

# Role of fired heater safety systems

**A fully automated burner management system operating as a SIS for burner control can meet minimum safety targets, improve system availability and lower costs**

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**S**afety and risk mitigation have always been, and always will be, an important topic for any operating company. Safety risks can be lurking anywhere throughout a facility and the consequences of an event range from minor incidents to catastrophic failures that lead to a loss of life. Protective systems are put in place to reduce the likelihood of occurrence of safety incidents and to take action in the event that unsafe conditions arise. While the safety and well being of personnel is of utmost importance, the financial impact of safety systems cannot be ignored. With so many options available, selection of a safety system can prove challenging but can also be rewarding.

Minimum safety goals must be met, but a safety system can go beyond meeting safety requirements to improve overall operations and profitability. This article will discuss common risks associated with fired heaters, the role of the safety system, applicable standards and practices, safety instrumented systems (SIS) and the benefits of an automated burner management system (BMS), including an example of cost savings.

## Fired heater operation and risk

Process fired heaters present significant safety risks. Common in refineries and chemical facilities, they are used for heating, vaporisation and thermal cracking of various process fluids. Heat energy, provided by the combustion of fuel, is transferred to a charge or feed in a controlled manner. The primary functions of a process fired heater

are to maintain the desired outlet temperature at the desired charge rate. Besides maintaining temperature and charge rate, control and safety systems are designed to maintain efficient combustion of fuel and safe operation throughout the full range of conditions the heater experiences. Figure 1 shows a typical process fired heater.

Burners in the heater transfer energy into the process through the combustion of fuel. As with any combustion process, care must be

taken to ensure safe operation. Fuel can accumulate when burners are off but should be on and also from substoichiometric conditions. Fuel must not be allowed to accumulate in the firebox as subsequent introduction of an ignition source could be catastrophic. In addition to combustion risks, fired heaters present risks associated with the process. Unlike boilers, where the process stream is water, the process stream for most fired heaters is highly flammable hydrocarbons.

