ACT – Advanced Crucible Technology

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KME Germany GmbH & Co. KG
ACT – Advanced Crucible Technology
[GB]

KME – Advanced Crucible Technology

KME offers a unique combination of expertise and experience in all key technologies for the production of high-performance crucibles and moulds.

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KME is one of the world's largest manufacturer of copper and copper alloy products. Today, KME employs nearly 6,000 people, manufacturing a wide range of semi-finished, finished and special products at locations across Europe and Asia.

The Company

KME's corporate goal is to develop and manufacture products that meet customer demands, finding solutions for their specific applications, and providing services as a long-term partner. KME's strategy for accomplishing this goal is based on a highly skilled and experienced workforce. KME has the ability to invent and develop new materials and innovative production processes via ongoing advancement and training of our employees and the continual improvement of its engineering capabilities.

Engineered products for melting and casting

Melting technology and product quality have seen major improvements in recent decades with regard to the remelting of nonferrous metals and special steels. This has led to considerable increases in productivity and paved the way for high-grade materials.

These advances in process technology were made possible by the further development of high-performance crucibles and moulds made of copper materials. KME was involved in these developments from the very beginning and has continued to set milestones in the development and production of copper crucibles and moulds for the manufacturing of nonferrous alloys and special steels. The Engineered Products Division was founded as part of a strategic reorganisation, with the aim of providing a flexible approach to market demands and improving the customer orientation of our business. Our customers are producers of steel and nonferrous metals, furnace builders and maintenance companies throughout the world.

The Engineered Products Division is available to our customers as a general contractor for the production of crucibles and mould assemblies as well as a flexible partner in working out detailed solutions for the remelting of nonferrous alloys and steel.

ACT – Advanced Crucible Technology

The increasing operational demands placed on components in machine tool, automotive and aerospace industry have resulted in a considerable increase in the requirements placed on the quality of the materials and the components used. As a manufacturer of crucibles, moulds and other copper components, KME provides essential support for the development of remelting and vacuum melting technologies.

Traditional production processes often reach their limits when it comes to manufacturing very high quality materials, such as those required for components placed under high stresses. The materials for such applications must be very pure and free of inclusions and impurities.

To refine these materials, copper crucibles and moulds are used in
- electroslag remelting and
- vacuum arc remelting.

The ingots and materials manufactured using these processes offer structures with uniform density and a high degree of homogeneity, no segregation or shrinkage cavities and no impurities or oxide inclusions. These properties are important criteria for the quality of materials such as nickel-based alloys, highly alloyed steels, titanium, molybdenum and other high-fusion materials.

Copper crucibles – usually water or sodium-potassium cooled – are key components in plants such as these, especially with regard to quality.

As a manufacturer of crucibles, moulds and other copper and copper alloy components, KME has supported the advances that have been made in these melting technologies. As a partner of machine builders and operators, KME has made a considerable contribution to the current state-of-the-art by developing, for example, high-strength copper materials with good thermal conductivity.

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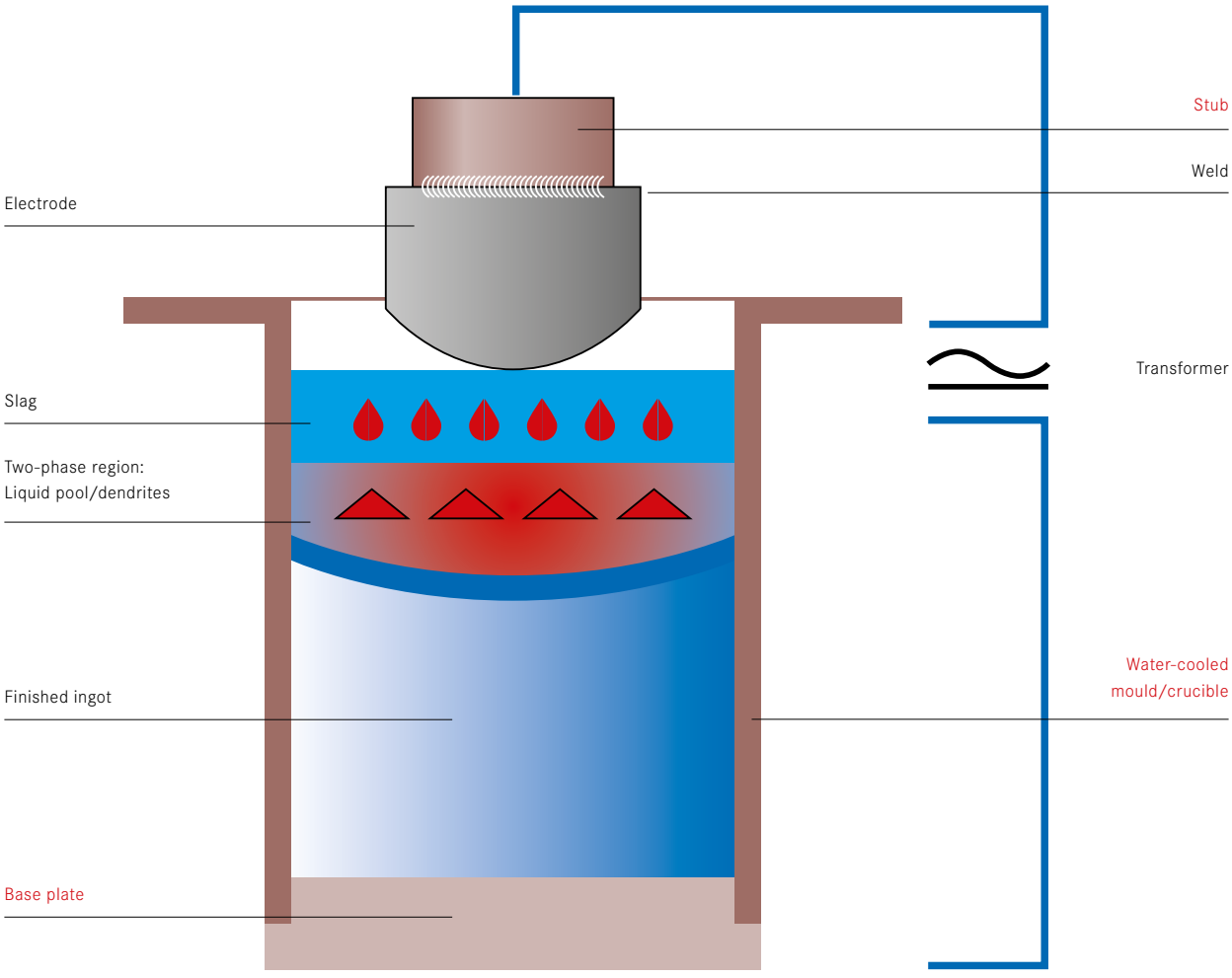
Schematic diagram of the electroslag remelting process



Spark emission spectrometry

Research and Development

The development of new materials involves testing new alloys and further improving known alloys. KME's R&D department handles both tasks. The crucible and mould materials used throughout the world today – such as ELBRODUR® G (CuCrZr) and others – have been developed by KME since the early 1960's.

