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How to Put Predictive Maintenance to Use in the Internet of Things

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Abstract

In an ever-changing world of increased automation and process efficiencies, and with Industry 4.0 and the Internet of Things at the forefront of these efforts, the most successful heat treaters globally employ a predictive maintenance platform that allows them to anticipate disruption before it occurs.

In this presentation, you will:

- Understand how costs associated with furnace downtime compare with and without predictive maintenance.
- Learn the fundamentals of predictive maintenance and how it's changing the heat treating industry.
- Hear a series of practical, data-driven examples in which the software anticipated hazards—like a broken (open) heating element or diffusion pump heater failure—avoiding potential part quality issues and hot zone damage.
- See real-life business cases on aged furnaces, where the risk and frequency of unplanned downtime is significantly higher.

We will show all the benefits of monitoring furnace health with real-time diagnoses.

Introduction

It's no secret that the Industrial Internet of Things/Industry 4.0 is shaping the way leading manufacturers improve efficiency, ultimately leading to less stress on operators and better customer satisfaction. When tech giants like Honeywell set the precedent for on-the-job training through mixed-reality (virtual and augmented), competency management and data analytics, it can seem difficult – or even impossible – for small and mid-size businesses to keep up.

Today in thermal processing, when a vacuum furnace breaks, the result is clear—production comes to a grinding halt. Managers might ask themselves: *What if I would have known that those parts did not reach set point temperature? What if the furnace could tell me before a vacuum pump rebuild is necessary?*

What if operators could rely on a proven approach through predictive maintenance software that identifies potential hazards and minimizes downtime? The answer is in data analytics. Not just data that signals an alarm, but data that is supported by time-tested, scientific calculations, that predicts events before they happen.

"Concepts such as predictive maintenance, demand forecasting, and digital twins not only reduce downtime and quality excursions, but can also help optimize production efficiency. As factories continue to evolve with the use of innovative technologies, manufacturers must ensure that their workers are evolving right along with them." [1]

Predictive Maintenance Fundamentals

At the core of Honeywell's training platform is advanced data analytics that connect process, assets, people and enterprise together to maximize performance. This is just one scenario in which data "empower[s] industrial workers to directly improve performance, uptime, reliability and safety." [2]

The goal of predictive maintenance in heat treating is to help avoid high-cost events, increase furnace uptime and reliability, reduce the need for frequent maintenance and repairs, and minimize the burden of unexpected downtime. Through analysis of critical furnace data, predictive maintenance software identifies trends and deteriorating conditions, helping operators schedule maintenance at a time that is most cost-effective and before the equipment's performance decreases below a set threshold. Furnace manufacturers that use predictive maintenance are also able to gather data on the furnace's overall performance, which assists with continuous product improvement and future innovations.

Today, there are tools that utilize sensors and control algorithms to determine the appropriate timing for replacing parts and servicing the furnace. By monitoring critical data and key parameters such as temperature, vibrations and pressure, users are able to improve the furnace's overall health and integrity by tracking several systems, including the hot zone, pumping system and quenching system. This technology also enhances the user experience, allowing them to monitor equipment anywhere, anytime, and to resolve maintenance issues by working through specified steps.

Figure 1: Vacuum furnace dashboard showing key parameters for predictive maintenance.

The following four cases demonstrate a few scenarios in which predictive maintenance software helped operators improve the company's bottom line.

Case Study 1: Catch Small Issues Now to Avoid Big Problems Later

An example of a situation that could be prevented with predictive maintenance is downtime caused by a broken ceramic in the hot zone. If unnoticed, this is also a common cause of poor temperature uniformity, resulting in part quality issues. When alerted early on, operators are able to fix the problem before running subsequent loads, avoiding damage to the parts and hot zone.

Figure 2: Broken ceramic (left). New ceramic assembly (right).

A company in the energy industry avoided potential catastrophic melting of the element hangers and heating element when their predictive maintenance software alerted the operator of a broken ceramic in a specific heating zone, guiding them to a timely, cost-effective solution. This resulted in about 50% less cost and 2.5 hours reduction in downtime, as outlined in Table 1. This is just for one instance of a broken ceramic, which can occur frequently throughout the year.

In this situation, the customer only incurred the cost of replacing the broken ceramic. Without predictive maintenance, they also may have had costs associated with a complete element hanger replacement, melted heating element, burned retaining pin and shielding damage as well as unplanned downtime.

Table 1: Cost comparison of a broken ceramic in the hot zone with and without predictive maintenance. (The difference between low and high range costs relies heavily on parts availability.)

