See degrees differently.

# Revolutionizing Glass Furnace Operations with AI-Enhanced AMETEK LAND Image Pro Software combined with NIRB- 2K thermal imaging

Philippe Kerbois – Global Industry Manager – Metals and Glass

Glassman – May 2025 – Istanbul

# Short Introduction

- Global Industry Manager - Glass

- Philippe has extensive sales and project management experience from working in the steel, glass and automotive industries including Rockwell Automation and ABB where he was specifically involved in major robot-based factory automation projects.
- Having worked at AMETEK Land since 2012, Philippe initially managed the sales of infrared temperature measurement solutions into line builders and glass and steel furnace OEMs within France, however now he works very closely with the global glass market and is actively promoting the award-winning Near Infrared Borescope (NIR-B) Glass thermal imaging solution for glass furnaces.

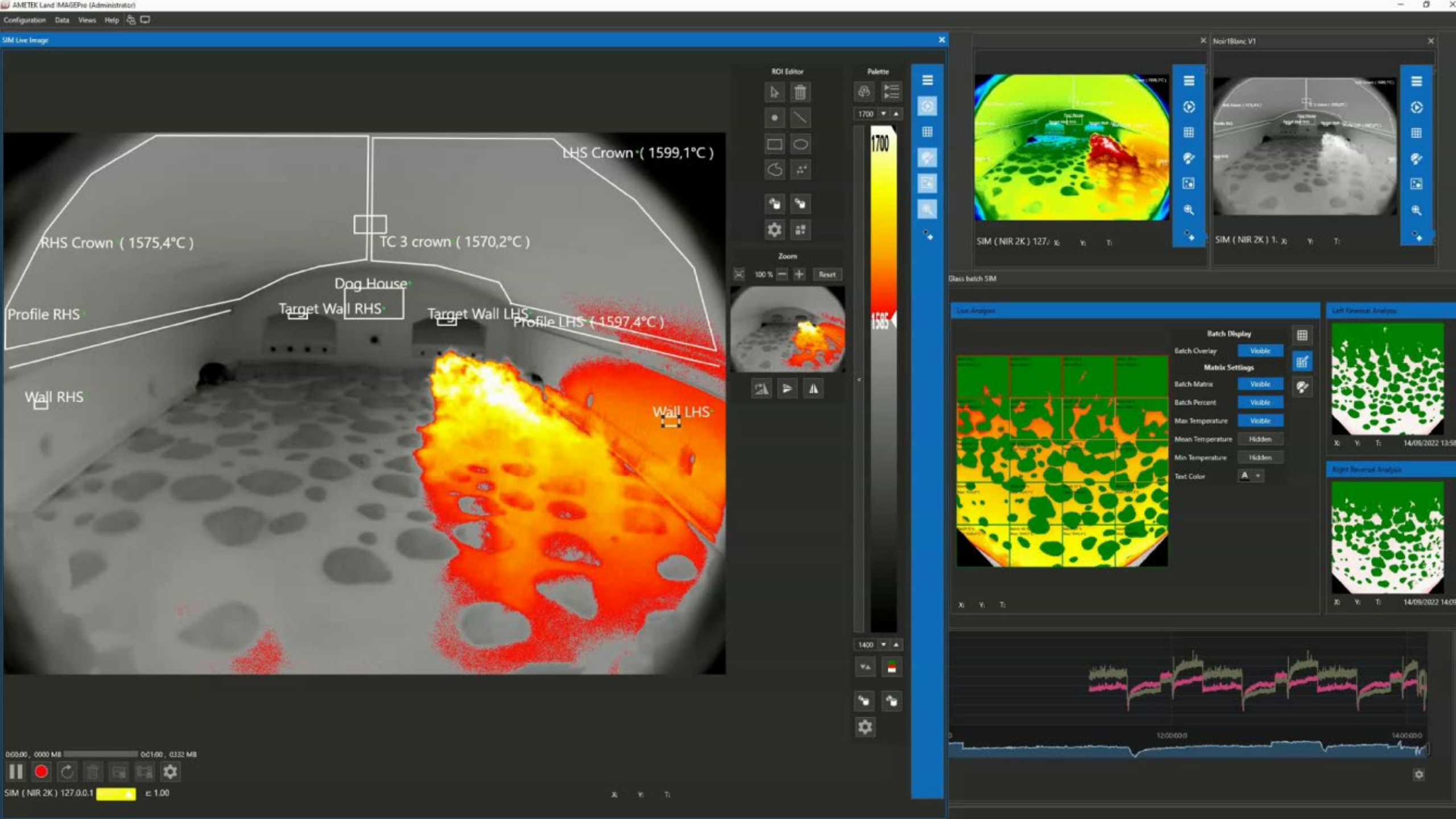

- philippe.kerbois@ametek.com
- +33 (0) 6.75.38.39.87


# LAND portfolio – complete temperature offering

- Leverage demand for the NIR-B borescope to promote a wider portfolio packages including :
- The Fiber Optics “Legend FG” for forehearth and furnaces
- Lancom 4 Gas analyser
- FLTs and LSPHDs for thin bath and Lehrs
- LWIR 640 cameras for glass leak detection and refractory monitoring ( Regens )
- As installation becomes more critical – possible to integrate and provide AMEcare
  - Advanced Services into the offering
- Thermal Surveys with NIR-B-2Kdemonstrating benefits of NIR-B
- More than 200 NIR-Bs implemented Worldwide in major producers in the Glass industry


AMECARE PERFORMANCE SERVICES

See degrees differently.


AMETEK Land IMAGEPro (Administrator)
Configuration
Data
Views
Help
SIM Live Image
LHS Crown ( 1599,1°C )
RHS Crown ( 1575,4°C )
TC 3 crown ( 1570,2°C )
Dog House
Target Wall RHS
Target Wall LHS
Profile RHS
Profile LHS ( 1597,4°C )
Wall RHS
Wall LHS
ROI Editor
Palette
Zoom
100 %
Reset
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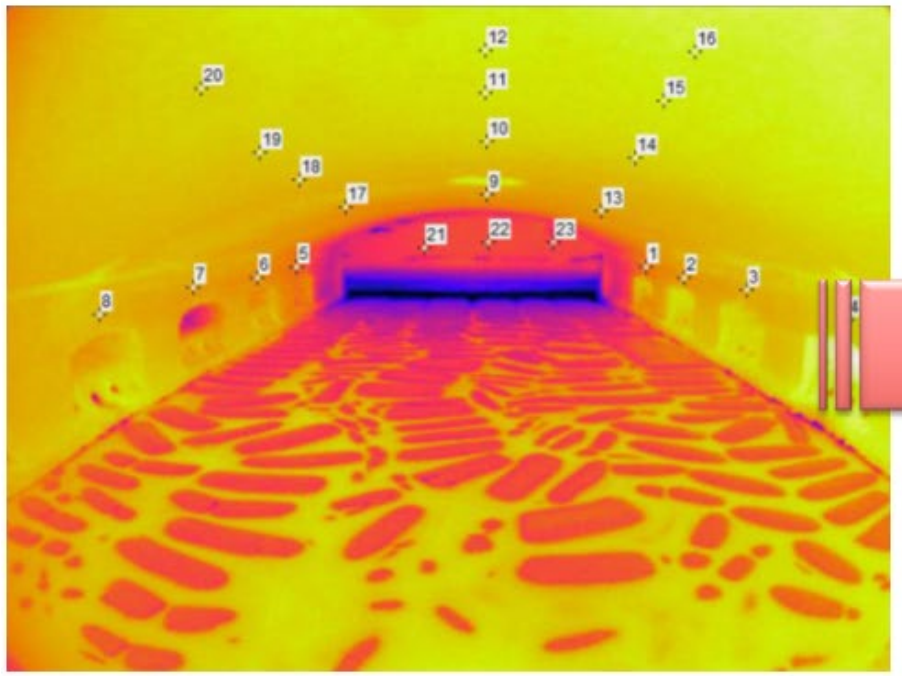
Glass batch SIM
Live Analysis
Batch Display
Batch Overlay
Visible
Matrix Settings
Batch Matrix
Visible
Batch Percent
Visible
Max Temperature
Visible
Mean Temperature
Hidden
Min Temperature
Hidden
Text Color
Left Reversal Analysis
Right Reversal Analysis
14/09/2022 13:58
14/09/2022 14:09

