White Paper

Improving safety compliance and cost-effectiveness of Burner Management Systems

Abstract

Regardless of the industry, safety must be a foremost concern wherever fuel is burned – furnaces, ovens, kilns, dryers, boilers and other kinds of facilities. Explosions can be deadly, costly and disruptive. 2015 revisions in U.S. National Fire Protection Association (NFPA) standards raised burner safety minimums. At the same time, integrations of safety PLCs into burner management systems – at nearly the same cost as regular PLCs – have boosted safety levels even further to meet SIL 2 and SIL 3 requirements. In addition, these advanced systems can offer improved operating efficiency, plus visibility via data feeds to higher-level DCS systems and easy-to-use, human-machine interfaces (HMIs), accessed remotely via tablets and even smartphones. These are among the key benefits upgrading to these systems can provide.

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Burner Management Systems: An introduction

One of the most widespread process safety applications used throughout the chemical, petrochemical and oil and gas industries is a burner management system (BMS). These systems are used in all boiler designs – water-tubes, fire-tubes and flex-tubes – and in furnaces, ovens and kilns as well as flares. Wherever a flame is present in an industrial environment, safety standards today require a BMS.

The purpose of a BMS is to prevent explosions and to control the combustion process in a productive, cost-effective and safe manner. Compared to older systems, an advanced BMS will provide operators and maintenance personnel with a great deal of relevant information about operating conditions and diagnostics. Newer systems also provide higher levels of safety and system security as well as traceability.

In 2015 the National Fire Protection Association (NFPA) released its fire safety standard, NFPA 86, that covers furnaces and allows the use of safety PLCs. Related to NFPA 86 are two other standards: NFPA 85 for boilers; and NFPA 87 for thermal fluid heaters.

Wherever a flame is present in an industrial environment, safety standards today require a BMS. Examples include boilers – water-tubes, fire-tubes and flex tubes – and furnaces, ovens and kilns as well as flares.

Top three causes of boiler accidents. BMS safety is paramount because, in many ways, furnace and boiler fires are explosions waiting to happen. To prevent accidents, operating conditions must be monitored at all times. If a malfunction does occur, operators need quick, safe and reliable ways to shut down the furnace or boiler operation. Then they must have the means to diagnose and fix problems as quickly as possible, in order to minimize process, production or heating disruptions.

According to research from the AIS Forensic Testing Laboratory, Inc., the top three causes of boiler accidents are, in order: maintenance (61.2%); operations (22.4%); and design (8.2%). What these data suggest is that accidents can be avoided if these facilities are properly operated and maintained, assuming the BMS is designed properly in the first place. Advanced BMS designs will incorporate safety PLCs, which, along with built-in safety features, can provide a wide range of operating data, including predictive maintenance. Safety PLCs will be covered in greater detail in the next few pages.

Burner management vs. combustion control. What's the difference between burner and combustion controls? Burner management control monitors the safety devices, such as pressure switches, low gas pressure, high gas pressure, water level and so on, and controls the safety shut-off valves like the pilot valves, main gas valves and oil valves. Combustion controls, on the other hand, manage the fuel and air mixture controls as well as the water controls in the case of boilers.

A brief history of Burner Management Systems

Early BMSs were called "Light, Observe and Pray" systems. That meant an operator would light a torch, put it in the furnace to light the fire and then everyone prayed that all should go well. Not surprisingly, explosions and related injuries were common in those days.

Next came BMSs with flame scanners. These early systems used relays and timers. They were simple systems and provided very little information regarding system shutdowns or troubleshooting information. Fireye and Honeywell were among the first branded types of these systems.

Early BMSs were called "Light, Observe and Pray" systems.

