

special melting

INTECO technologies



Have an eye on ...

VAR - Vacuum Arc Remelting

Version 07/2012

Have an eye on... INTECO special melting technologies

INTRODUCTION

INTECO special melting technologies GmbH has been founded in 1973 as a wholly private company with the objective to provide supply and services to the metals and related industries worldwide.

Since its foundation in 1973, INTECO has been engaged in special metallurgy technology and plant design, especially in the field of electroslag remelting (ESR). Working together with some of the worlds most acknowledged experts in the field of vacuum arc remelting (VAR) as well as using INTECO's fundamental engineering experience in special metallurgy, has lead to a successful entrance of INTECO's VAR furnaces on the market. In the last years, several VAR furnaces have been supplied to notable customers who are fully content with the state-of-the-art design, technology and reliability of INTECO's VAR furnaces.



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Have an eye on... VAR - Vacuum Arc Remelting

The vacuum arc remelting process was the first remelting process to be used commercially for the production of steels and superalloys. Being introduced on an industrial scale basis for the production of materials for aerospace applications in the 1950ies, the process is nowadays established for a wide range of specialty steels and superalloys.

The process has reached a very high degree of maturity to satisfy the ever increasing demands on extraordinary material properties. In addition, multiple process combination with other well established primary and secondary melting methods are expanding to achieve still higher performance levels in advanced high tech materials.

Main features of the VAR process

- Completely inert melting conditions regarding heat source, atmosphere and crucible
- Very low melt rates possible for any alloy and crucible size
- Controlled progressive solidification
- Melting and refining under various atmospheres and pressure conditions
- Exceptional material quality



VAR - Vacuum Arc Remelting

VAR is an industrial refining process which is carried out under inert conditions. A consumable electrode with a predefined composition is remelted by a direct current electric arc in a water cooled copper crucible.

The refining takes place in the arc zone between electrode tip and molten metal pool, on top of the ingot which solidifies continuously from the bottom upwards. The controlled solidification of the ingot in the water cooled copper crucible leads to an exceptionally sound and homogenous material with excellent metallurgical properties.

Furthermore, substantial improvement in nonmetallic cleanliness is accomplished by the furnace vacuum of $\leq 0,1$ Pa through dissociation of oxides at arc temperatures on the order of 4000 °C to 5000 °C.

Levitation and dispersion in the liquid metal pool of other non-metallic compounds, such as nitrides and more stable complex oxides, result in further refinement. The VAR process provides optimum refining and solidification control, leading to high quality products.

Quality aspects of VAR remelted material

- Low residual gas contents
- Improved cleanliness
- Superior hot and cold workability
- Better transverse mechanical properties
- Improved soundness

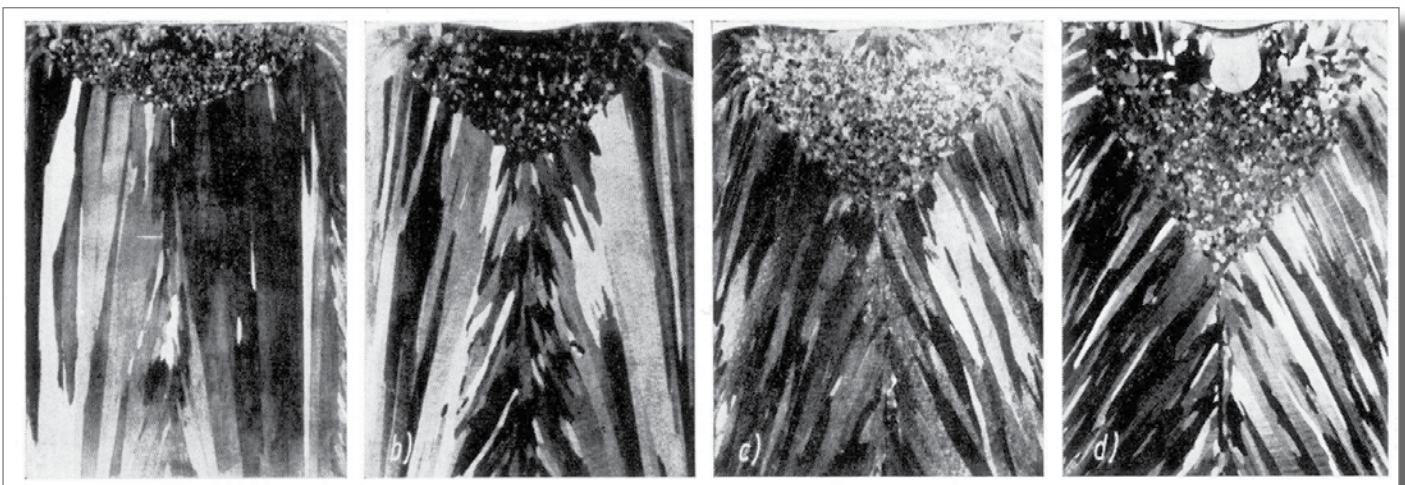


Solidification Structure and Surface Quality of VAR Ingots

The VAR ingot's solidification structure of a given material is a function of the local solidification rate and the temperature gradient at the liquid / solid interface.

To achieve a directed dendritic primary structure, a relatively high temperature gradient at the solidification front must be maintained during the entire remelting process. The growth direction of the cellular dendrites conforms to the direction of the temperature gradient.

A solidification structure with dendrites parallel to the ingot axis yields optimum results. However, a good ingot surface requires a certain level of energy input, resulting in respective remelting rates. Optimal melt rates and energy inputs depend on ingot diameter and material grade, which means that the necessary low remelting rates for large diameter ingots cannot always be maintained to achieve axis parallel crystallization.



