QUALITY PRODUCTION IN COPPER RE-DRAW ROD

Background

Rautomead commenced building continuous casting machines of its own proprietary design in 1978. The early machines were integrated melting, holding and horizontal casting furnaces for the production of multiple strands in brass and bronze alloys. The essential elements of the Rautomead design were based on the now out-dated but still high quality performance furnaces sold under the UNICAST name by United Wire of Edinburgh, Scotland in the 1950s and 1960s. The essential features of this design were electrical resistance heating, solid graphite crucible and a submerged casting die. Heat was transferred to the metal by radiation and convection from a low voltage chain of heating elements through the crucible wall.

Through the 1980s, design of Rautomead machines was refined, particularly in areas of process control and the range of alloy applications. This extended the use of the machines from the original brass and bronze recovery market into production of a wide range of copper based alloys in the forms of rod, strip, and hollow bars.

Fig 1
LCL horizontal casting installation in Melbourne, Australia

Other good applications were found in precious metals, where high product quality and ease of operation led to several multiple installations by specialist users in the jewellery, electronics, minting and dental alloy fields.

Fig 2
Horizontal continuous casting of silver strip in USA

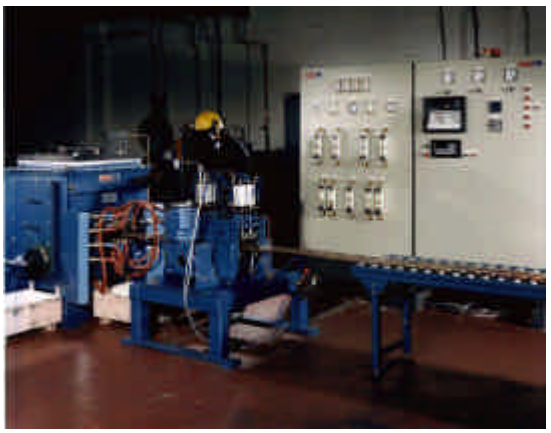

Fig 3
Horizontal continuous casting of gold strip for Kruggerand production in South Africa

Several Rautomead machines are in regular use manufacturing lightly dosed gold re-draw rod for microdrawing as bonding wire for the electronics industry.

Fig 4
Production of gold rod for fine drawing to bonding wire

Oxygen-free Copper Rod

In 1991 Rautomead took the decision to adapt this high quality and proven continuous casting system to upwards vertical casting, with the specific objective of manufactuirng oxygen-free high conductivity copper re-draw rod at 8 mm.

Fig 5
Model RS 3000/8/8 in production of Cu-OF at 8mm diameter

This adaptation of Rautomead methods to upwards vertical casting gave immediate advantages of higher casting speeds, rapid die change, higher production efficiency as well as inherently safer installations.

The concept was to provide a machine which could be directly fed with high grade cathode, without having to be chopped and which would melt, condition and cast the copper into 8mm re-draw rod in a single process step.

The basic features of a graphite crucible, electric resistance heating, inert gas protection and submerged die casting were all retained from well established Rautomead designs, while the orientation of the process was changed to upwards vertical.

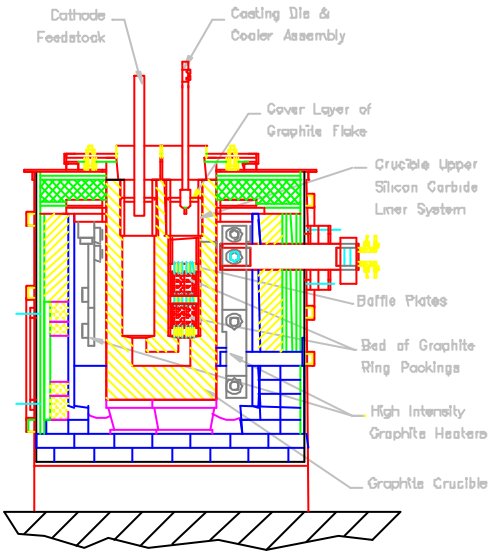

Fig 6
RS machine cutaway

The crucible of the RS machine is divided into two connected sections, a melting chamber and a casting chamber, joined at the bottom, so that the molten copper is not exposed to atmosphere at any stage. The surface of the melt is covered with graphite flake.

