

<p><b>KLM Technology Group</b></p> <p>Practical Engineering Guidelines for Processing Plant Solutions</p>	 <p><b>ENGINEERING SOLUTIONS</b></p> <p><b>www.klmtechgroup.com</b></p>	Page : 1 of 80
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<p>KLM Technology Group P. O. Box 281 Bandar Johor Bahru, 80000 Johor Bahru, Johor, West Malaysia</p>	<p><b>Kolmetz Handbook Of Process Equipment Design</b></p> <p><b>BURNER MANAGEMENT SYSTEMS SELECTION, SIZING AND TROUBLESHOOING</b></p> <p><b>(ENGINEERING DESIGN GUIDELINES)</b></p>	Co Authors Rev 1 Apriliana
		Editor / Author Karl Kolmetz

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## INTRODUCTION

### Scope

This guideline provides knowledge on designing a Burner Management System and the basic design of a Burner Management System. Fired heaters and boilers are essential components of most refineries, chemical plants and power generation facilities.

Process heaters are widely used in petroleum refineries. A fired heater will work well if designed properly. The design requirements must be properly addressed. Fired heater performance can be measured by a combination of operability and maintenance. A properly run furnace is a safe furnace. Skillful handling of a furnace means safety for the worker.

The majority of accidents that occur in plants are preventable and many are in heaters and boilers. Often, defective or incomplete monitoring of boiler functions is a primary cause of plant-related injuries. Unsatisfied permissive interlocks, unmonitored boiler conditions, and boiler and burner trips also pose a serious threat towards plant safety.

A Burner Management System is a complicated control system which requires continuous monitoring and inspection at frequent intervals. There are possibilities of errors at measuring and various stages involved with operators. These systems can help protect people, combustion process equipment, and surrounding areas in the event of an explosion or hazardous incident.

Design and installation of an effective state-of-the-art burner management system can be critical in ensuring the safety and efficient performance of industrial heating systems.

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## General Design Consideration

Burners, furnaces and boilers are very critical and complex systems. The burner is where the gas or fuel oil is delivered and burned to produce heat. The burner may be located in the floor and fired upward. Flame temperature resulting from the burner is set according to the needs of the desired heat. Large heaters have multiple burners. The burners are where the combustion process takes place.

Combustion is the oxidation of a mixture of fuel and air. Combustion will take place perfectly when fuel, temperature and turbulence are controlled. For this, turbulence is important because fuel and air must be mixed perfectly. If the fuel and air perfectly mixed and the entire fuel burning, temperature will be a high flame and combustion time will be shorter.

The majority of accidents that occur in plants are preventable. Often, defective or incomplete monitoring of boiler functions is a primary cause of plant-related injuries. Unsatisfied permissive interlocks, unmonitored boiler conditions, and boiler and burner trips also pose a serious threat towards plant safety.

Boiler burner management system is a complicated control system which requires continuous monitoring and inspection at frequent intervals. There are possibilities of errors at measuring and various stages involved with operators. These systems can help protect people, combustion process equipment, and surrounding areas in the event of an explosion or hazardous incident

Burner Management System (BMS) is a safety system for thermal power plant that enables the safe start-up, operation, and shut down of the multiple-burner furnace section of a boiler. These systems are designed to work efficiently with a variety of fuels including natural gas, oil, pulverized coal, solvents, off gases, biomass and other solid fuels for maximum reliability, flexibility and safety of thermal power plant. The system shall be designed to ensure the safe start-up, on-line operation and shutdown of fuel firing equipment.

The BMS initiates a safe operating condition or shutdown procedure to prevent an explosion if an unsafe condition exists, thus protecting equipment from damage and

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people from injury or death. The BMS essentially is on/off control system that permits firing of a boiler at any load when safe condition exist. If an unsafe condition occurs, the BMS automatically shuts off fuel or cause the boiler go to safe state. These systems are also designed to meet national and international standards and regulations. The proper designing of BMS increases the overall efficiency of the power plant and also decreases the maintenance cost as well as smooth operation of boilers.

