Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 61 (2013) 17059-17063

ISSN: 2229-712X

Generation of correction curves for power and heat rate by thermodynamic analysis of combined effect of inlet pressure (123.14bar) and different inlet temperatures on thermal power plant

Ankur Geete[1,*] and A. I. Khandwawala[2]

[1]Mechanical Department, S. D. Bansal College of Technology, Indore, Madhya Pradesh, India.
[2]Mechanical Department, SGSITS, Indore Madhya Pradesh, India.

ARTICLE INFO

Article history:
Received: 3 June 2013;
Received in revised form:
24 July 2013;
Accepted: 6 August 2013;

Keywords
Inlet Pressure,
Inlet Temperature,
Power Output,
Heat Rate,
Correction Curve for Power,
Correction Curve for Heat Rate.

ABSTRACT

The thermal power plants are used to generate power. The thermal power plants are designed based on required conditions, but actually inlet conditions are not as per the designed conditions. Variations in the power outputs from power plant are always a matter of disputes. So correction curves for power and heat rate are generated. In this paper, the thermodynamic analysis of 120MW thermal power plant has been done at a different inlet pressure (123.14 bar) and at different inlet temperatures (507.78°C, 517.78°C, 527.78°C, 537.78°C, 547.78°C, 557.78°C, 567.78°C). The correction curves for power and heat rate have been generated for the combined effect of inlet pressure and different inlet temperatures. These curves indicate that if inlet conditions vary then power output and heat rate also vary.

List of Symbols, Abbreviation and Nomenclature

Ex_1 = Extraction Quantity after Expansion in HP Turbine for Heater No. 6 (kg/sec).
Ex_2 = 1st Extraction Quantity from IP Turbine for Heater No. 5 (kg/sec).
Ex_3 = 2nd Extraction Quantity from IP Turbine for Deaerator (kg/sec).
Ex_4 = Extraction Quantity after Expansion in IP Turbine for Heater No. 3 (kg/sec).
Ex_5 = 1st Extraction Quantity from LP Turbine for Heater No. 2 (kg/sec).
Ex_6 = 1st Extraction Quantity from LP Turbine for Heater No. 1 (kg/sec).
FF = Flow Function
h = Enthalpy of Feed Water at Inlet of Boiler (kJ/kg).
h' = Enthalpy of Steam Before Entering Super heater (kJ/kg).
h_1 = Enthalpy of Steam at Inlet of HP Turbine (kJ/kg).
h_2 = Enthalpy of Steam at Outlet from HP Turbine (kJ/kg).
h_3 = Enthalpy of Steam at Inlet to IP Turbine or Outlet from Super heater (kJ/kg).
h_4 = Enthalpy of Steam after 1st Extraction from IP Turbine (kJ/kg).
h_5 = Enthalpy of Steam after 2nd Extraction from IP Turbine (kJ/kg).
h_6 = Enthalpy of Steam at Outlet from IP Turbine (kJ/kg).
h_7 = Enthalpy of Steam after 1st Extraction from LP Turbine (kJ/kg).
h_8 = Enthalpy of Steam after 2nd Extraction from LP Turbine (kJ/kg).
h_9 = Enthalpy of Steam at Outlet from LP Turbine (kJ/kg).
L_1 = Steam Used for Reducing Pressure Difference b/w 1st & Last Stage of HP Turbine (kg/sec).
L_2 = Leakage before Entering Steam in HP Turbine (kg/sec).
L_3 = Leakage before Entering Steam in HP Turbine (kg/sec).
L_4 = Leakage Before Entering Steam in HP Turbine (kg/sec).
L_5 = Leakage after Steam Expand in HP Turbine (kg/sec).
L_6 = Leakage after Steam Expand in HP Turbine (kg/sec).
L_7 = Leakage before Entering Steam in IP Turbine (kg/sec).
L_8 = Leakage before Entering Steam in IP Turbine (kg/sec).
L_9 = Leakage before Entering Steam in LP Turbine (kg/sec).
P = Pressure of Steam for 120MW Power Plant (design condition) (N/m^2).
Q_1 = Heat addition in Boiler (kJ/kg).
Q_2 = Heat addition in Super heater (kJ/kg).
V = Specific Volume of Steam for 120MW Power Plant (design condition) (m^3/kg).
W = Mass Flow Rate of Steam for 120MW Power Plant (design condition) (kg/sec).
W' = Mass Flow Rate Generated in Boiler at Different Conditions (kg/sec).
W_1 = Mass Flow Rate at Inlet of HP Turbine (kg/sec).
W_2 = Mass Flow Rate at Inlet of IP Turbine (kg/sec).
W_3 = Mass Flow Rate after 1st Extraction of Steam from IP Turbine (kg/sec).
W_4 = Mass Flow Rate after 2nd Extraction of Steam from IP Turbine (kg/sec).
W_5 = Mass Flow Rate at Inlet of LP Turbine (kg/sec).
W_6 = Mass Flow Rate after 1st Extraction of Steam from LP Turbine (kg/sec).
W_7 = Mass Flow Rate after 2nd Extraction of Steam from LP Turbine (kg/sec).

