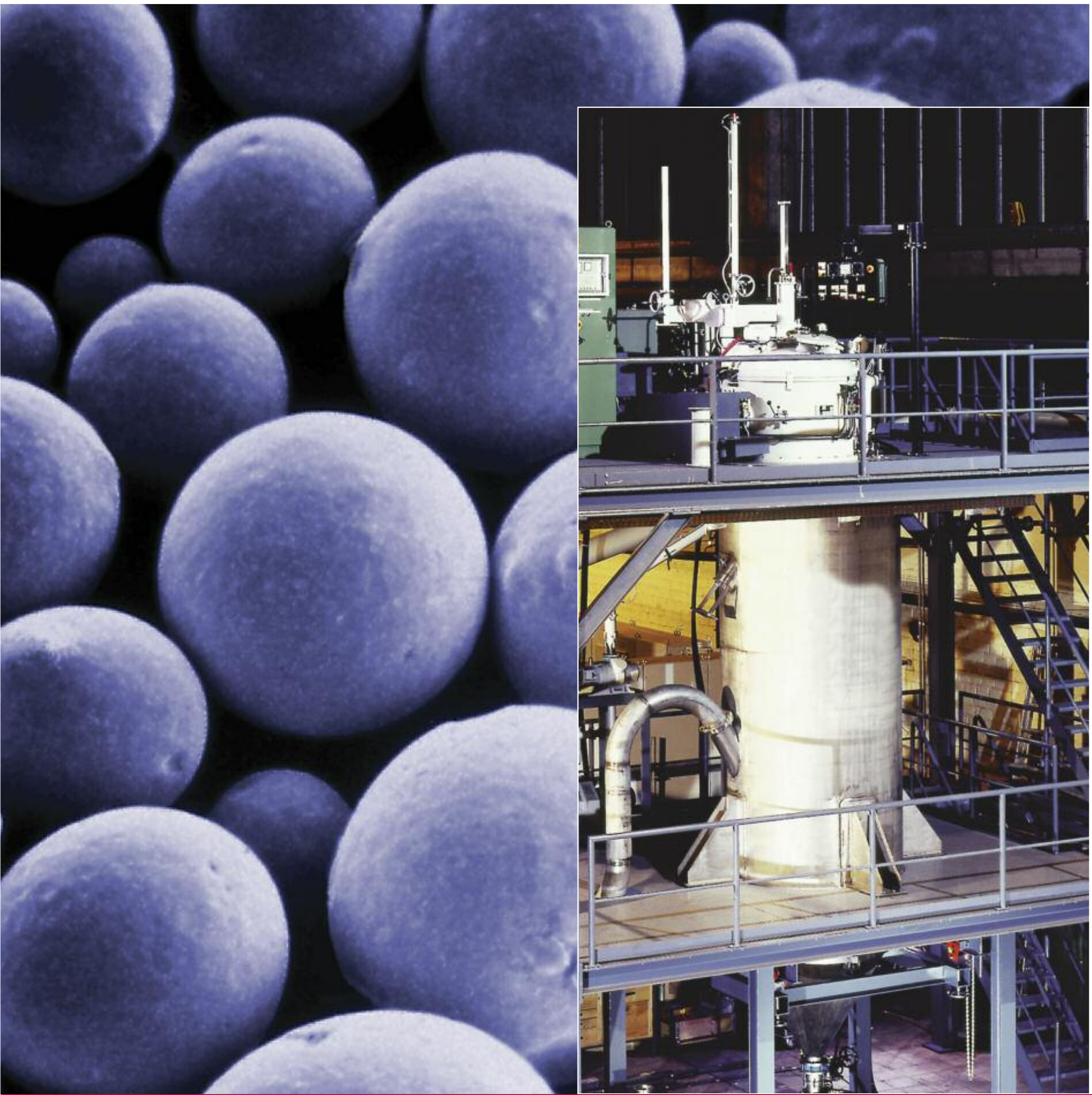


Metal Powder Technology

Vacuum Induction Melting and Inert Gas Atomization
Ceramic-Free Metal Powder Production
Inert Gas Recycling

