Intelligent Technologies for EAF Optimization

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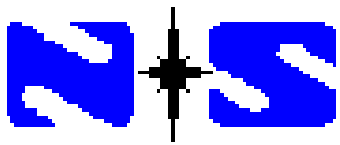

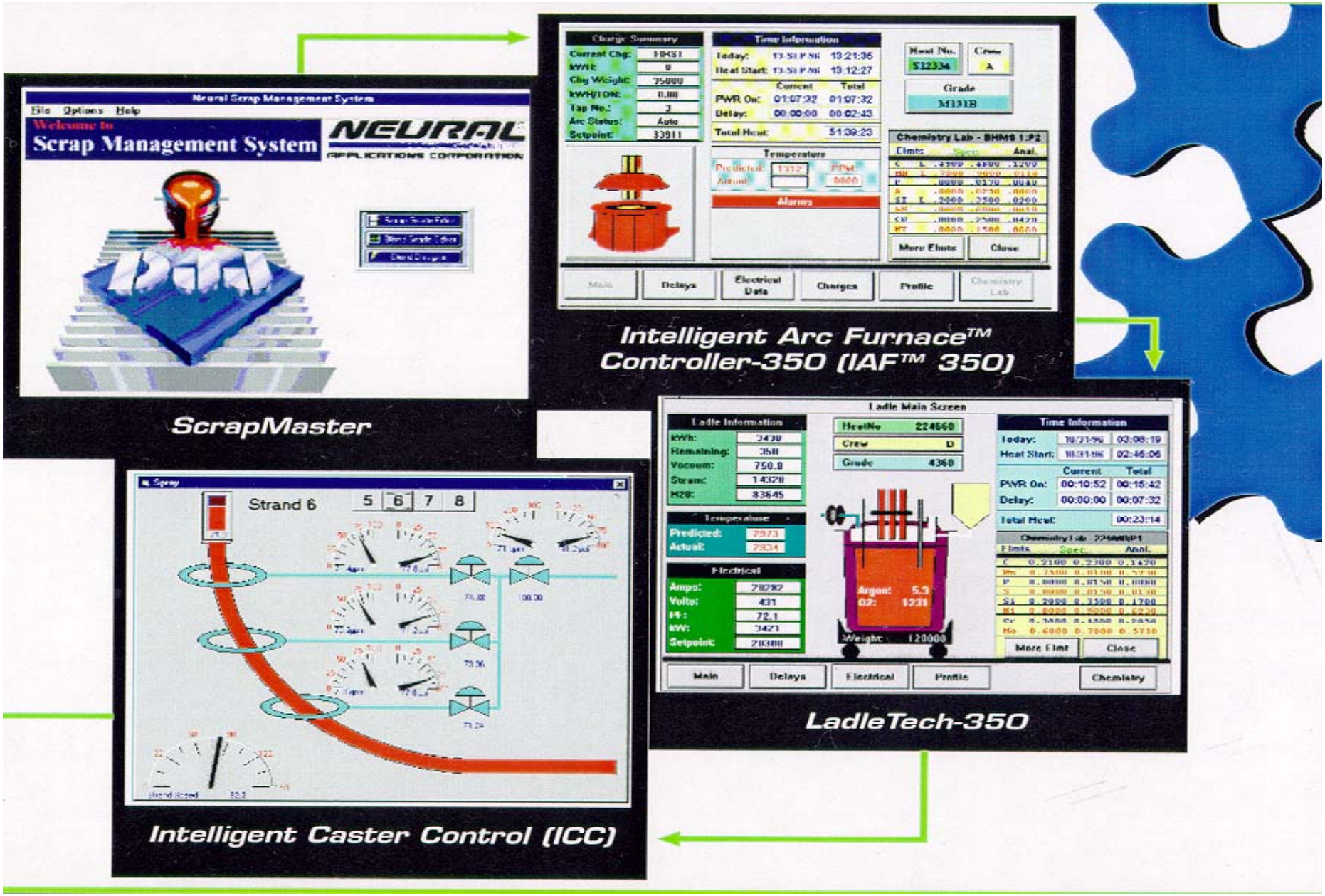

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Introduction

- Two research projects
- Furnace (process) optimization
  - total energy optimization at NSS-MN
  - technology ==> IAF®
- Scrap (raw materials) optimization
  - online identification of material properties
  - technology ==> ScrapMaster (ChemMaster)

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Outline

- Furnace optimization
  - Goals
  - Offgas analysis
  - Integrated electrical/chemical optimization
  - Intelligent control
- Scrap optimization
  - ScrapMaster
  - Linear programming recipe optimization
  - Identification of material properties
- Intelligent system development

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Furnace Optimization - goals

- Total energy optimization - Optimal coordination and control of all major energy sources (arc, lance O_2, PC O_2, Carbon, gas)
  - User-defined optimization goals (energy, electrode consumption, time, …)
- Electrode regulation, foamy slag control
- Level 2 control system - database, control, HMI, web-based reporting

