ROTARY FLUX INJECTION: CHLORINE-FREE TECHNIQUE FOR FURNACE PREPARATION

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Abstract

In order to reduce its chlorine use and consequently chlorinated emissions, Alcan developed, over the past years, a method to replace chlorine fluxing in furnaces. This chlorine-free technique, currently in permanent use in several Alcan installations, is called the Rotary Flux Injection (RFI) technique. The technique has proven to give equivalent or superior metallurgical performances when compared to the standard preparation technique of chlorine injection with lances, while offering significant reduction in gaseous and particulate emission levels. This paper will present the latest results obtained on alkali removal efficiency, metal cleanliness and dross generation on alloy series AA1XXX, AA3XXX, AA5XXX and AA6XXX, along with a description of the RFI equipment concept.

Introduction

Since the 1995 publication of a paper on the subject of furnace fluxing [1], many Alcan facilities have reduced their chlorine gas utilisation for the treatment of aluminum alloys. These efforts are part of a global Alcan objective for the reduction of atmospheric emissions.

In addition, long-time concerns on the handling and storage of large quantities of Cl_2, necessary when fluxing with lances in large furnaces, have convinced many Alcan facilities to reduce their chlorine gas utilisation. For some of them, this chlorine gas reduction has completely eliminated the use for furnace fluxing. An alternate process, based on the injection of solid fluxes, has started to replace chlorine gas with the advantage of reducing chlorinated compounds and particulate emissions.

Also, with today's demands for high quality aluminum products and the monetary premiums associated to their production, other Alcan facilities, which were not required to flux their previous selection of less critical alloys, started to use the injection of solid fluxes in their holding furnaces in order to cope with the new requirements of cleaner metal delivery to the casting pit.

Limitations of the lance injection technique, historically used for C12 injection and recently offered by vendors for solid flux injection (large size flux bubbles: small area of contact with the metal; short residence time of the flux in the melt; poor distribution of the bubbles [1], have brought Alcan to develop a new approach to improve the injection of salt. The approach is based on the use of a rotor system to inject the solid flux and is called the Rotary Flux Injection (RFI) technique.

Thus, this paper presents a description of the RFI technique (principle and industrial design) through which the advantages over the standard lance injection will be expressed. Metallurgical performance results obtained so far from the permanent use of the RFI in many Alcan facilities will also be disclosed; they will include alkali removal, metal cleanliness and environmental comparative results.

The Rotary Flux Injection Technique (RFI)

Principle of Operation

The RFI technique involves the injection below the metal surface of a fixed quantity of granular flux per furnace batch using a carrier gas. The flux and gas mixture is injected through a hollow rotating shaft at which end an impeller is installed.

The impeller used for the RFI has been selected to provide vigorous shearing and dispersion of the gas and flux mixture. However, to compensate for the lack of metal circulation of some impeller designs that imply the need to use multiple impellers [2, 3] in order to cover the large area of 65+ tonne capacity furnaces, the RFI impeller was designed to achieve ample metal circulation through the use of only one rotor. The amount of metal circulation is adjusted according to each furnace geometry. The equilibrium to be reached between vigorous shearing, dispersion and adjusted metal circulation is obtained by the selection of a rotor diameter, speed of rotation and orientation in the furnace. All the above parameters are related to the furnace design and capacity.

The granular flux is fabricated from the fusion of industrially pure $MgCl_2$ with other compounds. These compounds reduce the melting point of the fused mixture as well as provide positive effects on oxide film collection and separation. A reduction of the overall hygroscopic nature of pure $MgCl_2$ is also achieved from the fusion of the impurities with the $MgCl_2$ and renders the flux easier to handle and store.

The low melting point of the flux was selected in order to provide a liquid to liquid contact between the flux and the alloy facilitating the reactivity of the flux with the alkali in the melt. However, in order to obtain salt droplets small enough to increase the ratio of the surface of reaction over the salt droplet volume (thus the salt weight), a lot of shearing is required from the single impeller of the RFI.

