White Paper

New Ways to Achieve Top Quartile Performance for Refineries

EMERSON

New Ways to Achieve Top Quartile Refinery Performance

Executive summary

Refineries are continuously challenged to improve performance metrics in the areas of energy, availability, and safety. Identifying the root causes that degrade these metrics is critical, but traditional methods can be difficult to justify due to the high cost, lengthy installation time, and required downtime.

With advances in new technologies such as non-intrusive and wide-area sensing along with wireless communications, it is now easier and more cost-effective to add measurement points throughout a refinery. These technology shifts have empowered the development of Pervasive Sensing™ solutions.

Pervasive Sensing solutions enable automatic data collection and analytics for applications that were previously monitored manually or not at all. With predictive analytics, these solutions make predictive maintenance possible through actionable information, such as abnormal operation or imminent failure alerts. By solving problems before they happen in applications such as pumps, motors, steam traps, heat exchangers, valves, and piping systems, operators can maximize production and improve overall plant reliability, safety, and efficiency.

Based on existing installations, Pervasive Sensing solutions support first quartile performance goals by enabling significant reduction in monitoring costs. An average sized refinery has the opportunity to achieve $12.3 million per year in operating benefits through improved reliability, reduced energy use and safety/environmental incidents, providing a six month return-on-investment (ROI).

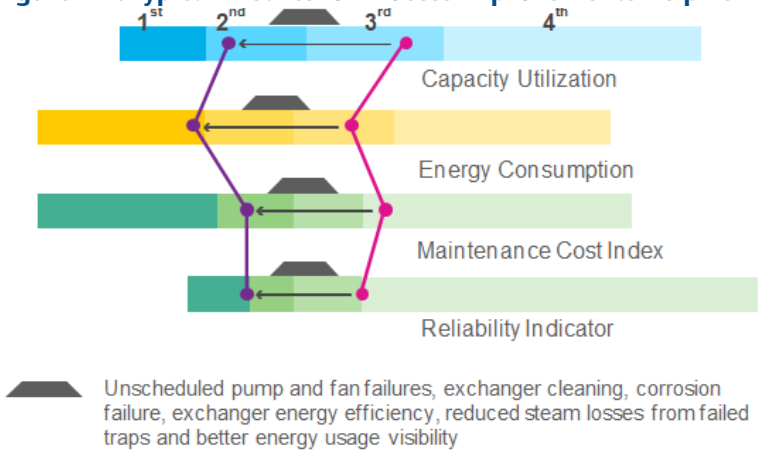
Over 27,000 wireless networks (the backbone of Pervasive Sensing strategies) are already installed in refineries around the world, proving the value and reliability of these networks with over six billion hours of operation.

In this white paper, we'll address the issues refineries face, and demonstrate how wireless sensors, combined with Pervasive Sensing strategies, can help solve these problems and *support top quartile performance goals*.

Refinery issues

Refineries have process improvement programs in place because data shows that many unscheduled or undetected incidents can reduce quartile performance of key metrics (Figure 1-1).

Figure 1-1. Typical Metrics for Process Improvements Help Refineries Improve Performance



Unscheduled outages and production slowdowns classified as mechanical unavailability occur from common problems such as rotating equipment failure, exchanger fouling, piping corrosion, and fired equipment constraints.

Energy losses occur from heat exchanger fouling, failed steam traps, and process unit inefficiencies—all of which may go undiscovered from a lack of complete energy measurements. Refineries understand macro energy performance through their Energy Intensity Index. However, determining exactly where energy is lost in a refinery is a typical challenge when driving an energy improvement program.

Below are specific applications examples, demonstrating how Pervasive Sensing solutions can improve quartile performance.

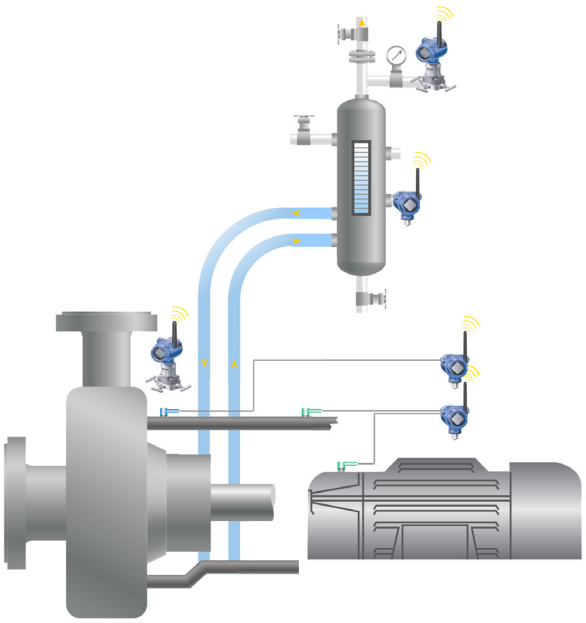
Availability loss example – refinery pump monitoring

For example, consider the light end areas of a refinery. Typically, there are 10-15 LPG pumps in a refinery that are usually checked manually once a month for vibration and bad actors checked once a week. With ever-changing process conditions, infrequent spot inspections are insufficient to detect pump problems and seal failures. In this application, hydrocarbon leaks are possible due to seal failures, which can lead to production losses, fires, and even safety incidents.