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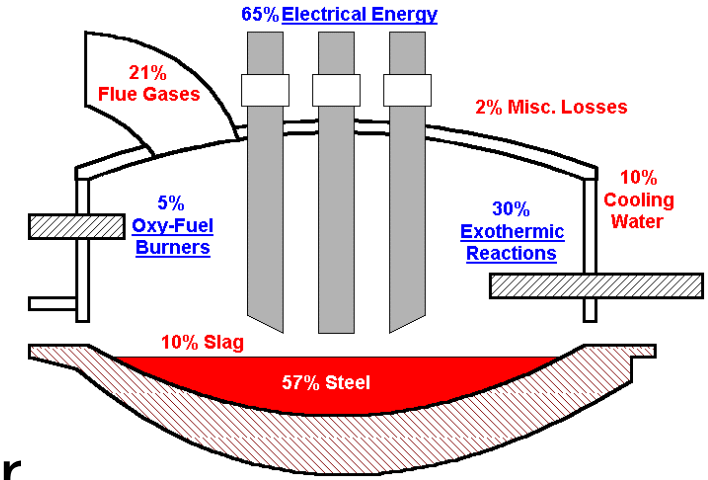
Offgas Analysis

- Required for development of chemical energy control
- Applied Automation analyzer/probe
- Difficult environment for monitoring
  - probe location - accuracy vs. maintenance
  - Extraction of information from data
- Permanent ==> real-time feedback vs. temporary installation ==> periodic tuning



* energy percentages from Vonesh and Perrin, 1995

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Post Combustion

- CO in offgas represents latent chemical energy
- It may be possible to recover some of this energy
  - PC O2 injection, heat transfer to steel

[Fe] + [O] = (FeO)

[C] + [O] = (CO)

[Si] + 2[O] = (SiO_2)

[Mn] + [O] = (MnO)

2 [P] + 5 [O] = (P_2O_5)

$$C + \frac{1}{2} O_2 = CO, \qquad \Delta H = -110.6\, kJ / mole$$

$$CO + \frac{1}{2} O_2 = CO_2, \qquad \Delta H = -282.1\, kJ / mole$$

$$Post\ Combustion\ Ratio = \frac{\%\ CO}{\left(\%\ CO + \%\ CO_2\right)}$$

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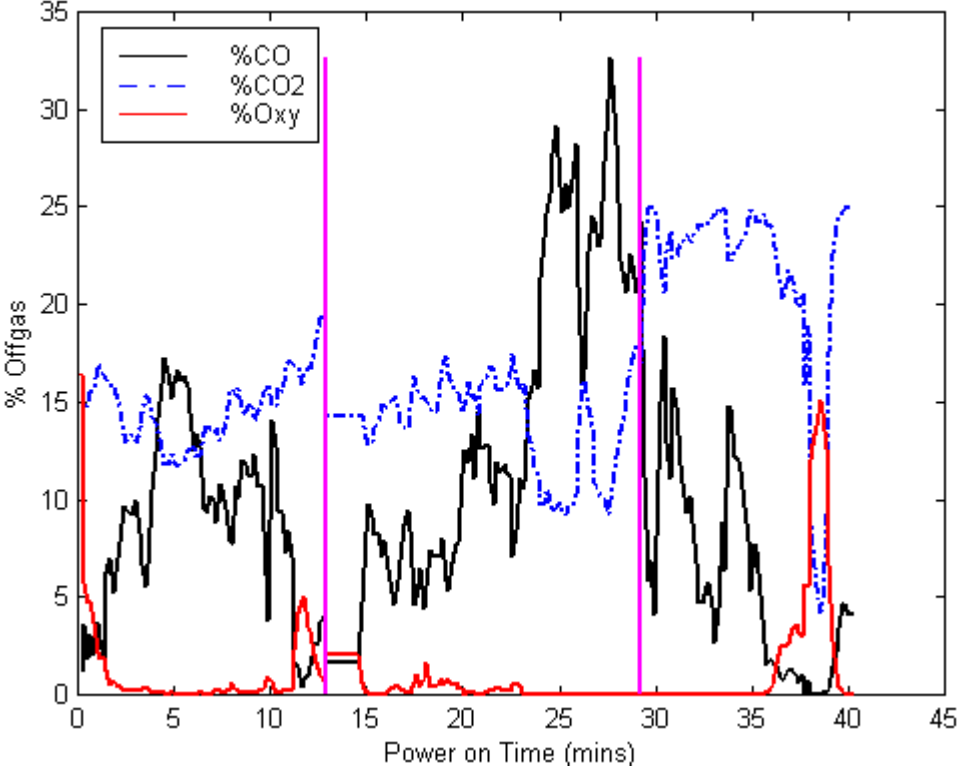
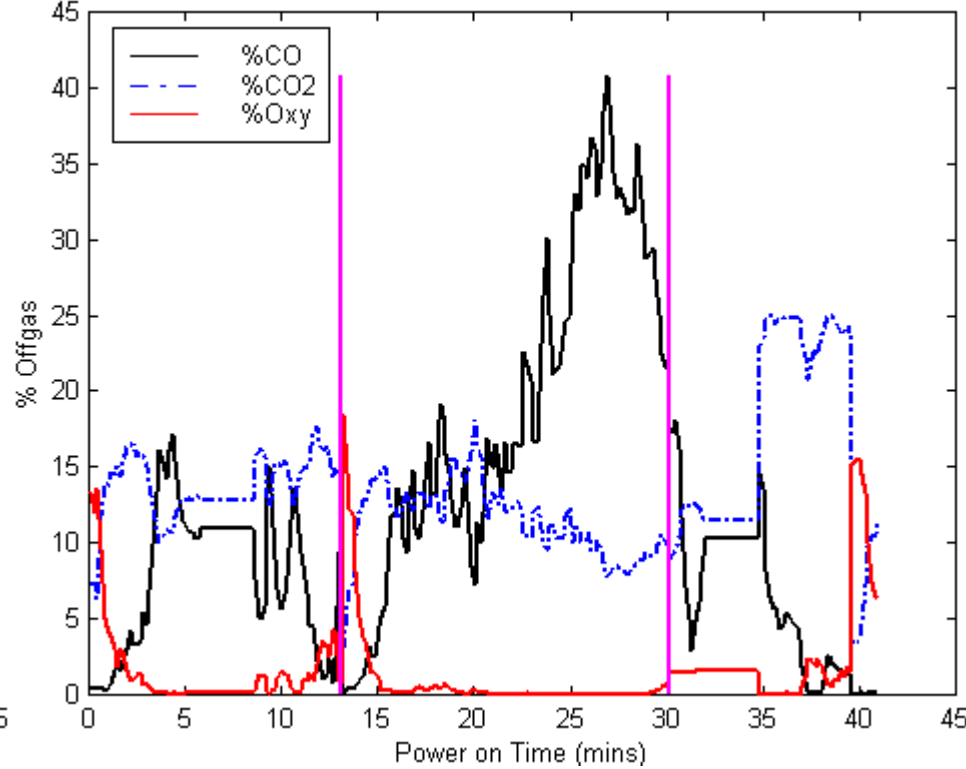

