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EXPERIENCE WITH THE SEALED ALCAN COMPACT DEGASSER (ACD)

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Abstract

The first commercial in-line compact degasser for treating molten aluminium in casthouses was installed by Alcan at the Grande-Baie plant, Canada, in 1994. There are now over 125 units operating in more than 20 countries. Since that time, the technology has continued to develop and advance with flow rates varying from as low as 28 kg/min up to as high as 1500 kg/min. The treated molten metal is cast into a variety of forms including sheet ingot, foundry ingot, billet and for continuous casting. Several applications are treating metal without the use of chlorine gas. Recently a totally sealed unit has been developed, with or without the use of chlorine. This paper provides some more recent metallurgical experience with the compact degasser, in particular the sealed units, and also indicates the emission levels of fumes from the same. Inconsistent inclusion removal has been noted where no chlorine gas is injected.

Introduction

The Alcan Compact Degasser (ACD) was developed by Alcan at the Arvida Research and Development Center in the early 1990s. The first published metallurgical results were reported in 1996 [1], comparing the "conventional degasser" (such as Snif, Alpur and Hycast) with the ACD. The main advantages of the ACD are the absence of heating and the elimination of the need to drain the alloy before alloy changing; degassing is carried out directly in the trough. The space requirements are consequently reduced enabling more easily a retrofitting and/or positioning of the ACD in the casthouse.

It is to be noted that the ACD is comparable in its metallurgical performance with competitive degassers in removing hydrogen, alkalis and inclusions [2, 3, 4]. Its capital and operating costs are generally lower.

Since the first commercial models were introduced to the market place, there have been several noticeable improvements especially with regard to the need to eliminate the use of chlorine. This paper describes some of the applications of the more than 120 installations in casthouses worldwide, where the ACDs are operating both with and without chlorine in sealed and non-sealed units. A particular attention is paid to inclusions present in the molten alloy both before and after the ACD, whilst respecting the need to effectively reduce hydrogen.

Brief History of Development

The first ACD commercial unit was introduced in 1994 for 6 [1] rotors used to treat molten alloy for casting into Rolling Slabs at an Alcan plant, treating mainly 3XXX and 5XXX alloys. Since this time, many more units have been fabricated, able to treat molten aluminium alloys with flow rates varying from 28 kg/min up to 750 kg/min using 2, 4 or 6 rotors. More recently, in the last three years, flow rates of as high as 1500 kg/min can be treated with 8-rotor units.

The first units employed baffles prior to each rotor, were non-sealed, and most of them used chlorine gas mainly to keep the dross dry and to carry out inclusion and alkali removal. Over the course of several years, trials were carried out on various units to optimise the life of the rotors by using ceramics, varying the rotor diameters, using coatings etc., To date, the optimum result in terms of cost/life seems to be the graphite rotor with a larger diameter than the original.

In so far as the baffles were concerned, it was evaluated that several of them could be eliminated. The baffle arrangement has been changed for the sealed unit (see Figure 1).

Tests on several of the ACDs have shown that the trough width and depth of metal in the trough can be varied according to the specific application in terms of alloy type, atmospheric conditions and other parameters. Questionnaires have been developed to assist the Applications Engineers to design units to the specific needs of the client.

Description of Standard and Sealed ACD

Technology Comparison: Conventional vs Sealed ACD

Figure 1 illustrates the design changes required to operate the ACD in a sealed condition.