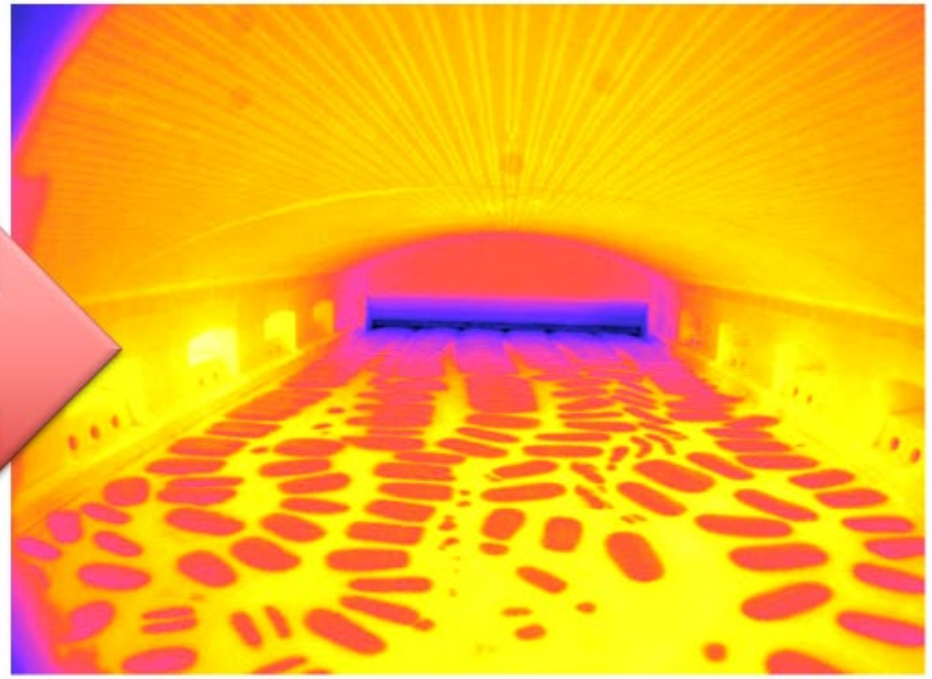
# Introducing NIR-B-2K HD

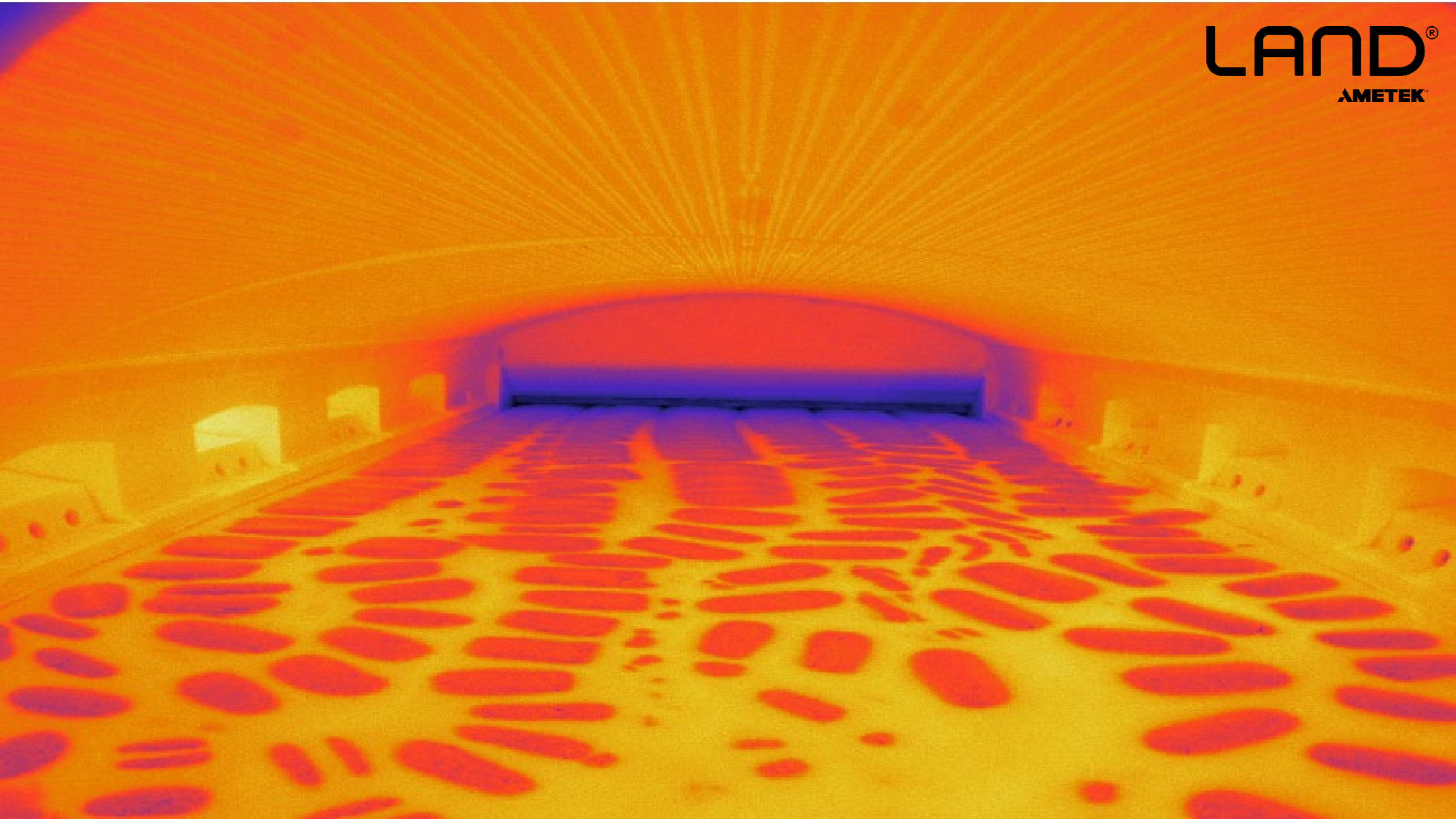
**NIR-B (GLASS)**
656x494 Pix = **324.064 PIXEL**

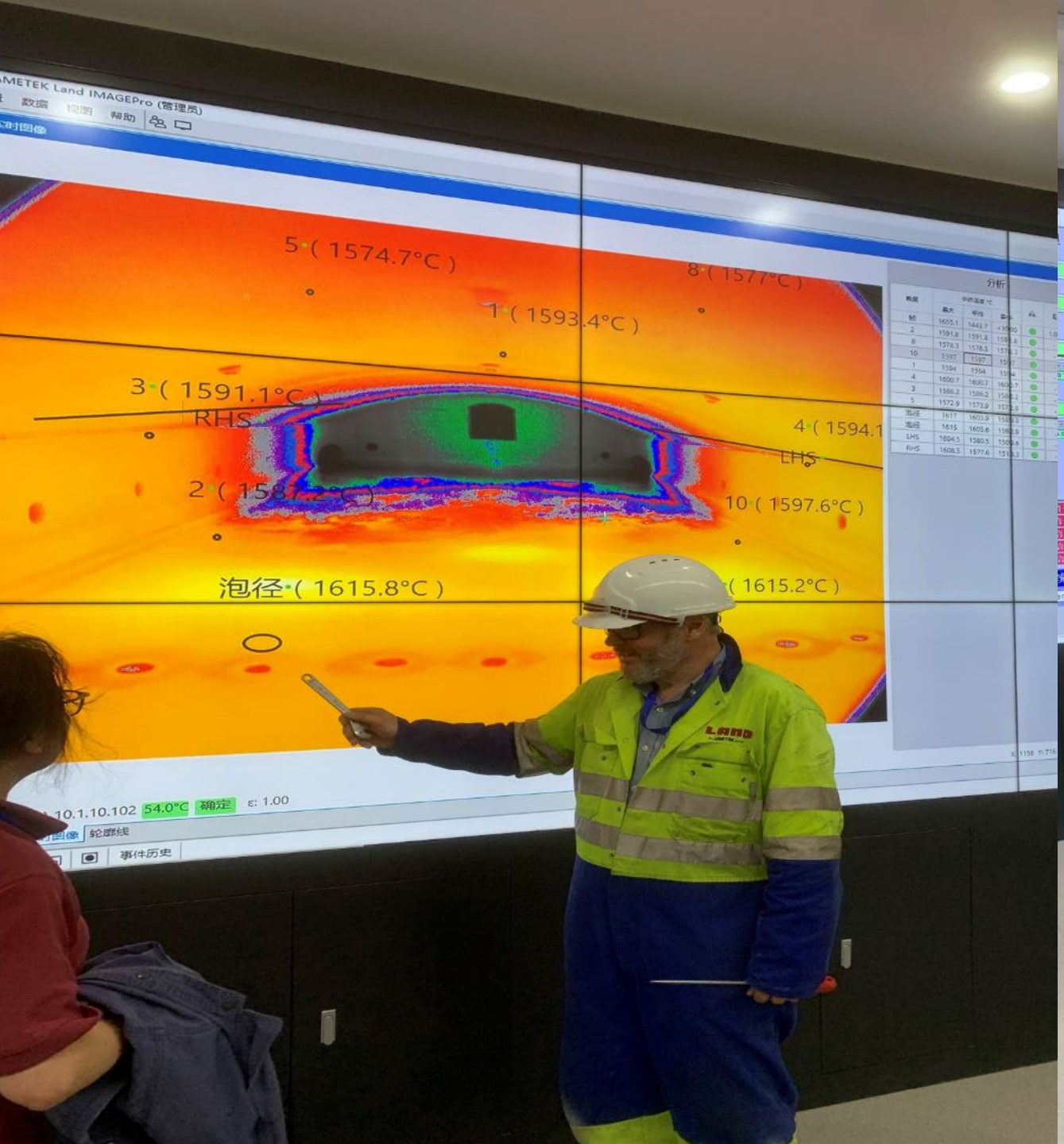



x10

**NIR-B-2K-95 (GLASS)**
2000x1500 Pix = **3 MIO PIXEL**



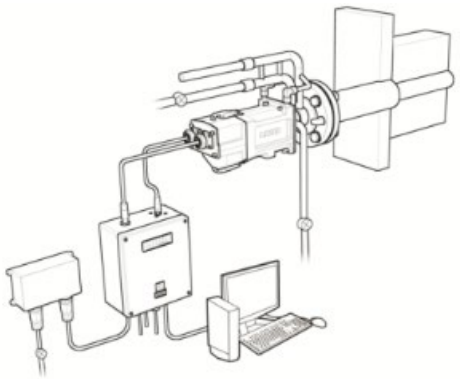

LAND®
AMETEK


AMETEK Land IMAGEPro (管理员)
5 ( 1574.7°C )
8 ( 1577°C )
1 ( 1593.4°C )
3 ( 1591.1°C )
RHS
4 ( 1594.1
LHS
2 ( 158
10 ( 1597.6°C )
泡径 ( 1615.8°C )
( 1615.2°C )
10.1.10.102
54.0°C
确定
ε: 1.00
事件历史


LAND
AMETEK
泡径 ( 1617.5°C )

# NIR-B-2K GLASS - 3 x possibilities

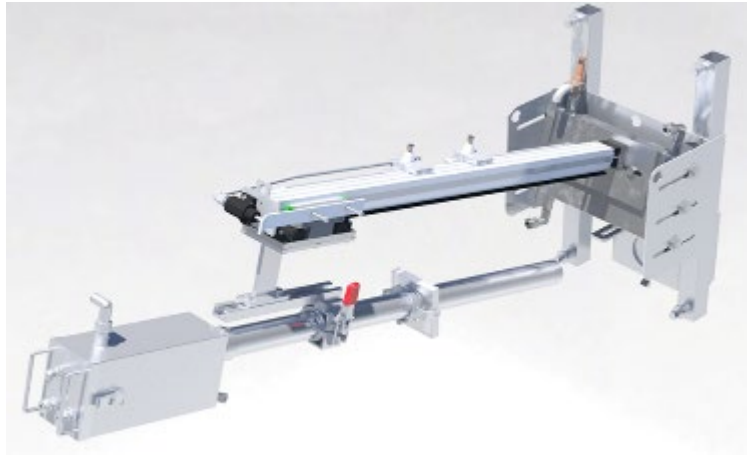
- NIR-B-GLASS-90-18-3-25 (50) –NR
- Stand alone version



- **NIR-B-2K-1000/1800C-95/3-25-LPARW-GLASS** Complete with Pneumatic auto retraction system – fixed Centerline location


* Recommended where airline pressure is below 6 bar.

**NIR-B-GLASS-90-18-3-25-PAR**
Complete with Pneumatic auto retraction system – fixed Centerline location



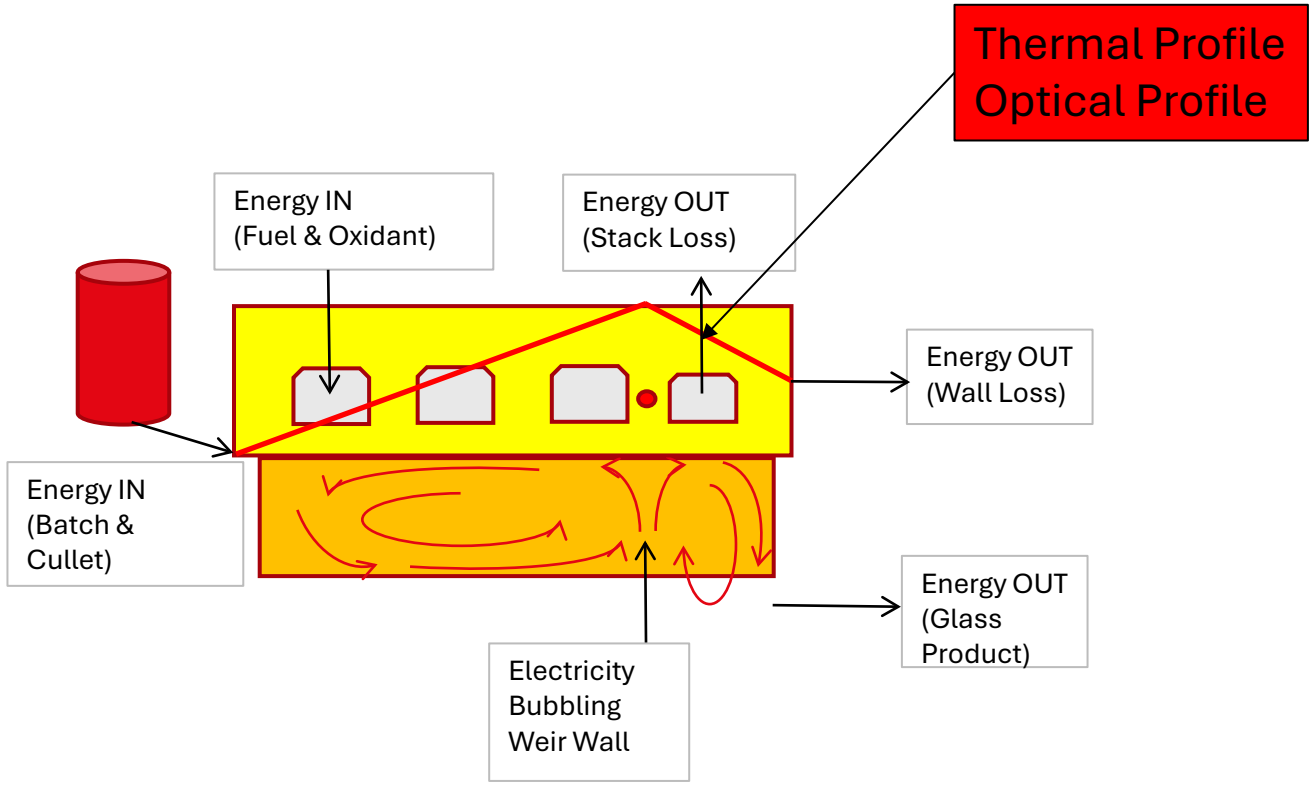
* Recommended for higher Ambient Temperatures