%CO
%CO2
%Oxy
% Offgas
Power on Time (mins)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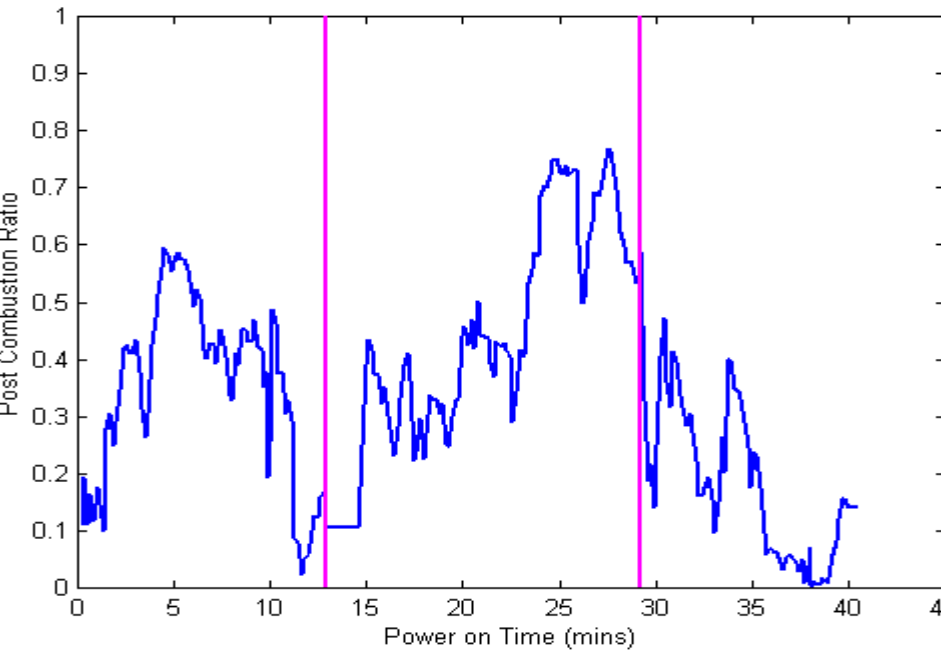
Post Combustion Ratio