Online monitoring of pumps through the addition of wireless measurement of vibration, pressure, and seal fluid levels allows early detection of excessive vibration, cavitation, and seal failure problems. By monitoring and creating predictive alerts, maintenance staff can be notified of pending problems before they occur. This can lead to improved production through fewer unscheduled outages.

Pump failure can have a big economic impact, particularly if a pump fails in an LPG area and seals break, as this presents a high risk of explosion. A refinery can see $1.5 million dollars per year in risk reduction through automated pump monitoring, based on 15 pumps (Figure 1-2).

Figure 1-2. Pump Health Monitoring using Wireless Pressure, Temperature, and Vibration Transmitters

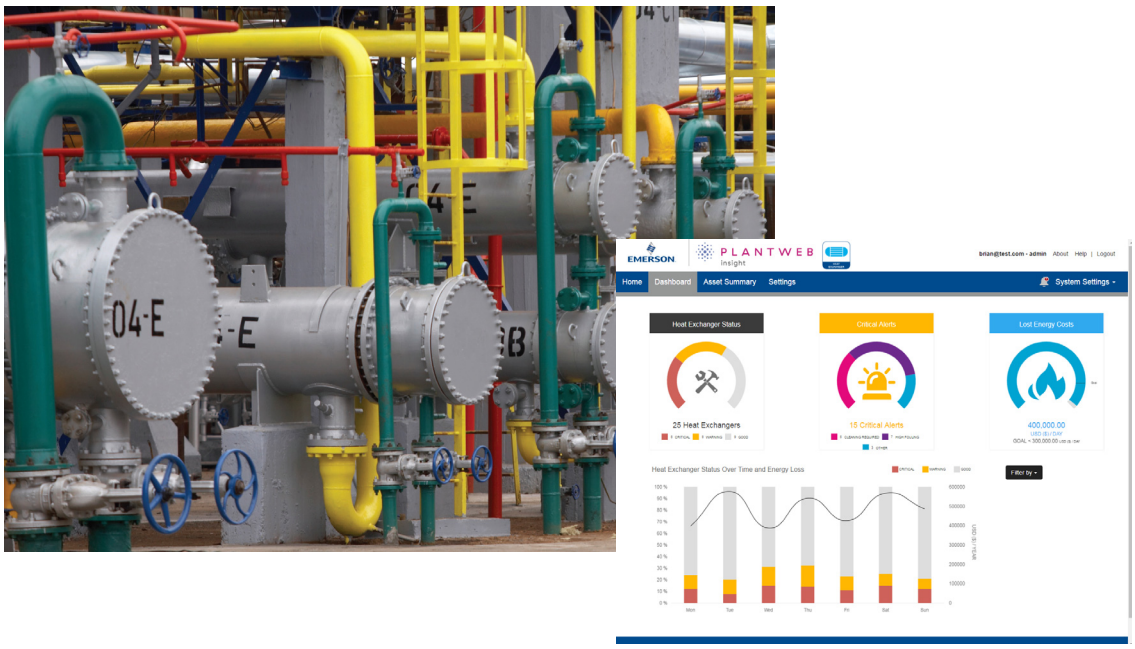


Energy savings example – fouled heat exchangers

Many refiners are trying to maximize their use of discounted opportunity crude oils, but utilizing this type of feedstock often presents significant processing challenges.

In crude unit preheat exchangers, some crude blends can be incompatible with varying crude oil properties, thus resulting in an accelerated rate of unexpected fouling. As a result, energy efficiency is lost and production limited. By adding wireless temperature measurements to exchanger banks, increased data and process analytics software can alert operations of excessive fouling conditions and rates. The information can be used to determine incompatible crude blends and when an exchanger bundle requires cleaning. Corrective action and optimized cleaning schedules can produce an improved Energy Intensity Index and Capacity Utilization to gain a return of over $3 million per year in an average size refinery. Typical heat exchangers use wireless, high density temperature measurement and analytics to know when equipment is healthy, has reached a warning stage, or has escalated to a critical condition (Figure 1-3).

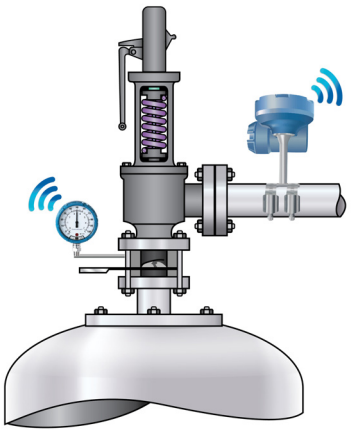
Figure 1-3. Heat Exchanger Monitoring using Wireless Temperature Transmitters and Analytics



Environmental and regulatory example – pressure relief devices

New regulations from the EPA and other environmental agencies will require all critical Pressure Relief Devices (PRDs) in a refinery to be electronically monitored in the next three years. Acoustic wireless sensing solutions ensure simple compliance at 80 percent CAPEX savings and $3 million annual OPEX savings when compared to current state. Over 200 of these devices exist in a typical refinery. Using wireless acoustic transmitters is a very reliable, effective, and economic way to monitor a PRD's operating condition, including releases, leakages, and simmering (Figure 1-4).

