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a leading global manufacturer
of heat treatment furnaces and equipment

SECO/WARWICK is a technological leader in innovative heat treatment furnaces. Expertise includes end-to-end solutions in 5 categories: vacuum heat treatment, atmosphere, and aluminum thermal processing, controlled atmosphere brazing of aluminum heat exchangers and vacuum metallurgy. SECO/WARWICK Group with 9 companies located on 3 continents with customers in nearly 70 countries, has its production facilities in Poland and China. In addition, the Group operates a number of service and sales offices in countries such as Germany or Russia. The company provides standard or customized state-of-the-art heat processing equipment and technologies to leading companies in the following industries: automotive, aerospace, electronics, tooling, medical, recycling, energy including nuclear, wind, oil, gas, solar and production of steel, titanium and aluminum.

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INVENTION MEETS RELIABILITY

THE FUTURE OF MAINTENANCE

Regardless of the type of business activity, the competitive environment requires companies to manufacture products of appropriate quality with the highest possible output while keeping costs as low as possible. Maintenance operations constitute a cost which should be compared against the cost of potential failures, and based on this decisions may be taken regarding preventive measures. Over the last few years, predictive maintenance has become a buzz word used in response to the majority of problems. But is that really so? How do predictions change current maintenance methods? What is predictive maintenance and what is it not? What are the potential benefits for a company arising from its implementation and how can they be achieved?

The answers to these and many other questions can be found in this study, which gives an overview of the issue and presents the inspiring world of Industry 4.0 in terms of maintenance and its slumbering potential.

- Global Predictive Maintenance Market By Component, By Deployment Type, By End User, Competition Forecast & Opportunities, 2012 – 2022" report published by TechSci Research suggests that the global predictive maintenance market is projected to grow at a CAGR of about 31% during 2017 – 2022
- "Global Predictive Maintenance Market for Manufacturing Industry Driven by the Advent of IoT & Industry 4.0, Reveals Persistence Market Research' report published by Persistence Market Research suggests that the global predictive maintenance market is projected to grow at a CAGR of about 26% during 2018 – 2026
- "Predictive Maintenance Market by Component, Deployment Type (Cloud and on-Premises), Organization Size (SMES and Enterprises), Vertical, and Region - Global Forecast to 2021" by Markets&Markets suggests that the global predictive maintenance market is projected to grow at a CAGR of about 28% during 2017 – 2021
- "Predictive Maintenance Market Research Report- Forecast to 2022" report published by Market Research Future suggests that the global predictive maintenance market is projected to grow at a CAGR of about 29% during 2018 – 2022

INTRODUCTION

The need for competitiveness is the driving force in the industry. Weaker companies vanish, and new ones that are quicker, cheaper or who have a product or service which is more innovative than others, or better suited to the needs of the end-customer, take their place. Therefore, companies try to specialize in the area of their production and tasks related to their core product. As a result, the burden associated with supporting auxiliary operations is increasingly being shifted outside the company, i.e. beyond the company's production area, towards equipment suppliers or service providers. This also happens to maintenance, which is significant from the perspective of a company's operating costs, but does not constitute its core activity.

Maintenance-as-a-Service is becoming an ever more popular model, one in which you do not simply pay for the equipment but for its actual production capabilities. Such a partnership model with the product or service provider ensures a win-win for both parties, as both of them focus on their core activity. An important element of this model is that business relations are based on trust resulting from the quality of service and the quickness of reactions to any events that may crop up.

Maintenance services in industry include, among other things: technical support during the delivery of machinery and bringing it online, operational and supervisory training, deliveries of consumables, required updates, and - first and foremost - the guarantee that machinery will work. Ensuring machinery and equipment availability is a critical success factor as it directly affects production capacity and costs related to it. For many years, maintenance operations evolved from the reaction model, through the planning model, to the predictive model, in which - on the basis of known symptoms - it is possible to prevent potential failures even before they occur.

