
The Use of Nitrogen to Degas Molten Aluminium—Comparison of Metallurgical Results with Argon and Nitrogen Used in an ACDtm

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Abstract

The use of argon to degas molten aluminium is a widespread practice in aluminium casthouses, and the removal of the hydrogen contained in the metal by using this noble gas is a proven method with no downside effect on the metallurgical quality of the resulting metal. On the other hand, an increasing number of producers are looking for cost reduction opportunities, and nitrogen often comes as an alternative to replace argon to degas molten aluminium. However, some are questioning the degassing efficiency of this gas or the risk to deteriorate metal cleanliness. STAS Inc. has carried out a series of comparative tests, using argon and nitrogen in an ACD. Metallurgical measures for degassing and metal cleanliness have been taken to compare both gases. This paper presents the results obtained during this test campaign carried out in North America.

Keywords

Degassing • Argon • Nitrogen • Inclusions • ACD • Metal treatment

Introduction

The main function of a degasser is to remove the dissolved hydrogen content in molten aluminium, while secondary functions are to remove alkali and alkaline earth metals as well as to improve metal cleanliness. Degassing occurs when an inert gas is injected into molten aluminium through one to several hollow shafts spinning at high speed (Fig. 1). The principle according to which gas is sheared into small bubbles into which hydrogen migrates and then rises to the surface has already been very well explained [1, 2]. When a

reactive agent like chlorine gas (Cl_2) or magnesium chlorine fluxes are injected with the inert gas, a reaction occurs with sodium and calcium, resulting in the flotation of the generated salt (NaCl , CaCl_2). Also, injecting Cl_2 or a flux changes the interfacial properties of the metal, which helps inclusions such as oxides, spinels and carbides to be removed by flotation [3, 4].

In theory, inert gases like argon (Ar) and nitrogen (N_2) should provide the same degassing performances when a high purity gas is used. But in practice, most degassers are operated with argon, even though this gas is more expensive, for it is believed that N_2 can deteriorate the metal cleanliness. Of the 245+ inline degassers sold by STAS to this day, more than 95% are operated with argon.

Upstream of the degasser, argon and nitrogen are often used in furnace treatment through Rotary Flux/Gas Injectors (RF/GI) (Fig. 2). But of the 155 RF/GI units sold by STAS to this day, approximately 80% are operated with N_2 , the remainder with argon. In an RF/GI, experience with customers have shown that the operation gas is chosen for economical rather than metallurgical reasons. However, it has also been argued that N_2 could affect the metal cleanliness

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Fig. 1 Degassing principle in an ACD

