



CONSARC

An Inductotherm Group Company

Induction Skull Melting Furnaces

ISM — The Process

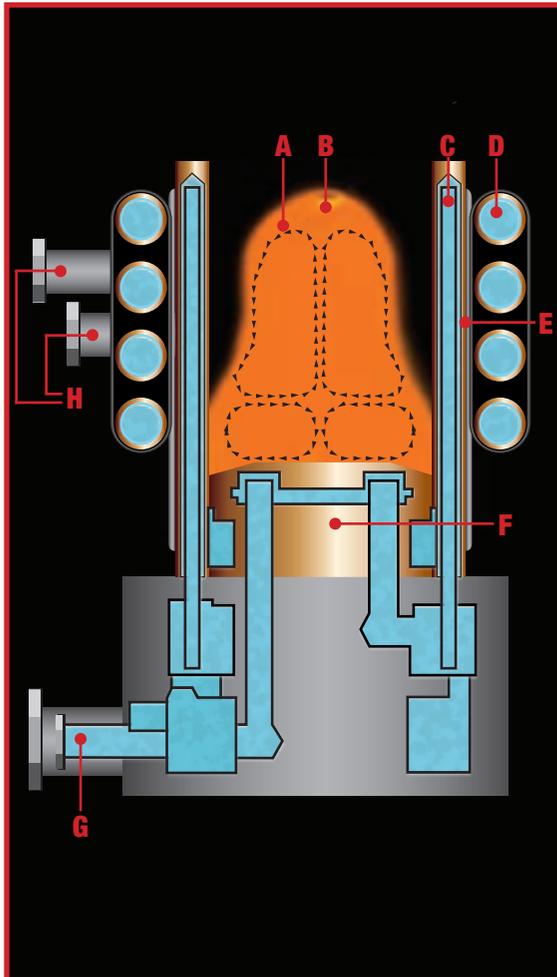
Induction Skull Melting ISM is a method of melting metals in a segmented, water-cooled copper vessel while under vacuum or controlled atmosphere using an induction coil. This is done metal-to-metal, without a refractory lining.

The copper crucible is made up of water-cooled segments or “fingers.” The magnetic field produced by the coil, in effect, passes through the crucible to induce heat in the metal charge causing it to melt. The field also intensely stirs the liquid metal pool in the pattern shown in the diagram. The stirring promotes a very homogenous melt pool and effectively distributes even higher density alloying elements evenly throughout the poured casting.

A thin layer of metal remains frozen against the bottom of the crucible forming a skull. The low velocity boundary layer in the liquid adjacent to the skull, together with the skull itself and the interface (joint) between the skull and the crucible all serve as thermal resistances, reducing the heat conducted from the hot liquid into the cold crucible.

When the crucible, coil, frequency, and power level are all properly designed and matched, the sides of the liquid metal pool are pushed inward, away from the interior sidewalls of the crucible. In effect, the sides of the pool are supported magnetically. The absence of physical contact with the sidewalls prevents the crucible segments from electrical shorting and further reduces the heat loss into the crucible.

The process is most often used in casting with over the lip pouring, but it can also be used in ingot production. In this case, open-bottom crucibles with a drawn down starter plug are used to slowly withdraw an ingot from top fed charge material.



- A Stirring Pattern**
- B Molten Titanium Pool**
- C Water Cooled Crucible Wall Segment**
- D Water Cooled Induction Coil**
- E Copper Crucible Barrel**
- F Copper Crucible Base plate**
- G Crucible Cooling Water In/Out**
- H Coil Cooling Water In/Out**

Induction Skull Melting Furnaces

Background – Exclusive Licensee of the Patent Holder

In 1985, Consarc entered into an agreement with the company that patented the Induction Skull Melting (ISM) process to be the exclusive worldwide licensee to promote the ISM Technology. Since that time Consarc has continuously strived to improve, develop and refine the ISM Technology to increase its efficiency. We developed correlations between materials melted and power levels, frequencies and crucible diameters. Consarc has pioneered new manufacturing techniques for ISM crucibles, and as a result have increased the crucible life by orders of magnitude. We also developed processes for maximizing superheat, and minimizing skull weight. The fully computerized controls provide a user-friendly interface and optimize repeatability and ease of operation. Our early collaboration with the patent holder and relationship with Inductotherm helped us develop power supplies specifically suited for the ISM process and positions us as the most experienced resource for Induction Skull Melting equipment



Induction Skull Melting Furnaces

Consarc designs, engineers, and builds a wide range of advanced vacuum and controlled atmosphere furnace technologies for the processing of metals, specialty alloys, and engineered materials.

Some Features of the Modern Consarc ISM Furnace are:



- Robust segmented copper crucible machined from a single forging
- Crucible life of tens of thousands of heats
- Frequency matched Inductotherm ISM power supplies
- Ability to make alloy additions
- Ability to superheat the molten bath
- Centrifugal casting available for thin walled sections
- Single chamber batch or multiple chamber semi continuous designs
- Vertically or horizontally oriented systems
- Systems interchangeable with traditional induction furnaces utilizing ceramic crucibles

Consarc and its technology partners have experience in melting over 3,000 different alloys in ISM. Pour weights from 1 kg to over 200 kg are available.

Alloys Melted with ISM

Below are some of the alloys that have been melted with ISM.

