Manufacturing FUNDAMENTALS

VARIATIONS AND THE EFFECTS ON FURNACE OPERATIONS, PRODUCTION AND FURNACE LIFE

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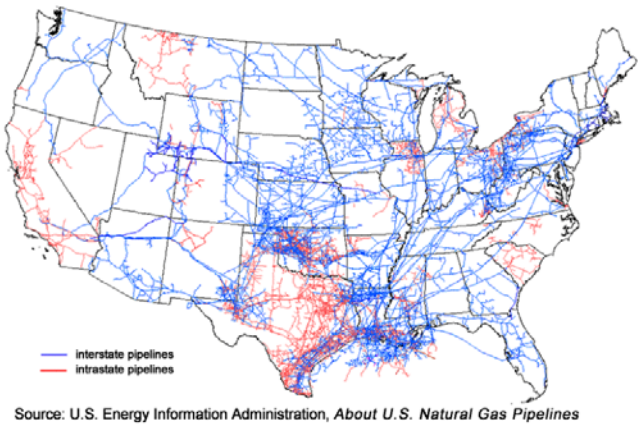
NATURAL GAS HEAT VALUE VARIATION

Variations in Natural Gas Heat Value

- Increased Mobility of Natural Gas
  - Increases in regional pipelines being built
  - Intercontinental pipelines
  - Liquid Natural Gas being transported across oceans
- Positives of Increased Mobility of Natural Gas
  - Increased reliability of fuel source
  - Access to open market
  - Lower costs of Natural Gas
  - Lower carbon footprint vs oil
- Negatives of Increased Mobility of Natural Gas
  - Abrupt heat value of the Natural Gas
  - Multiple changes throughout the day
  - Suppliers increasing air content to meet an average daily heat value

Map of U.S. interstate and intrastate natural gas pipelines



Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

1. Natural Gas Heat Value Variation
   a) 1% variation over the last 24 hour
   b) 7.5% variation over the last 20 days
   c) 9.7% variation over the last 40 days
   d) Largest variation in last 40 days –
      6.2% over 8 hours

Variations in Natural Gas Heat Value

- Options to decrease impact of Natural Gas Heat Value Variations
  - **Calorimeter**
    - Fast acting
    - Does not correct for change in gas density

      Flow meters will not read properly under large changes
    - Normally operating with upper structure temperature readings.

  - Flow controlled by valves ✓
  - Zero governor flow control ✗

Variations in Natural Gas Heat Value

- Options to decrease impact of Natural Gas Heat Value Variations
  - **Wobbe Index Compensation**
    - o Compensates for changes in heat value
      - Propane addition
      - Compressed air addition
    - o Normally correct to a lower heat value using compressed air
      - Decreased efficiency
      - Compressed air is typically the most expensive energy source
      - Increased NO_X
  - Flow controlled by valves ✓
  - Zero governor flow control ✓

Variations in Natural Gas Heat Value

- Options to decrease impact of Natural Gas Heat Value Variations
  - **Gas Chromatography**
    - Gas composition is known
    - Correction in gas flow can be made
    - Better efficiency
    - Not an contributor to NO_X
  - Flow controlled by valves ✓
  - Zero governor flow control ✗

Variations in Natural Gas Heat Value

- Impacts to Production
  - Glass quality impact
    - Batch stones
    - Blisters
    - Seeds
  - Conditioning issues
    - “Wrecked Machines” – Temperature Variations

Variations in Natural Gas Heat Value

- Impacts to Furnace Life
  - Melter upper structure damage
  - Regenerator upper structure damage
  - Checker damage
  - Rider Arch damage

EXCESS OXYGEN MEASUREMENT AND CONTROL

Variations in Oxygen during Firing (Excess Oxygen)

- Changes in excess oxygen
  - Spring/Autumn and Day/Night effect
  - Variation in fuel heat value
  - Damaged/Faulty equipment
    - Open melter
    - Faulty Analytical
- Technologies available
  - Zirconia
  - Sampling technology
  - Laser Spectrum Chromatography

