Techniques To Match Continuous Flow Thermal Processes

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Opening Comments

- We are part of an advancing technological front.
- Each year we step forward from what we discovered before and find the next most critical detail.
- Then we learn how to use it.

- And the cycle continues…

First - Some Questions…

- How many of you work with continuous flow thermal processes?
- How many of you find yourselves trying to understand or match "what is going on in there"?
- How many of you have actually constructed Time-Temperature Histories for your processes?
- How good are your results?

Where Are Small Scale HTST and UHT Systems Used?

- Ingredient Manufacturers
- Finished Product Manufacturers
- Co-Packers
- Product Development Companies
- Universities
- Cleaning Reagent Manufacturers
- Trade Associations

How Are They Used?

- Simulate larger processes for product development
  - Ingredient characterization, formulation
- Process development where the order and intensity of process operations is optimized

How Are They Used?

- Small-scale sample production
- Fouling studies
- Kinetic data generation
- Small capacity manufacturing

Process Matching & Simulation Definitions

- Target System: This is the one we wish to duplicate.
- Simulation: A mathematical model representing the target or simulating system
- Simulating System: This is one we are designing and operating properly to duplicate the Target

Success Of The Simulating System

- How well the quality of product from the simulating system matches that from the target system.
- Same For Lethality
- Eventually ALL simulations and simulating systems fail!

Process Matching or Scale-Down

- Techniques
  - Dimensional matching
  - Hold time matching
  - Process bracketing
  - Processing step matching
  - Matching Time-Temperature Histories
  - Equivalent Point Matching

Process Matching or Scale-Down

- Dimensional matching
- Hold time matching
- Process bracketing

Pitfalls Of Process Matching

- Assuming that one HTST or UHT process is the same as another.
  - Details count for a good match
  - Not all details are small just subtle

When You Have A Bad Match

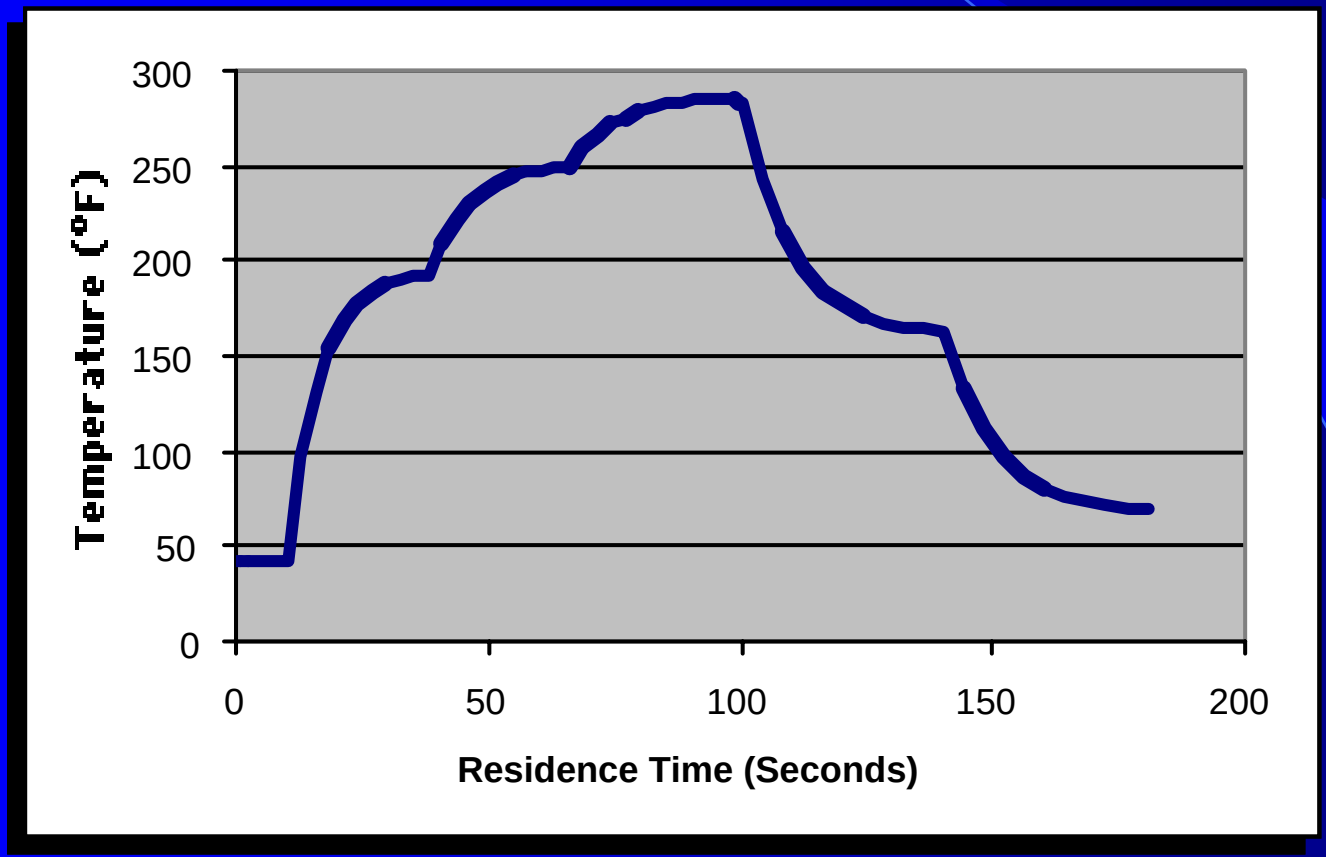
- Go back and check what you decided to not consider!

Why Is Process Matching Difficult?

