THERMAL MONITORING LADLE FURNACE *

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Abstract
From time-to-time ladle breakouts may occur, typically in the slag-zone. To prevent a ladle breakout, four infrared (IR) thermal cameras were installed in the ladle furnace station to prevent ladle refractory brick failure, thereby reducing maintenance costs and increasing operation safety. The system analyzes the temperature profile of the ladle shell during heating and is connected to the furnace's programmable logic controller (PLC) and Inteco smart electrode controller (ISEC), its electrode regulation system. In the event of hot spot detection, the furnace automatically stops the heating and signals an alarm to the operator via the furnace PLC and human machine interface (HMI). Additionally, a four-screen monitor was installed, allowing the operator to monitor the temperature profile of the ladle furnace at any time.
Keywords: Thermal Monitoring; Ladle Furnace; Aplan; Inteco.

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1 INTRODUCTION

Ladle breakout is a risk topic often discussed by industrial facilities that handle molten materials.
Over the years, several systems have been tested using infrared sensors and real time data by thermal cameras, typically in iron and steelmaking shops. The reliability, rapid scanning and compilation of data were proven despite the high cost of implementation.
Technological advances, industrial park expansions, as well as the globalization of world trade have made many technologies accessible and feasible.
A breakout of the liquid metal-filled ladle may cause equipment damage, loss of production and even loss of life.
Each operation has been developing controls to prevent the ladle refractories failure such as visual inspection and KPI's for each ladle, however, this information sometimes is not enough to avoid a ladle breakout.
To prevent this kind of incident, thermal cameras can detect hotspots on the cold side of the ladle shell and shut down the operation as well trigger alarms to inform the operational risk.
A thermal camera installation project at the ladle furnace station of Ferro-Nickel facilities in the Brazilian state of Goias was developed, implemented and commissioned by APLAN-INTECO.

2 DEVELOPMENT

The concept of covering the entire surface of the ladle shell requires the installation of four thermal cameras. Each camera must be protected with a water-cooled housing and allows for an operating temperature up to 200 °C. The pressurized compressed air system ensures clean lenses and provides additional cooling.
The four cameras are connected via a Gigabit Ethernet switch to the PC workstation that runs a special software to monitor and analyze the thermal images received from the cameras. Different alarms can be created with a range of individual measurement parameters. Through the Ethernet I/O card the alarm signals are transmitted to the Furnace PLC and the Electrode regulation system (ISEC). It is also possible to raise the electrodes automatically for select alarm signals.

* Technical contribution to the 54º Seminário de Aciaria, Fundição e Metalurgia de Não-Ferrosos, part of the ABM Week 9th edition, September 9th-11th, 2025, São Paulo, SP, Brazil.

