Condition Based Maintenance:

Putting predictive maintenance algorithms to work to optimize asset maintenance and performance in supermarket refrigeration systems

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Introduction

Supermarket industry executives and their management teams are navigating an increasingly complex operating environment that must address changing retail formats and customer preferences in tandem with a heightened focus on energy efficiency and environmental protection issues.

Equally complex is the typical supermarket refrigeration system, a maze of interdependent equipment and sensors all under the management of complex system controllers. Depending on your perspective, within that complexity lies either a lot of headaches, or an opportunity to harness the power of the modern M2M machine learning technologies to provide an unprecedented visibility into the condition of refrigeration assets – assets so energy intense that they comprise almost half of the watts per square foot consumed in a typical supermarket.

With all of the other challenges the industry faces to maintain market share and thin profit margins in a dynamic consumer environment, decision makers should not have to rely on maintenance practices from a bygone pre-system controls era. A more sustainable solution is needed, and available.

Maintenance call-outs under traditional time and materials contracts have relatively high cost because typically the equipment has already failed by the time maintenance is called. Advanced control technologies evaluate and analyze a significant amount of operational data about the supermarket refrigeration system that is already embedded in the equipment and stored in the cloud.

Real time data analysis can lead to an early assessment of equipment conditions against operating parameters. If the actual performance data falls outside of the expected, signaling performance degradation, a maintenance alert can be transmitted via messaging system to the appropriate technician or maintenance manager. This in turn can generate a work order to inspect, repair or replace the part that caused the alert. All of this can be conducted via a web-based user dashboard.

The outcome: real value achieved in reduction of energy and maintenance costs, with additional value in compliance for both refrigerant management and food quality. Just a 2 percent reduction in maintenance and energy costs equals a 1.3 percent increase in profits.

Condition Based Maintenance (CBM) eliminates unnecessary maintenance on components that might not need it, and focuses on actual or incipient problems by monitoring key indicators. Using CBM, retailers can expect to see typical equipment maintenance savings of 18-40 percent, compared to preventive maintenance (PM) or run-to-failure strategies. The regular reporting function, combined with technical expertise to interpret it, provides actionable intelligence with significant ROI.

The Concept of Condition Based Maintenance

CBM is an evidence-based concept that has been applied to maintenance programs on complex systems in the manufacturing sector for years. CBM is predicated upon experience that only 20 percent of failures are a function of age or normal wear and tear, while the other 80 percent have myriad causes not related to age. These include improper control configuration, oil management problems, system refrigerant leaks, contaminants in the system, and uncalibrated sensors.

In addition, CBM assumes that call-outs under regular PM or time and materials contracts for unrelated issues may never detect early deteriorating condition until a failure ultimately occurs. The costs are higher energy usage, after-hours service rates and unacceptable levels of product shrinkage.

The scenario illustrated in **Figure 1** shows how typical equipment failure develops over time. *(The scenario is not based on actual events. Specific dollars and days are only intended to represent cost increases or reductions that could typically occur over a period of time.)* Consider the case of a compressor operating at unusually high discharge temperatures. Initially this anomaly may have only a limited adverse affect on system performance. However, as the condition deteriorates the system will start consuming more energy than it should, accelerating damage to its internal components.

With no visibility or notification and left unattended, this issue could result in large unplanned maintenance and energy expenses, and could become customer-facing, with impending risk of direct impact to the product itself.