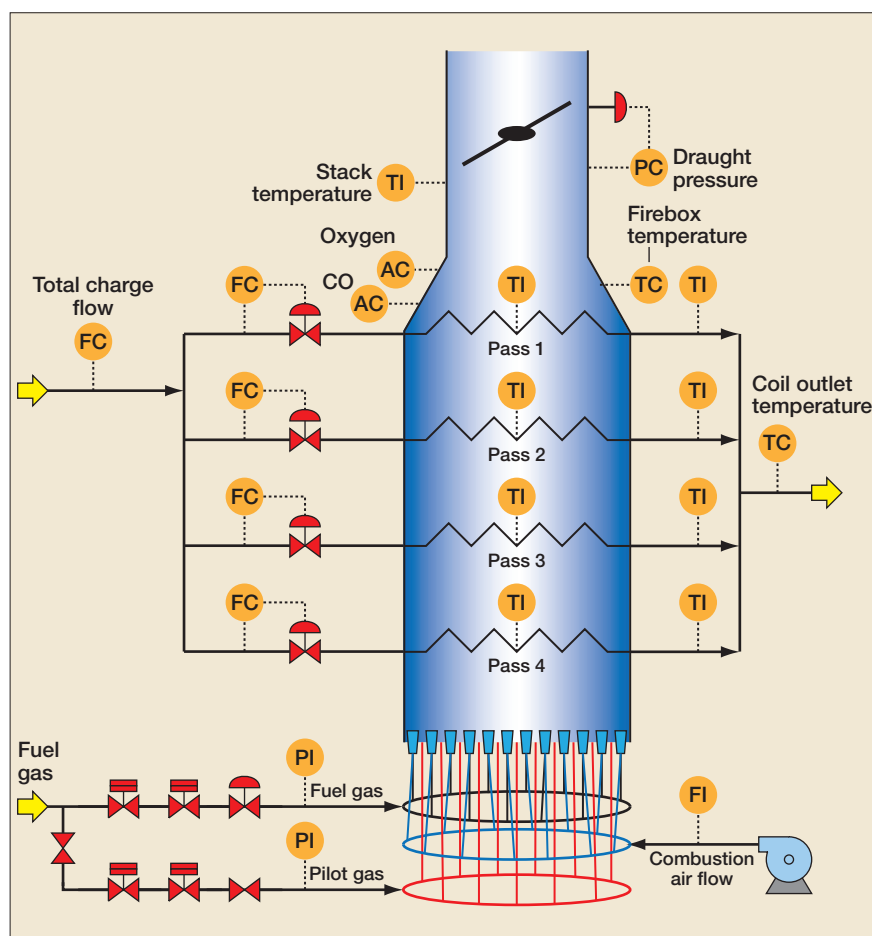


Figure 1 Typical process fired heater

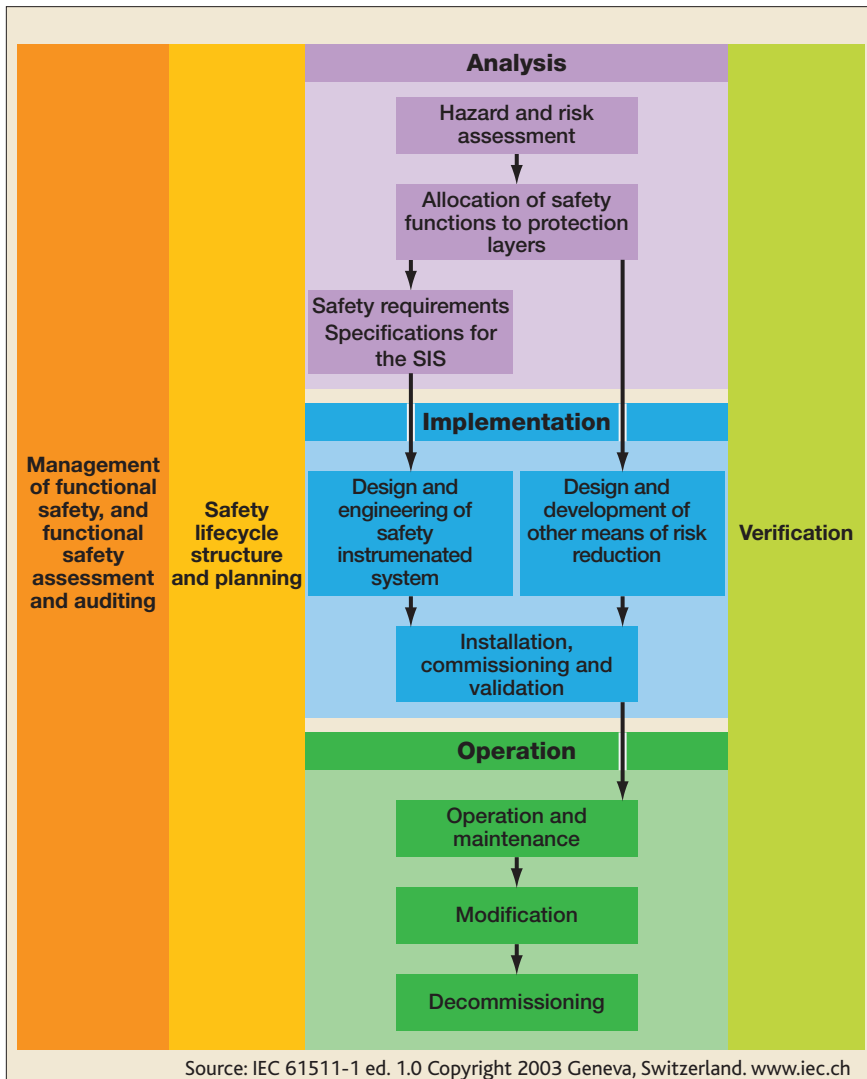


Figure 2 Safety lifecycle as per ISA 84.00.01 2004

Overheating or overfiring can cause process tubes to exceed metallurgical limits and rupture. In cases where tube leaks occur, resulting explosions can destroy process equipment and pose a threat to human life. The release of the process stream into the surroundings can pose an environmental threat. Even minor events can result in extended downtime for repair, impacting production.

The purpose of the fired heater safety system is to prevent disastrous combustion of accumulated fuel and to prevent overheating and the subsequent catastrophic release of the process stream. It sounds simple enough to inhibit the admission of fuel when unsafe conditions exist, but the determination of a safe state requires careful monitoring of many conditions. In particular, conditions such as fuel gas pressure and flow, furnace

draft pressure, flame detection, process stream flow, combustion air flow, tube skin temperature, stack temperature, per cent oxygen and combustibles all pose an operational threat if limits are exceeded. The safety system must continuously monitor for unsafe conditions and take action when necessary, making it critical to understand all of the possible equipment failure modes and the potential impact to both the operating unit and personnel.

