Light Metals 2012 *Edited by: Carlos E. Suarez*
TMS (The Minerals, Metals & Materials Society), 2012

Light Metals 2012

ELECTRODE TECHNOLOGY for ALUMINIUM PRODUCTION

Characterization of Cathode Materials

SESSION CHAIR
Egil Skybakmoen
SINTEF
Trondheim, Norway

Light Metals 2012 *Edited by: Carlos E. Suarez*
TMS (The Minerals, Metals & Materials Society), 2012

SPENT POTLINING: AN UPDATE

Rudolf P. Pawlek
TS + C, Avenue du Rothorn 14, CH-3960 Sierre Switzerland

Keywords: Spent potlining, low caustic and lining, Ausmelt process, pig iron, cement industry

Abstract

This paper continues of a review given in 1999 and resumes practices to treat the waste from used cathodes of the primary aluminium industry. The waste cathode lining consists of a carbon part and a refractory part. Spent potlining contains water-soluble fluorides and small amounts of leachable cyanides, and is therefore classified as hazardous.
Besides inertization - such as treatment at high temperature, by vitrification, or by leaching and flotation - the refractory component can also be used for instance in the manufacture of cement, of concrete and brick, or as a road pavement additive, or and as a potline electrolyte additive for the production of Al-Si pre-alloys.
The carbon components can be used as a fuel additive in cement kilns, but also as an additive in the pig iron and steel industry.
Various ways to treat and use spent potlining have been published in the meantime, and will be reviewed here.

Introduction

Besides some 40m tpy of primary aluminium, the world's smelters produce about a million tonnes per year of toxic waste in the form of spent potlining.This means about 25 kg of SPL per tonne aluminium produced. Hitherto, most of this SPL has gone to landfill. This must change if the industry wants to claim a reasonable degree of sustainability and environmentally tolerable emissions.
During the last years, methods for processing spent potlining (SPL) were reviewed several times [1-8]. However, an excellent overview was presented by Sørli and Øye [9]. The following update is a continuation of [1].
Liu and Lou [10] found that the carbon hearth made of anthracite and/or graphite undergoes great changes in its various physical properties, chemical compositions, internal microstructures, carbon morphology and crystalline structure during the aluminium smelting process. The generally applied physical, chemical, and thermal processes to process spent potlining are inefficient, but they could be reduced or possibly eliminated, according to Young [8], if the pots were designed for recyclability using a management technology which has been elaborated. So, as proposed by Sturm et al. [11] thermal insulation of electrolysis pots uses alumina instead of refractory bricks. Typical analyses of spent potlining have recently been published several times [12-15]. The analysis of Krüger [12] is presented in table 1.

Table 1
SPL typical components and concentrations [12]

Component	Both cuts together 100%	1st Cut Carbonaceous 56%	2nd Cut Refractory 44
Carbon	33.1	54-64	18.2
Total fluorides	15.7	6-20	4-10
Free alumina	22.3	0–15	10-50
Total aluminium	15.1	5-15	12.6
Total sodium	14.2	5-12	12.0
Calcium	1.8	0.5-4	1-6
Quartz	2.7	0-6	10-50
Phosphorous	0.3	0-650 g/t	0-300 g/t
Sulphur	0.1	0.1	0.1