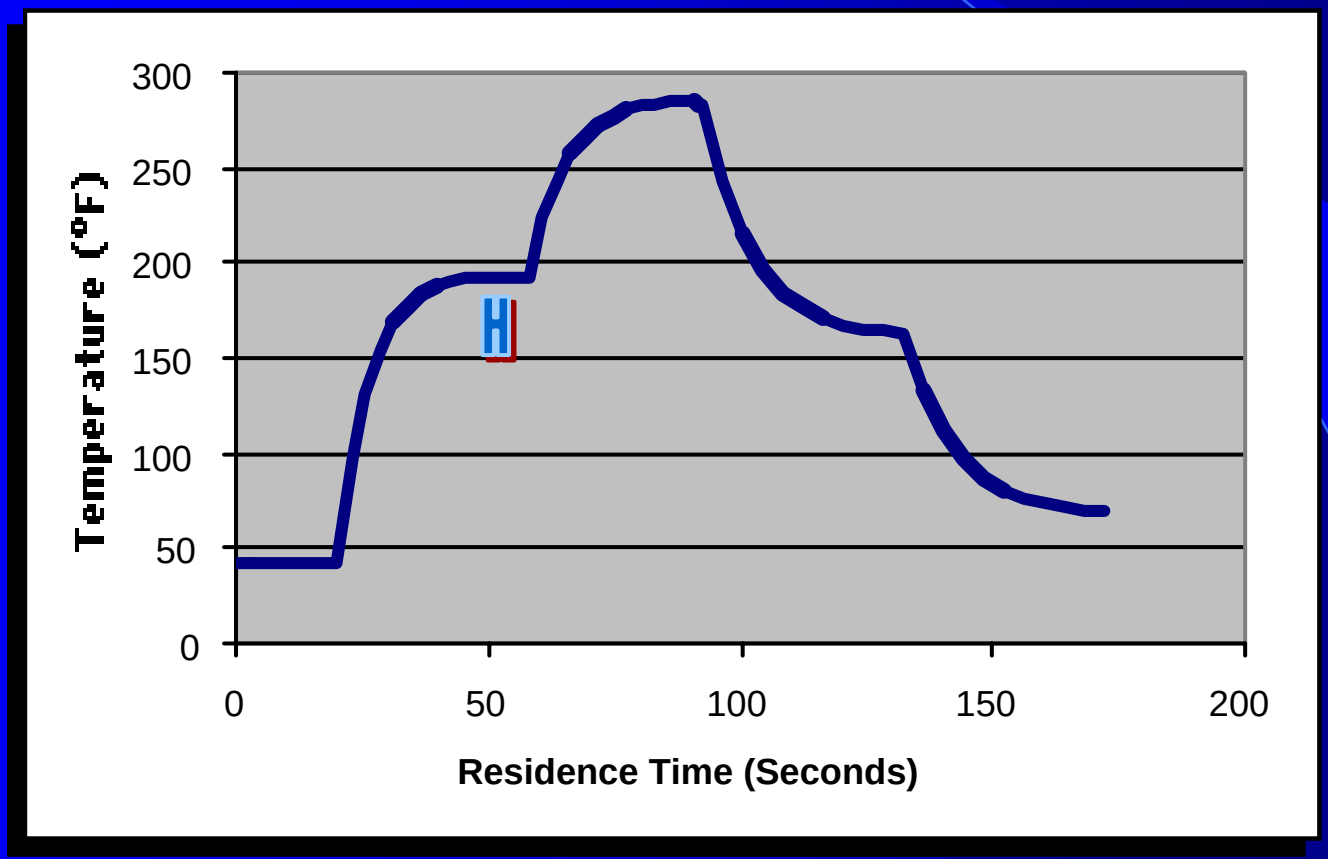
- There is no “typical” UHT or HTST process
- Even within one “style” HTST or UHT process, details vary considerably.
- Not everything is time and temperature!