METAL POWDER TECHNOLOGY

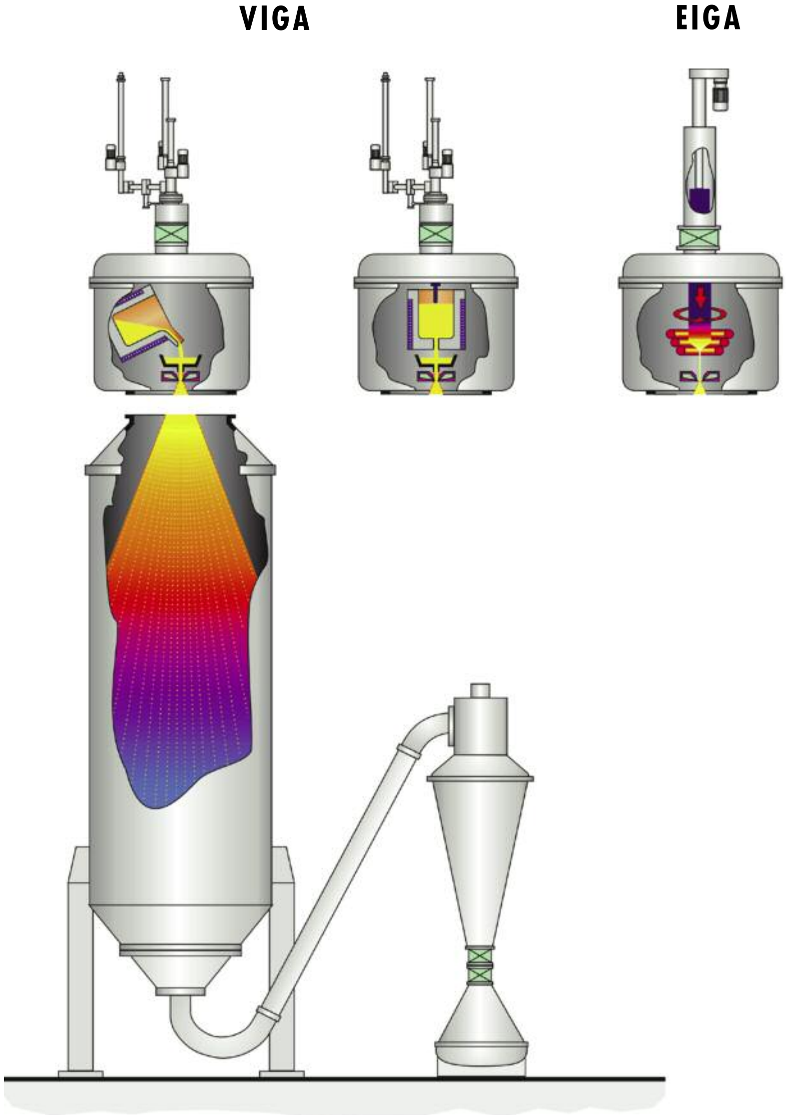
Metal powder technology is one of the most established production methods nowadays in all kinds of industries.

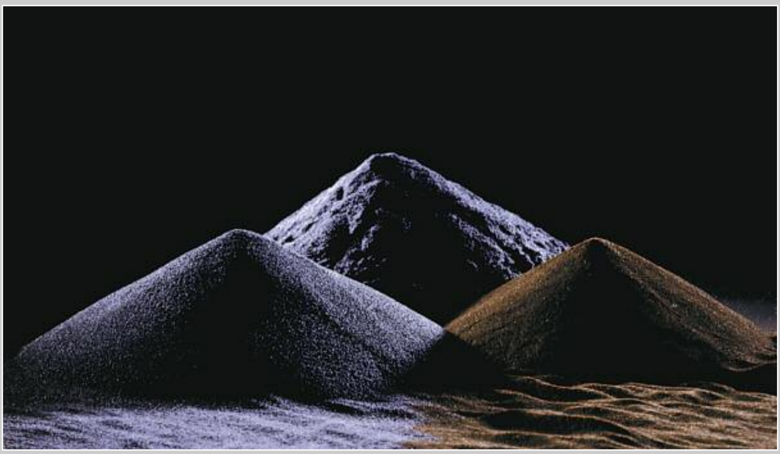
The process steps involved in the production of metal powders are melting, atomizing and solidifying of the respective metals and alloys. Metal powder production methods such as oxide reduction and water atomization, are limited with respect to special powder quality criteria, such as particle geometry, particle morphology and chemical purity.

