FIVE YEARS OF INDUSTRIAL EXPERIENCE WITH THE PLASMA DROSS TREATMENT PROCESS

Serge Lavoie
Alcan International Limited
Arvida Research and Development Centre
1955, Mellon Blvd. P.O. Box 1250
Jonquiere, Quebec, Canada, 67S 4K8

Jacques Lachance
Alcan Smelters and Chemicals
Glillaume-Tremblay Works
2040, Chemin de la Reserve
Chicoutimi, Quebec, Canada, G7H 5B3

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Edited by
Paul B. Quneau
Hazen Research Inc., Golden, CO 80403

Ray D. Peterson
Reynolds Metals Co., Muscle Shoals, AL 35633-1258

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Alcan's Guillaume-Tremblay plant, located in Jonquiere, Quebec, has been in operation since 1990. This was the first plasma dross processing plant ever built. In addition to the use of the plasma heating technology, Guillaume-Tremblay has other unique features making it a modem and efficient dross processing facility. This paper presents a general overview of the practical experience at the Guillaume-Tremblay plant. In particular, the utilization of plasma heating in industrial conditions, the metallurgical performance, the unique dross handling system, the control and information management system and the reclaiming of the by-products will be discussed. Finally, the use of the plasma process for salty dross will be addressed briefly.

An advanced preventive maintenance program has also been set up using the plant computers. Preventive maintenance schedules and work order emission has been automated. Critical equipment information such as temperature and vibration level are used as advance warning for mechanical problems. This system has helped to reduce the unscheduled equipment shutdown time to less than 5% of the production time.

Noval material

Noval is the trade name given to the by-product of the plasma treatment of salt free dross (white dross). The Noval material contains mainly alumina (Al_2O_3), aluminum nitride (AIN). magnesium spinel ($MgAl_2O_4$), some residual aluminum metal and minor amounts of oxides and salts already present in the original dross. It has a high alumina equivalent content of at least 70% and frequently up to 95% when precursors such as aluminum and AIN are included.

The end use of the dross residues is one of the most important questions to be addressed when planning a modem dross processing facility. One important project criterium considered when building Guillaume-Tremblay was the absence of landfilling. This was an ambitious challenge that required significant research and market development effort. This challenge was met by reclaiming the Noval material for the fabrication of other products.

The products developed using the Noval material as a raw material are sodium aluminate ($Na_2Al_2O_4$), spinel-based ceramic, brown fused alumina, sand blasting medium and calcium aluminate ($CaAl_2O_4$). All these applications involve high temperature processing of the Noval material; this takes advantage of its energy content and generates an inert final product. A combination of these applications currently consumes all Guillaume-Tremblay ' s Noval material production.

A complete technical discussion on the Noval material market opportunities is presented in Reference 3.

Black dross

Guillaume-Tremblay is in a special situation since only white dross is available. Black dross, which is mainly produced in aluminum recycling plants such as for UBC, is another important source of dross in the industry. Black dross can contain from 10 to 30% salt.

The plasma dross treatment process is particularly attractive with white dross because the Noval material can be reclaimed directly. This is why mainly white, salt free dross, has been processed by plasma so far. On the other hand, the plasma process can also be advantageous in the case of black dross.

Some black dross has been processed with success on an experimental basis with the plasma process. Since the aluminum content of black dross is generally very low, it would be preferable to mill and screen the black dross prior to furnace charging to concentrate the aluminum content (see Reference 5 for an example). Also, the salt contained in the black dross is mixed with the oxide dross residues; where landfilling is not allowed, a salt reclamation plant will be required.

If plasma furnaces are used, additional salt is not required whatever the salt content of the dross. This is particularly profitable in the cases where a mixture of white and black dross is processed. This is illustrated in Figure 7 in the comparative flow sheets of hypothetical dross plants using the RSF and the plasma processes.

Introduction

Most of the dross produced today is treated using the rotary salt furnace (RSF) process. In the RSF. salt is mixed with dross to protect the aluminum content from oxidation and help its drainage from the non-metallic part. The RSF dross treatment by-product is the 'salt cake', a mixture of salt and dross residues. 'Salt cake ' has traditionally been landfilled but higher environmental onsciousness and stricter environmental regulations have made this practice more and more questionable.

