Journal of Advanced Research in Mechanical Engineering and Technology
Volume 7, Issue 1&2 - 2020, Pg. No. 9-15
Peer Reviewed Journal

Research Article

Thermodynamic Aspects, Prerequisites, Major Considerations, Maintenance and Instrumentation of a High Pressure Boiler & Energy Auditing of a Cogeneration Plant

SA Mohan Krishna[1], GV Naveen Prakash[2], KB Vinay[3], KS Ravi[4], TA Prabhakar[5], Anil Kumar Nadiger[6]

[1,3,4]Associate Professor, [2]Professor and Head, Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Mysore, Karnataka, India.
[5]Project Engineer, RMP (BARC) Utilities, Mysuru, Karnataka, India.
[6]Managing Director, Rachna Ener Care, Mysore, Karnataka, India.

I N F O

Corresponding Author:
SA Mohan Krishna, Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Mysore, Karnataka, India.
E-mail Id:
mohankrishnasa@vvce.ac.in
Orcid Id:
https://orcid.org/0000-0002-9877-7189
How to cite this article:
Krishna SAM, Prakash GVN, Vinay KB et al. Thermodynamic Aspects, Prerequisites, Major Considerations, Maintenance and Instrumentation of a High Pressure Boiler & Energy Auditing of a Cogeneration Plant. *J Adv Res Mech Engg Tech* 2020; 7(1&2): 9-15.

Date of Submission: 2020-03-16
Date of Acceptance: 2020-04-09

A B S T R A C T

The mammoth development in the industries and sector of automobile engineering has elevated the socio-economic eminence of a country. This development is majorly attributed to the energy and its profile. In view of this continuous and reliable energy have become the key issue and this calls for a powerful qualitative approach with regard to energy and its effective exploitation. The conservativemode of generation of power and source to the customer is not operative in that only about one third of the principal energy nourished to the power plant is essentially made accessible to the user in the form of electricity. This necessitates additional techniques or methods to satisfy the energy requirement. Cogeneration plant is one of very operative and prevalent energy generating methods attainingprominence in the topical years. Cogeneration offersaextensiveassortment of know-hows for presentation in innumerabledominions of fiscal activities. The inclusiveefficacy of energy procedure in cogeneration approach can be approximately 85 per cent and above in particularcircumstances.In this paper, the thermodynamic aspects of a high pressure boiler and principles of energy auditing have been discussed.

Keywords: Sectors, Energy, Power, Cogeneration, Domains

Introduction

A 'Boiler' is defined as a padlockedreceptacle in which the amount of steam is formed from water by the phenomenon of combustion of fuel. Agreeing to American Society of Mechanical Engineers (ASME) a 'steam generating unit' has beenwell-defined as: "A amalgamation of contraption for generating, delivering or recuperating heat together with the apparatus for transferring the heat so made accessible to the fluid being heated and vaporized.[1] Every boiler operates on the essential thermodynamic basic concepts and pertinent principles. Consequently, extreme theoretical efficiency can be premeditated for a given boiler design. The maximum value characterizes the upper most

obtainable efficacy of the unit. The initial rating of a boiler is the bottommostserving of the boiler outlay. Fuel and maintenance costs embody the largest portion of boiler paraphernaliastock. Some rudimentary strategy differences can divulge variations in anticipated proficiency assessment or performance levels.[1-5]

A boiler has emerged as an important tool of industry with a high degree of versatility. As a source of hot water or steam it has found application in a variety of industries like aluminum, automobiles, concrete block and bricks, ceramic glass, inorganic and organic chemicals, copper primary and secondary, lumber, pulp and paper, selected plastics, rubber, textiles and sugar. A modern industrial boiler in the shape of a shell type multitubular boiler is an example of optimized design and efficiency, no single design can satisfy the need of wide range of requirements. Boiler has been increasingly employed for power generation especially for captive power plants, where the demands are more severe. In its essentials a boiler consists of a furnace in which any fuel – oil, coal, wood, husk, or gas are burnt to produce combustion products and thereby generate heat, and an arrangement to heat water or produce steam.[6-12]

