IWCC TECHNICAL SEMINAR – BARCELONA, MARCH 2009

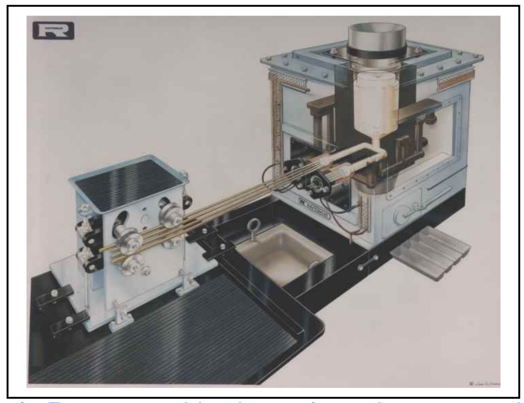
RAUTOMEAD GRAPHITE CONTINUOUS CASTING TECHNOLOGY

BEGINNINGS

Technology
Rautomead was founded in 1978 to exploit the technology of continuous casting of non-ferrous metals. The starting point was the patented "Unicast" process, developed originally by United Wire of Edinburgh in the 1950s for production of semi-finished brass and bronze bars used in manufacture of fine wire mesh. Unicast was excellent in concept, but machines of that type were large, cumbersome and efficient only in long production runs of a single product. Change-over was very time consuming, often with several days being required to complete the work.

From the outset, key features of Rautomead technology were the use of graphite crucibles, submerged casting dies, electric resistance heating and inert gas protection of hot working components.

This technical approach differentiated Rautomead technology from that of almost all of its competitors, who adopted various forms of induction heating usually with rammed ceramic furnace linings.



early Rautomead horizontal continuous casting machine

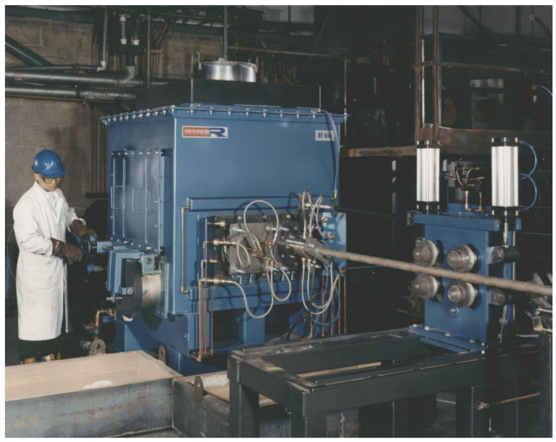
Materials
The materials around which the Rautomead process was initially developed and commercialised were leaded brasses to BS 2872 CZ122, now BS EN 12164, CW617N.
Applications were in forged and machined brass components widely used in the building, electrical, gas and water industries. The range of continuous cast copper alloys was quickly expanded to include leaded and unleaded bronzes, of which the most common was Gunmetal, BS 1400 LG2 now BS EN 1982, CC491K extensively used as a bearing material in the engineering industry, as well as a corrosion resistant alloy in underground plumbing applications.

brass forged & machined components

BEGINNINGS (CONT'D)

Novelty of Scale

A novel feature of Rautomead technology in its early days was that it made continuous casting of brasses and bronzes economic on a relatively small scale of around 200 kgs/hour. The opportunity which the company had identified was to site a continuous casting machine in the works of a secondary brass forging or machining company to recycle its own arisings of scrap and machining swarf – often amounting to 30% or more of the input material.



Rautomead RT 650 continuous casting machine
(70 litre crucible capacity, 275 kgs per hour)

Traditionally, such scrap and swarf would be sent back to a large brass extrusion mill for re-processing at substantial loss to the secondary producer. The high margin between the price at which the rod was sold and the scrap and swarf bought back was a source of much grievance in the industry at the time. In-house recycling resulted in substantial savings for the user. Many early machines were successfully installed in this type of application.

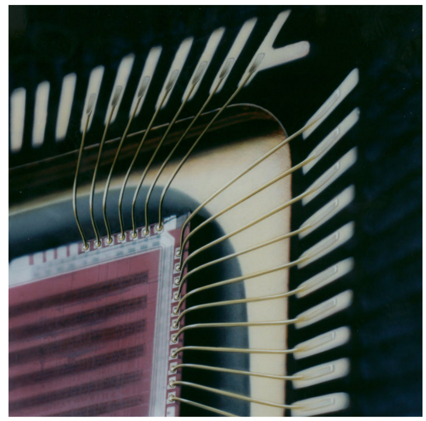
International Focus

In addition to the United Kingdom, demand in those early days stemmed from Malaysia, Australia and New Zealand. This forced Rautomead to address the challenge of designing equipment which could be operated successfully and safely without regular attention of the manufacturer; to instigate training programmes to ensure that customers' workers understood the process, its operation and machine maintenance and to develop a high standard of technical support. All of these characteristics remain hallmarks of Rautomead's business to this day.