Thermal processes

Crushing SPL on site and exporting it in bulker bags was proposed by [16]. As SPL is rich in carbon, this can be used as a fuel for instance in the brick, cement and pig iron industries. For crushing SPL, Chen and Li [17] determined its physical behaviour. They observed that graphite and sodium in SPL make it sticky, slippery and difficult to crush. They also carried out tests to determine the chemical stability of the fluorides in the SPL [18].
Crushed first cut of SPL can be used as collar paste for protecting anode stems [19].
In the USA landfill disposal of SPL without inertisation is forbidden [20, 21]; it is treated as hazardous material due to its water soluble fluorides and cyanides. Possible treatments include heating a crushed SPL mix to about 1000°C and adding lime to oxidize cyanides and to bind the fluoride, as proposed by Karpel [22] and by Li and Chen [23]. Oliveira et al.[24] proposed to heat second cut SPL up to more than 750°C to remove molten and volatile impurities , while Utkov et al. [25] treat the carbon rich part with an $FeSO_4$- solution in order to neutralise water soluble NaCN. Courbariaux et al. [26] propose to treat crushed SPL in a circulating fluid bed.
Balasubramanian et al. [27] proposed vitrification of SPL by adding small additions of glass former along with traces of nucleation agents to aid crystallisation, and then melting at around 1300°C.
Then Lazarinos [28, 29] treated SPL in a gasification combustion, the main reason being to destroy cyanide compounds mostly contained in the carbon fraction.
Because of its high energy and fluoride content, Blinov and co-workers [30] proposed a pyrohydrolysis process to recover fluorine as HF, while the carbon rich part is used in pig iron manufacture.
The development of the Ausmelt process to treat SPL was reviewed several times [22, 31-40] during 2001 and 2004. In 1995 Portland Aluminium of Australia invested about US$16m to

construct a research and development processing facility to treat SPL. Alcoa, in cooperation with Ausmelt Ltd., used a pyrometallurgical process to combust and melt SPL . On one side this produces hydrogen fluoride laden gas, which is cooled and converted into aluminium fluoride, and on the other side it produces an inert sand. Since 2001 the Ausmelt SPL treatment plant is in operation and can process 12,000 tpy of SPL.

Chemical processes

A low-technical method is needed to treat SPL material, but processing the cathode wastes (carbon cut and refractory cut) only with water [37] does not seem enough to eliminate all harmful elements. Therefore Baranovskii [41] proposed to crush first cut material, to mix it with limestone, and then to add this mixture to an aqueous slurry in order to recover soda and potash.

As aluminium electrolysis carbon froth and spent potlining are inevitable, Lu et al. [42] proposed to separate these components by flotation. In this respect Mirsaidov et al. [43] propose to use kerosene and pine oil as flotation agents. On one hand the scientists separated a cryolite- alumina concentrate, and they burnt out the remaining carbon at 800°C in a rotating furnace.

The principles for leaching SPL were elaborated by Silveira et al. [44, 45]. They observed that for all the pots studied the pH of SPL is at 10-11.8, and the total determined fluoride content at high pH was 5.13-11.41%. But the total fluoride content in leached fluid at pH 5 was only 0.26-3.46%. Therefore leach liquid must be alkaline above ph 12 in order to effectively process SPL.

Leaching SPL with water and concentrated H_2SO_4 was proposed by Zhao [46] to recover HF. The liquids are filtered for the manufacture of graphite powder, aluminium hydrate and alumina, while fluorides and sulphates are manufactured from the filtrate.

Lisboa et Steel [47] examined the leachability of NaF, CaF_2 and cryolite from spent potlining. By manipulating solution equilibira, they precipitated fluoride in a form that can be recycled back into the pot. Following removal of fluoride, they achieved high degrees of separation of graphite from the remaining refractory compounds by using a density separation technique.

Platt [48] proposes the complete treatment of spent potlining and salt slag in order to avoid landfill. Electrolysis produces 22-24 kg/t of spent potlining per tonne of aluminium. SPL is hazardous due to its high cyanide and fluoride contents. Befasa collects such material together with salt dross from remelters to treat chemically at special sites. Besides gases such as hydrogen, ammonia, methane, etc., at the end of the reaction stage Befasa obtains solids which are pumped to a vacuum belt filter. Here the resulting oxides and solids undergo in-process testing to ensure reduced levels of water-soluble chlorides in line with customer requirements.