COMPREHENSIVE MAINTENANCE

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Total Productive Maintenance (TPM) is a lean manufacturing-based approach, whose foundations were developed in Japan at the beginning of the 1970s. The main goal of TPM is to ensure the maximum efficiency of machinery and equipment by optimizing their maintenance system with the use of the existing resources of a company. Instead of having a machinery operator and maintenance personnel who are completely independent from one another, employees should be trained both in operation and in the maintenance in order to better understand the machinery's condition and the required inspections and repairs.

The main goals of TPM include:

- No short stoppages or non-optimal production factors
- No damage
- No unplanned outages
- No accidents

TPM is based on 8 pillars:

1. Autonomous maintenance.
The first pillar is a unique feature of TPM, which assumes that people working every day with a machine are those most accustomed to its behaviour and performance. In accordance with this idea, the operators become guardians of their machinery and are in change of routine maintenance such as cleaning, lubricating, or everyday inspections. They should also be the first to solve any problems they have been trained to handle.
With Industry 4.0, along with the increasing automation of machinery and equipment, monitoring it is now more precise and reporting more complete and clearer, and therefore less complicated. This in turn simplifies the role of being a guardian, making it more accessible to employees.

2. Planned Maintenance
Regular maintenance should prevent unexpected failures, but work requiring highly qualified technicians should be planned in advance in order to minimize outages. The scope of specialist work can include, e.g. a software update or replacement of complex parts.
With Industry 4.0, using predictive maintenance with support from machine learning leads to maintenance operations being performed only when they are really necessary and they can be planned, so as to completely eliminate unplanned stoppages.

3. Quality management
Employees are trained in and encouraged to regularly identify production-related problems which could eventually lead to a failure and/or quality problems.
With Industry 4.0, by introducing predictive factors for individual devices, where sensor data and machine learning help identify anomalies in machine behaviour, it is possible to notify operators in advance of such situations. As a result, root cause analysis and the resulting preventive operations can be performed much earlier than has previously been possible, limiting any potential financial losses related to loss of quality and/or failures.

4. Focused improvement
Companies establish multi-disciplinary teams which are encouraged to pro-actively engage in maintenance issues. Such groups, as part of internal workshops, solve various problems affecting production, starting with the most important ones and moving gradually towards more minor inefficiencies.
Industry 4.0: with the collection of data and use of artificial intelligence algorithms, it is possible to identify less obvious links between defects and root causes. Information and hypotheses regarding the occurring phenomena and control methods can be effectively shared with the entire company and beyond it, which enables quicker and more precise data analysis. New tools are also significantly improving how team members work together.

5. New equipment management
Design and installation of new equipment should be based on previous experience so as to ensure that the assumed efficiency targets are achieved as soon as possible with a minimum of problems when the equipment goes online.
Industry 4.0: in order to determine the best practices from earlier systems and designs, historic production data can be analyzed more quickly and in more detail. This also takes into account current plant conditions. And in addition, this is supported by digital visualization and machine operation simulation prior to its going online as part of an engineering process combining CAD, CAM and automation systems.

6. Education and training
Machinery operators receive training that provides them with the skills required to keep machinery operating and identify any potential problems. In turn, specialized maintenance personnel learn pro-active work methods, and management raises their qualifications in terms of leadership skills.

Industry 4.0: digital visualization (a digital twin) of how machinery operates facilitates understanding the complex production process at every level: from single components, through independent devices, to complete production lines and general management of the entire plant. The educational content itself can be accessed on-line, 24/7. In addition, new recruits can have assigned mentors who support new employees and respond to their questions by supervising the training process. Computer-based visualization technologies (virtual reality, augmented reality, mixed reality) also make it possible to carry out remote and system-wide training without any loss of quality.

7. Safety, Health and Environment
Pillar 7 is related to developing a safe working environment. By identifying health hazards and potentially dangerous situations, one can work to eliminate them. This also applies to the comfort of working conditions which affects the performance.
Industry 4.0: early detection of harmful gases, electrical faults or fire may save lives and prevent damage to equipment.
Additional sensors can measure air quality, radiation, temperature or other environmental conditions that affect employees' health and as a result their performance.

