Die Cast Copper Motor Rotor Workshop and Technology Demonstration Meeting

Welcome

Mr. Andrew G. Kireta, Sr.
President & CEO
Copper Development Association Inc.

Die Casting Background

Dr. Dale T. Peters

Consultant

Copper Development Association Inc.

Introduction

Program initiation - Background

- Development encouraged by motor manufacturers

- Program members include:
  - Motor manufacturers
  - Die-cast equipment manufacturers
  - Mold materials suppliers
  - Copper industry technical & financial support

- Members all contributing to process development

Introduction

Participants

- CDA— program management & technical direction
- ICA— major copper industry support
- US Dept. of Energy— NICE^3/OIT contributed $425,000
- Motor Manufacturers (multiple)
- Air Conditioning & Refrigeration Institute
- CDA Members – alloy testing suggestions
- Formcast— die casting/technology capability

Introduction

Objectives

- Development of mold (die) materials and processing for cost-effective copper motor rotor manufacturing
- Electrical energy efficiency improvement

Introduction

Background

Multiple analyses show additional 15% to 20% reduction in motor losses (input/output method) achievable with copper rotor compared to same motor design using aluminum.

Introduction

Advantages to motor performance - scenarios for manufacturers and users

- Improvement in motor electrical energy efficiency to reduce user operating costs
- Reduction in overall premium motor manufacturing cost at existing efficiency
- Reduction in potential motor weight

Introduction

Options for improvement in motor energy efficiency in operation

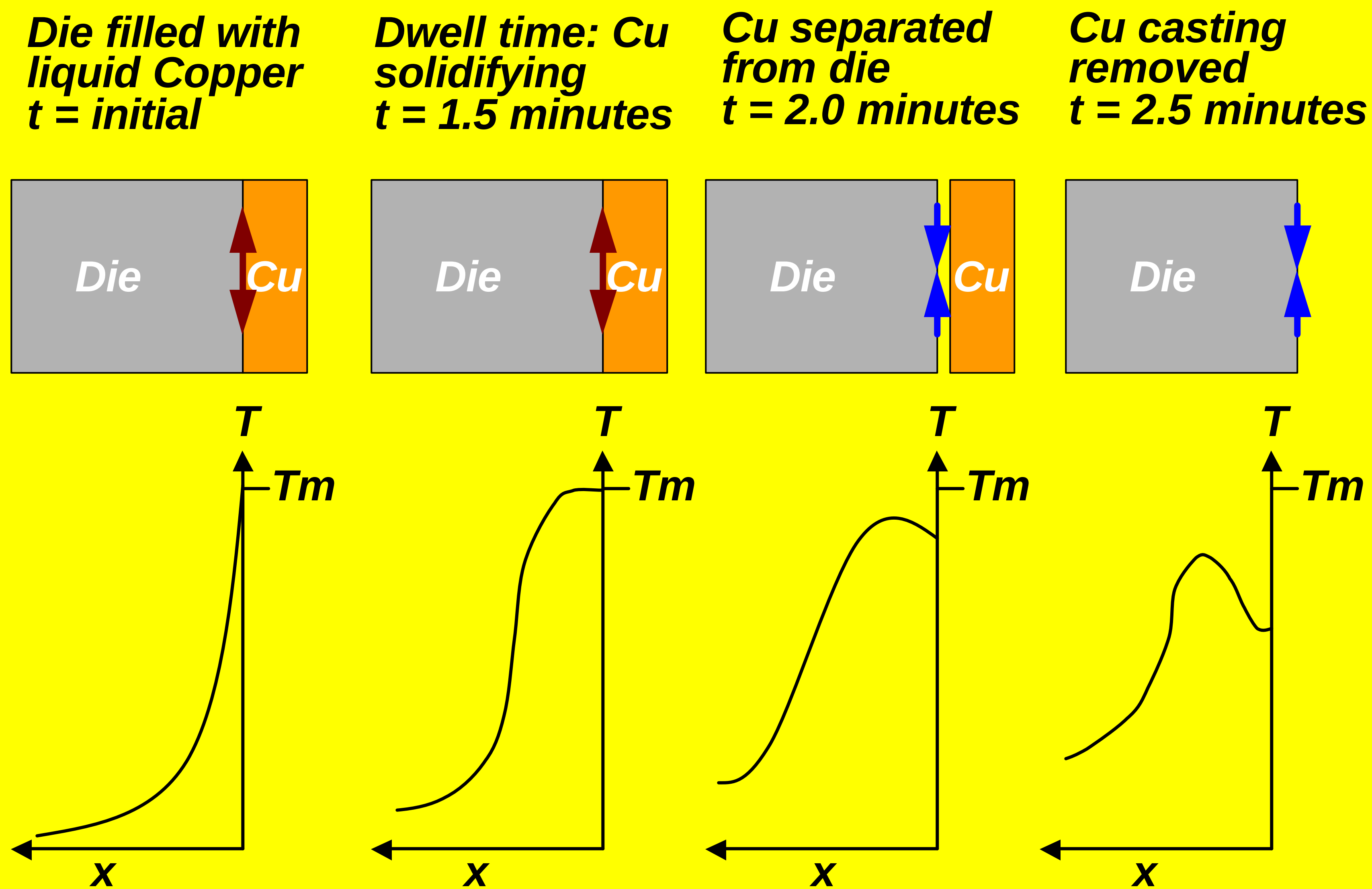
- Create a “super”- premium efficiency motor product line
- Improve existing motor efficiency without major re-engineering by replacing current aluminum with copper rotor

Die Materials Testing

Problem with common mold materials:

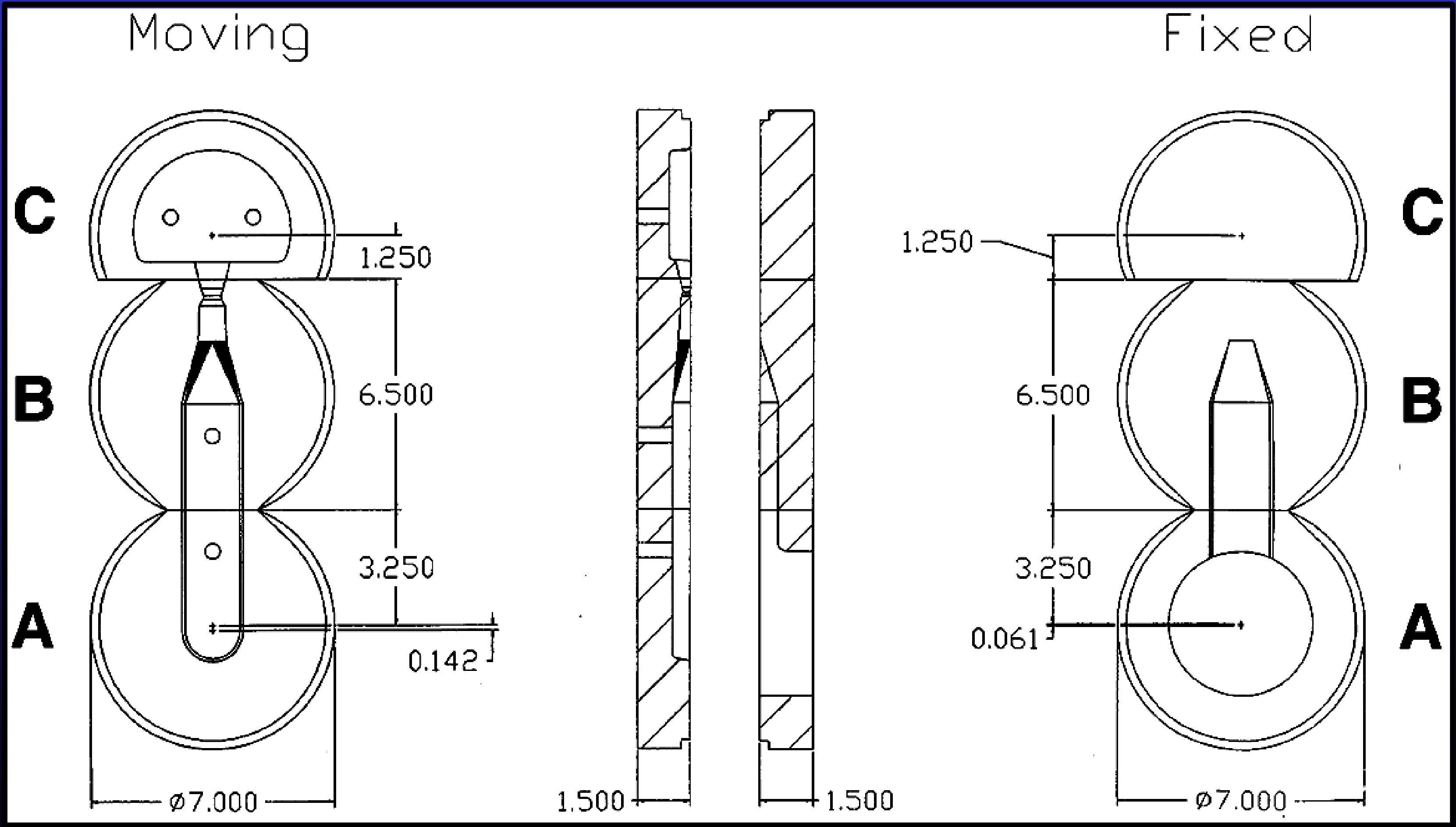
- High temperature
- Substantial latent heat
- Thermal shock
- Thermal fatigue (heat checking)
- High operating temperature: Loss of strength
- In previous studies: tool steel molds lasted only a few shots

Cracking –Thermal Expansion & Contraction



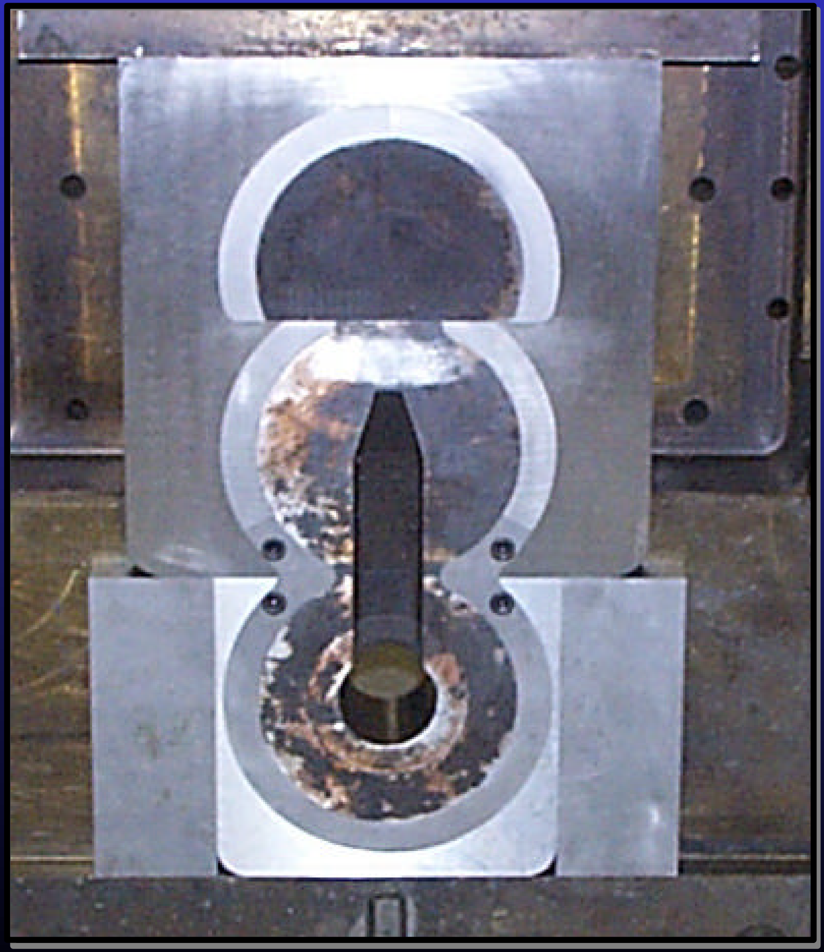
Die Materials Testing

Insert die sets used in material evaluations



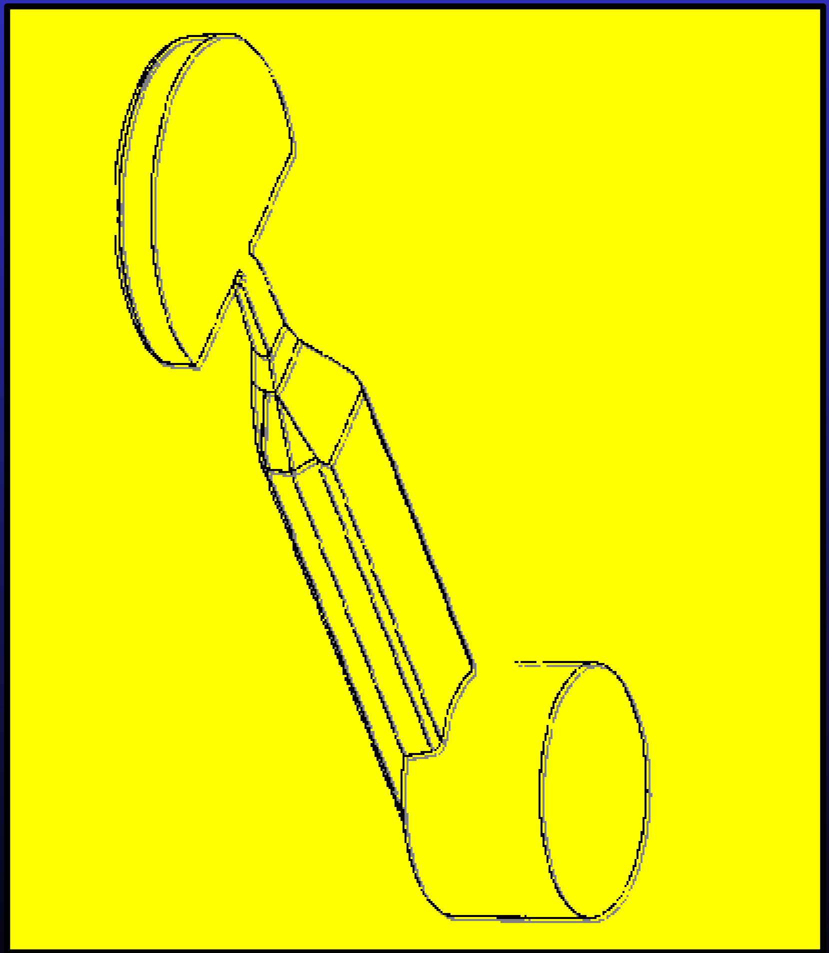
Die Materials Testing

H-13 tool steel die cavity insert tool set



Die Materials Testing

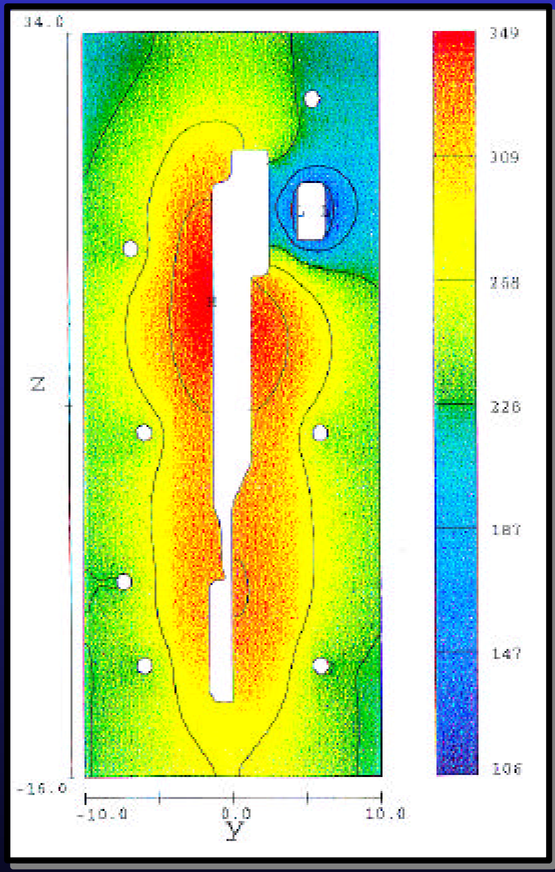
Test cavity design & first copper die casting

