РУСАЛ

КРАСНОЯРСКИЙ
АЛЮМИНИЕВЫЙ
ЗАВОД

M O N I T O R I N G   R E P O R T

ON JOINT IMPLEMENTATION PROJECT
«Reduction of PFC emissions from RUSAL Krasnoyarsk Aluminium Smelter»

PERIOD OF MONITORING: ***from 1 January 2010 to 31 December 2010***

VERSION OF REPORT: 1.1 (final after verification)

DATE OF REPORT ISSUANCE: 18 April 2011

Table of content

Section A. General information on the project activity

A.1. Introduction

The data presented in this monitoring report has been collected in line with the PDD for the JI project Reduction of PFC emissions from RUSAL Krasnoyarsk Aluminium Smelter (PDD version 3.0 of 27th October 2008, the positive determination opinion of DNV is received, report № 2008-1624) over the period 1st January 2010 – 31th December 2010.

The considered project has been approved in Russian Federation (RF) as Host Party by the Order of Ministry of Economic Development of RF # 709 of December 30, 2010.

The Declaration of Approval from State of the Netherlands, acting through the Ministry of Economic Affairs, Agriculture and Innovation and its implementing agency "NL Agency", being the Designated Focal Point for Joint Implementation (JI) in The Netherlands has been received for the project by 18th March 2011.

The purpose of this project is to reduce emissions of perfluorocarbons (PFCs) through the reduction of anode effect frequency (AEF) and anode effect duration (AED), by implementing a number of organizational and technical measures at the 24 potrooms of RUSAL Krasnoyarsk Aluminium Smelter (KrAZ), located in the city of Krasnoyarsk, Russian Federation. Twenty one of these potrooms use vertical stud Søderberg process with point feeders (PFVSS), the remaining – prebake anode process with point feeders (PFPB). The project is limited to CF_4 and C_2F_6 emissions.

Project started in 1st January 2006. The implementation of the project that is expressed in achievement of the annual targets for reduction of frequency and duration of anode effects will be held at least until 31st December 2012.

During the 2010 the target on AEF has changed several times and it was connected to the overcome of the negative consequences of the alumina deficit in January-February 2010 (see below). The target on AEF is prescribed in the Technological Regulation TR 449.01.01.01 "Technological parameters of production of crude aluminium in electrolytic cells of RUSAL Krasnoyarsk". The edition 11 of this document of 12.01.2010 established the target for PFVSS technology on 0.3 anode effects/cell-day (common for the majority of potrooms) and 0.1 anode effects/cell-day for PFPB technology. The edition 19 of the TR 449.01.01.01 of 14.12.2010 has established the AEF target for PFVSS technology on 0.35-0.4 anode effects/cell-day and for PFPB technology the target was set as 0.2 anode effects/cell-day.

The project uses own methodology for calculation of baseline and project line emissions based on the 3-rd version of the methodology "The Aluminium Sector Greenhouse Gas Protocol" (Addendum to the WRI/WBCSD Greenhouse Gas Protocol) 2006, which has been approved and included in 2006 IPCC Guidelines for National Greenhouse Gas Inventories. According to the IPCC methods, PFCs emissions are influenced by four parameters, which depend on the specific aluminium production: overall production of electrolytic aluminium, frequency and duration of anode effects, slope coefficient for CF_4 and weight fraction of C_2F_6/CF_4.

The volume of electrolytic aluminium output, frequency and duration of anode effects are the subjects of continuous monitoring at Krasnoyarsk aluminium smelter: every fact of anode effect appearance and its duration is logged, therefore the values of AEF and AED for the period of observation (month, year) for each potroom are averaged. The slope coefficient and weight fraction of C_2F_6/CF_4 are measured once in three years by each technology of electrolysis in accordance with PDD and recommendations of International Aluminium Institute (IAI). Thereby the values of slope coefficient and weight fraction of C_2F_6/CF_4 are correspondent by accuracy to Tier 3 level of IPCC Guidelines for National Greenhouse Gas Inventories.

Previous measurements were conducted in September 2007 with direct participation of Jerry Marks – consultant of IAI and IPCC. In July-August 2010 in accordance with contract # 29.03.04/2010 "Execution of instrumental measurements of GHG emissions at OJSC "RUSAL Krasnoyarsk", stage 2 the All-Russian Aluminium and Magnesium Institute (VAMI) carried out the new measurements of PFC emissions from aluminium production to determine the specified slope coefficient and weight fraction of C_2F_6/CF_4 for

PFVSS and PFPB technologies.

Thus in this report the calculation of PFC emissions for 2010 is divided into 2 parts:

- For the period from 1 January 2010 to August 31, 2010, the values of the slope coefficient and the weight fraction of C_2F_6/CF_4 for each technology determined by measurements in 2007;

- For the period from September 1, 2010 to December 31, 2010, the values of the slope coefficient and the weight fraction of C_2F_6/CF_4 for each technology determined by measurements in 2010.

A.2. Technology employed

The project has been realized at 21 potrooms with vertical stud Søderberg process and 3 potrooms with the prebaked anodes technology. Therefore within the project boundaries are 2233 electrolytic cells totally and all cells are equipped with point feeders.

In accordance with PDD the electrolytic cells for production of high-purity aluminium (74 pots in potroom 25) are outside the project boundary because these pots have been designed for aluminium refinement by three-layer method instead of its initial generation. During such electrolysis the anode is situated underneath in the layer of the metal and PFCs are not evolved due to the absence of anode effects.

A.3. Emission reduction for monitoring period

In 2010 project has generated **284 745** tones CO_{2eq} of emission reduction units (ERU) including in the period of 1 January 2010 to August 31, 2010 – **78 310** tones CO_{2eq} , and in the period of September 1, 2010 to December 31, 2010 – **206 435** tones CO_{2eq} that is higher than estimated in PDD (230 945 tones CO_{2eq}). The cause of nonconformity is the increase of anode effects frequency in the 1st quarter 2010 and application of the new values of slope coefficient and the weight fraction of C_2F_6/CF_4:

- A significant increase in the frequency of anode effects in January-February 2010 is associated with the reduction of alumina reserve below the technologically required minimum and accordingly disruption of timeline of point feeders bunkers loading. In further the raised number of anode effects was caused by following reasons: failure of treatment equipment, breakdown of point feeders system (largely due to damage and deformation of structures under high temperature at unsealed pots during the above mentioned period of alumina deficit). By the summer of 2010 the frequency of anode effects returned to normal values.