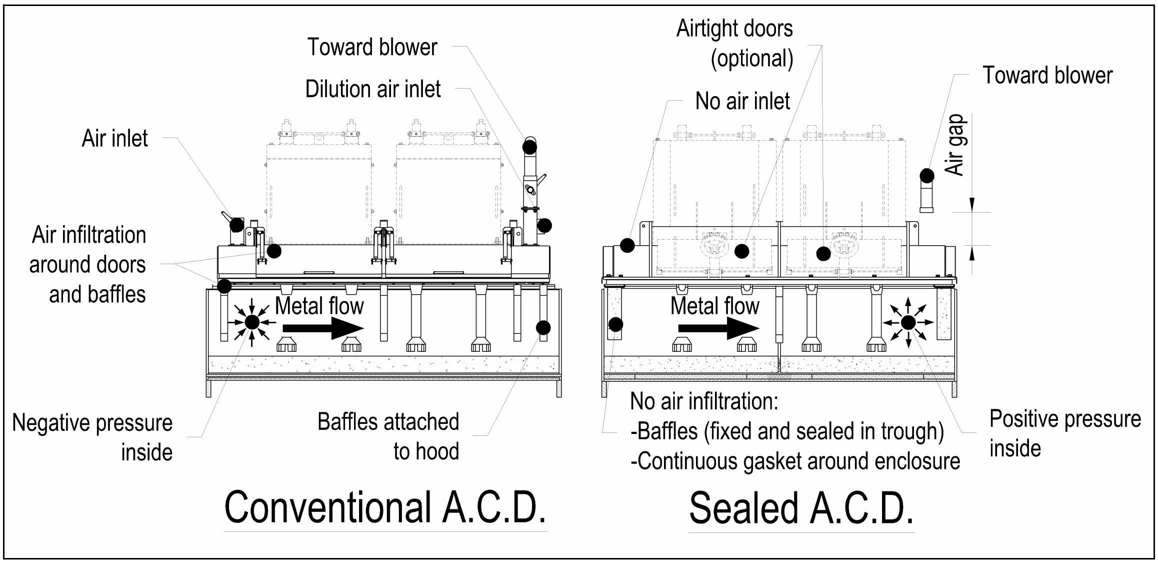

Figure 1

During operation of the conventional ACD, forced air circulation is created through the interior of the hood. This mode of operation was originally developed to eliminate dross reactivity (burning) after treating Al-Mg alloys.

In order to create the air circulation, the ACD hood exhaust outlet is connected directly to the gas extraction blower duct, and a small dilution air inlet is provided to lower the temperature of the exhaust gases. In addition, an air inlet is provided at the opposite end of the ACD hood. The vacuum created at the exhaust outlet of the ACD also eliminates the release of fugitive emissions into the working environment around the unit.

On the conventional ACD, all the baffles are attached to the hood, and there is a gap between the baffles and the trough. Even though seals are provided between the trough and the hood as well as around each of the skimming doors, these seals are not particularly effective. The oxygen content of the atmosphere inside the conventional ACD is just a few percent below that of the ambient air.

In the case of the sealed ACD technology, all means have been implemented to stop air infiltration into the interior of the ACD hood. All openings are sealed and only one outlet is provided to exhaust the process gases. The basic principle is to generate a slight overpressure inside the ACD hood which is created by injection of the argon process gas. To achieve such a condition, it is necessary to:

- Seal the contact surface between the hood and the trough;
- Seal (or eliminate) the skim doors;
- Eliminate all other potential air infiltration sites in the hood;
- Install two fixed and sealed end baffles in the ACD trough (inlet and outlet);
- Employ an air break at the connection between the ACD exhaust gas outlet and the gas extraction system.

These modifications and no forced air circulation inside the ACD hood affect the internal and shell temperatures of the hood, which are higher than with the conventional ACD. For this reason, the sealed hood design incorporates significantly improved insulation and uses metallic parts for the internal lining of the hood. The new hood design also minimises thermally induced physical distortion so that the hood lies flat on the trough. A new hood is required to convert a conventional ACD into a sealed ACD.

The benefits of the sealed ACD are:

i. a lower generation of dross,
ii. the possibility of operating the ACD without the use of chlorine,
iii. reduced emission of particulate matter.

Results of Metallurgical Performance in the Sealed vs Non-Sealed ACD

In this section, results of extensive tests are presented in a summary form for the metallurgical performance in various plants where there are both sealed and non-sealed units operating either with or without chlorine [5, 6].

For the last few years, there has been a movement towards the elimination of chlorine from casthouses, particularly where jurisdictions are modifying their legislation to take care of environmental and hygiene concerns. There are now more than a dozen (12) ACDs which have either eliminated chlorine or have been supplied with sealed units in which chlorine gas is not used.

During commissioning and start up of the ACDs in customer plants, it is usually permitted to verify the metallurgical performance (not only hydrogen removal but also alkaline and inclusion removal) of the ACD for both sealed and non-sealed units. In all cases to date, satisfactory values have been obtained.

Non-Sealed ACD – With Chlorine

<u>Hydrogen Removal:</u>

Hydrogen removal depends upon the volume of gas injected, its dispersion in the liquid melt and the residence time; the proportion of chlorine gas when injected represents a small fraction of the total gas volume.

Tests on ACDs using AlSCAN have shown hydrogen removal, as expected, is according to the Alcan model [7], attaining close to equilibrium for the metal casting temperature and the ambient humidity [8, 9] for the specific alloy and allowing for other operating parameters. Understanding the importance of humidity and casting temperature has been confirmed by others [10].