Cathodes are lowered either by manually operated hoist or automatically into the melting chamber at a rate of up to 800-1,000 kgs per hour, while the copper is cast out through the submerged casting dies in the casting chamber at a similar rate. Fluctuations in the metal level as batch feeding of cathode is converted to continuous production of rod are accommodated by rises and falls in the level of molten metal in the crucible. The casting dies are immersed in the copper in the casting chamber and are arranged to move up or down to maintain a constant metallostatic head, as the level of metal in the crucible rises or falls.

The process is designed for production of oxygen-free copper, utilising a grade A cathode feed stock. The relevant standard for Cu-OF re-draw rod calls for 10ppm maximum oxygen content. The cathode will typically have an oxygen content of 60-80 ppm and the process reduces this to less than 10ppm and usually to a level of less than 5ppm. Features of the RS process contributing to the reduction of oxygen content are:

a) the totally enclosed nature of the process, with no exposed hot metal transfers
b) graphite crucible, whereby the copper is exposed only to a carbon-based containment system
c) substantial holding crucible, whereby dwell time of the molten copper exceeds 3 hours in normal production
d) special graphite filter beds in the casting chamber

The process has been designed to be environmentally benign. No gas flame or carbon monoxide gas is introduced. The molten metal is held in a totally enclosed, nitrogen protected graphite furnace at all times.

The large volume of molten metal as well as the substantial mass of the graphite crucible itself permits very accurate control of process temperature.
Temperature of the furnace is monitored in both the melting and casting zones. As a new cathode is added, the cascade temperature control equipment automatically calls for more power to boost the melting rate, while temperature at the casting zone is maintained steady in production at less than +/- 5 deg C. This feature, together with a constant immersion depth of the casting dies in the melt and a still metal bath in the casting zone contribute significantly to consistency of product quality.
A taphole is provided at the base of the crucible, whereby the entire charge can be emptied in a matter of a few minutes.

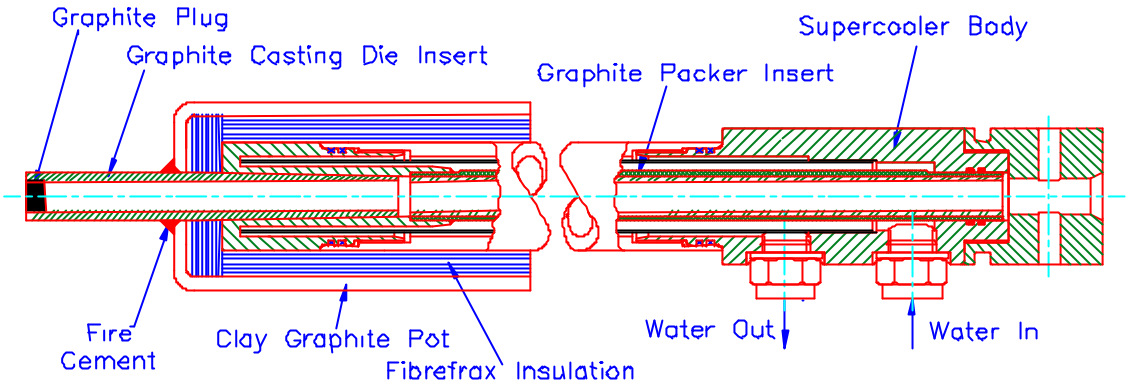

Fig 7
Casting Die assembly

Casting dies are made in high quality graphite. They are mounted in special cooler assemblies, through which cooling water is circulated. The metal solidifies in the primary casting insert and then passes up through a series of graphite secondary inserts until the copper rod exits the top of the die assembly at around 80 deg C, well below oxidation temperature. Casting die life is usually about six days in continuous production of 8mm rod.