- New values of slope coefficient and weight fraction C_2F_6/CF_4 used in the calculations since 01.09.2010 and resulted from measurements carried out in July-August 2010 by VAMI institute in accordance with contract # 29.03.04/2010 "Execution of instrumental measurements of GHG emissions at OJSC "RUSAL Krasnoyarsk", stage 2. In line with recommendations of IAI consultant Jerry Marks the previous coefficients acted during the three-year period, i.e. until 31.08.2010.

- During 2010 the work on enhancement in the sphere of planning of anode effects appearance has continued, in particular on the techniques for technological treatment of the cells partially without anode effect.

A.4. Contact information

RUSAL Krasnoyarsk	Maksim Yurievich Korobkov, Chief manager of electrolysis production tel: +7 (3912) 56 3860 Maksim.Korobkov@rusal.com
UC RUSAL	Ivan Ivanovich Rebrik, Environmental department director tel: +7 (495) 720 5170 ext. 8602 ivan.rebrik@rusal.com

Section B. Description of the project monitoring system

B.1. Monitored data

The following table highlights the data monitored during the project activity, and which is to be stored not less than 10 years after start of the monitoring period for the project. (See also B.2).

Data variable	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
MP	tones	m/c	monthly	100%	Overall production of electrolytic aluminium for Baseline and Project
AEFp	times/ cell-day	m	constantly	100%	Actual average frequency of anode effects
AEDp	minutes	m	constantly	100%	Actual average duration of anode effects
S_{CF_4}	(kg of CF_4/ tonne of aluminium)/ (number of minutes of anode effect/ cell-day)	m	Once in three years or in case of change of the pot type/ considerable change in technology	No less than 15 anode effects per each reduction technology type (PFVSS, PFPB)	Tier 3 Slope coefficient for CF_4 measured in accordance to last version of Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production, US EPA and IAI
Weight fraction of C_2F_6/CF_4	Unit fraction	m	Once in three years or in case of change of the pot type/ considerable change in technology	No less than 15 anode effects per each reduction technology type (PFVSS, PFPB)	Tier 3 Slope coefficient for CF_4 measured in accordance to last version of Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production, US EPA and IAI
Average weight of 1 cm of metal in the pot	Kg	c	Once per year for each potroom	10% of pots in the potroom	The method is based on estimation of the difference between mass fraction of the copper and aluminium during 24 hours, measurement if the level of metal in pot and following calculation by formula. The parameter is used for estimation of amount of liquid aluminium in

a) ***Overall production of electrolytic aluminium by potrooms***

Overall production of electrolytic aluminium per potroom for reporting period (month) is estimated by addition of weight of raw aluminium determined by weighting of ladles with metal taken from potroom and difference in weight of aluminium in progress (AIP) that consist of liquid aluminium being in pots and small amount of solid aluminium. The weight of aluminum in progress is determined at the end of each month and accordingly the subtraction of one volume from another results in the value of difference with positive or negative sign. These separation and methods for estimation are prescribed in “Regulation for estimation of cost-performance characteristics of electrolytic production at the smelters of aluminium division of RUSAL company”. It should be noted that the difference in the amount of metal in progress for reporting period is less than 1% of the annual production of electrolytic aluminium.

Weighting of ladles is performed with the scales “Scalex-1000” by the quality control department personnel according to the “Areal-type scales “Scalex-1000” User’s Manual. The scales are included into the “List of measuring tools subject to control”, and annually checked according to “Measuring tools check-up schedule” by the specialists of the Federal State Facility “Krasnoyarskiy TsSM” with issuing calibration certificates. Permissible maximum accuracy is ±20 kg within the range of 5,000 to 20,000 kg. (GOST 8.453-82 Scales for statistical weighting. Methods and means of verification).

Records on weighting of the ladles with metal are input by “Weighting workstation” terminal and stored in electronic form in Information and Technological System (ITS) database at Oracle. The time of data storage is limited only by volume of free disk space which is periodically enlarged.

Mass of liquid aluminium in pots is determined monthly according to valid standard: instruction I 10.03-2002 “Methodology of accounting of the stock of raw materials, goods and metal in progress in electrolysis potrooms” and “Standard methodology for inventory of working remains and goods-in-progress at smelters of OJSC “Russian Aluminium”.

The method of estimation is following: the quantity of liquid metal is calculated by multiplication of average level (height) of metal in pot to the average weight of one centimeter of the metal, and to the number of pots in progress. The measurements are done daily for formation of the day plan for pouring out of the metal from pots and planning of other operations. Data on the last day of the month is compared with same data for last day of the previous month and provides a basis for estimation of difference in metal in progress.

A level of metal is measured by the ruler which is a non-standard tool for measurement fabricated on drawing. In accordance with instruction I 8-21-2001 «Order of performance of the measurements at electrolytic cells with top current feed” a gauge for measurement of the level of metal and electrolyte are subject for Quality Control Department during issuance from fabrication line and by technological staff during exploitation. During fabrication a producer company OJSC “Siberian instrument and repair factory” performs an initial calibration with issuance of the certificate on calibration. In process of exploitation the personnel performing the measurements observe the state of the ruler by comparison with calibrated ruler and visual inspection to check the defacement of the bottom part of the ruler and its mechanic damage. Thereby the ability for further application of the ruler is done. Once in 6 months by schedule the rules are sent to the Metrological department for calibration. By results of the calibration the appropriate certificate is issued. The graduation of the ruler is 1 cm, according to work standard RS 211.010.2008 (Measurement of level of metal and electrolyte) the level of metal is measured with accuracy of ±1 cm.

An average weight of one centimeter of the liquid metal is defined not less than once per year with metal indicator. The method is based on estimation of the difference between mass fraction of the copper in aluminium during 24 hours, measurement of the level of metal and further calculation by formula. Measurement is done at 10% of the pots installed in the potroom according to valid standard “Methodology for determination of the weight of 1 cm of liquid aluminium in the cell by indicator technique”. The copper is weighted with accuracy of 1 g.

Records on quantity of aluminium in electrolytic cells are documented by “Act of definition of metal-in-progress in electrolytic cells of “OJSC “RUSAL Krasnoyarsk” and stored not less than 5 years in the archive of Group of planning and analysis of electrolytic production according to current practice. A quantity of solid aluminium is estimated by multiplication of volume of the metal to its density and documented in acts for inventory of working remains. The acts are stored in Group of planning and analysis of electrolytic production for 5 years. For proper reporting on the considered Joint Implementation project the additional copying of these documents is provided for the aim of their guaranteed storage during 10 years.

