METAL QUALITY COMPARISON OF ALCAN COMPACT DEGASSER AND SNIF AT ALCOA MOUNT HOLLY CASTHOUSE

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Abstract

LiMCA and Alscan measurements of inclusion and hydrogen concentrations were performed at the Alcoa Mount Holly Casthouse to compare the metal quality obtained with an Alcan Compact Degasser to that obtained with a SNIF degasser. The measurements were conducted at two casting pits that are identical except for the degassers. The in-line metal treatment at one pit has a two stage, R-140 SNIF degassing unit, while the other pit uses a six rotor Alcan Compact Degasser. Identical ceramic foam filters are used downstream of the degassers.

Data was obtained from 11 casts of 6xxx alloys over a four day period. This paper will summarize the data and will provide a statistical comparison between the two degassing units. Hydrogen concentrations entering and leaving the degassers, hydrogen removal efficiencies, LiMCA inclusion concentrations entering the degassers, and inclusion concentrations after the ceramic foam filters will be compared.

Introduction

In-line fluxing units are widely used to remove hydrogen and trace alkaline elements from molten aluminum. Multiple stage, continuous flow, stirred tank reactors have been developed by a number of companies (1-3). These units provide efficient and low cost processing when used to treat metal as it flows from the furnace to the ingot casting unit. Gas, usually a mixture of argon and chlorine, is introduced into the metal through the shaft of the rotating disperser. When the gas leaves the disperser, the shear of the disperser and the turbulence of the molten metal break it into fine bubbles. Hydrogen is removed by adsorption into the bubbles while alkaline metals are removed by reacting with chlorine.

In-line fluxing units have been shown to remove inclusions through flotation (4), but they may also add inclusions in the form of grain refiner agglomerates or molten salt droplets. The net effect may be either an increase or a decrease in inclusion concentrations. This study compares both the hydrogen removal efficiencies and the inclusion concentrations downstream of the filter for two different types of degassers operating under similar conditions.

Experimental Apparatus and Procedure

This study was conducted at two casting pits located at the Alcoa Mount Holly Casthouse. The two pits are identical except for the in-line degasser. Each pit has fixed taphole holding furnaces that are charged with molten potroom metal and a limited amount of internal scrap. There is no furnace fluxing. Both pits use identical ceramic foam filters downstream of the degasser. The grain refiner is AlTiB; it is added to the metal in the trough upstream of the degasser.

One casting pit uses a two stage, R-140 SNIF degassing unit. The SNIF (Spinning Nozzle Inert Flotation) system was developed by Union Carbide (5). The SNIF unit contains approximately 1950 kg of metal when operating and holds 1400 kg of metal between drops. At Mount Holly the SNIF unit is operated with 140 l/min argon in each rotor and 1 l/min chlorine in each rotor. Rotor speed is 380 rpm. All tests at this pit were conducted on alloy 6005.

At the other casting pit, a six rotor Alcan Compact Degasser (ACD) is used. Baffles inside the unit form two stages with three rotors in each. The ACD uses small dispersers rotating at high speed to allow degassing to be carried out in a widened section of trough (6). The ACD contains approximately 550 kg of metal when operating but holds no metal between drops. At Mount Holly, the ACD operates with 250 l/min argon distributed among the six rotors and 1.2 l/min chlorine distributed among the first five rotors. The rotor speed in the ACD is 800 rpm. Tests at this pit were done on alloy 6063.

Hydrogen concentrations were measured by Alscan (7), a closed-loop recirculation technique. The Alscan instrument circulates a small volume of nitrogen carrier gas through a porous ceramic probe immersed in the metal. The hydrogen content of the gas, measured by thermal conductivity, eventually reaches equilibrium with the hydrogen in the metal. To assure equilibrium, the carrier gas circulates for 10 minutes and the arm of the instrument moves the probe back and forth through the metal. The analyzer calculates the hydrogen content of the metal, corrected for both metal temperature and alloy composition, according to Sievert's Law. Alscan measurements were obtained immediately upstream and downstream of the degasser.