The Alcan plasma process is a salt-free dross treatment process that can answer these environmental concerns. In this process, the dross is heated using a plasma torch. Plasma heating only uses a small quantity of gas in the furnace, a quantity of gas so small in fact, that negligible oxidation can occur, eliminating the need for the salt cover.

In the case of salt free dross (white dross) the by-product of the plasma dross processing is a grayish powder mainly composed of oxides; it has been given the Noval trademark. Reclaiming the Noval material in other industries is possible and could eliminate landfilling altogether.
Several papers on the plasma technology [1,2,3,4] have been presented and have described all the aspects of it. Alcan started the Guillaume-Tremblay plant, the first industrial plasma dross treatment plant, in 1990; the plant had a dual mission, first, to demonstrate the plasma dross process (including the reclamation of the Noval material) on an industrial scale, and second, to process all Alcan's dross in the province of Quebec.

In addition to its plasma torch heating system, Guillaume-Tremblay features other modern and efficient concepts which are unique in the dross processing industry. The objective of this paper is to present these concepts after five years of operational experience.

Operational experience

Guillaume-Tremblay processes about 18000 tonnes of dross per year; the production is controlled by the dross availability. A second plasma dross plant was started in 1991 by Plasma Processing Corporation (PPC) in Millwood, West Virginia. The combined operation of these two plants exceeds 150,000 tonnes of dross treated with the plasma process.

Guillaume-Tremblay is a lolling center, the dross remains the property of the originating plant to which the recovered aluminum is returned. Three operators per shift are required to run the plant. The life of the furnace refractories is 26 months. The electrical energy requirement ranges from 250 to 300 kW-hr/tonne of dross.

The use of 'expensive' electricity instead of 'cheap' fossil fuel as the energy source for the process may be cause for concern at first glance. This is not the case for two reasons. First, the plasma process uses one quarter of the energy used by the RSF; this factor of four essentially is the difference between electrical and fossil fuel costs anywhere in the world. Second, the energy cost is not likely to influence the economic performance of the plant much because it represents less than 10% of the total dross processing cost.

The energy advantage of the plasma results from a better energy conversion efficiency and from the absence of salt to be melted. Effectively, at Guillaume-Tremblay, 81% of the electricity supplied to the plasma torches is converted into usable heat in the furnace (15% is lost to the cooling water of the torch and 4% is lost with the exhaust gases), compared with about 25% for a conventional burner (in good operating condition, a conventional burner loses 75% of the fuel energy in the exhaust gases). Also, the salt in the RSF requires energy to melt, for example, if 400 kg of salt is added per tonne of dross, the additional energy to melt the salt is equivalent to 25% of the energy to melt the dross itself. Combining these two factors, for one tonne of dross, a burner in an RSF has to supply about 1200 kW-hr (4 millions BTU) to get the same usable energy to the furnace as a plasma torch delivering 300 kW-hr.

The operation of plasma torches in production

Guillaume-Tremblay uses Westinghouse Mark IIH plasma torches operated at a power of 1.5 MW. The torch basic construction is illustrated in Figure I and its physical installation on the furnace door in shown in Figure 2.

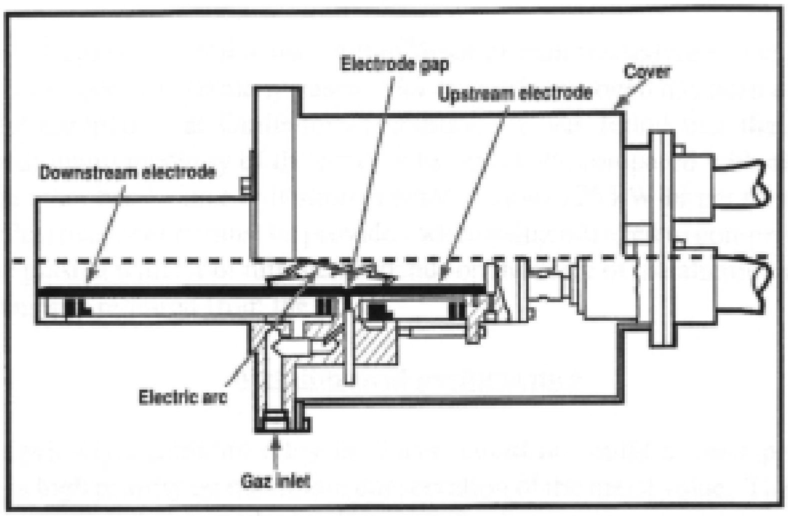

Figure 1 - Schematic of the Westinghouse Mark 11H plasma torch.