Typical Equipment Failure Impact (Conventional PM or Run-to-Failure)
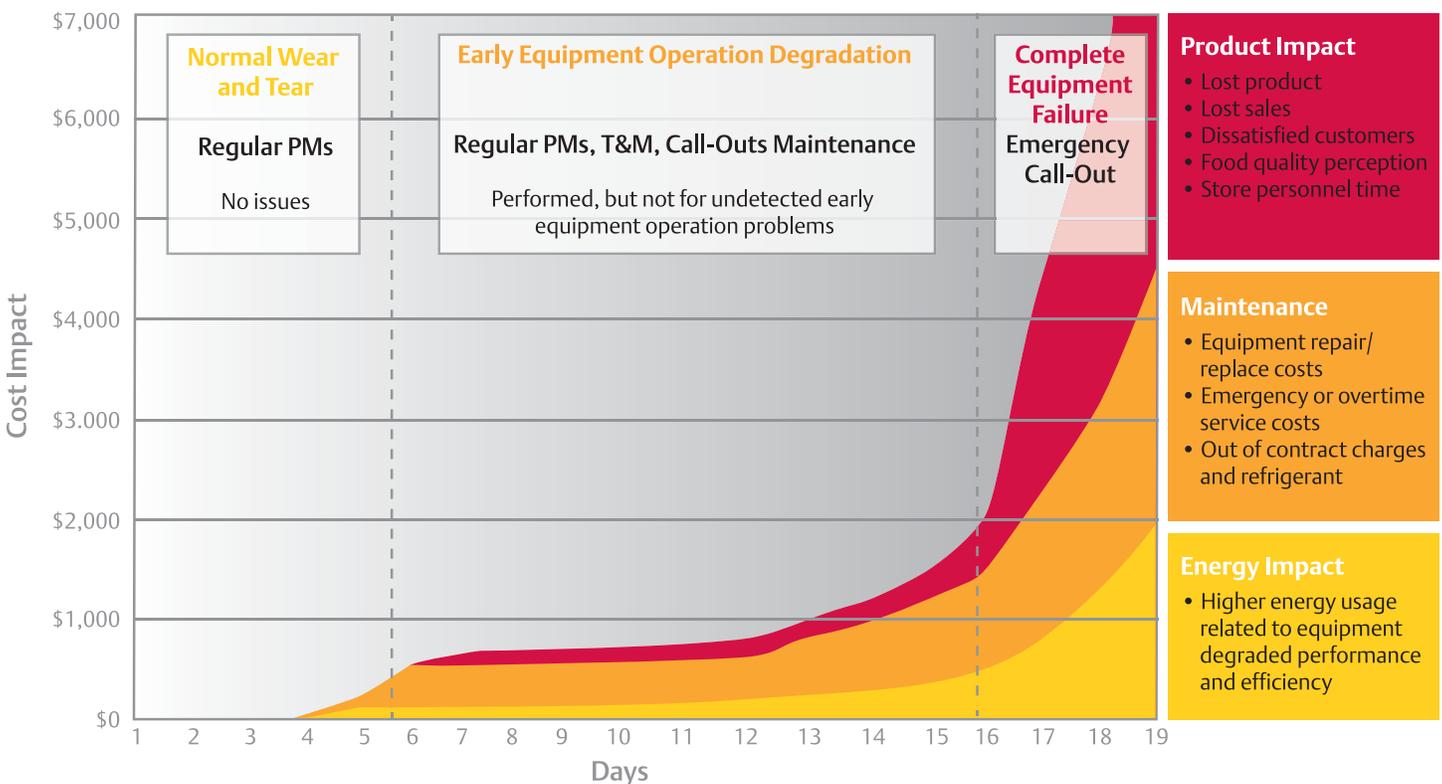
Figure 1

Compare this scenario to the outcome in **Figure 2** with CBM surveillance in place. Maintenance personnel are advised of the anomaly early with three levels of advisories, allowing them to remotely investigate the problem and take cost-effective action based on the severity of the problem.