Data on production of electrolytic aluminum are recorded in the monthly technical reports that are part of the documentation of an integrated management system of the enterprise. In the report for December, which is prepared in mid-January next year, there is information about the production of aluminum in each electrolysis potroom. Technical reports are sent to the office of the Management Company RUSAL (UC RUSAL) in Moscow. On the basis of an annual technical report and data of information portal, from which there is access to the ARM SMIT, the specialists UK RUSAL fill the reporting of emissions of perfluorocarbons for the International Aluminium Institute - form PFC001. This report is used for calculation of ERUs from the project because it contains all the necessary parameters for monitoring.

For the calculation of ERUs in 2010 the input data has been taken directly from the technical report of the Krasnoyarsk Aluminum Plant and System ARM SMIT, because the calculation is divided into two parts, while the data in the report of PFC001 form spread for the full year.

b) ***Average frequency and duration of anode effects***

Average anode effect frequency and duration by potroom for reporting period is measured by the aluminum electrolysis process automatic control system (ACS) SAAT-1. The responsibilities and work sequence of ACS operator is outlined in “SAAT-1 Operator’s Manual”. The process computer control SAAT-1 has a hierarchical two-level structure. The upper level is based on SUN server station (host computer). Information is achieved in electronic database of Information and Technological System (ITS) based on Oracle. Access to the date of frequency and duration of anode effects is provided through workstation ARM SMIT. A duration of the storage of these data is limited by free disk space only which is periodically enlarged. Therefore the data on frequency and duration of anode effects happened during the crediting period will be kept not less than 10 years.

To provide the maintenance and process personnel with information, the server station is connected via Ethernet 10Base-T to the control station operator workstation, to chief foremen workstations and to workstations of foremen of the anode facility. The data concentrator provides the data exchange between the host computer and the controllers of the control boxes of pots (lower level controllers). Both the data concentrator and the operator workstation are located in the control station of the potroom. Operation of the pot control system is based on the principle of generation (elaboration) of control actions on the actuating mechanisms of pots by means of mathematical processing of information on the electrolysis process, logical processing of signals about control positioning and actuating mechanisms condition.

One of the functions of the process control system is to control anode effects by the voltage measure channel on the anode and cathode (Ua-k) section. The operational voltage on the pot is 4.5 Volts in average. When it raises above 9 Volts the system fixes a start of anode effect and generate the corresponding sound and light information for the potroom staff shift. The average voltage of anode effect is 45 Volts. When the voltage drops down to 3.5 Volts (which happens after anode effect quenching measures have taken effect) the system fixes the duration of anode effect and it is counted as quenched. Thereby the information on frequency and duration of each anode effect is stored at the smelter.

The channel’s basic accuracy is ±0.2 %. The measuring channel is calibrated once per two years according to the “Guidelines. ACS for electrolysis of aluminium. Calibration procedure”. Calibration is performed by specialists of a contracted organization according to the Regulations for “check-up/calibration of measuring tools”.

Based on the data accumulated during the automatic control system operation, the percentage of lost information on frequency and duration of AE due to process automatic control system failure is approximately equal to 2%, therefore the degree of uncertainty is low, and it is composed of the channel accuracy and availability of the technological process control system.

c) *Slope coefficient for CF_4 and weight fraction C_2F_6/CF_4*

The slope coefficients and weight fractions C_2F_6/CF_4 have been determined by instrumental measurements of PFC emissions from potrooms according to the Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production, US EPA and IAI, 2003. In line with that the values of slope coefficient and weight fraction C_2F_6/CF_4 are taken to be equal for all potrooms of OJSC "RUSAL Krasnoyarsk" working on the respective technology.

The first series of measurements was executed in September 2007 under control and direct participation of Jerry Marks, an expert of IAI. The second series of the measurements was carried out in July-August 2010 by the specialists of VAMI which earlier participated in the team of measurements of 2007. These measurements were carried out in one potroom of PFVSS technology (potroom #22) and two potrooms of PFPB technology (potroom #7 and #8).

Based on conservativeness principle for calculation of PFC emissions in the project and baseline the values determined for the potroom #7 have been taken since they are less than the same ones for the potroom #8. Also to be conservative the values of weight fraction C_2F_6/CF_4 determined in 2010 and exceeding IPCC 2006 Tier 2 standard values, have been replaced to them in the calculations of ERUs.

In similar principles the new values of slope coefficient and weight fraction C_2F_6/CF_4 (IPCC Tier 2 value) are applied for calculation since September 2010, i.e. after the carried out measurements, while IAI has agreed with RUSAL to use new values in the PFC001 reporting for all the year 2010.

According to the data collected by Mr. Jerry Marks, and presented in the report on perfluorocarbon emission measurements in 2007, the main sources of uncertainty during continuous measuring are:

- spectrometer calibration uncertainty,
- the effectiveness of the analytical method in calculating the CF_4 and C_2F_6 concentrations from the measured spectrum,
- the measurement of the flow rate of exhaust gases in the collection ducts.

Another source of uncertainty in the Krasnoyarsk VSS measurements is the estimation of exhaust gas collection fraction and the short term variability of the collection fraction during anode effects.

The table below summarizes sources of uncertainty in the PFC measurement and estimates the magnitudes of each uncertainty source. Using IPCC Tier 3 guidelines (see IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Section 6.3.2, http://www.ipcc-nggip.iges.or.jp/public/gp/pdf/6_Uncertainty.pdf) for estimating uncertainty, the overall combined uncertainty from all sources is expected to give a result that is ± 12% of the actual value. The calculation methodology is based on the combined variances of all the major sources of uncertainty and is calculated as the square root of the sum of the squares of the individual uncertainties.