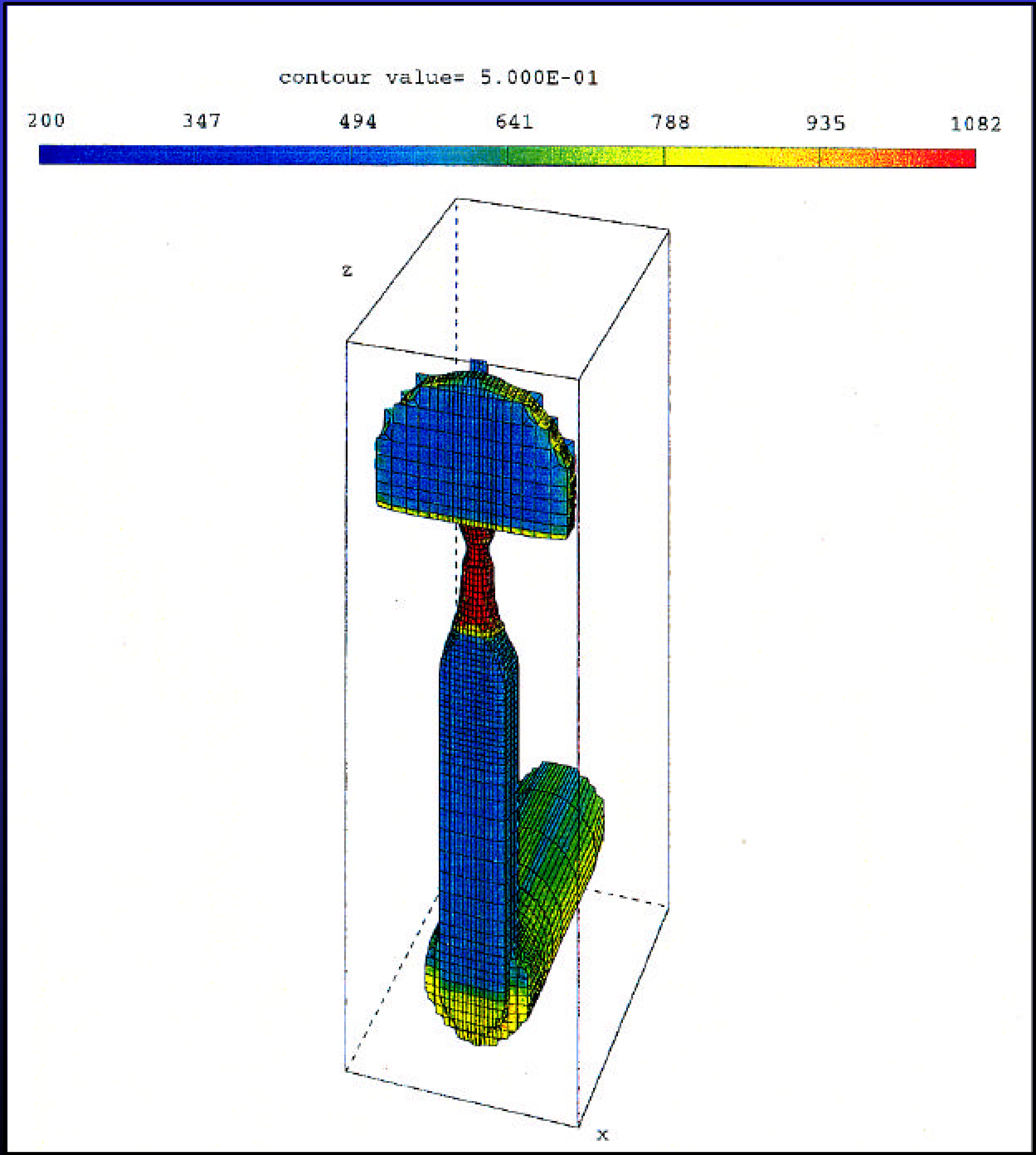


Thermal Modeling

Modeling studies

Temperature profiles in H-13 die inserts during cooling cycle

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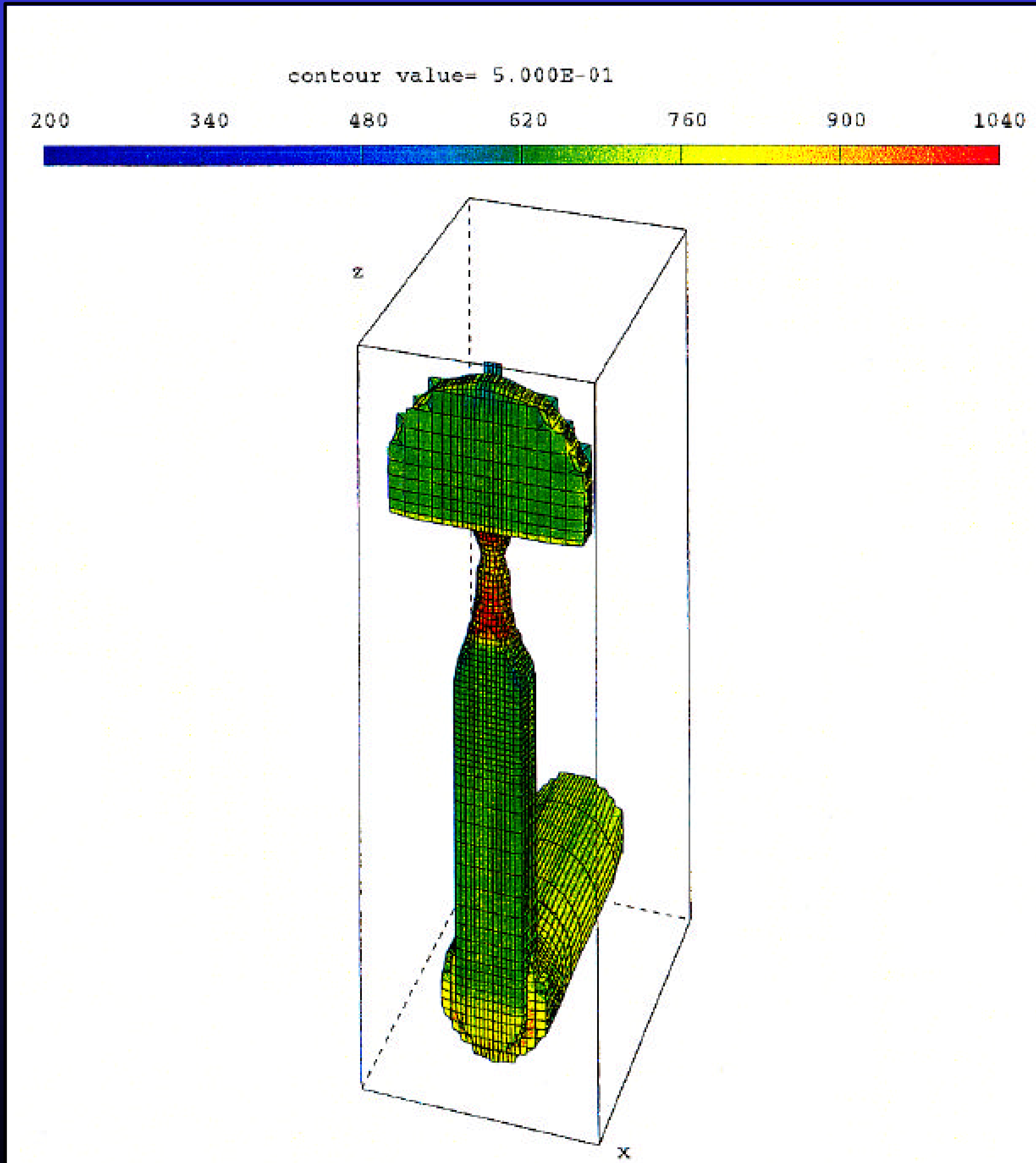
347
494
641
788
935
1082
z
x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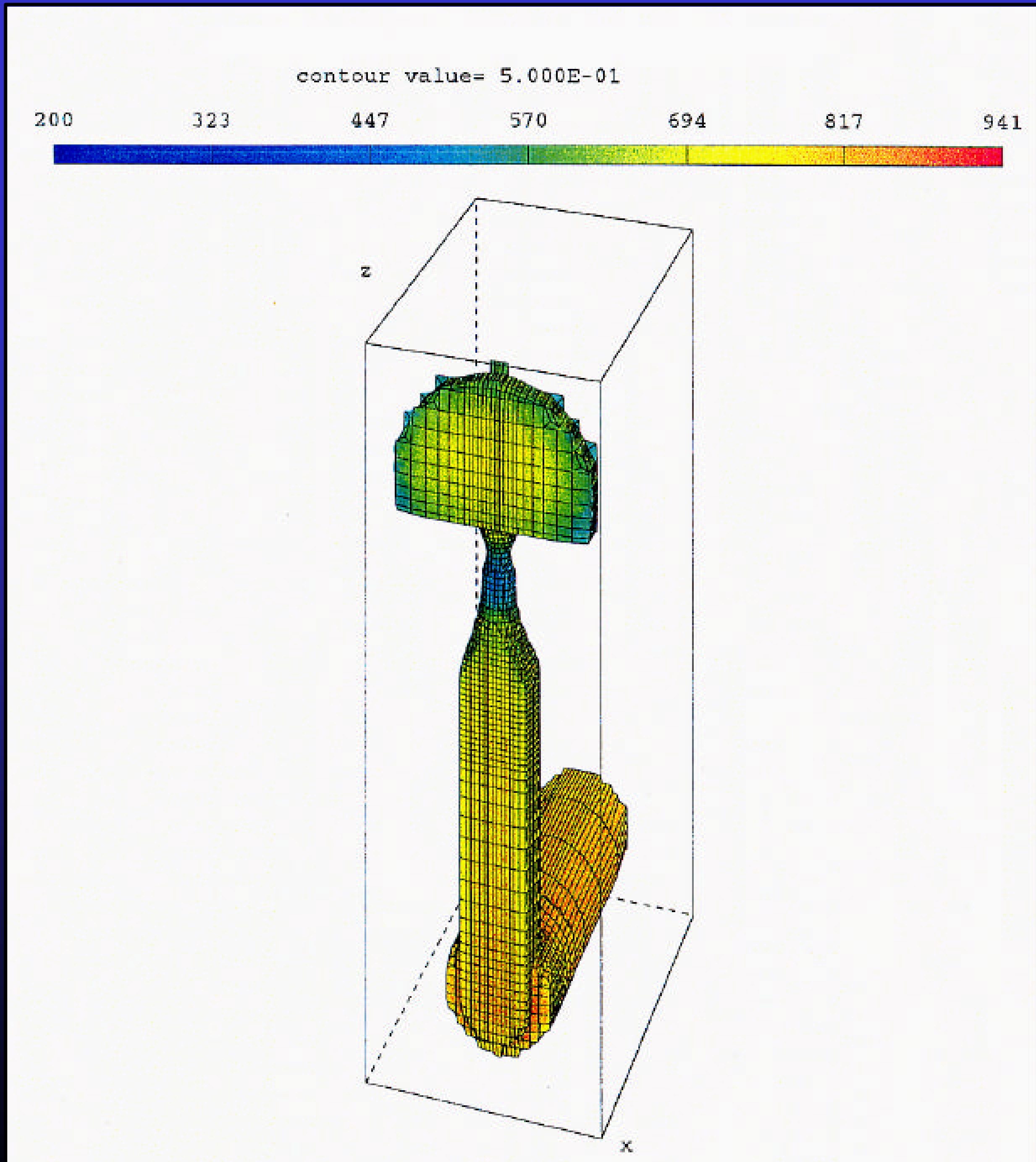
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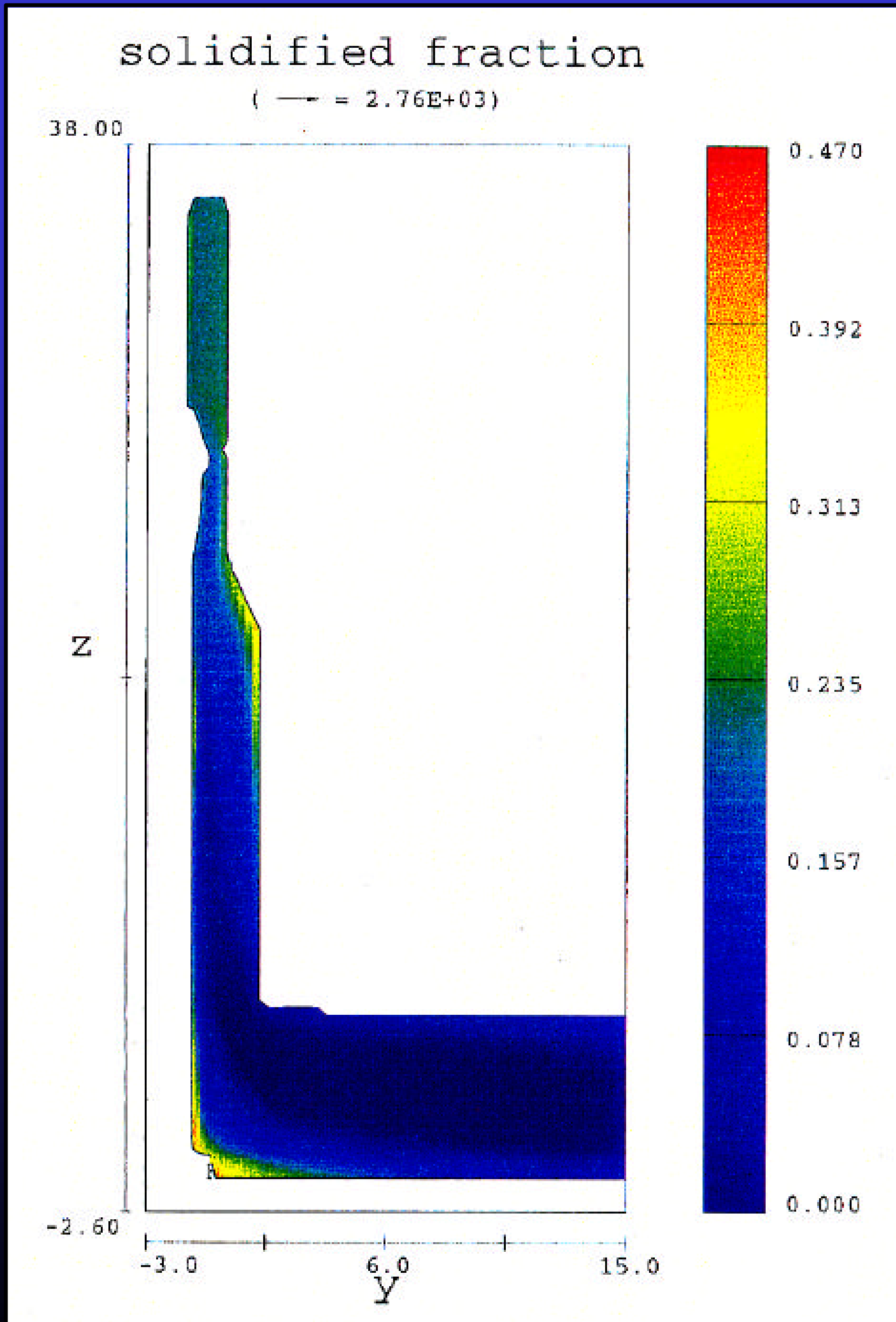
z
x


solidified fraction
(⟶ = 2.76E+03)
38.00
Z
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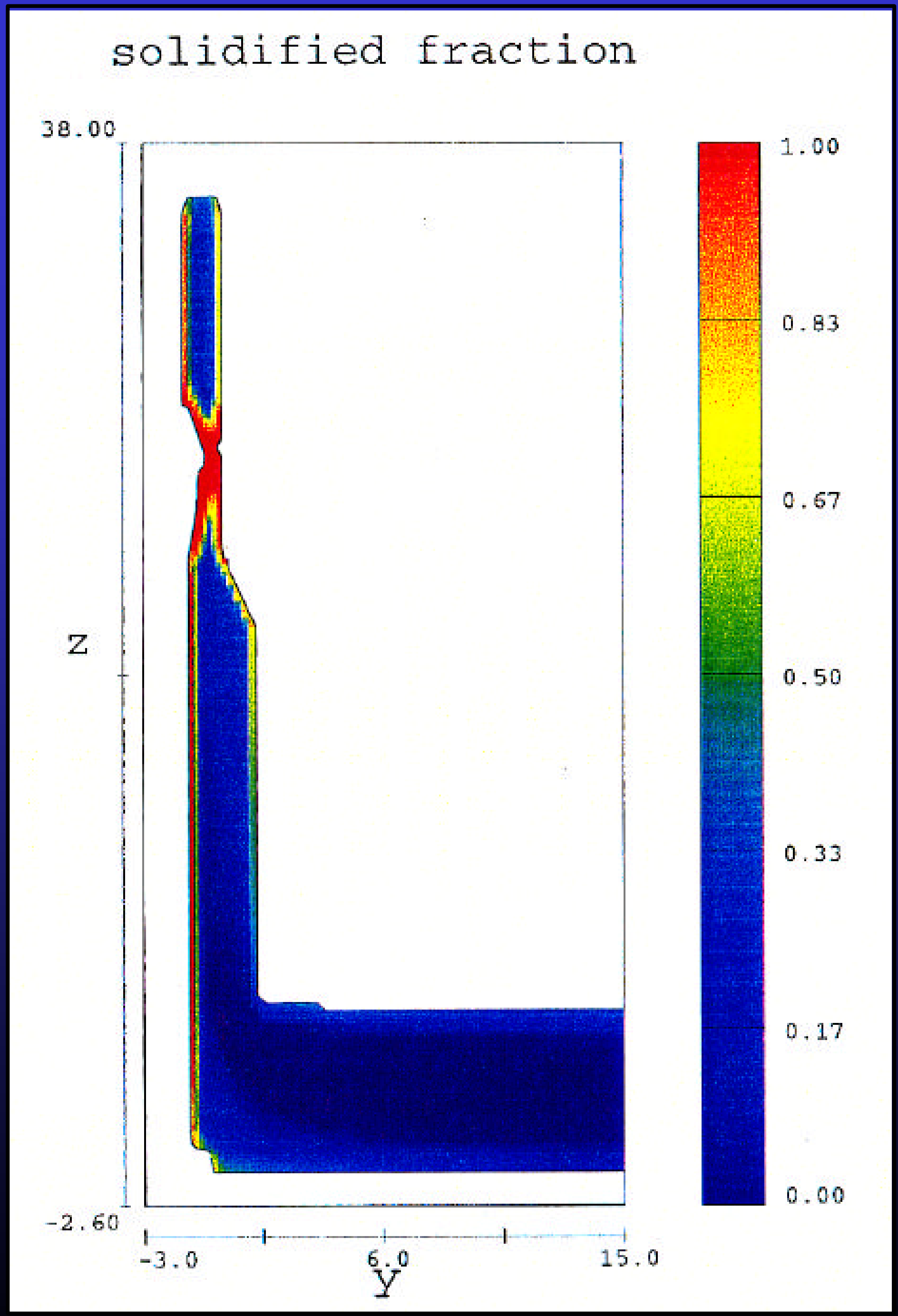
-3.0
6.0
15.0
Y
0.470
0.392
0.313
0.235
0.157
0.078
0.000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Z
Y
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15.0
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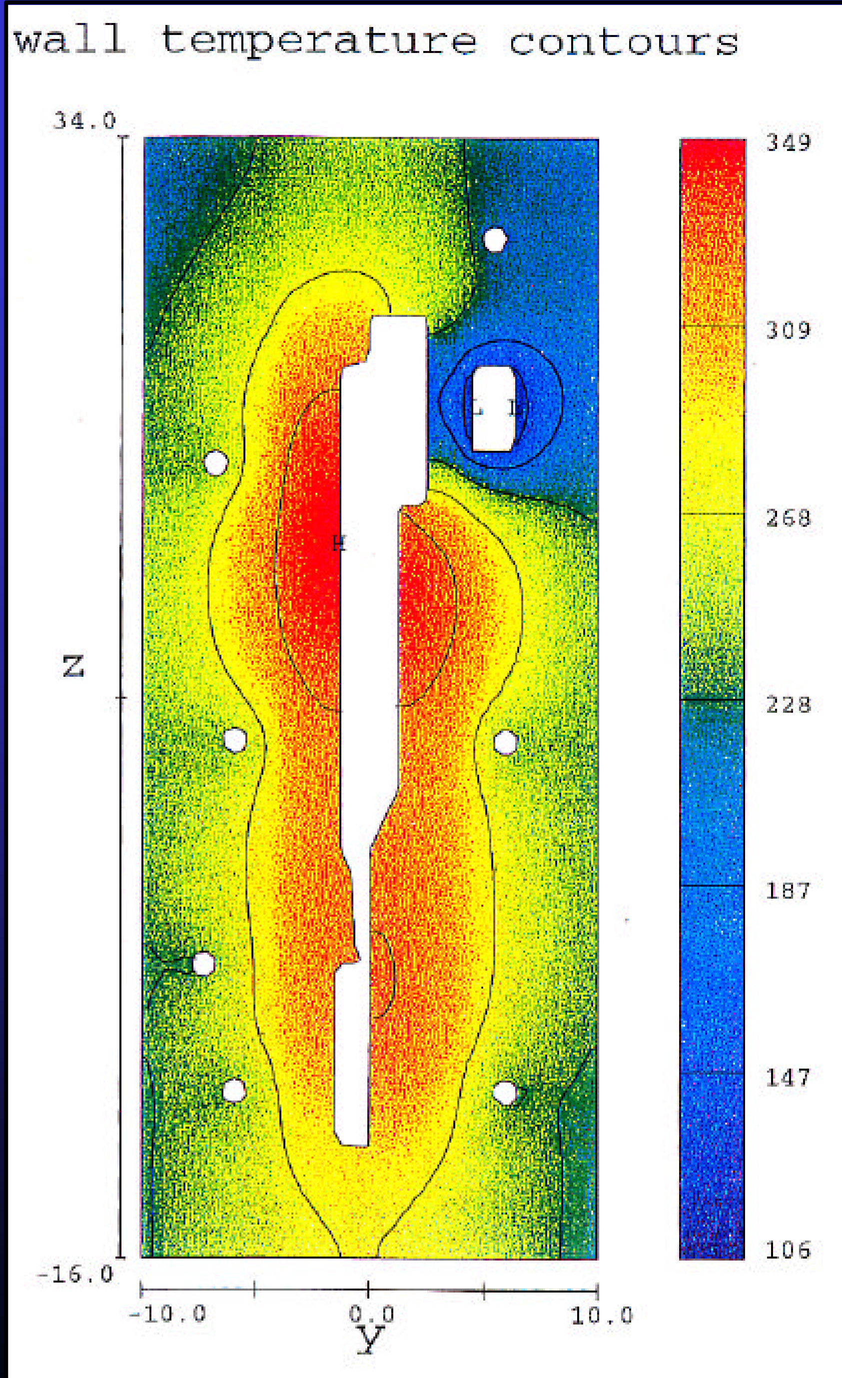
0.67
0.50
0.33
0.17
0.00


wall temperature contours
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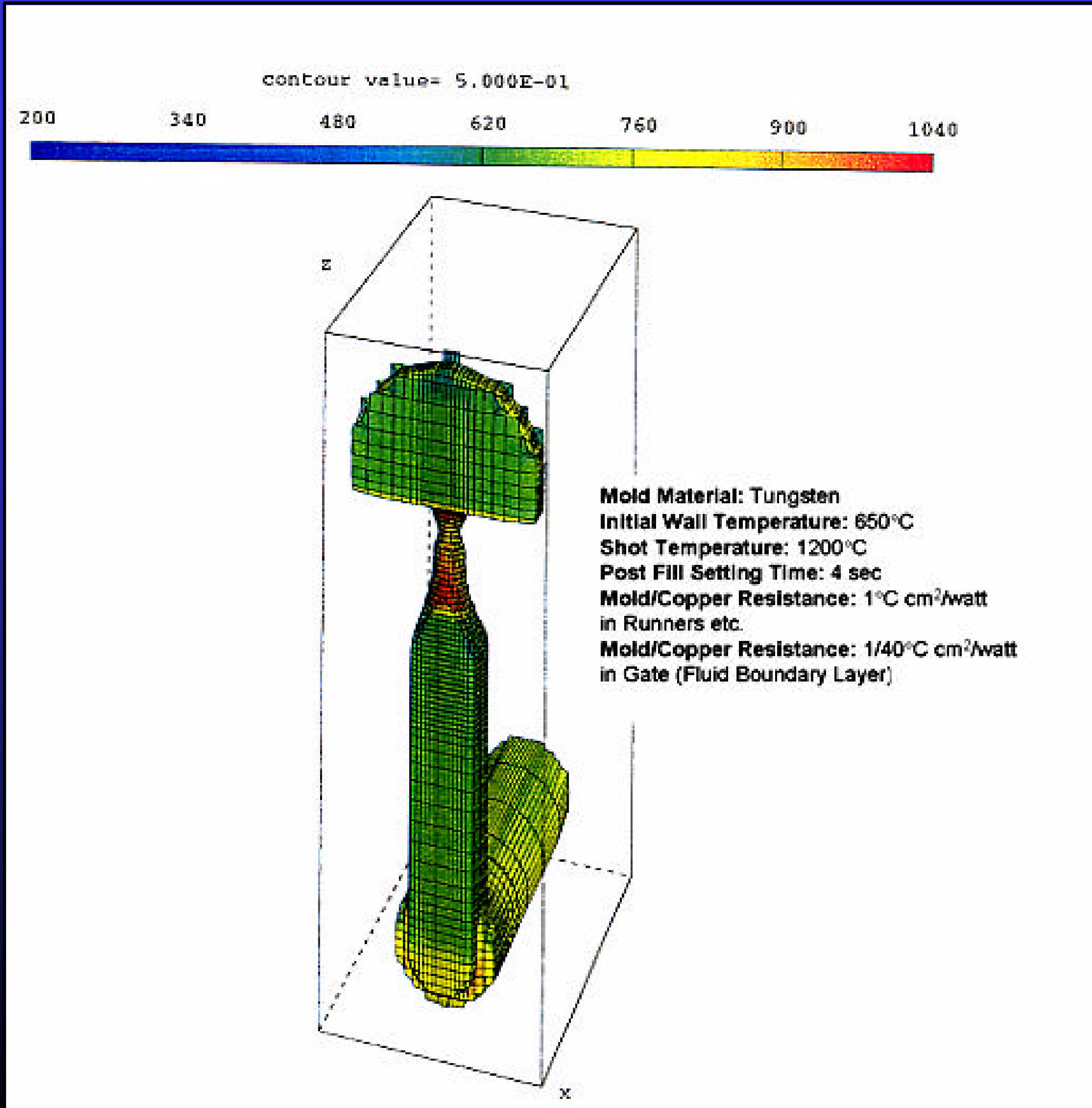
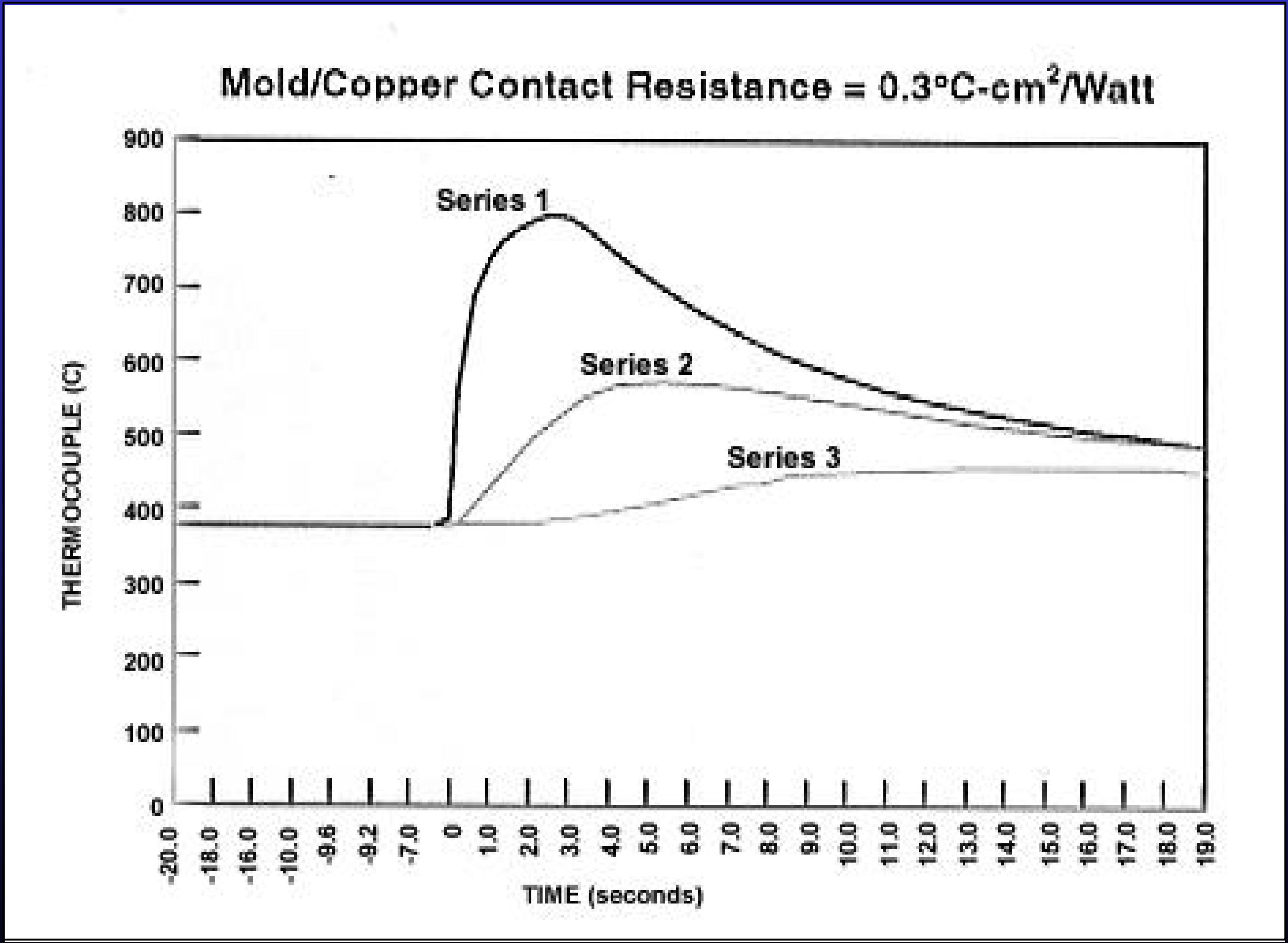
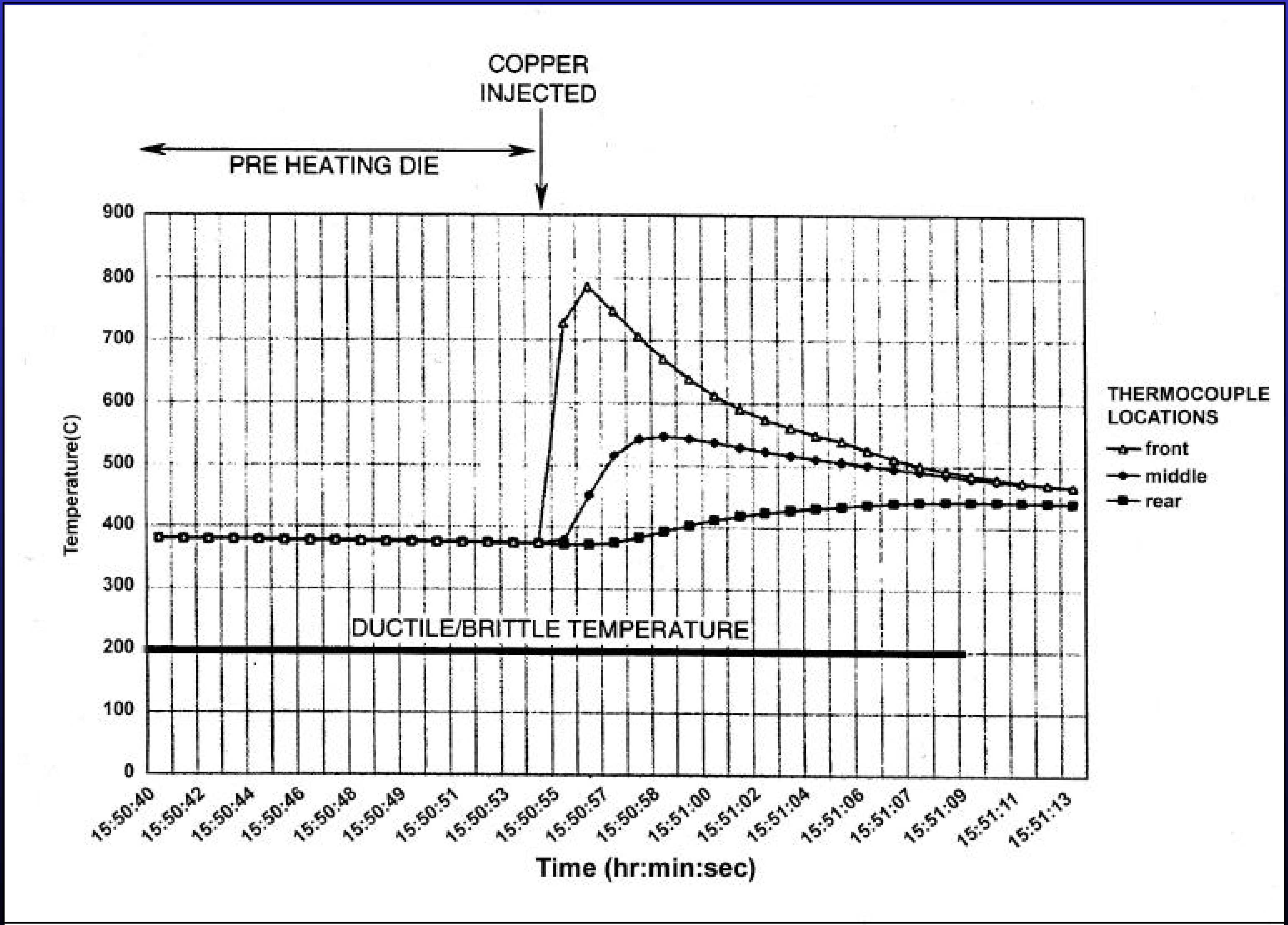
-16.0
Z
-10.0
0.0
10.0
Y
349
309
268
228
187
147
106


