A New Rammable Conductive Lining Material for Induction Furnaces

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Rammable Conductive Lining (RCL)

- What is RCL? - Features
- What does RCL do? - Benefits
- How does RCL work? - Technology
- Why use RCL? - Advantages
- Where can RCL be used?- Applications

What is RCL?

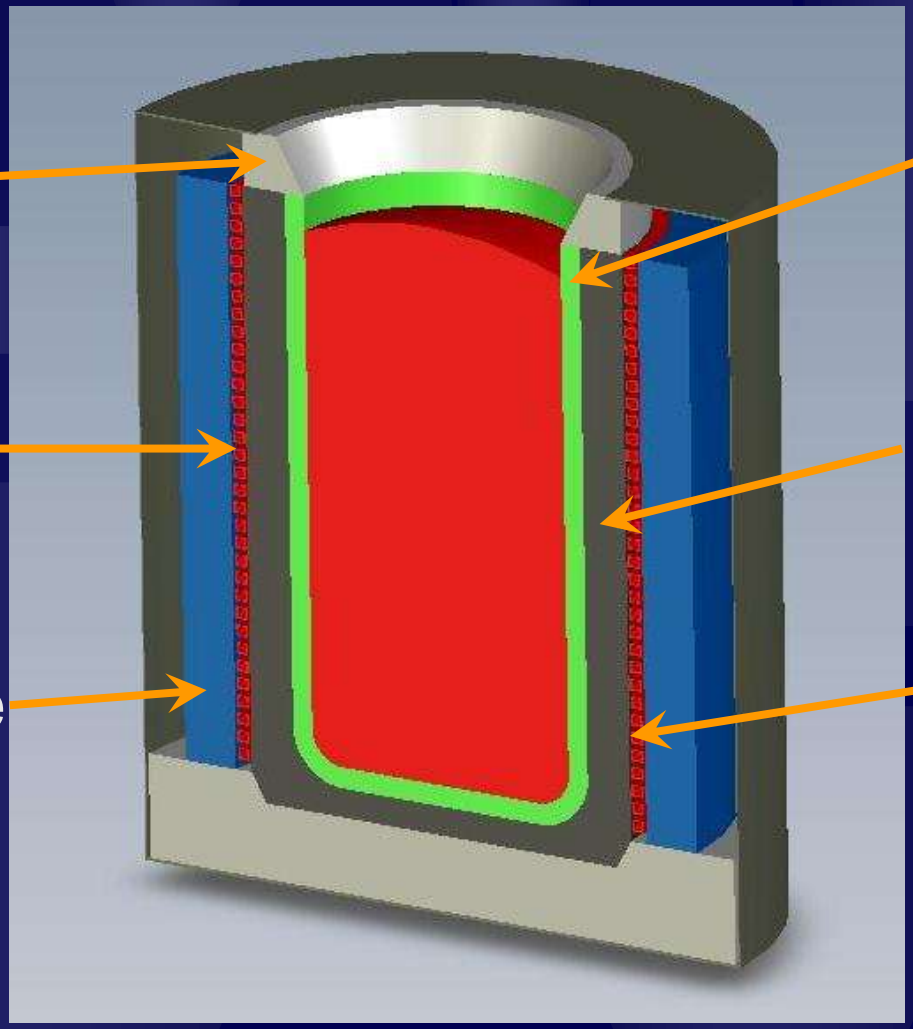
- Performance Features
  - In-situ rammable conductive lining material
  - Couples with an induction field in the unfired state
  - Can be fired in-situ;

- Without emission of noxious fumes
- Without pre-heating
- Without degradation through use by oxidation
- Without thermal shock
- Without moisture spalling

What does RCL do?

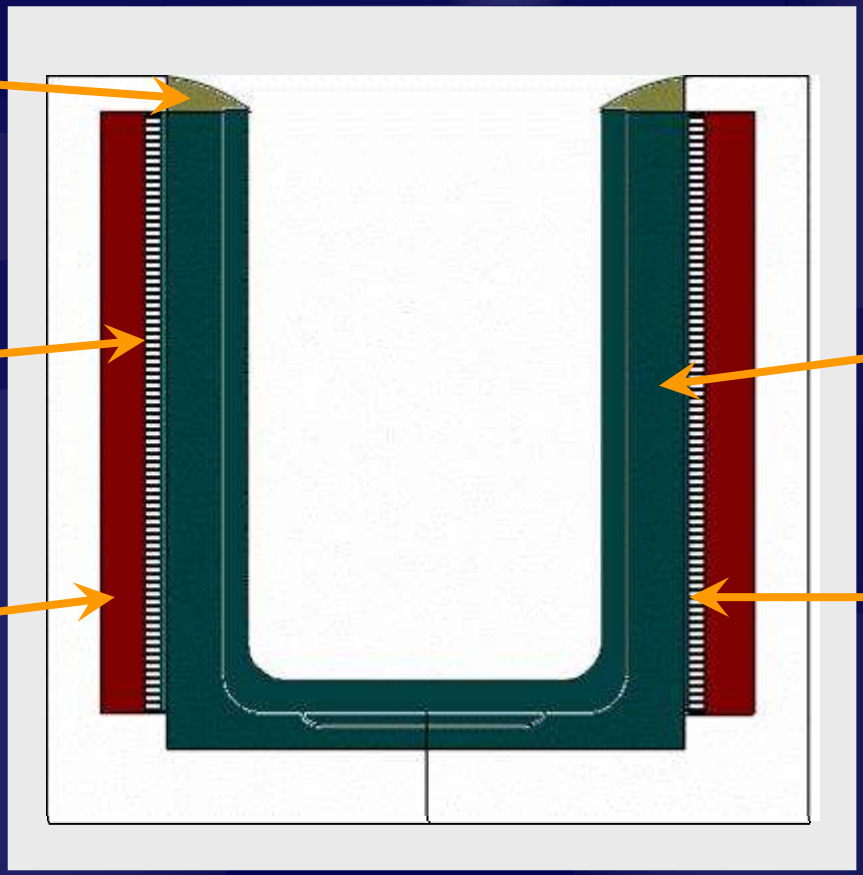
- The primary objective when developing this technology was to provide coreless induction furnace users with a rammable conductive lining material (rather than the more common non-conductive rammed linings) for applications where the melt is a poor susceptor
  - the incorporation of a refractory/insulating coil protection lining is vital when using RCL since the material heats up so rapidly

