Granular fluxes for aluminum alloys, environmental and technological advances

Abstract

In aluminum foundries the minimization of metal loss is a paramount need. The use of flux for this purpose is on to reduce emissions into the environment and especially those emissions which are toxic.

Foundries produce a variety of castings using a variety of furnace technologies and therefore a multitude of flux types exist.

This paper describes a new range of fluxes which have a substantially different morphology which allows the flux to work at different addition rates without loss of efficiency. It then quantifies the amount of emission of this new flux in comparison to existing powder fluxes. The environment benefits to the foundry and operatives becomes clearly evident.

Introduction

In the last 60 years, to a greater or lesser extent, fluxing practice of aluminum and its alloys has been adopted for the commercial production of aluminum castings.

In the last 30 years, the use of flux has continued to increase. However, the basic formulations and compositions of the fluxes readily available on the market has not changed dramatically over this period of time.

The purpose of fluxing has been two fold:

- To remove entrained metal from the aluminum oxide.
- To remove associated inclusions within the body of the melt.

In recent years other techniques have become widely available in order to remove entrained inclusions within aluminum melts, in a highly efficient manner. However, the need to reduce the amount of pure aluminum or aluminum alloy within the dross has also increased due to the high price of aluminum alloys on the world market.

Early fluxes practices revolved around bubbling pure chlorine through aluminum melts, which achieved the effect of removal of dissolved hydrogen inclusion and left a very dry dross that was low in aluminum content. This process was not particularly pleasant; the use of pure chlorine being particularly hazardous and the amount of entrained aluminum in the dross was still relatively high. The advent of powdered halide mixtures, combined with the chlorine injection process began to improve matters, leaving exceptionally low aluminum contents in the dross, and being of a very fine, powdery nature, allowed for easy removal.

Slowly, the types of alloys being cast commercially changed. The types of furnaces in which aluminum alloys were melted, or held, changed significantly and the requirements of the fluxes became much more specific.

In addition to fluxes being required to reduce the aluminum content in the dross, which today are commonly referred to as 'drossing fluxes', the need for prevention of further hydrogen pick-up from the atmosphere became a requirement, and with different alloy compositions, the temperature at which the alloy would be liquid began to vary dramatically for components such as pistons through to thick-section electrical motor housings and the like. Further, there was a need to prevent the loss of magnesium in particular alloys and in other alloys that were treated with either sodium or strontium for modification purposes, the need for non-poisoning effects was ascertained as well.

It was from this background that, today, we arrive at the variety of fluxes freely available, being:

- Exothermic drossing fluxes.
- High temperature fluxes
- Low temperature fluxes.
- Liquid fluxes for prevention of hydrogen pick-up.
- Refining fluxes.
- Modifying fluxes.
- Fluxes purely for dross treatment.
- Fluxes for furnace wall cleaning.
- Sodium-free fluxes.
- Fully-fused fluxes.

All of these fluxes would be suitable for either bale-out furnace, reverberatory furnaces, gas-fired or electric or oil furnaces.

Then, during the late 1970s and 1980s, the issue of refractory life in contact with flux began to be questioned and to where the best commercial position could be reached for optimum casting production. Many people felt that the reduction in furnace lining life was debatable and not measurable, other people – and principally the larger primary and secondary aluminum industry began to look at re-lining costs, and with increased labor cost, believed that separate treatment of drosses would be more beneficial.

Therefore, the picture of when and where to use fluxes began to change, and this was further enhanced during the 1980s as the environmental aspects were being considered to a much greater degree than previously.

However, with the high demand for productivity during the 1980s and the increasing cost of aluminum, the use of flux still grew and the balance was maintained in its favor; but with concerns on the environmental issues, quite rightly. Addition rates of flux were reduced by greater control, indeed, marginally below traditionally recommended levels.

Foseco, who has been a world-wide manufacturer and supplier of fluxes to the aluminum foundry industry for in excess of 60 years, began to study this issue of environmentally acceptable fluxing practice that would still offer technology and cost-reductions, or cost-efficiency, to the foundries, but would help position the foundry in a more environmentally-friendly light. This work commenced during the 1990s and was centered not so much around the formulation, but the nature of the emission that was coming from the fluxes.

Granular flux compared to conventional powder flux.

Work started to commence, looking at possible new formulations and variations of traditional mixes, and what was generally found was that fluorides which were a major concern environmentally, if completely removed from the formulation, rendered the flux powerless and very inefficient in use. However, there were people who, believing so strongly in the fluxing practice, would use fluoride-free fluxes, but in real terms, the benefit achieved was that of an on-cost, rather than a cost-efficiency in the casting process.

