CONSARC

An Inductotherm Group Company

Vacuum Precision Investment Casting Furnaces

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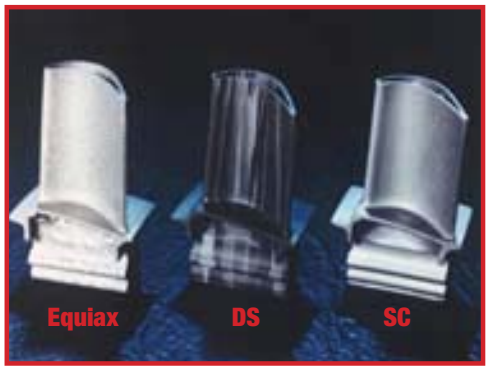
VPIC — The Process

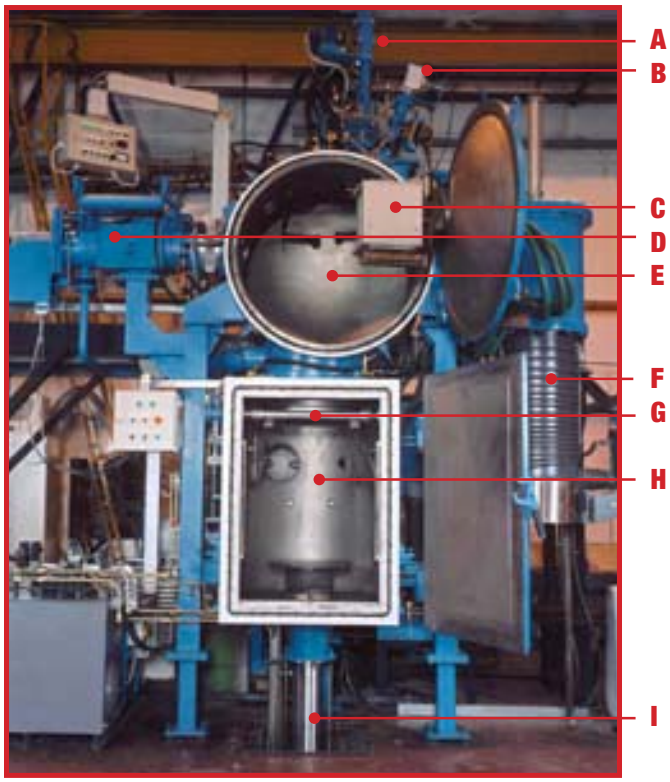
The production of advanced superalloy components for applications in aerospace, power generation, automotive, biomedical, chemical or recreational uses is accomplished in a Vacuum Precision Investment Casting Furnace.

Conventional processing produces castings having equiaxed, or randomly orientated, grain structures. Using the principles of the 'lost wax' process, a ceramic mold is prepared and heated prior to casting. A measured quantity of pre-alloyed metal is then rapidly re-melted and poured into the mold under vacuum.



Directionally solidified (DS) and single-crystal (SC) castings are required for use in aerospace and industrial gas turbine applications due to their improved mechanical properties at very high operating temperatures. Furnaces to cast these components contain features to control the solidification process in the casting.

Most production VPIC furnaces are of the semicontinuous variety. In this case, the furnace consists of two chambers isolated by a large vacuum valve. One chamber contains the melting coil and crucible assembly and the other is used as a mold loading and unloading chamber.



In controlled-solidification furnaces (DS and SC), in addition to the induction melting coil, the upper melting chamber contains a mold-heating zone to allow heating of the ceramic mold to temperatures above the alloy liquidus. The molds are placed on a water-cooled chill platen and withdrawn through a baffled cooling zone located directly below the heating zone. The high thermal gradient in combination with controlled withdrawal provides for controlled solidification in the cast component.

A Immersion T/C
B Optical Pyrometer
C Melt Coil
D Charger
E Melt Chamber
F Vacuum System
G Isolation Valve
H Mold Chamber
I Mold Raise/Lower

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DS / SC Casting Furnaces

Directionally solidified and single crystal castings have also become common place in advanced turbine technology due to their improved mechanical properties at very high temperature service. Furnaces to cast these components have additional features employed in their design to exert a high level of control over the solidification process in the casting.

Controlled solidification furnaces are in general appearance similar to the vertically orientated equiax furnace. However, in addition to the induction melting coil, the upper melting chamber also contains a mold heating zone to allow the ceramic mold to be heated to temperatures above the alloy liquidus prior to pouring. The mold heater is usually of multiple control zones and may either be induction or resistance heated.