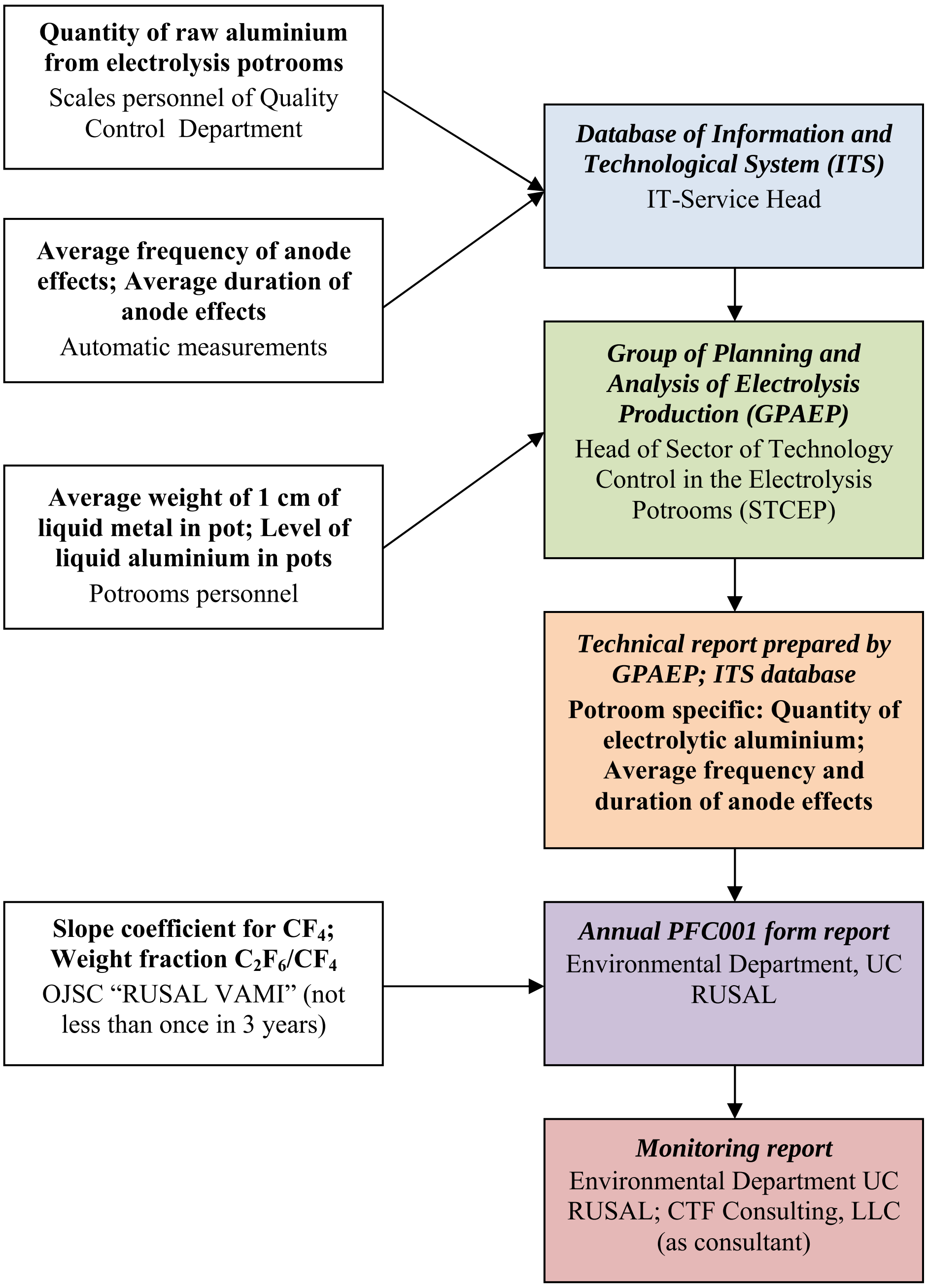
Summary table of sources and values of uncertainty

Uncertainty Source	Estimated Uncertainty
Spectrometer calibration	$< \pm 2\%$
Calculations performed with spectrometer	$< \pm 10\%$
Exhaust Stack Flow Measurement	$< \pm 5\%$
Collection Fraction Uncertainty	$< \pm 5\%$
Overall combined Uncertainty	$< \pm 12\%$

Thus, Uncertainty of slope coefficients is ±12%.

B.2 Accounting, registration and storage of data. Scheme of data flow

№	Data variable	Unit	Volume of data	Periodicity	Form of data	Way of storage (electronic / paper)	Place of storage	Storage duration	Responsibility	
									for data validity	for data retention
1	Quantity of raw aluminium from electrolysis potrooms	tones	100%	Each ladle	Information of database	Electronic form	Database of Information and Technological System (ITS)	Not less than 10 yr	Head of Quality Control Department (QCD)	IT-Service Head
2	Quantity of electrolytic aluminium produced	tones	Each potroom/ 100%	Monthly, annually	Technical report	Paper form	Group of Planning and Analysis of Electrolysis Production (GPAEP)	Not less than 10 yr	Head of Sector of Technology Control in the Electrolysis Potrooms (STCEP)	Head of Cathode Equipment Service of Department of Electrolysis Production (CES DEP)
3	Average frequency of anode effects	times / cell-day	Each potroom	Monthly, annually	Technical report	Paper form	GPAEP	Not less than 10 yr	Head of STCEP	Head of CES DEP
			100%	Daily	Information of database	Electronic form	Database of ITS	Not less than 10 yr	Head of STCEP	IT-Service Head
4	Average duration of anode effects	minutes	Each potroom	Monthly, annually	Technical report	Paper form	GPAEP	Not less than 10 yr	Head of STCEP	Head of CES DEP
			100%	Daily	Information of database	Electronic form	Database of ITS	Not less than 10 yr	Head of STCEP	IT-Service Head
5	Slope coefficient for CF_4	kg of CF_4/ tonne of aluminium)/ (number of minutes of anode effect/ cell-day	No less than 15 anode effects per each reduction technology type	Once per three years	Measurements report	Paper form	Environmental Department of UC "RUSAL"	Not less than 10 yr	OJSC "RUSAL VAMI"	Environmental Department of UC "RUSAL"
6	Weight fraction C_2F_6/CF_4	Unit fraction								
7	PFC emissions	t CO_{2eq}	Each potroom/ Smelter	Annually	Report on PFC emissions	Paper form	Environmental Department of UC "RUSAL"	Not less than 10 yr	Environmental Department of UC "RUSAL"	Environmental Department of UC "RUSAL"
8	Average weight of 1 cm of liquid metal in pot	kg	Each potroom	Annually	Technical report	Paper form	GPAEP	Not less than 10 yr	Head of CES DEP	Head of CES DEP



B.3. Environmental monitoring

The project participants do not expect any negative environmental impact resulting from implementation of activities within the frameworks of this project, and the Russian governmental bodies do not require any surveys regarding environmental impact of the project.

B.4. Management system

KrAZ has and certified integrated management system in accordance to ISO 9001, 14001 и OHSAS 18001. And all equipment related to electrolysis production and the project is covered by calibration procedures of plant. The equipment of VAMI used for PFC measurements are calibrated in accordance to technical requirements for measurement equipment maintenance.

B.5. Revisions of the monitoring plan in accordance with paragraph 40 of the Guidance on criteria for baseline setting and monitoring (version 02)

The monitoring plan has been implemented in accordance with PDD. No revisions were made during the monitoring period.

To improve transparency of the monitoring plan in accordance with recommendations of accredited independent entity Bureau Veritas received during the initial verification the monitoring plan was added with data variable "Average weight of 1 cm of liquid metal in pot", which is applied for estimation of mass of liquid aluminium in progress. Information on the value of this parameter is contained in the monthly and annual technical report of the smelter.