High Pressure Boilers is usually employed for the generation of power is for steam capacities 30 to 650 tonnes per hour and above with a pressure up to 160 bar and determined steam temperature of about 640˚C. The High Pressure Boiler generally in a power plant develops steam pressure at 65 bar and steam temperature at 500˚C. Water tube boilers are generally favored for high pressure and high production, however, shell boilers for low pressure and low output.[13-18]

Prerequisites of High Pressure Boilers

Some of the important prerequisites of High Pressure Boiler of any power station are:

i. In high pressure boiler, pumps are employed to preserve forced circulation of water through the tubes of the boiler. This guarantees positive circulation of water and upsurges evaporative capability of the boiler and less number of steam drums will be mandatory.
ii. The heat of combustion is operated more resourcefully by the use of small diameter tubes in large number and in multiple circuits.
iii. Pressurized incineration is used which intensificationsdegree of firing of fuel consequently increasing the rate of heat discharge.
iv. The propensity of scale materialization is jettisoned due to high quickness of water through the tubes.
v The discrepancydevelopment is abridged due to unvarying temperature and this diminishes the possibility of trickles of gas and air.
vi There is a greater tractability in the components arrangement.
vii. The steam can be raised hurriedly to meet the adjustable load necessities without the use of intricate control contrivances.

Generally, the selection of fuel for the generation of steam is coal. The coal is organized in to fine triturated during pulverization, which is best suited for the plant. A theoretical study is to be accomplished on the innumerable characteristicsviz., coal properties, coal classification, and analysis of coal, stowage, handling and preparation of coal and combustion occurrence. The chemical conformation of coal has a resilientstimulus on its combustibility.

Boiler Maintenance & Protection

Proper selection of tube material for coal fired boilers is very essential for its safety and performance. High pressures and temperatures, corrosion, erosion and stress, all must be accommodated in the boiler tubes. In addition to this, operating procedures and maintenance also have impact on tube performance. It is also necessary to keep the tubes clean internally and externally free from deposits that could impair heat transfer and lead to corrosion, ultimately causing tube failures. Some of the prominent engineering alloys used in boiler at Falcon plant are Carbon Steels, Ferrite alloys, Carbon-molybdenum steel and Chromium.

Some of the maintenance techniques adopted by the company are:

- Preventive Maintenance
- Breakdown Maintenance
- Annual Maintenance

Corrosion damage is always experienced inside tubes of the boiler, economizer and superheater when water chemistry is not maintained within limit as recommended by the boiler manufacturers. To avoid the corrosion, one should understand the importance of maintaining the iron oxide coating on the internal surfaces of the boiler tubes. Proper maintenance of boilers is done to safeguard from harmful deposits. In any power generating station, boiler maintenance is done once in every two months. Since the plant is new, the energy loss in minimum. In future, compulsorily maintenance must be done to enhance energy efficiency. It is envisaged that the service life of the boiler is approximately 12 to 15 years.

Entirely power production plants, perpetually, contaminate the atmosphere and the consequentialdisproportion on ecosystem has aunscrupulousupshot. The pollution is inevitable in some cases and has to be minimized to the extent possible. This is being achieved by effective legislations all over the world. Usually, in a Boiler or Steam Power Plant emissions can be classified as:

- Gaseous emission, includes pollutants namely SO_2, H_2S, NO_x and CO

- Particulate emission
- Solid waste
- Thermal pollution

It is clearly observed that, there is negligible environmental pollution from the Cogeneration plant, because of safe incorporation of Electrostatic Precipitators (ESP). Also, the dissipation of flue gases through chimney is systematic. The flue gases dissipated to the surroundings from the chimney at the plant is about 80 ˚C. Stack and heat losses are minimum, thereby avoiding environmental problems.