The molds are placed on a water-cooled plate on top of the mold ram. A thermal baffle is located at the base of the heater together with a water cooled chill ring directly below the heating zone in order to create a high thermal gradient for solidification in the cast component.

Movement of the mold into and withdrawal from the mold heating zone is accomplished by electric servo motor or hydraulic servo valve driven ram assembly which is PC/PLC controlled to an exact withdrawal profile. This level of control is essential during withdrawal of the mold from the heating zone into the cooling zone in order to create the optimum thermal gradient and hence solidification control in the cast product without defects.

An SC cast is produced in a similar fashion to a DS cast with the exception of a grain selector being added to the bottom of the mold.

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Controls and Automation

Historically, vacuum melting furnaces were essentially manually operated and it was not uncommon to have significant variances in product quality depending on the operators involved. Today, PLC and PC based supervision control systems have fully automated the VPIC furnace and operators merely have to select an appropriate 'menu' for the cast to be performed. All furnace operations can then be performed automatically, thus maintaining consistency between casts.

All Consarc furnace installations are supplied with a fully integrated and interlocked control system for safe and efficient operation of the furnace and its systems. The control system allows the furnace to operate in a series of automatic sequences (Step Sequences) created in a melt recipe. The operator is then prompted for action as required during a melt cycle. The operator has the facility to select previously defined recipes for a particular casting or alternatively enter a new set of recipe parameters if required.

'Teach in' and edit facilities have been developed to allow successful manual operations, such as speed of crucible tilting, position of crucible and mold location, to be saved by the computer, then edited for optimization for future reproduction in automatic mode.

The SCADA (System Control and Data Acquisition) system provides comprehensive data acquisition facilities along with trending and melt report generation. Consarc control systems can also be connected to a customers factory network for data transfer and management.

As part of the Consarc DS/SC control package a system of auto tracking for key withdrawal process parameters is provided. These parameters are constantly compared to a moving alarm window with a set of historical recipe values for the same mold type.

In the event that process control is moving out the anticipated levels (e.g. drift / failure of control thermocouples on the susceptor) then the system will automatically alert the operator. In the event of total control thermocouple failure the operator can select to complete the cast with the furnace using the recipe KW values. This changeover would give the opportunity to save the cast which would have been scrapped without this feature.

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Vacuum Precision Investment Casting Furnaces

VPIC is extensively used for the manufacture of high performance castings in the Aerospace, Industrial Gas Turbine, Automotive and Biomedical markets.

The two chamber design features a melt chamber, containing the induction melting coil, with a vacuum isolation valve separating the melt chamber from the mold chamber. The mold chamber incorporates the mold transfer mechanism system allowing for the melt down of the charge in the melt chamber independent of the ceramic mold handling and transfer operations.

Some features and advantages of the modern Consarc VPIC:

- Vertical, horizontal, or pitless vertical furnace configurations.
- Door mounted, rapid exchange melt coils, without any power connections internal to the vacuum chamber (no insulating of connections required)
- Melt coil horizontal translation system for accurate pouring with Teach Pour
- Hydraulic or fully electromechanical drive systems
- Horizontal or vertical billet charging with liner insertion/removal capability
- High speed mold transfer with multi position control (Equiax)
- Precision mold withdrawal system with electromechanical or hydraulic servo control (DS/SC)
- Large capacity vacuum systems for fast mold chamber evacuation
- Automatic temperature control of molten metal with optical pyrometer
- PLC based automated controls with full SCADA
- Multi Zone Induction (Inductotherm Dual Switch) or Resistance heated mold heaters
- Automatic Baffle Exchange – Exchange Baffles under vacuum without turning off mold heater

The specifications below are representative of the common furnace configurations supplied by Consarc.

FURNACE DESIGNATION	PC25-2 (-2DS)	PC75-2 (-2DS)	PC100-2 (-2DS)	PC150-2 (-2DS)	PC200-2 (-2DS)
Furnace Type	Vertical 2 chamber	Vertical 2 chamber	Vertical 2 chamber	Vertical 2 chamber	Vertical 2 chamber
Cast Weight (Ni Alloy)	10 - 25 kg	25 - 75 kg	35 - 100 kg	50 - 150 kg	75-200 kg
Max Mold Dia (Eq)	550 mm	700 mm	800 mm	950 mm	1000 mm
Max Mold Dia (DS/SC)	400 mm	550 mm	600 mm	700 mm	800 mm
Max Mold Height (Eq)	500 mm	750 mm	800 mm	1000 mm	1500 mm
Max Mold Height (DS/SC)	400 mm	600 mm	700 mm	800 mm	1000 mm
Isolation Valve Dia	600 mm	750 mm	900 mm	1000 mm	1050 mm
Ingot Charging Method	Horizontal/Vertical	Horizontal/Vertical	Horizontal/Vertical	Vertical	Vertical
Standard Melting Power Supply	125/175 kW	175/225 kW	225 kW	225/325 kW	225/325 kW
Mold Heating Power Supply (DS/SC)	125 kW Dual Switch	175 kW Dual Switch	175 kW Dual Switch	225 kW Dual Switch	225 kW Dual Switch

