	180	256	121.545

Survey Results

According to IPCC Tier 3 methodology, total PFC emission from seven potlines was calculated and compared with overseas smelters (see Table II).

Table II - PFC Emissions from Measured Potlines

Overseas and indoors PFC emission	PFC emissions, tCO_2-eq/t-Al
Measured PFC emission from Potline A	0.32
Measured PFC emission from Potline B	0.66
Measured PFC emission from Potline C	1.33 (newly-started)
Measured PFC emission from Potline D	2.38 (newly-started)
Measured PFC emission from Potline E	2.45 ([1]power-limitation)
Measured PFC emission from Potline F	1.24([2]new control-mode)
Measured PFC emission from Potline G	0.21
Australia average PFC emission in 2006	0.30
Original IAI PFC target in 2010	0.99

[1]Power limitation: The potline was running at lower line current 295kA (normal line current is 315kA) because of insufficient power.
[2]New control-mode: The potline was changing its control software which has different feeding intervals from original mode.

It can be learned from Table II that potline A and potline G have good AE performance and their PFC emissions are as low as Australia average value in 2006. But PFC emissions from power-limitation, new control-mode and newly-started potlines are much higher than normally-operated ones (3). Potline F in power-limitation emitted the highest PFC. Three of the seven potlines have PFC emission lower than original IAI PFC reduction target in 2010 (2).

PFC Concentration Curve

During measurement, when anode effects occurred, there would be peaks on the PFC concentration curve. Peaks for CF_4 and C_2F_6 always arose at the same moment (see Figure 4 and 5).

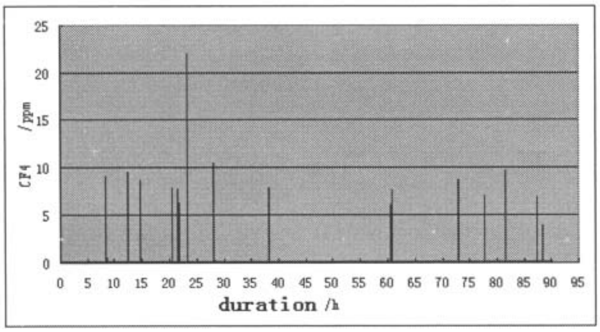

Figure 4 - CF_4 Concentration Curve (fourteen peaks)

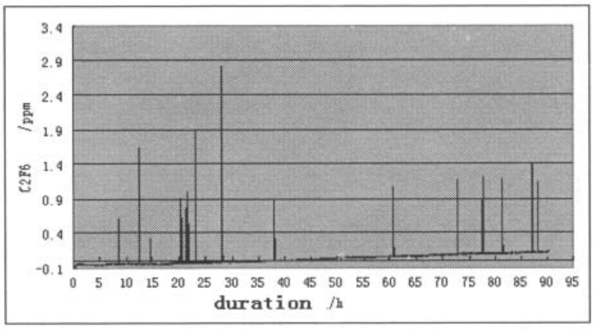

Figure 5 - C_2F_6 Concentration Curve (also fourteen peaks)

Table III - PFC Emissions and Continuous PFC in the Survey

Measured potlines	A	B	C	D	E	F	G
Line current, kA	182	335	239	202	295	215	180
*Including cells	68	13	36	95	45	53	39
Measurement duration, hr	86.29	72.22	72.11	72.07	71.85	73.03	90.14
Tapped metal during measurement, kg	339,594	101,358	189,938	430,198	291,666	260,619	197,598
AE CF_4 emission rate, kg/t-Al	0.0227	0.070	0.162	0.199	0.0628	0.135	0.0249
Non-AE CF_4 emission rate, kg/t-Al	0.0191	0.0163	0.0119	0.1121	0.2575	0.0271	0.0026
Total CF_4 emission rate, kg/t-Al	0.0418	0.0863	0.1739	0.3111	0.3203	0.1621	0.0275
The ratio of AE CF_4, %	54.26	81.13	93.17	63.96	19.61	83.28	90.70
The ratio of non-AE CF_4, %	45.74	18.87	6.83	36.04	80.39	16.72	9.30
Potlines running status	Normally operated	Normally operated	Newly started	Newly started	Power limitation	New control-mode	Normally operated

