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ANNEX IV

Activity-specific monitoring methodologies related to installations (Article 20(2))

8. PFC EMISSIONS FROM PRODUCTION OR PROCESSING OF PRIMARY ALUMINIUM AS LISTED IN ANNEX I TO DIRECTIVE 2003/87/EC

A. Scope

The operator shall apply the following for emissions of perfluorocarbons (PFCs) resulting from anode effects including fugitive emissions of PFCs. For associated CO₂ emissions, including emissions from electrode production, the operator shall apply section 7 of this Annex. The operator shall furthermore calculate PFC emissions not related to anode effects based on estimation methods in accordance with industry best practice, and any guidelines published by the Commission for this purpose.

B. Determination of PFC emissions

PFC emissions shall be calculated from the emissions measurable in a duct or stack ('point source emissions') as well as fugitive emissions using the collection efficiency of the duct:

$$\text{PFC emissions (total)} = \text{PFC emissions (duct)} / \text{collection efficiency}$$

The collection efficiency shall be measured when the installation-specific emission factors are determined. For its determination the most recent version of the guidance mentioned under Tier 3 of section 4.4.2.4 of the 2006 IPCC Guidelines shall be used.

The operator shall calculate emissions of CF₄ and C₂F₆ emitted through a duct or stack using one of the following methods:

- (a) Method A where the anode effect minutes per cell-day are recorded;
- (b) Method B where the anode effect overvoltage is recorded.

Calculation Method A – Slope Method:

The operator shall use the following equations for determining PFC emissions:

$$\text{CF}_4 \text{ emissions [t]} = \text{AEM} \times (\text{SEF}_{\text{CF}_4} / 1\,000) \times \text{Pr}_{\text{Al}}$$

$$\text{C}_2\text{F}_6 \text{ emissions [t]} = \text{CF}_4 \text{ emissions} \times \text{F}_{\text{C}_2\text{F}_6}$$

Where:

AEM	= Anode effect minutes / cell-day;
SEF _{CF₄}	= Slope emission factor [(kg CF ₄ / t Al produced) / (anode effect minutes / cell-day)]. Where different cell-types are used, different SEF may be applied as appropriate;
Pr _{Al}	= Annual production of primary Aluminium [t];
F _{C₂F₆}	= Weight fraction of C ₂ F ₆ (t C ₂ F ₆ / t CF ₄).

The anode effect minutes per cell-day shall express the frequency of anode effects (number anode effects / cell-day) multiplied by the average duration of anode effects (anode effect minutes / occurrence):

$$\text{AEM} = \text{frequency} \times \text{average duration}$$

Emission factor: The emission factor for CF₄ (slope emission factor, SEF_{CF₄}) expresses the amount [kg] of CF₄ emitted per tonne of aluminium produced per anode effect minute / cell-day.

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The emission factor (weight fraction $F_{C_2F_6}$) of C_2F_6 expresses the amount [t] of C_2F_6 emitted proportionate to the amount [t] of CF_4 emitted.

Tier 1: The operator shall use technology-specific emission factors from Table 1 of this section of Annex IV.

Tier 2: The operator shall use installation-specific emission factors for CF_4 and C_2F_6 established through continuous or intermittent field measurements. For the determination of those emission factors the operator shall use the most recent version of the guidance mentioned under Tier 3 of section 4.4.2.4 of the 2006 IPCC Guidelines⁽¹⁾. The emission factor shall also take into account emissions related to non-anode effects. The operator shall determine each emission factor with a maximum uncertainty of $\pm 15\%$.

The operator shall determine the emission factors at least every three years or earlier where necessary due to relevant changes at the installation. Relevant changes shall include a change in the distribution of anode effect duration, or a change in the control algorithm affecting the mix of the types of anode effects or the nature of the anode effect termination routine.

TABLE 1

Technology-specific emission factors related to activity data for the slope method.

Technology	Emission factor for CF_4 (SEF _{CF4})[(kg CF_4 /t Al) / (AE-Mins/cell-day)]	Emission factor for C_2F_6 (F _{C2F6})[t C_2F_6 / t CF_4]
Centre Worked Prebake (CWPB)	0,143	0,121
Vertical Stud Søderberg (VSS)	0,092	0,053

Calculation Method B – Overvoltage Method:

Where the anode effect overvoltage is measured, the operator shall use the following equations for the determination of PFC emissions:

$$CF_4 \text{ emissions [t]} = OVC \times (AEO/CE) \times Pr_{Al} \times 0,001$$

$$C_2F_6 \text{ emissions [t]} = CF_4 \text{ emissions} \times F_{CF_2F_6}$$

Where:

- OVC = Overvoltage coefficient ('emission factor') expressed as kg CF_4 per tonne of aluminium produced per mV overvoltage;
- AEO = Anode effect overvoltage per cell [mV] determined as the integral of (time \times voltage above the target voltage) divided by the time (duration) of data collection;
- CE = Average current efficiency of aluminium production [%];
- Pr_{Al} = Annual production of primary Aluminium [t];
- $F_{CF_2F_6}$ = Weight fraction of C_2F_6 (t C_2F_6 / t CF_4);

The term AEO/CE (Anode effect overvoltage / current efficiency) expresses the time-integrated average anode effect overvoltage [mV overvoltage] per average current efficiency [%].