The flux is conveyed by a carrier gas. Nitrogen is most commonly used due to its low cost and large availability. During the RFI flux treatment, the generation of aluminum nitride inclusions is not feared by the use of nitrogen, as the selected fused salt does not generate a "hot" dross; in the absence of a large amount of heat, aluminum nitride inclusions are less likely to form. The gas flow is adjusted to fit the feed rate of the salt to be injected. The objective is to maintain the carrier gas usage to its minimum in order to reduce the length of the gas plume i.e., maintain the flux within the impeller shearing zone for as long as possible. A minimum amount of carrier gas also limits the amount of turbulence at the metal surface during the treatment.

Metallurgical Performances

Metallurgical performances have been evaluated on four different types of alloys: AA1XXX, AA3XXX, AA5XXX and AA6XXX. Therefore, most major Alcan products such as sheet ingots (can body stock, foil and lithographic plates), fine wire and extrusion billets have been tested and closely monitored within the RFI involved plants.

Alkali Removal The control of alkali elements is necessary for many alloys. However, the elements to control change depending on the alloy and the source of metal (smelter: Na, Ca and Li; remelt: Ca, Na).

The results shown in Table I represent the rate coefficient (first order chemical reaction as defined by equation 1) for the mentioned alkali in the monitored alloy.

Table I: Comparison of Alkali Removal Rates for Various Alloys During furnace fluxing

Alloy	Alkali	Alkali Performance Results Removal Coefficient *k* (min^{-1})	
		Cl_2 with lances	RFI
1XXX	Na	0.091	0.081
3XXX	Ca	0.032	0.034
5XXX	N2	0.026	0.044
5XXX	Ca	0.022	0.024
6XXX	Na+Ca	No chlorine flux	0.053
6XXX	Na+Ca+Li	0.033	0.030

$$\frac{C_t}{C_0} = e^{-kt} \quad (1)$$

RFI results are either similar or better than those of optimized [1,4] C12 conventional lance fluxing systems.

Metal Cleanliness Due to the continuing increase in requirements for low inclusion levels in more and more alloys, the RFI system was never allowed, during its development and later its industrial implementation, to yield dirtier metal than the previously optimized [1,4] C12 lance fluxing system. Table II shows the RFI metal cleanliness improvement. In part, this is due to the stability of the process i.e., always injecting the same fixed amount of flux per batch, in the same manner, and with the same operation parameters.

For one case (6XXX), the requirement for metal cleanliness control was not needed on certain products but the market is slowly requiring some improvements and control.

Table II: Comparison of Metal Cleanliness Results From Holding Furnaces After a Nominal Settling Period (PoDFA Measurements)

Alloy	Metal Cleanliness Results (nun 2 /kg)	
	$C1_2$ with lances	RFI
1XXX	0.091	0.081
3XXX	0.034	0.027
5XXX	0.045	0.024
6XXX	No chlorine flux	0.06
6XXX	0.05	0.03

Environmental Performances

Environmental issues include the generation of dross that needs to be reclaimed or recycled, the fugitive emissions to the workplace and the stack emissions.

Dross The quantity of dross skimmed from furnaces fluxed by the RFI technique is lower than the conventional lance fluxing systems. This is partly due to the large reduction in the metal surface turbulence by the RFI technique, compared to the existing turbulent conditions of lance fluxing [4]. By the same effect, the amount of dross that adheres to the furnace walls also decreases and thus allows furnaces to be kept cleaner at all times. Alloys that require extremely low alkali levels have had the largest reduction in dross weight (-25% to -35%) due to the extent (duration and flux quantity) of the Cl2 lance fluxing practice.

The other part of the reduction comes from the fact that the salt injected by an RFI unit does not ignite the dross. The cycle (beat, ignition, thermites, oxidation, heat again, etc.), is not initiated and thus prevents important dust generation and additional loss of aluminum through oxidation.

Fugitive Emissions The use of the RFI technique also reduces fugitive emissions to the work area. On the other hand, the C12 lance fluxing system generates chlorinated and particulate emissions by two means. First, the frequent failure of graphite lances during treatment allows the escape of the unreacted C12/ N2 mixture from the furnace atmosphere to the workers' environment through the furnace door perimeter. Second, but not least, particulates are released from the thermitting dross whenever doors are opened to allow skimming.

Plants that operate the RFI unit have also noticed a reduction of corrosion related maintenance needs on electrical circuits, equipment (e.g., overhead crane) and building materials (structural, siding).