Excess Oxygen Measurement and Control

- **Zirconia probes**
  - Sintered zirconia probes placed in regenerator or flue atmosphere
- Positives
  - Established technology
  - Generally considered reliable
- Negatives
  - Mounting location important to life of probe
  - Atmosphere can shorten life
  - Prone to damage from batch carry-over

Excess Oxygen Measurement and Control

- **Sampling technology**
  - Atmosphere pulled from regenerator or flue for inline analysis
- Positives
  - Generally long life
- Negatives
  - Not continuous
  - Lag time between sampling and results
  - Prone to plugging from batch carry-over or sulfate build-up

Excess Oxygen Measurement and Control

- **Laser Spectrum Chromatography**
  - Spectral analysis
- Positives
  - Proven technology outside of glass
  - Generally long life
  - Large range of compounds
    - O_2
    - CO
    - CO_2
    - NO_X
    - SO_2
  - Immediate feedback
- Negatives
  - Historically expensive technology

Variations in Excess Oxygen

- Impacts to Production
  - Glass quality impact
    - Batch stones
    - Blisters
    - Seeds
  - Emissions
    - NOx
    - SO2
    - Particulate
    - CO

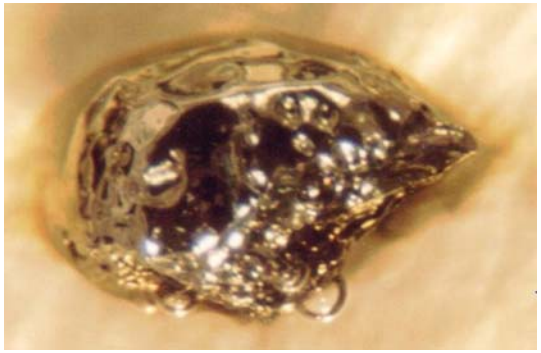
Variations in Excess Oxygen

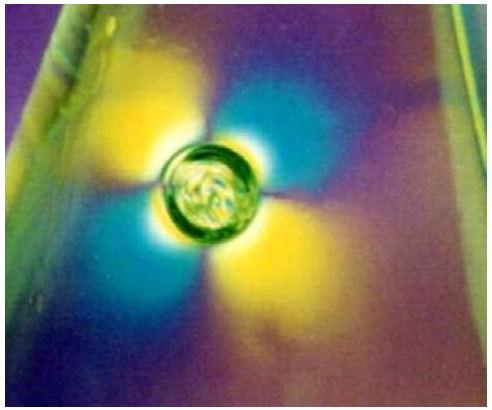
- Impacts to Furnace Life
  - Upper structure damage
  - Regenerator upper structure damage
  - Checker damage
  - Rider Arch damage

CULLET QUALITY

Cullet Quality

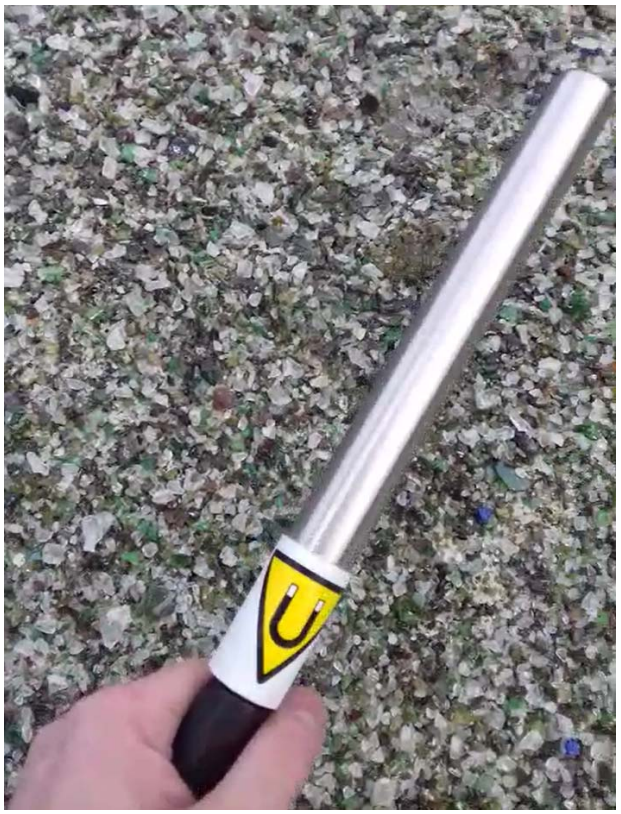
- Contamination
  - Ceramics
  - Glass Ceramics
  - Magnetic Metal
  - Non-Magnetic Metals
  - Organics
  - Heavy Metals
  - Medical Waste





