EVAPORATION BOATS: PROCEDURES AND NEW DEVELOPMENTS FOR IMPROVED METALLIZING PERFORMANCE

By Steve Sedlak, ESK – A Ceradyne Company

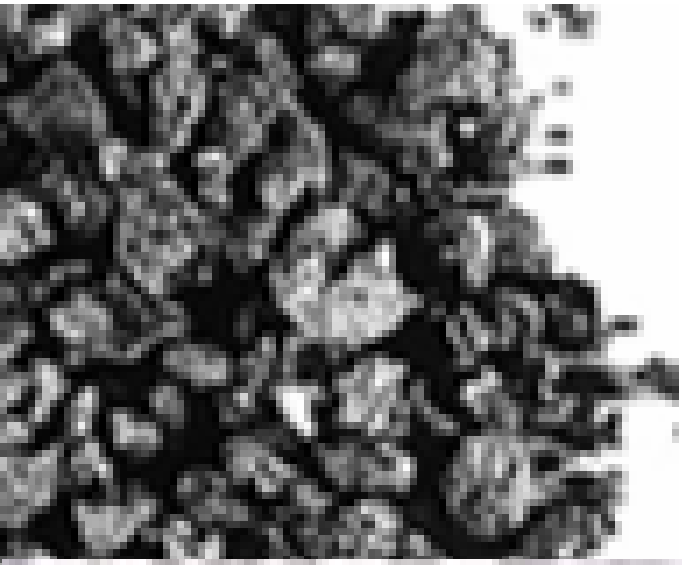
EVAPORATION BOATS

- Evaporation Boat Production

- Key factors for optimal performance
  - Hot resistivity
  - Evaporation rate
  - Heat up behaviour with respect to boat shape
  - Machine settings
  - Operator responsibilities

- Conclusions

RAW MATERIALS FOR EVAPORATION BOATS
TITANIUM DIBORIDE AND BORON NITRIDE



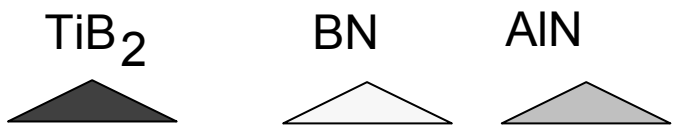
TiB_2 is the electrically conductive component in the evaporation boat.
Typical characteristics are:

- High thermal resistance and stability
- Excellent wetting ability by molten aluminum
- Corrosion resistance

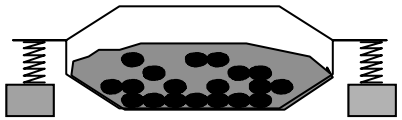
BN is the insulating component in the evaporation boat.
The typical characteristics are:

- Oxidation resistance
- Excellent thermal shock resistance
- Relatively high thermal conductivity
- Non reactive to molten metals such as aluminum

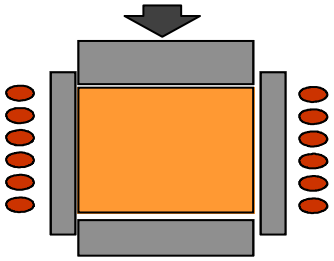
EVAPORATION BOAT PRODUCTION



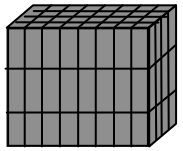
Powder Production
And Processing



Mixing & Blending

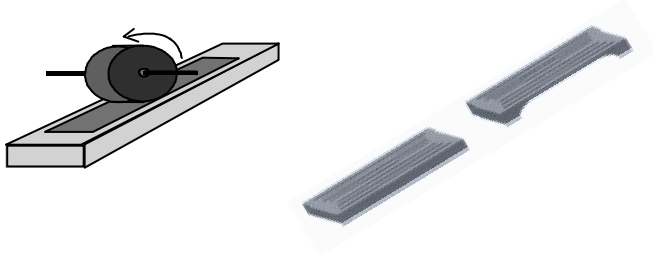


Hot Pressing
2000°C / 3632°F, 300 bar



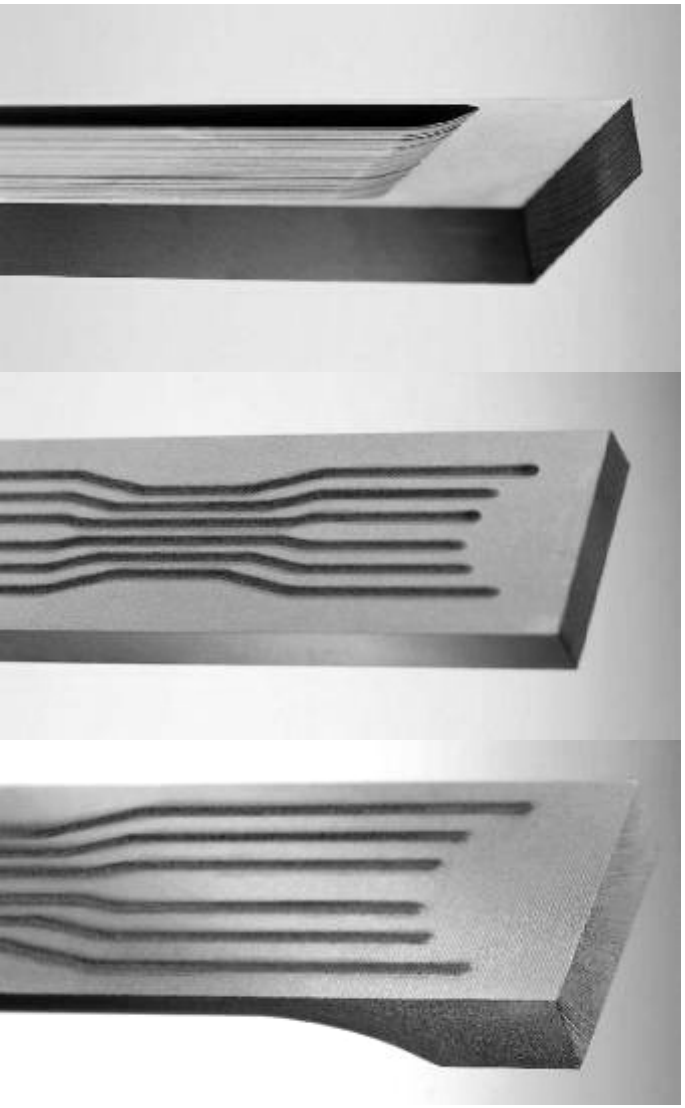
Cutting

Quality control after each
production step



Final Machining
(Lasering or Cavity)

