IMPROVING SAFETY AND PRODUCTIVITY

Why the Steel Industry Needs Continuous Thermal Monitoring

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Mitigating Risk in the Steel Industry: The Benefits of Continuous Thermal Monitoring

The steel industry is the foundation of the global economy. Nearly every sector relies on steel, from building and construction to transportation and energy. No matter where you look, steel was likely involved at some point in the process.

The steel industry has continued to find ways to innovate and improve. The widespread adoption of Electric Arc Furnaces (EAFs), for example, has pushed the industry toward greater efficiency, sustainability, and profitability. Likewise, the integration of connected devices, sensors, and other technologies has given steel manufacturers greater insight into their performance.

Despite these advances, many critical processes still rely on scheduled physical inspections. Ladle monitoring and EAF monitoring, for example, require highly skilled technicians to assess wear and evaluate the condition of the asset. These inspections are time-consuming and limited in their ability to predict failure. But, most importantly, they also put workers at risk.

Continuous Thermal Monitoring solutions leverage advanced thermal and visual cameras to provide steel plants with 24/7 coverage of ladles, electric arc furnaces, and other critical equipment. With access to real-time thermal data, steel plants can reduce the need for physical inspections, optimize maintenance schedules, and mitigate the risk of catastrophic failure.

This white paper will demonstrate the benefits of Continuous Thermal Monitoring solutions by focusing on two key applications - ladle monitoring and electric arc furnace monitoring. It will highlight the benefits of the technology before showing how steel manufacturers can successfully deploy the solution throughout their facilities.

A Globally Important Industry

The global steel production capacity has more than doubled in the past 20 years.[1] Looking forward, global demand for steel is expected to grow by more than one-third by 2050.[2] Much of this demand is being led by China, as well as India, Japan, and the United States.[3]

"Global demand for steel is expected to grow by more than one-third by 2050"

The US steel industry produced 81.4 million tonnes of crude steel in 2023.[4] Industry revenue has recovered since the shock of the pandemic, with revenues projected to grow to $139.6 billion in 2025.[5] The industry directly employs around 143,000 people[6] and indirectly supports nearly 2 million jobs in the US.[7]

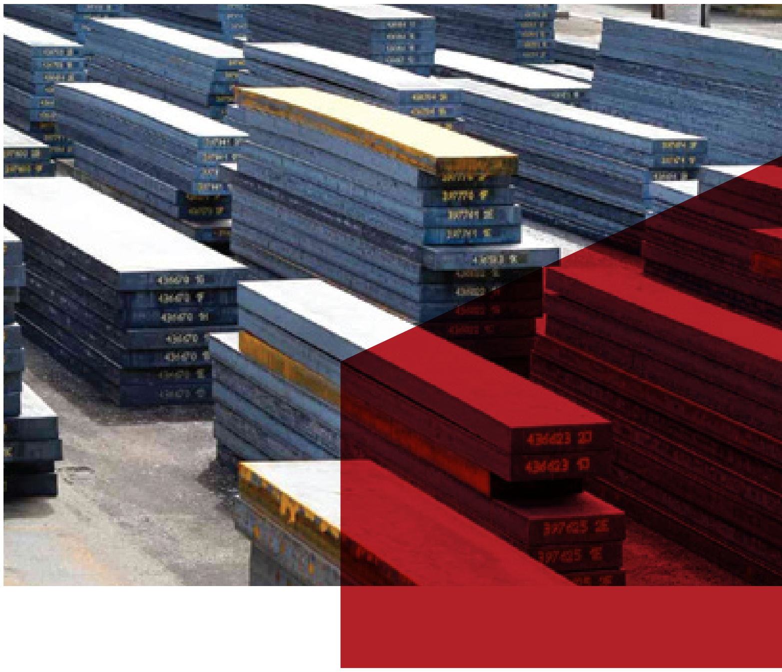
Sustainability and Emissions Reduction

A recent International Energy Agency report showed that the iron and steel sector contributes 3.7 gigatonnes of carbon dioxide (CO2) emissions per year or about 10 percent of the global total energy system.[8]

In response, global regulations and industry sustainability initiatives have taken steps to reverse these trends. According to FedSteel, the US steel industry has achieved a 37 percent reduction in CO2 emissions and a 32 percent reduction in energy intensity since 1990.[9]