New Paradigm with Condition Based Maintenance Surveillance
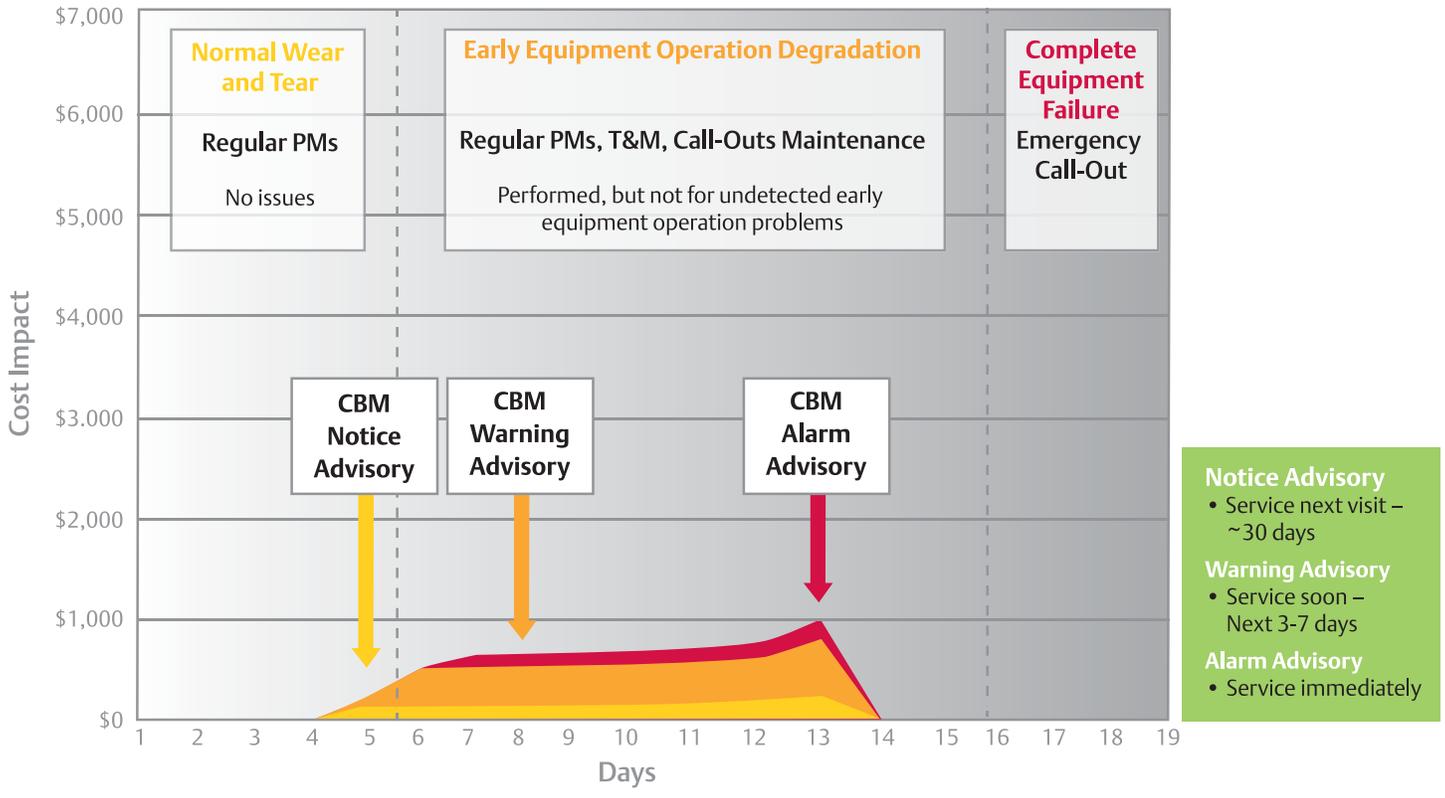
Figure 2

Increasing Availability and Reliability Through Added Visibility

A typical supermarket with approximately 40,000 square feet of sales area consumes on the order of 2 million kWh annually for total store energy use. Many larger superstores and supercenter can consume as much as 3-5 million kWh per year, according to the U.S. Department of Energy's Oak Ridge National Laboratory.

Refrigeration system compressors, condensers and cases account for 30-35 percent of total store energy consumption.

But supermarkets that have invested in advanced control systems like refrigeration rack and building systems controllers can further leverage these systems to monitor and analyze equipment performance with smart fault detection algorithms. The algorithms embedded in diagnostic software compare temperature and pressure sensor data of expected performance on key indicators that can be assessed remotely against actual performance to detect anomalies. The insights provided save energy, time and money.

If a refrigeration compressor issue is flagged, as an example, the sensor data provides the real-time remote intelligence to troubleshoot the appropriate response, which could range from dispatching a technician to the site automatically from an alarm to directing a technician to reset the compressor remotely.

Typical interventions from CBM could include:

- Determining the source of a refrigerant slow leak and repairing it
- Replacing a faulty compressor motor contactor that is causing trips

- Determining the source of compressor oil trips

- Activating an imbalance trip after detecting inconsistent phase-phase voltage in the compressor, protecting against damage from overheating

- Locking out the system after detecting low oil pressure, preventing compressor damage and avoiding system downtime

- Providing a warning, while the system is running normally, of an early low oil pressure situation

Data collected from alarm analysis from early adopters of this technology in supermarket retail settings have identified some of the most common system failure modes. These include:

- *High temperature in a refrigerated case.*
  Possible cause: Failed fan, or high/low superheat caused by blocked or stuck thermal expansion valve, or low refrigerant

- *High suction pressure in the compressor.*
  Possible cause: Compressor trip on oil, phase loss, welded contactor or compressor trip on high discharge pressure, temperature

- *High discharge pressure.*
  Possible cause: Condenser airflow being blocked or fouled, or condenser fan failure

Each of these early indicating issues can be addressed promptly with CBM monitoring of superheat, slow leaks and condenser performance.