Solidification structures of VAR-ingots remelted at different meltrates (meltrate increases from left to right)

Main Features & Characteristics of the INTECO VAR-Equipment and Process Technology

Fully Coaxial Design

results in elimination of the magnetic stray fields produced by the DC current for improvement of the structure of the produced ingots. This design ensures, that the bus system is far away from the liquid pool, water cooled cables are used only for power ram connection

Two Melt Stations

result in minimized preparation times and therefore increased productivity of the plant

Partial Pressure Remelting

results in the elimination or minimization of the evaporation of elements like Mn, Cu or N as well as a more flat metal pool and improved structure (especially for bearing steels)

Helium-Cooling between Crucible and Ingot

results in improved heat transfer of the ingot to crucible wall and therefore in a more flat metal pool

Smart Computerized Control System

automatically finds and maintains proper operating conditions and thereby ensures a close control of melt rate at a defined gap between electrode and metal pool

Current Control

results in a close control of the melting current fed by the DC-power supply

Melt Rate Control

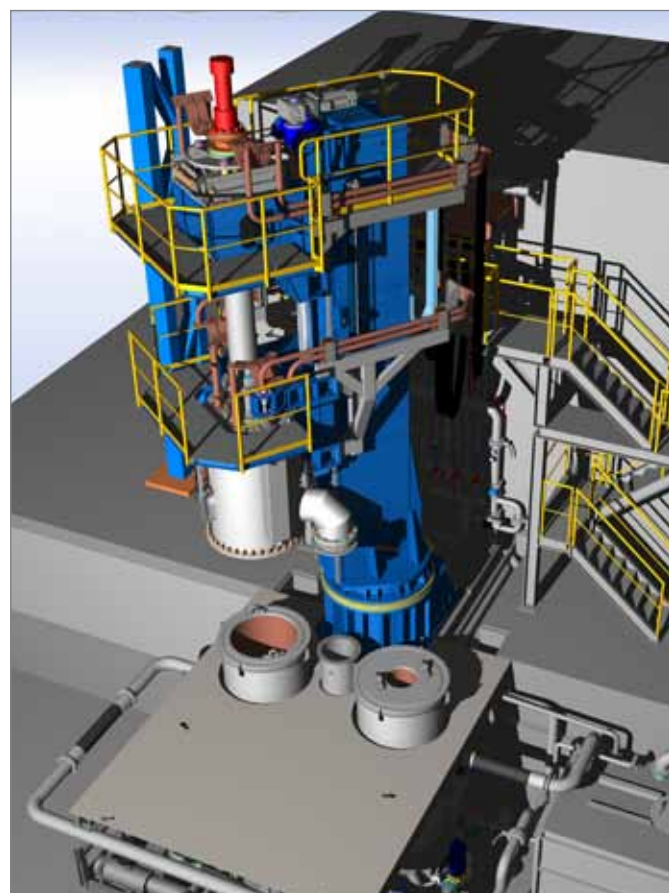
results in a close control of the melt rate due to the signals out of the weighing cell above the furnace

Voltage Control

results in a fast lifting or lowering of the electrode due to a continuous comparison between set point and actual value of voltage

Drip-Short Control

results in a fast lifting or lowering of the electrode due to a continuous comparison between set point and actual value of quantity of drip-shorts per second or time between two drip-shorts



Have an eye on... INTECO's VAR Furnace Design

Mechanical Equipment - Furnace Head

Electrode column assembly

- rigid construction
- no other wall supports or bracing members are required
- easy access to the furnace head lift and drive mechanisms
- electro mechanic rotation of the furnace head from one melting station to the other
- swivel operation can be performed automatically
- design results in short distance to electrode, therefore low momentum

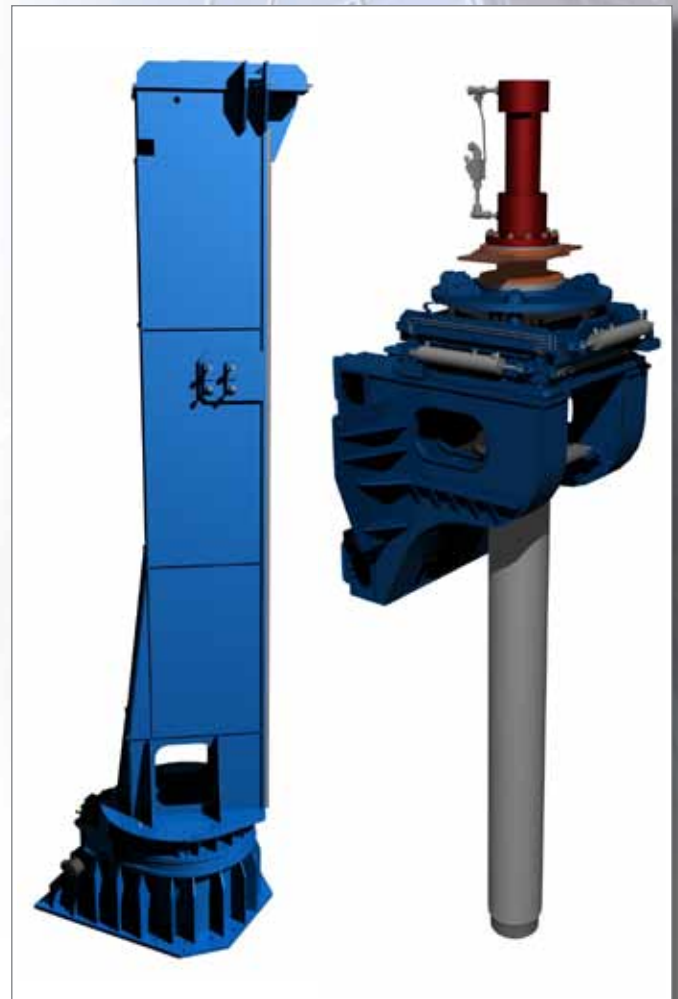
Electrode carriage assembly

Electrode carriage drive system

- accurate drive system
- optimized design for automatic control
- one combined drive unit for control and preparation mode running at various speed
- no couplings
- low backlash