MOVE TO CONTINUOUS CASTING OF PRECIOUS METALS

The totally enclosed graphite containment system proved advantageous in production of strip and wire rod production in a wide variety of gold and silver alloys. A range of smaller machines was introduced, which shared the same basic technical features as their larger equivalents. An early successful application was in production of Sn20 Au strip for making pre-forms for microchips in the electronics industry. The continuous casting process superseded casting into static moulds and extrusion, with substantial savings in production costs.

Rautomead RMT 200 continuous casting machine - up to 24 litres crucible capacity, 160 kg/hour (Ag)



gold bonding wire

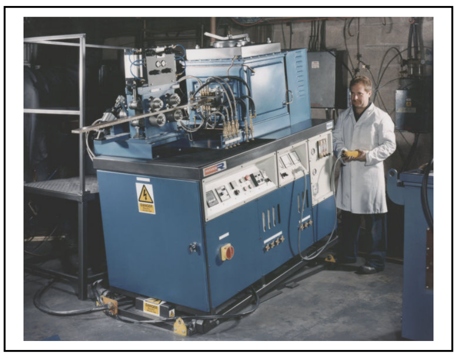
In 1985, Rautomead was approached by the Royal Mint of UK with a project to continuously cast 22 carat gold strip for production of bullion coins. This alloy is typically referred to as 'standard gold' and adopted as the British Standard for gold coinage. The general tolerance applied to the Au content to be maintained for continuous casting is + / - 0.05 %, the alloying element being mainly Cu, but may also include up to 0.5% Ag. As melting and alloying were both to be done in a single graphite crucible, extensive tests were carried out to prove the effectiveness of inert gas bubbling through the melt to achieve a very tight alloy tolerance throughout the cast strip. Rautomead technology has also been chosen for casting fine gold products adopted by the major mints throughout the world owing to the characteristics of the carbon melt containment and high quality of the cast product. In most cases, the continuous casting process took the place of traditional casting of gold into static moulds, followed either by hot rolling or extrusion. The saving in production costs and increase in good product yield were substantial.

Other precious metals applications developed for the process included gold and silver jewellery alloys, palladium gold and silver dental alloys and lead frame alloys for the electronics industry. These applications called for further miniaturisation of the equipment, for which the models RVS (0.5 litres) and RMJ (up to 5.7 litres) table-top machines were introduced. A downwards vertical machine was introduced especially for production of gold tube.

MOVE TO CONTINUOUS CASTING OF PRECIOUS METALS (CONT'D)

Smaller scale casting equipment has proved very effective for the production of ultra pure gold bonding wire and also gold alloys for the electronics industry including Au-Sn, Au-Si and Au-Ge, produced in strip form for subsequent rolling and stamping into brazing pre-forms for the semiconductor industry.

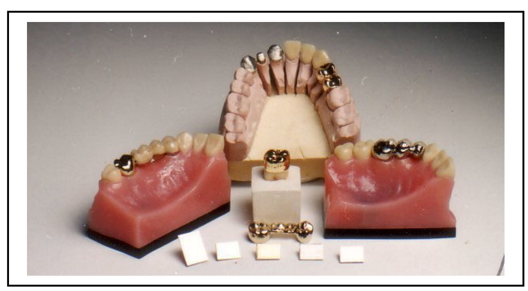
Dental alloy producers have also adopted Rautomead's small scale systems for casting a wide range of alloys to near net shape including elements such as Au, Ag, Pd and Pt . As a general rule, the graphite containment system is compatible with Pd content up to around 60%. The small volumes involved in the use of the small casting machines allowed the end user to keep metal inventories low as the yield from the average batch melt was in excess of 95%. Batches of alloy are either pre-alloyed and poured in or fed as ingot; however in some cases an alloy can be made up inside the graphite crucible using argon or nitrogen bubbling to ensure the alloy is completely mixed. This action can also help to displace unwanted dissolved gasses.