8. Administration.
The TPM approach can also be implemented in areas which are not directly engaged in production, including office administration. The idea of including administrative functions as one of the eight TPM pillars is related to the fact that this management level – order processing, planning, human resources, accounting – should be synchronized with other aspects of production by means of clear, efficient communication.
Industry 4.0: artificial intelligence algorithms are perfect for advanced analyses and processes that involve decision-making, making it possible to implement this technology in processes connected with the automation of operations on production lines in a very effective way. With the increased scope of available data, one can analyse cost centres much better and be more precise in managing an improvement strategy.

MAINTENANCE SERVICE MATURITY LEVELS

Maintenance can be divided into two major groups: traditional maintenance services which include reactive and preventive maintenance, and services related to Industry 4.0 capabilities with proactive and predictive maintenance.

- **Reactive maintenance**

  Reactive maintenance relies on a strategy in which a part, or an entire device, is replaced only when the part or the device fails. This strategy is attractive from a business perspective, as it makes it possible to make the maximum use of the device without any additional costs. However, it is beneficial only until a failure occurs. Repair costs after a failure can be higher than production profits. In addition, getting to the point when a component fails (due to increased vibration, overheating, breaking, etc.) can also damage other components of the device, increasing the time required for repair as well as the total cost related to it. Adoption of reactive maintenance can result in companies repairing the results of a failure, often without understanding their actual causes. However, there are items for which reactive maintenance is justified. This applies to parts which have no impact on production continuity, e.g. hall lighting.

- **Preventive maintenance**

  Preventive maintenance, also referred to as planned maintenance, is comprised of tasks and inspections performed during normal operation of the device. The main goal of such maintenance is to maintain machinery operations and prevent unplanned failures and stoppages. Equipment is shut down only for the purpose of major inspections in accordance with a maintenance plan adopted beforehand, so that defined maintenance operations and part replacement are performed.
  The purpose of preventive maintenance is to extend device lifetime, maintain or increase assumed production capacity and decrease repair costs.

- **Preventive maintenance is based on theoretical periods** (or cycles) of component and sub-assembly life. It does not account for their actual condition. This means that items are replaced regardless of their wear, and the company has to keep them in stock.

- **Proactive Maintenance**

  Proactive Maintenance or Condition Based Maintenance is an approach based on data describing something's technical condition. Maintenance operations depend on the actual state of the particular device. The equipment is monitored in terms of performance fluctuations, operational disturbance or wear of individual components.

  Proactive maintenance is believed to be more precise than preventive maintenance. CBM includes root cause analysis and the measurement of current indicators that potentially affect the operation of the entire device, not only those critical in terms of availability, but also those related to performance.

- **Predictive Maintenance (PdM)**

  With the use of advanced technologies, predictive maintenance combines historical data with CMMS system data and data from sensors installed in devices in order to predict and prevent the occurrence of failures. PdM works directly on equipment in service, measures a series of parameters and analyzes their values via artificial intelligence and machine learning algorithms. Such a set of current and historical data makes it possible to predict when a particular component might get damaged, allowing a maintenance team to plan and take the required actions before any failure occurs.
  In contrast to reactive maintenance (where a component is damaged), preventive maintenance (where a component is replaced despite the fact that it could carry on working for a long time) or proactive maintenance (where a component is diagnosed as one requiring replacement), predictive maintenance predicts in advance the condition of individual parts and components, helping companies to optimize their maintenance strategies and limit them to actions that are truly needed.

The actual idea of predictive maintenance is not new. Many plants employ specialists in charge of particular machinery who for years have worked as experts and helped in predicting failures before they occur. Currently, this can be implemented at a larger scale thanks to new technologies for collecting and analyzing large sets of data.