	With Predictive Maintenance	**Without Predictive Maintenance**	
Hot Zone Broken Ceramic	**Ideal Outcome**	**Low-Range Costs**	**High-Range Costs**
Time to Repair	1.5 hours	4 hours	16 hours
Labor Cost ($88/hour*)	$132	$352	$1,408
Material Cost	$175	$865	$6,000
Unplanned Furnace Downtime Cost**	$937.50	$2,500	$10,000
Total Cost	$1,244.50	$3,717	$17,408
Savings With Predictive Maintenance		$2,472.50	$16,163.50

**Based upon an average labor cost estimate.*
***Furnace downtime estimated at $5,000 per 8-hour shift ($625 per hour), based on furnace utilization at 100% (estimate provided by customer).*

Case Study 2: The Importance of Monitoring Vacuum Levels

Maintaining high vacuum performance levels is essential for efficient load times. If the diffusion pump heater fails, it could have a serious impact on production. Using predictive maintenance to monitor the health of the pumping system can result in significant cost savings by reducing downtime. To ensure that the diffusion pump is operating within the proper range, predictive maintenance software needs to monitor water and oil temperature, as well as heating power output. These parameters are then analyzed in the software and presented in a dashboard (see figure 4).

In this scenario, a commercial heat treater was alerted of a low kW reading, indicating a heater failure on the diffusion pump. Catching this early prevents diffusion pump fluid from back streaming into the hot zone, which can result in decreased part quality.

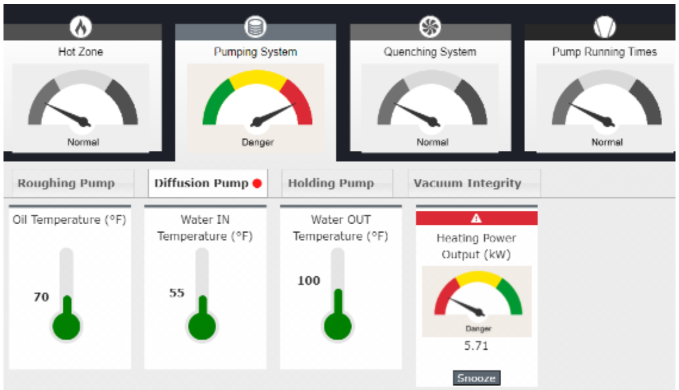

Figure 4: Vacuum furnace predictive maintenance dashboard showing a red condition for heating power output.

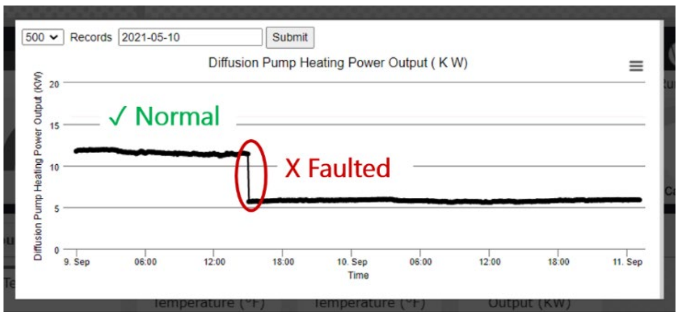

Figure 5: Data trend showing the kW drop from a green condition to red.

In this example, the cost savings of using predictive maintenance are estimated at nearly $10,000 with a 22-hour reduction in downtime, as outlined in Table 2. Although the material cost is the same with and without predictive maintenance, the cost associated with lost production is significantly higher with the added time it takes to clean the furnace and run an unplanned burnout cycle.

Table 2: Cost comparison of a diffusion pump heater failure with and without predictive maintenance. (The difference between low and high range costs relies heavily on parts availability.)

	With Predictive Maintenance	**Without Predictive Maintenance**	
Diffusion Pump Heater Failure	**Ideal Outcome**	**Low-Range Costs**	**High-Range Costs**
Time to Repair	2 hours	8 hours	40 hours
Labor Cost ($88/hour*)	$176	$704	$3,520
Material Cost	$3,341	$3,341	$3,341
Additional Downtime	0 hours	14 hrs. burnout	14 hrs. burnout
Unplanned Furnace Downtime Cost**	$926	$10,186	$25,002
Total Cost	$4,443	$14,231	$31,863
Savings With Predictive Maintenance		$9,788	$27,420

**Based upon an average labor cost estimate.*

***Furnace downtime estimated at $3,704 per 8-hour shift ($463 per hour), based on furnace utilization at 100% (estimate provided by customer).*

Case 3: Predictive Maintenance – it's not just for new furnaces

Although predictive maintenance is often used on new equipment, there is also a benefit to continuous monitoring and diagnosis of older furnaces. As the frequency and risk of unplanned downtime increases with use, so too does the value of retrofitting an effective predictive maintenance system.