Finally, for potential fugitive emissions, the use of the RFI technique has allowed plants to remove their centralized bulk liquid storage container installation and move towards the installation of small local 68 kg cylinders to solely supply their inline degassing systems nearby. Therefore, the extent of a leak on small C12 containers becomes smaller (lower risk and severity) than in the case of one ton cylinder installations. Also, Occupational Safety and Health Administration (OSHA) rules change accordingly. Reduction in the risks involved with C12 handling and storage, along with a reduction in the managerial cost associated with the upcoming June 1999 EPA - OSHA Cl2 related rules ("Risk Management Plan"), are goals that US Alcan facilities have.

Stack Emissions In many of its facilities, the approach Alcan has chosen to reduce their emissions to the atmosphere is to limit, at the source, the amount of gaseous or particulate effluents [1], Table III shows values that indicate the reduction in emissions achieved by some facilities as they switched from the traditional C12 lance fluxing technique to the RFI system.

With a reduction of emissions in the 90% range for the 1XXX series, and a smaller, but still as significant reduction for the 3XXX series, the RFI technique has allowed many plants to seek early reduction permits for Cl2 use from governmental agencies.

Table III: Reduction of Stack Emissions Obtained by the Use of the Rotary Flux Injection Technique

Fluxing Practice	Environmental Results (Arbitrary Units*)					
	1XXX			**3XXX****		
	HCL	CL_2	Dust	HCl	Cl_2	Dust
CHLORINE Injection Using Lances	100	5.4	63.1	24.1	8.6	11.3
SALT **R**otary **F**lux **I**njection	8.9	0.2	4.4	18.1	0.2	1.3
Environmental Benefits (%)	**-91**	**-96**	**-93**	**-25**	**-98**	**-88**

* All values relative to HCl level for chlorine injection using lances = 100
** Values obtained in a different installation than other values in this table

Industrial Design and Operation of the RFI

Design In order to consistently achieve the metallurgical and environmental performances mentioned earlier. industrial versions were designed from the original RFI concept tested a few years ago [1].

The RFI concepts, presented hereby, have been developed through a long-term collaboration between Alcan Int. Ltd. and STAS Ltd. These designs are built from three major modules.

The first module comprises the impeller, the shaft and its associated bearings and motor that provide the desired rotation speed. The shaft is hollow to feed the flux; the lower portion of the shaft, exposed to heat and aluminum, is made from high temperature materials (graphite or ceramics) while the remainder upper pan is manufactured from corrosion resistant alloys. Various sources of power can be used for shaft rotation: electricity (most common and preferred for efficiency and ease of control), hydraulic or pneumatic. To protect the major components of this module against prolonged exposure to the radiant heat of the furnace, an enclosure is built around them. In some extreme cases, an air cooling system can be added to maintain the interior of the enclosure within the operational limits of the components.

The second module involves the position and orientation of the shaft in the furnace. Linear actuators, usually powered from the same source as for the first module, yield precise and repetitive movements. This module requires most of the engineering works needed for an RFI installation. Position and orientation of the shaft in a furnace is critical and must be decided upon reviewing the furnace capacity and geometry. Both the depth and the angle of immersion in the melt are parameters that are reviewed.

The last module is the flux feeder. Although built from a commercially available technology, specifications for capacity, feed rate and construction materials are all given by Alcan. The gas panel that supplies the carrier gas to the flux feeder is, however, entirely built from Alcan specifications; it is capable of automatically adjusting the flow and pressure of the gas to suit the salt injection parameters. The flux feeder hopper is mounted in the back of the shaft assembly as, whenever the RFI unit is tilted to position in the furnace, the gravity helps feed the flux while requiring a minimal amount of gas. Also, the flux grain size is specified by Alcan to fit the feeder design and minimize the amount of carrier gas. Again, a reduction in carrier gas improves alkali and inclusion removal efficiency while reducing metal surface turbulence (responsible for dross generation).

Basically drawn from the original RFI prototypes, but improved for safety and ease of use, a fork-lift truck mobile conceptual design is illustrated in Figure 1. Very simple in design, this concept is mostly proposed to plants that operate multiple furnaces but have very limited space around the furnaces. One mobile unit can then be used for many furnaces. Also, because it is very simple, the cost of this concept, along with its implementation and training, remains low. However, the mobility of this system has shown to yield some operational hurdles.