Rautomead RMJ/H 025

Rautomead RMJ/V005

silver photo frames & jewellery



dental alloys

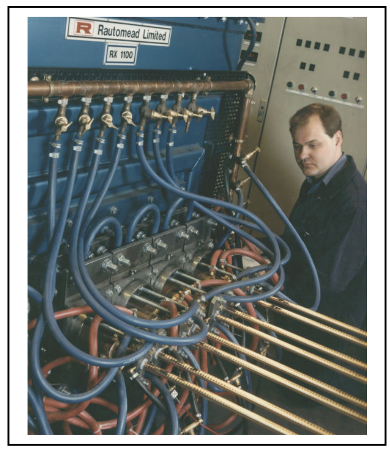
CONTINUOUS CASTING OF NICKEL BASED MATERIALS

During the mid to late 1980s there was growing interest in the continuous casting of high melting point alloys which were notably incompatible with a standard carbon based containment and casting die system. This initially included high Pd and Pt containing dental alloys but was soon followed by projects for casting Ni-Cr based bearing alloys. Rautomead developed the application of high alumina ceramic linings for the melt containment and boron nitride composites for casting die linings, whilst retaining the use of resistance heating and a graphite mother crucible.

Ni-Cr bearing alloys up to 88% Ni including Bi were not suited to the high rates of solidification in induction based equipment for steels owing to complexities presented by the chemistry of the alloys. Differential cooling of the elements in these complex materials also led to shrinkage and central unsoundness in the cast material. These issues were resolved by slower and more progressive cooling in a specially designed ceramic-lined jacket cooled graphite die in the Rautomead system. The containment was also a notable contributor to the success of the system, in that the still melt avoided oxides from entering the feed port to the die and very stable melt temperatures could be maintained throughout a casting run.

HORIZONTAL CONTINUOUS CASTING OF BRONZE AND COPPER-MAGNESIUM

While the RT 650 machines with a crucible capacity of 70 litres fulfilled a defined market niche, it became apparent in the late 1980s, that a demand existed for larger capacity horizontal machines with up to eight strands in production of Si1.5-3.5Cu silicon-bronze as low temperature brazing alloys and also for Mg0.1-0.5Cu trolley wire rod. Thus, the larger models RX 1100 (110 litres) and RX 1400 (155 litres) were introduced. These machines have also been supplied for making copper and brass extrusion billet in sizes up to 250mm diameter, including hollow billet for tube manufacture.



RX 1100 in production eight strands Cu-Mg rod

UPWARDS VERTICAL CASTING

In 1991, the decision was taken to adapt the process for continuous casting of 8mm diameter Cu-OF rod, using a single combined melting and casting furnace.

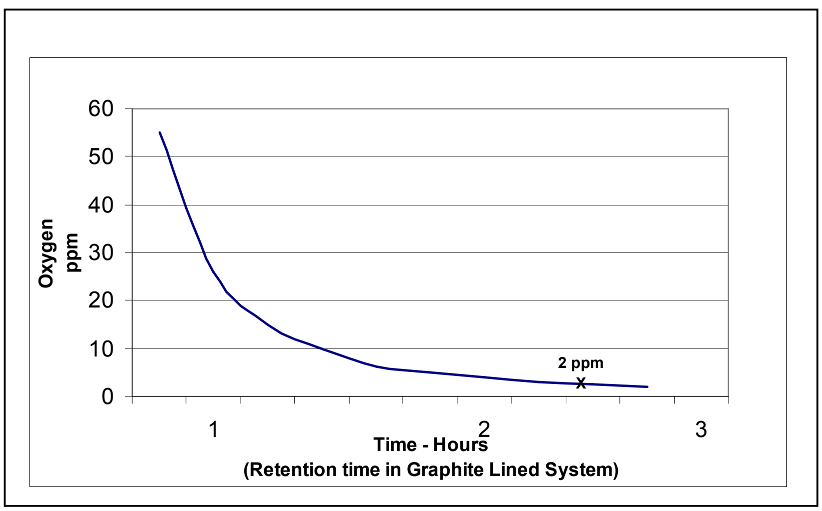
UPWARDS VERTICAL CASTING (CONT'D)

This involved reorientation of the process to cast vertically upwards, using a twin chamber graphite crucible. Cathodes were melted in one chamber; the liquid copper passed through to a separate casting chamber from which it was cast out vertically upwards to form the rod. Initial tests were done using a single strand machine; later a production-scale eight strand machine was built to complete the test series. Rod coilers were also designed to make neat layer wound 4-tonne packs. The first of these machines was sold in 1994, since when a total of 45 machines for this application have been supplied to 30 customers in 23 countries around the world.

Oxygen Reduction

The key differentiating feature of the Rautomead upwards vertical process was again the use of a graphite containment system and electric resistance heating, compared with virtually all competing systems with their channel induction heating and rammed ceramic furnace linings. It is common to all systems of this type, whether of the graphite furnace type or the induction-heated type that it is necessary that oxygen must be reduced to less than 10ppm to achieve an adequate casting die life and thus an economically viable performance. Normal grade A cathode may be expected to have an oxygen content of 60-80ppm.