Adoption of Electric Arc Furnaces

Steel is already one of the most sustainable materials available, being 100% recyclable without loss of quality. EAFs use scrap metal and electrical current to produce steel instead of iron ore and coal, reducing the need for new raw material extraction. In 2024, nearly 70 percent of crude steel in the US was produced via EAFs,[10] compared to a global average of only 30 percent.[11]



Technology and Automation

The introduction of smart sensors, cloud-based analytics, machine learning, and other Industry 4.0 technologies have given steel plants unprecedented insight into production processes. Steel manufacturers are embracing these technologies to improve visibility, efficiency, and performance throughout the facility.

[1] https://www.iea.org/reports/iron-and-steel-technology-roadmap
[2] https://www.iea.org/reports/iron-and-steel-technology-roadmap
[3] https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2024.pdf
[4] https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2024.pdf
[5] https://www.ibisworld.com/united-states/industry/iron-steel-manufacturing/569/
[6] https://www.statista.com/statistics/1243935/employment-in-the-us-iron-and-steel-industry/
[7] https://www.fedsteel.com/insights/emerging-trends-in-the-steel-industry-for-2024/
[8] https://www.iea.org/reports/iron-and-steel-technology-roadmap
[9] https://www.fedsteel.com/insights/emerging-trends-in-the-steel-industry-for-2024/
[10] https://www.steelhub.com/magazine/blast-furnace-to-eaf-transition-navigating-challenges-and-market-gaps/
[11] https://worldsteel.org/about-steel/facts/steelfacts/what-is-steel/what-is-the-eaf-bof-process-split/

Workplace Safety

Safety must always be the number one priority. From 2014 to 2023, global lost-time injuries fell by more than half from 5,040 to 2,486 per year.[12] During the same period, fatalities fell from 130 to 61 per year. Slips and falls, moving machinery, manual task tools, and gassing and asphyxiation were among the most common causes of workplace incidents.

"Global lost-time injuries fell by more than half from 5,040 to 2,486 per year from 2014 to 2023"

Labor and Skills Shortages

Like many industries, the steel sector is struggling to find workers with the right skills and experience. Experienced workers are retiring or otherwise leaving the industry, while new workers are not entering the job market at the same rate. Moreover, the introduction of new technologies and the adoption of new production processes have changed the nature of work and the required skills.

Putting Workers At Risk - The Limits of Physical Inspections

While the steel industry has made significant progress in adopting new technologies, time-based physical inspections are still the most common approach to evaluating the health and performance of critical assets such as the ladle refractory lining and EAF. These inspections are conducted at scheduled intervals regardless of the actual condition of the asset, leading to inconsistencies in maintenance planning and potential failure.

During the inspection, skilled technicians use a range of handheld sensors, visual cues, and experience to check for structural damage, wear patterns, slag buildup, or other mechanical issues. While these manual inspections were necessary in the past and now serve as a useful redundancy, they introduce several challenges.

The subjective nature of manual inspections means they can be prone to human error. They are limited by visibility in low-light, high-dust, or obstructed areas. And they only provide a periodic snapshot of the asset. Faults that occur between inspections can go undetected and unrepaired until a major failure occurs.

Inspections are also time-consuming and expensive. They disrupt operations and increase the total cost of production. A single inspection, for example, can take between 30 and 60 minutes and require a team of highly skilled personnel.

Most importantly, physical inspections expose workers to extreme temperatures, molten steel and slag, heavy equipment, and toxic gasses. In EAF operations, inspectors may also be working near live electrical components or active furnace operations, where arc flashes, molten metal splashes, and radiant heat pose significant risks.

[12] https://worldsteel.org/media/publications/safety-and-health-in-the-steel-industry-data-report-2024/

> ***"Physical inspections expose workers to significant risks, including extreme temperatures, molten steel and slag, heavy equipment, electric shock, and toxic gasses"***

Finally, a lack of timely maintenance increases the likelihood of dangerous breakouts or steam explosions that can lead to widespread equipment damage and potentially life-threatening situations.

Introducing Continuous Thermal Monitoring for Steel Manufacturing

Continuous Thermal Monitoring solutions leverage advanced thermal imaging cameras to provide steel manufacturers with 24/7 coverage of critical equipment throughout the production process.