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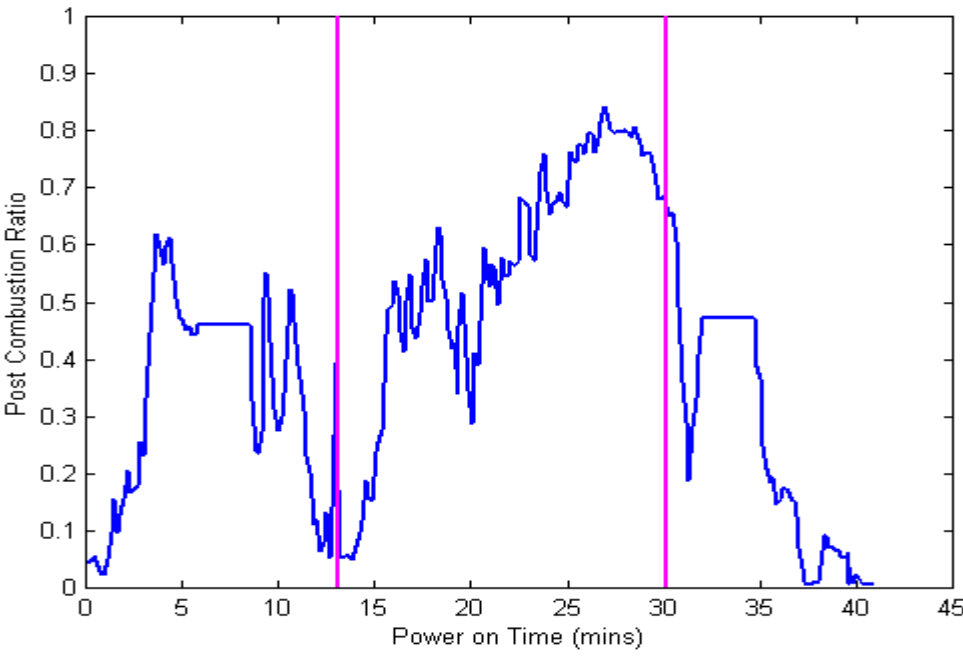
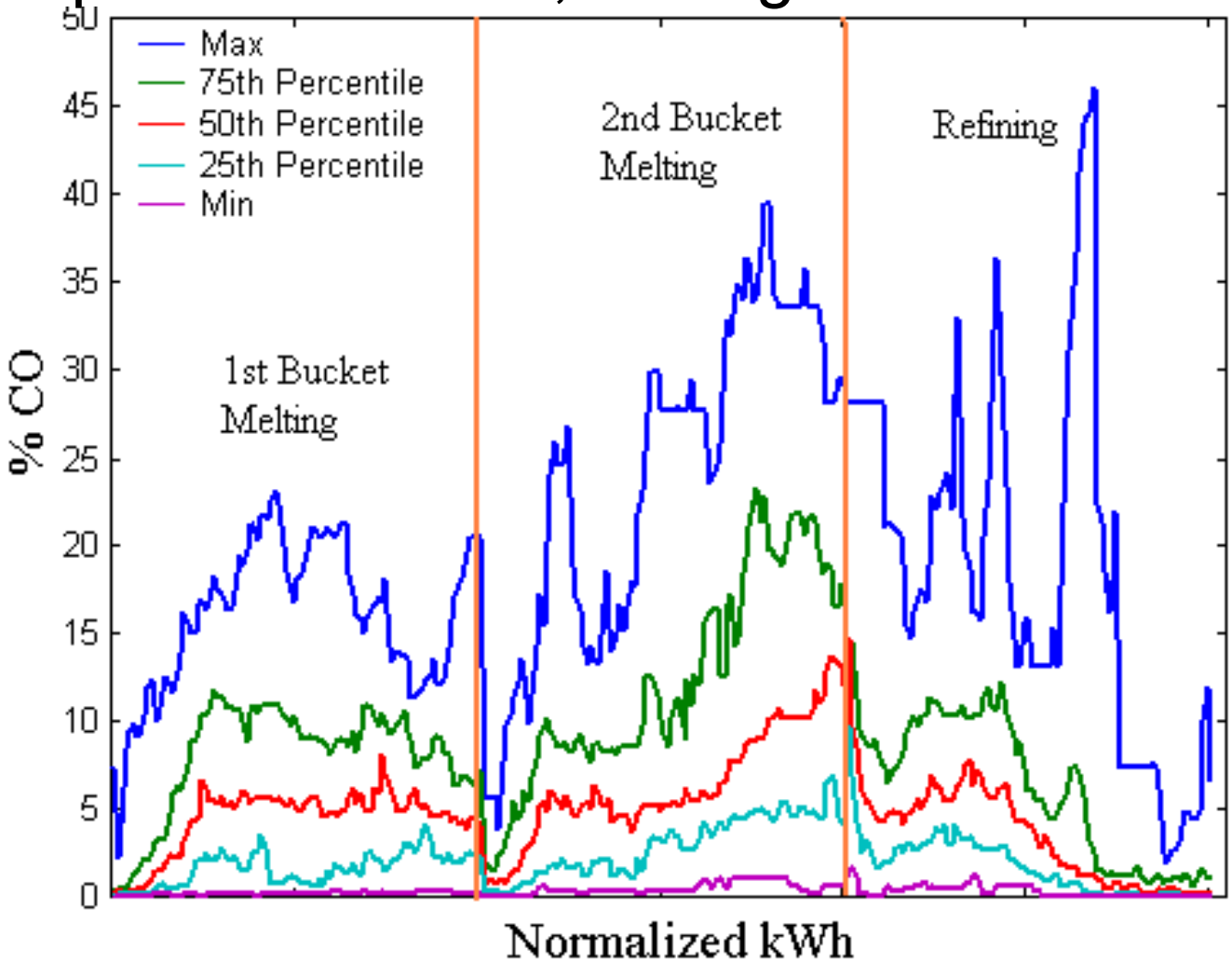
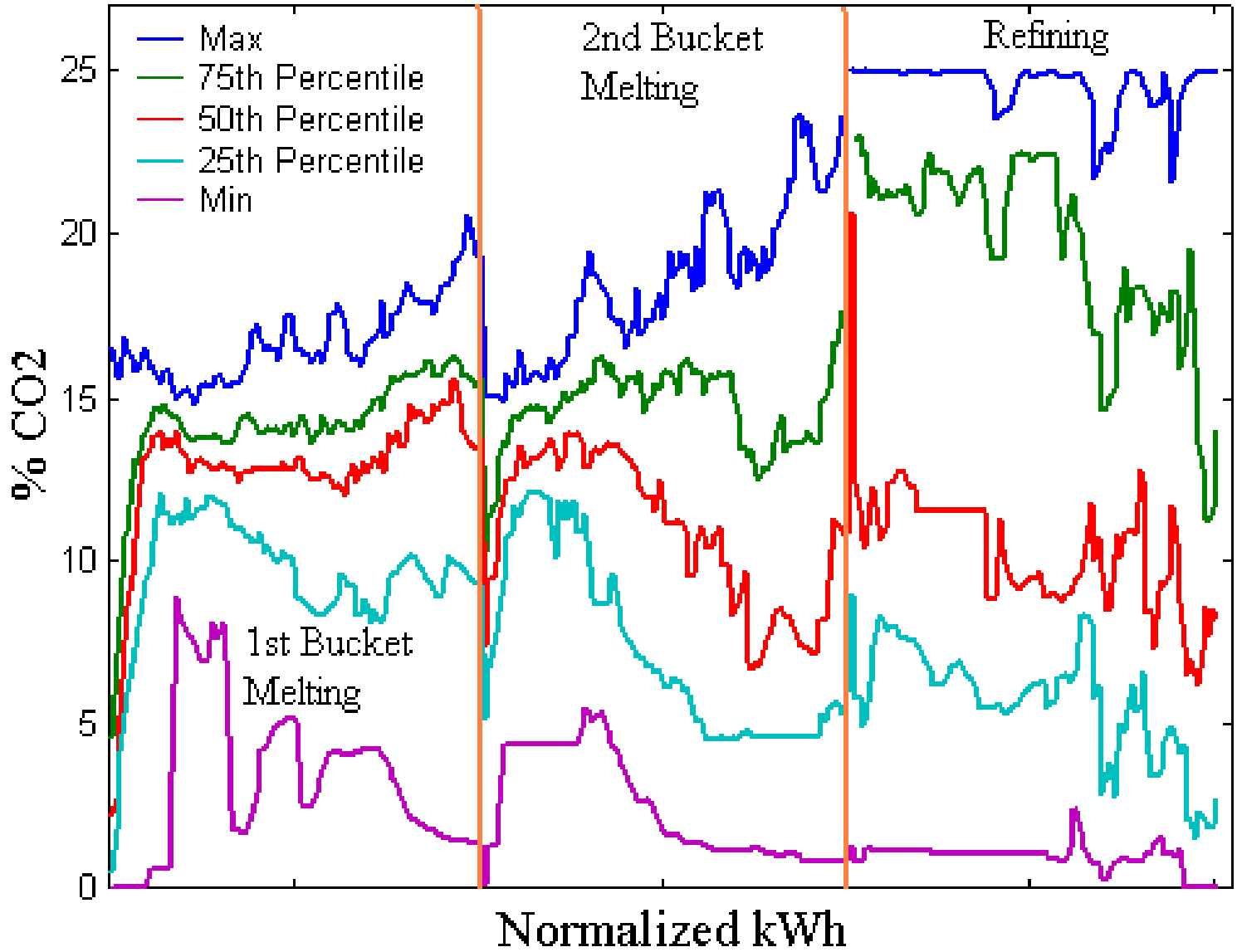