Examples Of “Standard” Time-Temperature Histories

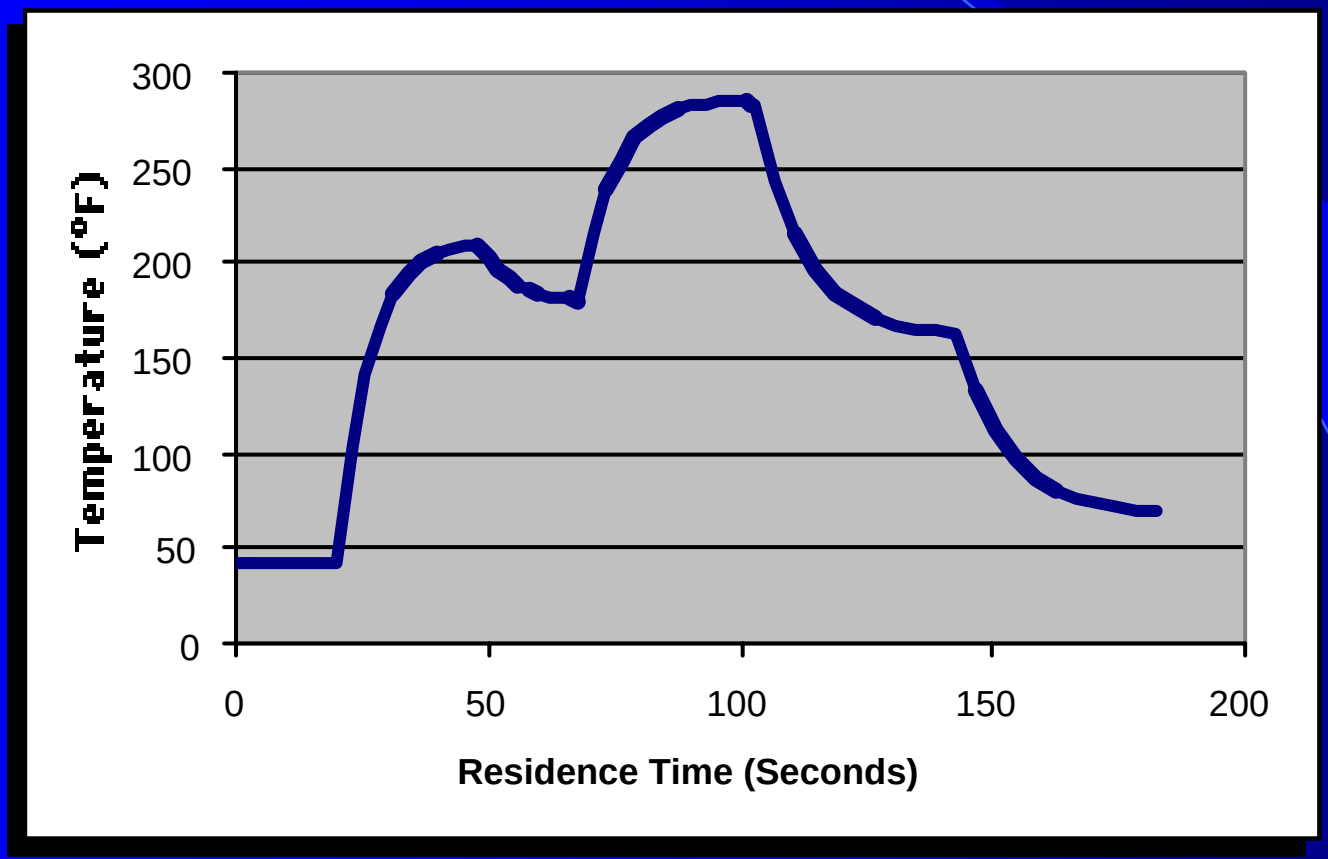
“Standard” Time-Temperature History #1



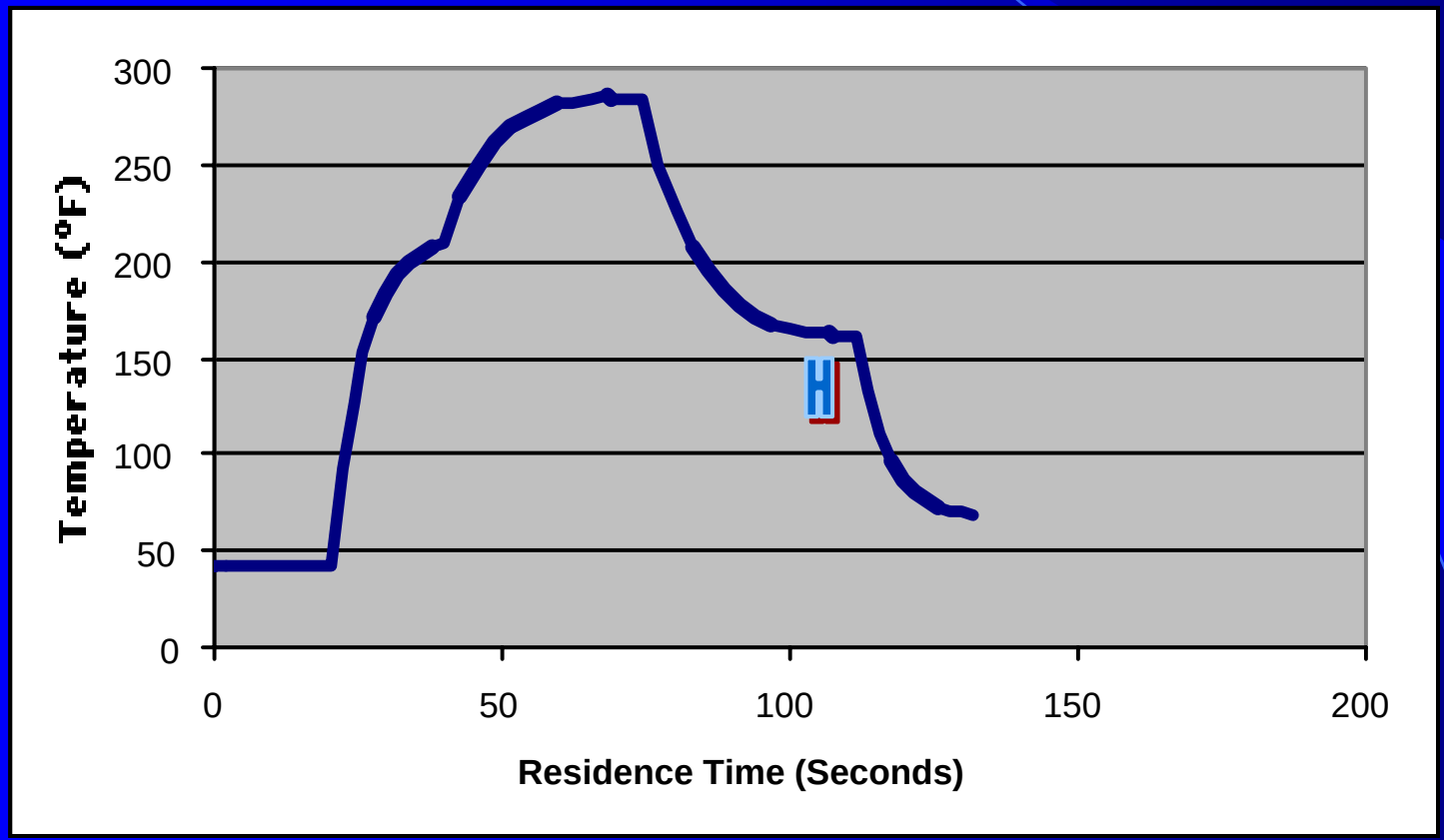
"Standard" Time-Temperature History #2



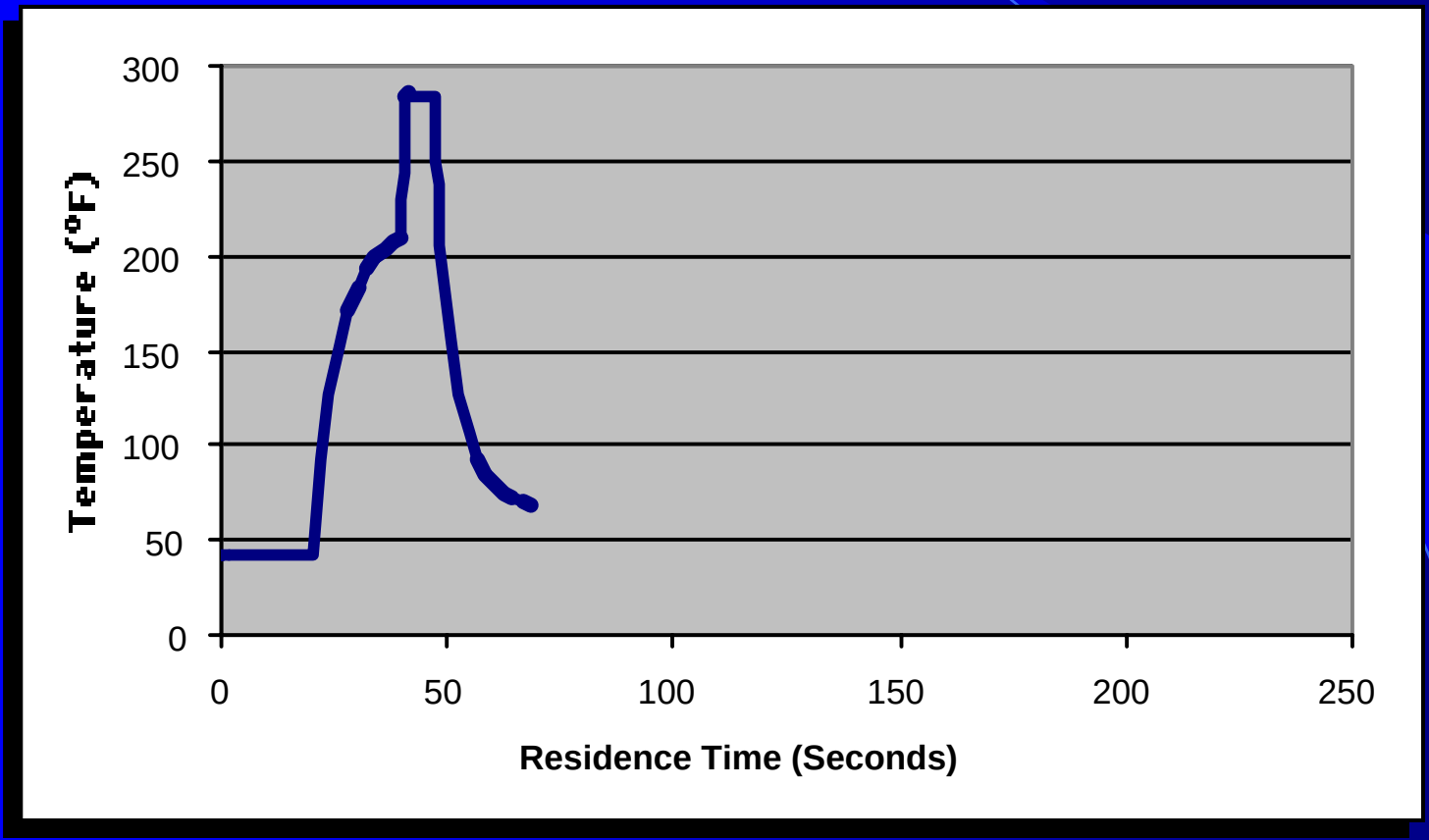
"Standard" Time-Temperature History #3



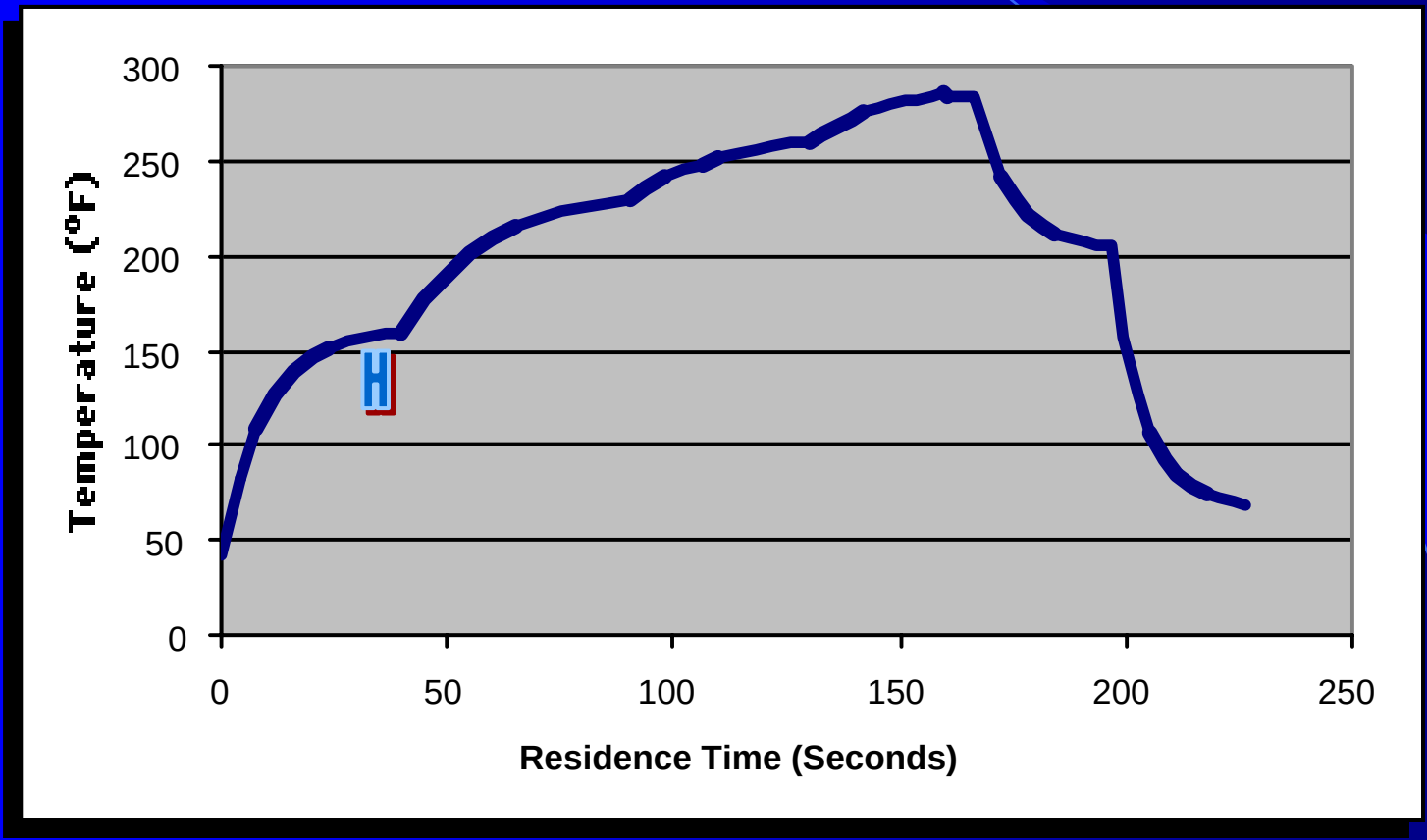
“Standard” Time-Temperature History #4



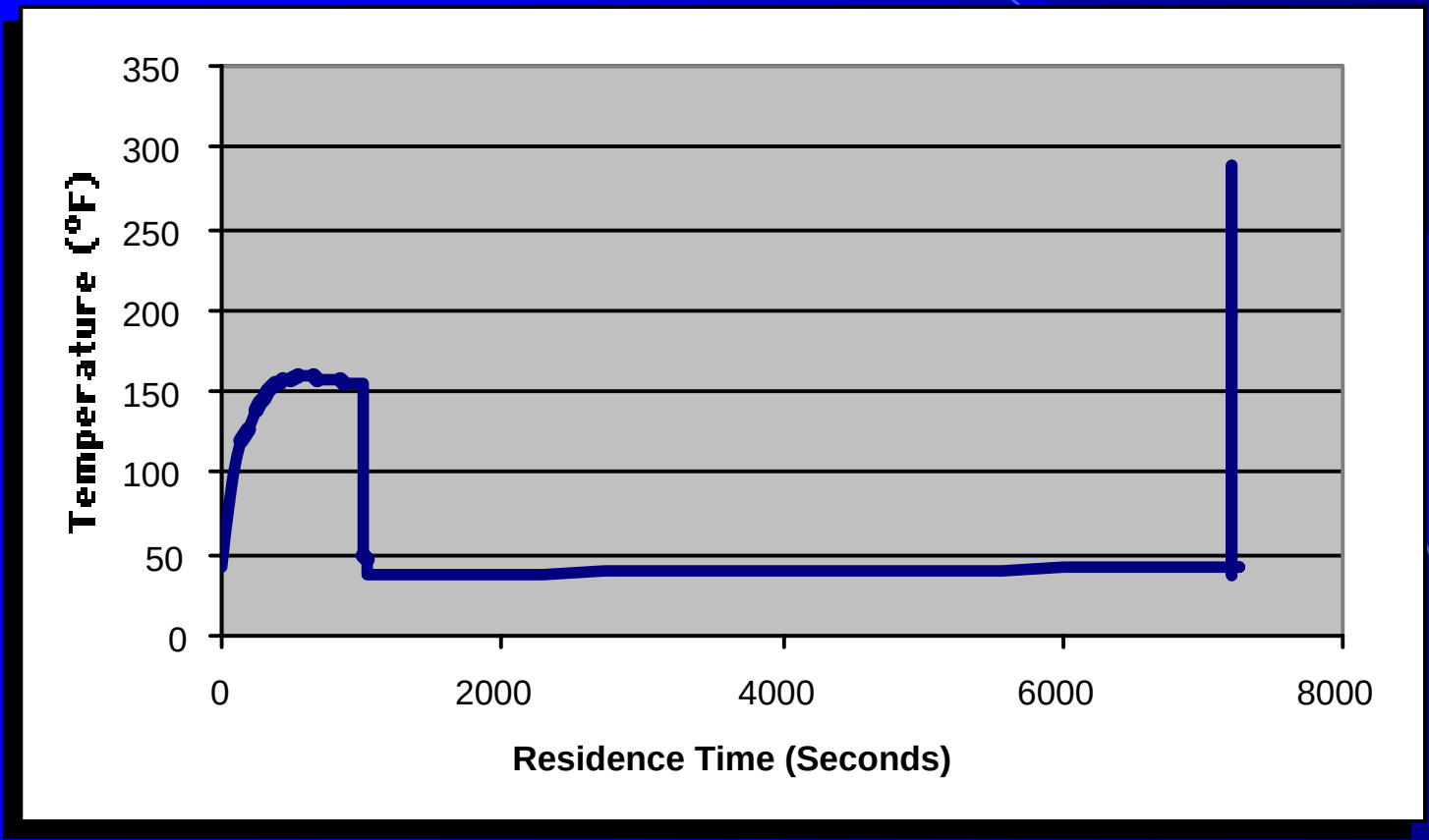
“Standard” Time-Temperature History #5



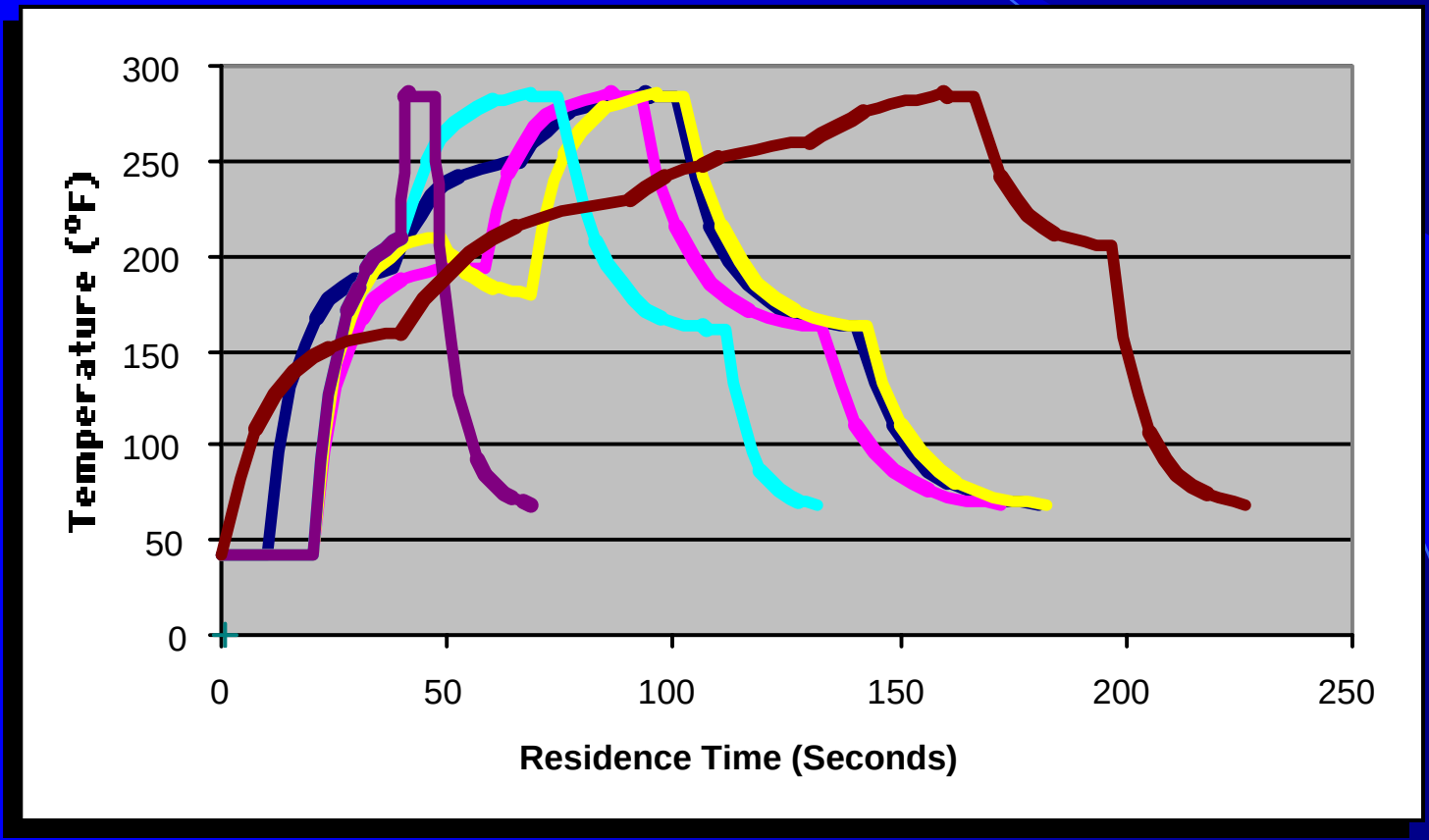
"Standard" Time-Temperature History #6



“Standard” Time-Temperature History #7



Comparative Time-Temperature Histories



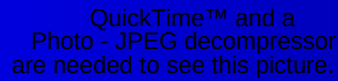
Pitfalls Of Process Matching By Component

- Assuming that using the same style heat exchanger as the target process will provide a good match.
  - Details again!

How Can This Be A Mistake?

- Using the same style heat exchanger only duplicates the style, not how it is set up.