Section C. Emission reduction calculation

C.1. Emission reductions generated

In line with the PDD for the project activity the total number of ERUs (tCO_{2eq}) is calculated from the following equation:

$$R_{CO_{2E}} = Eb_{CO_{2E}} - Ep_{CO_{2E}} \qquad \text{Formula (1)}$$

where,

$R_{CO_{2Э}}$ – Emission reduction, tonnes of CO_{2eq}

$Eb_{CO_{2Э}}$ – Baseline emissions, tonnes of CO_{2eq}

$Ep_{CO_{2Э}}$ – Project emissions, tonnes of CO_{2eq}

C.2. Baseline emissions

$$Eb_{CO_{2E}} = MP \times AEFb \times AEDb \times S_{CF_4} \times \left(\frac{6500 + F_{C_2F_6/CF_4} \times 9200}{1000} \right) \qquad \text{Formula (2)}$$

where:

MP	Overall production of electrolytic aluminium, tonnes of aluminium per year
AEFb	Average frequency of anode effects in the baseline, times / cell-day
AEDb	Average duration of anode effects in the baseline, mins
S_{CF_4}	Slope coefficient for CF_4, kg of CF_4 / tonne of aluminium / number of minutes of anode effect / cell-day
$F_{C_2F_6/CF_4}$	Weight fraction of C_2F_6/CF_4
6500	Global warming potential for CF_4
9200	Global warming potential for C_2F_6

For estimation of PFCs emissions in the absence of the project activity (baseline scenario), the smelter has provided a reasonable estimate of AEF and AED values, that would have been in the case of absence of the project (see Annex 2) of PDD, version 3.0 of 27 October 2008.

C.3. *Project emissions*

$$Ep_{CO_{2E}} = MP \times AEFp \times AEDp \times S_{CF_4} \times \left(\frac{6500 + F_{C_2F_6/CF_4} \times 9200}{1000} \right) \qquad \text{Formula (3)}$$

where:

MP	Overall production of electrolytic aluminium, tonnes of aluminium per year
AEFp	Average frequency of anode effects in the project, times / cell-day
AEDp	Average duration of anode effects in the project, mins

S_{CF_4}	Slope coefficient for CF_4, kg of CF_4 / tonne of aluminium / number of minutes of anode effect / cell-day
$F_{C_2F_6/CF_4}$	Weight fraction of C_2F_6/CF_4
6,500	Global warming potential for CF_4
9,200	Global warming potential for C_2F_6

C.4 Calculation of emission reductions

Calculation of emissions reduction is done in accordance with given formulae. As it was mentioned above the values of slope coefficient and weight fraction C_2F_6/CF_4 differ for two periods of monitoring in 2010: before and after 1st September 2010 (additional clarification is provided in Annex 1).

For the purpose of conservativeness in the calculation of baseline and project emissions the values of weight fraction C_2F_6/CF_4 estimated after measurements of 2010 and exceeding IPCC 2006 Tier 2 standard values, have been replaced to them:

Technology	Name and designation	Values applied for calculation (measurements of 2007)	Measurements of 2010	Values applied for calculation
Validity period for the coefficients		01.01.2010-31.08.2010	Since 01.09.2010	01.09.2010-31.12.2010
PFVSS	Slope coefficient (S_{CF_4})	**0,032**	0,088	**0,088**
PFVSS	Weight fraction ($F_{C_2F_6/CF_4}$)	**0,044**	0,065	**0,053** (IPCC 2006 Tier 2 standard value)
PFPB	Slope coefficient (S_{CF_4})	**0,133**	0,131	**0,131**
PFPB	Weight fraction ($F_{C_2F_6/CF_4}$)	**0,05**	0,264	**0,121** (IPCC 2006 Tier 2 standard value)

For calculation of the emission reductions, the key factors, those listed in 23 (b) (i)-(vi) of Determination and Verification Manual (DVM), influencing the baseline emissions and the activity level of the project as well as risks associated with the project were taken into account as follows:

- Metallurgical sector reform policies and legislation (the Strategy of development of the metallurgical industry of Russia until 2020 approved by Order of Ministry of Industry and Trade of Russia by March 18, 2009 № 150);
- Economic situation in the metallurgical sector of Russia as well as resulting predicted demand;
- Technical specifics of the electrolytic aluminium technology;
- Availability of capital;
- Local availability of technologies/techniques;
- Fuel prices and availability.

For calculation of the baseline emissions only AEF and AED values were fixed ex-ante according to the PDD version 3.0 of 27th October 2008. It is reasonably assumed that without paying the special attention to those main factors influencing PFC emissions (absence of the project) that is financially compensated through the sale of generated ERUs, RUSAL Krasnoyarsk would retain the higher values of the AEF and AED.

The output of electrolytic aluminum and values of slope coefficient and weight fraction C_2F_6/CF_4 are monitored during the crediting period and considered to be the same in the project and the baseline.

As noted in the Annex I in 2010 RUSAL Krasnoyarsk has started the implementation of the modernized electrolytic cells "EcoSøderberg" and one of the sources for financing of this measure during 2010-2014 will be the income from ERUs sale from considered project[1].

Therefore the key factors, those listed in 23 (b) (i)-(vi) of DVM are fully in line with the approach for calculation of baseline emissions and ERUs applied in the considered project.

The emission reduction is the difference between emissions calculated in the baseline and project that are attached in the Excel file. The table with calculations for 2010 is provided below.

[1] Letter # 6/UD-795/10 of 31.08.2010 from RUSAL Krasnoyarsk to Sberbank

Table C.1.A. Calculation of the actual PFC emissions and ERUs for potrooms in 2010 (period of 01.01.10-31.08.10)

