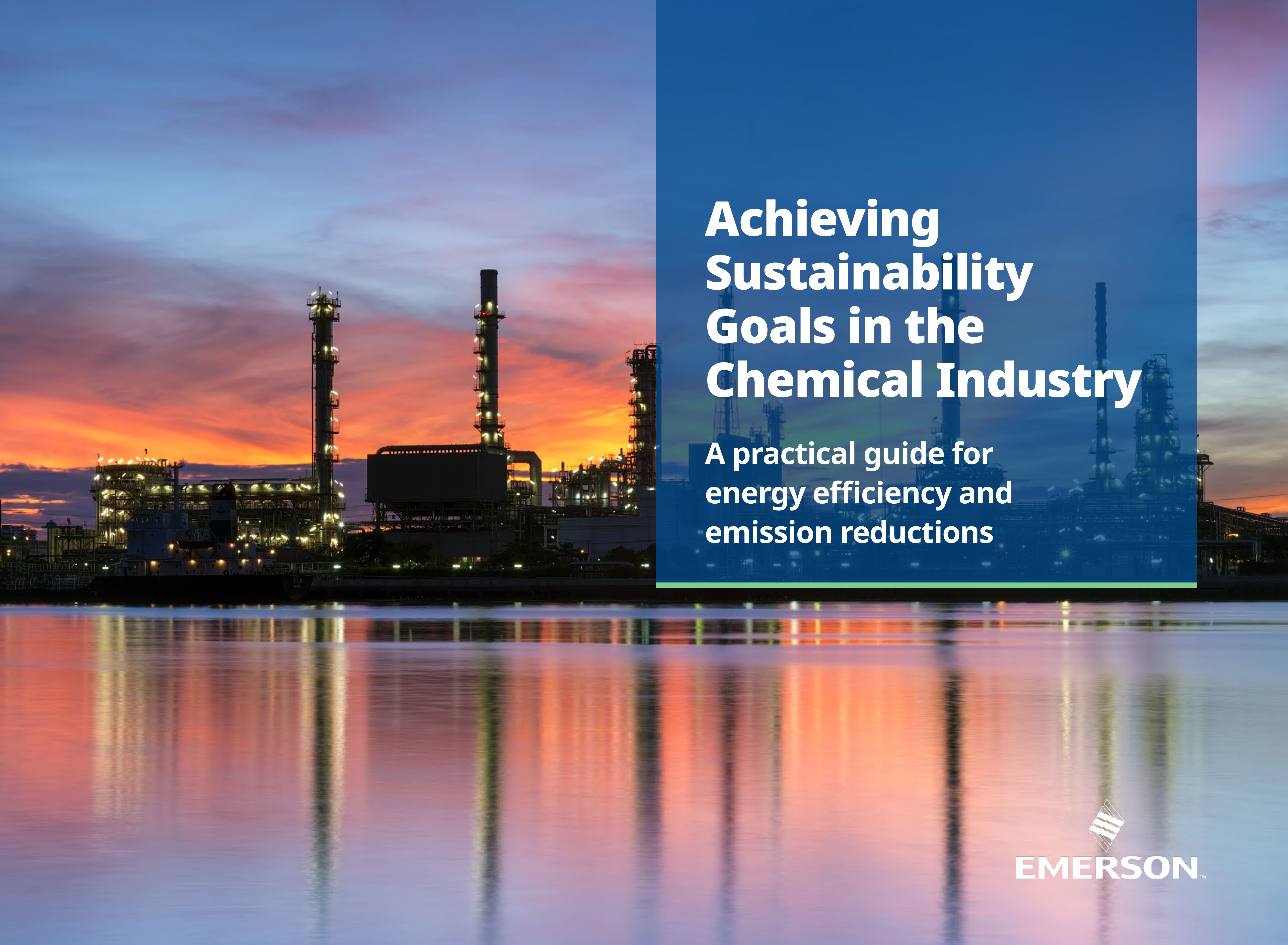


Achieving Sustainability Goals in the Chemical Industry

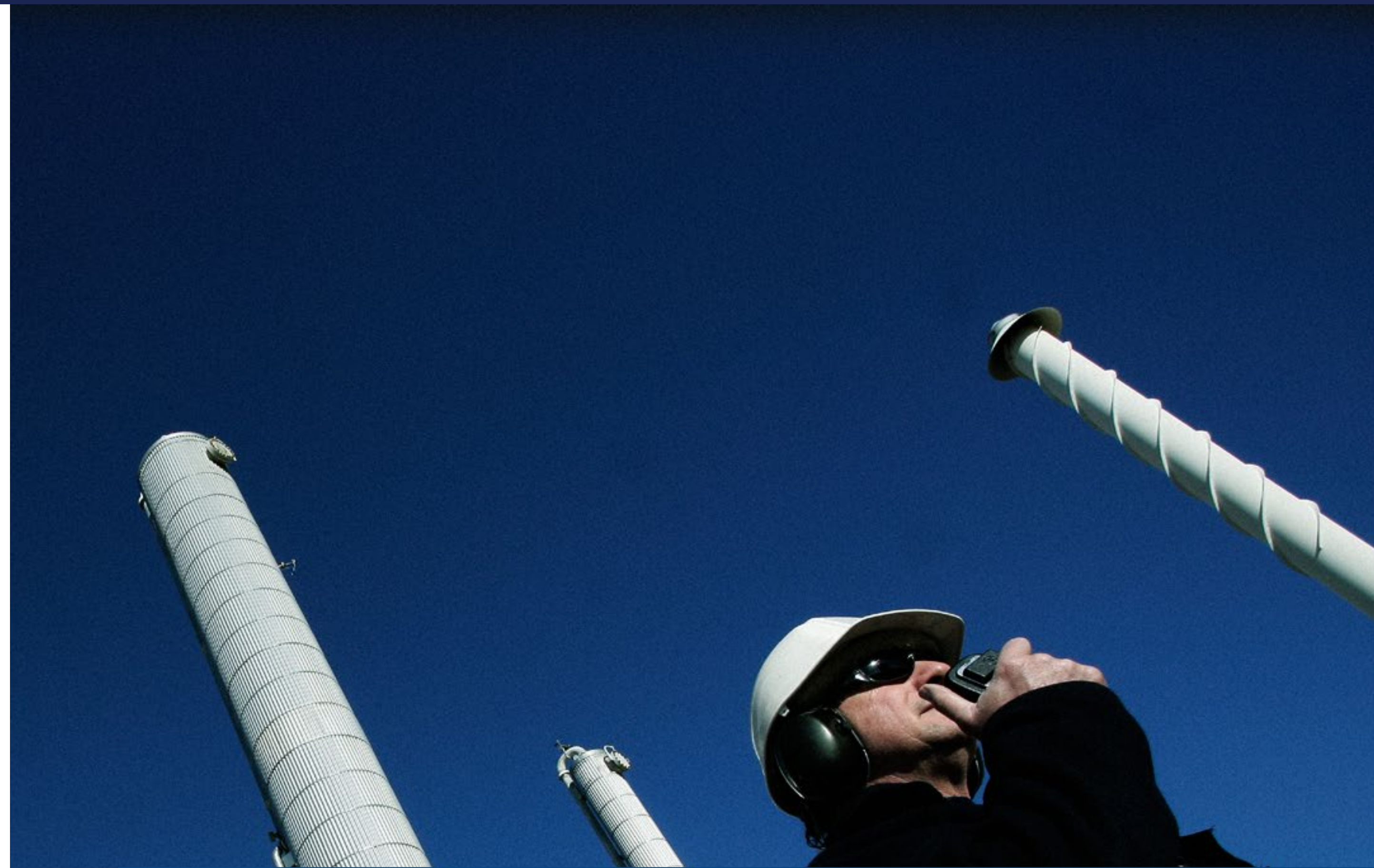
A practical guide for energy efficiency and emission reductions

EMERSON

Small and easy-to-implement projects can quickly become self-supporting financially, while moving the needle on efficiency, environmental, and sustainability scales. Here's how to get started in your chemical plants and facilities.

Effective process automation is an essential component of any comprehensive strategy for improving energy efficiency and reducing carbon dioxide (CO_2) emissions associated with chemical industry plants and facilities. Fortunately, in many cases, energy efficiency measures are among the most cost-effective investments that chemical plants can make to improve productivity, while simultaneously decreasing their carbon footprint. Therefore, careful analysis of the technical options and costs associated with implementing efficiency measures is required to establish sound energy policies to improve cost effectiveness and address global climate change concerns.

This eBook provides support for such technical analysis, and it suggests practical and actionable ways to improve efficiency without calling for major capital improvements. This eBook also examines seven areas and provides answers to this question in each: "How we can achieve better performance from the equipment we have with limited capital investment?"



The solutions we examine in this eBook have three common elements:

1. They focus on reducing energy use within a facility. Cutting energy consumed per unit of production equals greater sustainability, with correspondingly fewer emissions.
2. An overall digital transformation strategy is used to monitor and quantify relevant variables, making it possible to deliver measurable improvements. This calls for increasing deployments of instrumentation linked to sophisticated data analysis to determine what is occurring in the plant so automation can be applied.
3. These are not major capital-intensive projects, but they deliver significant results.

Contents

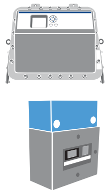
1 Fired heater efficiency and emissions

About 30% of the fuel used in the chemical industry is consumed by fired heaters, which are used to support high-temperature reactions and drive distillation, and for other applications.

There are several instrumentation, control, and analytical devices and techniques (Figure 1.1) that can significantly improve combustion efficiency, with enhanced fuel-to-air ratio control as one of the most pronounced benefits.

The composition of fuel feeding the burners often varies. Therefore, the stoichiometric air required for combustion also changes, making it challenging to keep the fuel-to-air ratio consistent. Too much air leads to inefficiencies in the heater, and too little air creates safety concerns. When the burner is properly balanced, the unit provides the maximum amount of recoverable heat per unit of fuel with the lowest emissions.

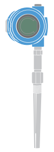
The two most common methods of control of the fuel gas supply include volumetric flow or pressure control. In these schemes, the outlet temperature of the heater cascades and resets either a volumetric flow controller or a pressure controller. Under steady operating conditions, these two methods can provide adequate response and control. However, when there is a disturbance in the system, especially one caused by a change in the fuel supply composition, these control methods may be inadequate for the desired level of safety, fuel efficiency, and environmental compliance.



