Common Crucible Failures and Causes

SELEE® Advanced Ceramics™ Technical Service

"Crucible failures are usually influenced by several failure modes. In order to maximize crucible life the primary mode of failure must be identified."

Crucible Modes of Failure:

1. Installation

- Cracking within the first several heats
  - Usually caused by the crucible not being held in compression due to poorly packed ram due to improper ramming procedure or tools. Refer to SELEE® Advanced Ceramics™ Technical Service Guide IM2, Crucible Installation for Induction Melting, for recommended installation procedures and tools.
  - Narrow particle size distribution in ram results in inferior particle packing, which leads to poor crucible packing. A ram with a wide particle size distribution has coarse, intermediate, and fine-grained materials to fill in voids resulting in maximum packing density.
  - Insufficient ram thickness does not allow enough material to hold crucible in compression.
- Uneven wear or increased wear
  - Crucible is not installed level, causing one side to erode more during the melt.
  - Crucible is not positioned in center of furnace making one side of the crucible cooler than the other, generating uneven wear.
  - Coil condition is not examined before installation of crucible. Coils must be working properly in order to cool crucible evenly. If they are not, the crucible superheats and decreases in strength, which causes an increase in wear or uneven wear.
  - Excessive ram thickness causes insufficient cooling of the crucible.

2. Thermal Shock

- Thermal shock cracks include, but are not limited to, bottom radial cracks and horizontal side wall cracks. However, horizontal side wall cracks can also be caused by improper installation.
  - No or insufficient preheat, as a crucible is heated the inside of the crucible expands more than the outside creating uneven stresses that crack the crucible.
  - Forced cooling creates uneven contraction of the refractory resulting in stresses that crack the crucible. Refer to SELEE® Advanced Ceramics™ Technical Service Guide IM3, Operational Guidelines for Crucibles Used in Induction Melting.
  - Coils located too close to the crucible cool the crucible unevenly at point contacts rather than removing heat through the ram. This results in thermal shock cracks that follow the same spacing as the coils. To overcome this, a smaller crucible is necessary so there is a thicker layer of ram to lessen this effect.
  - A low metal level in the crucible causes a large enough thermal gradient between the melt line and the top of the crucible that creates a thermal shock crack.

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3. Mechanical Stress

- Charging
  - Ingots dropped into the crucible may cause mechanical failure due to impact, which cracks the bottom of the crucible and breaks off chunks of material, which float up during melting.
  - Bridged metal and wedged ingots crack the crucible since metal expands more than the refractory. To eliminate such problems, the crucible should not be overloaded upon initial heat up to ensure metal is not bridged or wedged.
  - A leftover heel of metal in the bottom of the crucible may crack the crucible upon heat up due to the difference in expansion between the metal and the crucible.
- Cleaning
  - Ceramics are brittle and care must be taken when cleaning so the crucible is not damaged.
  - Abusive cleaning causes cracks and loose chunks of refractory in a melt.
- Erosion
  - Excessive hold times result in excessive erosion. When holding at a temperature, the metal is in constant motion continually eroding the refractory. Once the heat is up to temperature, the power should be turned off and the metal should be poured to maximize refractory performance.
  - Always turn power off when in the tilt position. When the power is left on the crucible shows uneven wear since the power keeps the metal in motion eroding the refractory on the one side.

4. Chemical Attack

- Signs of chemical attack are an increase in erosion (decrease in life), or an increase in slag.
  - Chemical attack is due to improper material selection for the alloy being melted. Refer to SELEE Advanced Ceramics Technical Service Guide IM1, Crucible and Ram Selection for Induction Melting.
  - Additions or over additions of de-gassing additives produce chemical attack of the refractory if the flux is incompatible with the refractory.
  - Slag conditioners are generally comprised mostly of SiO_2, which is acidic and reacts with neutral and basic refractories, which causes chemical attack.
  - Always use slag conditioners sparingly with one application, turn power off and remove with slag rod.

When faced with crucible failures, first determine the type of failure. Was the failure cracking, erosion or chemical attack? Then, always review the entire process from installation to operational use to determine the primary mode of failure since the failure is usually influenced by all failure modes.

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