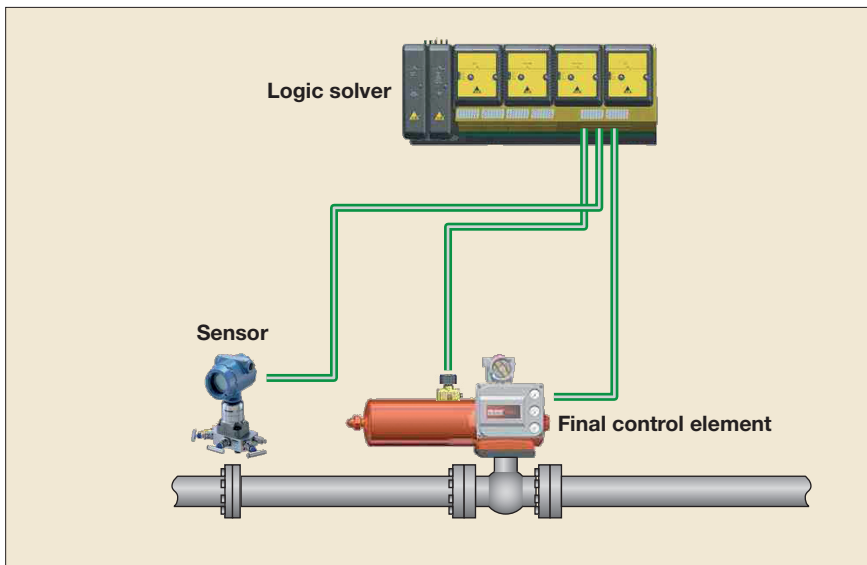
### Safety system design and selection

Every fired heater must have some type of safety system in place. It may be as simple as a written procedure for manual intervention or it may be a fully automated emergency shutdown system. The design and selection of a safety system starts with the evaluation of risk factors and risk tolerance. It

can be quite a daunting task to assess risk factors, assemble the interlock and permissive conditions and then determine which safety system to implement that meets both safety and financial targets. Fortunately, organisations such as NFPA, ISA, IEC and API publish documents that offer guidance for protective systems, which inform a user how to avoid a situation where the fuel supply should be off but is not, where the flame should be on but is off, where the process equipment is overheated, and where the protective system itself is prevented from working as it should. These standards also describe possible actions that the protective system can perform when it detects any of these situations. Each document has been developed based on experience and offers valuable information. The fact that accidents and disasters are as infrequent as they are is due to the long experience that has been incorporated into the various standards and recommended practices.

The National Fire Protection Association (NFPA) publishes *NFPA 86 Standard for Ovens and Furnaces*, which covers protective systems for process fired heaters. It applies to heated enclosures regardless of heat source. NFPA 86 is a prescriptive, conservative standard written like instructions with few options. While NFPA develops the standards, it does not enforce compliance to the standard. Insurers or local authorities may, in certain cases, enforce compliance.

IEC 61508 *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems*, developed by the International Electrotechnical Commission (IEC), provides the framework and core requirements for safety-related system design of hardware and software, independent of industry sector. IEC also released the document IEC 61511 *Functional Safety – Safety Instrumented Systems for the Process Industry Sector*, which defines the functional safety requirements established by IEC 61508 for the process industry sector specifically. The International Society of Automation (ISA)



**Figure 3** Elements of a safety instrumented system

released a document very similar to IEC 61511, ANSI/ISA 84.00.01-2004, and the two documents were merged into one standard, IEC 61511 - Mod. This standard is a performance-based, rather than prescriptive, standard that applies to SIS regardless of application, with no specific functions defined. S84-2004, as the merged standard is more commonly known, focuses on the safety lifecycle. Steps include identifying risks, assessing the risks and then reducing the risk by means of a SIS. Figure 2 shows the safety lifecycle as defined by S84-2004. The standard clearly defines the steps for designing the SIS and requires that users have a good understanding of their process hazards and risks. ISA also published a technical report, TR84.00.05 *Guidance on the Identification of Safety Instrumented Functions (SIF) in Burner Management Systems (BMS)*, which offers specific guidance on SIS used as BMS. This technical report offers recommendations for assessing SIF within a BMS and provides some example safety assessments.