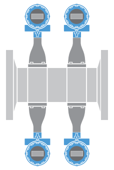
Rosemount X-STREAM Enhanced Continuous Gas Analyzer

Rosemount CT5100 Continuous Gas Analyzer

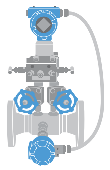
CEMS



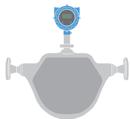
TT Rosemount 3144P Temperature Transmitter



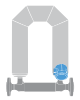
FT1 Rosemount 8800 Quad Vortex Flow Meter



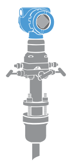
FT2 Rosemount 9295 Process Flow Meter



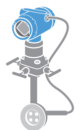
FT3 Micro Motion Coriolis Flow Meter



FT4 Micro Motion ELITE Coriolis Flow Meter

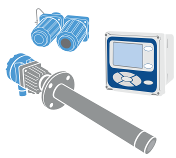


FT5 Rosemount 3051SFA Annubar Flow Meter with 485/585 Averaging Pitot Tube



FT6 Rosemount 3051SFC Compact Conditioning Orifice Plate Flow Meter

PT Rosemount 3051S Series Pressure Transmitter



AT1 Rosemount 6888A In Situ Oxygen Analyzer and Rosemount OCX 8800 Oxygen and Combustibles Transmitter

Fully instrumented fired heater

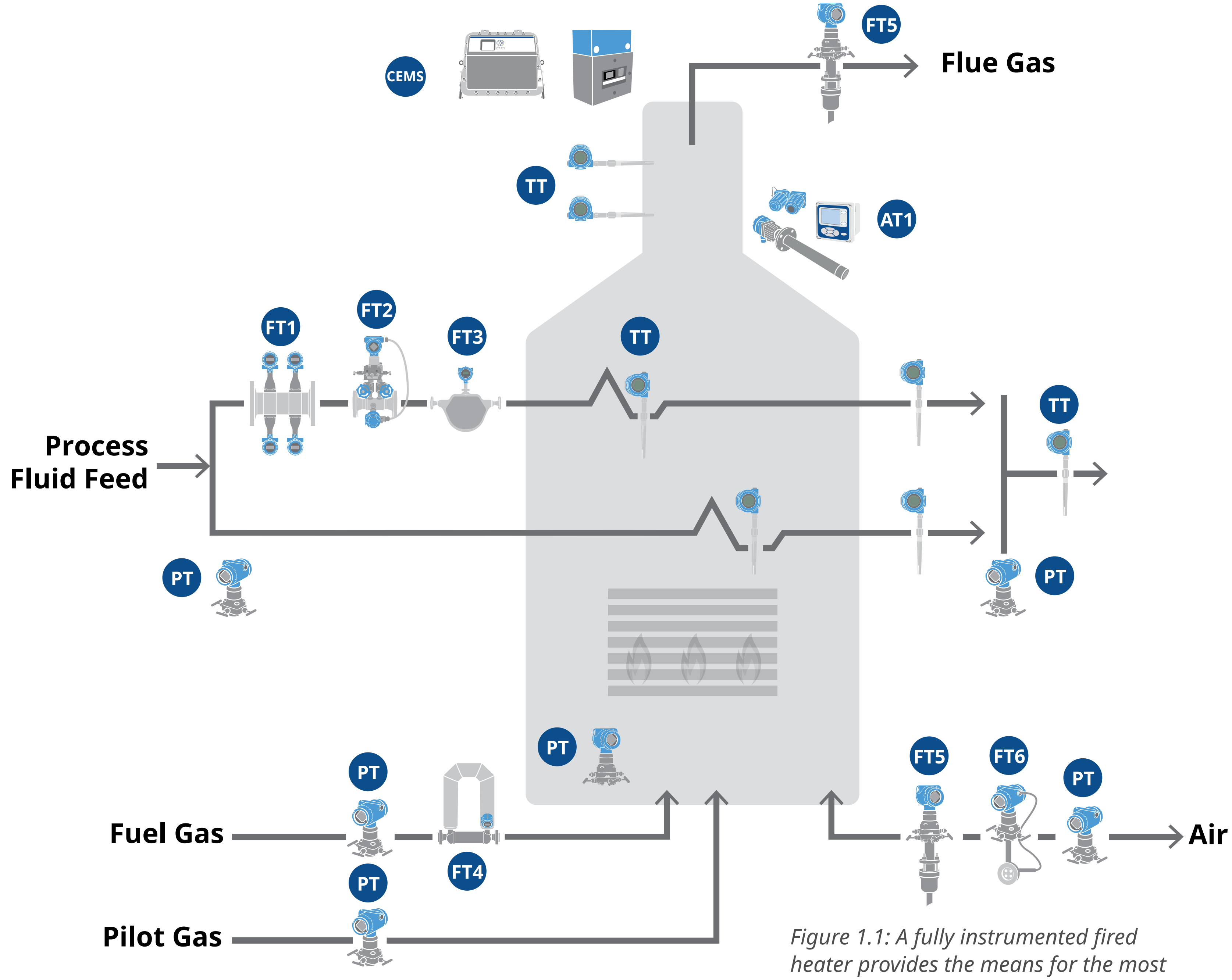


Figure 1.1: A fully instrumented fired heater provides the means for the most sophisticated control, ensuring maximum efficiency with the lowest emissions.

More sophisticated users often measure combustion efficiency by monitoring the percentage of oxygen (O_2) in flue gas, for example by using Rosemount™ In Situ Oxygen Analyzers or Close-Coupled Extractive Oxygen and Combustibles Analyzers (Figure 1.2). Rosemount's In Situ and Close-Coupled Extractive Analyzers are a cost effective, accurate, and very reliable solution for measuring these variables either in flue gas, or in the bridge wall of a fired heater.

Figure 1.2: Rosemount 6888A In Situ Oxygen Analyzer and Rosemount OCX8800 Oxygen and Combustibles Transmitter

High levels of O_2 assure an added margin of safe heater operation, but negatively affect thermal efficiency and environmental compliance. High levels can also lead to increased nitrogen oxide (NO_x) emissions and issues with meeting environmental permit requirements.

On the other hand, operating with too low O_2 creates a risk of sub-stoichiometric combustion, possibly tripping the heater, or in extreme cases, causing heater damage. Sub-stoichiometric conditions can result when the composition of the fuel suddenly changes to a richer blend that is higher in heating value, requiring more oxygen.

If this change is anticipated and the new fuel characteristic is understood, feed-forward control can make the transition much easier and eliminate many of the associated challenges. This feed-forward scheme is much easier to implement when fuel flow is measured using a mass flow meter, rather than with volumetric- or pressure-based control, since energy content is more closely related to mass versus volume (Figure 1.3). Also, the stoichiometric air required for combustion is much more consistent across the hydrocarbons found in fuel gas on a mass versus a volumetric basis, as shown in the table.

Fuel Gas Components		Stoichiometric Air Required for Components		Gross Heating Values for Components	
		Mass Basis kg air/kg HC	Volue Basis kg air/kg HC	Mass Basis KJ/Kg	Volume Basis KJ/Nm3
Methane	CH_4	17.23	9.56	55,561	37,706
Ethane	C_2H_6	16.09	16.85	51,923	66,023
Propane	C_3H_8	15.67	24.30	50,402	93,967
i-Butane	C_4H_{10}	15.46	32.09	49,279	121,129
n-Butane	C_4H_{12}	15.46	31.97	49,574	121,837
i-Pentane	C_5H_{12}	15.33	40.47	48,995	149,483
n-Pentane	C_5H_{12}	15.33	40.27	49,090	149,781
n-Hexane	C_6H_{14}	15.24	45.35	48,390	176,347
Hydrogen	H_2	34.29	2.39	120,719	10,172

Figure 1.3: Critical fuel characteristics are more consistent when measured on a mass basis rather than volume.

Hydrogen, on the other hand, is an anomaly because it is so light compared to hydrocarbons. Still, a mass-based control scheme is superior to a volumetric-based control scheme, even when hydrogen is blended into a hydrocarbon fuel gas mix at a proportion up to 80%.

Advantages of Coriolis flow meter technology

If fuel flow is specified and measured as pounds or kilograms per hour, the fuel controller can maintain a more consistent energy flow, even where the gas mixture is highly variable. Since stoichiometric air flow must match energy content rather than volume (Figure 1.4), air flow control becomes more stable and far easier to balance.

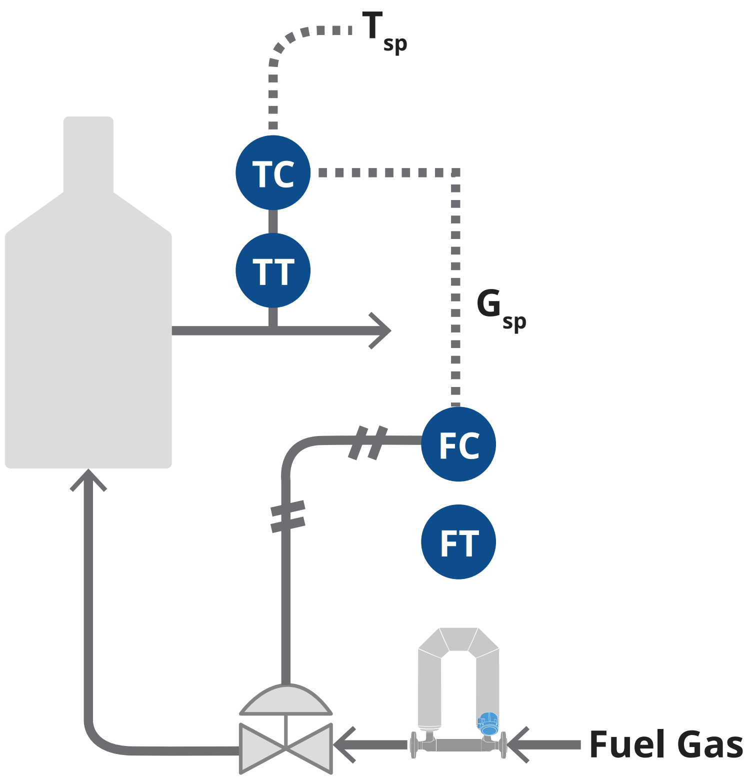


Figure 1.4: Fuel flow measured in pounds or kilograms per hour makes it much easier determine optimal stoichiometric air flow.

Coriolis flow meters measure mass directly and can therefore adjust automatically to changes in fuel gas heat value. Micro Motion™ flow meters (Figure 1.5) are available across a wide range of sizes, and all feature a wide turn-down ratio to accommodate varying operating conditions. Keeping burner control more stable using mass flow measurements ensures consistent high efficiency with the lowest internal energy consumption per unit of fuel produced, and the lowest emissions. Using this method, a given heater, depending on its capacity, can save $250,000 to $1 million per year in fuel costs.

Figure 1.5: Micro Motion Coriolis flow meters measure mass natively, so there is no need to make a correction when density changes.

Continuous emissions monitoring

As just discussed, chemical plants can burn a variety of available fuels with a range of heat content, but this also affects emissions since there can be various pollution-causing contaminants. Environmental regulatory agencies generally require all fired heaters to have a continuous emissions monitoring system (CEMS) to ensure what is going out of the stack does not exceed limits. The impact of the fuels being fired, the resulting flue gas emissions, and how to monitor these emissions must be considered to ensure proper operation.