Electrode ram and clamping mechanism

- Reliable automatic high current connection
- Secure holding of electrode in case of hydraulic failure
- No impact of friction forces on measured electrode weight
- All sensitive components are water cooled
- Vacuum tight sealing



Electrode Column

Electrode Carriage

XY adjustment and load cell system

- Max. weighing accuracy
- No influence of friction forces
- Minimized dead weight

Mechanical Equipment - Furnace Head and Melt Stations

Vacuum hood assembly

- water cooled design
- contact shoes for coaxial high current supply and return line
- integrated camera system

Melt Stations

- Good accessibility for starting preparation
- Easy loading and unloading of crucibles and ingots of various sizes by overhead crane



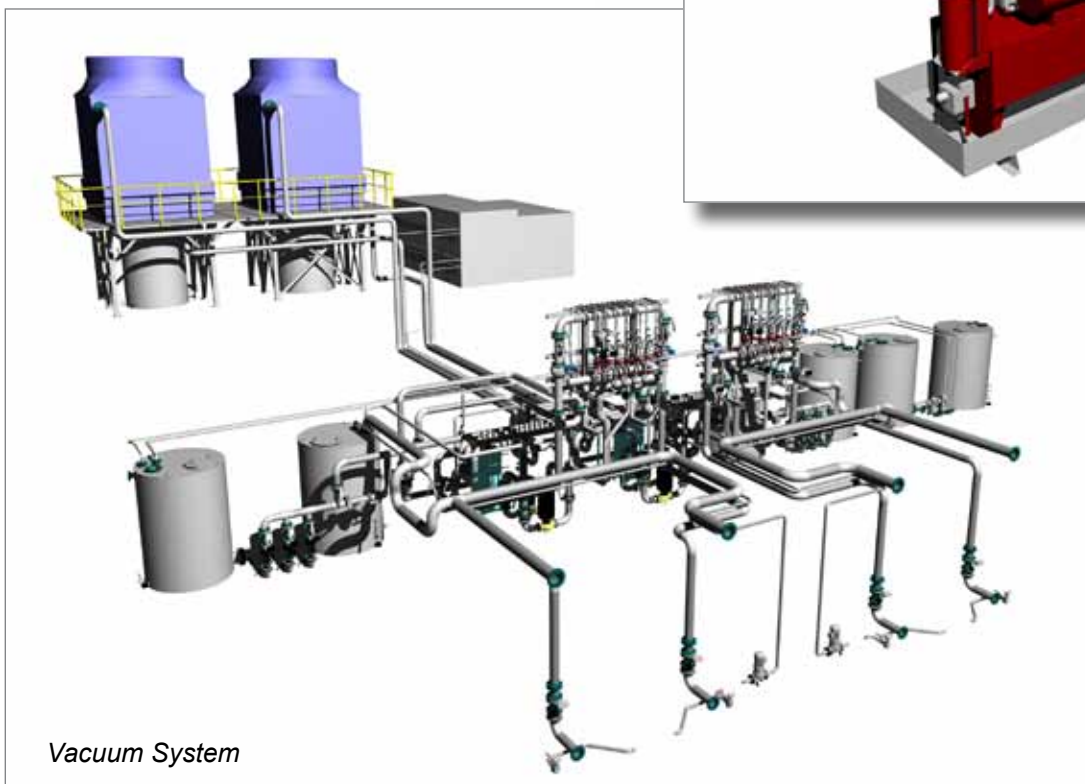
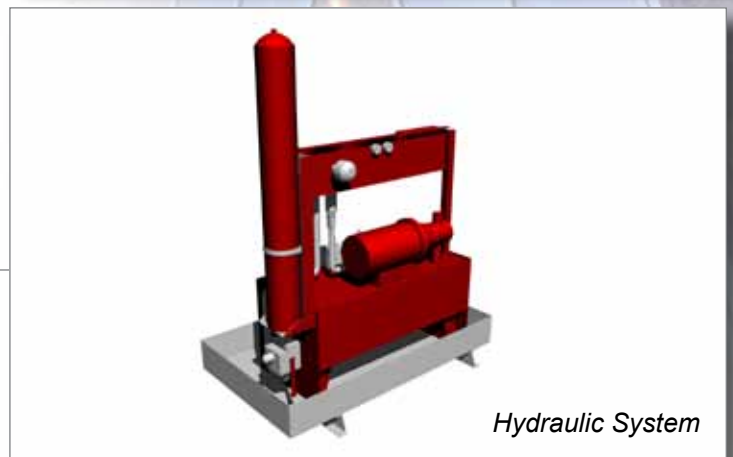
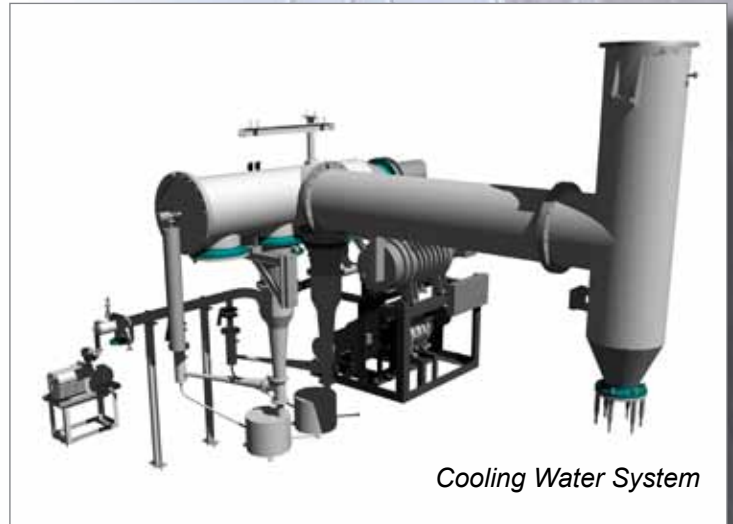
Melt Stations