Coreless Induction Furnace



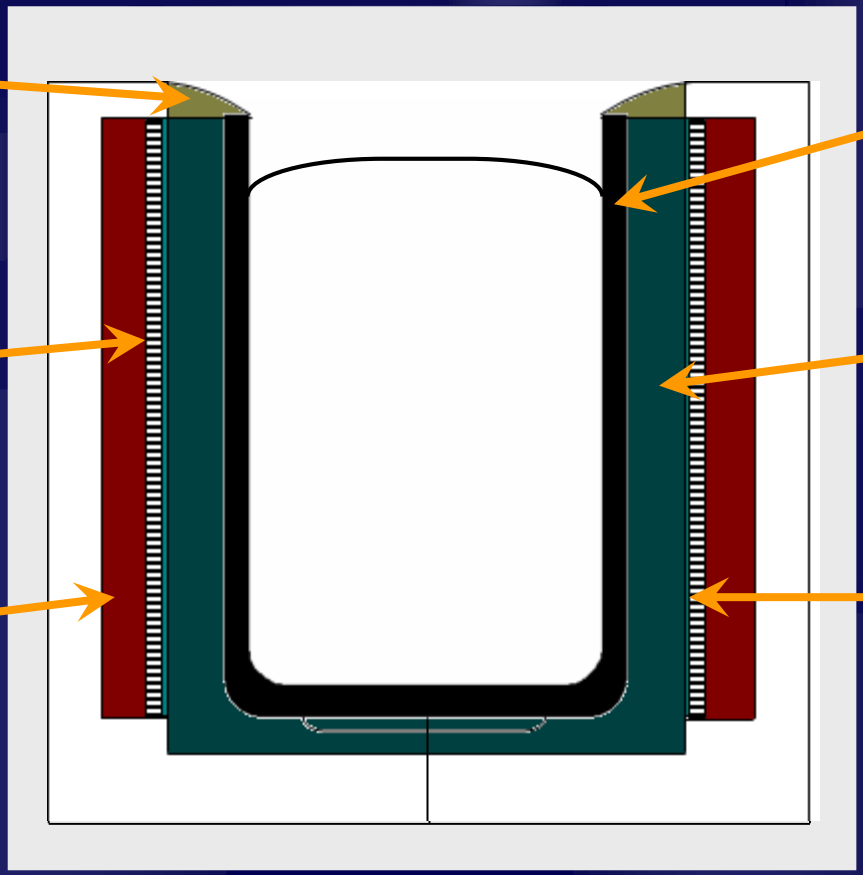
Coreless Induction Furnace

For Ferrous Alloys



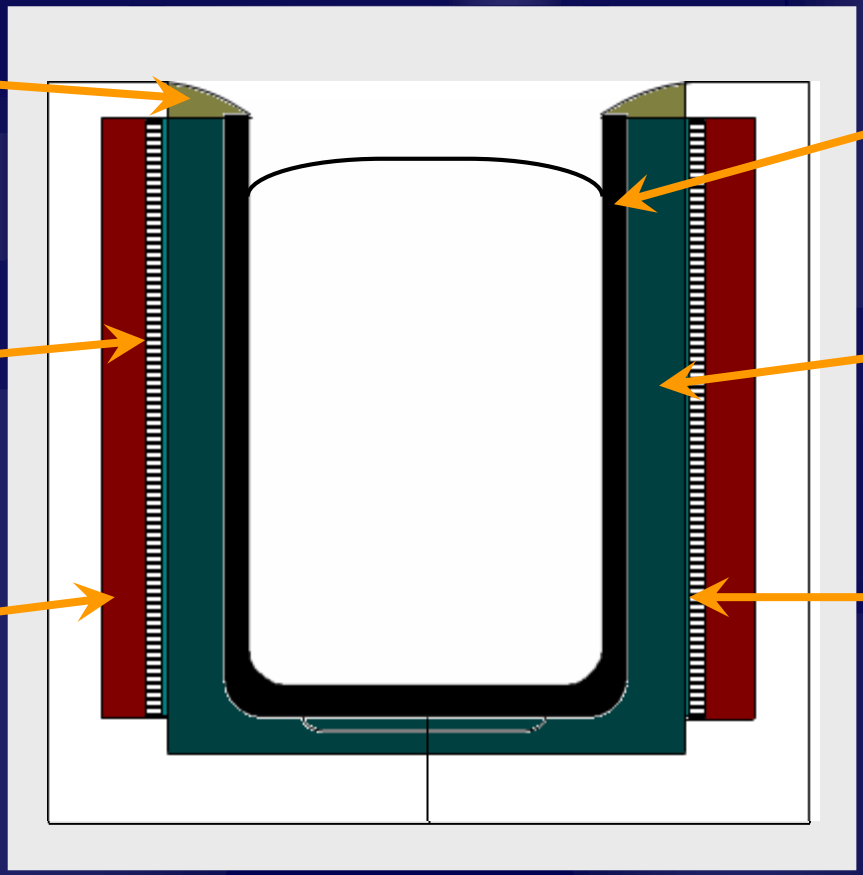
Coreless Induction Furnace

For Non-Ferrous Alloys



Coreless Induction Furnace

For Non-Ferrous Alloys



Where no crucible is available

RCL should not directly replace a pre-formed SiC/graphite crucible in traditionally crucible based applications as densities of RCL are lower

How does RCL work?

- RCL is a Graphite/SiC formulation containing several novel patented technical innovations that provide a number of unique and useful properties
  - Emits no noxious volatiles during heat up
  - Self protecting from oxidation
- Electrically conductive in both green & fired states

RCL – “emits no noxious volatiles”

- Eddy currents are induced into the electrically conductive material by the action of the induction field
  - These provide enough heat to cure and fire the material
- Curing/firing of carbon-based materials is normally accompanied by the emission of noxious hydrocarbon fumes
  - generated by the decomposition of carbonaceous binders
  - e.g. tar, pitch, phenolic resin, sugars, etc.
- RCL does not generate such noxious fume as it contains a unique water-based Colloidal graphite binder
- The colloidal graphite binder;
  - provides sufficient electrical conductivity to maintain the eddy currents that heat the lining
  - only generates water as the temperature rises rapidly and the material hardens
  - cures at around 200^{o}C.