Alcan identified its low caustic leaching and liming (LCL & L) hydrometallurgical process as the most efficient means of recuperating the chemical values contained in SPL. This process Alcan has reviewed several times [49-50]. An initial water leach was followed by a dilute caustic extraction and washing steps. Cyanides leached as NaCN in the initial water slurry were precipitated as solid ferrocyanide compounds which underwent tests for leachable fluorides. SPL leachate of the LCL&L process yields valuable crystalline NaF and caustic liquor for recycling into the Bayer plant. In December 2000 [51], Alcan deposed a project at the ministry of Quebec for the treatment of up to 80,000 tpy of SPL using the LCL&L process. To construct the plant Alcan put aside some C$150m [52, 53]. Schaffer reported [54] that this plant would create more than 50 jobs, would reduce Alcan's treatment costs considerably [55], and would also be able to treat SPL from third parties. In the meantime the investment costs increased to US$180m [56] and construction started in the Autumn of 2006. Alcan reported about the progress of the construction [57-59] and after the plant was finished in February 2008 [60], the treatment centre was officially inaugurated in June 2008 [61]. Then Hamel and co-workers [62] reported about the valorization potential of the main by-products of LC&L, which are: a carbonaceous by-product (CBP); a concentrated caustic liquor; and fluorides including NaF or CaF_2. Once operating at its full capacity of 80,000 tpy, the plant will produce 78,000 t of CBP (30% water); 80,000 t of caustic liquor (27% NaOH) and 54,000 t of CaF_2 (50% water). In 2009 about 26,000 t [63] of SPL were already processed in this new plant.

Final use of SPL

The literature relates that untreated spent potlining can be used especially in the klinker (cement) industry and also in pig iron or steel making. For first and/or second cut SPL other special solutions have been developed.

Cement kiln

Processing SPL in klinker furnaces has been proposed several times [14, 22]. In general the first cut serves as fuel while the second cut of SPL serves as klinker aid [64-66]. Venancio et al. [66] determined the calorific power in the first cut of SPL to be up to 5 MJ/kg. Therefore the coke fuel for the klinker furnace could be reduced by 111 tpm, and the klinker forms at a lower temperature by 80°C allowed the use of a cheaper coke with higher sulphur content, with no impact on emissions.

Hillside and Bayside Aluminium [65] have worked for years with Pretoria Portland Cement to develop a one-step solution. Introducing SPL into the cement kiln at high temperature destroys cyanides and binds fluorides with calcium which is present in the cement or lime.

The carbon rich first cut of SPL is, according to Cardoso [67], a high calorific material with an heat input of 16 MJ/kg, and the second cut is used in large quantities in the cement industry.

For Chen [68] it is only inert SPL, which can be recycled and forwarded as raw material for cement production.

Pig iron and steel

The use of SPL in the pig iron industry both as fuel and for decreasing the slag viscosity was reported several times [69, 70]. SPL is added in amounts of between 5-25 kg/t pig iron [69] and the SPL refractory part and bath material dissolves in the slag. Olsen [70] points out that the slag is designed so that any leaching of environmentally dangerous elements is minimised.

Rusal [71] signed a cooperation agreement with the administration of the Kemerovo Region on recycling waste to innovative products for ferrous metallurgy. In a first step the Novokuznetsk Aluminium Smelter will supply up to 3,000 tpy of SPL to the environmental regional centre for processing.

For the manufacture of special steels von Krüger [12] proposes to use only the carbon-rich first cut SPL material. Volynkina and co-workers [72] see the possibility to use first cut material as a fuel additive.

2^{nd} cut special products

Istomin [73] performed an in depth literature review on the recycling and use of fluorine containing wastes from the aluminium industry, and found out that the refractory-rich 2^{nd} cut of SPL can be used in the production of aluminium silicon alloys. Moxnes et al. [74] also used 2^{nd} cut material and tried this in the manufacture of Al-Si alloys directly in the electrolysis pots. Crushed refractory-rich SPL is mixed with alumina but does not exceed about 15 wt % that of normal industrial smelter grade alumina. This means that large and concentrated batches should be avoided.