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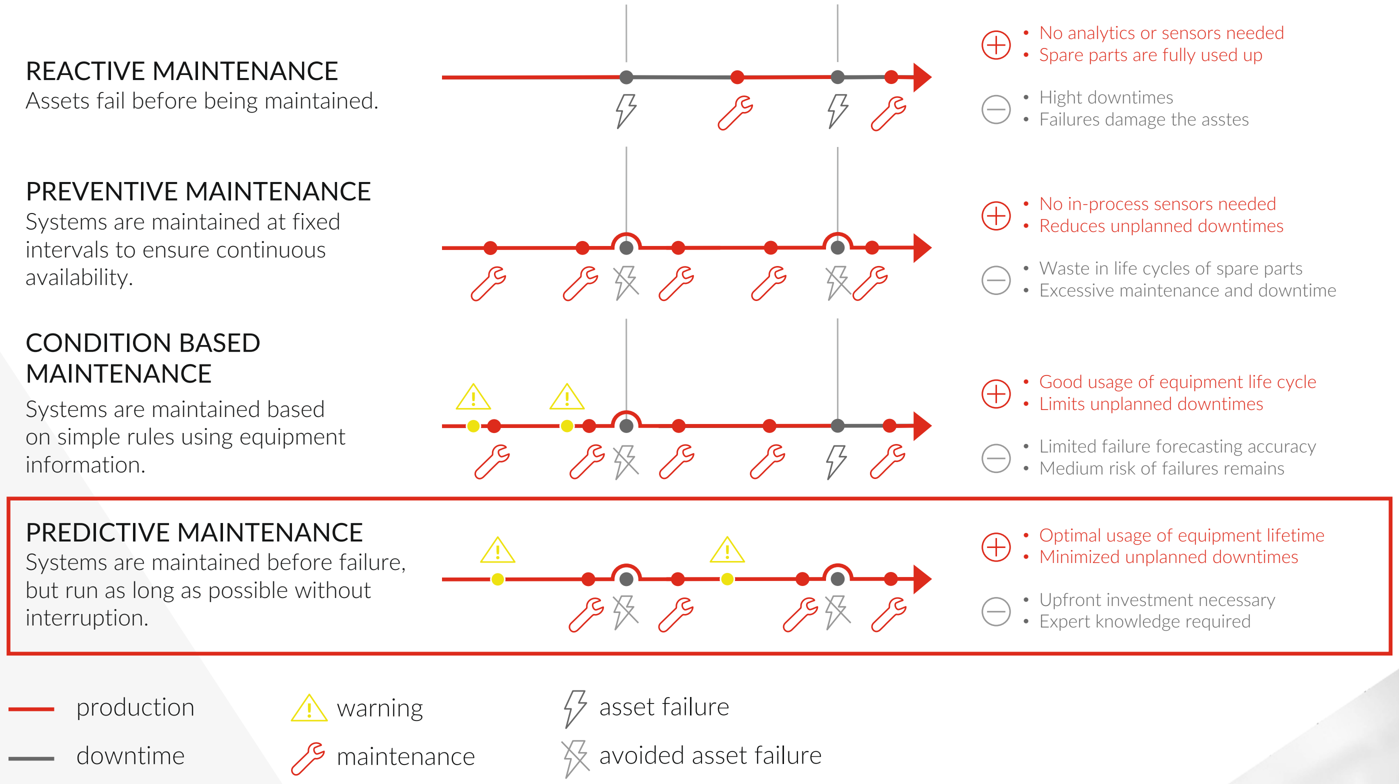