- For example, plate-style heat exchangers can be set up many ways, for single and multiple passes, for short and long heating times.
- The critical consideration is the time-temperature history.

Plate-Style Heat Exchangers



Factors Critical To Product Quality Are Identified By

What Is Experienced By The Product!

Critical Task

- Define the process steps and the order of these steps that is critical to yield desired product quality.

Be Careful!

When The Only Tool You Have Is A Hammer…

Every Problem Looks Like A Nail!

Factors Critical To Product Quality

- Time-Temperature History
- Process Order (Process Layout)
  - Location of homogenization
  - Location of specific reactions in the equipment
- Additions or Removals
- Shear History
- Manufacturing Procedures
  - Batching
  - Product Transfer

Define The Impact On The Product

- What is the impact of a process operation?
- How important is it to what we need?

Examples

• Indirect Heater Style	• TTH • Residence Time Distribution (RTD)
• Steam Injection • Steam Infusion	• - • High Temperature Pool and RTD
• Vacuum Cooling	• Volatile Removal • RTD

What Is Most Often Known About A Processing System?

- Hold Time and Temperature
- Type of Heat Exchangers Used

What Is Most Often Not Known About A Processing System?

- Operational Details
  - Transit Times In Specific Components
  - Entrance and Exit Temperatures
  - Where Critical Reactions Are Occurring
    - Fouling/Burn On
    - Starch Hydration
    - Others

What Is Most Often Not Known About A Processing System?

Where does the process begin & end?

What are the most influential steps?

When not to get lost in the details!

Create A Time-Temperature History

Where does the process begin & end?

What are the most influential steps?

When not to get lost in the details!