contour value= 5.000E-01
200
340
480
620
760
900
1040
z
x
Mold Material: Tungsten
Initial Wall Temperature: 650°C
Shot Temperature: 1200°C
Post Fill Setting Time: 4 sec
Mold/Copper Resistance: 1°C cm²/watt
in Runners etc.
Mold/Copper Resistance: 1/40°C cm²/watt
in Gate (Fluid Boundary Layer)

Predicted Temperature Profiles



Actual Temperature Profiles



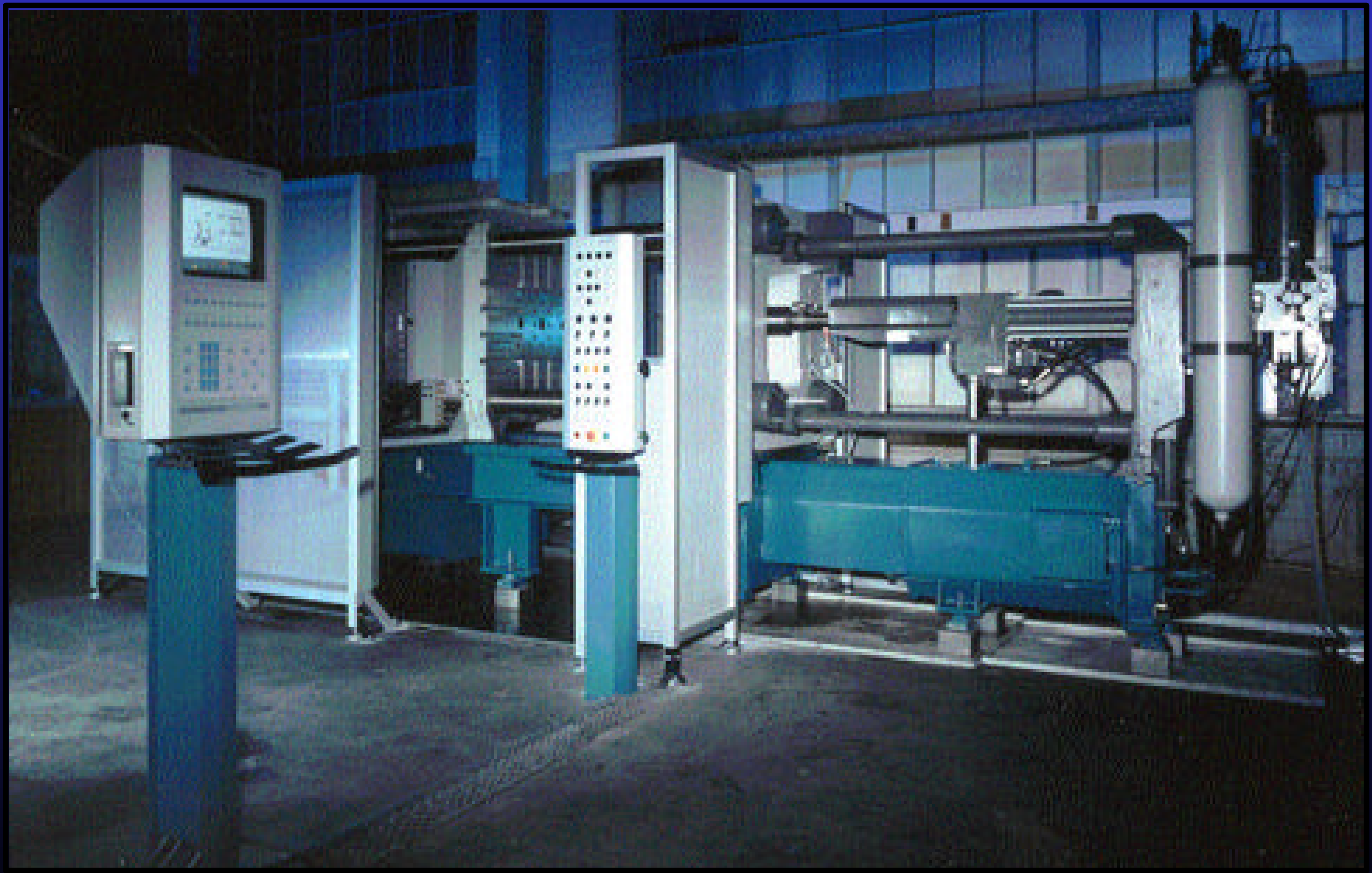
The Die Casting Process

System design at Formcast test facility

- 660 metric-ton Buhler SC (independent computer controlled - closure & shot)
- Induction melting (15 kg of copper in 9 minutes for rotors – earlier design used 4 kg of copper per 2 minute cycle for material testing)
- High-temperature mold (die) materials and handling to achieve long life-in-service

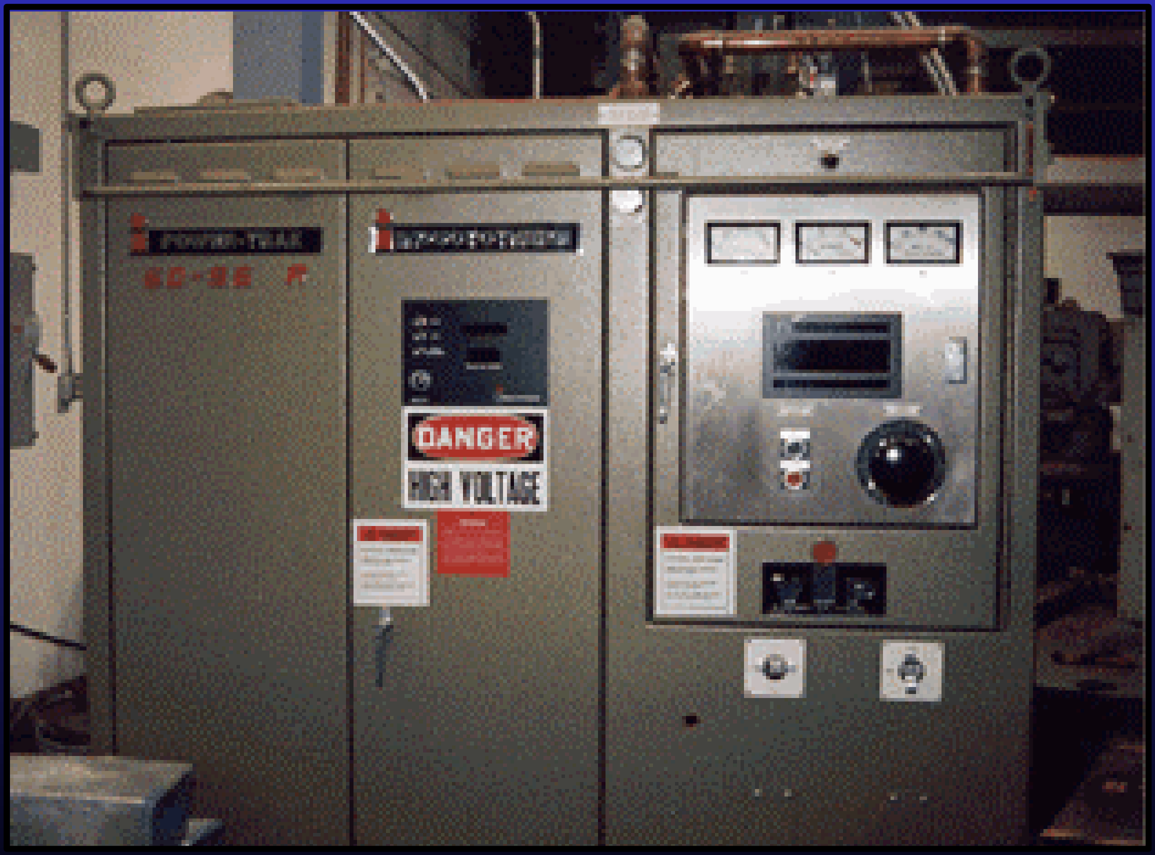
The Die Casting Process

Bühler horizontal die caster



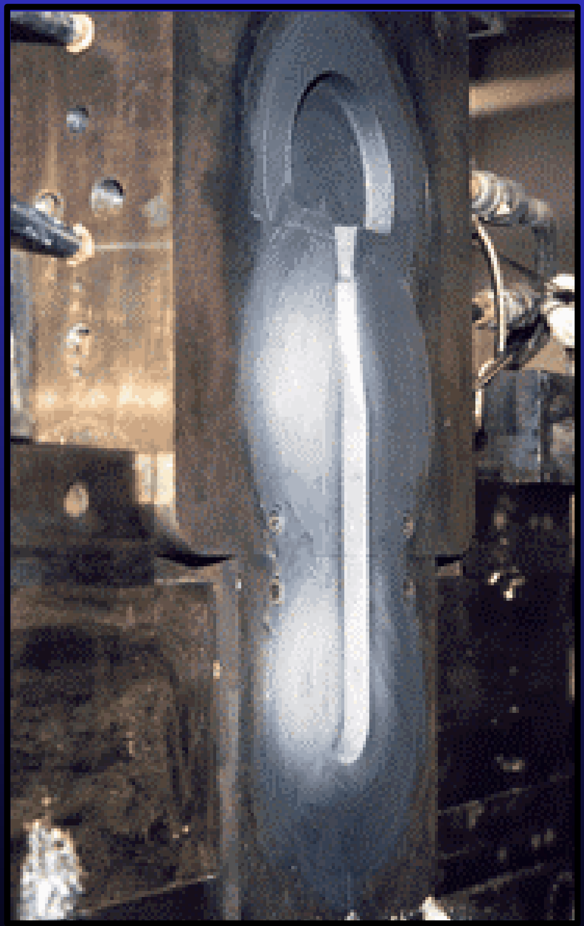
The Die Casting Process

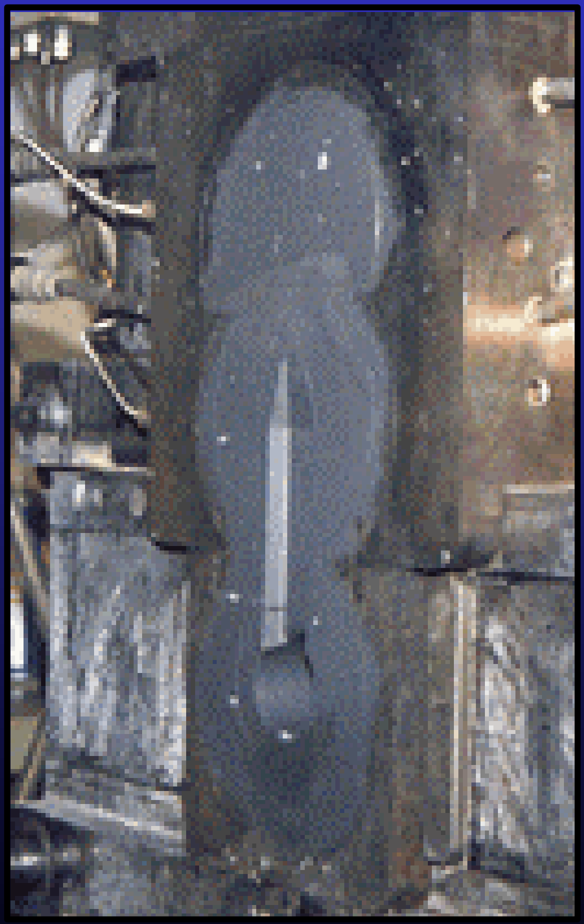
Inductotherm induction furnace



The Die Casting Process

Die halves – H-13 tool steel





The Die Casting Process

Applying dry film lubricant

The Die Casting Process

Measuring copper charge

The Die Casting Process

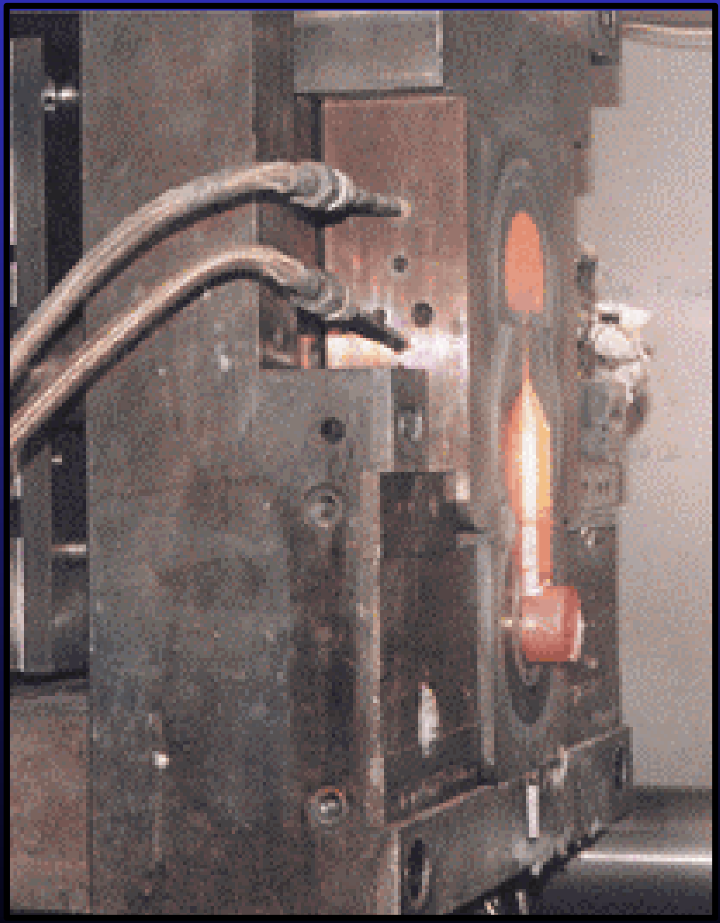
Transferring molten copper to shot sleeve

The Die Casting Process

Pouring copper into shot sleeve

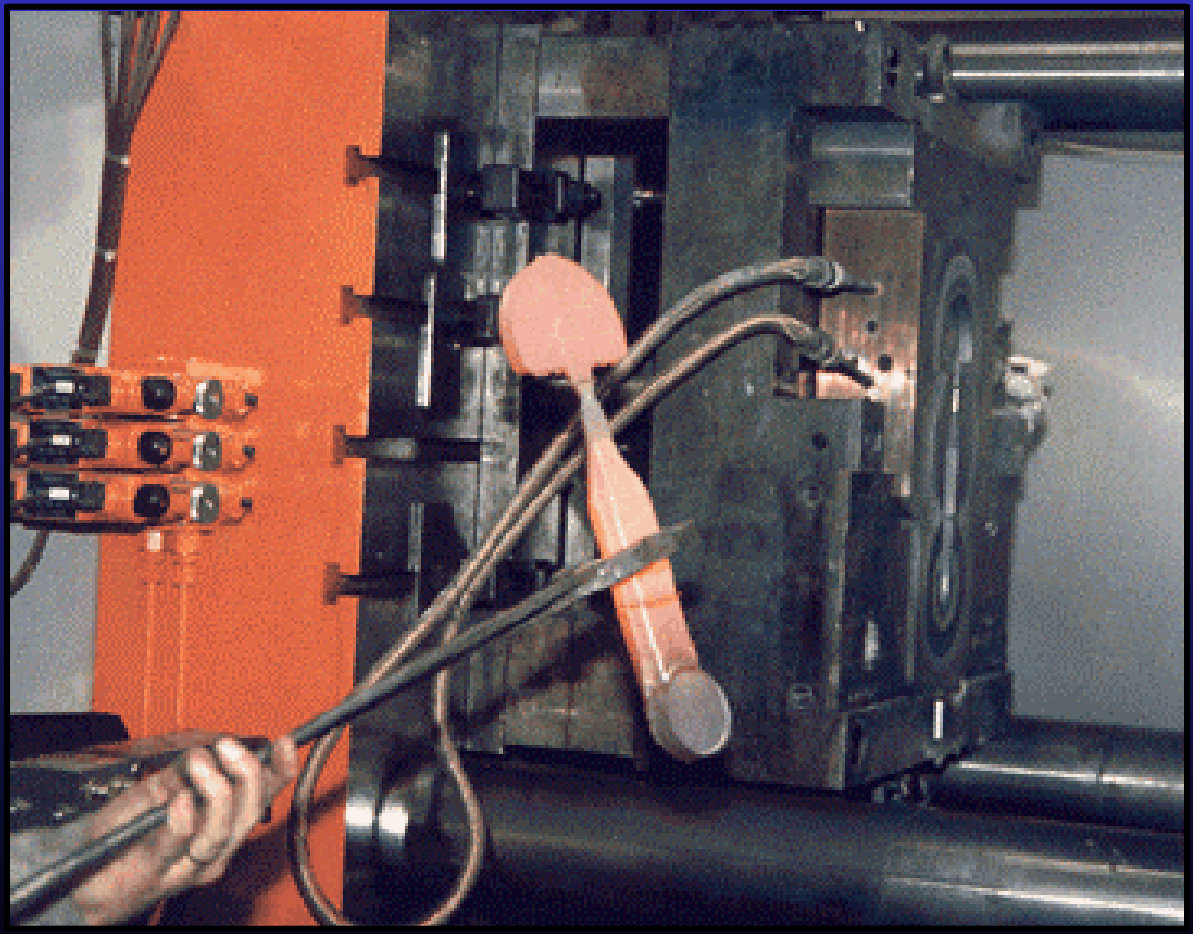
The Die Casting Process

Ejecting copper casting and runner



The Die Casting Process

Extracting die cast copper



Testing Die Materials

Dr. John G. Cowie

Vice President

Copper Development Association Inc.