Figure 1-4. Relief Valve and Rupture Disc Monitoring using Wireless Acoustic Transmitter and Wireless Pressure Gauge



Locating investment opportunities

In a complex operation like a refinery, it is sometimes difficult to make timely and informed decisions about operations and maintenance strategies. Quite often the necessary appropriate information is not available to pinpoint performance issues.

The first step toward improvement is to define the new sensing point locations, determine how the economic information will be used, and determine the economic values associated with each Pervasive Sensing application. This helps address challenges when prioritizing budgets and plant improvement projects.

Companies building new refineries are exploring the benefits of Pervasive Sensing and predictive analytics strategies. A typical modern facility will have greatly expanded inputs and outputs to and from control and monitoring systems, compared to the past. These connections are both wired and wireless, depending on the specific nature and location of each input and output.

Older refineries were built using wiring and only the instruments required to safely operate the plant, not necessarily available to optimize or operate the plant reliably. The lack of inputs to control and monitoring systems can cause refineries to run blind in many critical areas, or to perform expensive, time-consuming, and resource-using manual checks via field rounds. Now, with innovations in technology, additional measurements can be added cost-effectively.

Wireless resolves issues

So why haven't all refineries added thousands more measurement points, given the proven financial benefits? One reason is that in the past, these inputs would have been wired from the sensing point—such as a pump—to a control and monitoring system. Adding this wiring to an existing facility is usually a very expensive undertaking. It often requires significant downtime, which isn't an option as many refineries operate at or near full capacity.

But proven technologies allow these points of measurement to be added quickly and inexpensively with wireless sensors. These sensors are connected through a plant-wide wireless mesh network to control and monitoring systems. Wireless sensors allow points of measurement to be added at a fraction of the cost and time compared to their wired equivalents, and sensors not requiring process penetrations can be installed without any downtime.

In short, adding wireless applications extensively throughout the refinery is the quickest and most cost-effective way to get comprehensive plant-wide monitoring. These key measurement points, coupled with data analysis and asset management systems, improve operating performance, asset reliability, and safety—resulting in higher profits.

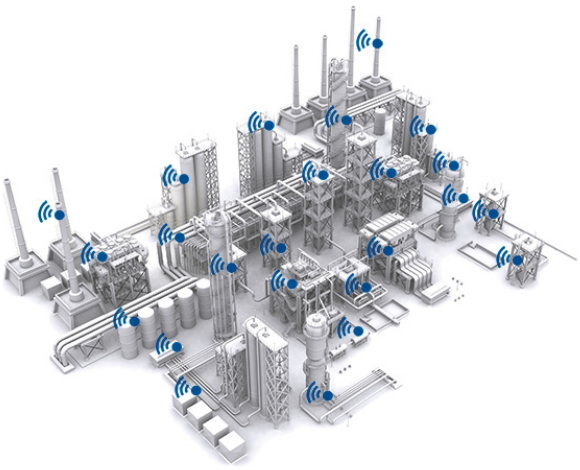
The following sections show how to locate and address these issues with Pervasive Sensing solutions, enabling improved performance.

Proven applications

These following examples show where Pervasive Sensing solutions have overcome key reliability, process, energy, and Health, Safety, Security, and Environment (HSSE) issues:

- A pump monitoring solution for a refinery avoided pump fires and associated shutdowns for five straight years at 1/10 the cost of other solutions.
- A pressure relief valve monitoring solution was installed, resulting in a five-month payback and total annual savings of $3 million.
- A steam trap monitoring solution increased production by 12 percent and saved $100 thousand annually in preventative maintenance.

Figure 1-5. Pervasive Sensing Strategy with Wireless Measurement Points



Using this approach coupled with industry experience, the following representative improvements/savings have been determined for a 250,000 bpd refinery.

Application	Monitoring and analytics	Savings ($M)	Implementation cost ($M)	ROI (months)
Heat Exchanger Monitoring	Fouling and efficiency	2.7–3.6	0.62	3
Cooling Tower Monitoring	Efficiency and health	0.3–0.5	0.16	4
Steam Trap Monitoring	Energy waste and water hammer risks	0.4–0.6	0.30	7
Relief Valve Monitoring	Emissions and leaks	2.4–3.2	1.59	6
Pump Monitoring	Cavitation and pump health	0.5–0.6	0.55	11
Air Cooled Heat Exchanger Monitoring	Fan health and fouling	0.9–1.1	1.20	13
Mobile Workforce	Startup and turnaround efficiency	1.6–2.1	0.40	3
Safety Shower and Eye Wash Monitoring	Instant trigger indication	Per incident	0.39	Safety
	TOTAL	**8.8–11.7**	**5.2**	**6**

Applying Pervasive Sensing solutions

The more you sense the more you solve. Pervasive Sensing strategies give a refinery the necessary information at the right time to the right people by using familiar devices in new ways. All applications are based upon site requirements, and are typically found in the following five disciplines:

Health, Safety, Security, Environment (HSSE)

HSSE application solutions help to reduce costs by enabling your refinery to predict and prevent abnormal situations, instead of simply reacting to them. By monitoring equipment, you can reduce safety and security risks, and be alerted to any issues that arise so you can respond quickly. Besides being able to protect your personnel and the environment, your team can better maintain the mechanical integrity of equipment, improve operational procedures for dealing with potential problems, and streamline regulatory compliance.

