# AIGMF – AMETEK Land – October 2019
# Furnace optimisation and NOx reduction

**Authors:** Mark Bennett[1] - Co Author
Neil G. Simpson[2] - Presenter

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1. AMETEK Land (Land Instruments International Ltd)
2. Simpson Combustion and Energy Ltd

QUALITY CUSTOMER SOLUTIONS

# USE OF CONTINUOUS INFRARED TEMPERATURE IMAGE TO OPTIMIZE FURNACE OPERATIONS

- Introduction
  - Equipment used in study
    - Verify Thermocouples
  - Continuous In-furnace thermal imaging
    - Thermal profile
    - Heat loss, air ingress and Batch patterns
    - Specific Isotherms
    - Flame shape and intensity
- Encirc Elton - Case Study Part 1
  - Optimise Furnace Operations
- Encirc Elton - Case Study Part 2
  - Visual flames and Nox

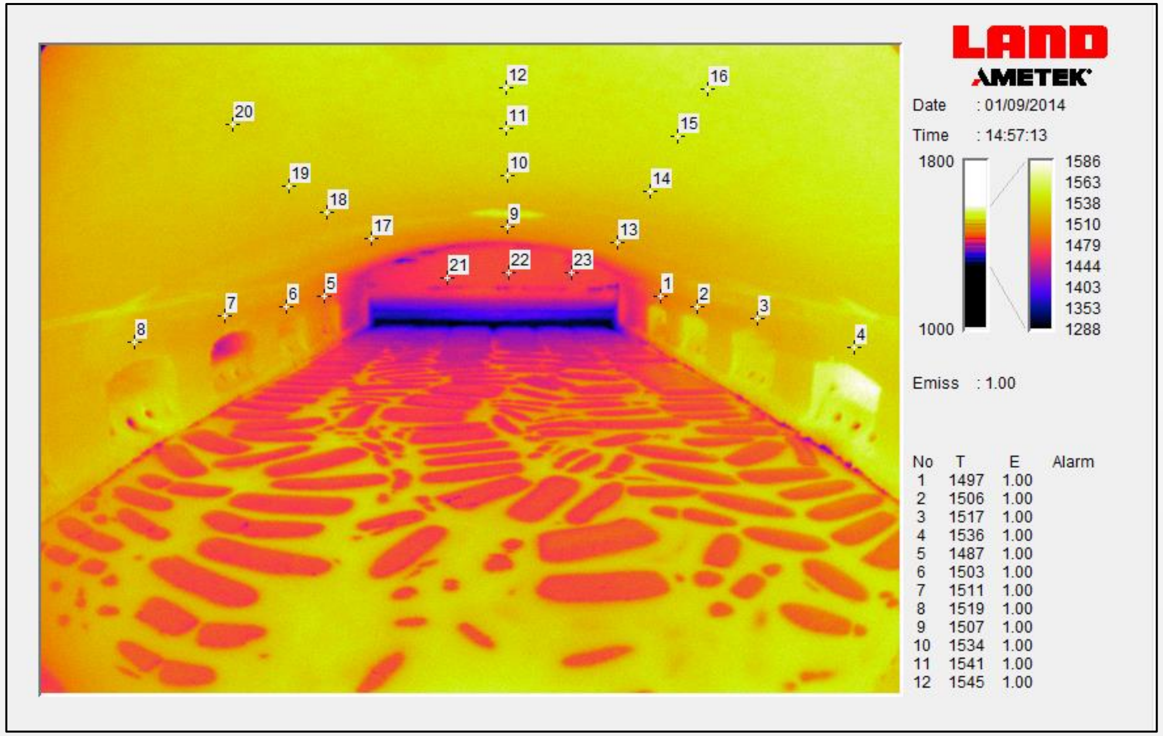
# EQUIPMENT USED IN STUDY – Point Measurements verify Thermocouples

**NIR-B GLASS - Near Infrared Borescope Glass Solution**

324,000 pixels each measuring temperature – like 324,000 Cyclops (100 x measurement points)

Max, min and average temperatures with user defined emissivity.