Inclusion Removal:

This section does not deal with inclusion removal by filters, either Ceramic Foam Filters (CFFs) or Deep Bed Filters, the subject of which has been adequately dealt with by others [11, 12]. For a uniform and consistent removal of inclusions, the Deep Bed Filter (DBF) remains the technology of choice.

In fact, it has long been known that a minimum quantity of chlorine gas is necessary to achieve a permanent and consistent removal of inclusions by an in-line fluxing unit[13, 14]. This, ensures that the dross generated is "dry" and floats easily to the surface of the melt. In the absence of chlorine, the dross is "wetter" and can be more easily entrained into the melt, thus risking the re-entrainment of inclusions.

Results are shown for two plants [8, 9] in Tables 1 and 2 where up to 90% inclusion removal is possible.

- *Plant A (non-sealed, with chlorine)*

Table 1: Inclusion removal (hard particles only) – 4-rotor ACD

AA Code	PoDFA "pre" ACD (mm^2/kg)	PoDFA "post" ACD (mm^2/kg)
7013	0.840	0.029
7013	0.901	0.005
7013	0.022	0.015
7013	0.024	0.013
7013	Unavailable	0.004
7013		0.008
7013		0.007
7013		0.005
7013		0.008
7013		0.007

- *Plant B (non-sealed, with chlorine)*

Table 2: Inclusion removal (hard particles only) – 6-rotor ACD

Alloy Type	"Pre" ACD (PoDFA) (mm^2/kg)		"Post" ACD (PoDFA) (mm^2/kg)	
6262	0.036	0.010	trace	trace
6262	0.032	0.027	trace	0.001
6262	0.119	0.449	0.010	0.004
2011	0.001	0.003	trace	trace
2011	0.003	0.001	trace	trace
6262	0.037	0.057	0.006	trace
6262	0.098	0.116	0.004	0.004
7075	0.910	0.281	0.122	0.068
7075	1.209	N/A	0.093	N/A

Alkali Removal [8, 9]:

Up to 90% removal of sodium can be obtained, but usually 70% is more typical; up to approximately 50% of calcium may also be obtained under certain conditions .

- *Plant A (non-sealed, with chlorine)*

Table 3: Alkali removal – 6- and 4-rotor ACDs

AA Type Alloys	Nb of Rotors	Cl_2 (ml/min)	Na "pre" (ppm)		Na "post" (ppm)		Ca "pre" (ppm)		Ca "post" (ppm)		Removal Efficiency	
			1	3	2	4	1	3	2	4	Na (%)	Ca (%)
6262	6	483	7.6	7.9	2.1	1.5	36.2	35.5	37.6	34.3	76.8	-0.3
6262	6	1000	5.1	4.5	1.4	1.0	16.1	14.7	11.8	11.4	75.0	24.7
6262	6	1000	5.5	4.6	1.8	1.5	13.5	13.2	11.4	11.3	67.3	15.0
6262	6	1000	4.5	4.6	2.3	1.1	14.1	14.3	12.2	9.8	62.6	22.5
7075	4	670	8.5	8.2	4.3	4.3	28.9	28.3	25.4	26.1	48.5	10.0
7075	4	1000	9.2	8.0	1.0	0.6	46.7	47.0	36.9	37.6	90.7	20.5
2030	4	1000	10.1	9.9	1.5	0.4	33.1	33.9	23.7	27.3	90.5	23.9
2030	4	350	0.1	0.1	0.1	0.1	32.9	32.7	27.7	27.0	0.0	16.6
2030	4	335	0.1	0.1	0.1	0.1	34.3	35.9	29.6	30.2	0.0	14.8

- *Plant B (non-sealed, with chlorine)*

Table 4: Alkali removal (flow rates: 40-45 kg/min) – 4-rotor ACD

Ar (l/min)	Alloy	# Rotors	Total Cl_2 (ml/min)	"Pre" ACD		"Post" ACD	
				Na (ppm)	Temp (°C)	Na (ppm)	Temp (°C)
181	5052	4 rotors	599	2	736	0	727
181	5052	4 rotors	599	2	804	1	788
181	5052	4 rotors	600	0	743	0	729
181	5356	4 rotors	599	3	747	1	727
181	5356	4 rotors	599	15	743	3	718
181	5356	4 rotors	599	3	743	2	732
181	1350	4 rotors	598	3	746	1	736
100	1350	2 rotors	397	1	739	1	732
Average Removal Efficiency:						66%	

Non-Sealed ACD – Without Chlorine

Hydrogen Removal:

Hydrogen removal is effected with or without the use of chlorine and with both the sealed and non-sealed units.