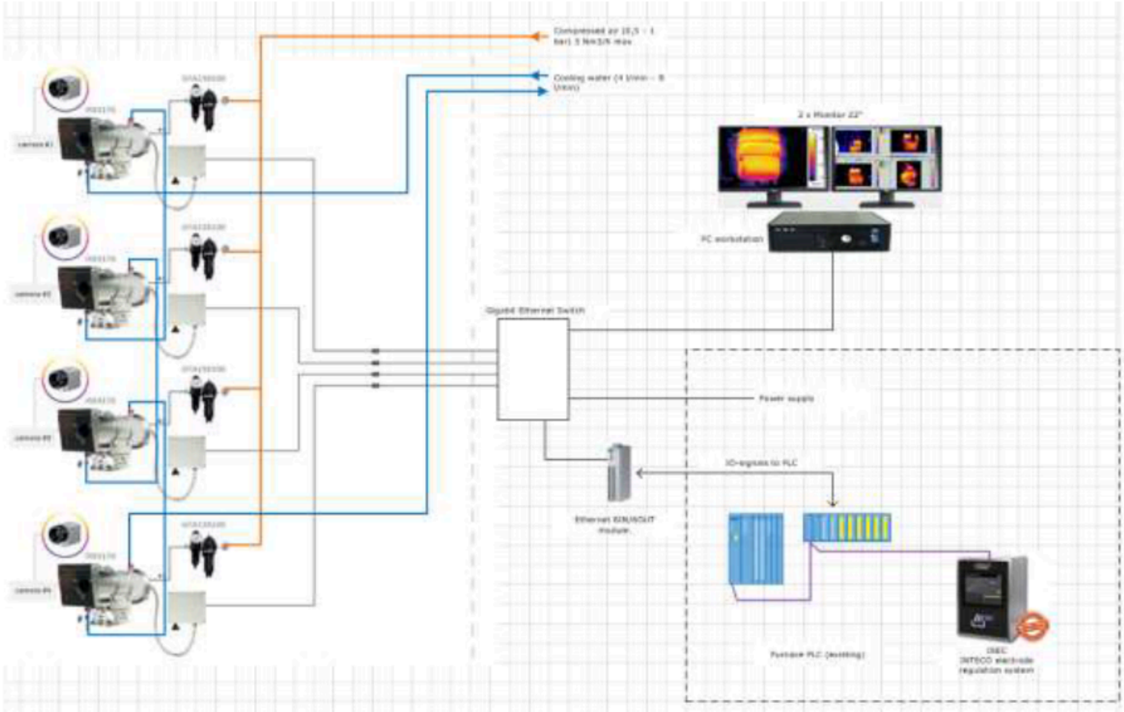

Figure 1. System overview.

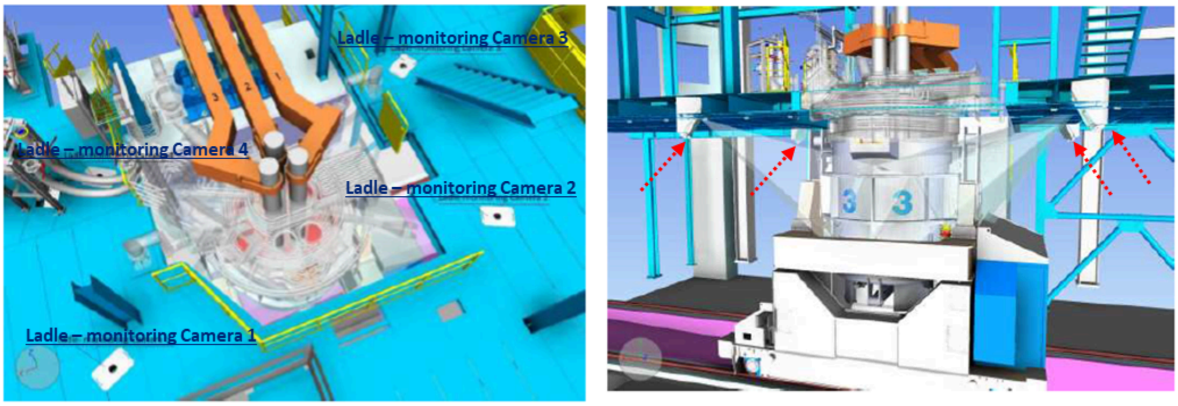

Figure 2. Location of cameras.

A thermographic 382x288 pixel resolution camera with radiometric video recording capabilities at 80Hz is protected inside a water-cooled housing with Zinco-Selenium window.

The housings are endowed with a high efficiency water cooling system allowing operation for temperatures of up to 200°C (≈752°F). They also are "pressurized": an integral compressed air system supplies clean air (or appropriate gas) for cooling and particulate removal from the lens. In this a way, the lens doesn't require any expensive protection glass, crystal and protection porthole. A constant supply of clean air is essential for proper camera operation and protection.

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Figure 3. Thermal imaging camera including housing.

This I/O card allows communication with the furnace PLC. The I/O card must be installed into the PLC-cabinet.

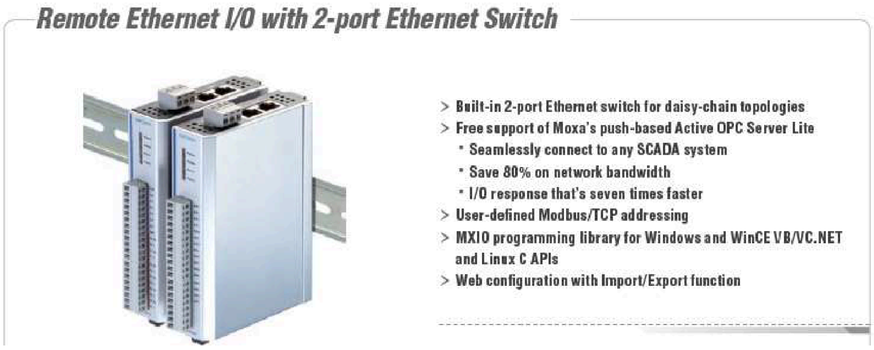

Figure 4. Ethernet I/O card.

The IR-Scan-Software manages the communication between infrared cameras and the remote I/O module. It allows for the management of up to 16 analogue outputs or 16 digital input/outputs to be associated with up to four thermal imaging cameras.
It also allows individual cameras to generate streaming video in various formats, management of up to four maps, and temperature trend graph monitoring.