New LPAR EXTRACT

# The benefits in furnace operations
# “Not just a pretty image”

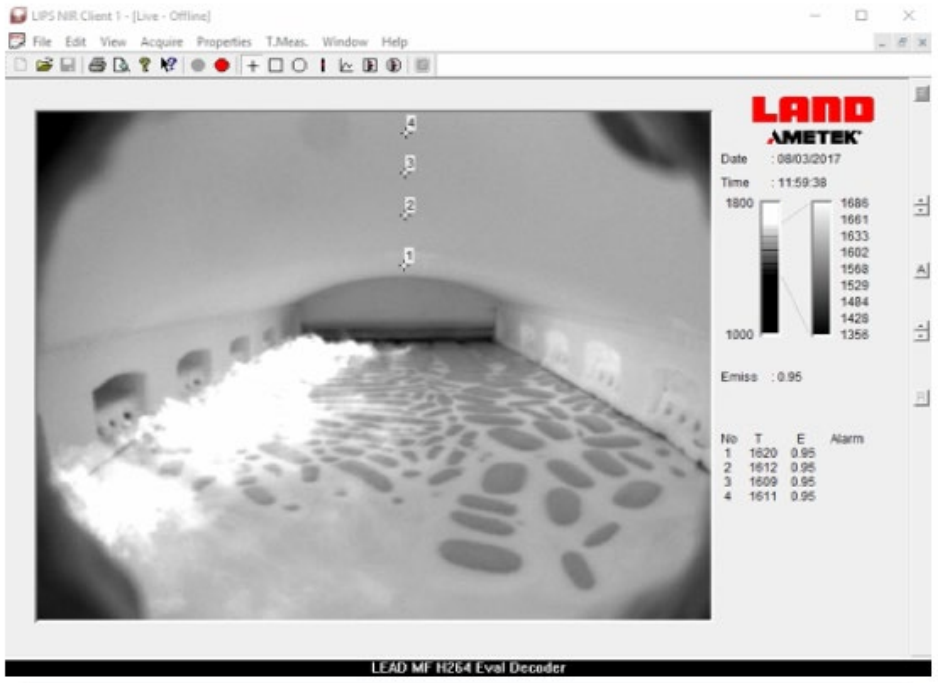
# Primary goals of melting => Energy & Emission

- Maintain Temperature Profile for Good Glass
- Use materials that are easier to melt
- Optimise wall losses (insulate) or increase pull to reduce%
- Reduce Stack losses through heat recovery
- Optimise Combustion and Heat Transfer
  - Note: Glass furnaces do not use PID control- typically manual

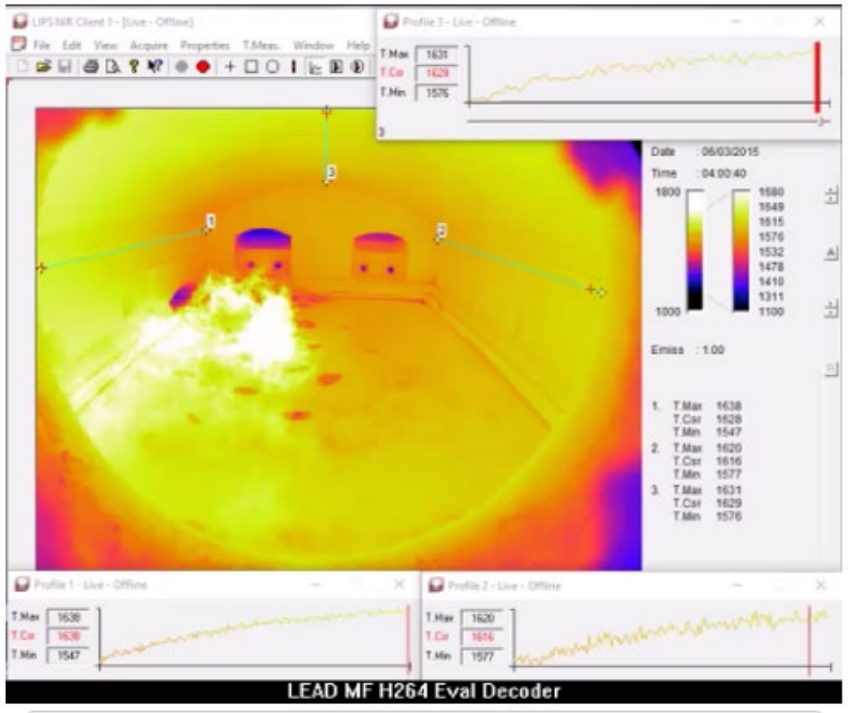


# Remember the four pillars of benefits with thermal imaging NIR-B! This is not only a pretty image!

## Thermocouple Verification



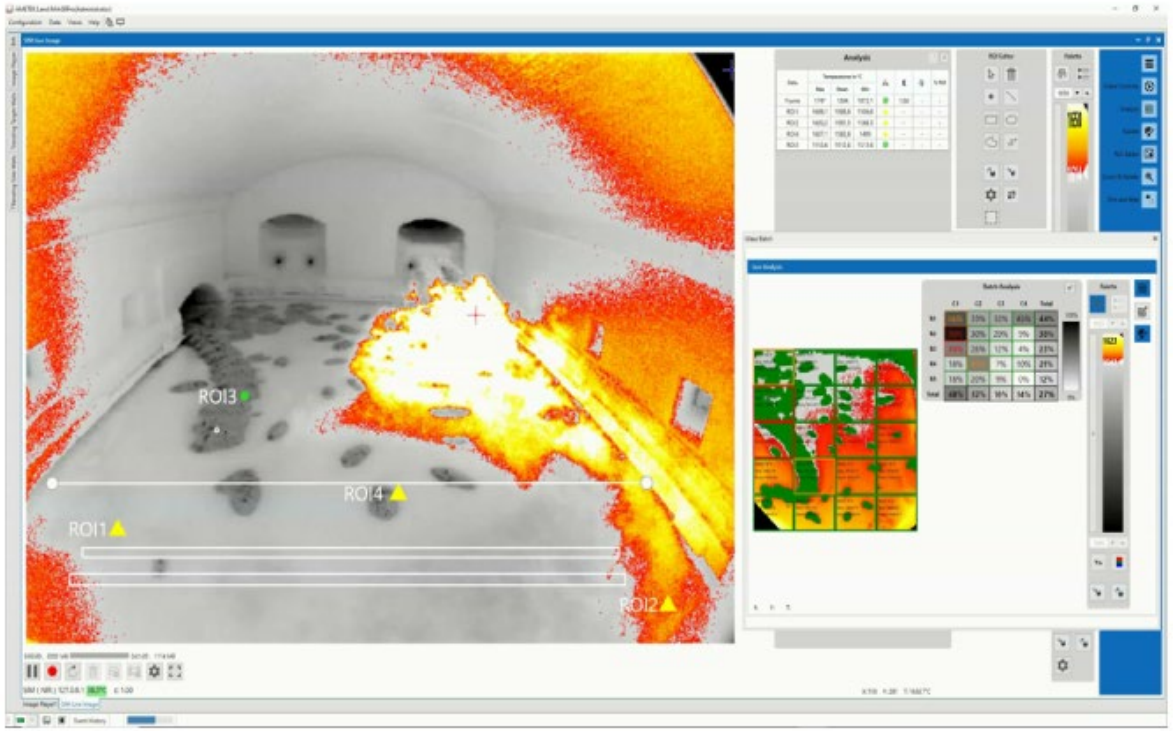

## Optical-Thermal profiles with hot spots



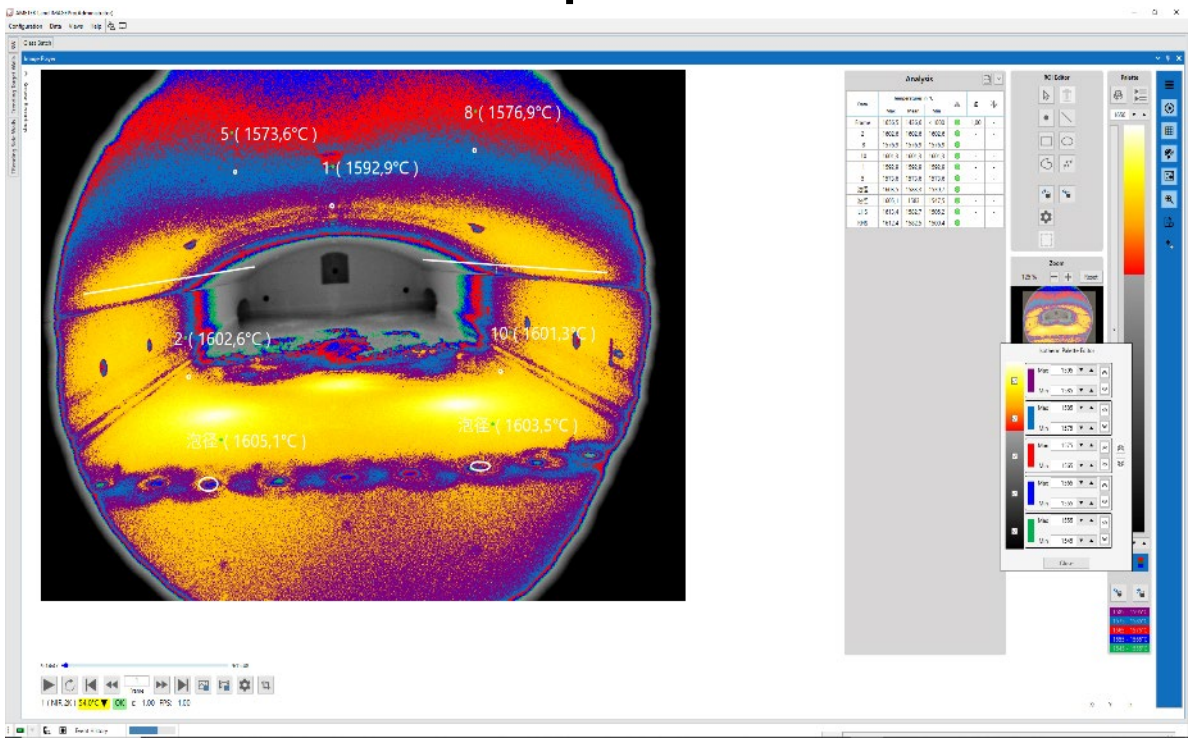

See degrees differently.

