CHAPTER - 16
Furnace Safeguard System

Introduction:
In case of boilers with Grate Firing as also in case of boilers with Fluidised Bed Firing, the time available for the fuel to reside in the furnace uses to be quite substantial. Therefore, a momentary or even short time stoppage of input of fuel in the furnace and spontaneous restart of the same is not likely to cause any unwarranted effect on the furnace safety.

However, in case of boilers with gaseous fuel firing, liquid fuel firing and pulverised fuel firing, such an incident of even momentary stoppage of fuel input to the furnace is likely to cause loss of flame in the furnace and restart of input of the fuel can result in formation of unburnt explosive mixture of fuel and oxygen (from combustion air) which can result in serious accident if this explosive mixture ignites either due to combustion temperature having been reached or an ignition spark occurring due to a boiler restart signal being given by the operator upon his sensing that flame has been lost.

Similarly, partial combustion of Carbon present in the fuel can occur in case the combustion air is not available in adequate quantity at any time and CO may be formed in place of CO\textsubscript{2}. The CO can form explosive mixture and cause accident.

In order to prevent such accidents of explosions, control systems known as ‘Furnace Safeguard Systems’ have been devised in modern boilers. Such control systems have also been given such names as ‘Flame Safety Supervisor System’ or ‘Furnace Safeguard Supervisory System’ and are commonly abbreviated as ‘FSSS’ as also ‘Master Fuel Trip’ Logic, abbreviated as ‘MFT’.

Description of FSSS and MFT:
The key to safe burner operation is to shut off the burner immediately at slightest indication of indication of any slightest accumulation of unburned combustibles or if ignition energy is insufficient to sustain the fuel burning process. No practical means exist to detect and monitor the accumulation of unburned combustibles or the ignition energy. Its existence can only be inferred from the lack of burner flame when the fuel is being admitted into the furnace through the burners. A “flame detected” or “no flame detected” condition for a burner is an indication of whether the fuel admitted is being burned or not. For this reason, flame detection plays a vital role in the functioning of burner control system. A variety of techniques exist for flame detection. The detectors used for utility boilers are those sensing the light emitted by burning the fuel (ultra-violet and infrared detectors) or the flickering frequency of light produced by the burning process (flicker detectors). The selection is largely dependent on the type of fuel burned, burner design, and the particular design considerations of the boiler and burner control system.

In general, igniter flame is monitored on an individual basis. The monitoring philosophy for main flame varies depending on the firing pattern of the boiler. In a wall-fired furnace, a detector is typically installed for each burner. In a tangentially fired furnace, the detectors are shared between burners on adjacent elevations. The main flame is monitored either on an individual or group basis depending upon the manufacturer’s arrangement of the burners.
The purpose of MFT Logic or FSSS Logic is to protect the boiler by automatically stopping all fuel supplies to the furnace on detection of any unsafe operating condition. The National Fire Protection Association, USA, (NFPA) has specific guidelines for the tripping operation of utility boilers. [NFPA Code 85C, “Standard for Prevention of Furnace Explosion/Implosion in Multiple Burner Boiler Furnaces”]. Designers and manufacturers throughout the power industry accept this code as established minimum standards for operation and for system design of multiburner boilers. The Institute of Electrical and Electronic Engineers (IEEE) also provide recommendations for tripping in the “IEEE Guide for Protection, Interlocking and Control of Fossil Fuelled Unit-Connected Steam Stations”.

In addition, each boiler manufacturer has standard recommendation for boiler operation that address the specific characteristics of their boilers. The NFPA Code recommends that a running boiler be tripped on the occurrence of any unsafe of any unsafe conditions.

Examples of such unsafe conditions are:
- Loss of all Forced Draft Fans,
- Loss of all Induced Draft Fans,
- Combustion Air Flow below minimum,
- Excessive (high or low) furnace pressure,
- Loss of all flames, and
- Partial loss of flame introducing hazardous operating conditions.

Other tripping conditions may also cause an automatic master fuel trip. These conditions are determined by the station designer on a case-by-case basis: low boiler drum level, high drum level, loss of control power to control system, low fuel supply pressure condition for gas- or oil-fired boilers, low circulation pump circulation pump differential pressure for forced circulation boilers, low feed water flow for once through boilers, and other conditions required by boiler manufacturer’s design. To enhance the reliability of the tripping logic, redundant sensing devices are used, where practical, to detect unsafe operating conditions that will automatically activate the Master Fuel Trip.

On a boiler trip, all fuel supply is immediately cut off. This is accomplished by closing all fuel valves (main fuel gas or oil supply valves, gas and oil burner valves, igniter valves, and coal burner line valves), and stopping pulverizers and feeders. Airflow control is rejected to manual mode and the airflow remains constant for ‘post trip furnace purge’.

