

## CH04 - Initiatives to Minimize Dross Generation in Casthouse

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### Abstract

Dross is a mixture of oxide films and aluminium. Aluminium-oxide is wetting; it absorbs molten aluminium like a sponge, creating fine aluminium droplets encapsulated by aluminium-oxide. Some of the primary factors causing dross generation and melt loss include disturbance of the clean aluminium surface, turbulence, contaminants on the scrap, burners ingesting air, burners improperly adjusted to fire either too much gas or too much air and overheating the scrap. This study is focused on reducing dross generation and recovering metal from dross.

Some of the initiatives have been implemented to reduce the dross generation in the cast house by implementing some of the actions related to the furnace practice, increasing siphon operation, improving dross cooler efficiency, reducing the door open time, usage of fluxes, and modifying the dross pans. As a result of implementing the initiatives and actions, the dross generation was minimized to the required targets.

Ma'aden also installed a new environmental friendly dross recovery technology DROSRITE™ in the casthouse. The metal recovery project helped to minimize the dross inventory in the casthouse and to improve the casthouse yield. The recovered metal is being reused in the casthouse furnaces as scrap for producing value-added products.

**Keywords:** Dross generation, Metal from dross, Hydrogen removal, DROSITE furnaces, Siphon operation.

### 1. Introduction

#### 1.1 Dross and Chemical Composition

Dross arises primarily from the oxidation of molten aluminium and can be divided in two different types:

1. "White dross" or primary dross, from smelter and remelt operations, which is characterized by a very low or no salt content.
2. "Black dross" or secondary dross, from scrap recycling operations and having a high salt content.

To a large extent, the chemical composition of a metal determines its oxidation rate. The ratio of the volume of oxide to the volume of metal from which it is produced is particularly critical. This ratio is known as the Pilling-Bedworth ratio (P-B ratio). The metal oxide P-B ratio [1] can be described as the ratio of the metal oxide volume produced by the oxygen and metal reaction to the consumed value of metal. This can be further defined in the equation:

The PB Ratio is defined as:

$$R_{PB} = \frac{V_{oxide}}{nV_{metal}} = \frac{M_{oxide}\rho_{metal}}{nM_{metal}\rho_{oxide}} \quad (1)$$

where:

- $M$  Atomic or molecular mass,
- $n$  Number of atoms of metal per molecule of the oxide,
- $\rho$  Density,
- $V$  Molar volume.

Using the P-B ratio as the basis for gauging protective films, the following can be assumed:  
 If the P-B ratio is less than 1, the oxide film is too thin and will most likely break down, such as in magnesium.

If the P-B ratio is greater than 2, the oxide film chips off and offers no protection, such as in iron.  
 If the P-B ratio is greater than 1, but less than 2, the oxide film is passivating and offers protection from surface oxidation such as in titanium, aluminium and chromium.

During aluminium melting dross is generated, typically 15-25 kg of dross is produced per metric tonne of molten aluminium. Dross is classified into three different categories based on the metal content i.e., White, Black, and Salt cake. The main constituent of dross is aluminium metal, which varies from 10-90 % depending upon grades. Apart from aluminium metal, dross may also contain other chemical compounds e.g.  $Al_2O_3$ ,  $AlN$ ,  $Al_4C_3$ ,  $MgF_2$ ,  $NaAlCl_4$ ,  $KAlCl_4$ ,  $SiO_2$  and  $MgO$  etc.

**Table 1. Typical dross chemistry.**

SNO	Component	Percentage (%)
1	Aluminium oxide (non-fibrous)	10 - 90
2	Aluminium	10 - 90
3	Metal Chloride salts	0 - 40
4	Silicon	0 -23
5	Zinc	0 - 11
6	Copper	0 - 11
7	Metal Nitrides	0 - 10
8	Metal Carbides	0 - 10
9	Magnesium	0 - 10
10	Magnesium Oxide	0 - 10
11	Iron	0 - 10
12	Tin	0 - 7
13	Nickel	0 - 5
14	Manganese	0 - 2
15	Chromium	<1

## 2. Dross Management

It appears from literature that earlier processing of dross for recovery of aluminium metal content was not a concern. However, in recent years it has become an area of interest to the aluminium producers due to the large production of aluminium metal as well as dross. The recovery of metal from dross is done by conventional metallurgical process all over the world. It is generally considered that dross is waste, and is disposed after recovery of the metal content from it. The remaining portion of dross after recovery of metal is a threat to the eco-system because it contains many hazardous chemical compounds. In the process, the well-advocated claim of aluminium as “An Eco- Friendly” metal has a dark spot, which is damaging to the environment. Hence, it is necessary to minimize dross generation and the treatment of dross in an environmentally friendly manner.