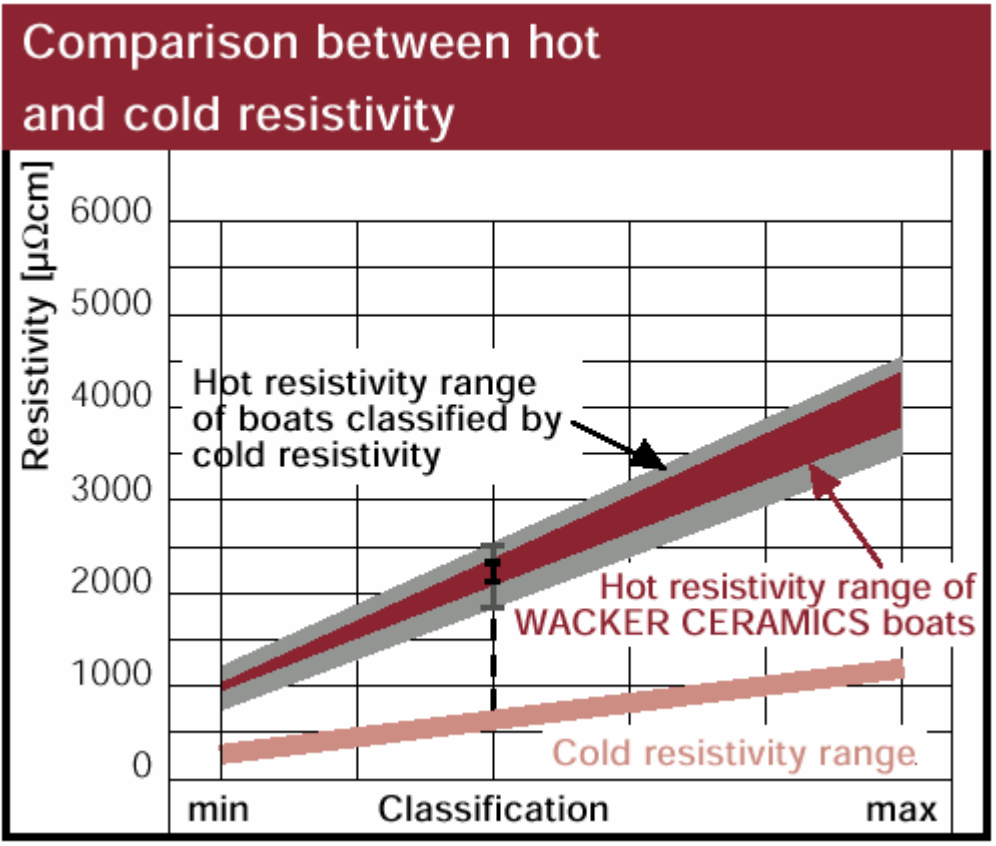
TWO COMPONENT EVAPORATION BOATS
DIFFERENT DESIGNS – VARIOUS SOLUTIONS FOR METALLIZATION



Key requirements for two component boats made of titanium diboride and boron nitride:

- Long service life
- High evaporation rates
- Excellent temperature resistance
- Good control of operation parameters
- Excellent wetting behavior
- Homogeneous metallization
- Reduced spitting and bending
- Easy handling for all clamping systems

KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE
PROCESS DATA – HOT RESISTIVITY



- Cold resistivity measured at room temperature (25°C / 77°F)
  - wider hot resistivity tolerance range due to inconsistent cold/hot ratio
- Hot resistivity measured at metallizing operation temperature at 1500°C / 2732°F
  - tighter hot resistivity tolerance range leads to:
    - Better uniformity
    - Less process adjustments
    - Reach operating speeds earlier

Stable process conditions can be reached within the first roll; this leads to improved overall productivity.

KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE
PROCESS DATA – EVAPORATION RATE

The evaporation rate is the key factor determining boat design. The choice of the right boat has direct influence on the boat lifetime. In order to determine proper boat specification the following formula should be considered:

$e = A * k * \eta$

with e: evaporation rate [g/min]
with η: 0.7 – 0.8 (degree of efficiency) dependent on wetting behavior
0.7 = cavity boats
0.8 = surface treated boats
with A theoretical surface area [cm^2]
with k: specific evaporation rate [$g/(cm^2 * min)$]

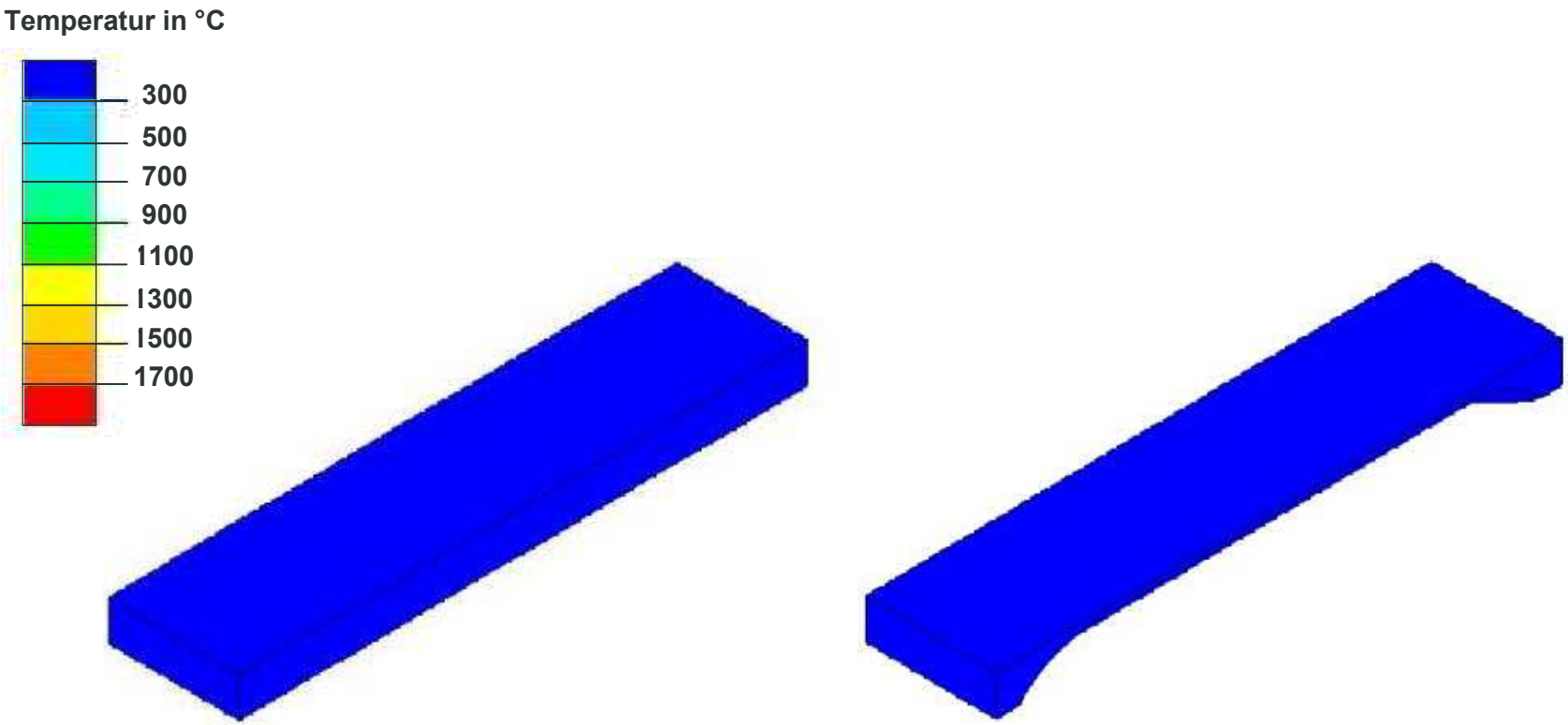
Typical calculation values for k are in the range of 0.25 – 0.4 $g/(cm^2 * min)$

KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE
HEAT UP BEHAVIOUR WITH RESPECT TO BOAT SHAPE

Metallizing Parameters			
Cross section EllipsoMet® DiMet®	Power consumption [%]	Al-wire consumption [%]	Metallized product per boat [%]
	80 – 85	90 – 95	110
	100	100	100

Constant parameters: Optical density (2.0) and wire feed (1195 mm/min)

KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE
HEAT UP BEHAVIOUR WITH RESPECT TO BOAT SHAPE



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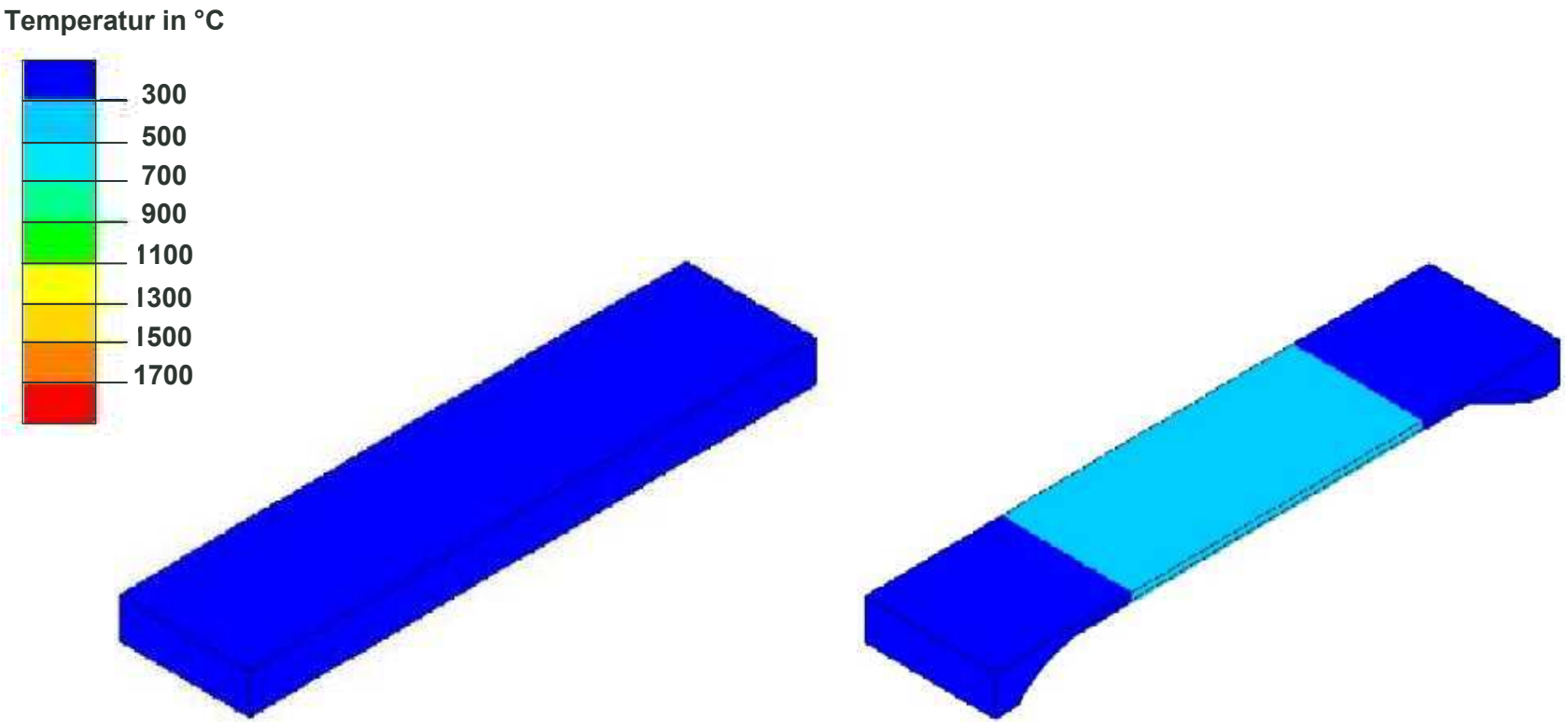
HEAT UP BEHAVIOUR WITH RESPECT TO BOAT SHAPE