> ***"Continuous Thermal Monitoring solutions leverage advanced thermal imaging cameras to provide steel manufacturers with 24/7 coverage of critical equipment throughout the production process."***

Compared to traditional inspections, Continuous Thermal Monitoring allows Operators to monitor the health and performance of high-value assets from a safe, centralized location. Thermal cameras capture real-time video and temperature data to provide early detection and warning of equipment degradation, water leaks, or other faults before catastrophic failure occurs.

The industrial-grade cameras are housed in air or water-cooled enclosures that are rated to withstand the extreme temperatures and conditions found in steel manufacturing. The cameras are mounted to existing infrastructure and installed in positions where they have a clear field of view of the asset.

Sophisticated visualization software allows Operators to view and control multiple cameras simultaneously from a remote location, reducing the number of personnel needed on the plant floor. The solution offers seamless integration with leading video management systems (VMS) such as Avigilon, Milestone, Exacqvision, and Orchid Fusion using real-time streaming protocol (RTSP). Users can obtain critical temperature data through their company VMS for real-time monitoring and response applications.

Alarms automatically trigger if thermal data falls outside predefined parameters, and users can locate the precise location of the failure to take corrective action. The solution also integrates with most industrial platform controllers and systems using standard industrial protocols including Modbus, OPC, select Allen-Bradley, and Siemens PLC via OPC or S7 Protocol to connect with systems controls and data historians such as IBA or Pi. This allows the system to automatically trigger emergency shutoff and evacuation protocols in case of an incident.

"While previous generations of thermal cameras were often unable to withstand the harsh conditions typical of steel plants, Continuous Thermal Monitoring solutions are designed and built to operate in hazardous environments. The IP67-rated enclosures keep the sensor clean, cool, and protected so that they can be deployed throughout the facility."

Rich Shannon
VP of Sales and Marketing,
Viper Imaging

Continuous Thermal Monitoring for Ladle Monitoring Applications

Ladles are critical for transporting and refining molten steel. However, they also present several maintenance challenges that must be addressed to ensure their safe and reliable operation. They are repeatedly exposed to extreme temperatures that can degrade the refractory lining, requiring constant monitoring and relining to mitigate the risk of breakouts. This frequent maintenance adds to the cost of steel production and puts workers in hazardous situations.

Mitigating the Risk of Breakouts

Breakouts are among the most dangerous and costly failures that can occur in steel manufacturing, and they can lead to injury or death if workers are exposed to molten materials.

Continuous Thermal Monitoring solutions reduce the risk of breakouts by providing real-time thermal data to the Operations & Maintenance teams. Mounted thermal cameras measure external ladle temperature profiles to detect uneven heating or hotspots that may indicate refractory degradation.

With greater visibility into the actual condition of the refractory lining, steel plants do not need to wait for physical inspections to detect faults, cracks, or wear. Instead, Operators can immediately identify the issue, stop production, and schedule a repair.

Optimizing Relining Intervals

Determining optimal relining frequency is a complex and inexact science. Each ladle typically has a maximum heat capacity of between 100 and 300 heats. Relining too often increases costs and leads to unnecessary downtime, while delays can lead to degradation of the refractory lining and breakouts.

Further complicating relining schedules is the fact that ladle service life can vary greatly based on a number of factors that affect wear rates, such as slag composition, oxygen injection rates, tapping temperature, and alloying elements.

Continuous Thermal Monitoring provides real-time data on refractory wear, hot spots, and operational efficiency. Instead of relying on rough estimates, steel plants can optimize relining schedules based on the actual condition of the refractory lining. This allows for partial repairs to localized, high-wear areas instead of unnecessary full relines. Not only does this extend the life of the ladle, but it also allows steel plants to schedule relining during convenient windows to reduce downtime.

"Continuous Thermal Monitoring allows steel plants to optimize relining schedules based on the actual condition of the refractory lining"

Ladle Preheating and Temperature Monitoring

Ladles must be properly preheated before receiving molten steel to prevent thermal shock, protect refractory integrity, and ensure efficient heat retention. In severe cases, steel can freeze upon contact, disrupting the process and requiring extensive rework. On the other hand, overheated ladles result in excessive fuel consumption and accelerated refractory wear.