Alkali Removal:

No measurements in alkali removal have been carried out in view of the fact that under the operating conditions present in a degasser, only negligible quantities of sodium might be removed.

Inclusion Removal:

- *Plant C (non-sealed, without chlorine)*

  In an unusual application of continuous casting, with a flow rate of less than 30 kg per min., it has been found that the life of the CFF downstream of the ACD was increased considerably by a factor of 4 following the implementation of ACD. This indicates that a significant amount of inclusions are removed by the ACD thus reducing the loading on the downstream filtration process.

  It is noticed on the other hand that in the absence of chlorine, the dross generated in the ACD is much more voluminous and "wet" than is the case for applications where chlorine is present.

- *Plant D (non-sealed, without chlorine)*

  Tests carried out in an Alcan plant with an ACD, which had been retrofitted for sealing without using chlorine, showed that chlorine gas was indeed desired to ensure inclusion removal. See "Sealed – Without Chlorine".

- *Plant E (non-sealed, without chlorine)*

  Results obtained for treatment of foundry alloy with a 4 rotor ACD are shown in Table 5.

  In this casthouse, aluminium carbide particles, which are particularly small, are the main constituent of the total inclusions. Studies have shown that where there is no protective dross cover, then splashing or turbulence can be a problem [15]. An increase in the inclusion count could be explained by the fact that inclusions are entrained back into the melt. Another hypothesis could be the fragmentation by the rotors of the large aluminium carbide particles to a smaller size.

Table 5: PoDFA results

	Inclusion Count (mm^2/kg)					
	"Pre" ACD			"Post" ACD		
	Total	Sonims *	% Al_4C_3	Total	Sonims *	% Al_4C_3
Avg	0.129	0.081	78.0	0.203	0.084	86.0
Std Dev	0.109	0.073	28.2	0.183	0.073	14.7
Removal Efficiency (%)				- 157	≈ 0	- 110

Sealed – General Comments

The first sealed unit, a 2-rotor system without the possibility of using chlorine, was installed in a billet producing plant in 2002 to produce billets. Space constraints were so severe that only an ACD could be considered for the application.

In the sealed ACD, it has been found that whilst the generation of dross is dramatically reduced, there is a tendency to create splashing by the rotors, probably due to the absence of a protective dross layer. Equipment design modifications are required to overcome this problem.

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[*] Includes all inclusions with the exception of titanium and/or vanadium di-borides, aluminium carbides (all diameters considered) and potential chlorides. Note: This definition could depend on the metallograph analysing the PoDFA samples.

On the other hand, according to extensive measurements it has been shown that EPA standards for particulate emissions are now met with the sealed unit to emission rates of approximately 0.1-0.2 kg/h; a standard non-sealed unit can generate emissions greater than 1 kg/h. It also has been noted that graphite rotor life is extended due to the absence of oxygen under the hood.

Sealed ACD – With Chlorine

Inclusion Removal:

Chlorine is essential to ensure the removal of inclusions [16] in non-sealed units (see above). However tests have been carried out in several plants where sealed units have been installed or have been retrofitted for sealing to determine the rate of inclusion removal.

- *Plant F (sealed, with chlorine)*

  6-rotor ACD: main constituent = grain refiner particles (added at the furnace spout).

Table 6: PoDFA results (flow rate: 610 kg/min)

	Inclusion Count (mm^2/kg)					
	"Pre" ACD			"Post" ACD		
	Total	Sonims	% TiB_2	Total	Sonims	% TiB_2
Avg	0.092	0.018	69.8	0.038	0.005	65.1
Std Dev	0.042	0.017	15.8	0.021	0.005	11.7
Removal Efficiency (%)				57.5	59.3	60.0

- *Plant G (sealed, with chlorine)*

  8-rotor ACD: main constituents = grain refiner particles (TiB_2, $(Ti,V) B_2$) and aluminium carbide.

Table 7: PoDFA results (flow rate: 625-700 kg/min)

Alloy	Inclusion Count (mm^2/kg)		Removal Efficiency (%)
	"Pre" ACD	"Post" ACD	
	Total	Total	
1100	0.036	0.004	88.9
1100	0.060	0.004	93.3
1050	2.750	0.261	90.5
		Avg	90.9
		Std Dev	2.2

Sealed ACD – Without Chlorine

Inclusion Removal:

Following the introduction of sealed units, it was necessary to check the metallurgical performance to determine if inclusions could be removed or the level remained steady before and after the ACD (or even added!) during treatment; so, tests were subsequently carried out taking trough samples using PoDFA. The results are shown in Table 8 (plants H, I and J).