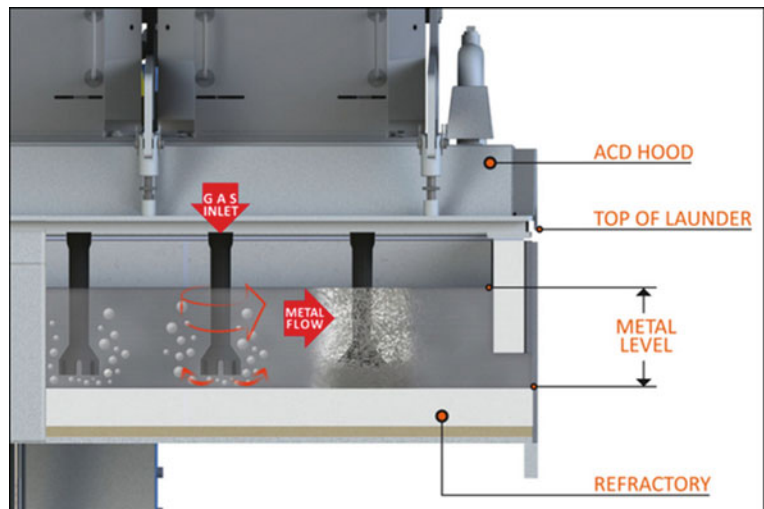
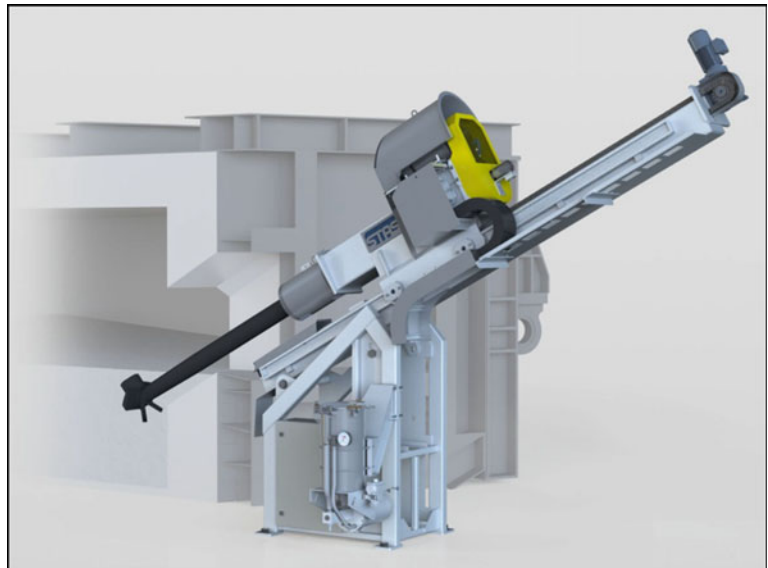


Fig. 2 Rotary flux injectors (RFI)

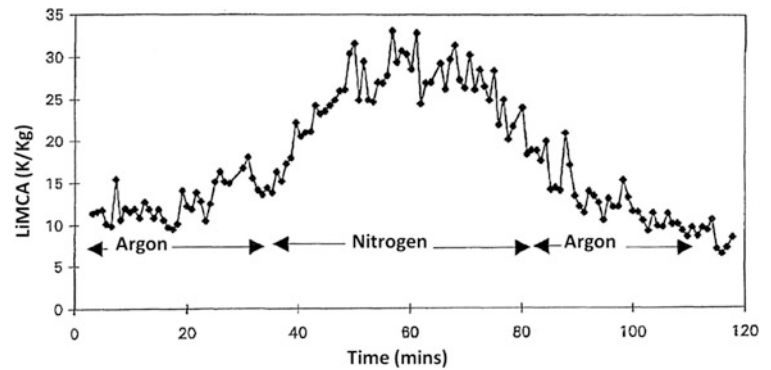


[5, 6] and produce wetter dross when used without a reactive agent like Cl_2 or a flux. But as Cl_2 or a flux is always used with nitrogen in a furnace, no significant difference in metal cleanliness has been demonstrated [7]. The presence of Cl_2 or flux prevents the generation of hot and wet dross which could boost the production of aluminium nitrides (AlN). N_2 can react with aluminium to produce AlN, but this reaction needs some time and a high temperature [5]. And when AlN is generated, this compound takes the form of solid inclusions that can have a deleterious effect on the casting. However, treatment in a furnace always involves some settling time to allow inclusions to float on the surface of the metal or to settle

to the bottom of the furnace, which prevents most of them from moving downstream.

In a degasser, the picture is somewhat different since the metal residence time is much less and Cl_2 or a flux are not always used with the gas. Doutré et al. compared Ar and N_2 with the same amount of Cl_2 and reported a decline in metal cleanliness [8]. Moreover, previous works from STAS' customers to compare Ar and N_2 in a box type degasser have shown the same efficiency in terms of hydrogen removal, but with a detrimental effect on the amount of inclusions (Fig. 3) —unfortunately, no details were available on the method, especially with respect to gas quality. The same works

Fig. 3 LiMCA comparison between efficiency of Ar and N₂ in a box degasser in terms of amount of inclusions



showed that N₂ also seemed to produce a wetter dross, though this was not measured. Additionally, an analysis of metal cleanliness did not show any AlN but rather oxides with grain refiner.