Creating a Time-Temperature History

- How Is This Calculated/Estimated?
  - i. Flow Rate (Volume/Time, L/Hr, L/Sec)
  - ii. Component Volume
  - iii. Component Time = Component Volume/Flow Rate
- Plate Volume: L * W * H * n
  - Measured inside gaskets
- Tube Volume: $\pi * R^2 * L * n$ + atrium
- SSHE: (Outer Shell $\pi * R^2 * L$)-Shaft Volume

Creating a Time-Temperature History (continued)

- Component Residence Time
  - Component Volume/Flow Rate = Residence Time
  - Mass Average or Bulk Mean Residence Time

Residence Time Table Creating a Time-Temperature History (continued)

- Component Residence Times and Temperatures
  - 1. Transit Times
  - 2. Product Temperatures (estimates)
  - 3. Example:

Component Residence Times & Exit Temperatures

Component	Residence Time Seconds	Temperature °F
Pump	0	70
Preheater Exit	35	180
Final Heater Exit	20	288
Hold Tube Exit	10	287
Cooler 1 Exit	20	140
Cooler 2 Exit	25	50

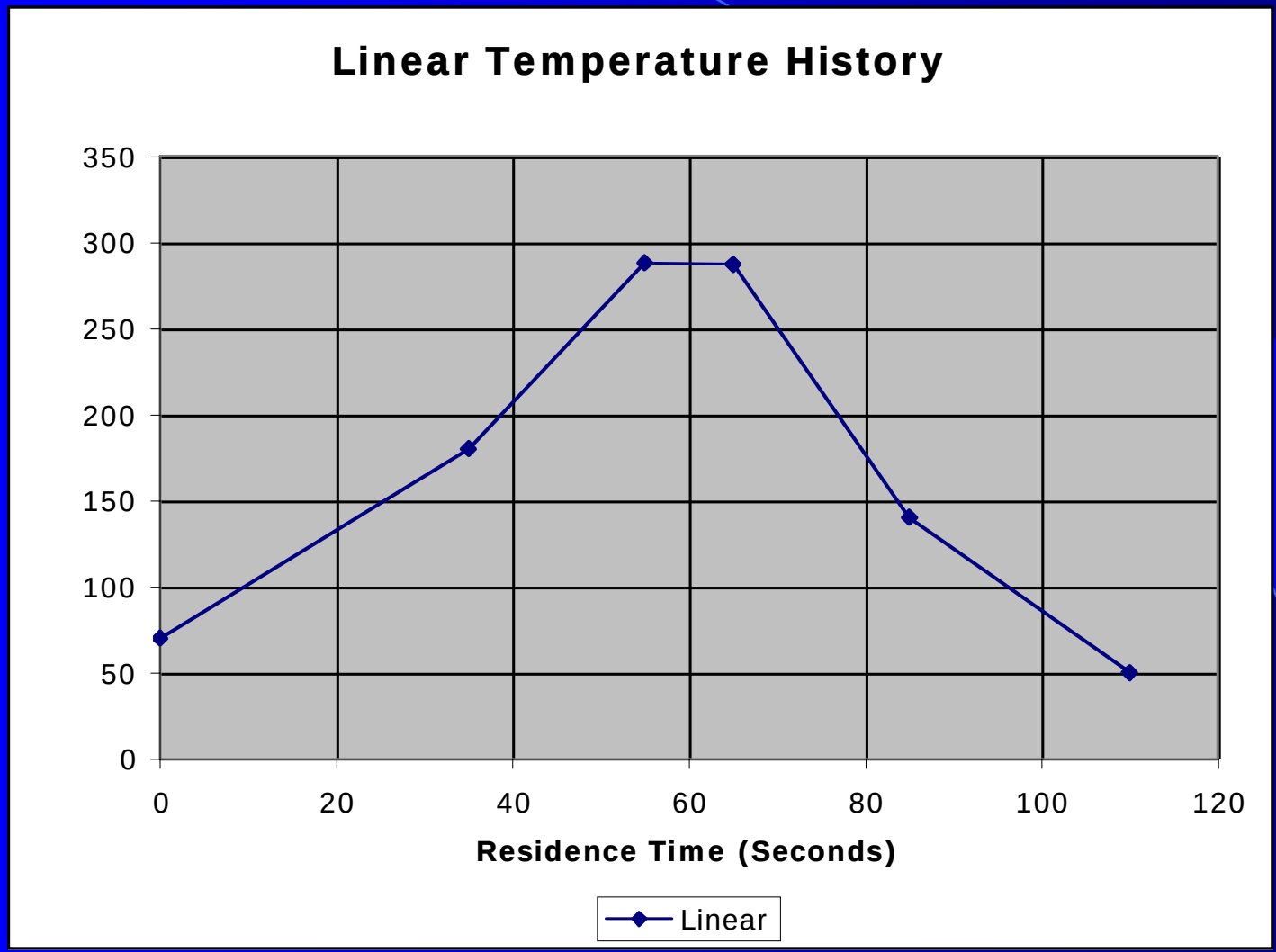
Creating a Time-Temperature History (continued)

- Cumulative Residence Times
- Same as the Residence Time Table but times are cumulative.

Cumulative Residence Times & Exit Temperatures

Component	Residence Time Seconds	Temperature °F
Pump	0	70
Preheater Exit	35	180
Final Heater Exit	55	288
Hold Tube Exit	65	287
Cooler 1 Exit	85	140
Cooler 2 Exit	110	50

