White Paper

Predictive Maintenance for Chemical Plants

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Predictive Maintenance for Chemical Plants

Production processes used in the chemical industry often involve reactive, corrosive, or toxic chemicals operating at high pressures and temperatures. When critical production assets fail, this can result in interrupted processes, reduced or halted productivity, and the loss of valuable raw materials. In the worst case, unexpected equipment failure can have even more serious consequences including environmental damage and health hazards to operators and to the public.

While chemical processes vary significantly from product to product, and chemical plant layouts vary greatly as well, the total number of asset types found within chemical plants is not extensive. There are a number of common electrical, mechanical, and electromechanical equipment types, such as pumps, valves, fans, reactors, vessels, heat exchangers, filters, and homogenizers, which can be found at almost every industrial process plant. During operations, these assets are subjected to high pressures, large temperature variations, mechanical stresses, and corrosive environments that limit their useful life. The ability to accurately predict the future health of production equipment under these varying conditions will deliver tremendous value to chemical plant operators. In this white paper, we discuss some of the barriers and opportunities on the road to Zero Unplanned Downtime.

Unplanned downtime costs industrial manufacturers $50 billion annually.[1]

ASSET CLASSES	FAILURE MODES	IMPACT
Reactors	Leaks; explosions; fouling	Safety hazards; process interruption; cleanup, product quality impact;
Pumps	Bearing failures; blade failures; leaks	Safety hazards; process interruption; cleanup
Fans	Bearing failures; blade failures	Process interruption
Valves	Sticking; leaks	Process interruption
Heat exchangers	Fouling	Process interruption; product quality impact
Filters	Clogging	Process interruption; product quality impact
Pressure seals	Leaks	Process interruption; product quality impact

Table 1: Typical asset types used in chemical processing, their possible failure modes, and the potential impact of failure.

[1] Deloitte Insights, "Making maintenance smarter," 2017.

Maintenance Practices are Evolving

Many heavy industries have successfully matured their operations to follow structured maintenance approaches such as reliability-centered and preventive maintenance. The chemical industry is no exception.

Although preventive maintenance is better than deferring maintenance until a failure occurs, it is not the most efficient maintenance strategy in terms of maintenance costs and production impact. Replacing or overhauling assets on a fixed-time schedule ignores the variability in component wear due to actual use conditions, and replacing lightly used components results in unnecessary planned downtime and direct maintenance expenses.

As a result, many plants have moved to scheduling maintenance based on actual asset condition, a practice often referred to as Condition-Based Maintenance (CBM). CBM employs sensors to measure the status of an asset over time while it is in operation. However, most CBM approaches rely on periodic and infrequent inspections, which are not adequate for detecting early signs of wear.

A recent survey of more than 100 plant managers commissioned by Novity™, showed that 41% of plant managers are still relying on condition based monitoring to understand asset operational health, meaning they are being reactive rather than proactive. Real-time monitoring of this kind it is often limited to diagnosing the occurrence of a failure after the fact and not able to predict failures well before they happen.

By contrast, Predictive Maintenance (PdM) is based on continuous assessment of asset health and actionable predictions of remaining useful life for monitored assets. It is the next logical step in the evolution of maintenance practices. A carefully designed PdM strategy allows plant managers to optimize production activities while minimizing maintenance costs and risks due to unintended shutdowns.

In fact, zero unplanned downtime is an aspirational goal of PdM.

Given its potential impact on operational costs, PdM is one of the fastest growing elements of industrial digital transformation with wide adoption in the oil and gas (both downstream and upstream) and aerospace industries.

Despite its success in other industries, the impact of PdM in chemical processing has been lackluster until now. A recent survey has found that only a quarter of chemical operators have reported high or very high success in implementing PdM, while over 15% claimed low or very low success rates.[2] Across the chemical industry, preventive maintenance through periodic shutdowns is still the norm. As a consequence, Overall Equipment Effectiveness (OEE) losses stemming from downtime of 5–10% are very common. Unplanned downtime is responsible for as much as half of these losses.[3] Given that the chemical industry directly contributes over $1.1 trillion to global GDP, even a percentage point of efficiency gain across the industry could unlock billions of dollars of value for shareholders and society at large.[4]

[2] Sean Ottewell, "Predictive Maintenance Efforts Boast Uneven Success," Chemical Processing, January 2019.

[3] Oxford Economics, "The Global Chemical Industry: Catalyzing Growth and Addressing Our World's Sustainability Challenges," March 2019.

[4] Novity survey of 100 industrial plant operators, 2021.

Barriers to PdM Adoption in the Chemical Industry

Every industry has its unique challenges and the chemical industry is no exception. There are a few key reasons why the success of PdM in other industries has not yet directly translated to the chemical industry.

