

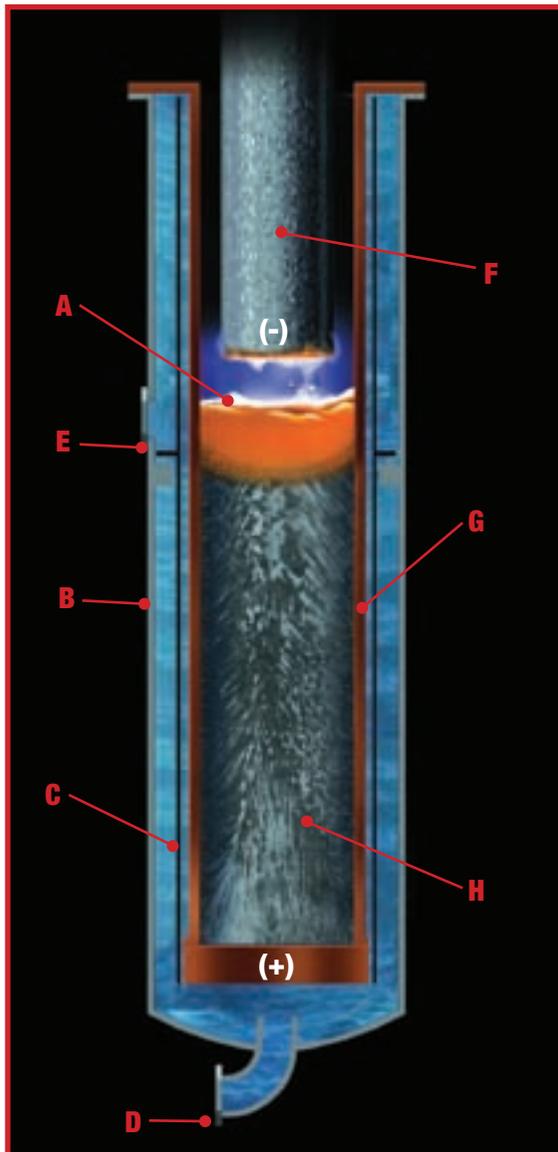


CONSARC

An Inductotherm Group Company

Vacuum Arc Remelting Furnaces

VAR — The Process



- A Arc Zone**
- B Water Jacket**
- C High Velocity Guide**
- D Water In**
- E Water Out**
- F Electrode**
- G Crucible**
- H Ingot**

Prior to start up, the electrode to be melted is loaded into the furnace. For specialty steels and superalloys, the electrode is previously cast in air or vacuum. For primary reactive metals like titanium, the electrode is fabricated from compacted sponge and/or scrap, or from a hearth melt process like Plasma or Electron Beam.

Two major mechanical assemblies combine to form the vacuum vessel in which melting occurs - the movable furnace head and the fixed melt station. The movable furnace head is the upper section of the vessel. An integral ram assembly connected to a highly sophisticated servo drive supports and controls the movement of the electrode. The water-cooled ram extends through a vacuum seal in the head and the electrode clamps to its lower extremity thus becoming the cathode of the arc melting operation. The fixed melt station, which forms the lower half of the vacuum vessel, consists of a removable copper crucible that is placed into a fixed stainless steel water jacket.

Once the electrode is clamped to the ram assembly the ram lifts the electrode while furnace head is lowered to create a vacuum seal on top of the crucible. Once a vacuum is established, the DC power supply is activated and the control system automatically strikes a high current arc between the consumable electrode (cathode -) and the crucible base (anode +) which quickly forms a molten pool of metal.

The gap between the melting electrode and metal pool (arc gap) is precisely maintained and a controlled melt rate is established. The metal droplets falling through the arc gap are exposed to the vacuum environment and the extreme temperatures of the arc zone. This causes removal of dissolved gasses, vaporization of tramp elements, and improvement in oxide cleanliness.