Patent Pendin




**Cyclops C100L**

Portable Infrared Thermometer

**Industry Standard**

**Verify spot temperatures**

550 to 3000° C

1022 to 5432° F

**Lancom 4 –** Portable

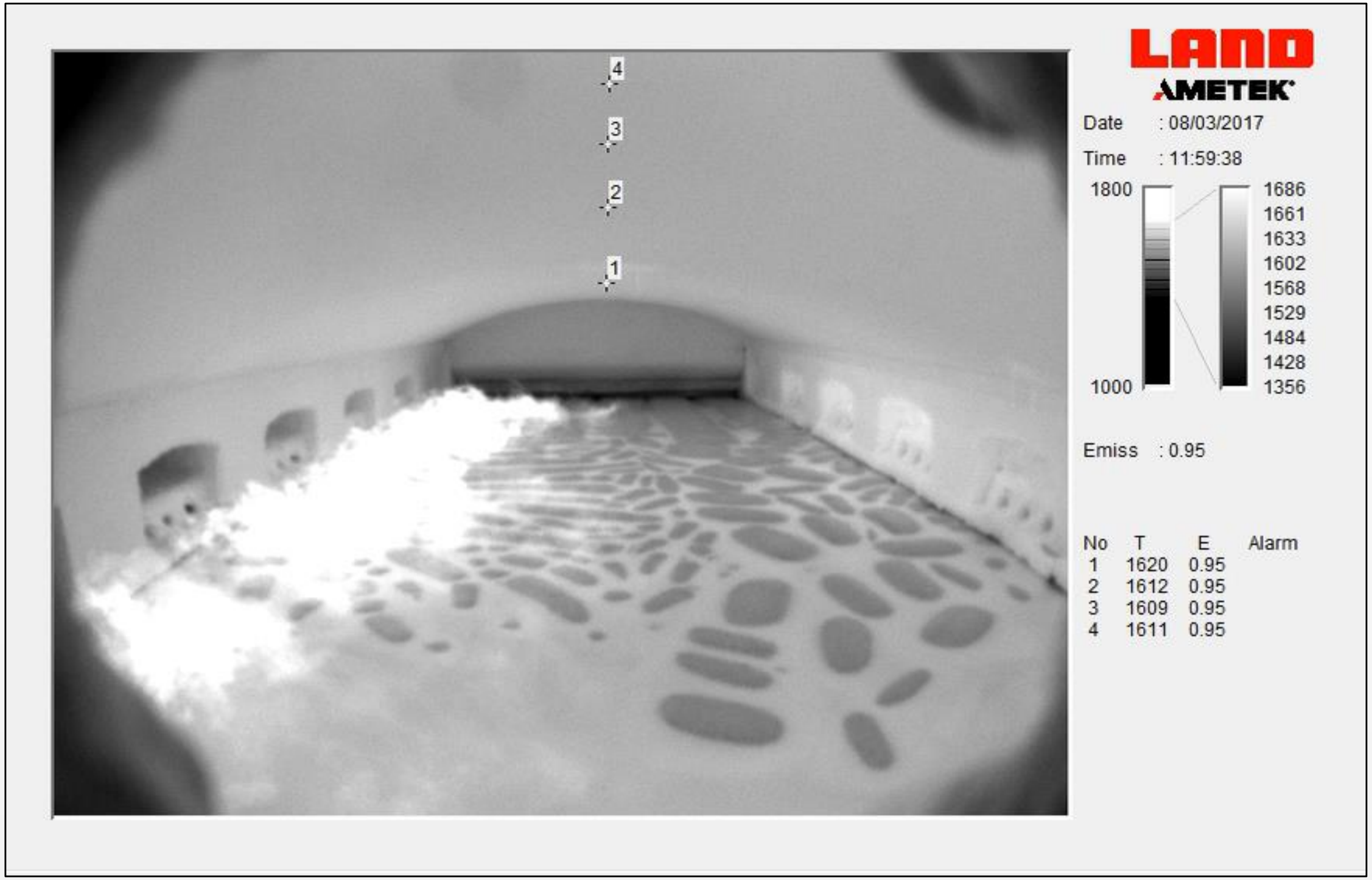
9 Gas Analyser for NOx

CO low • CO high • O2

NO • NO2 • NOx

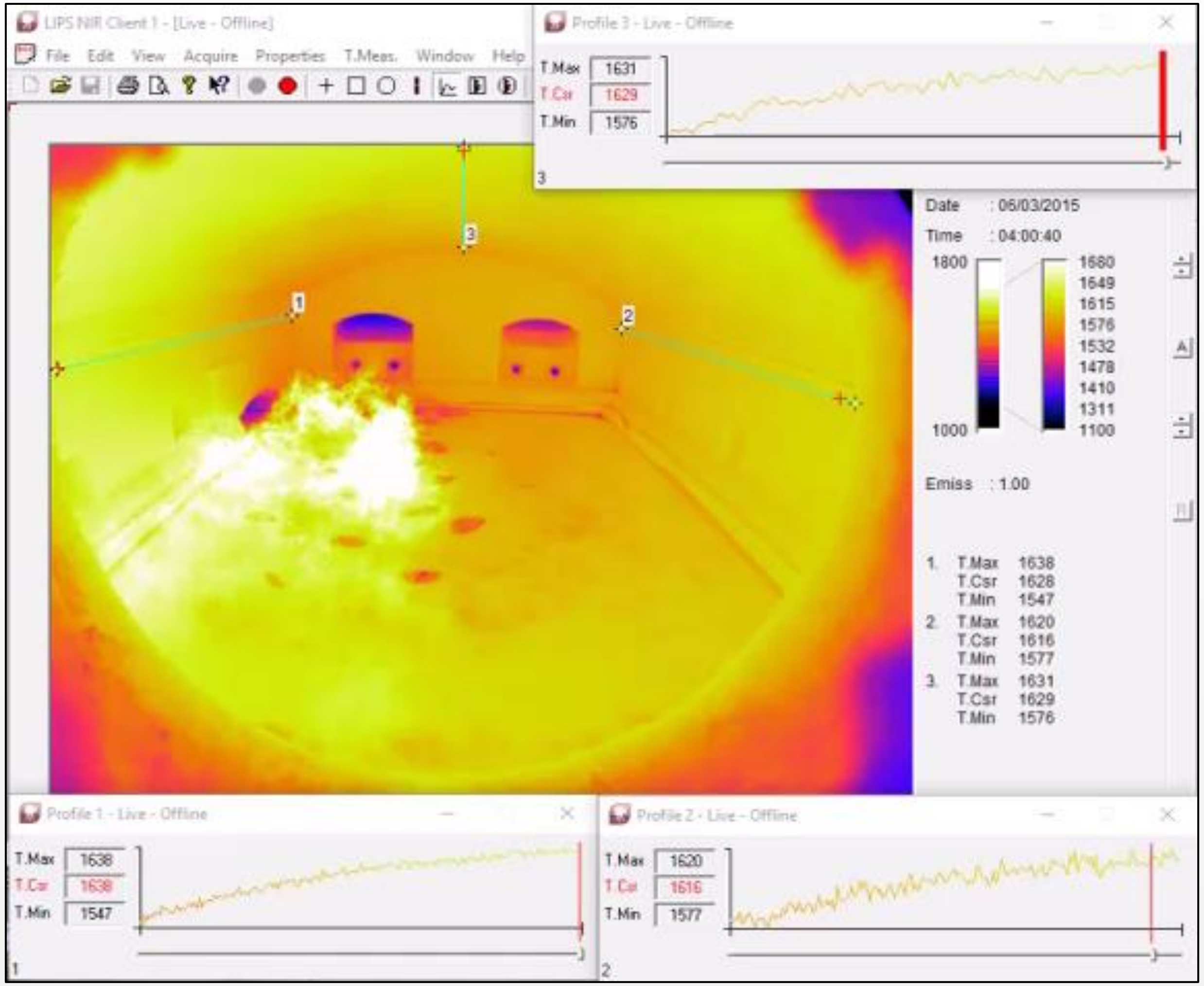
CO2 • H2S • SO2 • CxHy

# VIDEO of Continuous Temperature Measurement – Thermocouple Verification



# Time Lapse VIDEO of Continuous Measurement of Optical-thermal Profile

- Verify Thermal Profile
- Continuously Every reversal
- Optimise Burners Angles
- Troubleshoot quality
- Avoid time/delay for optical profile



# Time Lapse VIDEO of Thermal Image Monochrome Colour Pallet for Heat loss and Air Ingress and Batch Pattern


- Continuous real time Temperature data.
- Contrast enables best visual tracking of batch.
- Monochrome pallet used to enhance clarity of image for identifying leakage and damaged refractory.

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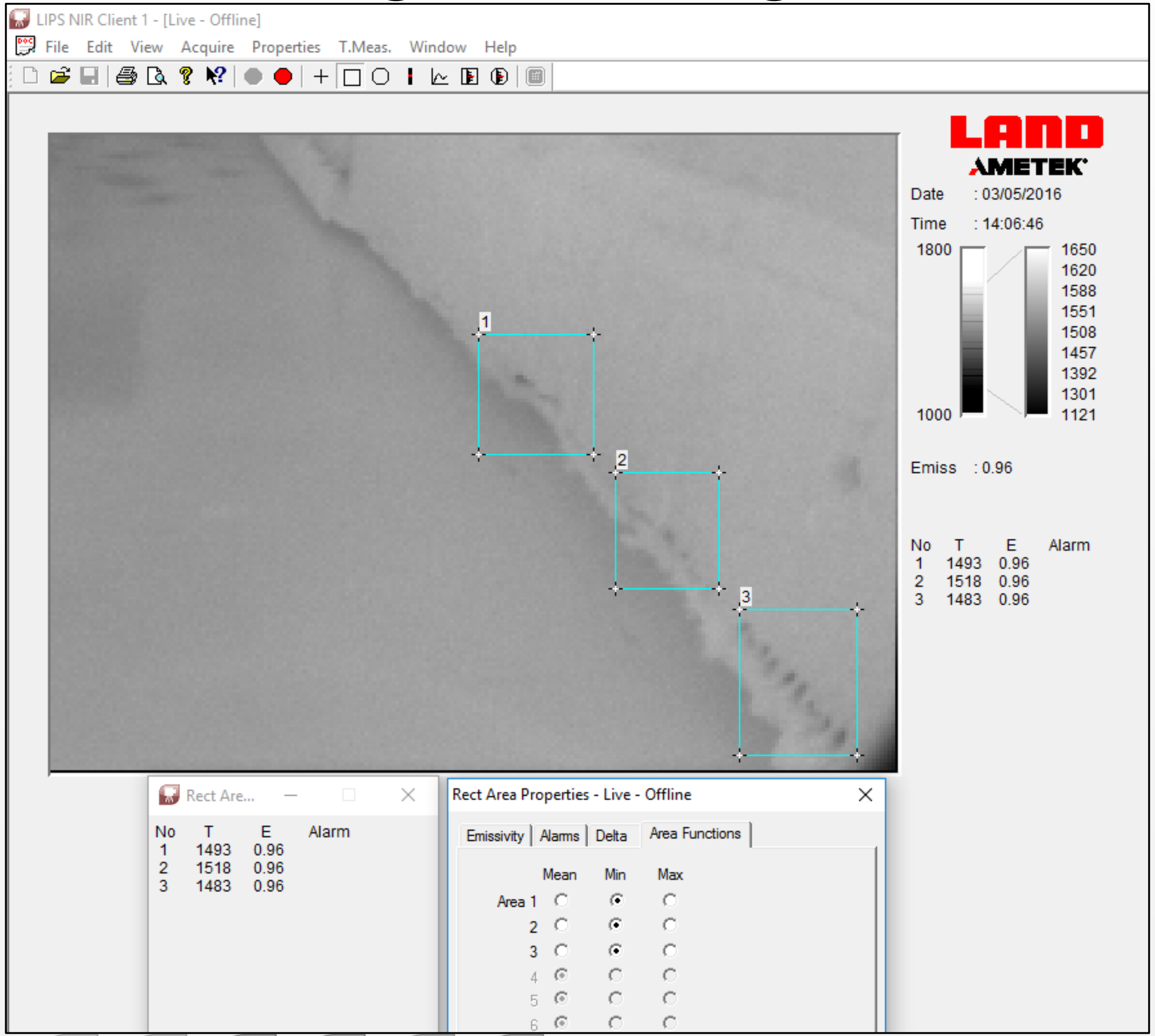
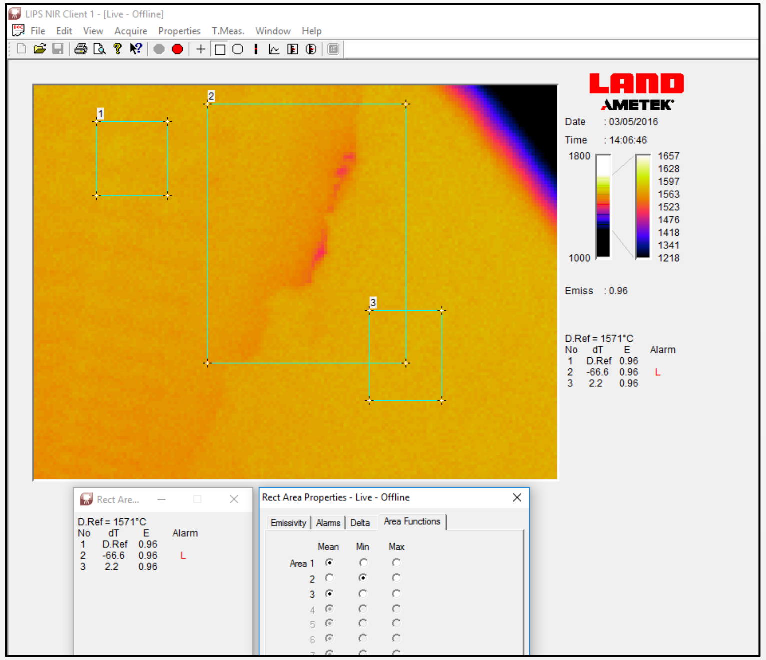
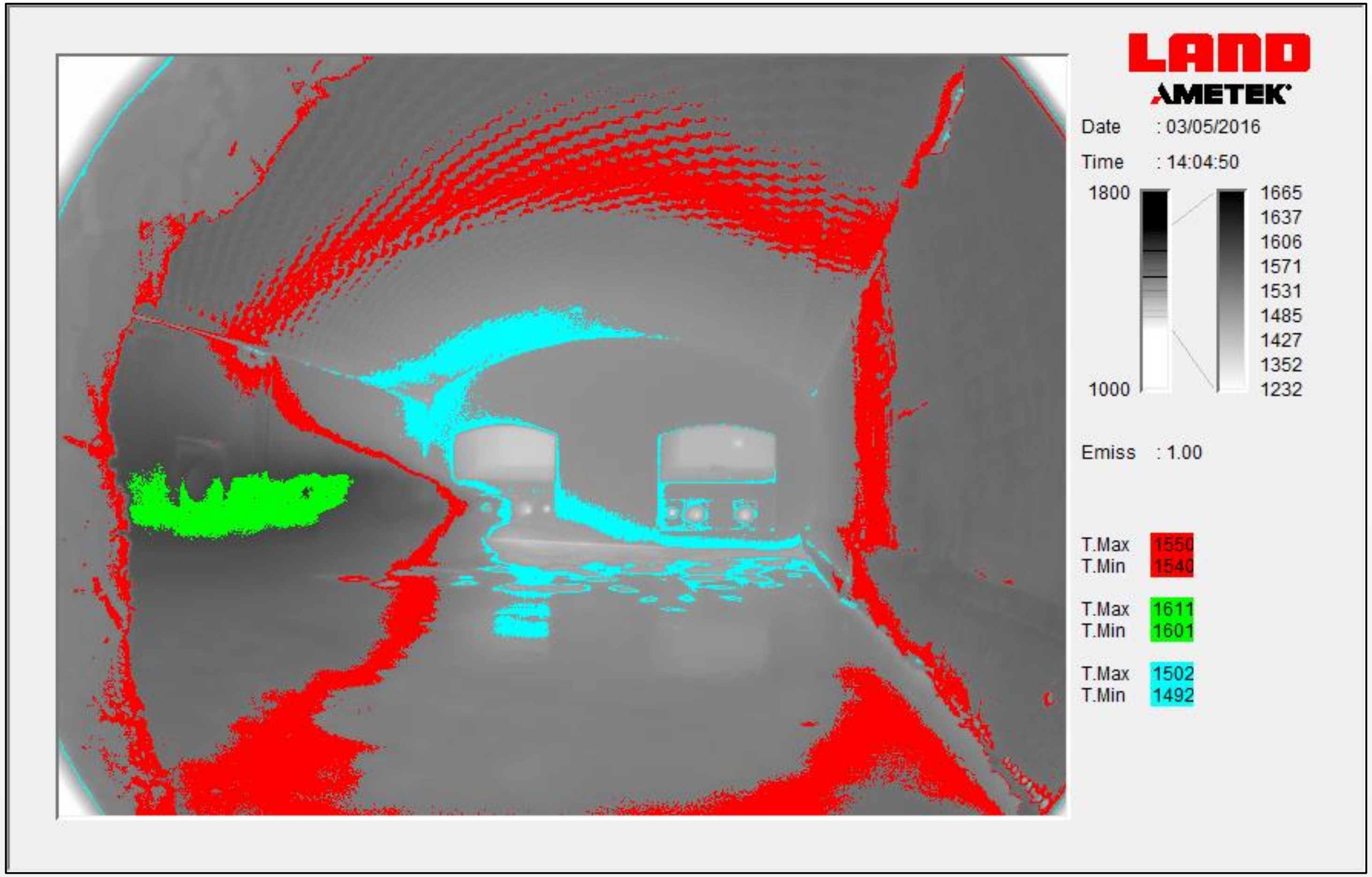
# Air Ingress / Leakage & Monitoring of Damaged Refractory