In consideration of all the information stated above, STAS has decided to carry out some tests in an Aluminium Compact Degasser (ACD) to clarify the results on the use of N₂ when no chlorine gas or flux is used. The main objective of the tests was to compare Ar and N₂ with regard to their degassing and inclusion removal efficiencies (including the formation of AlN).

Scope of Experiment

In early 2015, experiments were conducted in a sealed 6-rotor ACD commissioned in 2010. Since the degassing efficiency was achieved beyond expectations, only 5 of the 6 rotors were operated. The average metal flow was 460 kg/min, and 50 L/min of gas per rotor was injected (Ar or N₂). The alloy cast was from the 3xxx series with low Mg concentration. The degassing efficiency was measured on 3 casts with Ar and 3 casts with N₂, while the metal cleanliness was measured on 4 casts with Ar and 4 casts with N₂.

Method

AISCAN was the method used to measure the hydrogen concentration. Only one AISCAN unit was available, and it was moved before and after the ACD. A PoDFA unit was used to measure the metal cleanliness. Each time, one sample was taken before and after the ACD, with another one taken after the filter. Since no Cl₂ or flux was used, the alkali and alkaline earth metal removal was not measured.

Particular attention was paid to gas purity, for the presence of as low as 1% of humidity could be very detrimental

to the degassing efficiency. A certificate of analysis showed a purity over 99.999% for both nitrogen and argon.

Results and Discussion

Degassing

Figure 4 shows the AISCAN results for the tests. The degassing efficiency is the same for argon and nitrogen, as expected. Overall, the efficiency rate is really good, averaging 77%. One test was carried out with only 4 rotors in operation but still showed very good efficiency.

Metal Cleanliness

Figure 5 shows a graph of the PoDFA value for the total concentration of inclusions without grain refiner. Grain refiner is not counted as an inclusion, since it is added on purpose. Besides, samples before the ACD were taken before the addition of grain refiner.

Carbides constitute most of the inclusions, averaging 86% of total inclusions before the degasser (the remainder comprising oxides and spinels). According to the PoDFA analysis, no AlN was detected in any of the samples after the degasser, even when N₂ was injected. But with further Scanning Electron Microscope (SEM) and spectrometer (EDS) analysis, some nitrogen structures combined with spinels were identified. These were very thin structures which could not be quantified. But overall, the amount of spinels was very low in all the samples analysed. And the spinels were mostly removed by the ACD (see Fig. 6), while the rest was removed by the filter.

On average, the inclusion removal efficiency with an ACD is 85% when Ar is injected and 60% when N₂ is injected. During the tests, both gases removed magnesium