Continuous Thermal Monitoring allows Operators to measure the temperature of the ladle and ensure even heat distribution. If the visualization shows one part of the ladle is too cool, Operators can adjust the preheating systems in real-time to ensure they reach the correct temperature before receiving molten steel.

Electric Arc Furnace Monitoring

Electric Arc Furnaces have changed the way steel is produced, offering greater flexibility, energy efficiency, and sustainability compared to traditional blast furnaces. However, they also create unique risks and operational challenges that require specialized expertise. EAFs generate high-voltage currents and intense electromagnetic fields. They can be susceptible to steam explosions, furnace wall failure, electrode overheating, and other catastrophic events that disrupt operations and pose serious safety risks.

Preventing Steam Explosions

Water-cooled panels prevent the furnace shell and roof from overheating, while other cooling systems protect critical components such as the transformer, hydraulic actuators, and electrodes.

However, water and molten steel do not mix. Any leakage into an EAF can result in violent steam explosions that eject molten metal, slag, and debris. Even small leaks can trigger a catastrophic event, leading to injuries, production shutdowns, and costly repairs.

Thermal sensors monitor the EAF shell, roof, panel, and electrode temperatures to provide early warning of water leaks from the cooling system. The sensors automatically detect a sudden or localized temperature drop that could indicate a leak. This triggers an emergency shutdown in the affected areas and alerts Operators to the issue. For example, the system can automatically shut off water flow to the cooling panels before the water reaches the molten steel.

"Continuous Thermal Monitoring solutions automatically detect a sudden or localized temperature drop that could indicate a leak, automatically shutting off water before it causes a steam explosion."

Detecting Furnace Wall Failure

The refractory lining of the EAF wall is repeatedly exposed to extreme temperatures. Each heat cycle expands and contracts the lining, weakening its structure and leading to localized failures.

Similarly, molten slag can chemically react with the refractory lining and break down protective materials, corroding furnace walls and increasing the risk of burn-through. If not repaired, damage to the refractory lining can lead to a molten metal breakout, fires, and severe equipment damage.

Thermal sensors continuously track furnace wall temperatures to detect hot spots and signs of localized wear. Operators can use this data to identify thin refractory zones before they lead to collapse, shut down the EAF, and conduct partial repairs.

EAF Transformer Monitoring

The EAF transformer can fail in a number of ways that lead to arc instability, production downtime, and electrical failures. For example, voltage surges or sudden spikes in demand can damage transformer windings, while loose connections can cause arcing and overheating in components.

Thermal monitoring sensors can detect sudden or prolonged temperature differentials that fall outside of predefined ranges. Automated alarms alert Operators to potential faults before failure occurs, allowing them to remotely diagnose the cause of the issue and schedule corrective action. This reduces the likelihood of arc-induced electrical overloads, mitigates the risk of a thermal runaway event, and maximizes transformer reliability.

Applications for Continuous Thermal

- Ladle Refractory Lining
- Electric Arc Furnace
- Water Wall Leak Detection
- Ladle Metallurgy Furnace
- Continuous Casting
- Reheat Furnaces
- Coke Plant
- Substation Monitoring
- Basic Oxygen Furnace
- Argon Oxygen Decarburization

The Benefits of Continuous Thermal Monitoring

Continuous Thermal Monitoring solutions equip Operators with real-time temperature data, enabling them to proactively identify faults and take corrective action before catastrophic failure occurs. With greater visibility into the steel production process, Operators can mitigate safety risks, improve productivity and performance, and reduce operations & maintenance costs.

Better Visibility and Data

Maintaining real-time visibility into high-temperature operations is a significant challenge, especially in areas where manual monitoring is difficult and hazardous. But without precise data, inconsistencies in heat distribution, refractory wear, and cooling efficiency can go undetected. Traditional monitoring strategies may miss early signs of deterioration, while technologies such as pyrometers, visual cameras, and handheld temperature sensors may not provide sufficient data.

Continuous Thermal Monitoring provides real-time, automated insights into the health and performance of critical assets throughout the facility. Instead of reacting to failures, Operators can track performance trends, identify potential faults, and take action immediately to mitigate risk.