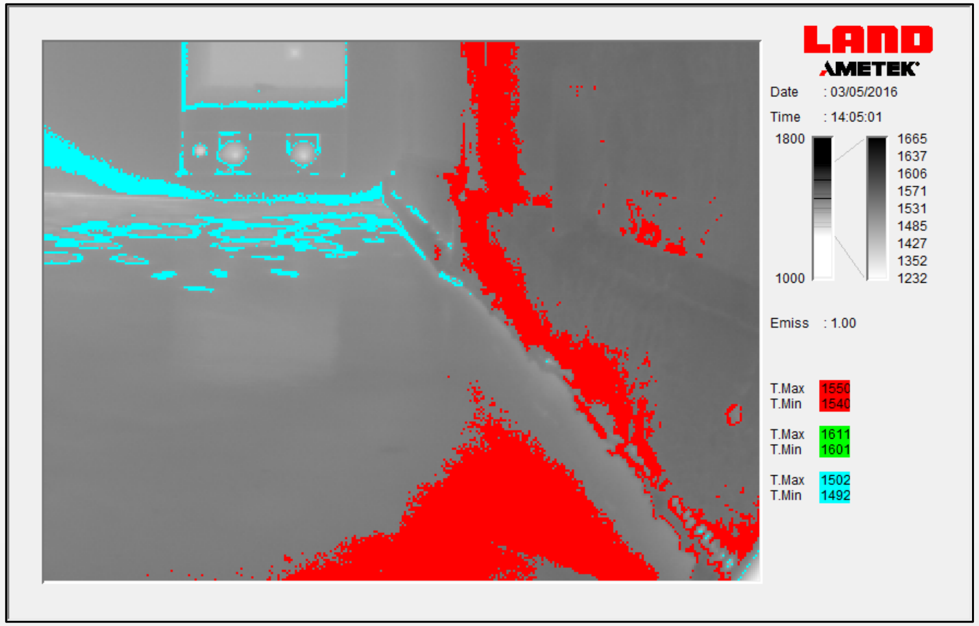



- Air ingress / leakage & monitoring of damaged refractory
- Monochrome Thermal Image with 3x zoom.
- Rectangle areas of interest
- Low temperature alarm warning



# Zoom and Variable Isotherm Functions Enable Zones or Specifically Isotherm Bands of Thermal Interest to be Highlighted.



# VIDEO 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.

# Original Goals and Objectives for Encirc Elton Case Study

1 Ability to correlate thermal images with thermocouple data

2 Potential to measure thermal profile continuously and specifically at the end of every reversal to optimise/troubleshoot quality and throughput.

3 Identify potential over temperature or venting to avoid melting refractory

4 Identify potential cold temperature or blockage to avoid condensation

5 Identify areas of over-cooling and/or air ingress

6 Identify area of high peak flame intensity to generate NOx

# Encirc Elton - Case Study Part 1

- Optimise Furnace Operations

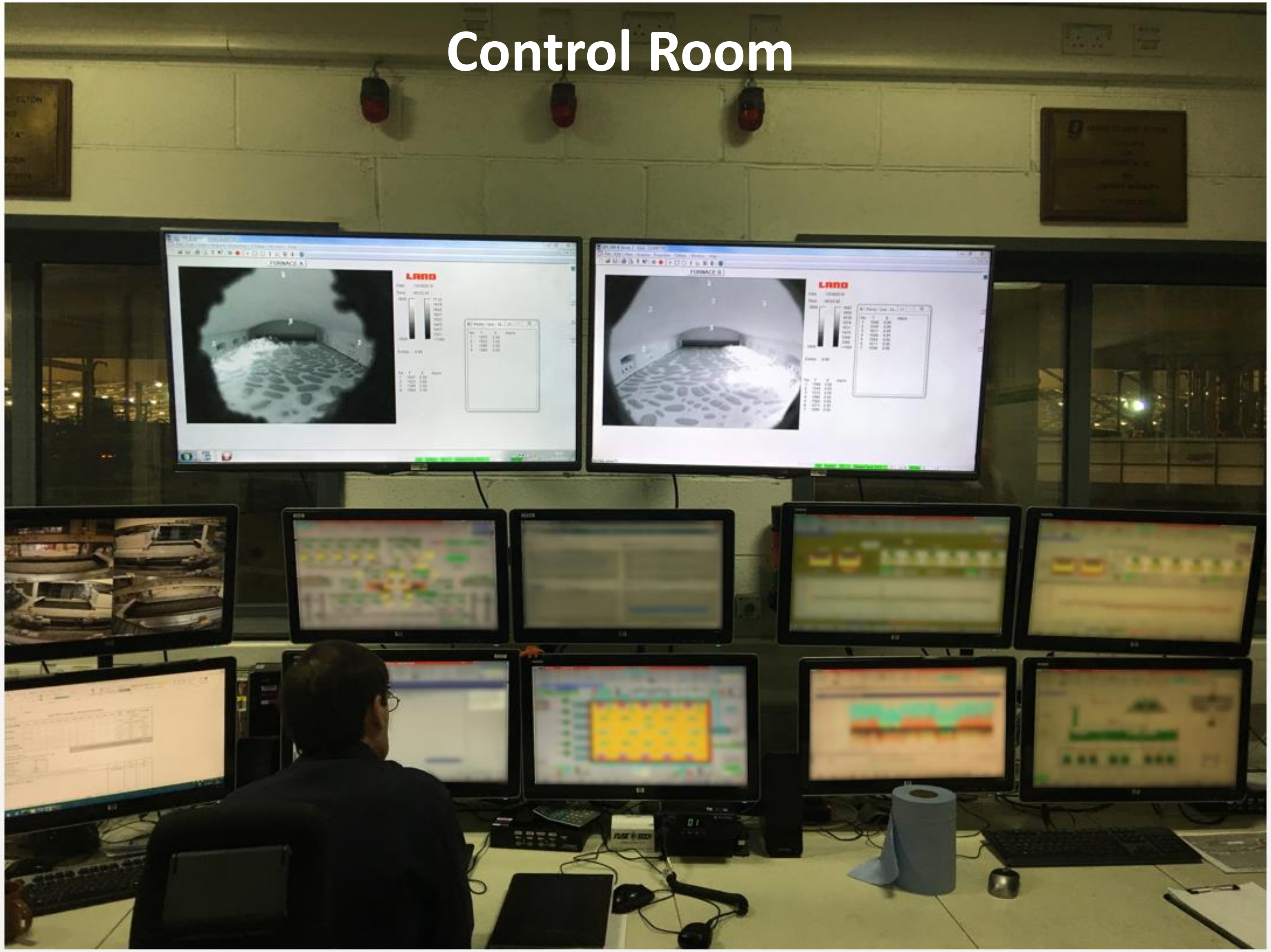
## Original Installation in 2014

- System installed to give superior view of the batch pattern/line
- Verify crown thermocouples and selected single points
- Both goals achieved and customer extremely happy with NIR B