Potroom	Technology of electrolysis	Production of electrolytic aluminium, tones	AEF, times / cell-day		AED, mins		Slope coefficient for CF_4	Weight fraction C_2F_6/CF_4	PFC emissions, t CO2eq		Amount of ERUs, t CO2eq
			Project	Baseline	Project	Baseline			Project	Baseline	
1	PFVSS	27 749	0,67	0,69	1,99	2,61	0,032	0,044	8 143	11 042	2 899
2	PFVSS	25 430	0,65	0,69	1,89	2,61	0,032	0,044	6 892	10 119	3 227
3	PFVSS	25 384	0,68	0,69	1,94	2,61	0,032	0,044	7 359	10 101	2 742
4	PFVSS	27 802	0,70	0,69	2,01	2,61	0,032	0,044	8 589	11 063	2 474
5	PFVSS	25 021	0,64	0,69	1,92	2,61	0,032	0,044	6 765	9 956	3 191
6	PFVSS	25 589	0,67	0,69	1,90	2,61	0,032	0,044	7 206	10 182	2 977
7	PFPB	30 860	0,41	0,64	1,79	2,14	0,133	0,05	20 850	39 125	18 274
8	PFPB	29 851	0,45	0,64	1,70	2,14	0,133	0,05	21 140	37 845	16 705
9	PFVSS	26 663	0,68	0,69	2,09	2,61	0,032	0,044	8 342	10 610	2 268
10	PFVSS	25 673	0,66	0,69	2,00	2,61	0,032	0,044	7 544	10 216	2 672
11	PFVSS	26 996	0,52	0,69	1,92	2,61	0,032	0,044	5 971	10 742	4 771
12	PFVSS	27 457	0,52	0,69	1,84	2,61	0,032	0,044	5 804	10 926	5 122
13	PFVSS	26 953	0,59	0,69	1,96	2,61	0,032	0,044	6 850	10 725	3 875
14	PFVSS	26 802	0,65	0,69	1,99	2,61	0,032	0,044	7 688	10 665	2 977
15	PFVSS	26 427	0,85	0,69	2,10	2,61	0,032	0,044	10 350	10 516	166
16	PFVSS	26 177	0,78	0,69	2,17	2,61	0,032	0,044	9 797	10 416	620
17	PFVSS	28 316	0,94	0,69	2,03	2,61	0,032	0,044	11 872	11 267	-605
18	PFVSS	28 421	1,04	0,69	2,05	2,61	0,032	0,044	13 389	11 309	-2 080
19	PFVSS	28 637	1,04	0,69	2,00	2,61	0,032	0,044	13 150	11 395	-1 755
20	PFVSS	28 712	0,87	0,69	1,93	2,61	0,032	0,044	10 589	11 425	836
21	PFVSS	28 195	0,94	0,69	2,02	2,61	0,032	0,044	11 746	11 219	-526
22	PFVSS	28 216	0,98	0,69	2,00	2,61	0,032	0,044	12 238	11 228	-1 011
23	PFVSS	28 857	0,88	0,69	2,10	2,61	0,032	0,044	11 789	11 483	-306
26	PFPB	15 181	0,45	0,64	1,67	2,14	0,133	0,05	10 448	19 247	8 799
Totally for the smelter		645 369							244 511	322 820	**78 310**

Table C.1.B. Calculation of the actual PFC emissions and ERUs for potrooms in 2010 (period of 01.09.10-31.12.10)

Potroom	Technology of electrolysis	Production of electrolytic aluminium, tones	AEF, times / cell-day		AED, mins		Slope coefficient for CF_4	Weight fraction C_2F_6/CF_4	PFC emissions, t CO2eq		Amount of ERUs, t CO2eq
			Project	Baseline	Project	Baseline			Project	Baseline	
1	PFVSS	13 984	0,39	0,69	1,86	2,61	0,088	0,053	6 214	15 486	9 271
2	PFVSS	12 876	0,32	0,69	1,65	2,61	0,088	0,053	4 234	14 259	10 025
3	PFVSS	13 005	0,42	0,69	1,90	2,61	0,088	0,053	6 368	14 402	8 033
4	PFVSS	14 260	0,41	0,69	1,94	2,61	0,088	0,053	6 992	15 791	8 800
5	PFVSS	12 278	0,41	0,69	1,87	2,61	0,088	0,053	5 715	13 597	7 881
6	PFVSS	12 973	0,45	0,69	1,78	2,61	0,088	0,053	6 427	14 366	7 939
7	PFPB	15 756	0,38	0,64	1,77	2,14	0,131	0,121	10 458	21 522	11 064
8	PFPB	15 134	0,47	0,64	1,65	2,14	0,131	0,121	11 667	20 672	9 005
9	PFVSS	13 511	0,47	0,69	1,90	2,61	0,088	0,053	7 348	14 962	7 614
10	PFVSS	13 729	0,52	0,69	1,86	2,61	0,088	0,053	8 132	15 203	7 072
11	PFVSS	13 556	0,35	0,69	1,77	2,61	0,088	0,053	5 202	15 012	9 810
12	PFVSS	13 975	0,32	0,69	1,63	2,61	0,088	0,053	4 408	15 476	11 068
13	PFVSS	13 916	0,34	0,69	1,83	2,61	0,088	0,053	5 259	15 410	10 152
14	PFVSS	13 919	0,36	0,69	1,88	2,61	0,088	0,053	5 712	15 414	9 702
15	PFVSS	13 754	0,49	0,69	1,83	2,61	0,088	0,053	7 646	15 231	7 585
16	PFVSS	13 649	0,47	0,69	1,91	2,61	0,088	0,053	7 581	15 115	7 533
17	PFVSS	14 798	0,42	0,69	1,84	2,61	0,088	0,053	7 041	16 387	9 346
18	PFVSS	14 721	0,45	0,69	1,90	2,61	0,088	0,053	7 781	16 302	8 521
19	PFVSS	14 873	0,56	0,69	1,85	2,61	0,088	0,053	9 474	16 470	6 996
20	PFVSS	14 744	0,44	0,69	1,85	2,61	0,088	0,053	7 300	16 327	9 027
21	PFVSS	14 728	0,42	0,69	1,81	2,61	0,088	0,053	6 855	16 310	9 455
22	PFVSS	14 637	0,50	0,69	1,83	2,61	0,088	0,053	8 200	16 209	8 009
23	PFVSS	14 864	0,54	0,69	1,93	2,61	0,088	0,053	9 473	16 460	6 987
26	PFPB	7 757	0,40	0,64	1,65	2,14	0,131	0,121	5 056	10 596	5 540
Totally for the smelter		331 397							170 543	376 978	**206 435**

ERUs totally for 2010	**284 745**

Annex 1

Clarification on change of slope coefficients and weight fraction C_2F_6/CF_4 during monitoring since 1st September 2010

The monitoring plan which is a part of the PDD for the project "Reduction of PFC emissions from RUSAL Krasnoyarsk Aluminium Smelter" (version 3.0 of 27th October 2008, the positive determination opinion of DNV is received, report № 2008-1624) provide for the change of value of the slope coefficient and weight fraction C_2F_6/CF_4 *"Once in three years or in case of change of the pot type/ considerable change in technology"*. The VAMI is defined as source of data.

As it was earlier mentioned in the text of this report the measurements of PFC emissions for determination of slope coefficient and weight fraction C_2F_6/CF4 for PFVSS and PFPB technologies were carried out in September 2007 and July-August 2010.

