

# DROSRITE SALT-FREE PROCESSING OF HOT ALUMINUM DROSS

Michel G. Drouet, Rodney L. LeRoy and Peter G. Tsantrizos  
*PyroGenesis Inc.*  
*1744 William Street, Suite 200*  
*Montreal, Quebec, Canada H3J 1R4*  
*mail@pyrogenesis.com*

## ABSTRACT

DROSRITE is a unique process that makes possible economic in-plant recovery of metal from hot aluminum dross. It is environmentally friendly, requiring no salt and producing no CO<sub>2</sub> or NO<sub>x</sub> gases. The salt-free residues of the process are suitable for production of calcium aluminate or for other value-added use. The process is highly energy efficient, extracting process heat from energy in the residue and, thus, it does not require an external plasma torch, electric arc or fuel heat source.

A DROSRITE pilot unit built by PyroGenesis has been tested with both black and white dross types. The unit was installed at two different aluminum plant locations, and tests were conducted for a total of six weeks “online” with hot metal holding furnaces where the dross was skimmed.

Results of both of these industrial trials are presented, together with an economic analysis indicating cost savings on the order of \$200 per ton of dross treated.

**Paper presented at the fall meeting of the Minerals, Metals & Materials Society (TMS) in Pittsburgh, Pennsylvania, October 22-25, 2000. Proceedings, pp. 1135-1145.**

## INTRODUCTION

Dross, a major byproduct of all processes involving molten aluminum, forms at the surface of the molten metal as the latter reacts with the furnace atmosphere. It generally represents 1 to 5 wt% of the melt, depending on the process, and typically contains about 50% free aluminum dispersed in an oxide layer. Since aluminum production is highly energy-intensive, dross recycling is attractive from both the energy and economic standpoints.

Dross is produced both at primary smelters where aluminum is obtained by electrolysis of alumina and also at remelt plants where aluminum scrap and used beverage cans are recycled.

The conventional dross treatment process, using gas or oil-heated rotary salt furnaces (RSF), is thermally inefficient and environmentally unacceptable because of the salt slag produced. In the past several years, a number of salt-free processes have been developed and some of these have found limited commercial use. One of these uses a plasma torch as the energy source and it has been implemented at Alcan's plant in Jonquière, Quebec (1). Another approach makes use of a graphite arc (2, 3), with the advantage (over the torch technology) of not requiring water cooling and not producing additional nitrides and burning recoverable metal.

In all existing dross treatment processes, heating of the cold dross in a rotary furnace requires an external energy input that varies between 375 and 2,500 kWh per tonne of dross (4-7). Molten metal separated during processing of the heated dross is tapped, and the remaining solid residue is discharged from the furnace.

The novel process developed by PyroGenesis (8), named DROSRITE, does not require any external energy input. Process energy is extracted from the solid residue, stored in the furnace refractory wall, and released to the next batch of fresh dross. Furthermore, the process is operated online with the molten aluminum holding furnace where the dross is generated. Thus, the hot metal can be returned to the furnace immediately after tapping, still in its molten form.

Energy savings in comparison with conventional processes can exceed 2,500 kWh per tonne of dross.

The differences between the conventional RSF method and the DROSRITE method are illustrated in Figure 1. The RSF process is characterized by five unit operations while, with DROSRITE, only a single step is required. In addition, the RSF-produced metal must be reheated, which is not the case for the hot metal returned to the holding furnace when using the DROSRITE process.

A further and critical advantage of DROSRITE over conventional dross treatment processes is that no fluxing salt is used. Thus, the residue is not

contaminated by as much as 50% salt, as in the case of the RSF process. The salt-free residues of the DROSRITE process are suitable for production of calcium aluminate or for other value-added use (9).