Inert gas atomization, combined with melting under vacuum or under protective atmosphere therefore is the leading powder-making process for the production of high-grade metal powders which have to meet specific quality criteria such as:

- Spherical shape;
- High cleanliness;
- Rapid solidification;
- Homogeneous microstructure.

ALD has the capability to combine various melting technologies with inert gas atomization which enables the production of superalloys, superclean materials and additionally reactive metals.

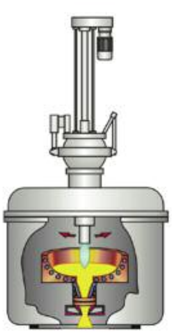




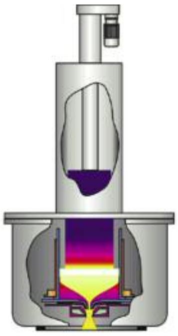
Metal powder technology - an established production method for all kind of industrial applications

VIGA Production Unit
Inert Gas Atomization Plant

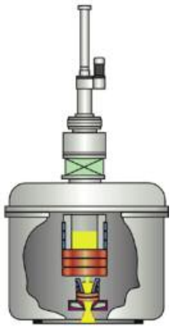
PIGA



ESR-CIG



VIGA-CC



ALD has developed through over 30 years in gas atomization technology process know-how to atomize a broad range of materials for various applications. Each particular application needs a special particle shape and powder morphology.

With the right adjustment of the process parameters it is possible to cover a wide range of desired powder size distributions and to meet the demands for various applications.

The following pictures show some examples for different types of alloys.

- Solder/Brazing/Precious Alloys
- Iron-based- and Superalloys
- Refractory and Reactive Metals

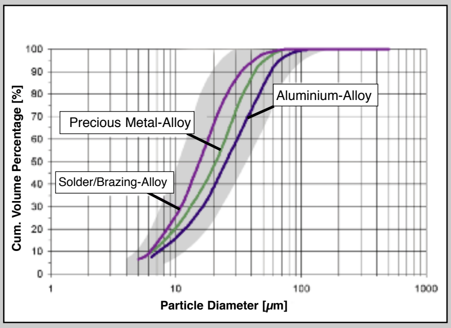
Melting Alternatives in Metal Powder Production

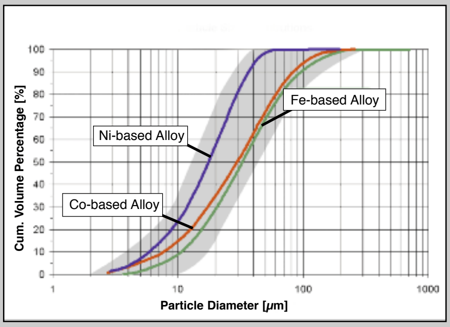
- VIGA: Vacuum Induction Melting combined with Inert Gas Atomization;
- EIGA: Electrode Induction Melting Gas Atomization;
- PIGA: Plasma Melting Induction Guiding Gas Atomization;
- ESR-CIG: Electroslag Remelting Coldwall Induction Guiding;
- VIGA-CC: Vacuum Induction Melting based on Coldwall Crucible Melting Technology combined with Inert Gas Atomization.

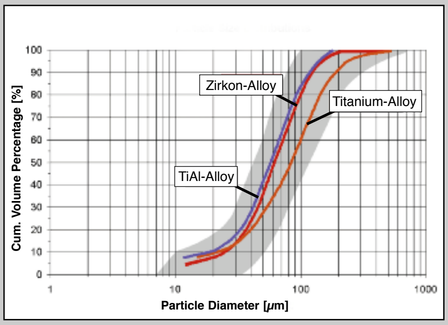
Metal Powder Applications:

- Ni-base superalloys for the aviation industry and power engineering;
- Solders and brazing metals;
- Hydrogen-storage alloys;
- Wear-protection coatings;
- Thermal Spray coatings;
- MIM powders for components;
- Magnetic alloys;
- Sputter target production for electronics.

Particle Size Distribution of various Alloys







Solder/Brazing/Precious Alloys

Solder, Brazing and Precious Alloys have a high quality demand with regard to particle size and particle morphology. Especially solder/brazing alloys need fine powders with a low percentage of agglomerated particles.

