# Aluminum Oxidation

## A Friend at Room Temperature, A Foe in the Furnace

THOUGHT LEADERSHIP

Oxidation is a critical issue in aluminum foundry and die casting operations — the transition of aluminum oxide from a protective advantage at ambient temperatures to a costly liability at elevated temperatures.

Aluminum is renowned for its ability to form a thin, protective oxide layer almost instantaneously upon exposure to air. Under normal ambient conditions, this characteristic is advantageous, preventing further corrosion and enabling surface enhancements such as anodizing, which improves durability and aesthetic appeal.

However, at elevated temperatures — particularly in melting and holding furnaces used in foundries and die casting facilities — this same property becomes a costly operational challenge:

### The High-Temperature Downside:

- Dross Formation = Metal Loss
  The conversion of molten aluminum to oxide creates a layer of dross, a mixture of oxides and trapped metal that must be skimmed and discarded. This represents direct metal loss — meaning you must melt more metal than you actually use for castings.
- This dross layer is also an insulator reducing heat transfer into the molten bath, increasing chamber temperatures and energy usage as well as encouraging corundum formation.
- Corundum Growth
  At sustained high temperatures, aluminum oxide can form corundum ($Al_2O_3$) — a dense, hard material that adheres to and within furnace linings and increasing cleaning times.
- Corundum is second only to diamond in hardness making removal extremely difficult.
- Increased Cleaning Time and Downtime
  Accumulated dross and oxide buildup require frequent cleaning, increasing furnace downtime and labor effort.
- Refractory Degradation and Premature Reline
  Corundum formation, reactive oxide layers and increase flux usage chemically attack furnace refractories, accelerating wear and leading to early and expensive reline cycles — often well before the expected refractory lifespan.
- Poor refractory choices. Refractories containing higher levels of available Silica are prone to creating corundum growth within the lining wall when combined with high temperatures and oxidizing atmospheres.

NOTE: corundum can grow externally to the refractory surface within a furnace

4Al (l) + 3O2 (g) + Q (heat) = 2Al2O3 (s)

or internally into the refractory lining, replacing the aluminum silicate.

4Al (l) + 3SiO2 (s) + Q (heat) = 2Al2O3 (s) + 3Si (l)

When the growth is internal there is also a consequent volume growth of the corundum which can split the steel shell of the furnace.

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## What causes high oxidation and dross creation

Multiple factors combined are involved in the creation of oxides and dross in a melting and/or holding furnace including:

- Slow melting and insufficient energy to melt quickly.
- Air (oxygen) ingress into the holding chamber.
- Poorly adjusted burners running high excess air levels or ON/OFF radiant heaters at full power.
- Over rated holding burners creating high temperatures.
- Low bath levels increasing the distance to metal surface and consequent lower energy transfer and higher chamber temperatures.
- Overfilled bath level bring molten metal surface closer to heating source and risking flame impingement for fuel burners.
- Badly cleaned metal surface allowing oxide build up to insulate metal bath.
- Poorly designed burner / chamber arrangement creating turbulence in turn spreading oxides and metal droplets around chamber walls.

All of the above if left unchecked will result in the development of corundum and refractory destruction.

## Mitigation Strategies to Minimize Oxidation and Dross in Aluminum Furnaces

Effectively managing oxidation at high temperatures can lead to significant cost savings, longer refractory life, and improved metal yield. Below are proven methods used across modern foundries and die casting operations:

### Fluxing Agents

- Purpose: Remove non-metallic inclusions and reduce oxide films.
- Exothermic fluxes induce a reaction in the dross/oxide layer that increases to temperature releasing metallic aluminum and enabling more efficient removal of non-metallic oxides.
- Caution: Choose fluxes compatible with your alloy, refractory and furnace type to avoid contamination or excessive corrosiveness.
  - Excessive use of aggressive exothermic fluxes can damage furnace linings.

### Burner maintenance

- Maintaining correct burners settings avoids excess air (oxygen) being injected into the holding chamber.
- Operating melting burners ate their optimum power levels. Moderating melting burners simply ensures insufficient power to melt but enough to oxidise the charge material.

### Managing charge material

- The wrong or poor quality charge material can add to the oxide level in a furnace.
- Clean ingot is the best but may also containing oxides in shrink cavities in poor quality ingot.
- Aluminum oxidises rapidly in air so in house returns bring small amounts of oxides depending on surface area.
- External scrap and shred material with very high surface areas will bring excessive oxide contamination to the melt hearth.



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| Charge Material | Oxide Risk | Notes |
|---|---|---|
| Clean primary ingot | Low | Best option but still porous |
| In-house returns | Medium | Depends on surface area and process residues |
| External scrap/shred | High | High surface area = more oxides |

**Inert or Reduced-Oxygen Atmospheres**

- Limiting oxidation by controlling the furnace atmosphere through optimum burner setup, minimizing purge periods, and ensuring well maintained door seals helps.
- The use of nitrogen, argon, or a controlled vacuum to blanket the melt surface,

**Metal Movement Minimization**

- Why it matters: Every disturbance or agitation increases the melt's contact with oxygen, accelerating oxidation.
  - Maintaining consistent metal levels within a holding bath.
- Strategies:
  - Gentle charging and alloy addition practices.
  - Minimize turbulence during transfer.
  - Avoid over-stirring with flux paddles or tools.

**Thermal Coverings or Insulating Blankets**

- Application: Placed directly on the molten metal surface.
- Function: Forms a temporary barrier between the melt and air, reducing heat loss and oxidation simultaneously.

*Figure 1 Corundum growth on the refractory lining*

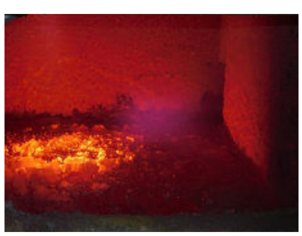

*Figure 2 Burner flame impingement creating open area and increased oxidation.*

**Protective Coatings on Refractory Surfaces**

- Benefit: Prevent direct contact between aluminum oxide and refractory linings
- Types: Zircon-based or spinel-bonded coatings designed to resist corundum formation and chemical attack.
- Outcome: Increases refractory life and simplifies furnace cleaning.

**Furnace Design and Lid Control**

- Impact: Open furnace lids lead to higher air ingress and oxidatio.n
- Improvements:
  - Use tight-fitting, insulated lids.
  - Automate lid movements to reduce operator-induced exposure.

**Regular Skimming and Maintenance Schedule**

- Why: Accumulated dross acts as a heat sink and oxidizer.
- Best Practice: Maintain a strict skimming schedule and monitor melt cleanliness with in-line or sampling-based analysis.

## Bottom Line:

Reducing dross isn't just about saving aluminum — it's about optimizing furnace performance, extending refractory life, reducing unplanned downtime, and ensuring consistent casting quality. Every kilogram of avoided dross is a win for profitability and process stability.

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