Reliability

Reliability application solutions help your team avoid unplanned slowdowns or shutdowns caused by previously unmonitored or manually monitored equipment. These solutions detect conditions that can lead to equipment failure, and replace manual, periodic readings with online insight into equipment health, minimizing trips to the field. Besides increased process availability and improved asset reliability, you will be able to decrease maintenance costs while mitigating safety and environmental risks.

Energy

Energy application solutions help your team identify inefficiencies and optimize facility performance. It's estimated that half the energy consumed by process manufacturers is used for producing and managing steam. By wirelessly monitoring steam traps, you can significantly reduce energy consumption and improve overall operational efficiency.

Process

Process application solutions increase plant efficiency by reducing material costs and increasing plant throughput. A common cause of poor efficiency is process variability—often small, undetected shifts in process variables that, when added up, take a toll on overall profitability. By implementing wireless solutions, your team can extend mobility applications and provide benefits in start-up efficiencies while reducing operator rounds. It also becomes possible to get data from process points that were previously too expensive, too hard to reach, or in tough environments. This data helps automate many manual and inefficient process safety and control functions.

People and productivity

People and productivity solutions help your team improve plant worker efficiency and accuracy by simplifying and streamlining commissioning and setup in real-time, and by allowing field workers to resolve operation problems faster. Wireless mobile worker technology allows access to control and monitoring system data, and to maintenance data and operation procedures, enabling your team to make fast, accurate repair decisions before unplanned downtime occurs. Wireless also helps prepare your facility for the workforce of tomorrow as inexperienced workers come onboard and those more senior retire. Wireless requires less training to be proficient for installing, operating, and maintaining your facility.

Pervasive Sensing applications

The following application examples show how consolidating budgets and using a facility-wide wireless infrastructure can help increase productivity and reduce costs through a comprehensive range of solutions. Many of these solutions were previously too costly and time consuming to automate with traditional wired solutions.

Applications examples are:

- Heat exchanger monitoring
- Cooling tower monitoring
- Steam trap monitoring
- Relief valve monitoring
- Pump monitoring
- Air-cooled heat exchanger monitoring
- Wireless mobile workforce
- Safety shower and eye wash station monitoring

For more application-specific and return-on-investment details, see the Applications appendix at the end of this white paper.

Methodology

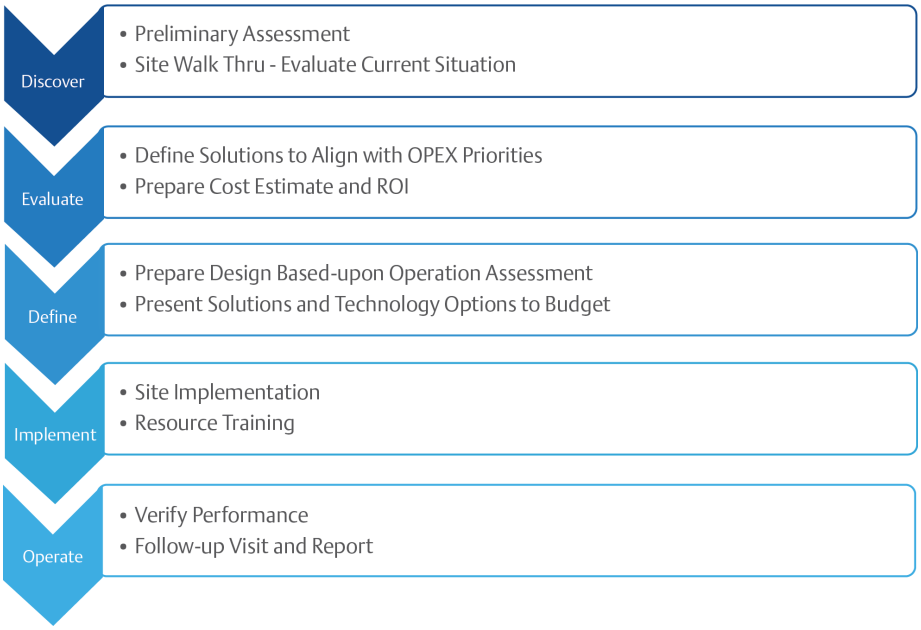
Emerson™ services are designed to ensure that the maximum potential benefit is achieved from the solutions detailed in this white paper. These services include:

- Establishing a collaborative process to understand and develop how these technologies can contribute to your business needs and OPEX strategy to maximize the value added.
- Providing application expertise to ensure that a prioritized set of solutions applications are identified and specified against an agreed set of criteria/objectives.
- Defining a project management plan (integrated with business strategic plan as appropriate) to apply Pervasive Sensing strategies.

Project application study

The five-step process shown in Figure 1-6 helps identify a refinery's priorities with key plant personnel.

Figure 1-6. Emerson Works with Refinery Personnel to Identify Best Investment Areas



Conclusion

A typical 250,000 bbl/day refinery has hundreds if not thousands of unmonitored processes, devices, and systems subject to unplanned failures or degraded operations. This insufficient monitoring reduces a refinery's quartile performance through reduced availability, wasted energy, safety issues, and escalated repair costs—and in the worst case, shuts down processes or even an entire refinery.

Pervasive Sensing solutions enable the ability to automatically collect process and asset health measurements. This data can be automatically analyzed and alert of abnormal operation or imminent failure. These solutions can also improve safety, prevent releases that could result in fines and penalties, and extend the life of expensive process equipment.