Machine Learning Based Refrigerant Leak Detection

Slow leaks of refrigerant are a pervasive concern in the industry, in part because normal fluctuations in refrigerant level make leaks notoriously hard to identify. Consequently, it's common for slow leaks to be considered a problem that must be tolerated; however, left unresolved, more refrigerant charges are inevitable, and low refrigerant charges can lead to excessive wear on the compressors and premature failure. The equipment continues to run, but at reduced capacity, run times are longer and more energy is consumed than necessary without anyone becoming aware of it. Research has shown that typical undercharged refrigerant levels can produce double digit efficiency losses.

In CBM, the slow leak detection process is comprised of the following elements:

• Data available would include ambient temperature, discharge pressure, liquid level and time of day.

• The software algorithms establish models for normal liquid level behavior, and store multiple models for varying operating envelopes.

• Anomaly/exception generation occurs when the best model for a given operating envelope deviates from the actual level over time. If the deviation increases, either a refrigerant leak advisory (where actual is below expected) or a refrigerant addition (where actual is above expected) is generated.

Figure 3 depicts the emergence of a leak after several days where the receiver level is matching the expected level, despite fluctuations. The leak alarm is generated when the expected receiver level and actual receiver level begin to diverge.

Refrigerant Level Modeling with Slow Leak Detection
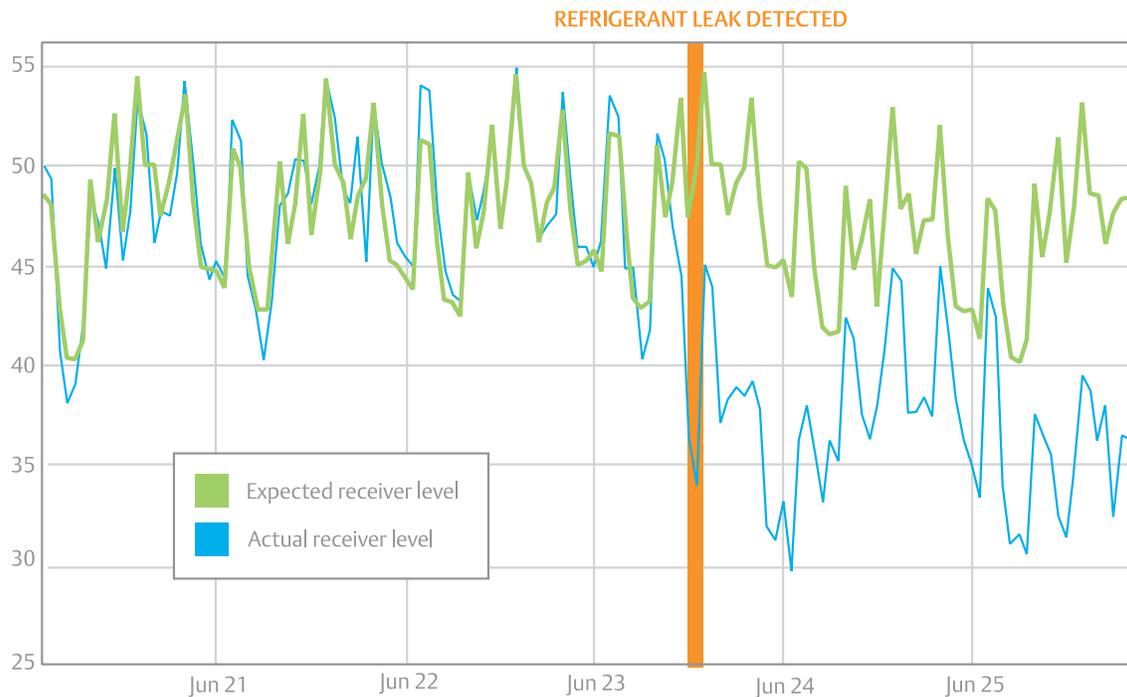
Figure 3

The model in this algorithm enables early detection and potential resolution, saving refrigerant, equipment, product and labor time.