PREDICTIVE MAINTENANCE 4.0

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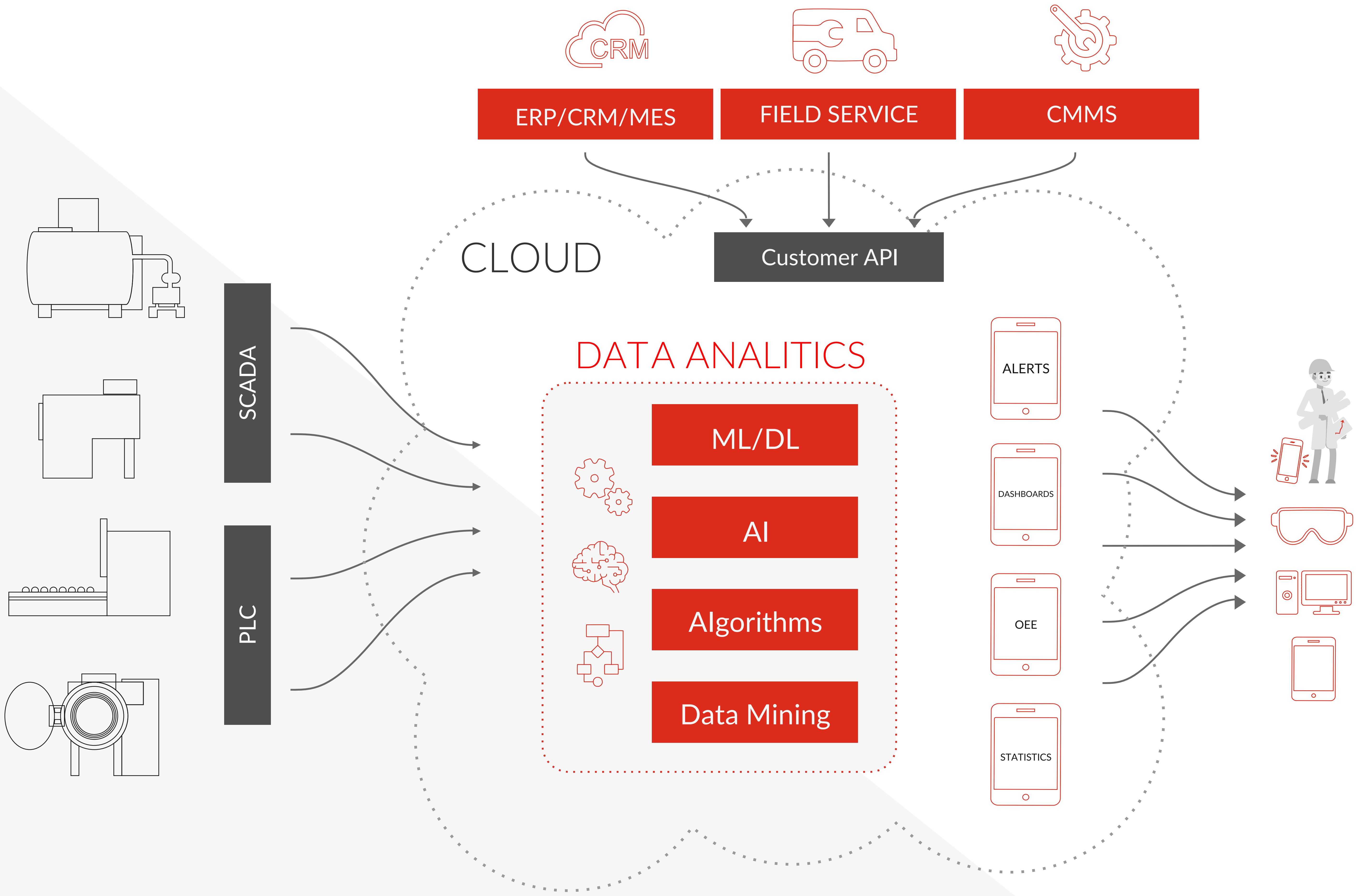

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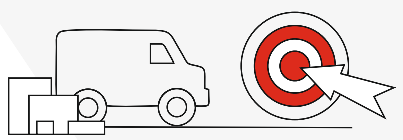
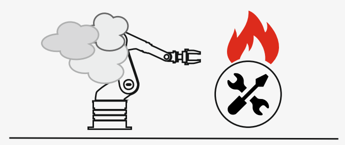
BENEFITS OF IMPLEMENTATION PREDICTIVE MAINTENANCE (PdM)



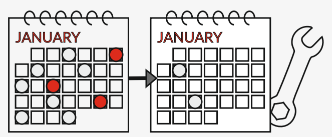
BOOST DELIVERY ACCURACY

If there`s one thing your customers hate, it`s poor delivery accuracy. By emplaying PdM, you can drastically reduce unexpected brakoedownsin your vehicle fleet or site machinery. With demanding players like Amazon, this can be a strategic make-or-brake for many big manufacturers.