Need for Cogeneration

Thermal power plants or Steam Power Plants are a foremostbasis of electricity stream in India. The foremostfont of forfeiture in the adaptationprocedure is the heat precluded to the adjacent water or air owing to the characteristicconstrictions of the dissimilar thermodynamic sequencesengaged in the cohort of power. Generallypower plants will gain standing because of Cogeneration plant. The collective thermal energy and power generated in the plant is satisfying the requirements to greater extent. Before the installation of Cogeneration plant, the production rate of tyres was moderate. Because of Cogeneration unit, the production of tyres in the company is increased by 20%.[19-26]

Control & Instrumentation

Control and Instrumentation is compulsory for a boiler plant. The necessity and role of control and instrumentation in a boiler plant and the various techniques adopted are to be surveyed. In boiler instrumentation, it is necessary to know the various instruments used, its operational features and applications. It is apparent that the products of combustion or the flue gases are expected to contain the constituents like carbon dioxide, carbon monoxide, nitrogen, water, oxygen and may be even excess fuel. Sulphur and nitrogen oxides may be expected to be present in traces. The estimation of carbon dioxide, carbon monoxide, unburnt oxygen provide a clue to completeness or otherwise of combustion and forms the basis of control instrumentation to achieve optimization. Generally microprocessor based measurement and control systems a facility to monitor in situ the combination parts continuously with a view to improve efficiency by automated adjustment of air fuel ratio.[25-31]

Microprocessor Based Combustion Control Techniques have emerged in the form of incessantconnected sensors that quantity and show the gas temperature, oxygen, combustion efficiency. This leads to a better understanding of the equipment performance, and helps achieve, quantitative energy conservation controls. Most of these are based on in situ measurement techniques such as probes for oxygen and wide path visible light and infrared transmission meters for the measurement of particulate matter and CO. In any company preferably, Microprocessor Based Combustion Control Technique is adopted.

Some of the important control methods are:

- Chemical Absorption Methods
- Physical Absorption Methods
- Microprocessor Based Combustion Control Techniques
- Hybrid Microprocessor Based Measurement and Control Systems

Control and Instrumentation is generally done in an organized manner minimizing technical hindrances. Instruments provide precise information for supervision to safe, unceasing and proper plant operation. The functions which the various instruments are required to perform in any boiler plant are itemizedunderneath:

i. Functioning direction-Instruments provide guidance to activate the power plant competently and economically
ii. Performance calculations-render help in making performance calculations in respect of plant working
iii. Maintenance and repair guidance – As the instruments enable us to plaid the internal circumstances of the equipment, thus they affordpreservation and overhaulregulation
iv. Cost-effective administration-enable us to supervise the plant economically
v. Cost allocation-Instruments extend a helping hand in dealing with the problems concerning accounting and cost allocations.[1]

Energy Audit & Necessity

Energy Audit is the crucial to a methodicalmethod for supervisory in the expanse of Energy Management. It challenges to poise the total energy involvementsor responses with its usage, and serves to recognizeentire energy brooks in a capability. It quantifies energy usage according to its distinctpurposes. Energy audit pertaining to industries is an operative tool in significant and trackingall-inclusive energy management programmes. As per the Energy Conservation Act, 2001, Energy Audit is defined as "the corroboration, observing and examination of use of energy including suggestion of technical report containing recommendations for cultivating energy efficiency with cost benefit investigation and an action to reduce energy ingesting."

The concept of energy audit as a prelude to the identification of energy conservation schemes in any industrial complex, and the selection of the final one for implementation based on criteria dictated by the cost appraisal techniques. The identity of energy audit as a tool for energy management has been recognized. The ultimate objective of conducting an energy audit of an industrial complex is to examine and conclude whether the total energy in any form being spent in the plant is being used efficiently or not.

Contingent on the behavior and convolution of the location, a wide-rangingreview can take from numerous weeks to some months to thorough. Comprehensiverevisions to create, and examine, energy and quantifiablepoises for explicit plant subdivisions or items of progression equipment are accomplished. The inspection report will compriseaexplanation of energy contributions and product productivity by chief department or by foremostdispensationpurpose, and will appraise the productivity of each step of the manufacturing process. The audit report should clinch with specific commendations for engineering studies and probability analysis.