Post Combustion Ratio
Power on Time (mins)

Offgas Data Repeatability

- Repeatable trends, but significant variation





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Electrode Regulation, etc.

- Electrode regulation ==> increase arc stability
- Foamy control ==> improve heat transfer to melt, reduce furnace wear, electrode consumption
- Uses high-speed data acquisition system
- DC and AC furnaces
- Intelligent electrode control
  - Similar to Neural regulator in IAF ®
  - Combination of intelligent, optimal, and classical control technologies

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Integrated Control System Synergy

- Synergy - interaction of two or more agents so that their combined effect is greater than the sum of their individual effects.
- Optimizing electrical and chemical inputs depends on the furnace state, and therefore eachother
- Synergies in optimization of:
  - Electrode regulation
  - Electrical setpoints
  - Foamy slag control
  - Oxygen, carbon, gas setpoints, regulation
  - Raw materials (ScrapMaster)
- Complexity ==> intelligent technologies

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Furnace (Process) Optimization Summary

- Total energy optimization - synergy
- Offgas analysis
- Prototype development through 10/99
- Technologies integrated into Neural's Intelligent Arc Furnace controller

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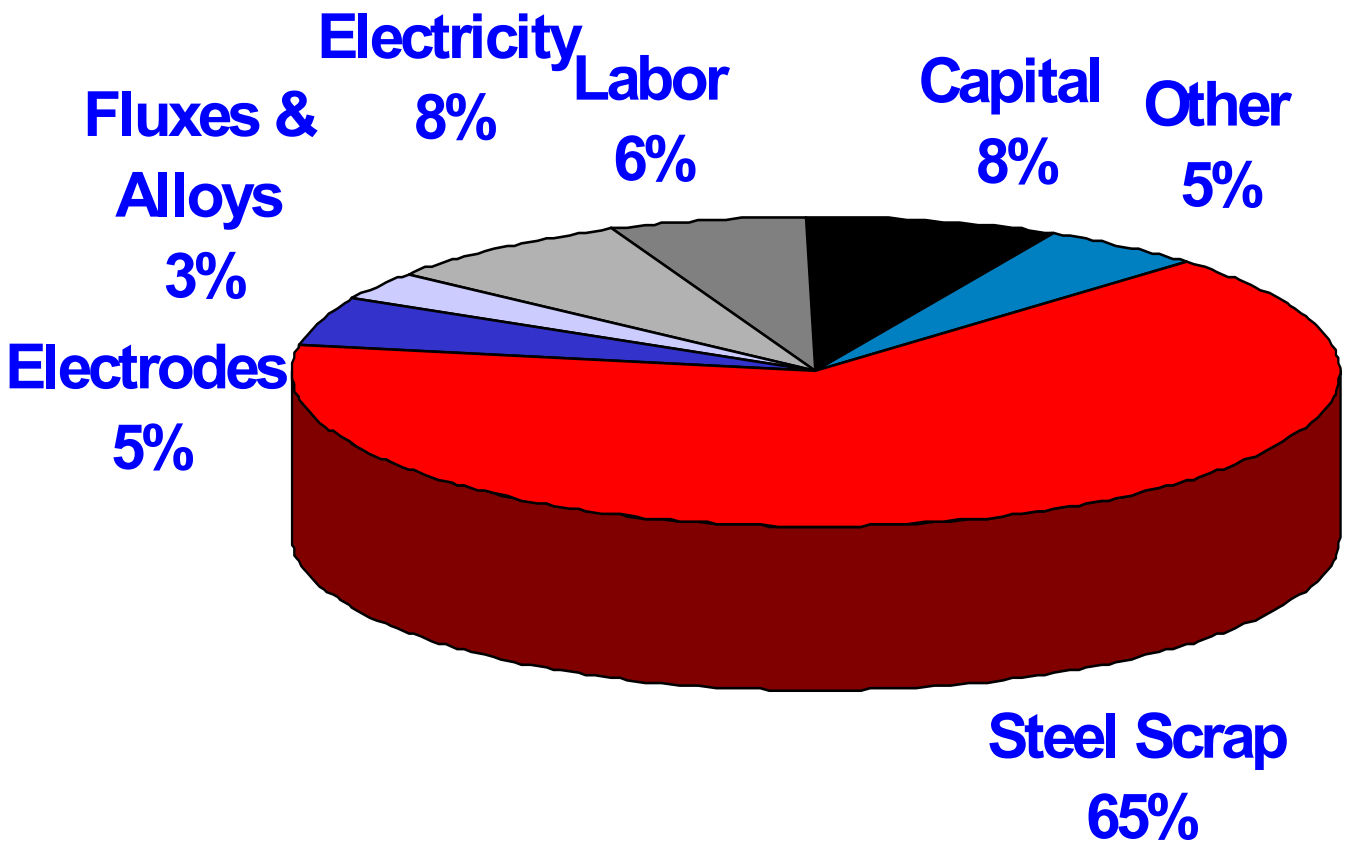
Scrap Optimization

- Electric furnace steelmaking costs



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Requirements for Scrap Management

- Accurate base of scrap properties data
- Accurate inventory data
- Accurate recipe tracking
- Tracking and feedback of operational data
- Attention to detail