RCL – “self protecting from oxidation”

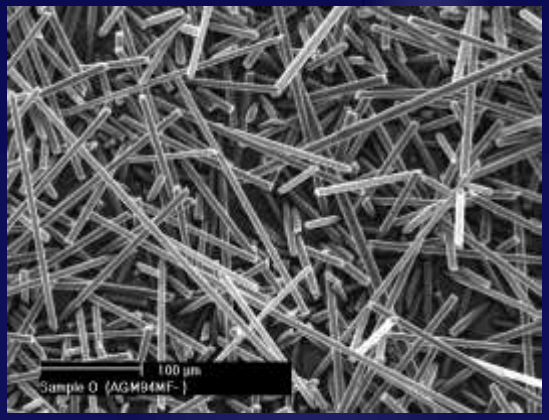
- Preformed SiC/Graphite Crucibles use Glazes on the surface to prevent the burn-out of the graphite in air at high temperatures.
- RCL contains graphite, but does not require a surface glaze
  - RCL contains boron carbide (B_4C) which acts an internal oxidation protection mechanism in the formulation
  - B_4C prevents burn-out of the critical carbon-based components of the material without the need for external protection by reacting preferentially with any O_2 present

RCL – “electrically conductive from green”

- RCL is designed to maintain relatively constant electrical properties throughout the installation and heat up process over a wide temperature range
- This ensures a smooth transition and constant rise in temperature from the unfired to the fired state
- This is achieved by maintaining a high degree of connectivity between the conductive particles using high aspect ratio materials that are designed to bridge the gaps between particles in the lining formulation;
  - Carbon fibres
  - Expanded graphites
- This ability of RCL is unique amongst carbon based ceramic and composite materials

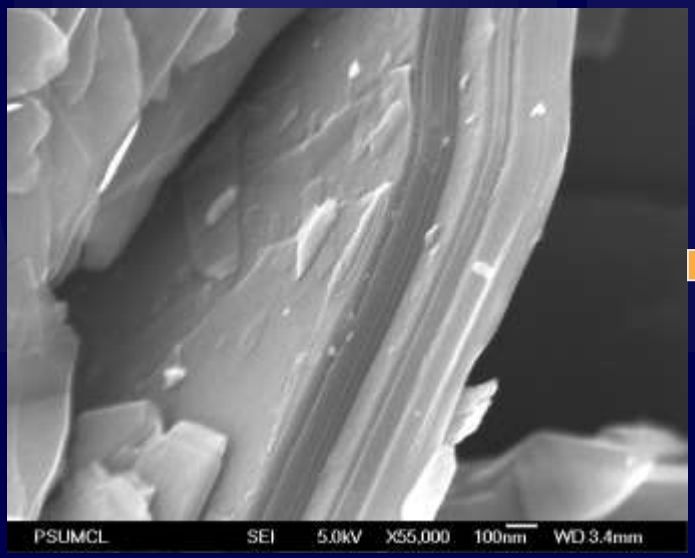
RCL – “electrically conductive from green”

Carbon Fibres



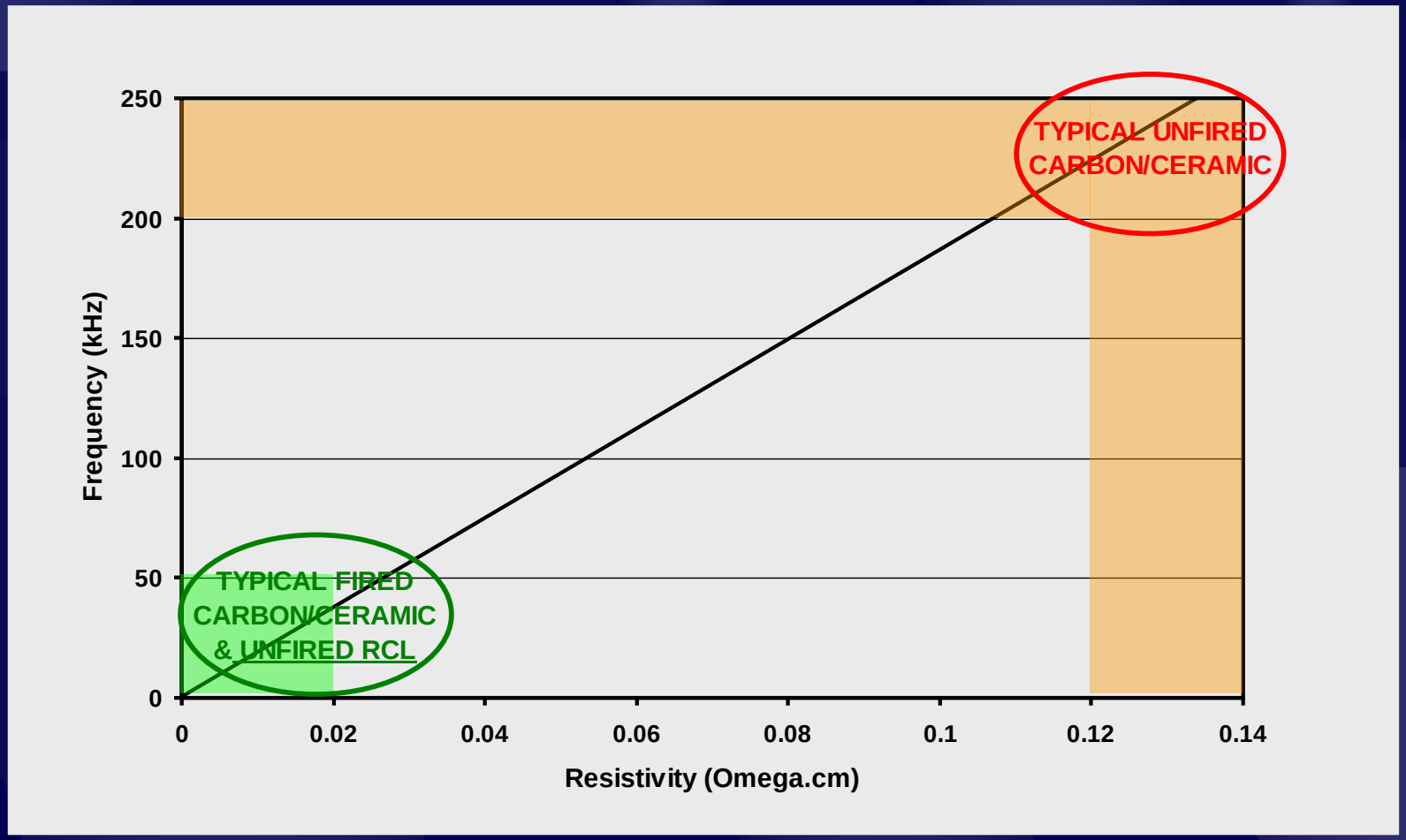
Both increase points of contact in the structure and increase conductivity