Early design studies showed that the oxygen could be reduced in such a graphite system to close to zero in a dwell time of around 3 hours. Thus the Rautomead crucible capacities are designed to provide a dwell time in excess of this.



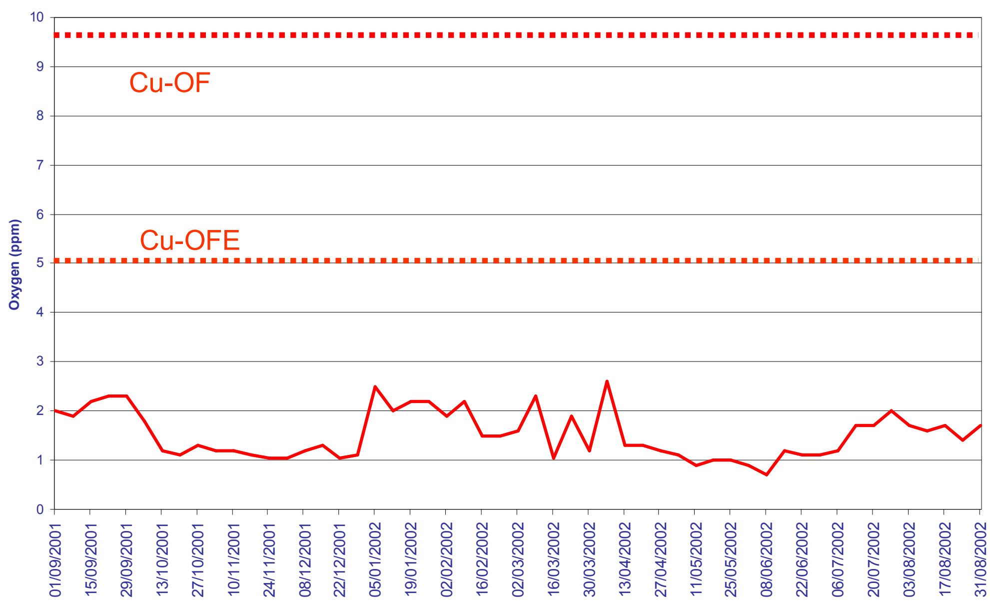
UPWARDS VERTICAL CASTING (CONT'D)

In the case of the Rautomead direct cathode melting and casting system, there are six stages where the oxygen is reduced:

- graphite pellet metal cover over melting chamber
- graphite sacrificial lining of upper part of melting chamber
- graphite walls of crucible
- graphite filter bed
- graphite sacrificial lining of casting chamber
- graphite flake cover over casting chamber

The RS 3000 model, for example, has a crucible holding capacity of 2.5 tonnes and a rated throughput capacity of 700 kg per hour. Two points are significant:

first, that it is almost impossible for an operator to make a product which is not oxygen-free using the Rautomead system, second, this can be achieved in a much smaller furnace than is required in a single furnace induction-heated system, where the only means of oxygen-reduction is the metal cover.



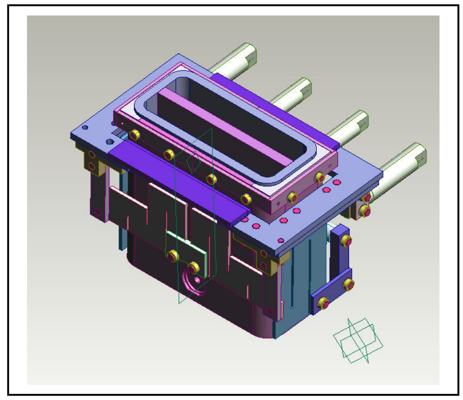
Oxygen measurements in cast Cu-OF rod over 12 months

Electric Resistance Heating

Low voltage electric resistance heating is a special feature of the Rautomead furnace design. A mains transformer is supplied as part of the principal equipment which transforms the voltage down to a secondary 36 volts.

Electric Resistance Heating (cont'd)

Low voltage three phase power is fed to the furnace through water-cooled bus bars, linked to a carefully designed chain of graphite heating elements to provide just the right level of resistance. Power is transmitted to the copper by radiation and convection from the heating elements through the walls of the graphite crucible. This arrangement results in a still metal bath with no electro-magnetic stirring. Operating at low voltage, it is also very safe for the operators. The system is electrically efficient, requiring around 320-330 kWh per tonne of copper for melting, holding and casting combined.



graphite heating elements

Automated Controls

Depending on the model selected, control systems used on Rautomead upwards vertical casting machines include a high level of automation, such that a machine does not require a full time operator.

All alarmed parameters are accessible through the main user control console (touch screen type) by selecting the appropriate page from a menu. Parameters considered sensitive may be locked off by an administrator where necessary. Over 30 production parameters are constantly monitored, covering temperatures, pressures and movement. Records for up to one year are stored in the control system and can be downloaded to an external computer.