Using 2^{nd} cut material in foam-silicate manufacture was proposed by Proshkin et al [75]. This can be used as thermal insulation filling powder and as raw material for the manufacture of non-formed thermal insulation items.

And the Alouette Aluminium Smelter in Canada [76] uses refractory material of spent potlining for the manufacture of special movable concrete blocks, used for bordering highways, but also used as removable walls for rapid access to buildings' basements.

Conclusions

There are now several thermal and chemical processes available for processing and treating spent potlining. The most basic of these seem to be inertisation followed by landfill, but this does not seem an efficient and sustainable solution. A better way is to cooperate with cement manufacturers, who can add spent potlining to both reduce fuel input and to improve slag conditions. The Rio Tinto Alcan LCL & L process has been developed and an industrial pilot plant is now in the start-up stage and expects reach its optimal drive to process up to 80,000 tpy of spent potlining in the near future.

A million tonnes per year of SPL represents a considerable environmental hazard and an expense to contain or neutralise. But it also represents a great opportunity to use or recycle SPL as a resource.

Acknowledgement

The author acknowledges with thanks the help of Mr. A. Bushnell during the preparation of this paper.

References

[1] R. Pawlek, "Spent potlining: an update", Proceedings of X. Slovak-Norwegian Al Symposium on Aluminium Smelting Technology, Stara Lesna – Ziar nad Hronom, Sept. 21-23, (1999), 148-154

[2] M. Mistry et al., "Integrated resource-oriented analysis of waste streams from aluminium manufacture", Abfallvermeidung – verwertung, Deponietechnik, Altlastensanierung, Konferenzbericht DepoTech Abfallwirtschaftstag., 5th (2000), 183-188

[3] C. A. Young, M. Foote and S. Nordwick, "Review of technologies and the development of a novel approach for spent potlining remediation", 4th Int. Conf. on Materials Engineering Resources [Proc. Conf.] Akita, Japan 11-13 Oct. (2001), Vol.1, 13-25

[4] G. C. Holywell, "A survey of the processes used to store, treat, recycle and recover spent potlining (SPL)", IX Int. Conf. Krasnoyarsk, Sept. 9-11 2003, Proc. Aluminium of Siberia (2003), 4-6

[5] B. P. Kulikov, "Technical aspects of aluminium production environmental safety at the contemporary stage", X Int. Conf. Krasnoyarsk, Sept. 7-10, 2004, Proc. Aluminium of Siberia (2004), 14 pp.

[6] S. Karpel, "Spent potlining tamed", Metal Bulletin Monthly (2008) 10, 12-13

[7] W. Li and X. Chen, "Development status of processing technology for spent potlining in China", Light Metals 2010, ed. J. A. Johnson (TMS, Warrendale, Pa.), 859-861

[8] C. Young, "Splash technology: applying the design-for-recyclability concept to spent potlining management", REWAS (2008); Global Symposium on Recycling Waste Treatment and Clean Technology, Cancun, 12-15 Oct., Mexico, (2008)

[9] M. Sørli and H. A. Øye, "Cathodes in aluminium electrolysis", 3rd Edition, Aluminium Verlag Marketing und Kommunikation Düsseldorf, Germany (2010), 662 pp.