Flake Graphite



Exfoliated Graphite

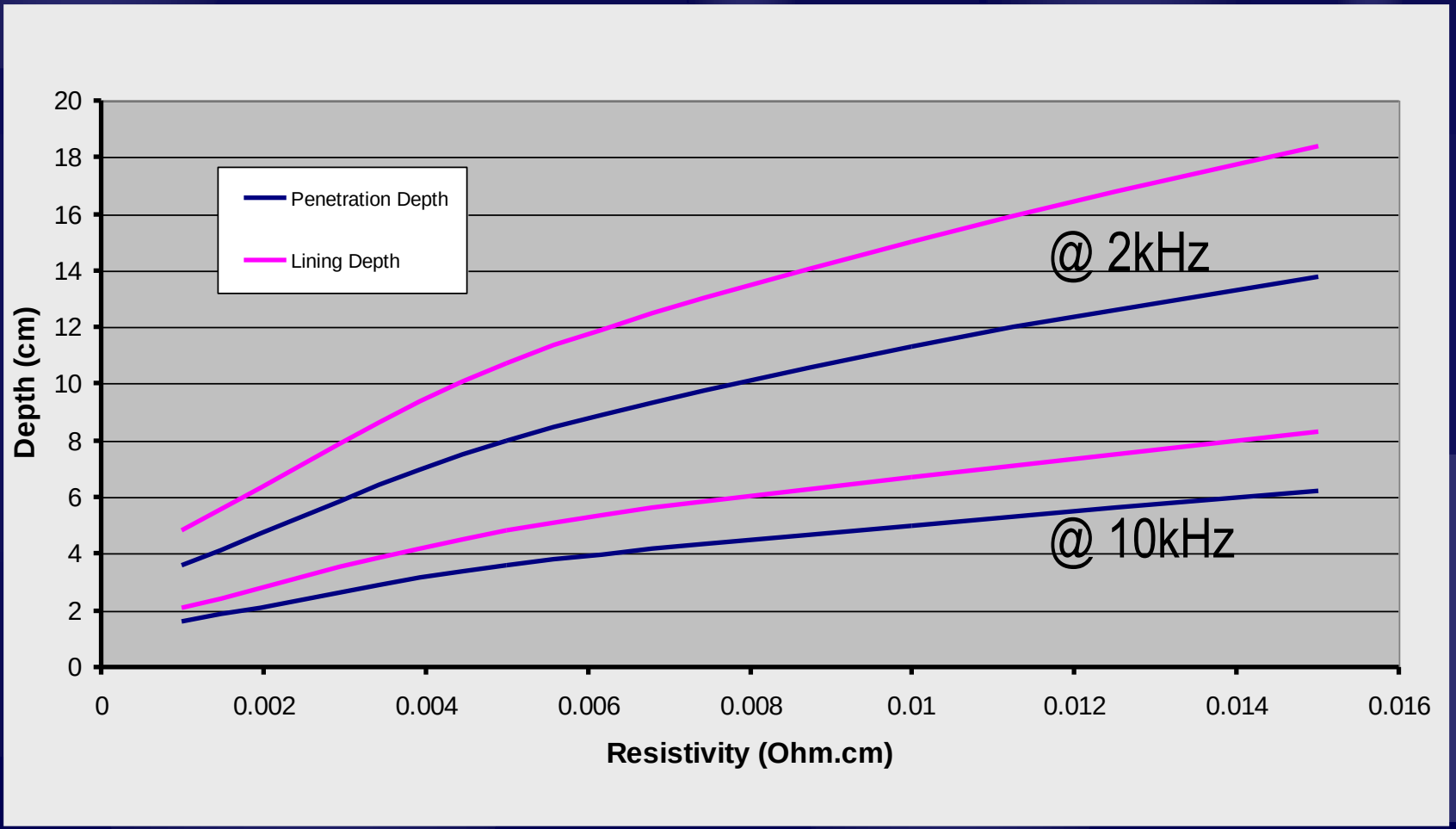
Frequency vs Resistivity



RCL - installation

- The rate of lining heat up is dependant on;
  - the electrical properties of the lining
  - and on the frequency and power of the induction coil
- RCL's electrical properties are related to the density, which is heavily influenced by the method of installation.
- The more tightly packed the lining material;
  - the higher will be the conductivity
    - to enhance coupling with the induction field
  - and the higher will be the density
    - to enhance resistance to erosion and corrosion during use in contact applications
- For severe contact applications, where erosion and corrosion is a significant life limiting factor for the lining, RCL can be supplied as an isostatically pressed preform to maximise density

Thickness vs Resistivity



RCL - installation

- With well compacted RCL heat up rates are rapid
  - some practical demonstrations having reached 1600^{o}C in under 30 minutes.
- Such rapid temperature rises would destroy most ceramic materials through thermal shock,
  - but the structure of RCL is specifically engineered with high aspect ratio, bridging materials to optimise thermal shock resistance
  - allowing it to survive even the most rapid of heat up rates from the as installed, cold state

RCL - installation

- Unlike other water based refractory materials, no controlled careful heat up schedule is required for RCL
- Most water-based refractories need to be heated up slowly through the 100^{o}C region as water is released very rapidly at this point, leading to explosive spalling.
- RCL contains a unique patented mechanism (superabsorbent polyacrylate) to assist in the release of this free water through this normally sensitive temperature range, and thus can be heated up rapidly without concern for spalling of the lining.
- It is possible to have the charge material already positioned inside the freshly placed RCL lining from the start, such that no subsequent charging procedure is needed on the first melt (or heat treatment).
  - Although, since water will be evolved during the first heat up of RCL, this procedure should be avoided for materials that are sensitive to moisture.

Why use RCL?

- Design & Application benefits;
  - High temperature induction melting & heat treatment of metals & non-metals which have poor coupling characteristics with induction fields.
  - Large capacity or irregularly-shaped induction furnaces, where pre-formed conductive crucibles are not available.
  - Longer campaigns due to RCL's ability to be patched between uses.
  - Conductive back up material as a heat source for poor susceptor crucible/melt arrangements.
  - The ability to create hot zones to improve control of existing induction heat treatment processes.