Applying CBM to Energy Consumption Concerns in Supermarket Refrigeration

Excessive energy consumption can be avoided and asset life extended with the adoption of CBM. Figure 4 shows three typical scenarios where a compressor, condenser or refrigerant leak can negatively affect energy consumption in a supermarket, and how a CBM solution can address these issues.

	Energy Liability	CBM Solution	Asset/Maintenance Benefit
Compressors	High cycling can increase energy use by 10%; high superheat decreases system efficiency	Monitor for refrigerant and AC compressor cycling and return gas, perform diagnostics and optimized dispatching based on severity	Faster, accurate diagnosis and failure prevention extends life
Condensers	Fouled coil can increase energy use by 5-10%	Monitor for optimized control strategy and setpoint, as well as condenser temperature differential	Lower condensing pressures reduce wear and failure rate; cleaning based on fouling severity
Refrigerant	A 50% refrigerant loss can reduce system efficiency by 5-10%	Detect slow leaks, keep records of refrigerant additions and losses	Reduce leak rate by 10-20%, provide tracking for compliance

Figure 4

ProAct™ Conditioned Based Maintenance from Emerson

Preparing your facility for a more information-driven operation via Condition Based Maintenance is an initiative of Emerson Climate Technologies Retail Solutions, Inc. It broadens Emerson's existing ProAct™ Services portfolio, offering new value to retailers in the areas of maintenance and energy management, and in compliance for refrigerant management and food quality.

With CBM service, advisories are issued based on the equipment condition and forwarded to Emerson's ProAct Service Center where technicians triage and analyze the related performance curves and data to determine whether the advisory indicates a need for maintenance. When combined with Emerson's Smart Dispatch service, CBM advisories are triaged with all store advisories and cross-referenced against other potentially related store alarms or events – setpoint changes, recent work orders or past alarms – to determine the optimized dispatching of technicians. The CBM software supports Emerson's E2 Facility Management System and Copeland Discus™ and Copeland Scroll™ compressors with CoreSense™ Protection and Diagnostics, allowing retailers to realize new maintenance and energy management value from their existing Emerson equipment.

About the Author

James Mitchell
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As a product manager within Emerson Climate Technologies Retail Solutions business, James Mitchell is responsible for energy and maintenance applications and services. With more than 20 years of experience in the HVAC/R industry, he held previous positions in engineering and project management at Hill-Phoenix, Hussmann/Krack, Alfa Laval and Johnson Controls. Throughout his career, James has worked with various retail customers on facility HVAC/R energy and maintenance solutions, including chain-wide performance contracts with energy saving initiatives such as controls and equipment upgrades, lighting retrofits and enterprise-wide building energy management system upgrades. James earned a Bachelor of Science in mechanical engineering from Auburn University.

About Emerson

Emerson (NYSE: EMR), based in St. Louis, Missouri (USA), is a global leader in bringing technology and engineering together to provide innovative solutions for customers in industrial, commercial, and consumer markets around the world. The company is comprised of five business segments: Process Management, Industrial Automation, Network Power, Climate Technologies, and Commercial & Residential Solutions. Sales in fiscal 2012 were $24.4 billion. For more information, visit **www.Emerson.com.**

About Emerson Climate Technologies

Emerson Climate Technologies, a business segment of Emerson, is the world's leading provider of heating, air conditioning and refrigeration solutions for residential, industrial and commercial applications. The group combines best-in-class technology with proven engineering, design, distribution, educational and monitoring services to provide customized, integrated climate-control solutions for customers worldwide. The innovative solutions of Emerson Climate Technologies, which include industry-leading brands such as Copeland Scroll™ and White-Rodgers™, improve human comfort, safeguard food and protect the environment. For more information, visit **EmersonClimate.com**.

About Emerson Retail Solutions

Emerson Climate Technologies Retail Solutions, Inc., a company of the Emerson Climate Technologies business segment, is the leading provider of energy and site monitoring services for the U.S. supermarket, retail, convenience store and restaurant industries. The company offers a comprehensive array of technologies and services, including remote equipment monitoring, food quality and safety monitoring, power monitoring and energy efficiency analysis, mechanical and control system engineering, energy efficiency project management and service dispatch. Emerson Climate Technologies Retail Solutions is headquartered in Atlanta. For more information, visit **EmersonClimate.com/RetailSolutions.**

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