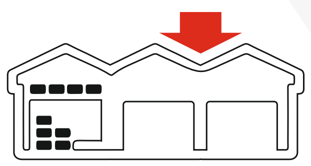
MINIMIZE ASSET DOWNTIME

By fixing issues before they lead to breakdowns, you`ll immediately reduce downtime. Further, a CAN bus PdM system provides your technicians with extensive asset-specific data. This way, they`ll know the issue beforehand – letting them skip generic checklists and cut downtime dramatically.



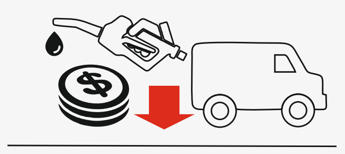
REDUCE MAINTENANCE COSTS

Preventive maintenance is costly as it relies in e.g. time based intervals. These are weak predictors of failure, hance conservatively freaquent checkins are needed. With PdM, the asset-specific big data is far more precise in predicting on issue – enabiling for less frequent maintenance.



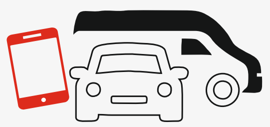
OPTIMIZE SPARE PARTS INVENTORY

With reactive or preventive maintenance, a massive inventory of spare parts is necessary – you don`t know what you`ll need until the asset is taken out of operation. With PdM, you`ll estimate time-to-failure for each sub component via the cloud, alllowing a for more lean inventory.



CUT FUEL COSTS & EXTEND LIFE

By setting up PdM for e.g. a vehicle fleet, you can track the remaining life of each vehicle component. This lets yo truly optimize total cost of ownership (TCO), by deciding the oprimal replacement costs vs. Impacts on fuel costs and vehicle.



IMPROVE WORKER SAFETY

In worst case, breakdowns of machinety or vehicles can leas to catastrophic events and harm workers. By predicting issues before they escalate, you'll be able to reduce accidents and boost team morale.

Decreased maintenance costs – actual costs associated with maintenance can be decreased by more than 50%. This covers direct work costs, the costs of the department itself, as well as the costs of spare parts, tools and other equipment required for the performance of the work.

Decreased failures – regular monitoring of the current condition of the device and processes can decrease unexpected failures, critical from an operational point of view, by at least 55%. This number was established on the basis of the frequency of critical failures before the implementation of prediction tools and the frequency of analogous failures during a 2-year period after the implementation of the PM 8 CBM program. We estimate that up to 90% of such failures could be eliminated with full use of PdM.

Shortening machine outage time required for repairs – PdM makes it possible to shorten the real time required for repairs or overhauls of existing machinery. Mean Time to Repair (MTTR) can be decreased by 60%. This indicator was established on the basis of measurements taken before implementation of PdM tools and during a 1-year period after their implementation. Regular maintenance monitoring supported by advanced analysis of the device's condition makes it possible to identify in advance failures of individual components and to plan their repair or replacement.

Limiting stocks of spare parts – the ability to predict failures, and therefore to predict the parts and components requiring repair as well as the associated tools and knowledge, makes it possible to reduce the time needed for such work as well as the costs associated with the purchase of materials. Expenditure on stocking spare parts can be reduced by 30%. Instead of purchasing all the materials required for the performance of repair and maintenance operations, the plant has enough time to purchase such materials when they are actually needed. In addition, the system is able to more precisely determine the parts which should be kept in stock.

Extending components' lifetime – preventing critical failures, and early detection of problems with devices and their components, extends the total lifetime of industrial machinery by 30% on average. This value is bases on a five-year study of the operating period after the implementation of a PdM program. These calculations take into account repair frequency, the extent of machinery damage, and the machinery's condition after repair. The mere implementation of CBM makes it possible to avoid serious damage to entire pieces of equipment as well as individual systems. Reducing critical failures increases the durability of the entire device and also prevents the spreading of the results of potential failures to the surrounding environment.