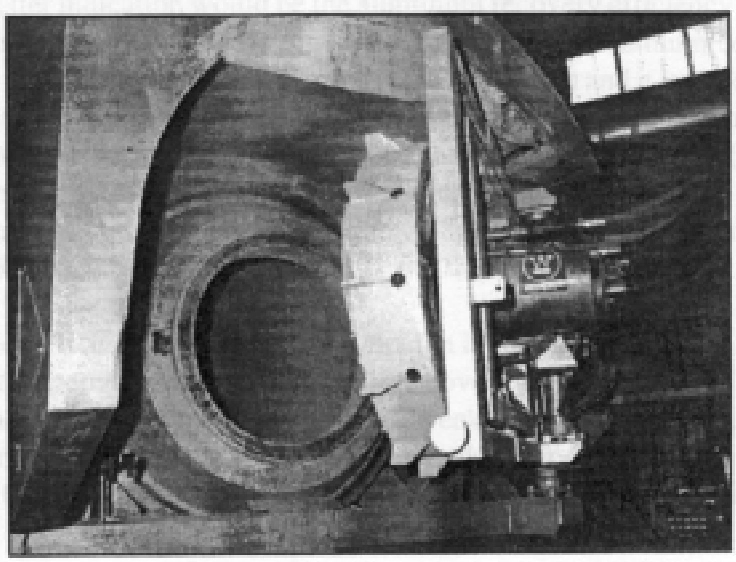

Figure 2 - View of the installation of the plasma torch on the furnace door.

At first glance, plasma heating may be perceived as an exotic 'high-tech' operation. With experience, this perception rapidly disappears as its use is safe, simple and reliable. The operation of the plasma at Guillaume-Trcmblay has been completely automated and requires only a few hours of training. An operator has no difficulty in making the transition from a combustion heating to a plasma heating system.

Maintenance is minimal; the only wear parts are the two copper alloy electrodes in the torch. The average life of the two electrodes is about 2500 hours (more than 14,000 tonnes of dross) and their cost amounts to less than 30 cents per tonne of dross. The torches are removed for inspection and cleaning once a month. To avoid any loss of production time, a third torch is kept as a spare. The switch over from the torch in operation to the spare takes a few minutes and the inspection, performed by the plant's mechanic, takes place offline. In addition to the reliability and the cost, the use of non-consumable electrodes has the advantage of not adding any contaminant to the recovered aluminum or residues.

The torches at Guillaume-Tremblay use 300 m /hour of compressed air as the plasma gas. The plasma torches can operate with many gases. For example, nitrogen has been used instead of air on experimental campaigns at Guillaume-Tremblay. It was found that the nitrogen plasma increased the aluminum recovery of the process by about 3% compared with air which contains oxygen. On the other hand, since oxidation generates about 125 kW-hr per tonne of dross in the furnace, more electrical energy must be provided when using nitrogen to compensate. The choice of operating the plasma with air or nitrogen depends on the price of the aluminum, of the nitrogen and of the throughput required from the plant.

Metallurgical performance

Alcan, being a primary aluminum alloy producer, could not build a dross processing facility without putting a high priority on maximum conservation of the metal value. The quantity and the quality of the recovered aluminum had to be maximized.

Because the aluminum content in the dross, even if it comes from a single source, varies widely, it is not possible to use directly the aluminum recovery from two operations to compare their performance. A better indication would be the aluminum recovery efficiency which is defined as the ratio of the aluminum recovered by the process to the total aluminum content of the dross. Unfortunately, the aluminum content of the dross is never known and it is generally impossible to take truly representative samples of large lots of dross that could be analyzed in a laboratory. One has to rely on indirect methods to measure the aluminum recovery efficiency (see Reference 4 for a presentation of three different methods) of a dross treatment process. For the plasma process this efficiency has been measured to be 90%, to our knowledge equivalent measurements have not been performed for an RSF operation.