Metal Melting Trials, USA

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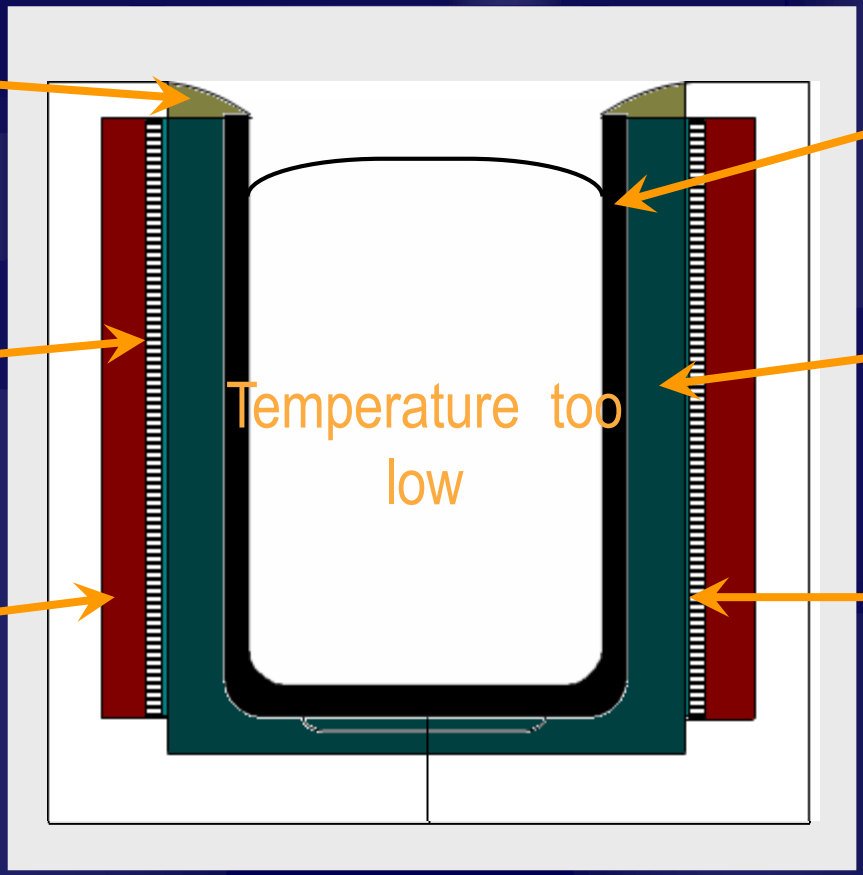
Foundry Applications; 1

Copper Recovery From Ore



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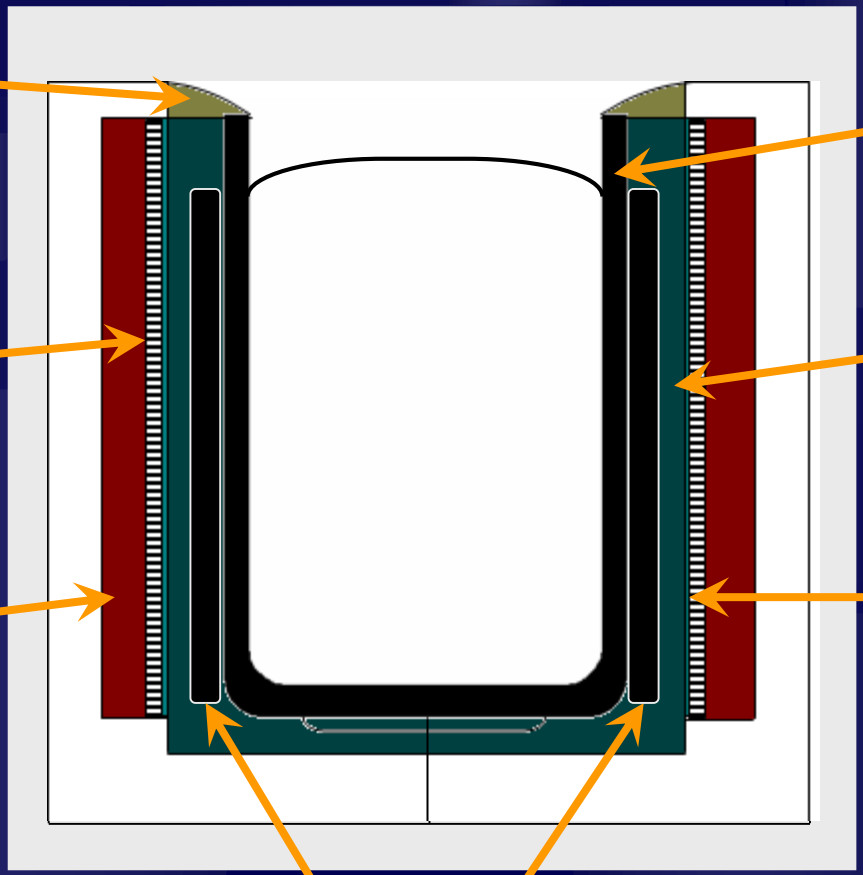
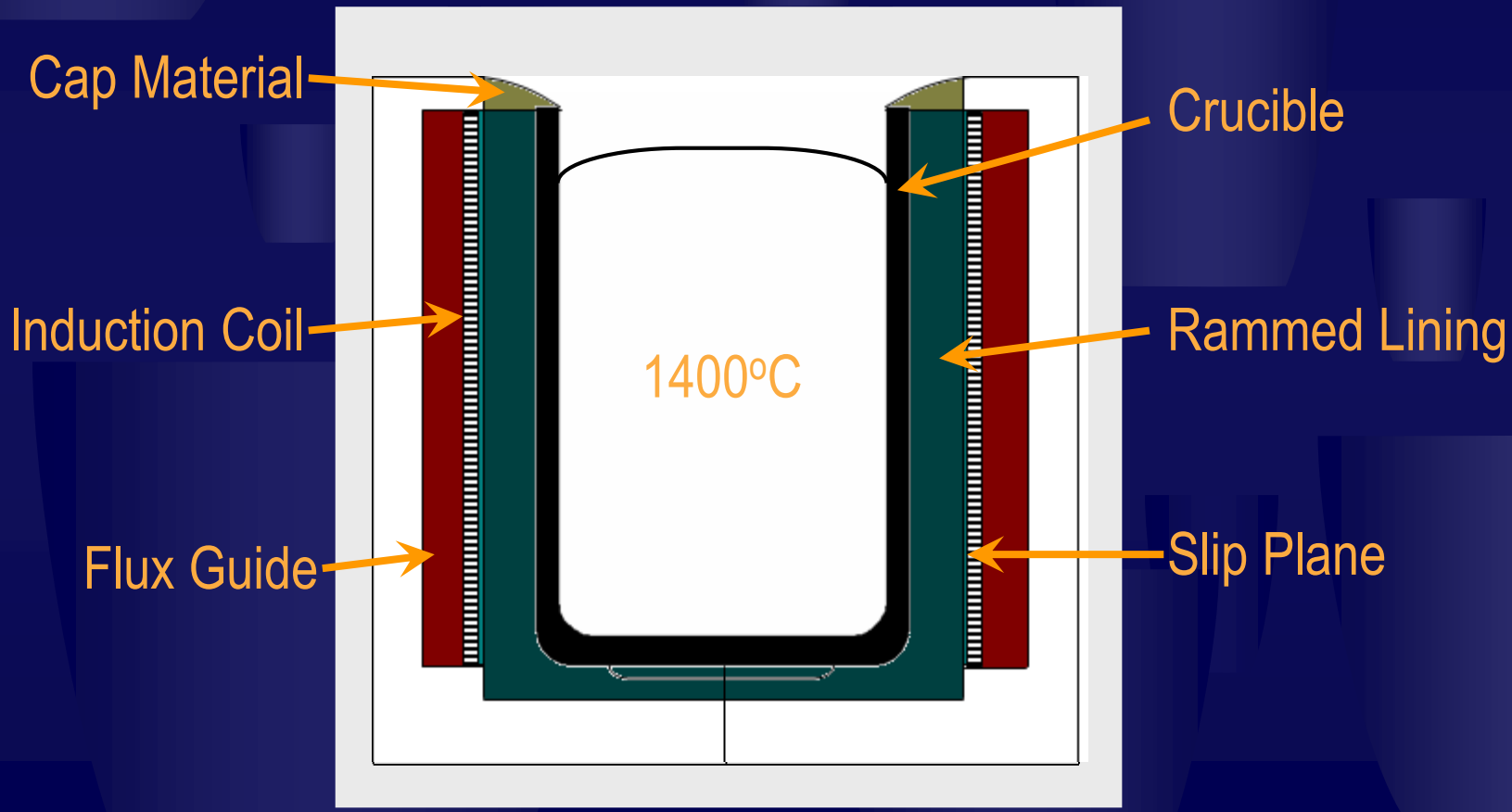