Enhanced Safety

Steel manufacturing environments are inherently dangerous. Physical inspections require workers to operate in hazardous areas, potentially exposing them to high temperatures, toxic fumes, arc flashes, explosions, and other safety risks.

Continuous Thermal Monitoring dramatically improves workplace safety by reducing the number of workers in hazardous zones. Operators can monitor multiple assets or production processes from a single, safe location. Further, reducing the risk of steam explosions or molten metal breakouts helps to maintain a safer work environment and efficient production.

> ***"Continuous Thermal Monitoring dramatically improves workplace safety by reducing the number of workers in hazardous zones and mitigating the risk of catastrophic failure"***

Extended Equipment Life

EAFs, ladles, and other equipment undergo intense thermal, mechanical, and chemical stress. Fixed maintenance schedules do not account for actual wear rates and operational variations, leading to premature or delayed maintenance. Over time, cumulative stress on improperly maintained assets shortens their operational lifespan and increases the need for full replacements.

Continuous Thermal Monitoring extends the lifespan of critical equipment by providing early warnings of overheating, wear, structural stress, and other faults before failure occurs. Steel plants can optimize maintenance schedules based on the actual condition of the asset rather than fixed schedules, minimizing unnecessary repairs and extending the life of existing equipment.

Reduced Maintenance Costs

Maintenance is a significant expense that adds to the overall cost of producing steel. Traditional maintenance strategies increase these costs by relying on fixed schedules or reactive repairs. Unexpected breakdowns not only drive up the cost of replacement parts but also result in labor-intensive interventions. On the other hand, over-maintenance wastes resources and shifts resources away from other, more valuable initiatives.

Continuous Thermal Monitoring allows steel manufacturers to transition toward a predictive, Condition-Based Maintenance strategy that reduces the total cost of maintenance and repairs. By analyzing thermal data and wear patterns, crews can schedule repairs based on the condition of the asset, reducing unnecessary servicing, mitigating the risk of an emergency shutdown, and ensuring maintenance resources are used effectively.

Increased Plant Uptime

Steel production is a capital-intensive industry that relies on high equipment utilization rates. Unplanned equipment failure can lead to production stoppages, financial losses, and supply chain disruptions that can take hours or days to rectify. Given that a single minute of downtime can cost tens of thousands of dollars, the cost of a failure is significant.

Continuous Thermal Monitoring increases overall plant uptime by preventing unexpected failures. Operators can proactively address minor issues before they grow into major breakdowns and schedule repairs to have the least impact on production.

“People make steel. And the steel industry will always need skilled people. Technology acts as a tool to make steel production faster, more efficient, and more productive. But most importantly, technology helps make steel production safer for people. Continuous Thermal Monitoring solutions take people out of harm’s way while providing greater visibility into the health and performance of the equipment. It’s a win-win for steel manufacturers and workers.”

Jamie Hansen
Hansen Metallurgical Services

Deploying Continuous Thermal Monitoring

Continuous Thermal Monitoring solutions from Viper Imaging have been designed and built to withstand the challenging environments commonly found in steel plants. While the solution does require some upfront investment in hardware, software, and installation, the total cost is far lower than the cost of a ladle breakout or EAF steam explosion.

Many steel manufacturers start by deploying cameras to monitor a specific asset or production process. This pilot project helps their personnel become familiar with the features and capabilities of the solution before expanding into additional facilities or applications.

As with all technology projects, having an effective strategy will help to ensure that you achieve the full benefits of the solution.

Step 1 - Identify Project Goals

How you deploy Continuous Thermal Monitoring solutions will depend on the application and how you expect to use the sensors. Start by identifying where thermal cameras could have the greatest impact on performance. This could be an aging machine that is prone to breakdowns, or it could be a process that currently requires frequent maintenance and repairs.

From there, understand how thermal data will help to address the problem and determine the key performance metrics that will be used to evaluate the deployment. For example, if you choose to install thermal cameras to monitor the ladle refractory lining, key metrics could be the number of heats between relining, the frequency of breakouts or other incidents, or the energy used for preheating the ladle.

Step 2 - Determine the Location of the Cameras

How many cameras you need, and where they should be located, will vary based on a range of factors. Consider the type of equipment being monitored, the capabilities of the camera, the required field of view, and the availability of suitable mounting infrastructure. The Viper Imaging team will work closely with you to help determine the best location for each sensor and make sure that you can capture the required data for your application.

