# Boiler Control System Using Yokogawa Centum CS3000 DCS

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## Abstract

*Boilers account for steam generation. The Drum level control system and Combustion control system are very critical in nature as far as Boiler instrumentation is concerned. This project deals with the said control systems of a 23 T/hr capacity boiler producing steam pressurized to 20.2 Kg/cm2.The drum level control scheme is a Lead - Lag cascaded control system in which the corrective action is taken on air flow and fuel flow through a lead / lag approach which depends on whether the load is increasing or decreasing. The combustion control system is designed to maintain a proper air/fuel ratio under varying load conditions and within safe limits. The control performance of the operating parameters of the boilers such as the steam temperature and steam pressure will directly determine the economic performance and the safety of the plants and life-time of the boiler themselves. So control of boilers is always an important subject in plant automation.*



## Introduction

A boiler is an enclosed vessel that provides a means for combustion wherein heat is transferred to water until it becomes heated water or steam. The steam or hot water under pressure then becomes usable for transferring the heat to a process. Water is the cheapest medium for transferring heat to a process. The source of heat for a boiler is combustion of any of several fuels, such as wood, coal, oil, or natural gas. Boiler control is designed to control the activity within a boiler while ensuring safe and efficient operation [1]. The control performance of the operating parameters of the boilers such as the steam temperature and steam pressure will directly determine the economic performance and the safety of the plants and life-time of the boiler themselves. So the control of the boilers is always an important subject in plant automation.

The important control systems of a boiler are combustion control, drum level control and Burner Management System. Apart from this there are simple control loops like furnace pressure, fuel temperature, de-aerator level etc.

Boiler Drum level control is a safety feature that will shut the boiler off if the water level drops to an unacceptable level. Boilers have two water level controllers as a safety feature in case one fails. The two level controllers are also set at different levels with the controller at the higher level sounding an alarm and the controller at the lower level actually shutting the boiler down. Boiler level controls may be a float type pictured at right or a probe type that operates by testing for conductivity to determine if the water level is adequate [2]. The drum level measurement is interrupted by certain factors known as priming, foaming and carry over. Priming is the spouting or surging of water into the steam outlet. Priming is highly dangerous because of the possibility of suddenly lowering the water level below the danger line of the drum. Great difficulty in ascertaining the current water level may be experienced due to such factors. Keeping level too high a water level, which means if the level shots high out of control priming can occur [3].

Combustion is the rapid oxidation of fuel accompanied by the production of heat and/or light. In order for combustion to occur, three things must be present: fuel, oxygen, and a source of ignition. In a boiler, combustion occurs in the combustion chamber. Perfect combustion, also called Stoichiometric combustion, can occur only with precisely using the correct and minimal amounts of air and fuel. Complete combustion needs excess air to ensure enough air for good combustion, which is the goal in the boiler process. Incomplete combustion occurs when there is insufficient air, leaving unburned fuel as part of the flue gases [4]. Complete combustion depends on the three T's of Combustion: Time, Temperature and Turbulence (mixture and atomization of fuel). Combustion Control Systems regulate furnace fuel and air ratio within limits for continuous combustion and stable flame throughout the demand operating limits of the boiler and includes draft control. To maintain high combustion efficiency, the air to fuel ratio must be balanced from the lowest firing rate to the highest firing rate. If there is any imbalance in the air to fuel ratio, explosion could result. Combustion control also regulates the removal of the gases of combustion by maintaining a consistent furnace pressure throughout different firing rates. By maintaining a consistent firing rate, combustion control improves regulation of feed water and superheat temperature. A consistent firing rate reduces fluctuation of boiler water level and increases the life of the boiler drum and tubes.

## Boiler Control Systems

The boiler control system works on Steam pressure based on four process variables namely Steam pressure, Steam flow, Air flow and Fuel flow. The control scheme maintains steam pressure steadily irrespective of load changes without compromising safety. Boiler control system is basically three fold which includes the Burner Management System, Combustion Control, and Drum level control.