Features:

- Display of multiple camera images in different windows.
- Real-time temperature information displayed within the main window as either digital or graphic.
- Analysis supported by measurement fields, automatic hot and cold spot searching.
- Logic operation of temperature information (measurement fields and image subtraction).
- Temperature display in °C or °F.
- Individual alarm setup depending on the process.
- Definition of visual or acoustic alarms and analog data output via the process interface.
- Adjustment of recording frequency to reduce data volume.
- Snapshot history display for immediate analysis.

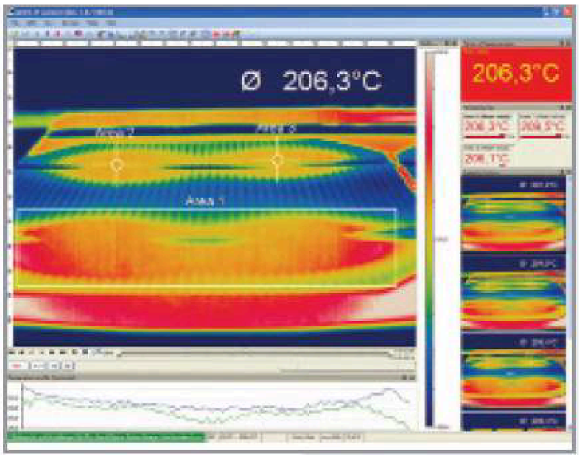

Figure 5. IR-Scan-Software.

2.1 Materials and Methods

The optical point of view of the cameras is optimized in terms of the current installation and site environment. This means despite unavoidable interferences, the number of cameras, their angulation and positioning are calculated with the final objective of focusing the optical cone on selected areas, leaving minimal area under shadow.
The positioning and angulation of the four cameras are depicted in figures 6, 7 and 8.

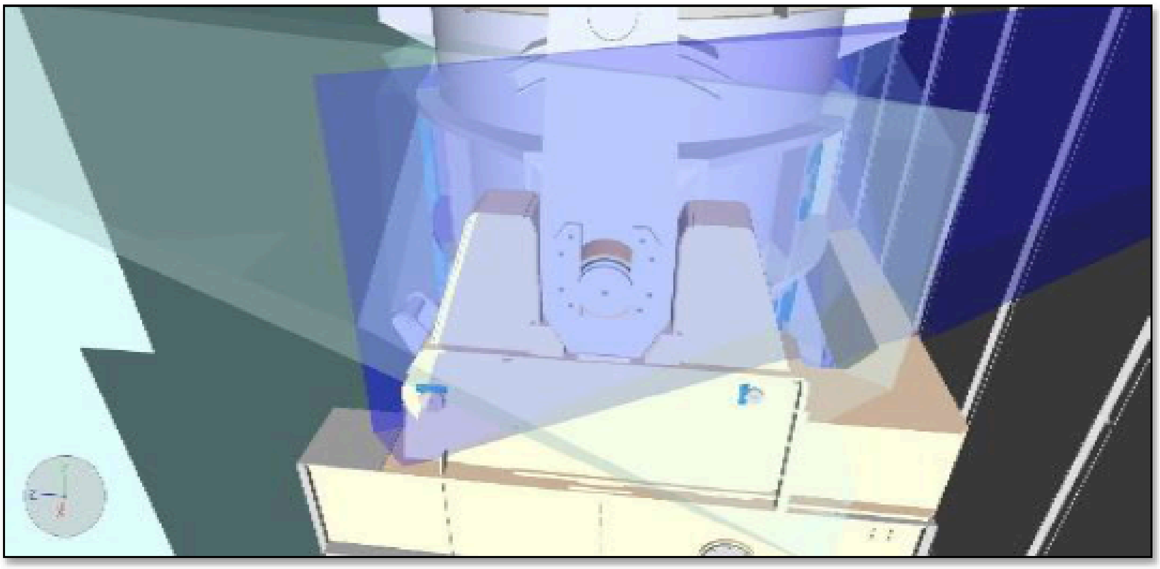

Figure 6. Area coverage (spout side).