Supporting decision-making processes – an indirect benefit of the implementation of PdM is the possibility to automatically establish the Mean Time Between Failures (MTBF). This value, among other things, supports the decision-making process related to the need to replace an entire device with a new one instead of bearing elevated maintenance costs. The MTBF value decreases after every critical failure. PdM algorithms monitor and report the MTBF. When it reaches the point at which the costs of maintenance and continued operation exceed the investment costs, the device should be replaced with a new one.

Increasing production – device availability resulting from the implementation of CBM and/or PdM directly leads to increased production. Depending on the industry, this increase can reach up to 30%. This change results directly from availability of the machinery and does not include any return on improving processes. A complete PdM program, which includes continuous monitoring of performance and quality indicators, can additionally increase the production output for individual devices, lines and the entire plant.

Improving occupational safety – early warnings about potential problems reduce the possibility of a failure that could endanger the health or life of employees. Apart from increasing the occupational safety of employees, insurance discounts can end up as being another benefit. Many insurance companies offer special discounts for facilities which apply CBM / PdM programs.

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THE COMPREHENSIVE DIMENSION OF PdM

It is commonly assumed that implementation of a PdM system involves just installing additional sensors on a device and collecting data. Yet PdM is a complex and comprehensive activity. It includes, among other things, the following actions:

- Data collection,
- Data modelling,
- Failure classification,
- Data analysis based on advanced algorithms, e.g. regression, binary or multi-level classification,
- Failure prediction,
- Failure diagnostics (root cause analyses),
- Repair action recommendations,
- Preventive action recommendations,
- Operational reporting,
- Statistical reporting,
- Management reporting.

PdM is an element of Comprehensive Maintenance. It does not compete with comprehensive maintenance, instead it supports and supplements it, offering brand new analysis and reporting tools which were previously not commonly available. PdM uses data from CMMS, ERP or MES systems to better understand and predict possible events.

PdM does not completely eliminate all the aspects of traditional maintenance programs, but it can decrease the number of unexpected failures as well as provide a more reliable tool to schedule routine preventive maintenance operations. PdM does not guarantee 100% reliability of device operation. With prediction, the value gets closer and closer, but PdM mostly enables more precise prediction of any coming failures, optimizing the costs associated with inspections and the volume of spare parts kept in stock.

The accuracy of predicting potential failures is a derivative of the algorithms used for predictive analysis. The more extensive the knowledge and expertise of the implementing company, the closer to reality the results are. However, we should not confuse CBM and PdM systems, as the former is based on current data and predefined alarm thresholds, whereas the latter analyses the full operational history of the device and of the component, learning and drawing conclusions with each new piece of information.

Implementation of PdM, like any other investment, needs to be well planned and carried out. Companies taking such a step face many challenges. The most important include:

New skills – fully independent implementation of PdM can require a completely new set of skills for managing a system which goes far beyond traditional maintenance scheduling and skills for performance of maintenance. Data analysts would need to cooperate with reliability engineers in order to develop prediction algorithms and models. Many organizations find these skills difficult to develop. In order to obtain the best results, such work may require collaboration with multiple providers and consultants.

Equipment improvement – often equipment that has been operating for decades can be found in production halls. The costs of upgrading equipment or replacing it with smart components and sensors may involve significant expenditure.

Data collection – collecting appropriate data that enable companies to correctly predict important emergency models is of key importance for PdM. Therefore, access to and collecting appropriately prepared data is usual the first, most important task. At first this can require a lot of effort related to data cleaning and event mapping. It can also require employees to adopt new practices.

Handling large data sets – artificial intelligence algorithms provided with higher amounts of data can be more precise, therefore, complete equipment operating history needs to be gathered, if possible. This will constitute the basis for future solutions. On the other hand, storing and processing large data sets can be challenging from the technical point of view. Cloud services may be a solution to this problem.