Cullet Quality

- Source – External cullet
  - Sometimes clean cullet is not clean



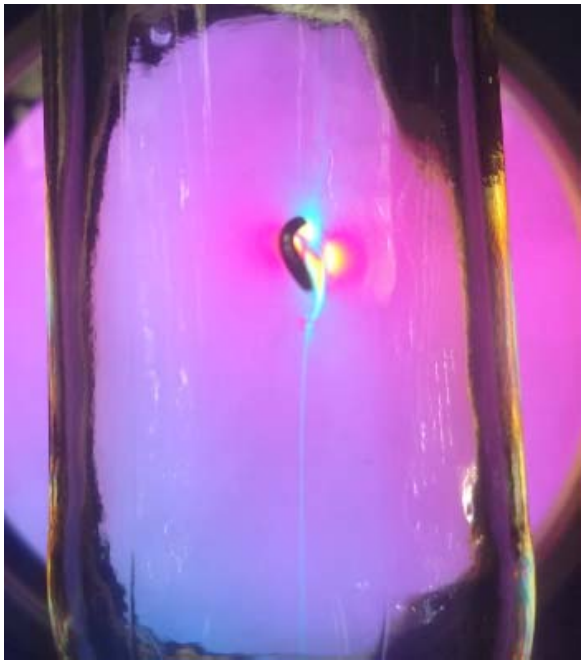
Cullet Quality

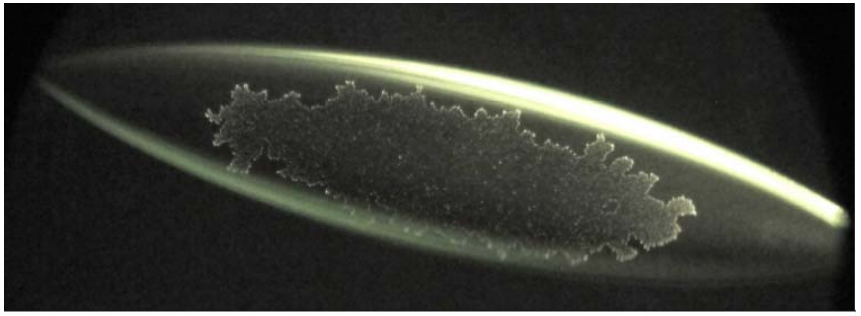
- Source - Internal
  - We are our own worst enemy
  - Maintenance
  - Cleaning crews

- Education is the strongest deterrent
- Magnets
- Non-magnetic detection

Cullet Quality

- Impacts to Production
  - Glass quality
    - o High stress stones
    - o Visual stones
    - o Blisters
    - o Glass color
      - Colorants
      - Redox
    - o Composition
  - Emissions
    - o SO2
    - o Particulate
    - o CO
  - Governmental regulation
    - o Lead
    - o Cadmium





Cullet Quality

- Impacts to Furnace Life
  - Floor
  - Bottom electrodes
  - Areas around bubblers
  - Throat
  - Refiner and forehearth bottoms

Thank-you

- Any Questions?
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