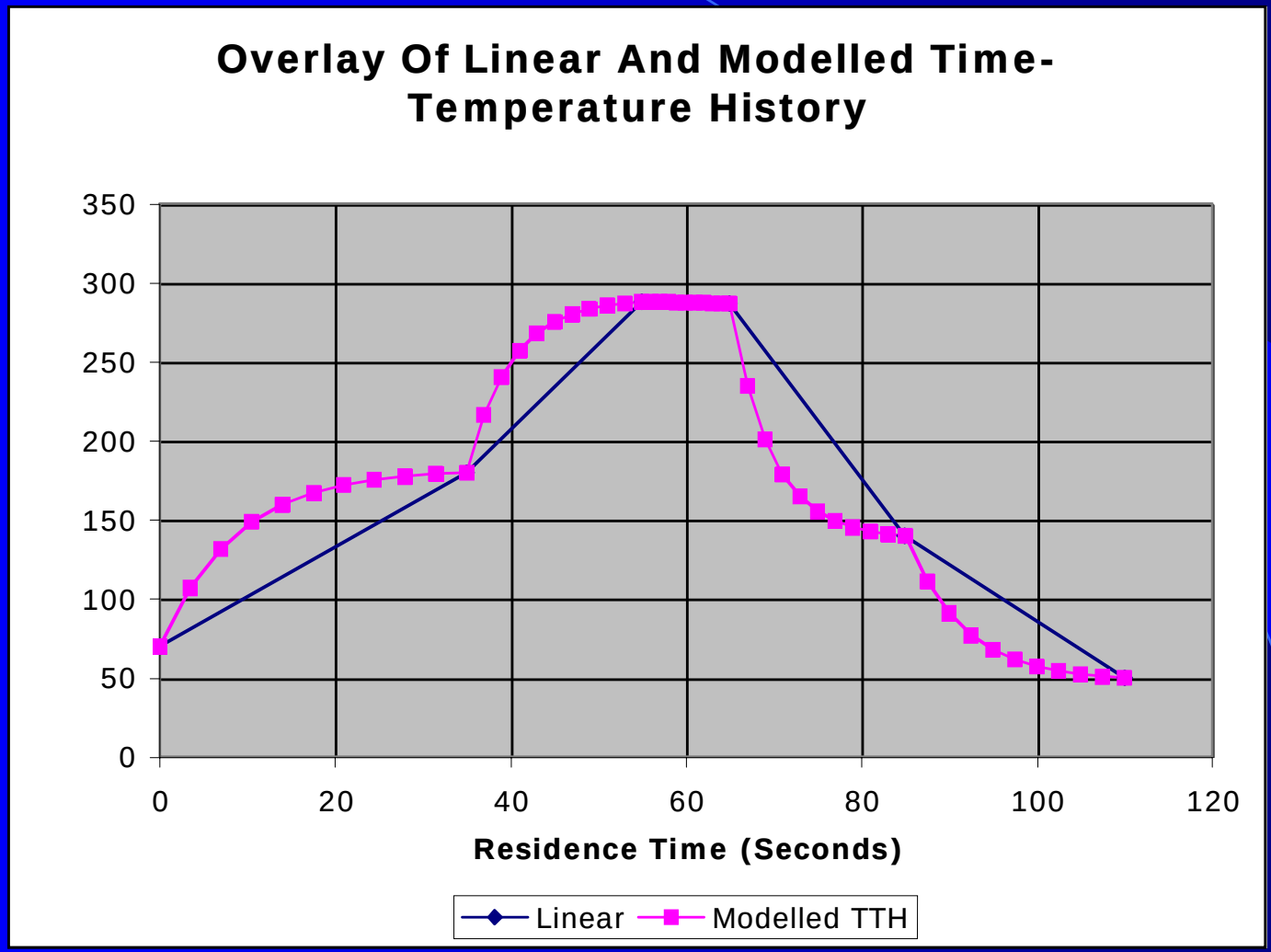
Graph Of “Linear” TTH



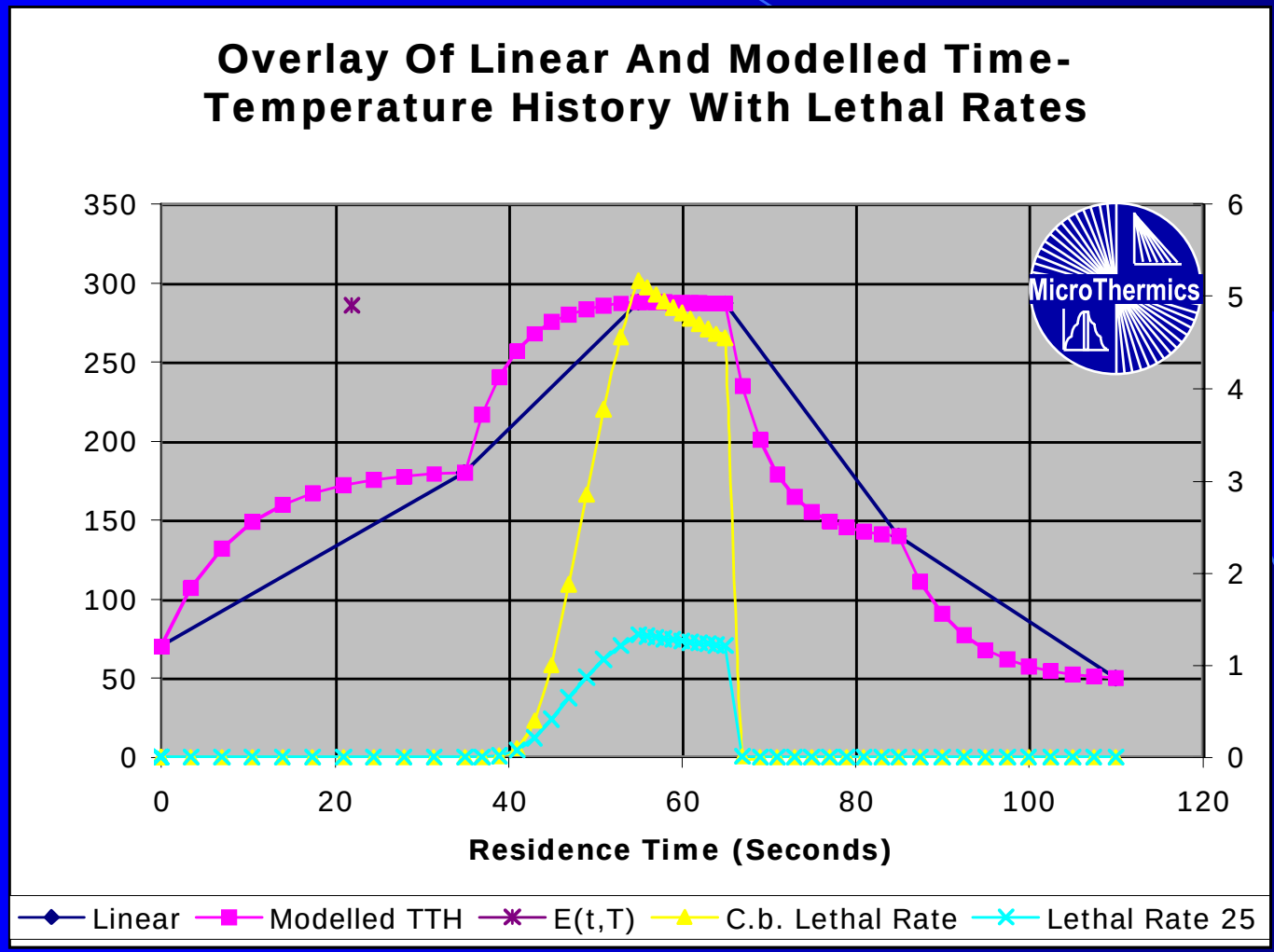
How Do We Interpret The Time-Temperature History?

- i. We need to know what parts have the most important impact on the product.
- ii. Add detail to get more realism. Add a modeled TTH curve.

Graph Of “Modeled” TTH



vi.“Modeled” TTH & C. *botulinum* Lethal Rate & “*Quality*”