The next generation of systems were microprocessor-based systems. These systems include basic single- or two-line operator displays. Their displays, however, only provided limited amounts of operating information and not the diagnostics available with today's human-machine interfaces (HMIs) or even some of the three-line or multi-line displays. They used simple burner management logic and had limited capability and flexibility. Although they complied with safety codes at that time, those codes were not so rigorous as they are today. These systems are used today mostly in the fire-tube boiler market, but they are limited in their capabilities. Their display modules show sequences of events, indicating their operational stages, such as the light-off sequence and current status.

For simple types of boilers and fuel-burning systems, these BMS solutions may be a good approach. However, if a BMS requires non-standard features, such as special-limit devices or safety devices, then pre-packaged systems are limited in what capabilities they can provide. For example, they are not usually appropriate for multi-burner applications or for redundancy requirements. They also cannot easily communicate with other systems such as building management systems or manufacturing execution systems.

Finally, many of the operating strategies and capabilities required to accommodate various options that water-tube boilers need cannot be accommodated with these types of BMSs.

Comparison of microprocessor and PLC-based BMS solutions

Microprocessor-based BMS...

- Provides limited flexibility
- Is not appropriate for multi-burner systems
- Has a single flame scanner
- Yields limited information regarding status and shutdowns
- Difficult networking communications

PLC-based BMS...

- Provide great flexibility
- Extend communications capabilities dramatically
- Have both single- and multiple-burner capability
- Provide diagnostics, if programmed into the PLC
- Are much easier to troubleshoot
- Allow use of various flame scanners

The rise of the PLC-based BMS

Of all BMS designs, PLC-based systems offer the most capabilities and benefits, especially implementation flexibility. When these systems first debuted, they replaced relays and timers, which helped reduce wiring, and could be programmed. Early PLC-based BMS solutions often came with panel indicator lights, push-buttons and selector switches instead of today's sophisticated HMIs.

Typically in these early PLC-based BMSs, if another function was required, then another indicator light had to be added to the panel. This meant that if an application needed many safety devices or options, then it would have a multitude of lights and operator switches. The problem with these kinds of systems is that operators have to watch for the indicator lights to go on or off. If they overlook the indicators because they're not present or distracted, an operating issue can turn critical, leading to an accident. Today's HMIs, in contrast, offer much more information to operators and maintenance personnel via specific software packages or flat-panel computers whichever they may prefer.

Among the main advantages of a PLC-based BMS is more flexibility, especially in designing systems for specific applications. In water-tube boilers, for example, customers typically require a wide variety of features and also want their BMS to connect with existing systems, such as a building management system, a manufacturing execution system, distributed control system, or to other parts of their plant.

PLC-based BMS solutions can control single burners or multiple burners, while providing much more operating information and diagnostics. For example, they can indicate whether a specific damper is not open or not closed, or if particular valves are functioning as they should. BMS designers can choose flame scanners from any manufacturer. For redundancy, they can use more than one flame scanner. As one of the examples, when coupled with special voting logic in the PLC, this redundancy can provide the basis for high integrity systems that eliminate unnecessary shutdowns due to faults in an I/O circuit or field device. Predictive maintenance can be programmed into the systems, while diagnostics make them much easier to troubleshoot.

Safety standards governing BMS design

Many standards govern BMS design, among them are the NFPA, ISA, and TÜV as previously described. Equipment standards also apply, such as the Underwriters Laboratories (UL) that govern the components that are in such a system, as well as approvals from FM and IRI organizations. Most of these standards refer to what is called "as listed," a term used frequently. But what's not common is a piece of equipment that's standards-listed as a whole. Altogether, many standards have roles in deciding BMS safety requirements.

In the U.S., implementation is governed by the NFPA. NFPA 85 applies to boilers, while NFPA 86 applies to furnaces and ovens. The 2015 revision updated many parts of these standards. NFPA 85 allows the use of safety PLCs, when SIL 3 capable, for both BMS and combustion (process) control in single burner boilers. It does require that multi-burner boilers feature a master fuel trip (MFT) relay, which is an electromechanical relay used to trip all required system components, including the fuel shutoff valves, in case of unsafe conditions. It also mandates that a hard-wired connection exist between the MFT relay and a flame safeguard. This can shut down the boiler's fuel supply, if sensors indicate that its flame has failed.