Depending on the fuel, air combustion control, and system design, the concentration of air pollutants in flue gas will vary widely. These air pollutants include, but are not limited to, carbon monoxide (CO), nitrogen oxides (NO_X), and sulfur dioxide (SO_2). Where selective catalytic or selective non-catalytic reduction units utilize ammonia (NH_3) to reduce NO_X emissions, a regulatory agency may include NH_3 monitoring as part of the CEMS requirements. In some areas of the U.S., local agencies have also required the continuous monitoring of CO and/or total hydrocarbons.

A CEMS must meet a range of performance and quality assurance requirements set by the regulatory bodies to determine ongoing compliance and satisfy the mandated availability. Emerson offers a family of continuous process gas analyzers as well as pre-engineered modular CEMS solutions (Figure 1.6) and custom engineered systems designed to help chemical plant personnel prove compliance with environmental regulations and meet reporting requirements.

Figure 1.6: The Rosemount XE10 CEMS provides reliable analysis of stationary source emissions. It is a standardized solution certified to the European emissions directives EN 14181 and EN 15267-3 (QAL1), and it complies with the U.S. EPA 40 CFR Part 60 and Part 75 regulations.

Furthermore, Emerson's CEMS solutions are designed to meet not only the needs of cold/dry applications, but also address the challenges of hot/wet measurements because they can provide analysis of gas components that are highly soluble in water, such as ammonia (NH_3), hydrochloric acid (HCl) and hydrofluoric acid (HF).

The hot/wet CEMS utilize the Rosemount hybrid Quantum Cascade Laser (QCL)/Tunable Diode Laser (TDL) gas analyzers which can deliver interference-free measurement of up to 10 flue gas components in a single analyzer at temperatures up to 374 °F (190 °C). This helps simplify and reduce the size of the CEMS solution, enabling it to be placed next to the extraction point while delivering significant cost savings. The systems are expandable and can house multiple analyzers to cover a larger suite of gas components.

Figure 1.7: A hybrid QCL/TDL analyzer, such as Emerson's Rosemount CT5100 Continuous Gas Analyzer, can measure up to 10 gas components simultaneously in real time, from parts-per-million (ppm) to percent concentrations. It is ideal for hot/wet CEMS applications and features a purged and pressurized enclosure for hazardous areas.

2 Heat exchanger efficiency

Heat exchangers are very common throughout chemical plants where they are used to transfer heat amongst various processes (Figure 2.1). Optimal control of heat exchangers is a key area for improvement in energy efficiency and is recognized by regulatory bodies, for example the USA ENERGY STAR Guide. Fouling is the largest contributor to inefficient heat exchanger operations, especially in dirty processes where deposits can coat and build up on coils and tubes.

Figure 2.1: Heat exchangers are widely used in chemical plants in all sorts of sizes and applications, but they share common problems and solutions.

Numerous studies have shown that heat exchanger fouling may lead to 1 – 2.5% of global CO_2 emissions. Furthermore, cost penalties associated with heat exchanger fouling are estimated to be roughly 0.25% of the gross domestic product for industrialized countries.

Despite the magnitude of the problem, many chemical plants depend on manual inspections or schedule-based cleanings because few heat exchangers have more than the most rudimentary instrumentation. Solving the problem begins with determining its extent and determining how efficiently a heat exchanger is operating depends on its functionality. Ideally, any installation should be equipped with at least a minimum complement of instrumentation (Figure 2.2).

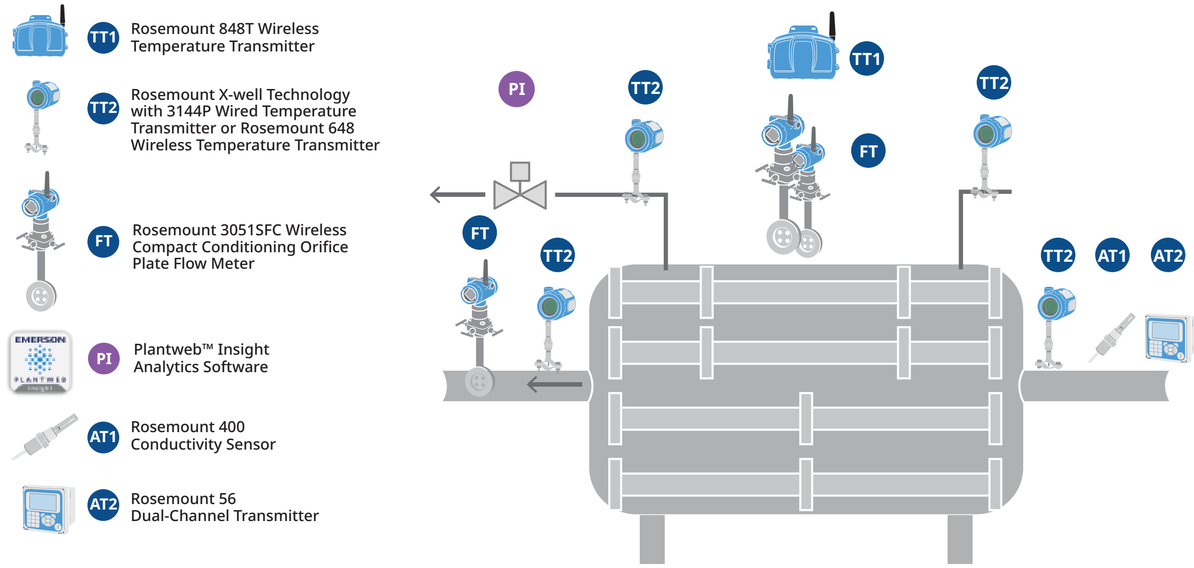


Figure 2.2: With a set of basic instruments, it is possible to determine much about heat exchanger performance.

With the values from these instruments, it is possible to determine the heat exchanger's efficiency. WirelessHART®-based transmitters make this kind of monitoring much easier and less expensive since they eliminate the cost of wiring. If added to existing WirelessHART networks, the cost is especially low.

- Temperature instruments can be added to the process fluid and transfer fluid pipes without penetration. Reading through the pipe wall, (Figure 2.3, left) they measure the interior fluid temperature accurately, regardless of ambient conditions.
- If it is practical to use conventional temperature sensors, a single transmitter can send data from up to four sensors on one wireless signal (Figure 2.3, middle).
- Reading differential pressure (DP) across the process fluid inlet and outlet can determine when fouling is beginning to accumulate, or if there is a leak in any heat exchanger tubes.
- Wireless DP flow meters (Figure 2.3, right) can monitor the process fluid and transfer flow rates if they are not already being measured elsewhere.
- Leaking heat exchangers can be a source of potential emissions. Using a conductivity sensor can detect a contaminant indicating a heat exchanger leak.

Figure 2.3: Using WirelessHART instruments for heat exchangers simplifies installation. Rosemount X-well™ Technology (left) does not require a thermowell or process penetration. Where conventional temperature sensors are preferred, the Rosemount 848T Wireless Temperature Transmitter (middle) can send data from four sensors via one signal. A Rosemount 3051SFC Wireless Compact Orifice Plate Flow Meter (right) can measure fluid flow in tight spaces.

Evaluation of heat exchanger performance depends on proper analysis of the data measured by the instruments. Plantweb™ Insight offers a heat exchanger app (Figure 2.4) specifically designed to perform asset monitoring and evaluation functions for this type of equipment. When used in conjunction with WirelessHART instruments, users often find they can reduce energy losses by 10-20% and maintenance costs by 15%. The initial investment can be fully recovered in just six months

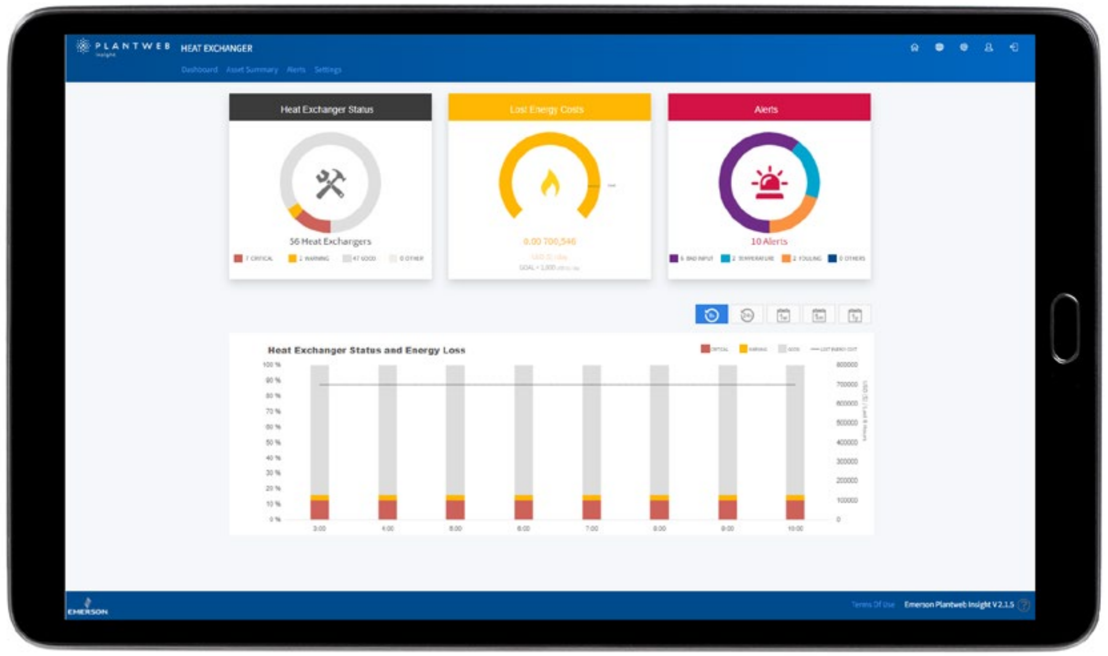


Figure 2.4: The Plantweb Insight Heat Exchanger application provides in-depth monitoring of shell and tube heat exchangers by analyzing data acquired through wired and wireless instruments. This application features real-time status and alerts for fouling, heat duty, and other items of interest

Using data from the basic instruments combined with data related to an individual heat exchanger and process fluid characteristics (heat of vaporization, inlet/outlet vapor fraction, etc.), a list of actionable information is provided:

- Overall heat exchanger health
- Fouling factor
- Fouling rate
- Heat duty
- Duty error
- Lost energy costs
- Heat transfer coefficient
- Cleaning recommendations

Collectively using this data, the application delivers information to support maintenance planning and scheduling, while ensuring optimal energy efficiency is maintained. The application also helps identify abnormal situations and sends alarms when certain conditions are met, such as when fouling passes a threshold. These findings are presented via dashboards, but detailed data behind the summary graphics is just a few clicks away, allowing technicians to drill down.

