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NFPA 85 COMPLIANCES OF BMS: A CASE STUDY OF BOILER CONTROL AT SBM OFFSHORE MALAYSIA COMPANY[1]

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ABSTRACT

Boilers are used in industrial facilities to generate electricity. Many hazards can occur on the boiler and affect boiler operational performance. Boiler hazards might cause explosions, injuries and death within unsafe conditions. It is vital to analyse hazards and take some precautionary steps to minimize boiler hazards. This paper outlines boiler hazards and safety control methods which verify the requirements of international standards and safety regulations as NFPA and ASME to be checked on Burner Management System and safety requirements to be developed. The paper presents safe arrangement of boiler components in a simple design to achieve functional safety requirements.

Keywords: Boiler, Burner Management System (BMS); National Fire Protection Association85 series (NFPA 85); Master Fuel Trip (MFT); Furnace & igniter; American Society of Mechanical Engineers (ASME).

INTRODUCTION

This paper deals with the control of steam fuel-fired boilers as applied for power generation. Boiler control is a subject that describes the coverage of start-up, shut-down, flame monitoring, and safety interlock measures. Brief information of boiler mechanism is useful for understanding boiler control procedures.

Boiler

Boiler is a generating unit that generates steam which is pumped to generator connected with turbine to generate electric power (Dukelow, 1991). The steam might be used for personal uses such as producing heat and hot water. Boilers contain two basic systems. Steam water system where water is heated and converted to steam.[3]

Insert Figure 1 about here

The fuel air-flow gas system provides the heat which is transferred to the water. The system inputs are the fuel and air required to burn the fuel. The fuel and air chamber is also referred to as the wind-box. The system outputs are the flow gas and ash (Liptak, 2006).

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[3] See Fig.1 in attached Appendix

Burner Management System (BMS)

The general term used for a boiler safety is burner management system (BMS). BMS is considered a combustion safeguard, boiler safety system, burner control system, flame safeguard system, safety shutdown system, furnace safeguard supervisory system, emergency shutdown system or a safety instrumented system (SIS) (Gilman, 2005).

The main requirement for BMS is to monitor boiler operation (Dukelow, 1991). BMS protects equipment from implosions and people from injury or loss of life by initiating a safe operating condition and fuel trip. The code authority that covers practices in this area is the National Fire Protection Association (NFPA). The published documents are the 85 series (Liptak, 2006; NFPA, 2011).

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National Fire Protection Association (NFPA)

The NFPA 85 is a Boiler operation and Combustion Systems Hazards Code 2011 Edition (NFPA, 2011). The Code ensures safe boiler operation and prevents explosions and property implosions (Liptak, 2006; NFPA, 2011). The Code establishes minimum requirements for boiler design, installation, operation, training and maintenance of boilers, fuel burning, air supply, and combustion products removal (NFPA, 2011). The most common cause of boiler explosions is human error.

Master Fuel Trip (MFT)

An action requires all fuel to be closed, igniter sparks shall be de-energized by using a master fuel trip relay which is an electromechanical relay used to trip all required equipment during any unstable condition. With the initiation of a master fuel trip, all fuel shall be stopped from entering the boiler (NFPA, 2011).

The rest of paper is organized as follows. Section II introduces related boiler hazards and advantages of boiler control. Section III describes boiler hazards and the proposed integrated safety control methods of each hazard that keep the boiler in a safe mode are introduced in Section IV. Section V presents the initial boiler design and the proper arrangement of boiler components. Section VI states the advantages of system implementations. Finally, section VII outlines our conclusions and future works.

RELATED WORKS

Peterschmidt and Taylor (2007) proposed "Boilers and Boiler Control Systems" which is based on control methods that affect boiler operation and efficiency calculations (Peterschmidt and Taylor, 2007). As there are several methods that affect boiler start-up, shutdown and flow parameters such as pressure, temperature and flow volume.

"Steam explosions in boiler ash hoppers" is another study outlines steam hazards in steam boilers and the proper control methods that help to avoid steam explosions (Stanmore and Desai, 1993). The main cause of steam explosions is ash leakage (Stanmore & Desai, 1993).

In another study, the fire protection systems are essential for industrial facilities using insulation materials designed with passive fire protection systems which can avoid fires, injures and save life and property (Liptak, 2006).

Dukelow (1991) explained boiler mechanism, boiler control methods such as start-up, purging and shut down and boiler automatic control (BAC) in his book "The Control of Boilers". The book outlines the proper methods for boiler installation, testing and maintenance. Boiler hazards cannot be avoided but minimized to operate the boiler in a safe way (Dukelow, 1991).