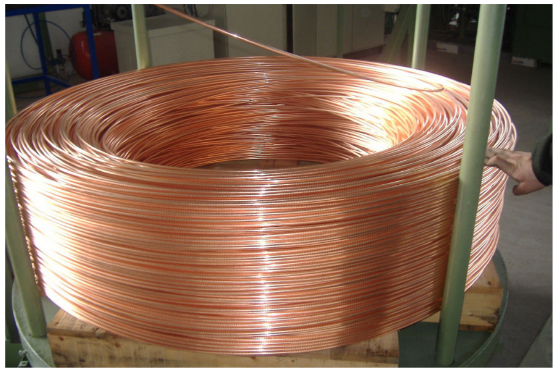
Remote plant monitoring is available, whereby plant status may be interrogated either through a user's own computer network or by modem telephone connection.

Product Quality & Consistency

The combination of the inherent oxygen-reducing characteristics of the Rautomead furnace design and its automated control systems are conducive to production of consistent high quality Cu-OF rod, largely independent of operator intervention.

Typical properties of 8.0mm Cu-OF continuous cast wire rod produced using a Rautomead machine are typically :

Diameter :	7.98 mm
Elongation :	39 - 41%
UTS :	170 – 175 N/mm²
Density :	8.89 kg/dm^3
Conductivity :	101% IACS
Oxygen content :	less than 10 ppm, typically less than 5ppm
Surface oxide :	less than 15 Angstroms
Carbon content :	less than 3 ppm



coil of 8mm Cu-OF rod

Failsafe Emergency Systems

Another important safety aspect of the Rautomead design is its reaction to mains power failure. In such an event, a battery-operated emergency hoist, automatically lifts the super-coolers from the molten copper to make the system immediately safe. Thereafter, the operator has at least an hour in which to take action. This may be:

- mains power restored
- emergency power initiated
- molten copper dumped

These relatively relaxed emergency actions contrast sharply with the actions required in case of an induction-heated furnace, where a metal freeze in the channel inductor may occur very quickly on power failure and can lead to an expensive and time-consuming repair or inductor replacement.

Rautomead RS 3000/6

UPWARDS VERTICAL CASTING (CONT'D)

Upwards Vertical Casting of Brasses and Bronzes

As so often in the past, the development of the Rautomead upwards vertical casting process for one application led logically to its adaptation for other products. A specific challenge faced by Rautomead had been to achieve adequate physical properties and casting speeds in horizontal casting of Zn30 Cu brass, Sn5-8 Cu bronze and Zn25 Ni12-18 Cu nickel silver wire rods. In-house upwards vertical casting tests were carried out which showed a significant improvement both in physical properties and in casting speed, compared with results obtained in horizontal casting.

An eight stand machine was designed to act as a holding and casting furnace, to be fed with pre-alloyed molten metal on a batch basis. These alloys are cast typically at 19mm, before rolling, annealing and drawing to wire.

More recently, this same process has been developed for production of binary brasses, Zn40Cu and Zn35Cu which are now routinely cast at 8mm, before drawing and annealing used in manufacture of EDM wire. The novelty in this case was to cast at 8mm, rather than 16mm in earlier technology, thus reducing the amount of downstream working and reducing also cost of production.

Historically the horizontal casting of Ni-silver cast horizontally presented significant issues in die service life. Casting rates were also moderately low, both factors adversely affecting process viability. There was a natural advantage in adopting the upwards vertical system in that the tooling change could be made readily with minimal downtime. Also the vertical casting tooling was of simplified geometry and lower cost. Early exploratory work on the casting of a range of Cu-alloys noted that both the throughput and quality of the rod was much improved over horizontal cast products. The trend with Ni-silver indicated a more favourable service life owing to reduced chemical related attack of the Ni on the graphite casting die by using lower melt temperatures and also in part relating to very low applied metal pressures and reduced friction during the break-off from the die wall.

This pattern was observed with the casting of the more challenging Cu alloys including Cu-Si and Cu-Mg. Taking 19 – 20mm diameter products as an example, horizontal production was commonly in the region of 40 - 60kg/hr/strand. This was readily increased to 100 – 110 kg/hr by the vertical method. The product was relatively free from surface oxidation owing to the rod exit temperatures from the tooling being in the region of 100 – 120 degC as compared to 400 – 500 degC commonly measured on horizontal arrangements. The method of extracting the rod by a succession of rapid but short pull widths helped to reduced surface fissures; clean-out cycling was also introduced to remove accumulations of condensed Zn, Mg and segregated elements such as Pb and Sn.