Drum level control is critical for both plant operation and equipment safety and applies equally for high and low levels of water within the boiler drum. The purpose of drum level controller is to bring the drum up to level at boiler start up and maintain the level at constant steam load. A dramatic decrease in this level may uncover boiler tubes, allowing them to become overheated and damaged. An increase in this level may interfere with the process of separating moisture from steam within the drum, thus reducing boiler efficiency and carrying moisture into the process or turbine. The functions of these control modes are operator adjustment of the set point for drum level, compensation for the shrink and swell effects, automatic control of drum level, indication of drum level, feed water flow and steam flow and deviation alarms for drum level.

Boiler combustion control maintains a constant steam pressure at the drum of the boiler. It is designed to maintain a proper air / fuel ratio under varying load conditions and within safe limits. The system should provide nearly complete fuel combustion as efficiently as possible. This is done using a ratio station. The Burner Management System takes care of combustion. The combustion produces heat. This heat of water in the tubes inside the furnace is transferred to heat water in the drum. Water evaporates and steam is produced. The steam pressure is decided by the rate of evaporation of water, which in turn depends on the combustion rate. Thus to maintain a constant steam pressure, combustion must be controlled.

## Modeling

A drum level control system tightly controls level irrespective of disturbances like increase/ decrease of steam demand and feed water flow variations. Drum level control systems are basically of three kinds: Single element control, two element control and three element control. Two element drum level will maintain the required water / steam interface level under moderate load changes. If unstable feed water system exists or if large unpredictable steam demands occur a three element control level is required to effectively control level taking care of the shrinking and swelling phenomena [5]. The three elements are made up of level element, steam flow element and feed water flow element. In order to achieve optimum control, both steam and feed water flow values should be corrected for density. The three element system provides tighter control for drum level with fluctuating steam load. It is ideal where a system suffers from fluctuating feed water pressure or flow. The demand of steam may vary as per the requirement in the plant. There can be two extreme conditions, a sudden withdrawal of steam and a reduction in the steam demand. A sudden withdrawal of steam will cause the swelling of water. This is because of the strong suction of steam. Water in the drum is pulled upwards. The level transmitter mistakes this for an increase in level. So the level controller output increase resulting in a reduction in the feed water flow rate. This phenomenon called swelling deceives the very purpose of level control in a single or two element controller. When the demand of steam reduces suddenly, the pressure in the boiler drum builds up pushing the water column down. This is called shrinking. The level transmitter mistakes this phenomenon for a reduction in level. The controller output goes down making the feed water valve to open more. This will increase the feed water flow to the drum which may mislead the controllers. The

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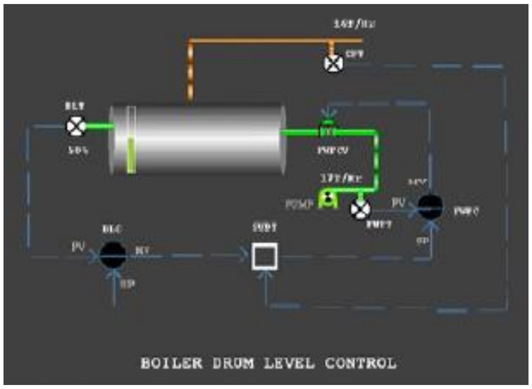
three element drum control is used to overcome this as shown in figure 1.