Emission factor: The emission factor for CF_4 ('overvoltage coefficient' OVC) shall express the amount [kg] of CF_4 emitted per tonne of aluminium produced per millivolt overvoltage [mV].

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The emission factor of C₂F₆ (weight fraction F_{C₂F₆}) shall express the amount [t] of C₂F₆ emitted proportionate to the amount [t] of CF₄ emitted.

Tier 1: The operator shall apply technology-specific emission factors from Table 2 of this section of Annex IV.

Tier 2: The operator shall use installation-specific emission factors for CF₄ [(kg CF₄ / t Al) / (mV)] and C₂F₆ [t C₂F₆/ t CF₄] established through continuous or intermittent field measurements. For the determination of those emission factors, the operator shall use the most recent version of the guidance mentioned under Tier 3 of section 4.4.2.4 of the 2006 IPCC Guidelines. The operator shall determine the emission factors with a maximum uncertainty of ± 15 % each.

The operator shall determine the emission factors at least every three years or earlier where necessary due to relevant changes at the installation. Relevant changes shall include a change in the distribution of anode effect duration or a change in the control algorithm affecting the mix of the types of anode effects or the nature of the anode effect termination routine.

TABLE 2

Technology-specific emission factors related to overvoltage activity data.

Technology	Emission factor for CF ₄ [(kg CF ₄ /t Al) / mV]	Emission factor for C ₂ F ₆ [t C ₂ F ₆ / t CF ₄]
Centre Worked Prebake (CWPB)	1,16	0,121
Vertical Stud Søderberg (VSS)	N.A.	0,053

C. Determination of CO_{2(e)} emissions

The operator shall calculate CO_{2(e)} emissions from CF₄ and C₂F₆ emissions as follows, using the global warming potentials listed in Annex VI section 3 Table 6:

$$\text{PFC emissions [t CO}_{2(e)}\text{]} = \text{CF}_4 \text{ emissions [t]} \times \text{GWP}_{\text{CF}_4} + \text{C}_2\text{F}_6 \text{ emissions [t]} \times \text{GWP}_{\text{C}_2\text{F}_6}$$

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- (1) International Aluminium Institute; The Aluminium Sector Greenhouse Gas Protocol; October 2006; US Environmental Protection Agency and International Aluminium Institute; Protocol for Measurement of Tetrafluoromethane (CF₄) and Hexafluoroethane (C₂F₆) Emissions from Primary Aluminum Production; April 2008.

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Changes and effects yet to be applied to :

- Regulation amendment to earlier affecting provision S.I. 2020/1265, Sch. 4 by [S.I. 2020/1557 art. 35\(3\)-\(8\)](#)
- Regulation amendment to earlier affecting provision S.I. 2020/1265, Sch. 4 by [S.I. 2021/1455 art. 22\(2\)-\(9\)](#)
- Regulation amendment to earlier affecting provision S.I. 2020/1265, Sch. 4 by [S.I. 2022/1173 art. 13](#)
- Regulation amendment to earlier affecting provision S.I. 2020/1265, Sch. 4 by [S.I. 2023/850 art. 8\(2\)](#)
- Regulation amendment to earlier affecting provision S.I. 2020/1265, Sch. 7 para. 13 by [S.I. 2022/1173 art. 17\(3\)](#)
- Regulation modified by [S.I. 2020/1265 art. 24Sch. 4](#)
- Regulation modified by [S.I. 2020/1265 Sch. 7 para. 13](#)
- Regulation modified by 2019 c. 1, s. 77(4) (as substituted) by [2020 c. 14 Sch. 12 para. 7\(3\)](#)
- Regulation power to amend conferred by 2019 c. 1, ss. 76, 77 (as amended) by [2020 c. 14 Sch. 12 para. 4\(4\)\(b\)\(i\)7\(2\)\(b\)](#)
- Regulation power to amend conferred by 2019 c. 1, ss. 76, 77 (as amended) by [2020 c. 14 Sch. 12 para. 5\(b\)7\(2\)\(b\)](#)
- Regulation restricted by [S.I. 2020/1265 Sch. 8 para. 5\(3\)](#)