To get around these difficulties, a large scale campaign involving more than 1500 tonnes of dross was organized to compare directly the aluminum recovery from Guillaume-Tremblay with two reputed RSF operations. The campaign lasted for 6 weeks during which truckloads of dross from a remelt plant were selected randomly to be processed by any of the three dross plants. This campaign showed that the plasma process could recover 3 to 5% more aluminum than a good RSF operation.

The aluminum recovery of the plasma process is improved because of a lower oxidation rate and a smaller quantity of metallic aluminum in the process by-products. The basic principle of the plasma process is to limit the amount of oxidizing gas in contact with the dross, about 2% of the aluminum is oxidized in the plasma furnace. In comparison, in an RSF, the oxidation can reach 5%, depending mainly on the control of the excess air and the infiltration in the furnace and the type of salt being used. In addition to oxidation, some metallic aluminum remains trapped with the dross by-products at the end of the process because it would not drain completely. In the case of the plasma process, the residual amount of aluminum in the by-product, the Noval material, varies from 10 to 15% [3]. The typical amount of metallic aluminum in the salt cake. the by-product of the RSF, is similar, being of the order of 8 to 15% [6]. Since the volume of salt cake is larger than the volume of Noval material, the mass of aluminum involved is larger. The net effect on the aluminum recovery is illustrated in the comparative mass balances for processing dross containing 70% aluminum with plasma or RSF (300 kg salt addition per tonne of dross) in Figure 3. In Figure 3, the oxidation rate is 2% for the plasma and 3% for the RSF and the metallic content of the residue is 10% in both cases.

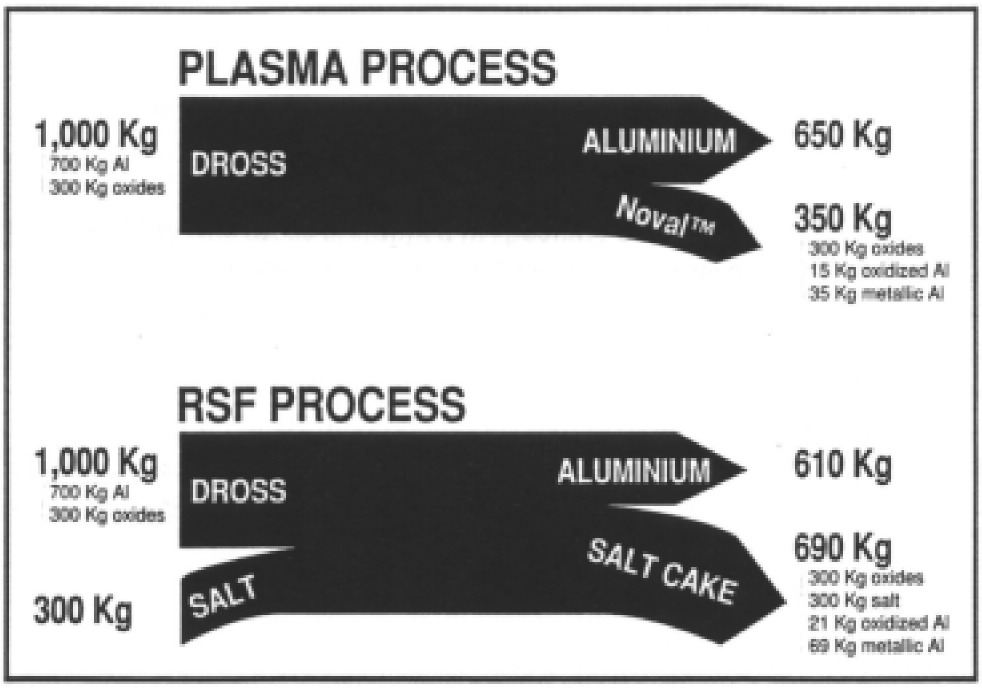

Figure 3 - Comparative mass balance of dross processing by the plasma and the RSF processes (neglecting the weight gain from oxidation).