Lack of data

Over the last decade, PdM flourished in the oil and gas industry due to an abundance of sensor data and breakthroughs in machine learning (ML). However, even though a plant typically has thousands of deployed sensors, the chemical industry is still not considered a "data rich" environment for PdM purposes. The reason is that plant instrumentation is designed around process control and not asset health. PdM applications based entirely on ML often require different data, and much more of it, than process control instrumentation provides. Another contributing factor is the need to instrument and monitor unique custom assets in the chemical industry, which makes it difficult to collect training data.

Short actionable time horizon

Some ML-based PdM applications are able to predict a limited number of failures up to two weeks before they occur. Within the long time horizon of chemical plant operations, however, having only two weeks of advance notice is not optimal. Procuring custom spare parts for unique assets often takes months of lead time, while maintenance on production-critical assets requires carefully orchestrated shutdowns with months of advanced planning.

Data security

Within the chemical industry, production recipes and processes involved in creating core products are valuable trade secrets. PdM offerings that process data in the cloud (or anywhere outside the plant IT firewall) are not acceptable for most chemical plants.

These factors show that the chemical industry has unique challenges related to PdM. In addition, asset health is only one aspect of chemical production, and it is often of secondary importance compared to overall process efficiency and product quality. Therefore, a successful PdM deployment in the chemical industry needs to minimize impact on production activities while reducing maintenance costs.

Novity TruPrognostics™ Engine for Predictive Maintenance

Novity is an exceptionally accurate PdM solution developed by PARC based on decades of experience in technologies related to asset and process health. Our TruPrognostics can be used to predict near-term threats to industrial production, understand the health status of each monitored asset, and plan operational maintenance while reducing the risk of unplanned production downtime due to failed assets.

Our mission is to eliminate unplanned downtime by helping manufacturers see the future health of their production assets with perfect clarity.

All Novity products are thoroughly tested in a Xerox chemical production environment before they are offered to the market. Novity is designed and built for the chemical industry and we only build solutions that we use ourselves.

We also understand the barriers to successful PdM deployment in the chemical industry. Here is how Novity overcomes them.

Discovery

Each Novity client engagement starts with a discovery phase conducted by chemical industry experts. This involves a thorough review of the plant layout, including the identification of safety-critical and mission-critical process paths and assets, redundancies, potential failure risks, maintenance and failure histories for critical assets, and existing maintenance processes.

In addition, a failure modes, effects, and criticality analysis (FMECA) is carried out to understand the underlying failure modes that are responsible for ultimate equipment malfunction. This is matched with a survey of installed sensors to understand which failure modes can be observed through instrumentation and which should be augmented with additional sensors.

The outcome of the discovery phase is a report that identifies safety- and mission-critical assets and presents a deployment plan for a Novity PdM solution with a goal of **zero unplanned downtime**.

No dependence on massive data sets

Most ML-based PdM solutions require massive data sets from identical assets in order to build workable predictive models. While data is very important for accurate predictions, Novity uses a variety of technical approaches to limit its dependence on large data sets. Besides ML

techniques, Novity also employs physics-based models of critical assets in order to make accurate predictions of asset health with limited data. In addition, a typical Novity deployment includes provisioning new sensors onto critical assets in order to increase prediction accuracy and time horizon.

Approach for predicting failures months ahead

Typical PdM failure predictions that come only one or two weeks before the failure will occur are not acceptable for most chemical plants. In order to extend the time horizon on failure predictions, Novity uses two different approaches:

1) Building out physics-based models that target specific fault mechanisms to calculate hidden damage parameters
2) Deploying advanced sensors, which observe early signs of damage that are not identifiable through the use of standard process control sensors.

With these advances, Novity's TruPrognostics can predict critical asset failures months in advance, providing ample time for operators to procure spares, schedule downtime, and minimize the impact on production.

Embracing data security

Novity is a PdM solution designed from the ground up for the Chemical industry.

With Novity, critical process know-how never leaves the plant. Novity is deployed on-premises and requires no connection to the Internet in order to operate.

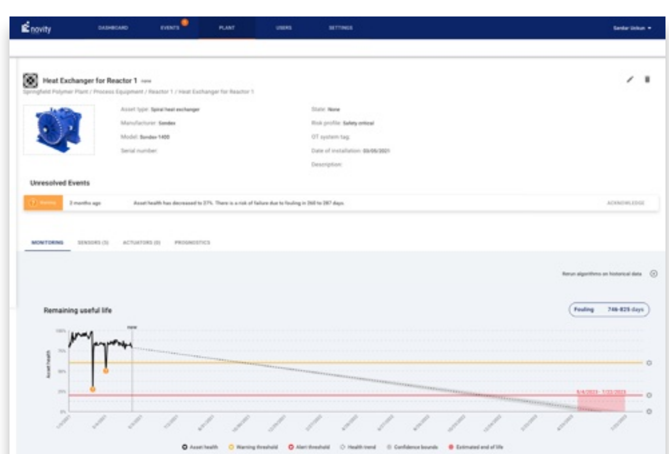
Novity is built on a state-of-the-art web services architecture. This allows for seamless scalability as asset coverage and end-user activity increases, ensuring that critical operational information is up-to-date at all times. Security is tested regularly against all known cyber threats.