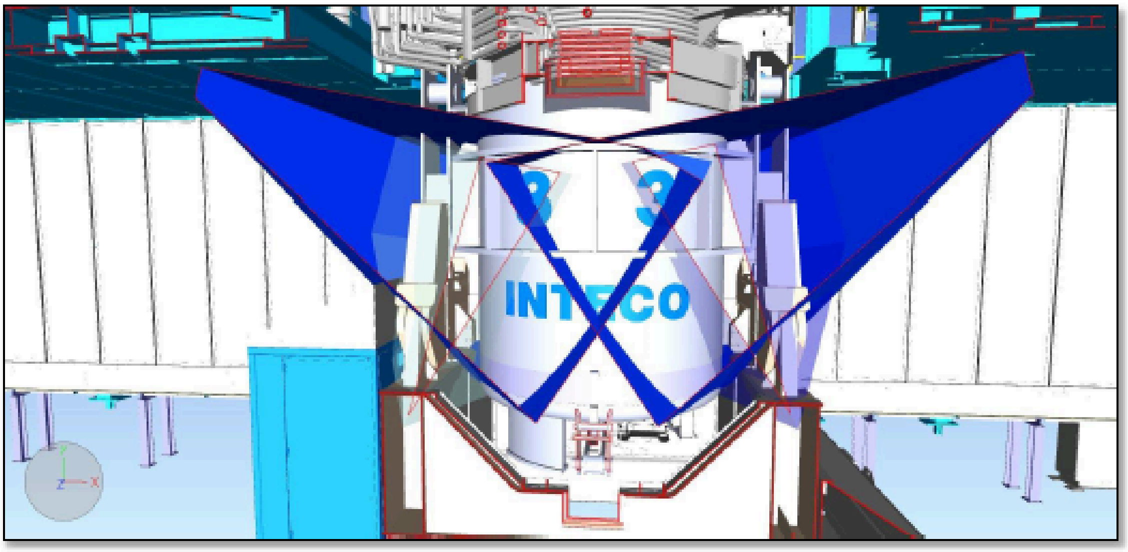

Figure 7. Area coverage (trunnion side).

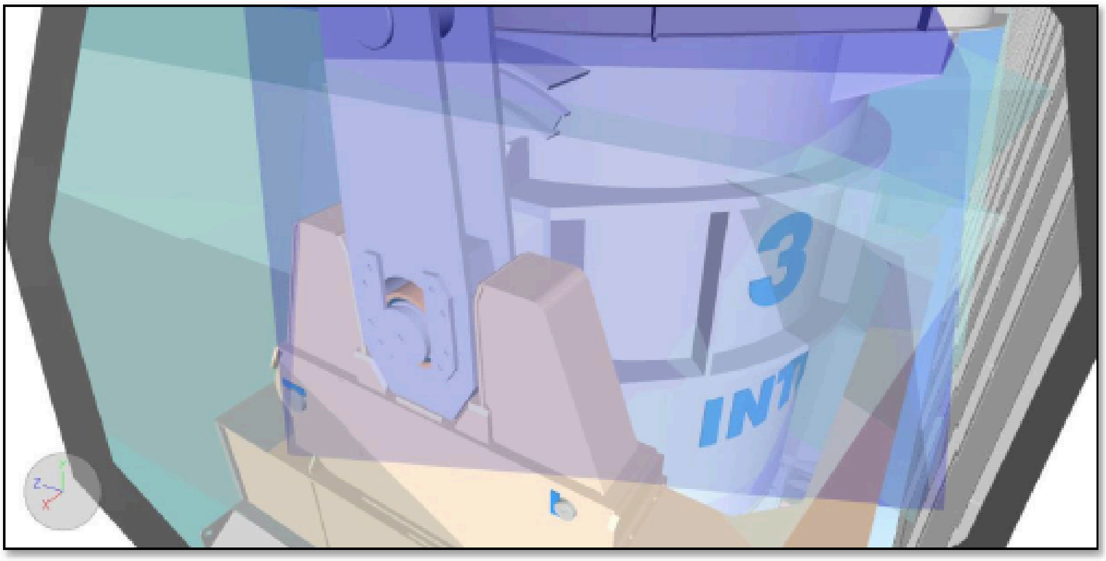

Figure 8. Area coverage (trunnion side - detail).

In terms of process/operation-related safety, the steel/slag area is the most important part of the ladle to be monitored. This area is critical mainly due to its high temperatures.

Considering the circumference of the steel/slag area line, shadow is created only by the ladle fish plates. There, approximately 89% of the line is fully viewed by the cameras. This can be observed in Figure 9.