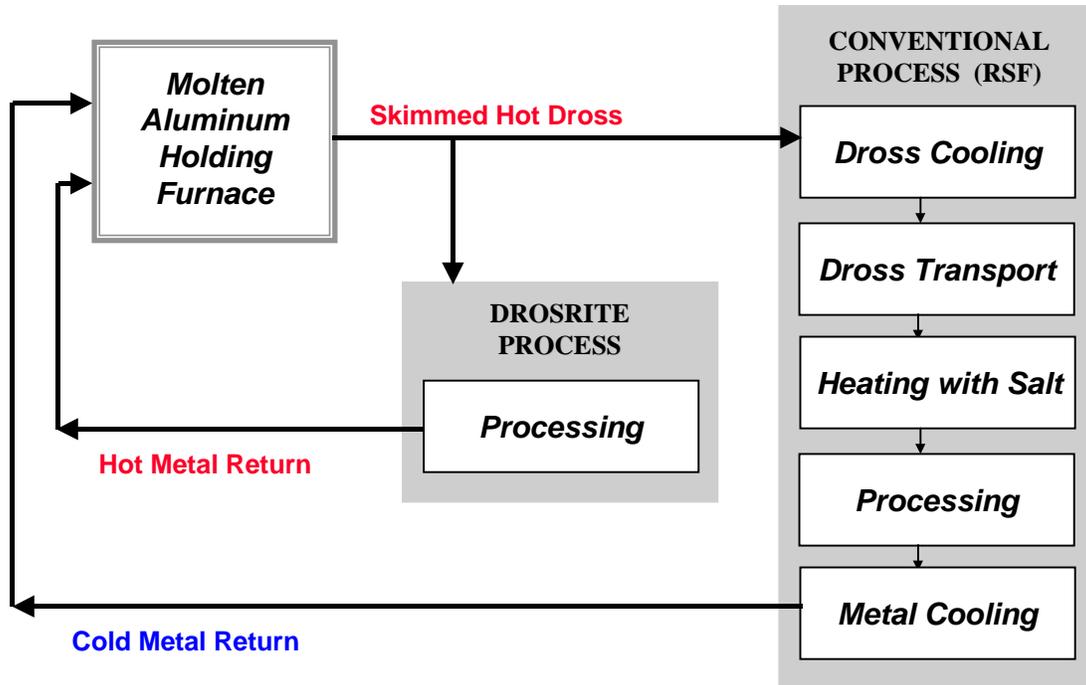


Figure 1 – The Conventional Rotary Salt Furnace (RSF) Process and the DROSRITE Process

## SEPARATION OF ALUMINUM METAL FROM DROSS

The separation of metallic aluminum from aluminum dross is not well understood. It is known, of course, that the dross must at least be heated to the temperature of molten aluminum and that tumbling the charge (in a rotating furnace, for example) is required to make the molten aluminum droplets that are contained in the dross coalesce and form a molten bath. However, in spite of many studies on the effects of parameters such as the temperature of the dross, the rotation rate of the furnace, the composition of the metal bath itself and the addition of salt, it is still impossible to predict the recovery rate for a given dross. One reason is that the dross itself is a very heterogeneous material, and its metal content varies enormously within a given sample. Another reason is that the separation phenomenon is, as indicated above, not well understood.

In spite of the lack of understanding of the phenomenon, separation fortunately *does* occur and most of the metal contained in the dross is recovered. Furthermore, the mode of heating (fuel burner versus plasma torch versus electric

are) does not seem to be a dominating factor, as long as the charge is heated above the melting point of the metal.

In fact, for all of the heating modes considered, most of the energy provided by the heat source is picked up by the furnace wall and then transferred by contact to the charge as the furnace rotates. Very little energy is transferred directly to the charge, as this is covered by a thick insulating layer of dross.

In the case of DROSRITE, the source of heat during processing is also the wall of the rotary furnace. Thus, DROSRITE does not differ significantly from earlier technologies in terms of the mode of transferring energy to the dross or the separation phenomena at work. The major difference is in the novel way in which energy is released into the furnace.

## **THE DROSRITE PROCESS**

With DROSRITE, hot dross is charged to a refractory-lined rotary furnace, immediately after skimming from the aluminum holding furnace. The DROSRITE furnace is sealed and maintained under an argon atmosphere. The only heat source for the furnace is the controlled reaction of oxygen with residual aluminum contained in the dross residue, after the recoverable metal has been tapped.