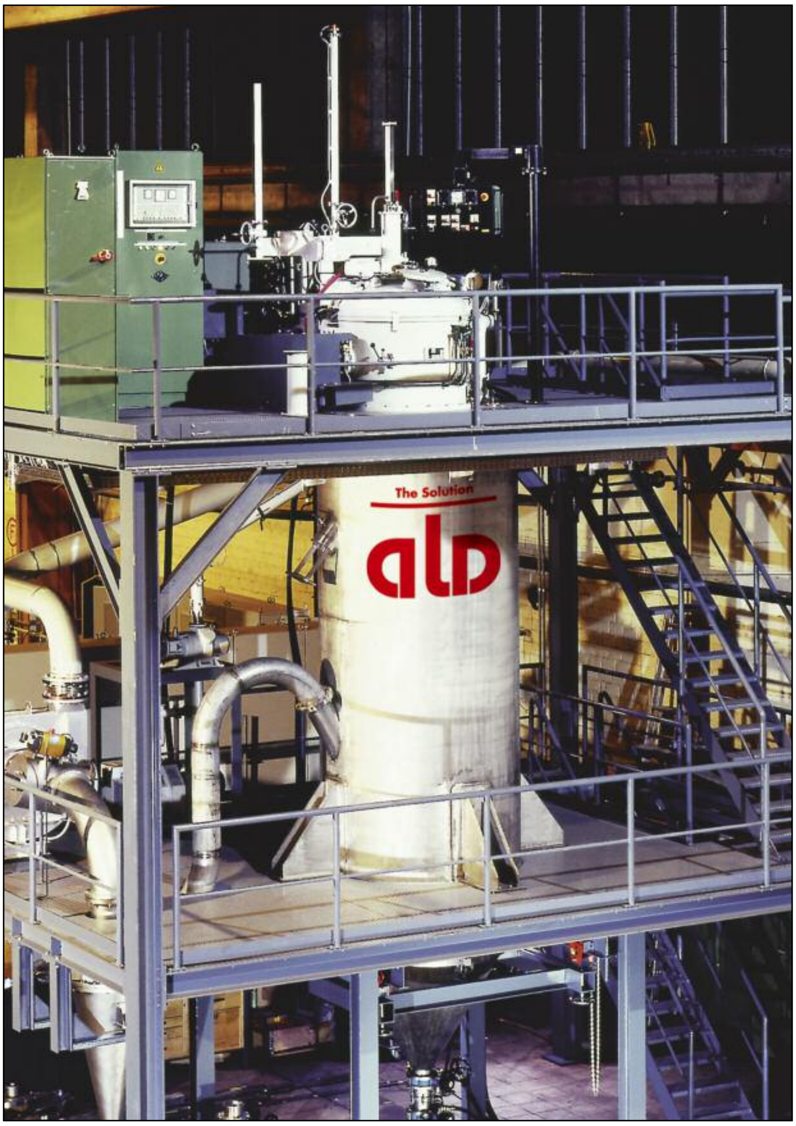
Iron-based- and Superalloys

Plasma Spray powders for special coatings, powders for MIM applications as well as Superalloy powder for aerospace applications are covered by ALD's atomization technology.

Refractory and Reactive Metals

Atomization of refractory and reactive metals with high melting temperatures (up to 2000 °C) is carried out with a ceramic free melting and atomization technology. The atomization takes place in a specially designed free-fall-atomization nozzle configuration.

Vacuum Inert Gas Atomization System (VIGA)

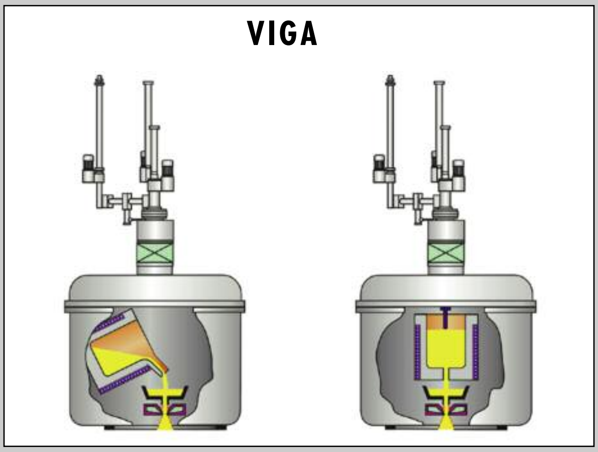


Vacuum Inert Gas Atomization System (VIGA)