[10] F. Liu and Y. Lou, "Study on cathode property changes during aluminium smelting", Light Metals (2006), ed. T. J. Galloway (TMS, Warrendale, Pa.), 639-643

[11] E. Sturm, J. Prepeneit and M. Sahling, "Economic and environmental aspects of an effective diffusion barrier", Light Metals (2002), ed. W. Schneider (TMS, Warrendale, Pa), 433-437

[12] P.v. Krüger, "Use of spent potlining (SPL) in ferro silico manganese smelting", Light Metals (2011), ed. S. J. Lindsay (TMS, Warrendale, Pa.), 275-280

[13] Q. Li et al., "The effect of sodium-containing additives on the sodium penetration-resistance of TiB_2/C composite cathode in aluminium electrolysis", Light Metals (2005), ed. H. Kvande (TMS, Warrendale, Pa.), 789-791

[14] V. Gomes et al., "Co-processing at cement plant of spent potlining from aluminium industry", Light Metals (2005), ed. H. Kvande (TMS, Warrendale, Pa.), 507-513

[15] W. Li and X. Chen, "Running results of the SPL detoxifying pilot plant in Chalco", Light Metals (2006), ed. T. J. Galloway (TMS, Warrendale, Pa.), 219-222

[16] Anonymous, "SPL export to Italy proves winner for the environment", Tomago Aluminium News 1, March (2003), p. 19

[17] X. Chen and W. Li, "Research on crushing character of spent cathodes", Light Metals (2007), ed. M. Sørli (TMS, Warrendale, Pa.), 853-855

[18] W. Li and X. Chen, "Chemical stability of fluorides related to spent potlining", Light Metals (2008), ed. D. H. de Young (TMS, Warrendale, Pa.) 855-858

[19] Y. Wang, "Manufacture of carbon protecting rings from used cathode carbon blocks", CN patent 1,273,955 (Appl. date 21 April 2000)

[20] EPA, "Land disposal restrictions: Granting of two site-specific treatment variances to U.S. Ecolo Idaho, incorporated in Grandview, Idaho and CWM Chemical Services, LLL in Model City, New York", Federal Register 22 May 67 (2002) 99, 35924-35928

[21] EPA, "Hazardous waste management system: identification and listing of hazardous waste final exclusion", Federal Register 25 July 67 (2002) 143, 48555-48558

[22] S. Karpel, "Finding solutions for spent potlining", Metal Bulletin Monthly No. 397 (January 2004), 31

[23] W. Li and X. Chen, "Development of detoxifying process for spent potliner in Chalco", Light Metals (2005), ed. H. Kvande (TMS, Warrendale, Pa), 515-517