RCL used to create enough heat to extract the copper

Foundry Applications; 2

Tungsten Ore Refining



Foundry Applications; 2

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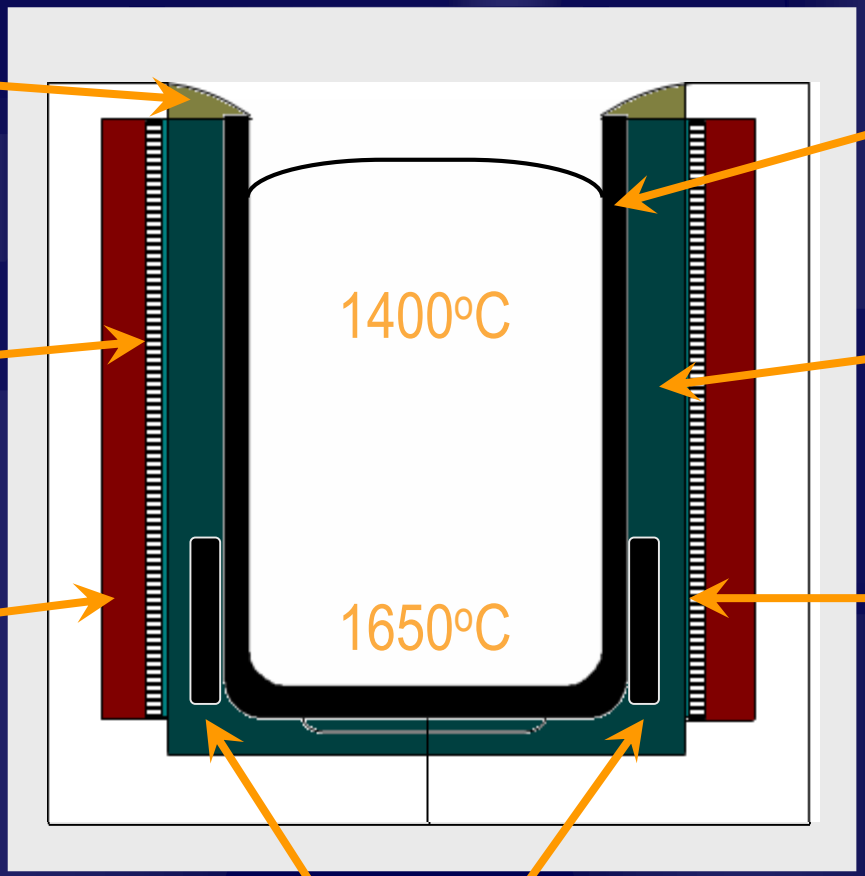
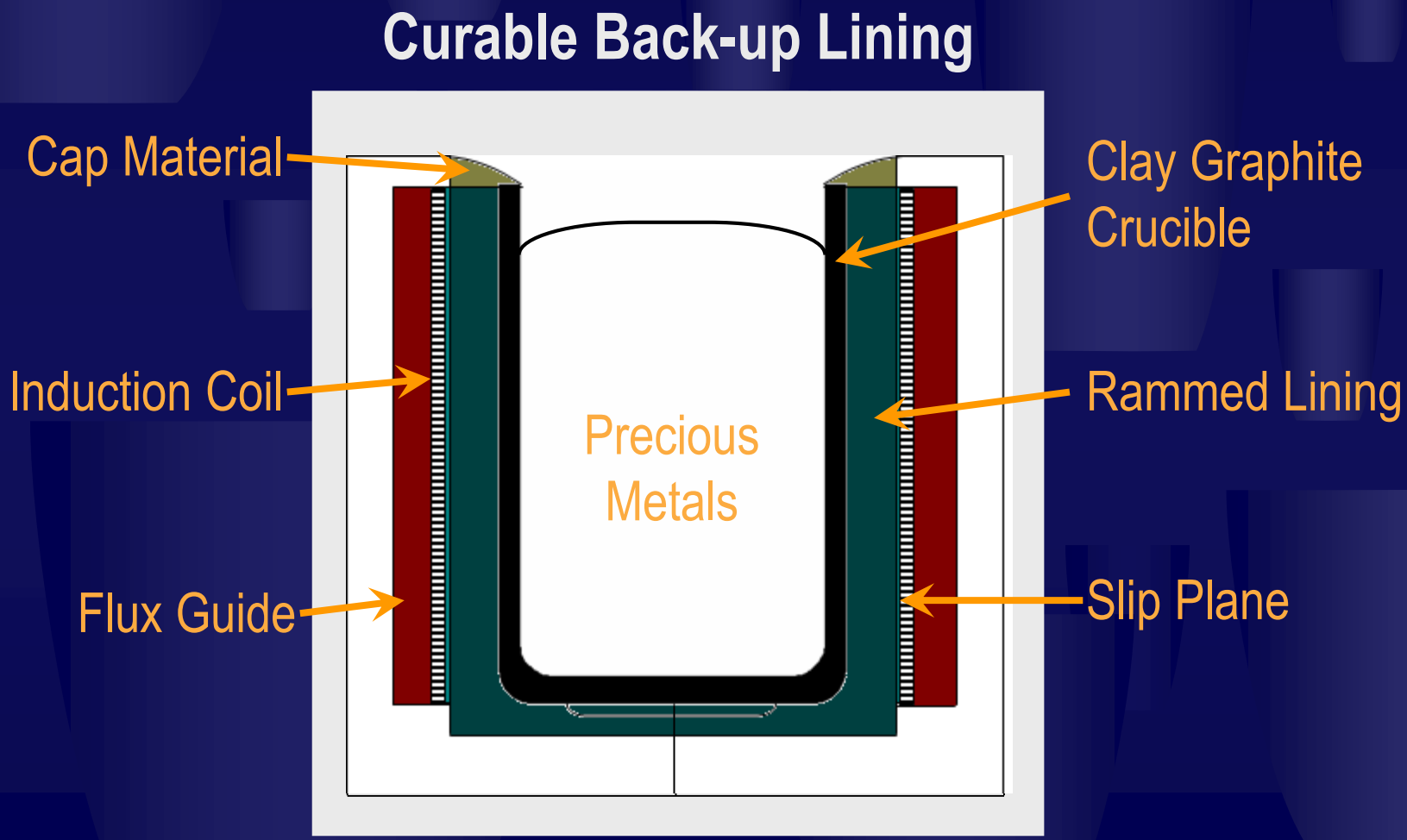