Although Novity is based on a modern, scalable web services architecture, it is possible to deploy Novity entirely on premises with no connection to the internet except for billing, platform software updates, and error reporting. With Novity, critical process know-how never needs to leave the plant.

Production-centric design

Novity is built in response to the needs of producers. Too many PdM technologies suffer from asset-centric thinking, whereas Novity puts production readiness front and center.

To date, the Novity team has completed several dozen interviews with operations and maintenance experts from process industries. Feedback from these experts was used to make the platform more usable and useful. In addition, Novity regularly conducts usability tests with our users for continuous product improvement purposes.



Case Study

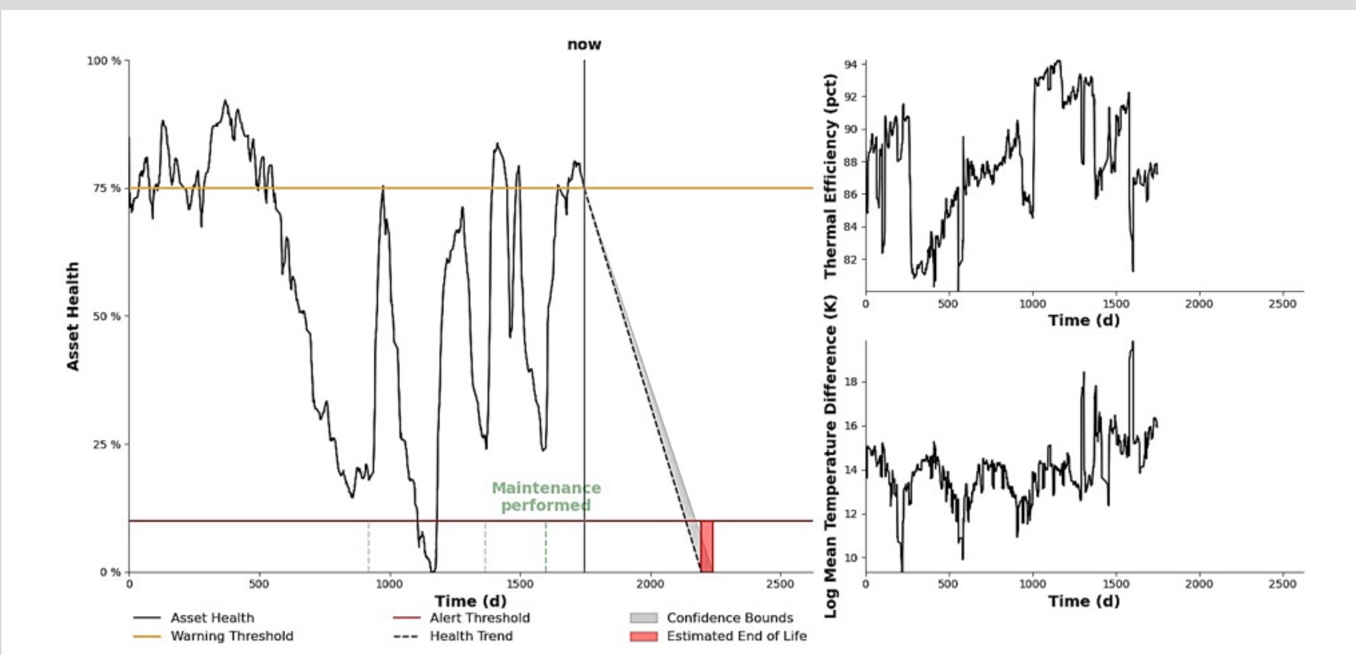
Heat Exchanger Fouling

Spiral heat exchangers used in toner production are subject to fouling. A major challenge is that fouling is not directly observable in a sealed heat exchanger system. Rather, heat exchanger fouling becomes apparent only by observing long-term trends in process parameters and end-product specifications. While cleaning cycles generally help reduce fouling, finding the right cleaning regimen for each cycle might require several trial-and-error runs.

To address heat exchanger fouling, Novity scientists devised a physics-based model to estimate fouling using sensor measurements such as slurry temperature and flow rates. By estimating the change in thermal resistance over time, Novity scientists can estimate the amount of fouling and accurately predict when cleaning was needed.

When historical data is analyzed, operators can immediately see estimated internal process parameters, the progression of fouling, and the impact of cleaning cycles (and the relative strength of each cleaning regimen). By using their deployment of the Novity tool, plant operators can determine the ideal cleaning regimen for their spiral heat exchangers while maintaining product quality.

In the figure below, each dot represents the estimated thermal resistance for a spiral heat exchanger per day. The figure shows that the amount of fouling is not always increasing and so cleaning at appropriate times is imperative. By tracking how the overall thermal resistance of the heat exchanger increases per day, Novity can predict when fouling will affect quality to an unacceptable degree, helping plant managers and operators determine the right cleaning regimen.



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