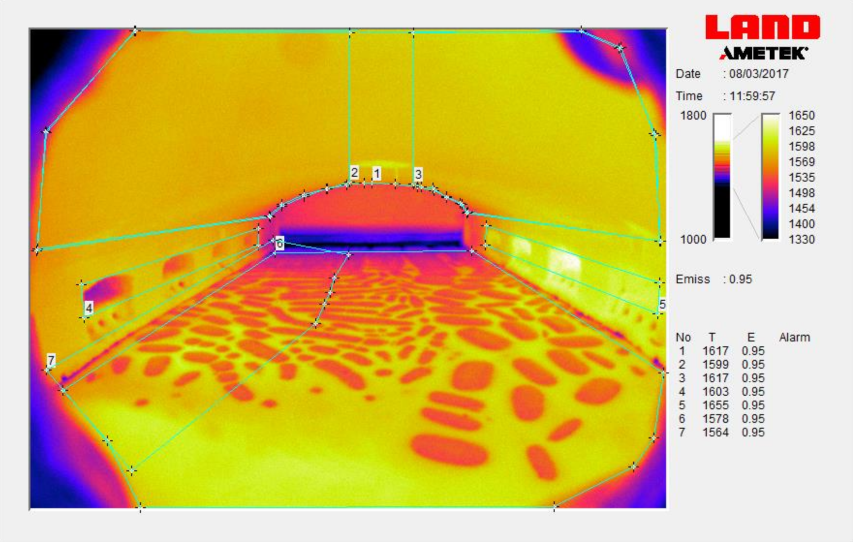
## Original Goal in 2016

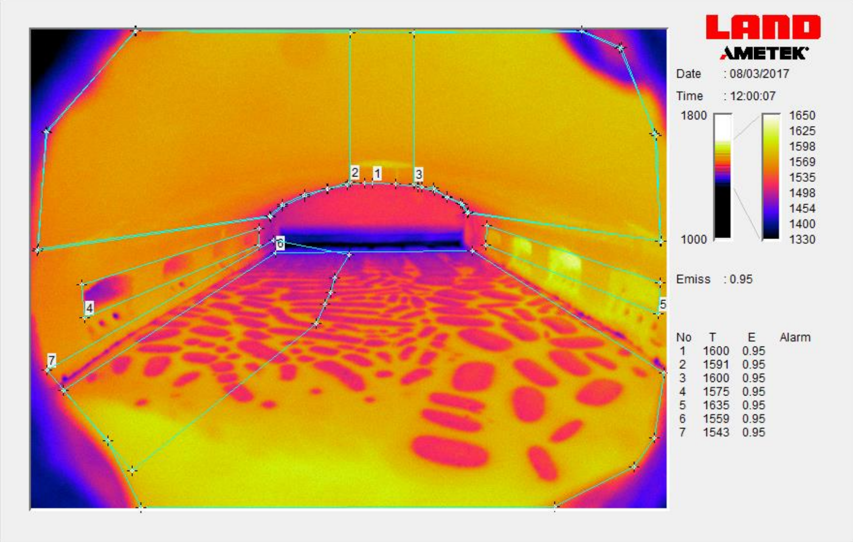
- Demonstrate that the NIR B can be used to highlight “challenges”
- Use NIR B to establish thermal profile and then optimise fuel/energy profile

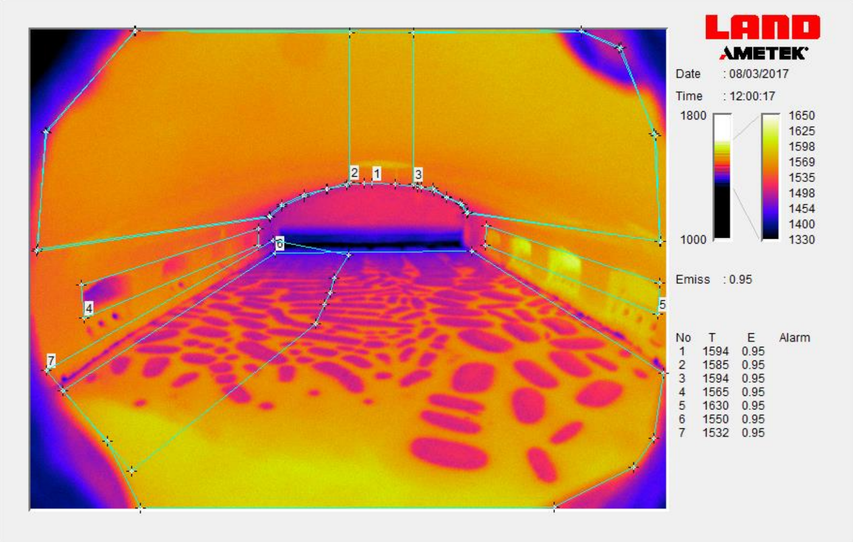
# Control Room

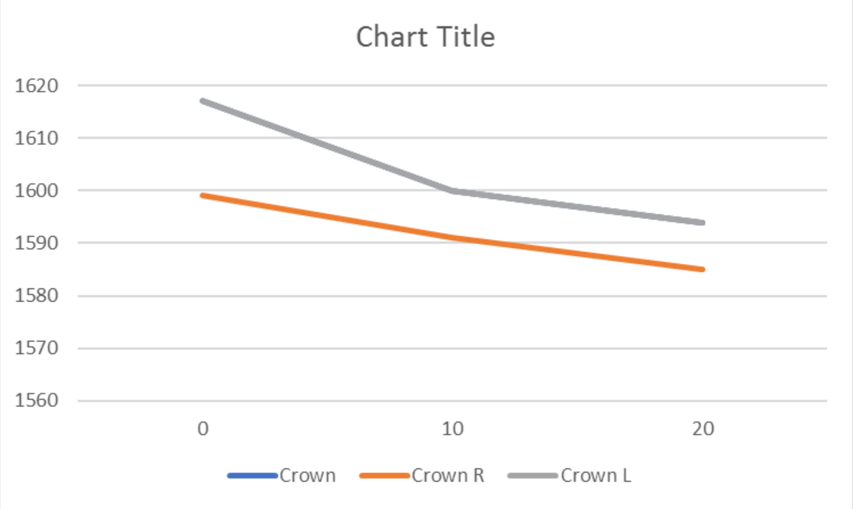


# Impact of Time on Temperature after Flame Off



## October 2016

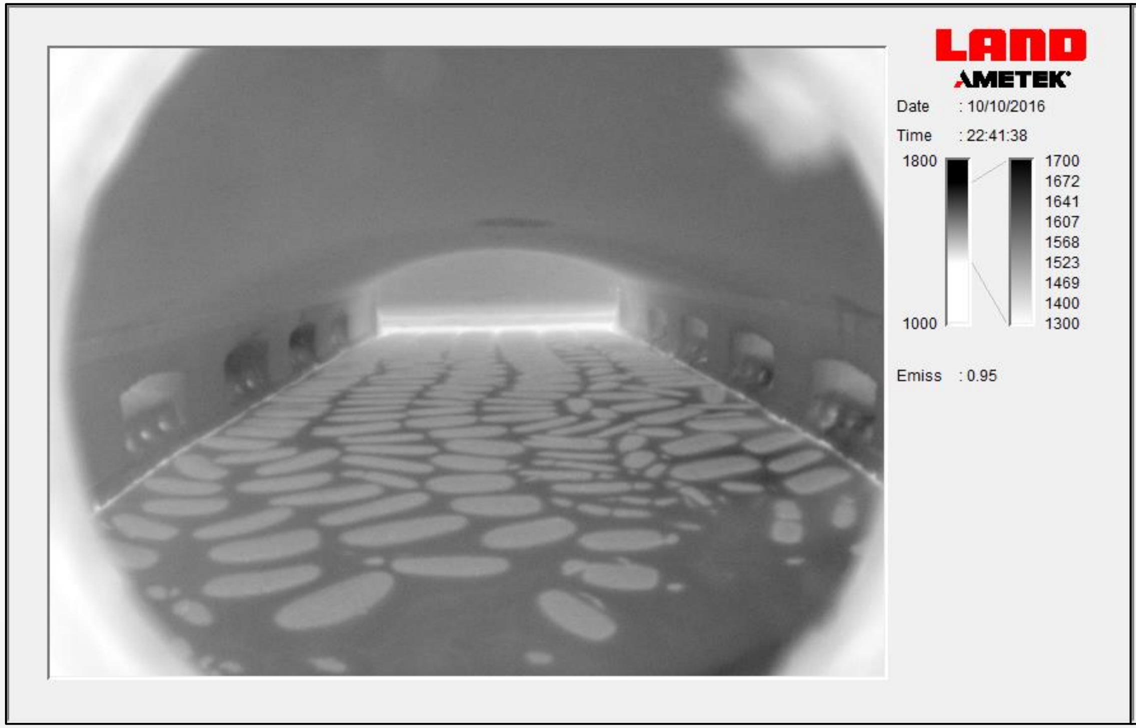
- Initial Survey and comparison of 2014 data indicated deterioration of regenerators and that the thermal profile was not optimised.
- Recommendation that regenerator maintenance performed ASAP
- Negative image showed over-cooling of tuck line and fans backed off.

## March 2017

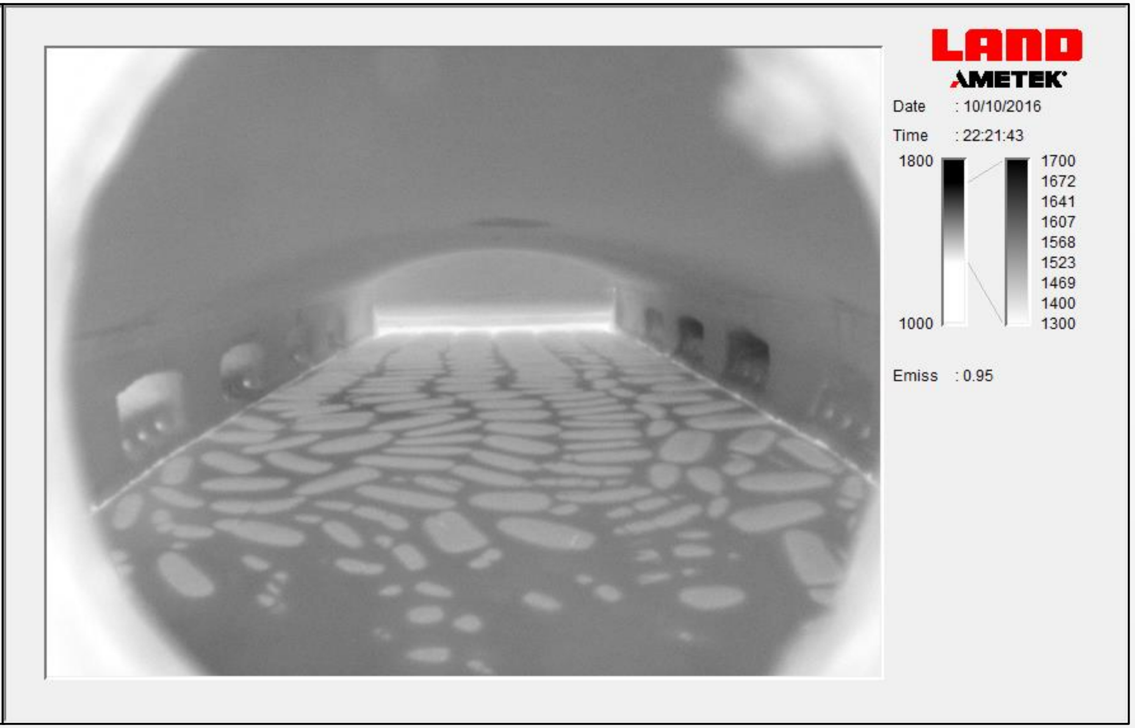
- Regenerator maintenance completed and combustion optimised
- Operators moving energy and using NIR B to optimise thermal profile.
- Record pull rate achieved with +10 year asset!