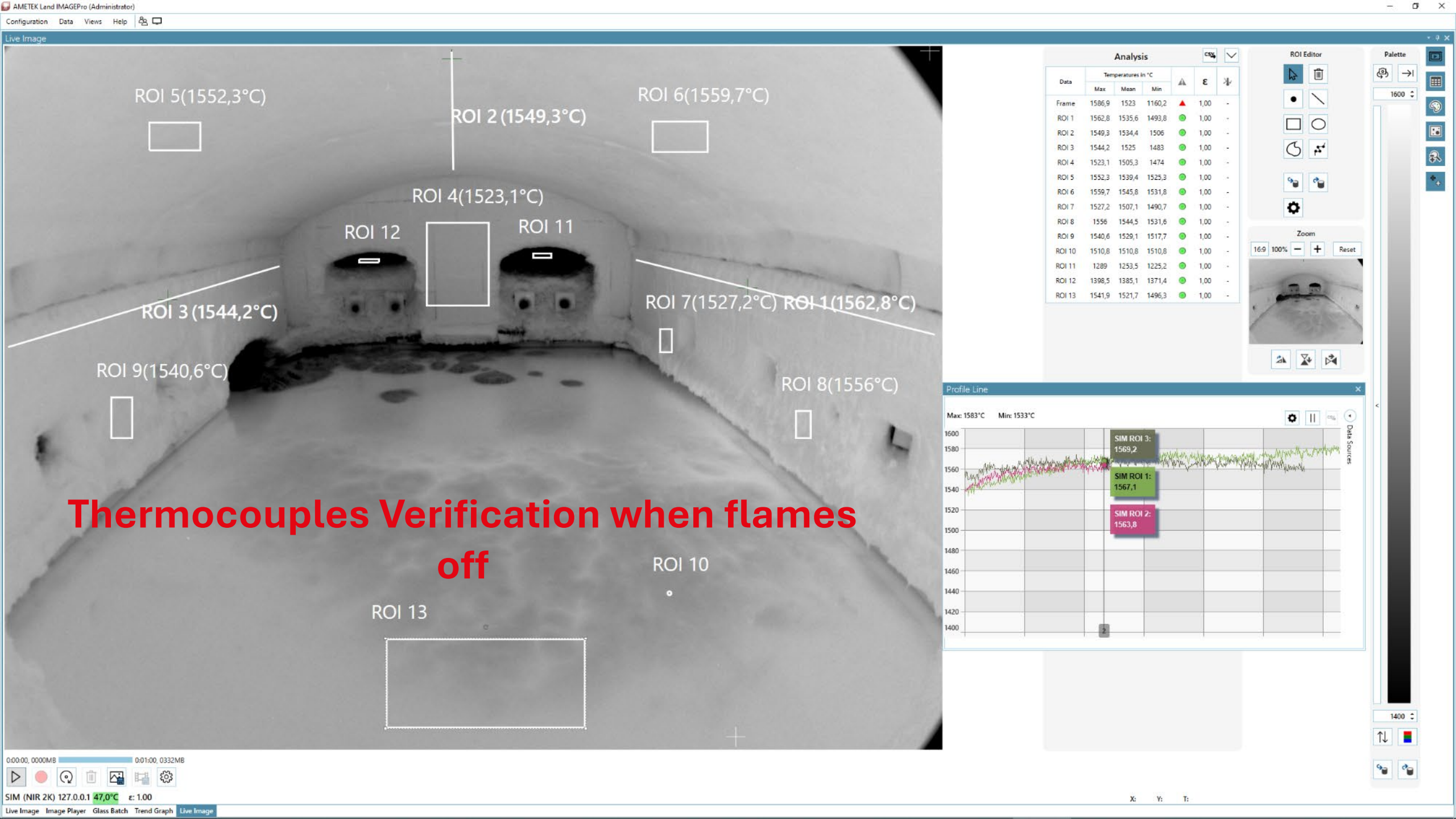
# Remember the four pillars of benefits with thermal imaging NIR-B! This is not only a pretty image!

**BW Palette for Air ingress and Batch pattern**

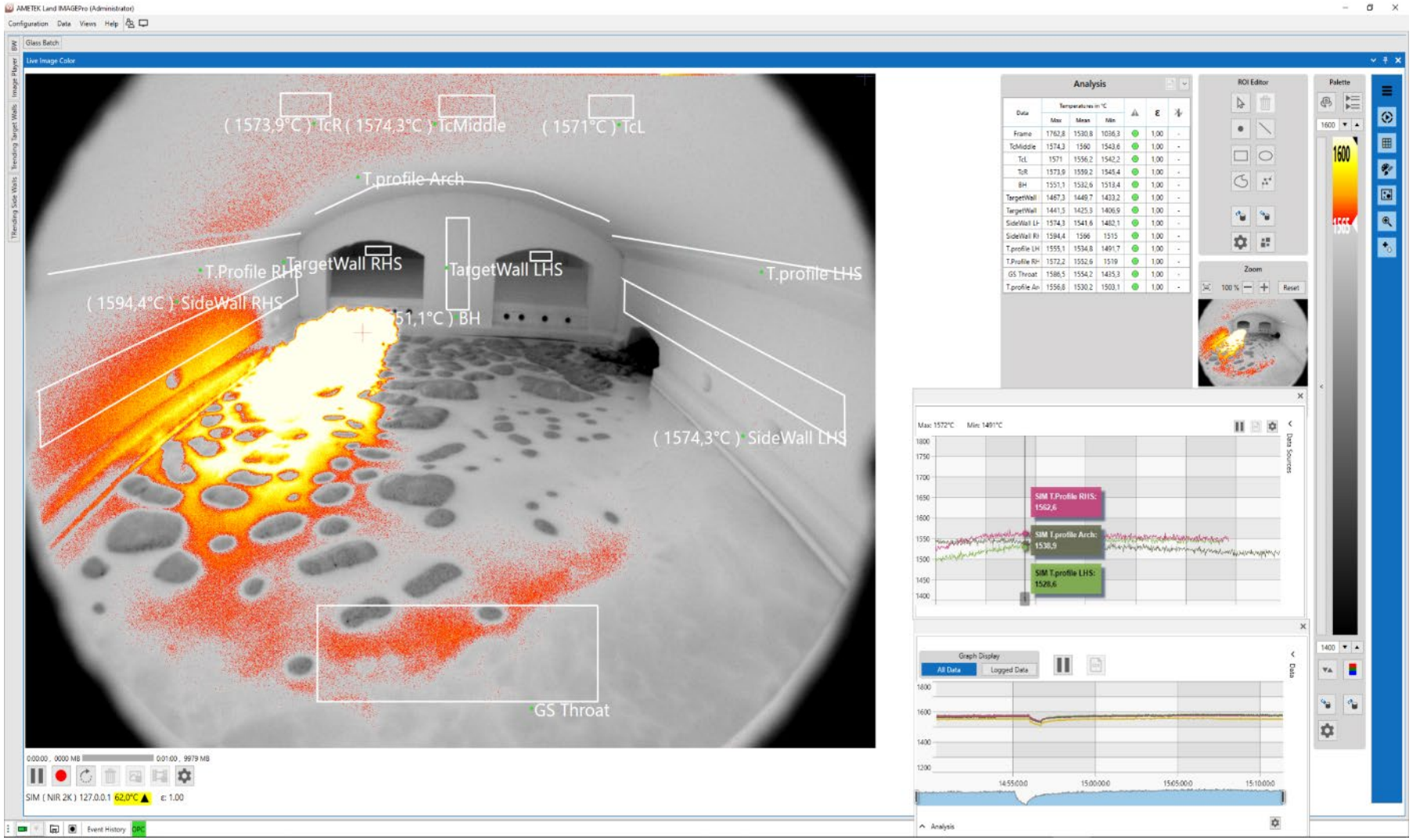



**Rainbow Isotherms with 5 bands for hot and cold spot locations**




AMETEK Land IMAGEPro (Administrator)
Configuration
Data
Views
Help
Live Image
ROI 5(1552,3°C)
ROI 2 (1549,3°C)
ROI 6(1559,7°C)
ROI 4(1523,1°C)
ROI 12
ROI 11
ROI 3 (1544,2°C)
ROI 7(1527,2°C)
ROI 1(1562,8°C)
ROI 9(1540,6°C)
ROI 8(1556°C)
Thermocouples Verification when flames off
ROI 10
ROI 13
Analysis
Data
Temperatures in °C
Max
Mean
Min
ε
Frame 1586,9 1523 1160,2 1,00
ROI 1 1562,8 1535,6 1493,8 1,00
ROI 2 1549,3 1534,4 1506 1,00
ROI 3 1544,2 1525 1483 1,00
ROI 4 1523,1 1505,3 1474 1,00
ROI 5 1552,3 1539,4 1525,3 1,00
ROI 6 1559,7 1545,8 1531,8 1,00
ROI 7 1527,2 1507,1 1490,7 1,00
ROI 8 1556 1544,5 1531,6 1,00
ROI 9 1540,6 1529,1 1517,7 1,00
ROI 10 1510,8 1510,8 1510,8 1,00
ROI 11 1289 1253,5 1225,2 1,00
ROI 12 1398,5 1385,1 1371,4 1,00
ROI 13 1541,9 1521,7 1496,3 1,00
ROI Editor
Zoom
16:9
100%
Reset
Palette
1600
1400
Profile Line
Max: 1583°C
Min: 1533°C
SIM ROI 3: 1569,2
SIM ROI 1: 1567,1
SIM ROI 2: 1563,8
Data Sources
0:00:00, 0000MB
0:01:00, 0332MB
SIM (NIR 2K) 127.0.0.1 47,0°C ε: 1.00
X:
Y:
T:
Live Image
Image Player
Glass Batch
Trend Graph
Live Image