Inclusion concentrations were measured by LiMCA (8), a method based on the Coulter counter principle. Metal is cycled in and out of a glass probe through a 300 µm orifice. Non-metallic inclusions passing through the orifice produce a perturbation in the voltage between electrodes situated inside and outside of the glass probe. The inclusion size range covered by LiMCA is nominally 20 to 320 µm, although the maximum size that can be resolved is 140 µm. One LiMCA unit was positioned between the holding furnace and the degasser, while the other unit was located downstream of the ceramic foam filter at one corner of the billet table.

Figure 1 shows a schematic diagram of the casting pits illustrating the locations of the Alscan and LiMCA units. Measurements taken between the holding furnace and the degasser are identified as "Taphole" or "Before Degasser" measurements. Alscan measurements taken between the degasser and the ceramic foam filter are labeled as "After Degasser" and LiMCA measurements from the billet table are identified as "After Filter".

Regular LiMCA probes were used for measurements made at the taphole because acceptable voltage baselines were obtained at that location. Extension probes were needed for measurements made after the filter, however, because an acceptable baseline was difficult to obtain with regular probes. This is an indication that either a high concentration of salt inclusions or small gas bubbles existed in the metal at this location. Extension probes are designed for situations where the salt or gas content of the metal is high – they allow a stable voltage baseline to be obtained.

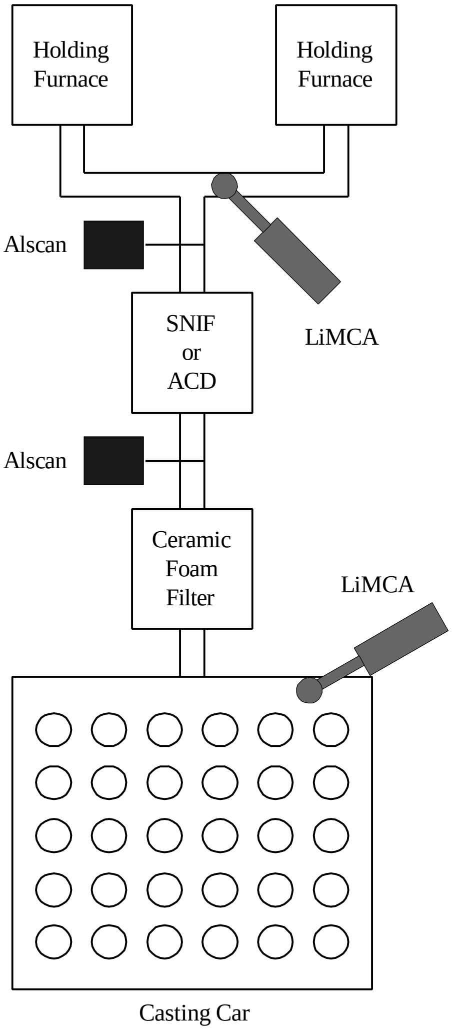

Figure 1: Casting pit layout at Alcoa Mount Holly Casthouse

Statistical analyses of the cast average Alscan and LiMCA values were made using "JMP" software (SAS Institute, Cary, North Carolina). An alpha of 0.05 was used in these analyses, meaning that the probability that the averages are equal needs to be 0.05 or less before a difference is considered to be significant.

Alscan Comparison between Degassing Units

Table I summarizes the average Alscan hydrogen concentrations at the taphole and after the degasser for each drop. The cast average hydrogen concentrations at the taphole ranged from 0.24 to 0.35 ml/100g. This is probably a bit lower than would be expected for taphole readings from furnaces that had not been fluxed and was likely due to the unusually cold and dry weather that existed during most of the test. The cast average hydrogen concentration after the degasser ranged from 0.14 to 0.18 ml/100g. It should be noted that the Alscan reads higher than a Telegas unit or Leco analyses. This bias has been observed at many locations and has been reported by others in the literature (9).

The hydrogen removal efficiency was calculated for the drops where both taphole and downstream hydrogen measurements were taken; these values are also included in Table I. The hydrogen removal efficiency ranged from 47 to 54% for the ACD and from 28 to 60% for the SNIF. The inlet hydrogen concentration measured during the first test on the SNIF was considerably lower than those measured during the other tests; this may have reduced the hydrogen removal efficiency.