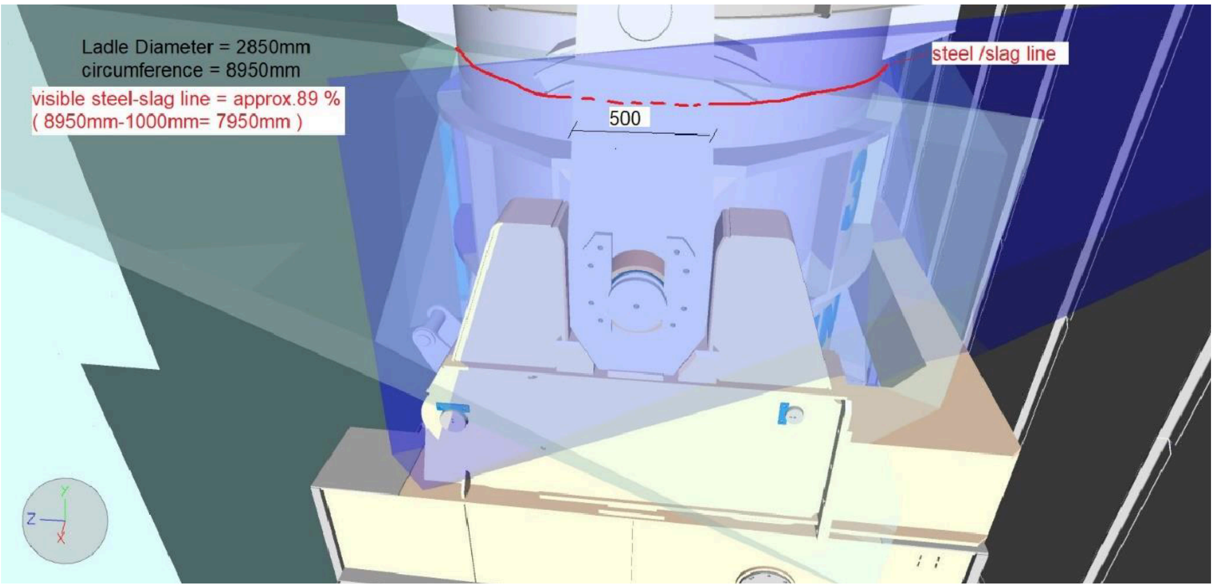

Figure 9. Steel/slag line coverage.

By an approximate calculation of the total percentage of the side surface of the ladle visible by the cameras system, a total of 74% is found. However, this calculation does not consider the inclined view of the cameras (as shown in Figures 1, 2 and 3). This means the total percentage of the side surface of the ladle visible by the cameras system is higher than 80%.
The results of the aforementioned calculations are depicted in Figure 10.

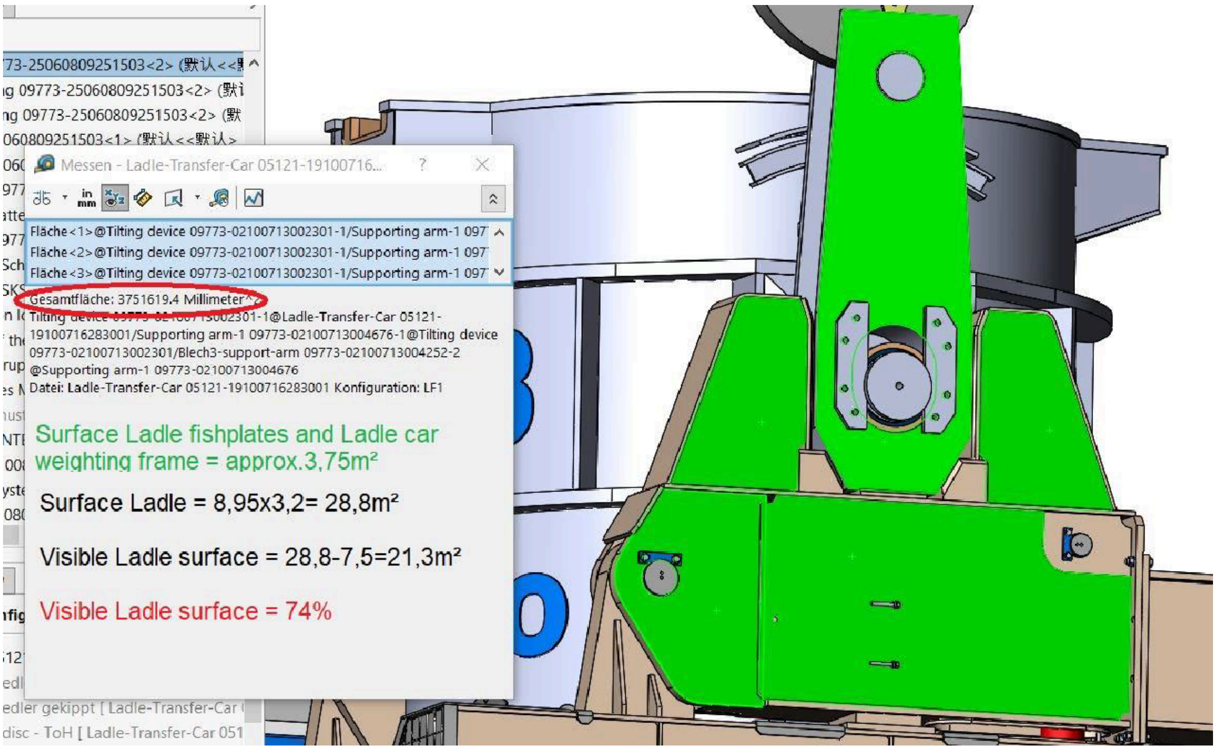

Figure 10. Calculation of total % of the side surface of the ladle visible by the camera system.