# Negative Image Showing Cooling (10/10/2016)

## End of Firing Left to Right

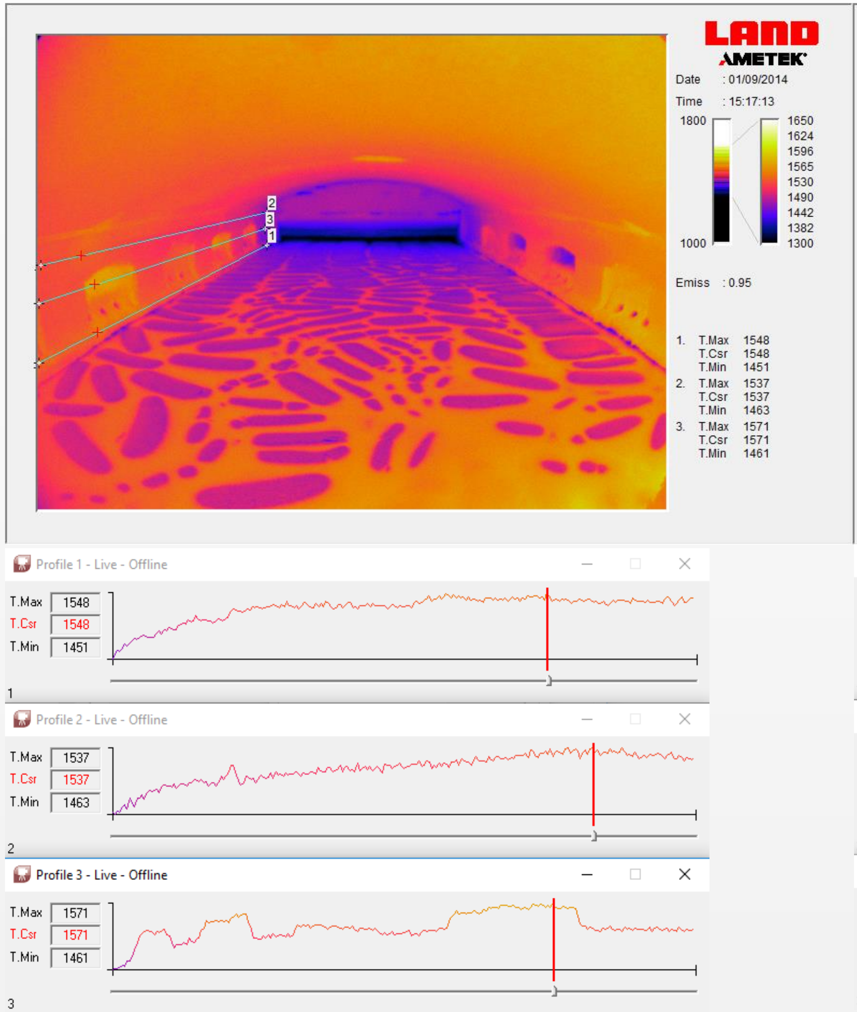



## End of Firing Right to Left

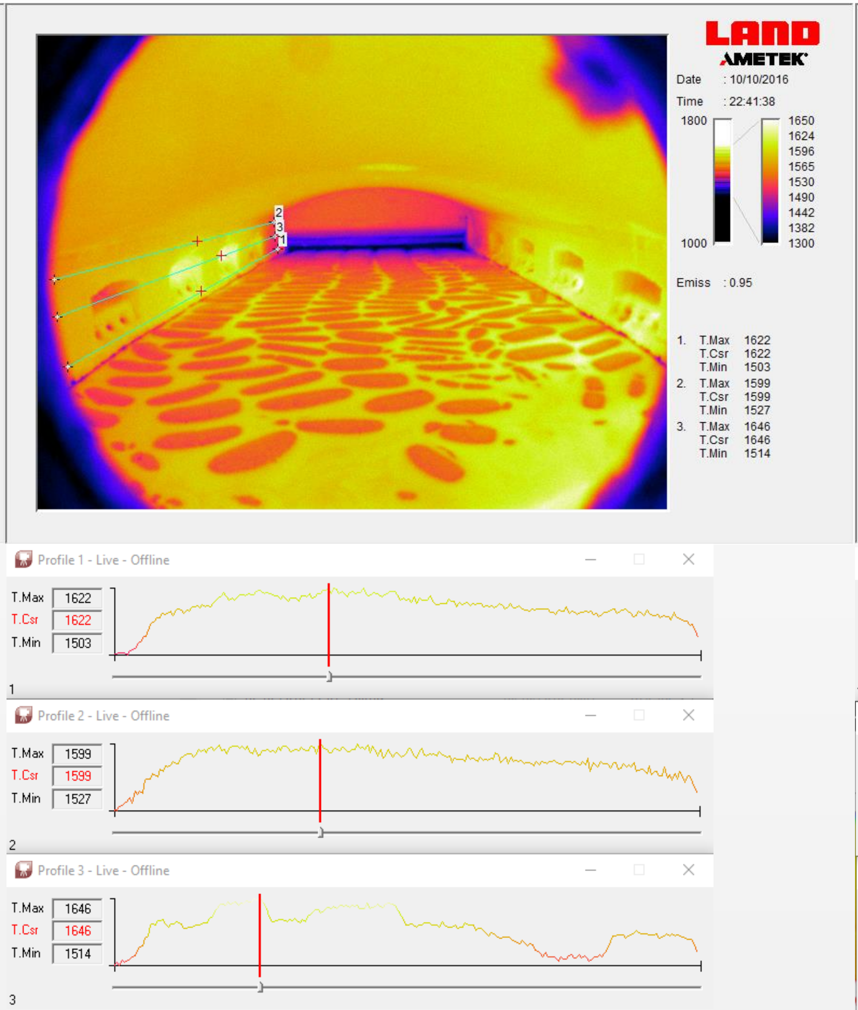


# End of Firing L-R

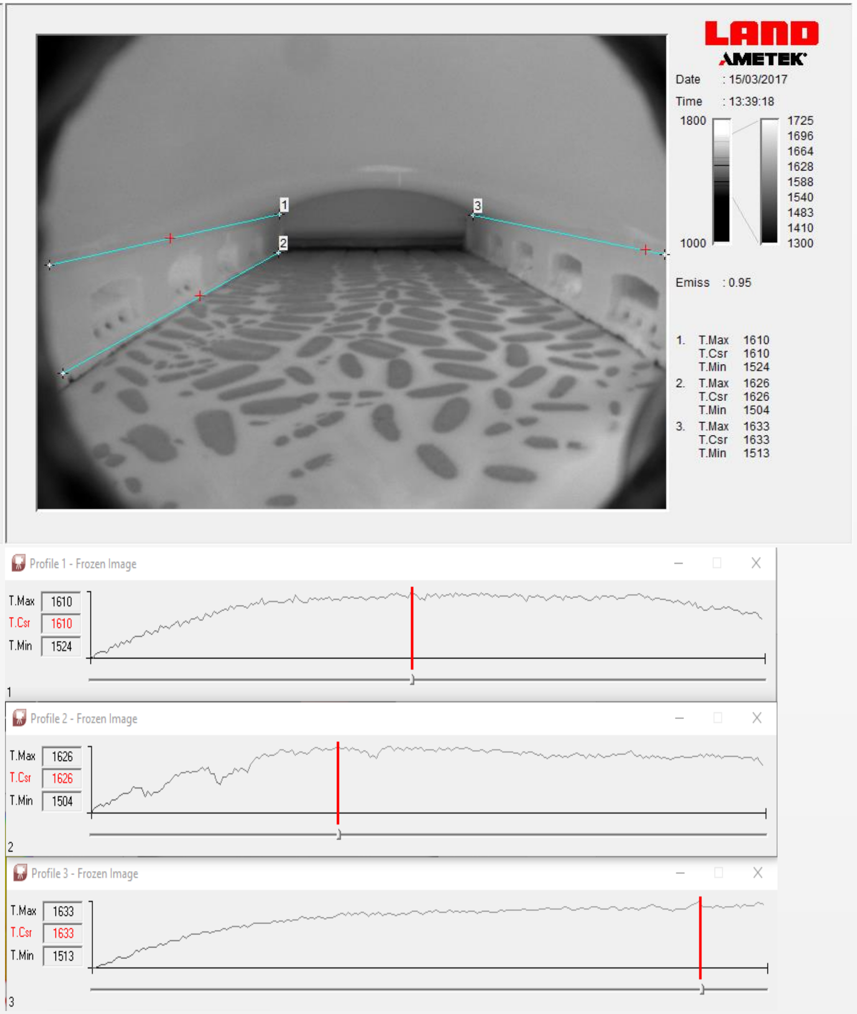
01/09/14




10/10/16

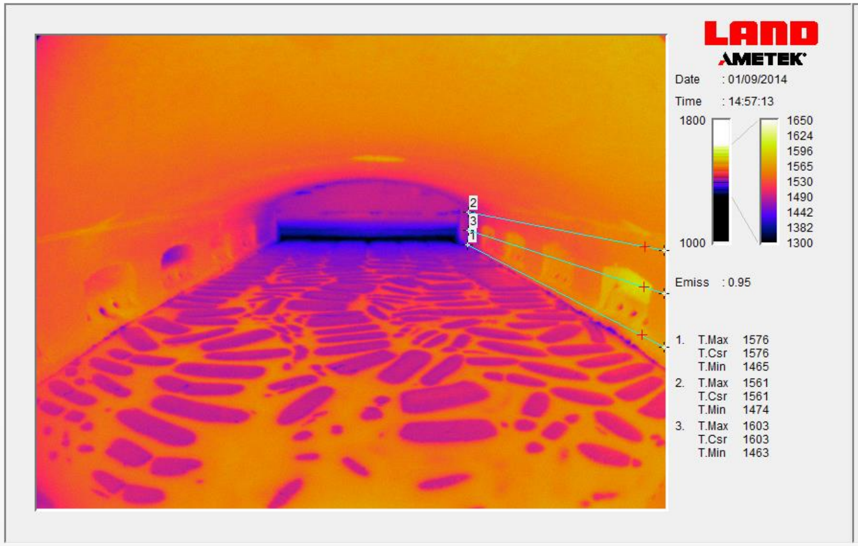


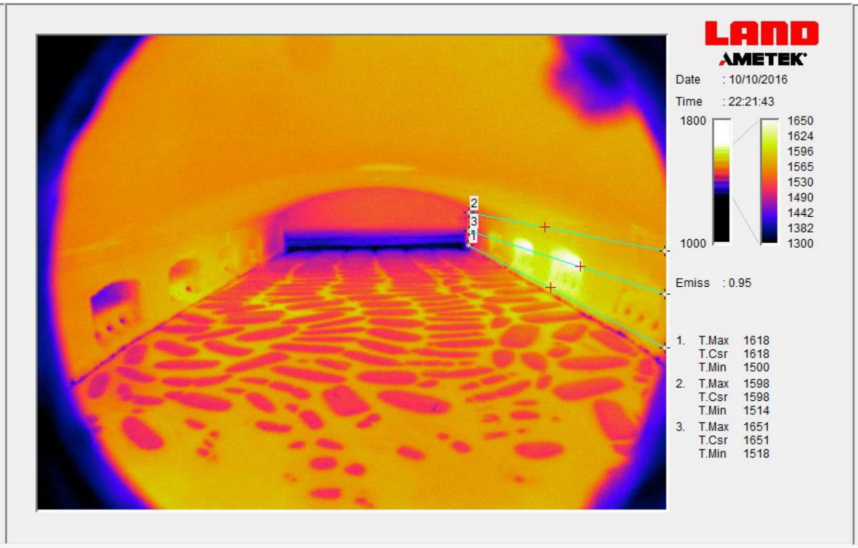

15/03/17

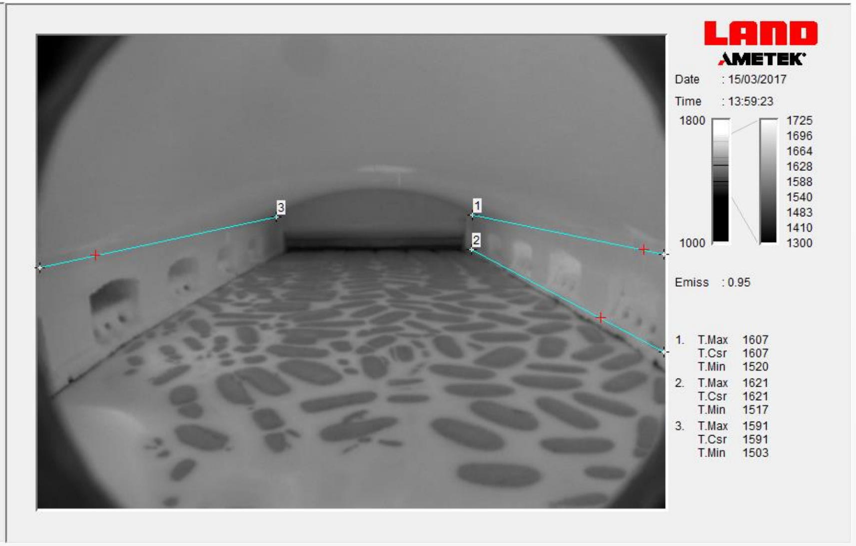


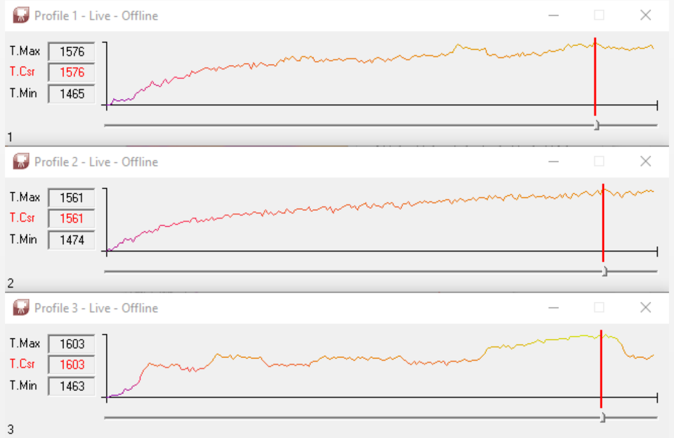
# End of Firing R-L

01/09/14 | 10/10/16 | 15/03/17