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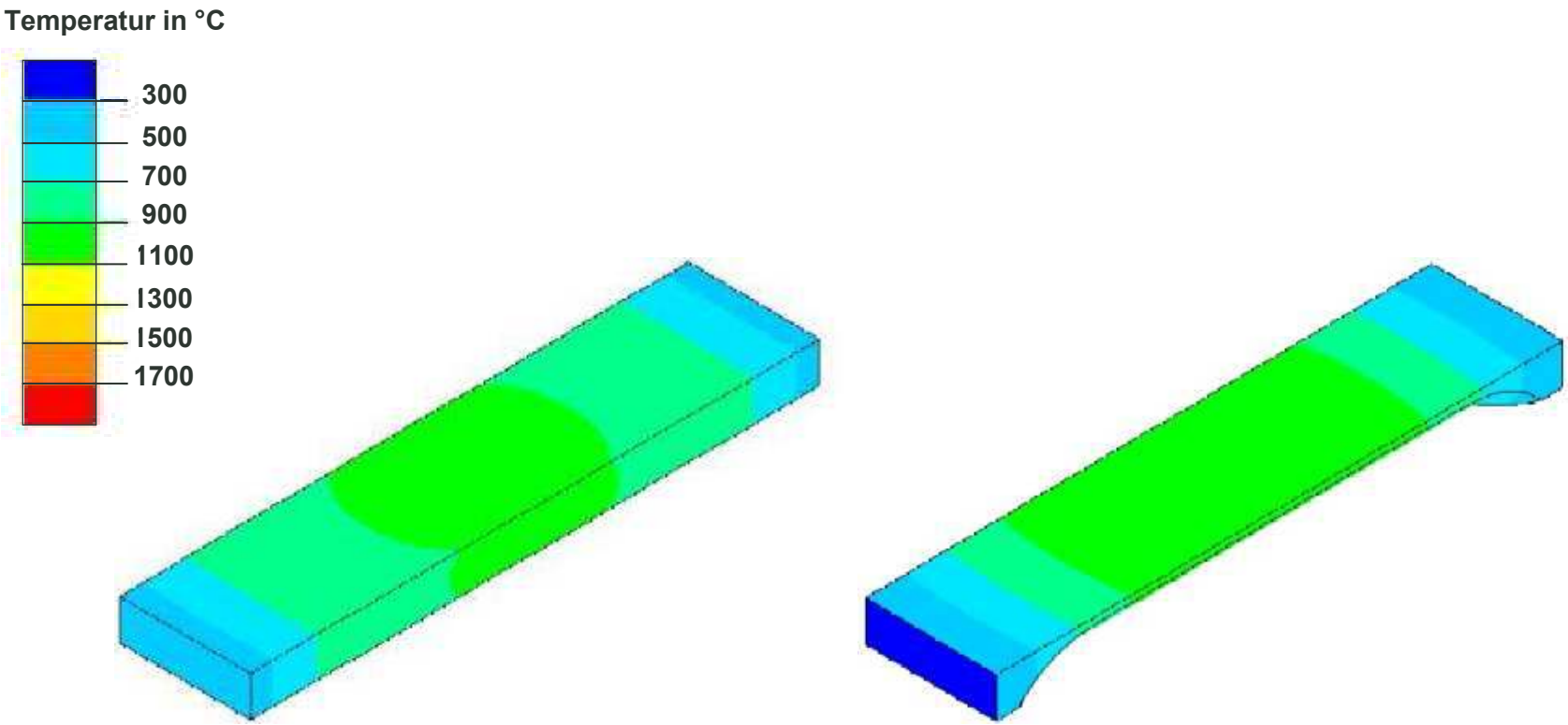
KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE
HEAT UP BEHAVIOUR WITH RESPECT TO BOAT SHAPE



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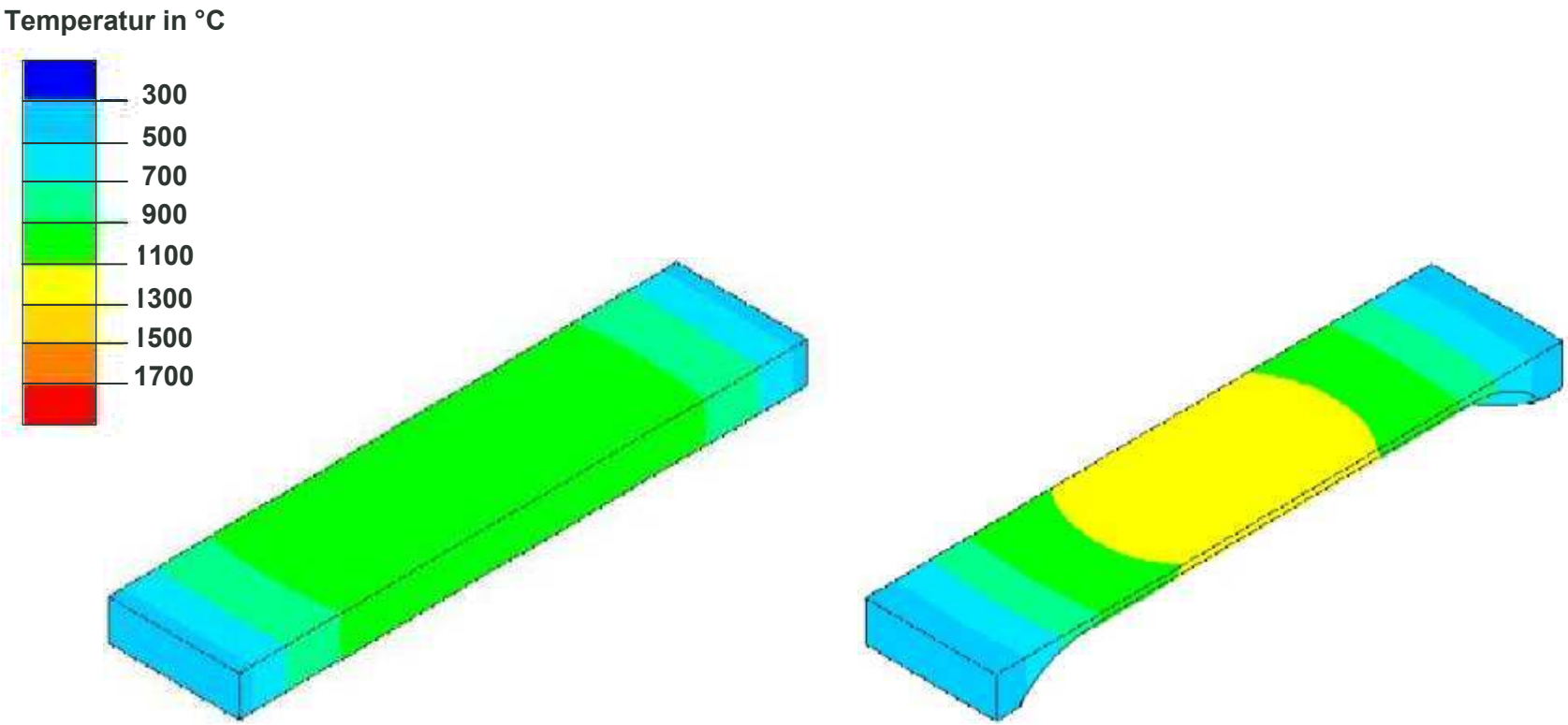
HEAT UP BEHAVIOUR WITH RESPECT TO BOAT SHAPE