Summary table for parameters and results of the measurements of CF_4 and C_2F_6 emissions carried out at RUSAL Krasnoyarsk in 2010

Parameter	Unit	Value	
		Potroom № 22 PFVSS	Potroom № 7 PFPB
CF_4 emissions	kg CF_4/tonne Al	0,09	0,051
C_2F_6 emissions	kg C_2F_6/tonne Al	0,0058	0,0135
Total PFC emissions per tonne of aluminium	tonnes CO_{2eq}/tonne Al	0,64	0,46
Slope coefficient, actual	(kg of CF_4 / tonne of aluminium) / (number of minutes of anode effect / cell-day)	**0,088**	**0,131**
Slope coefficient, Tier 2 IPCC standard value	(kg of CF_4 / tonne of aluminium) / (number of minutes of anode effect / cell-day)	0,092	0,143
Weight fraction C_2F_6/CF_4, actual	dimensionless quantity	**0,065**	**0,264**
Weight fraction C_2F_6/CF_4, Tier 2 IPCC standard value	dimensionless quantity	0,053	0,121
Measurements duration	hours	118,37	117,1
Number of cells at the measured section	units	20	48
Anode effects during measurements	times	55	63
Anode effect frequency	times / cell-day	0,58	0,27
Average duration of anode effects	minutes	1,77	1,45

Summary table for parameters and results of the measurements of CF_4 and C_2F_6 emissions carried out at RUSAL Krasnoyarsk in 2010

Parameter	**Unit**	**Value**	
		Potroom № 22 PFVSS	Potroom № 26 PFPB
CF_4 emissions	kg CF_4/tonne Al	0,044	0,047
C_2F_6 emissions	kg C_2F_6/tonne Al	0,0019	0,0024
Total PFC emissions per tonne of aluminium	tonnes CO_{2eq}/tonne Al	0,30	0,33
Slope coefficient, actual	(kg of CF_4 / tonne of aluminium) / (number of minutes of anode effect / cell-day)	**0,032**	**0,133**
Slope coefficient, Tier 2 IPCC standard value	(kg of CF_4 / tonne of aluminium) / (number of minutes of anode effect / cell-day)	0,092	0,143
Weight fraction C_2F_6/CF_4, actual	dimensionless quantity	**0,044**	**0,05**
Weight fraction C_2F_6/CF_4, Tier 2 IPCC standard value	dimensionless quantity	0,053	0,121
Measurements duration	hours	138,4	89,5
Number of cells at the measured section	units	20/19	64
Anode effects during measurements	times	52	35
Anode effect frequency	times / cell-day	0,47	0,15
Average duration of anode effects	minutes	2,96	2,42

When comparing the results of measurements in 2007 and 2010 one can see that for the Søderberg technology with point feeders there is a significant increase in the value of the slope coefficient, while for the technology with prebaked anodes and point feeders it actually remained the same. At the same time both technologies are characterized by substantial increase of C_2F_6 emissions most obviously influenced on the change of weight fraction C_2F_6/CF_4 for technology with prebaked anodes.

Nevertheless when comparing the values of the slope coefficient and the weight ratio C_2F_6/CF_4 with standard values given in IPCC Guidelines "Guidelines for National Greenhouse Gas Inventories", 2006 the difference to the bigger scale from the standard values is identified only for the weight fraction C_2F_6/CF_4, but in the used calculation formula the "contribution" of C_2F_6 in total emissions of PFCs characterizing the values of weight fraction of 2010: for the PFPB technology is 37%, and for the PFVSS technology, which is a main at the Krasnoyarsk aluminum plant - only 8.5%.

However for the purpose of conservativeness in the calculation of baseline and project emissions the values of weight fraction C_2F_6/CF_4 estimated after measurements of 2010 and exceeding IPCC 2006 Tier 2 standard values, have been replaced to them:

Technology	Name and designation	Values applied for calculation (measurements of 2007)	Measurements of 2010	Values applied for calculation
Validity period for the coefficients		01.01.2010-31.08.2010	Since 01.09.2010	01.09.2010-31.12.2010
PFVSS	Slope coefficient (S_{CF_4})	**0,032**	0,088	**0,088**
PFVSS	Weight fraction ($F_{C_2F_6/CF_4}$)	**0,044**	0,065	**0,053** (IPCC 2006 Tier 2 standard value)
PFPB	Slope coefficient (S_{CF_4})	**0,133**	0,131	**0,131**
PFPB	Weight fraction ($F_{C_2F_6/CF_4}$)	**0,05**	0,264	**0,121** (IPCC 2006 Tier 2 standard value)

During preparation of this monitoring report by the request of UC RUSAL Environmental department the specialists of VAMI have analyzed[2] the possible reasons for differences in measurement results in 2007 and 2010 and following conclusions were drawn:

1. When comparing the methods and procedures of measurements and calculations of emissions of PFCs at RUSAL Krasnoyarsk ", held under the leadership of Jerry Marks in 2007 and by VAMI specialists in 2010 any significant differences that may affect the results of the determination of the slope coefficient and the weight fraction of C_2F_6/CF_4 have not been revealed. In this connection there is no reason to assume that the data of 2010 are less representative than the data of 2007.
2. According to the Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production, IAI, 2003 it is fully acceptable to determine slope coefficient and weight fraction C_2F_6/CF_4 for one potroom of the specific technology used at the smelter and spread the values for the other potrooms of this technology.
3. The mechanism of anode effect, and factors influencing the formation of PFCs are the subject of research in the theory and practice of the electrolytic production of aluminum and to date they are not fully studied.

   In the works "Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production, IAI, 2003, and J. Marks, A. Tabereaux, D. Pape, V. Bakshi and E. Dolin, «Factors affecting emissions of PFCs from industrial electrolytic recovery of aluminum. "Light Metals, 2001, pages 295-302 it states:" If the anode effect occurs the rate of formation of CF_4 and C_2F_6 are dependent on several factors. The main process of formation of PFCs - electrolytic oxidation of fluoride on the anode, so the speed of the electrolytic reaction is proportional to the current. The more the common current the greater the intensity of the emission during the anode effect. Measurements showed that the total voltage across the electrolytic effect on emission intensity. Besides the formation of resistive film on the anode base, a voltage increase is contributed by other operational factors such as tub capacity and surface area of the anode. The content of fluoride in the bath can also influence the emission intensity ".

   This implies that technological and operational factors affect on the formation of PFCs. The determination of the correlations between technological, operational factors and the release of PFCs

[2] Detailed analysis is provided in the Analytic Reference of "RUSAL ITC", LLC, which is to be passed to the Accredited Independent Entity performing verification.

requires special studies that are not covered by the approved project documentation (PDD) and the IPCC methodology.