The process operates in five distinct steps:

### Step 1: Charging

The furnace, having been preheated at the end of the previous batch to between 800 and 900 C, is flushed with argon. The furnace door is opened and the dross is charged. The furnace door is then tightly closed. In some cases this may be repeated as two or more pans of dross are charged.

### Step 2: Processing

The furnace cavity is purged with argon. The furnace is rotated as necessary to gently tumble the charge, for roughly 15 to 30 minutes. Duration of this tumbling is as required to achieve transfer of energy from the refractory walls of the furnace to the charge.

### Step 3: Metal Tapping

The tap hole is opened, and the metal is poured into the receiving vessel or ladle.

In certain cases, it may be beneficial to repeat steps 2 and 3, to maximize aluminum recovery.

#### Step 4: Furnace Heating

A controlled amount of oxygen is injected into the furnace cavity, burning some of the non-recoverable aluminum contained in the residue. The temperature of the inside surface of the refractory wall is monitored, its value corresponding approximately to that of the charge. When the temperature reaches the target value, typically in the range of 800 to 900 C, oxygen injection is stopped.

#### Step 5: Discharging the Residues

Purging with argon is repeated. The furnace door is opened, and the residue is discharged into a suitable pan. The door is closed. The furnace is ready for the next cycle.

### **An Industrial DROSRITE Unit**

An industrial DROSRITE unit will typically be installed in close proximity to the casting department of the aluminum plant. The furnace unit will be sized according to the operating characteristics and total treatment requirements of the particular installation.

As an example, consider an aluminum plant producing 6,000 tonnes of white dross per year, with approximately one furnace skimming of 700 kg each hour. A suitable DROSRITE configuration in this case would comprise two furnace units, each having a capacity of 2.1 tonnes. Up to three pans containing 700 kg of dross could be charged into the standby unit as dross became available. The furnace in this case could have an internal diameter of two meters and a length of 2.5 meters. One furnace would be on standby while the second was processing.

Mass and energy balances for such a 2.1 tonne unit are presented in Figures 2 and 3 respectively, with the assumption that the process will in this example recover 600 kg of aluminum from each tonne of dross.

Figure 2 indicates that 15.6 kg of oxygen are required in this case to “burn” a sufficient amount of the aluminum remaining in the residue to return the furnace to its initial temperature of 850 C at the conclusion of a run. The quantity of aluminum that is burned in this case corresponds to 0.8% by weight of the original dross charge, and this percentage has been found to be quite insensitive to detailed operating parameters.

The energy balance of Figure 3 illustrates quantitatively how the energy generated by the controlled reaction of oxygen with residual aluminum balances the other energy inflows and outflows in a process cycle.

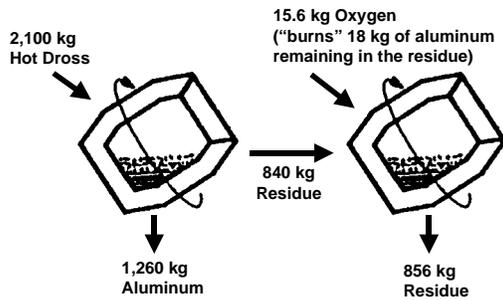


Figure 2 – Mass Balance for an Industrial DROSRITE Installation

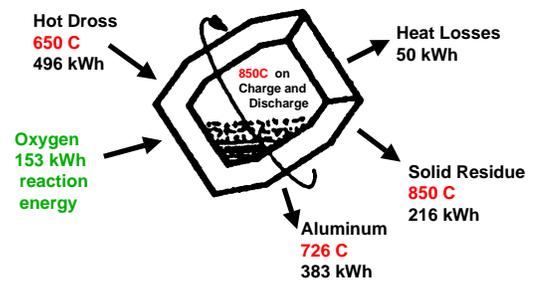


Figure 3 – Energy Balance for an Industrial DROSRITE Installation

## INDUSTRIAL DEMONSTRATION OF DROSRITE

### The Pilot Unit

A small rotary furnace was constructed for use in demonstrating the feasibility of the DROSRITE process in an industrial environment. The unit, illustrated in Figure 4, has overall dimensions of 5-ft x 7-ft x 7.5-ft and weighs approximately two tonnes.