Because Pervasive Sensing solutions are based on *Wireless*HART® technology, wireless sensors can be installed throughout a refinery to monitor key equipment, and the information they provide is compatible with any refinery control system, regardless of the original vendor.

The return-on-investment for these Pervasive Sensing solutions is typically only a matter of months, and implementation is relatively quick and simple as compared to installing traditional wired sensor solutions.

Applications appendix

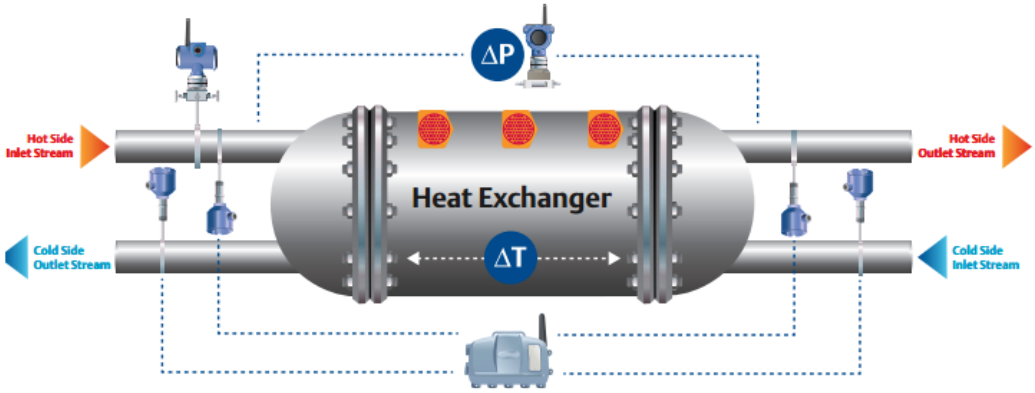
Heat exchanger monitoring benefits

See abnormal situations – Get early detection of accelerated fouling in crude unit pre-heat exchangers (asphaltene precipitation).

Know optimum time to clean – Receive alerts based on heat transfer degradation and economic calculations.

Be alerted to potential safety hazards – Know when intermediate heat exchanger bundles are near temperature design limits.

Figure 1-7. Heat Exchanger Monitoring using Wireless Transmitters



See Table 1-1 for savings that can be obtained by using wireless sensors to measure key parameters in a heat exchanger.

Table 1-1. Heat Exchanger Savings

Units, capacities, and margins			Energy loss recovery			Capacity loss recovery		
Unit name	**Capacity input (BPD)**	**Assumed margin ($/Bbl)**	**Loss from fouling (MBtu/Yr)**	**Loss from fouling ($/Yr)**	**Loss recovery ($/Yr)**	**Loss from fouling (%)**	**Loss from fouling ($/Yr)**	**Loss recovery ($/Yr)**
Crude unit	250,000	2.00	1,640,000	9,860,000	990,000	11	5,020,000	502,000
Vacuum unit	112,500	1.00	490,000	2,960,000	300,000	11	1,140,000	114,000
Fluid Cat Cracker (FCU)	87,500	5.00	460,000	2,730,000	270,000	11	4,440,000	444,000
Naptha Reformer	50,000	2.00	160,000	990,000	100,000	4	370,000	37,000
Coker	37,500	8.00	230,000	1,400,000	140,000	7	1,830,000	183,000
Hydrocracker	25,000	6.00	120,000	740,000	70,000	7	910,000	91,000
Hydrotreaters	175,000	0.50	560,000	3,350,000	340,000	8	610,000	61,000
Total recovery					**2,210,000**			**1,432,000**
Annual benefit = $3,642,000								

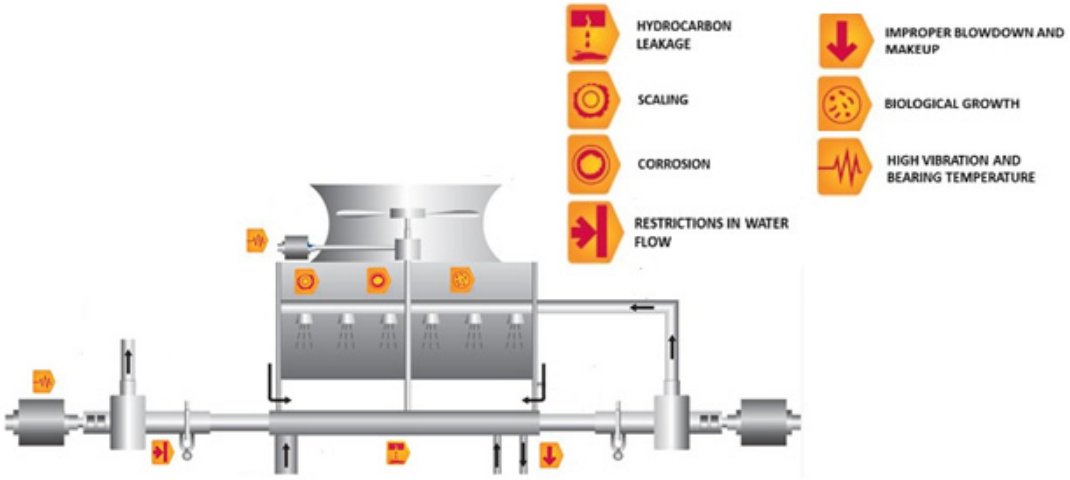
Cooling tower monitoring benefits

Spot imminent failure – Get early alerts of bearing, lubrication, or alignment problems in cooling tower fans and pumps.

