SOLBERG®
Filtration - Separation

Training Paper
Vacuum Arc Remelting (VAR) Manufacturing Processes

TR-VAR-BE0916

What is VAR

VAR is a consumable electrode remelting process performed inside a vacuum chamber. Exposure of molten metal droplets to vacuum reduces free gas content in the steel providing a cleaner product with little segregation. Consistently higher yields and reproducible metals are assured through fully automated computer/load cell control throughout the remelt process eliminating the need for operator intervention. The end product is a dense ingot with minimum segregation and very low hydrogen and oxygen levels.

VAR is widely used to improve the cleanliness and refine the structure of standard air-melted or vacuum induction melted ingots, then called consumable electrodes. VAR steels and superalloys as well as titanium and zirconium and its alloys are used in a great number of high integrity applications where cleanliness, improved fatigue and fracture toughness of the final product are essential. Aerospace, power generation, defense, medical and nuclear industries rely on the properties and performance of these advanced remelted materials.

VAR is used most frequently in high value applications. Essentially it is an additional processing step to improve the quality of metal. Because it is both time consuming and expensive, a majority of commercial alloys do not employ the process. Nickel, titanium, and specialty steels are materials most often processed with this method. The conventional path for production of titanium alloys includes single, double or even triple VAR processing. Use of this technique over traditional methods presents several advantages:

- The solidification rate of molten material can be tightly controlled. This allows a high degree of control over the microstructure.
- The gases dissolved in liquid metal during melting in open furnaces, such as nitrogen, oxygen and hydrogen are considered to be detrimental to the majority of steels and alloys. Under vacuum conditions these gases escape from liquid metal to the vacuum chamber.
- Elements with high vapor pressure such as carbon, sulfur, and magnesium (frequently contaminants) are lowered in concentration.
- Centerline porosity and segregation are eliminated.
- Certain metals and alloys, such as Ti, cannot be melted in open air furnaces

Process Description

The alloy to undergo VAR is formed into a cylinder typically by vacuum induction melting (VIM) or ladle refining (airmelt). This cylinder, referred to as an electrode is then put into a large cylindrical enclosed crucible and brought to a metallurgical vacuum (0.001–0.1 mmHg or 0.1–13.3 Pa). At the bottom of the crucible is a small amount of the alloy to be remelted, which the top electrode is brought close to prior to starting the melt. Several kiloamperes of DC current are used to start an arc between the two pieces, and from there, a continuous melt is derived. The crucible (typically made of copper) is surrounded by a water jacket used to cool the melt and control the solidification rate. To prevent arcing between the electrode and the crucible side walls, the diameter of the crucible is larger than that of the electrode. As a result, electrode must be lowered as the melt consumes it. Control of the current, cooling water, and electrode gap is essential to effective control of the process, and production of defect free material.

Ideally, the melt rate stays constant throughout the process cycle, but control of the process is not simple. This is because there is very complex heat transfer going on involving conduction, radiation, convection (within the liquid metal), and advection (caused by the Lorentz Force). Ensuring the consistency of the melt process in terms of pool geometry, and melt rate is pivotal in ensuring the best possible properties from the alloy.

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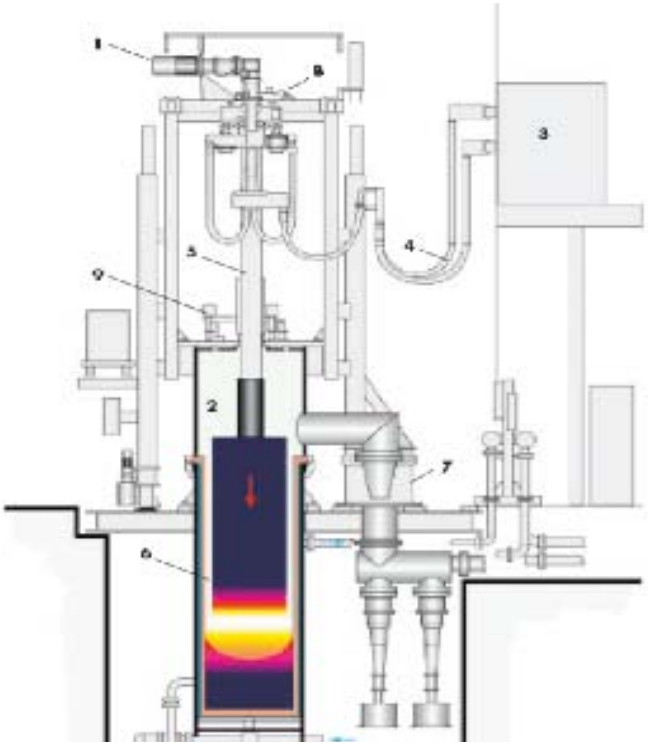

Schematic of the VAR furnace
1 Eletrode feed drive
2 Furnace chamber
3 Melting power supply
4 Busbars / cables
5 Electrode ram
6 Water jacket with crucible
7 Vacuum suction part
8 X-Y adjustment
9 Load cell system

Solberg Filtration Solutions for VAR

Solberg designs and manufactures state-of-the-art inlet vacuum filters that protect vacuum pumps from contamination in VAR processes. Our experience with VAR applications has led us to the conclusion that our standard CSL line will often provide a low cost effective solution.

Our filters are perfectly suited for the rugged steel processing environment and include the following features :

- Heavy duty industrial construction in carbon and stainless materials.
- Ease of servicing without having to disturb pipe work
- Robust pleated cartridge design to provide excellent integrity and maximize surface area.
- Helium leak tested as required
- Choice of vacuum flanges
- Multiple media options to suit varied process environments including high temperatures.
- Optional gauges to monitor cartridge condition along with cleanable cartridges

Typical Filter Canister

Typical Filter Cartridge

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Design Examples

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