The processing vessel is cylindrical, having a capacity of approximately 100 kg of dross depending on the density of the material being processed. It is lined with an alumina refractory and equipped with a refractory-lined door. The furnace is rotated at three turns per minute during processing, to achieve separation of the metal from the oxide in the dross by tumbling in the furnace cavity.

The unit is equipped with two hydraulic cylinders. One is used for tilting the furnace at different angles during the various stages of the operation ... charging, processing, tapping and discharging ... and the second is used for opening the furnace door.

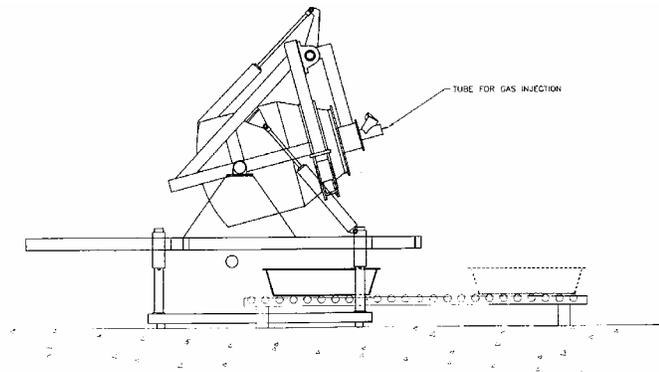


Figure 4 – Processing of the Dross Under Inert Argon Atmosphere

A controlled amount of gas (argon or oxygen) is injected into the furnace cavity at various stages of processing. The gas is injected through a tube located along the furnace axis on the door mount, as shown in Figure 4. A 1-in OD glass fibre gasket maintains the door-to-vessel seal. The door mount is equipped with a gas vent to allow the escape of any gas produced in the furnace during processing. Figure 4 also shows how pans were manipulated on a conveyor, to bring them under the furnace to collect metal during tapping or residue during discharge.

## Industrial Trials

Trials were conducted at a large aluminum recycling plant and at the pilot plant of a second aluminum producer, both in the U.S.A. Various charges of hot white and black drosses were treated. At the beginning of a series of runs, the cold furnace was preheated using either natural gas or propane. In one case, the cold furnace was preheated to 830 C using hot white dross alone, with oxygen injection.

The test results obtained at the recycling plant have been published previously (10). The dross, both black and white, which was tested at the aluminum producer pilot plant was quite different from that tested previously at the recycling plant, most notably being much “wetter” or richer in aluminium. It was found that the processing recipe could be adjusted readily to achieve successful processing.

A typical processing test is illustrated in Figure 5. In this test, preheating of the furnace was stopped at 18:40 and 66 lb of hot white dross was charged when it arrived from the melt shop. The temperature of the process was monitored with a thermocouple embedded in the refractory, approximately 0.13-in from the inner surface.

A first tapping yielded 49 lb of aluminum, corresponding to 74% of the initial charge. A second tapping 14 minutes later did not recover any further aluminum.

Injection of 0.5 m<sup>3</sup> of oxygen following tapping raised the temperature of the vessel to 860 C in a controlled manner. Note that the temperature rise, and thus the thermiting reaction, stopped as soon as the oxygen flow was switched off. Controlling oxygen intake controls the thermiting process.

A total of 1 m<sup>3</sup> of argon was used in this test, for purging on charging and discharging, and during tapping. It is noteworthy that, when argon was injected to the furnace, smoke was always visible in the furnace exhaust. By contrast, when oxygen was injected there was no visible exhaust. This supports the conclusion that essentially all of the oxygen reacts with the charge.