In contrast, NFPA 86 does not require an MFT relay, providing for direct valve control of fuel gas or oil. It also removes the hard-wired connection requirement of the flame safeguard. This allows the use of safety-rated PLCs in BMS and combustion control system designs. (NOTE: While this implies that safety PLCs can only be used on NFPA 86 applications, they can be used equally well with NFPA 85 and 86. In fact, we have used them on boilers.)

In NFPA 86-2015, for example, ratings of the Safety Integrity Levels (SILs) of an overall system design depend on the lowest (less safe) SIL level of a system component – the lowest common denominator. So, if a system incorporates a safety PLC with a SIL 3 rating, but the sensors and limit switches are wired in a way that achieves a SIL 1 rating, the overall system will be rated SIL 1.

NFPA 86-2015 specifically defines key terminology as related to furnace applications. Most important is the definition of a flame safeguard. It's a safety control device that responds to flame properties, senses a flame and indicates if a flame is present in a burner.

In prior versions, the flame sensor directly de-energized the fuel safety valve in the event of a flame failure. Now the flame safeguard that senses the flame only provides an indication whether a flame exists or has been lost. It no longer has to be hardwired to the fuel safety valve. This is of critical importance, as now the flame safeguard can be connected to a PLC controller in lieu of a direct connection to the safety valve circuit.

Regulations Summary

As BMS systems have evolved, so to have the standards that govern them and establish the best practices for their implementation and use. The National Fire Protection Association (NFPA) and UL have written most of the regulations. Other guidelines are provided by factory documentation.

Specifically, NFPA 85 (Boiler and Combustible Systems Hazard Code) covers boilers delivering less than 12.5 million BTU/hr.; NFPA 86 (Standard for Ovens and Furnaces) covers virtually all applications other than boilers. UL 795 (Commercial Industrial Gas Heating Equipment) applies to systems delivering less than 400,000 BTU/hr., while UL 508 (Industrial Control Equipment) governs construction standards. Generally accepted design standards can vary based on the manufacture.

For PLC-based BMSs, implementation is governed by the NFPA. Implementation of the PLC logic and other components, such as timers and relays, is crucial for safe systemic operation. Importantly, safety integrity levels (SIL) can be affected by improper implementation of the hard-wired portion of BMS systems, so the BMS system design is critical.

Other key changes In NFPA 86-2015 include the following:

- **Safety shutdown** – This is now defined as “stopping operations by means of a safety control or interlock that shuts off all fuel and ignition energy in a manner necessitating manual restart.” Another definition change is the “proof-of-closure” switch. While determining the position of the valve, whether oil or gas, there is typically a proof-of-closure switch that verifies a valve is in a full closed position. Before, the code said that this was to be built into the switch by the manufacturer and be activated when the valve closed. NFPA 86-2015 removed the part that said it was “installed in a safety shut-off valve by the manufacturer.” This particular change now allows the user to maintain the switch, adjust it and replace it if necessary. Previously the complete fuel valve had to be replaced.
- **Emergency shutdown valve** – This manual shutoff valve cuts off a system’s fuel, oil or gas, in case of a problem. The fuel typically resides outside the room where the equipment is located or outside the building in case of a small building. This way, if the whole structure is in flames, the burner flame can still be shut off from outside the building.

Safety PLC standards

NFPA 86-2015 section 8.4 covers the use of PLCs in BMS designs, starting with section 8.4.1 defines PLCs and their use. Section 8.4.4 defines the requirements for application of safety PLCs new. Because it is independent from the sections before it, the standards for conventional PLCs need not be followed, if a safety PLC is used, given the accepted safety principles that are inherent in safety PLCs.

The most important point of this part of NFPA 86-2015 is that the processor and I/O will be listed for control reliable service (not burner-specific) with a SIL rating of at least 2.