In this situation, a manufacturer had two older furnaces, aged 18 and 31 years. Both were maintained as needed and generally ran well, but management believed a predictive maintenance system could be more effective (and less expensive) than sporadic service visits. After installing predictive maintenance software on the 18-year-old furnace, and after a successful year of testing and analysis, the customer retrofitted the second furnace as well.

For the owner of this furnace, during a particularly active week, the system alerted them to three major events:

- A reduction of power draw on one of the heating zones (the 18-year-old furnace)
- Increasing vibration levels on the quenching motor (the 18-year-old furnace)
- Broken ceramics in the hot zone (the 31-year-old furnace)

When the software notified the operator and OEM through an email alert with details of the location of the damage, the maintenance technician was able to investigate and correct it in a single day, intercepting potential problems before they caused unscheduled and extended downtime and affected more loads.

Case 4: Using Reporting Metrics to Identify Energy Consumption Flaw in Hot Zones

"Critical importance must be placed on classifying data and designing systems to process the various types of data available. Industry 4.0 unlocks a great deal of data, and not all data is created equal." [3]

A predictive software is only good if its predictions are accurate, which is why teams of dedicated subject matter experts and developers work to improve these products every day. This not only benefits the end-user mentioned in each study, but that knowledge is also applied to other users on the platform indirectly through software iterations.

There are established metrics users can expect when the software is installed on furnaces with an OEM hot zone. In this case, the original hot zone was replaced. After two years of the software operating as it should and identifying potential maintenance opportunities, the software indicated a condition of too much heat loss. The software's three indicators for the condition are green (good), yellow (warning) and red (immediate action needed).

By continually monitoring heat loss through the hot zone, predictive maintenance software alerts customers when it is time to replace the insulation and/or indicates when the kW usage is higher than normal. Heat loss is measured when the customer runs a burnout cycle. The calculations are formulated once the furnace has reached a specific burnout temperature and soaked for one hour to reach steady-state heat loss. When the customer ran a burnout cycle on their furnace, the software indicated a red condition for a heat loss of 1.14 kW/ft^2. The software identified that the hot zone was degrading more rapidly than it should be, which was an indication that something was wrong.

While the insulation had been replaced about two and a half years prior, the hot zone was rapidly degrading, indicating the OEM hot zone offered thicker walls and better insulation. In order to highlight this high heat loss value, we calculated the energy consumption to run the furnace with the existing hot zone and compared it with the original.

	OEM Hot Zone	Other Hot Zone
kW usage during ramp (1.5 hrs)	45 kW	117 kW
kW usage @1960°F (4 hrs)	240 kW	422 kW
Total kW hrs/cycle	285 kW (47% less)	539 kW
Additional cost per cycle @ $0.10/kW	$25.40	
Additional cost over one calendar year	$14,400 (526 cycles)	

Figure 6: Energy consumption calculation of vacuum furnace with OEM hot zone compared to non-OEM hot zone.

With the average kW/hr. cost at $0.10, the additional cost per load (using the non-OEM hot zone) is $25.40. Over the course of one calendar year, with the customer running 526 loads, the additional cost is estimated at $14,400.

Conclusions

Predictive maintenance is just the first step in an encompassing data analytics platform for heat treaters. Using a combination of preventive, routine and predictive maintenance sets operators up for the best success in their jobs.

Although Ipsen's PdMetrics® platform was launched in 2016, the product development team continuously analyzes trends, working to improve the software. This began by establishing baseline data through trials, fine-tuning that data, and determining rules based upon the diagnostics gathered during this process. Therefore, the more systems that are installed, the more accurate the predictions become. The 150+ installations in 20 countries include new and retrofitted, Ipsen and non-Ipsen and atmosphere and vacuum systems. With continuous, real-time monitoring, the program is always improving, and changes can be implemented immediately. They key to its success has been combining the use of machine learning with decades of expert knowledge. Once enough data is gathered, the use of AI will play a large role in the future of predictive maintenance. With prescriptive maintenance—the next PdMetrics milestone—furnaces would not only predict future events but also provide actions to take based on machine learning (AI).

Heat treaters can only get better with a combination of systems driving proactive maintenance. New developments and interactive features—such as augmented reality and real-time monitoring—are transforming the way equipment is operated and maintenance is performed. Although predictive maintenance is just one way heat treaters are using the Internet of Things, the future calls for connected cells and systems. Integrated factories are essential to driving operational efficiency today.

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*PdMetrics is a licensed trademark of Ipsen.
*Case studies are based on a best-case conservative estimate scenario where PdMetrics is the only variable changed. Other potential issues, such as not having parts in stock, etc. could lead to additional downtime and added cost.