RAD-CON INC.

Annealing Furnace Specialists since 1966

Technology: *Innovative* and *Proven*

RAD-CON

Flat Rolled Copper Base Alloy Manufacturing

Improving Efficiency and Sustainability through Optimizing the Batch Annealing Production Unit

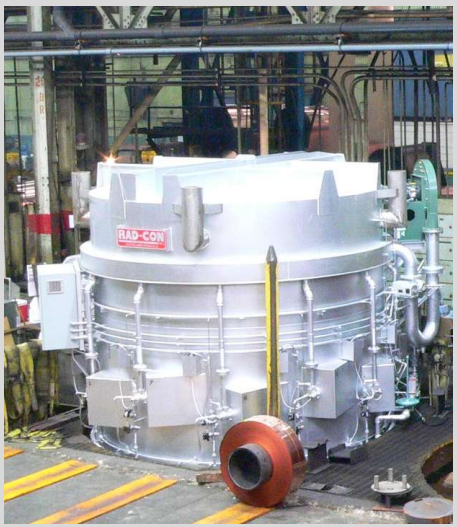
IWCC Legal Disclamer

The purpose of this presentation is to guide programs benefiting the copper industry and to provide attendees with information to make independent business decisions

Improving Efficiency and Sustainability

Copper Annealers are expected to:

- Produce consistent product quality
- Have a sustainable process with limited environmental impact
- Provide workers with a safe and ergonomic workplace
- Operate with low operating costs



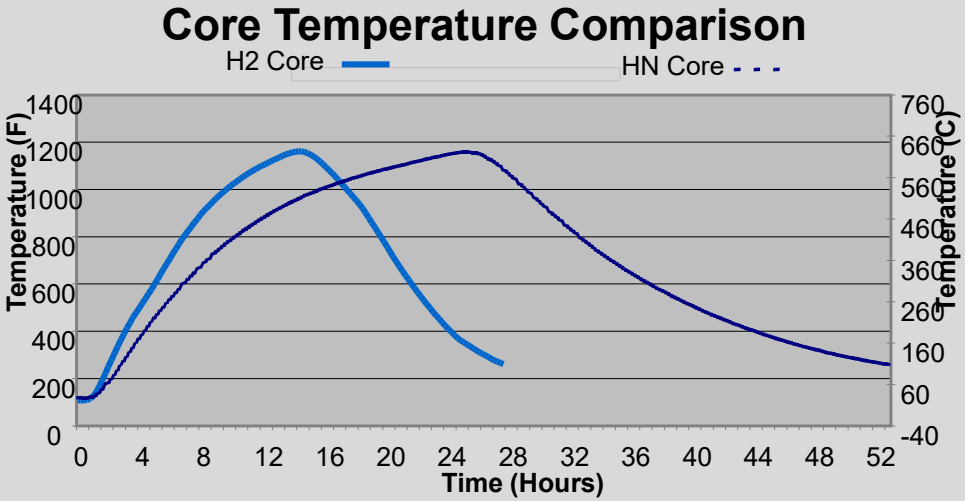
Improving Efficiency and Sustainability

Modern Batch Annealing Facilities:

- Use Hydrogen Atmosphere
- Designed for Safe, Ergonomic Operation
- Have Low Carbon Footprint
- Leverage Physical Modeling to Optimize Processing Times
- Implement Industry 4.0

Hydrogen Anneal

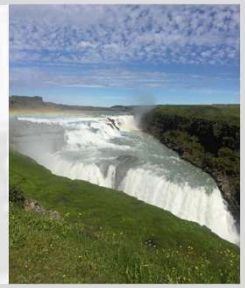
- Typically, 50% Less Heating/Cooling Time
  - Less equipment required lowers overall cost
  - Less equipment space
  - Improved customer service and lead times
- Utility Consumption Reduction



Hydrogen Anneal

- Better Product Uniformity
  - Less dense hydrogen improves convection flow 350-1000% thru use of VFD's and highly engineered convection system
  - Reduction in mechanical property variation.
- Improved Surface Quality
  - Reactivity of hydrogen and consistent temperature uniformity allows for better control of surface carbon and oxide reactions.