Tele: +91 - 9926081734
E-mail addresses: ankur_geete@yahoo.co.in

Introduction

This paper is based on 120 MW thermal power plant, so a brief description of 120 MW thermal power plant is given as under –

Thermal power plant consists of five major components – (1) Boiler, (2) Steam Turbines – High pressure turbine, Intermediate pressure turbine and Low pressure turbine, (3) Condenser, (4) Feed Water Pump – Pump after condenser and Pump after deaerator and (5) Feed Water Heater – one feed water heater for high pressure turbine, two feed water heater for intermediate pressure turbine and three feed water heater for low pressure turbine.

In the boiler, water converts into high pressure and temperature steam by the constant pressure heating process. Then high pressure and temperature steam enters into a high pressure steam turbine, in which steam expands and some amount of steam extract for feed water heating process. Then steam enters into an intermediate pressure turbine, in which steam expands and some amount of steam again extract for feed water heating process. And finally steam enters into a low pressure turbine, in which steam expands and some amount of steam again extract for feed water heating process. After passing through the low pressure turbine steam is converted into saturated water. Then water enters into the boiler with the help of a pump [1]. Bekdemir Sukrii, Ozturk Recep and Yumurtac Zehra [2] have been worked on condenser optimization in steam power plant. Sharda G. G. and Batra K. R. [3] have been worked on super thermal power station to improve the performance of the plant by distribution control system technology. Bednorz Richard and Henken Fritz [4] have been worked on modernization of turbine and condenser for improving the performance of power plant. Kaushik Prabhakar and Khanduja Dinesh [5] have been applied six sigma DMAIC methodologies in thermal power plants. Amir Vosough, Alireza Falahat, Sadegh Vosough, Hasan Nasr Esfehani, Azam Behjat and Roya Naseri Rad [6] have been worked on condenser to improve the efficiency of power plant. Mateen Abdul Sk. and Roa Nageswara Amar N. [7] have been done structural and thermal analysis of the condenser by finite element analysis. Carvalho L.M. and Cristiani P. [8] have been analyzed the corrosion in condenser tubes. Humbert F. Claude [9] has been worked on step-by-step approach to the evaluation and life extension of feed water heaters. Linda Riley, Carroll Willsie and Claude Humbert [10] have been worked on a feed water heater. Schaarschmidt Andreas, Jenikejew Eduard and Nitch Greg [11] have been worked on power plant to improve the performance by an elaborate design process. Schimon Rene, Simic Dragan, Haumer Anton, Kral Christian and Plainer Markus [12] have been worked on a simulation of the components of a thermal power plant. Dr. Quinkertz Rainer, Ulma Andreas, Gobrecht Edwin and Wechsung Michael [13] have been worked on operational flexibility and improve efficiency of the plant. Xu Cheng, Hary R. Winn, Robert A. Beveridge and Jefferey J.Williams [14] have been worked on cascade shell and tube type feed water heater. Becker R. Bryan and Pearce E. Richard [15] have been worked on life management and its applications on a feed water heater. Eike Roth, [16] has been worked on the efficiency of thermal power plants. Dr. A. Kaupp, [17], has been published a paper on thermal power plant. Copen H. John and Sulliwan B. Terrence [18] have been explained the complementary fired combined cycle plant design concept and compared its plant performance characteristics with conventional duct fired plants. Smiarowski W. Michael, Leo Rainer and Scholten Christof [19] have been worked on modernization of steam turbine. Cheski R. Jeffrey, Patel Ramanlal, Rockaway Kent and Osaghae Henry [20] have been worked on retrofit design and operation for large steam turbine. Lahoda Jaroslav, Arndt Olaf and Hanstein Walter [21] have been worked on the reheat concept by biomass fuel to increase efficiency of the plant. Mateen Abdul Sk. and Roa Nageswara Amar N. [22] have been done structural and thermal analysis of the condenser by finite element analysis. Vora Yogesh, Patel B. M. and Tewari C. P. [23] have been worked on performance evaluation of the turbo generator system of a thermal plant by the use of probabilistic approach. Sharma Meeta and Singh Onkar [24] have been worked on the thermodynamic evaluation of waste heat recovery boiler for its optimum performance. This work deals with the generation of correction curves for different inlet pressure and inlet temperature conditions. These curves help as a reference or as a document to prove the design of thermal power plant. A layout of 120MW thermal power plant