The purge logic is used to ensure an adequate airflow supply through the furnace to get rid of any unburned combustibles in the furnace following a Master Fuel Trip and before lighting off the first burner(s) after a trip. This is generally accomplished by opening all air and flue gas dampers in the boiler and running the Forced Draft Fans and Induced Draft Fans for a specific time period (typically 5 minutes) to ensure that all volume in the furnace is turned over several times during the purge operation.
The Furnace Implosion protection is integral with the Furnace Draft Control and is important for boilers having furnace with membrane wall construction.

**Protection against Explosion and Implosion through FSSS:**
FSSS takes care of interlocks required for starting, supervising the operating and safe shut down of the equipments connected with fuel firing system. Other devices burner management system and programmable logic control system are used now a day.

The earlier control systems for interlock and protection used electromagnetic relays for implementation of logic. Later solid-state hardwired systems were used. Presently, sophisticated distributed control systems are used for boiler auxiliaries interlock and protection system and furnace safe guard supervisory system.

A boiler analog control system is an interconnected package of control loops and functions, into which a numbers of inputs are connected and a number of outputs are connected to final control devices. A change from one input affects more than one output. In addition, change in one output may have an effect on more than one boiler measurement or input. Because of this, a specific arrangement of control system has a very significant effect on control interaction. Good design of control system minimizes the interaction between different control loops. To perform these functions, all basic control functions, feedback (closed loop), feed forward (open loop), cascade, ratio controls are used individually and linked together in any needed combination. Originally mechanical type of controls with linkages was used far combustion control and drum level controls. Later pneumatic controls were used. This was replaced by solid-state hindered controls, which used analog controllers, computing devices. This was followed by distributed computer control system. Today with distributed control systems with its enormous computing potential, the most sophisticated control strategy is implemented with ease. State variable controls have also been implemented for specific areas such as steam temp. Control system for large sized utility boilers.

**Furnace explosions:**
Numerous conditions can arise in connection with the operation of a boiler that produces explosive conditions. The most common of these are as follows.

a) An interruption of the fuel or air supply or ignition energy to the burners, sufficient to result in momentary loss of flames, followed by restoration and delay re-ignition of an accumulation.

b) Fuel leakage in to an idle furnace and the ignition of the accumulation by a spare or other source of ignition.

c) Repeated unsuccessful attempts to light off without appropriate purging, resulting in the accumulation of an explosive mixture.

d) The accumulation of an explosive mixture of fuel and air as a result of flame is at one or more burners in the presence of other burners, operating normally or during lighting of additional burners.

e) The accumulation of an explosive mixture of fuel and air as a result of a complete furnace flame out and the ignition of the accumulation by a spark or other ignition source, such as could occur where attempting to light a burner(s).

f) Purging with an airflow that is too high, which stirs up combustibles
smouldering in hoppers.

**Furnace Implosions:**

A furnace implosion is the result of the occurrence of excessively low gas side pressure, which causes equipment damage. Two conditions that have caused furnace implosion include:

a) A mal-operation of the equipment regulating the boiler gas flow, including air supply and flue gas removal, resulting in furnace exposure to excessive induced draft fan head assembly.

b) The rapid decay of furnace gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip.

The FSSS is designed to perform the following functions:

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

Pre-firing purge ensures that unburned fuel in the furnace is completely removed before initial firing. To do this a minimum airflow (usually 30% of MCR flow) is passed through the steam generator far 5 minutes. Upon completion of purge, the steam generator is ready to be fired. The 30% MCR minimum airflow is maintained till the steam generator reaches a 30% load in order to assure an air rich furnace mixture during the entire start up phase. Light fuel oil is used as start up fuel (typical capacity is 7.5% MCR) and heavy fuel oil is used as warm up fuel (typical capacity is 22.5% MCR). The light fuel oil and heavy fuel oil, oil gun nozzles are lighted up with high energy are igniters. Flame monitor the individual oil burner flames. The oil elevations in service are used to light up the coal elevations. The oil elevation is kept in service until two adjacent coal elevations are fired at 50% of their rated capacity, thereby ensuring sufficient ignition energy to maintain stable firing conditions during the steam generator start up phase of operation.

The basic components of the FSSS system can be divided into operator console, driven devices, sensing elements and logic system.

The operator panel contains all command devices (push buttons) to manipulate the firing system equipment and feed status lamps. The driven devices are those by which fuel and air is admitted to the steam generator. Typical examples are valve operators in fuel system, feeder and pulverizer motor starters and air damper drives.