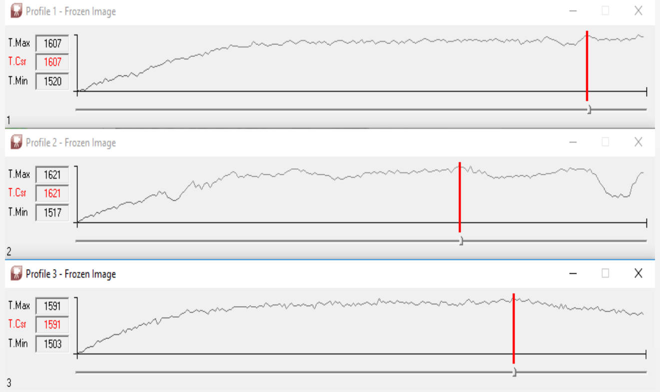






# Encirc Elton - Case Study Part 2

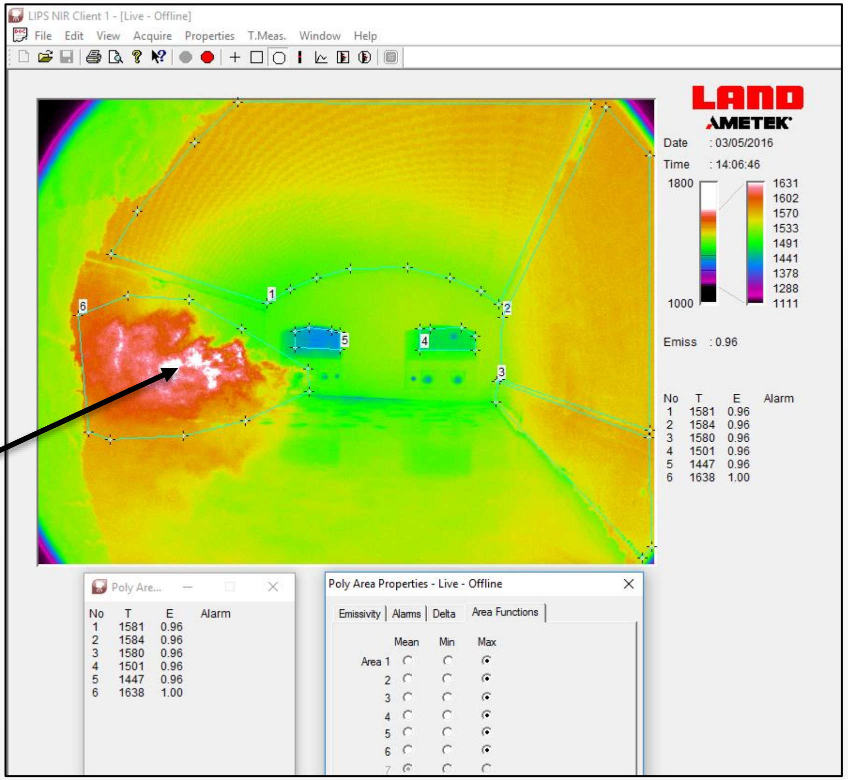
- Visual flames and NOx

# Nitrogen Oxide NOx formation

There are typically 4 modes of NOx formation:

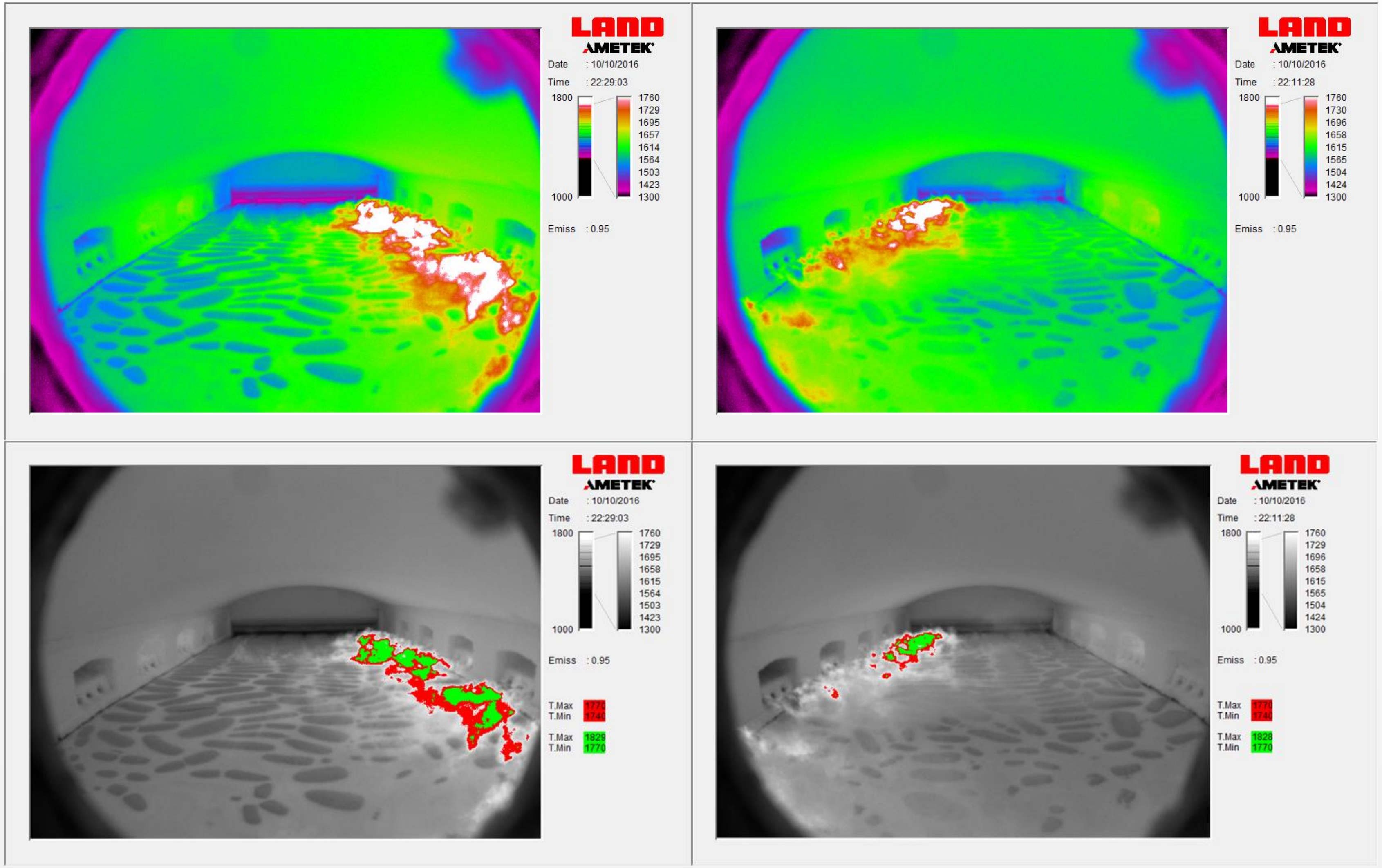
- Fuel NOx – from Nitrogen elements in fuel
- Prompt NOx – relatively low temperature reaction
- Feed NOx – from raw ingredients such as Niter in the past
- Thermal NOx - at temperatures in excess of 1600°C