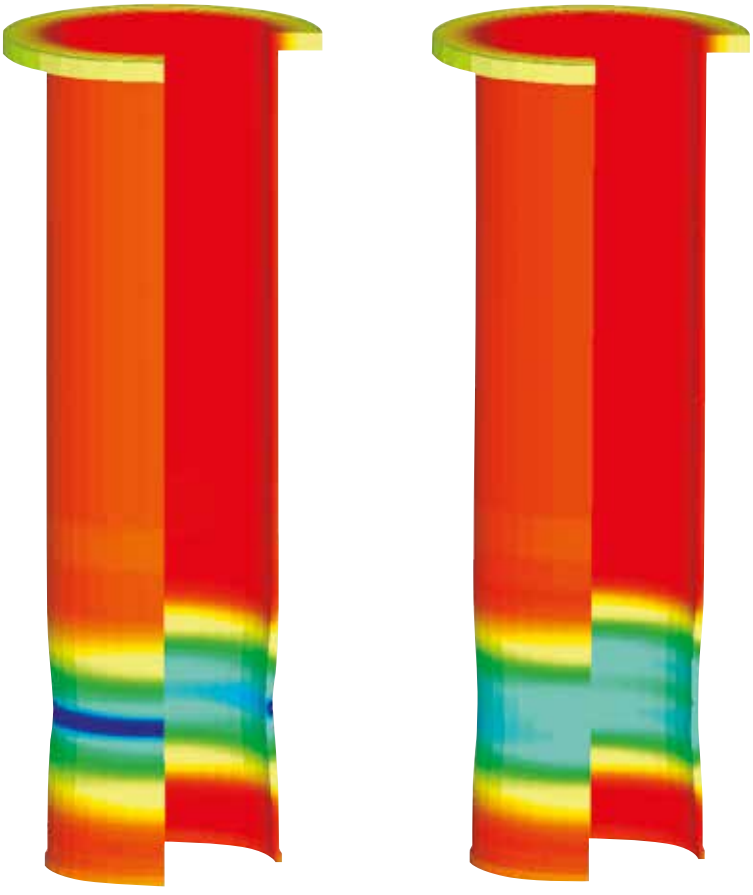
KME's laboratory's melting and casting facilities are capable of casting blocks weighing 1,000 kg which can be further processed in our production facilities, allowing optimal production parameters to be determined in advance. A rolling mill and press, together with annealing and salt-bath furnaces, are used for thermo-mechanical treatments within the department.

The development of materials is supported by a full range of chemical analysis (S-OES, XRS, ICP, GF-AAS, etc.) using metallography, SEM/TEM electron microscopes and EDX/WDX analysis systems. The technological laboratories for physics and mechanics are equipped with all of the necessary devices for testing and measuring. Destructive tests provide additional data, making it possible to compile customer-specific information.

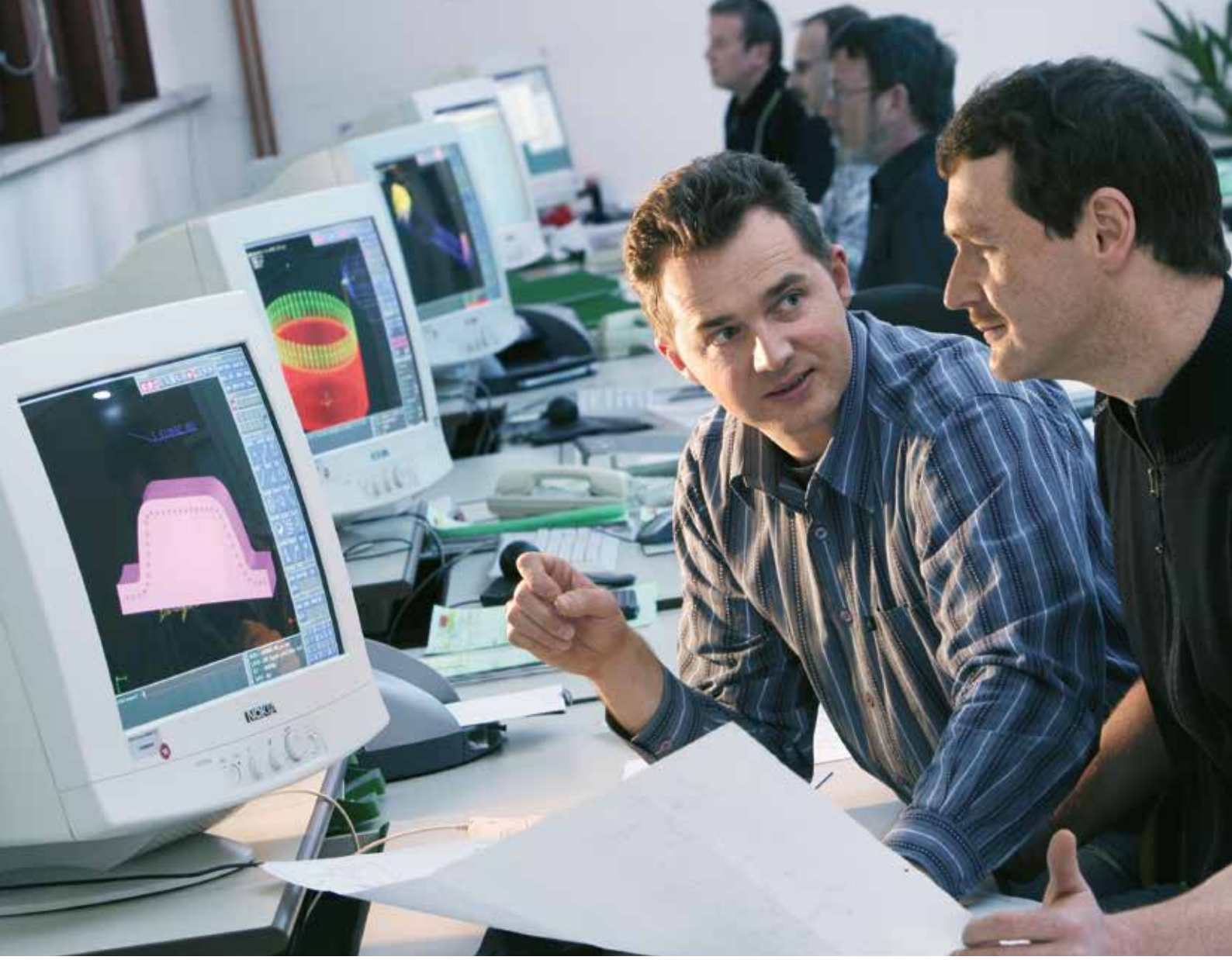
Today, basic laboratory work is supplemented by development work for the customer, focusing on the highest reliability and service life of the crucibles in the industrial applications they were designed for. The goal of our work is to constantly improve our products for the benefit of our customers. For this reason KME is working on new materials and processing technologies. The knowledge of the entire group is applied to the development of moulds and crucibles.