Figure 3 shows that the metallic aluminum in the by-product (Noval material or salt cake) is the most important contributor to the aluminum loss. Early experiments have shown that more than 50% of this aluminum content can be recovered from the Noval material by simple concentration techniques such as screening. More sophisticated dry separation processes could also be applied (see for example Reference 5).

In addition to the aluminum recovery, the compatibility of the recycled ingot with the alloys produced in the casting plant where the dross originated, the conservation of the alloying elements and the metal cleanliness are important aspects of Guillaume-Tremblay metallurgical performance.

At Guillaume-Tremblay, the dross from one customer is never mixed with the dross from another customer to assure alloy compatibility. The container dross handling system (see next section) guarantees absolute dross segregation. Avoiding downgrading of the alloy is a significant cost factor adding a value of about five cents US per pound to the recycled ingots. The conservation of the alloying elements is another important cost consideration. Most alloying elements are more stable than aluminum and are not affected by the process. Magnesium, which is oxidized more than aluminum, is conserved at 75%. Finally, the metal cleanliness of the recycled ingots has been verified and found to be fully compatible even for critical products such as can body stock.

Containerized dross handling

Guillaume-Tremblay was designed to be a dust free plant. To attain this objective, a container based dross handling system is used.

In bulk handling, trucks dump the dross on the floor of the plant warehouse. From the warehouse, front end loaders pick up the dross to fill the furnaces. It is not practical to have ventilation to collect all the dust generated by bulk dross handling. Even if the ventilation system was powerful enough to control the dust while the trucks are tipping the dross onto the floor, the motion of the mobile equipment charging the furnaces would still create an almost impossible dust problem. This dust is a common hygiene problem in the plant and even an environmental issue as fugitive dust escapes outside.

At Guillaume-Tremblay, the dross is shipped in specially designed containers. The volume of the containers is 9 *3* which corresponds exactly to the usable volume of the furnaces. Figure 4 shows the containers with the transporter. At reception, the containers are weighed and stored in the warehouse using an overhead crane. The dross is charged into the furnace using a dedicated furnace charger shown in Figure 5. The content of the container is transferred to the charger using a tipping device under a tightly fitting dust collection hood (Figure 6) which captures all the dust generated during the operation with a small air flow to a dust collector. Dust is not released into the environment during these operations.

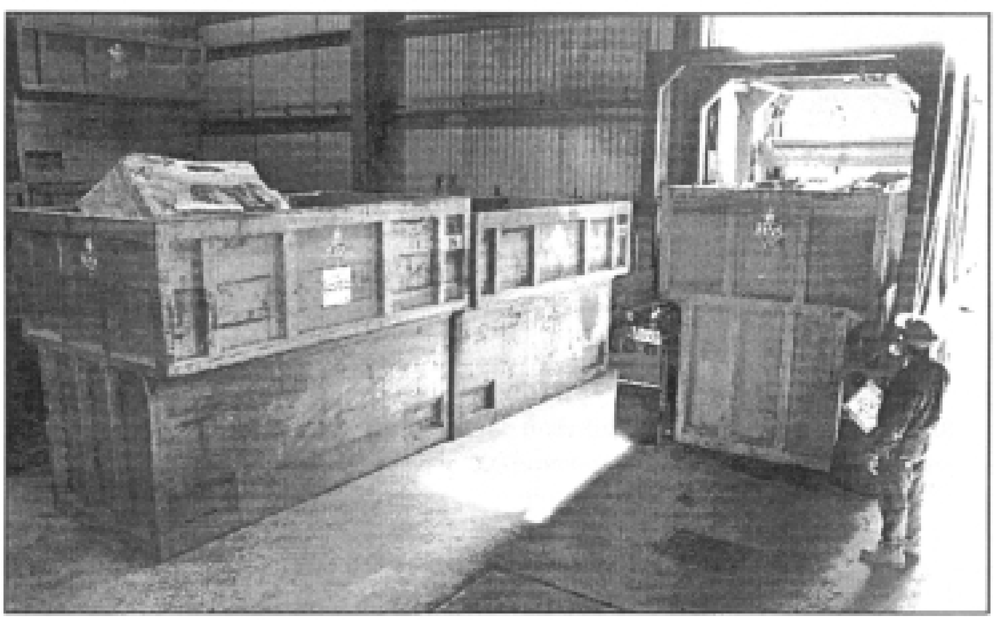

Figure 4 - Dross containers and transport truck.