First, because of its mobility, thus the intent to keep the unit as small as possible, such an RFI requires that a regular furnace door be kept open to allow for the shaft and rotor immersion in the melt. Heat loss then occurs during the treatment and fugitive emissions, although very limited in quantity, are allowed to escape in the work place. Secondly, the mobility has had its toll on accidental shaft breakage as well as increased maintenance requirements on electrical, pneumatic or hydraulic hook-ups. Finally, in order to prevent accidental burns, moving an RFI unit that has just come out of the furnace requires a "secured" perimeter along the path taken by the truck to the RFI idling site between casts.

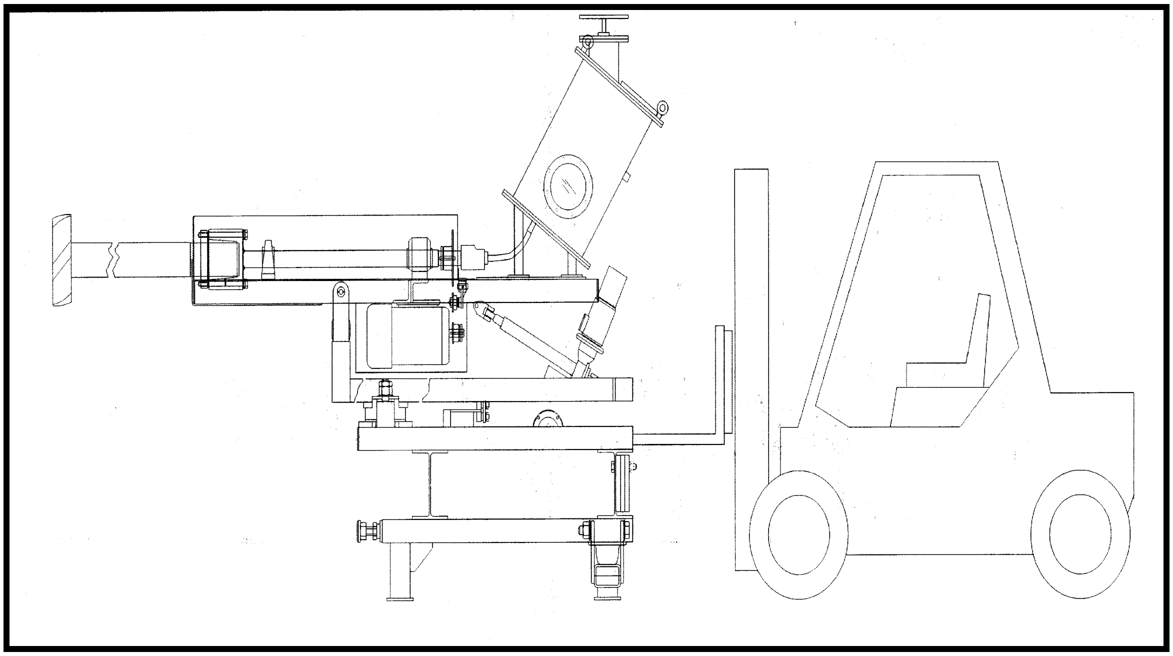

Figure 1: Schematic Illustration of a Fork-lift Truck Mobile Rotary Flux Injection Unit

