IMPROVING SAFETY AND RELIABILITY IN PETROCHEMICAL PLANTS WITH CONTINUOUS CRITICAL VESSEL MONITORING

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Critical vessels are key process units in chemical and refinery operations. They typically handle high pressures, temperatures, or hazardous materials, making their integrity essential to safe and reliable plant operations. Failure could result in the release of toxic or corrosive chemicals, fire, explosions, or runaway reactions, which could put workers, equipment, and surrounding communities at risk.

Facilities already use various tools to monitor the health and performance of these critical vessels. Through temperature monitoring, physical inspections, and preventative maintenance, operators ensure that vessels are operating in good condition.

Unfortunately, many of the traditional tools and approaches fail to provide comprehensive coverage of the entire vessel. Without access to continuous temperature data, operators may not be able to detect the telltale signs of failure before it's too late.

Continuous Critical Vessel Monitoring solutions leverage advanced thermal and visual cameras to provide complete, 24/7 coverage of the entire vessel. With greater access to data, operators can enhance safety, optimize operations, and reduce maintenance costs, all while mitigating the risk of catastrophic failure.

This white paper will demonstrate the need for Critical Vessel Monitoring and explain why traditional approaches are no longer suited to today's facilities. It will introduce the benefits of Continuous Critical Vessel Monitoring and show how refineries and chemical plants can deploy the system to improve performance.

The Need for Better Solutions

The petrochemical industry is inherently volatile. Companies must adapt to unpredictable market forces, geopolitical risks, and changing regulations that are often outside of their direct control.[1] This has led many companies to seek out new technologies that provide greater flexibility, responsiveness, and efficiency across the production process.

Workplace Safety

Safety must always be the number one priority, especially when workers operate in hazardous environments. A recent report found that there were at least 825 hazardous chemical incidents in the US since 2021, including 344 in plastics and petrochemical manufacturing and 44 at downstream refineries.[2]

Decarbonization and the Energy Transition

The US petrochemical industry contributed an estimated 306-343 million metric tons of greenhouse gas (GHG) emissions in 2023, or around 5 percent of total US GHG emissions. With expected increases in chemical production and manufacturing capacity, that level is projected to grow by as much as 32 percent by 2030.[3]

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Labor Optimization & Skill Development

As in many industries, the petrochemical industry is facing an acute shortage of skilled and experienced workers. Senior employees are retiring or moving to other industries, while fewer new graduates are entering the workforce. Companies are finding it difficult to fill critical positions, and many are turning to technology to optimize their labor force and allocate skilled resources more effectively.[4]

Changing Regulatory Environments

Petrochemical companies must comply with a broad range of local, national, and international regulations. Many governments have specifically targeted chemical manufacturers and refineries as part of broader efforts to reduce emissions. Keeping up with these changes across jurisdictions is challenging and places an additional burden on companies to accurately measure and report on key metrics.

[1] https://www.ey.com/en_us/insights/oil-gas/oil-and-gas-and-chemicals-industry-outlook
[2] https://comingcleaninc.org/assets/media/images/Chemical%20Disaster%20Prevention/Key%20Findings%202021-2023%20FINAL.pdf
[3] https://rhg.com/research/petrochemicals-emissions/
[4] https://www.deloitte.com/us/en/insights/industry/chemicals-and-specialty-materials/energy-chemicals-workforce-transformation.html

Technology Adoption & Analytics

The petrochemical industry has always been a leader in technology. A recent Deloitte report found that investments in R&D in the petrochemical industry are growing, specifically in areas such as artificial intelligence, connected sensors, and predictive analytics.[5] Companies are looking to these technologies to drive process improvements, implement predictive maintenance strategies, and strengthen decision-making at all levels of the organization.

Critical Vessel Monitoring

Critical vessels are enclosed, capsulated vessels used for the large-scale production of chemicals or other oil & gas products. They include gasifiers, steam methane reformers, reactors, distillation columns, and pressurized storage tanks, among other vessels. They operate at high temperatures and pressures, and often contain flammable, corrosive, or toxic materials.

The consequences of failure are significant, with potentially serious and long-lasting consequences. Fire or explosions can result in damaged equipment, production downtime, emergency repairs, and potential health and safety risks. Further, incidents can lead to regulatory penalties, fines, or litigation.