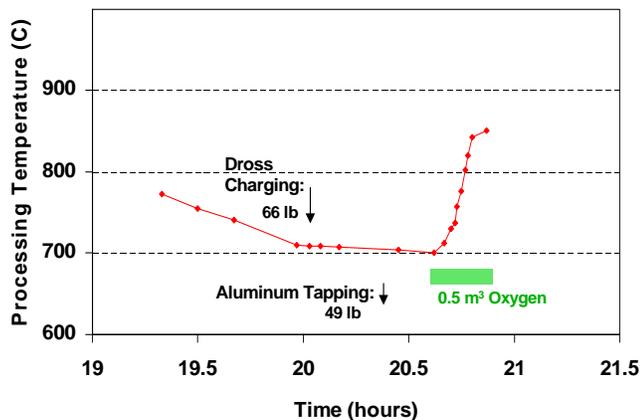


Figure 5 – Temperature Variation in a Typical DROSRITE Test Processing White Dross

Figure 6 presents the results of three consecutive DROSRITE white dross runs. The first of these is the same as was presented in Figure 5. Good aluminum recovery was achieved in each case, and oxygen addition successfully reheated the furnace following tapping. Processing temperatures were quite different in each of the three runs, indicating the robustness of the process.

During operation, the furnace assembly was mounted on a scale to allow monitoring of the charge weight, the weight of aluminum tapped, and the weight of residue produced. Weighing accuracy was within 1 to 3 pounds. In each case, overall weight increase during processing corresponded to the weight of oxygen injected.

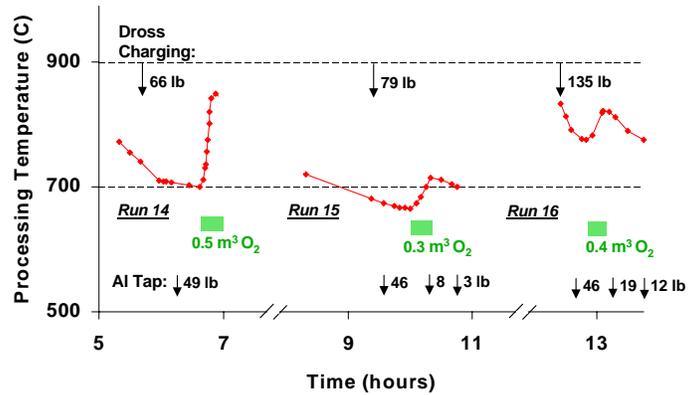


Figure 6 – Three Consecutive Runs, Treating White Dross by the DROSRITE Process

Figure 7 presents the results of seven consecutive DROSRITE runs processing black dross. In this campaign the charges of black dross, varying between 140 and 172 lb, were much heavier than the lighter density white dross charges used in earlier trials. Furthermore, it was found necessary to inject some oxygen into the furnace before tapping in order to heat the charge and promote separation. As noted in figure 7, metal recovery from the black dross varied between 18% and 40%.

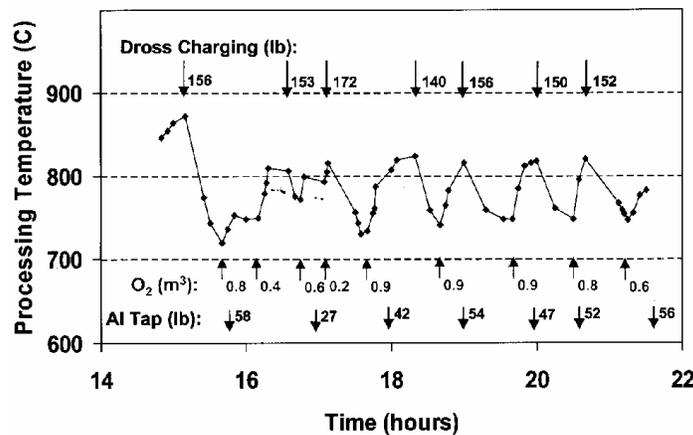


Figure 7 – Seven Consecutive Runs, Treating Black Dross by the DROSRITE Process

Analyses of the chemical composition of residue from three different DROSRITE runs with white dross are presented in Table I. All figures are percentage by weight.

Given the very low salt content, each of these materials would be suitable for use in production of calcium aluminate or of other value-added products.