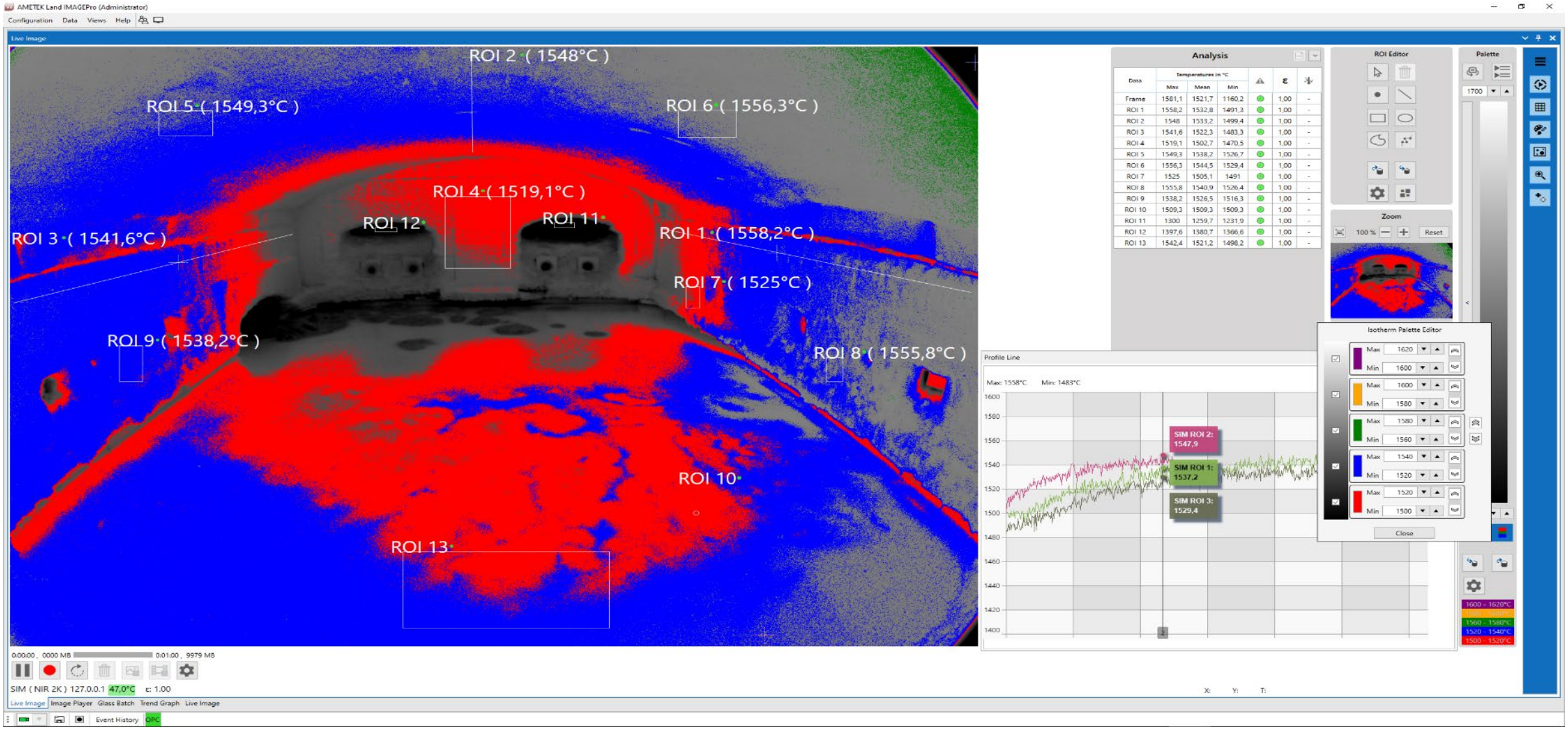
# Flame shape and intensity – mono / rainbow / integrator




- Highlights flame shape and areas of high intensity for combustion and emissions optimisation
- Continuous real time Temperature data.
- Areas used to monitor Highest or Average or Lowest Temperature.
- Crown, Regenerator and Side Wall temperature monitoring.

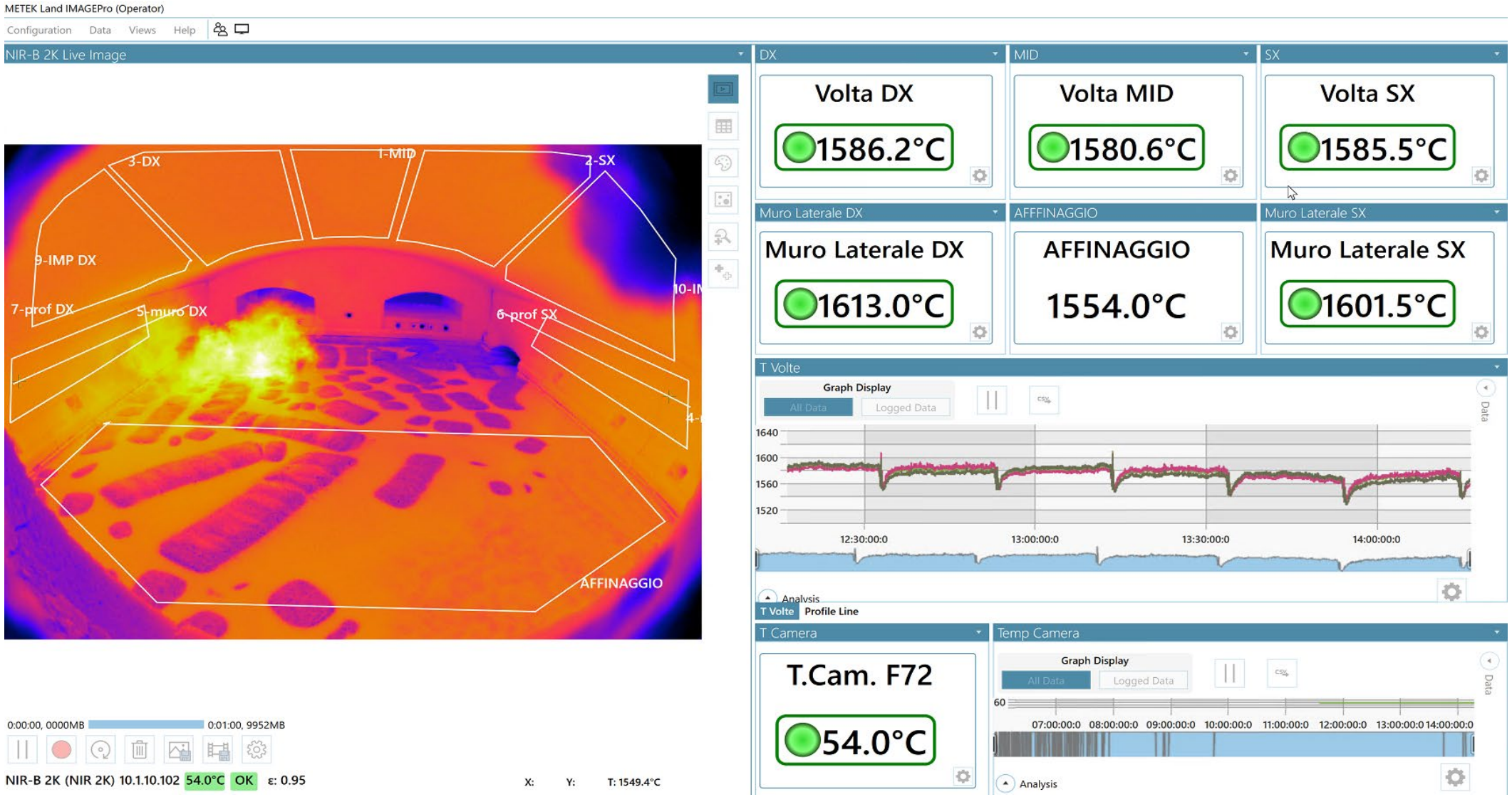
**See degrees differently.**

# Isotherms




See degrees differently.

# Flexible HMI interface with ImagePro V2

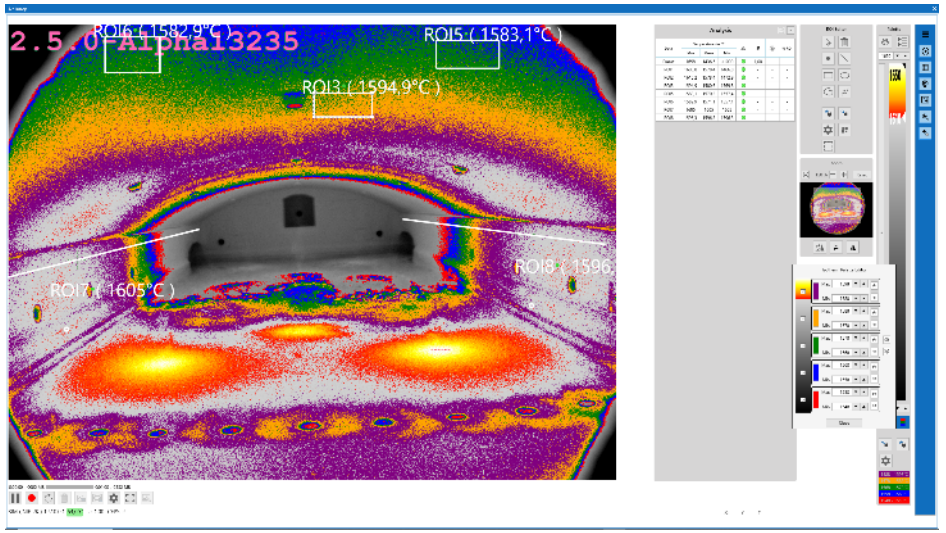



See degrees differently.

# NIR-B-2K and oxygas furnaces

# Benefits of NIR-B-2K on oxygas or Hybrid furnaces

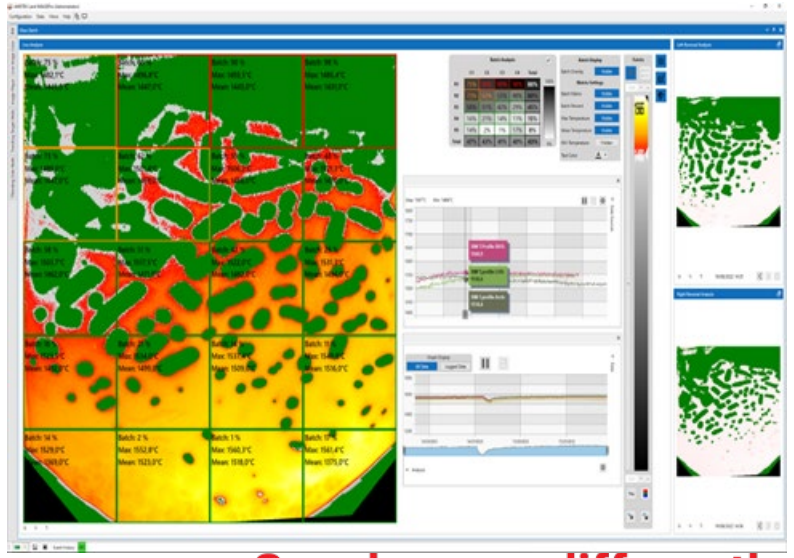
- Batch line location in conjunction of thermal profiling and isotherms
- Burners block cleaning and overheating
- Isotherms with hot spots and cold spots
- Burner Block inspection where possible
- Flame impacts on refractories
- Identify areas of concern and recommendations for further investigation



# Batch coverage and crown temperature with ImagePro V2 glass

# The Grid
# Threshold-Based Batch coverage with a Top Down 2D view of Batch coverage

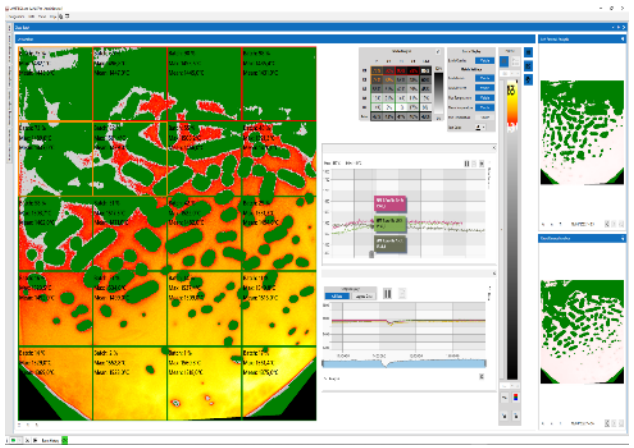
- A simple method uses a single temperature threshold to distinguish melt from batch creating a Grid on melter surface
  - The key point is to determine the batch coverage and batch line location and make sure the zone near by the throat is glass only
- Limitations with the threshold method :
  - Incorrect measurements due to varying energy levels across the furnace.
  - Reflections, flames, and hotspots cause inaccuracies especially for cross fired and large float furnaces.