Vacuum Hood Assembly

Media Equipment

- Cooling water system
- Hydraulic system
- Vacuum system
 - Mechanical pump stand
 - Oil booster pumps
- Inert gas system for partial pressure remelting
- Helium cooling system



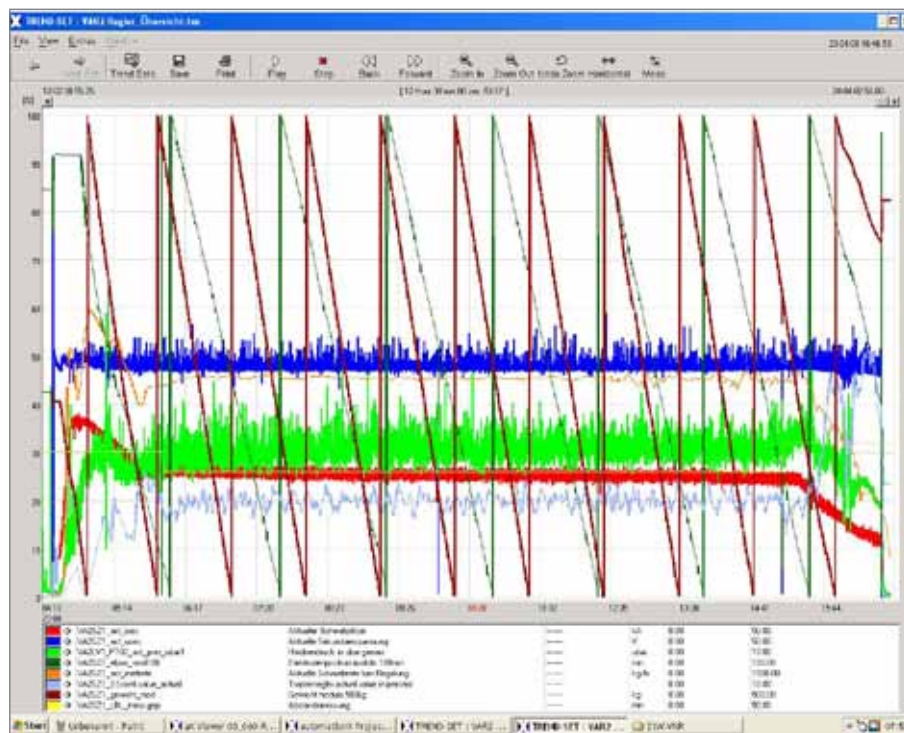
VAR Control System

At various screens at the MMI-monitor of the central station the complete VAR-process can be controlled. It provides all functions for an automatic VAR-operation like:

- Control of melting voltage
- Control of melting current
- Control of arc gap
- Control of meltrate
- Presetting of controller setpoints
- Visualization of controller functions
- Display of various trends
- Storage of relevant process data

Among others, the following melting parameters will be indicated and are displayed as trends:

- Melting Current
- Melting Voltage
- Melting Power
- Drip-shorts
- Meltrate
- Electrode feed rate
- Electrode weight
- Setpoints for controllers
- Electrode (Ram) Position
- Water temperatures, etc.



Vacuum System

INTECO's vacuum system is designed for utmost flexibility and minimized pump down times, which can be achieved by one three-stage mechanical pumping unit and, for fine vacuum, one oil booster ejection unit. Each of the pumping units is switchable individually as well as in series.

The pipe work is arranged in a way, that the oil booster pump is connected to the vacuum chamber directly by means of a large diameter high vacuum line.

The vacuum system is equipped with all required valves which enables a flexible switching of the pumping units in regard to the process needs. The vacuum pumping units are located in a way, that the length of the piping is minimized. In between the mechanical pumps and the pipe work compensators are built in.

For preventing particles entering the mechanical pump set, a filter is installed in front of the vacuum pumps in order to protect the mechanical pumps against solid particles.



INTECO Features and Technologies: Dripshort Control

The metal transfer creates the only known electrical signal that is related to the arc gap, a very important parameter in VAR. For short arc lengths, the major portion of the metal transferred from the electrode to the pool occurs by rupturing of drops. Stretching of a molten metal spike takes place, then a liquid metal bridge is established and the arc is shut off. The arc is extinguished, and the current flows through this molten wire.