The standard design of a vacuum inert gas atomization (VIGA) system comprises a Vacuum Induction Melting (VIM) furnace where the alloys are melted, refined and degassed. The refined melt is poured through a preheated tundish system into a gas nozzle where the melt stream is disintegrated by the kinetic energy of a high pressure inert gas stream. The metal powder produced solidifies in flight in the atomization tower located directly underneath the atomization nozzle. The powder gas mixture is transported via a conveying tube to the cyclone where the coarse and the fine powder fractions are separated from the atomization gas. The metal powder is collected in sealed containers which are located directly below the cyclones.

ALD has developed atomization systems where a variety of melting processes can be combined with inert gas atomization. The atomization systems built by ALD have a modular design and are applicable from laboratory scale (1 – 8 l crucible volume), through pilot production (10 – 50 l crucible volume) up to large-scale atomization systems (with 300 l crucible volume).

Operator platform with state-of-the-art process visualization



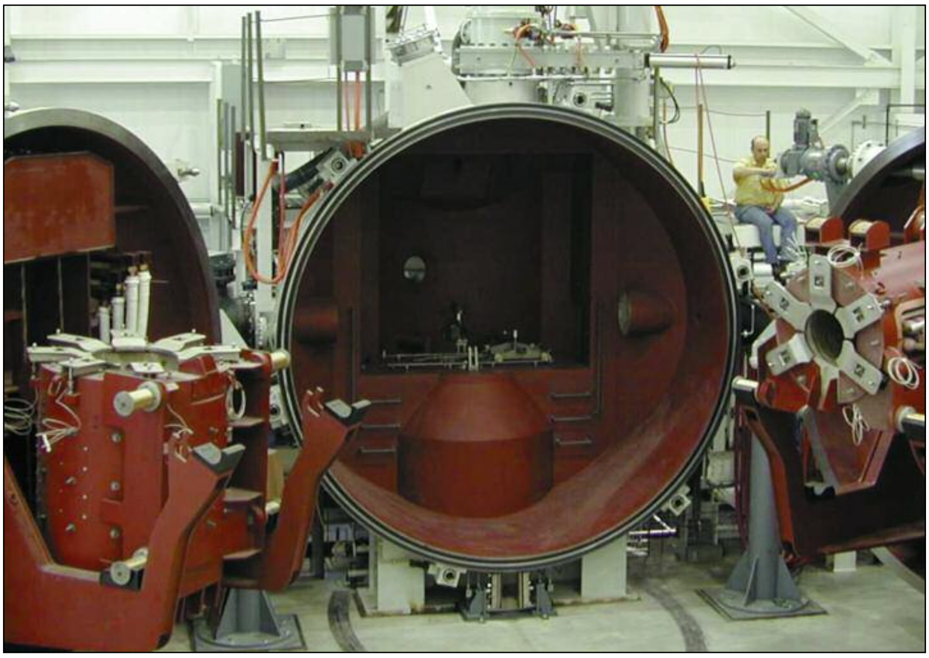
With Tilting Crucible

With Bottom Pouring Crucible

Large Scale VIGA Atomization Unit

The photo on this page shows a large scale inert gas atomization system. The melting crucible of this production atomization system has a maximum capacity of 2 tons. The atomization tower is connected to a melt chamber with a double-crucible door arrangement. Each furnace door is equipped with a vacuum induction melting furnace. This design allows very fast crucible changing. While one crucible is in production the second crucible can be cleaned or relined in stand-by position. This minimizes the down time for furnace change operations. Additionally, the double-door design enhances the production flexibility, because different furnace sizes can be used in the same equipment. The melting chamber is equipped with a bulk charger, two temperature measuring devices and a redundant tundish system.

The redundant tundish configuration allows a high flexibility in case clogging of the outlet nozzle occurs. In that situation, the second preheated tundish nozzle system which is in stand-by position can be moved into the atomization position to continue the process. Each pouring tundish, including the gas nozzle arrangement, is mounted on a tundish cart.