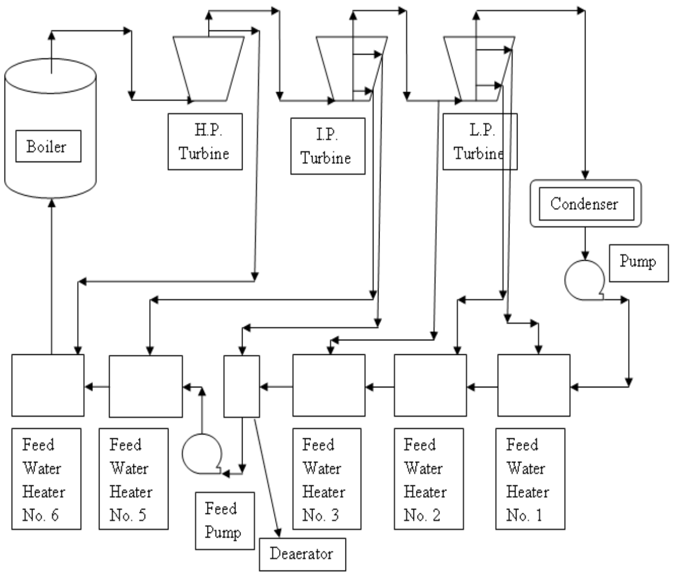


Figure 1 – Layout of 120 MW thermal power plant

Methodology

Flow Function Calculation

First of all flow function has been calculated with the relationship between mass flow rate, pressure and specific volume [25].

$FF = W/\sqrt{(P/V)}$ Eq. (1)

$FF = 363313/\ \sqrt{(125.1/0.0186)} = 4430.051$

$W = 363313.0$ kg/hr, $P = 125.1$ bar and $V = 0.0186$ m³/kg for 120MW power plant. (Ideal condition)

Mass Flow Rate Calculation

Then mass flow rate (W) has been calculated for given condition [25].

$FF = W/\sqrt{(P/V)}$

$4430.051 = W\ /\ \sqrt{(P/V)}$, here P and V given as per given condition.

Mass Flow Rate Calculation for Different Stages of HP, IP and LP Turbines

Then different mass flow rates have been calculated at different stages for HP, IP and LP Turbines for given condition [26].