Critical Vessel Monitoring is the observation and assessment of high-risk process vessels to detect abnormal operating conditions, structural issues, or other potential failures before a major incident occurs. It plays an important role in the organization's broader Asset Integrity Management strategy and ensures the safe and effective operation of critical vessels.

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The Limitations of Current Approaches to Critical Vessel Monitoring

A comprehensive Critical Vessel Monitoring strategy will always include a range of tools and techniques. However, many of the existing approaches are limited in their effectiveness.

Thermocouples

Thermocouples are point-based temperature sensors used to measure localized temperatures on or within process vessels. They are common in chemical production facilities and refineries and are typically installed in thermowells or directly embedded in vessel walls.

Because they come into direct contact with the vessel, thermocouples provide highly accurate temperature readings. However, they only measure the point they are in contact with, and cannot detect localized anomalies that occur between sensors. Further, they are subjected to

[5] https://www.deloitte.com/us/en/insights/industry/chemicals-and-specialty-materials/chemical-industry-outlook.html

vibration, heat, and corrosion, making them prone to fatigue or failure. They require frequent calibration, maintenance, and repairs, necessitating downtime so that technicians can safely access the vessel.

Fiber Optic Temperature Sensing Systems

In contrast to thermocouples, fiber optic temperature sensing systems are used for distributed temperature measurement along the entire length of the fiber. This makes it possible to detect temperature gradients, hotspots, or other anomalies across a broader surface of the vessel.

However, fiber optic systems still only measure temperature along the fiber path, meaning they are still prone to missing localized anomalies or hotspots around the vessel circumference. They are also very difficult and expensive to install and maintain, while requiring specialized software and expertise to interpret the data.

Physical Inspections

Physical inspections are commonly used to assess the structural integrity, surface condition, and overall health of critical vessels. Highly trained technicians use visual checks along with specialized tools, such as handheld thermal cameras or pyrometers, to check for signs of corrosion, cracks, leaks, refractory damage, or mechanical wear.

Physical inspections will always be fundamental to asset integrity management and regulatory compliance programs. They are also still useful for baseline and post-maintenance validation. However, they are costly, labor-intensive, and intermittent, meaning issues that occur between inspections can go undetected and unresolved. Moreover, they require that workers access hazardous areas and can only be performed during shutdowns or asset turnarounds.

"Critical Vessel Monitoring is vital to an organization's Asset Integrity Management strategy. If operators can't understand vessel behavior under a range of operating conditions, they risk missing out on the telltale signs of an issue. Given the high temperatures and pressures these vessels are under, any failure can quickly become catastrophic."

Andy Beck
Viper Imaging

Introducing Continuous Critical Vessel Monitoring

Continuous Critical Vessel Monitoring solutions leverage advanced thermal and visual cameras to provide 24/7 coverage of the entire vessel.

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Compared to traditional tools, Continuous Critical Vessel Monitoring solutions offer a complete, real-time temperature profile of the outside of the vessel.

Operators can measure temperature, rate of change, and temperature differential (min/max/average) to immediately detect temperature anomalies and hotspots that could indicate a potential fault. Temperature and visualization data is stored for future analysis, incident investigation, or compliance documentation.

Ruggedized enclosures specifically designed for Class I and Class II environments ensure the sensors withstand exposure to high temperatures or corrosive materials. The HazLoc-certified, explosion-proof housing features cooling, purge, and pressurizing features that protect the sensitive camera equipment.

On-premises software analyzes and compares the temperature data against predefined parameters. Automated alerts notify operators of anomalies that exceed these limits via email, SMS, or the facility's existing control system.

Alerts include information about the duration and severity of the event, while instant alarms trigger in cases of severe failure. Seamless integration into the existing plant control system means the solution can automatically initiate a shutdown or other mitigation measures if required.

The system also integrates with leading video management systems (VMS) such as Avigilon, Milestone, Exacqvision, and Orchid Fusion using real-time streaming protocol (RTSP). This allows it to bring together data from other sensors and provide a complete picture in a unified dashboard.

With greater visibility, operators can remotely monitor changes over time, identify the location of the issue, conduct an initial diagnosis, adjust operating inputs, or schedule maintenance to resolve the issue before it grows into a more severe failure.

Deploying Continuous Critical Vessel Monitoring Solutions

Continuous Critical Vessel Monitoring solutions are reliable, non-intrusive, and easy-to-use. They provide operators with a simple visualization of exterior vessel temperature so they can optimize production and mitigate the risk of failure.