** All furnace systems will be configured to meet individual customer specifications and casting requirements.*

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Latest Technologies

The following are a selection of some design features we have developed that are available to customers:

Rapid Exchange Melt Coil

Fast melting technology

The productivity of an equiax furnace is limited only by the rate at which the base charge material can be melted. With the assistance of electromagnetic modeling, induction power supplies can be designed with the melting power KW maximized for a given range of melt capacities and charge sizes.

Rapid exchange melt coils

The time required to exchange melt coils is also a detriment to productivity. Consarc rapid exchange melt coils can be changed in less than 60 minutes and do not have any electrical connections internal to the vacuum chamber requiring electrical insulation.

Liner Extractor

Automatic charging & liner removal

Accurate and consistent ingot charging and spent liner removal is critical to the productivity of the casting operation. Consarc's chargers allow ingots and liners to be inserted into the crucible at the push of a button or automatically in step sequence operation. Spent liners can be automatically removed with a gripper device or overturned out of the crucible into a separate liner dump chamber.

Pouring consistency and accuracy

The nature of the molten metal stream entering a mold has a significant bearing on the solidification. Consarc has therefore developed translational tilt pour systems which allow the induction coil and crucible to be traversed during the pour, thus ensuring the complete molten stream enters the mold as accurately as possible from cast to cast. The translational pouring systems also provide an added element of flexibility to the furnace and allow the caster to pour molds with pour cups located off centre in large mold configurations, e.g. large vane sections.

Tilt Translation System

Automatic baffle clamping

The thermal baffle in a DS / SC system is normally positioned in place during the heater set up, with the furnace open and heater cold. Consarc has developed reliable automatic baffle clamping systems that allow the baffle to be exchanged automatically without cooling down the heater or opening the melt chamber. The baffle auto-clamping system utilizes a series of externally mounted actuators and internal clamps to secure and release the baffle underneath the heater. The baffle can be introduced and removed through the mold chamber vacuum lock in a matter of minutes thereby saving considerable production time.

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Equiax Casting Furnaces

In Equiax casting furnaces, no special consideration is given to controlling the solidification conditions in the mold from the furnace design. Solidification is controlled by the customers mold design and thermal insulation placed around the mold. The resulting casting has a crystalline structure with randomly oriented grains.

With the melting chamber under vacuum, the two-chamber design allows a pre-heated ceramic mold to be loaded into the mold chamber and the chamber rapidly evacuated. The interconnecting valve between the two chambers is then opened and the mold transported by either a vertical ram located in a pit below the furnace (vertical furnace) or trolley mechanism (horizontal furnace) into the melt chamber. Pouring is then carried out immediately. The filled mold is then retracted into the loading chamber and the interconnecting valve closed. Melting can therefore continue uninterrupted in the melting chamber (without breaking vacuum) independent of mold handling. This maximizes the production rate of the furnace with the rate-limiting factor being the melting rate of the induction power supply.

Other operations in the melting chamber such as crucible liner removal, recharging the melt unit with pre-alloyed bars and crucible liners, taking immersion thermocouple readings, etc., are also carried out using vacuum locks so there is no requirement to break the vacuum in the melting chamber.

The semi-continuous VPIC furnace can be designed with either a vertical or horizontally arranged mold chamber, the capacity of such furnaces being only practically limited by the customer's maximum mold size.

Vertical furnaces are the most widely used and offer an excellent technical solution for the vacuum casting process with compact floor space and fast mold transfer times. A key benefit of a vertical furnace is also the ability to easily manipulate the vertical position of the mold relative to the crucible lip, prior to and during the pour to ensure the shortest metal drop height into the mold. A pit in the foundations is normally required below the vertical furnace and furnace heights can be an issue in some buildings. Horizontal furnaces normally require no pit in the foundations and can also be supplied for very large mold sizes.

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