1. $W_1 = (W' - L_1 - L_2 - L_3 - L_4)$ kg/sec Eq.(2)
2. $W_2 = (W_1 + L_1 - L_5 - L_6 - Ex_1)$ kg/sec Eq.(3)
3. $W_3 = (W_2 - Ex_2 - L_7 - L_8)$ kg/sec Eq.(4)

4. $W_4 = (W_3 - Ex_3)$ kg/sec Eq.(5)
5. $W_5 = (W_4 - Ex_4)$ kg/sec Eq.(6)
6. $W_6 = (W_5 - Ex_5 - L_9)$ kg/sec Eq.(7)
7. $W_7 = (W_6 - Ex_6)$ kg/sec Eq.(8)

Total Power Calculation

Then power has been calculated with the relationship between mass flow rate and enthalpy drop in the turbine for given condition [26].

Power = (Mass flow rate) x (Enthalpy drop in the turbine) Eq. (9)

P = HP Turbine $\{W_1 (h_1 - h_2\}$ + IP Turbine $\{[W_2 (h_3 - h_4)] + [W_3 (h_4 - h_5)] + [W_4 (h_5 - h_6)]\}$ + LP Turbine $\{[W_5 (h_6 - h_7)] + [W_6 (h_7 - h_8)] + [W_7 (h_{8\,-}\, h_{9)}]\}$ kW Eq. (10)

Net Power Calculation

Then net power has been calculated for given condition [26].

P_{net} = (Power – Mechanical Losses) x Generator Efficiency Eq. (11)

Heat Rate Calculation

And then heat rate has been calculated with the relationship between total heat addition in boiler and net power output from the power plant for given condition [26].

Heat rate = (Total heat addition in boiler) / (Net power) Eq. (12)

$HR = Q/ P_{net,}$ kJ/MW-sec Eq. (13)

$HR = (Q_1 + Q_2)/ P_{net,}$ kJ/MW-sec Eq. (14)

$Q_1 = W' (h_1 - h)$, (Heat addition in Boiler) Eq. (15)

$Q_2 = W_2 (h_3 - h')$ (Heat addition in Super heater) Eq. (16)

Case Study1 - Inlet Pressure

$FF = W/\sqrt{(P/V)}$

$FF = 363313/ \sqrt{(125.1/0.0186)} = 4430.051$ kg^2/bar m^3 hr

W = 363313 kg/hr, P = 125.1 bar and V = 0.0186 m^3/kg for 120MW power plant. (Ideal condition)

Inlet Pressure - 123.14 bar

Flow Function Calculation

$FF = W/\sqrt{(P/V)}$

$4430.051 = W / \sqrt{(123.14/0.0189)}$

$W' = 357583.440$ kg/hr

$W' = 99.33$ kg/sec

Power Calculation

- $W_1 = (W' - L_1 - L_2 - L_3 - L_4) = 99.33 - 1.263 - 0.042 - 0.311 - 0.108 = 97.606$ kg/sec
- $W_2 = (W_1 + L_1 - L_5 - L_6 - Ex_1) = 97.606 + 1.263 - 0.233 - 0.083 - 6.466 = 92.087$ kg/sec
- $W_3 = (W_2 - Ex_2 - L_7 - L_8) = 92.087 - 4.14 - 0.366 - 0.101 = 87.480$ kg/sec
- $W_4 = (W_3 - Ex_3) = 87.480 - 5.575 = 81.905$ kg/sec
- $W_5 = (W_4 - Ex_4) = 81.905 - 2.111 = 79.794$ kg/sec
- $W_6 = (W_5 - Ex_5 - L_9) = 79.794 - (2 \times 1.916) - 0.041 = 75.921$ kg/sec
- $W_7 = (W_6 - Ex_6) = 75.921 - (2 \times 1.711) = 72.499$ kg/sec

P = HP Turbine $\{W_1 (h_1 - h_2\}$ + IP Turbine $\{[W_2 (h_3 - h_4)] + [W_3 (h_4 - h_5)] + [W_4 (h_5 - h_6)]\}$ + LP Turbine $\{[W_5 (h_6 - h_7)] + [W_6 (h_7 - h_8)] + [W_7 (h_{8\,-}\, h_{9)}]\}$ kW