Fig. 4 Comparison of AISCAN results for argon and nitrogen degassing efficiency

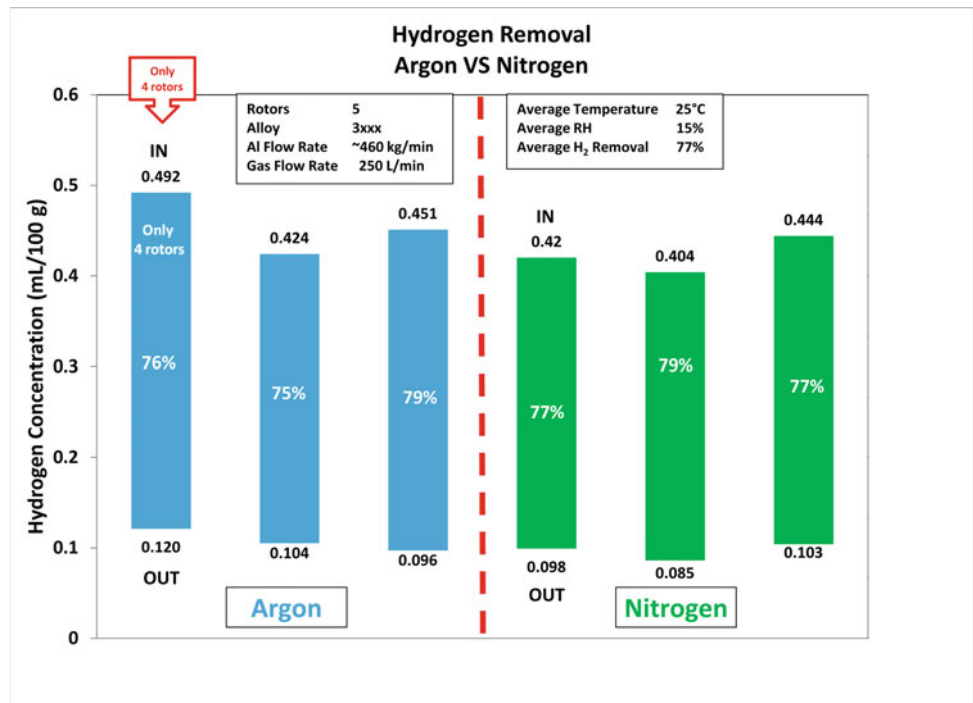
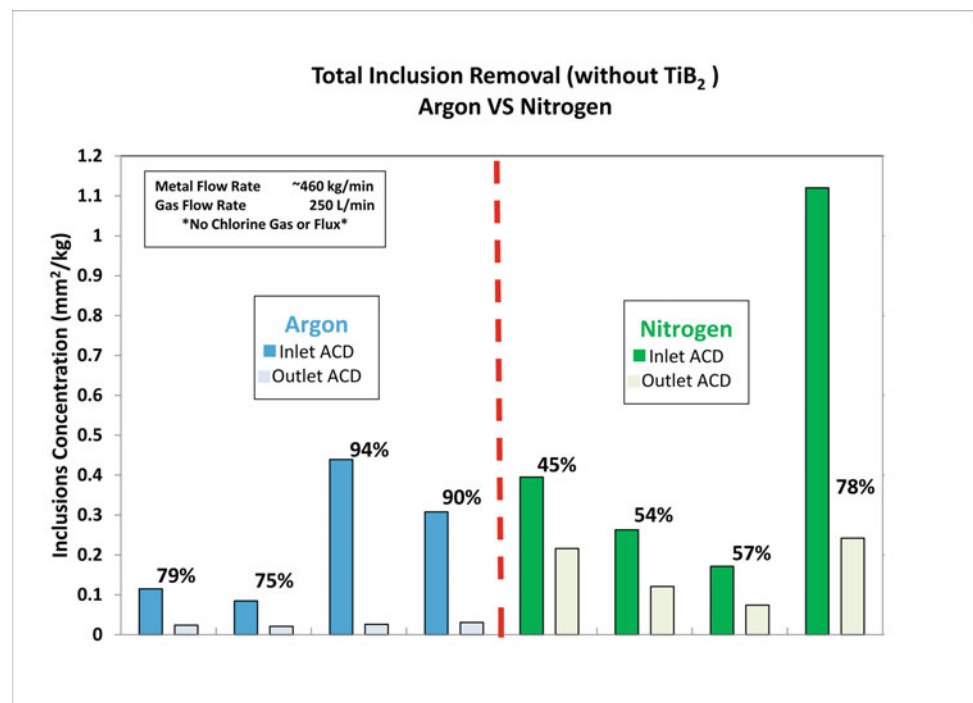


Fig. 5 PoDFA value for the total concentration of inclusions without grain refiner while degassing with argon and nitrogen



oxides and spinels adequately and with similar efficiency. But while most of the carbides were removed when Ar was injected, N₂ seemed to slightly struggle with the former. Figure 7 compares carbide removal between N₂ and Ar.