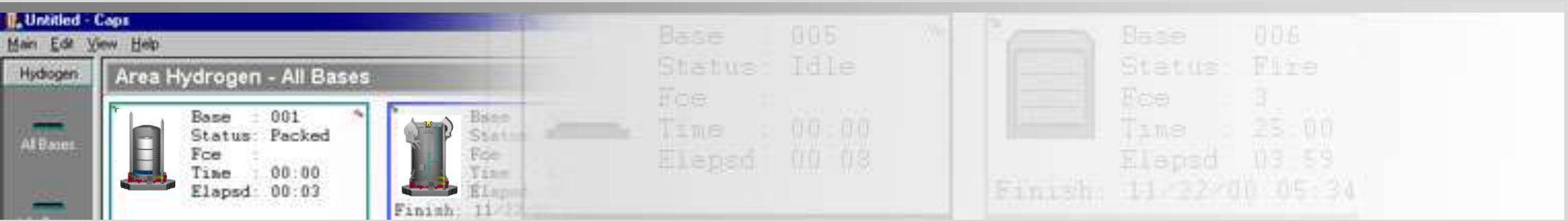
Sustainable Annealing



Use Resources Wisely:

- Minimized heating and cooling times
  - Lower fuel and electricity consumption
- Low emissions (CO_2 and NO_x) combustion systems
  - Recuperation to recover waste heat
  - High efficiency burners
- Electric heating
- Atmosphere monitoring and modeling to efficiently use hydrogen

Modeling in Anneal

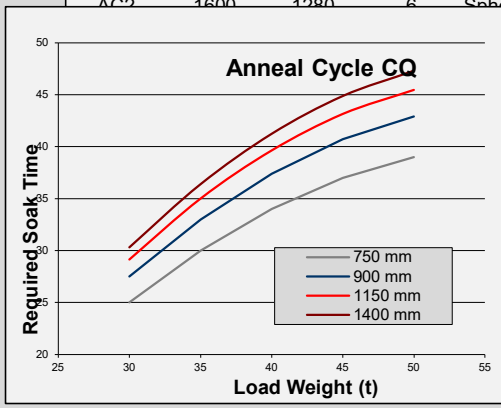


All annealing shops are using a model…

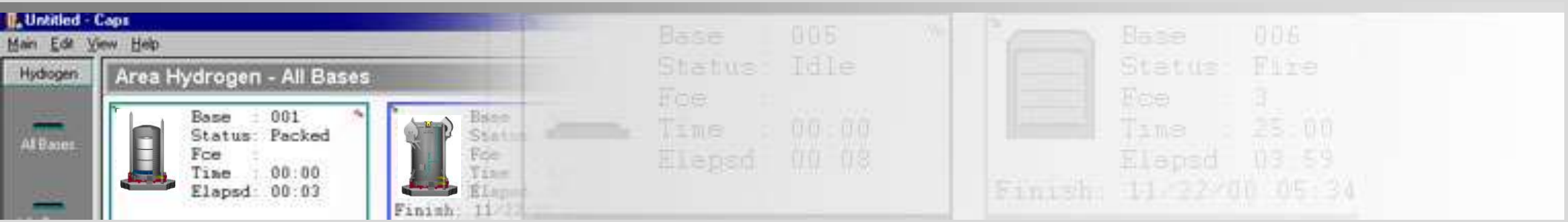
- Look-up Tables developed through trial-and-error
- Tables or Graphs developed through empirical analysis (like regression) of thermocouple test data
- Physical Model of the process using laws of physics and geometry of the system

Annealing Cycle Table

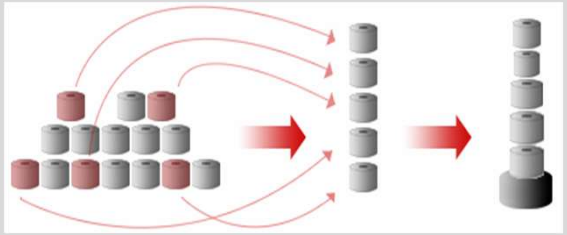
Cycle	Furn Temp	Soak Temp	Soak Time	Comment
AA	1600	1260	2	CQ/DQ-high rockwe
EE	1600	1260	4	CQ/low carbon
BB	1600	1260	7	AKDQ/low carbon
AB	1600	1260	10	AKDQ/low carbon
AC2	1600	1280	6	Spheroidization/mo