P = {[97.606 x (3438.969 – 3089.569)]} + {[92.087 x (3539.122 – 3387.304)] + [87.480 x (3387.304 – 3200.542)] + [81.905 x (3200.542 – 2918.559)]} + {[79.794 x (2918.559 – 2827.728)] + [75.921 x (2827.728 – 2654.718)] + [72.499 x (2654.718 – 2478.029)]}

P = 34103.463 + 13980.464 + 16337.939 + 23095.817 + 7247.768 + 13135.092 + 12809.775 kW

P = 120.710 MW

P_{net} = (120.710 – 0.69) x 0.983 = <u>**117.979 MW**</u>

Heat Rate Calculation

$HR = Q/ P_{net}$

$HR = (Q_1 + Q_2)/P_{net}$

$Q_1 = W' (h_1 - h)$, $Q_2 = W_2 (h_3 - h')$ (Summation of heat addition in Boiler and Super heater)

HR = [99.330 x (3438.969 – 981.21) + 92.087 x (3539.122 – 3091.653) /117.979

HR = 285335.278/117.979

HR = 2418.525 kJ/MW-sec or 2082.9 kcal/kW-hr

Table for Power

Sr. No.	Pressure (in bar)	Mass Flow Rate (in kg/hr)	Power (in MW)	Correction Factor
1	123.14	357589.43	117.979	1.017

Table for Heat Rate

Sr. No.	**Pressure (in bar)**	**Total Heat Input (in kJ/sec)**	**Heat Rate (in kJ/MW-sec)**	**Correction Factor**
1	123.14	285335.278	2418.525	0.998

<u>**Case Study-2 - Inlet Temperature**</u>

Inlet Temperature - 547.78*C

Flow Function Calculation

Flow Function = $W/\sqrt{(P/V)}$

Flow Function = 4430.051 kg^2/bar m^3 hr, P = 125.1 bar and V = 0.0188 m^3/kg

Then Mass Flow Rate $W' = 361375.292$ kg/hr

$W' = 100.382$ kg/sec

Power Calculation

- $W_1 = (W' - L_1 - L_2 - L_3 - L_4) = 100.382 - 1.263 - 0.042 - 0.311 - 0.108 = 98.658$ kg/sec
- $W_2 = (W_1 + L_1 - L_5 - L_6 - Ex_1) = 98.658 + 1.263 - 0.233 - 0.083 - 6.494 = 93.111$ kg/sec
- $W_3 = (W_2 - Ex_2 - L_7 - L_8) = 93.111 - 4.187 - 0.366 - 0.101 = 88.457$ kg/sec
- $W_4 = (W_3 - Ex_3) = 88.457 - 5.633 = 82.824$ kg/sec
- $W_5 = (W_4 - Ex_4) = 82.824 - 2.130 = 80.694$ kg/sec
- $W_6 = (W_5 - Ex_5 - L_9) = 80.694 - (2 \times 1.936) - 0.041 = 76.781$ kg/sec
- $W_7 = (W_6 - Ex_6) = 76.781 - (2 \times 1.736) = 73.309$ kg/sec

P = HP Turbine $\{W_1 (h_1 - h_2\}$ + IP Turbine $\{[W_2 (h_3 - h_4)] + [W_3 (h_4 - h_5)] + [W_4 (h_5 - h_6)]\}$ + LP Turbine $\{[W_5 (h_6 - h_7)] + [W_6 (h_7 - h_8)] + [W_7 (h_{8\,-}\, h_{9)}]\}$ kW

P = {[98.658 x (3462.779 – 3111.212)]} + {[93.111 x (3539.122 – 3387.304)] + [88.457 x (3387.304 – 3200.542)] + [82.824 x (3200.542 – 2918.559)]} + {[80.694 x (2918.559 – 2827.728)] + [76.781 x (2827.728 – 2654.718)] + [73.309 x (2654.718 – 2478.029)]}