3 Steam distribution systems and steam trap effectiveness

It is common for steam generation to account for 40% to 50% of a chemical plant's entire energy budget, so efficiency gains will significantly improve sustainability and profitability. Complex steam distribution systems providing access to all those applications create numerous opportunities to save energy. Reducing steam distribution losses starts with improved measurements to establish a baseline, but the mass imbalance of a steam network often exceeds the limits necessary to make meaningful assessments. Improved flow measurements utilizing a Rosemount 8800 MultiVariable Vortex Flow Meter (Figure 3.1) or Rosemount 3051SFA Annubar™ Flow Meter can significantly reduce the uncertainty in these measurements.

Figure 3.1: Rosemount 8800 MultiVariable Series Vortex Flow Meter or Rosemount 3051SFA Annubar Flow Meters are both ideal for the steam flow measurement necessary for distribution system analysis.

When flow meters can be installed in strategic locations around the system, it is possible to identify specific applications that are using steam inefficiently. This way, poorer performers can receive immediate attention for the fastest return on investment.

Corrosion and erosion monitoring

Wireless solutions to monitor corrosion and erosion in steam systems (Figure 3.2) provide early warning of possible issues related to deteriorating equipment, which can be used to optimize maintenance planning and prevent losses. Rosemount Permasense corrosion and erosion products are particularly easy to install and maintain, with associated software providing real-time data on the condition of relevant piping. These non-intrusive systems use unique sensor technology and wireless data delivery to monitor pipework continuously for metal loss.

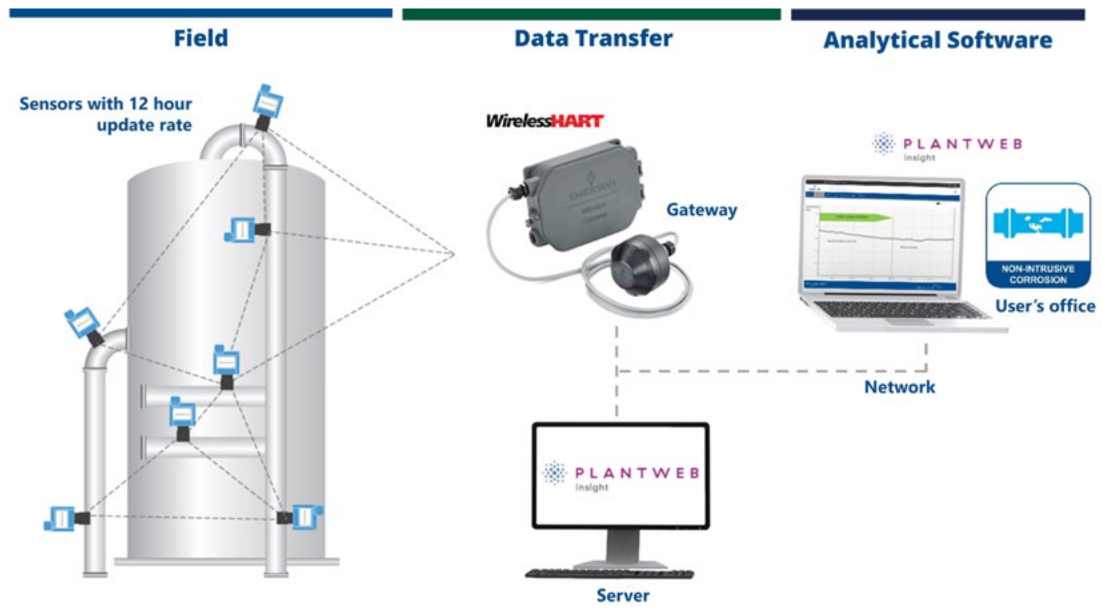


Figure 3.2: Rosemount Wireless Permasense Sensors can be added to strategic points of piping systems to monitor metal loss, with no piping or vessel penetrations required.

Steam traps

Improving steam trap effectiveness provides another significant opportunity for energy savings. Once steam traps are three to five years old, they often become maintenance headaches. Studies by the analyst firm Gardner and the U.S. DOE suggest 15% to 30% of steam traps of that age are malfunctioning at any given time, and 10% will likely fail in any given year. Even so, companies by-and-large pay surprisingly little attention to them, even though a malfunctioning trap can easily waste $10,000 worth of energy over a year, and often much more.

An acoustic transmitter mounted on the inlet pipe to a steam trap (Figure 3.3) can listen to the ultrasonic noise it makes while cycling, and it can also measure the pipe's temperature. This data is sent via WirelessHART to an algorithm that learns the characteristic activity for each trap where operators can see how all the steam traps equipped with acoustic transmitters are performing.

Figure 3.3: Emerson's Rosemount 708 Wireless Acoustic Transmitter gathers data on steam trap operation and sends it to a data analytics application to determine proper functionality.

Dashboards display (Figure 3.4) which steam traps are working correctly and which are in failure mode. The software estimates lost energy and resulting costs at any time. Maintenance personnel can easily identify which steam traps need attention and plan activities appropriately, allowing them to deal with small problems before they become costly issues.

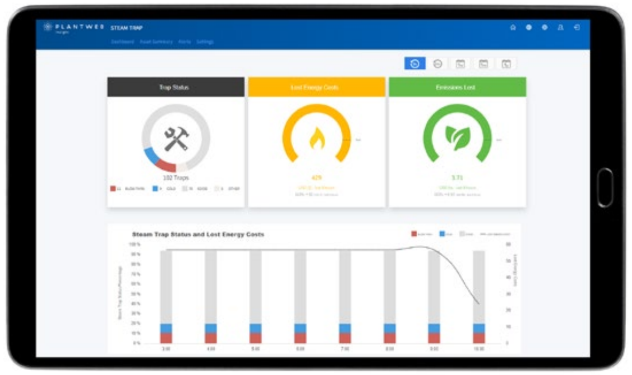


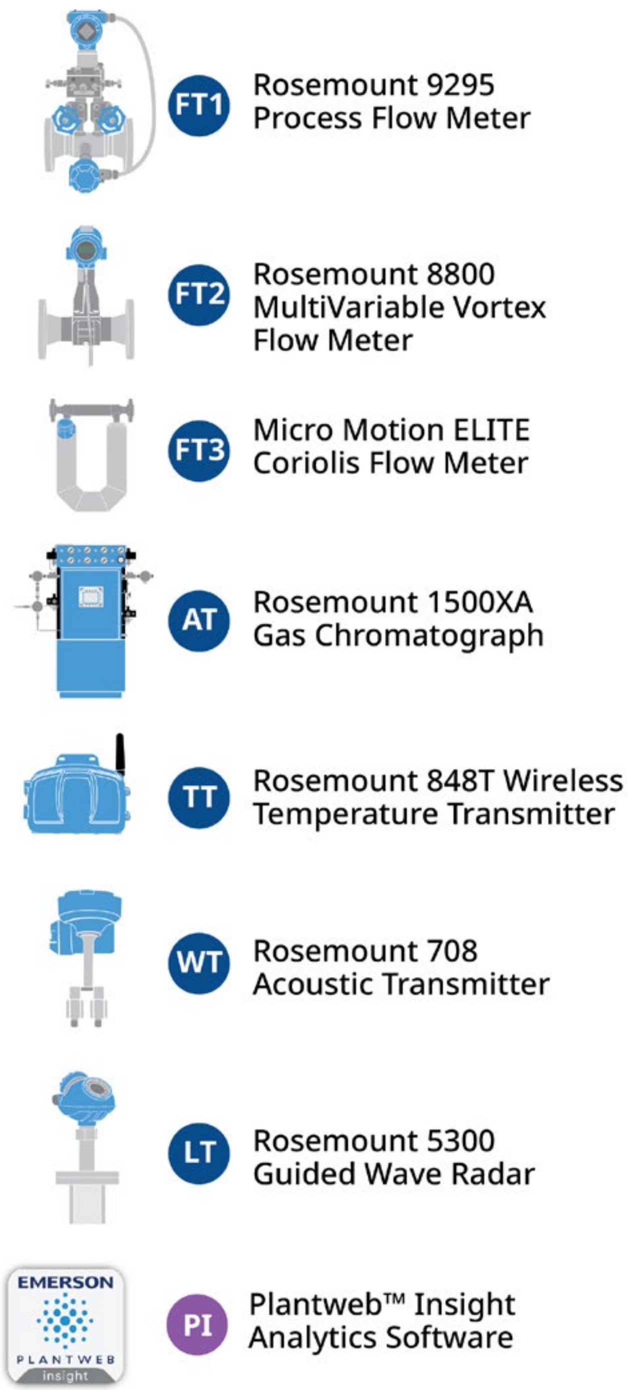
Figure 3.4: Emerson's Plantweb Insight Steam Trap application shows operators and maintenance teams which steam traps are functionally normally and which are malfunctioning. The application looks at each steam trap individually, and all of them collectively, to help determine how much energy is being lost and show which steam traps need the most attention.

Naturally, the data may need some interpretation. For example, a steam trap reported as blow through could require repair, or it could be incorrectly sized for the steam line. A steam trap attached to a process that runs continuously or at least regularly will have a mechanical cycling pattern. If patterns change, such as a sudden increase in mechanical cycling, there may be some other cause for a deviation from normal process operation, and this condition can be flagged for investigation.

4 Pressure relief valve reliability and flare management

A plant wanting to improve its sustainability image should be doing its best to minimize the volume of products fed to the flare or atmosphere (Figure 4.1).