**The upper limit of the NIR B is 1800°C areas above the upper limit are shown in white colour, by adjusting the range limits to increase contrast it is possible to determine what parts of the flame are the hottest and thereby assess generation of thermal NOx.**

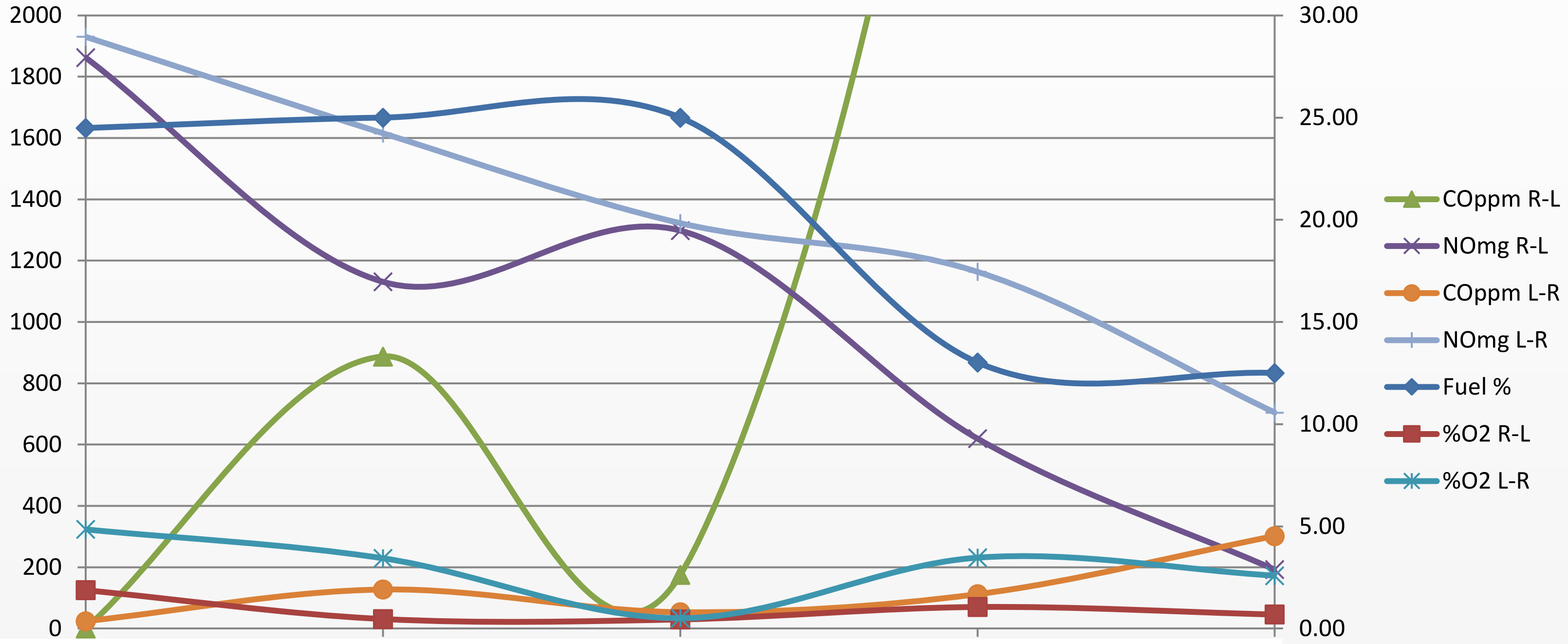



In glass manufacture as a result of modern batch materials typically the greatest source of NOx is believed to be thermal according is by Thermal NOx. At temperatures in excess of 1600°C (2900°F) the Oxygen molecules in air start to dissociate into elemental atoms. The higher the process or flame temperature, the higher the dissociation and therefore the greater formation of NOx. In the hottest zone of the flame a super equilibrium level of Oxygen atoms exists.

# Flame Intensity – TANK B Oct 16

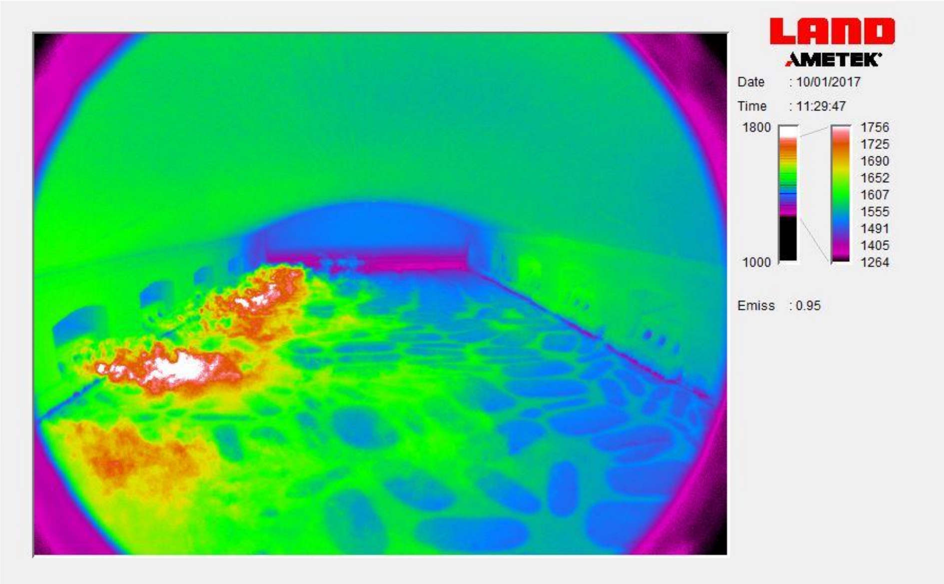


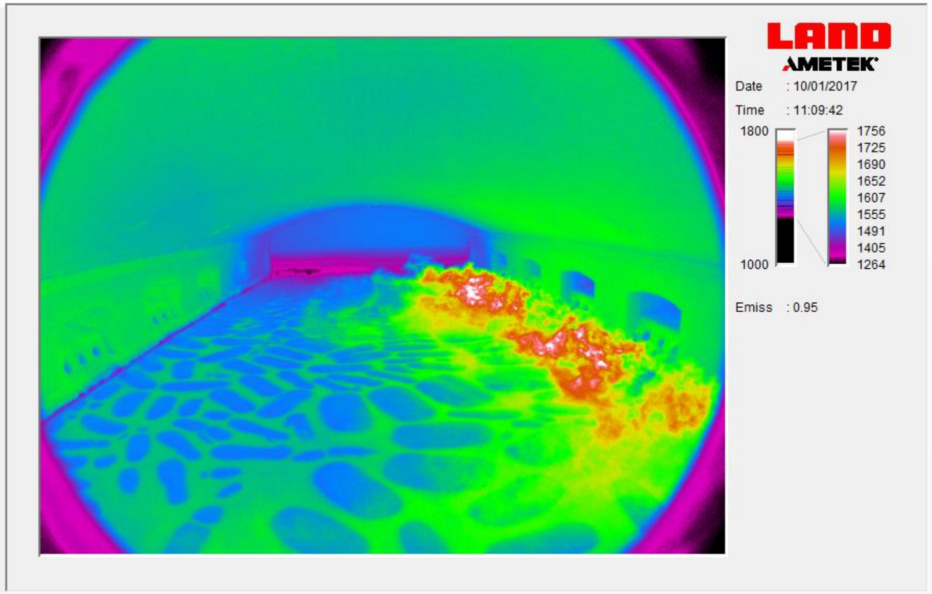
# Lancom 4 Target Wall Port Gas Analysis OCT 16




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Fuel % | 24.49 | 25.00 | 25.00 | 13.01 | 12.50 |
| %O2 R-L | 1.88 | 0.47 | 0.45 | 1.06 | 0.69 |
| COppm R-L | 0 | 887.7 | 175.3 | 4050 | 17541 |
| NOmg R-L | 1862.3 | 1131.2 | 1298.3 | 619.7 | 192.4 |
| %O2 L-R | 4.85 | 3.44 | 0.51 | 3.47 | 2.59 |
| COppm L-R | 24.3 | 127.2 | 53.3 | 112 | 301.6 |
| NOmg L-R | 1930.2 | 1615.6 | 1322.4 | 1163.5 | 704.5 |