The crystalline structure was also notably improved with enhanced tensile properties (UTS and % elongation) which favoured subsequent cold rolling. The vertical cast rod presents greatly superior structural symmetry compared with horizontally cast rod. The latter tends to lean forward owing to the uneven effects of gravity around the circumference of the solidifying metal. Higher rates in casting (cooling) also led to the grains being more refined and more evenly distributed.

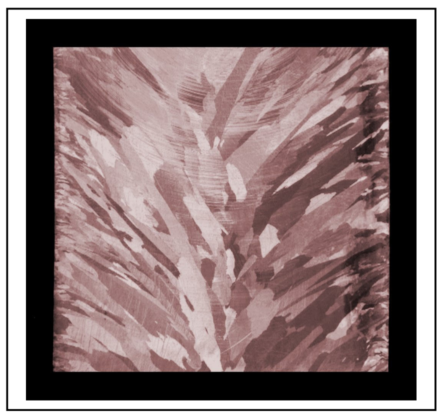
UPWARDS VERTICAL CASTING (CONT'D)

Upwards Vertical Casting of Brasses and Bronzes (cont'd)

In the upwards vertical mode, the characteristic mix of central equiaxed grains and fine chill grains on the outer diameter remained, but the larger columnar grains were of a steeper angle towards the direction of cast, typically 50 – 70 deg rather than 40 – 45 deg in horizontal casting.

Rautomead RS 2500 in production of 8mm binary brass

Cu-Mg horizontally cast section



Cu-Mg upwards vertically cast section

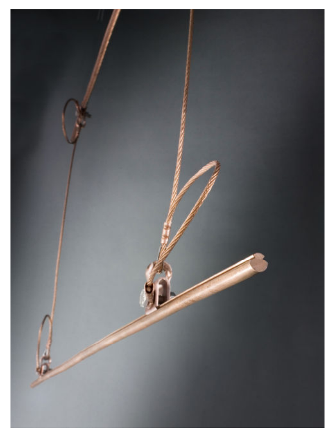
UPWARDS VERTICAL CASTING (CONT'D)

Upwards Vertical Casting of Cu-Ag, Cu-Mg and Cu-Sn Alloys for Trolley Wire
Upwards casting of silver-bearing copper alloys was only a small step from Cu-OF. Rautomead designed an automatic dosing device, whereby a controlled weight of Ag grain is added to the crucible, corresponding to the weight of each cathode. The rate of diffusion of the Ag in Cu in very rapid, leading to a consistent alloy composition

Rautomead horizontal machines have been in production of Cu-Mg alloys for trolley wire applications since 1990. The horizontal process was relatively slow and costly. An extensive series of tests was carried out in 1997 into upwards vertical casting of 30mm diam rod in Cu-Mg alloys. It was found that the totally enclosed nature of the Rautomead upwards vertical process as well as its external resistance heating source lent itself well to production of consistent quality Cu-Mg to tight alloy tolerances (better than +/- 0.05%), despite the volatile nature of Mg and its strong tendency to form slag in casting. Formation of slag on exposed crucible walls as metal level rose and fell had been a particular difficulty in horizontal casting of Cu-Mg.

Cu-Mg is now the preferred alloy for profiled contact wire and stranded messenger and dropper wires in many of the world's high speed rail systems (300 kms/hour and over), offering a good combination of low resistivity with good tensile strength. Though with not as high a performance specification, Cu-Sn is another commonly used high speed trolley wire alloy which is now routinely cast on the Rautomead upwards vertical system.

high speed rail, SNCF, France



catenary wire assembly

Rautomead RS 3000/5/30 Cu-Mg machine

UPWARDS VERTICAL CASTING (CONT'D)

PROCESS TEMPERATURES

Furnace temperatures and casting temperatures are features of the alloys in production and are also influenced by whether the casting machine is used as a combined melting-holding-casting machine, or only as a holding-casting machine, with a separate molten metal feed. In terms of the materials discussed above, furnace temperatures range from 1,030 deg C (60:40 brass) to 1,600 deg. C (24%Pt 15%Pd Au dental alloys). Casting temperatures are normally around 100 deg C lower than furnace temperatures, though in some cases this differential may be significantly greater. These temperatures are well within the normal working range of graphite materials. For example, graphite electrodes in arc furnaces operate conventionally at temperatures up to 2,800 dec C.

THE FUTURE

The pattern of progressive development described is an indication of the continuing commitment of Rautomead to the continuous casting process itself and to the never-ending quest to extend the application of the process to new materials where traditional production process stages may be shortened or eliminated, product quality and yield improved and costs saved.