- *Plant H (sealed, without chlorine)*

  Results obtained when treating 1050 alloy with a 4 rotor ACD unit – sealed version.

  Grain refiner (Ti/B) added at the furnace spout constituting the major inclusion type.

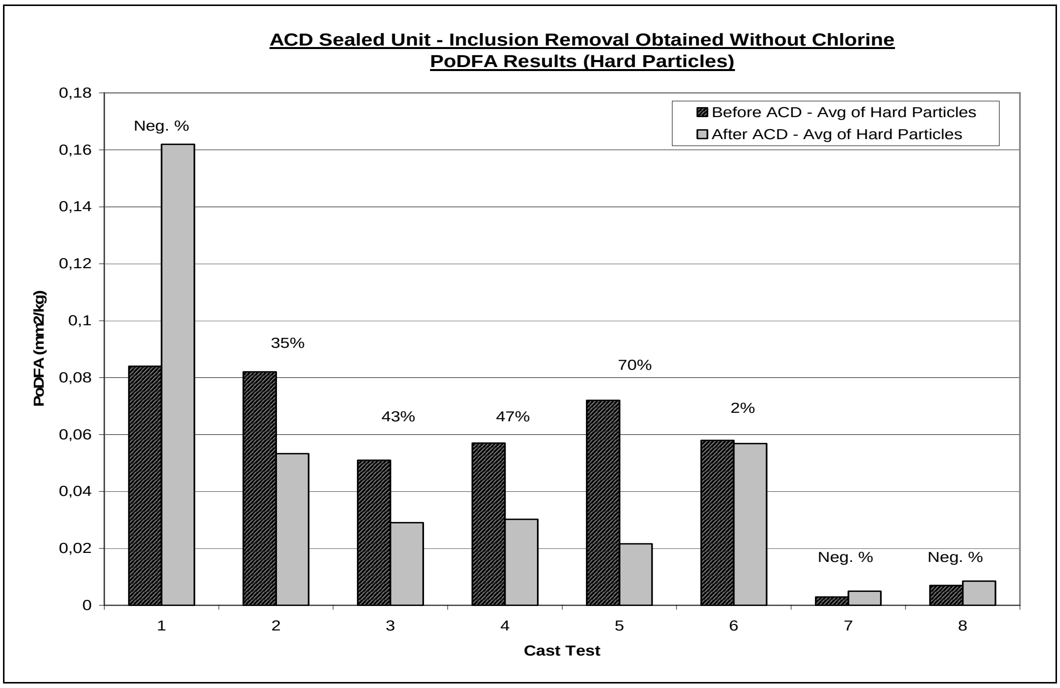
Table 8: PoDFA results (flow rate: 400-420 kg/min)

	Inclusion Count (mm^2/kg)					
	"Pre" ACD			"Post" ACD		
	Total	Sonims	% TiB_2	Total	Sonims	% TiB_2
Avg	0.303	0.005	98.0	0.052	0.003	93.6
Std Dev	0.089	0.003	1.7	0.002	0.001	1.4
Removal Efficiency (%)				81.9	26.9	4.5

- *Plant I (sealed, without chlorine)*

  Tests showed no consistent inclusion removal and even some inclusion entrainment.

- *Plant J (sealed, without chlorine)*



Although some tests show clearly that there is inclusion removal for hard particles for the majority of the tests, however, there were tests where inclusions were added back; in two cases at extremely low inclusion levels going into the degasser, there is a small increase in inclusion levels following the degasser. For test 1 at a high inclusion input level, there was an increase in inclusions following the degasser.

Conclusion

With chlorine: Our experience shows that positive and consistent removal of inclusions, as measured by PoDFA, can be achieved for both the non-sealed and sealed ACD units.

Hydrogen removal is as expected, obtained under all conditions as well as the removal of alkalis.

Without chlorine. Hydrogen removal is as expected, although alkali removal is not considered.

Positive inclusion removal can be achieved without the use of chlorine, particularly in the case of a sealed ACD unit; however, the results presented cannot support data published in 2002 for a new type of degasser [17], which indicated that it was able to consistently remove inclusions. It seems that although some inclusion removal can be expected without the use of chlorine in a sealed ACD, the results are not consistent enough to claim they are removed under all conditions.

Fume emissions. Fume emissions have been significantly reduced with a sealed degasser.

Acknowledgement

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