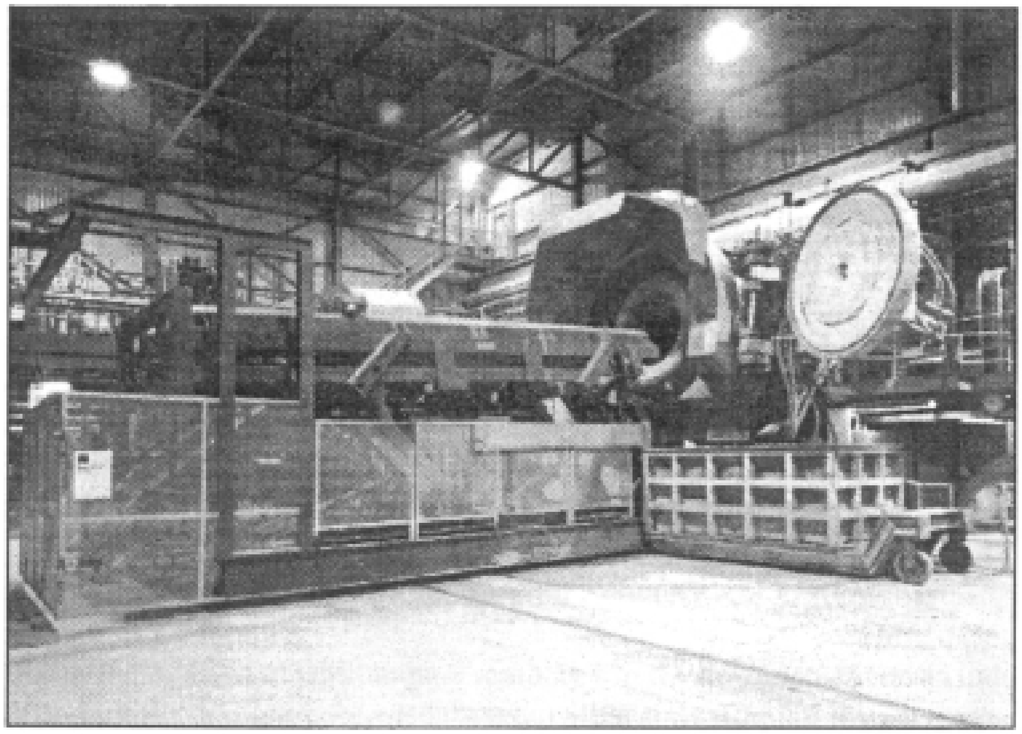

Figure 5 - Furnace charging machine.

Figure 6 - Container tipper and dust hood.

Container dross handling requires less storage space. Containers can be stored two or three high, maneuvering area is not required for the truck, the floor space can always be fully occupied even if dross segregation (by alloy type or by customer) is required. Moreover, containers covered with canvas can be stored outside in case of emergency. For example, in a particular case, a dross plant serving twelve different customers and/or alloy types, the bulk storage area required 450 m^2 compared with 110m for the equivalent container option.

From the operating point of view, the containers are very efficient. The charging operation is fast and is less dependent on the operators skill than the front end loaders. The weighing operation is perfectly accurate and does not slow down the charging as the containers are weighed a reception. Also, most problems associated with heavy and fast traffic of mobile equipment in the plant such as damage to structures, damage to furnace refractory, accident hazard and noise are eliminated.

The use of containers requires an overhead crane in the storage area. a container tipper and a furnace charger. These machines are specially adapted for their functions, they are very sturdy and require minimum maintenance compared with conventional mobile equipment. The capital cost of the container option is about equivalent to that for bulk handling. The cost of the special equipment being compensated by the reduced floor space requirement, the surplus ventilation and the front end loaders.