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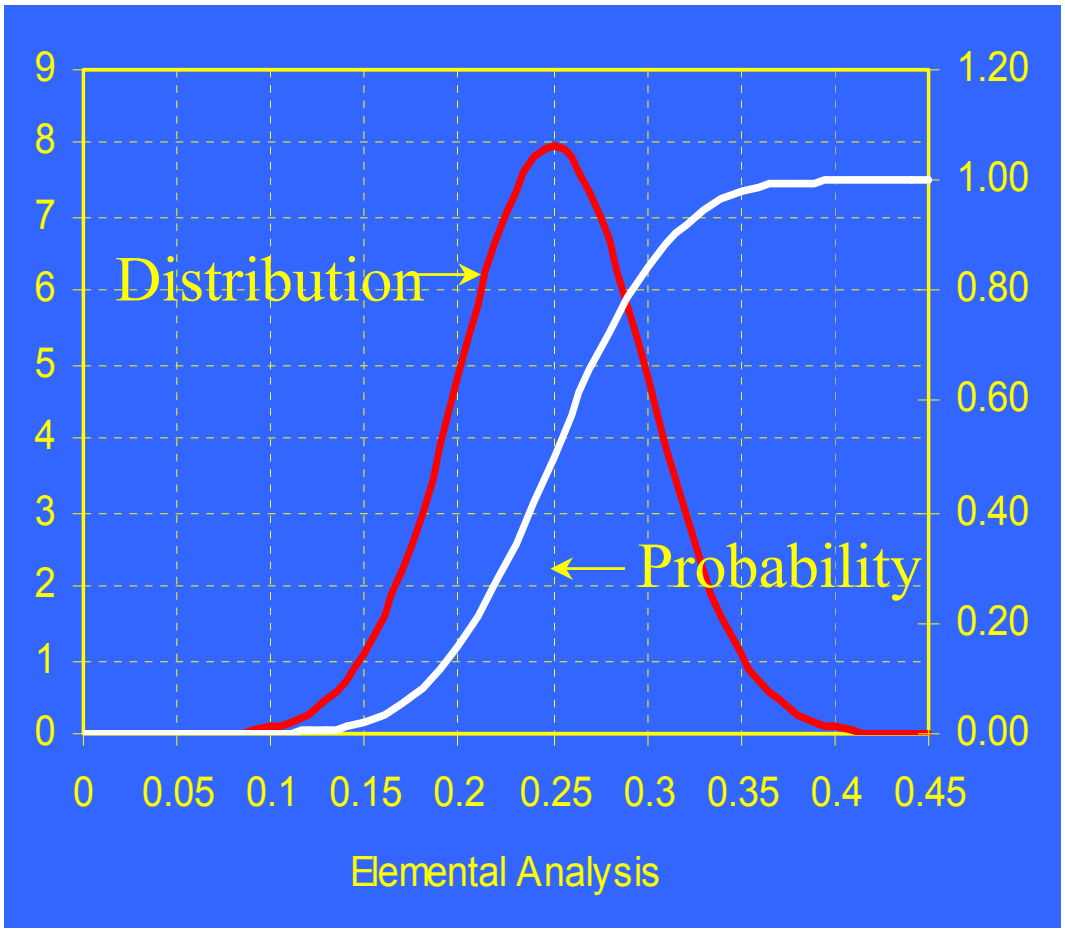
Charge Optimization

- Least cost based on metal produced
- Allow for the variability of scrap analysis
- Design for specific heats