Energy Audit of a TYPICAL Cogeneration plant

Table 1.Energy Audit report for the power boiler

Particulars	Numerical Value	General Remark/ Recommendation
Plant Details and Specifications		
Boiler Make		Make- CVL, Trichy
Quantity of steam	40 tonnes per hour	
Steam Pressure and temperature	66 kg/cm^2 and 500 deg C	
Quantity of coal consumed	6 TPH	
Feed water temperature	105 deg C	
Boiler efficiency	75% - 78%	Reasonable efficiency
GCV of Coal	5000 kcal/kg	Variable GCV
Type of coal		Highly volatile Bituminous coal
Air fuel ratio	6 to 18	
Heating surface	2700 m^2	
Flue gas temperature at Furnace	505 – 520 deg C	
Flue gas temperature at Chimney outlet	80 deg C	
Feed water temperature at boiler drum	220 deg C	
Diameter of Chimney	1.8 m	
Height of Chimney	60 m	
Temperature at the inlet of Economizer	380 – 480 deg C	
Temperature at the exit of Economizer	180 – 200 deg C	
Coal size	6 – 8 mm	
Compressor pressure	6 kg/cm^2	
Turbine speed	8200 – 8400 rpm	
Turbine efficiency	78%	
Energy Balance Sheet For The Boiler		
Heat loss due to dry flue gases	13.49%	In the Cogeneration plant, the energy losses are minimum, as the plant is functioning from past 2 years only. The boiler efficiency of the plant is 75%.
Heat loss due to Evaporation of Water formed due to H_2 in fuel	4.69%	
Heat loss due to moisture present in air	0.193%	
Heat loss due to radiation and unaccounted losses	4.5%	
Blow down losses	2%	
Annual Heat Loss		
Heat rate	396.8 W/m	
Annual heat loss	750.81 GJ	

Cost Benefits For The Existing Cogeneration Plant		
Energy consumed per annum	432×10^5 kWh per annum	
Heat input to generate above calculated units	1382400×10^5kCal	
Coal quantity required per annum	27.85×10^6 kg	
Cost of fuel per annum	11 crores to 1 crores	
Cost of capital and operation charges/ annum	1.5 crore	
Overall cost of power from cogeneration plant	12 to 13 crores	
Power consumption at 90% Load Factor or Average load	5400 kW	
Annual Energy Saving Potential	432×10^5 Units/year	
Annual Generation Cost	$432 \times 10^5 \times$ Rs.3.70 = Rs. 59,840,000	
Power selling cost per unit	Rs. 5	
Annual power selling cost	$432 \times 10^5 \times$ Rs.5 = Rs. 216,000,000	
Profit per year	Rs. 216,000,000 – Rs. 159,840,000 = Rs. 56,160,000	
Payback Period	6 years	
Energy Saving Oppurtunities		
Optimizing flue gas temperature through excess air control		In the plant, flue gas temperature is optimized continuously by supplying excess air for combustion
Heat recovery from the flue gases with the use of economizer and air pre heater		In the plant, heat loss is moderate. Also, the flue gas temperature is not affecting any thermodynamic aspects of the boiler
Control of TDS and blow down		Level of concentration of TDS is controlled by giving 1 to 2% blow down
Condensate recovery		Normal
Water treatment and its role in energy conservation		In the plant, both RO and DM units are maintained. This is a major advantage
Deposits		Moderate to low
Scale formation		No problem
Convective and radiation losses		Minimum
Maintenance		Three particular methods of maintenance are done in the plant. They are preventive, breakdown and annual. Once in every two months, maintenance is done to achieve the energy savings and monitor efficiency
Boiler Thermodynamic Conditions		
Air and flame leakage		No problem

Periodic cleaning of flue ducts, waste heat recovery systems		Occasionally done in the company. This may lead to the deterioration of the boiler components and hence periodic cleaning is compulsory
Condition of Chimney		Good
Soot deposit		No problem
Fuel selection		C Grade Coal with good features
Flame pulsations		Normal
Frequency of blow down		Both continuous and intermittent blow down is given
Steam distribution to various parts of the plant		Continuous supply
Excess air supply		Normal
Coal pulverization		Good
Boiler loading schedules		Variable load condition
Steam leakage		No problem
Proper selection, placement, installation, functioning, maintenance of steam traps		Thermostatic steam trap is used to recover condensate easily
Feed water treatment		Normal
Clinker control		No problem
Control and Instrumentation		
Microprocessor based combustion control system		Company follows a recognized control method, Supervisory Control and Data Acquisition, popularly called SCADA
Instrumentation		Very reliable instruments namely flow meter, PH measuring instrument, gas analyzers, thermometers and pressure gauges. Company has good instrumentation facility
Service Life of the Plant		It is approximately estimated as 12 to 15 years.