P = 34684.897 + 14135.925 + 16520.406 + 23354.959 + 7329.516 + 13283.880 + 12952.893

P = 122.262 MW

P_{net} = (122.262 – 0.69) x 0.983 = <u>**119.505 MW**</u>

Heat Rate Calculation

$HR = Q/ P_{net}$

$HR = (Q_1 + Q_2)/P_{net}$

$Q_1 = W' (h_1 - h)$, $Q_2 = W_2 (h_3 - h')$ (Summation of heat addition in Boiler and Super heater)

HR = 100.382 x (3462.779 – 981.21) + 93.111 x (3539.122 – 3091.653)/119.505

HR = 290769.145/119.505

HR = 2433.112 kJ/MW-sec

Table for Power

Sr. No.	Temperature (in ◦C)	Mass Flow Rate (in kg/sec)	Power (in MW)	Correction Factor
1	507.78	102.840	120.775	0.9935
2	517.78	102.304	120.580	0.9951
3	527.78	101.744	120.355	0.9970
4	537.78	100.920	120.000	1.0000
5	547.78	100.382	119.505	1.0041
6	557.78	99.852	119.276	1.0060
7	567.78	99.330	119.042	1.0080

Table for Heat Rate

Sr. No.	Temperature (in ◦C)	Total Heat Input (in kcal/hr)	Heat Rate (in kJ/MW-sec)	Correction Factor
1	507.78	287054.517	2376.770	1.0156
2	517.78	288258.218	2390.597	1.0097
3	527.78	289363.759	2404.252	1.0040
4	537.78	289671.178	2413.926	1.0000
5	547.78	290769.145	2433.112	0.9921
6	557.78	291862.434	2446.950	0.9865
7	567.78	292948.537	2460.883	0.9809

Result

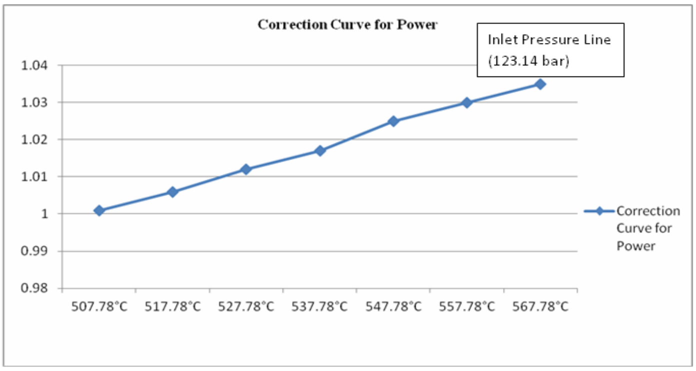
Table for Power with Combined Effect of Inlet Pressure and Inlet Temperature

Sr. No.	Temperature (in °C)	Pressure (in bar)	Power (in MW)	Correction Factor (120/Power)
1	507.78	123.14	118.776	1.0103
2	517.78	123.14	118.577	1.0120
3	527.78	123.14	118.354	1.0139
4	537.78	123.14	117.979	1.017
5	547.78	123.14	117.520	1.0211
6	557.78	123.14	117.290	1.0231
7	567.78	123.14	117.061	1.0251

Table for Heat Rate with Combined Effect of Inlet Pressure and Inlet Temperature

Sr. No.	Temperature (in °C)	Pressure (in bar)	Heat Rate (in kJ/MW-sec)	Correction Factor (2413.926/HR)
1	507.78	123.14	2381.772	1.0135
2	517.78	123.14	2395.718	1.0076
3	527.78	123.14	2409.348	1.0019
4	537.78	123.14	2418.525	0.998
5	547.78	123.14	2438.062	0.9901
6	557.78	123.14	2451.930	0.9845
7	567.78	123.14	2465.957	0.9789