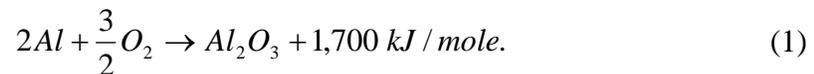
Table I – Chemical Composition of Residue from Three DROSRITE Runs

	Al (as metal)	Al (other)	F	Na	Mg	Si	Cl	Ca	Mn	Fe
<b>Sample 1</b>	0.8	51.8	0.7	0.28	5.57	0.16	0.84	0.8	0.46	0.71
<b>Sample 2</b>	13	56.2	0.5	0.28	6.6	0.29	0.59	0.54	0.43	0.35
<b>Sample 3</b>	6.2	45.1	0.56	0.28	9.73	0.21	1.81	0.67	0.33	0.35

### Analysis and Discussion

The results presented in Figure 5 support a useful qualitative confirmation of the principle of operation of the DROSRITE process. In this case, addition of 0.5 m<sup>3</sup> of oxygen resulted in a temperature increase of 160 C at the refractory wall, from 700 C to 860 C. Further, thermocouples embedded in the refractory 1 inch and 2 inches from the inner surface indicated corresponding temperature increases of 100 C and 50 C respectively.

The thermiting reaction at approximately 800 C is



The amount of heat generated is 8.7 kWh per kg of Al reacted or 9.8 kWh per kg of O<sub>2</sub>.

Addition of 0.5 m<sup>3</sup> (0.72 kg) of oxygen in the case of Figure 5 would have generated approximately 0.72 x 9.8 x 3600 = 25,400 kJ of energy. This energy served to heat the 16 lb (7.7 kg) of residue and the refractory wall of the crucible.

The specific heat of alumina at 800 C is approximately 1.1 kJ/kg-°C. Thus, energy consumed heating the residue in this example was on the order of 1.1 x 7.7 x 160 = 1,350 kJ. For the refractory wall, the data indicated that approximately 2.3 inches of the alumina refractory (200 kg) were heated to an average temperature increase of 100 C, consuming 1.1 x 200 x 100 = 22,000 kJ. Heating of the wall and the residue (23,350 kJ) thus accounts for 92% of the energy contributed by the controlled thermiting reaction.

Within the uncertainty of the estimate, this calculation supports the claim that DROSRITE can successfully separate aluminum from dross using only the energy content of aluminum contained in the residue, energy that would otherwise be lost. Most if not all of the injected oxygen is consumed by this heating.

## ECONOMIC ANALYSIS

The detailed cost analysis for a particular DROSRITE installation will depend very much on the scale and on the manner in which the system is to be integrated into existing facilities. Only an indication will be included here of the possible savings in operating costs that can be realized with DROSRITE. The estimate is made from the point of view of an aluminum plant operator.

Consider a plant producing 10,000 tonnes of dross per year. Treatment cost paid to a dross treater is typically on the order of \$200 U.S./tonne. In-house treatment using DROSRITE may require an additional operator on all shifts. Argon and oxygen consumption are respectively 5 m<sup>3</sup> and 10 m<sup>3</sup> per tonne (although this argon requirement may displace argon currently used for inert-gas cooling of dross prior to shipping). Thus, annual operating cost can be estimated at \$335,000 annually, as follows:

Additional operator per shift (5x)	\$200,000
Relining furnace each two years	35,000
Other maintenance costs	35,000
Argon, oxygen gases	60,000
Power cost	<u>5,000</u>
T O T A L	\$335,000

This operating cost must be compared with the alternative tolling cost of \$200 x 10,000 = \$2.0 million. The corresponding operating cost benefit is approximately \$1.7 million annually or \$170/tonne.