Current development projects being undertaken at Rautomead include:

Ecobrass

With the ever growing need to work towards eco-friendly materials Rautomead conducted trials work in 2006 and 2007 in Ecobrass, in efforts to cast to near net shapes and high quality cast surfaces.

The work concentrated on casting of Ecobrass alloys based on C693 (Cu, Si 3.0% , Zn 21 %, P 0.09%) in hexagonal hollows < 40mm AF and with modest wall thickness ratios of 25%. The aims were to cast the product range up to rates of 110 kg/hr/strand for continuous periods up to 120 hrs and maintaining the following as-cast qualities:

- Surface defects (fissures) no greater than 400 micron
- Minimal Zn deposits
- Across Flats (AF) of +0 to +0.8 %
- Included angles between flats (3 pairs) of +0 to + 0.25%
- Internal bore concentricity up to 3%
- Bar straightness of no greater than 3mm in 2000mm length

The objective of the exercise was to develop a system to produce this quality of as-cast section and thus to avoid further downstream processing, such as shaving and reel straightening, enabling the cast product to be used as suitable feed material for CNC machining operations. The end-user's requirements were fully met.

THE FUTURE (CONT'D)

Ecobrass (cont'd)

The work focused mainly on a combination of withdrawal pulsing techniques and careful selection of graphite grade for the casting die in order to achieve consistent high quality as-cast surface qualities over prolonged periods. Previous work in casting of thin wall hollow sections in CuSi alloys was a useful precedent Condensing Zn exacerbated by the presence of Si formed a distincy technical challenge. These issues were overcome through the use of graphite with a particularly low coefficient of friction and low wetting properties. Zn and Si compounds were controlled by predetermined clean-out cycling, as well as by casting at high rod exit temperatures (300-350 degC) from the die tooling.

RS SQ Rod

Since the adoption of 8mm as the common redraw standard for wire and cable making there has been an increasing demand for higher quality from as-cast Cu-OF processes. This relates principally to drawing to super-fine (>0.05mm) wires, but there are other products, namely enameled flat wire in the region of 3 – 4mm^2 section which relies greatly on the integrity and surface finish of the as-cast material, as only modest (cold) reductions are applied to finish it.

Conventional quality 8mm Cu-OF rod is suitable for enamelled wire of up to approx. 1.8mm diameter, but not greater. In larger enamelled diameter wires, standard (HVCT) current tests have highlighted quality issues by indication of blistering due to the presence of micro scale surface cracks in the magnet wire. The origin of such cracks stems from the casting pulse interface in the continuously cast rod.

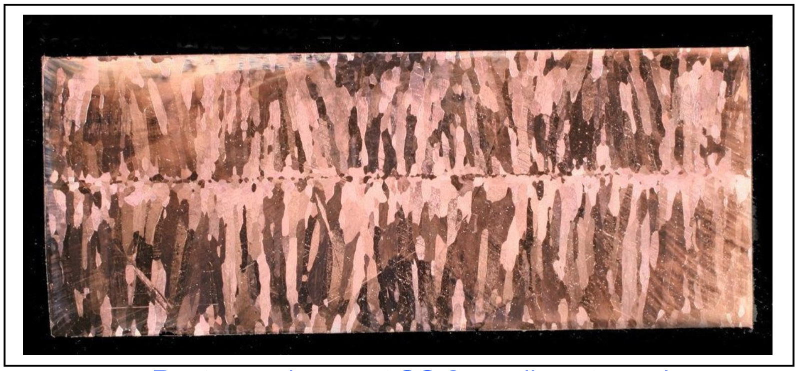
With this background, Rautomead conducted a worldwide market survey to determine the qualities commonly produced by the vertical method from it's own customers as well as others. This involved studies of the longitudinal and transverse sections of the grain structure as well as surface cracks i.e. pulse fissures due to the casting process, the general observations for surface qualities were:

Crack Depth (μ)	Comment on quality	Occurrence in market
5 – 10	Highest quality for super fine wires (< 0.20mm)	Few cases
10 – 15	Good general quality for fine wires (0.2mm)	Common
15 – 20	Marginal quality for medium gauge wires (0.2 – 0.5mm	Common
20 - 45	Low quality for heavier gauges only (0.5 – 1.0mm)	Few cases

Also taken into account was the nature of the crack, it's width and form i.e. V or U in shape. In essence only the highest quality rod available was suited to fine wires and in particular the high specification enameled flat wire, noted above.

THE FUTURE (CONT'D)

RS SQ Rod (cont'd)



Rautomead as-cast SQ 8mm diameter rod

Rautomead as-cast CuOF 8mm diameter rod

The crystalline forms indicated that the favoured structures were also those observed in the highest quality rod. This exhibited finer columnar grains, more evenly distributed. These properties improved tensile strength for wire drawing.

