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Waste Heat Recovery Boilers (WHRBs) and Heat Recovery Steam Generators (HRSGs) used for Co-generation and Combined Cycle Power Plants

Emin Taner ELMAS*

Vocational School of Higher Education for Technical Sciences, Iğdır University, Turkey

*Corresponding author: Emin Taner ELMAS, Assistant Professor Dr., Vocational School of Higher Education for Technical Sciences, Division of Motor Vehicles and Transportation Technologies, Department of Automotive Technology, Iğdır University, Turkey & Graduate School of Natural and Applied Sciences - Major Science Department of Bioengineering and Bio-Sciences, Iğdır University, Turkey

Abstract

This article explains the general design structure of Waste Heat Recovery Boilers (WHRBs) – Heat Recovery Steam Generators (HRSGs) which are used for Co-generation and Combined Cycle Power Plants.

As a result of energy shortage and electrical interruptions, the investors have been guided for alternative solutions in order to be able to produce energy in a more efficient way. Co-generation and Combined Cycle Power Plants can produce both electrical energy and heat energy together. They also provide a great considerable amount of fuel saving and to realize an efficient energy economy. Since they provide a high level of fuel economy, the pollutant emission level decreases, so the air pollution effect is minimized, causing a cleaner and more friendly environment. That means, both environmental benefits and also economical savings can be obtained by the application of such type energy production models. Waste Heat Recovery Boilers (WHRBs) – Heat Recovery Steam Generators (HRSGs) are used in order to be able to obtain heat energy from the exhaust waste heat of gas turbines, motors and gas motors. The gas turbines and motors are used combined with generator systems and provides directly electrical energy. The exhaust flue gases coming from the gas turbine have a great potential of heat energy which can be recovered. Therefore, WHRBs – HRSGs are the main heat recovery items that is used to recover the heat energy of exhaust gases of gas turbines, motors and gas motors. These types of applications increase the thermal energy efficiency rate to a highly considerable amount [1].

The waste heat of exhaust flue gases can be recovered and converted either hot water, superheated water, saturated steam or superheated steam. The obtained hot water, superheated water or saturated steam is used for industrial process purposes. The superheated steam obtained is used either for industrial processes or for steam turbine – generator set in order to be able to obtain electricity. The thermal design of the WHRB – HRSG is accomplished in accordance with the required recovery working fluid or fluids. After that, the constructional structure and the mechanical design works are carried out accordingly. [1-17].

Keywords: Waste Heat Recovery Boiler; WHRB; Heat Recovery Steam Generator; HRSG, Co-generation; Combined Cycle Power Plant; Gas Turbine; Gas Motor; Motor; Energy Efficiency; Energy Transfer; Electrical Energy; Heat Energy; Thermodynamics; Fluid Mechanics; Heat Transfer; Mathematics; Energy Production Systems; Thermal Energy; Energy Economy

Introduction

Waste Heat Recovery Boilers (WHRBs) – Heat Recovery Steam Generators (HRSGs) are designed in two different constructional structures which are "Smoke Tube Boiler Type" and "Water Tube Boiler Type". The construction type is determined according to the required flow rate capacity, temperature and pressure rates. Most recently, Smoke Tube Type WHRBs – HRSGs are preferred for boilers under 7.5 MWth of thermal capacity and working pressure up to 18 Bar(g). For higher capacities and pressures, Water Tube Type WHRBs - HRSGs are used [1].

WHRBs – HRSGs; at the downstream of gas turbines, motors or gas motors in every kind of industry; at the downstream of furnaces in the glass, ceramic and cement industry; in marine applications special designed vertical WHRBs – HRSGs, at the downstream of marine motors, are used to produce steam, superheated water, using the exhaust gas of turbines, motors and furnaces. There are many kinds of these type installation applications all over the world [1].