- Integrated with furnace operation
- Must be simple to use
- Linear programming-based optimization

Analysis Variance



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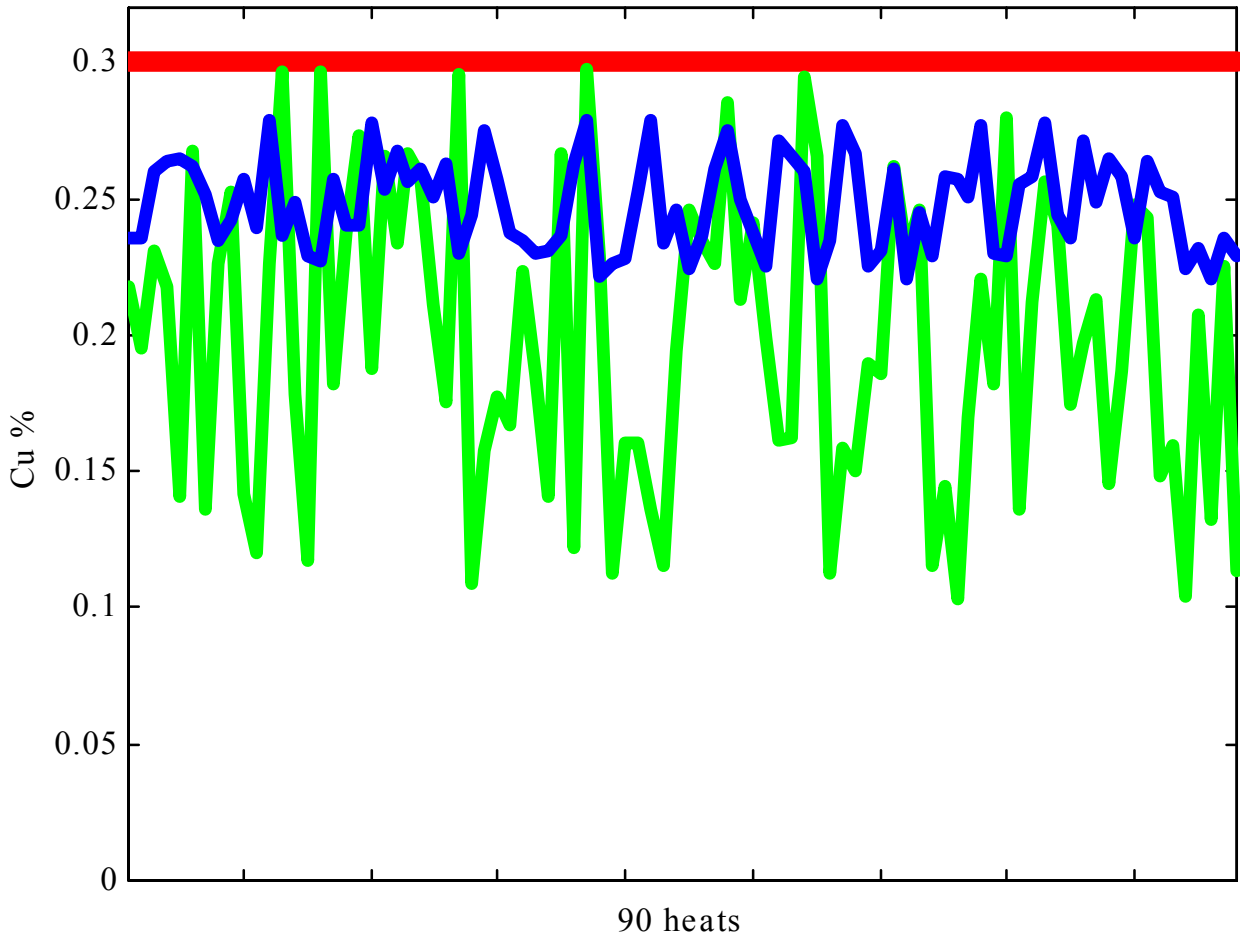
0.30 Max Copper Heats



