Fuel combustion in the industrial sector[i]

1. Introduction

Boiler and kiln are the main boiler types in industry. They are a major energy consumer in both factory (especially food factory) and buildings (especially in hotels). In Thailand, based on the Department of Industrial Works (DIW) under Ministry of Industry database, there are 8,816 boilers in the country. Their capacity is 110,000 ton/hr. 6,306 of them are fire tube boilers with the capacity of 31,000 ton/hr., while the other 2,510 boilers are water tube boilers with the capacity of 79,000 ton/hr. Most of the fire tube boilers are used in small- and medium-sized factories which require low technology level and yield low energy efficiency as well. Improving burner technology can lead to significant energy efficiency yield for Thailand.

2. Technology characteristics

There are various types of burners with unique characteristics as follows:

2.1 On / off control system

This is the simplest control system. It means that the burner is either firing at full rate or turned off. The major disadvantage of this system is that the boiler is subjected to large and often frequent thermal shocks every time the boiler fires.

2.2 High / low / off control system

This is a slightly more complex system where the burner has two firing rates. The burner operates first at the lower firing rate and then switches to full firing as needed, thereby overcoming the severe impact of the thermal shock. The burner can also revert to the low fire position at reduced loads, again limiting thermal stresses within the boiler.

2.3 Modulating control system

A modulating burner controller will alter the firing rate to match the boiler load over the whole turndown ratio. Every time the burner is shut down and restarted, the system must be purged by blowing cold air through the boiler passages. This wastes energy and reduces efficiency. Full modulation, however, means that the boiler keeps firing over the whole range to maximize the thermal efficiency and minimize the thermal stress.

The pros and cons of each type are shown in Table A12.

Table A 12 Pros and cons of burner technology

Technology	Advantages	Disadvantages
On / off control system	• Simple • Inexpensive	• Low energy efficiency • If a large load comes on to the boiler just after the burner has switched off, the amount of steam available is reduced. In the worst cases this may lead to the boiler priming and locking out • Fluctuating output of steam
High / low / off control system	• The boiler can respond to large loads better as the 'low fire' position will ensure that there is additional excessive energy stored in the boiler • If the large load is applied when the burner is on the 'low fire' position, it can immediately respond by increasing the firing rate to 'high fire'. Thus, the purge cycle can be omitted	• More complex than on-off control • More expensive than on-off control
Modulating control system	• The boiler is very effective in tolerating large and fluctuating loads • Should more energy be required at short notice, the control system can immediately respond by increasing the firing rate, without pausing for a purge cycle	• Most expensive • Most complex • Burners with a high turndown capability are required

Modulating Burner

Boilers are often the principal steam or hot-water generators in industrial plants. Consequently, they must be designed to operate efficiently and safely while respond promptly to the demanded changes. Fig A 11 represents an adaptive burner-management system. Control techniques are capable of reducing operating costs while providing greater flexibility in plant management and control. Tools for burner combustion controller generally include regulation of excess air, oxygen trim, burner modulation, air/fuel cross-limiting, and total heal control.

Fig A 11 Modulating burners

Modulating burners are designed to control the burner output (size of flame) to match the boiler variables and load requirements. During this process, the burner is designed to stay at the correct fuel-to-air ratio across the complete firing range to ensure the maximum combustion and boiler efficiency.

There are three basic types of modulating burner control:

Fully Electronic:

- This will independently control the fuel and air volume to the burner via separate fuel and air valves; normally this type of control will have an integral PID load control to ensure that the boiler's set point is being maintained to the boiler's load requirements. This type of system offers high level of combustion control and consistency.

Fully Mechanical:

- This controls the non linear relationship between the fuel and air ratios. A characterization cam is used (sometimes called a compound control). This is linked directly to the fuel valve and the air damper of the burner. This has limited control resolution due to the hysteresis and lost motion of mechanical systems i.e. inertia, friction, wear and tear.

Fully Pneumatic:

- This type of system is commonly used by burner manufacturers as a low cost solution for gas fired burners only. The burner has a gas control valve that is operated by a diaphragm and an impulse line from the burner's air supply. The burner will have a PID load control. This directly controls the burner air damper to give the required air volume. The gas valve will operate to give a directly proportional gas volume according to the correct fuel/air ratio.
- Modulating burners are designed to constantly match the firing rate according to the boiler load demands. In a perfect case, the burner would remain firing constantly whilst heat is required. This, is, however, rarely achieved for the following reasons:

(i) Limited turn down ratio:

- The "turn down ratio" is a function of the burner's capacity to match the current base load of the boiler. For example, the burner, at high fire rate, will give anoutput of 400 kW (100%) and, at low fire rate, will give an output of 100 kW (25%). This would be referred to a "turn down ratio" of 4:1.
- According to the previous example, if the base load remains at above 100 kW, the burner will modulate without turning off and "dry cycling" will not occur. However, if the base load is below 100 kW, the burner will reach and exceed the set point. and the burner will turn off and "dry cycle".

(ii) Other factors that will cause the burner not to modulate:

- Boiler manufacturers do not normally manufacture the burner to be fitted to the boiler. This is left to the application and the customer's requirements to remain flexible and is not limited to the boiler market. In this case, the specified burner and type of burner will be deemed suitably.
- The burner manufacturers offer a range of burner types and capacities. In most cases, the burners output is not perfectly matched to the boiler output and as a consequence the burner is not able to fire below the minimal base load. This will cause the burner/boiler to cycle on and off, i.e. wasting energy.
- Modulating burners with poor "turn down ratios" i.e. 2:1 will act as a high / low or on/off burner again causing excessive boiler cycling, i.e. wasting energy.
- Incorrectly sized boilers for their applications will also cause modulating burners to operate as on/off burners.
- Incorrectly commissioned modulating burners with poor combustion and/or incorrectly commissioned PID load controllers will also cause the burner not to modulate.