Sensing devices includes position-sensing devices of driven devices, pressures, temperatures and flow and flame monitors. The system design has been developed to offer maximum protection, minimum nuisance trips, minimum power
consumption and maximum life for the components used. The heart of the system is the logic system, which is functionally divided into unit logic, elevation logic and corner logic.

Unit logic supervises the overall furnace conditions. It monitors all critical parameters of the fuel firing system and supervises furnace purge. During the operation of the boiler, the unit logic continuously monitors critical feedback to ensure maximum safety and trips off all fuel, if dangerous conditions build up.

A list of typical conditions for furnace purge is as follows:

- Heavy fuel oil trip valve closed
- Heavy fuel oil BNRS trip values closed
- Light fuel oil trip valve closed
- Light fuel oil Burners trip valves closed
- Flame scanners on each elevation indicate no flame
- Air flow greater than 30% and less than 40%
- All pulverizers off
- All feeders off
- Pulverizer outlet gates closed
- All hot air gates closed
- All cold air dampers not greater than 5° open
- Both PA fans off
- No boiler trip existing
- All auxiliary air dampers modulating
- Scanner air fan running.

A list of typical conditions that would cause an emergency shut down is as follows:

- Loss of all FD fans
- Loss of all ID fans
- Loss of all fuel
- Reheater protection acted
- Air flow less than 30%
- Loss of flame
- Furnace pressure very high
- Furnace pressure very low
- Drum level very high
- Drum level very low
- Loss of AC at any elevation in service and less than fireball.
- Loss of DC
- Both emergency trip push buttons pushed.

The elevation logic is an intermediate logic, which depends on the operator or the unit logic for initiation of start or stop actions. In addition, it also provides essential trip commands to the corner logic. The elevation logic is designed to suit the type of fuel it controls. For example, if the elevation logic is designed for a pulverized fuel, the logic elements will be designed to suit that particular type of pulverizer and its associated equipment like feeder hot air gate, etc. Also since the pulverizer outlet directly feeds the coal nozzles in the four corners without any remote shut-off devices for each corner, there will not be any corner logic for this fuel.
However, in case of oil firing, the corner sequencing etc. is performed by their respective elevation logic and therefore the elevation logic should be designed to include commands and feedback from corner logic sections. In general, the elevation logic receives commands from the unit logic or the operator as to and when to start, shut down or trip the elevation. Besides this the elevation logic will provide feedback to the unit logic on actions taken by the elevation logic.

The corner logic depends an elevation logic commands for initiation of an action. During manual operation, the corner logic computes its own permissive based on ignition energy availability, status of various corner devices and other factors for sequencing of individual fuel air, or steam valve operations. In the case of oil firing, the logic performs an oil scavenge cycle before the gun is allowed to retract, however emergency trip signals, originating in unit logic and transmitted via elevation logic will by pass corner logic permissive and cause immediate closure of fuel valve.

Automatic system for placing in service or removing from service a group of firing equipment in the proper sequence by initiating a single command can also be designed. A typical example would be feeder, air dampers and other equipment associated with a single pulverizer. In the automatic mode of operation, a single operator command to start a pulverizer would initiate the following appropriately timed sequence of events provided all the permissive are satisfied.

Associated ignition system is placed in service

- Pulverizer motor started
- Hot air gate opened
- Pulverizer airflow and temperature controls released for automatic operation.
- Feeder started
- Feeder speed control released for automatic operation
- Associate wind box dampers released for automatic operation

As the required load on the boiler is varied over a wide range, firing subsystem sub loops are placed in or removed from service to maintain the most stable flame conditions and make the most efficient interaction is evidenced by uneven flow of feed water such slugs of water may cause upset to steam pressure, thus resulting in firing rate changes with no changes in the steam flow rate. The firing rate changes cause shrink or swell and accentuate the problem.

Following an increased influx of cold water into the drum, condensation of steam bubbles in drum water takes place and this may considerably delay the final effect of change in supply on drum level. The level first drops (shrinks) and starts rising only afterwards.

The same effect is produced when the load decreases because drum pressure momentarily increases. On the other hand when the demand for steam increases, an increase steam flow causes a fall in pressure, which in turn leads to the expansion of the submerged steam volume in the drum and rises. The water “swells” and the drum water monetarily rises. As steam flow increases, an increase in feed water flow would be indicated if the boiler drum level did not swell. The drum level increase should cause a reduction in feed water flow if the steam flow had not increased. The proper adjustment of the feed water control system
balances the opposing influences of shrink and swell. If the influence of drum level were too great, the initial control action would be to reduce the feed water flow. This will ultimately cause the drum level to move beyond the control set point to make up for the lost water. If the influence of use of firing system components with load programming feature the FSSS system will take care of the above function automatically as the steam generator load demand changes.