Fig 8
Casting die and withdrawal arrangement

Casting dies are normally changed as a set, coinciding with the completion of a batch of coils. This takes approximately one hour to complete. In the event of a rod break, an individual casting die can be changed at any time, without affecting production of the remaining strands. Rod withdrawal is by pinch rolls, powered by mechanical cam indexing drive. One or two independent drives are provided, depending on the size of machine. A standard machine is configured for production of rods 8.0mm to 12.7mm diameter. Machines can be specified for production at up to 30mm diameter if required.

Fig 9
Rod Coilers

After casting, the rods are guided over the machine and down into rod coilers. Normal coil dimensions for 8mm rod are 1.8m OD x 0.8m ID, with a coil weight of either 2.5 tonnes, 4.0 tonnes as required. Coils weights of up to 5 tonnes can be specified. Coiling speed is synchronised to production speed by means of a loop controller. Facilities are provided for waxing of the rod surface where required.

Safety Features

To the extent that the reservoir of molten metal is held beneath the casting station the upwards vertical process has important inherent safe characteristics. In the Rautomead RS machines, the electrical energy used in the furnace heating element chain is transformed down to a low 35 to 40 nominal volts - another very safe characteristic, unique to the Rautomead design. Simplicity of design itself contributes to safe operation. All key operating parameters, including status of cooling water, nitrogen gas and furnace temperature are closely monitored and linked to a safety alarm system. The machine is designed to fail-safe on interruption of mains power. A UPS is normally provided to provide continuity of supply to control circuits and to provide emergency lighting in such circumstances. A larger capacity UPS can be offered to maintain power to cooling water pumps. As a fail-safe measure, casting dies are lifted from the melt by emergency battery-operated motor drive. A manually operated emptying valve and taphole are provided at the base of the furnace, to enable it to be emptied in a matter of minutes if required. A standby generator can also be provided.

Ancillary Equipment

a) primary water cooling

Fig 10
Primary water cooling module

The water circulating through the casting die assemblies is subjected to very rapid rise and fall in temperature. Thus, chemical composition of this water of key importance, if a build-up of salts in the coolers is to be avoided. Rautomead offers to supply a small closed circuit pumped primary water cooling system, to be filled with de-ionised water. This primary system is fitted with a water-to-water heat exchanger for connection to the user's own secondary system.

b) nitrogen gas

Though consumption of gas is not substantial, the presence of an inert gas atmosphere within the furnace is essential for the protection of the graphite hot working components. Where supplies of oxygen-free bottled nitrogen are not easily available, Rautomead offers to supply a nitrogen generator.

fig 11
nitrogen generator

c) emergency power

fig 12
emergency power generator

Depending on the reliability of the mains power supply, emergency generators can be supplied of capacity sufficient to run the whole plant, or to maintain the furnace at standby temperature, pending restoration of mains power.

d) quality control
Rautomead will specify or can supply all the necessary quality control equipment to use with the casting machine.

Product Quality
The re-draw rod produce by the RS process is a fully soft cast material.

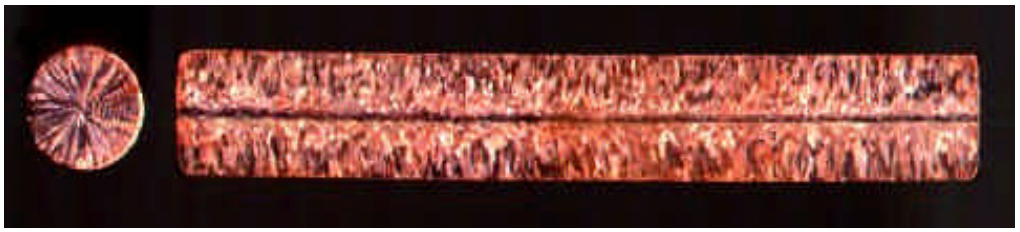

Fig 13
Photomicrograph of as-cast 8mm rod

The material exhibits a characteristic layer of chill grains close to the rod surface, long columnar grains and an equiaxed core. The structure is symmetrical, showing even influence of cooling around the circumference of the rod. Typical physical properties of the as-cast 8mm rod are