[24] D. Goncalves de Oliveira et al, "Hot processing of spent refractory linings from aluminium electrowinning cells", BR patent 00,004,425 (Appl. date 4 August 2000)
[25] V. A. Utkov et al. "Neutralization of spent cyanide-containing carbon lining from aluminium electrowinning cells", RU patent 2,157,418 (Appl. date 27 August 1997)
[26] Y. Courbariaux et al., "Thermal treatment of spent potliners in an internal circulating fluidized bed using natural gas burner", Proc. 16th Int. Conf. Fluid Bed Combustion (2001), 1174-1190
[27] G. Balasubramanian, M. T. Nimje and V. V. Kutumbarao, "Conversion of aluminium industry wastes into glass-ceramic products", Trav. Com. Int. Etude Bauxites, Alumine, Alum. (13th Int. Symp. of ICSOBA, 2000), 27 (2000), 396-402
[28] J. G. C. Lazarinos, "Treatment of spent pot liner", 62nd ABM International Annual Congress, Victoria, 23-27 July, Brazil (2007), 2055-2066
[29] J. G. C. Lazarinos, "Characterisation and treatment of spent potliner", Tecnologia em Metalurgia e Materiais 5 (2009)3, 127-132
[30] V. Blinov, T. Grande and H. A. Øye, "Generation of HF from a spent potlining slag", Proc. 1st Int. Cong., Non-Ferrous Metals of Siberia (2009), ed. G. L. Paskov and P. V. Polyakov (Krasnoyarsk 8-10 Sept. 2009), 259-265
[31] J. Harpley, G. Swayn and K. Mansfield, "SPL treatment and fluoride recycling project", Proc. VIIth Australasian Aluminium Smelting Technology Conference and Workshop, Melbourne, Australia 11-16 Nov. (2001), 14 pp.
[32] Anonymous, "Process development to recycle aluminium spent pot liner", HazTECH News 16 (2001) 15-18, p.107
[33] K. Mansfield, G. Swayn and J. Harpley, "Spent Pot Lining (SPL) treatment and fluoride recycling process", EPD Cong. (2002) and Fundamentals of Advanced Materials for Energy Conversion, Proc. Sess. and Symp. held at TMS.Meeting in Seattle, ed. P. R. Taylor, D. Chandra and R. G. Bautista (TMS, Warrendale, Pa.) 315-327
[34] Anonymous, "Portland Aluminium develops process to treat spent potlining", JOM 54 (2002) 1, 5
[35] R. Matusewicz and J. S. Roberts, "Ausmelt technology smelting unit for the processing of spent pot lining (SPL) at Portland", Aluminium 78 (2002)1-2, 47-50
[36] M. Pinkham, "Spent potlining processes gain moment", Aluminium International Today 14 (2002) 2, 39-40
[37] Anonymous, "Aluminium waste takes to the road", Metal Bulletin Monthly 383 (Nov. 2002), 57
[38] J. Worsley, "Informations about the Ausmelt process", private communication 21 Nov. 2002
[39] Anonymous, "Smelting solutions – creating useful materials from toxic waste", Materials World 10 (2002) 9, 36-37
[40] R. J. Batterham and M. J. Hollitt, "Production of primary metals – towards improved sustainability", Erzmetall 56 (2003) 9, 519-528
[41] V. V. Baranovskii and A. V. Baranovskii, "Processing of spent carbon linings from electrowinning cells", RU patent 2,171,853 (Appl. date 11 May 1999)
[42] H. Lu et al., "Comprehensive utilization of spent pot lining and carbon slime from aluminium electrolysis cells", Aluminium 77 (2001) 7-8, 594-597
[43] U. M. Mirsaidov et al., "Use of aluminium – and fluorine – containing wastes from aluminium production", Ekologiya I Promyshlennost Rossii (2002), 10-11
[44] B. I. Silveira et al. "Fluorides evaluation in spent pot liner: toxicity characteristic leaching procedure limitations", Southern Brazilian Journal of Chemistry 9 (2001) 10, 41-46
[45] B. I. Silveira et al., "Characterization of inorganic fraction of spent potliners: evaluation of the cyanides and fluorides content", Journal of Hazardous Materials 89 (2002) 2-3, 11-183
[46] L.-C. Zhao, "Comprehensive recovery of waste linings of aluminium electrolysers", CN patent 1,320,491 (Appl. date 28 February 2001)
[47] D. F. Lisboa and K. M. Steel, "Treatment of spent pot-lining for recovery of fluoride values", Light Metals (2007), ed. M Sørlie (TMS, Warrendale, Pa), 843-848
[48] A. Platt, "Spent pot lining and salt slag treatment services", Aluminium 87 (2011) 3, 38-40
[49] V. Kasireddy, J.-L. Bernuer and F. M. Kimmerle, "Recycling of spent pot linings", US patent appl. US 2002 114,748 (8 December 2000)
[50] F. M. Kimmerle, V. Kasireddy and J.-G. Tellier, "SPL treatment by the LCL&L process: oilot study of two stage leaching", MetSoc, Light Metals CiM (2001), ed. M. Sahoo and T. J. Lewis, 199-211
[51] Anonymous, "Le point sur le projet de traitement de la brasque usée", Le Lingot 59 (2002)2, 8
[52] Alcan, "Alcan's journey towards sustainability", Alcan Inc., Corporate sustainability report 2002, ed. (2003), 47
[53] Alcan, "Alcan développe une solution créatrice de valeur et durable pour le traitement de la brasque usée", Le Lingot 60 (2003) 10, 3
[54] P. Schaffer, Alcan to build US$114m plant to treat spent potliner", Am Met. Mark. 111 (2003) 42-2, 6
[55] Alcan, 2003 Annual Report, "SPL treatment plant showcases breakthrough Alcan technology", 14, 72
[56] Anonymous, "Alcan construit une usine pilote de C$200m au coeur du complexe Jonquière", Le Lingot 63 (2006) 8, 3 (3 October 2006)
[57] Anonymous, "La construction progresse à bon rythme", Le Lingot 64 (2007) 1, 12
[58] Anonymous, "Le virtuel cède de la place aux operations concrètes!", Le Lingot 64 (2007) 8, 8
[59] Anonymous, "Alcan recognized for its new spent potlining recycling plant in the Saguenay region", Alcan press release (15 October 2007)
[60] Anonymous, "La construction finie, c'est l'heure de la mise en service des équipements", Le Lingot 65 (2008) 2, 3 (29 février)
[61] Anonymous, "Rio Tinto Alcan inaugure son usine pilote de traitement de la brasque", Le Lingot 65 (2008) 6, 1, 3, 6, 7
[62] G. Hamel et al., "From the low caustic leaching and liming process development to the Jonquière spent potlining treatment pilot plant start-up, 5 years of process up-scaling, engineering and commissioning", Light Metals (2009). Ed. G. Bearne (TMS, Warrendale, Pa.), 921-925
[63] Anonymous, "L'usine pilote de traitement de brasque poursuit sur sa lancé", Le Lingot 67 (2010) 2, 5
[64] P. R. Choudhary and A. K. Sharma, "Swot perspectives of mid age prebaked aluminium smelter", Light Metals (2011), ed. S. J. Lindsay (TMS, Warrendale, Pa..), 431-436
[65] Anonymous, "Recycling of spent potlinings", Hillside Aluminium, Sustainability Report 2001/2002, 26
[66] L. C. A. Venancio et al., "Residues recycling: reduction costs and helping the environment", JOM 62(2010) 9, 41-45
[67] A. B. Cardoso, "Spent potliner management in primary aluminium production", 62nd ABM Int. Cong., Vitoria 23-27 July, Brazil (2007), 2186-2195
[68] X. P. Chen, "Hazardous spent potlining from aluminium smelters and its countermeasures in China", REWAS (2008), Cancun, Mexico, 12-15 Oct. 2008