Optimize fan operation – Receive timely alerts for reverse fan operation in periods of cold weather, and for suggested fan sequencing for optimal power consumption.

Control cooling water quality – Receive timely alerts on cycles of concentration and get recommended blowdown and makeup flows to help minimize chemical and water costs. More blowdown means more chemicals and fresh water makeup.

Figure 1-8. Common Threats to Cooling Towers



See Table 1-2 for possible savings when wireless instruments are used to monitor key variables on a cooling tower.

Table 1-2. Cooling Tower Savings

Input	
Tower capacity (GPM)	350,000
Temperature range (CW in-CW out, °F)	10
Cost of 1 °F water temperature increase ($/hr)	$57
Days at cooling limited operation	60
Actual cycles of concentration	4.5
Optimal cycles of concentration	5.0
Cost of water supply ($/1000 gallons)	$2.20
Cost of water disposal ($/1000 gallons)	$2.93
Maintenance chemical cost ($/ton cooling)	$8.77
Cost of electricity ($/kWh)	$0.0651
Value model based on operational benefits	
Water temperature reduction from increase in airflow (°F)	0.23
Annual savings from reduced water temperature	$19,193
Power consumption savings with optimization	33%
Annual savings with power consumption optimization	$25,780
Water supply savings	$122,570
Water disposal savings	$163,241
Maintenance chemical cost savings	$127,595
Water savings	5%
Total annual savings at optimal cycle	$413,406
Annual benefit: $458,378	

Steam trap monitoring benefits

Improve personnel safety – Reduce water hammer incidents, manual rounds, and foot traffic in risk areas.

Improve reliability – Reduce equipment damage caused by water hammer, impingement, and corrosion.

Improve yield and product quality – Ensures required temperatures are maintained and optimal transfer of steam enthalpy.

Improve energy efficiency – Expedite addressing of leaks and blow-through failures.

Improve environmental impact – Reduce greenhouse gas emissions and water usage.

Figure 1-9. Steam Trap Monitoring

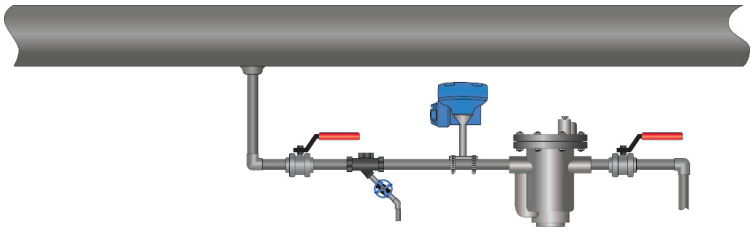


Table 1-3. Energy Loss(1)

Orifice diameter (in)	Pressure (psig)					
	50	100	150	300	500	750
0.188	$1,737	$3,079	$4,421	$8,448	$13,816	$20,527
0.250	$3,087	$5,474	$7,860	$15,018	$24,563	$36,493
0.313	$4,824	$8,552	$12,281	$23,466	$38,379	$57,021
0.375	$6,947	$12,316	$17,684	$33,791	$55,266	$82,110
0.438	$9,455	$16,763	$24,070	$45,993	$75,223	$111,760
0.500	$12,350	$21,894	$31,439	$60,072	$98,250	$145,973

1. Based on steam cost of $6/1000 lbs. (~$13/ton) and complete blow-through failure.

Table 1-4. Value Model Based on Energy Management

Steam traps in service	10,000
Percentage of traps considered critical	2%
Number of critical traps to monitor	200
Annual steam trap failure rate	12 – 15%
Annual fuel loss per critical trap	$19,000
Annual impact	
Reduction in annual greenhouse gases	3,840 – 4,800 metric tons
Annual preventable losses due to critical steam trap failures: $456,000 – $570,000	

Relief valve and rupture disc monitoring solutions benefits

Gain real-time visibility– Time-stamped alerts allow you to conduct root cause analyses so you can avoid future releases.

Reduce fines and environmental impact – Immediate notification of a release to enable you to act quickly and reduce the severity of the release. Note that new environmental regulations now require monitoring of relief valves and rupture discs in many countries.

Identify leaking and sticking valves – Detect leaking caused by improper valve seating and stuck open valves.

Eliminate manual data collection – Safely monitor data without manual rounds, keeping your employees out of hazardous areas or remote locations.

