DROSRITE PLUS™ TREATMENT OF ALUMINUM AND ZINC DROSSES

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ABSTRACT

In both the *hot* rotary-salt-furnace (RSF) treatment of aluminum dross and the *cold* ball-mill-sieving (BMS) treatment of zinc dross, enormous amounts of energy and recoverable metal are wasted and large amounts of greenhouse gas are produced. Such wastes and the environment pollution could be avoided by using the DROSRITE PLUS™ technology. Economic and GHG production comparisons between the presently used industrial treatment processes and DROSRITE PLUS™, supported by over one hundred tests conducted in Canada, the US and Europe, are presented. The savings, with DROSRITE PLUS™, would be about $193 and $418 per MT of aluminum and zinc dross, respectively.

KEYWORDS

Aluminum, Zinc, Dross, Recovery, Rotary Furnace, Drosrite Plus

INTRODUCTION

Dross is a material, which forms on the surface of molten non-ferrous metal, such as aluminum or zinc, during melting, metal holding and handling operations when the molten metal is in contact with a reactive atmosphere. Dross normally consists of metal oxides entraining a considerable quantity of molten free (unreacted) metal, and for economic reasons it is desirable to extract the free metal before discarding the residue. In the case of aluminum dross, recovery of the metal is usually carried out by treating the dross in a furnace at a high temperature (Peterson et al., 2002). By contrast, cold zinc dross is crushed in a ball mill followed by sieving to separate the coarse metal portion from the fine oxide residue.

The conventional aluminum dross treatment process, using gas or oil-heated rotary salt furnaces (RSF), is thermally inefficient and environmentally unacceptable because of the salt slag and CO_2 produced from the combustion of fossil fuels. In the past several years, a number of salt-free processes have been developed and some of these have found limited commercial use (Gripenberg et al., 1994; Lavoie et al., 1990). In all these 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 (metric) tonne of dross. Molten metal separated during processing of the heated dross is tapped, and the remaining solid residue is discharged from the furnace.

DROSRITE™, developed and patented by PyroGenesis (Drouet et al., 2000) does not require any fluxing salt. It does not require any external energy input either, as process energy is extracted from the solid residue, 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, further maximizing energy efficiency.

The differences between the conventional RSF method, for aluminum dross, and the DROSRITE™ method are illustrated in Figure 1. The RSF process is characterized by cooling and transport of the residue and metal (Paget et al., 1990) while, with DROSRITE™, hot dross is treated on-site and hot metal is returned to the holding furnace. 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.

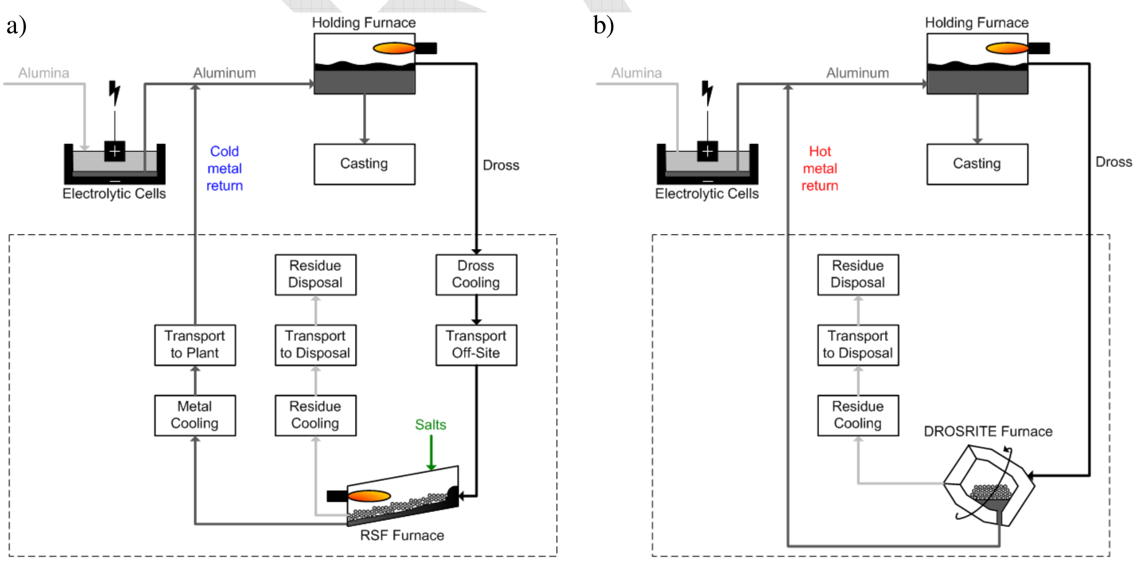

Figure 1 – (a) The conventional rotary salt furnace (RSF) process and (b) the DROSRITE™ process for aluminum dross