Tensile strength	175 N mm^2
Elongation	50% +

As an as-cast product, it has none of the characteristic inclusions and other faults associated with rod rolling.

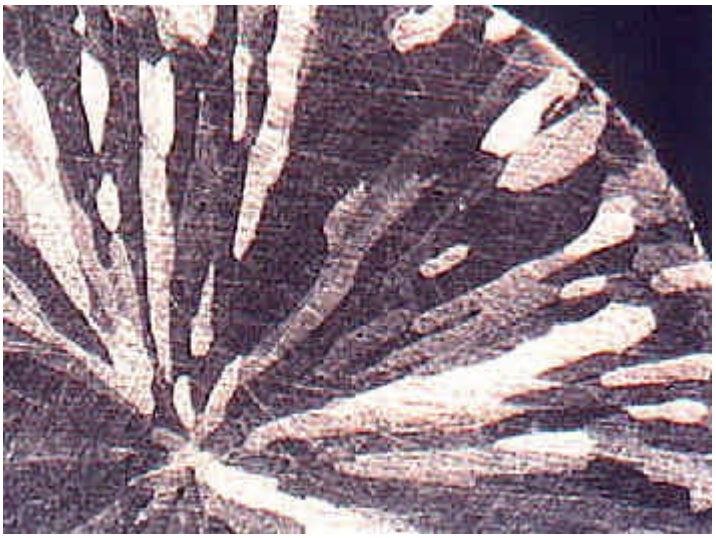

Fig 14
Magnified photomicrograph of grain boundary area

Keys to good quality in wire rod for drawing to fine wire sizes include a homogenous metallurgical structure with no porosity resulting from trapped gases in the rod-making process. Where these are present, they can often be detected at the grain boundaries.

The as cast 8mm rod is processed on conventional rod break-down machines and in many applications is annealed in line at around 2.6mm. The as cast structure is completely broken down and recrystallised. Physical properties of the wire rod at that stage can be expected to be:

Elongation	40% +
Conductvity	101 % IACS

Where enamelled wire is to be produced, the rod is drawn down to the final size and annealed as an integral part of the enamelling process.

Drawing to Fine Wire

The absence of occluded oxides, gas porosity and surface impurities in the Rautomead RS re-draw rod make it particularly suitable for drawing to superfine wire sizes. At 0.050mm, a wire break performance of better than one break in 300kg is being regularly achieved.

Magnet Wire

Production of magnet wire calls for close attention to rod surface quality, in terms of roundness, cleanliness and absence of flakes and slivers. Because the RS re-draw exits the casting die well below oxidation temperature and is not rolled, the surface oxide layer on the as-cast rod is minimal, usually less than 20 Ä., making it particularly suitable for this application.

Copper Alloys

While the Rautomead RS process was deigned essentially fo the production of oygen-free copper rod, it is also being used commercially in production of dilute copper alloys.

Fig 15
Model RS 2300/4/30 in production of 19mm diameter rod in CuMg0.35

Alloys for which the RS system is either in regular use or for which it has been tested satisfactorily include:

CuCd1.0	for automotive and trolley wire
Cu Sn0.4	for trolley wire
CuMg0.35	for trolley wire
CuAg0.1	for high temperature conductors
Cu-DHP	for engineering applications

The equipment required is almost the same as for Cu-OF rod production, though special care is needed to deal effectively with cadmium fume in the case of CuCd alloys. The copper cathodes are weighed individually as they are fed to the machine and the weight of alloying element is automatically calculated. Alloy addition is usually in the form of manually added master alloy. The labyrinthine nature of the passage of the metal through the crucible and the in-built filter systems are quite adequate to ensure a homogenous alloy composition at casting. The totally enclosed nature of the process also contributes significantly to close control of volatile elements, such as magnesium, which can be controlled to tight tolerances. In production of CuCd alloys, the totally enclosed nature of the process assists greatly in eliminating cadmium fume emissions.