It was noted particularly that not all the flux put onto the surface of the melt would be utilised. Depending upon the practice and the type of furnace, some flux simply disappeared up the chimney.

Whilst in other practices the layer of flux on the melt, or the rabbling techniques employed, rendered the process inefficient. Therefore, the morphology of the flux began to take on increasing significance.

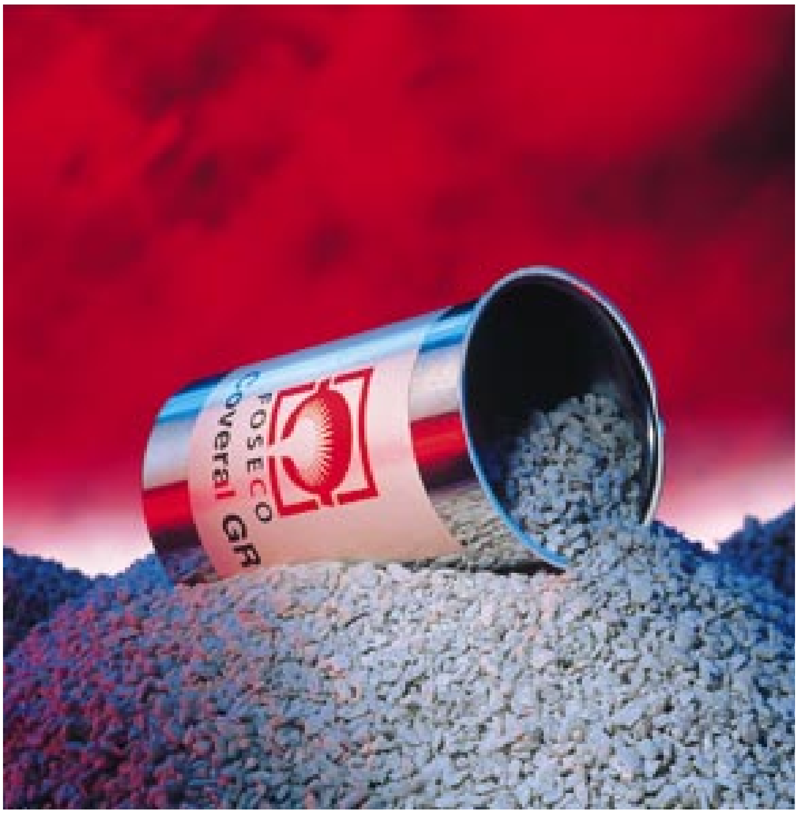
Previously, in the use of fully-fused fluxes the morphology of the flux was not powder, but was particles. They were chips or fragments from plates of flux which had not been segregated or refined, but certainly had a totally different shape, and tended to emit less dust on application.

Another feature during this time in the industry was the drive towards lower and lower moisture content within fluxes and this too was taken on board as part of the overall design criteria.

It was felt that a granular material, or flux of a granular form may begin to meet some of these requirements and help the environmental emissions and what this paper will begin to address is the specific emission from two fluxes which are powder and granular in form. These fluxes have the same composition and show the type of emission with different furnace type, and also the amount of emission. In this analysis two fluxes are assessed:

- Flux A which is normal exothermic drossing.
- Flux B which is a sodium-free drossing flux.

Materials have been tested on a conventional bale-out furnace on contact with A356 type alloy and then also examined in a reverberatory-style environment with flame impingement on the furnace, again using alloy A356 and for both types of furnace, the assessment has been in an extracted, i.e. with the hood totally covering the furnace, and an unextracted form, so that the type and nature of the emission can be gauged.



One of the difficult aspects of this work was to try and look at the rate of emission, over time, and this is one of the ongoing aspects which will be discussed towards the end of this paper.

The results are summarised in Tables 1, 2, 3 and 4, showing the different types of emission in mg/m^3 for the different furnace types and then an overall summary in Table 5.

Experimental technique

The main requirement for achieving direct comparison between each flux trial was the standardisation of sampling procedures and techniques.

The programme considered two discreet environmental conditions being:

- Captured emissions, which could then be assessed relative to external emissions to atmosphere (in the UK this is called the 'environmental protection act').
- Unextracted emissions, which would provide an indication of personal exposure to a furnaceman involved in the act of a fluxing process (this is equivalent to the control of substances hazardous to health regulations – COSH).