ACE – Advanced Crucible Engineering

In addition to supporting our customers in selecting suitable materials and design variants, KME's advanced crucible engineering service assists in optimising cooling conditions, maintenance practices and operational conditions.



FEM simulation of the distortion of a crucible during cyclic thermal stress for different materials



The range of crucible materials and manufacturing processes available from KME enables us to offer customised solutions for many different plant concepts and operating conditions. KME also provides comprehensive engineering service for the development of solutions that will achieve optimum material qualities and crucible service life.

Cooling conditions
Cooling conditions are a critical factor in the quality of manufactured materials and in the in-service behaviour of the crucibles. Our engineers' extensive knowledge and advanced FEM calculation programmes are the basis for optimising cooling conditions and process parameters.

Improving service life
With increasing use, the distortion and constriction of crucibles are a common cause of failure in these plant components.

Based on the operational parameters of the plant and with the aid of available calculation processes and material properties, it is possible to simulate the long-term behaviour of crucibles. This provides important data that plant operators can use to reduce crucible distortion or constriction.

KME engineers and technicians provide these calculations within the scope of our Advanced Crucible Engineering service as a pre-sales- and after-sales-service to our customers.

ACM – Advanced Crucible Materials

The development and manufacture of copper crucible materials has long been a focus of activities at KME. We have a wide range of copper and copper alloys at our disposal. This enables us to provide customised solutions for many different applications.

The right combination of the following properties, precisely tailored to a particular application, is crucial in determining the behaviour of the crucible:
- high degree of thermal conductivity
- adequate mechanical strength
- high dimensional stability
- high softening/recrystallisation temperature

KME's advanced crucible materials offer an ideal, graduated combination of these properties, leading to the optimum solution for the application (crucible tube, base plate or flange). Forged crucibles offer more homogeneous properties compared to longitudinal welded ones. To achieve optimum performance and service life, KME therefore recommends the forged version crucible design with ELBRODUR® G.

DHP-Cu (SF-Cu)
DHP-Cu was developed as a standard material for crucibles and moulds, with high thermal conductivity and better softening behaviour than HCP-Cu. It performs well under normal operating conditions and has superior solderability and weldability.

HCP-Cu (SE-Cu)
The copper alloy HCP-Cu is a low P-alloyed copper type. It was developed for applications under which high to very high demands are placed on the thermal conductivity of the crucible material. Its thermal loading capacity is medium range. Solderability and weldability are good.

DPS-Cu (CuAg)
Copper-silver alloys used in applications which are subject to high thermal exposure and medium to high mechanical/thermal stress. The material's very good thermal conductivity contributes to improved heat dissipation, which limits wall temperature. DPS-Cu has a favourable softening behaviour. Solderability and weldability are good.

ELBRODUR® G (CuCrZr)
ELBRODUR® G is an age hardening alloy with excellent mechanical and thermal properties. The high degree of thermal conductivity and creep resistance allow the material to be used in applications where it is subjected to high thermal stress. In addition to crucibles, base plates made from ELBRODUR® G have proven their outstanding properties in many applications. Crucibles made of ELBRODUR® G are available as a forged version only.

Flange materials
The above-mentioned materials for crucible tubes can be combined with similar or alternative flange materials. The following are used as flange materials:
- Copper alloys
- Steel
- CuNi alloys

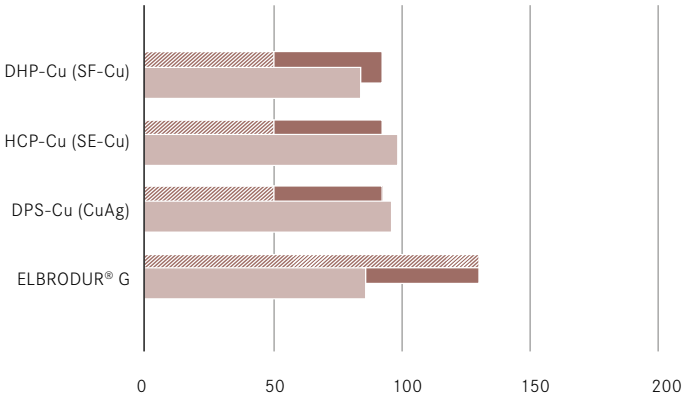


Fig. 1
Hardness and electrical conductivity of KME crucible materials

Brinell hardness (plate crucible)
HBW 2.5/62.5
Brinell hardness (forged crucible, longitudinally welded crucibles)
HBW 2.5/62.5
Electrical conductivity
% IACS

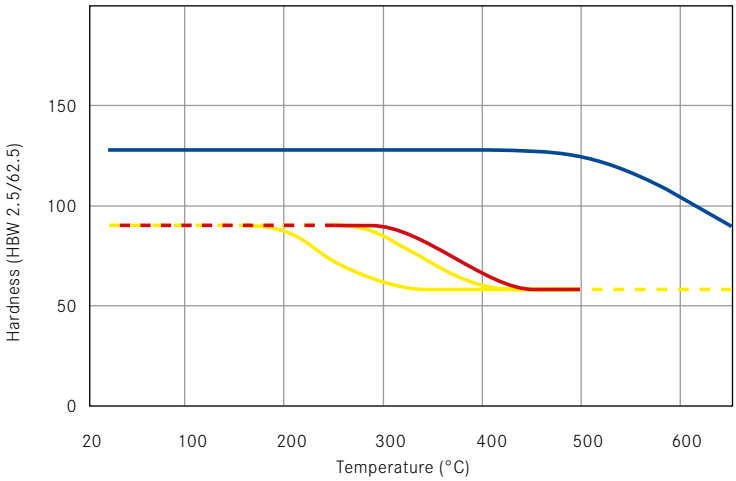


Fig. 2
Recrystallisation/softening behaviour of KME crucible materials

ELBRODUR® G (CuCrZr)
DPS-Cu (CuAg)
DHP-Cu (SF-Cu)/HCP-Cu (SE-Cu)