Figure 1-10. Pressure Relief Device Monitoring Applications

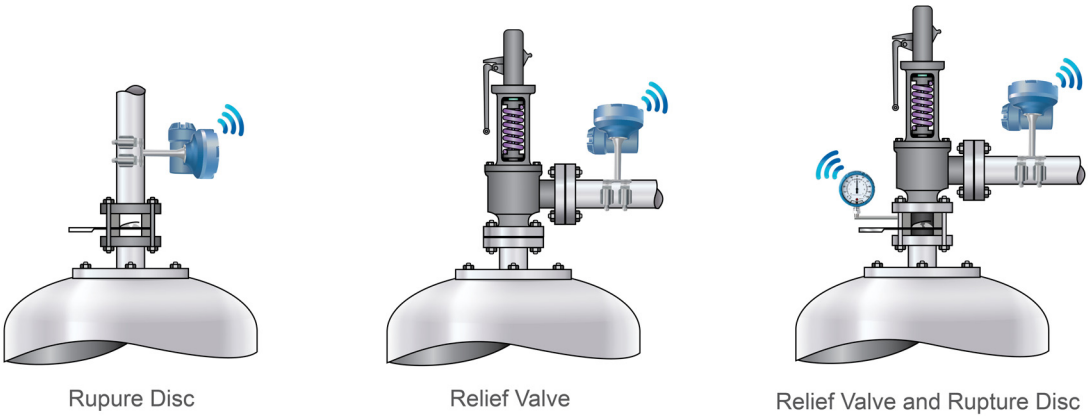


Table 1-5. Value Model

Value model based on relief valve operation			
Number of "essential" pressure relief valves not currently monitored	200		
Potential relief valves not operating properly	Small leak	Large leak	Stuck open or isolation valve open
Percentage of pressure relief valves not operating properly	5%	2%	0.50%
Losses per relief valve not operating properly (annual)	$25,000 ($137/day)	$100,000 ($274/day)	$1,000,000
Annual preventable losses from all leaking PRVs	$250,000	$400,000	$1,000,000
Value model based on fines and production losses			
EPA fine due to fugitive emission (manual recorded rounds)	$350,000		
Process capacity limitation due to safety operation limits to prevent relief valves from lifting	$1,200,000		
Annual losses: $3,200,000			

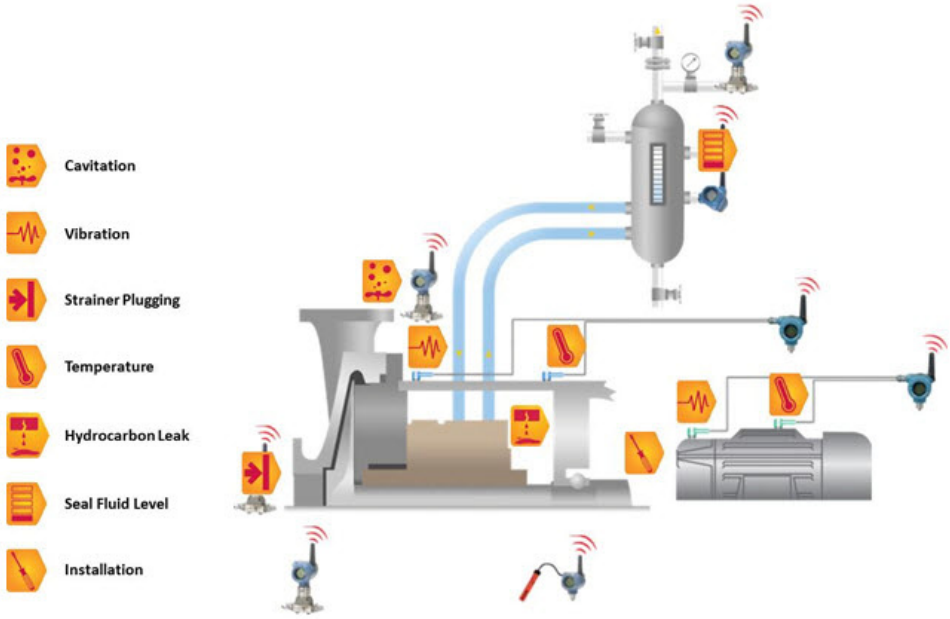
Pump health monitoring benefits

See abnormal process situations– Receive warning of pump cavitation, plugged strainers, and dead-head pumps.

Spot imminent failure– Get early warning of bearing and gear wear, as well as implementation issues.

Be alerted to potential safety or environmental hazards– Avoid pump seal failure through early vibration alerts and seal leak monitoring.

Figure 1-11. Common Threats to Pump Health



See Table 1-6 for possible savings when using wireless transmitters to monitor 80 pumps in a typical 250,000 bbd refinery.

Table 1-6. Pump Health Savings

Value model based on production	
Plant capacity in barrels per day	250,000
Plant net margin per barrel	$5
Production capacity lost due to essential pump failures	0.18%
Reduction of lost productions with process pump monitoring	30%
Annual preventable losses	$246,375
Value model based on maintenance	
Annual maintenance budget per pump	$15,000
Number of “essential” pumps not currently monitored	80
Reduction in average cost to repair if pumps weren't run to failure	30%
Annual maintenance costs savings	$360,000
Annual benefit: $606,375	