The dripshort frequency decreases with higher current, higher arc gap and higher power (see also Fig. 3). The dripshorts are measured with an oscilloscope, by counting the voltage drops caused by the above described metal bridges.

$$l_{LB} = C_1 * I^{c2} * f_{DS}^{c3}$$

l_{LB} Arc length (mm)
 I Melting current (kA)
 f_{DS} Dripshort-frequency (Hz)



Dripshort Control

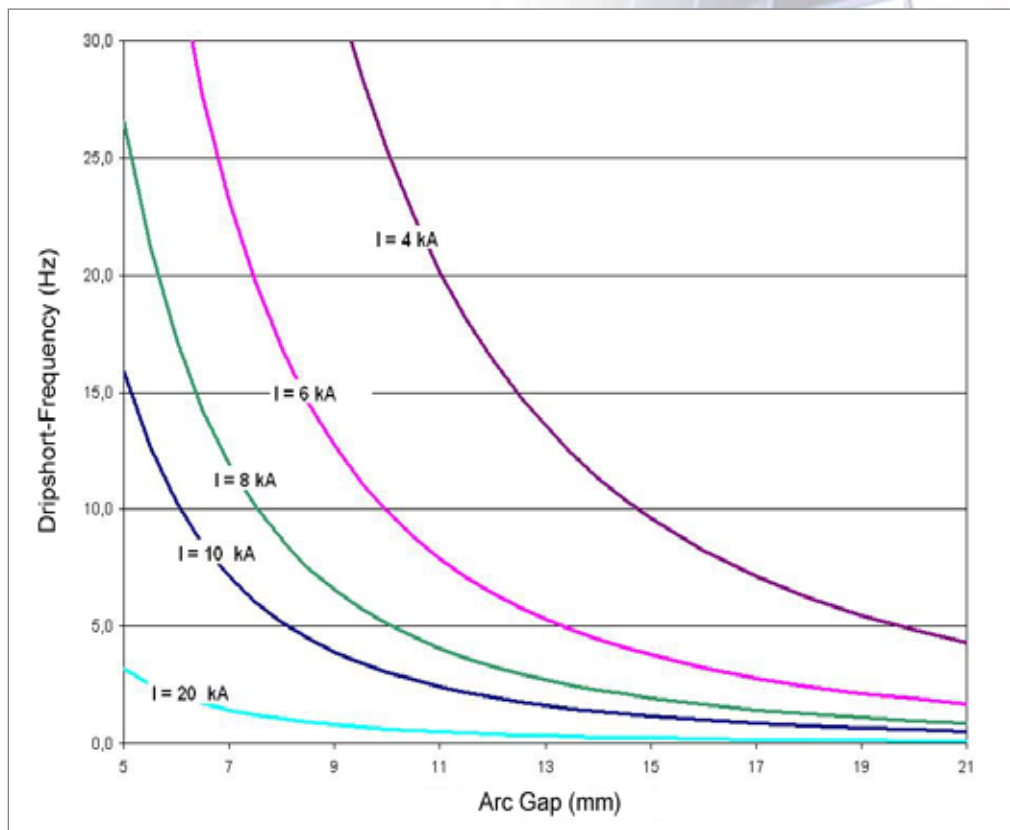
During normal operation this controller is used to control the electrode feed rate and with that the arc gap. However, at starting and / or hoptopping, the electrode feed can also be done via voltage control, if necessary.

The setpoint for the dripshort control is between 5 and 20 dripshorts per second. The actual value is compared with the setpoint, and if the actual value is higher, the electrode is being lifted upwards. If it is too low, the electrode is lowered, respectively.

The drip short pulses superimposed on the arc voltage are separated from the arc voltage by a filter and trigger combination. Subsequently the drip short width is checked and selected to fall within a freely programmable range.

The following parameters are used to sense drip shorts:

- Voltage (trigger) level compared to mean arc voltage
- Drip short width

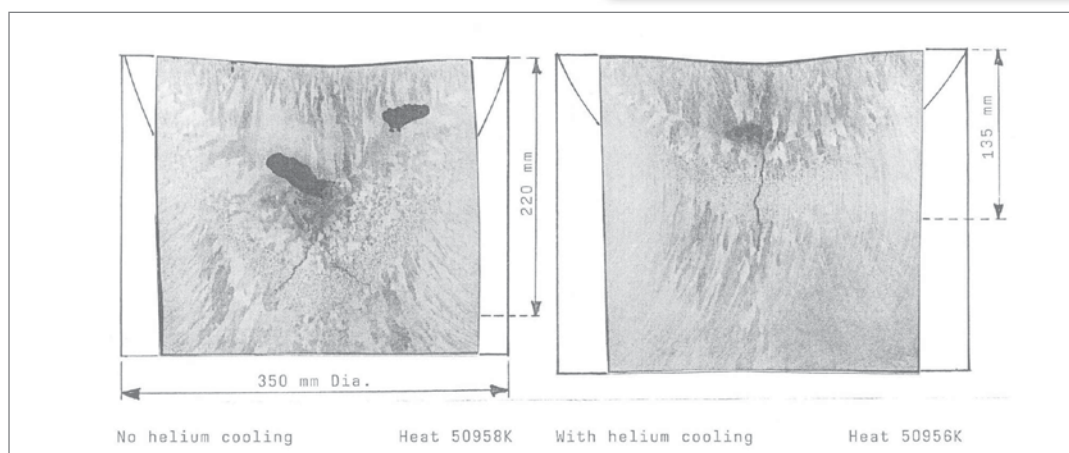
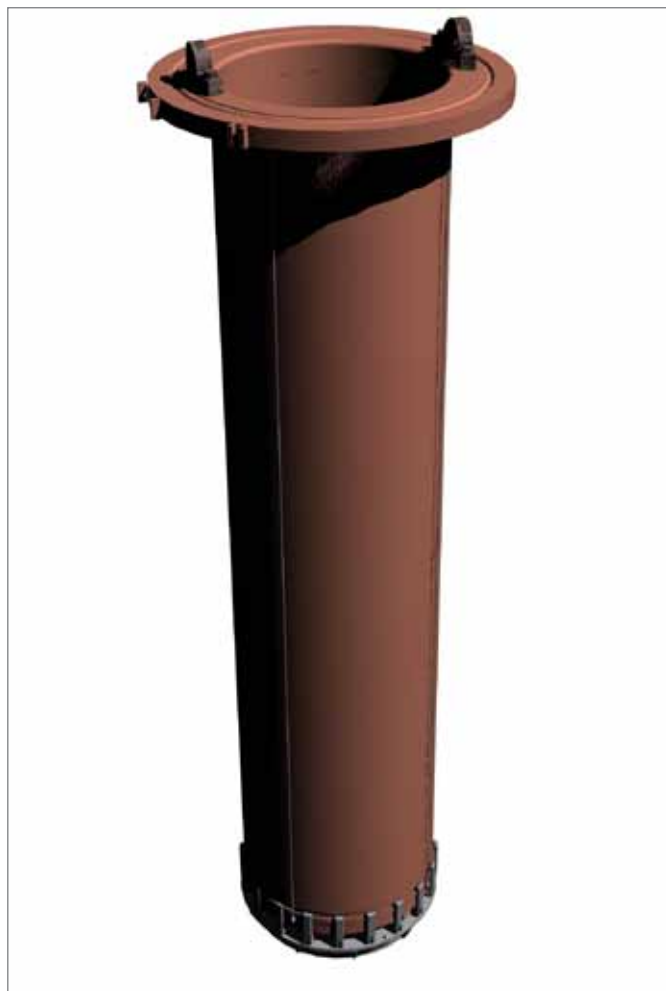