The American Petroleum Institute (API) issued the second version of recommended practice, RP 556 *Instrumentation, Control, and Protective Systems for Gas Fired Heaters*, in April 2011. RP 556 applies only to gas-fired heaters and excludes boilers. In contrast to RP 560 *Fired Heaters for General Refinery Services*, which applies to

design and construction of heaters with little focus on instrumentation, the scope of RP 556 includes process measurement, process control and protective systems. RP 556 defines protective actions as basic process control action, operator action and SIS action, and includes input devices, logic solvers and output devices as components. Compliance with IEC 61511-MOD is recommended for SIF. Specific recommendations for safe states and startup and shutdown

## The design and selection of a safety system starts with the evaluation of risk factors and risk tolerance

sequences are described. This document, meant to be a recommended practice, is not a prescriptive standard and allows the sophisticated user to determine the best practice for their heater, leaving room for improvement and innovation. RP 556 was updated from an earlier release in May 1997 to reflect advances in safety automation and design procedures and implementation. The revised edition represents current cumulative best practices and provides a good

design specification for the process fired heater.

The preceding list is not an exhaustive list of standards and practices. There are more available, such as FM 7605, developed by Factory Mutual, which requires that any programmable logic controller (PLC) listed for use in combustion safeguard service meets the SIS requirements contained in IEC 61508. A European standard, EN 50156-1, covers electrical equipment for furnaces and invokes SIS requirements for BMS.

There is no regulation requiring compliance to any specific standard or practice so it is left up to the user to sort through the standards and recommended practices, adopt the methods best suited to their needs, and then follow through with those practices. While it may seem overwhelming, the freedom to select a system best suited to a specific user's needs provides an opportunity for innovation and improvement beyond minimum safety requirements.

### Safety instrumented systems

A common trend in all of the standards is the use of SIS for protective actions. By definition, a SIS is a set of components such as sensors, logic solvers and final control elements arranged for the purpose of taking the process to a safe state. Figure 3 shows the components of a SIS. These are separate from all other control systems such that, in the event of a failure of the control system, the SIS is not prevented from performing the SIF. Certified SIS systems follow a stringent certification process and are designed, maintained, inspected and tested per applicable standards and recommended practices. Safety rated hardware is more robust and experiences fewer device failures than traditional hardware. SIS offer the benefits of improved safety, increased system availability and compliance with standards and practices. The benefits can be extended to operational benefits by taking advantage of safety systems that go beyond meeting minimum safety requirements and can actually improve operational efficiency.