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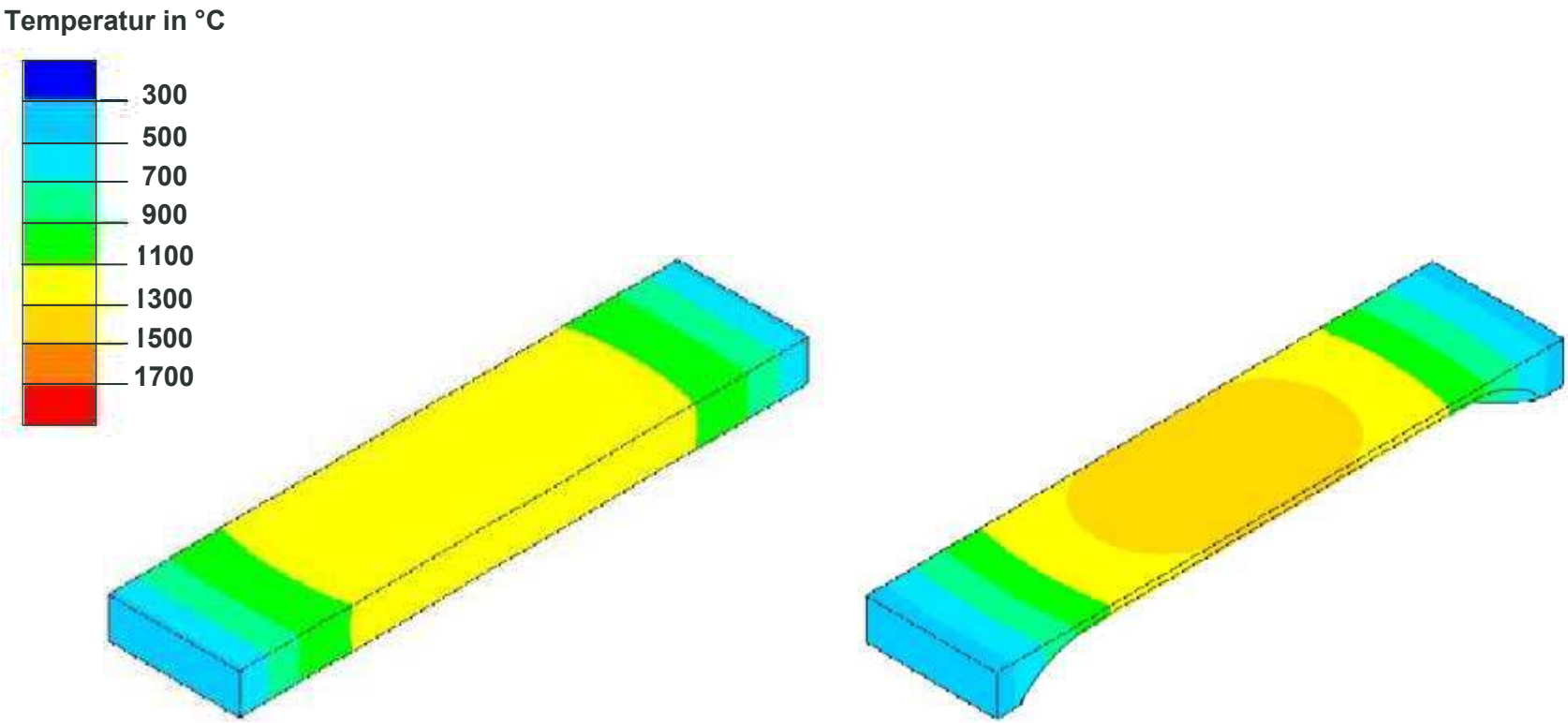
HEAT UP BEHAVIOUR WITH RESPECT TO BOAT SHAPE



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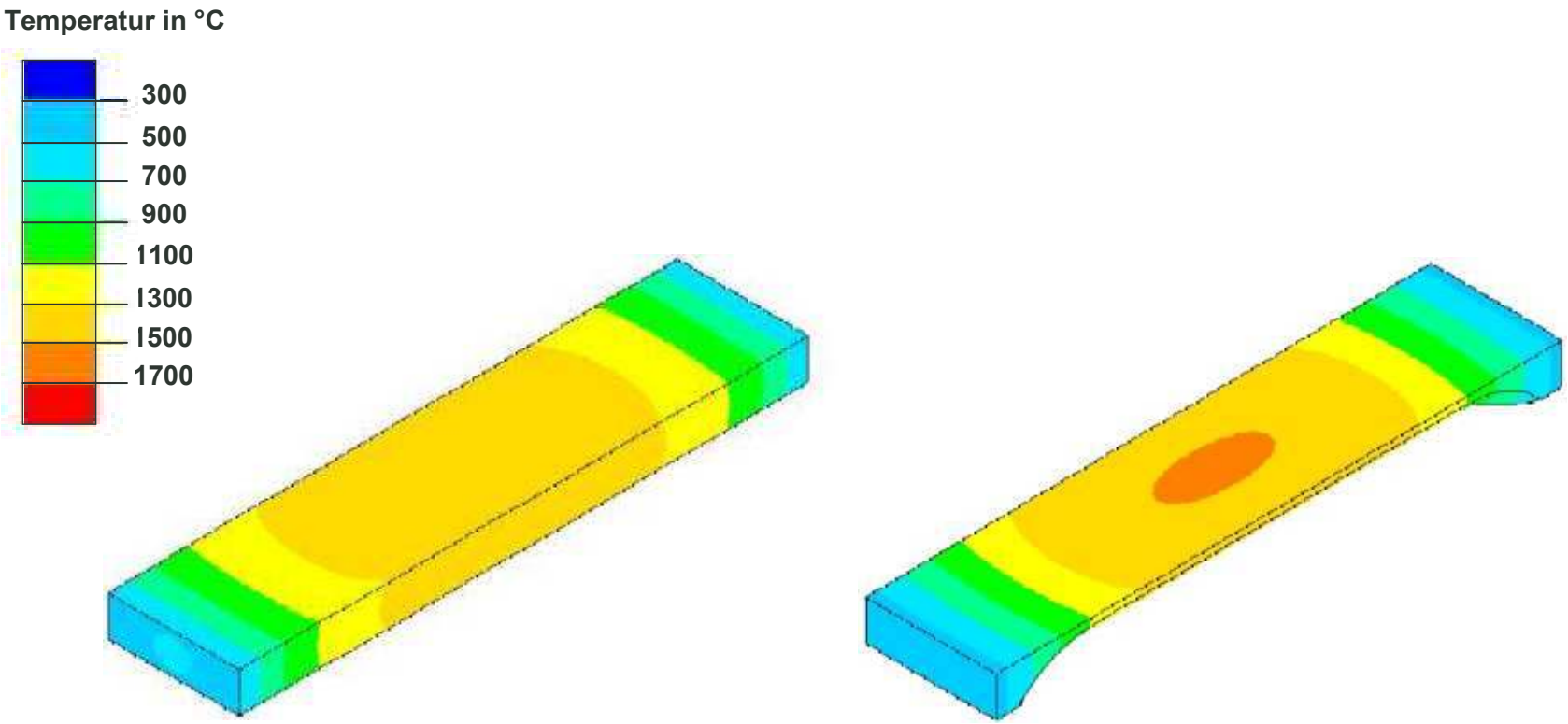