Rautomead undertook to develop a system aimed to produce rod of the highest quality on a consistent basis on a multi-strand production scale. This involved an investigation into designs of both casting tooling, product withdrawal equipment, services and also casting techniques.

Efforts were concentrated on the effectiveness of heat transfer which has a direct influence on the crystalline form and also in part the nature of the pulse interface. The standard tooling design was reviewed and refined to promote greater heat transfer through the die. This was only one parameter amongst several others having influence on the crystalline form, but it was key to enabling other parameters to show their effectiveness, such as cooling water delivery, temperature and flow rate.

THE FUTURE (CONT'D)

RS SQ Rod (cont'd)

Product withdrawal pulsing sequence has long been observed as being one of the most significant features of the continuous casting process, having a direct effect on the quality of pulse interface. Conventionally Rautomead has successfully adopted a fixed mechanical solution (cam indexer) for the pulsing of Cu-OF rod. In most cases this yields good quality rod which can be readily used for fine wire production. For the purposes of this research project, the fixed system limited scope for experimentation. Thus, a precision servo system, ordinarily applied to alloy casting, was chosen.

Pulse waveforms ranging in pulsing rate (mm/sec), pulse displacement (mm) and pulse acceleration / deceleration (sec) in both pull and push-pull motions have been applied in trials work and the effects noted with respect to surface quality as well as the internal crystalline form. This work continues with a view to optimizing the sequences to achieve consistent high quality.

CuCrZr Rod

The conventional method for processing this alloy is long established whereby an initial billet is cast vertically downwards by a direct chill system. This is subsequently extruded to rod where it then undergoes further thermal treatments and mechanical reductions to make semi-finished products.

The attraction to reduce processing costs by casting directly to or near to the extruded rod diameter/s has led to interest in the continuous casting of both Cu-Cr and Cu-Cr-Zr alloys. Rautomead has undertaken to develop a vertical casting system aimed to cast rod between 25 and 30mm diameter at rates from 100 kg/hr/strand to a structural quality which lends itself to cold working from the as-cast state.

Exploratory trials to date have been based on using graphite (carbon) melt containment to help control oxide levels through its naturally reducing environment. The casting system uses ceramic inserts for the die / cooler tooling assembly in order to minimise chemical reactions between the Cr (and Zr) elements and the 'break-off' point in the die. Control of the rate of solidification is controlled to help maintain the integrity of the pulse interface on the surface of the rod, as well as avoiding extreme mixes of longitudinal growth of columnar grains in between pulse interfaces, as this also leads to rod failure in cold processing. The work is on-going.

THE FUTURE (CONT'D)

RS CC Machine
This machine is purposely aimed at supplying a lower cost alternative to Rautomead's existing range of RS upwards vertical casting machines. The output capacity is lower than the larger RS models but the RS CC models retain the same capabilities for casting high quality Cu-OF and high Cu alloys. It features simplified mechanics, reduced operating features and minimal systems monitoring and alarming. Cathode feedstock requires to be chopped into pieces to feed the machine.

The machine is configurable to cast a range from 8 to 22 mm diameter and is suited for wire and cable applications as well as input feedstock for continuous extrusion operations of Cu-OF as well as Cu-Ag alloys, among others.

The furnace construction is based on graphite resistance heating and melt containment to designs which are aimed at utilising less expensive standard graphite blocks available from manufacturers throughout the world. The heating elements and crucible arrangements are shown in the figures below. The RS-CC employs a smaller and more compact heating system than the larger RS scale but retains the three-phase circuit as in the larger machines. The crucible is of a simple geometry whereby the dividing of the melt from the casting chambers is effected by removable dividers rather than being an integral feature of the crucible body, this helps to keep fabrication costs low.

Zn Rod & Billet
Zn products including wire for spraying, among others, have commonly been continuous cast in the region of 10 – 22mm diameter whether by horizontal or vertical methods. Other larger products of non-round sections continue to be produced through extrusion of billets that have been initially static or continuous cast.

Rautomead has developed a vertical system to cast re-draw 8mm diameter up to rates 105 kg/hr (5m/min) of suitable qualities for hot-drawing to smaller wire gauges.

The continuous casting of Zn billet is another such product which Rautomead offers to replace static casting methods of making same in diameters ranging from 55 to 120mm.

The casting tooling designs applied to the vertical system have been scaled up and will be applied for horizontal casting at rates of up to 250 kg/hr (diameter dependent). The aims of this project work are to produce as-cast billet of consistent good surface quality as well as high integrity internal structure critical for subsequent extrusion. It is expected to be able to maintain such production quality for prolonged periods.