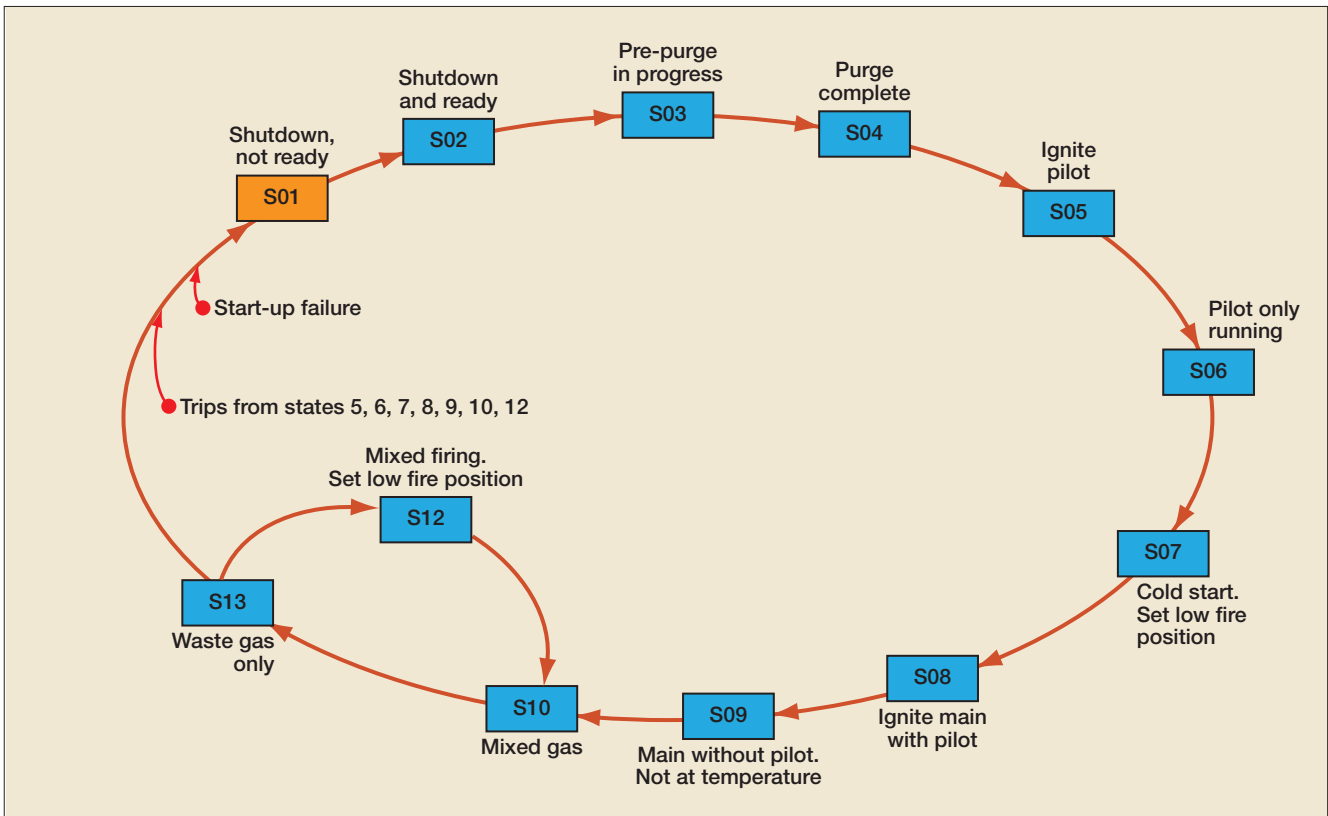


Figure 4 Example of a burner management sequence

**Going beyond minimum safety requirements**

A BMS represents a great opportunity to go beyond the minimum requirements and can simultaneously meet safety targets and provide operational benefits. By definition, a BMS is a system to monitor and control fuel burning equipment during all startup, shutdown, operating and transient conditions. They can range from a simple procedure that requires manual verification before proceeding or a fully automated system that automatically detects conditions and takes action.

A fully automated BMS uses sequence logic designed with a set of states, transitions, outputs and trips. The sequence is only allowed to proceed to the next step and take action if the permissive conditions for the transition are met. Permissive conditions are designed such that a safe environment is confirmed before proceeding. Examples of permissive conditions include fuel block valve positions, flame detection, minimum process flow, purge flow and purge timer. While in any state, interlock or “trip” conditions are designed so

that a safe state is initiated when unsafe conditions are detected. Example interlocks include loss of flame, loss of combustion air, high or low fuel pressure, and excess process pressure or temperature. Should an interlock condition be detected, a fully automated BMS will initiate a safe state and, if necessary, shut off the fuel supply.

Consistent with the standards and recommended practices, a BMS can be treated as a SIS and the safety lifecycle can be followed. Minimum safety requirements can be satisfied through permissive and interlock conditions in the sequence logic and the associated SIF can be SIL rated. Figure 4 shows an example of a BMS sequence.

The sequential framework of a fully automated BMS provides additional value beyond meeting minimum safety requirements. One benefit is a significant reduction in startup time. Light-off events for fired heaters may only occur once every two to three years, so the startup procedure may be unfamiliar to operators. Due to the inherent danger associated with light-off, each step in the process must be carefully executed. A manual

startup procedure may, therefore, be a lengthy process to complete.

When the startup procedure is a manual operation, each permissive must be manually verified before proceeding. Let us consider a fired heater with multiple burners and each with the associated gas valves. It could take a significant amount of time for an operator to manually check the valve positions based on the location of the heater and the individual valves. This also assumes the operator can correctly locate each valve and is careful to check them all. This manual confirmation may take a significant amount of time and has the potential for human error. A BMS with an automated sequence for light-off can save valuable startup time by eliminating the need for operators to manually verify valve position, detect a flame or manually time a purge.

The automated sequence ensures that each step is properly executed and eliminates human error associated with possibly verifying the wrong valve or condition, as the sequence will check for the correct condition at the correct time. Even further, a BMS with a graphical



user interface that is easy to understand and clearly indicates status eliminates the need for operators to understand and sort through complex logic diagrams. A clear first out indication should be provided to the operator to ensure they know exactly what is preventing a startup or what caused a trip. This saves many hours' troubleshooting when compared to a manual process or PLC-based solution, where inherently dangerous trial and error procedures must be used to determine what condition is preventing startup. Instead, the specific trip condition can be addressed quickly. Figure 5 shows an example of a graphical user interface for an automated BMS.

