

Effects of Frequent Regulation Control System of 9.3 MW Hot -Water Boiler

Serbian Energy Efficiency Agency, Serbia & Montenegro

Summary

Test of the 9.3 MW hot water boiler was performed to establish the effect of implementation the frequent regulation control system and continuous measurement of oxygen content of flue gases. The results of measurements before and after the combustion process control system improvement are presented.

The boiler efficiency is improved for 2 % in a whole range of load except at maximum load. The electrical energy consumption by fan was more than 50 %. The simple pay back period of this investment is less than one year.

Key words: Boiler efficiency, Frequent regulator, Zircon sensor

End-user area	Target Audience	Technical
<input type="checkbox"/> New buildings	<input type="checkbox"/> Citizens	<input type="checkbox"/> Energy efficiency
<input type="checkbox"/> Refurbishment of buildings	<input type="checkbox"/> Households	<input checked="" type="checkbox"/> Heating
<input type="checkbox"/> Transport and mobility	<input type="checkbox"/> Property owners	<input type="checkbox"/> Cooling
<input type="checkbox"/> Financial instruments	<input checked="" type="checkbox"/> Schools and universities	<input type="checkbox"/> Appliances
<input checked="" type="checkbox"/> Industry	<input type="checkbox"/> Decision makers	<input type="checkbox"/> Lighting
<input type="checkbox"/> Legal initiatives (municipal regulations, directives, etc)	<input type="checkbox"/> Local and regional authorities	<input type="checkbox"/> CHP
<input type="checkbox"/> Planning issues	<input type="checkbox"/> Transport companies	<input type="checkbox"/> District Heating
<input type="checkbox"/> Sustainable communities	<input type="checkbox"/> Utilities	<input type="checkbox"/> Solar energy
<input type="checkbox"/> User behaviour	<input checked="" type="checkbox"/> ESCOs	<input type="checkbox"/> Biomass
<input type="checkbox"/> Education	<input type="checkbox"/> Architects and engineers	<input type="checkbox"/> Wind
<input type="checkbox"/> Other	<input type="checkbox"/> Financial institutions	<input type="checkbox"/> Geothermal
	<input type="checkbox"/> Other	<input type="checkbox"/> Hydro power
		<input type="checkbox"/> Other

Context

Public heating company "Novsadska toplana" (Novi Sad Heating Plant) has 7 boiler plants. Total installed heat power is 450 MW and majority of this capacity is used for space heating purposes while minority is used for preparation of consumable warm sanitary water and necessary quantities of process water. This company services the part of city Novi Sad, Serbia & Montenegro.

The design winter temperature is -18 °C . Design summer temperature is 34 °C and relative humidity is 45 %. Duration of heating season is from October 15 to April 15.

Objectives

The main goal of this project was to improve the energy efficiency of boilers and to reduce the energy cost.

Process

The Project was realized in period from March to May 2000. The Oxygen content was measured in flue gas and this signal was used for fuel/air ratio adjusting of speed of fresh air fan electrical motor. The test was performed to quantify the effects and to make decision for introduction of the same energy conservation measure to 6 more boilers.

The measurements of plant's parameters and analysis of operation at two regimes:

- With mechanical regulation by keeping the fix ratio of fuel and air. There is possibility of adjusting this ratio at all loads;
- With frequent regulation of the ratio of fuel and air by metering the Oxygen content in flue gas. Frequent regulator adjusts the airflow rate of fresh air fan.

The main technical characteristics of the hot water boiler used for testing are as follows:

Manufacturer: TPK Zagreb
Year of production: 1978
Nominal heat capacity: 9.3 MW
Efficiency: 90 %
Water temperatures: 130/70 °C
Operating pressure: 9.8 bar
Fuel: Natural gas (33.5 MJ/sm³)
Burner:

- Manufacturer: Sacke-Bremen
- Year of production: 1979
- Capacity: 11.63 MW

Fan:

- Manufacturer: Ventilator, Zagreb
- Volume flow rate: 3.44 sm³/s
- Total pressure: 3900 Pa
- Power of electrical motor: 30 kW
- Speed: 1460 rpm

Hot water boiler is fire tube type, horizontal. The additional air pre-heater is installed on the top of the boiler room, with the purpose of air heating.