Several other factors can impact this analysis, most of them favourably:

- Aluminum separated from dross by DROSRITE can be returned directly to the holding furnace, without remelting. Annual savings can be on the order of 6,000 tonnes x 400 kWh/tonne x 4.5 ¢/kWh = \$110,000.
- Some companies would give substantial credit for the sharp reduction in in-process aluminum inventory.
- The need for cover salt during dross cooling is eliminated, corresponding to annual savings of approximately \$65,000. If inert gas cooling is currently used, a corresponding saving will result from elimination of this operating cost.
- There could be a cost for disposal of the 4,000 tonnes per year of DROSRITE residues. For example, at \$75/tonne this would correspond to \$300,000 annually. However, DROSRITE residues are particularly clean, with no added salt or nitrides. Thus, it is likely that cost-neutral or value-added outlets can be found.
- Aluminum metal recovery is expected to be superior to recovery obtained with processes where hot dross is exposed to air, such as the RSF process and the plasma process. This can result in a substantial further cost advantage.

## SUMMARY AND CONCLUSIONS

The industrial trials presented here have demonstrated that DROSRITE can successfully treat aluminum dross, on-line with the melting furnaces of an aluminum plant. The results demonstrate the viability of batch-to-batch heating with energy stored in the refractory of a DROSRITE furnace, with heating based on “burning” of some of the residual aluminium contained in the residue of the process. Thermiting is effectively controlled, and efficient aluminum separation results. This is achieved using a robust industrial rotary kiln, without significant energy input.

Compared to existing technologies, DROSRITE offers economic advantages due to elimination of the need for salt, high metal recovery, hot metal return, low capital and operating costs and reduced residue disposal costs.

Environmental advantages are even more marked. There is no salt cake requiring disposal. No carbon dioxide or NO<sub>x</sub> gases are produced. No nitrides are formed. The process has little off-gas and produces a residue that is suitable for production of calcium aluminate or for other value-added use.

## ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of the Industrial Energy Research and Development Program of the Department of Natural Resources Canada.

## REFERENCES

1. S. Lavoie and J. Lachance, “Five Years of Industrial Experience with the Plasma Dross Treatment Process,” Proceedings of the Third International Symposium, Recycling of Metals and Engineered Materials, The Minerals, Metals and Materials Society, 12-15 November, 1995, 791-801.
2. M.G. Drouet, J. Meunier, B. Laflamme, M.D. Handfield, A. Biscaro and C. Lemire, “A Rotary Arc Furnace for Aluminum Dross Processing,” Proceedings of the Third International Symposium, Recycling of Metals and Engineered Materials, The Minerals, Metals and Materials Society, 12-15 November, 1995, 803-812.
3. M. G. Drouet, “Use of a Rotating Arc Furnace for Treating a Dross Containing a Metal in Order to Recover that Metal,” US Patent, No. 5,245,627, 4 September 1993.

4. M.W. Paget, M. Lefebvre, J.F. Heffron, and C. Bazinet, "A Novel Burner Retrofit to Increase Productivity in an Aluminum Rotary Furnace and Reduce Baghouse Loading," Proceedings of the Second International Symposium, Recycling of Metals and Engineered Materials, The Minerals, Metals and Materials Society, 1990, 671-678.
5. M.G. Drouet, "Waste Treatment and Clean Processes," International Union for Electroheat (UIE), Paris, 1996.
6. J. Meunier, H. Zimmermann and M.G. Drouet, "Aluminum Recovery from Dross: Comparison of Plasma and Oil-Fired Rotary Furnaces," Proceedings ISPC-9, Italy, 1989.
7. H. Gripenberg, H. Gralo, M. Müllerham and G. Flesh, "Salt-Free Process for Recovery of Aluminum from Dross and Aluminum-Containing Materials," Second International Conference on the Recycling of Metals, ASM, October 1994.
8. M.G. Drouet and P.G. Tsantrizos, "Recovery of Metal from Dross," PCT Patent, No. CA97/00242, 23 October 1997.
9. R. Breault, J. Lachance and Y. Huard, "Market Opportunities for the Alcan Plasma Dross Residues," Light Metals, J. Evans, Ed., The Minerals, Metals and Materials Society, 1995, 823-827.
10. M.G. Drouet, R. LeRoy and P.G. Tsantrizos, "In Plant Recycling of Aluminum Dross, with DROSRITE", 39<sup>th</sup> Annual Conference of the Canadian Institute of Mining, Metallurgy and Petroleum, 20-23 August, 2000.