The operational cost is also lower, mainly because of the reduction of the maintenance cost of the mobile equipment and of the other repairs caused by the traffic in the plant.

Control and information management system

Because part of the mission of Guillaume-Tremblay was the development on an industrial scale of the plasma process, a complete control, data acquisition and information management system was installed when the plant was built. This original system was later expanded to integrate the operation and the management of the plant.

The control and information management system is organized on a multi-level hierarchy. At the first level, instruments and measurement devices collect the raw data such as the temperatures, the flows or the pressures. At the second level, the programmable logic controllers (PLC) control the operation of the equipment. At the next level, a computer collects the data and organizes it in usable form in databases and produces specialized reports on the process. Finally, at the last level, the computer produces management level reports for performance follow-up and accounting.

The computers and PLC's are all connected in a local area network forfree exchange of information between the levels. Each level can work independently so that maintenance on one level does not disturb the operations on the other levels. Man-machine interfaces allows easy access to the information without particular computer knowledge.

Commercially available software is used at all levels. The higher level computers are IBM compatible personal computers. For these reasons, the information system is relatively inexpensive and easy to set up and use.

Most of the data is recorded automatically, including all the weights; the only information input by the operators are the identification numbers of the dross containers, the ingots and the bags of Noval material.

The information system helps all the personnel in the plant in their effort to reduce costs and improved performance. The computer controls the process in real time; the operators can monitor all the critical parameters with a minimum of direct supervision and easily generate production reports. The automation promotes consistency from batch to batch and from team to team; each operator gets instantaneous feedback on the performance against the plant average. Since the data is shared from one level to another, a large portion of the clerical work is eliminated minimizing time and errors. A summary report and a bill is automatically generated at the end of each month for each customer. Management can follow the operation using customized performance indices and up to the minute inventory and cost status reports.