The conventional method of treatment of the zinc dross, illustrated in Figure 2, also comprises several unit operations: dross cooling, crushing of the agglomerated dross blocks in a ball mill, sieving to separate the metal from the oxide powder, dumping of the recovered metal in the holding furnace. This method is referred in this text as the ball-mill-sieving (BMS) process. By contrast, with DROSRITE™ as illustrated in Figure 3, only a single step is required as the just skimmed hot dross is fed to the furnace and the separated metal is returned, molten, to the holding furnace.

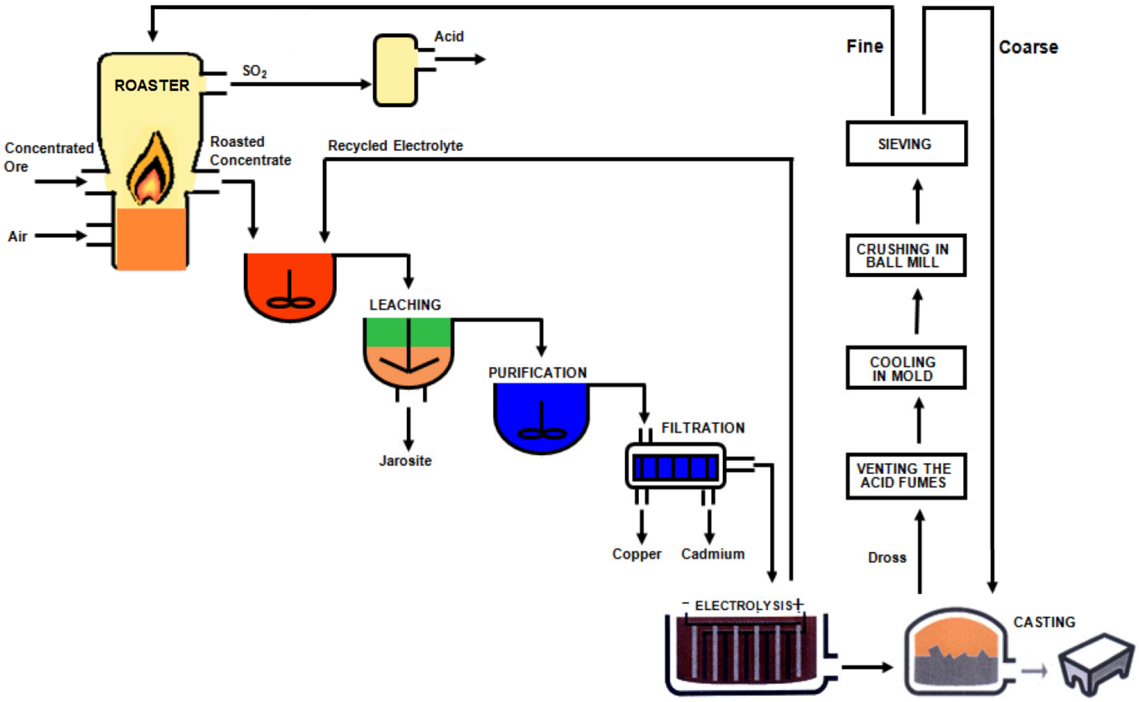

Figure 2 – The conventional ball-mill-sieving (BMS) process for zinc dross

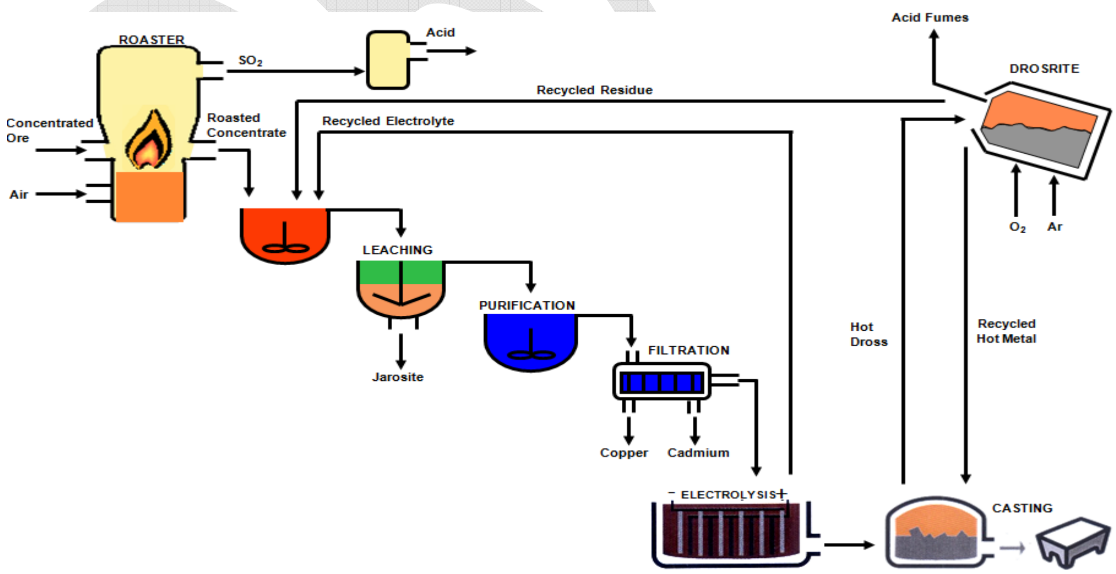

Figure 3 – The DROSRITE™ process for zinc dross

DROSRITE PLUS™ TECHNOLOGY

With DROSRITE PLUS™, hot dross is charged to a refractory-lined rotary furnace, immediately after skimming from the aluminum or zinc holding furnace. The DROSRITE PLUS™ furnace is sealed and maintained under an argon atmosphere. The only heat source for the furnace is the controlled reaction of oxygen with unrecoverable metal contained in the dross residue, after the recoverable metal has been tapped. After each treatment cycle, the residue is discharged except for an amount which, when heated at 1000°C for aluminum or 800°C for zinc, will hold enough energy to heat the next batch of dross to the required temperature.

INDUSTRIAL TRIALS

A small rotary furnace, of 100 kg capacity, was used in the demonstration of the DROSRITE™ process in industrial environments. Over a hundred DROSRITE™ tests were carried out in six different metallurgical plants in Canada, the United States and Europe. Various charges of white and black aluminum dross and of zinc dross were treated. At the beginning of each series of runs, the cold furnace was preheated using either natural gas, propane or, preferably, hot dross alone with oxygen injection.