Classical combustion regulation, which was delivered with the burner, governs the ratio of fuel and airflow rates over adjusting cam gear and system of mechanical levers that are moving appropriate valves. Previously adjusted cam gear's one position determines always the same ratio fuel - air. Oxygen content measurement in flue gasses was not included in regulation system. In regulation circle of fresh air flow rate were included:

- Sensor of Oxygen measurement in flue gases

- YOKOGAWA EXA OXY O₂ with zirconium probe; fast response; analogue output 4-20 mA
- Frequent regulator with possibility of PID regulation
- DANFOSS ULT 5042 with analogue input of the O₂ signal

Financial resources and partners

The total investment in reconstruction of whole regulation system was approximately 15,000 EUR.
Energy prices:

Electrical energy

Price: 0.0500 EUR/kWh

Paid electrical energy bill per month or year divided with consumed electrical energy. VAT is included.

Natural Gas

Price: 0.1750 EUR/sm³

0.0176 EUR/kWh (based on NCV)

NCV = 35.71 MJ/sm³

GCV = 39.74 MJ/sm³

$\rho = 0.692 \text{ kg/m}^3$ (15 °C, 1.013 bar)

The project was realized in cooperation with the Institute of energy and process engineering at the Faculty of technical sciences in Novi Sad.

Results

14 tests were performed and 4 loads of boiler were set:

- app. 100 % of maximum load;
- app. 75 % of maximum load;
- app 50 % of maximum load;
- minimum load, app 20 % of maximum load.

The first seven tests were performed with active frequent regulation and second seven tests with were done with classical mechanical regulation (constant fuel/air ration).

The boiler efficiency versus load of boiler is presented in Figure 1. Changing the load from lower to higher and vice versa were performed and differences of results were recognized. But the significant differences were exited only in experiment with mechanical regulation. It was explained with worn-out mechanical system. The results of these measurements shown that except maximum load, the boiler efficiency is higher for approximately 2 % in case when frequent regulation is used.

The majority of operating time the boiler operates with 70 % of maximum load (by analysis of daily log sheets for couple of years). The annual number of working hours was 5760. For this load the efficiencies of boiler were as follows:

With mechanical regulation $\eta_{mr} = 87.9 \%$

With frequent regulator $\eta_{fr} = 90.5 \%$

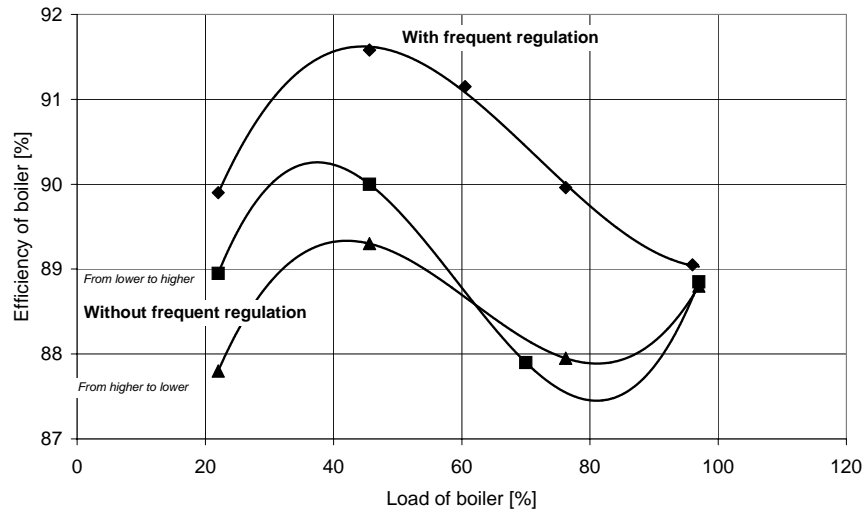


Figure 1: Efficiency of boiler versus load

The fuel saving by implementation of frequent regulator is:

$$\Delta M = \frac{Load \times Q}{NCV} \times \left(\frac{1}{\eta_{mr}} - \frac{1}{\eta_{fr}} \right) = \frac{0.7 \times 9.3}{35.71} \times \left(\frac{1}{0.879} - \frac{1}{0.905} \right) = 0.005958 \text{ sm}^3 / s$$

or, the annual cost saving is:

$$\Delta FC = \Delta M \times NOH \times P = 0.005958 \times 5760 \times 3600 \times 0.175 = 21622 \text{ EURO / year}$$

where:

Q = Nominal boiler capacity, MW

NCV = Net calorific value of fuel, MJ/sm³ (35.71 MJ/sm³)

(Standard conditions, T = 283.15 K and p = 1.013 bar)

η_{mr}, η_{fr} = Efficiency of boiler with mechanical and frequent regulation, respectively

Load = Load of boiler, % (70 %)

NOH = Annual number of operating hours, h/yr (5760 h/yr)

P = Unit price of natural gas, EUR/sm³ (0.175 EUR/sm³)

In Figure 2 the power of fan's electrical motor is presented versus load of boiler. The significant energy consumption reduction can be recognized by implementation of frequent regulator. For the average boiler load the electrical power of fresh air fan was as follows:

With mechanical regulation $N_{mr} = 25.5 \text{ kW}$

With frequent regulator $N_{fr} = 13.0 \text{ kW}$

The annual electrical energy consumption can be reduced by implementation of frequent regulator as:

$$\Delta FE = (N_{mr} - N_{fr}) \times NOH = (25.5 - 13.0) \times 5760 = 72,000 \text{ kWh}$$

The electrical energy saving is $72,000 \text{ [kWh]} \times 0.05 \text{ [EUR/kWh]} = 3600 \text{ EUR/yr}$.

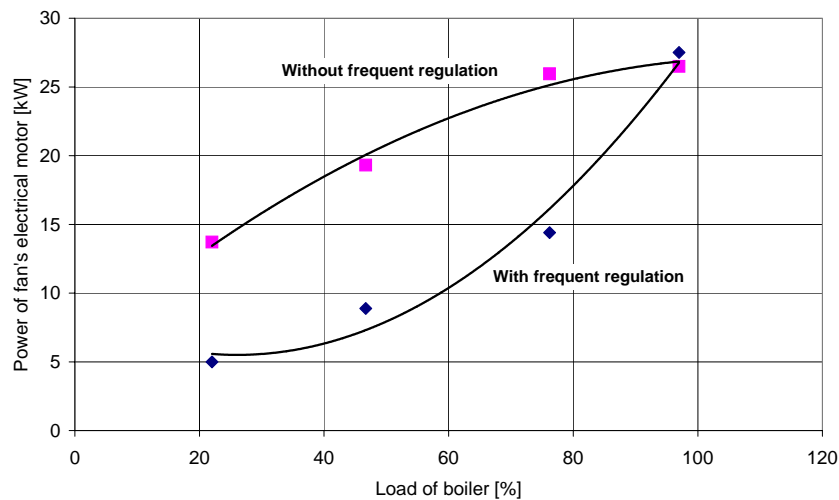


Figure 2: Power of fan's electrical motor versus load of boiler

Total cost reduction is now: $\Delta C = 21,622 + 3,600 = 25,222 \text{ EUR/yr}$

The simple pay back period was as follows:

$$\text{Simple Pay Back} = \frac{\text{Project Cost}}{\Delta C} = \frac{15,000}{25,222} = 0.60 \text{ year}$$

Lessons learned and repeatability

Simple and relatively low cost energy conservation measure was used. After test performed, the same energy conservation measures were completed to all boilers. The installation has been a complete success technically and as well as economically. Replication of such a project is possible in many industrial sectors and the expecting results could be similar as presented one.

Contact for more information:

Organisation / Agency: Serbian Energy Efficiency Agency
 Main contact: Dusan Gvozdenac
 Address: Koste Glavinica 2, 11000 Belgrade, Serbia & Montenegro
 Tel: + (381) (11) 369 0987
 Fax: + (381) (11) 369 1160
 E-mail: d.gvozden@seea.sr.gov.yu; gvozden@uns.ns.ac.yu