Max. = 0.30

Avg.=0.25

Avg. = 0.20

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Intelligent Determination of Scrap Properties

- Neural Network feedback of actual furnace results to Inventory DB
- Identifies property variance from DB values
  - Residual chemical elements
  - Energy requirements
  - Melt productivity
- Vendor accountability

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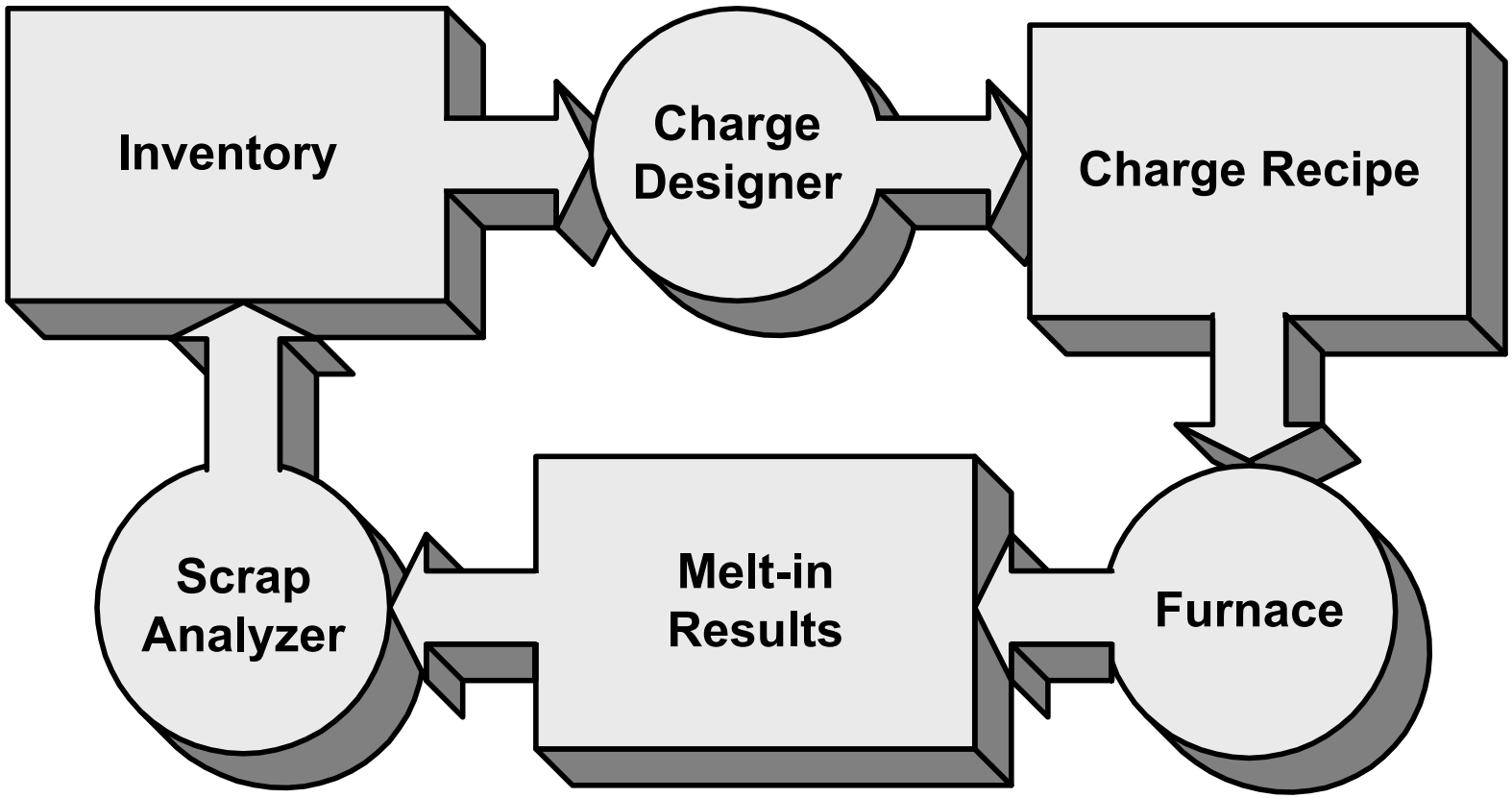
Intelligent Data Generation



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Intelligent System Development

- Use the right tool for the job
- Data validation important - higher level of autonomy depends on data

1. Data collection and management
2. Baseline level of control optimization

   Classical, optimal control
3. Intelligent control where beneficial

   (reduces “black box” problem with NNs)

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