4. When comparing the values of the slope coefficient and the weight fraction C_2F_6/CF_4 determined by the measurements in 2007 and 2010 it is needed to take into account the uncertainty of the method, which is 12%.
5. The main criterion to confirm the correctness of the determined values (mentioned by Jerry Marks in the report of 2007) is the correspondence of the value of slope coefficient determined by instrumental measurements to the interval provided in the IPCC Guidelines for Tier 2 with accounting of the standard deviation. The slope coefficient obtained in 2010 completely fulfills this criterion.

It can be concluded that the results of measurements in 2010 are much closer to standard values of the IPCC for the production of aluminum by the respective technology.

In 2010 RUSAL Krasnoyarsk has started the programme of replacement of the standard electrolytic cells of Søderberg technology type S-8B and S-8BM to the type S-8B(E) and S-8BM(E) "EcoSøderberg" of modernized construction. New type of the cell differs from the old one by use of colloid anode, construction of bell cover and number of structural and technological improvements.

The new type of Søderberg based technology together with use of colloid anode will ensure a high technical and economical performance and at the same time the reduction of emissions of harmful substances (not PFCs) down to the levels prescribed by the Russian environmental legislation and recommendations of OSPAR[3].

In particular the "EcoSøderberg" electrolytic cell would allow to reach:

- Reduction of anode mass consumption from 525 to 490 kg/tonne Al;
- Reduction of fluorides emissions from 2,4 kg to 0,6 kg/tonne Al;
- Reduction of technological electricity consumption from 15950 to 15500 kWh/tonne Al, etc.

So far US RUSAL decided to replace electrolytic cells to "EcoSøderberg" type only in the potrooms #1-6 of Krasnoyarsk Aluminium Smelter during the planned overhaul of the cells. It means that around 3 cells/months are replaced in each potroom while full replacement will take place not earlier than 5 years.

Despite the difference in construction and improvements of the performance of the "EcoSøderberg" cells the main parameters influencing PFC emissions like surface area of anode and cell voltage remain the same and by international gradation the "EcoSøderberg" type of cell classified as "vertical stud Søderberg" technology for which the IPCC Tier 2 standard coefficients for PFVSS technology remain applicable.

However from point of view of the measurements by Tier 3 accuracy the conversion from Søderberg to "EcoSøderberg" type of the cell may request the additional study to determine associated PFC emissions. It shall be taken into account that existing approach for the instrumental measurement of PFC emissions applies the exhaust gas current from potroom, not individual cell, therefore as soon as process of replacement of the cells to "EcoSøderberg" type would take 5 year the new approach for the estimation of PFC emissions from "EcoSøderberg" technology should be applied.

Based on the fact that "EcoSøderberg" technology has no principal difference with Søderberg one from PFC emission factors point of view, and the fact that new value of slope coefficient for PFVSS and PFPB technology does not exceed IPCC Tier 2 standard value, as well as small number of "EcoSøderberg" cells installed at RUSAL Krasnoyarsk Aluminium Smelter, it is reasonable to apply new values of slope coefficient (determined by measurements in 2010) and weight fraction C_2F_6/CF_4 (IPCC Tier 2 standard values) for PFVSS and PFBP technologies in 2010 for the period of September 1, 2010 to December 31, 2010.

[3] Technical Policy of UC RUSAL, approved by 21.02.2011.

Annex 2
Response to the Further Action Request(s) in the Verification report issued for the previous monitoring period

In the Initial and First Verification report of Bureau Veritas No. Russia/0048-2/2010 version 1 the verifier issued 6 Further Action Requests (FARs). FAR02 was closed during verification. Table 2.1. provides the response on 5 remaining FARs in order to close them.

Table 2.1. Response to the FARs open in the Initial and First Verification report of Bureau Veritas No. Russia/0048-2/2010 version 1.

FAR 01. Based on the first experience of monitoring, RUSAL Krasnoyarsk Aluminium Smelter (KrAZ) may wish to issue a separate Manual of the Monitoring Management System though the present managerial set up is observed by the verifier as appropriate enough.	By 26.04.2009 the Managing Director of RUSAL Krasnoyarsk Aluminium Smelter mr. E.V. Nikitin has approved the "Regulation of data control for Joint Implementation project "Reduction of PFC emissions from RUSAL Krasnoyarsk Aluminium Smelter". This regulation describes the methods and frequency of JI project monitoring data gathering and safekeeping and establishes the responsibility for verification of the data integrity and its protection.
FAR 03. Please develop a procedure, which provides emergency concepts in case of unexpected problems with data gathering and/or data quality.	The following measures should provide a protection and mitigate the consequences of unexpected problems with data access and/or data quality at RUSAL Krasnoyarsk Aluminium Smelter: The data of production of crude aluminium after weighting is stored at the server of Information and Technological System (ITS) where put through "Weighting workstation" terminal. The preservation of data on weight of the crude aluminium is ensured by: - Maintenance of the weighting equipment; - Maintenance of the "Weighting workstation" terminal and ITS server equipment; - Reservation of the server equipment, backup of data for tape carrier, storing of data at Oracle database; - Limitation of access to the database by Oracle means. The data frequency and duration of anode effects is stored in electronic form at the server of aluminum electrolysis process automatic control system (ACS). The preservation of data in ACS is ensured by: - Maintenance of ACS equipment; - Reservation of the server equipment, backup of data for tape carrier, storing of data at Oracle database; - Limitation of access to the database by Oracle means.

FAR 04. Based on the first experience of monitoring, RUSAL Krasnoyarsk Aluminium Smelter (KrAZ) may wish to issue a formal procedure for data archiving as partialy defined in the MR.	See response to FAR 01.
FAR 05. Based on the first experience of monitoring, RUSAL Krasnoyarsk Aluminium Smelter (KrAZ) may wish to issue a formal procedure for the calculation of emission reductions and the preparation of the monitoring report in particular respect to internal verification and validation of data and responsibilities assigned for that. The extended and comprehensive Responsibility Structure of the MR is observed and discussed on the site visit.	See response to FAR 01.
FAR 06. Based on the first experience of monitoring, RUSAL Krasnoyarsk Aluminium Smelter (KrAZ) may wish to issue a formal procedure for the internal control procedures (Internal audits and management review), which allow the identification and solution of problems at an early stage of calculation of emission reductions and the preparation of the monitoring report.	The internal verification of the monitoring data in the context of the project is performed by the relevant departments of RUSAL Krasnoyarsk Aluminium Smelter according to existing procedures and duties. The internal audit of each production department is carried out by the group of internal audit at as a part of certified QMS. The preparation of the annual Monitoring report is performed by UC RUSAL Environmental Department but supervised and assisted by CTF Consulting, LLC consultancy company which represent the interests of Carbon Trade & Finance SICAR S.A. that is a contracted buyer of ERUs generated by the project.