Air-cooled heat exchanger health monitoring benefits

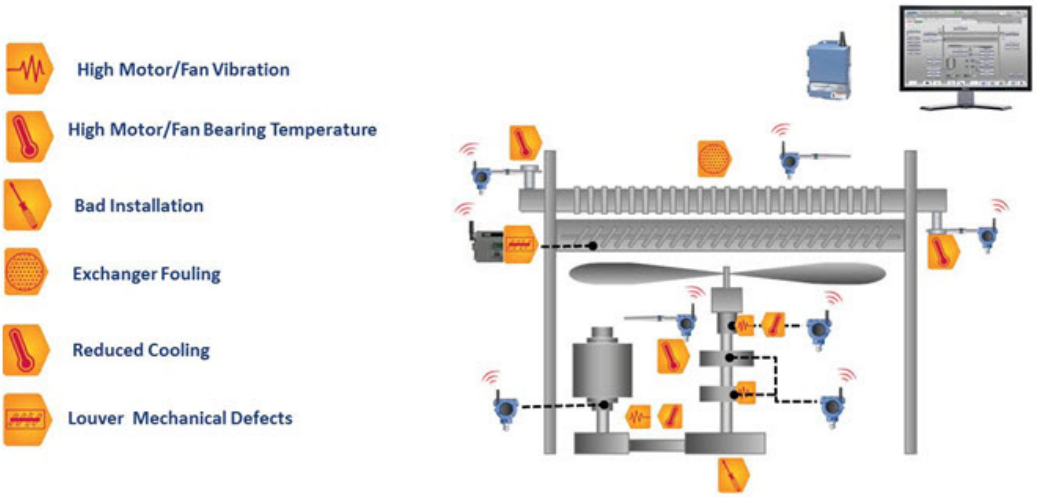
See abnormal situations– Receive alerts for motor and louver problems and louver pitch actuator defects.

Spot trouble– Get early warnings of high fan bearing temperature and vibration.

Detect exchanger fouling– Receive alerts based on heat transfer degradation.

Limit column flaring– Receive early warning of conditions that limit cooling capacity.

Figure 1-12. Common Threats to Air-Cooled Heat Exchanger Health



See Table 1-7 for possible savings when monitoring heat exchangers to prevent an unplanned shutdown.

Table 1-7. Air-Cooled Heat Exchanger Possible Savings

Value model based on production	
Plant capacity in tons per day	200,000
Plant net margin per ton	$5
Production capacity lost due to exchanger failures	0.20%
Annual preventable losses	$912,500
Value model based on maintenance	
Annual maintenance budget per exchanger	$5,000
Exchangers not currently monitored	150
Reduction in average cost to repair if exchangers weren't run to failure	30%
Annual maintenance costs savings	$225,000
Annual benefit: $1,137,500	

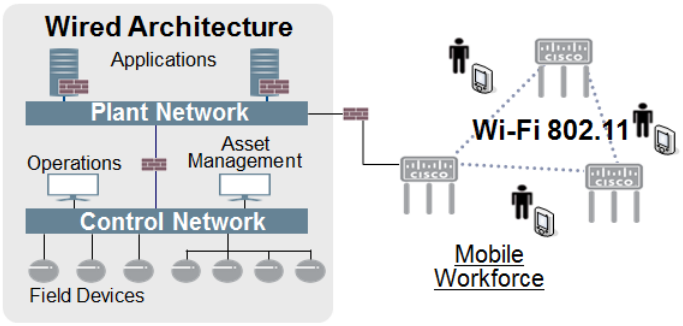
Wireless mobile workforce benefits

Simpler and cost-effective commissioning and startup – The commissioning task can be dramatically simplified because it no longer requires multiple operators to coordinate actions among the control room, loop checking, and equipment commissioning teams.

Increased worker productivity and accuracy – With comprehensive real-time information from control and asset management systems, field workers can resolve operation problems much faster.

Shortened turnaround schedule – The mobile workforce solution is able to reduce the turnaround execution time by no longer being tied to the number of work stations available in the control room, or having to schedule and coordinate multi-person loop and equipment commissioning teams.

Figure 1-13. Mobile Workforce Setup



The following estimate considers a sample mobile workforce implementation on a 25,000 loop process area, including savings during implementation and day-to-day operation, which may lead to additional revenue by shortening turnaround schedules.

Table 1-8. Value Model

Value model based on labor savings	Including turnaround savings	Not including turnaround savings
Labor savings for CAPEX project	$700,000	$700,000
Additional profit from shortened turnaround (1 day)	$1,428,000	N/A
Annual losses due to inefficiency	**$2,128,000**	**$700,000**
Annual benefit: $2,128,000		

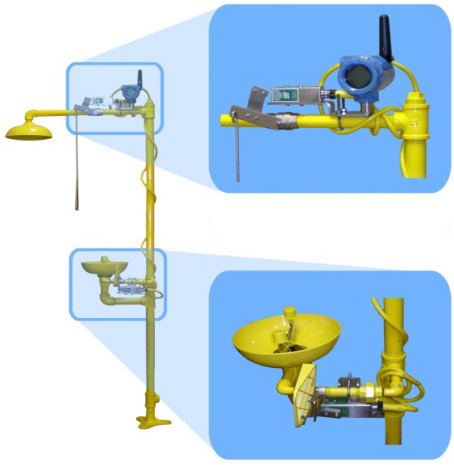
Safety shower and eye wash station monitoring benefits

Improved safety and response time – Real-time automated safety shower monitoring enables faster response to injuries.

Safety in remote locations – Individuals in remote locations or working alone can be assisted more rapidly in an emergency with station monitoring.

Improved incident reporting – Provides timestamp data on shower use for incident reporting and safety compliance audits.

Figure 1-14. Safety Shower and Eye Wash Station Setup



For more information on Pervasive Sensing, visit Emerson.com/Pervasive-Sensing.

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