**Including cells: Cells in PFC measurement.*

Table IV – Measured and Calculated Flow Rate

Measured potlines	A	B	C	D	E	F	G
Line current, kA	182	335	239	202	295	215	180
Measured flow rate, Nm^3/h	275178	81481	161357	507476	408742	273964	186261
Calculated flow rate, Nm^3/h	302616	89018	177432	492728	344830	252046	176634
Measured uncertainty, %	9.97%	9.25%	9.96%	-2.91%	-15.64%	-8.00%	-5.17%
Remeasured flow rate, Nm^3/h	/	/	/	/	380704	/	/

Observation of Continuous PFC Emission

In this survey, low concentration of PFC emission not related to anode effects, named as non-AE PFC, was found (see Table III). Non-AE PFC rapidly attracted interests of ZRI and IAI experts. Non-AE PFC has characteristic of continuous emitting and low concentration, also called as continuous PFC emission. What cause non-AE PFC emission? Why potline F in power-limitation running emitted a large portion continuous PFC, but potline G in normally-operated gave off a small percentage continuous PFC emission?

Discussion

PFC Survey plan was mapped out by ZRI on the base of experiences from overseas research work on PFC from primary aluminum industry. The first survey was performed under the urgent need for reduction of PFC emission. Different abnormal statuses such as power-limitation, newly-started and new control-mode were included in the survey. Satisfactory results were obtained from the first survey.

PFC emission was obtained by calculation from anode effect performance and related data. Influences of aluminum production, collection efficiency, and especially duct flow rate were considered when PFC emissions were calculated.

In this survey, duct flow rate was measured by Pitot tube. Carbon balance calculation was carried out in order to prove accuracy of measured duct flow rate.

Carbon Balance Calculation

During aluminum electrolysis, following anode consumption, carbon changed into gaseous carbon compounds such as CO_2, CO, COS, CH_4, CF_4 and C_2F_6. Total carbon amount from these compounds should be equal to net carbon consumption per tonne aluminum. This carbon amount can be calculated based on duct flow rate and gas concentration. If the calculated value is close to measured value, the measured duct flow rate is reliable, or the duct flow rate should be remeasured. The formula for carbon balance calculation is as following.

$$C = 12 \times [(M_{CO2}/44) + (M_{CO}/28) + (M_{COS}/56) + (M_{CH4}/16) + M_{CF4}/88] + (M_{C2F6}/138)$$

Here,
C - Total carbon amount from gaseous carbon compounds, kg;
M_{CO2}, M_{CO}, M_{COS}, M_{CH4}, M_{CF4} and M_{C2F6}—Amount of CO_2, CO, COS, CH_4, CF_4 and C_2F_6,which can be calculated from measured duct flow rate and gas concentration, respectively, kg.
Duct flow rates of seven potlines were measured and calculated (see Table IV). D and G potlines had lower uncertainty, but potline E had a higher uncertainty and its duct flow rate was given a remeasurement.

Conclusions

PFC emission from Chinese normally-operated smelters is similar to that of Western ones. The lowest PFC emission is 0.21 tCO_2-e/t-Al. The potlines operated in various abnormal situations emitted much more PFC than normally-operated ones. Power-limitation was the worst circumstance which caused the most PFC emission. Potlines in newly-started and control-mode changing period released much PFC emission as well.
There is still a way ahead for PFC survey and investigation in China although some work has been done by ZRI. Continuous PFC emission will be focused on in the future surveys. Factors causing continuous PFC emission will be fully investigated.

Acknowledgement

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