Burner management system components shall be located in the combustion control cabinet and shall be fully integrated for automatic sequencing of light-off and shutdown. An industrial duty microprocessor-based BMS shall monitor safety interlocks, Actuator position, and flame status. The controller shall sequence the Burner through purge, light-off, run, shutdown, and post-purge.

Many BMS systems are capable of firing up to different fuels. Fuel selection must be determined by hard-wired contact or Modbus link according to user configuration. Additional BMS functions shall include as a minimum:

- All recycle and shutdown interlocks will be wired to separate, parallel 120 VAC inputs. Analog sensors for gas or oil pressure shall not be required.
- The controller shall supply both 120 VAC and 24 VDC power for flame scanner(s). To prevent nuisance trips, dual flame scanners shall be wired into separate digital inputs. Analog (flame signal quality) inputs shall be used for flame strength indication only.
- To minimize thermal stress to fired equipment "assured low fire cutout" shall be provided to drive the burner firing rate to low fire before shutting down the burner.
- Because dry boiler operation is a leading cause of boiler explosions and meltdown, flue gas temperature shall be input to the controller and monitored to alarm or trip the burner in the event the boiler is dry-fired and the low water cutouts malfunction.
- Adjustable time delays (up to four seconds) shall be provided for the low fuel pressure, low atomizing flow, and low draft cutout interlocks to reduce nuisance shutdowns due to transient conditions.
- The controller shall accommodate automatic gas valve leak detection when required by the user.

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- To prevent unsafe purging of oil guns, oil gun purge logic shall be provided to enable either the safe purging of any resident oil in the atomizer into the furnace (with pilot energized), or the activation of a scavenging pump to draw the unused oil out of the oil gun.
- A minimum of five user-configurable auxiliary relays shall be provided for alarm, or to start auxiliary fans, oil pumps, oil heaters, gas booster pumps, etc.
- When the optional in-situ oxygen analyzer is provided, the controller will alarm and/or shut down the burner when a user-configurable low stack oxygen set point is reached.
- To allow easy controller trouble-shooting, individual annunciation shall be provided for up to nine recycle limits and thirty-three non-recycle (shutdown) limits.
- The controller shall provide time/date stamp of individual servo positions, status of each digital input, and the status of all controlled functions for up to the last ten boiler shutdowns.
- BMS shall include Modbus communications. A common dry alarm contact output shall be supplied for the Building Management System for any fault or alarm condition related to the Flame Safeguard System.
- To ensure a safe and reliable system, flame safeguard logic and associated software shall be recognized by Underwriters Laboratories

The main control strategies in boiler burner management system are: primary control and combustion control. In the primary control allows fuel to flow only when all of the safe conditions for fuel ignition are met. The combustion control regulates furnace fuel and air ratio within limits for continuous combustion and stable flame throughout the demand operating limits of the boiler.

The major steps in boiler burner management system are:

- checking boiler self-protection for startup,
- pre-purging, pilot trial and ignite,
- main burner trial and ignite,

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- maintaining air/fuel ratio according to the load demand and
- post-purging after burner stop.

A burner management system (BMS) is a safety solution that manages a combustion system and is responsible for:

- Start-up and main flame detection
- Control and monitoring
- Shutdown sequences