Table I Alscan Hydrogen Concentrations

Test No.	Degasser	Metal Flow (kg/hr)	H_2 at Taphole (ml/100g)	H_2 after Degasser (ml/100g)	H_2 Removal (%)	Rate Constant (min^{-1})
1	SNIF	30,900	0.24	0.17	28	0.096
2	SNIF	30,900	0.34	0.18	46	0.192
3	SNIF	30,900	-	0.17	-	-
4	SNIF	30,900	0.35	0.14	60	0.311
5	SNIF	30,900	-	-	-	-
6	ACD	39,300	-	0.16	-	-
7	ACD	39,300	0.34	0.16	54	1.191
8	ACD	36,400	0.30	-	-	-
9	ACD	38,300	-	-	-	-
10	ACD	38,800	0.31	0.14	53	1.146
11	ACD	39,300	0.29	0.15	47	0.928

Figure 2 shows statistical comparisons of the hydrogen concentrations before and after the degasser for the two pits. The diamond for each test indicates the average value by the line across its center and the 95% confidence level by its height. There were no statistically significant differences in the hydrogen concentrations before or after the degasser. The inlet hydrogen concentration averaged 0.31 ml/100g at both pits. On average, the ACD reduced the hydrogen concentration to 0.15 ml/100g, while the SNIF reduced it to 0.17 ml/100g. Alscan measurements are typically accurate to ± 0.01 ml/100g. Figure 2 also includes a statistical comparison of the hydrogen removal efficiency at the two pits. There was no significant difference in performance between the two stage SNIF and the six rotor ACD. The average hydrogen removal efficiency for the SNIF was 45% versus 51% for the ACD.

Table I also lists the first order rate constants calculated from the average hydrogen concentrations before and after the degasser. The rate constant is calculated from the equation:

$$kA = \frac{F}{V}\left[\left(\frac{Hin}{Hout}\right)^{\frac{1}{n}} - 1\right]$$

where F is the metal flow rate, V is the metal volume of each stage, and n is the number of stages. This rate constant is a measure of the effectiveness of a stage in each degassing unit. The rate constant for the SNIF ranged from approximately 0.1 to 0.3 min^{-1}, whereas the values for the ACD are much higher, ranging from 0.9 to 1.2 min^{-1}. This difference reflects the fact that the ACD accomplishes the same hydrogen removal in a much smaller volume of metal than the SNIF. The greater reaction intensity of the ACD is achieved by using more argon per rotor and more rotors per stage.