The downstream processes required to finish alloys for specific applications usually call for casting of larger sizes of rod. The RS machines can be configured to produce up to 30mm diameter rod.

Customer Training, Installation & Commissioning

In addition to providing comprehensive operating and maintenance manuals, Rautomead places strong emphasis of training of customers' personnel. Normally, a customer will depute two members of staff who will be closely involved with start-up and operation of the plant to spend two weeks in Dundee during the latter stage of construction and testing of the casting machine at Rautomead's works. During this time, they are given hands-on experience of the necessary procedures and work closely with Rautomead engineering staff.

A Rautomead engineer will supervise installation of the machine on arrival at the customer's work and will start-up and commission the plant. Training is continued throughout this period, to the point where customer's personnel are confident to operate the plant.

Model Range

model	output
RS 1050/4/8	2000/2500 tonnes/annum
RS 2200/8/8	3750/4500 tonnes/annum
RS 2300/4/30	3750/4500 tonnes/annum
RS 3000/8/8	5000/6000 tonnes/annum
RS 6000/16/8	10000/12000 tonnes/annum
RS 9000/24/8	15000/18000 tonnes/annum

Modular increases in capacity can be made as demand grows. As examples, the 4-strand model RS 1050/4/8 can be upgraded to 8-strands at comparatively little capital cost. The 8-strand model RS 3000/8/8 can be upgraded to 16 strands by adding an additional furnace. The 16-strand model RS 6000/16/8 can be upgraded to 24 strands also by adding an additional furnace.

Space Requirements

The plants are compact. Layout can be adapted to customer's buildings available. Space required ranges from 220 sq.m. for a small model RS 1050/4/8

Fig 16
Layout model RS 1050/4/8

to 1030 sq.m for the largest RS 9000/24/8.

