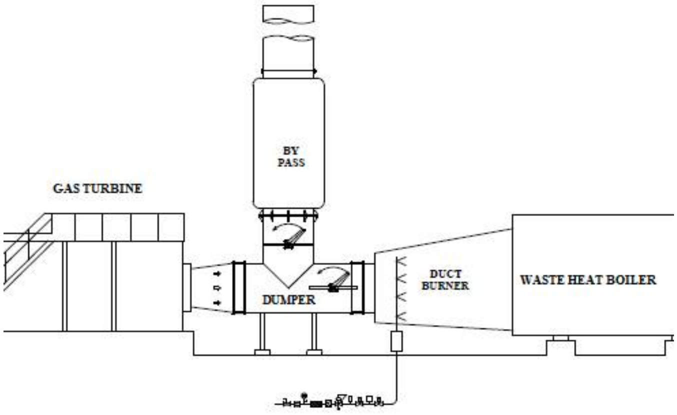
SUPPLAMENTARY FIRED WASTE HEAT BOILERS

Cagdas YESIL, ENEVA ENERGY SYSTEMS LTD.

As is known, a significant part of the energy of the fuel used in cogeneration systems is carried by exhaust, which can be retrieved with energy recovery equipment called waste heat boiler. Waste heat boilers can be classified in many ways such as smoke tube or water tube, vertical type or horizontal type. As a result, the waste heat in the high temperature exhaust gas is given to the steam, hot water or hot oil fluid on the secondary side via a tubular heat transfer mechanism. The most important parameters in the design can be listed as permissible pressure losses on the primary and secondary sides, suitable heat transfer surface area, temperature and pressure strengths. The efficiency of waste heat boilers can generally be determined as the ratio of the heat energy taken from the boiler to the fuel energy given to the system (engine). Therefore, the lower the exhaust temperature from the waste heat boiler, the more the recovered heat and the higher the efficiency will be. The low exhaust outlet temperatures in waste heat boilers are largely related to the temperature of the fluid on the primary side, as well as the boiler design. In other words, it would not be wrong to say that the lower pressure (hence the temperature) steam is produced in the boiler, the higher the boiler efficiency will be.

SUPPLAMENTARY FIRED WASTE HEAT BOILER

The amount of energy that can be obtained from waste heat boilers can be increased by keeping the exhaust outlet temperature low as well as by keeping the exhaust inlet temperature high. In this way, it is possible to increase the capacity and efficiency of the waste heat boilers by loading additional heat. Especially in the exhaust gases released as a result of the combustion of gas turbines, there is a high percentage of unused oxygen (around 14%). In gas engines, this rate is around 9%. The oxygen ratio of 14% makes it possible to increase the heat capacity by using only fuel, without using additional air in these systems. The only thing that needs to be done is to feed natural gas into the exhaust gas at the turbine outlet.



Additional Combustion Waste Heat Boiler Principle Diagram

In this way, the ready and hot oxygen in the exhaust gas will enter into a combustion reaction (burning) with the fuel, raising the exhaust mixture temperature. Thereby, the amount of heat that will enter the waste heat boiler will increase, and the amount of steam produced in the boiler will also increase. With the increase in steam production for the same boiler, the amount of heat to be taken from the economizer after the boiler will increase and the flue temperature will decrease significantly. (While the exhaust side flow rate and temperature do not rise much in the economizer, more heat is drawn from the exhaust since the feed water flow rate on the secondary side increases too much). As a result, the steam produced will be produced with high efficiency.

In conventional boilers, steam is produced by using the hot gases released as a result of the burner burning the fuel. Only 21% of the atmospheric air used in combustion is oxygen, and the rest consists of unreacted inert gases such as nitrogen and argon. Therefore, 80% of the air entering the combustion is heated and thrown back into the atmosphere without being used. This is a loss of efficiency for boilers with burners, and therefore, the efficiency of boilers with conventional burners generally cannot exceed 93%. By this efficiency to produce 1 ton of steam, an average of 73 Sm^3 natural gas consumed in this conventional system.

However, below, additional non-combustion and combustion waste heat boiler operating modes are compared for a gas turbine cogeneration waste heat recovery system.

From the difference between the two cases, it was calculated with which fuel consumption and steam production can be achieved by using the additional combustion system.

		WITHOUT ADD. COMBUSTION	WITH ADD. COMBUSTION
Inlet temperature of the exhaust gas to the waste heat boiler	°C	486	800
Inlet flow rate of the exhaust gas to the waste heat boiler	kg/h	78.675	79.367
Volumetric oxygen ratio in the turbine exhaust gas	%	14,25	11,8
The temperature of the exhaust gas leaving the WHB (Eco outlet)	°C	178	125
Waste heat boiler steam generation pressure	barg	16	16
Waste heat boiler steam production flow	t/h	10,5	25,2
Fuel consumption required for additional steam	Sm^3/h	-	865
Amount of heat gained by additional combustion	kW	-	9.600
Production cost of additional steam in a waste heat boiler with additional combustion	Sm^3/ton	-	58,8
Steam generation cost in a conventional boiler (with 93% efficiency)	Sm^3/ton	73,4	
Fuel savings per unit of steam with additional combustion	Sm^3/ton	14,5	

Comparison of a Waste Heat Boiler with and without Supplamentary Combustion Mode

Accordingly, it is seen that only 58.8 Sm^3 of natural gas will be consumed for each additional 1 ton of steam if the oxygen in the existing turbine exhaust is used. In conventional boilers, this value was around 73 Sm^3. Therefore, it can be said that there is a natural gas saving potential of 14.5 Sm^3 per additional ton of steam. It can be seen that 54,288 Sm^3 of natural gas can be saved for each ton of additional steam production per year for an operational period lasting 12 hours per day, 26 days per month and 12 months per year. For ex., if we look at the scenario in the table; If a supplementary firing waste heat boiler system is installed instead of using an additional boiler in a facility that receives 10.5 tons/h of steam from the waste heat boiler and has an average steam consumption of 25 tons/h or more under normal conditions, there is a natural gas saving potential of 787,000 Sm^3 per year it could be. Of course, this value may decrease according to real usage profile. Additional combustion systems in the market can reduce the oxygen in the turbine exhaust gas up to 10%. The parameter taken into consideration while designing here is mostly the mixture temperature after combustion. For example, in the above application, the end-of-combustion temperature was chosen as 800 °C in terms of the resistance of the system equipment. The natural gas consumption that will provide this mixture temperature and the corresponding steam production have been determined. Again, in our case, although we burn enough fuel to receive an additional 14,5 t/h of steam, there is still 11.8% of oxygen in the exhaust, that is, a high amount of oxygen. In these systems, if desired, combustion and steam production can be continued like a conventional boiler by using a fresh air fan to feed the plant during turbine stops. Thus, the facility can be fed from the same waste heat boiler without the need for a new boiler, even if a cogeneration unit is not working. Another advantage of this system is that the gas turbines' exhaust flow rates (i.e. ready oxygen) do not change much according to the load. In other words, the exhaust flow rate in a gas turbine operating at 50% load is slightly below the flow rate at 100% capacity. Thus, it is possible to realize high additional steam production even at low cogeneration unit loads. To summarize, the applicability of this system depends on the fulfillment of the following conditions;

- The need for continuous and high capacity steam/heat in the facility
- Operational, geographical and climatic conditions are suitable for gas turbine application
- Application to a newly designed facility rather than an existing system
- Considering the NO_x emission that will increase as a result of additional combustion

It can be said that the increase in efficiency in production is achieved through the use of existing pre-heated oxygen and the additional heat gained by further reducing the exhaust outlet temperature.