Titanium Based	Others	Nickel Based
Ti (Grades 1, 2, 3, 4)	Zr (Pure, Grade 702)	Pure Ni
Ti-.15 Pd (Grades 7, 8)	Zr 2.5 Nb (Grade 705)	NiAl
Ti 6-4 (ELI and Grade 5)	Zircalloy II	Ni ₃ Al
Ti 6-2-4-2	Custom Zr Alloys (20 alloys)	In718
Ti 15-3-3-3	Pure Cr	In713C
Ti 3-8-6-4-4	Nb based alloys	C101
Ti .3Mo-.8Ni (Grade 12)	Pure Cu and alloys	Ni Alloys
Ti 6-6-2	Pure Al and alloys	
Ti 5-2.5	DC8 (Colbalt alloy)	
Ti 5-2.5 ELI	Sn Alloys	
Proprietary Beta Alloys (Over 50 alloys)	Fe Alloys	
Ti-45Nb and alloys		
Ti 55 Ni and alloys		
Ti ₃ Al (Alpha-2, over 100 alloys)		
TiAl (Gamma, over 600 alloys)		
TiAlNb (Over 20 alloys)		

Furnace Designs

Consarc provides four different design styles with the ISM furnace. Each design has its own benefits and features which allow the customer to choose a suitable design based on their casting requirements. As a custom furnace manufacturer, we are accustomed to designing around Customer specific needs and requirements.

SINGLE CHAMBER

- Excellent for R&D and Prototype Facilities
- Centrifugal Casting
- Low Overhead Clearance
- Small Footprint
- Flexible
- Upgradable to a Tandem Unit
- Lowest Cost

TANDEM CHAMBER

- Independent Units Sharing a Power Supply
- Maximum Utilization of Power Supply
- High Throughput even in a Batch Operation
- Built in Redundancy with Two Melt Chambers
- Centrifugal Casting
- Low Overhead Clearance

TWO CHAMBER HORIZONTAL

- Semi-continuous operation
- High Throughput
- No Vacuum Break to Re-charge Furnace
- Good for Alloys Requiring High Vacuum Melting
- Centrifugal Casting

TWO CHAMBER VERTICAL

- Semi-continuous operation
- High Throughput
- Conventional, Robust Casting Design
- No Vacuum Break to Re-charge Furnace
- Good for Alloys Requiring High Vacuum Melting
- Pit Required
- Higher Overhead Clearance Requirement
- Centrifugal Casting is Difficult



Advantages of Casting with ISM



Skull after pouring

The ISM process has some inherent advantages over the Vacuum Arc Skull Casting (VASC) process that has traditionally been used in many titanium and reactive metal casting applications.

The biggest advantage is in the flexibility of the charge material that can be used. A cylindrical electrode must be fabricated for use in the VASC furnace. A large amount of effort and expense goes into producing the electrode needed at the beginning of the process. Compacted sponge, other raw material, and alloying elements are compacted and welded together to form the electrode. In addition, 'double melts' of the same material must be done in order to meet quality requirements in many applications. In this situation, an electrode is welded together then remelted in a VAR. The resulting fully dense ingot is then re-used as the electrode in the VASC process again.



Centrifugal Cast TiAl Engine Valves

Alternatively, a pre-alloyed electrode can be purchased from an outside source at considerable expense. An ISM furnace by comparison, can use nearly any type of charge material that will fit within the confines of the crucible. Revert, commercially purchased scrap, loose turnings, and sponge can be charged directly into the ISM crucible and melted successfully. The variety of materials available for use as well as the minimal amount of pre-charging prep work greatly reduces the cost of raw materials. The direct result of this is a lower cost per part for an ISM cast product.

The vigorous stirring that is inherent in the ISM process is another advantage versus the VASC equipment. With little or no stirring in the VASC melt pool, homogeneity of alloying elements is difficult to achieve and is another reason for 'double melting' of charge material. In ISM, the four quadrant stirring generated by the induction field promotes uniform alloy composition and allows for dense, high melting point alloying elements to dissolve and be dispersed evenly. This allows for more complex alloys to be melted using the ISM process. The original patent holder alone is claimed to have cast more than 3000 different alloys.



Golf Club Head

The ISM process also produces a consistent skull thickness, so that after the initial skull is formed all additional melts will use the same charge weight and generate the same pour weight. In VASC the skull continuously increases in thickness. The ISM process will generate a skull weight of less than 10% of the initial charge weight, a substantially better yield than the VASC system.

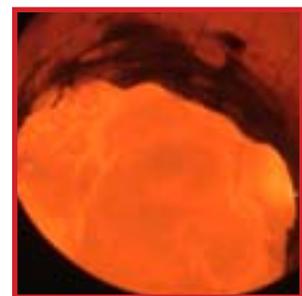
Inductotherm VIP ISM Power Supply

In conjunction with Inductotherm Corporation, the largest manufacturer of induction air and vacuum melting equipment in the world, Consarc has developed a line of solid state power supplies specifically tailored to the particular demands of Induction Skull Melting. These designs are based on the VIP Power-Trak technology that Inductotherm introduced in 1977 and has continually updated and refined over the years.

The ISM power supplies maintain all the fine features that VIP Power-Trak users around the world have enjoyed for many years with additional refinements that allow the designs to meet the needs of the vacuum induction skull melters. The unique stirring characteristics of the ISM process require higher output frequencies to insure optimized metal stirring. Due to the much higher current levels at which these units run more rugged components have been built into the design to increase reliability and uptime.

The Inductotherm VIP Power Supplies feature:

- The highest electrical efficiency, 94 to 97%, available in any induction melt system due to their unique use of a voltage fed, series inverter.
- The design uses an uncontrolled rectifier which means that the 3 phase line power factor will never be any less than .95 regardless of line and load conditions.
- This design also guaranties the absolute lowest amount of harmonic content on the 3 phase lines possible as well.
- A built-in deionized water system with a water-to-water heat exchanger insures long term reliability of the power supply with a minimum of maintenance required.
- The use of just a single electronic board containing all the control circuitry for the unit increases reliability while greatly simplifying troubleshooting and maintenance procedures.





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