Helium Cooling

Regulating the rate of ingot cooling during VAR by delivering an inert gas with a high thermal conductivity into the gap between the ingot and the crucible affects the depth and shape of the liquid metal pool as well as the linear rate of solidification of the ingot.

The input of Helium into that gap results in a higher impact pressure, thus ensuring a better temperature dissipation. The bigger the ingot and the higher the meltrate, the higher is the contact area between ingot and crucible, and the higher values for the impact pressure can be achieved. The average impact pressure is between 15 and 25 mbar.

INTECO's Helium cooling system is equipped with automatic flow control valves as well as pressure control valves. Adjustment of parameters can be carried out directly from the control room. The Helium supply line is connected to the crucible flange and further to the crucible base.



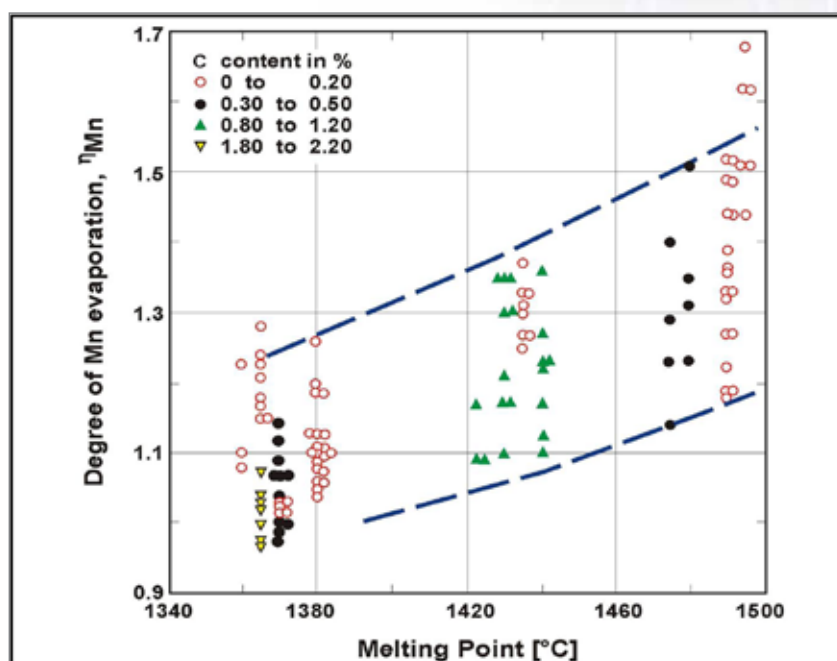
Molten pool configuration and depth of 350 mm dia. waspaloym ingots vacuum arc remelted at identical melt rates without and with helium injection