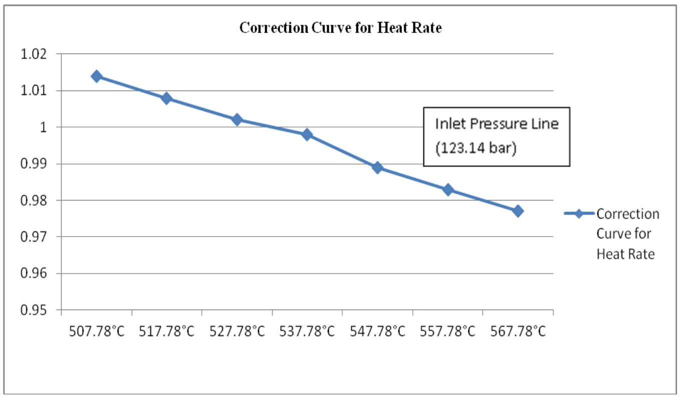
Correction Curve for Power



X axis – Different Inlet Temperature Conditions, Y axis – Correction Factor

Figure 2 – Correction curve for combined effect of inlet pressure and temperature for power

Correction Curve for Heat Rate



X axis – Different Inlet Temperature Conditions, Y axis – Correction Factor

Figure 3 – Correction curve for combined effect of inlet pressure and temperature for heat rate

Conclusion

Power, heat rate and correction factor have been calculated by the thermodynamic analysis of 120MW thermal power plant. And with the help of calculated correction factors, correction curves have been generated. From this work following conclusion has been found –

(1) If inlet pressure is 123.14 bar and inlet temperature is 547.78°C then power output from the power plant is 117.520 MW and correction factor is 1.0211. For the same conditions, heat rate is 2438.062 kJ/MW-sec and correction factor is 0.9901.

(2) Similarly, if inlet pressure is 123.14 bar and inlet temperature is 517.78°C then power output from the power plant is 118.577 MW and correction factor is 1.0120. For the same conditions, heat rate is 2395.718 kJ/MW-sec and correction factor is 1.0076.

References

[1] Yadav R., 'Steam & gas turbines and power plant engineering' 2007, Central Publishing House Allahabad, Vol. 1, pp7-8.

[2] Bekdemir Sukrii, Ozturk Recep, Yumurtac Zehra from Yildiz Technical University of Istanbul, Turkey, "Condenser Optimization in Steam Power Plant" 2007, International journal published in Thermal Science, Volume 12, Issue 2, pp. 176-178.

[3] Sharda G. G., Batra K. R., "Improvement in Super Thermal Power Stations by Distributed Control System (DCS) – KSTPS Stage – I : A Case Study" 2011, An research paper published in International Journal of Computer Application, 34-42.

[4] Bednorz Richard, Henken Fritz, "Turbine and Condenser Modernization in the Farge Power Plant" 2006, Technical paper published in Power-Gen Europe in Germany, pp 1-8.

[5] Kaushik Prabhakar, Khanduja Dinesh, "Application of six sigma DMAIC methodology in thermal power plants: A Case Study" 2009, International journal published in Total Quality Management And Business Excellence, Volume 20, pp. 197-207.

[6] Amir Vosough, Alireza Falahat, Sadegh Vosough , Hasan Nasr Esfehani, Azam Behjat, Roya Naseri Rad, "Improvement of Power Plant Efficiency with Condenser Pressure" 2011, A technical paper published in the International Journal of Multidisciplinary Sciences And Engineering, Volume 2, Issue 3, pp 38-43.

[7] Mateen Abdul Sk., Roa Nageswara Amar N., "Structural and Thermal Analysis of Condenser by Using Finite Element Analysis" 2011, A research paper published in International

Journal of Mathematical Science, Technology and Huminities 4, pp. 37-52.

[8] Carvalho L.M., Cristiani P., "Experiences of On-Line Monitoring of Microbial Corrosion and Antifouling on Copper Alloys Condenser Tubes" 2011, A research paper published in International Conference on Heat Exchanger and Fouling, pp. 385-390.

[9] Humbert F. Claude, "Life Extension of Feed Water Heaters a New Approach Using Predictive Maintenance and Today's Technology" 2000, A research paper published in Feed Water Heater Technology.