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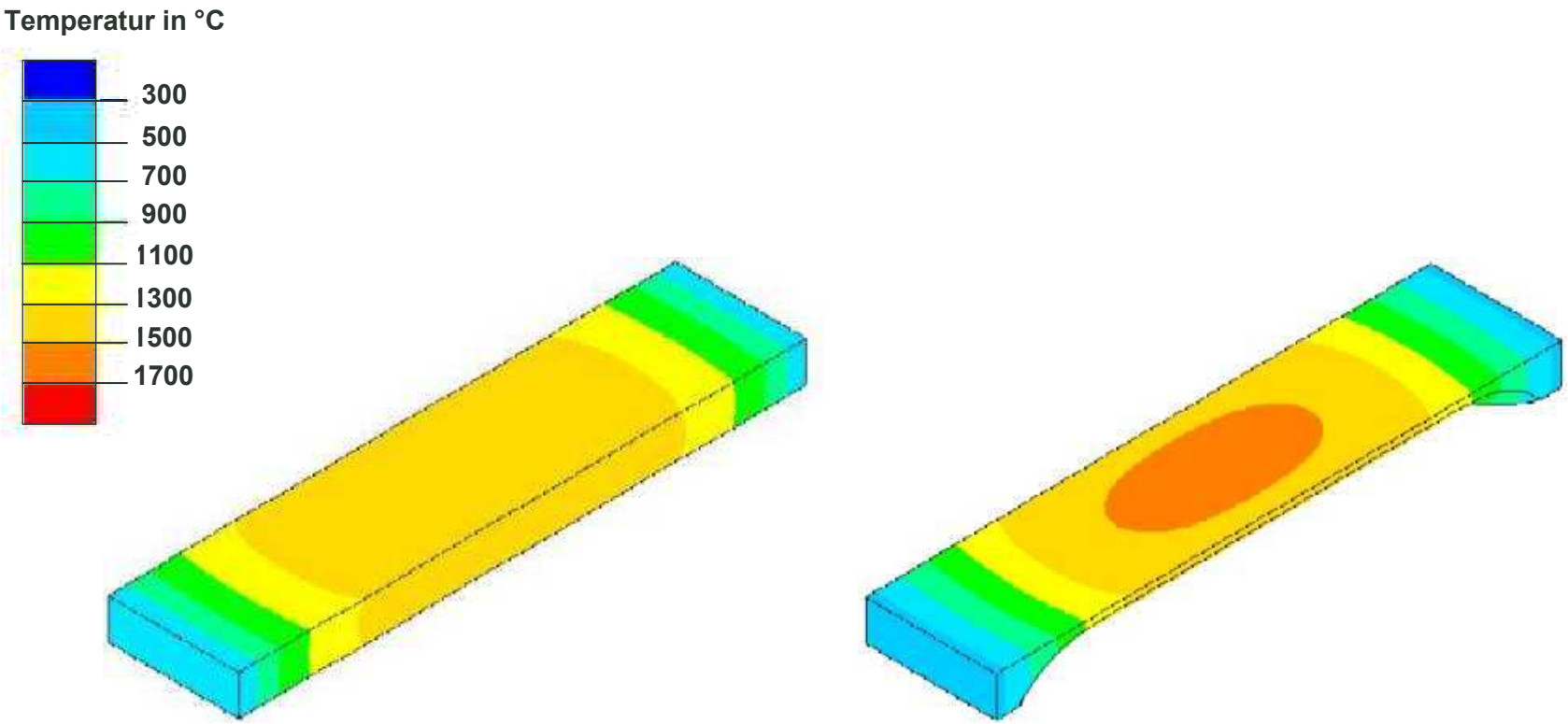

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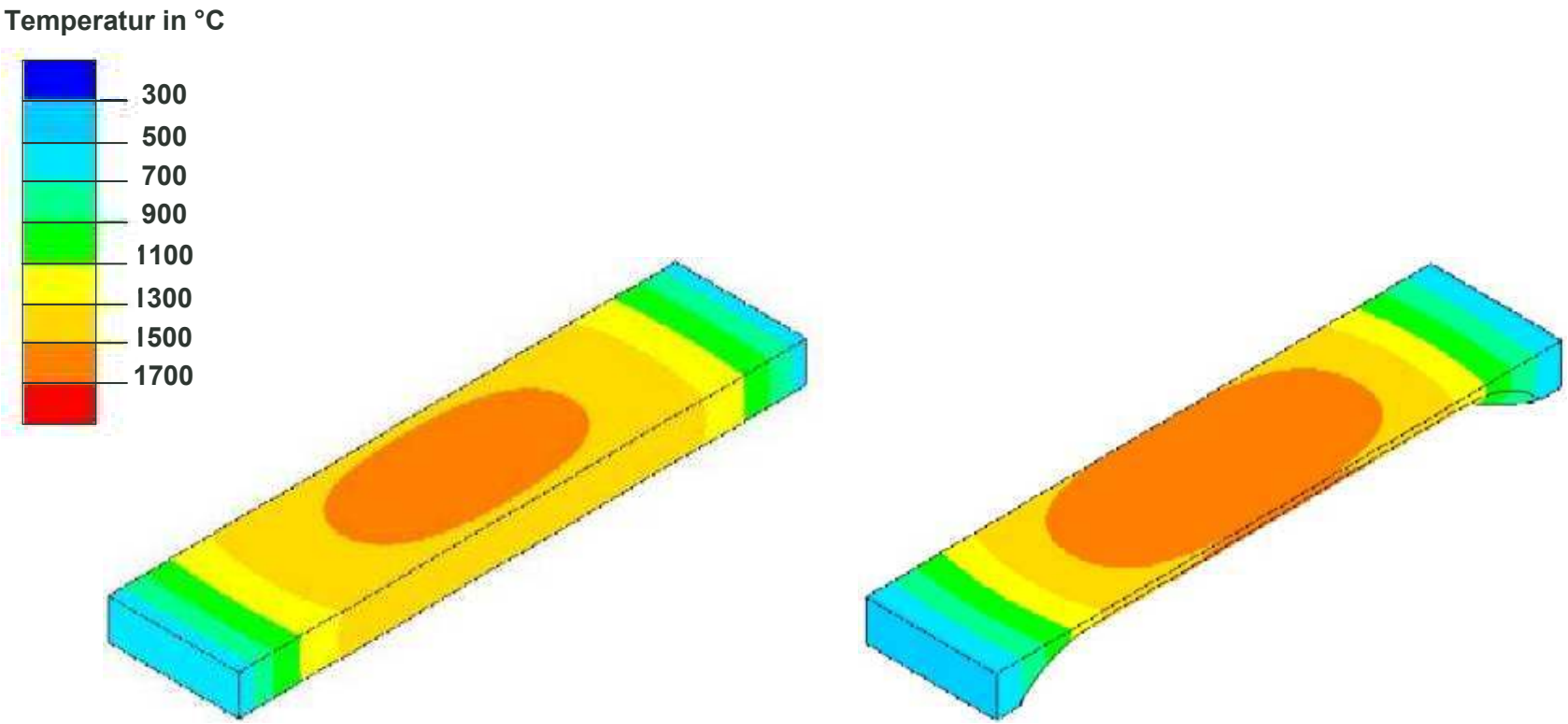