Some test results on aluminum dross have been published previously (Drouet, 2004). A typical processing test is illustrated in the following Figure 4. The processing temperature was monitored by a thermocouple embedded in the furnace refractory. Hot aluminum dross was charged at 20:00 and the separated metal was tapped about 20 minutes later. Following tapping, 0.5 m^3 of oxygen was injected to raise the vessel temperature from 700°C to 860°C. The recording shows that the heat source, in the DROSRITE™ process, is that generated by burning the non recoverable metal remaining in the residue, after metal tapping. It shows also that the temperature increase stops as soon as the oxygen flow is switched off indicating that the thermiting reaction can be well controlled.

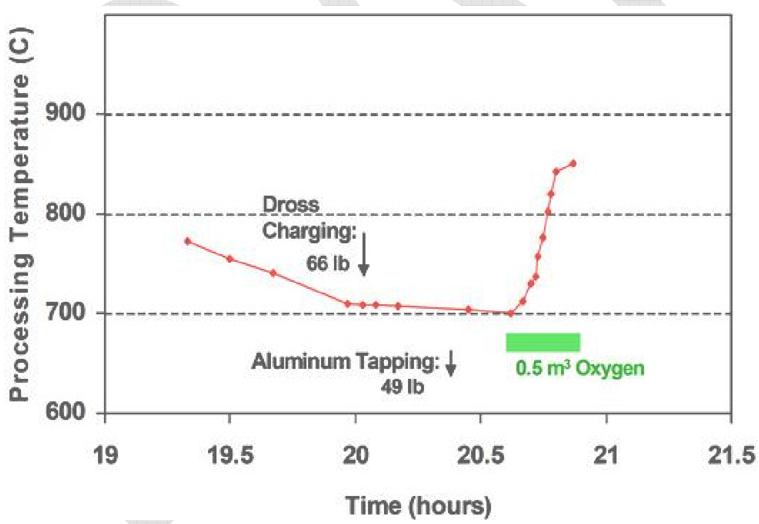

Figure 4 – Variation of the refractory temperature during treatment of aluminum dross with DROSRITE™

COMPARING DROSRITE PLUS™ AND RSF FOR ALUMINUM DROSS TREATMENT

The conventional, most used in the world, aluminum dross treatment process uses a gas or oil-heated rotary furnace which operates with the addition of salt to the charge in order to protect it from oxidation at the melt surface by the ambient air. It is called "RSF" for Rotary Salt Furnace. RSF treatment of aluminum dross is detrimental to the environment as it results in both the production of salt contaminated residue and of large amount of carbon dioxide (CO_2) from the combustion of gas or oil. By contrast, DROSRITE PLUS™ gives a salt-free residue suitable for the production of value-added products and does not produce any CO_2.