Generic flare with instrumentation



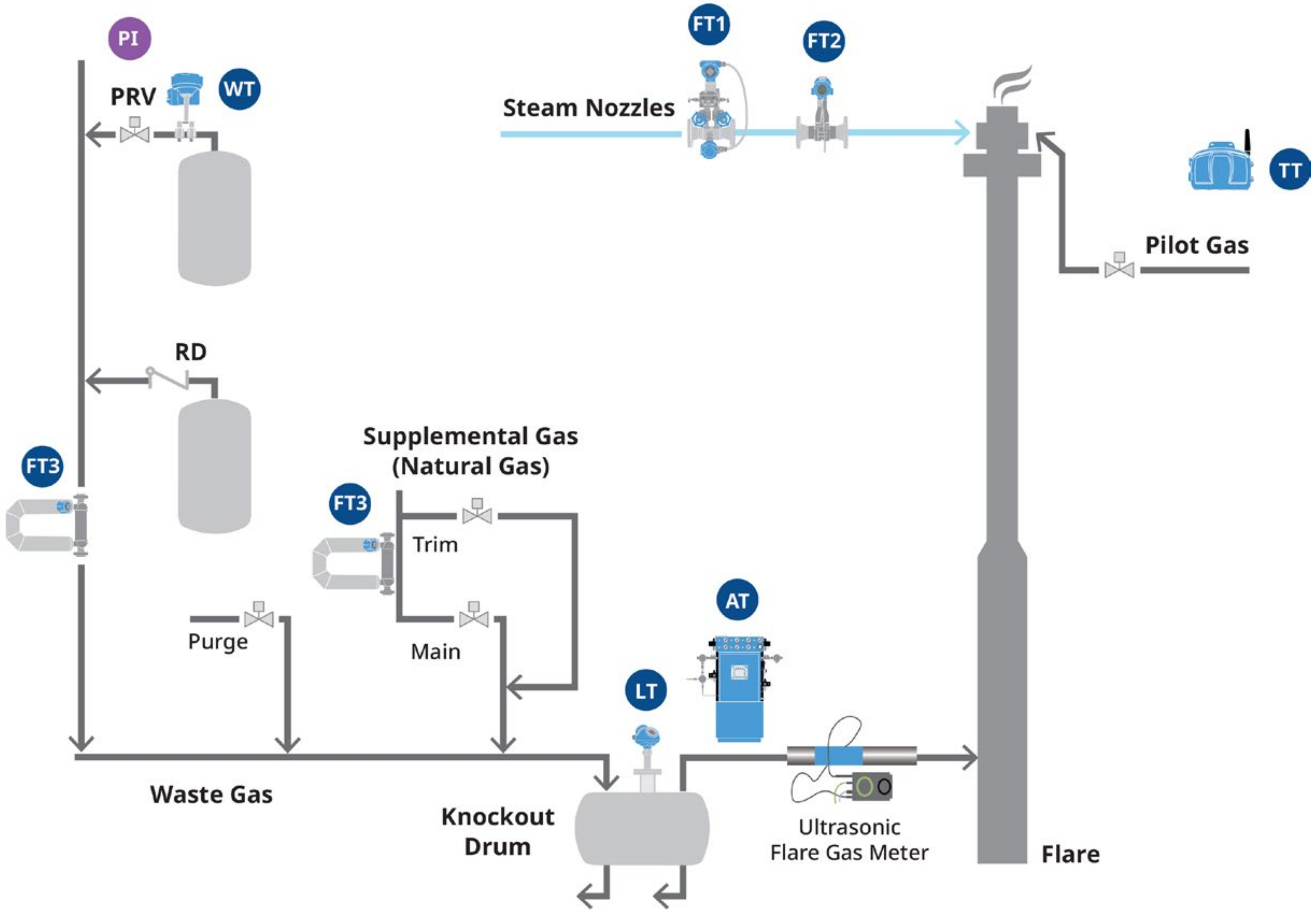


Figure 4.1: While flares serve environmental functions, they create a bad impression and suggest a facility has not implemented a more positive way to recover and utilize the burning fuel.

One source that feeds a flare, and may also be responsible for atmospheric releases, are pressure relief valves (PRVs, Figure 4.2). If the pressure of piping, a vessel, or reactor exceeds safe limits, PRVs open and allow pressure to reduce to an acceptable level. The PRV will then reseal when tolerable pressure levels are restored.

Figure 4.2: PRVs are critical for safety, but they can create maintenance headaches. They also tend to be at the high end of piping and vessels, so access is often difficult.

Since PRVs are mechanical, like steam traps, they can malfunction. The biggest problem is that they do not close fully after a release due to debris in or damage to the valve seat. Continuous low-level leakage, often referred to as "simmering," feeds product to the atmosphere or recovery system, and eventually to the flare.

Whatever the case, such leakage results in lost product and all the energy expended to get it to that point. Moreover, many regulatory bodies worldwide, such as the U.S. EPA, require accounting of all such releases to regulate hazardous air pollutants under 40 CFR 63, and 63.2480 for miscellaneous organic chemicals, with fines and penalties when regulations are not met. In addition, after a relief event occurs, a mitigation plan is often required for submission to regulators showing how a future event will be prevented.

Most PRVs (Figure 4.3) are direct spring-loaded designs, often referred to as “pop valves.” They’re held closed by direct spring pressure, and these types are designed to operate at 90% of set pressure, making them most subject to "simmering" and leakage problems. Less common are pilot-operated PRVs where the main valve seat is held closed by the system pressure itself.

Pilot-operated PRVs can operate at 98% of set pressure, resulting in fewer releases. They can be fitted with wired or wireless DP transmitters to notify operators of a release event, and to calculate the volume of the release for regulatory reporting.

Figure 4.3: Direct spring load (left) and pilot-operated valves (right) function differently, but both can leak, making characteristic sounds. Pilot-operated valves can also be diagnosed by monitoring internal pressures.

The challenge is identifying which valves are not working correctly. If operators want to know what is happening with a particular PRV, they typically rely on local inspection, or they monitor normal process pressure measurements for indication of operation near the PRV's setpoint.

The best solution is to use a pilot-operated PRV with a DP transmitter, allowing closer operation to the setpoint and notification of relief events. Another simpler approach, which doesn't require PRV upgrading, calls for acoustic monitoring devices equipped with WirelessHART instruments mounted directly to pipes adjacent to direct spring-loaded PRVs and pilot-operated PRVs (Figure 4.4). No shutdown, welding, or process penetration is necessary for mounting.

An acoustic transmitter detects the sound of a pressure relief event and reports the activity to the automation system. When pressure returns to normal, the PRV should close automatically. Data from the acoustic transmitter can verify the action, reporting the time the discharge began and ended, while giving some approximate indication of the magnitude of the discharge. If the PRV does not close completely, the acoustic transmitter will hear the ongoing leakage, even if very slight.

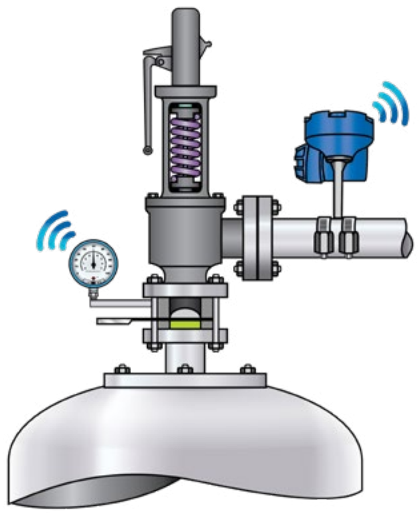


Figure 4.4: Mounting a Rosemount 708 Wireless Acoustic instrument on the discharge pipe of a PRV detects when release incidents happen, and if leakage continues due to an incomplete seal. No process penetration or shutdown is necessary for mounting.

Emerson's Plantweb Insight application for PRVs (Figure 4.5) collects data from all the acoustic transmitters and characterizes each release event through the facility. This helps eliminate guesswork by operators and false positives. This is critical information not just for environmental compliance, but also for supplying data into the larger PRV maintenance management program.

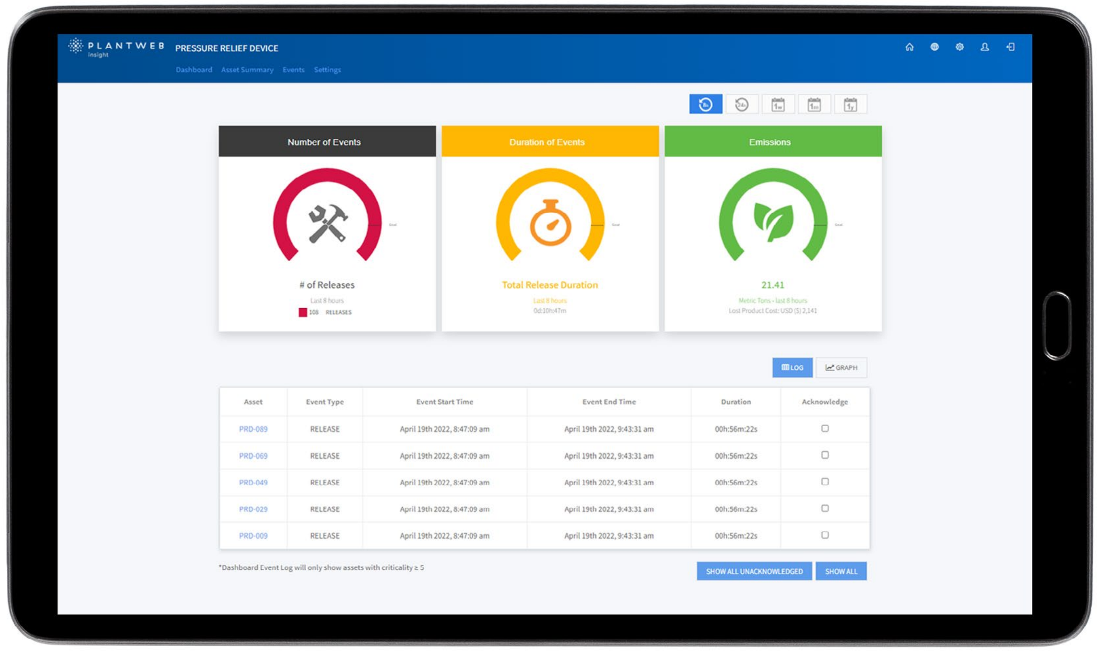


Figure 4.5: Emerson's Plantweb Insight PRV Application automates monitoring, including start and end time of individual release incidents. It also records production and emissions loss, along with event log records for EPA reporting.

Combining historical maintenance records with online monitoring data supports predictive maintenance programs. Decreasing relief events and detecting PRV leaks minimizes product losses, reduces energy usage, and extends equipment lifecycles.

With prompt action, overall effectiveness can be assured, while avoiding product loss and potential environmental consequences.

A U.S.-based ammonium nitrate manufacturer incurred $1.7 million in EPA fines caused by a failure to monitor and report PRV ammonia releases. Emerson provided 30 of their Rosemount 708 Wireless Acoustic instruments to monitor their PRVs, each connected to an Emerson 1420 Gateway via a WirelessHART network. The gateway was in turn connected to the plant's host system, and their personnel used the data from these instruments to ensure EPA compliance.

Flare steam management

Chemical plant flare stacks must burn off all manner of unrecoverable hydrocarbon gases and vapors before releasing them into the atmosphere. Steam is commonly added to the flare feed to assist mixing, ensure complete combustion of all hydrocarbons, and avoid visible emissions—and EPA 40 CFR Part 63 requires accurate measurement of steam flow to chemical plant flares. The mixture of steam and hydrocarbon feed must be optimized, because adding either too much or too little steam can reduce combustion efficiency, while increasing emissions of volatile organic compounds.

This is complicated because the amount of hydrocarbon flowing to the flare can vary widely, with a stack gas flow range of 100:1 common. To comply with the regulation and reduce emissions, metering of the steam assist flow must cover the same range. To achieve this very wide turn-down range with the required ±5% of mass flow accuracy, two parallel steam flow lines are necessary (Figure 4.6), each with an appropriate flowmeter.