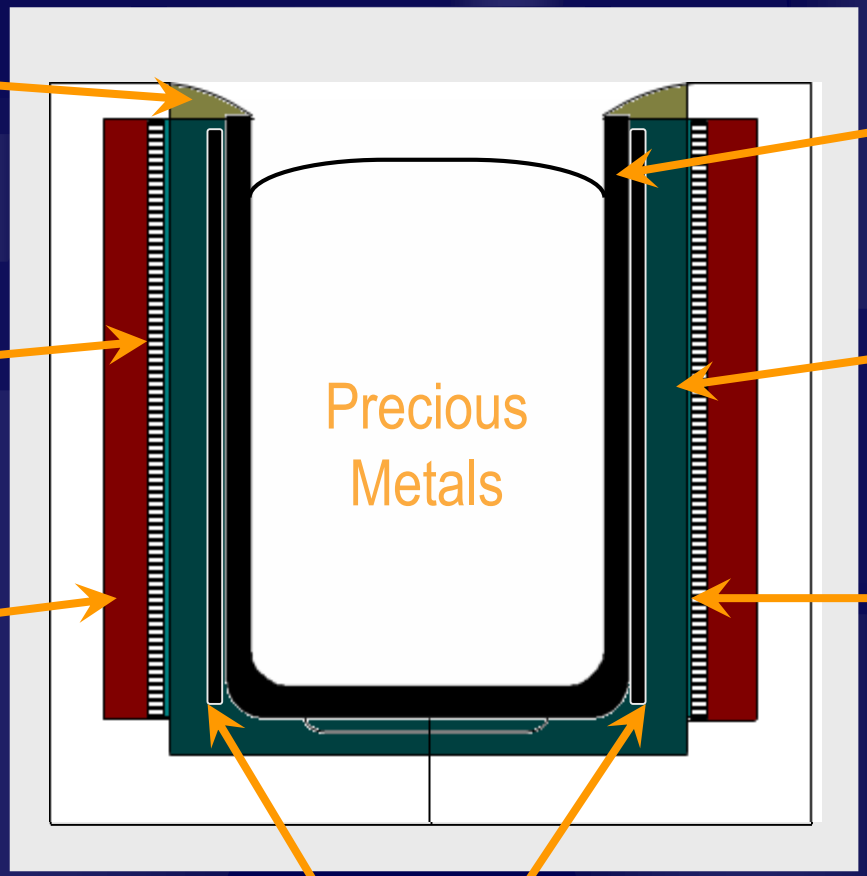
RCL used to create hot zone in the base of the crucible