Testing of Die Materials – H-13 Steel

First Casting Trial:

H-13 Steel Dies
Baseline Data

Testing of Die Materials – H-13 Steel

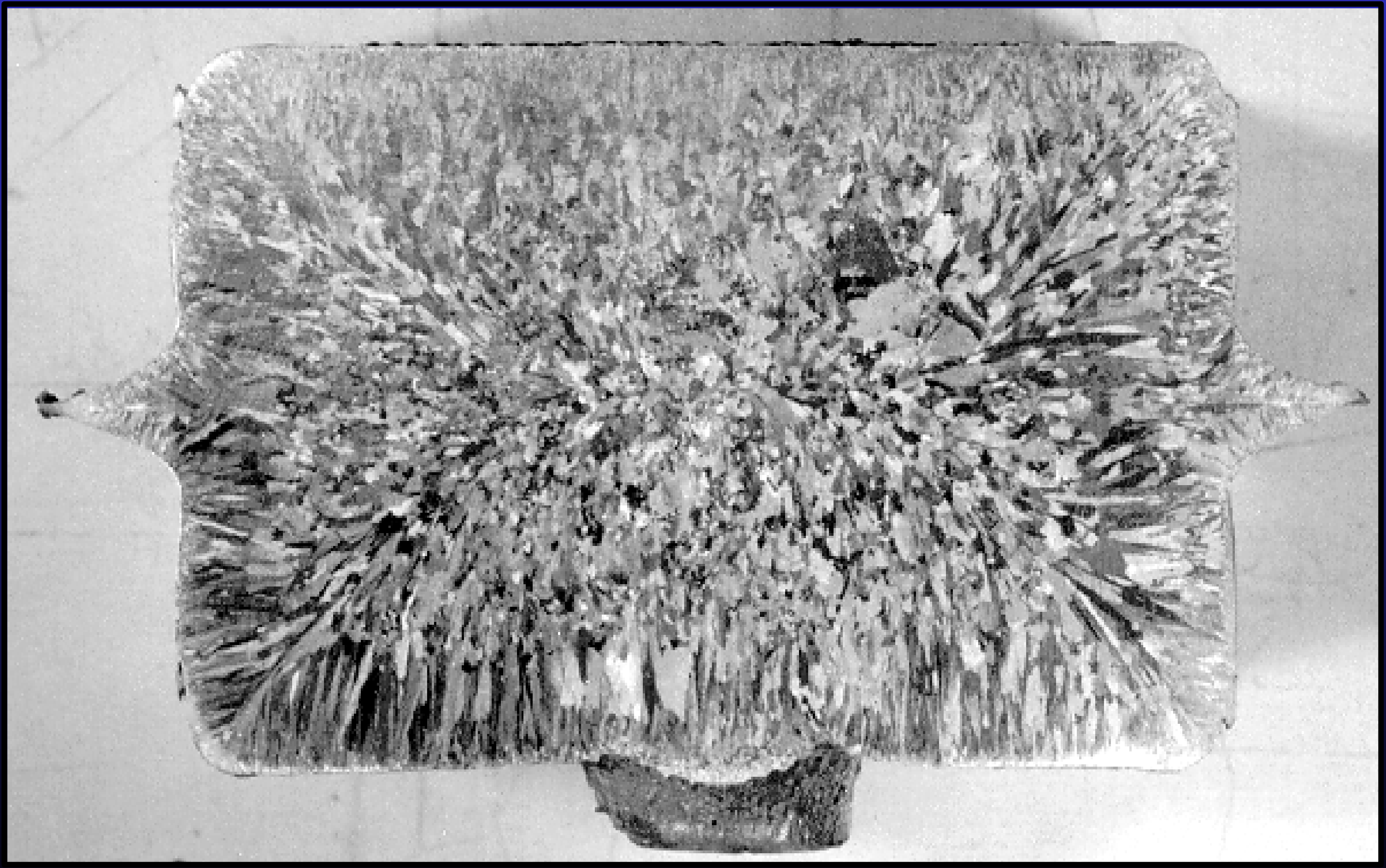
Visual Examination – Thermal Fatigue Cracks

Shot # 9

Shot # 800

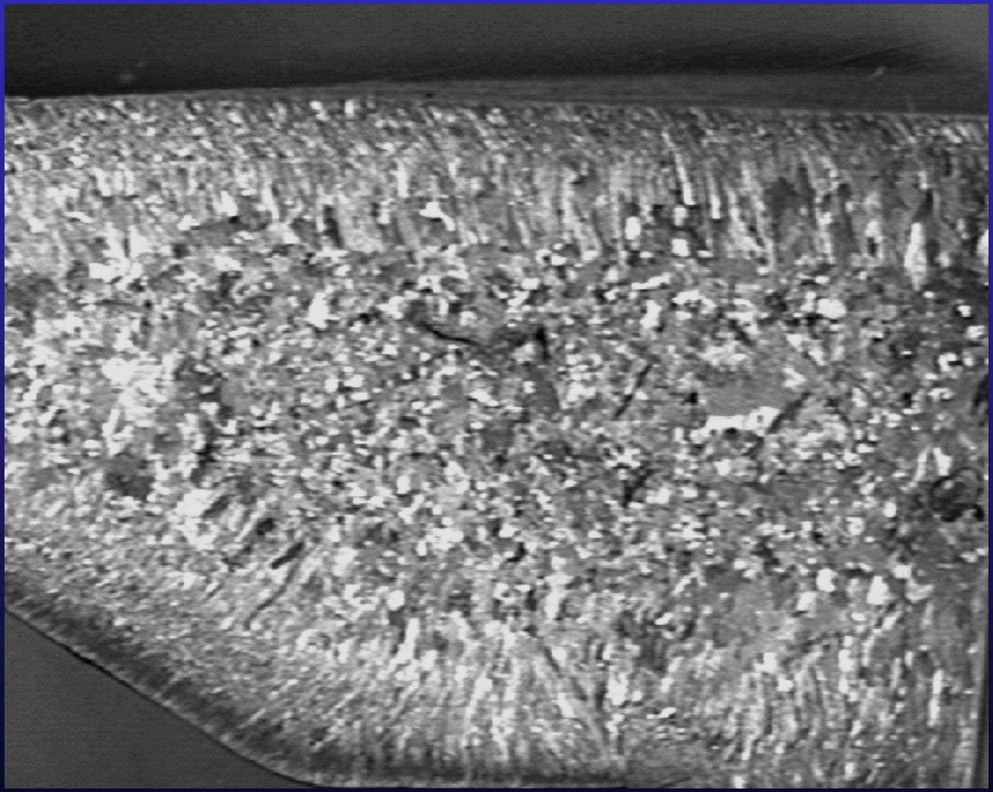
Testing of Die Materials – H-13 Steel

Macrostructure of die cast copper



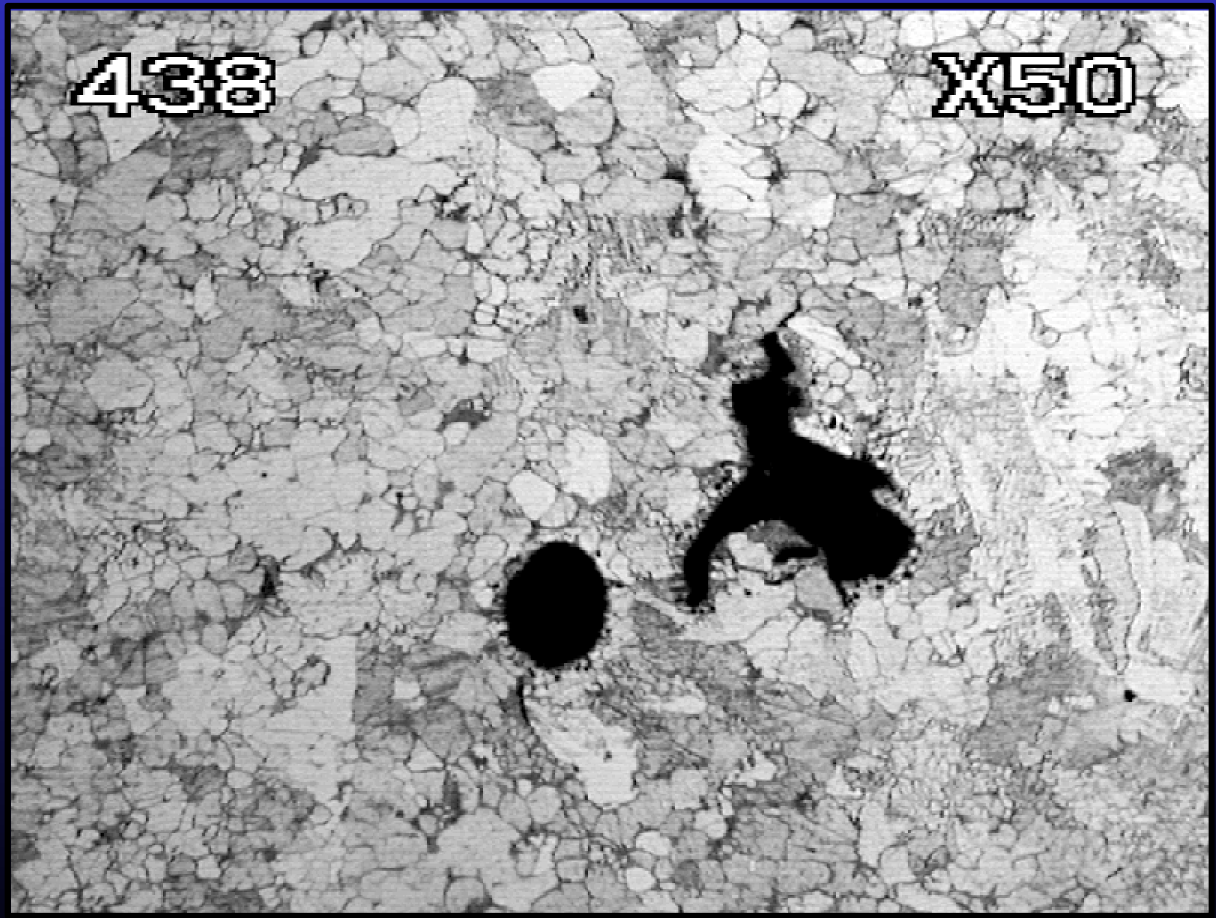
Testing of Die Materials – H-13 Steel

Microstructure of die cast copper near gate region



Testing of Die Materials – H-13 Steel

Microstructure of die cast copper



Testing of Die Materials – H-13 Steel

Iron & Oxygen Contamination

Shot Number	Iron Content ppm	Oxygen Content wt. %
9	17	0.059
11	350	0.11
438	56	0.15
600	61	0.057
800	10	0.055

Testing of Die Materials – H-13 Tool Steel

Conductivity

Shot Number	Average % IACS
9	97.8
11	95.2
438	96.8
600	99.7
800	99.4
Average	98.8

Testing of Die Materials – H-13 Steel

Alternative Shot Sleeves

- Liner insert below pouring hole
- Reduced erosion & wear
- Reduced contamination of copper
- Retained electrical conductivity in cast copper
- Remelting runners and gates sections

Testing of Die Materials – CVD-W & TZM

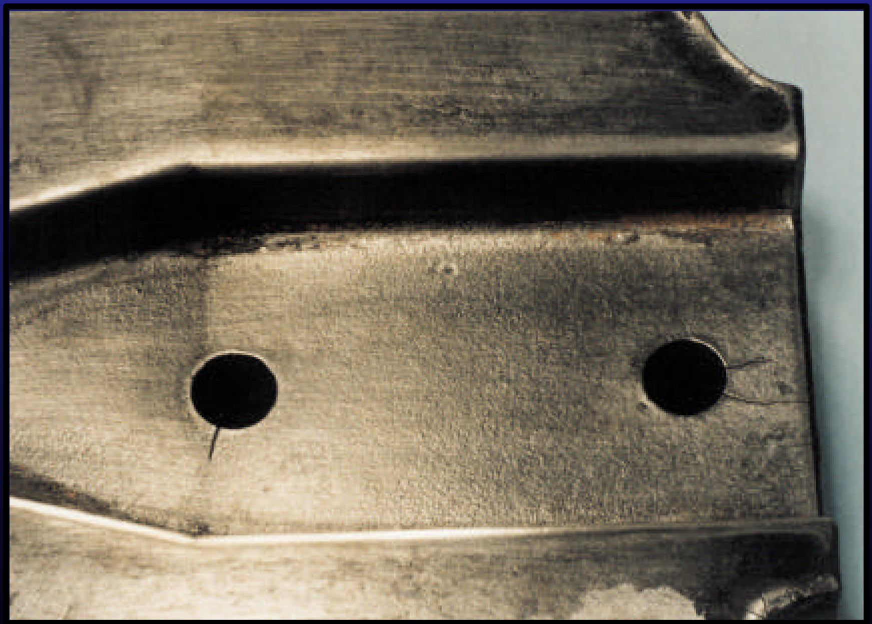
Second Casting Trial:

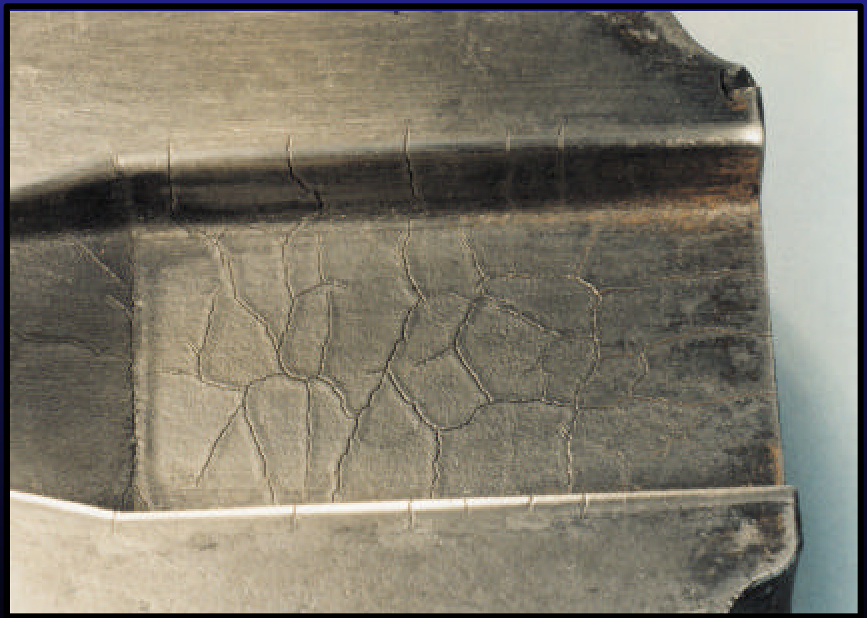
Chemical Vapor Deposition (CVD) Tungsten Coated on TZM Modified Molybdenum Dies

Testing of Die Materials – CVD-W on TZM

CVD tungsten

After 50 shots, cracking from ejector pin holes and heat-checking. Preheated 350 C.





Testing of Die Materials – Inconel

Third Casting Trial:

Nickel Alloy Dies -
617
718
MA-754

Testing of Die Materials – Inconel

Visual examination

Preheat 320 C to 410 C

Shot # 50

Shot # 235

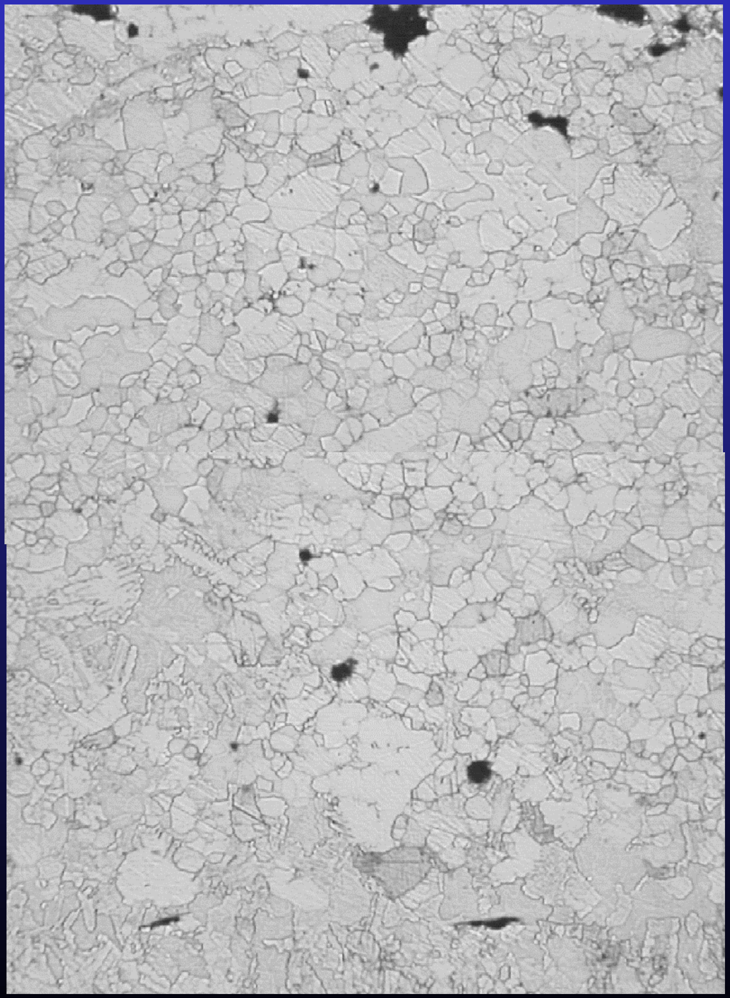
Testing of Die Materials – Inconel

Alloy comparison

Alloy	Heat Checking Observed
MA 754	Shot# 50
718	Shot# 100
617	Shot# 200 (minor crazing)

Testing of Die Materials – Inconel

Porosity



Testing of Die Materials – Inconel

Electrical conductivity

Shot Number	% IACS
50	99.4
150	99.1
235	101.2
Average	99.9

Testing of Die Materials – TZM & Anviloy

Fourth Casting Trial:

TZM & Anviloy Dies

Testing of Die Materials – TZM & Anviloy

TZM & Anviloy dies

- TZM (molybdenum alloy)
  - Oxidized at die operating temperatures
- Anviloy (tungsten alloy)
  - Brittle below 450C
  - Difficult to machine

Testing of Die Materials – TZM & Anviloy

Anviloy dies

- Moving half
- Preheat 450C to 560C

Testing of Die Materials – Nickel Alloys #2

Fifth Casting Trial:

Nickel Alloy Dies 617 & 625
at Elevated Temperature

Testing of Die Materials – Nickel Alloys #2

Inconel Alloy Dies at Elevated Temperature

- After 950 shots, minor cracking
- Preheat 560C to 660C

Die Materials Testing

Initial findings

- Multiple high-temperature mold (die) materials may perform adequately in various die locations—depending upon thermal stresses/load requirements

- Mold (die) material handling—preheat requirements are critical—to reduce thermal stresses and assure long die-life in-service

Die Materials Testing

Nickel-based superalloy compositions (wt.%)

Alloy	Ni	Co	Cr	Mo	W	Fe	Al	C	Others
230	Bal.	5*	22	2	14	3*	0.3	0.1	0.4 Si, 0.5 Mn, 0.02 La
617	Bal.	12.5	22	9	-	1.5	1.2	0.07	0.30 Ti
625	Bal.	1*	21	9	-	5*	0.4*	0.1*	0.4* Ti, 0.5 Mn 3.7 Nb+Ta

* maximum

Die Materials Testing

Superalloy comparison – 0.2% YS (MPa)

Alloy	20C	540C	650C	760C	870C	980C	1100C
230	393	276	269	283	221	124	57
617	352	228	214	221	214	110	55
625	490	372	372	345	207	83	39

Die Materials Testing

Superalloy comparison – UTS (MPa)

Alloy	20C	540C	650C	760C	870C	980C	1100C
230	862	710	669	586	400	228	117
617	759	593	565	503	352	200	110
625	903	772	759	600	345	166	97

Die Materials Testing

Superalloy comparison – % elongation

Alloy	20C	540C	650C	760C	870C	980C	1100C
230	48	56	55	46	59	71	50
617	58	64	69	56	54	64	50
625	49	54	56	53	46	44	45

Die Materials Testing

Conclusions – Phase I of study

- Five copper die casting trials completed
- Inconel alloy 617 best candidate tested

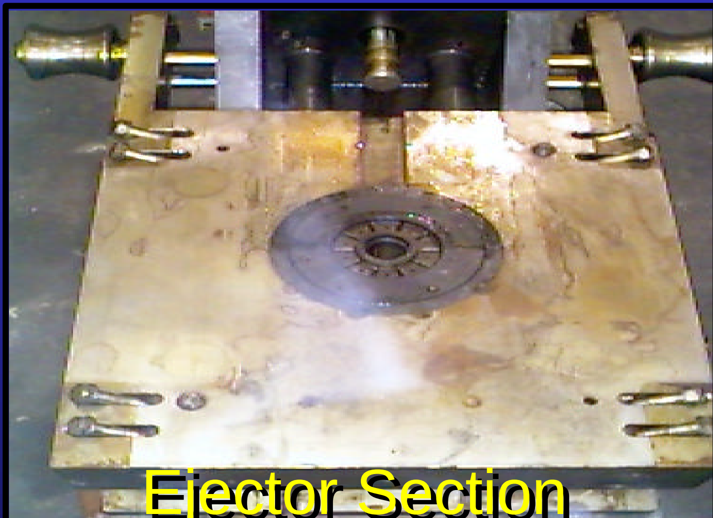
  Haynes alloy 230 alternate die material
- <u>Must</u> run dies hot: 650C
- Copper microstructure exhibited minor defects
- Conductivity very good
- Elimination of iron in system should improve conductivity
- Reduction of oxygen contamination should improve ductility