As a result of energy shortage and electrical interruptions, the investors have been guided for alternative solutions in order to be able to produce energy in a more efficient way. Co-generation and Combined Cycle Power Plants can produce both electrical energy and heat energy together. They also provide a great considerable amount of fuel saving and to realize an efficient energy economy. Since they provide a high level of fuel economy, the pollutant emission level decreases, so the air pollution effect is minimized, causing a cleaner and more friendly environment. That means, both environmental benefits and also economical savings can be obtained by the application of such type energy production models. Waste Heat Recovery Boilers (WHRBs) – Heat Recovery Steam Generators (HRSGs) are used in order to be able to obtain heat energy from the exhaust waste heat of gas turbines and gas motors. The gas turbines are used combined with generator systems and provides directly electrical energy. The exhaust flue gases coming from the gas turbine have a great potential of heat energy which can be recovered. Therefore, WHRBs – HRSGs are the main heat recovery items that is used to recover the heat energy of exhaust gases of gas turbines, motors and gas motors. These types of applications increase the thermal energy efficiency rate to a highly considerable amount [1].

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The design, manufacturing and installation periods of WHRBs – HRSGs are realized in accordance with a quality management system which covers all the requirements of both quality control and quality assurance processes. In addition, all the required national / international technical Norms and Standards must be applied depending upon the technical specifications according to the thermal and mechanical design conditions of WHRBs -HRSGs [1-17].

Method, Findings and Discussion

Figure 1 shows a general view of Waste Heat Recovery Boilers (WHRBs) - Heat Recovery Steam Generators (HRSGs) used for Co-generation and Combined Cycle Power Plants [1].

Figure 2 shows the main parts and sections of WHRBs - HRSGs [1].

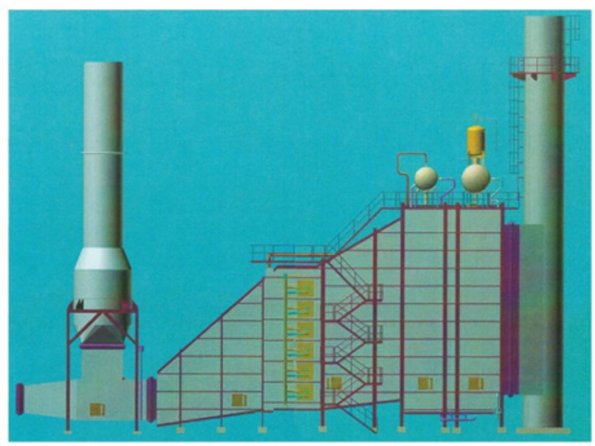

Figure 1: A general view of Waste Heat Recovery Boilers (WHRBs) - Heat Recovery Steam Generators (HRSGs) used for Co-generation and Combined Cycle Power Plants [1].

The numbered parts and sections on Figure 2 are explained as follows: [1]

1. Turbine outlet expansion joint; to compensate expansions on the gas turbine outlet duct.

2. Gas turbine outlet reduction duct.

3. By-pass damper to regulate the gas flow amount according to the steam consumption.

4. By-pass stack expansion joint; to compensate

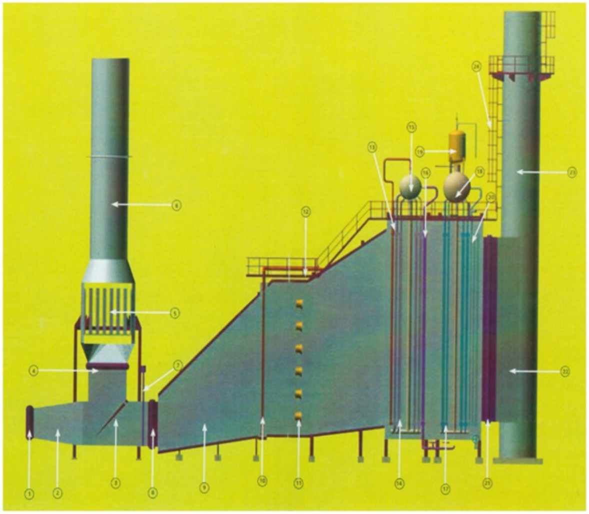

Figure 2: The main parts and sections of Waste Heat Recovery Boilers (WHRBs) - Heat Recovery Steam Generators (HRSGs) used for Co-generation and Combined Cycle Power Plants [1].

expansions on the by-pass stack.