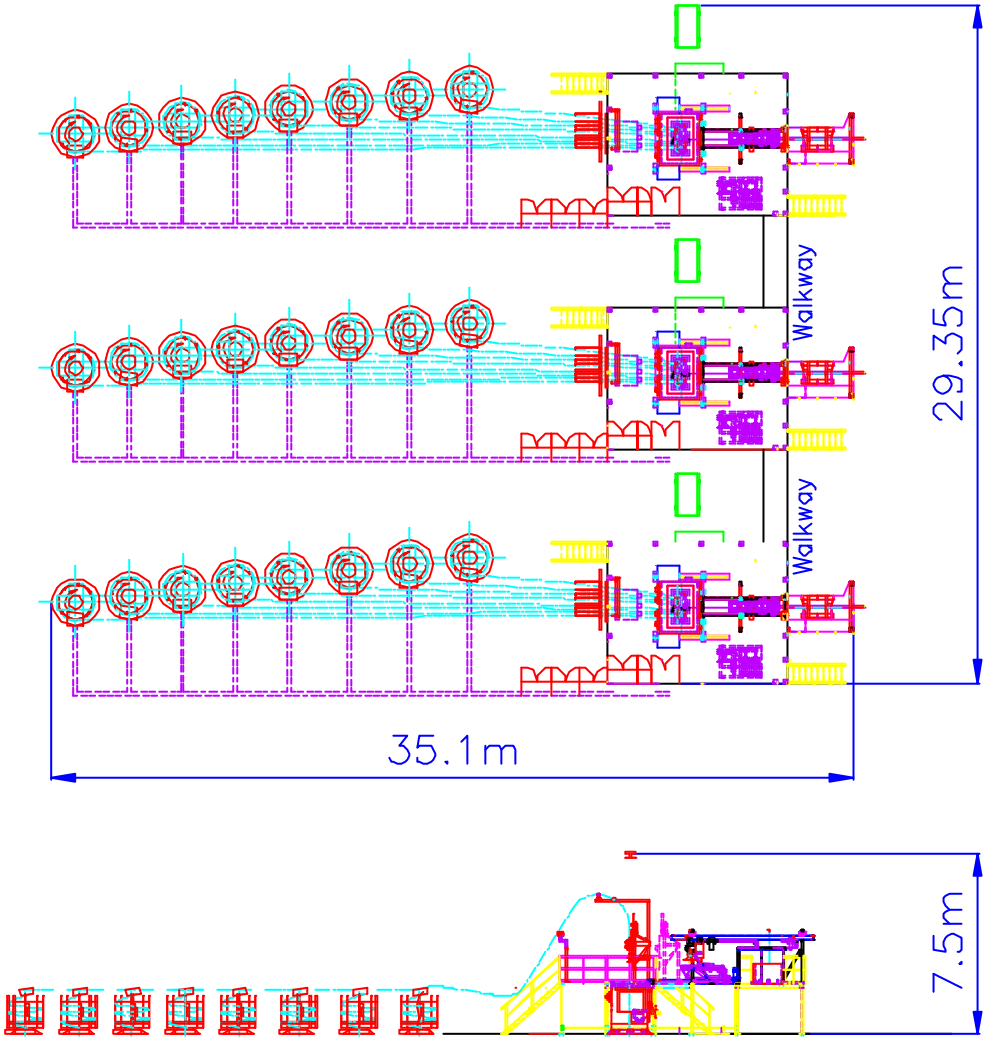

Fig 17
Layout model RS 9000/24/8

Operating height is 7.5 m., though only over the immediate area of the furnace. No pits in the floor are required and any of the plants can be conveniently positioned on a conventional 150mm reinforced concrete floor.

Customer Service

A special feature of the Rautomead service is the attention paid by the company to service and support in the longer term. Rautomead maintains a close and active working relationship with customers to ensure that user obtain the best service and performance from their Rautomead equipment. The benefit of improvements in technology are made available to all existing customers without charge.

RS Machine Installation Reference List (July 1999)

Installed or under construction

country	model	no. of machines	application
Iran	RS 2200/8/8	3	Cu-OF re-draw rod
Belgium	RS 2500/8/8	1	Cu-OF re-draw rod
	RS 2300/4/30	1	Copper conductor alloys
Germany	RS 2500/8/30	1	Brass & bronze wire rod
U.K.	RS 750/2/40	1	Leaded bronzes
Chile	RS 1050/4/8	1	Cu-OF re-draw rod
Taiwan	RS 3000/8/8	2	Cu-OF re-draw rod
Malaysia	RS 3000/8/8	2	Cu-OF re-draw rod
	RS 6000/16/8	1	Cu-OF re-draw rod
Sudan	RS 1050/4/8	1	Cu-OF re-draw rod
Japan	RS 2300/4/30	1	Cu-OF re-draw rod
U.S.A.	RS 22500/4/30	2	Cu-OF re-draw rod
	RS 2300/4/30	1	Cu-OF & Cu-DHP rod
Australia	RS 3000/8/8	1	Cu-OF

Summary

- **small to medium sized plants for conversion of cathode to re-draw rod**
- **unique graphite furnace technology**
- **oxygen-free copper rod**
- **coil weights up to 5 tonnes**
- **important safety features**
- **highest and consistent product quality**
- **for drawing to superfine wire**
- **for magnet wire**
- **for copper alloys**
- **customer training installation & commissioning**
- **comprehensive and modular range of machines**
- **emphasis on customer service**
- **international references**