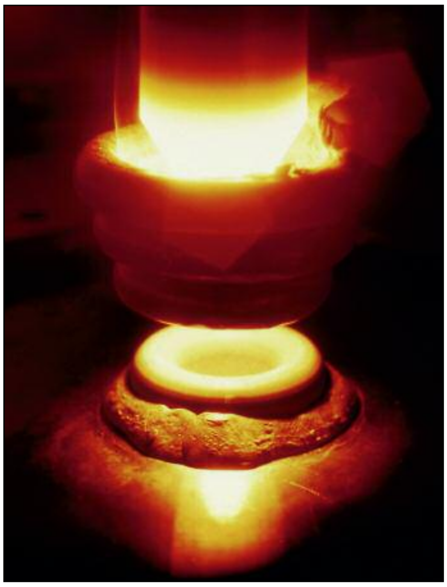
Double-door crucible VIGA atomization unit with redundant tundish systems
Each vacuum induction furnace has a rated batch capacity of 2,000 kg.
A gas recycling system recovers the inert gas for reuse.

The tundish cart can be moved sideways to a location for loading and unloading without venting the system and without breaking the ambient atmosphere.

Schematic design of a large scale atomization unit with a double-door melting furnace chamber

Powder collection system of a large-scale atomization unit

Ceramic-Free Metal Powder Production



Due to the contact between the melt and the ceramic lining and nozzle material, in standard VIGA systems ceramic inclusions in the melt can occur, which influence the material properties of high-strength PM-components in a negative manner. Reactive metal powders, such as titanium based alloys, can not be produced with this method at all, due to the reactions between the reactive melt and the ceramic lining. In order to overcome the "ceramic problem" it is necessary to use melting techniques where the melt is not in contact with ceramic lining material. Additionally, a refining of the melt during the melting process would be desirable. Typical materials that need ceramic-free production processes are refractory and reactive materials, such as Ti, TiAl, FeGd, FeTb, Zr and other materials.

EIGA

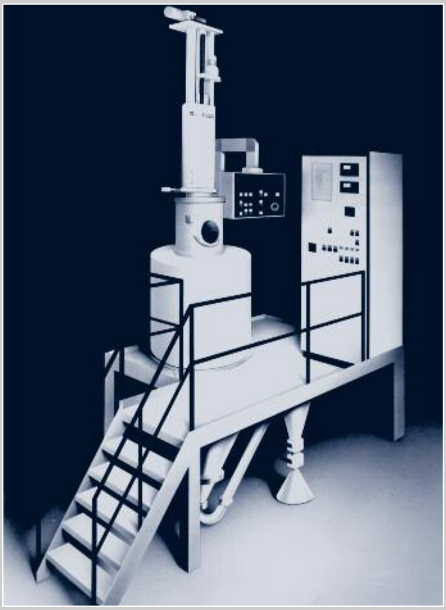
In the EIGA process, prealloyed rods in form of an electrode are inductively melted and atomized without any melting crucible at all. The melting of the electrode is accomplished by lowering the slowly rotating metal electrode into an annular induction coil.

The melt droplets from the electrode fall into the gas atomization nozzle system and are atomized with inert gas. The EIGA process was originally developed for reactive alloys such as titanium and high-melting alloys. It can also be applied to many other materials.

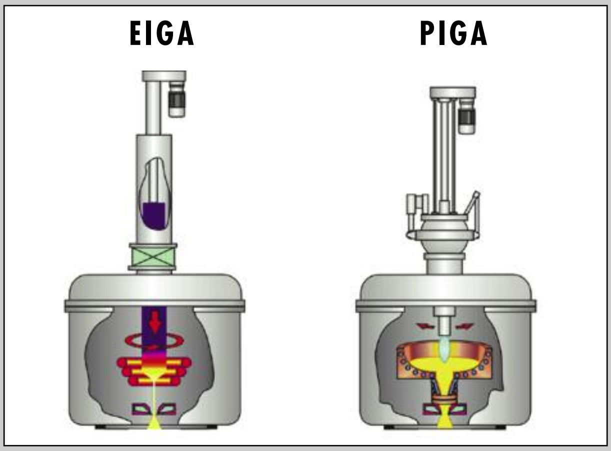
PIGA

For the production of ceramic-free powders and for the atomization of reactive, and/or high-melting alloys, melting can also be accomplished by means of a plasma burner in a water-cooled copper crucible. PIGA stands for plasma-melting induction-guiding gas atomization.