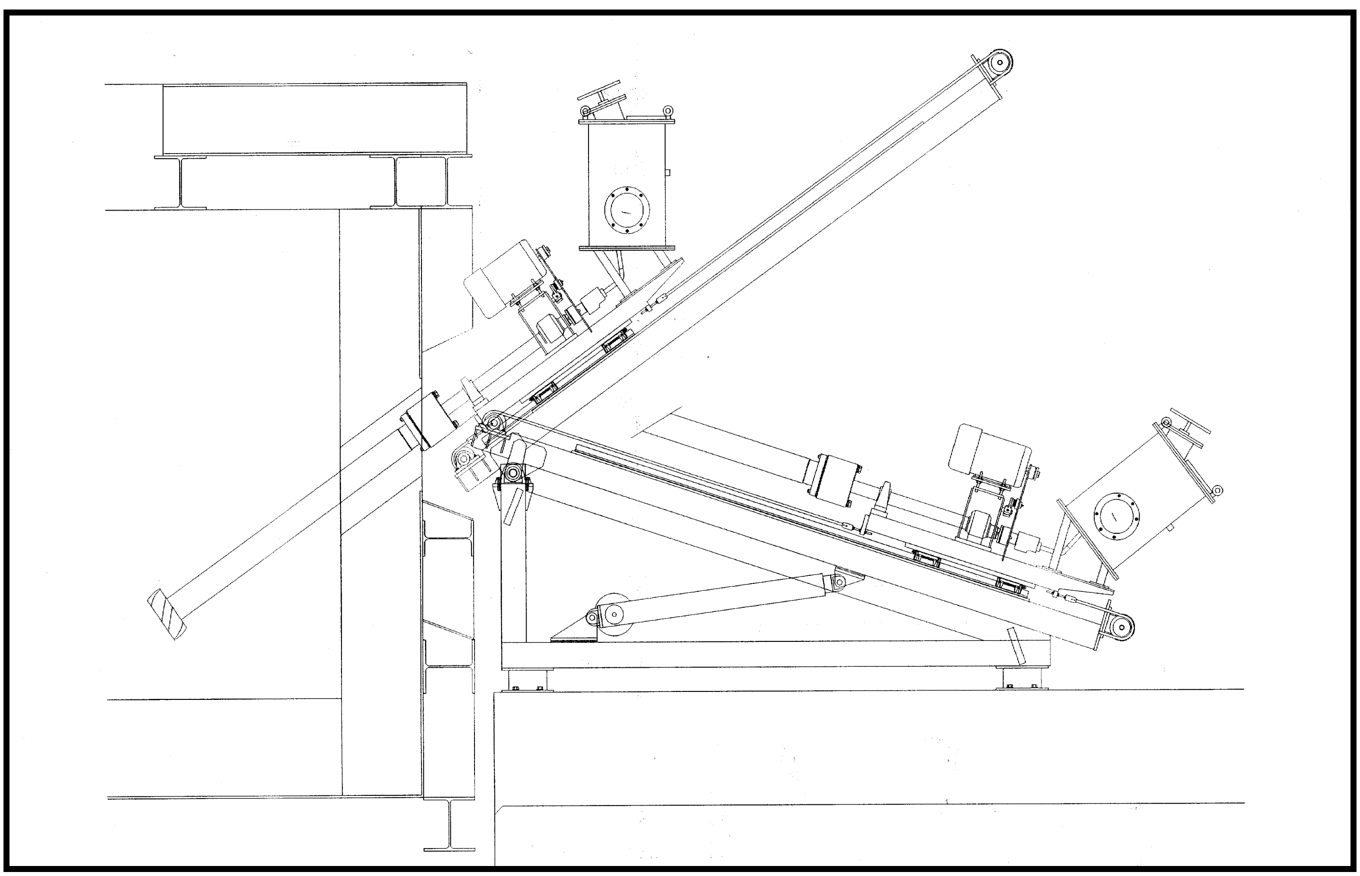

Figure 2: Schematic Illustration of a Fixed Industrial Rotary Flux Injection Unit

In order to solve the hurdles of the mobile RFI unit design as well as case the establishment of a safe operation zone around the equipment at all times, a fixed unit concept has been drafted (Figure 2). In this case, the rotor assembly is inserted into the furnace using a dedicated pocket door built onto the side of the furnace, including the side where normal doors are installed. Being a smaller opening, the pocket door minimizes heat loss during treatment.

Conclusion

The use of chlorine gas fluxing is rapidly becoming, or has already become, the focus of stricter environmental rules by government agencies around the world From its early involvement in research programs in order to reduce and eliminate chlorine usage in its furnaces, Alcan has now started to industrially implement the concept of the Rotary Flux Injection Technique to replace chlorine for furnace fluxing. Its present implementation in six plants has been well accepted and appreciated by workers.

RFI benefits listed by plants include:

- metallurgical efficiency at least similar to Cl_2
- elimination of bulk liquid Cl_2
- reduction in fugitive and atmospheric emission
- reduction in dross generation
- simple implementation of process and equipment
- increase of furnace productivity

Alcan has proven that a viable alternative to Cl_2 lance fluxing exists in the form of the RFI technology. Alcan continues to investigate means to further reduce the environmental impact of its operation by pursuing more reduction in Cl_2 usage and supporting replacement programs.

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