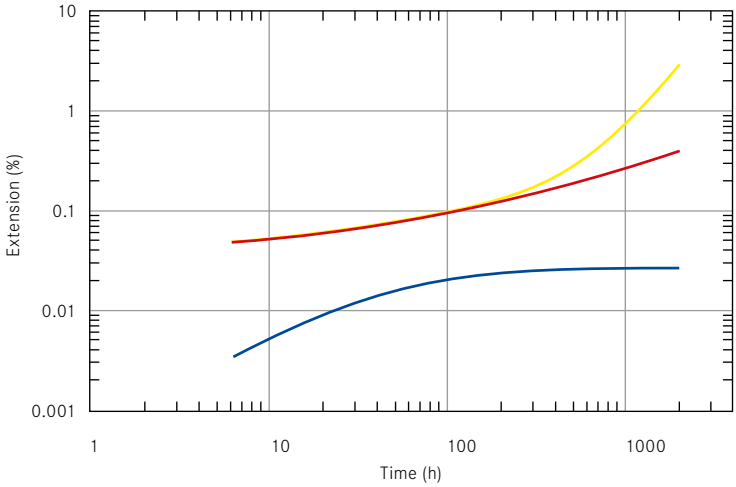


Fig. 3
Creep characteristics of plate crucible materials (temperature 200 °C/392 °F, stress 150 MPa)

DHP-Cu (SF-Cu)/HCP-Cu (SE-Cu)
DPS-Cu (CuAg)
ELBRODUR® G (CuCrZr)

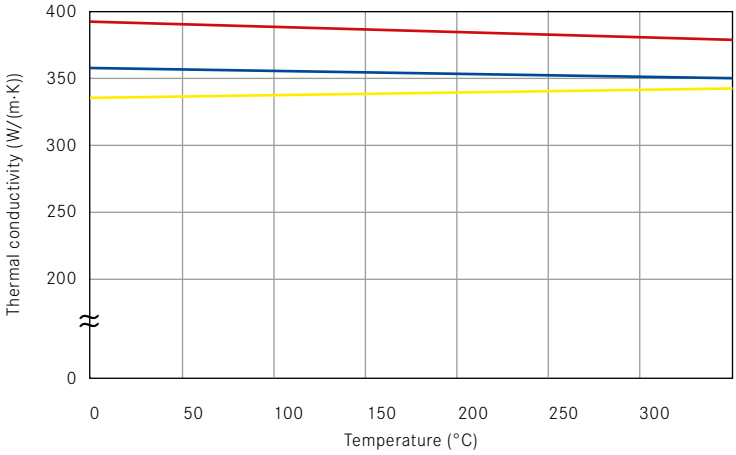


Fig. 4
Thermal conductivity of KME advanced crucible materials as a function of temperature

DPS-Cu (Cu-Ag)
ELBRODUR® G (CuCrZr)
DHP-Cu (SF-Cu)/HCP-Cu (SE-Cu)

Properties and applications of crucible materials

Material	DHP-Cu (SF-Cu)	HCP-Cu (SE-Cu)	DPS-Cu (CuAg)	ELBRODUR® G
Thermal conductivity	High	Very high	Very high	High
Softening/Recryst. temp.	Good	Medium	Good	Very high
Strength/Hardness	Good	Good	Good	Very high
Application	Crucibles, longitudinally welded or forged, base plates	Crucibles, longitudinally welded or forged, base plates	Crucibles, longitudinally welded or forged, base plates	Forged high-performance crucibles, base plates

ACM – Advanced Crucible Materials

Table 1 **KME Materials for crucibles and longitudinally welded crucibles**

Material Properties*	Temperature		Units	DHP-Cu (SF-Cu)	HCP-Cu (SE-Cu)	DPS-Cu (CuAg)	ELBRODUR® G**
Chemical composition (without copper)			%	0.03 P	0.004 P	0.09 Ag	0.6 Cr
						0.006 P	0.1 Zr
Physical Properties	°C	°F					
Electrical conductivity	20	68	S·m/mm²	48	57	55	49
			% IACS	83	98	95	84
Thermal conductivity	20	68	W/(m·K)	340	395	375	350
Coefficient of thermal expansion	20–300	68–572	10^{-6}/K	17.7	17.7	17.7	18
Recrystallisation temperature	-	-	°C	350	250	370	700
Softening temperature***	-	-	°C				590
Modulus of elasticity	20	68	10^3 MPa	120	120	125	128
Mechanical Properties	°C	°F					
0.2 % Proof stress $R_{p\,0.2}$	20	68	MPa	50	50	50	280
	200	392		40	45	40	260
	350	662		(30)	(35)	(30)	260
	500	932		(20)	(25)	(20)	(200)
Tensile strength R_m	20	68	MPa	210	200	210	390
	200	392		170	160	170	340
	350	662		(120)	(120)	(120)	290
	500	932		(80)	(70)	(80)	(230)
Elongation A_5	20	68	%	50	45	50	25
	200	392		45	45	45	24
	350	662		(40)	(45)	(40)	22
	500	932		(50)	(55)	(50)	(22)
Hardness HBW	20	68	2.5/62.5	50	50	50	120

Units: 1 MPa = 1 N/mm² = 0.102 kgf/mm² = 0.145 ksi; 1 W/(m·K) = 2.388 · 10^3 cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure

** Values can be modified to customer's demands

*** Measurement according to DIN ISO 5182

( ) Limited reproducibility of measurement due to softening/recrystallisation

Table 1 KME Materials for plate crucibles

Material Properties*	Temperature		Units	DHP-Cu (SF-Cu)	HCP-Cu (SE-Cu)	DPS-Cu (CuAg)	ELBRODUR® G**
Chemical composition (without copper)			%	0.03 P	0.004 P	0.09 Ag	0.6 Cr
						0.006 P	0.1 Zr
Physical Properties	°C	°F					
Electrical conductivity	20	68	S·m/mm²	48	57	55	49
			% IACS	83	98	95	84
Thermal conductivity	20	68	W/(m·K)	340	395	375	350
Coefficient of thermal expansion	20–300	68–572	10^{-6}/K	17.7	17.7	17.7	18
Recrystallisation temperature	-	-	°C	350	250	370	≥ 800
Softening temperature***	-	-	°C				580
Modulus of elasticity	20	68	10^3 MPa	120	120	125	128
Mechanical Properties	°C	°F					
0.2% Proof stress $R_{p\,0.2}$	20	68	MPa	265	265	265	280
	200	392		235	235	235	260
	350	662		(195)	(195)	(195)	230
	500	932		(30)	(30)	(30)	200
Tensile strength R_m	20	68	MPa	275	275	275	390
	200	392		240	240	240	340
	350	662		(200)	(200)	(200)	290
	500	932		(80)	(70)	(80)	(230)
Elongation A_5	20	68	%	18	18	18	25
	200	392		16	16	16	24
	350	662		(14)	(14)	(14)	22
	500	932		(70)	(70)	(70)	(22)
Hardness HBW	20	68	2.5/62.5	90	90	90	120

Units: 1 MPa = 1 N/mm² = 0.102 kgf/mm² = 0.145 ksi; 1 W/(m·K) = 2.388 · 10^3 cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure

** Values can be modified to customer's demands

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Advanced Crucible Materials

Melting and casting
In KME's melting and casting facilities, copper and copper alloys are produced by state-of-the-art systems. Cathodic, high-purity copper is mainly used for producing crucible materials. The composition of the melt is monitored by an analysis system. Billets and slabs can be cast on various casting systems in different geometries, so that the dimensions of the starting material offer favourable properties for subsequent downstream production stages, e.g. when certain degrees of formability must be ensured for forging operations.

Forming
Close coordination between the casting process and the subsequent forming process is absolutely essential for ensuring optimal material properties and tight tolerances in crucible production.

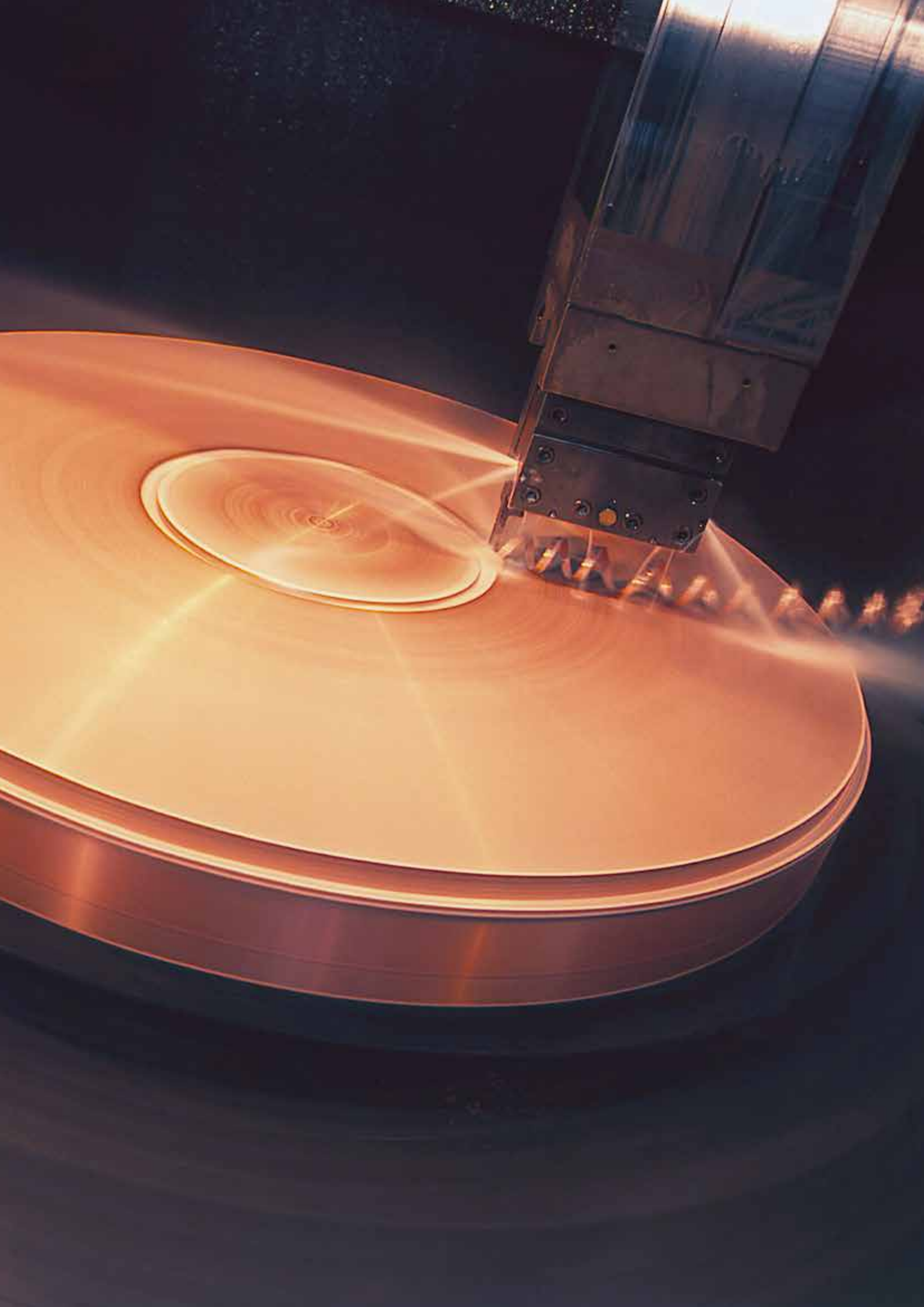
KME has hot and cold rolling systems for forming the material in addition to systems for forging, bending and heat treatment of crucible materials. Special procedures and process sequences developed by KME make it possible for us to produce complex geometries and dimensions while maintaining the highest levels of quality.

Welding
KME has different welding processes at its disposal including robot-supported, automated processes. Depending on the product requirements, either Metal Inert Gas (MIG) or Tungsten Inert Gas (TIG) processes can be used.

Electron-beam welding equipment (EB) is also available for special applications. KME's highly skilled welding specialists possess all the necessary certifications and approvals required to perform this type of work.