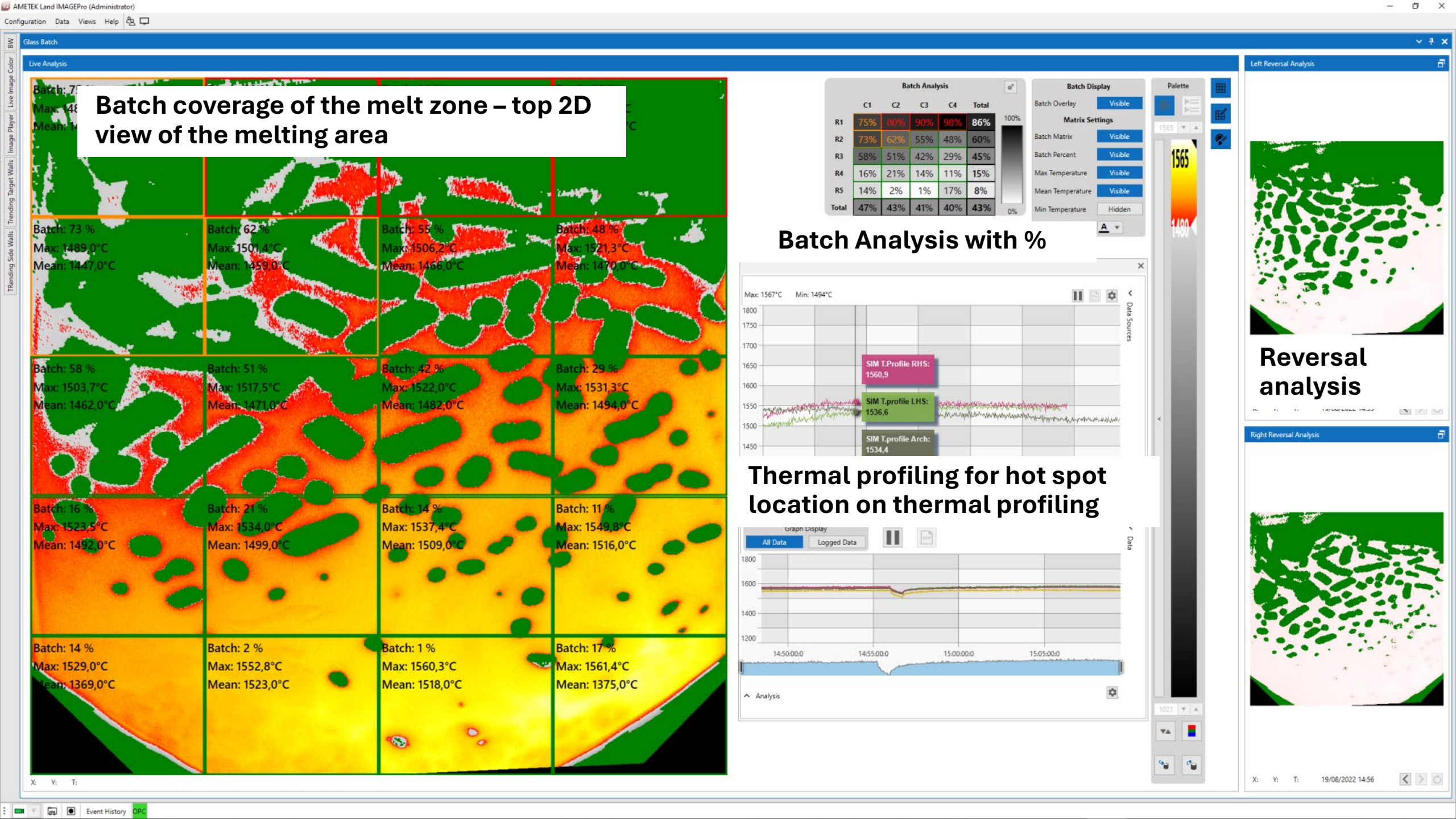


# Batch Coverage and Crown Temperatures

**Variation in Batch coverage has a direct impact on furnace temperatures . The temperature clearly drops when the batch moves to the front of the furnace.**

**Better efficient control of the batch coverage by adjustment of the batch charging direction can be adjusted tp prevent glass defects.**



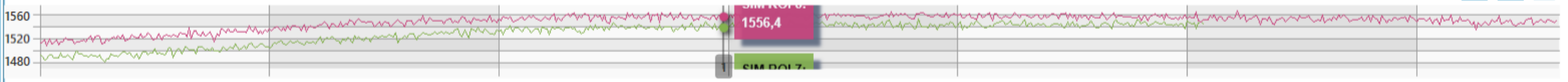

Batch coverage of the melt zone – top 2D view of the melting area
Batch: 73 %
Max: 1489,0°C
Mean: 1447,0°C
Batch: 62 %
Max: 1501,4°C
Mean: 1459,0°C
Batch: 55 %
Max: 1506,2°C
Mean: 1466,0°C
Batch: 48 %
Max: 1521,3°C
Mean: 1470,0°C
Batch: 58 %
Max: 1503,7°C
Mean: 1462,0°C
Batch: 51 %
Max: 1517,5°C
Mean: 1471,0°C
Batch: 42 %
Max: 1522,0°C
Mean: 1482,0°C
Batch: 29 %
Max: 1531,3°C
Mean: 1494,0°C
Batch: 16 %
Max: 1523,5°C
Mean: 1492,0°C
Batch: 21 %
Max: 1534,0°C
Mean: 1499,0°C
Batch: 14 %
Max: 1537,4°C
Mean: 1509,0°C
Batch: 11 %
Max: 1549,8°C
Mean: 1516,0°C
Batch: 14 %
Max: 1529,0°C
Mean: 1369,0°C
Batch: 2 %
Max: 1552,8°C
Mean: 1523,0°C
Batch: 1 %
Max: 1560,3°C
Mean: 1518,0°C
Batch: 17 %
Max: 1561,4°C
Mean: 1375,0°C
Batch Analysis with %
Thermal profiling for hot spot location on thermal profiling
Reversal analysis

AMETEK Land IMAGEPro (Administrator)

Configuration Data Views Help

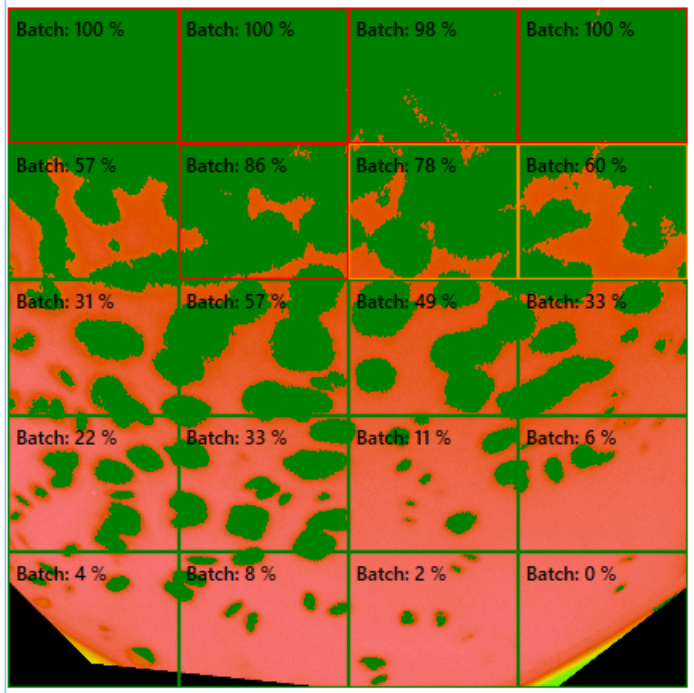
## Profile Line

Max: 1566°C Min: 1480°C




## Glass Batch

### Live Analysis




X: Y: T:

### Batch Analysis

| | C1 | C2 | C3 | C4 | Total |
|---|---|---|---|---|---|
| R1 | 100% | 100% | 98% | 100% | 100% |
| R2 | 57% | 86% | 78% | 60% | 70% |
| R3 | 31% | 57% | 49% | 33% | 42% |
| R4 | 22% | 33% | 11% | 6% | 18% |
| R5 | 4% | 8% | 2% | 0% | 4% |
| Total | 43% | 57% | 48% | 40% | 47% |

100%
0%

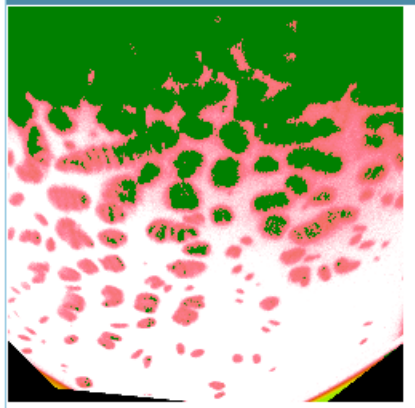
### Batch Display

Batch Overlay: Visible

### Matrix Settings

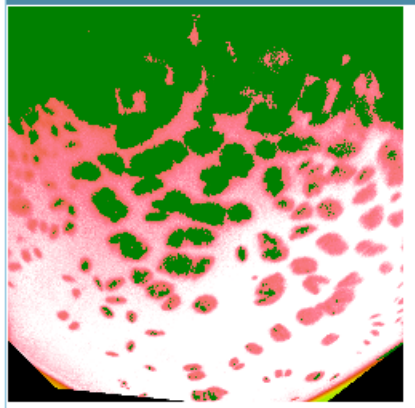
Batch Matrix: Visible
Batch Percent: Visible
Max Temperature: Hidden
Mean Temperature: Hidden
Min Temperature: Hidden
Text Color

### Left Reversal Analysis



X: Y: T: 21/09/2021 22:23

### Right Reversal Analysis



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Trendgrafik Bildwiedergabegerät Glascharge Image Player Live Image Glass Batch

Live SIM

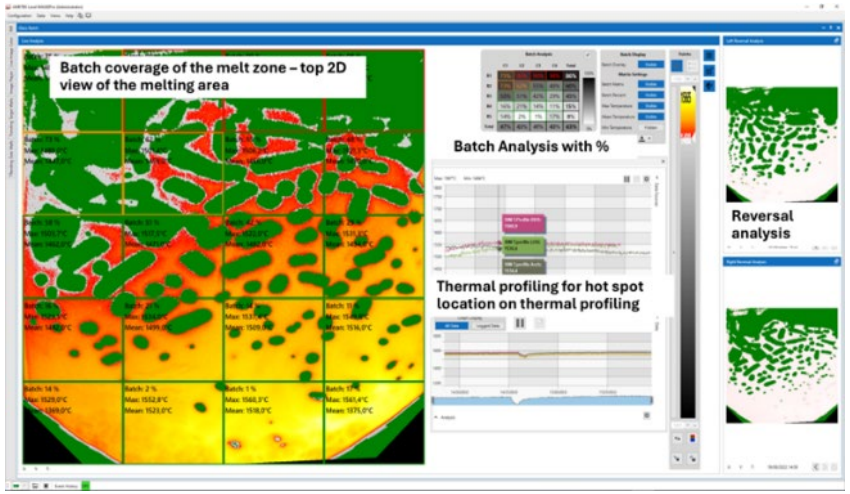
# How Machine Learning is improving  Batch Tracking in Glass Furnaces ?

# Introduction

- Tracking batch in a glass furnace is challenging due to environmental obstacles especially for regenerative cross fired and large float furnaces.
- Machine learning can improve accuracy over traditional threshold-based methods whatever the furnace technologies.
- This study explores and proposes the use of neural networks for batch tracking and batch line determination.