[10] Linda Riley, Carroll Willsie, Claude Humbert, "Restoring Heat Transfer Surface to Feed Water Heaters Using Explosively Welded Sleeves at La Cygne Generating Station" 2002, A research paper published in Feed Water Heater Technology.

[11] Schaarschmidt Andreas, Jenikejew Eduard, Nitch Greg, "Performance Increase through World Class Technology and Implementation" 2005, Technical paper published in Power-Gen Science in Germany, pp. 1-14.

[12] Schimon Rene, Simic Dragan, Haumer Anton, Kral Christian, Plainer Markus, "Simulation of Components of a Thermal Power Plant" 2006, A technical paper publication in The Modelica Association, pp. 119-125.

[13] Dr. Quinkertz Rainer, Ulma Andreas, Gobrecht Edwin, Wechsung Michael, "USC Steam Turbine Technology for Maximum Efficiency and Operational Flexibility" 2008, A technical paper published in Power-Gen Asia 2008, Kuala Lumpur, Malaysia, pp 1-17.

[14] Xu Cheng, Hary R. Winn, Robert A. Beveridge, Jefferey J. Williams, "Coordinated Multi-Stage Boiler Feed Water Heater Level Optimization" 2009, International journal published in Mechanical Engineering.

[15] Becker R. Bryan, Pearce E. Richard, "A case study of Feed water Heater Life Management" 2011, Paper published in Feed Water Heater Technology.

[16] Eike Roth 2004 "Thermal Power Plants have Relatively Low Efficiency", International journal published in *Efficiency of Thermal Power Plants*, Volume 10, Issue 2, pp. 1-8.

[17] Dr. A. Kaupp 2005, "How Much Rupees Could be Invested per MW Installed Power to Improve the System Efficiency of Thermal Power Plant", An article published in *Energy Manager Training*, pp. 1-6.

[18] Copen H. John, Sullivan B. Terrence 2005, "The Complimentary Fired Combined Cycle Power Plant", International Paper published in *Power-Gen Science*, pp. 1-9.

[19] Smiarowski W. Michael, Leo Rainer, Scholten Christof 2005, "Steam Turbine Modernization Solutions Provide a Wide Spectrum of Options to Improve Performance", Technical paper published in *Power-Gen Science*, Germany, pp. 1-14.

[20] Cheski R. Jeffrey, Patel Ramanlal, Rockaway Kent, Osaghae Henry, Christianson Marc 2005, "A Large Steam Turbine Retrofit Design and Operation History", International paper presentation in *Power-Gen International Conference* in Las Vegas.

[21] Lahoda Jaroslav, Arndt Olaf, Hanstein Walter 2006, "Biomass Looking for Efficiency Utilization – The Reheat Concept", Technical paper published in *Power-Gen Science*, Germany.

[22] Mateen Abdul Sk., Roa Nageswara Amar N. 2011, "Structural and Thermal Analysis of Condenser by Using Finite Element Analysis", A research paper published in *International Journal of Mathematical Science, Technology and Huminities 4*, pp. 37-52.

[23] Vora Yogesh, Patel B. M., Tewari C. P. 2011, "Simulation Model for Stochastic Analysis and Performance Evaluation of Steam Generator System of a Thermal Power Plant", A research paper published in *International Journal ofEngineering Science and Technology*, Volume 3, pp. 5141-5149.

[24] Sharma Meeta, Singh Onkar 2012, "Thermodynamic Evaluation of WHRB (Waste Heat Recovery Boiler) for its Optimum Performance in Combined Cycle Power Plants", A research paper published in *IOSR Journal of Engineering*, Volume 2, Issue 1, pp. 11-19.

[25] Cotton K.C., 'Evaluating & improving steam turbine performance', 1st end., (Cotton Fact, Inc. Rexford, NY 12148 USA, 1993), Vol. 1, pp 254 - 262.

[26] Documents from Steam turbine engineering (STE) department BHEL Bhopal.