The bottom of the PIGA crucible shown below is connected with an inductively heated discharge nozzle, also made of a copper base material. This ceramic-free discharge nozzle system guides the liquid metal stream into the gas atomization nozzle, where it is disintegrated by the inert gas.



Electrode Induction Melting Gas Atomization System



Electrode Induction Melting Gas Atomization (EIGA)

Plasma Melting Induction Guiding Gas Atomization (PIGA)

ESR-CIG

High performance superalloys for the aircraft industry are typically produced via the so-called “triple melt process”. In the triple melt process the refining of the material is carried out by the reactive slag in the ESR melting step. The combination of the ESR remelting technique with a ceramic-free melt guiding system (CIG) represents a process technology to produce powder material with a high level of cleanliness and chemical homogeneity.

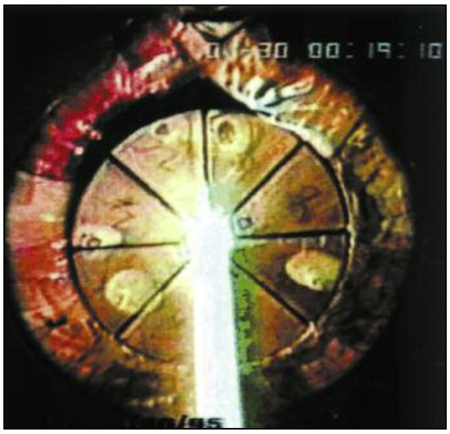
In the ESR-CIG process, the material to be atomized is fed in form of an electrode. The electrode is lowered into the metallurgical refining slag. As the electrode tip is melted at its point of contact with the slag, droplets of the refined metal are formed and these droplets pass down through the reactive slag layer.

The refined metal droplets which pass through the reactive slag form a liquid melt pool underneath the slag layer. The melt pool is enclosed by a water-cooled crucible made of copper. The refined liquid metal is guided through the cold-wall induction guiding system and is disintegrated by a high kinetic inert gas stream in a free-fall-type gas nozzle.

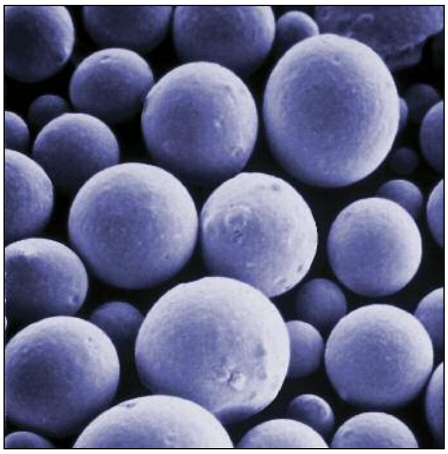
Besides powder production, the disintegration process of the liquid metal stream can be used to collect the spray droplets to form a so-called spray formed billet. The collection during the sprayforming process is shown in the picture below.

VIGA-CC

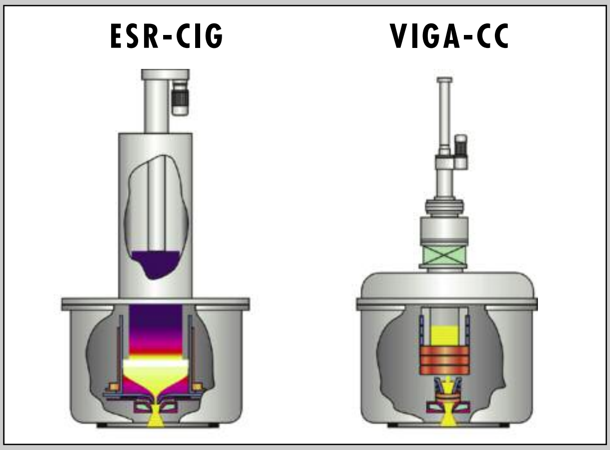
Reactive alloys like titanium or intermetallic TiAl alloys can also be melted in a copper-based cold wall induction crucible which is equipped with a bottom pouring system. The bottom pouring opening of the cold crucible is attached to a CIG system. The bottom pouring opening of the cold crucible is attached to a Coldwall Induction Guiding (CIG) System.