The experimental practice was to use two common aluminum melting practices, gas fired, bale-out furnace and reverberatory furnace.

For the first of these, a 550 lbs standard gas-fired crucible bale-out furnace, containing 500 lbs of A356 type alloy, was used. The second furnace was modified by the addition of the ladle heating burner, angled to play across the molten metal surface to simulate reverberatory conditions.

In the extracted situation, the hood was fabricated to capture all emissions from the furnace. In the unextracted conditions, the hood and duct were removed and sampling equipment was mounted on a scaffold, such that the sampling nozzle which is a height of 5 ft 8 inches, namely 2 ft above the furnace top.

It should be noted that these tests can be considered worse case environments because furnacemen do not normally stand with their head over the top of the furnace for a 20 minute period. Metal temperature was 1364°F and addition rates were 0.25% for powdered fluxes, by metal weight, and 0.125% for the granulated fluxes.

The sampling procedure was as follows:
Sampling apparatus was turned on, after one minute flux was sprinkled onto the surface (pre-weighed amount), after five minutes the furnace operator commenced drossing and sampling then continued until a total of 20 minutes from start was reached for the extracted situations, and 15 minutes for the unextracted situation.

Carbon dioxide measurements were made and it found that the $C0_2$ resulting from the addition was negligible, compared with that produced by the gas burners. Temperature drop was not significant during the sampling period and the emission of CO_2 was found to be virtually complete after 10 minutes had elapsed.

Discussion

Of all the emissions tested for, those which have the most serious health implication are fluoride and sulphur oxide. In both cases the granular flux has demonstrated significantly lower emissions than that achieved with the powder material, although it is still prudent to show that the emissions from the powder material are not at an abnormally high level.

It is in looking at this overall summary, that the picture really begins to crystallise in terms of what the effect of granulation is adding to the flux performance. First and foremost, we can see the total particulate is substantially reduced from 19 mg/m^3 to less than 0.46 mg/m^3. Total chlorine, emitted as hydrogen chloride (gas) reduces by more than half in most instances and total chlorine which is very low in the powder form stays roughly constant. Now these are significant changes, but the reduction become more significant when the fluoride is analysed. In reducing from an extreme of 19 mg/m^3 to less than 4 mg/m^3.

In performing this analysis, there are other factors which need to be highlighted.

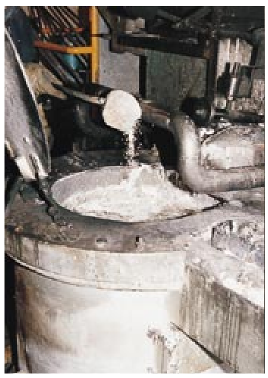
First and foremost, the addition rate of a conventional flux is utilised at about 0.25% addition by weight, and the granular material is utilised by an addition rate of 0.125% by weight. Therefore, immediately, we have 50% less material being added so the logic flows that there will consequently be less emission. This is certainly true, but what is apparent from these results is that it is not a 50% reduction in fume that has been achieved, it varies substantially from a small adjustment, or reduction, depending on furnace type, to in excess of 85% reduction, and is perhaps where our knowledge is now beginning to expand, in that the provision of a granulated material is actually allowing the flux to work in a fundamentally different way. The overall comparison shows very little change in total chlorine emission again supporting the view that the flux is reacting differently.

As was stated earlier, previous beliefs have been that in adding flux, a proportion was emitted out of the stack, without ever coming into contact with the aluminum. This then leads one to consider whether, or not, the formulation, or recipe of the flux constituents that is actually hitting the surface of the melt is, indeed, in the same proportion as the original blend. If the flux covering layer is now the more consistent thickness, the reaction time of the flux may be more consistent, this too leading to a better utilisation of materials that are available. In some instances, although the total particle emitted was significantly reduced, the total chlorine element was not substantially reduced, thereby adding to the argument that the flux is fundamentally performing in a different way.

ALL FURNACES

Product Name	Description of flux function
COVERAL GR2510	Mild exothermic drossing
COVERAL GR2560	Hot exothermic drossing
COVERAL GR6510	Sodium free drossing
COVERAL GR2515	Low temp. drossing
COVERAL GR2612	High temp. drossing
COVERAL GR 2410	Cleaning
COVERAL GR2220	Low temp. cleaning
COVERAL GR2712	High temp. modifying
COVERAL GR2715	Low temp. modifying
COVERAL GR2815	Grain refining

Going back to the summary table, the most important issue, without doubt, is the fact that overall fluoride is reduced substantially more than half. This again supports the argument that even with an addition rate of 50% of the powder flux, the granular material is still working in a different way so as to provide less fluoride emission to the environment yet maintaining efficiency.