To start, develop a pilot program to evaluate the sensors and understand how they fit into existing systems. To gain the most immediate benefits, the pilot program should be at a facility where continuous monitoring could have the most impact, such as facilities with known issues or aging vessels that require additional maintenance.

From there, work closely with the vendor to identify the number of cameras and the optimal location for each camera to ensure full coverage of the vessel. The non-contact, remotely deployed cameras are vessel agnostic and can easily be mounted to existing infrastructure with minimal installation requirements.

The cameras are powered and connected using Power-over-Ethernet (PoE) or other sources that are available at the facility. The on-premises software keeps sensitive data within the organization's network, minimizing cybersecurity risk.

As the benefits become clear, expand the deployment to additional sites. Over time, operators will gain greater visibility across locations with minimal disruption to current operations.

"Thermal cameras used to be prohibitively expensive for many applications. But as the technology has improved, the cost of these cameras has fallen considerably. Today, thermal cameras offer a viable and cost-effective solution to refineries and chemical manufacturers with critical vessels. By deploying multiple cameras, facilities gain complete coverage of the vessel and far more data on the health and performance of the asset."

Jon Lowenberg
Vice President of Solution Delivery & Customer Support, Systems With Intelligence

Using Continuous Flare Stack Monitoring Solutions

Continuous Critical Vessel Monitoring solutions are highly versatile and can be used for a range of applications.

Early Fault Detection and Warning

While traditional approaches to Critical Vessel Monitoring provide some insight into the health and performance of the vessel, the lack of continuous coverage means that some issues may go undetected until it's too late.

Continuous Critical Vessel Monitoring solutions detect intermittent or localized temperature fluctuations under a range of operating conditions long before pressure or process alarms are triggered. The thermal cameras provide real-time, full-surface thermal visibility, allowing operators to detect subtle deviations that may precede failure.

> ***"Continuous Critical Vessel Monitoring solutions detect intermittent or localized temperature fluctuations under a range of operating conditions long before pressure or process alarms are triggered"***

For example, the software may identify developing hotspots that signal refractory degradation, cold zones that indicate insulation failure, or temperature differentials that suggest uneven burner performance. Using historical and trend data as a baseline, operators can identify these patterns and intervene before conditions escalate.

Photo credit: Duke-Energy.com

Predictive and Condition-Based Maintenance

Reactive maintenance, as the name suggests, is performed after a failure occurs. Preventive, or scheduled maintenance, on the other hand, is performed at regular intervals regardless of the actual condition of the equipment. While it can reduce the likelihood of failure, it can also lead to unnecessary or premature maintenance.

Continuous Critical Vessel Monitoring allows for the implementation of predictive and condition-based maintenance strategies. Trending temperature data reveals gradual changes in patterns over time, such as slowly developing hotspots that often precede mechanical failures. Facilities can detect these deviations before they reach critical thresholds, forecast potential issues, and trigger maintenance at the most cost-effective times based on the actual condition of the asset as opposed to fixed schedules.

Process Optimization

Critical Vessel Monitoring should not be thought of solely as a safety measure. Comprehensive temperature data is also a powerful process optimization and performance enhancement tool.

Continuous Critical Vessel Monitoring supports process optimization by providing real-time, full-field thermal data that reveals how efficiently heat and reactions are distributed within and across a vessel. Thermal cameras can detect temperature profiles that indicate process inefficiencies.

For example, uneven temperature gradients on the surface of reactors could reveal catalyst fouling or poor mixing. Operators can then adjust feed rate, flow distribution, or mixing intensity to correct thermal imbalances. Similarly, continuous thermal data ensures even burner firing and proper flame alignment, allowing operators to modify burner firing patterns or fuel flow rates based on actual observed temperature gradients.

By trending these patterns over time, plants can optimize fuel usage, stabilize product quality, and improve yield, all while minimizing waste and improving safety.

The Benefits of Continuous Critical Vessel Monitoring

Continuous Critical Vessel Monitoring solutions deliver downstream oil & gas refineries and manufacturing plants substantial safety, reliability, and operational benefits.