# Jan 17 Furnace A Flame Intensity V NOx




| Fuel % | 22.5 | 23.5 | 22.5 | 18 | 13.5 | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | # 1 L-R | # 2 L-R | # 3 L-R | # 4 L-R | # 5 L-R | | |
| % O2 | 1.87 | 1.15 | 1.21 | 0.82 | 0.43 | | |
| CO ppm | 0 | 0 | 0 | 0 | 0 | | |
| NO ppm | 865 | 1236 | 1385 | 1004 | 1036 | | |
| NO2 ppm | 0 | 0 | 0 | 0 | 0 | | |
| | | | | | | | |
| NOx mg | 1202.0 | 1655.0 | 1860.1 | 1322.3 | 1338.4 | | |
| | 270.4602 | 388.9223 | 418.5334 | 238.005 | 180.6838 | 1496.605 | |
| | 18% | 26% | 28% | 16% | 12% | | |

| Fuel % | 22.5 | 23.5 | 22.5 | 18 | 13.5 | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | # 1 R-L | # 2 R-L | # 3 R-L | # 4 R-L | # 5 R-L | |
| % O2 | 1.22 | 0.45 | 0.89 | 1.79 | 1.45 | |
| CO ppm | 0 | 128 | 0 | 0 | 835 | |
| NO ppm | 922.4 | 863 | 1269 | 806 | 634 | |
| NO2 ppm | 0 | 0 | 0 | 0 | 0 | |
| | | | | | | |
| NOx mg | 1239.5 | 1116.0 | 1677.1 | 1115.4 | 862.0 | |
| | 278.8819 | 262.2581 | 377.3468 | 200.7661 | 116.3716 | 1235.624 |
| | 19% | 18% | 25% | 13% | 8% | |

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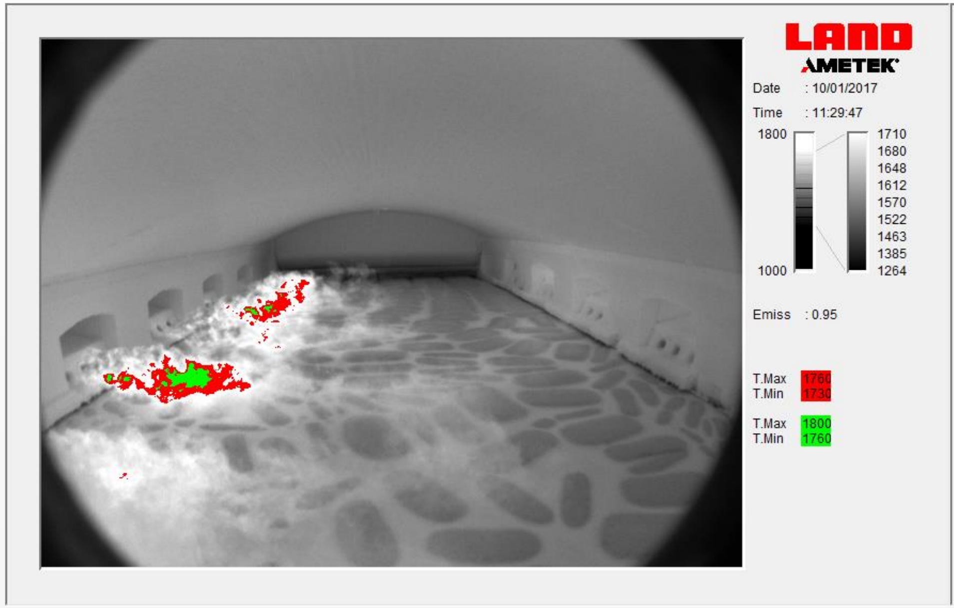
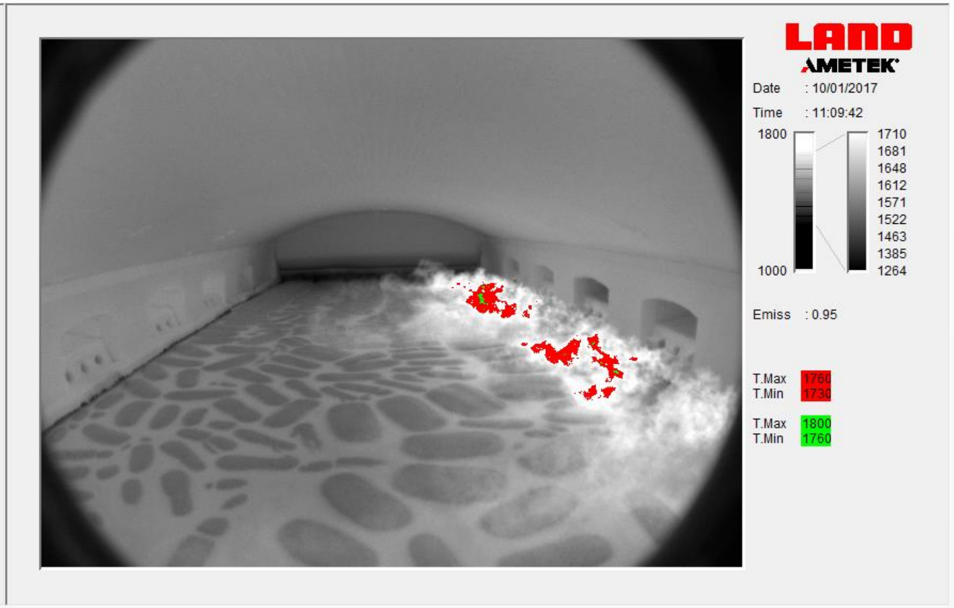
# Flame Intensity V NOx – Mono Pallet with Isotherms




| Fuel % | 22.5 | 23.5 | 22.5 | 18 | 13.5 | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | # 1 L-R | # 2 L-R | # 3 L-R | # 4 L-R | # 5 L-R | |
| % O2 | 1.87 | 1.15 | 1.21 | 0.82 | 0.43 | |
| CO ppm | 0 | 0 | 0 | 0 | 0 | |
| NO ppm | 865 | 1236 | 1385 | 1004 | 1036 | |
| NO2 ppm | 0 | 0 | 0 | 0 | 0 | |
| | | | | | | |
| NOx mg | 1202.0 | 1655.0 | 1860.1 | 1322.3 | 1338.4 | |
| | 270.4602 | 388.9223 | 418.5334 | 238.005 | 180.6838 | 1496.605 |
| | 18% | 26% | 28% | 16% | 12% | |

| Fuel % | 22.5 | 23.5 | 22.5 | 18 | 13.5 | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | # 1 R-L | # 2 R-L | # 3 R-L | # 4 R-L | # 5 R-L | |
| % O2 | 1.22 | 0.45 | 0.89 | 1.79 | 1.45 | |
| CO ppm | 0 | 128 | 0 | 0 | 835 | |
| NO ppm | 922.4 | 863 | 1269 | 806 | 634 | |
| NO2 ppm | 0 | 0 | 0 | 0 | 0 | |
| | | | | | | |
| NOx mg | 1239.5 | 1116.0 | 1677.1 | 1115.4 | 862.0 | |
| | 278.8819 | 262.2581 | 377.3468 | 200.7661 | 116.3716 | 1235.624 |
| | 19% | 18% | 25% | 13% | 8% | |

# NOx Conclusions

- In October there appears to be a correlation with peak flame intensity and NOx with higher area of peak flame has higher Nox.
  - Firing R-L the weighted NOx is 14% higher on first 3 ports and 24% overall compared to L-R.
  - This corresponds to NIR B showing larger area of high temp flame firing R-L.

- In January data repeatable on second furnace.

# Summary of Case Studies

- Initial goal was to use the NIR B data to analyse furnace operations with a view to improve furnace performance. Since SNCR installed furnace NOx emissions not critical.
- Initial survey identified that hot spot had moved as a result of fuel profile arising from port blockages. Survey identified relative port exhaust flows
- Data used by customer to justify refractory regenerator maintenance.
- Lessons/experience gained enabled operators to redistribute fuel and recover hot spot resulting in new record pull on an asset in last 20% of projected life.
- By comparing peak flame intensity with flue and target wall emissions gave a strong correlation with NOx. It is possible to predict firing side with higher NOx and port/flame contributing the greatest.

# Conclusions

- Operations -Temperature thermal profile
  - Potential energy reduction, pull or yield increase on unrestricted furnace
  - Demonstration of recovery post repair
- Emissions - Flame Intensity and NOx correlation
  - Potential to use as part of NOx/NH3 reduction
- Maintenance – Furnace Sealing
  - Energy and emission reduction with asset protection
- Asset Protection
  - Over and under temperature alarms
  - Identify regenerator restrictions before blockage/deterioration
  - NaOH condensation
  - Preventative maintenance on weak/thin refractory

# Regenerative Furnaces

Potential for automatic reversal control  based on target wall temperatures
Ability to take full optical profile at end of each firing cycle
Identify impact of batch flow (whirlpool  witnessed)
Identify burners requiring cleaning
Potential to use during a hot hold regenerator repair when using short-term oxy-fuel

# Recuperative Furnaces

Monitor temperatures opposite and adjacent burners to optimise heat release
Identify air distribution based on NOx profile

# Oxy-fuel Furnaces

Alarm on burner block run-down necessitating block cleaning to avoid cutting.
Flames almost invisible with ability to see batch and bubblers clearly at all times Monitor temperatures opposite and adjacent burners to optimise heat release
Ability to see thermal difference and profile from  side to side with resulting batch flow
If multiple flues can see dominant flows and compensate as required

**Summary of potential benefits of using NIR B (Patents Pending)**

Validation of CFD models and understanding of specific furnace operations
Potential to use as part of the furnace heat-up to "see" problems of expansion, overheating/cold spots etc below visible.
Thermal profile optimisation to get hot spot where it is needed.
Batch monitoring with alarm potential
Identify air ingress or excess cooling with alarms on volatile condensation temp.
Flame optimisation for heat transfer and energy reduction
Flame optimisation for emission and NOx reduction
Burner monitoring for highlighting cleaning
Optimisation of colour/glass changes
Monitoring of refractories for asset protection to extend furnace life
Potential to use as tool to better see ceramic welding or other repair
Troubleshooting tool
Justification for an action
Remote access enables support from corporate or 3rd party resources.
Training tool on Best Operating Practice

# Glass Focus Awards 2017 – the winners

## Innovative Solution


AMETEK Land, Encirc and Simpson Combustion and Energy

For the collaboration between AMETEK Land, Simpson Combustion and Energy and Encirc in which temperature data from AMETEK Land's near infrared borescope (NIR-B) was used to optimise furnace operation at Encirc's Elton site. The work has also demonstrated potential for future reductions in operating costs and emissions. Find out more...

Sponsored by: Glass Technology Services Ltd

# Thank-you

# Any questions now?