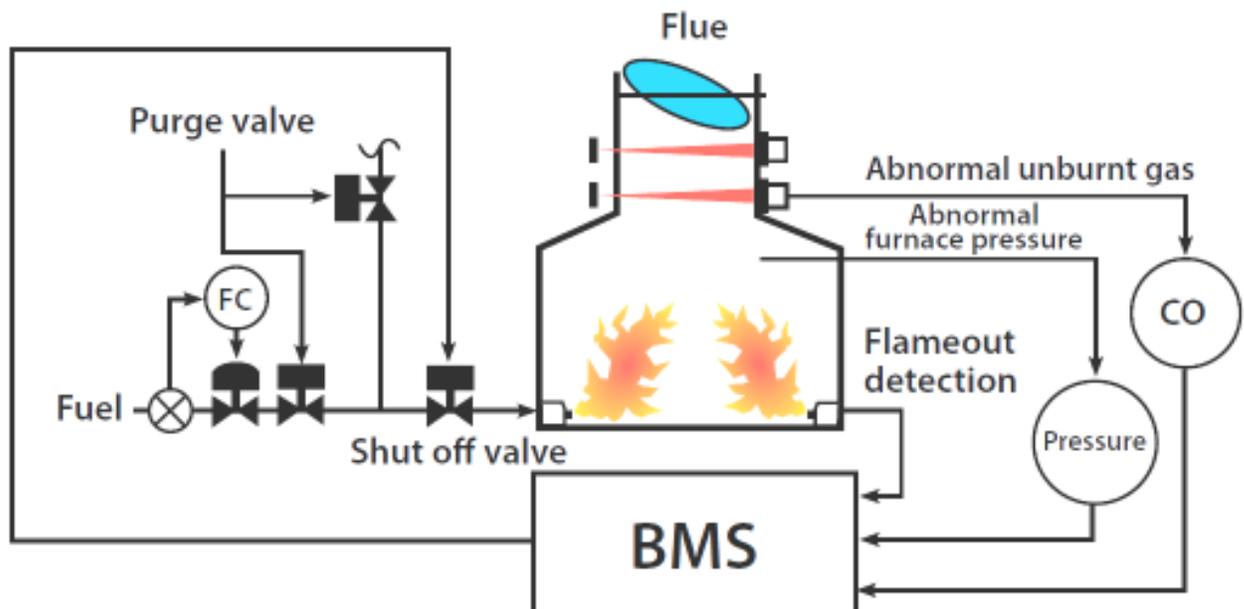


Figure 1: A burner management system (BMS)

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The purpose of a BMS

- To inhibit / stop startup when unsafe conditions exist.
- To protect against the unsafe operating conditions and admission of improper quantities of fuel to the furnace.
- To provide the operator with status information – operator assistance
- To initiate a safe operating condition or shutdown interlock if unsafe condition exists.
- The BMS is a control system dedicated to boiler furnace safety and operator assistance

Burner Management Systems have been typically designed in the past through applying the prescriptive requirements contained in codes / standards.

A furnace explosion requires both a sufficient flammable mixture and sufficient energy for ignition within the furnace. The ignition requirements for an explosive charge are very small, making it almost impossible to protect against all possible sources of ignition, such as static electricity discharges, hot slag, and hot furnace surfaces. Therefore, the practical means of avoiding a furnace explosion is the prevention of an explosive accumulation of fuel.

The explosive accumulation is formed in the following basic ways:

- A flammable input into any furnace atmosphere (loss of ignition)
- A fuel-rich input into an air-rich atmosphere (fuel interruption)
- An air-rich input into a fuel-rich atmosphere (air interruption)

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The specific safety interlocking depends upon the physical characteristics of the firing system and the type of fuel or fuels being fired. All Burner Management Systems, however are typically concerned with the following functions:

- A pre-firing purge of the furnace.
- Establishment of the appropriate permissive for firing the ignition fuel (i.e. purge complete, fuel pressure within limits).
- Establishment of the appropriate permissive, including ignition permissive, for the main (load carrying) fuel.
- Continuous monitoring of the firing conditions and other key operating parameters.
- Emergency shutdown of portions or all of the firing equipment when required.
- A post-firing purge.

### **BMS and Safety**

There are many BMS systems running today which do not comply with current standards. They are either using non approved standard PLC's or antiquated relay based control systems. Not only is the potential failure to danger a risk to man and machinery but even non dangerous sporadic failures can be difficult to troubleshoot (fault find) and lead to costly down time.