BOILER HAZARDS

Boilers, furnaces and burners are considered as high-risk machinery within oil and gas industry. Today's boilers are operated at high conditions of pressure and temperature (Liptak, 2006). Also the flammable and toxic inputs creates hazardous conditions should be controlled in a safe way to avoid any explosions, property implosions, injuries and loss of life (NFPA, 2011). Listed below some boiler hazards (NFPA. 2011; ISA, 1999; ISA, 2007):

- Boiler Transmitter Quality Trip (Boiler Airflow)
- Boiler Drum Level Low-Low (Transmitter)
- Boiler Steam Drum Pressure High-High
- Control Air Pressure Low-Low
- Low Flame Strength
- Wet Steam during Atomizing
- Excessive Water Temperature
- Fire & Gas Master Boiler Tri
- FD Fan Not Running
- Loss of All Flame
- Delay in First Gas/Oil Burner Start
- Gas Header Test Fault (No Burner in Service)
- Air Heater Not Running Trip

These hazards are considered as the main high-risk boiler hazards that might cause boiler explosions. The first action shall be taken to control those hazards and avoid explosions is shutting off fuel valves and creating master fuel trip (MFT), but fuel tripping is not the only action that should be taken to avoid the disaster (NFPA, 2011). Unfortunately there are some historical incidents of boiler explosions confirm the probability of disaster occurrence in the future. Table 1 summarizes most recent boiler explosions.[4]

Table 1 about here

Safe control methods should be implemented during boiler operation to run the boiler in a safe way avoiding any explosion or boiler implosion. This paper presents a safe way to control the boiler during any hazardous situation based on several standards have been published recently in order to control design and implement safety requirements. Those standards state boiler control methods in general ways which were used as references to fulfill boiler control information and safety requirements (Dukelow, 1991; Gilman, 2005).

. The main standards are:

- NFPA – National Fire Protection Association
- ANSI – American National Standards Institute
- ASME – American Society of Mechanical Engineers
- ISA – International Society Of Automation

These standards lead to a fully understanding of boiler mechanism, control methods and safety requirement. All boiler hazards were compiled in "EXCEL" file and each hazard is followed by actions shall be taken to make a safe boiler control during this hazardous condition.

A basic boiler design was developed using "MICROSOFT VISIO" in accordance to NFPA 85 codes with the proper arrangement of boiler components required by the functional standards in order to optimize the equipment design.

[4] See Table 1 in attached Appendix

SAFETY CONTROL METHODS

Safety and risk are related. The more safety is obtained the fewer risks are present. Property damage is considered a risk that might cause injury or loss of life (NFPA, 2011). Current regulations demand the implementation of safety requirements to keep risks under safe control (NFPA, 2011; ISA, 1999; ISA, 2007).

This study ensures the achievement of Process Safety. The results obtained are compiled in cause and effect data sheets that got all boiler hazards or risk causes and effect or hazard control methods all in an "EXCEL" file. All boiler hazards were discovered one hundred eighty five hazards are divided into several sections. Each section describe one part or component of the boiler such as oil pipeline, gas pipeline, burners, master fuel trip hazards, boiler implosion hazards and many more. Each hazard is followed by the safety requirements and best control methods to avoid any disaster such as explosions, property implosions and damage to health or environment. Shown below the control methods of some boiler hazards (NFPA, 2011; ISA, 1999; ISA, 2007):

Master Fuel Trips (MFT)

Hazard: Loss of all flame

Suggested Control Methods:

1. De-energise MFT relay
2. MFT first out indication
3. De-energise oil fuel trip (OFT) relay
4. OFT first out indication
5. Close boiler oil trip valve
6. Close Boiler atomising media trip valve
7. Close diesel oil supply valve
8. Close heavy fuel oil supply valve
9. Open heavy fuel oil recirc valve
10. Open boiler oil recirc valve
11. De-energise gas fuel trip (GFT) relay
12. GFT first out indication
13. Close supply gas trip valve
14. Open supply gas vent valve
15. Close boiler gas trip valve
16. Open boiler gas vent valve
17. Close burner oil trip valve
18. Close burner atomising media valve
19. Close burner oil gun purge valve
20. Close burner gas trip valve
21. Block N2 burner purge
22. Hold forced draft (FD) fan vane position constant
23. Burner management system (BMS) alarm

Gas Fuel Trips (GFT)

Hazard: Boiler gas pressure low-low

Suggested Control Methods:

1. De-energise gas fuel trip (GFT) relay
2. GFT first out indication
3. Close supply gas trip valve

4. Open supply gas vent valve
5. Close boiler gas trip valve.
6. Open boiler gas vent valve
7. Close burner gas trip valve
8. Burner management system (BMS) alarm

Burner Trips
Hazard: Burner Loss of flame (flame failure or detector fault)
Suggested Control Methods:
1. Close burner oil trip valve.
2. Close burner atomising media valve.
3. Close burner oil gun purge valve.
4. Close burner gas trip valve.
5. Burner management system (BMS) alarm.

Oil Fuel Trips (OFT)
Hazard: Oil header pressure high during start up process
Suggested Control Methods are shown in the logic sequence.[5]

Insert Figure 2 about here

Other hazards and trips
Ex-1. Hazard: Loss of feed-water
Suggested Control Methods are shown in Fig. 3 of Appendix.[5]

Insert Figure 3 about here

Ex-2. Hazard: Loss of forced draft (FD) fan(s)
Suggested Control methods are shown in Fig. 4 of Appendix.[5]

Insert Figure 4 about here

If they are the last fans in service, the FD fan dampers shall remain open and the introduced draft (ID) fan shall remain in controlled operation. All FD fan dampers shall be opened after a time delay to prevent high duck pressure during fan coast-down (NFPA, 2011).