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KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE MACHINE SETTINGS

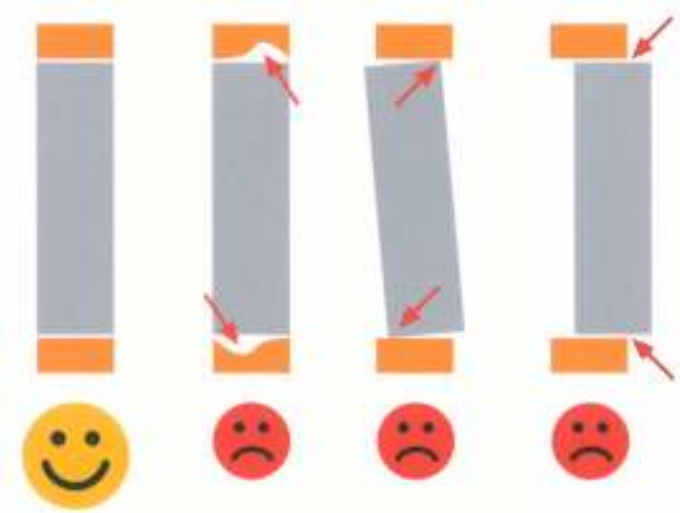
- Transformer secondary output (volts and amps)
- Vacuum
- Clamp condition
- Wire position

Above information gives maximum voltage and current applied to the boat. With this the highest possible resistivity range of the boat can be determined.

KEY FACTORS FOR OPTIMUM BOAT PERFORMANCE OPERATOR RESPONSIBILITIES

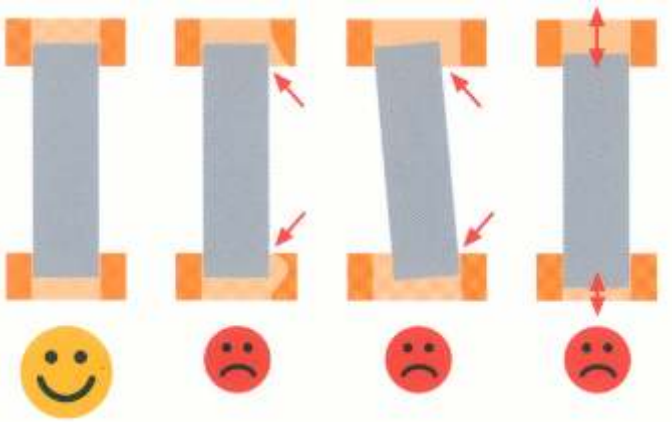
- Machine condition monitoring
- Boat condition monitoring
  - Clamp contact
  - Cleaning
- Process control
  - Break-in procedure
  - Boat temperature control: continuous visual inspection
  - Wetting behavior

SET-UP PROCEDURES
END CLAMPING



- Make sure that the evaporation boats are in-line with clamps
- Check that the clamping systems are in a good condition:
  - sharp edges
  - no damages
  - clean
  - proper alignment
- Use one layer graphite foil tape in order to improve the electrical contact
- Clean the clamps with a scraper

SET-UP PROCEDURES
SIDE CLAMPING



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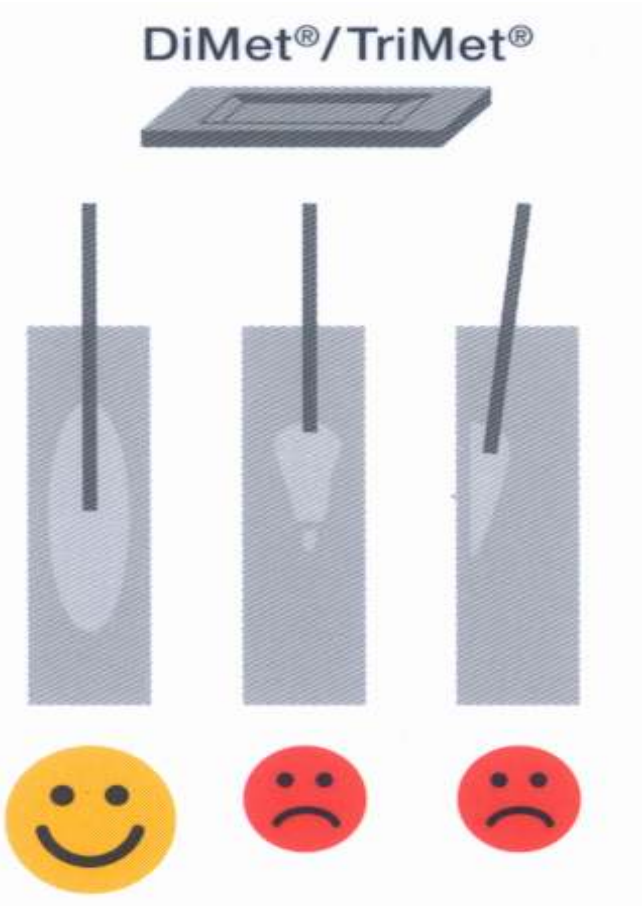
- Check that the clamping systems are in a good condition:
  - sharp edges
  - no damages
  - clean
  - proper alignment