Table 1 and Figure 5 present operation data that was obtained for a RSF furnace operating in the US, and an estimate of the corresponding data for a DROSRITE PLUS™ system with the same treatment intput of 25,053 metric tons (MT) of dross.

Table 1 – Operation data of RSF vs. DROSRITE PLUS™ (per year)

Parameter	**RSF**	**DROSRITE PLUS™**
Amount of dross treated (MT)	25,053	25,053
Oil consumption (l)	594,236	0
Oxygen injected (m^3)	1,622,456	350,000
Electricity used (kWh)	1,742,150	438,000
Salt used (MT)	1,253	0
Metal recovered (MT)	11,289	12,546
Increase in the total weight (MT)	1,117 (4.46%)	500 (2%)
Metal recovery (% w/w)	45.06	50.08
Argon used (m^3)	0	200,000
Recoverable metal consumed (MT)	1,257	0
Amount of residue (MT)	16,134	13,007

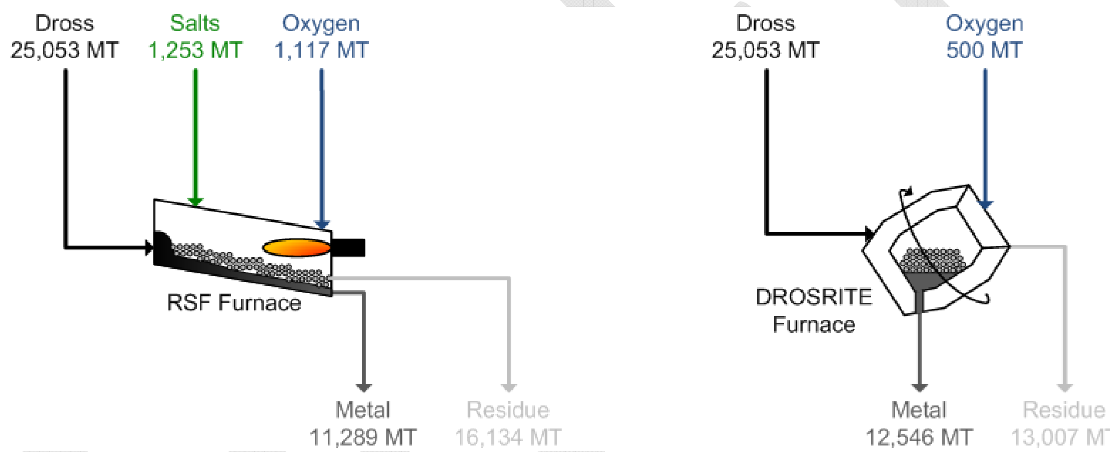

Figure 5 – Mass balances RSF vs. DROSRITE PLUS™ (per year)

To ensure complete combustion of the fuel in the RSF, excess oxygen of 22% is maintained in the exhaust gas. The presence of oxygen in the RSF results in the oxidation of some of the recoverable metal; this oxidation explains the increase in the total output weight of 4.46 % or 1,117 MT observed which corresponds to the oxidation of 1,257 MT of metal which, otherwise, would have been recovered.

By contrast, the DROSRITE PLUS™ operation being conducted under inert atmosphere, there is no oxidation of recoverable metal during the process of metal separation from the residue and therefore an increase of 11.14 % in metal recovery could be expected. In the case of DROSRITE PLUS™, the 350,000 m^3 of oxygen would be injected only after metal tapping and therefore there would not be any recoverable metal consumption. The much lower DROSRITE PLUS™ electricity consumption, comes from the fact that the amount of exhaust gases which have to be treated is very small as compared to the amount generated in the RSF process. The amount of residue generated by the RSF is larger by 3,127 MT as a result of the 1,253 MT salt addition plus the 1,117 MT of oxygen captured in the oxidation of the 1,257 MT of metal minus the 500 MT increase in weight in the case of DROSRITE PLUS™.