There are three ways to handle the dross as below:

1. Minimizing the Dross Generation
2. Protect the hot dross from oxidation.
3. Process the dross without environmental impact.

### 2.1 Minimizing the Dross Generation

There are many steps to follow and some of the steps taken at Ma’aden are described below.

#### 2.1.1 Siphon Operation

- The siphon system consists of a Cast Iron Siphon tube, one end of which is lowered into the furnace through a port in the furnace sidewall. The other end lowers into a crucible of aluminium positioned alongside the furnace. With both ends immersed in aluminium, a vacuum is applied to the top end of the tube and the aluminium is pulled up the tube. The aluminium then carries on flowing from the crucible at high level, into the furnace at lower level (Figure 1).
- Surface turbulence causes aluminium oxidation together with physical entrapment of metal into the dross. Surface turbulence can occur at different stages of the process as, for example, during the transfer of hot metal during crucible handling, in launders, during furnace stirring and fluxing operations (Figure 2).
- The oxidation that occurs during metal transfer from crucible to furnace by a Metal Pouring Transport Vehicle (MPTV) or other vehicles can be minimized by using a siphon system. We have implemented the siphon system in Ingot furnaces, with 90 % of the metal transferred by siphon operation, which significantly reduced the dross generation in Ingot furnaces. The dross generation decreased from 1.5 % to 0.6 %; it varies based on the number of crucibles transferred by using the siphon system (Figure 3).



Figure 1. Metal pouring through siphon system.



Figure 2. Metal pouring through MPTV.

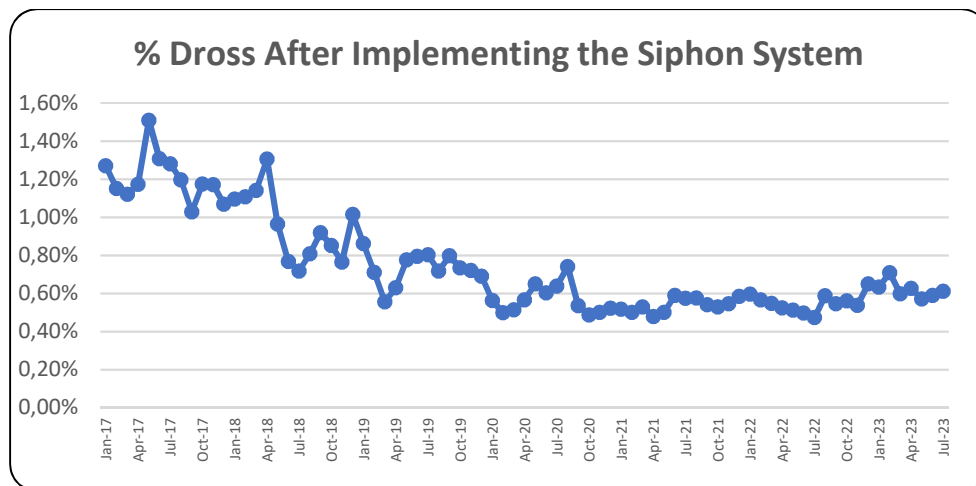


Figure 3. % Dross after implementing the siphon system.

### 2.1.2 Improving Furnace Practices

- Furnaces shall be prepared at controlled temperatures (less than 750°C) to minimize oxidation.

- Excessive stirring creates turbulence in the molten metal, which increases oxidation and dross generation.
- Proper stirring and skimming practices will minimize dross generation.
- Certain alloys (high magnesium) should be prepared in a controlled manner at a controlled temperature. Furnace preparation time is critical in high-Mg alloys, the longer the furnace preparation time, the higher the dross generation. High-Mg alloys are prepared at lower temperatures (below 750°C) in our plant.
- While skimming the dross, the dross has to be kept on furnace seal refractory to allow metal in the dross to return to the furnaces.
- Metal pouring is happening from the door, not from the sidewall of the furnace. Hence, the door opening time is critical in the billet and slab furnaces at Ma'aden.
- The team developed an auto-report recording the door-open-times per day. This focus door-open-time created awareness in the operation and changed behavior to close doors immediately after jobs are done.
- After skimming, dross is transferred to Dross cooling, which will help minimize the oxidation of dross and increase the metal content in the dross.
- The actual dross pan used in Ma'aden (Figure 4) does not have a bottom sow to collect the metal while skimming. The new design (Figure 5) will help recover some of the metal during skimming. Studies have shown that approximately 10 to 20kg of metal can be recovered from each batch, which adds up to ca. 350 mt/year. The new pans are being deployed in the casthouse.