[69] L. D. Nikitin et al, "Use of aluminium production wastes in the charge of blast furnaces at the West Siberian Metallurgical Plant", Chernaya Metalllurgiya, Byulleten Nauchno-Tekhnicheskoi I Ekonomicheskoi Informatsii (2001) 11, 33-36
[70] F. Olsen, "Elkem spent potlining recycling project", REWAS 2008, (Global Symposium on Recycling, Waste Treatment and Clean Technology), Proc. Conf. (2008)
[71] Anonymous, "UC Rusal signs agreement with Kemerovo Region and environmental regional centre (ERC) to create recycling production", Rusal Press Release (30 June 2011)
[72] E. P. Volynkina, A. A. Stolyar and V. N. Polyakov, "Use of spent carbon-containing lining from electrolysers in blast furnace charge", Stal (2002) 2, 11
[73] S. P. Istomin, "Recycling and use of fluorine containing wastes at cryolite and aluminium plants", Tsvetnye Metalli (2002) 1, 82-86
[74] B. Moxnes et al., "Addition of refractories from spent potlining to alumina reduction cells to produce Al-Si alloys", Light Metals (2003), ed. P. N. Crepeau (TMS, Warendale, Pa.), 329-334
[75] A. V. Proshkin, V. F. Pavlov and A. I. Khokhlov, "Recycling of the reduction cells used lining into thermal insulating materials", Proc. VIII Aluminium of Siberia (2002) Symp., Krasnoyarsk 10-12 Sept., 105-111
[76] Anonymous, "Innovations", Aluminerie Alouette Highlights (2004), p. 12