These data were used to produce the economic comparison presented in Table 2. For the transport of the dross, it was assumed that 40 MT capacity containers would be used and that the distance from the plant to the recycler was only 160 km (100 miles), each transport costing $ 2,000. In fact, in most cases in the US, the distance is very much larger than 160 km (100 miles) and therefore the cost would be higher than indicated here. By contrast, with DROSRITE PLUS™, installed at the plant site, there is no transportation cost.

Table 2 – Economic comparison RSF vs. DROSRITE PLUS™ (per year)

Parameter	**RSF**	**DROSRITE PLUS™**
Cost of transport of the dross to recycler ($50/MT)	$ 1,252,650	$ 0
Cost of oil ($ 3.65/US gallon)	$ 573,799	$ 0
Cost of oxygen injected ($ 0.21/m^3)	$ 340,716	$ 73,500
Cost of electricity ($ 0.1/kWh)	$ 174,215	$ 43,800
Cost of salt ($165/MT)	$ 206,745	$ 0
Cost of metal burned ($ 2,000/MT)	$ 2,514,000	$ 0
Cost of argon ($ 1.25/m^3)	$ 0	$ 250,000
Cost of disposal of residue ($ 46/MT)	$ 742,164	$ 598,322
Total cost	$ *5,804,289*	$ *965,622*
DROSRITE PLUS™ economic advantage	**$ 4,838,667 or $ 193/MT**	
Return on investment (ROI)	**< 1 year**	

Greenhouse gas emissions have been calculated taking into account the transportation of the dross, metal and residue, the energy required by both the RSF and DROSRITE™ process, the manufacturing process for the salts, oxygen and argon, the disposal of the residue, the extraction and production of fuels, the energy to remelt the aluminum produced by the RSF process, and the avoided emissions associated to the increased metal recovery with DROSRITE PLUS™. The calculations lead to a reduction of emissions of about 5,600 MT of CO_2e per year when using DROSRITE PLUS™ instead of RSF, or 0.2 MT of CO_2e per MT of aluminum dross

With regard to the recovered metal, it is consider here that the metal recovered by the RSF is of the same quality as that recovered at the plant site by DROSRITE PLUS ™. In fact, this is not the case as the RSF recovered metal is only a high value scrap while the DROSRITE PLUS™ recovered metal is returned right away in the melt of the furnace from which the treated dross was skimmed; therefore it has the same alloy composition and the same value. In addition it is returned molten.

Of interest is also the fact that, with DROSRITE PLUS™ and recycling ''in time'', there is no inventory of dross either in the dross house, on the road or at the recycler plant and the recovered metal is recycled the same day, not weeks later.

This comparison of the operating costs for the two processes is extremely favorable to DROSRITE PLUS™ which, in addition, generates less GHG and a non salt-contaminated residue.

CONTROL OF ALUMINUM DROSS SKIMMING PRACTICES WITH DROSRITE PLUS™

The results presented in this section, are results from an extensive on-site hot dross treatment series of 50 runs conducted over a period of 5 weeks at an industrial site. Additional details have been published previously (Drouet, 2004). The metal content corresponding to each skimming was determined for each of the 50 skimmings treated in the pilot furnace. Although the average metal content was only about 40%, much less than the value of 50% quoted in the industry, the metal content values, determined for each skimming, were found to vary widely, from 15% up to 87%.

These variations are illustrated in Figure 6 where the metal content is plotted versus the day of the week when the dross was skimmed; day 1 corresponds to Monday, day 2 to Tuesday, etc. The trend line for the average value for each weekday is also shown as a dotted line in the figure. The following observations can be made, bearing in mind that the results correspond to only a fraction of the content of each dross pan and not to its full content:

a. The trend line shows an increase in metal content of approximately 5% from Monday to Friday. If this trend can be extrapolated to the full dross pan content, then for the aluminum smelter plant where the test were conducted and which produces 20 000 tpa of dross, this 5% increase in dross metal content correspond to a loss of metal valued at approximately:

5 % x 20 000 MT/yr x $ 2000 /MT = $ 2,000,000 / year

b. This 5% increase in the trend can be attributed to an increase in the metal content of most skimmings from Monday to Friday; unfortunately, no test was conducted on the weekends.
c. The low metal value observed can be attributed either to careful skimming or possibly to a pan full of hot dross not sent immediately from the cast house to the test area and, on the contrary, left to burn, thus loosing metal content.

In Figure 6, an operator's name could be associated with each data point. Therefore, the performance of each skimming operator could be monitored on a continuous basis and measures taken to reduce metal content in the dross by changing the skimming practices.