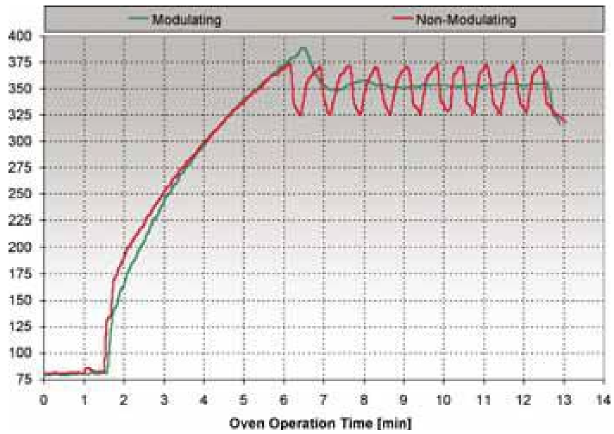

Fig A 12 Results for modulating vs. non-modulating burner in a conveyor oven.

Once-through Boilers

The term "once-through boiler" refers to a special type of water-tube boiler composed of tubes, in which water is input at the bottom, and steam is produced from the top.

This panel shows a typical structure for such a boiler, comprising a drum, a burner, pumps, other accessories, and a control section. Since the drum is composed of tubes, there is little water in the drum, and the boiler thus offers little risk of damaging the surrounding area in the unlikely event of a rupture. The compact design saves installation space. It is safe and no fear of an explosion because of the small water content. A typical structure and its properties are shown in **Fig A 13** and **Fig A 14**, respectively**.**

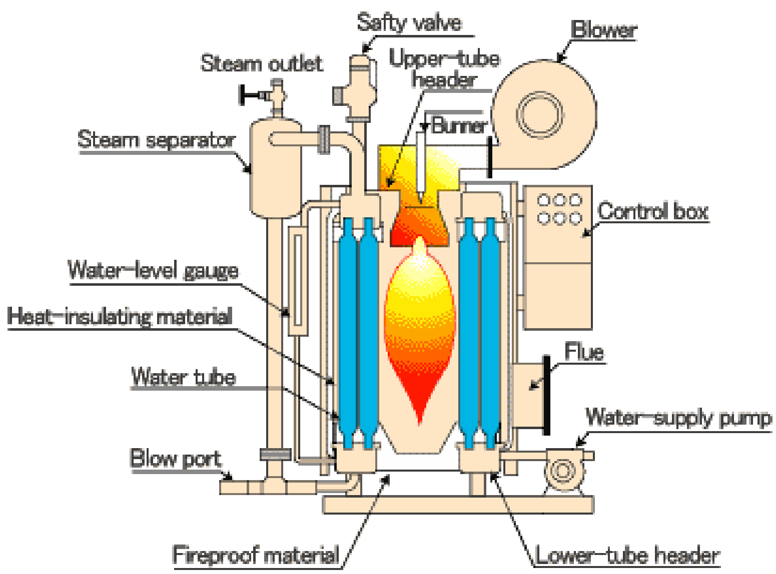

Fig A 13 A Typical Structure of a Once Through Boiler

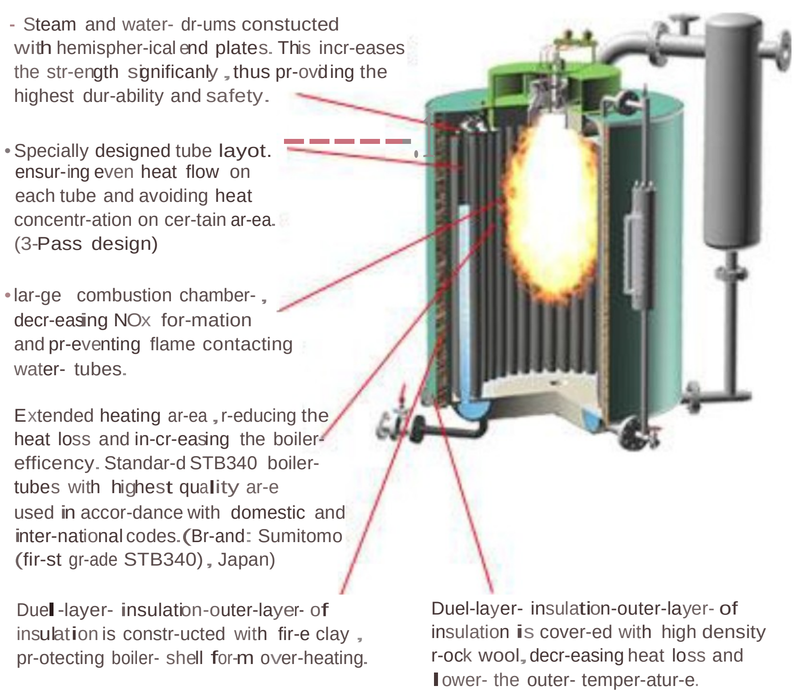

Fig A 14 An Example of a Once Through Boiler

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[i] **This fact sheet has been extracted from TNA Report – TECHNOLOGY NEEDS ASSESSMENTS REPORT FOR CLIMATE CHANGE MITIGATION – Thailand. You can access the complete report from the TNA project website http://tech-action.org/**