Machining
Modern, precise CNC machine tools are available for final machining of crucibles. The construction data of components, used to produce the desired work-piece geometry, is acquired via integrated CAD/CAM systems.

Not only does KME possess comprehensive experience in milling and drilling copper, we also have many years of expertise in the field of deep-hole drilling. This technique ensures optimum cooling conditions for moveable moulds in remelting installations.



Advanced Crucible Manufacturing

Quality assurance

Supplying high quality components is an essential prerequisite of our business that assures our customers smooth, trouble-free plant operation. To ensure that our customers only receive high quality components, all processes and operational procedures at KME are certified in accordance with the DIN ISO 9000 series.

In addition to the analysis of ACM material, KME has a wide range of test procedures such as ultrasonic-, X-ray-, pressure-, vacuum- and eddy current test facilities for the required quality tests. These in-house tests give KME the assurance that its own quality philosophy can be implemented in all stages of manufacture.

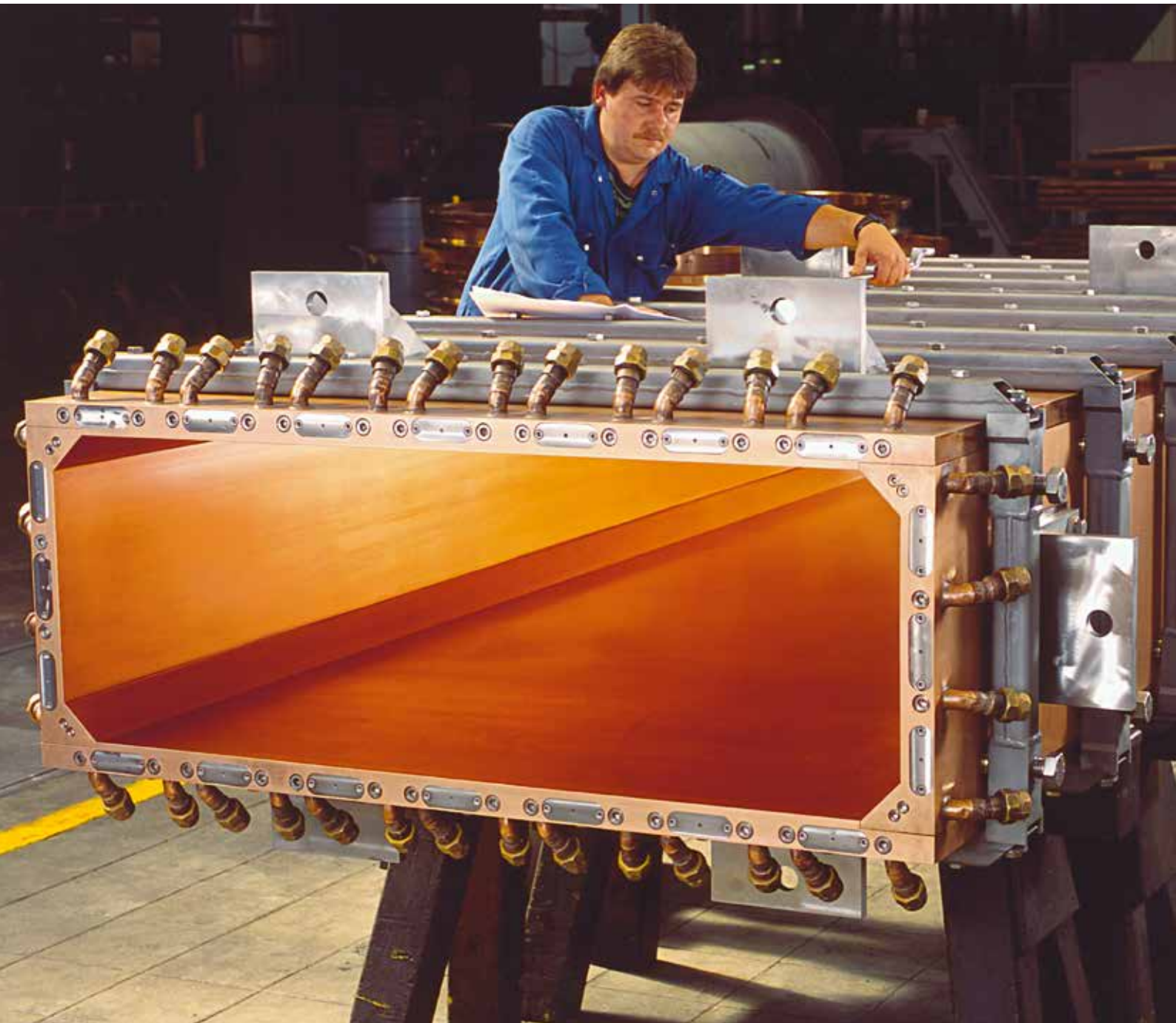
Melting

Casting

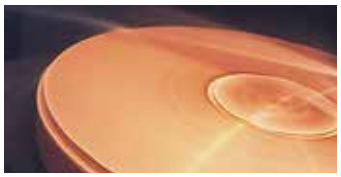
Hot and cold rolling	**Forging**
Bending	**–**
Welding	**Welding of flange**
Machining	**Machining**
Quality control	**Quality control**
Final product Longitudinally and welded crucible	**Final product Forged crucible**

Product Range

KME supplies a complete spectrum of crucibles and copper accessories for all types of remelting plants. Depending on the application we can deliver stationary or moving crucibles. All crucibles are manufactured according to the design specifications of our customers. If required, KME can also handle detail engineering when optimisation measures need to be carried out on existing equipment.







Using ACM crucible materials, KME can process many different types of crucible constructions. We manufacture longitudinally welded and plate crucibles as well as forged crucibles in any required dimension. The crucibles are welded with either TIG or MIG welding processes. Forged crucibles are supplied as tubes or, if required, with a forged flange. In addition, crucibles can be manufactured in rectangular or polygonal form in any required size as a plate or tube construction.

KME also supplies
- base plates
- electrode stinger rods
- complete mould assemblies, incl. stub, water jackets, baffle plates and steel bottom plates.