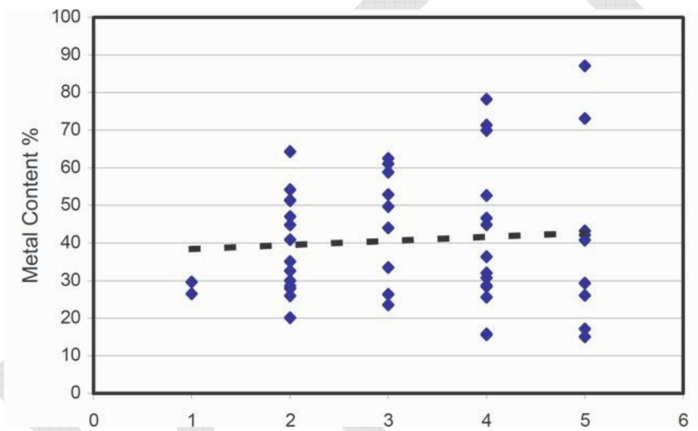

Figure 6 – Dependence of the aluminum content in each of 50 skimmings on the day of the week

DROSRITE PLUS™ TREATMENT OF ZINC DROSS

At present, in the zinc industry, the treatment of the dross is carried out as illustrated in Figure 2. The pan of hot dross is left in front of the holding furnace to allow venting of the acid fumes while the dross is cooling down. The cooling lasts for 2 to 3 hours during which oxidation of some zinc metal occurs in the pan, thus reducing the amount of recoverable metal. The agglomerated blocks of cold dross are later crushed in a ball mill before sieving to separate the coarse metal portion going back to the holding furnace from the fine oxide residue, the latter is sent to the roaster.

A lot of energy could be saved by (i) avoiding to operate the holding furnace with the door open for 2 to 3 hours while the cooling dross, in the pan, is venting its acid fumes, (ii) avoiding the loss of metal by oxidation in the pan during cooling, (iii) avoiding the loss of the latent heat of the hot dross, (iv) avoiding the use of a ball mill and (v) returning the recovered metal to the holding furnace as molten. This can be done using the DROSRITE PLUS™ technology as illustrated in Figure 3: the hot dross is charged in the DROSRITE PLUS™ furnace right after skimming, it is then processed under argon to prevent oxidation and the separated molten metal is returned, still molten, directly into the holding furnace while the oxide fines, freed from their contaminants, are sent, not to the roaster, but directly for leaching.

Using the DROSRITE™ pilot furnace, a total of 28 treatment tests were conducted on zinc dross at four different industrial locations. The tests have shown that the metal can indeed be separated from the oxide and that, the residue being in the form of a very fine powder as illustrated in Figure 7, there is no need for using a ball mill. In addition, the DROSRITE™ processing of the residue reduces greatly its contaminant content as shown in

Table 3, below, for up to six different runs conducted on zinc dross with DROSRITE™.

Figure 7 – Appearance of the fine powder residue from DROSRITE™

Table 3 – Contaminant reductions with DROSRITE™ for zinc dross

Contaminants	Test #	Content in dross (%)	Content in residue (%)	Reduction (%)
Chlorides	1	0.95	0.01	99.0
	2	2.55	0.21	91.8
	3	3.60	0.45	87.5
	4	1.07	0.01	99.1
	5	1.78	0.01	99.4
	6	4.40	1.68	61.8
Ammonia	1	0.13	0.02	85.0
	2	0.36	0.02	94.4
	3	0.35	0.10	71.4
	4	0.10	0.05	50.0
	5	0.15	0.01	93.3
	6	0.01	0.01	-
Thallium	1	0.0082	0.0013	84.0
	2	0.0117	0.0009	92.3
	3	0.0158	0.0041	74.1
	4	0.0049	0.0009	81.6
	5	0.1720	0.0019	96.9
	6	0.0006	0.0003	50.0
Sulfur	1	0.76	0.50	34.0
	2	1.01	0.50	50.5
	3	0.80	0.30	62.5
	4	0.05	0.05	-

COMPARING DROSRITE PLUS™ AND BMS FOR THE ZINC DROSS TREATMENT

Presently, the fines are sent back to the roaster where the metal fines burn; as a result, the roaster is difficult to control because both the fines feeding in not constant and the metal content in the fines is not always the same. Furthermore it is observed that some of the metal recovered, by sieving the milled dross, is burnt when dumped on the melt surface of the holding furnace.