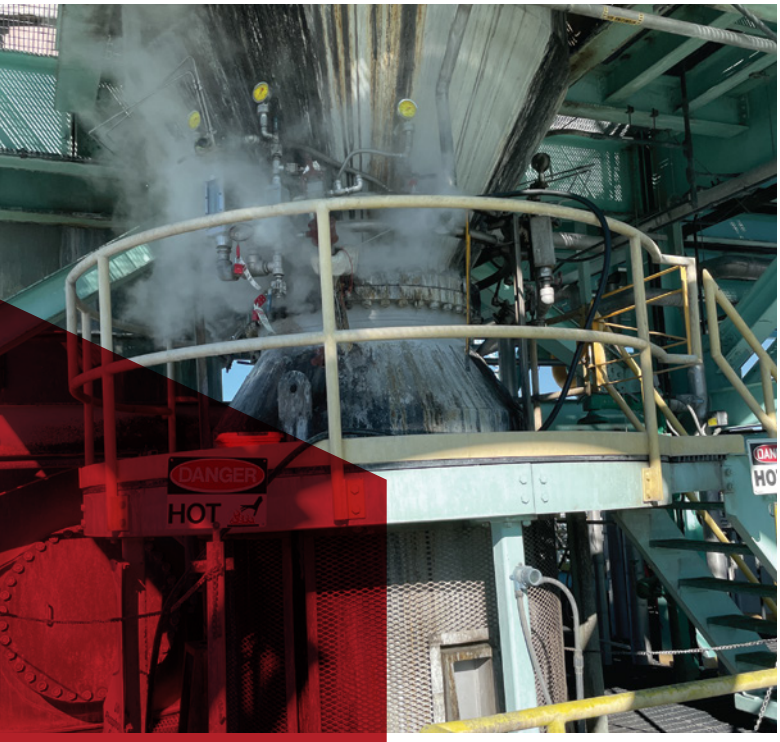
Enhanced Safety

Vessel failures create serious safety risks. Ruptures can lead to the uncontrolled release of toxic or corrosive chemicals that pose immediate and long-term health risks. Similarly, flammable gases or liquids can ignite, sparking fires or explosions, while hot fluids or steam can cause severe burns and scalding.

Early detection and repair of potential issues mitigates the risk of catastrophic failure. Moreover, the sensors reduce the need for personnel to access and operate in hazardous areas. Operators can monitor the health and performance of the vessel remotely, reducing the need for physical inspections.

> ***"Operators can monitor the health and performance of the vessel remotely, reducing the need for physical inspections"***

The cameras themselves do not come into contact with the vessel, meaning they require only minimal maintenance to remain calibrated and operational. Finally, transitioning to a condition-based maintenance strategy reduces time spent conducting repairs, while also allowing crews to go into sites with prior knowledge of the issue.



Extended Equipment Life

Many facilities schedule maintenance based on usage intervals and historical maintenance records. However, this approach doesn't necessarily reflect the actual condition of the vessel and fails to account for operating variability between repairs.

Continuous Critical Vessel Monitoring can significantly extend equipment life. By continuously tracking the vessel's thermal profile, operators can optimize conditions and mitigate issues before irreversible damage occurs.

For example, operators can adjust temperatures, flow rates, or heating patterns to reduce thermal stress and avoid overheating. This data-driven approach to asset management allows facilities to make repairs, retrofits, and component replacements as needed. This reduces downtime and increases the time between turnarounds and relining.

Reduced Operations and Maintenance Costs

Reactive repairs are expensive. Equipment failure causes immediate production stoppages, leading to lower output, missed deadlines, and lost revenue. Failure may also damage secondary equipment, increasing the total scope of the incident. Further, emergency repairs often require overtime, rapid procurement, and other expenses that increase the total cost.

Predictive or condition-based maintenance strategies anticipate failures and avoid costly emergency repairs. Facilities can schedule downtime at intervals that minimize disruption, repair and replace several pieces of equipment at the same time, and allocate skilled resources more efficiently.

Greater Visibility of Critical Vessels

Critical vessels are vital to refinery and chemical manufacturing operations. Any failure can have severe and long-lasting consequences, ranging from damaged equipment and production downtime to litigation and loss of life.

Continuous Critical Vessel Monitoring solutions provide an additional layer of coverage compared to traditional tools. Advanced thermal and visual cameras enable 24/7 coverage of the vessel, allowing operators to view a complete temperature profile of the vessel under all operating conditions.

With greater access to both historical and real-time data, operators can detect anomalies, diagnose potential issues, adjust inputs, and mitigate the risk of catastrophic failure. The results are enhanced safety, extended equipment life, and improved operational performance.

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.