Partial Pressure Remelting

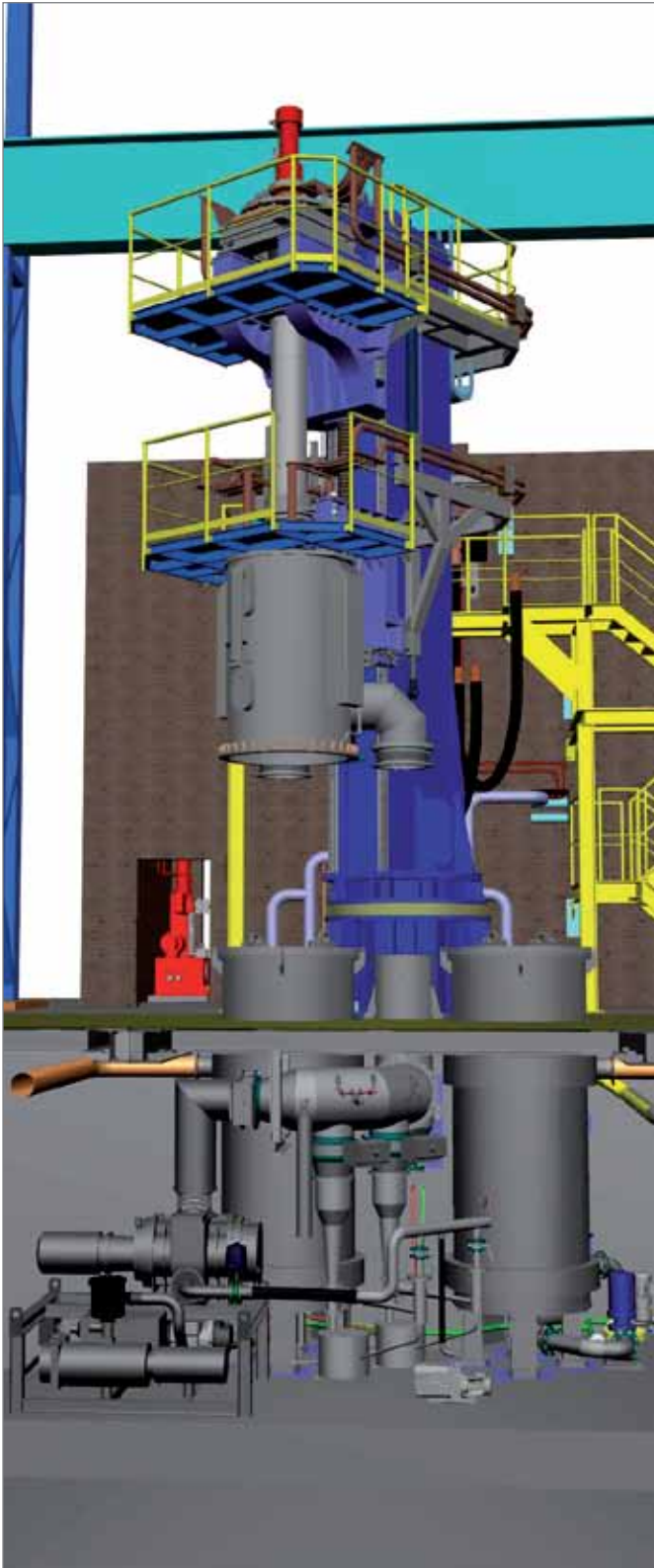
Partial pressure remelting is done in order to avoid or minimize the evaporation of elements like Copper, Manganese or Nitrogen. A better heat dissipation from the pool results in a better cooling of the pool surface, which also leads to a more shallow liquid metal pool.

Furthermore, the temperature gradient in the cooling water is enlarged. For example, partial pressure remelted ledeburitic steels with a high carbon content show a significantly better ingot structure, resulting from a shallow pool and a cooler pool surface.

Helium, Argon and Nitrogen are commonly used for partial pressure remelting. The pressure measurement is done in the upper part of the furnace. Helium pressure can be higher, Argon pressure is limited and Nitrogen pressure is even critical, because Nitrogen has a major influence on the electric arc in a way that it is no longer diffuse, but directional. This reduces the number of rotating arcs and leads to a poor ingot surface.



INTECO Selected References: Daye Special Steel, China



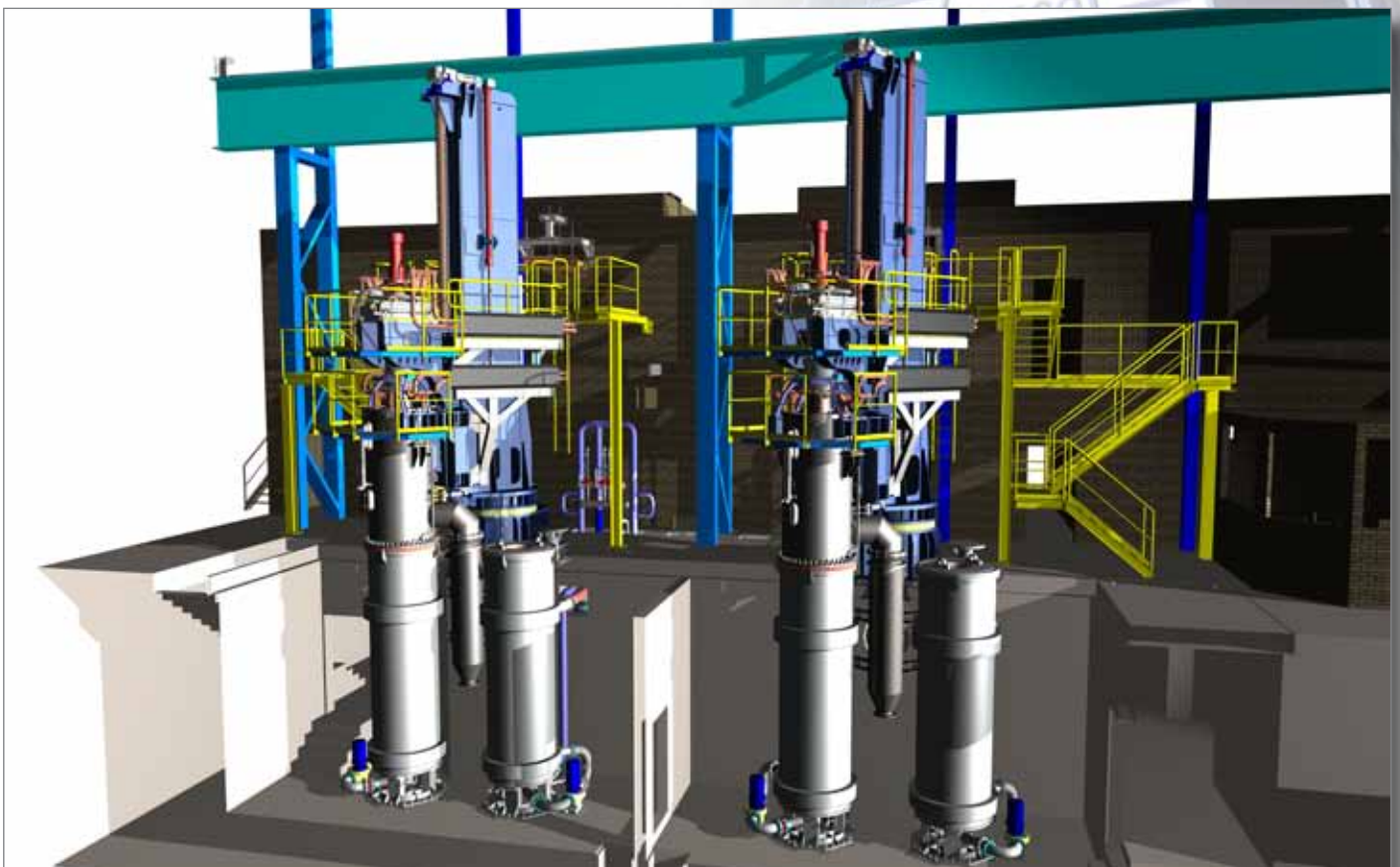
Type	VAR
Max. ingot diameter	620 mm
Max. ingot length	2600 mm
Max. ingot weight	6 tons
Power supply	20 kA
Customer	Daye Special Steel
Start Up	2010