CHALLENGES ASSOCIATED WITH PdM IMPLEMENTATION

Data security may be the greatest challenge in the contemporary world. As more and more resources are connected, and the Internet of Things becomes omnipresent, companies should consider in their plans appropriate protections against accessing critical data and systems, and should adopt a pro-active position in terms of equipment cyber-security.

Costs and time need for analyses and for developing system learning algorithms – AI algorithms are based on a large amount of appropriately correlated data. Developing a system on the basis of one or several devices can take longer for many reasons, and the unit costs can be higher. Companies that specialize in developing algorithms, mostly those that have large data sets, will in general be able to decrease the cost of producing appropriate solutions, and more importantly, they will be able to achieve this faster. On the other hand, this can constitute a barrier for small companies to independently implement PdM.

Quality of self-learning algorithms – no commercial off-the-shelf algorithms dedicated to individual devices are available on the market, however there are certain data processing methods which need to be carefully selected for the type of device and data set available. The quality of the result will also be decided, regardless of the amount of available data, by the knowledge and expertise of those in charge of implementation.

How should one approach implementation? The safest way is to start with a pilot implementation, by selecting one area and several key parameters. Then such a solution can be mapped to additional devices and supplemented with less important parameters, gradually developing a complex PdM tool for the entire facility.

SECO/PREDICTIVE

SECO/WARWICK specializes in developing metal heat treatment equipment. They are a renowned technological leader in this area. Apart from the typical work of the R&D department related to new designs and technologies, the company continuously works to improve the performance, availability and quality of its solutions.

For many years statistical data has been collected from industrial furnaces produced by the company. Continuous collaboration with scientific establishments and commercial heat treatment service providers, as well as work with furnaces installed in their research facilities, has given the company online access to thousands of records related to failures and maintenance operations.

Based on this knowledge, SECO/WARWICK has developed a comprehensive PdM tool for heat treatment divisions – SECO/PREDICTIVE.

- Self-learning algorithms based on artificial intelligence neural networks have been developed by SECO/WARWICK, together with renowned universities and research centres, to ensure that the obtained results will be able to predict potential hazards in the best possible way.

- The designs of the heat treatment equipment were verified in terms of the implemented measurements. Where needed, existing solutions were supplemented. In places where standard components could not be used, brand new sensors for measuring operational parameters and designed for PdM were developed in conjunction with companies specializing in creating measuring instruments. A comprehensive solution for collecting large data sets was developed together with Microsoft, paying particular attention to safety issues (both in terms of data accessing as well as its long-term storage) which is of particular importance to some branches of industry (e.g. aviation and nuclear).

- The final result is the SECO/PREDICTIVE offering, which provides supervisors of heat treatment divisions with a comprehensive PdM solution for their machinery.

- It is not ambition to provide PdM to every company which decides to implement it. Instead, we wish to become the unquestionable leader among providers of metal heat treatment equipment. Therefore, our top priority is a completely proven solution, ready for operation, which has been developed with the best experts in their corresponding disciplines.

- In accordance with our philosophy, we are able to provide small-scale implementation of SECO/PREDICTIVE, proving the strength and benefits for maintenance resulting from the new capabilities. Our portfolio is as flexible as our customers and their needs are different. We have a product for computers running Microsoft operating systems as well as mobile devices with Android and iOS. Our application can be downloaded directly from Internet stores.

SECO/PREDICTIVE can be considered PoC which, after a stabilization period, will be developed according to an adopted plan and budget.

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Global trends clearly show that in the light of changes brought about by the fourth industrial revolution, Predictive Maintenance will soon become the standard. Companies are left with the decision of when and how to handle this issue. There are many challenges as we need to consider existing machinery and its IT environment, processes and procedures associated with its operation, safety and data access models, analytics and reporting maturity at individual management levels, investment abilities, as well as the use of existing resources.

One could attempt to develop the technical background, substantial competences and operating teams for that purpose on one's own. However, one can also entrust this responsibility to companies that specialize in the field. Looking at the service market and the growing popularity of outsourcing, this choice seems very appealing as it enables companies to focus on their core activity, entrusting these services to experts while ensuring oneself better results in these areas while incurring lower costs.