Diagnostic data can also play a role in an automated BMS. The use of smart devices and HART communication for system hardware fault identification and field device failure alerts provides continuous monitoring of sensors, logic solvers and final elements so that faults can be diagnosed early. This diagnostic data can be integrated with the BMS so that its overall integrity can be maintained, reducing spurious trips that significantly reduce operations and maintenance cost.

Table 1 shows an example of a cost savings calculation associated with a two-hour reduction in startup time for a typical 200 000 b/d refinery with typical downstream processing capacities. The savings calculated are for a single light-off event. For example, a two-hour reduction in startup time for a single heater in a hydrocracker unit equates to savings of \$100 000 and \$300 000 if you consider all three heaters in the unit. In the case of the reforming unit, where margins are even higher, the savings equate to over \$250 000. A typical refinery may have three or more hydrotreating units, and thus the \$17 000 estimated savings would apply to each unit, such as hydrotreating units for naphtha, diesel, heavy oil and possibly jet fuel. The total annual savings will depend on the number of light-off events for each heater and the margin associated with the

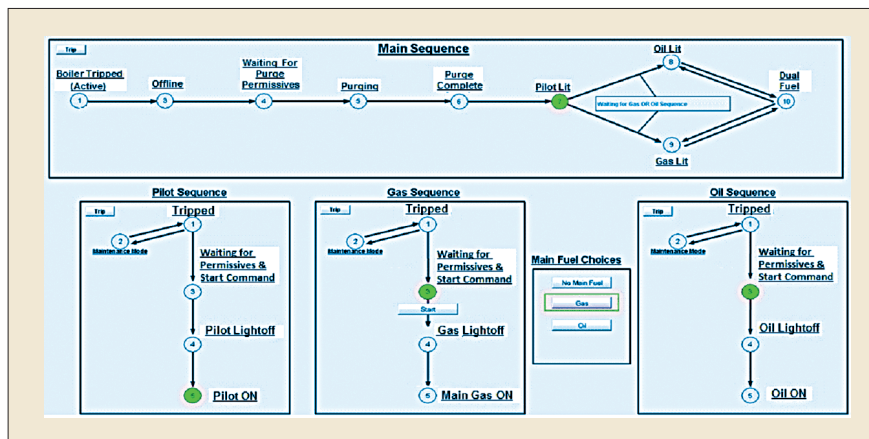


Figure 5 Graphical user interface for BMS

specific unit. In cases where spurious trips are reduced through integration of device diagnostics in the BMS, the savings are even greater. The savings associated with automating the light-off sequence to reduce the startup time and integrating device diagnostics to reduce spurious trips are significant and simultaneously ensure a safer facility.

### Conclusion

Safety systems are required to protect personnel and environment, but can go beyond meeting the minimum requirements and provide financial benefits as well. The applicable standards and recommended practices provide guidance for safety system design and selection criteria, and also provide an opportunity for innovation and

improvement. Implementing a fully automated BMS as a SIS for burner control and monitoring can simultaneously meet minimum safety targets, improve system availability and lower costs.

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Sample cost savings for a fully automated BMS to reduce startup time				
Unit	Heater	Margin \$/bbl	Two-hour value	Unit total
Crude distillation	Crude heater	\$2	\$33 334	
	Preflash heater	\$2	\$33 334	\$66 668
Vacuum distillation	Vacuum heater	\$1	\$16 666	\$16 666
FCC	Feed heater	\$6	\$100 000	\$100 000
Alkylation	Isostripper reboiler			
	Heater	\$4	\$66 666	\$66 668
Hydrotreating	Reactor feed heater	\$1	\$8334	
	Stripper reboiler heater	\$1	\$8334	\$16 668
Reforming	Reactor feed heaters	\$8	\$133 334	
	Stabiliser reboiler heater	\$8	\$133 334	\$266 668
Hydrogen plant PSA	Reformer reactor furnace	\$8	\$133 334	\$133 334
Hydrocracking	Feed heater	\$6	\$100 000	
	Fractionator heater	\$6	\$100 000	
	Stabiliser reboiler heater	\$6	\$100 000	\$300 000
Coking/thermal cracking	Feed heater	\$8	\$133 334	\$133 334

Example savings calculation associated with two-hour reduction in unit startup time for a 200 000 bpd refinery with typical downstream processing capacities.

Table 1