Also, the section states that safety functions shall be restricted to a certain area of the PLC. This answers the question about needing separate PLCs for combustion control and burner management, the latter of which is essentially a safety function. That is, if a safety PLC can also meet the code required for combustion control, one safety PLC can do both.

Note, however, that this does not apply to boiler BMS designs, which are governed by NFPA 85-2015. In other words, while combustion and burner control can use same safety PLC in furnaces, these functions must be separate in boilers. More specifically, NFPA 86-2015 says that all safety function sensors and final control elements shall be independent of operating sensors and final control elements shall be independent of operating sensors and final control elements. For example, if a limit switch, a pressure switch or an air flow transmitter is used in a boiler BMS design on the safety side of the system, then the same transmitter cannot be used on the control side.

Safety PLC-based BMS benefits

- **Increased safety at little-to-no added cost,** to lower risk profile and save insurance costs, not to mention lives
- **More security,** to protect system integrity and provide additional peace of mind
- **Greater deployment flexibility,** to provide cost-saving placement and multi-burner/facility options
- **Improved operational visibility/ efficiency/flexibility,** to lower fuel, training and labor costs, as well as faster troubleshooting
- **Improved uptime,** to reduce costly downtime, via predictive maintenance and preemptive diagnostics
- **Future-proof,** to provide cost-effective expandability

There are four exceptions to the use of a safety PLC:

- **Manual emergency switches,** because a BMS needs to have a manual way of shutting down, irrespective of the state of the PLC.
- **Continuous vapor controllers** must operate outside of the PLC. This refers to trying to operate a sensor or an analyzer must be outside the PLC to make the decision when the vapor concentration is too high.
- **Flame safeguards** must operate outside the PLC. That is, if a standard flame detection system is used that has a contact closure output, that contact closure can be wired to a safety-rated input on a PLC, so the flame sensor becomes a flame switch. This shows if a flame exists or not, so the logic and response can be moved to the safety PLC.

- **Excess temperature limit interlocks** that use a temperature controller, wired in series with the gas valve control signal from the PLC, so that the limit controller can shut down the gas valve, even if the PLC fails or is no longer in service.

Burner Management Systems: Design best practices

Advancements in PLC technology, especially safety-rated PLCs, have revolutionized BMS design. Safety PLCs are important because safety is a core goal of a BMS, along with operational control and efficiency. Today BMS designers can achieve these goals cost-effectively with a safety PLC. With this point in mind, let's look at the following four best practices in BMS system design and then consider each one in greater detail:

- **Meet and exceed NFPA safety-standards,** up to SIL 3, plus UL, FM, IRI and NEMA standards;
- **Ensure critical input checking** as well as diagnostics for predictive maintenance and troubleshooting;
- **Simplify burner operation via an easy-to-use HMI,** with remote accessibility and alarming;
- **Communicate with higher-level systems,** such as building management systems or DCS systems for facility- and enterprise-wide control;
- **Meet and exceed NFPA safety-standards** While the NFPA standards clearly define the safety features that BMS solutions require, many system design generalists – developers of conveyor systems, packaging systems and, today, a BMS – often think that just reading through the NFPA standards is sufficient for compliance.

  But it's not quite that simple. To comply with the NFPA standards up to SIL 3 and, at the same time, meet UL, FM and IRI standards, designers need to properly implement the system inputs and outputs in order to dynamically manage the flame controls and safety features. While NFPA standards clearly define the safety features and requirements of a burner management system – developers of conveyor systems, packaging systems, or other control systems (companies that might not regularly engage in designing burner management systems) need to know much more information than just what is contained within the NFPA standards. Proper design and implementation of burner management systems requires burner knowledge, understanding of safety devices and valves, and how all these components and systems integrate with the boiler or furnace.