# Existing Thresholding with batch Grids

- A dynamic threshold approach using a grid and overlay improves accuracy.
- Each grid cell has a calculated threshold using Otsu's method.
- However, this method still has potential errors for regenerative cross fired furnaces :
  - Cells dominated by batch may result in incorrect thresholds being under the temperature of the batch.
  - Incorrect measurements at the far end of furnace
  - Gradients and hotspots caused by reflections, Flames and other sources can create inacuracy of the batch grid
  - Even if Additional checks (bimodal verification) can reduce errors.



# Neural Networks for Batch Tracking

- Advancements in deep learning allow for improved batch tracking.
- Two potential network types:
  - The first is an object localization networks (bounding boxes) – unsuitable for tracking irregular batch shapes.
  - or the Semantic Segmentation networks – provide pixel-level classification, multiple category segmentation with single pass making them more effective.

- A modified U-Net architecture was used - a U-Net Based Model for Batch Tracking developed by LAND .
- The convolutional Encoder-decoder structure is based on :
  - Encoder compresses image data, extracting features.
  - Decoder reconstructs the image, segmenting key features.
  - Outputs a segmented matrix indicating batch locations and flames identification.

# Training of the Neural Network

- Built using End-to-End platform for machine learning with input images (256x256).
- Training data based on :
  - Thermal NIR-B camera images with manually labeled ground truth.
  - Data augmentation (rotation, zooming) prevented overfitting.
    - Figure 1: Original and ground-truth overlay.
    - Figure 2: Example of augmented images.

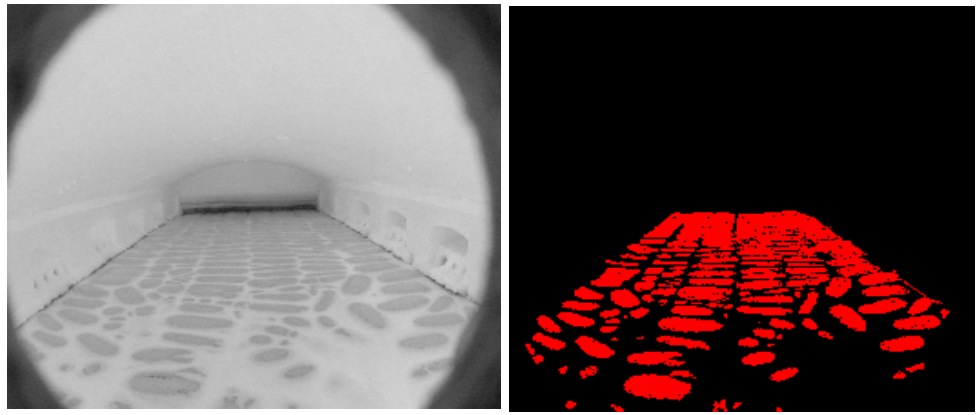


*Figure 1. Original image (left) and ground-truth overlay (right)*

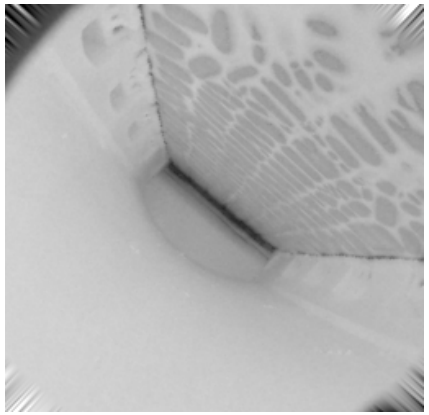


*Figure 2. Example of augmented image*

# Model Evaluation & Results

- Performance was tested using unseen furnace scenes.
- 50 trainings images generated 300 augmented images.
- Model trained with 3.4M parameters showed good results after 25 epochs.
- No further improvements after 100 epochs (overfitting risk).
- Figure 3: Initial detection results

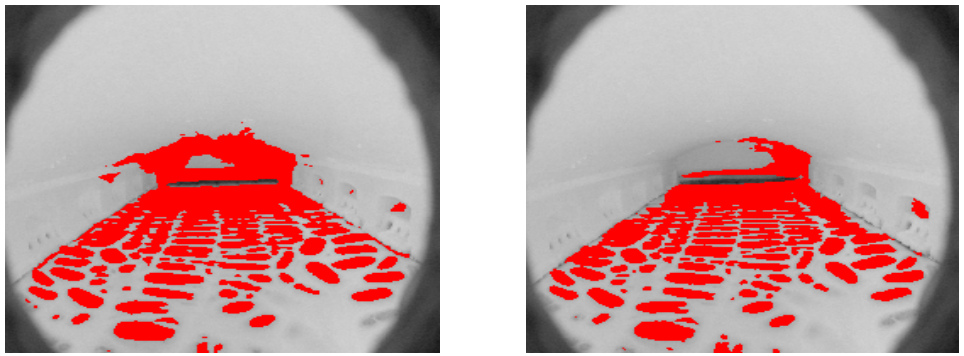


*Figure 3. Result after 25 training epochs (left) and 100 epochs (right)*

# Multi-Category Training for Improved Accuracy

- Additional categories like ‘obscured’ and ‘flame’ were introduced.
  - Multi-category segmentation improved batch tracking accuracy.
  - Adding a single evaluation image dramatically enhanced precision.
- Figure 4: Results from a 4-category segmentation model.

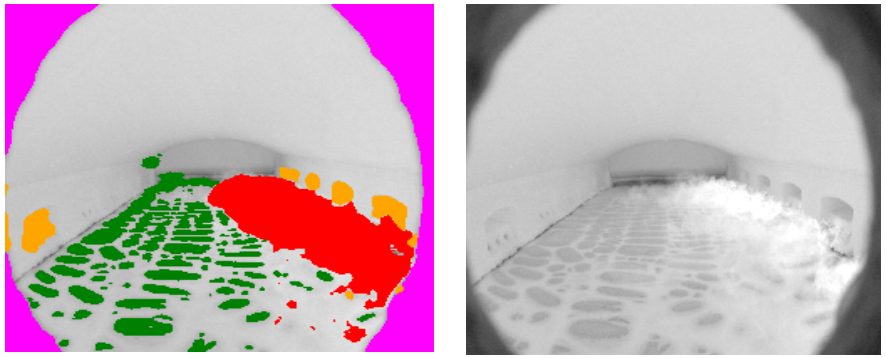
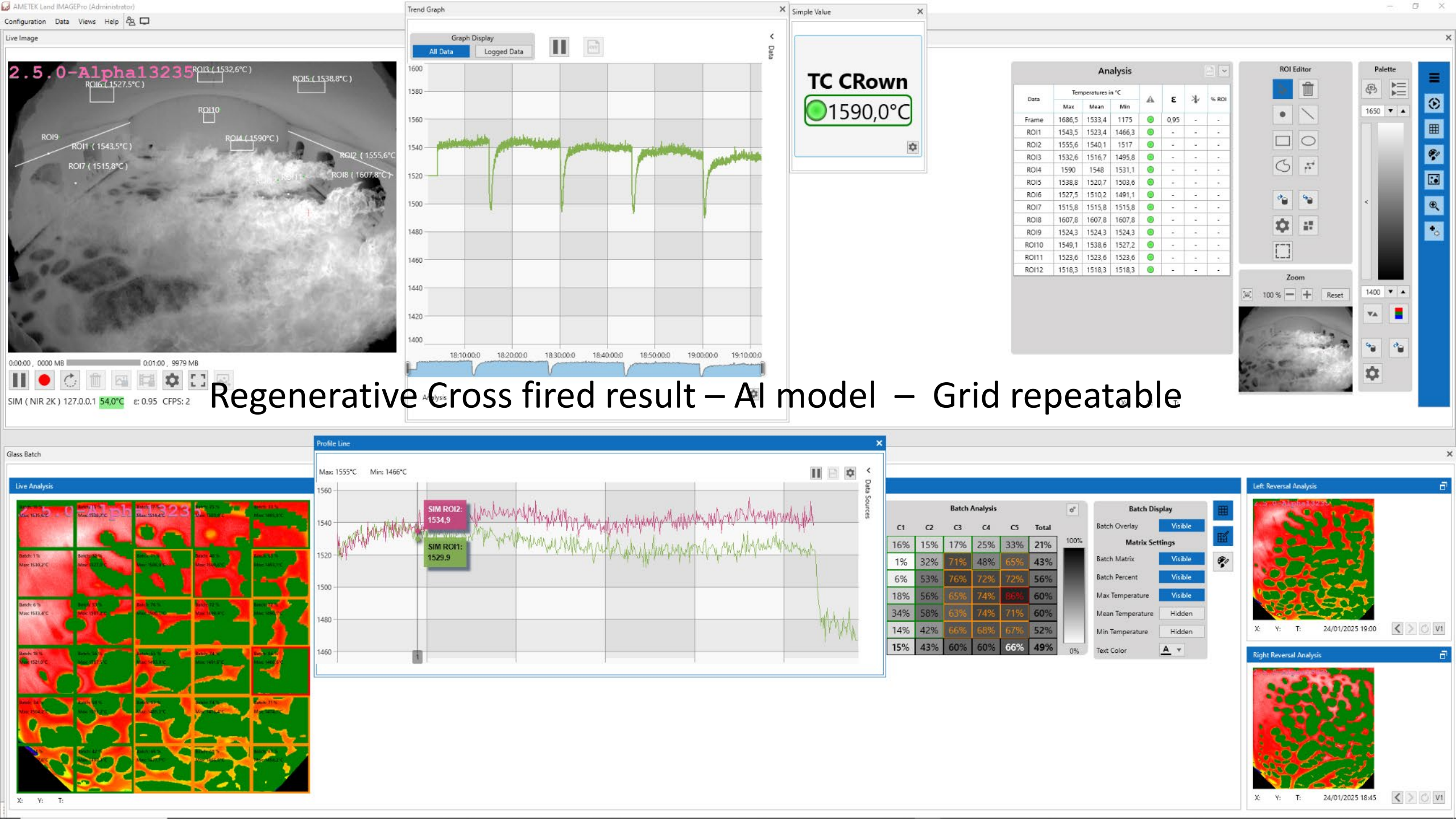