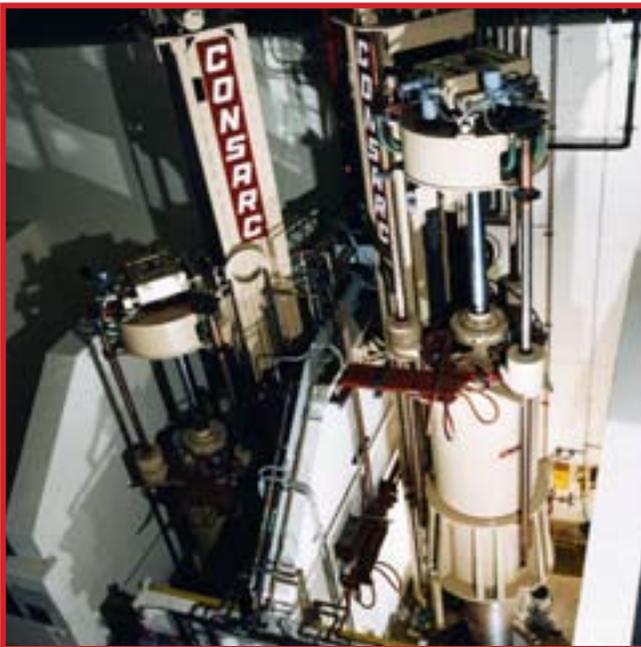
Because of the water-cooled crucible, the molten pool of metal formed by the metal droplets is solidified in a directional fashion. When the melt rate and arc gap are correctly controlled this directional solidification prevents macro segregation and reduces the amount of micro segregation thereby enhancing the material properties of the solidified ingot.

Towards the end of the process the power is gradually reduced providing a controlled hot top maximizing the yield of useful product.

Vacuum Arc Remelting Furnaces

Background - Pioneers in VAR Technology

Consarc is well known to producers of speciality steel, superalloys, and reactive metals. We pioneered commercial ingot production using automated Vacuum Arc Remelting (VAR) furnaces. We were the first to apply load cell weighing of electrodes to improve process control. We developed coaxial furnace designs to minimize uncontrolled stirring. We fully computerized the controls to optimize reproducibility and ease of operation. Users of Consarc VAR furnaces get proven process technology, state-of-the-art computerized controls, robust custom designed DC power supplies, and world wide support, from the industry's most innovative and experienced resource.



Vacuum Arc Remelting Furnaces

Advantages of Consarc VAR furnaces

The Consarc VAR process overcomes serious problems that have been historically associated with conventional VAR operations. Problems such as strong magnetic fields in the electrode melt area that cause uncontrolled metal stirring, uneven solidification, and alloy segregation. Imprecise positioning of the electrode that compromised ingot reproducibility and in the case of titanium, system safety. Consarc has developed and implemented solutions to all of these problems. Solutions that have proven their worth through years of field use.



Some Features of the Modern Consarc VAR Furnace are:

- **Melt uniformity by coaxial design:** Our furnaces provide coaxial current paths that close the electrical circuit for the cathode-anode current.
- **Quality control by X-Y axis electrode positioning:** Remote TV viewing and adjustable electrode positioning is used to achieve and maintain centering within the melt chamber.
- **Precision melt control via load cells:** These high accuracy sensors continuously monitor electrode weight through out the melting process. Optimum melting conditions are maintained by the automated system control.
- **Consistent yield from electrode to ingot through load cell based hot topping:** Consarc incorporates the process of hot topping into the end of the melt cycle. It enhances reproducibility and is fully automated, eliminating the need for operator intervention.
- **Ease of operation through full automation:** Once the VAR melt is initiated by the operator, the process is fully automated to the completion of the hot top
- **Reliability assured by proprietary power supply (Reactor or Thyristor based):** Consarc designs and produces power supplies to meet the exact requirements of the specific melting application. The VAR power source is a rugged, water-cooled, DC power supply.

Furnace Configurations

Consarc's VAR furnaces are available in the following standard sizes as well as custom sizes to meet any customer requirements.

DESCRIPTION	24" (600 mm) VAR	28" (700 mm) VAR	36" (900 mm) VAR	42" (1050 mm) VAR
Maximum Ingot Weight	6,000 kg	9,000 kg	16,000 kg	27,000 kg
Maximum Crucible Diameter	610 mm	711 mm	914 mm	1075 mm
Crucible Flange Diameter	36"	44"	49.5"	60"
Power Supply Rating	12,000–15,000 amps	15,000–20,000 amps	20,000–25,000 amps	25,000–30,000 amps
Maximum Ram Travel	70" (1778 mm)	70" (1778 mm)	70" (1778 mm)	70" (1778 mm)
Maximum Head Lift	50" (1270 mm)	50" (1270 mm)	50" (1270 mm)	54" (1370 mm)

Reactive Vacuum Arc Remelting Furnaces 'RVAR'



Primary Melt Furnace

A Consarc Reactive Metals Vacuum Arc Remelting (RVAR) Furnace is a precision machine specifically designed and built for the remelting of reactive metals such as Titanium.

