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PG test of 250 TPH, 9.8 Mpa Circulating Fluidized Bed Combustion Coal Fired Boiler and 4 X 61.5 MW Condensing Steam Turbine.

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***Abstract:** The objective of this paper is study the various methods and procedures involved in performance guarantee of 250 TPH, 9.8 Mpa CFBC (Circulating fluidized bed combustion coal fired Boiler and 4 X 61.5 MW, 238 TPH, 8.83 MPA, 537 °C condensing turbine. Contractor has to demonstrate the guaranteed performance in accordance with relevant section of the Contract Document. The tests will be carried out as per ASME PTC 4.1 - 1991 code for 04 hours duration. The various values, parameters, conditions mentioned herein are in line with the contract specifications. In case of any clarification, the Purchase order shall be referred. This paper describes the procedure of performance test to be conducted for testing of 61.5 MW Steam turbine generator. Performance test will be conducted to establish the following agreed performance requirements. 1) Heat Rate 2) Auxiliary Power consumption*

***Keywords:** performance guarantee test, circulating fluidized bed combustion, heat rate, auxiliary power consumption, power factor.*

I.INTRODUCTION

The objective of this paper is study the various methods and procedures involved in performance guarantee of 250 TPH, 9.8 Mpa CFBC (Circulating fluidized bed combustion coal fired Boiler and 4 X 61.5 MW, 238 TPH, 8.83 MPA, 537 °C condensing turbine. Contractor has to demonstrate the guaranteed performance in accordance with relevant section of the Contract Document. The tests will be carried out as per ASME PTC 4.1 - 1991 code for 04 hours duration. The various values, parameters, conditions mentioned herein are in line with the contract specifications. In case of any clarification, the Purchase order shall be referred. This paper describes the procedure of performance test to be conducted for testing of 61.5 MW Steam turbine generator. Performance test will be conducted to establish the following agreed performance requirements. 1) Heat Rate 2) Auxiliary Power consumption.

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II.PG TEST OF 250TPH CFBC BOILER

The Boiler when working with its associated equipment is guaranteed to give the following performance:

Sr. No.	Parameters	Unit	Performance specified
1	MCR at outlet of Superheater	TPH	250
2	Steam temperature at Boiler Outlet	°C	540 ± 0/5
3	Steam pressure at Boiler Outlet	MPa (g)	9.8
4	Efficiency with specified fuel	%	87
5	Power Consumption at motor terminals and ESP corona power.(60MW)	KW	To be discussed

Also the above figures are guaranteed based on operating the Boiler as per the fuel quality and feed water quality mentioned below and following operating conditions.

Sr. No.	Indian Coal on ARB	Unit	Values
1.	Carbon	%	39.70
2.	Hydrogen	%	2.50
3.	Nitrogen	%	1.00
4.	Sulphur	%	0.50
5.	Oxygen	%	9.00
6.	Moisture	%	7.30
7.	Ash	%	40.00
8.	Volatile	%	20.00
7.	GCV	Kcal/Kg	3750

Feed water temperature at economizer inlet = 235 °C
Ambient Temperature = 30 °C
Relative Humidity = 60 %

A. Required Feed water quality at battery

pH at 25 deg C	-	9-9.5
Total Hardness (Max)	ppm	Nil
Oxygen (Max)	ppm	0.007
Iron (Max)	ppm	0.02
Copper (Max)	ppm	0.003
Silica (Max)	ppm	0.02
Conductivity at 25 °C	µs/cm	0.2
Total CO2 (Max)	ppm	Nil
Permanganate (Max)	ppm	Nil
Total Dissolved solids (Max)	ppm	0.1
Total suspended solids (Max)	ppm	Nil
Oil (Max)	ppm	Nil
Hydrazine Residual (Max)	ppm	0.02
Residual phosphate (Max)	ppm	Nil

B. Inputs Required from customer during the tests

1. Fuel (Performance fuel as specified above for 24 hrs operation, considering stabilization period and PG Testperiod)
2. Feed Water, as per temperature and quality mentionedabove.
3. All related plants like Coal feeding, Ash handling, steam utilization (Process / Turbine etc.), DM Plant, Condensate & other related plants are working stable without anyfluctuations.
4. Following materials needs to be arranged by customer before starting thetest.

C. Method of Fuel Sampling

a. Sample of fuel to be taken from Fuel feeders and to be collected in a container, oncean hour.
b. The final sample collected will be mixed thoroughly and be distributed in three parts. These three parts will be put in 3 tins/packets and sealed by both theparties.
c. First packet will be taken by DFPS for analysing at a recognized laboratory in India for analysis purpose.
d. Second sample will be taken by AINL for theiruse.
e. Third sample will be kept in safe custody by M/S AINL for future reference ifrequired.