Conclusion

The work was carried out in a Cogeneration plant aimed at enhancing the energy efficiency of Cogeneration plant by performing thermal analysis and energy audit for the existing power boiler. The theoretical study is also carried out involving fuel selection and properties, water treatment plant, steam distribution system, energy conservation opportunities, control and instrumentation and cost benefits for existing steam turbine based cogeneration. The performance evaluation of boiler is done by using direct and indirect methods, which is also helpful for tabulating energy balance sheet to analyze the heat losses.

The energy audit report in the project will provide the information about the boiler plant involving plant details, energy balance, cost benefits, energy saving opportunities, thermodynamic conditions and maintenance. For any plant, Cost economics plays a very dominating role to extract information about energy consumption per annum, fuel consumption and various cost factors.

References

1. Rajput RK. Applied Thermodynamics. Laxmi Publications, Fourth Edition, 2007.
2. Murgai MP, Chandra R. Boiler operations – Progress in Energy Auditing and Conservation. New Age International Publishers, New Delhi, First Edition, 1990.
3. Cengel YA, Boles MA. Thermodynamics – An Engineering Approach. Fifth Edition, Tata McGraw-Hill Publishing Limited, New Delhi, 2007.
4. Kohan AL. Boiler Operator's Guide. Tata McGraw-Hill Education Private Limited, New Delhi, Fourth Edition, 2009.
5. Gunn D, Horton R. Industrial Boilers. Longman Scientific

and Technical, New York.
6. Carl D Shields. Boilers McGraw Hill Book Company, United States, 1961.
7. Jackson JJ. Steam Boiler Operation. Prentice-Hall Inc, New Jersey, 1980.
8. Pincus LI. Practical Boiler Water Treatment. McGraw Hill Inc, New York, 1962.
9. Wakil MM. Power Plant Technology. McGraw Hill Publication, Fourth Edition, 2001.
10. Malhotra H. Parameters for Selection of Fuel Efficient Coal Fired Boilers. Workshop on Fuel Efficient Boilers, PHD House, New Delhi.
11. Chiogioji MH. Industrial Energy Conservation. Marcel Dekker Inc, New York. 1979.
12. Shah AK. Combustion Engineering and Fuel Technology. Oxford and IBH Publishing Company.
13. Lawan CJ. Principles of Combustion Engineering for Boilers. Academic Press, New York.
14. Williams JN. Steam Generation. George Allen and Unwin Limited, London, 1969.
15. Dehnel PD. Fundamentals of Boiler House Techniques. Hutchinson & Company (Publishers) Limited, Great Portland Street, London.
16. Goodall PM. The efficient use of Steam. Westbury House, England.
17. Northcroft LG, Barber WM. Steam Trapping and Air Venting. Hutchinson and Company Limited, London Cogeneration – Training Material by NIFES, UK.
18. Energy Cogeneration Handbook Criteria for Central Plant Design by George Polimeros, Industrial Press Inc, New York.
19. Skrotzki BGA, Vopat WA. Power Station Engineering and Economy. Tata McGraw-Hill, New Delhi, 1979.
20. Kenny WF. Energy Conservation in the Process Industries. Academic Press, New York 1984.
21. Murphy WR, McKay G. Energy Management. Butterworths, London, 1982.
22. Harker JH, Backhurst JP. Fuel and Energy. Academic Press, New York.
23. Dyer D, Maples G. High Technology Improvements for Boiler Efficiency. Energy Engineering, 1986.
24. Robertson WS. Boiler Efficiency and Safety. The Macmillan Press Limited, London, 1981.
25. Smith CB. Energy Management Principles. Pergamon Press, New York, 1981.
26. Pyne GA. Energy Manager's Handbook. Westbury London.
27. Dryden IGC. The efficient use of Energy. IPC Science and Technology Press, England.
28. The Prudent use of Gas – An Industrial Guide to Energy Conservation, American Gas Association.
29. Thumann A. Optimizing HVAC systems. The Fairmount Press Inc, 700 Indian Train, Liburn, GA 30247, USA.
30. Arora, Domkundwar. A Course in Power Plant Engineering", DhanpatRai and Sons, Fifth Edition.