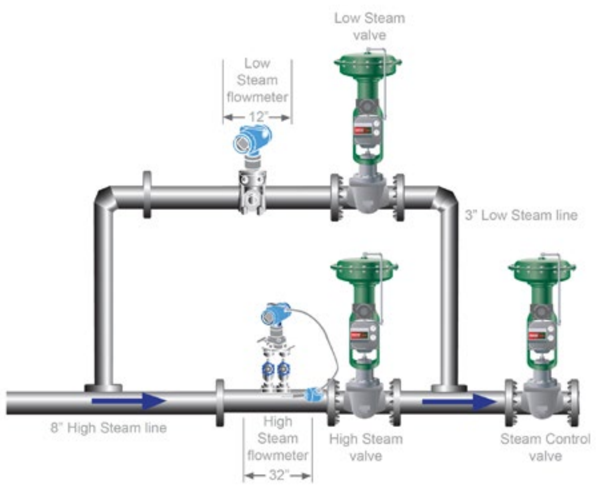


Figure 4.6: To cover a flow turndown range of 100:1 with the degree of accuracy required, one flow meter can't do the job, so two must operate in parallel on low- and high-steam lines. Valves direct the flow appropriately.

First, there must be a large line with a high-steam flow meter for 0-100% of flow, but this will not have sufficient accuracy below 10%, so a second low-steam flow meter is necessary to operate in parallel. Typically, the low-steam flow meter covers from 0% to 10% of flow. Measurements from the two flowmeters are added in the control system for total flow. A single final steam control valve handles overall steam throttling.

This application of course calls for flow meters capable of measuring steam (Figure 4.7), and both the Rosemount 8800 Vortex Flow Meter, and the Rosemount 9295 Process Flow Meter provide accurate readings, with minimal maintenance and calibration requirements.

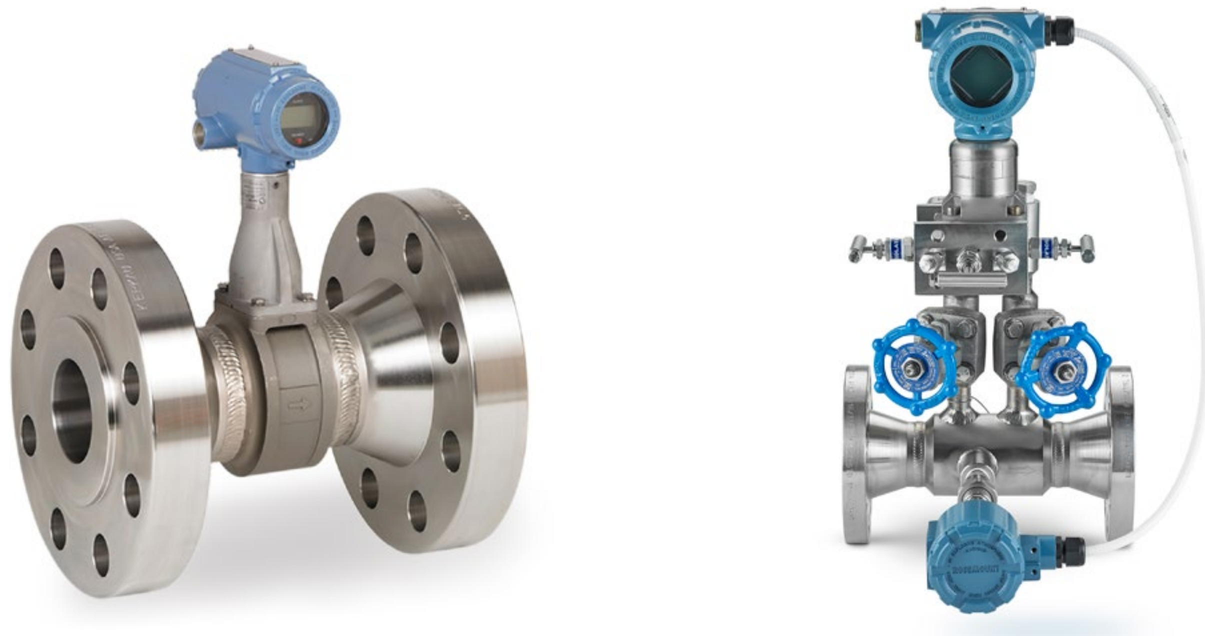


Figure 4.7: Both Rosemount 8800 Series Vortex Flow Meter and the Rosemount 9295 Process Flow Meter can be used to monitor steam flow.

5 Boilers and steam production

As mentioned in Section 3, it is common for steam generation to account for 40% to 50% of a chemical plant's entire energy budget. A recent study by the U.S. Department of Energy estimates the overall potential for energy savings in the U.S. chemical industry at 12.4% of the fuels used to generate steam (U.S. DOE, 2002a). The payback time of the nineteen measurement methods included in the analysis ranged from 2-34 months, with eleven methods having a payback time of less than one year.

Creating steam is an expensive and energy-intensive process, so evaluating boiler performance offers many areas of potential improvement. First and foremost is combustion and emissions control, areas that boilers share with fired heaters, refer to Section 1 for an extensive discussion of those topics. However, boilers have additional unique requirements, so let's look at those.

Steam boiler with measurement instrumentation

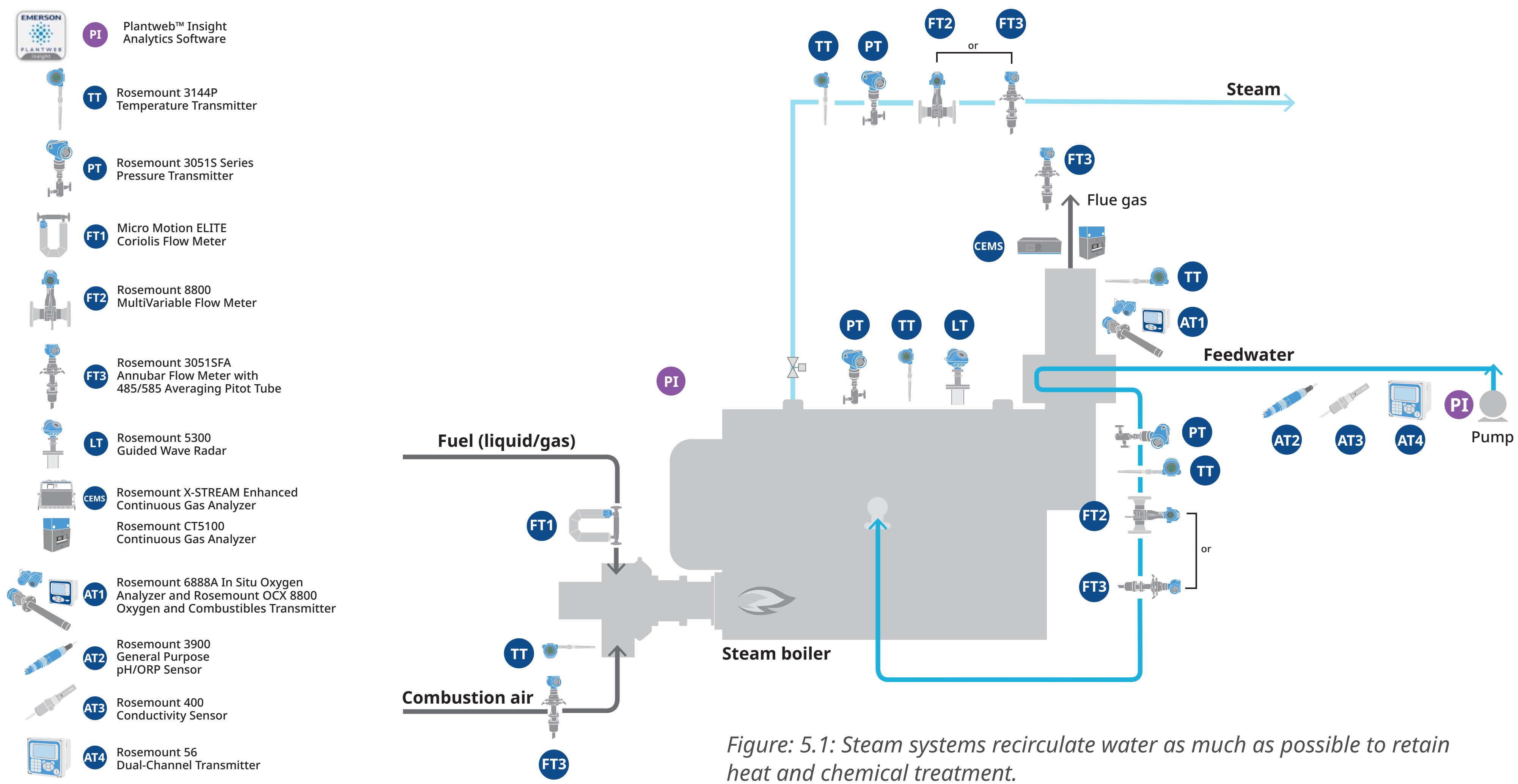


Figure: 5.1: Steam systems recirculate water as much as possible to retain heat and chemical treatment.

Feedwater and condensate treatment

The water a boiler turns to steam must be recirculated as much as possible to increase efficiency (Figure 5.1). Water leaves the boiler as steam, performs its function, condenses back into water, and is pumped back into the boiler. As it goes through countless cycles, its chemistry changes as impurities build up. These can deposit on internal surfaces, reducing heat transfer and overall boiler efficiency.

A Rosemount 56 Dual-Channel Transmitter equipped with Rosemount 400 Conductivity and 3900 pH sensors (Figure 5.2) can monitor condensate and make-up water, helping operators avoid conditions capable of mineral deposits or corrosion. Such analysis can also point to situations where leaks in heat exchangers are adding other contaminants to the circulation.

Figure: 5.2: A Rosemount 56 Dual-Channel Transmitter can support a variety of probes, including Rosemount 400 Conductivity and 3900 pH sensors used to monitor feedwater chemistry.

Boiler drum level control

The design of many large boilers common to chemical plants uses a drum to circulate the boiling water and collect steam. Controlling level in the drum is very critical because boilers will trip if the level gets too high to avoid sending water into the steam line. They will also trip if it gets too low as this could cause the boiler to run dry. Depending on the size of the boiler, a level deviation of as little as two or three inches can cause a trip. Maintaining this critical level is challenging because a boiler drum is a very turbulent place, where density is variable and the separation between liquid and gas is hard to define.

One choice capable of solving the problem is guided wave radar (GWR), such as a Rosemount 5300 Level Transmitter (Figure 5.3). This design can see through density variations, and it also tolerates the temperatures and pressures involved. The Rosemount 5300 includes a self-diagnostic capability able to evaluate changes in dielectric constant caused by saturated steam within the drum. This dynamic vapor compensation reduces level measurement errors down to 2%, even in turbulent conditions.