For Primary Melt Furnaces the material to be melted is initially formed by welding low density titanium sponge or scrap 'compacts' into an electrode under an inert protective atmosphere. Primary electrodes are especially long for a final given ingot weight due to their inherently low density. This requires that the Primary Melt RVAR furnace have extensive ram travel and head lift to accommodate such long, low density electrodes. This fact demands special design parameters to be considered if inordinately high furnace structures are to be avoided. The Consarc Primary Melt RVAR with its column design allows the ram drive and head lift to collapse on one another minimizing the overall furnace height while maximizing the head and ram travel available.



Secondary Melt Furnace

For Secondary / Tertiary Melt Furnaces, the electrode to be melted has previously been melted either by a hearth process, like Plasma or Electron Beam, or by a Primary Melt RVAR. The electrode is essentially fully dense so the extensive ram and head lift travels of Primary furnaces are not required. However, due to titanium's potentially explosive nature, the RVAR designed for titanium requires extensive safety considerations.

All Consarc RVAR's have a variety of safety features. Argon gas purged, resealing, overpressure relief valves are standard to vent overpressure while maintaining an inert environment. High flow, emergency, argon backfill is provided to maintain an inert environment even in the case of a furnace breach. The ram drive and control system is provided with a series of limits to prevent the arc gap from opening up too far, possibly allowing the arc to strike to the crucible wall rather than the ingot surface. Finally, Consarc insists that all RVAR furnaces are placed within protective concrete bunkers which are closed during furnace operation.



Vacuum Stub Welder

RVAR furnaces also require the electrode stubs to be welded to the electrode under vacuum. The standard Consarc RVAR allows the stubs to be welded in situ, however this utilizes valuable furnace time for welding rather than remelting. To overcome this, Consarc offers an adjunct to its RVAR furnaces – a Vacuum Stub Welder. The Vacuum Stub Welder is a plunge welder consisting of a vacuum chamber, stub clamp and drive, DC power supply, vacuum system, and plunge control system. Once the electrode is inside the vacuum chamber, the stub connected to the drive, and the vacuum established, a DC arc is struck between the bottom of the stub and top of the electrode. Once a pool of metal forms, the stub is plunged into the pool creating a full penetration weld of the stub to the electrode.

Proprietary High Current DC power supply (Reactor or Thyristor based):



15,000 amps

Consarc is the only VAR furnace supplier that designs and builds our own custom designed DC power supplies. These units are specifically designed to meet the demanding requirements of the VAR melting application. This provides Consarc VAR customers with a single source responsibility for the complete VAR and power transmission system.

Consarc offers both its signature Variable Reactance Transformer (VRT) power supply as well as Thyristor SCR based units. Both systems are internally water cooled by a dedicated, dual pump, closed loop, water pumping module which substantially reduces the overall power unit footprint, and offers exceptional reliability.

The VRT design represents the latest technology in VAR Power Supply development. Each VRT combines the function of a phase shift transformer, a saturable reactor, and a single-phase transformer in one package. This arrangement allows three VRT's with internal phase shift arranged for three-phase connection, to replace a combination of a phase shift transformer, six saturable reactor cores, and a three-phase step down transformer. The rectifier stage uses water cooled diodes assemblies to output DC current.



30,000 amps

The traditional Thyristor SCR power unit utilizes a series of 3 line reactors and two phase shift transformers to feed the rectifier stage. DC rectification is accomplished using water cooled SCR assemblies rather than diodes. This allows the output current to be controlled by the fast acting SCR's instead of the VRT's (Saturable Reactors).