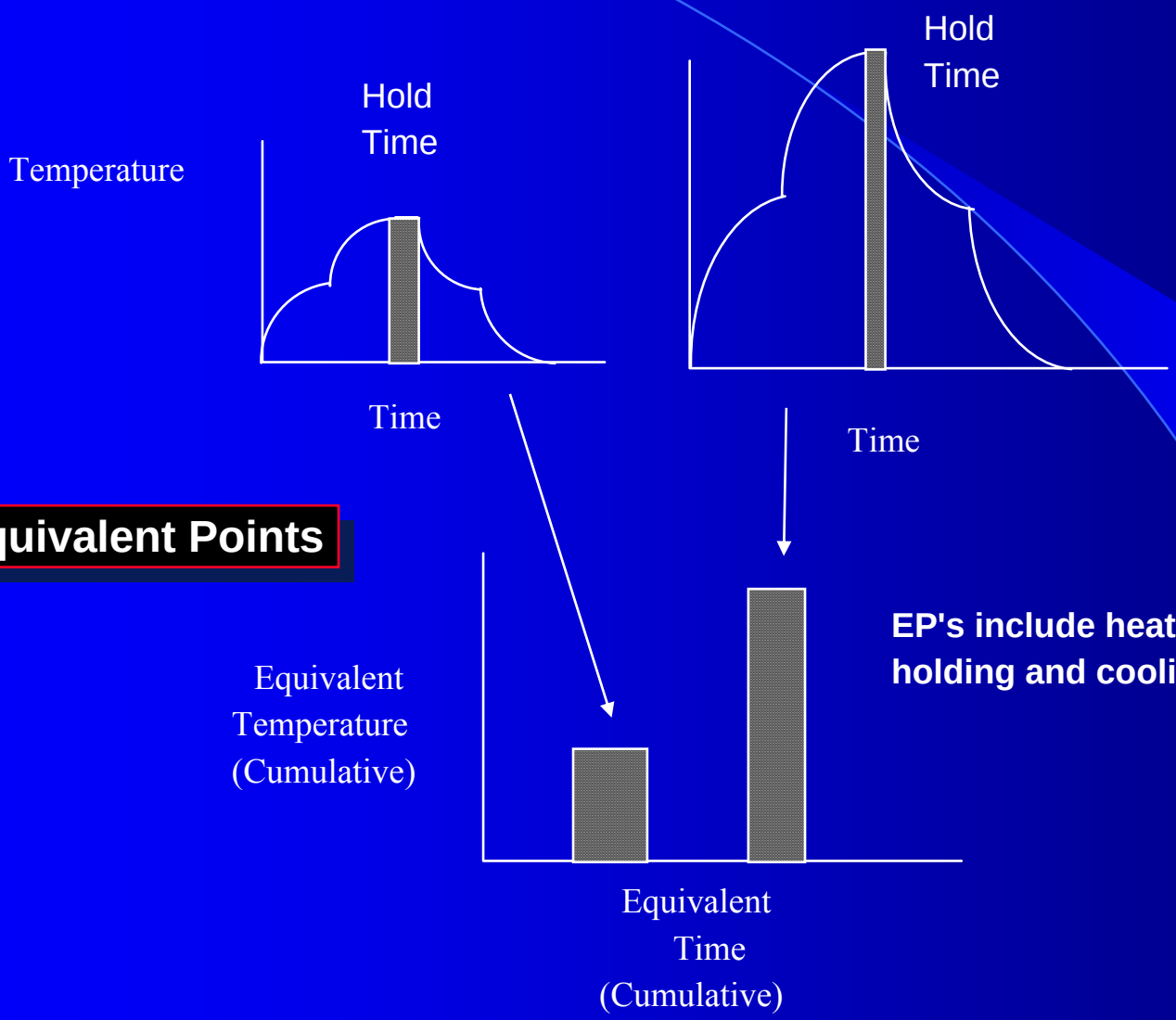


Useful Guideline

- Product 36°F lower than the heater exit would have to remain at that temperature for 100 seconds to do as much damage as one second at the heater exit temperature.

- Match the high temperature portion of the processes first!

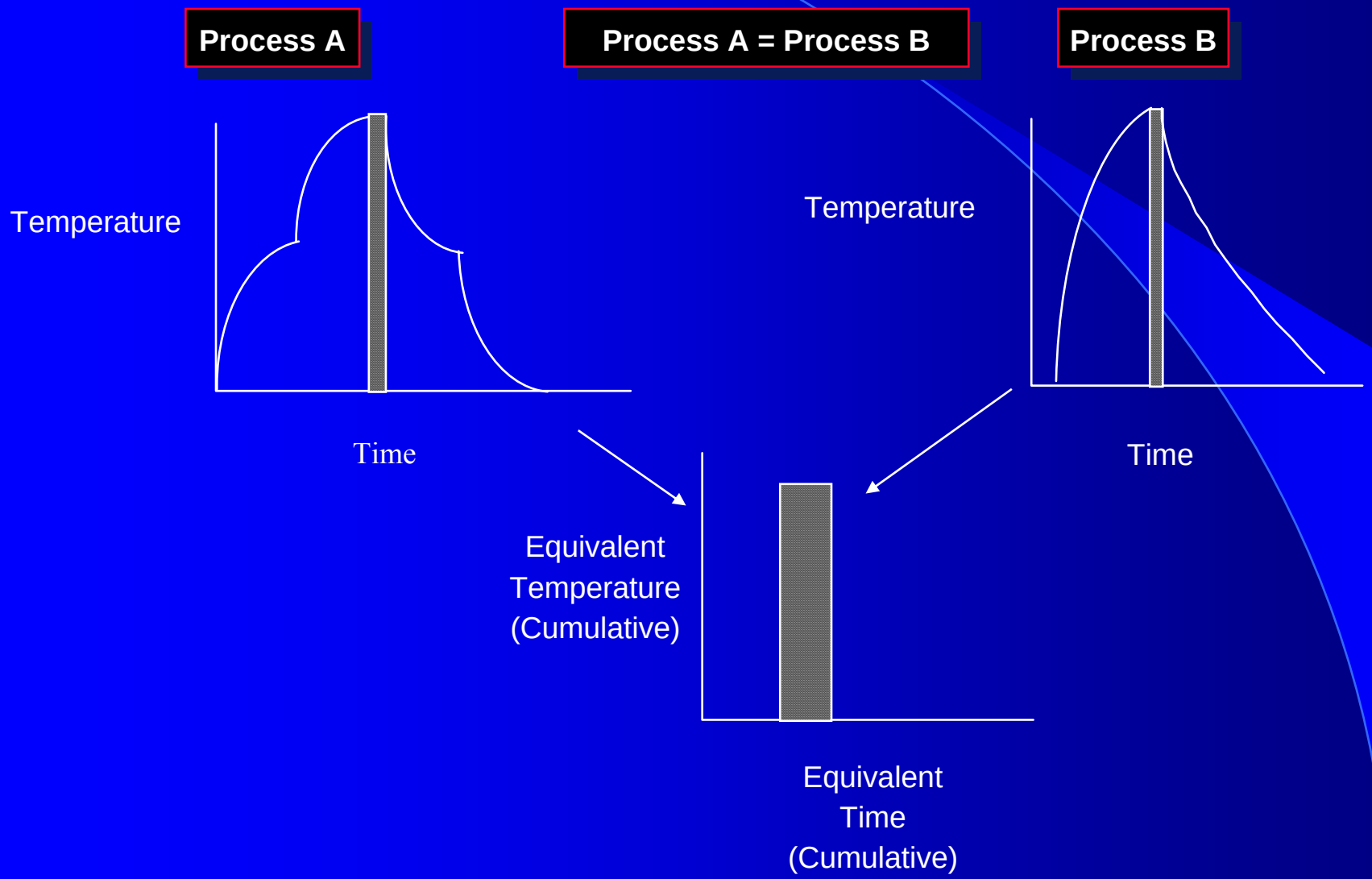
Equivalent Point Description



Equivalent Points

EP's include heating holding and cooling.

Equivalent Point Use



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Summary

- Always create TTH's!
- Identify the most critical steps.
- Put the detailed attention into those steps.
- Understand where your match is weak!
- Don't be afraid to use a new method!

In Closing

- Each year we step forward from what we discovered before and find the next most critical detail.
- Then we learned how to use it.
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Thank You

- Further Questions Or Information:
- Contact: MicroThermics
  - John Miles, President
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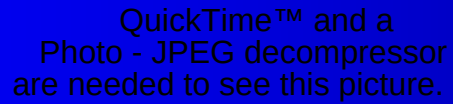

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