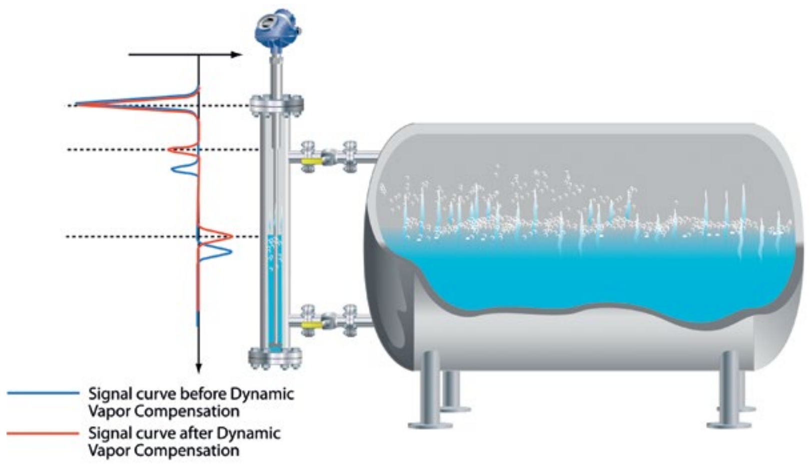


Figure 5.3: The dynamic vapor compensation capability of a Rosemount 5300 Level Transmitter enables it to provide accurate level measurements of a turbulent boiler drum, ensuring dependable and smooth performance even when steam demand is variable.

6 Distillation column control

Many chemical plants must distill a variety of intermediate and final products. These processes require precise product separation, typically performed via fractional distillation in tall columns. While they may be common, they are notoriously difficult to control, potentially resulting in poor product quality, low yields of desirable product streams, and even major safety incidents (Figure 6.1). Distillation is also highly energy intensive and therefore costly, so improved measurement and control is a major step toward reduced energy consumption.

Simplified distillation column with measurement instrumentation

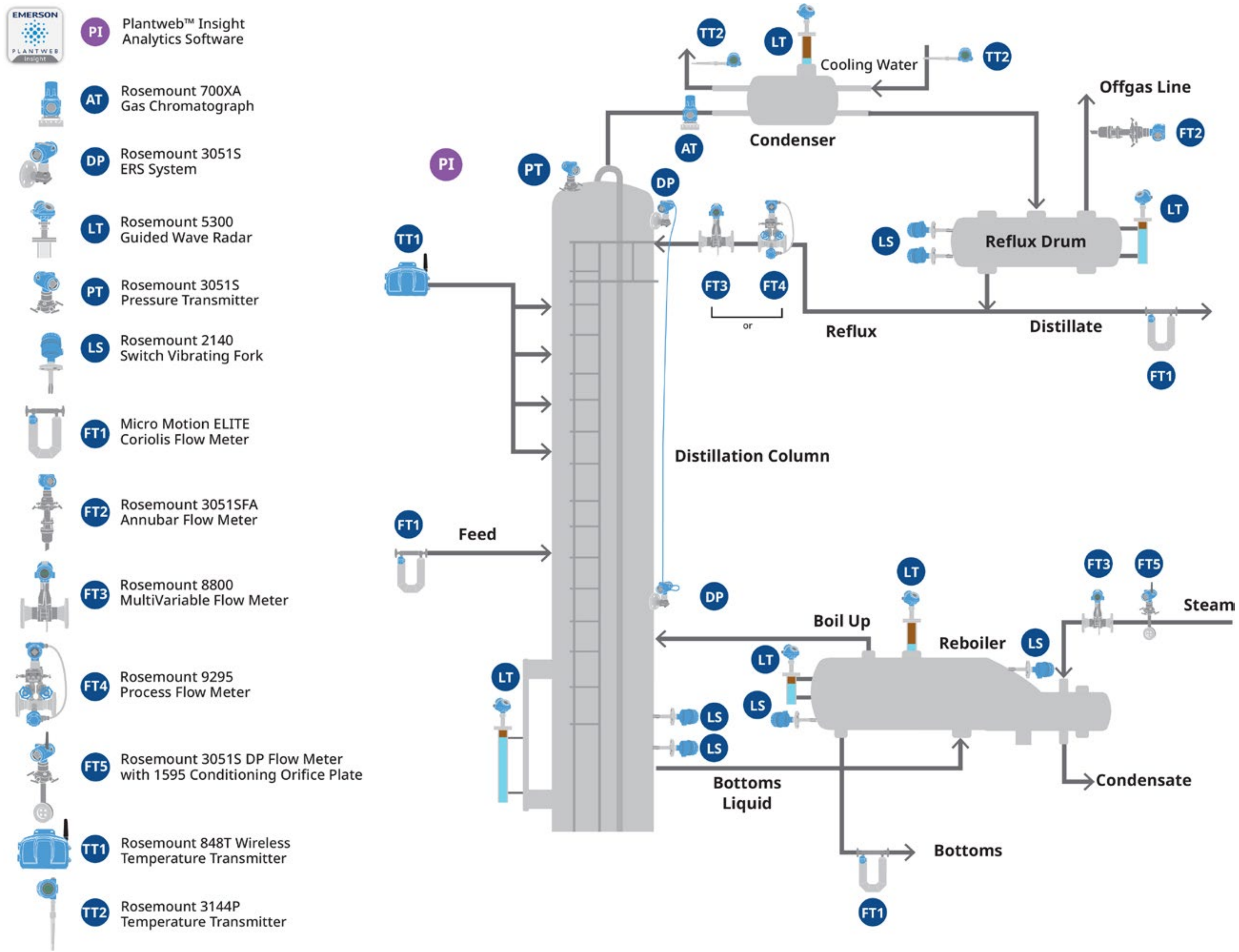


Figure 6.1: Distillation columns and their associated equipment can cause a wide range of problems, resulting in high costs and low-quality products.

Solving distillation problems, both common challenges and those unique to a specific application, usually begins with additional instrumentation, or improved utilization of what's already installed.

Data generated by these field devices must be supported by well-designed analytics and corresponding control strategies. This eBook doesn't provide the space necessary to take a deep dive into the individual solutions, but here are some typical examples:

- Rosemount Pressure Transmitters— Feature Process Intelligence diagnostics and advanced diagnostics capabilities to quickly detect early column flooding and tray malfunctions.
- Micro Motion Coriolis Flow Meters—Directly measure mass flow of gas streams, liquid streams, and liquid density for quick reactions to process changes for improved product quality control.
- Rosemount Wireless Temperature Transmitters—Measure temperature profile of distillation columns using RTDs or thermocouples. Some transmitters handle a single sensor, others up to four.
- Rosemount Guided Wave Radar—Level transmitters accurately measure tower levels regardless of fluid density and viscosity, even in extreme temperatures.
- Rosemount Multivariable Flow Meter—In addition to flow, DP technology measures static pressure and process temperature, providing the data needed to perform fully compensated mass and energy flow calculations for tighter control of critical process parameters.
- Rosemount Electronic Remote Sensors—Measure level using DP to detect flooding, overpressure, and excessive energy use. Design reduces maintenance by using two digitally linked sensors instead of impulse tubing.
- Rosemount Analytical Gas Analyzer or Chromatograph—Quickly measures overhead compositions and can be field-mounted. Localized installation reduces operating cost while providing the data required for closed-loop control of product quality to reduce energy use, improve quality, and increase product recovery.
- AMS Suite for Maintenance—Uses predictive diagnostics to identify developing asset problems, enabling maintenance personnel to schedule repairs, thereby reducing downtime and costs.

7 Tank overfill protection

Chemical storage and transfer facilities deserve careful consideration due to the potential for disaster in the event of a spill. Incidents with loss of life and major equipment damage are not difficult to find, with many resulting from operators trying to put more into a tank than it can hold. Such incidents have common causes:

- Poor level measurement or control room data presentation, leaving operators with a false or misleading indication.
- Malfunctioning or absence of overfill protection mechanisms that should automatically shut down a transfer into a tank when it is nearing capacity.
- Inadequate or absent gas detectors to sound an alarm when flammable vapor clouds form due to a spill in progress.

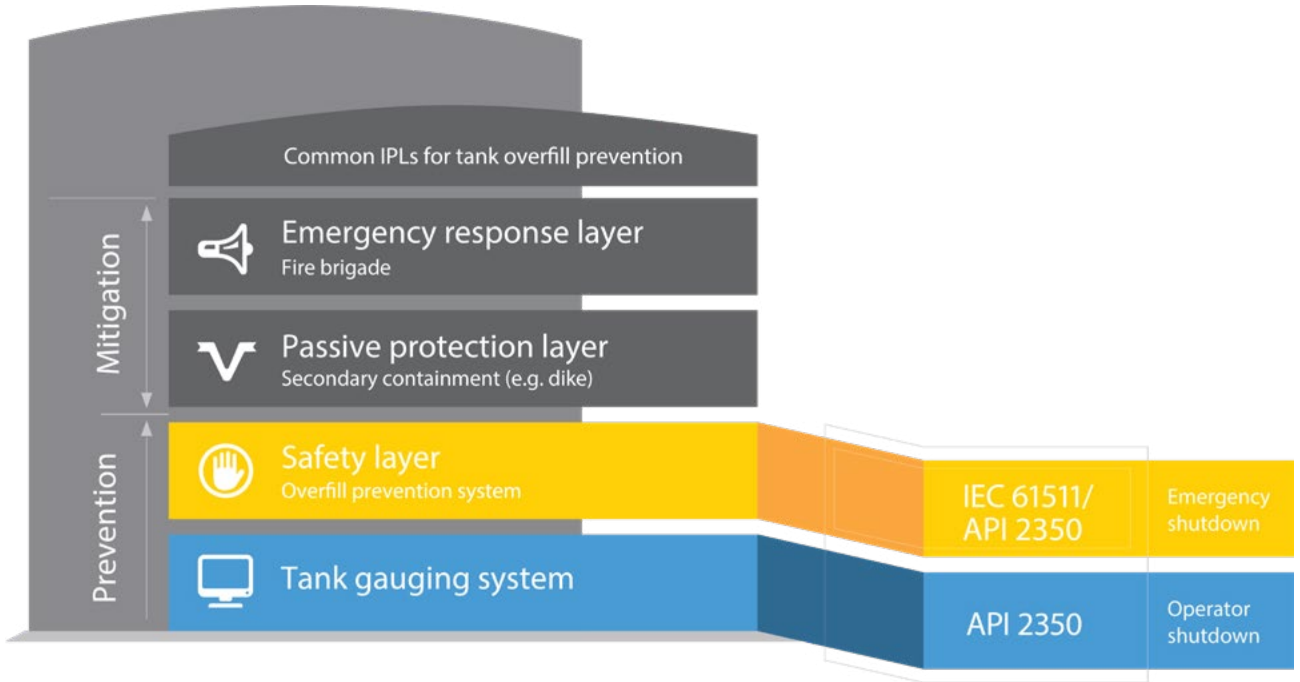
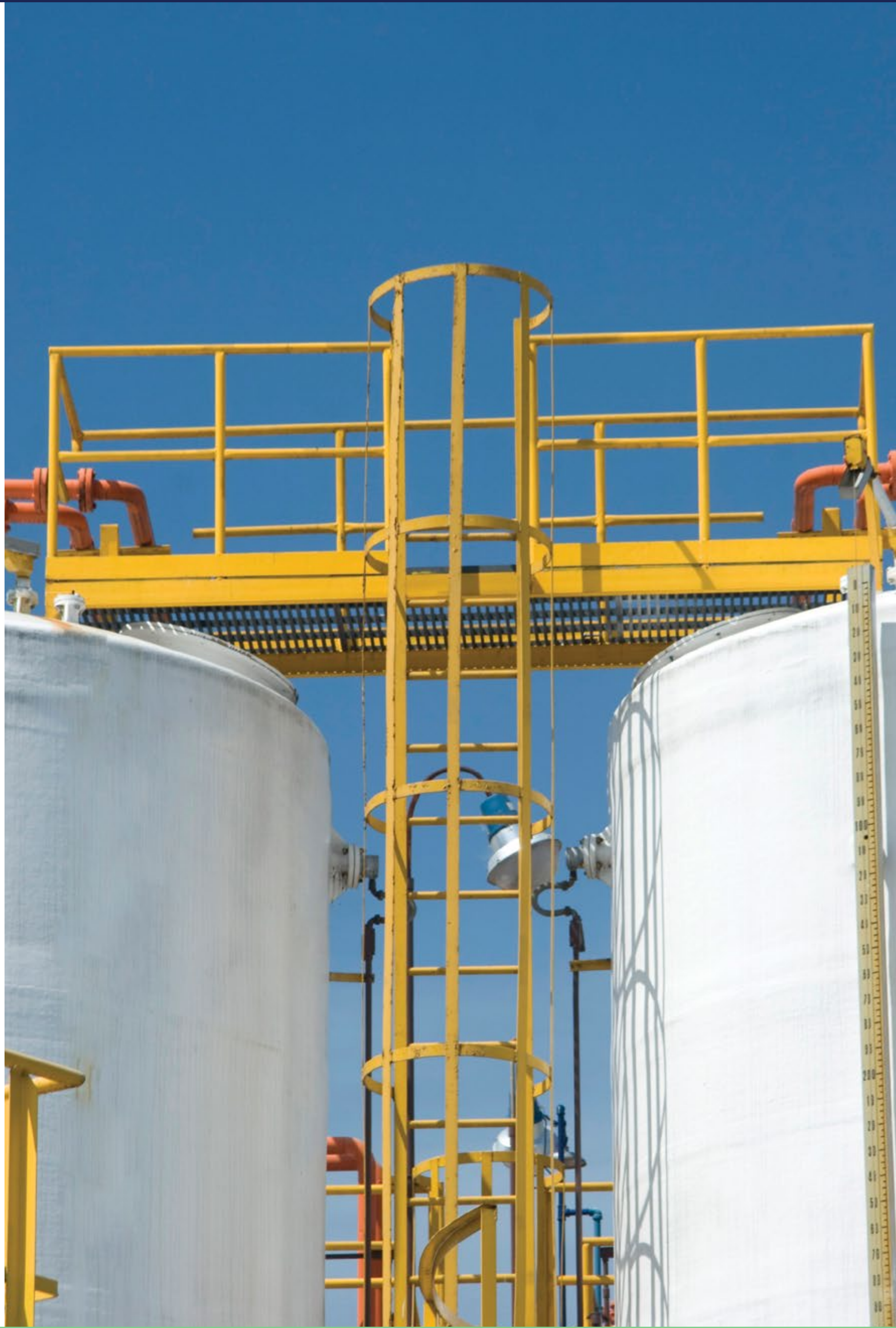