Range of crucibles for remelting plants

Shapes	– round, square, rectangular or polygonal
Structural design	– seamless forged tube: forged with integral flange, forged with welded-on flange – bended and welded from plate – plate assembly design

Range of crucibles for vacuum arc furnaces

Shapes	– round
Structural design	– seamless forged tube: forged with integral flange, forged with welded-on flange – bended and welded from plate – double-shell, inner tube forged with welded-on flange, outer sleeve bended and welded from plate

Crucible Maintenance and Service

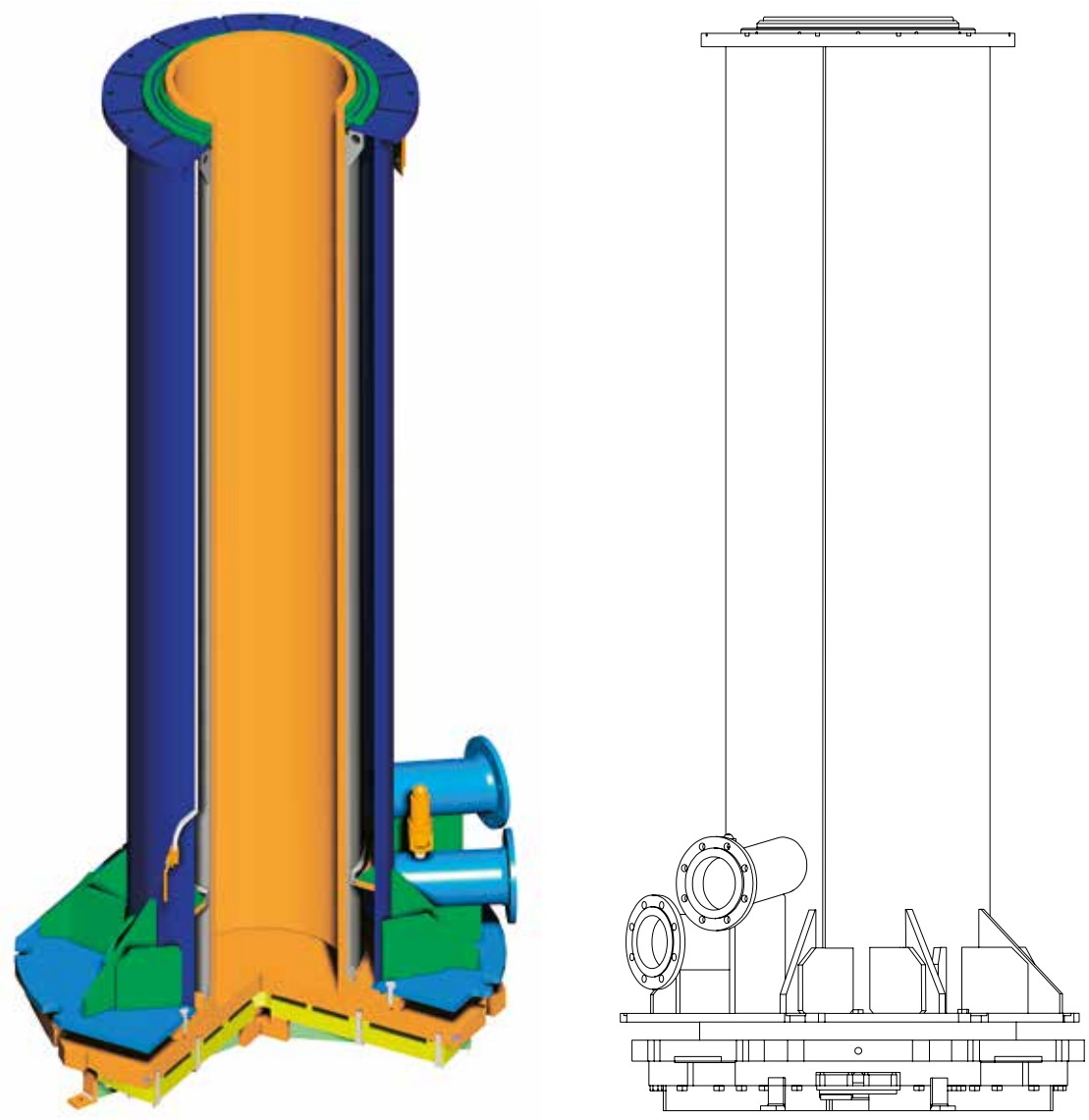
KME offers a comprehensive maintenance service in addition to the manufacture of new crucibles and accessories. Within the scope of crucible maintenance, the supplied moulds and water-cooling jackets are dismantled, all mechanical components are examined and, if required, reconditioned.

KME's maintenance department offers our customers the following services:
- Straightening of deformed crucibles
- Repair welding
- Reconditioning and cleaning service
- Taper adjustment
- Leak tests

Individual services can also be combined in customer-specific service packages on request.