The DC section of either type of power unit is the same. For twelve pulse operation, an inter-phase transformer is provided to connect between leading and lagging rectifier sections. A DC current shunt is provided in the output for accurate current monitoring and feedback control. A single ripple reactor is used to limit the ripple voltage to five (5) peak to peak volts over the current range from 10% to 100% of full rated load. This provides a smoother power delivery to the electrode promoting increased stability at the arc zone. Additionally, fused power factor correcting capacitors for correcting the full load power factor up to 0.9 lagging can be provided with each power supply.



50,000 amps

The power supply components are located inside a completely enclosed NEMA 12 fabricated steel enclosure. Windows and lights are provided for visual observation of the various components within the power supply cabinets. Access to the power supply system is through front opening doors that are interlocked to provide intrinsically safe operation. For the benefit of maintenance personnel, lighting and a power tool outlet are provided in the interior of the enclosure.

Power units are available with VAR furnace systems or as stand alone replacements for existing VAR furnaces.

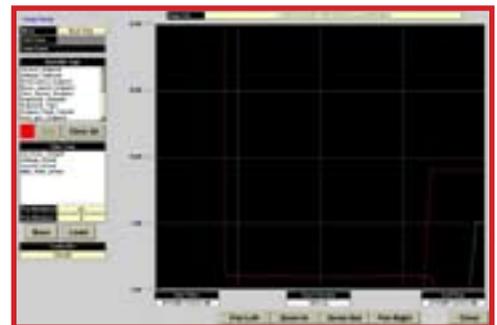
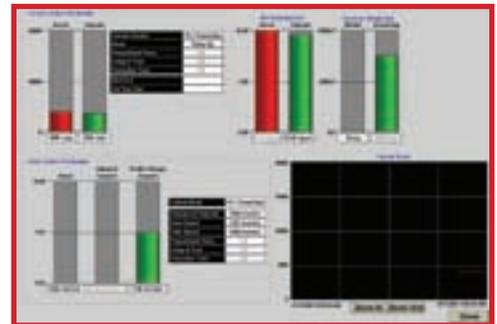
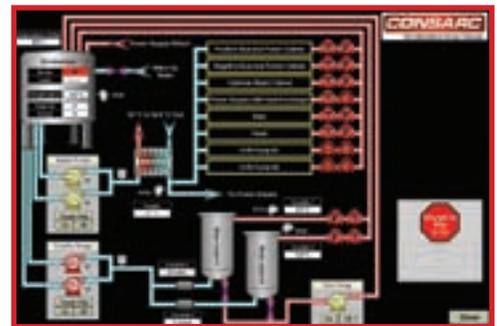
Automatic Melt Controls

Consarc pioneered in Automatic Melt Controls in the early 1970's. At that time, before personal computers, melt rate was maintained using programmable calculators while operators adjusted the arc gap by changing the furnace reference voltage settings. 35 years later, Consarc is on its 7th Generation of Automatic Melt Controls.

The Generation 7 Automatic Melt Controls are a full SCADA system (System Control And Data Acquisition) consisting of a PLC, a separate dripsort processor, and a Personal Computer interface. The PLC controls the furnace logic functions and sequencing along with processing all of the melt rate calculations. The dripsort processor continuously measures the instantaneous short circuits created by the melting metal dripping from the electrode tip to the ingot top. The drip shorts are classified into 15 categories, each of which can be used in the control algorithm to maintain the arc gap. The PC serves as the Human Machine Interface (HMI) to the furnace allowing components like vacuum and water pumps to be controlled, remelt profiles to be created and stored, and furnace data to be logged, stored, and analyzed.

The Generation 7 remelt profile separates the melt into 3 segments – Ramp Up, Main Melt, and Hot Top. Each segment can be further broken into up to 10 sequences offering a nearly unlimited ability to customize and fine tune the remelt profile. Once the remelt profile is accepted, the operator initiates the Autostrike sequence. The control system automatically positions the electrode, turns on the power supply, and strikes the initial arc starting the melt sequence. The entire melt progresses automatically through the segments until the hot top alarm weight is reached and the operator is prompted to turn off the power supply.

Full data logging is provided for all measured and setpoint data including vacuum levels, power input, current, voltage, melt rate, ram travel, ram speed, water flows, water temperatures, alarms and errors. The software allows analysis by graphing multiple logged values at user selected time intervals. This allows a detailed look into the melt and is invaluable for process analysis and optimization.





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