The fact BMS are installed which do not fulfill appropriate safety levels is not the only reason to change such a BMS: often these relay based control systems have reached a life cycle stage where relays do not work reliably any longer.

For small BMS it is rather easy to fix such an error. But as many modifications are done during time critical situations (unexpected downtime during a failure: the system has to be made operable again) changes are often not documented which makes the next repair more difficult. Therefore even small BMS applications with traditional relay control are not maintainable after a certain time.

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## DEFINITIONS

**Alarm** - An audible or visible signal indicating an off standard or abnormal condition

**Atomizer.** The device in a burner that breaks down liquid fuel into a finely divided state.

**Boiler Control System** - The group of control systems that regulates the boiler process, including the combustion control system but not the burner management system.

**Boiler-** A closed vessel in which water is heated, steam is generated, steam is superheated, or any combination thereof by the application of heat from combustible fuels in a self contained or attached furnace.

**Burner Management System** - The control system dedicated to combustion safety and operator assistance in the starting and stopping of fuel preparation and burning equipment and for preventing mis-operation of and damage to fuel preparation and burning equipment.

**Burner** - A device or group of devices for the introduction of fuel and air into a combustion chamber at the velocity, turbulence, and concentration required to maintain ignition and combustion of fuel.

**Combustion Air** - Air used to react with the fuel in the combustion process. For duct burners, this generally is combustion turbine exhaust

**Combustion Chamber** - The portion of the boiler or HRSG enclosure into which the fuel is fed, ignited, and burned.

**Combustion Control System in a Fluidized Bed** - In a fluidized bed, the control system that regulates the furnace fuel input, furnace air input, bed inventory, and other bed heat transfer mechanisms to maintain the bed temperature and the air fuel ratio within the limits necessary for continuous combustion and stable bed operation throughout the operating range of the boiler in accordance with demand.

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**Combustion Turbine** - A turbine in which the rotating element is actuated by the pressure of combustion gases on curved vanes.

**Commissioning** - The time period of plant testing and operation between initial operation and commercial operation

**Duct Burner** - A burner, mounted in a duct or discharging into a duct, used to heat the air, flue gas, or combustion turbine exhaust gas in the duct.

**Flame Detector** - A device that senses the presence or absence of flame and provides a usable signal.

**Flame Envelope** - The confines (not necessarily visible) of an independent process that converts fuel and air into products of combustion.

**Flame** - A body or stream of gaseous material involved in the combustion process and emitting radiant energy at specific wavelength bands determined by the combustion chemistry of the fuel. In most cases, some portion of the emitted radiant energy is visible to the human eye

**Fluidize** - To maintain a bed of finely divided solid particles in a mobile suspension by blowing air or gas through the bed at such a velocity that the particles separate and behave much like a fluid

**Fluidized Bed** - A bed of granular particles maintained in a mobile suspension by the velocity of an upward flow of air or gas.

**Fuel Trip** - The automatic shutoff of a specific fuel as the result of an interlock or operator action

**Furnace** - The portion of the boiler enclosure within which the combustion process takes place and wherein heat transfer occurs predominantly by radiation.

**Heat Recovery Steam Generator (HRSG).** A heat exchanger that uses a series of heat transfer sections (e.g., superheater, evaporator, and economizer) positioned in the

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exhaust gas flow of a combustion turbine to recover heat and supply a rated steam flow at a required temperature and pressure.

**HRSG Control System** - The group of control systems that regulate the HRSG process, including the combustion control system but not the burner management system.

**HRSG Enclosure** - All ductwork from the combustion turbine exhaust through the steam generator to the stack, including any bypass duct connection.

**Igniter** - A permanently installed device that provides proven ignition energy to light off the main burner

**Interlock** - A device, or an arrangement of devices, in which the operation of one part or one mechanism of the device or arrangement controls the operation of another part of another mechanism.

**Logic System** - The decision making and translation elements of the burner management system. A logic system provides outputs in a particular sequence in response to external inputs and internal logic.