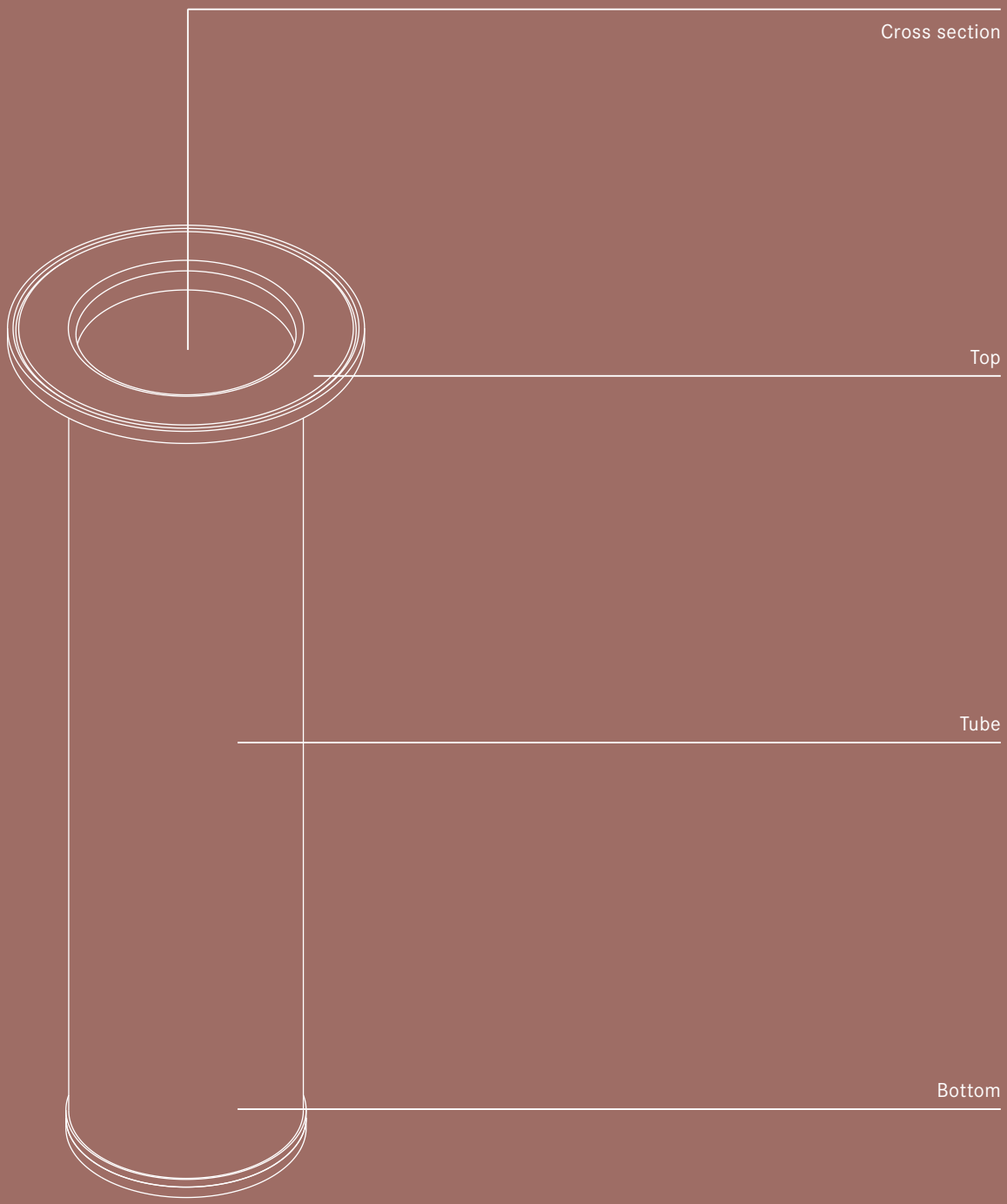
Crucible Assemblies

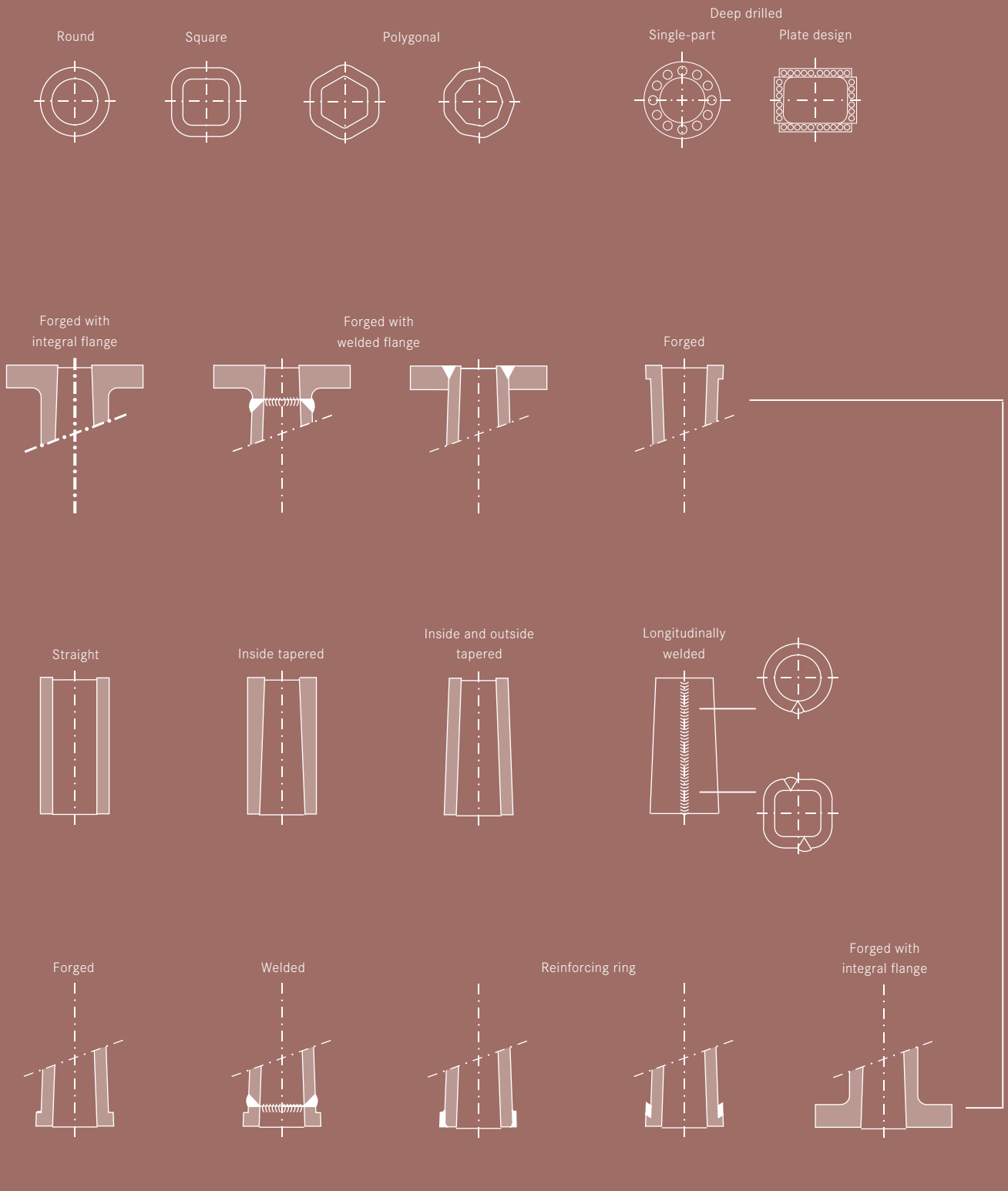
In addition to the manufacture of copper components, KME manufactures water-cooling jackets and the crucible frames as well as supplying complete, integrated modules. These components are manufactured according to the same uncompromising quality standards for furnace builders, plant operators and maintenance companies.



Crucible construction with water-cooling jacket

Crucible constructions and design examples




Round
Square
Polygonal
Deep drilled
Single-part
Plate design
Forged with integral flange
Forged with welded flange
Forged
Straight
Inside tapered
Inside and outside tapered
Longitudinally welded
Forged
Welded
Reinforcing ring
Forged with integral flange
With base plate
Double-shell crucible
With water path
Skull crucible
Movable mould

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