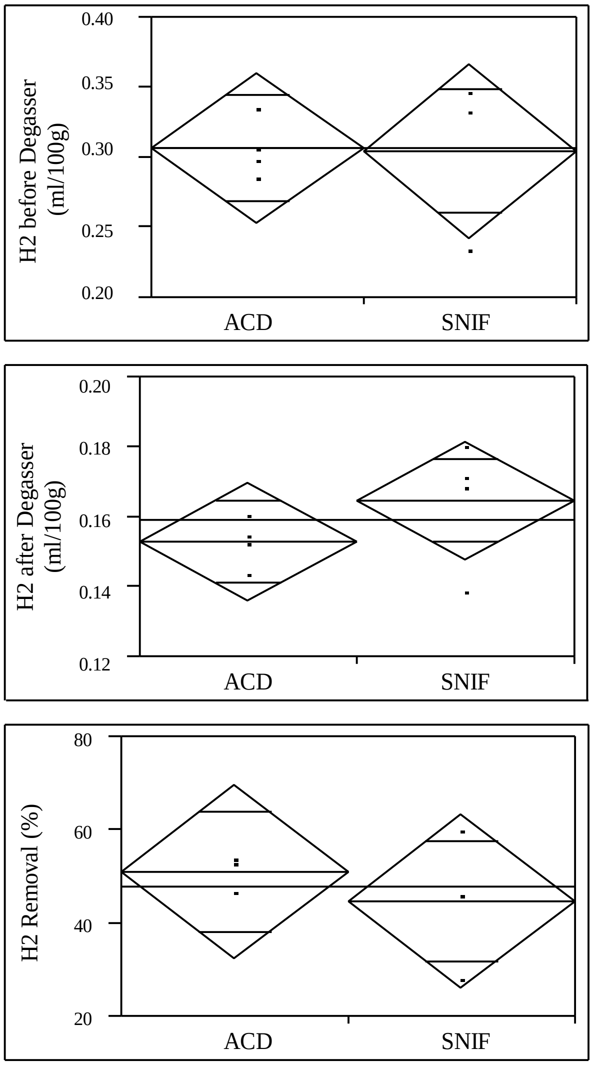

Figure 2: Statistical Comparison of Hydrogen Removal

LiMCA Inclusion Concentrations

Table II gives a summary of average LiMCA values measured for each cast during the campaign. N20, N30, N50, and N100 represent the concentrations of particles larger than 20, 30, 50, and 100 μm, respectively. The average N20 values at the taphole ranged from 8 to 31 K/kg. After the ceramic foam filter the cast average N20 ranged from 9 to 23 K/kg.

The N20 values measured after the filter were often greater than the N20 values measured at the taphole. While it appears the metal treatment system is not effective, the larger particle size fractions show a different story. As seen in Table II, the N30 concentrations after the filter are always lower than at the taphole. This holds true for larger particle size fractions as well. The higher concentrations of 20 to 30 μm particles after the filter, which are seen as an increase in N20, are probably due to additions of grain refiner and chlorine between the two measurement locations. Molten salt droplets and agglomerates of TiB_2 particles can be formed in the degasser and can be large enough to be measured by LiMCA.

Table II LiMCA Inclusion Concentrations

			LiMCA Values at Taphole (K/kg)				LiMCA Values after Filter (K/kg)				Filtration Efficiency (%)			
Test No.	Degasser	Metal Flow (kg/hr)	N20	N30	N50	N100	N20	N30	N50	N100	N20	N30	N50	N100
1	SNIF	30,900	8.1	2.3	0.22	0.00	17.2	2.0	0.15	0.00	-113	13	32	100
2	SNIF	30,900	21.6	5.2	0.60	0.01	23.0	3.3	0.18	0.00	-7	36	69	100
3	SNIF	30,900	28.8	7.2	0.52	0.03	16.0	1.4	0.03	0.00	44	80	94	100
4	SNIF	30,900	9.4	2.7	0.50	0.00	9.2	0.9	0.03	0.00	2	67	94	-
5	SNIF	30,900	-	-	-	-	12.2	1.4	0.07	0.00	-	-	-	-
6	ACD	39,300	-	-	-	-	15.6	1.9	0.06	0.00	-	-	-	-
7	ACD	39,300	31.0	9.0	1.22	0.08	13.9	1.6	0.04	0.00	55	83	97	100
8	ACD	36,400	20.1	9.3	3.29	0.36	18.8	2.8	0.13	0.00	7	70	96	100
9	ACD	38,300	-	-	-	-	15.2	2.4	0.12	0.00	-	-	-	-
10	ACD	38,800	9.2	3.5	0.75	0.05	8.8	0.8	0.06	0.00	4	76	92	100
11	ACD	39,300	-	-	-	-	14.1	1.6	0.03	0.00	-	-	-	-

Filtration efficiencies for the combination of the degasser and the ceramic foam filter are included in Table II. Because extension probes had to be used for measurements after the filter, comparisons between the taphole data and the after filter data need to be made with some caution. Measurements made with both regular and extension probes on the same metal stream have shown that the extension probe can give lower values, particularly for the smaller inclusion sizes. Filtration efficiency increased with increasing particle size. The average filtration efficiency was –1% for N20, 61% for N30, and 82% for N50. The filtration efficiency for N100 was 100% for all drops – no particles larger than 100 μm were detected in any of the LiMCA samples after the filter at either casting pit.

LiMCA Comparison between Degassing Units

The cast average inclusion concentrations at the taphole were slightly higher at the casting pit with the ACD for all size ranges (N20, N30, N50, and N100). These differences, however, were not statistically significant at a 95% confidence level.

Figure 3 gives plots of the N20, N30, and N50 LiMCA data obtained after the filter during each cast. The data is coded according to the degasser used. This plot shows that there is no apparent difference between the two units.

Figure 4 shows a statistical comparison of the mean LiMCA values obtained after the filter at the two casting pits. There are no statistically significant differences between the mean values for any of the size ranges. For example, the probability that the N20 means are not different is 0.67. (A probability of 0.05 or less would indicate a statistically significant difference.) This analysis shows there is no difference in metal cleanliness between the two pits.