DROSRITE PLUS™ offers several advantages compared to conventional practice of BMS. By allowing the recovered zinc oxide to be sent to leaching and not to the roaster, the roaster throughput can be increased, the control of the roaster is easier, and the plant production is increased. Furthermore, the liquid zinc metal recovered is fed into the holding furnace: it does not burn.

In addition, DROSRITE PLUS™ allows for removal of the chlorides from the residue, allowing clean zinc oxide to be sent to leaching, preventing damage to the roaster and its gas cleaning equipment, while also increasing the life of the aluminum cathodes.

Finally, DROSRITE PLUS™ allows for improved energy efficiency of the plant and higher metal recovery rates. Presently, the hot dross heat is wasted, the holding furnace often operates with the door open, the exhaust fans moving more air than required, recoverable metal is oxidized during the long dross cooling, large amount of energy are used to power the ball mill, the sieve and to melt the recovered metal, etc. With DROSRITE PLUS™**,** the hot dross is being fed right away in the furnace and its heat is not wasted; the furnace is under an inert argon atmosphere, resulting in no oxidation of metal, meaning higher recovery of zinc metal; the residue is in the form of a fine powder: no ball milling is required translating into additional energy and maintenance cost savings; and there is no inventory of dross to manage, as it gets treated as soon as it is produced.

Furthermore, in the case of aluminum, the dross is sent for treatment to an outside recycler and data are available to conduct comparative evaluations of competitive processes in terms of metal recovery, energy savings and environment benefit as illustrated earlier in Table 1 and Table 2 above. In the case of zinc, such data is not available as the dross is recycled at the plant site and the costs associated with low recovery of metal, wasted energy, equipment damage and environmental impacts are harder to quantify. Furthermore, in the case of aluminum, efforts have been made for years to develop a process, which would eliminate the production of the salted residue produced by the RSF technology, which is so damaging to the environment. Here again the situation is very different for the zinc industry where process residue is recycled internally seemingly at no cost. However, this couldn't be further from the truth. For example, it has been observed that a large fraction of the recovered metal, when dumped into the holding furnace, floats at the surface of the melt and burns. Of course, burning zinc is not a complete loss as heat is released, but it is a rather expensive fuel at $1.3/kWh compared to oil at $0.1/kWh.

Table 4 and Figure 8 present operation data estimates for a conventional zinc dross treatment process, and estimates of the corresponding data for a DROSRITE PLUS™ system with the same treatment input of 6,000 metric tons (MT).

Table 4 – Operation data of BMS vs. DROSRITE PLUS™ (per year)

Parameter	**BMS**	**DROSRITE PLUS ™**
Plant zinc production (MT)	300,000	300,000
Amount of dross treated (MT)	6,000	6,000
Holding furnace energy consumption (GJ)	215,500	204,725
Oil consumption (l)	5,525,641	5,249,359
Fan electricity consumption (kWh)	91,980	87,600
Ball mill electricity consumption (kWh)	394,000	0
DROSRITE PLUS™ electricity consumption (kWh)	0	219,000
Oxygen consumption (m^3)	13,228,385	12,635,904
Argon consumption (m^3)	0	48,000
Metal recovered (MT)	1,620	2,700
Metal recovery (% w/w)	33.75	45.00
Fines/residue production	4,048	3,349

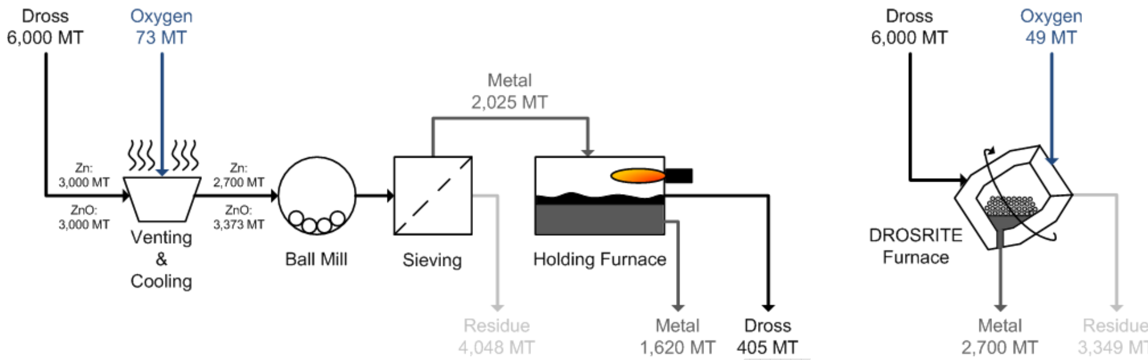

Figure 8 – Mass balances of BMS vs. DROSRITE PLUS™ (per year)