2.2 Results

A basic and detailed engineering of the project was done by APLAN-INTECO.
The installation at a ferronickel facility in the Brazilian state of Goias was performed by the customer under the supervision of APLAN-INTECO specialists along the cold commissioning and hot commissioning.
Triggers and parameters for safety interlocks and trips were discussed during commissioning.
E.g. temperatures above 450°C must be monitored and alarms issued on the supervisory system and camera monitors; a temperature of 500°C is the maximum temperature to trip the furnace and remove the ladle.
The below figures show the installed monitoring system.

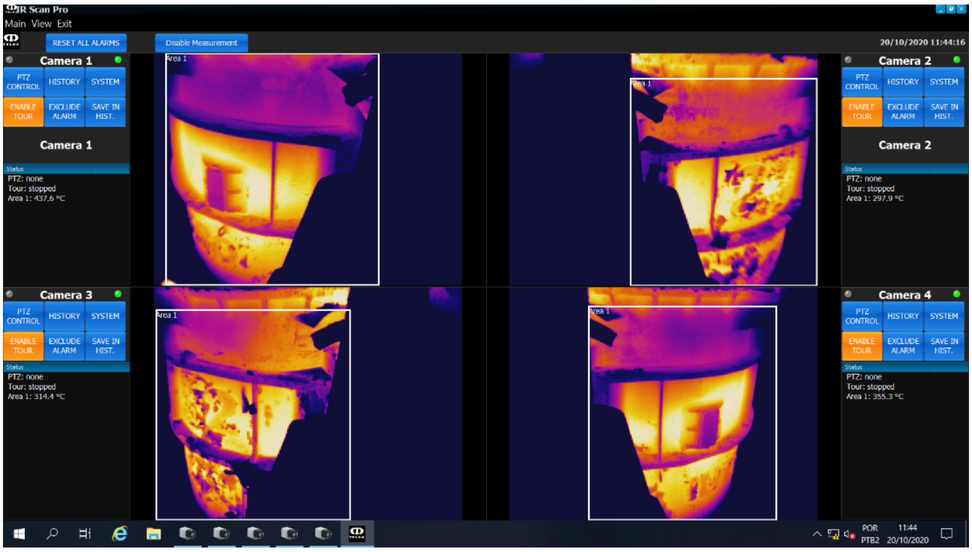

Figure 11. Quart screen for online monitoring.

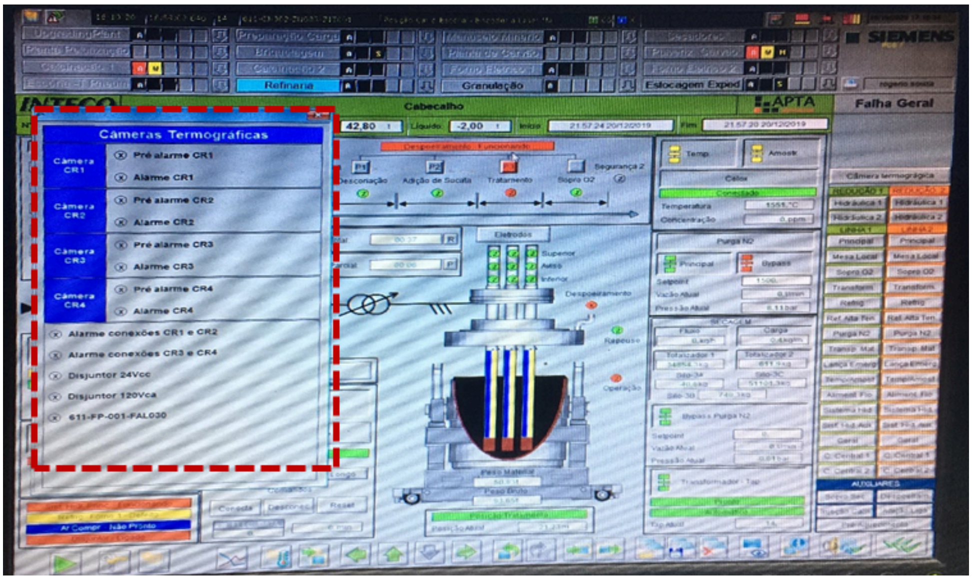

Figure 12. Alarm signal via the furnace PLC (HMI).