The amount of dross was not measured during the tests, but it appears that Ar and N₂ produce approximately the same type and amount of dross. Figure 8 shows the typical appearance of the dross after treatment with Ar and N₂.

Fig. 6 Comparison of spinel removal when degassing with N₂ and Ar

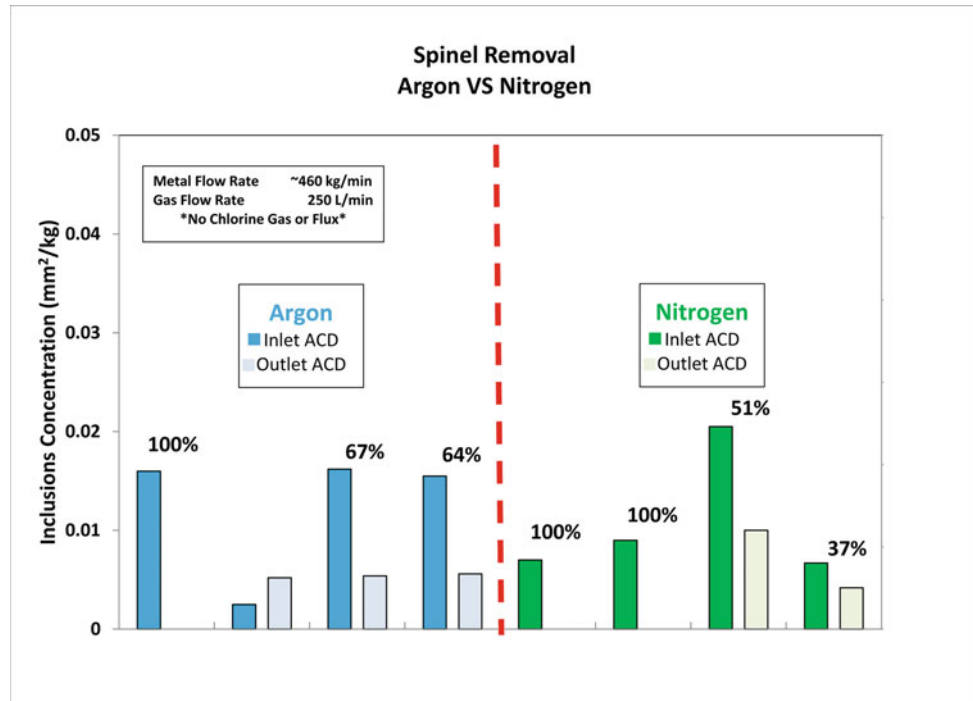


Fig. 7 Comparison of carbide removal between use of N₂ and Ar for degassing

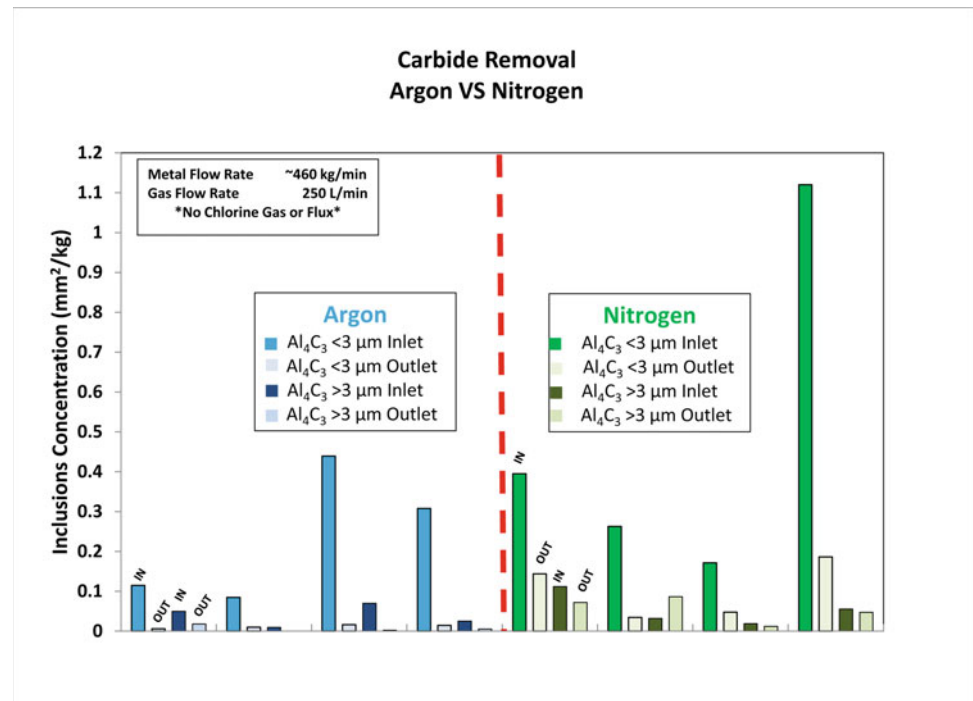
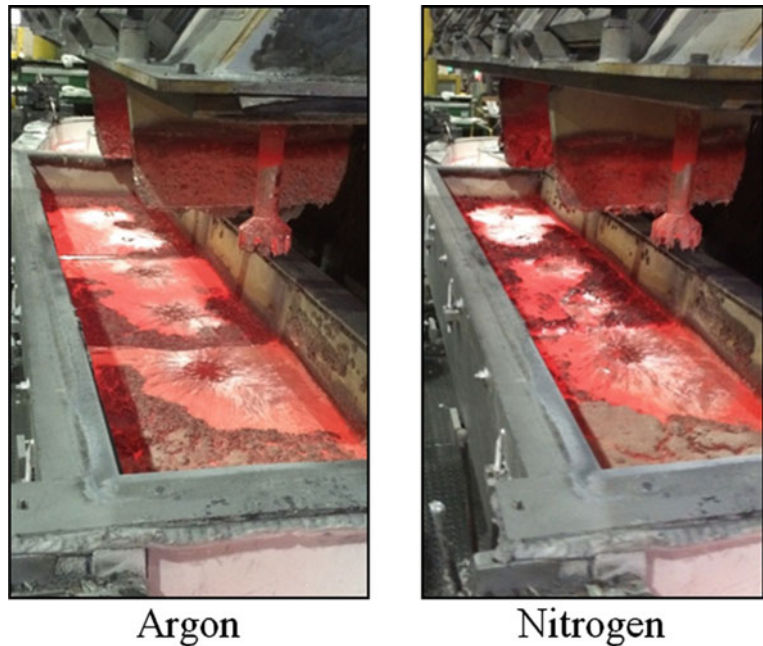


Fig. 8 Typical appearance of dross after treatment with Ar and N₂



Conclusion

At this stage, our investigation has led us to conclude that nitrogen can replace argon, since degassing with high purity N₂ or Ar provided the same efficiency for the alloy tested. Thus, the use of nitrogen instead of argon, the former being less expensive than the latter, could bring important cost reductions in the operation of a casthouse. However, further trials will be required to confirm this result with other alloys, but for now the results seem conclusive with respect to the 3xxx series alloys.

In terms of inclusion removal, the results are positive with both gases, even when no Cl₂ or flux is injected. With N₂, a lower removal efficiency was achieved, but no aluminium nitrides were generated.

To ensure excellent metallurgical results at the lowest operation and maintenance costs, the ACD/Aluminium Compact Degasser[®] already tops the list of available technologies on the market. And the possibility of using nitrogen is another cost-saving option that could be beneficial for many users.

Future Work

To conclude on a larger use of nitrogen, we believe the following would prove helpful:

- More tests with different concentrations and types of alloys.
- More tests when Cl₂ or a flux are injected.
- Measuring weight and composition of dross when performing further tests.

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