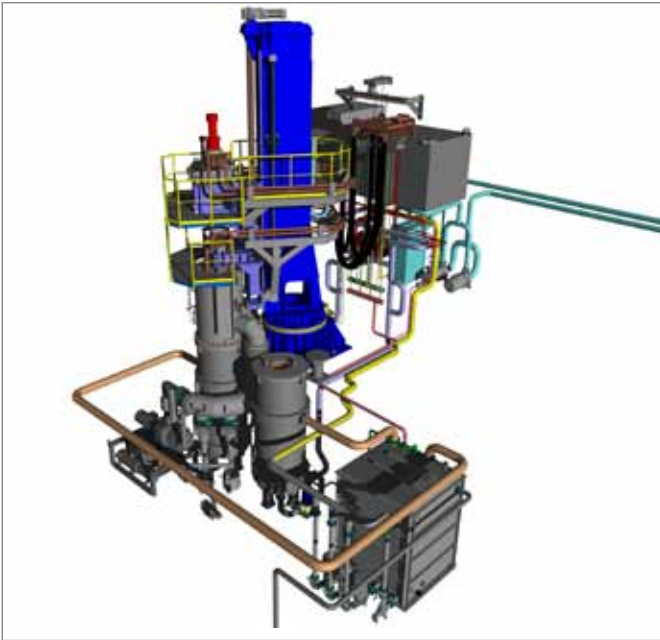
INTECO Selected References: DEW - Deutsche Edelstahlwerke - Krefeld, Germany



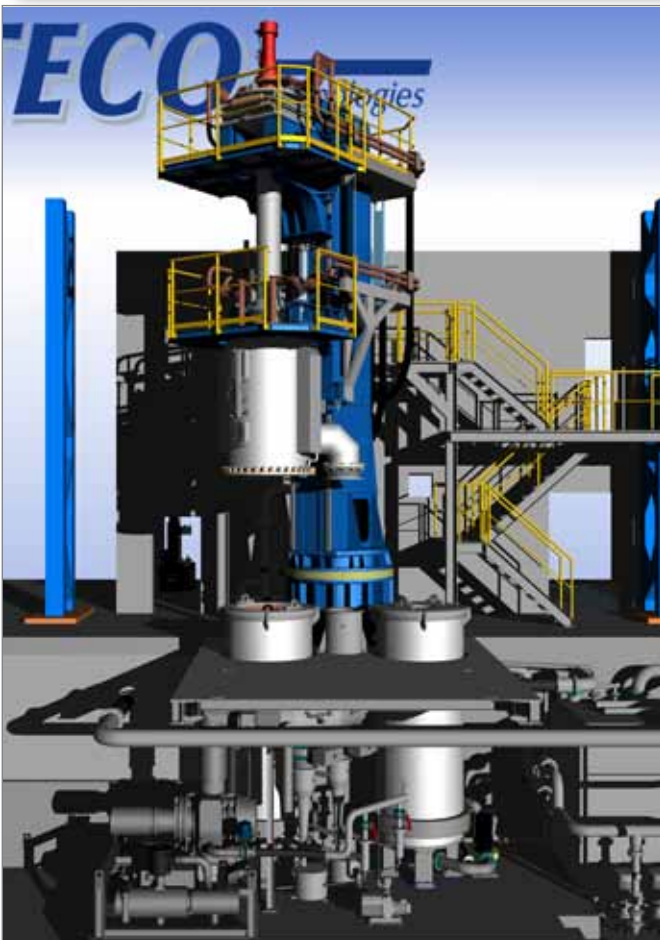
Type	VAR
Max. ingot diameter	930 mm
Max. ingot length	3800 mm
Max. ingot weight	20 tons
Power supply	25 kA
Customer	Deutsche Edelstahlwerke GmbH
Start Up	April 2008



INTECO Selected References: Breitenfeld Edelstahl AG, Austria



Type	VAR
Max. ingot diameter	1100 mm
Max. ingot length	3000 mm
Max. ingot weight	20 tons
Power supply	25 kA
Customer	Breitenfeld Edelstahl AG
Start Up	April 2007



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