Foseco has launched a completely new range of fluxes in granular form, to accommodate the range of furnace type and applications such as refining drossing that we discussed earlier, and in so doing, is able to offer a far more limited, but structured range of fluxes to the aluminum foundry industry,

Table 1

Emission concentrations – extracted gas fired bale-out furnace
Concentrations are mg/m^3

	Flux A		Flux B	
	Powder	Granular	Powder	Granular
Total particulate	0.85	0.6	1.1	0.6
Gaseous Cl	0.98	0.49	0.98	0.46
Total Cl	0.99	0.47	0.99	0.6
F	11.7	2.4	6.5	2.6
NOx	–	–	–	–
SOx	12.6	1.76	7.4	0.77

Table 2

Emission concentrations – extracted reverbatory furnace
Concentrations are mg/m^3

	Flux A		Flux B	
Powder	Granular	Powder	Granular	
Total particulate	2.9	0.7	2.6	0.7
Gaseous Cl	0.93	0.36	1.24	0.26
Total Cl	0.82	0.72	0.98	0.32
F	13.7	3.53	10.2	3.74
NOx	–	–	–	–
SOx	4.69	0.2	3.23	0.57

Table 3

Emission concentrations – unextracted reverbatory furnace
Concentrations are mg/m^3

	Flux A		Flux B	
	Powder	Granular	Powder	Granular
Total particulate	3	0.53	2.53	0.4
Gaseous Cl	1.03	0.62	1.44	0.69
Total Cl	1.04	0.82	1.45	0.71
F	19	3.65	14.7	5.05
NOx	–	–	–	–
SOx	15.43	1.18	5.13	2.98

Table 4

Emission concentrations – unextracted gas fired bale-out furnace
Concentrations are mg/m^3

	Flux A		Flux B	
	Powder	Granular	Powder	Granular
Total particulate	0.33	0.07	1.27	0.07
Gaseous Cl	0.34	0.34	0.34	0.34
Total Cl	0.35	0.35	0.35	0.35
F	4.14	2.95	4	3.29
NOx	–	–	–	–
SOx	7.52	5.38	6.72	5.28

Table 5

Overall comparison of emissions for all furnace types in all conditions
Concentrations are mg/m^3

	Flux A		Flux B	
	Powder	Granular	Powder	Granular
Total particulate	1.5	0.46	1.34	0.52
Total Cl	0.73	0.72	0.83	0.82
F	11	3.4	7.5	3.6
NOx	–	–	–	–
SOx	8.5	1.6	4.9	2.5

in a granular form, where addition rates are typically 50% or below that of a conventional powder flux. This paper presents some of the arguments behind the environmental issues with fluxes, for the benefit of the foundry industry, and obviously the data contained herein has been generated under certain conditions, as close to foundry industrial practice as possible, but differences will always exist, needless to say. The important point is the trend in the overall reduction, and the commitment that Foseco is placing on this area of metal treatment for aluminum foundries.

The overall indications from the work are that the amount of emission is significantly reduced using the granular fluxes, to a level that should not give any problems, in terms of exposure on either line extracted level to operators over normal fluxing period and further, it can be concluded that the time for exposure with the granular material, because of this lower emission rate, can be increased compared to that of powdered material.

What is perhaps most intriguing in this work is that the most significant differences are from powdered granular fluxes rather than from individual formulation from one powder flux to another powder flux. This really supports the theory postulated earlier that the morphology of the flux is a very significant contributor to the type of pollutants that may emanate.

Conclusion

It is impossible to determine accurately the emission that will be observed in one foundry, compared to another foundry, without doing the physical testing. What this work shows, and the importance of this work, is that the move from a powder flux to a granular flux will significantly improve the working environment by the reduction of toxic pollutants to the atmosphere to well below those that are deemed to be safe working limits, currently.

The complete new range of COVERAL GR fluxes being launched by Foseco all fall under this banner, and the adoption of this type of technology will allow the foundries for the foreseeable future to focus their efforts and energy on other important aspects, to increase the profitability of aluminum casting production, knowing that they are meeting today and tomorrow's requirements for a safe working environment for operatives.

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