Rotor Die Casting

Dr. Edwin Brush (Ned)
Consultant
BBF & Associates

Die Casting Copper Rotors

Master die set for casting rotors

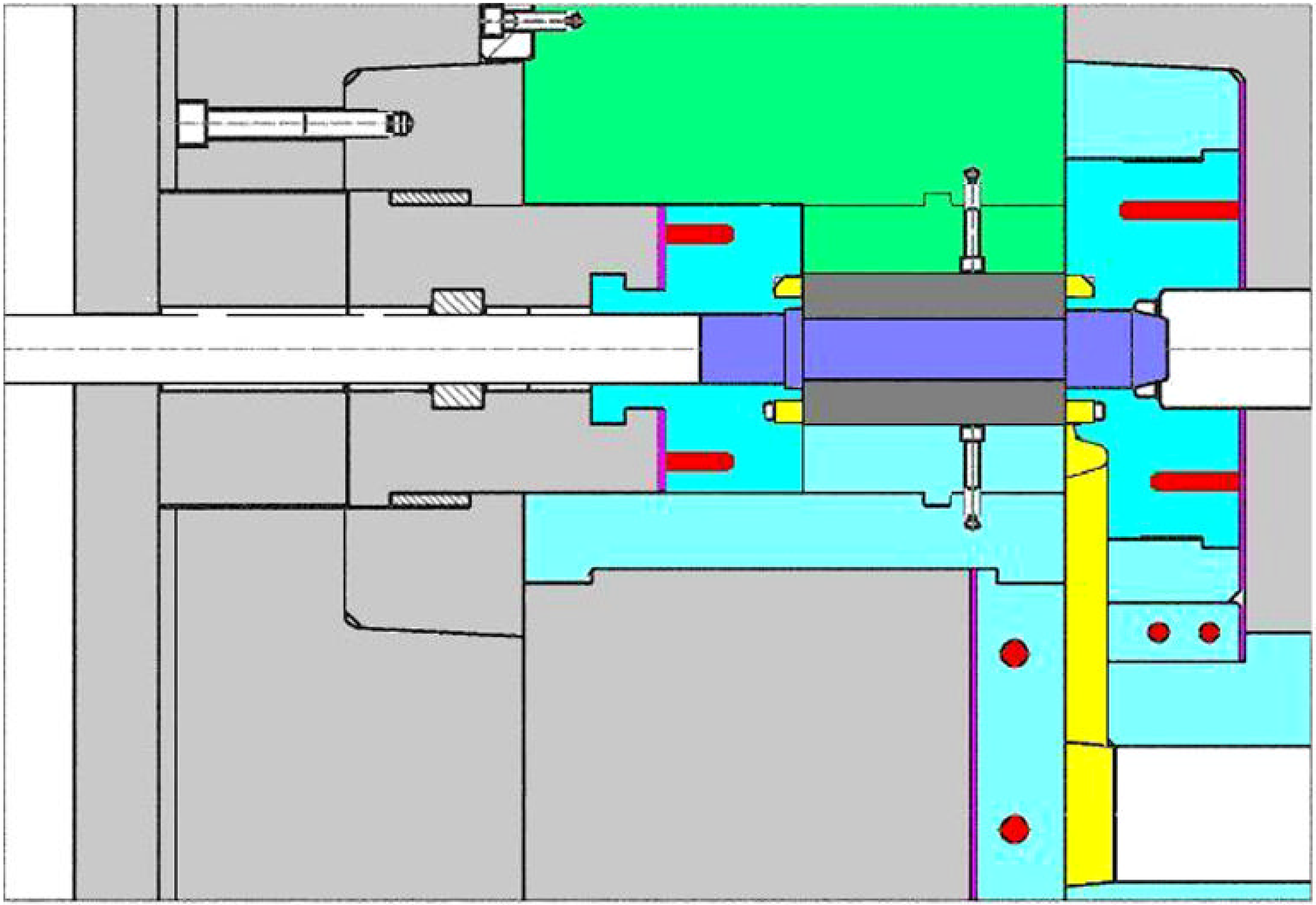


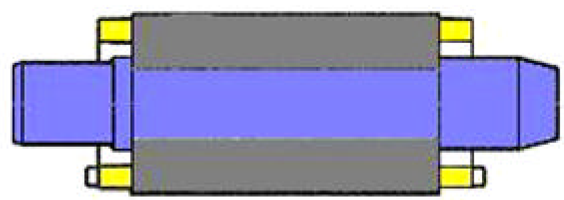
Ejector Section

Center Section

Stationary Section

Alternate (Thick) Center Section





Die Casting Copper Rotors

Larger Induction melting furnace

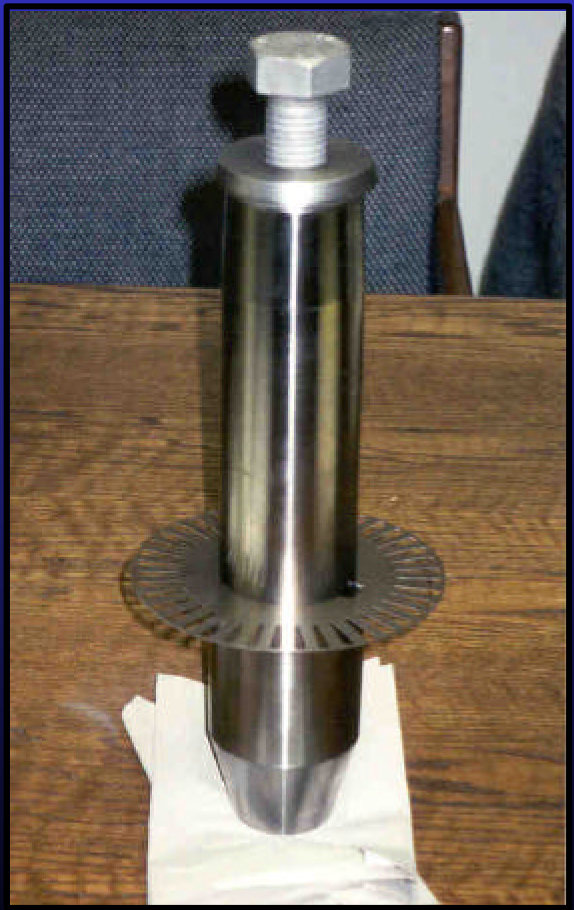
Inductotherm

Die Casting Copper Rotors

Die cavity inserts — gates and runner

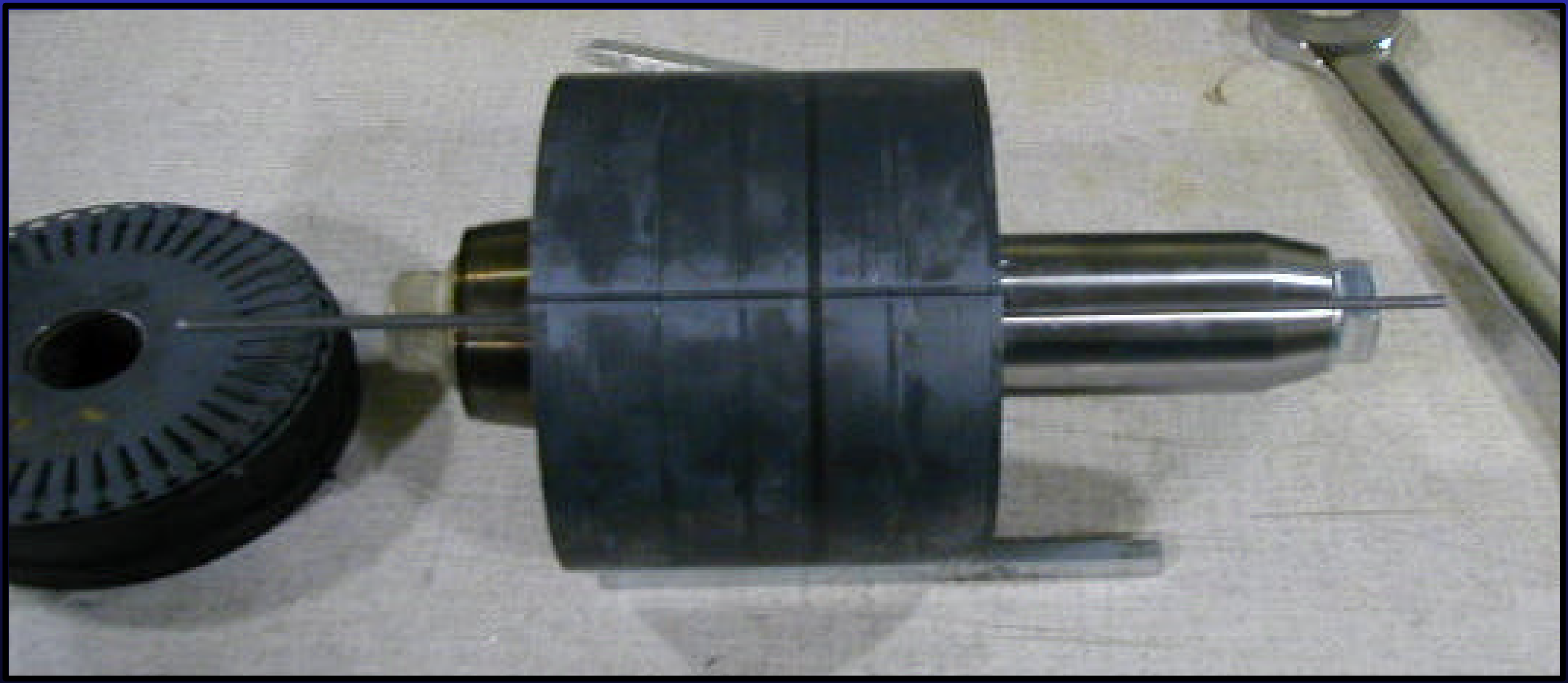
Die Casting Copper Rotors

Arbor (Mandrel)



Die Casting Copper Rotors

Core stack being assembled



Die Casting Copper Rotors

Assembled core stacks

Die Casting Copper Rotors

Compressing laminations

Die Casting Copper Rotors

Inserting laminations (core stack)

Die Casting Copper Rotors

Inductotherm (Induction melting) furnace

Die Casting Copper Rotors

Copper pellets melting in the crucible

Die Casting Copper Rotors

Removing crucible from furnace

Die Casting Copper Rotors

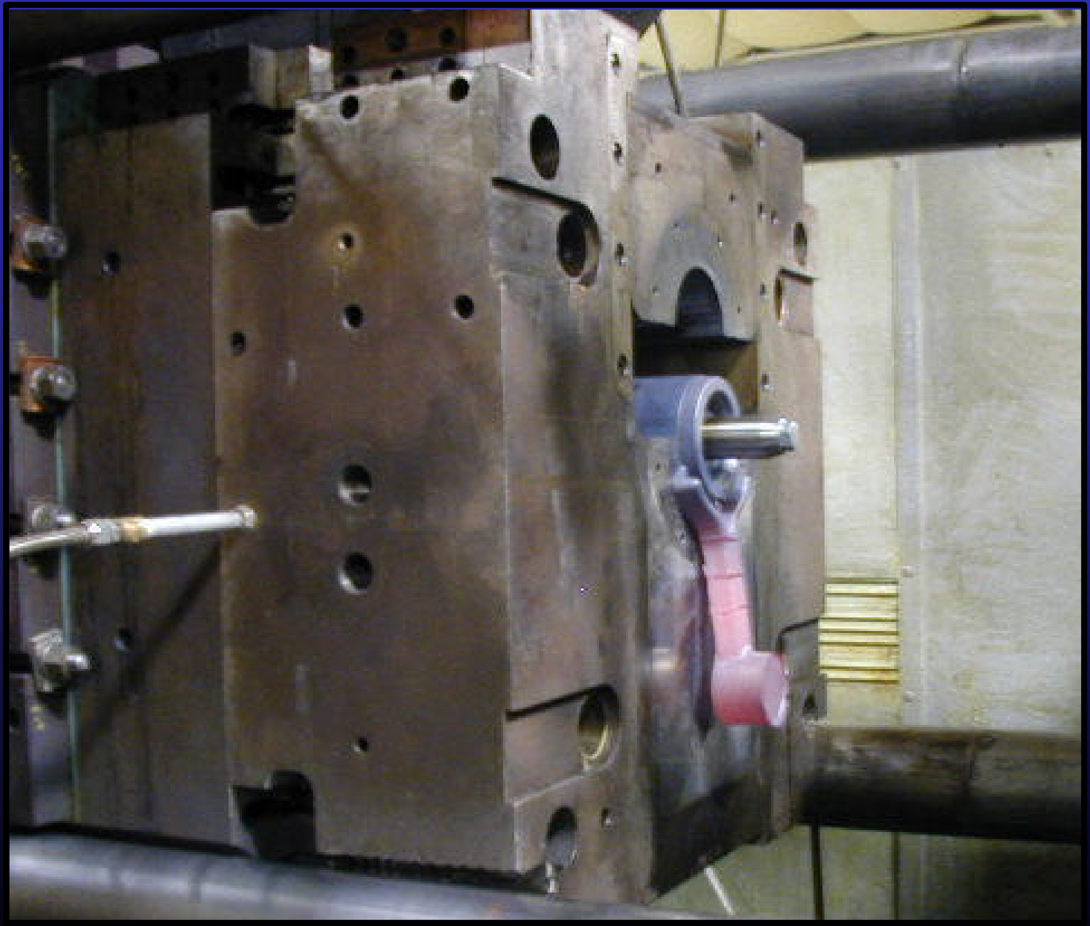
Pouring copper into the shot sleeve

Die Casting Copper Rotors

Programming computer controlled die-caster

Die Casting Copper Rotors

Ejecting rotor with runner



Die Casting Copper Rotors

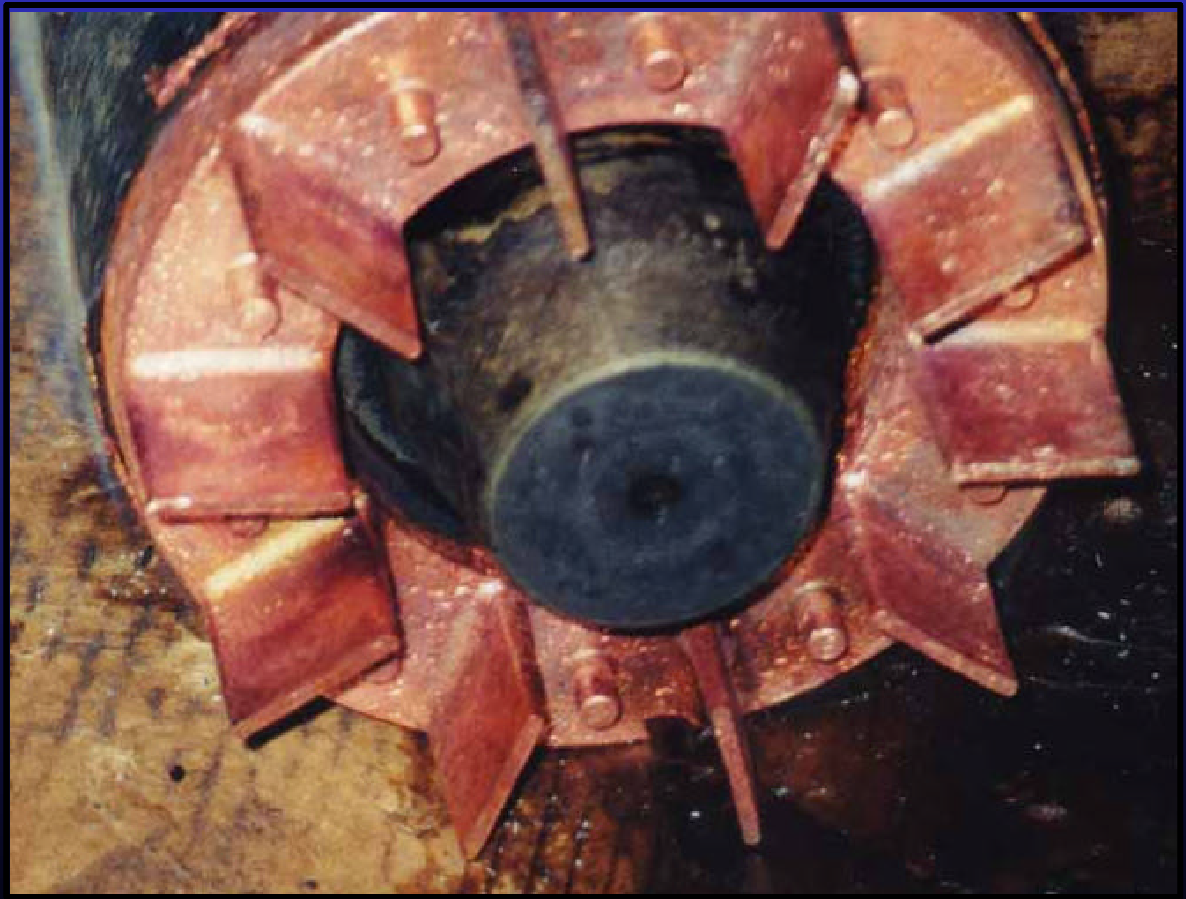
Extracting rotor

Die Casting Copper Rotors

Water-quenching rotor

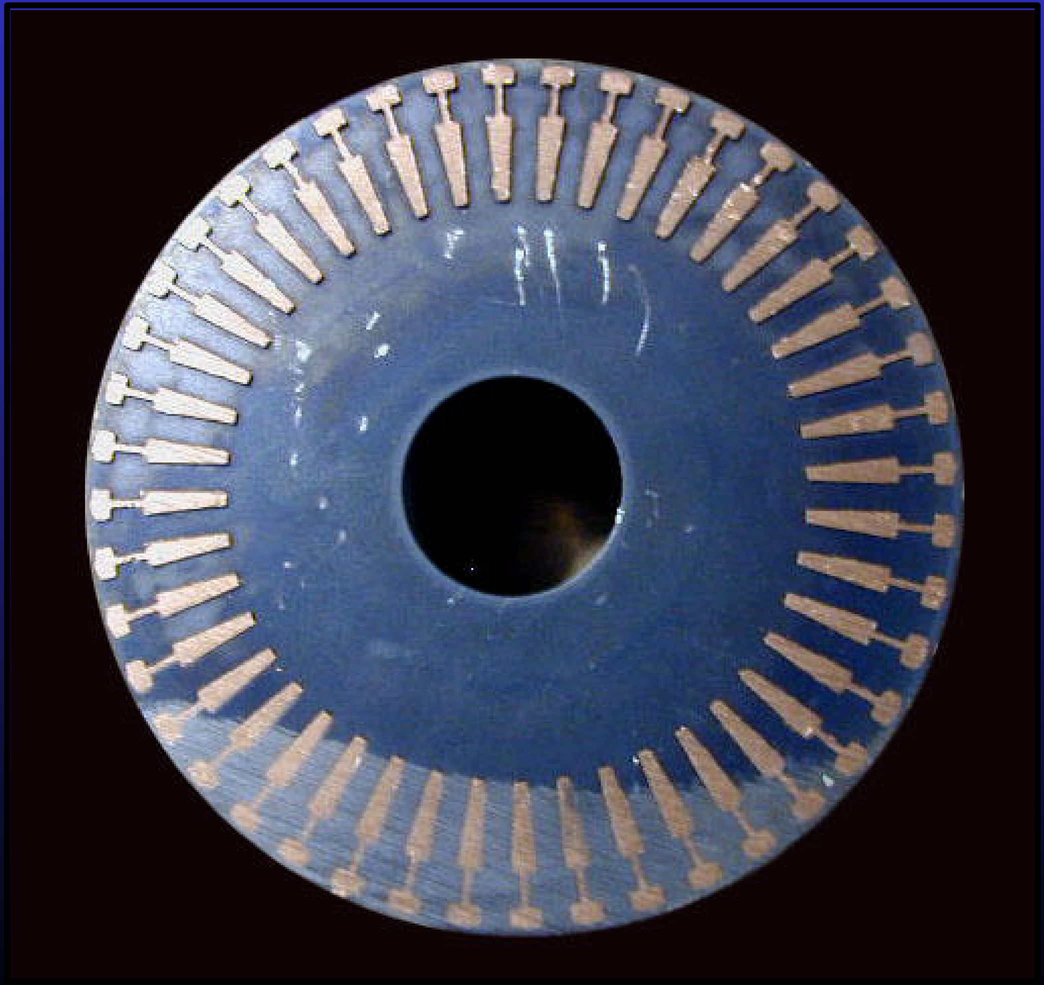
Die Casting Copper Rotors

Fin detail - complete fill on a large rotor



Die Casting Copper Rotors

Cross-section of a cast copper rotor



Die Casting Copper Rotors

Rotor die-casting

- Rotor die casting evaluation runs for four motor companies completed
- Evaluation of prototype motor performance - three sets of results (next)
- Run of 200 to 500 rotors for production motors planned

Rotor Steel Specification for Copper

Recommend Review of Current Specifications Developed for Aluminum Die Casting

Indications to Date:

- High temperature anneals, utilized in many “larger" rotors, appear NOT affected –
- No increases in losses observed (IEEE Tests)

- Low temperature anneals, utilized in some “smaller" rotors, appear affected
- Increases in core (Iron) losses observed

Target for Opportunity

Advantages to motor performance - scenarios for manufacturers and users

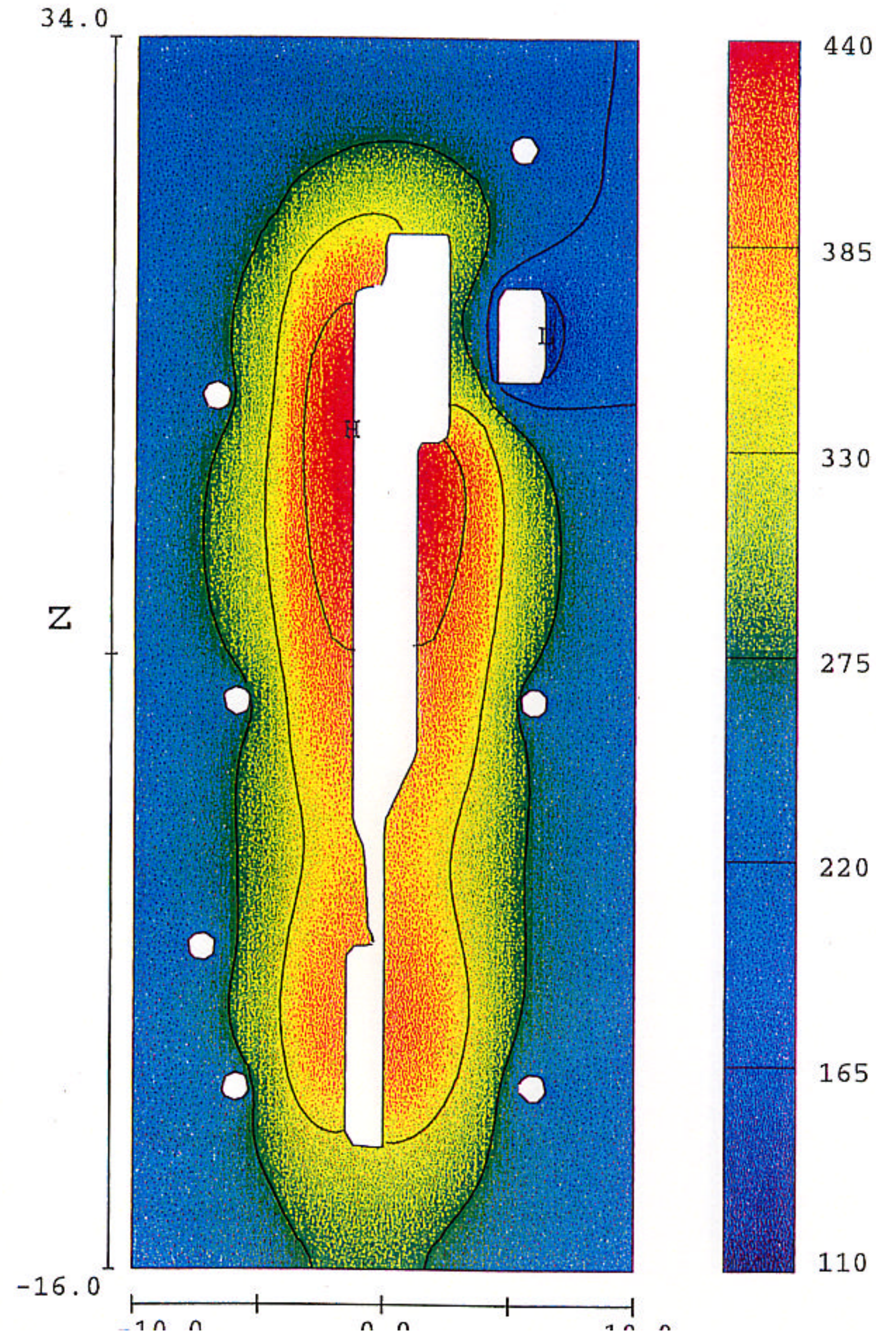
- Improvement in motor electrical energy efficiency to reduce user operating costs
- Reduction in overall premium motor manufacturing cost at existing efficiency
- Reduction in potential motor weight

Capabilities for Future Die Casting

System design at Formcast test facility

- 660 metric-ton Buhler SC (independent computer controlled - closure & shot)
- Induction melting (15 kg of copper in 9 minutes for rotors – earlier design used 4 kg of copper per 2 minute cycle for material testing)
- High-temperature mold (die) materials and handling to achieve long life-in-service

wall temperature contours



Motor Test Results

Mr. Darryl Van Son

Consultant

Copper Development Association Inc.