**Natural Gas** - A gaseous fuel occurring in nature and consisting mostly of a mixture of organic compounds, normally methane, ethane, propane, and butane. The calorific value of natural gases varies between about 26.1 MJ/m<sup>3</sup> and 55.9 MJ/m<sup>3</sup> (700 Btu per ft<sup>3</sup> and 1500 Btu per ft<sup>3</sup>), the majority averaging 37.3 MJ/m<sup>3</sup> (1000 Btu per ft<sup>3</sup>).

**Open Flow Path** - A continuous path for movement of an airstream from the forced draft fan inlet to the stack; in an HRSG or other combustion turbine exhaust system, a continuous path for movement of an airstream through the HRSG system or other combustion turbine exhaust systems.

**Operating Range** - The range between the maximum fuel input and minimum fuel input within which the burner flame can be maintained in a continuous and stable manner.

**Pressure/Air Lock** - A device for transferring pulverized fuel between zones of different pressure without permitting appreciable flow of air or gas in either direction.

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**Pulverizer** - A machine for reducing the particle size of a solid fuel so that it burns in suspension.

**Purge** - A flow of air or an inert medium at a rate that will effectively remove any gaseous or suspended combustibles and replace them with the purging medium.

**Scavenging** - The procedure by which liquid fuel left in a burner or igniter after a shutdown is cleared by admitting steam or air through the burner passages, typically through a scavenging medium valve.

## NOMENCLATURE

A	= the area of the pool, (ft <sup>2</sup> )
A <sub>Pool</sub>	= the flammable pool area, (ft <sup>2</sup> )
C <sub>p</sub>	= liquid heat capacity, (J/Kg-K°)
d	= the distance to a given overpressure, (ft).
F <sub>IndividualRisk</sub>	= individual risk target, failure/year.
F <sub>LOPA</sub>	= the frequency of the event per the Layer of Protection Analysis, failure/year
F <sub>Target</sub>	= the risk target, failure/year.
H <sub>c</sub>	= the heat of combustion, (J/Kg)
H <sub>v</sub>	= the heat of vaporization, (J/Kg)
MEZ <sub>Area</sub>	= Maximum Effect Zone Area, (ft <sup>2</sup> ).
m <sub>flammable</sub>	= the flammable mass, (lbs)
m <sub>TNT</sub>	= the equivalent weight of TNT, (lbs)
o <sub>p</sub>	= the peak overpressure, (psi)
P	= the bursting pressure of the vessel, (psia).
PFD	= Probability of Failure of Demand.
PF <sub>EffectZone</sub>	= the the Physical Explosion Effect Zone, (ft <sup>2</sup> ).
PFF	= the Pool Fire Factor.

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- PLL = Probable Loss of Life (i.e. number of fatalities in the effect zone)  
 R = the radiation intensity endpoint, (kW/m<sup>2</sup>)  
 RRF = Risk Reduction Factor.  
 Tb = the Boiling Temperature, (K°)  
 V = the volume of the vessel, (ft<sup>3</sup>).  
 VCE<sub>EffectZone</sub> = the Vapor Cloud Explosion Effect Zone, (ft<sup>2</sup>).  
 Yf = the explosive yield factor, which EPA has defined as 10%

### Greek Letters

- $\Delta H_c$  = the heat of combustion, (kcal/kg)

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## THEORY

The specific safety interlocking depends upon the physical characteristics of the firing system and the type of fuel or fuels being fired. All Burner Management Systems, however are typically concerned with the following functions:

- A pre-firing purge of the furnace.
- Establishment of the appropriate permissive for firing the ignition fuel (i.e. purge complete, fuel pressure within limits).
- Establishment of the appropriate permissive, including ignition permissive, for the main (load carrying) fuel.
- Continuous monitoring of the firing conditions and other key operating parameters.
- Emergency shutdown of portions or all of the firing equipment when required.
- A post-firing purge.

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