*Figure 4. Multiple category segmentation and original image*


AMETEK Land IMAGEPro (Administrator)
Configuration Data Views Help
Live Image
2.5.0-Alpha13235
ROI3 ( 1532,6°C )
ROI6 ( 1527,5°C )
ROI5 ( 1538,8°C )
ROI10
ROI9
ROI4 ( 1590°C )
ROI1 ( 1543,5°C )
ROI2 ( 1555,6°C )
ROI7 ( 1515,8°C )
ROI8 ( 1607,8°C )
0:00:00 , 0000 MB
0:01:00 , 9979 MB
SIM ( NIR 2K ) 127.0.0.1 54,0°C e: 0.95 CFPS: 2
Trend Graph
Graph Display
All Data
Logged Data
Data
1600
1580
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1520
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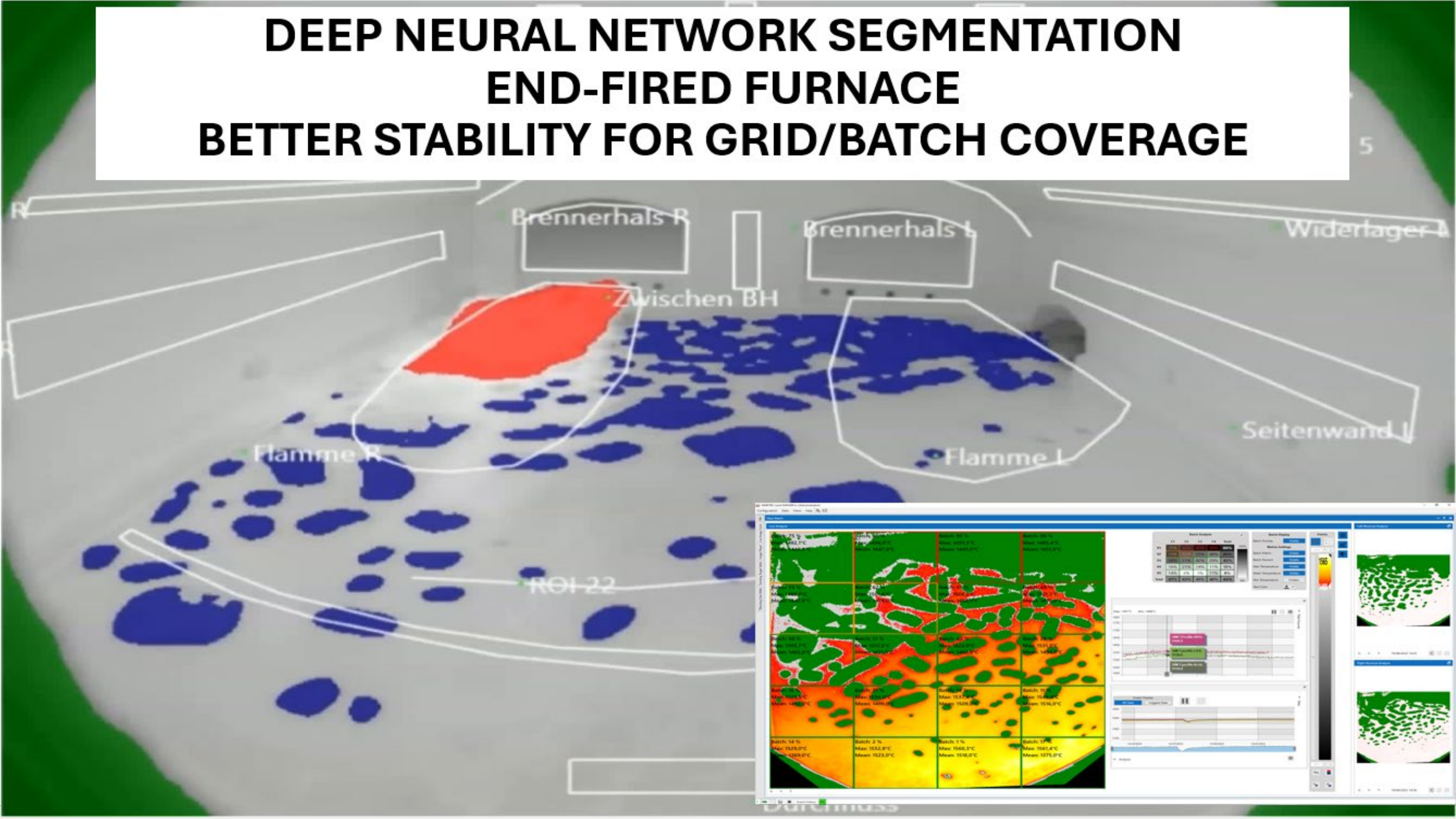
1420
1400
18:10:00:0
18:20:00:0
18:30:00:0
18:40:00:0
18:50:00:0
19:00:00:0
19:10:00:0
Analysis
Simple Value
TC CRown
1590,0°C
Analysis
Data
Temperatures in °C
Max
Mean
Min
ε
% ROI
Frame 1686,5 1533,4 1175 0,95
ROI1 1543,5 1523,4 1466,3
ROI2 1555,6 1540,1 1517
ROI3 1532,6 1516,7 1495,8
ROI4 1590 1548 1531,1
ROI5 1538,8 1520,7 1503,6
ROI6 1527,5 1510,2 1491,1
ROI7 1515,8 1515,8 1515,8
ROI8 1607,8 1607,8 1607,8
ROI9 1524,3 1524,3 1524,3
ROI10 1549,1 1538,6 1527,2
ROI11 1523,6 1523,6 1523,6
ROI12 1518,3 1518,3 1518,3
ROI Editor
Palette
1650
1400
Zoom
100 %
Reset
Regenerative Cross fired result – AI model – Grid repeatable
Glass Batch
Live Analysis
Profile Line
Max: 1555°C Min: 1466°C
SIM ROI2: 1534,9
SIM ROI1: 1529,9
Data Sources
1560
1540
1520
1500
1480
1460
Batch Analysis
C1 C2 C3 C4 C5 Total
16% 15% 17% 25% 33% 21%
1% 32% 71% 48% 65% 43%
6% 53% 76% 72% 72% 56%
18% 56% 65% 74% 86% 60%
34% 58% 63% 74% 71% 60%
14% 42% 66% 68% 67% 52%
15% 43% 60% 60% 66% 49%
100%
0%
Batch Display
Batch Overlay Visible
Matrix Settings
Batch Matrix Visible
Batch Percent Visible
Max Temperature Visible
Mean Temperature Hidden
Min Temperature Hidden
Text Color
Left Reversal Analysis
X: Y: T: 24/01/2025 19:00
Right Reversal Analysis
X: Y: T: 24/01/2025 18:45

# Conclusion & 2025 IPV2 release

- The Grid with Neural networks improve batch tracking over traditional threshold-based methods.
- Better accuracy for batch detection based on Neural existing model.
- U-Net segmentation allows pixel-level accuracy in furnace tracking.
- Future improvements for ImagePro Glass ready to be released mid-2025:
  - Best robust Grid results . Even for scenes unfamiliar to the model with just 25 rounds of the training.
  - More training data yields better results than just increasing model complexity for all Furnace technologies including regenerative, Oxygas and Hybrid furnaces.
  - Use of SCADA possible to share values of the Grid
  - A simple way to support the operation team to optimise and balance any Furnaces

# DEEP NEURAL NETWORK SEGMENTATION
# END-FIRED FURNACE
# BETTER STABILITY FOR GRID/BATCH COVERAGE



# Why to use NIR-B-2K on glass furnaces? Extended benefits

- Possible Thermal Surveys with transportable NIR-B combining  bundles Lancom 4 and Cyclops C100L
- Combustion optimisation for energy reduction
- Digitalisation with thermal distribution and bird eyes pictures – Modbus or OPC UA server
- Predictive software or SCADA – EU References
- Traceability and Data for quality management
- Extended life of assets and improved daily furnace operations

# Thermal Imaging Systems For Continuous Monitoring In Different Furnace And Boiler Applications – Examples

## NIR-B-656

Standard resolution (656 x 494 pixels) gives over 300 thousand temperature points.

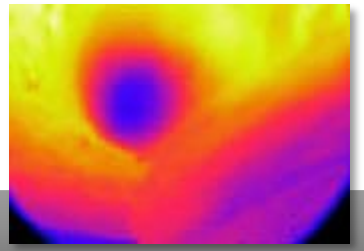
| | |
|---|---|
| Image Pixels: | 656 x 494 |
| Measurement Ranges: | 600 to 1000 °C / 1112 to 1832 °F<br>800 to 1400 °C / 1472 to 2552 °F<br>1000 to 1800 °C / 1832 to 3272 °F |
| Field of View (Horizontal x Vertical): | 90° x 67.5°, 44° x 33° |
| Glass Melt Tank Model - **NIR-B-656-GLASS** (please refer to NIR-B-GLASS Brochure) | 1000 to 1800 °C / 1832 to 3272 °F<br>90° x 67.5° |

**TYPICAL APPLICATIONS**

| | |
|---|---|
| Reheat Furnace | Glass Melt Tanks |
| Reformer Tube Furnaces | Cement Kilns |
| Coal Fired Power Boilers | Biomass Boilers |

*Example*:
Cement Furnaces (rotary kilns) or boilers

**Medium & Small Furnaces**



## NIR-B-2K

High resolution (1968 x 1472 pixels) gives nearly 3 million temperature points.

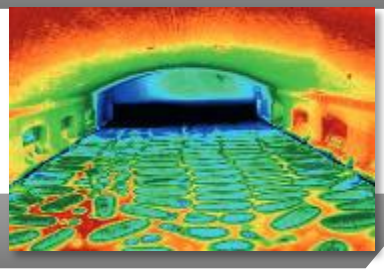
| | |
|---|---|
| Image Pixels: | 1968 x 1472 |
| Measurement Ranges: | 600 to 1000 °C / 1112 to 1832 °F<br>800 to 1400 °C / 1472 to 2552 °F<br>1000 to 1800 °C / 1832 to 3272 °F |
| Field of View (Horizontal x Vertical): | 95° x 71° |
| Glass Melt Tank Model - **NIR-B-2K-GLASS** (please refer to NIR-B-GLASS Brochure) | 1000 to 1800 °C / 1832 to 3272 °F<br>95° x 71° |

**TYPICAL APPLICATIONS**

| | |
|---|---|
| Reheat Furnace | Glass Melt Tanks |
| Reformer Tube Furnaces | Cement Kilns |
| Coal Fired Power Boilers | Continuous Casting |

*Example*:
Glass Melt Tanks

**Large Furnaces**



## NIR-B-640

Wide dynamic range imaging technology for furnace applications where a wider temperature measurement range is required from a single imager.

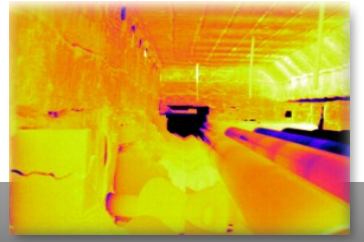
| | |
|---|---|
| Image Pixels: | 640 x 480 |
| Measurement Range: | 600 to 2000 °C / 1112 to 3632 °F |
| Field of View (Horizontal x Vertical): | 90° x 67.5° |

**TYPICAL APPLICATIONS**

| | |
|---|---|
| Cement Kiln | Cement Cyclone Furnace |
| Reheat Furnace | Continuous Casting (zone 1) |
| Heat Treatment Furnace | Annealing Furnace |

*Example*:
Reheat Furnaces

**Heat & Reheat Furnaces**



## NIR-B-3XR

Hazardous area compliant to ATEX, IECEx and CSA. Wide dynamic range imaging technology for furnace applications where a wider temperature measurement range is required from a single imager.

| | |
|---|---|
| Image Pixels: | 640 x 480 |
| Measurement Range: | 600 to 1800 °C / 1112 to 3272 °F |
| Field of View (Horizontal x Vertical): | 90° x 67.5° |

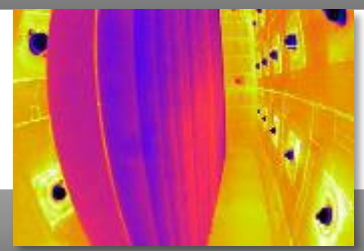
Hazardous Area Certification: EX NIR-B WG1: Ex nA IIC T4 Gc Tamb=-20 °C to +55 °C (ATEX certificate: CML 15ATEX4086X / IECEx certificate: IECEx CML 15.0042X) EX NIR-B WG2: Class I, Division 2, Groups A, B, C, D; T4 Tamb=-20 °C to +60 °C (CSA certificate for US and Canada: 70080206)

**TYPICAL APPLICATIONS**

| | |
|---|---|
| Hydrogen Reformer | Ammonia Production |
| Ethylene Cracking Furnaces | Methanol Production |
| Syngas Production | |

*Example*:
Tube Furnaces (Reformers & Crackers)

**Tube Furnaces (HPI)**



**See degrees differently.**

Philippe Kerbois
Global Industry Manager - Glass
philippe.kerbois@ametek.com

+33 (0) 6.75.38.39.87

See degrees differently.