A zinc plant producing 300,000 MT of metal per year usually generates about 2% of dross, i.e. 6,000 MT. An energy input is required by the holding furnace to melt the zinc metal and this energy is provided by burning oil that has a calorific value of 39 MJ/l in burners and assuminhg energy transfer efficiency of 40%. In the case of the BMS practice, the holding furnace door has to be kept open to vent the dross that is cooling. With DROSRITE PLUS™, it is assumed that 5% of the holding furnace energy can be saved by keeping the door shut, and an additional 5% can be saved on the fan electricity consumption. Also, for this throughput, a 45 kW ball mill is required compared to a 25 kW DROSRITE PLUS™ furnace. Furthermore, it is considered that 20% of the coarse, cold particles that are dumped in the furnace after sieving will oxidize since they float on the surface of the melt and are exposed to excess oxygen.

Table 5 – Economic comparison BMS vs. DROSRITE PLUS™ (per year)

Parameter	**BMS**	**DROSRITE PLUS™**
Cost of oil for holding furnace ($ 3.65/US gallon)	$ 5,335,606	$ 5,068,825
Cost of oxygen ($ 0.21/m^3)	$ 2,777,961	$ 2,653,540
Cost of electricity ($ 0.1/kWh)	$ 48,618	$ 30,660
Revenue from metal recovered ($ 2,000/MT)	$ -3,240,000	$ -5,400,000
Cost of argon ($ 1.25/m^3)	$ 0	$ 60,000
Total cost	$ *4,922,185*	$ *2,413,025*
DROSRITE PLUS™ economic advantage	**$ 2,509,159 or $ 418/MT**	
Return on investment (ROI)	**< 1 year**	

Greenhouse gas emissions have been calculated taking for account the energy required by the holding furnace, the energy required by both the BMS and DROSRITE™ process, the fabrication of the oxygen and argon, the extraction and production of fuels, the energy to remelt the zinc produced by the BMS process, and the avoided emissions associated to the increased metal recovery with DROSRITE PLUS™. The calculations lead to a reduction of emissions of about 2,800 MT of CO_2e per year when using DROSRITE™ instead of BMS, or 0.5 MT of CO_2e per MT of zinc dross.

CONCLUSION

For economic reasons, the recovery of metal from the dross formed at the surface of molten non-ferrous metal is desirable. In this paper, the dross treatment technologies in use in the aluminum and the zinc industries have been studied. It has been shown that, in both cases, the waste of large amounts of energy and metal and the production of large quantities of GHG could be avoided by using the dross processing technology called DROSRITE PLUS™.

Economic and GHG production comparisons between the current industrial treatment processes and DROSRITE PLUS™, supported by over one hundred tests conducted in Canada, the US and Europe, have been shown that the savings, with DROSRITE PLUS™ can reach $193 and 0.2 MT of CO_2e per MT of aluminum dross treated and $418 and 0.5 MT of CO_2 per MT of zinc dross treated, resulting into immediate benefits to cast house operators.

REFERENCES

Drouet, M. G., & Tsantrizos, P.G. (2000). *Recovery of Metal from Dross and Apparatus Therefore* . US Patent No. 6,159,269.

Drouet, M. G. (2004). *Drosrite Extensive On-Site Hot Dross Treatment Tests*. Light Metals 2004 – Proceedings, Pages 931-936.

Peterson, R.D., & Newton, L. (2002). *Review of Aluminum Dross Processing*. In Light Metals 2002, Schneider, W., Ed., TMS–AIME, Warrendale, PA, 1029.

Gripenberg, H., Gralo, H., Müllerham, M., & Flesh, G. (1994). *Salt-Free Process for Recovery of Aluminum from Dross and Aluminum-Containing Materials*. Second International Conference on the Recycling of Metals, ASM.

Lavoie, S., Dube, C., & Dube, G. (1990). *The Alcan Plasma Dross Treatment Process, A New Salt-Free Dross Processing Technology*. Second International Symposium on Recycling of Metals and Engineered Materials, In The Minerals, Metals, and Materials Society, Van Linden, J.H., Stewart, D.L., & Sahai, Y., Ed., TMS, Warrendale, PA, 451-462.

Paget, M.W., Lefebvre, M., Heffron, J.F. & Bazinet, C. (1990). *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, TMS. 671-678.