Step 3 - Ensure Adequate Cooling, Power, and Connectivity

Previously, the high temperatures and challenging conditions found in steel manufacturing plants made it difficult to reliably deploy thermal and visual cameras. But Continuous Thermal Monitoring solutions from Viper Imaging are housed in durable, protective enclosures that have been designed to withstand these environments.

Depending on the application, the sensors will use either air or water cooling systems to maintain operating temperatures. The sensors also feature Power Over Ethernet capabilities to ensure data from the sensors can be transmitted to a central monitoring location with minimal wiring runs, decreasing the overall cost of installation.

Step 4 - Integrate With Other Technologies

Continuous Thermal Sensors are intended to be used as part of a comprehensive, multi-layered monitoring system. The cameras and software seamlessly integrate with other diagnostic tools such as acoustic emission sensors, laser scanning systems, thermocouples, and AI-driven predictive analytics platforms using standard industrial protocols that are compatible with existing automation and control infrastructure.

To maximize operational benefits, all technologies must be effectively integrated into a unified system that allows Operators to access real-time data from multiple sources in a single dashboard.

> ***"To maximize operational benefits, all technologies must be effectively integrated into a unified system that allows Operators to access real-time data from multiple sources in a single dashboard"***

Step 5 - Expand to New Applications or Facilities

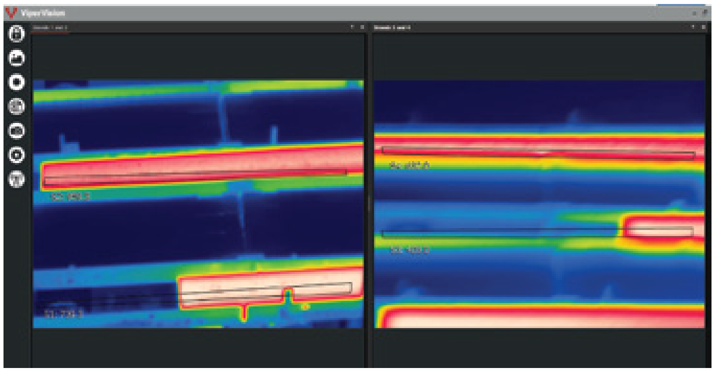
Once the technology has been proven, start to identify additional applications or facilities that would be suited to Continuous Thermal Monitoring. This could be another production process in the same facility, or it could be monitoring equipment in another plant. Over time, you'll be able to transition toward a Condition-Based Maintenance strategy that leverages data from thermal cameras and other sensors to reduce maintenance costs and improve equipment performance.

Deeper Insights Into the Steel Manufacturing Process

The steel industry will continue to find ways to innovate and improve performance. From introducing new production processes and adopting electric arc furnaces to deploying a wide range of Industry 4.0 technologies and sensors, the steel industry has always been a leader in using technology to achieve better results.

Continuous Thermal Monitoring solutions build on these technologies to provide greater visibility and insight into important production processes. Real-time thermal data can be used in critical applications such as ladle refractory lining and Electric Arc Furnace monitoring to optimize performance and reduce maintenance costs.

Rather than rely on time-based physical inspections or reactive maintenance strategies, steel plants can take a proactive approach that improves asset utilization, enhances workplace safety, and mitigates the risk of catastrophic equipment failure.



Monitor processes using ViperVision software, which provides both visual and thermal data.

About Viper Imaging

Monitoring industrial processes often seems like a complicated endeavor, but it doesn't have to be. Using top-of-the-line devices creates a seamless thermal monitoring system that's designed to prevent disasters, reduce costs associated with catastrophes and allow your industrial complex to continue operating at optimal performance levels.

At Viper Imaging, we understand the needs of our industrial customers. As a top supplier and integrator of thermal imaging-based systems and industrial process monitoring equipment, we have a track record of success in various industrial settings, such as metals, energy production and distribution, oil and gas, wood products, and industrial automation. Our systems are specially designed to scale from a small-scale plant or mill to the largest industrial complex, and our experienced team of application specialists and engineers are here to help build a solution that works for you.