Motor Tests

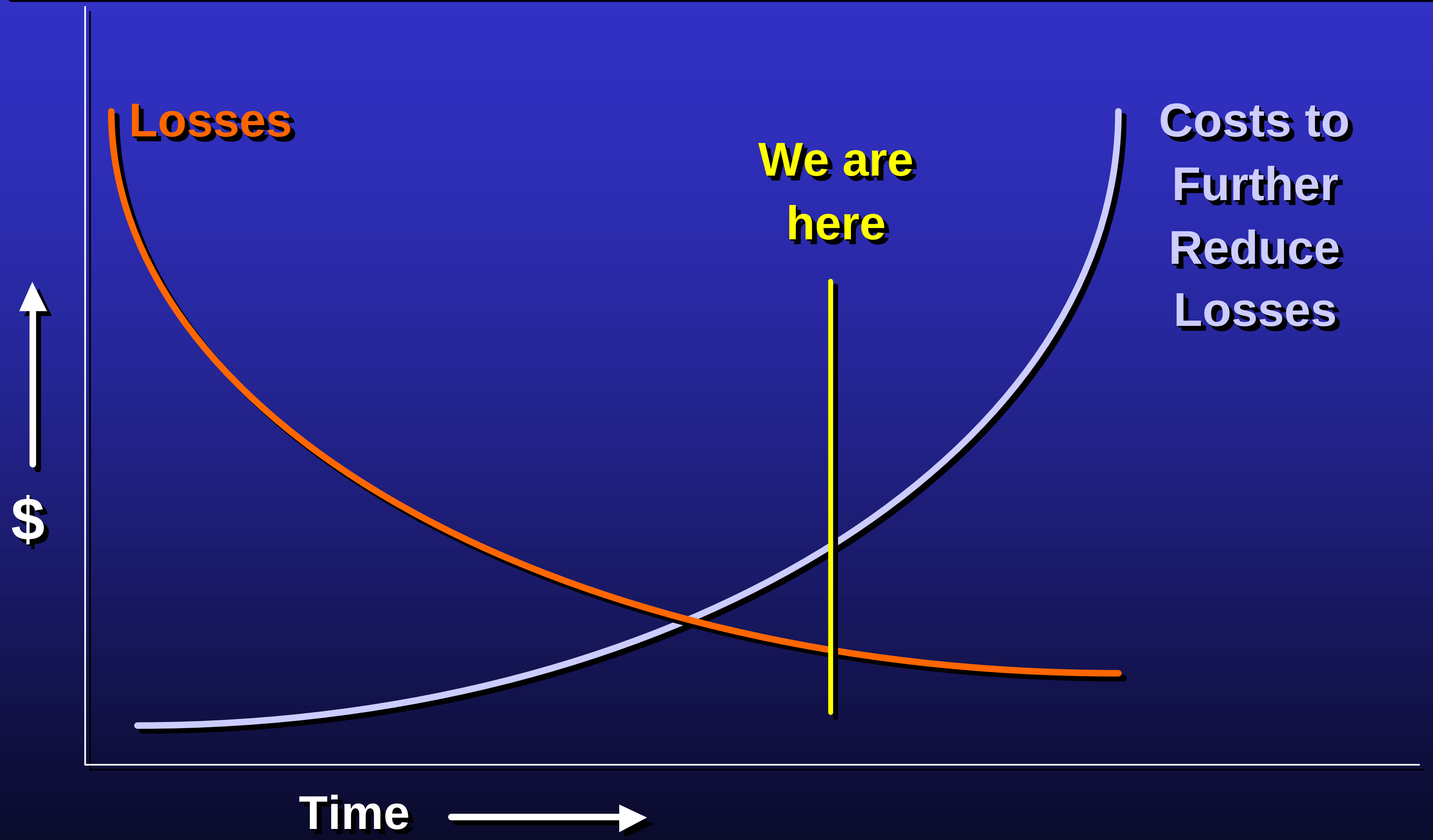
What is 1% motor efficiency worth? (USA)

- Two-thirds (2/3) of all industrial electricity is used to run motors
- Motors use 680 Billion kW-Hr per year

1% better motor efficiency would save:

- 6.8 Billion kW-Hr per year
- $US 500 Million at 7 cents per kW-Hr
- Equivalent to 13 Million barrels of oil

Diminishing Returns



Motor Tests

			Efficiency			Loss
HP	kW	Poles	Al	Cu	Difference	Reduction
4	3	4	83.2	86.4	3.2	19.0%
7.5	5.5	4	74.0	79.0	5.0	19.2%
10	7.5	4	85.0	86.5	1.5	10.0%
15	11	4	89.5	90.7	1.2	11.4%
25	19	4	90.9	92.5	1.6	17.6%
40	30	4	88.8	90.1	1.3	11.6%
120	90	2	91.4	92.8	1.4	16.3%
270	200	4	92.0	93.0	1.0	12.5%
					Average:	14.7%

Motor Tests

Rotor I^2R Losses (Watts)

HP	kW	Poles	Al	Cu	Difference	Reduction
4	3	4	221	92	129	- 58%
5	3.7	4	-	-	-	- 38%
15	11	4	262	157	104	- 40%
25	19	4	410	292	118	- 40%

Motor Tests

Temperature Rise

	Al	Cu	Difference	Percent
15 HP (11kW) Motor	64.9C	59.5C	- 4.5C	- 7%
25 HP (18.5 kW) Motor	79.9C	47.2C	- 32.7C	- 41%

- Affects life expectancy of the motor
- For every 10 degrees C hotter a motor runs, life can be reduced in half
- Copper rotors could increase life expectancy
- Similar results have been seen in premium efficiency motors since their introduction 20 years ago

Motor Tests

Copper rotor consistency

- Copper rotor motors averaged 90.7% efficiency
  Range: 90.6% – 90.8%
- Copper rotor losses averaged 157 Watts
  Range: 153 Watts – 167 Watts
- Stray load losses were down 23%
- Process variables tested had no predictable affect on final test results
- No balancing weights were required
- This is a very robust process with consistency not seen in current rotor die casting methods

Motor Tests

Motor designed around a copper rotor

Tests of an “optimized” copper motor

Rotor losses	- 40%	
Total losses	- 23%	
Temperature rise	- 41%	
Efficiency	+ 1.6%	90.9% vs. 92.5%

Stator windings and iron core were modified from standard motor design to gain best possible results

Motor Tests

Rotor Cost Implications

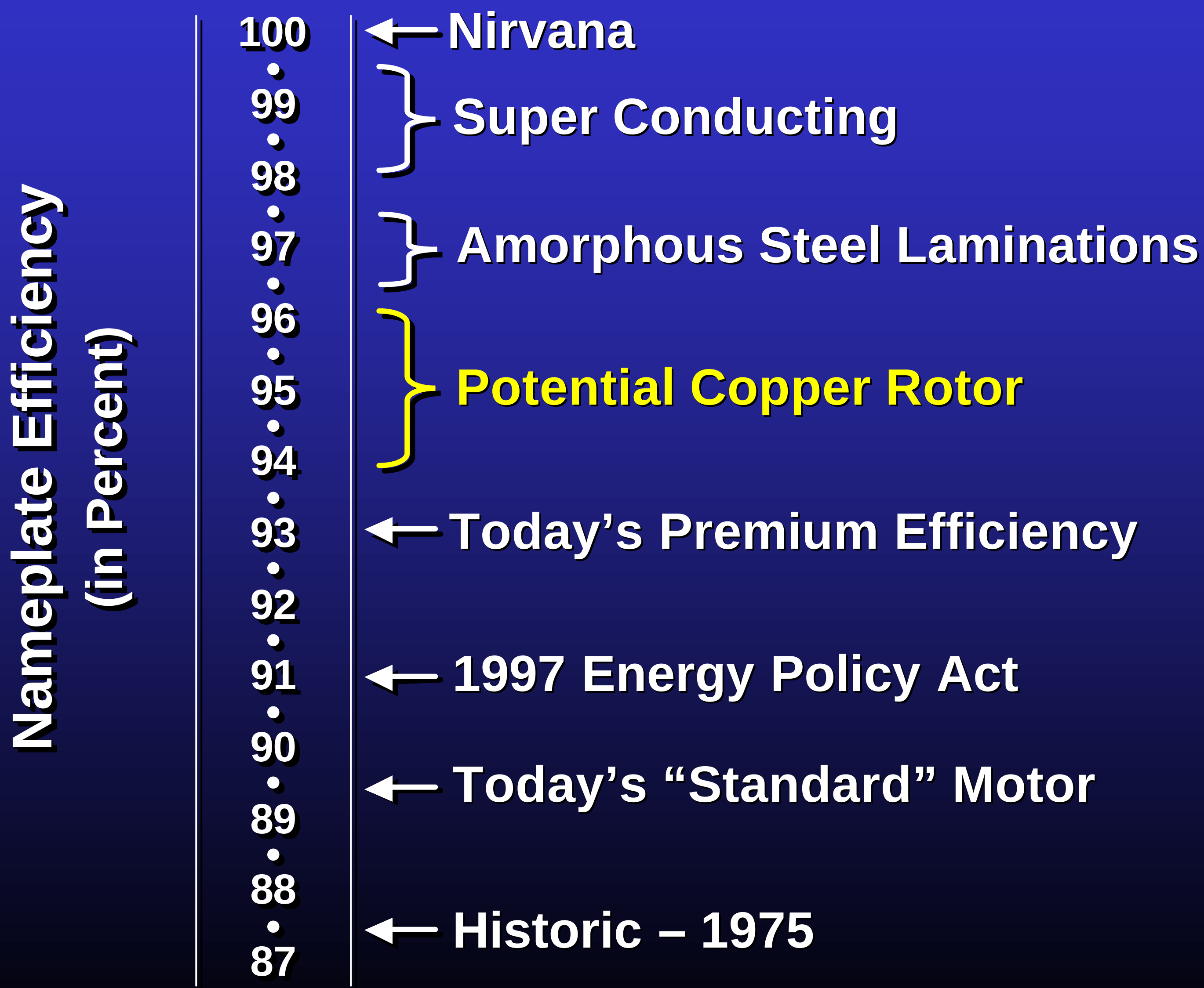
- Example: 15 HP (11 kW), +1.2% Efficiency
- Rotor conductive material cost: $4 Al, $14 Cu
- Melt energy & die insert amortization: $1.30
- Motor list price range: $900 - $1500
- User payback measured in months
- Adjusting cost of other factors like stack and heat control can offset material cost
- One manufacturer reduced total motor cost 7% (average of many ratings)

Motor Tests

Additional Implications

- Higher efficiency in the same stack length
- Same efficiency in a reduced stack length
  Offsetting material cost differences
- Some combination in between
- Minimize balancing requirements
- Elimination of “safety factor” extra stack length
  to compensate for rotor irregularities

15 kW Motor - Past, Present and Future



Die Design

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DieTec GmbH
Die Designer
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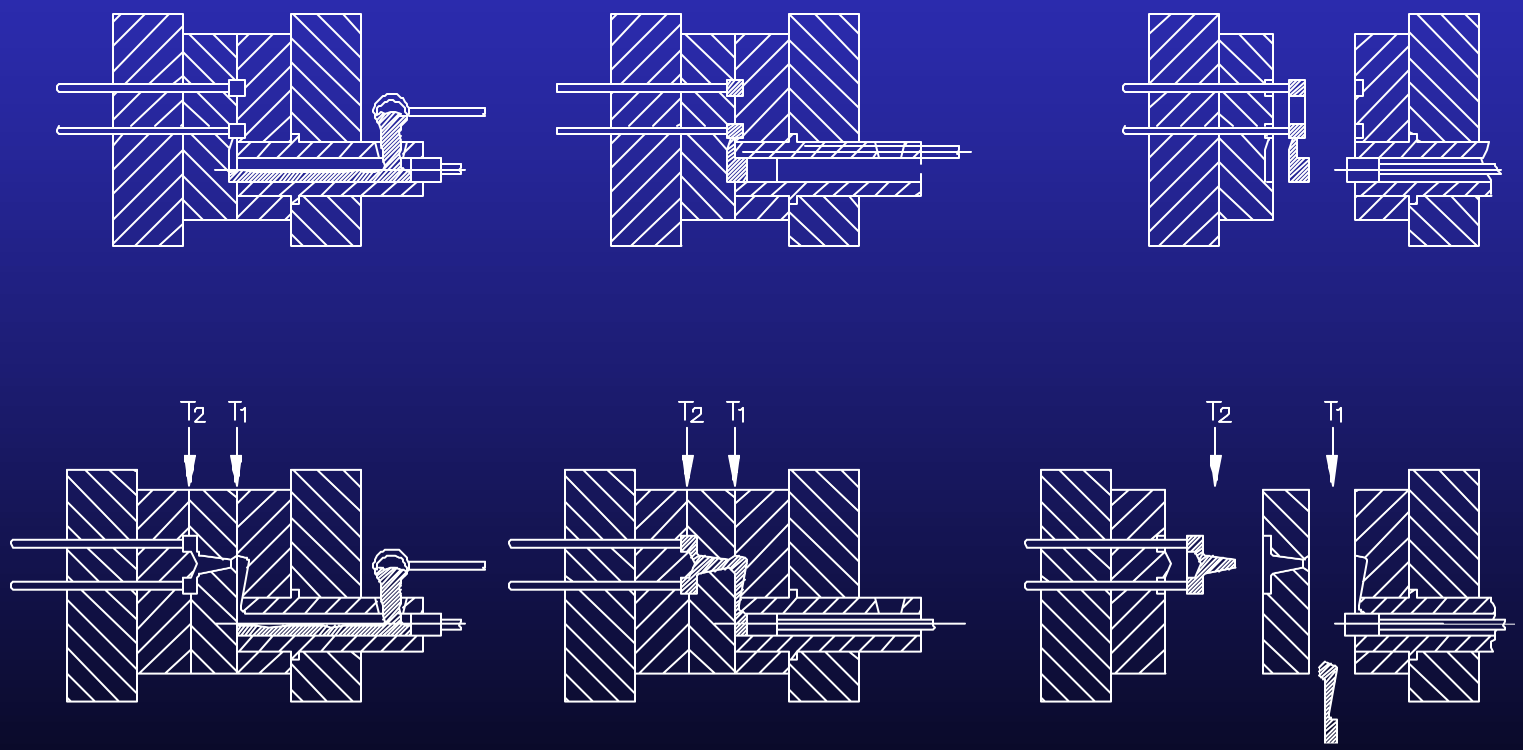
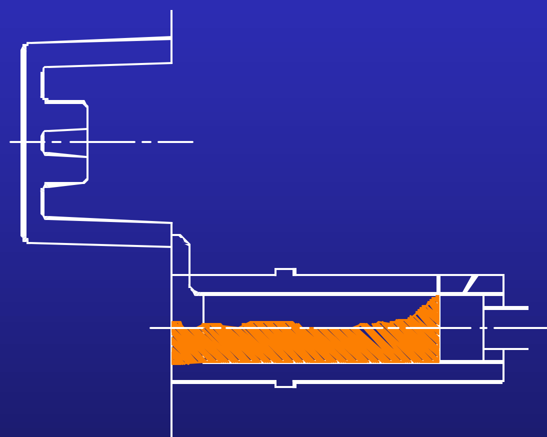
Principles of die casting technology

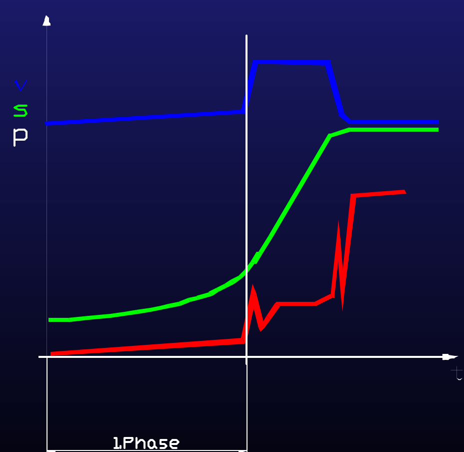
Cold chamber



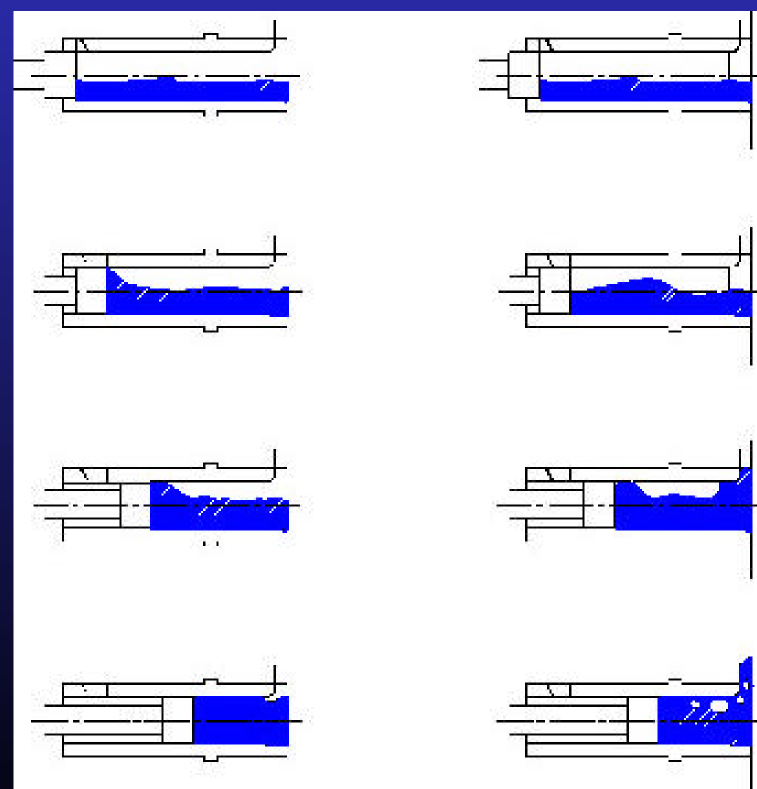
Cold chamber technology

1st phase The metal is slowly brought up to the gate, according to shot volume and procedure 1-4 s





Conventional **Parashot**



Abbreviations for die casting

A	= area	[mm²]
A_k	= runner area	[mm²]
A_{IM}	= projected area	[mm²]
d_m	= plunger diameter	[cm²]
F_{LI}	= opening force	[mm]
F_{LN}	= closing force	[kN]
%F	= filling rate	[%]
l_{Maktiv}	= active shot length	[mm]
m_A	= weight after gate	[g]
m_I	= shot weight	[g]
m_{part}	= part weight	[g]
$m_{overflow}$	= overflow weight per part	[g]
m_{runner}	= runner weight	[g]
n	= number of cavity	[ ]
p_{I3M}	= final casting pressure	[bar]
Q_M	= flow rate	[cm³/s]
S_A	= gate section	[mm²]
S_V	= venting area	[mm²]
t_F	= filling time	[s]
V_A	= volume after gate	[cm³]
v_C	= plunger speed	[m/s]
v_{MA}	= gate velocity	[m/s]

Gate technology

Gate area S_A

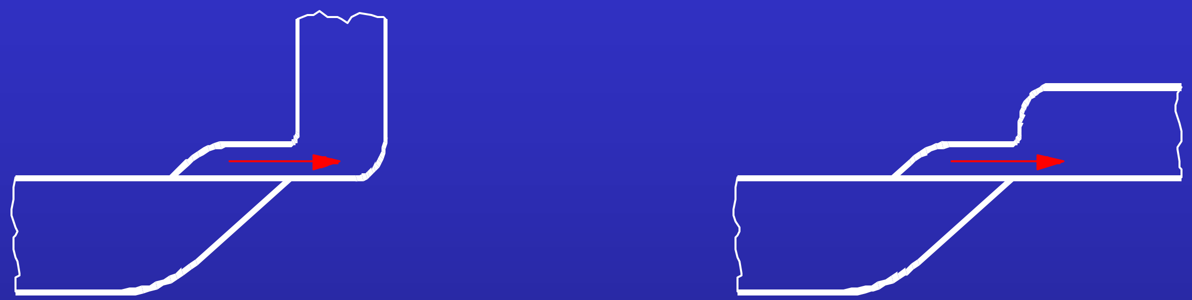
$$S_A = \frac{V_A}{V_{MA} ? \; t_F} = \frac{m_A}{? \; ? \; V_{MA} ? \; t_F}$$

$$m_A = n * (m_{part} + m_{overflow})$$

Example :

m_{part}	=	450 g
$m_{overflow}$	=	20 g
m_{runner}	=	1450 g
v_{MA}	=	45 m/s
t_F	=	0.05 s
?	=	2.5 g/ cm^3

Gate velocity V_{MA}



V_{MA} = ____________________ V_{MA} = ____________________

Aluminum			
	20 … 60 m/s		Standard
	15 … 30 m/s		Vacuum
Zinc			
	30 … 50 m/s		Standard
Copper	30 … 45 m/s		Standard

Filling time t_F

s [mm]	t_F [ms]
1.5	10 … 30
1.8	20 … 40
2.0	20 … 60
2.3	30 … 70
2.5	40 … 90
3.0	50 … 100
3.8	50 … 120
5.0	60 … 200

Metal flow rate Q_m

$$Q_M = \frac{m_A}{?\quad ?t_F}$$

m_{part}	=	450 g
$m_{overflow}$	=	20 g
m_{runner}	=	1450 g
v_{MA}	=	45 m/s
t_F	=	0.05 s
?	=	2.5 g/ cm^3

Venting area; S_V

$$S_V \; ? \; \frac{Q_M}{200 \frac{m}{s}}$$

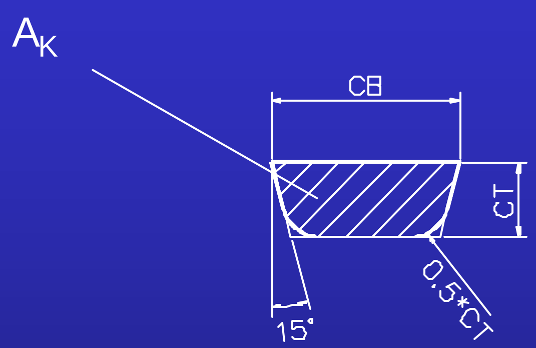
It means:

$$Q_M \; ? \; \frac{m_A}{? \; ?t_F}$$

Example:

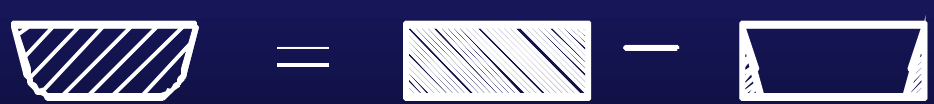
m_{part}	=	450 g
$m_{overflow}$	=	20 g
m_{runner}	=	1450 g
v_{MA}	=	45 m/s
t_F	=	50 ms
r	=	2,5 g/ cm^3

Runner cross section A_k



$A_K = 1.6 \ldots 2.2 * S_A$

$C_B = 1.5 \ldots 2.5 * C_T$



$A_K = C_B * C_T - C_T\ 2 * \tan(15°)$

$A_K = C_B * C_T - C_T\ 2 * 0.27$

Die temperature: Heat transfer

Heat Conduction :

Heat transport inside a substance.