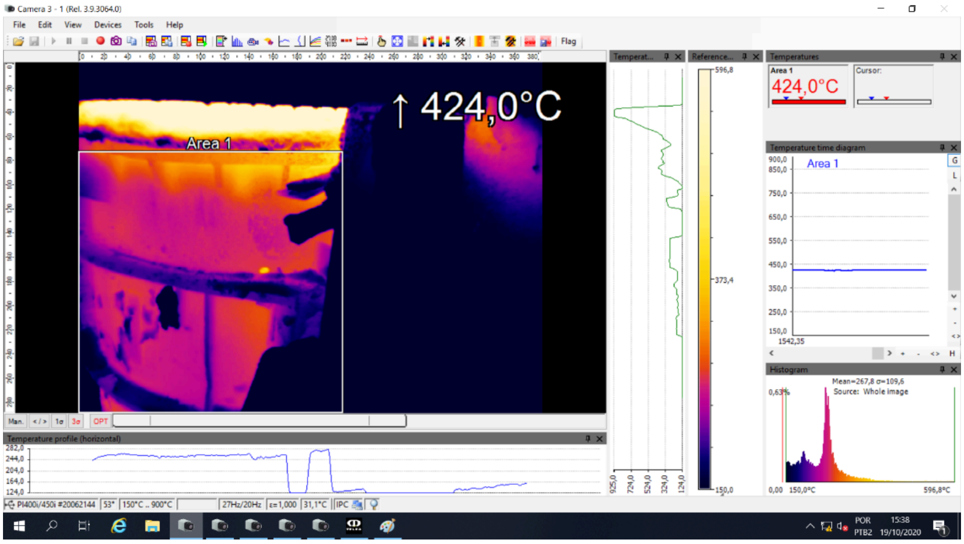

Figure 13. Camera screen of the hot spot detection.

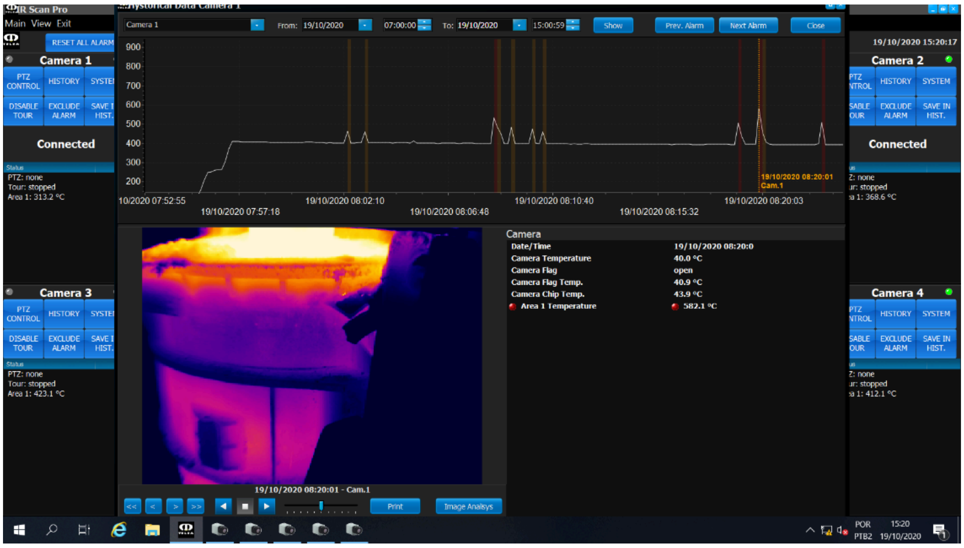

Figure 14. Historical data of the temperature profile.

After hot commissioning the ladle furnace is protected against the ladle breakout during the operation thereby avoiding equipment damage and production losses.

Figure 14. Example of ladle breakout.

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Figure 15. Example of ladle breakout and equipment damage.

2.3 Discussion

A few days after the thermal monitoring installation was complete, the system caught an incident due to refractory lining wear.
Upon becoming aware, the operator took immediate action to remove the ladle based on information from the thermal camera (hot sport) and PLC (HMI) system.