Molten metal stream out of CIG system before entering the high pressure gas nozzle

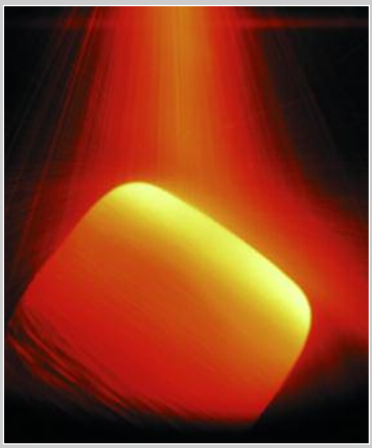


Particle shape of high grade metal powder



Electroslag Remelting Coldwall Induction Guiding (ESR-CIG)

Vacuum Induction Gas Atomization based on Coldwall Crucible Melting Technology (VIGA-CC)



Collection of atomized particles to a sprayformed billet

Inert Gas Recycling

At a certain batch size of the atomization system, recycling of the inert gas is recommended, to reduce the total inert gas consumption and thus achieve a more economical production process. ALD offers two different process technologies to recycle the inert gas.

Inert Gas Recycling Based on Compressor Technology

One method of reusing the inert gas is to "drive" the gas in a closed gas circulation loop, using a suitable compressor unit. Behind the cyclone and the filter system, the "dust-free" gas is repressurized using a 2-stage compressor unit. The compressors have to be gastight to prevent contamination of the recirculated inert gas. After each compressor, a gas buffer tank is used to minimize pressure fluctuations during the atomization process. This results in stable atomizing process conditions with respect to atomization pressure and gas-flow rate.

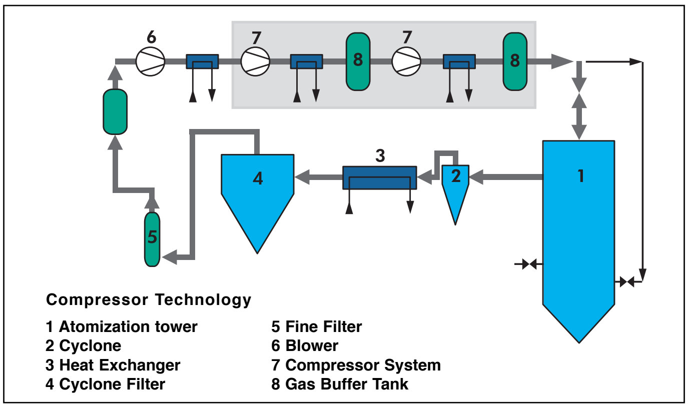
In case the permissible impurity levels in the atomization gas are set very low, the oxygen, hydrogen and nitrogen contents can be measured at several locations in the gas circulation loop.

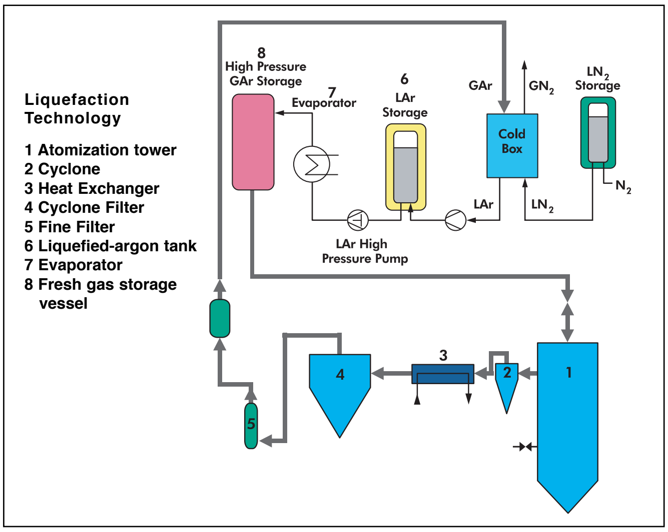
For large-scale atomizing systems this type of gas recycling is economically operated in a pressure range up to 50 bar.

Argon Recycling Based on Liquefaction

To achieve a higher gas supply pressure, the recycling concept described above has to be changed to the principle of reliquefying the argon by using evaporating liquid nitrogen as the refrigerant. In this situation, the 2-stage compressors with the pulsation buffer are replaced by a concurrent flow argon liquifier and a set of high-pressure liquid argon pumps.

Argon recycling system based on liquefaction





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