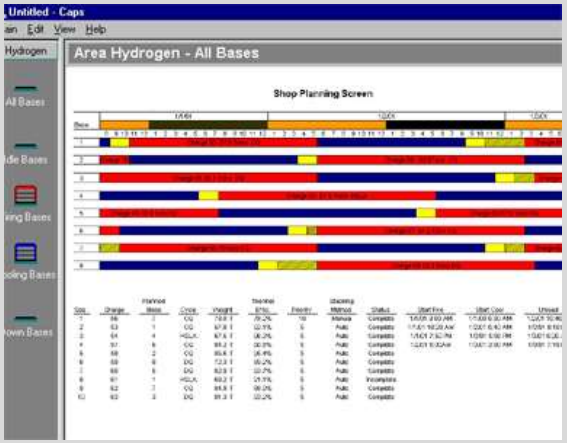


Modeling in Anneal

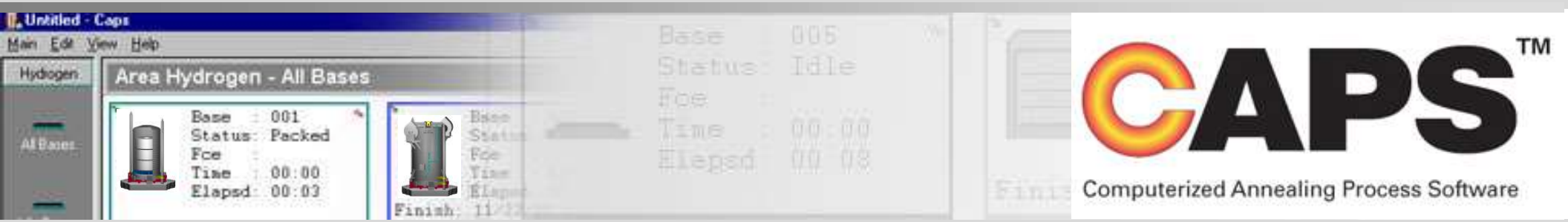


- The more accurate the model, the more benefit it can bring
  - Reduced cycle times
  - Improved mechanical property uniformity
  - Efficient utility usage
- Modeling can/should also be used to build charges and schedule equipment



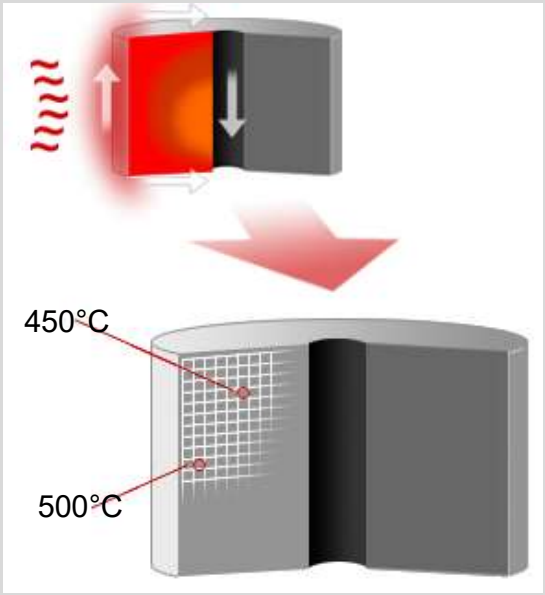


RAD-CON Thermal Model



CAPS™ Model Accounts for:

- Coil weight, width, and thickness
- Conduction
  - Lap-to-lap contact
  - Thermal conductivity of solids, gases, and oils
- Radiation
- Convection variations
  - Equipment type
  - Convector plates
  - Stack position



On-line Feedback from:

- Temperature
  - Gas stream
  - Furnace
  - Spray water
  - Ambient air
- Atmosphere flow rates
- Convection fan
  - Current
  - Power
  - Speed

Industry 4.0 in Annealing

Annealing Equipment

Smart Sensors

- Remote Configuration
- Industrial IoT
- Condition Monitoring

On-Board Machine IO

- Pre-Commissioning
- Simplified Installation
- Expanded Diagnostics

PLC Logic

- Virtual Commissioning and Support
- Preventative Maintenance
- Network Security

Process Modeling

CAPS™
Computerized Annealing Process Software

- React to Process Events
- Preventative Maintenance
- Convert Anneal Data to Metallurgical Data Analysis
- Communication to Other Systems

Production Database

- Anneal Metallurgical Data for Analytics
- Anneal Production Visibility
- Big Data Lake

Improving Efficiency and Sustainability

	H2 Anneal	CAPS™	Industry 4.0
Product Quality	• Uniformity within a charge	• Charge-to-charge uniformity	• Predictive maintenance
Sustainability	• Surface cleanliness	• Reduced heating and cooling times	• Added monitoring
Safety	• Improved ergonomics		• Clear status indication
Operating Cost	• Significant reduction on utilities	• Efficient use of utilities	• Reduced downtime