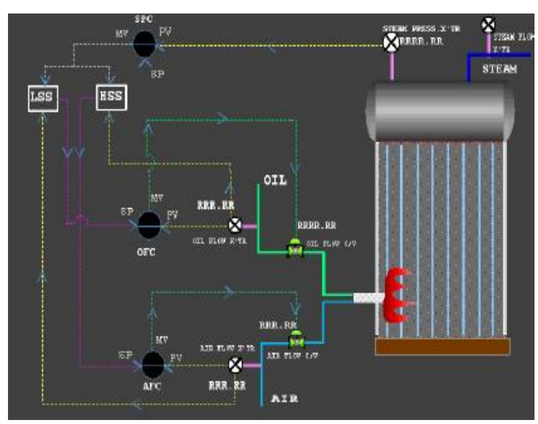



A combustion control system regulates oil flow and air flow, irrespective of steam load conditions, to maintain a constant steam pressure. The parameters are steam pressure, steam flow, oil flow, air flow [7]. The subtractor has two inputs: one from the steam flow transmitter and the other from DPC. Subtractor finds the difference between these inputs. LSS has two inputs, one from subtractor and the other from air flow transmitter. It selects lower signal out of the two. HSS has two inputs, one from the subtractor and the other from the oil flow transmitter. It selects the higher signal out of the two. The output of LSS goes to OFC and that of HSS goes to AFC. When steam outflow increases, the pressure in the drum increases. So we have to increase the combustion to maintain the steam pressure a constant. To ensure optimum use of fuel, first air must be increased and then only oil. And, while reducing, the oil flow should be reduced prior to air flow. If steam demand increases, the steam flow transmitter senses it and gives it to the subtractor. The SPC output is also fed to the subtractor. So the subtractor output also increases with steam flow. As steam flow increases, pressure in the drum decreases. So more combustion means more oil and air is needed. The LSS has two inputs; one from the subtractor and the other from the FT. LSS selects the lower of the two. In this case, it selects the signal from AFT. The external set point of OFC does not change now. So oil flow will also not change. At the HSS there are two inputs, one from the subtractor and the other from the OFT. As the steam flow increases, HSS selects the output of subtractor. This is processed in ratio station. Since the external set point to AFC increases, output of AFC increases and more air flows. Thus as oil flow has not changed, but air is in excess now, we can supply more oil ensuring efficient combustion. As AFT senses the increased air flow, the same output is available at LSS. The LSS now selects the subtractor output which is lower at this instant. This increases the set point of OFC and since it is reverse acting, OFC output increases and more oil flows. Thus oil flow is made to increase only after increase of air flow. When demand for steam decreases, combustion must be reduced first and then the air. This is called lead lag control. Thus by controlling the combustion, we maintain constant steam pressure at the top of the drum. An oxygen analyzer is used to ensure optimum use of fuel. It is through the oxygen analyzer that the flue gas is sucked out using induced draft fan. If excess air, than needed is used then there are chances of the fuel getting cooled. This may reduce the efficiency of the boiler. By monitoring oxygen in the flue gas, we can know how much air is being mixed. We find that oxygen content is high in the flue gas, it infers that excess air is being used. The air flow can be reduced as per requirement and thus heat loss can be prevented.



## DCS Configuration

Boiler Combustion and Drum level control inside the DCS begins with point building wherein the related input / output points are to be configured. The points for drum level control are input points as drum level, steam flow, feed water flow. Control Points as drum level control, feed water control and output point as feed water flow. Once the I/Os are built, the I/O modules are to be configured. Here each I/O terminal is to be detailed. In the Yokogawa Centum CS 3000, this is done using the FCS builder of System view. This is followed by the configuration of control drawings. It is used to register function blocks graphically as shown in figure 2.




Boiler Combustion Control

Each block in the control drawing is the regulatory control block in which appropriate tag name is given for each block. Using tag names has been standard practice in process control. A tag name is an alias conveniently formed to make it easier for our frail human memory to associate with an abstract item. Tag names are associated with the primary control or measurement technology (Pressure, Temperature, Flow, Level, etc.) and a location item associated with a portion of a plant or manufacturing process. The analog inputs coming from different field devices of the boiler plant associated with both the drum level control and combustion control are configured.

## Simulation and Results

Once all the input and output blocks are configured, the next step is to simulate the system so as to obtain the trends in the drum level controller action [13]. The drum level control simulation procedure is as follows: Using a simulator we provide a 4 – 20 mA signal corresponding to the drum level, feed water flow and steam flow. This signal is fed directly to the input module of the DCS. In the engineering station, i.e. in the Human Interface Module, all points are made. The input signal from the simulator is varied. Then the trend display is monitored for changes corresponding to the variations.



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