5. Silencer; designed to reduce the noise to the required level.

6. By-pass stack; used to exhaust the flue gas from the gas turbine which will not be processed in Heat Recovery Steam Generator (HRSG).

7. Guillotine damper; used during the maintenance of HRSG or only during electric production. This damper maintains the sealing and prevent the exhaust gas from leaking to the boiler side.

8. HRSG inlet duct expansion joint; to compensate expansions on the HRSG inlet duct.

9. Exhaust gas boiler inlet duct; internally insulated with rockwool and stainless steel liners.

10. High pressure superheater I; comprised of "all welded" harp sections.

11. Supplementary firing system; installed at the boiler inlet duct to increase the turbine outlet gas temperature to get more steam flow.

12. Desuperheater connection; as required to regulate the superheated steam temperature with spray water, between intermediate and final stage superheaters.

13. High pressure superheater II, comprised of "all welded" harp sections.

14. High pressure boiler section comprised of "all welded" vertical module harp sections, downcomer piping and lower feeder headers. The natural circulation design allows for rapid start-up.

15. High pressure steam drum; with shop installed internals to meet stringent steam purity requirements.

16. High pressure economiser section; comprised of "all welded" vertical module harp sections. A full scope of customs economiser design is available for various load following capabilities, while avoiding any potential economiser steaming.

17. Low pressure boiler section comprised of "all welded" module harp sections, downcomer piping and lower feeder headers. The natural circulation design allows for rapid start-up.

18. Low pressure steam drum; with shop installed internals to meet stringent steam purity requirement, modified for integrated deaerator arrangement.

19. Integrated deaerator; purify O2 from water, deaerate the boiler feed water.

20. High- or low-pressure economiser; comprised of "all welded" module harp sections. A full scope of customs economiser design is available for various load following capabilities, while avoiding any potential economiser steaming.

21. HRSG outlet duct expansion joint; to compensate expansions on the HRSG outlet duct.

22. HRSG outlet exhaust gas duct.

23. HRSG main stack.

24. Galvanized access platforms, ladders and stairway.

The HRSG inlet duct with shop installed insulation covered by stainless steel liner panels are designed for exhaust gas temperatures up to 750 °C. Top supported high-pressure superheater and reheater section to minimize expansion of associated external piping. Superheaters / Reheaters are fully drainable. Desuperheater piping is designed as required for intermediate or final stage de-superheating arrangements. The economiser section can be designed for partial or full water by-pass. The low pressure (LP) steam is typically used for a deaerator. Superheated LP steam may, in some applications, be used for admission to the steam turbine. Carbon steel or stainless-steel condensate preheater section is equipped with "all welded" module harp section. In many applications, the preheater increases the overall HRSG thermal efficiency. Intermediate steam drum is equipped with shop installed internals. The deaerator tank with pegging steam lines and equalizer lines.

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The deaerator is modified for an integral arrangement [1-17].

Conclusion

Waste Heat Recovery Boilers (WHRBs) - Heat Recovery Steam Generators (HRSGs) increase the total system thermal efficiency up to 48-53% in combined cycle power plants, and up to 75-82% in co-generation power plants, while converting waste energy to useful process heat energy, the investment pays itself back in a very short period of time for any kind of operating condition; as the power plant saves the energy and decreases operating costs. By implementing such type of power plants, it is also possible to provide a great considerable amount of fuel saving and to realize an efficient energy economy. Since they provide a high level of fuel economy, the pollutant emission level decreases, so the air pollution effect is minimized, causing a cleaner and more friendly environment. That means, both environmental benefits and also economical savings can be obtained by the application of such type energy production models. [1-17].

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*Corresponding author: : Emin Taner ELMAS, e.taner.elmas@igdir.edu.tr