Figure 7.1: Keeping chemical storage safe calls for multiple layers of protection.



Overfill prevention

As just discussed, overfilling incidents often stem from ineffective level instrumentation, resulting in poor situational awareness for the operators. A transfer should be stopped by an automatic safety system able to shut down liquid movement, or at least trigger an alarm to warn operators of the developing situation.

In most situations, as the level nears capacity, an instrument will provide the data needed to sound an alarm and warn operators so they can stop the transfer. If they do not, the situation will trigger a safety instrumented function, and an emergency shutdown of the relevant pumps, including closing valves, bringing the transfer to a halt. This is a disruptive act, so it is better for operators to handle it earlier and more proactively.

This approach calls for at least two level instruments. The first is a conventional transmitter sending data to the automation system, governed under API 2350. The second is a safety-certified device, compliant with IEC 61511 for the safety instrumented function. The two systems (Figure 7.2) are automatic tank gauging and automatic overfill prevention system (AOPS), respectively. These exist side-by-side, operating in parallel so they can provide two layers of protection.

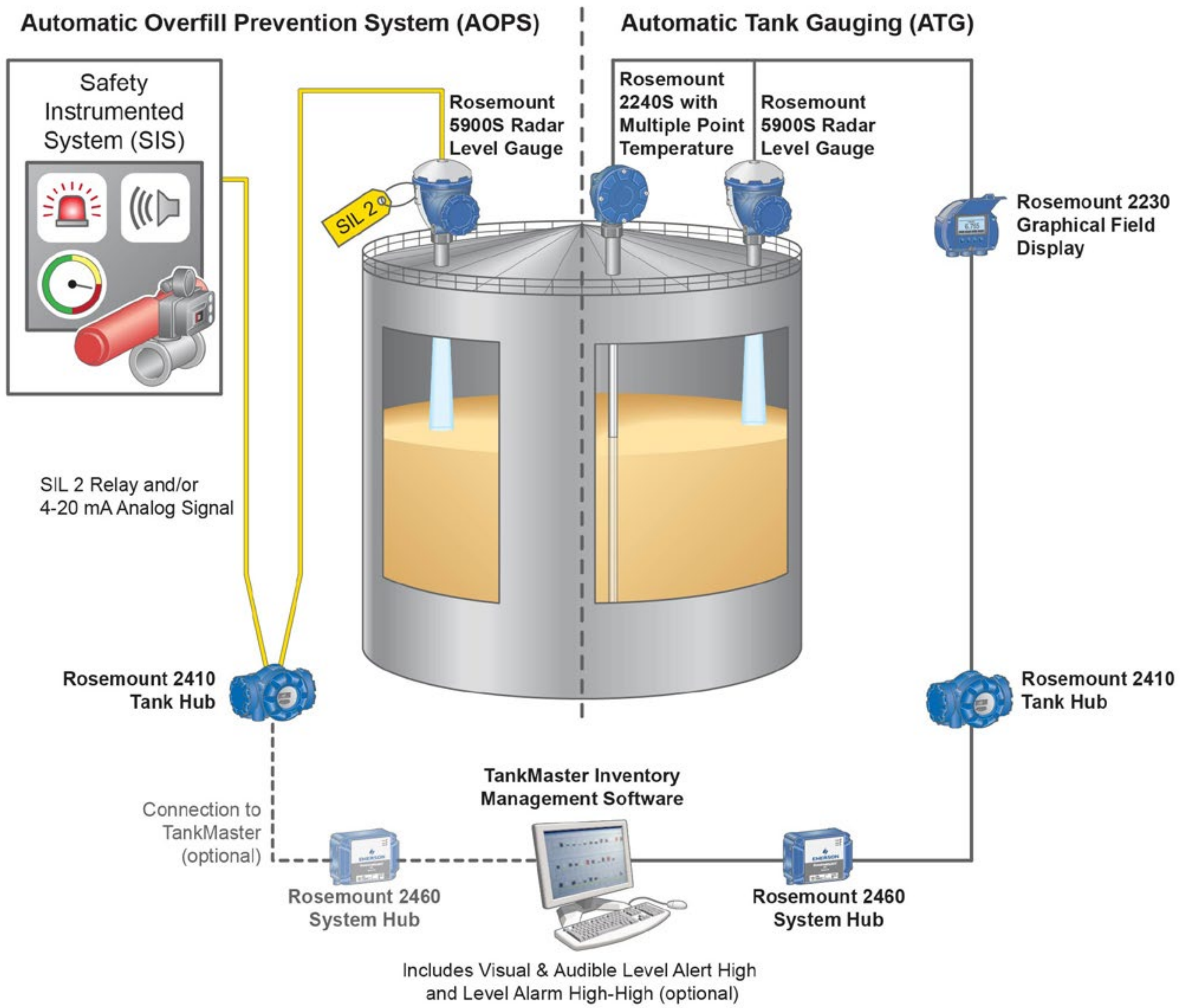


Figure 7.2: Level instruments for safety and control must function separately, even when monitoring the same tank.

Emerson offers a full range of products to meet the requirements of a comprehensive overfill prevention solution, including:

- Rosemount 5900 Radar Level Gauge—Provides exceptionally high accuracy for custody transfer and inventory management.
- The 5900S with its patented 2-in-1 option can serve as an automatic tank gauge (ATG) and an independent overfill prevention sensor simultaneously.
- Rosemount 3408 Level Transmitter Non-Contacting Radar—Provides fast response and robust measurement using a continuous echo in most applications, including storage tanks and mixing tanks.
- Rosemount 5408 Level Transmitter Non-Contacting Radar—Provides accurate level measurement in challenging applications including reactors, and vessels containing turbulence and high temperatures and pressures.
- Rosemount 5300 Level transmitter, Guided-Wave Radar—Provides accurate level and interface measurement.
- Rosemount 2410 Tank Hub—Handles communication between field devices and automation systems.

An effective AOPS following this approach can provide a 99% coverage factor, but this does not eliminate the need for additional layers of protection. The shutdown mechanisms to turn off pumps and close valves must also perform flawlessly, but these are outside the immediate control of the AOPS and are instead handled by separate safety systems. Additionally, there are other potential causes for leaks and spills, including equipment failure or operator error.

The larger sustainability picture

The solutions discussed here, when considered on an individual basis, require minimal investment. Adding an acoustic transmitter to a steam trap or PRV costs only a few thousand dollars. Improving fuel monitoring for a fired heater or adding instrumentation to a heat exchanger will break into five figures, but again, these are not major capital items. Nonetheless, the payoff of each can be substantial, and the improvements captured frequently deliver positive ROI in a matter of weeks or months.

The advantage here is the incremental nature of the improvements and their cumulative effects toward energy savings, with corresponding reduced costs and overall sustainability improvements. If one heat exchanger can be retrofitted with a Rosemount 3051SFC Wireless Compact Orifice Plate Flow Meter each week, and two or three PRVs or steam traps can be outfitted with acoustic instruments, a facility could be transformed in the space of a year.

Since most of these monitoring instruments and devices can communicate via WirelessHART, either natively or via a Emerson Wireless 775 THUM™ Adapter, no additional cabling is necessary. Plus, analytics platforms such as Plantweb Insight require essentially no system integration or custom engineering to perform their functions because all user graphics and data analysis functions are built-in.

Many equipment condition monitoring devices are now available to determine how well various types of assets are functioning. This information can help plant personnel optimize maintenance efforts and avoid costly unplanned shutdowns. When taken together, the cumulative cost savings of all these small efforts will improve the bottom line, while burnishing the facility and company sustainability profile. Emerson experts are available to assist, and they can suggest which investments will yield the greatest return. These initial successes can provide the funds needed for additional upgrades, along with the organizational momentum required for continued success.

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