Ex-3. Hazard: Oil pump discharge pressure low-low
Suggested Control Methods:
1. Trip oil pump(s).
2. Burner management system (BMS) alarm.

BOILER BASIC DESIGN

NFPA code establishes minimum requirements for boiler design. Implementation of those requirements ensures a safe boiler operation, reduces hazards occurring on the boiler and prevents boiler explosions and implosions. The design shows the proper arrangement of boiler components and where the valves have to be located. It also shows specific equipments to be used to ensure steady and safety operation.

[5] See Fig.1 to Fig.4 in attached Appendix

It is important to have a boiler design verifies all safety requirements of international standards and safety regulations such as NFPA 85. I was capable of applying more complete and rigorous analysis to special or unusual problems has the latitude in the development of such boiler design requirements learned from NFPA 85 and other standards.

The design shown in fig. 5 of Appendix was made using "Microsoft Office VISIO". The design shows the boiler with all expected inputs; water, gas, oil and the atomizing medium (air). There are several outputs; flue gases, ash and the main desired output is the steam which is pumped to a generator connected with turbine to generate electric power. The design shows boiler components.[6]

Insert Figure 5 about here

Insert Figure 6 about here

- ZSC = Position switch closed proves valve closed
- ZSO = Position switch open proves valve open
- Pi = Pressure indicator
- Ti = Temperature indicator
- PSH = Pressure switch high
- PSL = Pressure switch low
- TSL = Temperature switch low
- TSH = Temperature switch high
- FMF = Flame detector
- IGN = Burner igniter
- FM = Oil/Gas strainer
- FSL = Failsafe switch low
- FSH = Failsafe switch high
- LSH = Level switch high
- LSL = Level switch low

Safety shutdown interlocks (not shown):

- Auxiliary low water cut-off (one required)
- Combustion air supply interlock.

Fig. 5 shows boiler basic design following safety requirement established in NFPA 85 code. It shows the proper arrangement of boiler components and safety equipment. Fig. 6 shows boiler gas igniter with relief valves and safety shut off valves required to keep ignition process safe.

This design suits high pressure boilers. By definition high pressure boilers are steam boilers that operate at a pressure greater than 15 psig (Liptak, 2006). Because the boiler water temperature rises as the pressure is increased, the flue gas temperature is increased as the pressure increases, increasing the boiler heat losses (Gilman, 2005).

SYSTEM IMPLEMENTATION ADVANTAGES

This study provides initial process hazard analysis to determine the failures that can lead to hazardous scenarios and provides safe control methods for each hazard to control the boiler and keep it in a safe mode during any unstable condition. This analysis enables to identify those safety functions and it should be implemented to avoid the possible consequences of failure on demand.

[6] See Fig.5 & Fig.6 in attached Appendix

As study result one hundred eighty five hazards and the safety control methods of each hazard were identified and implemented in the basic boiler design to compose the BMS. The implementation of those safety control methods has some advantages (NFPA, 2011):

1. Insure high safety limits during operation.
2. Insure a Safe and complete boiler purging process.
3. Insure a safe start-up.
4. Insure a safe shutdown.
5. Demand safe combustion control system for proper fuel burnings and air flows.
6. Insure continues boiler operation with high safety interlocks satisfied.
7. Establish MFT conditions during boiler operation.

The specification of safety requirements for the basic boiler design means what the safety function is intended to do. Moreover, NFPA standards require integrity requirements to create a safe boiler design with equipment fit for purpose (NFPA, 2011). The proper arrangement of boiler components and equipment achieves the process safety by the risk reduction (Liptak, 2006). The implementation of the safety control methods and boiler design requires additional safety components and equipment to be added to the boiler to operate the boiler in a safe way. This might has larger investment and operational cost but it demands boiler operation with high safety levels avoiding life, property and monetary losses (Gilman, 2005).

CONCLUSION

Boiler is used to produce steam for generating electricity, heat and personal uses. Many hazards are affecting boiler operation process causing boiler implosions, injures and loss of life. This study describes proposed control methods to operate the boiler in a safe way avoiding any hazards. Moreover, it outlines the safety control methods to trip and shut down the boiler during any hazardous situation. All control methods are based on several standards as NFPA 85, ASME and ISA 77 that have been published recently in order to implement safety requirements for BMS systems.

Moreover, standards establish the requirements for boiler design, maintenance and operation. Based on those requirements, an initial proposed boiled design was made for high pressure fuel fired boilers. To validate the design, a proper determination of real safety actions was established. The implementation of safety requirements achieves process safety during boiler operation and reduces boiler hazards by following the safety control methods and the boiler design with proper arrangement of boiler equipment.

Future works might follow newer standards and safety regulations with upgraded safety system requirements and proper boiler designs for each pipeline of the unit such as header (water pipeline), oil, gas, atomizing media (air) pipelines, igniter and furnace designs. The correct selection of safety equipment and boiler components has very important benefits to operation costs and boiler safety. Equipment selection has to be made in accordance to risk reduction.

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