**Figure 4. Existing dross pans.**



**Figure 5. New modified dross pans.**

### **3. Protect the Hot Dross from Oxidation**

Several methods are in use in the industry to cool down the dross but to avoid thermiting and oxidation from the hot dross, Ma'aden is using Inert gas dross cooling technology from STAS.

### 3.1 Dross Coolers

- As shown in Figure 6, this Alcan patented system is essentially composed of a container (pan) to hold and provide cooling for the dross and a cover (hood) to enclose both the container and the dross. This process also uses a chemically inert gas.
- The dross is skimmed off from the furnace directly into the specially designed pan. This pan, filled with hot dross, is rapidly placed under the hood. An inert gas, argon, is then injected in order to maintain a positive pressure under the hood and prevent any air infiltration. Deprived of oxygen, the exothermic oxidation reaction of the aluminium contained in the dross is prevented.
- By using dross coolers, the evaporation of dross and oxidation can be minimized, which will reduce the oxidation and increase the metal content in the dross. During the dross recycling process, the aluminium recovery will be high.
- Ma'aden is using Dross cooler for all three casting lines: Ingot, Billet and Slab casting (Figure 7).



**Figure 6. Dross cooler.**



**Figure 7. Dross coolers in Ma'aden Aluminium.**

### 4. Process the Dross Without Environmental Impact

- Ma'aden is using a new technology DROSRITE™ to process the dross in rotary furnaces. The process flow is shown in Figure 8. It is salt-free, cost-effective and sustainable and maximizes the recovery of aluminium [2]

- DROSRITE™ is a batch process where hot dross is introduced into an argon-filled rotary tilting furnace, quenching any oxidation reaction. The furnace rotates to separate out the metal phase from the non-metallic. The molten metal is removed and then returned to the holding furnace, while a controlled amount of oxygen is introduced to the furnace to heat up the non-metallic product (NMP) remaining in the residue. Some of the residues are then discharged, but the remaining residue, along with the heat build-up from the oxidation ensures that the furnace is ready to receive the next batch.

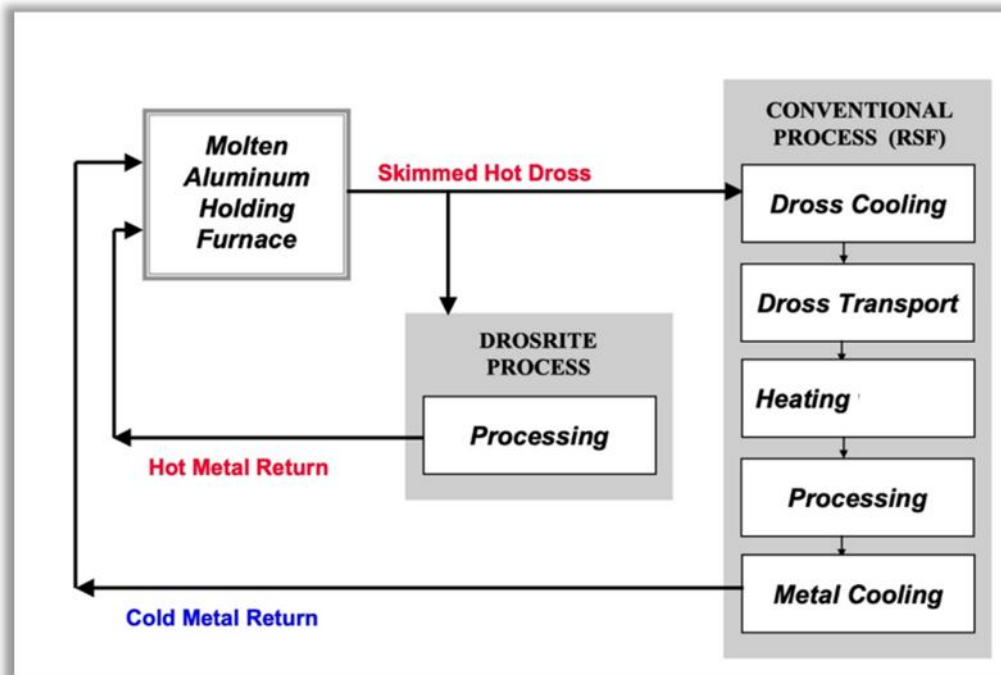


Figure 8. DROSRITE process flow.