This study shows that there were no differences in the quality of the metal produced by the SNIF degasser and the Alcan Compact Degasser in terms of hydrogen or inclusion concentrations. It should be noted that the metal flow rate was higher at the casting pit with the ACD (~38,600 kg/hr) than at the pit with the SNIF degasser (~30,900 kg/hr). Since both the metal flow rate and the taphole inclusion concentrations were somewhat higher at the casting pit with the ACD, it could be argued that the ACD actually performed somewhat better than the SNIF.

Operating Experience

The ACD has provided a number of operating benefits to the Alcoa Mount Holly Casthouse. Although some metal must be drained from the ACD after each drop because of the fixed taphole furnaces, no metal is retained in the degasser between drops. This eliminates the need to drain or flush the degasser for alloy changes and eliminates the need for heaters to maintain metal temperature between drops. The ACD provides better accessibility for removing dross and changing rotors, reducing the time required to change a rotor from as long as 5 hours for the SNIF to 30 minutes for the ACD. There is also a considerable reduction in the rebuild time, 2 days for the ACD compared to 5 days for the SNIF.

The ACD has thus provided significant savings in drain metal for alloy changes, energy consumption for heating, equipment costs for heating elements, and production time for changing rotors or rebuilding the degasser.

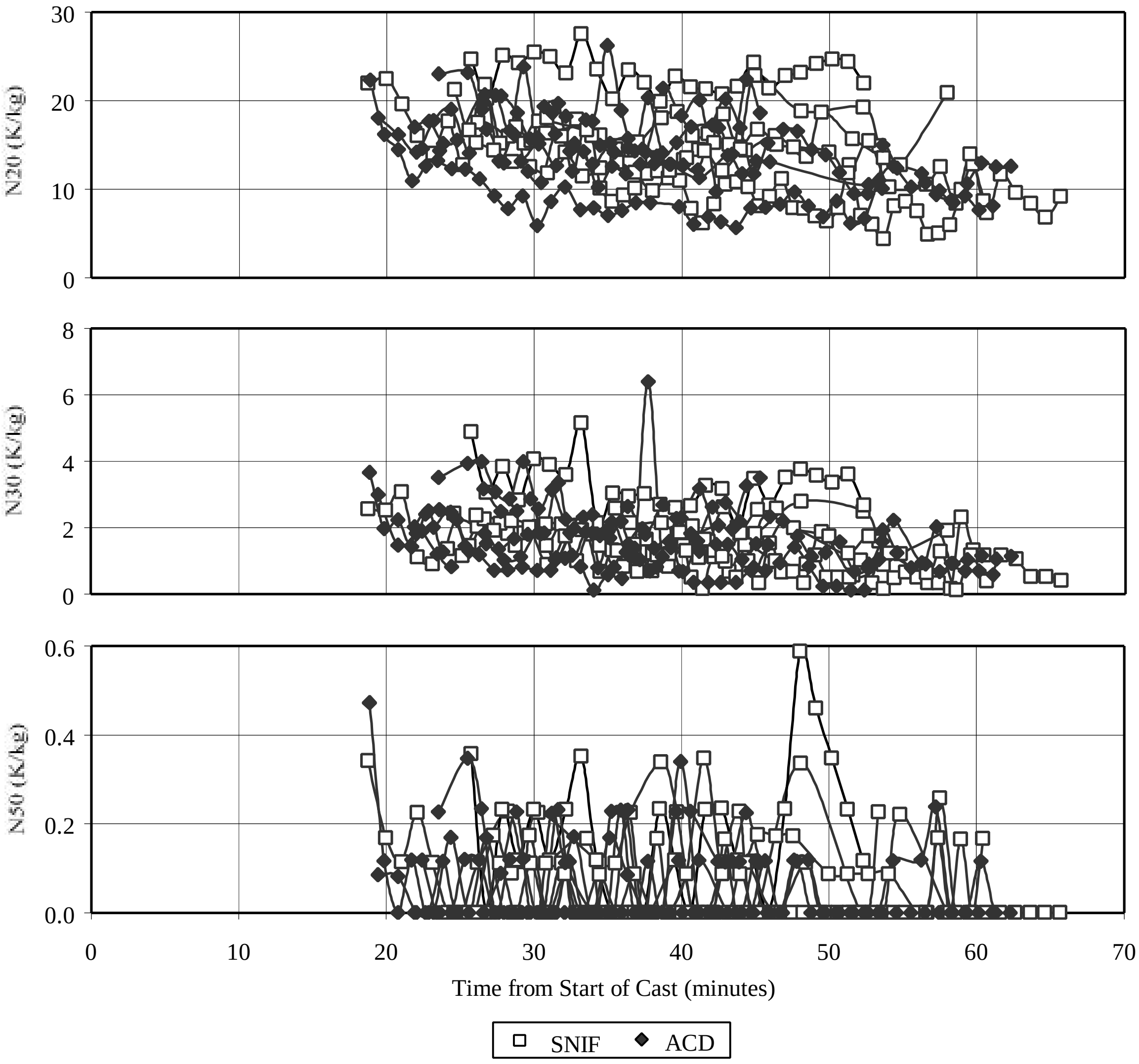

Figure 3: LiMCA Inclusion Concentrations Measured Downstream of the Filter

Conclusions

1. There were no significant differences in hydrogen concentrations before or after the degassers or in the hydrogen removal efficiency between the two stage, R-140 SNIF unit and the six rotor ACD.
2. The average inclusion concentrations measured after the filter at the two casting pits were not statistically different. This holds for N20, N30, N50, and N100 concentrations. There were also no significant differences in the average inclusion concentrations measured at the taphole of the two casting pits.

3. The six rotor Alcan Compact Degasser (ACD) produced metal quality equal to that obtained with the 2 stage, R-140 SNIF unit for 6xxx alloys at Alcoa Mount Holly.

4. The ACD has produced savings in drain metal for alloy changes, energy consumption for heating, equipment costs for heating elements, and production time for changing rotors or rebuilding the degasser.

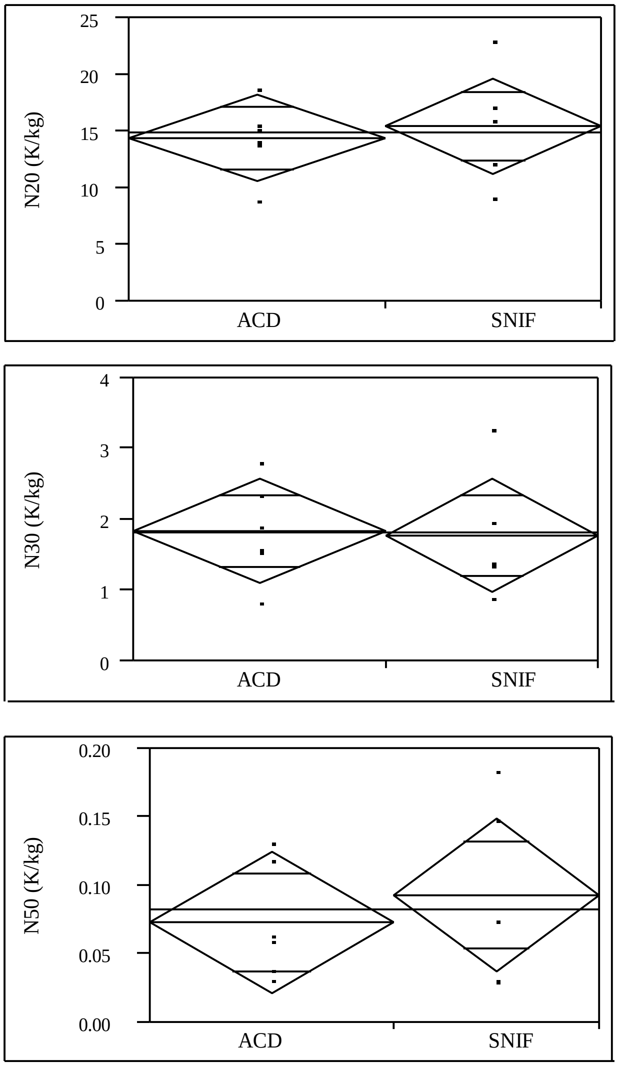

Figure 4: Statistical Comparison of Average LiMCA Values Measured Downstream of the Filter

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