Foundry Applications; 3



Foundry Applications; 3

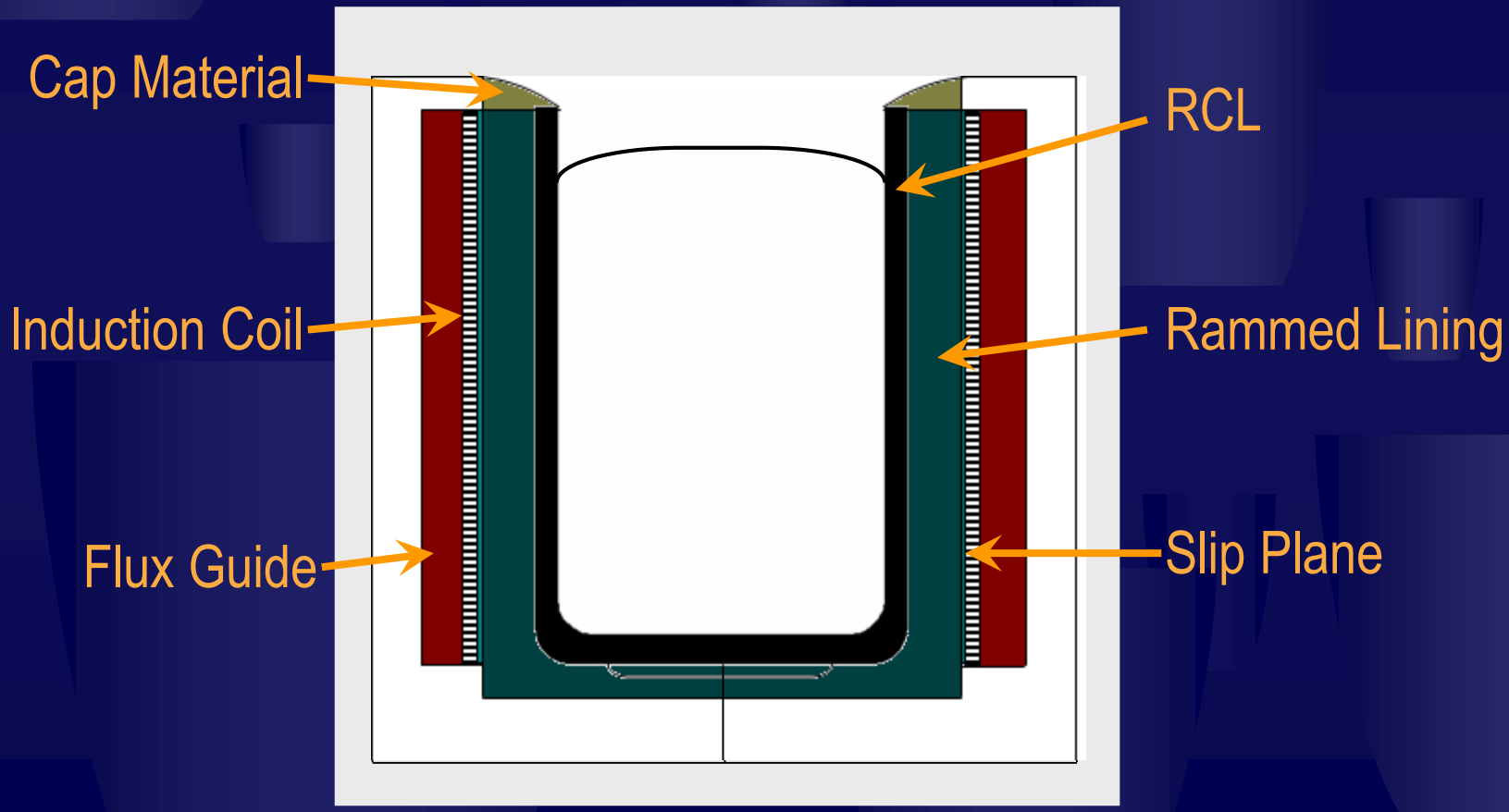
Curable Back-up Lining



RCL used to allow faster crucible changeover

Foundry Applications; 4

Melting of Silicon



Silicon does not suscept enough when solid to melt by induction

Where can RCL be used?

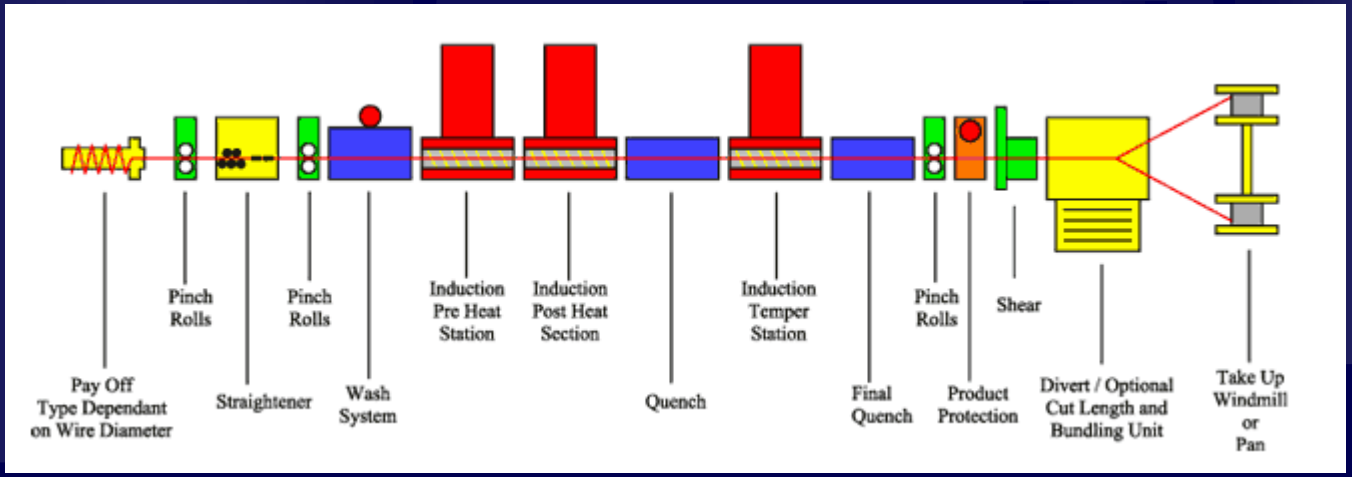
- Other Metal Applications;
  - Air pre-heater for cupola furnace
  - RCL can be used to create an inductively generated heat source.

Where can RCL be used?

- Other Metal Applications;
  - Ferrous & Non-ferrous billet heaters
  - RCL can be used to create an inductively generated heat source prior to extrusion.

Where can RCL be used?

- Other Metal Applications;
  - Wire heat treatment – RCL used to increase heat treatment temperature up to 1400ºC, much higher than the current Inconel lined system, improving the physical properties of the wire.



Where can RCL be used?

- Non-Metal Applications;
  - Incineration of liquid waste – RCL used to create an inductively heated ignition source,
  - Incineration of solid waste – RCL used to heat transfer pipes to allow pumping of slag generated from the incineration process,
  - Melting of high purity glasses – RCL used as a furnace lining,
  - Coal gas refining – RCL used to generate a hot zone around a ceramic tube.

Incineration of Liquid Waste

Incineration of Liquid Waste

- Scandinavian Trials;
  - Rammed a strong, free standing cylinder
  - Heated cylinder to 1600^{o}C in 30 mins
  - Susceptance better than a crucible (lower Q-factor)
  - Incinerated jet of oil/water waste through cylinder
- Application;
  - Incineration units for waste disposal for shipping
  - New EU legislation is tightening control of waste disposal emissions from ships

Incineration of Liquid Waste

RCL - Features

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- Couples with an induction field in the unfired state
- Can be fired in-situ
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  - Without degradation through use by oxidation

  - N.B. – RCL is not designed to directly replace a pre-formed SiC/graphite crucible in traditionally crucible based applications as densities of RCL are lower

RCL - Benefits

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