  System security is also important. In many PLC-based BMS solutions, especially earlier generations, operators and maintenance personnel could access and modify the PLC logic, often without documenting what they did. In addition, their modifications might have accomplished their intended optimization of one or more BMS feature or function, but they unknowingly may have sub-optimized or even disabled a feature or feature set – increasing the system's accident potential.

  With a safety PLC, all the front- and back-end logic and security comes built-in, already developed and tested by the manufacturer, such as Siemens. If a safety PLC is used and implemented correctly in a BMS design, the SIL 3 requirement is met right from the start. What's more, NFPA, FM and IRI requirements will not only be complied with but also exceeded. What's more, system security is assured and all logic and data are backed up on a memory card. Finally, safety PLCs offer a higher level of security by leaving a historical trail of any modifications made to the program.

  These systems are compatible with other PLC systems, too, so if there are other ones in the plant with which the BMS needs to communicate, it can be done easily. Last, BMS designs can incorporate safety PLCs for not much more cost than a standard PLC – but with much more functionality, safety and value.

- **Ensure critical input checking** Critical input checking refers to the continuous and automatic assessment by a safety PLC that its inputs are working. If a BMS does not use a safety PLC, then the NFPA mandates that the system designer needs to develop and implement a strategy to verify that these inputs are not failing in an "on-state." Safety PLCs monitor their outputs to ensure they do not fail in an "on" state. This same capability is not built into a standard PLC, which otherwise required that layers of redundancy be built into the system design. Also, the NFPA requires redundancy on output fuel valve circuits. For example, some BMS designs have three relays, all of which have to open in an on-state to shut off the safety valve.

  BMS boiler designs must include a watchdog timer. This is used to detect and shutdown the burner(s) in case of a PLC timing fault. During normal operation, the PLC will regularly send a continuous pulse to the watchdog timer to keep it from timing out. Then, should a hardware or software malfunction occur the watch dog timer will trip the burner. Safety PLCs utilize many more safety algorithms, which either eliminate or minimize the need for a watchdog timer.

  Good BMS designs provide fail-safe shutdown of the fuel and ignition sources. The systems should notify the operator and maintenance personnel of the cause of the shutdown, and the system may even offer corrective advice to trouble shoot the cause of the shutdown.

If problems do occur, these built-in diagnostics will enable faster troubleshooting and help to minimize operational disruptions. Good system designs will also include trending and historical recording of operating parameters, which help troubleshooting and are useful for analyzing operating efficiency. With historical data, operators can quickly tell what safety switch might have tripped repeatedly during the night and fix that particular switch, rather than having to stand by and wait for a system fault, then figure out which switch caused it. Historical alarming and trending can prove to be useful troubleshooting and predictive maintenance tools that will improve reliability and reduce downtime.

- **Simplify burner operations via an easy-to-use HMI** Today's HMI (Human-Machine Interface) has progressed far beyond yesterday's indicator lights, MFTs and e-stop buttons. Advanced HMIs, such as the Siemens SIMATIC HMI Comfort Panel, incorporate all these elements and are designed to be operator-friendly – that is, easy to learn and to use. These new HMIs coupled with operator prompting messaging and alarming, provide for easier operation making the transition from a maintenance technician to an operator much easier.

With a BMS using a Siemens HMI, operator information is readily available and alarms are annunciated right on the HMI, so operators can walk up and quickly see all the operating conditions. The typical boiler screen shows the operator the status of fuel valve(s), with color changes, all recent alarms, and easy navigation to other operator screens providing additional operating information. It can also show gas and air flows for combustion control, animated damper movements and position, and the status information for all other burner management and other related equipment. The HMI enables easy viewing of all operating information.

Other HMI screens provide additional information such as boiler pressures, flows, valve positions, valve open/closed status and the ability to change the operating set points as well as auto/manual control. Combustion control set up screens provide for one person setting of the fuel air curves eliminating the need for both a burner service engineer and a PLC expert. The HMIs can also provide push-button access to schematic wiring drawings, piping and instrument drawings, as well as drawings for the furnace, oven or boiler. For example, all drawings can be accessed with a simple PDF viewer, operators and maintenance personnel don't have documentation is available at the touch of a button.