Example: Machine plate

Convection :

Heat transfer from a liquid substance to a solid substance or turned back.

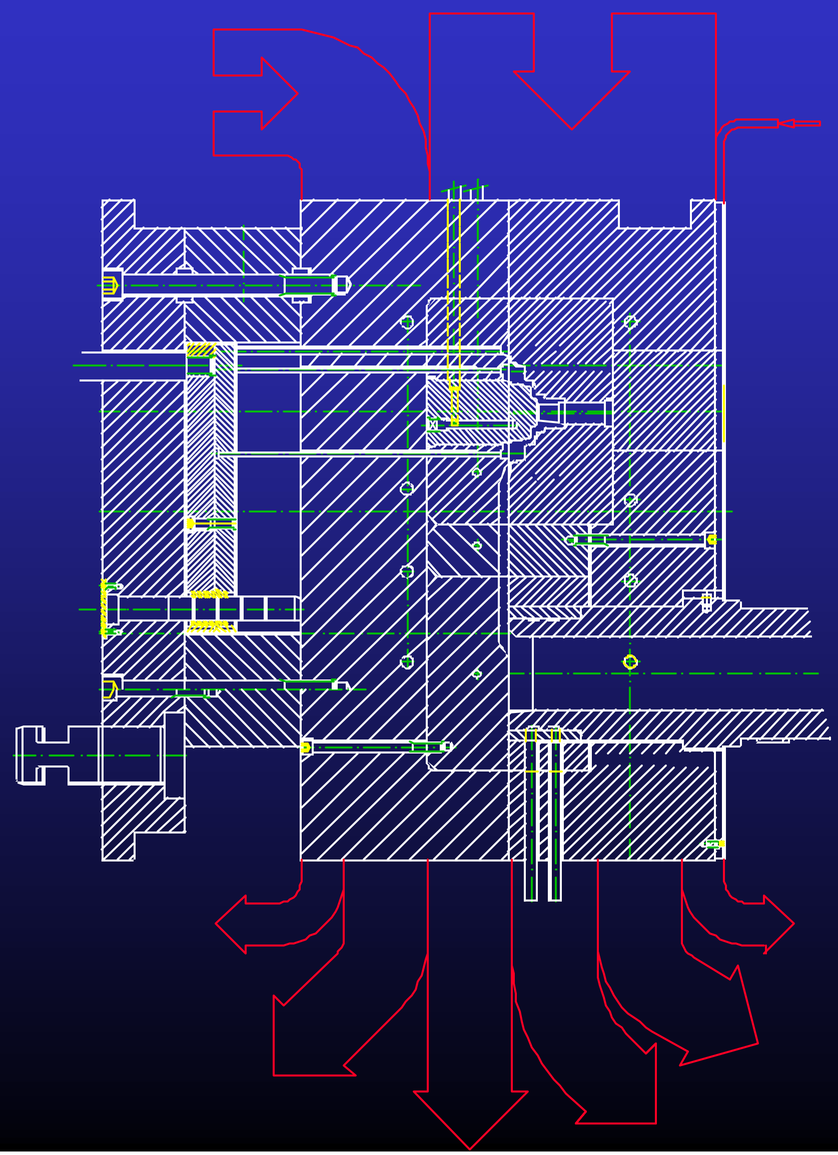
Example: Steel on cooling water

Radiation :

Heat transfer through electromagnetic radiation.

Example: Die frame on the air

Sankey diagram



Supplied heat quantity for copper

$$Q_{zu} = m_l * c_P * (T_{In} - T_{Ej}) + C * m_l$$

Q_{zu}	supplied heat quantity [kJ]	
ml	shot weight [kg]	
c_p	specific heat [kJ/kgK]	c_{pCu} = 0.394 kJ/kgK
T_{In}	metal temperature on filling [K]	
T_{Ej}	metal temperature on ejection [K]	
C	heat of fusion [kJ/kg]	C_{Cu} = 172 kJ/kg

Example:

ml = 1.2 kg ; T_{IN} = 1473 K ; T_{Ej} = 1123 K

Q_{ZU} = 1.2 * 0.394 * (1473 – 1123) + 172 * 1.2 = 371.9 kJ

1000 cm^3 ✍ 1.7 * Q_{Al} = Q_{Cu}

Heat Conduction Q_l

$$Q_l = ?_w * A_w * (T_{Ob} - T_{Med}) / s$$

Q_l	[kJ]
$?_w$	Conductivity of the tool [W/mK]
s	The distance of the temperature canal from the cavity [m]
A_w	The effective cross-section area of the tool [m^2]
T_{Ob}	The middle surface temperature [K]
T_{med}	The middle wall temperature on the thermal fluid medium [K]

Example: Conductivity of the steels

$?_w$	1.1730	50 W / mK
	1.2343	15 W / mK
	Cu	350 W / mK

Heat radiation Q_{St}

$$Q_{St} = A_{DGW} * ? * C_S * (T_{WO}^4 - T_{UM}^4)$$

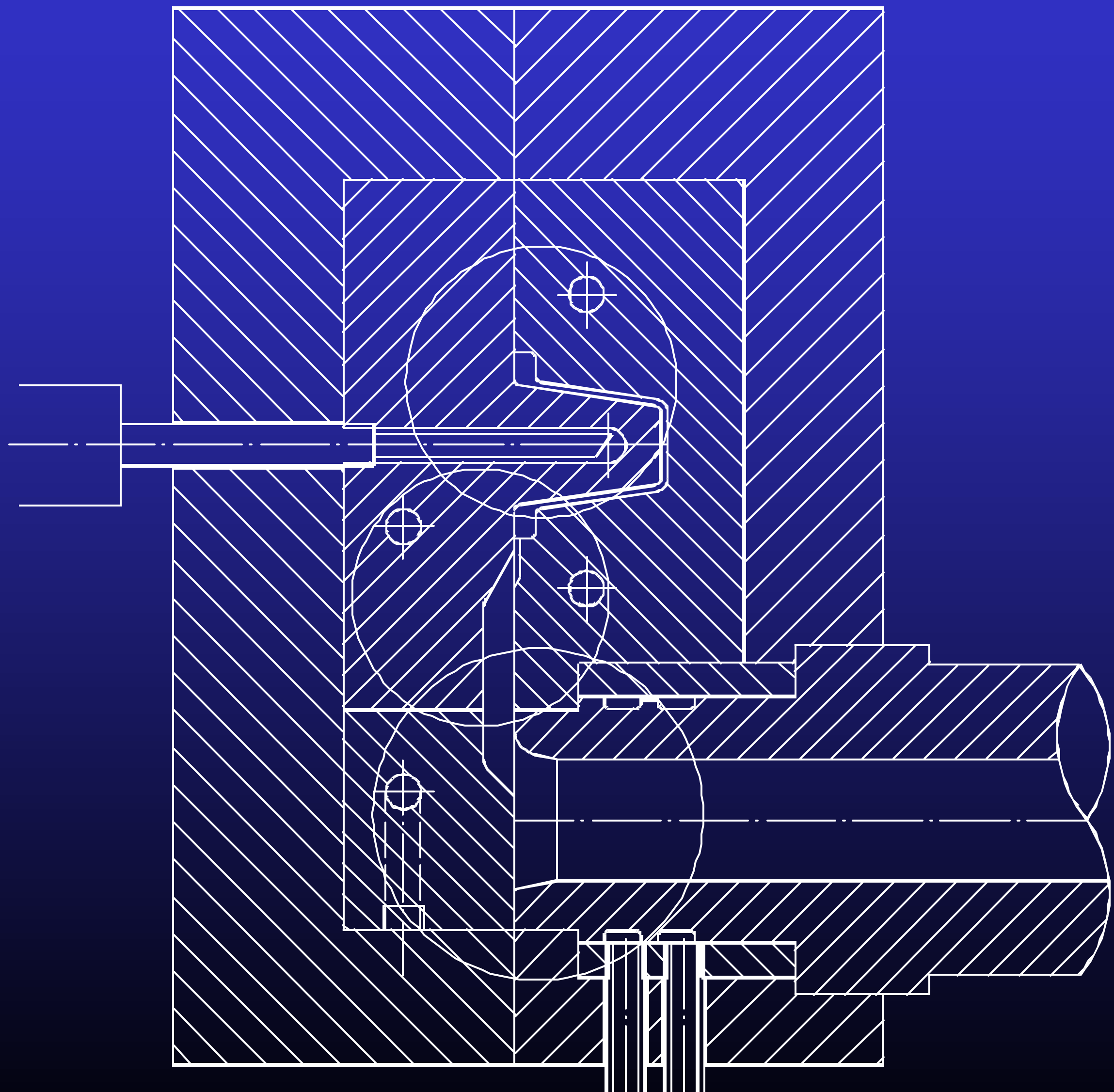
A_{DGW}	=	Contact face of the die to the surrounding air [m^2]
?	=	Emissions degree
C_S	=	Stefan-Boltzmann-constant for the black body
		$5.67 * 10^{-8}$ W / m^2K^4
T_{WO}	=	Surface temperature of the die [K]
T_{UM}	=	Surrounding temperature [K]

Example: Emissions degree of steel

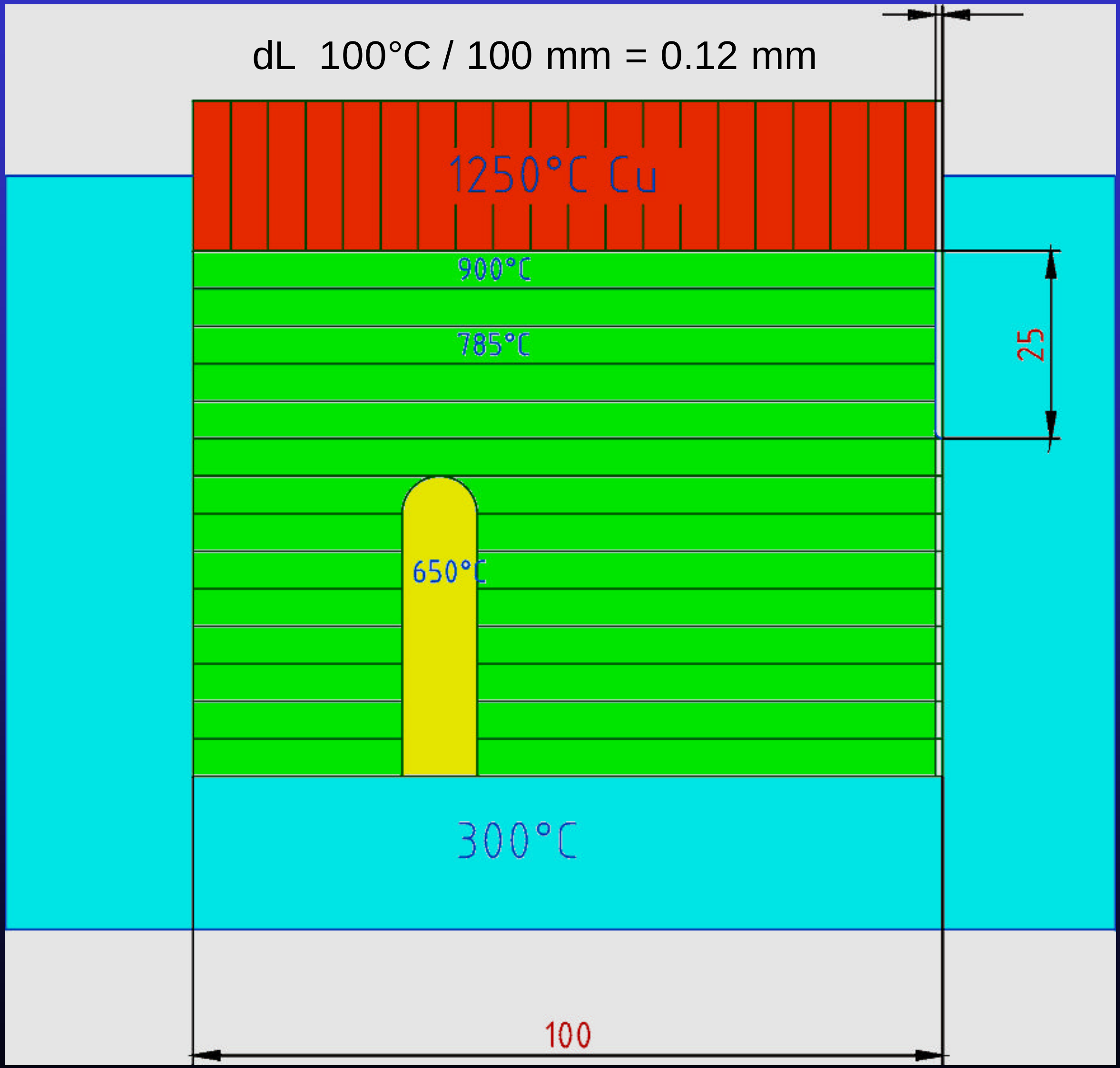
?	steel bright grinded	0.25
	steel little rusty	0.6
	steel strong rusty	0.8

(values at 293 K)

The three cooling areas



Thermal expansion



Insulation material

Selected
Technical Data

Brandenburger

Exports in High Technology Advanced Materia

Overview of Thermal Insulation and Engineering Materials

Thermal Insulation Materials

Grades	Thermal stability in °C long term	Thermal stability in °C short term	Compressive strength at ambient temperature in N/mm² DIN 53 453	Compressive strength at 200 °C in N/mm² DIN 53 453	Thermal conductivity W/mK at ambient temperature DIN 52 612	Water absorption in % / 24 hours DIN 53 495
Themal Insulation Boards						
S 4000	200	230	300	100	0,13	0,10
BRA-GLA N	210	230	600	290	0,30	0,20
BRA-GLA HT	220	230	600	400	0,30	0,05
BRA-GLA VT	230	240	650	430	0,30	0,05
BRA-GLA VP	220	240	600	400	0,30	0,20
KV 3	240	250	600	400	0,25	0,075
GL-M	400	600	400	250	0,30	< 0,10
GL-P	500	800	330	240	0,31	< 0,10
Side Insulation						
S 2000 A	200	220	100	70	0,10	< 1
BRA-FLEX	280	–	1	I	0,06	
Compensating Inlay						
AL 2000 N	200	–	max. 300	max. 150	–	
Special Grade						
BRA-GLA Special	230	–	690	380	0,08...0,10	–
Other						
ISOFLEX AFV	825	–	–		0,05	–
Flexline	260		–	–	0,06	

Insulation material

Brandenburger materials enable a comprehensive thermal insulation for moulds and tools in injection moulding industries.

Following possibilities of application and resulting advantages mainly characterize our products:

- **S 4000 and BRA-GLA Grades**
  ... compression- and dimensionally stable thermal insulation at the clamping area in order to avoid effectively heat contacts with the machine.
- **S 2000 A Grade**
  ... insulation with reflective properties on exterior surfaces, specially for large moulds and exposed heat surfaces. The profiled finish forms small hollow chambers, such as those in foam structures, and increases the degree of insulation provided.
- **BRA-GLA VP Grade**
  ... compression- and dimensionally stable thermal insulation in hot runner manifolds.
- **Flexline und BRA-FLEX Grades**
  ... for equipment using hot water, steam and temperature-controlled oil lines (Flexline) as well as exposed heating platen surfaces with flexible, oil-resistant insulation (BRA-FLEX).

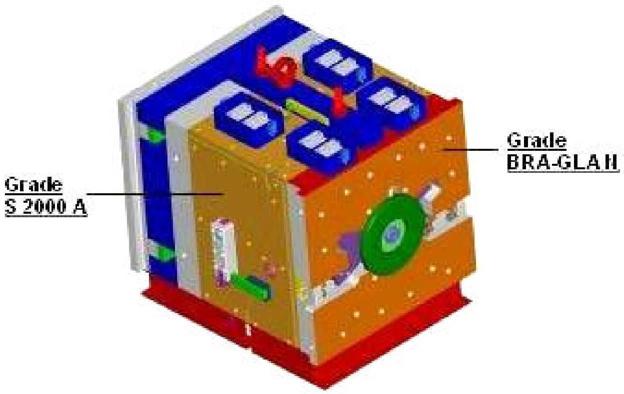


Photo: Injection moulding tool with Brandenburger thermal protection system

Insulation material

Grades	Thermal stability in °C	Compressive strength at ambient temperature in N/mm² EN ISO 604	Compressive strength at 200 °C in N/mm² EN ISO 604	Thermal conductivity W/mK at ambient temperature DIN 52 612	Water absorption in % / 24 hours DIN 53 495
Supratherm T	500	100	75	0,32	max. 15
Supratherm HT 4	850	15	10	0,09	85
Supratherm HT 175	1000	34	30	0,22	20

Insulation material

Selected Brandenburger High Temperature Insulation Materials

The outstanding attributes of the Supraterm grades are above all, the resistance to high temperatures up to 1000 °C, the very good thermal insulation, the noncombustibility, long application live and the ability to withstand aggressive gases in firing plants.

Supratherm T Grade

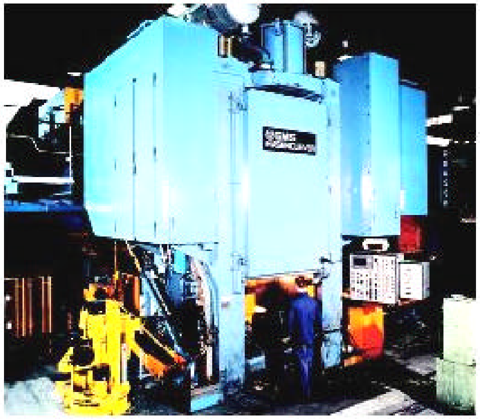
This tightly compressed fibre-cement material is especially suited as asbestos substitute.

Supratherm HT 4 Grade

This low compressed silicate fibre material can withstand high temperatures. Application temperatures are in the range up to approx. 850 °C.

Supratherm HT 175 Grade

This medium compressed thermal insulation material with a temperature resistance up to 1000 °C is based on high-grade magnesium silicates, inorganic fibres and binders.



Photos: Forging presses

Electrical heaters

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HJ or HK Type
HI Type - 4mm
HI w/cutting blade
LI Medium-Watt
NP Low-Watt
Exit Options
Connection Options

ISO 9001 Registered ISO 9001

Cartridge Heaters

High-Watt Density Cartridge Heaters

Hotset offers the following types of Cartridge Heaters:

- HI High Watt Density Cartridge Heater
- HJ or HK High Watt Density Cartridge Heater with Thermocouple
- HI 4mm High Watt Density Cartridge Heater
- High Watt Density Cartridge Heater with integral cutting blade
- LI Medium Watt Density Highly Compressed Cartridge Heater
- NP Low Watt Density Cartridge Heater

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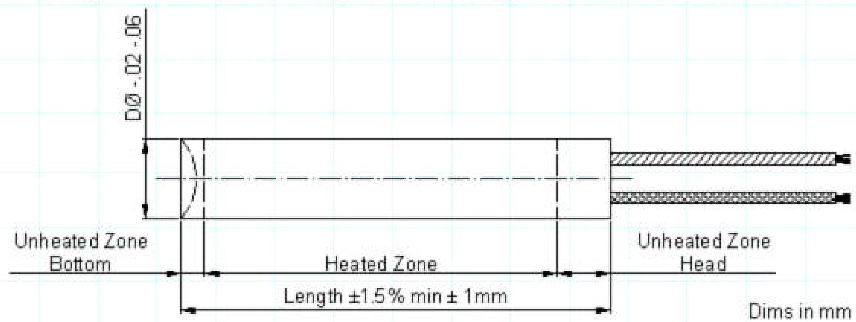
Up

HI - High Watt Density Cartridge Heaters without TC



Diameters Available:

Inch	1/8"	1/4"	3/8"	5/16"	1/2"	5/8"	11/16"	3/4"
Metric	3.17	6.5	8	9.5	10	12	12.5	15
	18	19	20	25				

Other Diameters Available - Please Consult Factory for Others

All HI Type Heating Elements Are Centerless Ground as Standard

Electrical heaters

TEMPCO Electric Heater Corporation

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Hi-Density Cartridge Heaters

Hi-Density Cartridge Heaters (swaged) are the solution for high temperature applications.