- Use one layer graphite foil tape in order to improve the electrical contact

- Clean the clamps with a scraper

SET-UP PROCEDURES
ALUMINUM WIRE POSITION

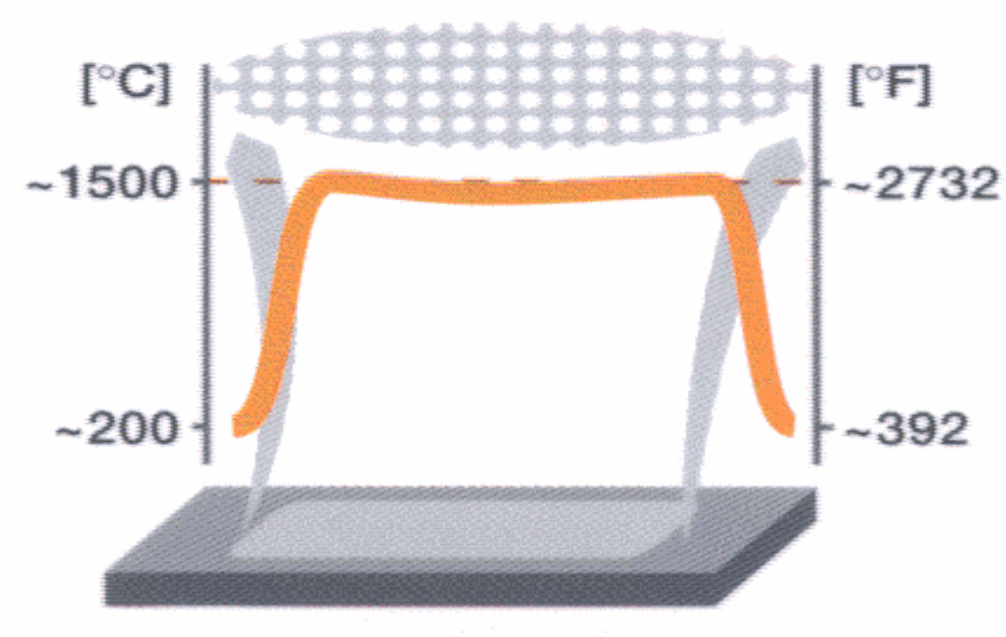


- Productivity and metallization quality can only be maximized with an optimal aluminum pool
- For an optimal pool, the wire should be positioned on the surface center
- Wire position affects uniformity and lifetime

IDEALLY WETTED BOAT

- Optimized temperature distribution
  - the evaporation boat experiences minimum heat stresses
  - the lifetime will be maximum

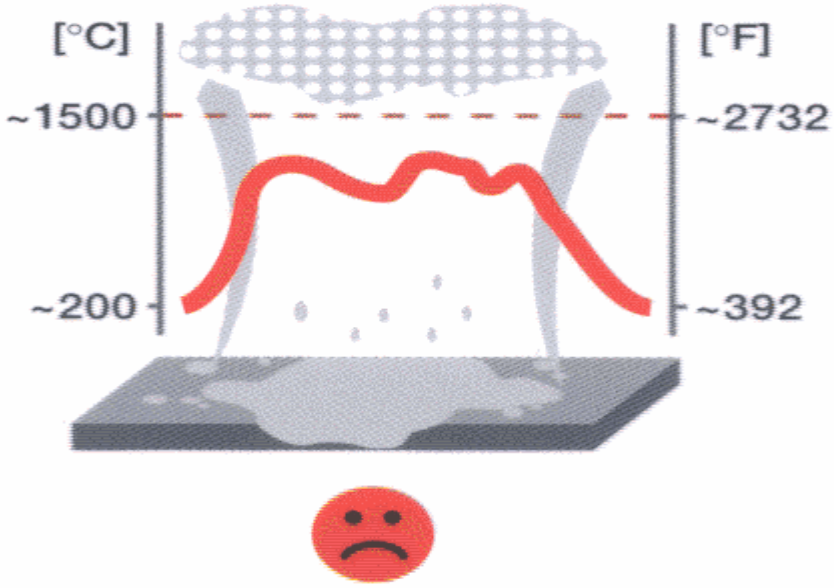
- Optimized aluminum vapor cloud
  - the aluminum evaporation will be excellent
  - the metallization is more homogeneous



FLOODED BOAT

- Boat is too cold or wire feed is too high
  - aluminum does not evaporate quickly enough
  - aluminum boils and starts spitting

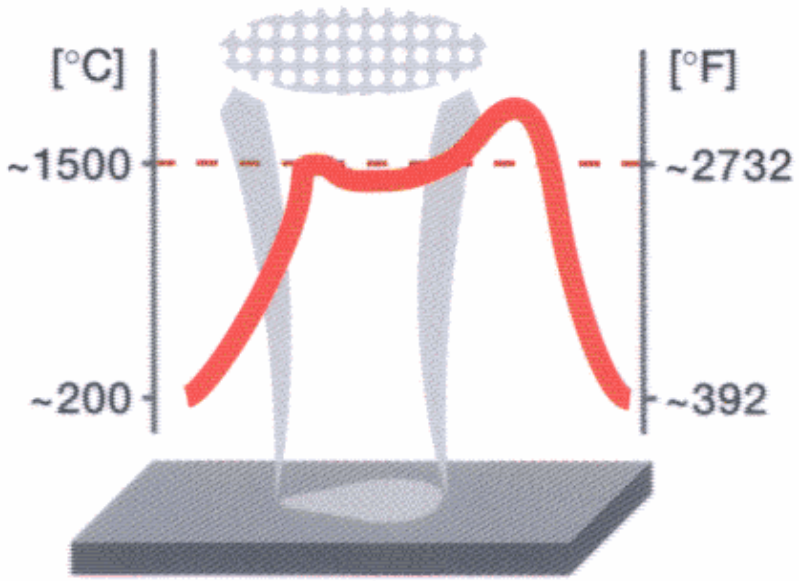
- Corrective measures
  - increase voltage
  - reduce wire feeding rate



POORLY WETTED BOAT

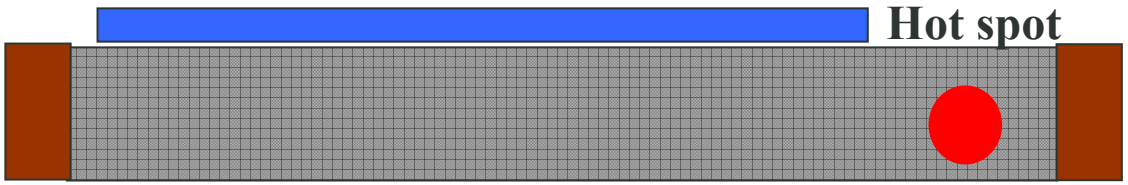
- Boat temperature is too high
  - bad wire position
  - not enough aluminum on the boat

- Corrective measures
  - adjust wire position
  - reduce voltage
  - increase wire feed
  - clean surface of the boat, after change of reel



POORLY WETTED BOAT: HOT SPOT

- Current density increases in non wetted areas leading to
  - local temperature increase
  - in boat deterioration
- Corrective measures
  - adjust wire position
  - reduce power
  - increase wire feed
  - clean surface of the boat after each run



CONCLUSIONS

In order to determine evaporation boat specification for a defined process, various criteria should be evaluated on a case by case basis. Optimal boat performance is based on proper resistivity, machine conditions, metallized applications, and operator diligence. Special attention to clamp contact, wire position, vacuum level, temperature control, and cleaning procedures result in maximum performance and lifetime. Individual consultation with the boat supplier is needed and then procedures should be reviewed with operators at regular intervals.

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