Remote accessibility and alarming are big conveniences that modern HMIs provide, tied into a safety PLC-based BMS. Now, operators and maintenance personnel can securely connect with a BMS from anywhere in a plant facility, via its wireless network, or, via the Internet, from anywhere in the world. They can use their smartphones and tablets to check in on a BMS and alarms can be sent to them. This can free them from being physically present to take care of operating issues, so they can attend to more important work.

- **Communicate with higher-level DCS systems**
Another big feature of an advanced HMI – and one that best-practice BMS design should incorporate – is the ability to communicate with other PLCs, higher-level building automation and plant control systems, like a manufacturing execution system (MES). Of course, external communication requirements for a BMS will vary, depending on the facility, but plant operators, environmental managers and management today want to know more – like what the operating issues are; what fuel consumption is; how many run-time hours; and other data – so they can have greater visibility into overall performance to ensure maximum safety and efficiency. HMIs now feature integrated USB interfaces for simple archiving via a USB flash drive as well as for communicating via field bus or Ethernet protocols.

Siemens offers two safety PLC-based BMS solutions:

1. A basic, economical BMS based on the Siemens SIMATIC 1200F safety PLC.
2. A mid-range BMS based on the Siemens SIMATIC 1500F safety PLC.

Conclusion

A major benefit of a safety PLC-based BMS with an integrated HMI is ease of operation coupled with the availability of operator status and alarm information both locally and remotely. Unlike traditional hard-wired systems that employ lights and an alarm annunciator, an HMI can display and track the status of all variables and alarm points in a concise, easy-to-understand way. Start-up and trip issues are clearly displayed for operator attention making troubleshooting easier.

In all, safety PLCs in a BMS solution increase safety and system availability via built-in safety checks and standards compliance. They are easy to program, easy to configure and easy to use, with integrated diagnostics, clear displays of critical safety information on the HMI, remote operator access and maintenance flexibility.

Safety PLC-based BMS systems can efficiently respond to critical events based on a variety of highly robust controls and sensors. For integration with standard control schemes, these same PLCs can communicate with almost any third-party control or monitoring systems via a variety of industrial networking protocols.

Finally, all this offers operators much less risk and complexity, along with compliance to all industry standards. At the same time, it provides a flexible design configuration that can save costs and boost productivity.

Application example for burner installations

For burner installations and furnace solutions (continuous furnaces or boiler melting furnaces), new function blocks are at your disposal. On the one hand, the burner application example for TIA Portal supports all national and international standards EN 746-2, EN 676, EN 298, ISO 13577, NFPA 85/86, etc. and, on the other hand, all relevant and important functions such as:

- Control of ignition/gas or oil burners
- Performing a (pre) purge of the combustion chamber
- Cleaning/blowing out an oil burner
- Performing a tightness test on gas valves
- Control and monitoring of air dampers (or actuators with discrete position feedback)
- Control and monitoring of analog actuators
- Function for fail-safe evaluation of standard AI values

The function blocks are additionally prepared for realization of an electronic ratio control. To receive this burner application example at no charge by email, please send an email to amps.automation@siemens.com

: First and Last Name, contact number, Company and Company email address, with the email subject "Request for Burner Application Example"
The Burner application example will be sent to you, as a ZIP-file (@ 5 Mbyte) by email. It includes: Burner Library blocks for the PLCs S7-1200F, S7-1500F, Burner Library blocks for the PLC S7-300F and detailed Documentation. The (archived) library must be integrated into the TIA Portal (Extras>Global Libraries>Retrieve Library...) and will then be available in the tab "Libraries".

Disclaimer

The products and information, described herein were developed for the assumption of safety-oriented functions as part of an overall system or machine. A complete safety-oriented system generally comprises sensors, evaluation units, signaling devices and concepts for safe disconnection.

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