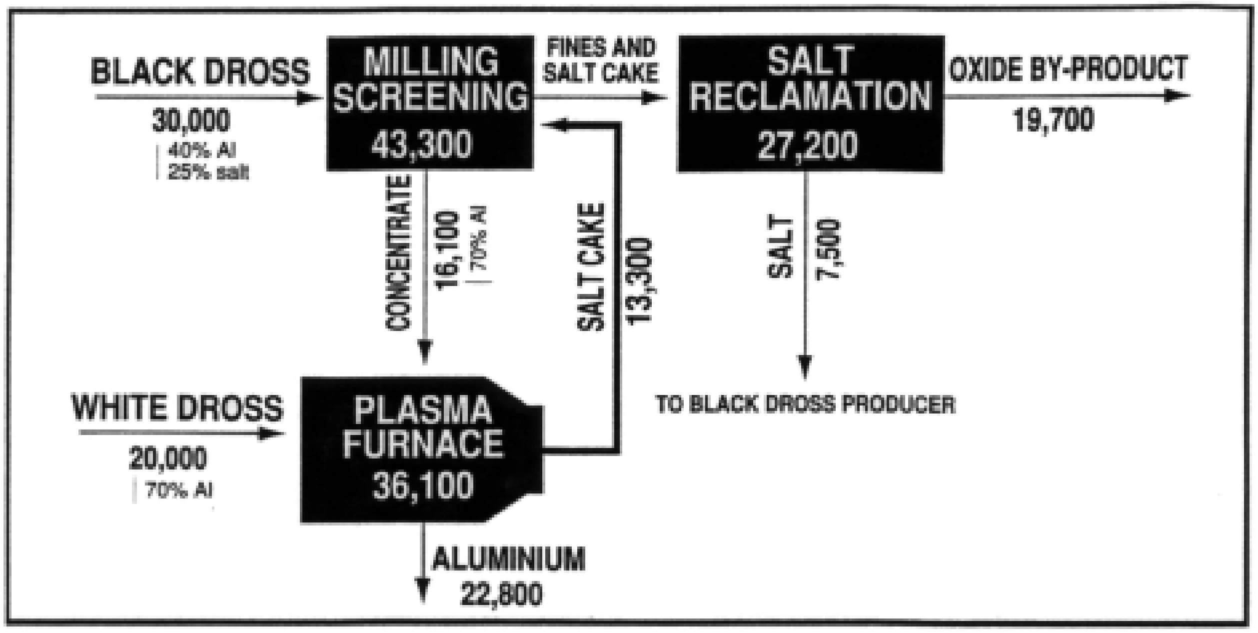

Figure 7.a

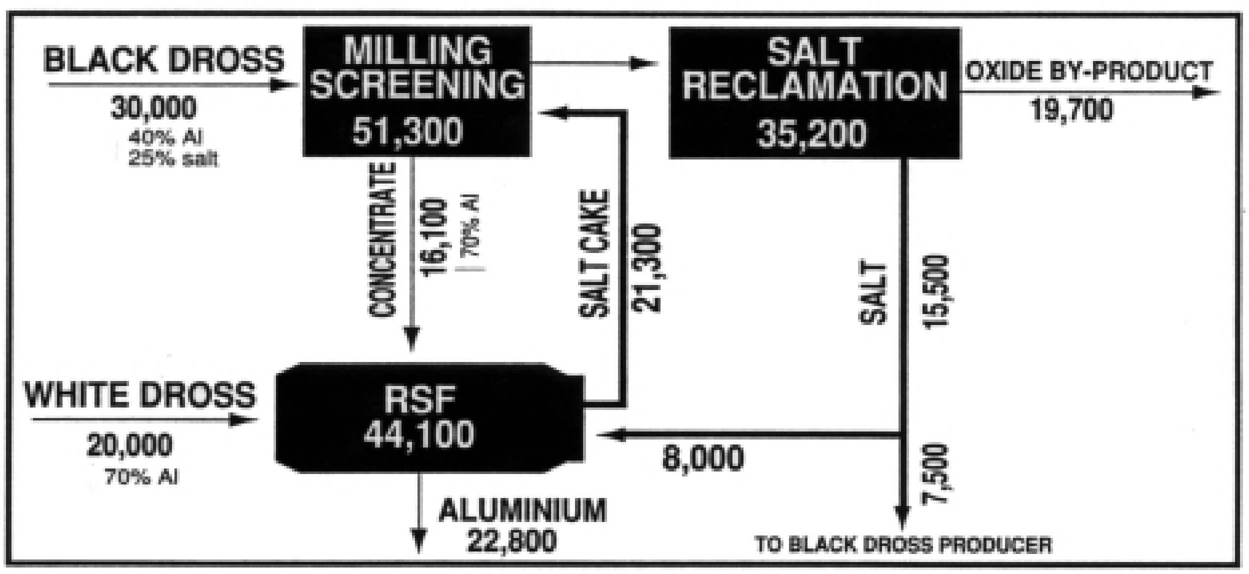

Figure 7.b

Figure 7- Comparative flow sheets of hypothetical dross plants using the RSF (7.a) and the plasma (7.b) processes for a mixture of white and black dross (quantities in metric tonnes per year, weight gain from oxidation neglected).

In Figure 7 black dross is first cold processed to concentrate the aluminium. The white dross is charged directly with the addition of 300 kg of salt in the RSF option. A salt reclamation plant recovers the salt from the furnace residues. As can be seen, the capacity of the salt reclamation plant (or alternatively, the amount of salt cake to be landfilled) is much smaller in the case of the plasma process. This capacity reduction would represent a significant capital and operating cost reduction.

Conclusion

The Alcan plasma dross treatment process has been demonstrated in full production plants for five years during which more than 150,000 tonnes of dross have been processed.

The operation of the plasma torch is safe, reliable and requires minimum maintenance and operator training. The energy cost, thanks to a better conversion efficiency, is equivalent to a fossil fuel burner used in RSF.

Alcan is a forerunner in the reclaiming of dross processing by-products as a raw material for value added products. A combination of value-added applications currently consumes all Guillaume-Tremblay's Noval material production.

Guillaume-Tremblay is an environmentally-friendly, modem and efficient dross processing plant. Its dust free containerized dross handling capability is unique and it features a fully integrated control and information management system. The plant operation is highly reliable and cost effective.

The plasma process has a clear advantage over the RSF process for white dross. It also has economical advantages when processing black dross in reducing significantly the total amount of salt cake production.

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