- The metal recovery from the dross processing plant ranges from 39 % to a maximum of 55 %.
- Metal recovery depends on various factors, including skimming practices, alloy used, dross cooler performance, and the operator's skills in furnace preparation. The trend shown in Figure 8 exists of a mix of 1xxx, 3xxx, 5xxx, and 6xxx and pure aluminium P1020 dross. The metal content in the dross is slightly higher in 5XXX alloys due to the high Mg levels in these alloys.

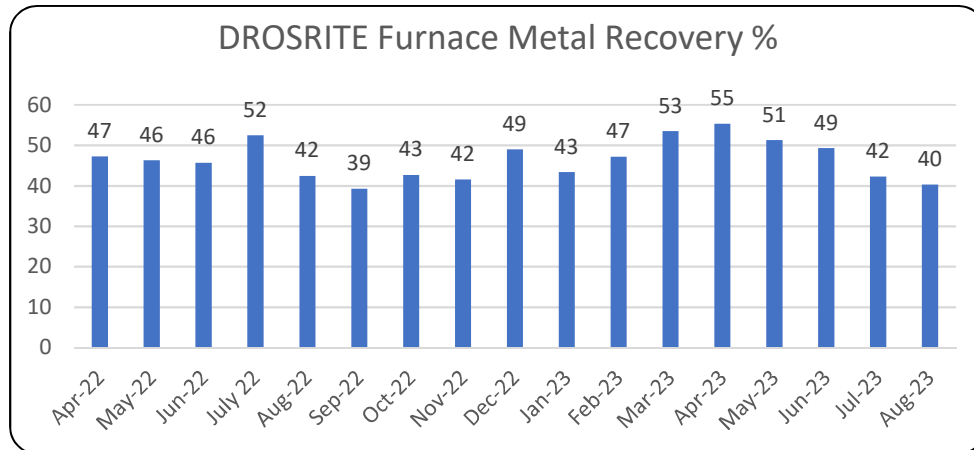


Figure 9. DROSRITE recovery.

## 5. Conclusion

- Dross is one of the highest single cost factors in a Casthouse and often, one of the least controlled costs. Through collective team effort and continuous improvement in the casthouse, dross generation is minimized through a collection of operational practices: in furnace operation, metal pouring, stirring, and skimming, as well as investment in state-of-the-art sustainable dross processing technology.
- Dross generation is reduced from 1.5 % to 1.03 % over a period of two years (Figure 10).
- A new Dross Recovery Plant is operational with an average of 45 % metal recovery across all alloys.

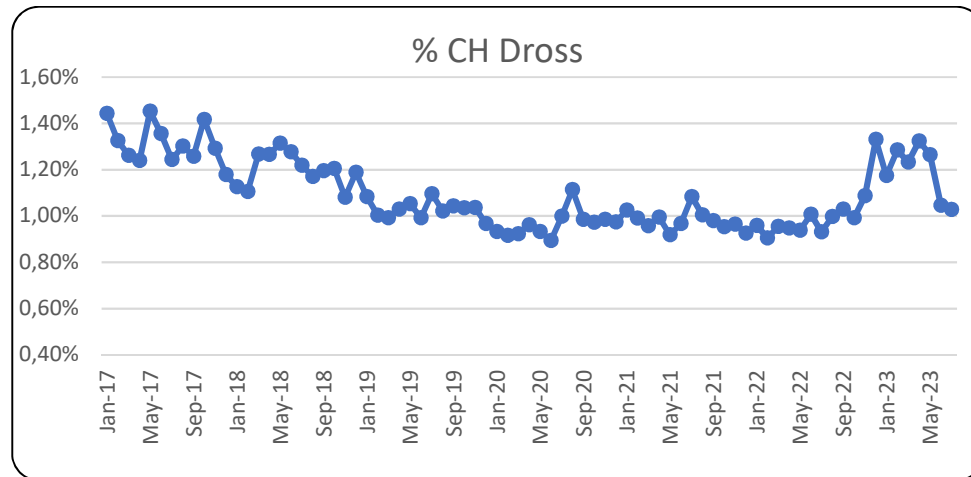


Figure 10. Casthouse dross trend in percentage

## 6. References

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