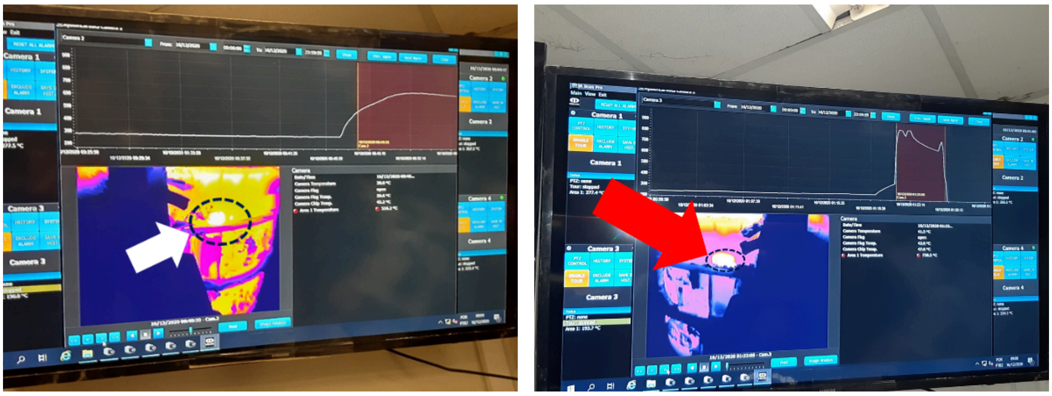


Figure 16. Hot spot on ladle shell during operation.

Figure 17. Refractory wear that caused hot spot on ladle shell during operation.

It was the first time in more than 10 years of operation that a ladle breakout did not happen due to improvements using thermal camera system and operator training/awareness.
The system proved its reliability. According to the customer, they recouped their investment with only one prevented incident due to the high cost of fixing the damages, reduction of refractory campaign life and production loss.

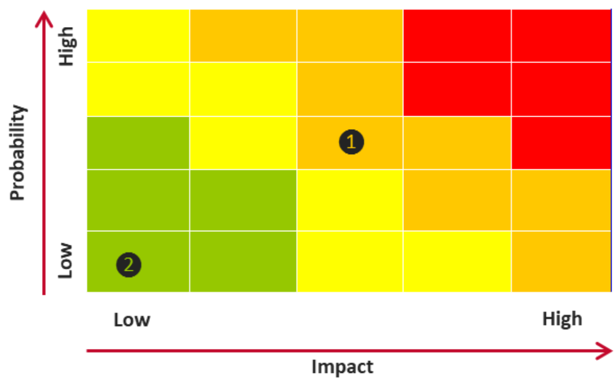
The customer implemented a maintenance plan for the system as well by storing a spare set of cameras and all components at the warehouse to keep the system 100% available.

2.4 Risk analysis

A risk analysis was performed comparing the risk without thermal camera (current operation) and with thermal cameras.
The table below shows the descriptions.

Table 1. Risk comparison

Risk 01: Current LF Operations	Controls	Risk Rating
• Description: There are no thermographic camera for monitoring the metallurgical treatment in the ladle during the operation. • Cause: The operators do not have informations about the temperature profile of the ladle during the heating process. • Consequence: Ladle´s break-through, Productions losses, Injuries.	Ladle´s Campaing historical data and visual inspections of the refractory.	13
Risk 02: Thermal Monitoring LF	**Controls**	**Risk Rating**
• Description: The system is analyzing the temperature profile of the ladle during heating and is connected to the furnace PLC. • Cause: In case of any hot spot detection the furnace stops the heating automatically and the operator get an alarm signal via the furnace PLC (HMI). • Consequence: Safety barriers to an engineering control.	Thermal Monitoring Ladle Furnace.	1



The implementation of thermal monitoring increased operational control from administrative (less effective) to engineering (more effective), according to the hierarchy of control graph.

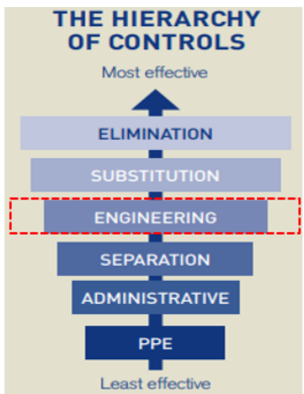


Figure 18. The hierarchy of controls.

3 CONCLUSION

This work is the product of the effective integration of the teams involved (Process, Production and Engineering) on customer's end in partnership with the Brazilian engineering company, APLAN, and Austrian engineering company, INTECO, in search of a high-performance production system, which has allowed the ferronickel operation to perpetuate best practices by the engagement of people.

Based on the results achieved with the implementation of the new thermal monitoring system, the ladle furnace performance has remained as expected (concept).

During commissioning, it was possible to observe the thermal images and set up triggers and parameters for safety interlocks and trips.

Once the system caught the first hot spot on the ladle shell during metallurgical treatment, it also eliminated the risk of injuries in emergency operations to remove the ladle with molten material leakage to a safe place.

Feedback from operators has been very positive throughout the implementation and commissioning of the new system, due to the ease of operation and reduction of operating procedures, thereby eliminating various safety risks.

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