Hi-Density heaters are approved as components under the UL (file number E65652)and CSA (file number LR43099-4) recognition programs.

Hi-Density Heaters provide localized heating in processes requiring close temperature control such as:

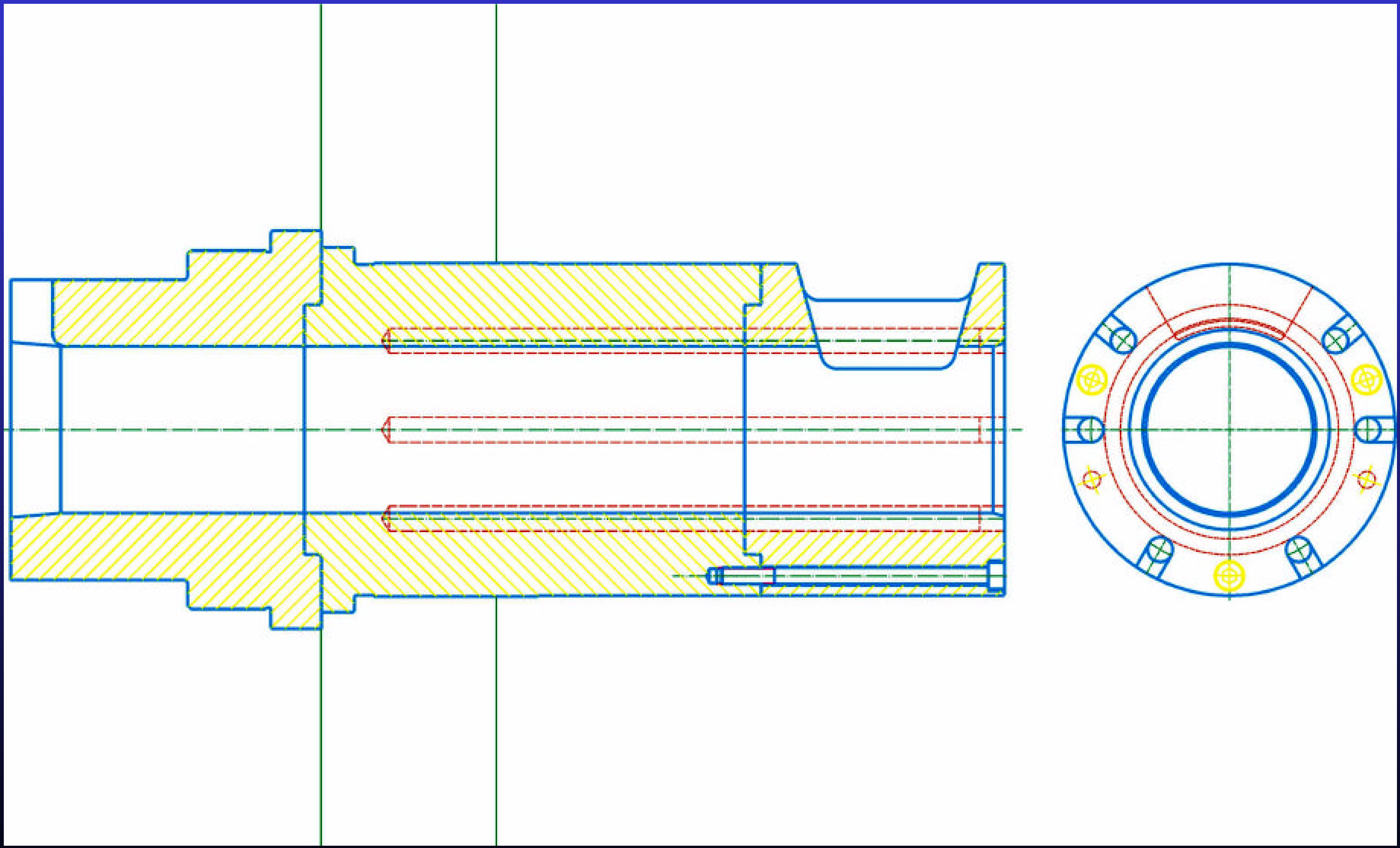
- Dies
- Molds
- Hot stamping
- Packaging equipment
- Plastic extruders
- Injection molding mach.
- Platens
- Labeling
- Bag sealing
- Medical equipment

Maximum Temperature:
1500°F (820°C).

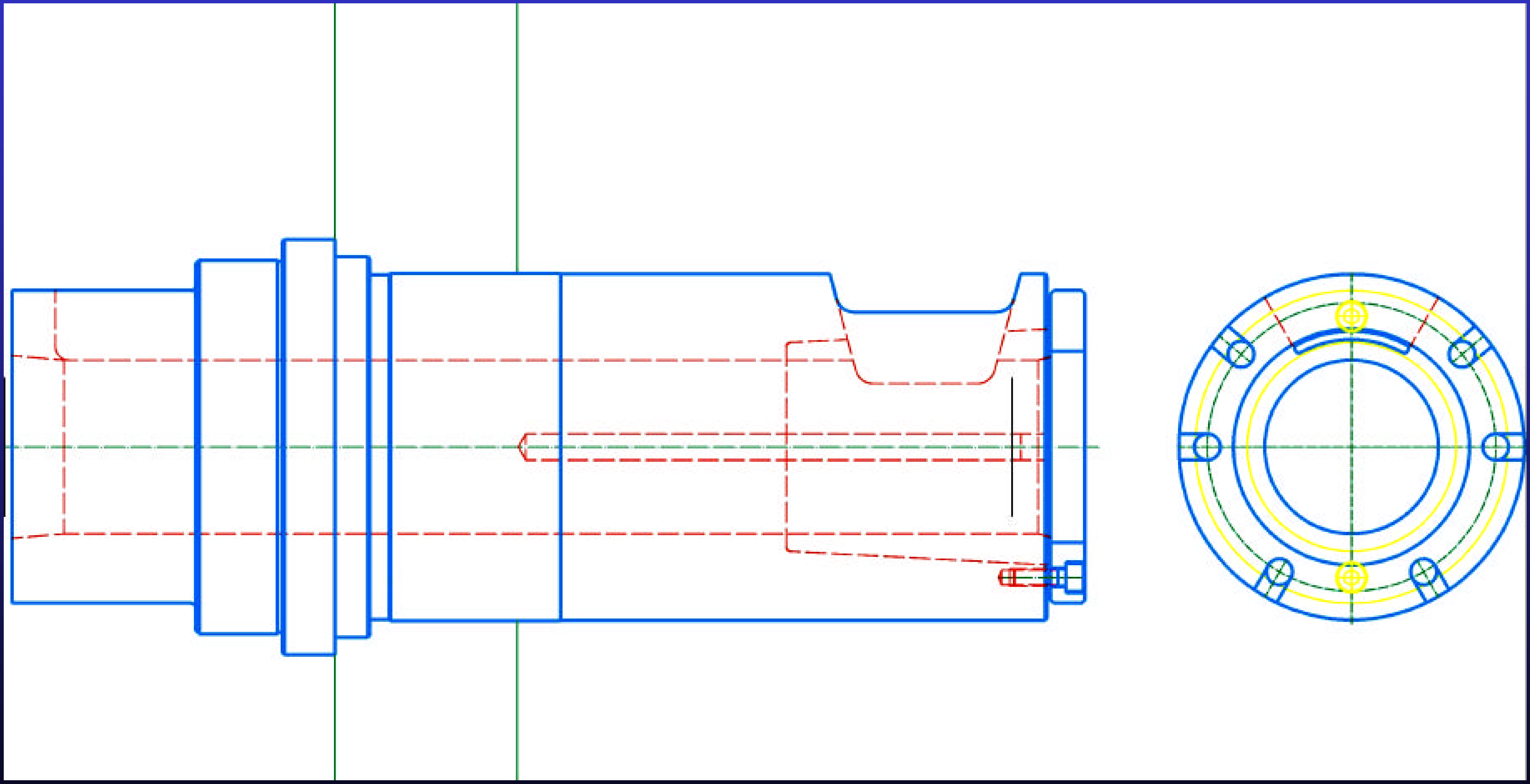
Custom Terminated Hi-Density Cartridge Heaters From Stock

Click to view Stock Sizes and Ratings by Diameter
1/4" 5/16" 3/8" 1/2" 5/8" 3/4"

The shot sleeve design



The shot sleeve design



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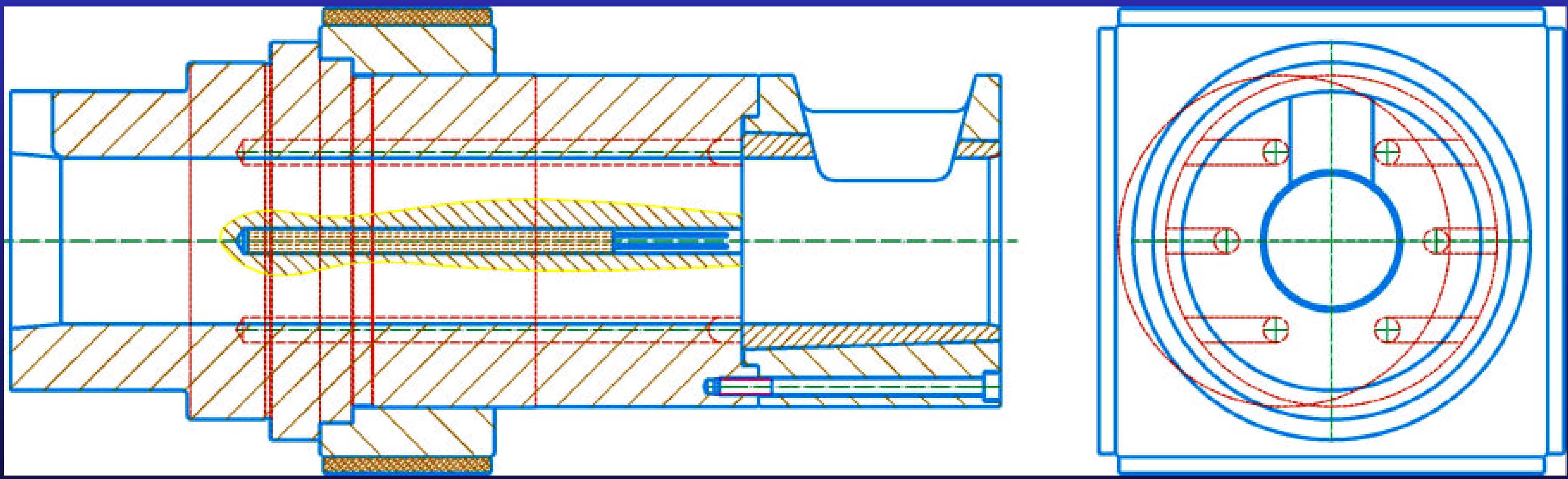
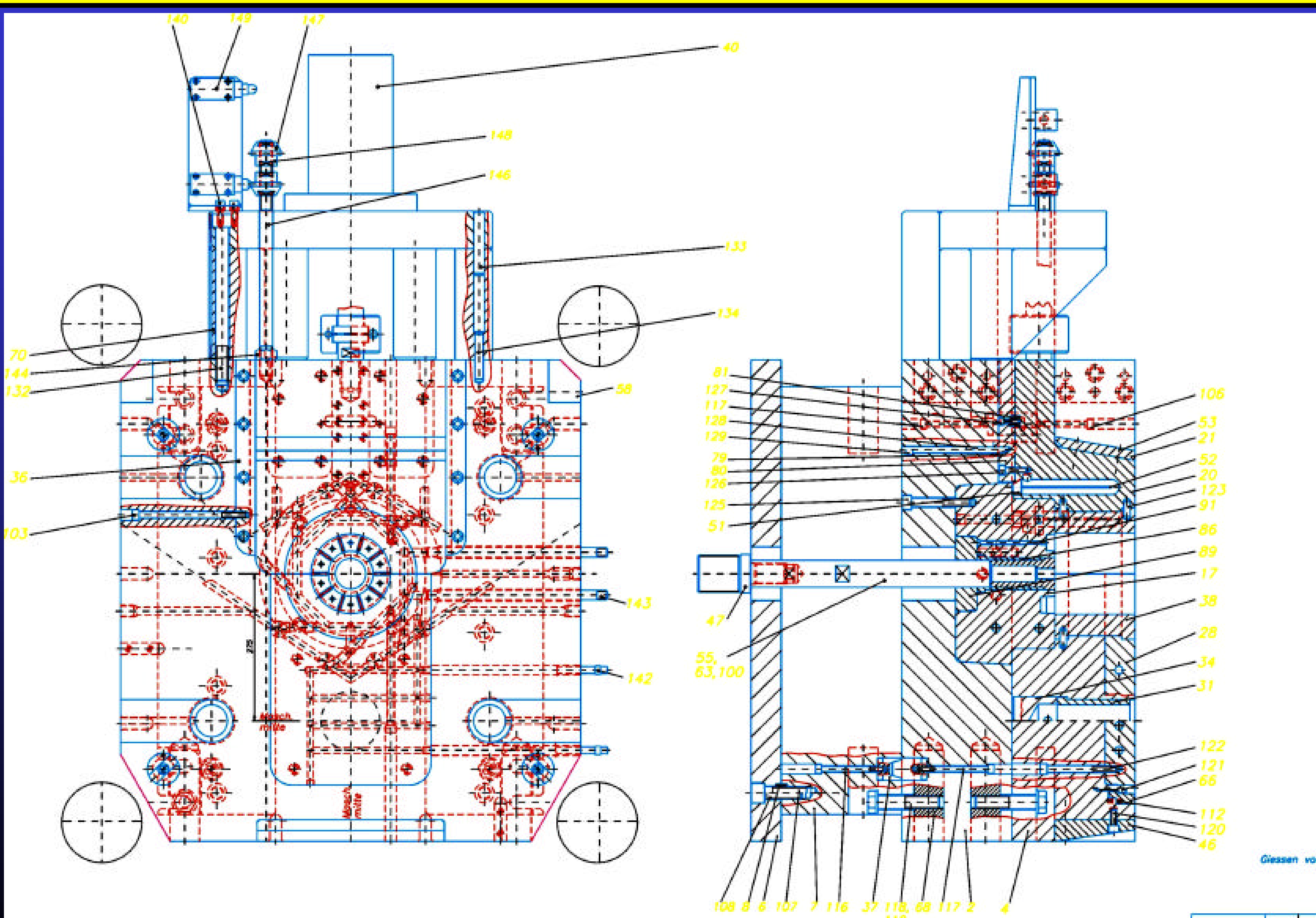


The die design



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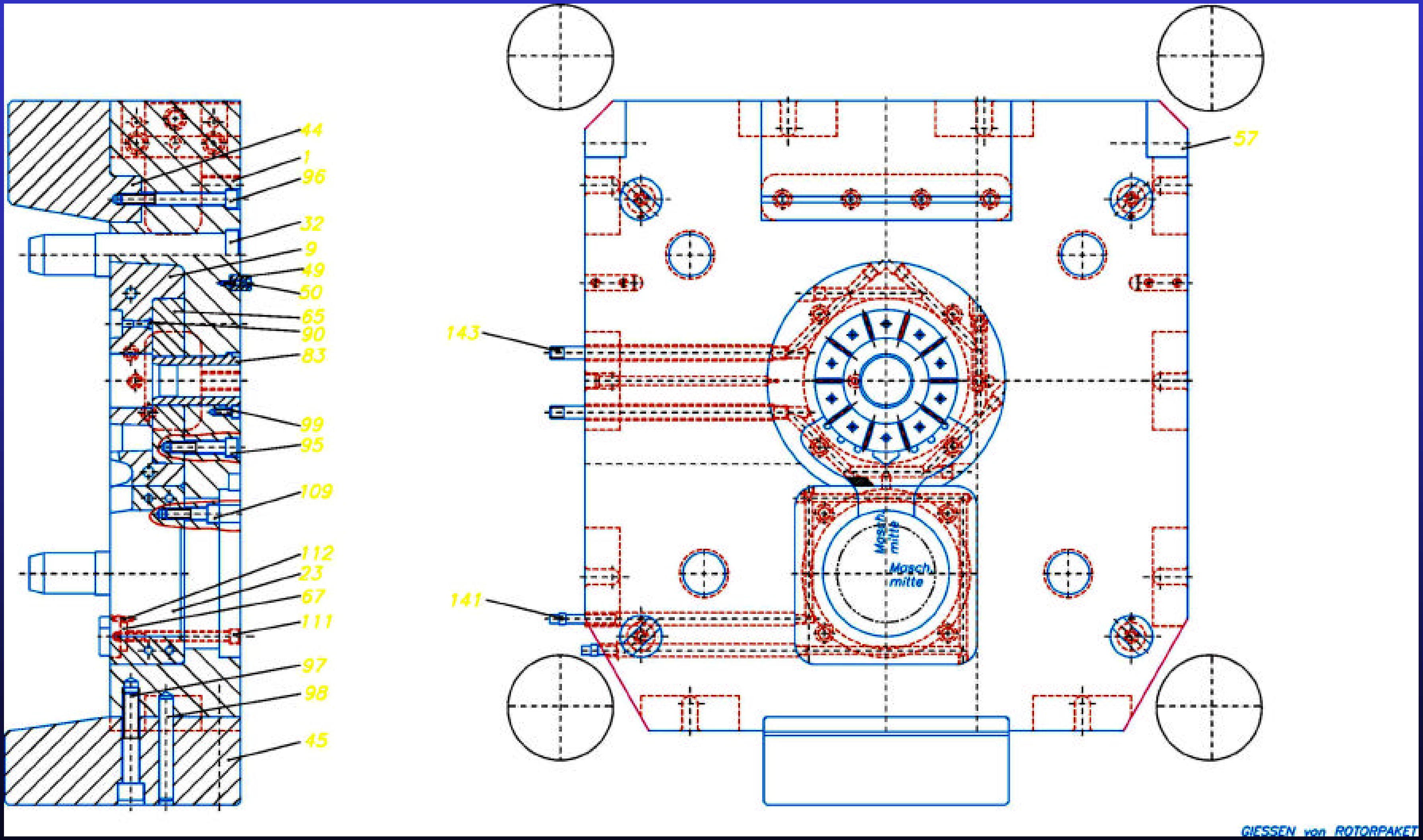

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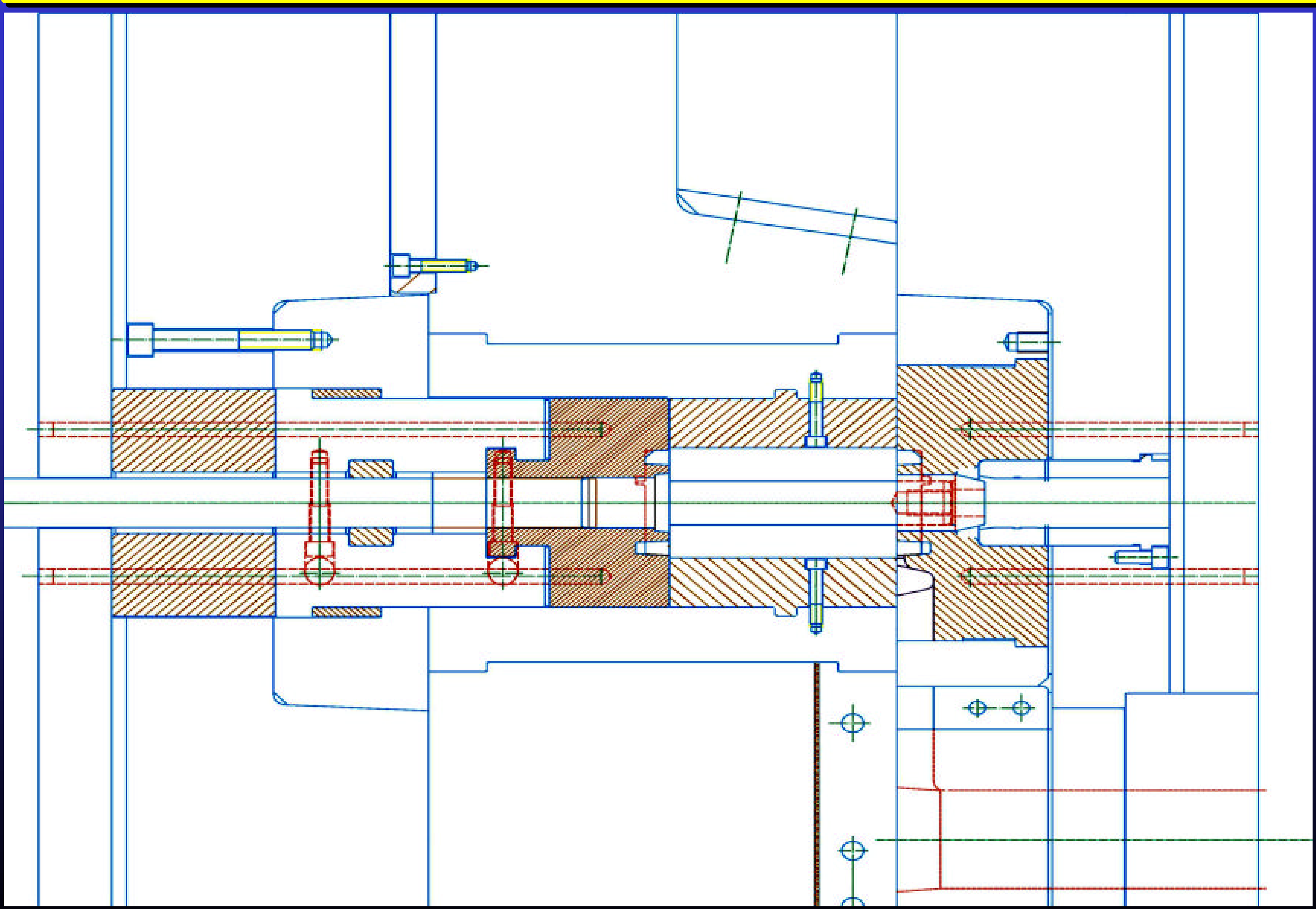

CDA