D. Ash Samples

Samples of bottom ash, fly ash and Economizer ash shall be collected to determine the loss due to combustible matter in the ash at intervals of 1 hr. Samples are also to be kept in sealed tins. Bed ash to be collected at discharge of ash cooler and economizer & fly ash to be collected from respective hoppers at intervals of 1 hr. The final samples collected will be mixed thoroughly and be distributed in three parts for each type as mentioned at above.

E. Methods of Operation during Test

a. During the efficiency test no Blow down will bedone.
b. No Soot blower shall be operated. However, Soot blowing as many times as required by the lead engineer will be done prior to starting the test for cleaning of heat transfersurfaces.
c. CBD shall be kept closed and Safety Valve is not allowed to beblown.
d. No steam and water should be allowed to pass without their respectivemeasurements.
e. Plant should be run for 8 hrs at rated conditions to attain temperature equilibrium before the test isstarted.
f. During whole of this period the unit shall be fired with guaranteefuel.
g. The load should be steady and withoutfluctuations.
h. Readings of power consumed by individual drives should be noteddown.

F. Method of EfficiencyCalculation

a. Test code: ASME PTC 4.1 –1991
b. Efficiency calculation method: Indirect heat loss method as per ASME PTC 4.1 –1991
c. Correction for variations: for Fuel analysis, calorific value, ambient temperature, oversize bed material & any other relevant correction if applicable by way of correction curves will be applied on the calculated efficiency. Relevant correction for Auxiliary power consumption will be applied on recorded powerconsumption.

III. PG TEST OF 4X61.5 MW CONDENSING STEAM TURBINE

A. Heat Rate

Heat rate test is conducted to establish performance of STG for 61.5 MW. Heat rate shall be 2218.16 Kcal/Kw-hr as per the Heat Balance Diagram No. (RL0308196301) which is 100% TMCR with 3% make up. The cycle heat rate depends on individual performance of equipment as mentioned below.

a. Turbine
b. Generator at output of 61.5MW.
c. Condenser
d. Cooling water system with inlet temperature
e. Deaerator.
f. HPHeater
g. LPHeater
h. Power factor of0.8.

<u>Conditions to be achieved for Heat rate test</u>:

1. Steam parameters shall be maintained at 100% rated conditions. In the event parameters are different from rated, suitable corrections shall be applied in the analysis for Inlet steam pressure, Inlet steam temperature & Exhaust pressure.
2. Machine shall be loaded to 100%TMCR at rated power factor. In the event power factor is different from design value correction shall be applied on output for analysis.

Duration of test:

Test reading shall be taken for a minimum of two hours of stable operation. TG shall be running at stable rated condition for at least one hour prior to starting of test. Frequency of collection of test data shall be as given in instrument list.

However, the following guidelines shall be followed for data acquisition.

a) Primary flow (Feed water flow to Boiler, Main steam flow to Turbine):2 minutes.
b) Electrical Output: 2 minutes.
c) Secondary flow : 5 minutes.
d) Pressure and temperatureIntegrated flows, Integrated power measurement, storage level changes:30minutes.

B. Calculation of Heat Rate for Design Condition

Heat rate @ 61.5 MW output=((Steam inlet flow to turbine) X (Enthalpy of inlet Steam to Turbine - Enthalpy of Feed water inlet to Economizer)-(Make up water flow) x (Enthalpy of Feed water inlet to Economizer – Enthalpy of Make up water))/(Power at Generator Terminals)

Heat rate = ((Q1 x (H1 – H2) -(Q2 x (H2 – H3))/P) kcal/Kw-hr

Where as

Q1 = Steam Inlet Flow (Kg/hr).
Q2 = Make up water Flow(Kg/hr)
H1 = Enthalpy at Steam Turbine Inlet (Kj/Kg).
H2 = Enthalpy of Feed waterinlet to Economizer (Kj/Kg).
H3 = Enthalpy of Make-up water (Kj/Kg)
P = Recorded Power output(Kw)

C. Procedure for calculating Heat Rate and correction factor

Hear Rate @ 61.5 MW output=2218.16 Kcal/Kwhr

a) Guarantee ConditionParameters

InletSteamPressure	Pd = 90.04Kg/cm^2
InletSteamTemperature	Td = 537 °C
InletSteamEnthalpy	Ed = 3480KJ/Kg
ExhaustPressure	P1 = 0.0917Kg/cm^2
PowerFactor	PF1 = 80%
HeatRate	Hd = 9287KJ/Kwh

b) Performance test parameter

InletSteamPressure	Pt Kg/cm^2
SteamTemperature	Tt °C
InletSteamEnthalpy	Et KJ/Kg
ExhaustPressure	P2 Kg/cm^2
Feed water Temperature at the outlet ofHPHeater-1	T1 °C
FeedwaterEnthalpy	E KJ/Kg Feed
waterFlow	Q Kg/Hr
GeneratorOutput	P KW
PowerFactor	PF2%

c) Correction Factors from the Turbine Manufacturers curves

Description	Heat Rate correction values	Output correction value
Inlet Steam Pressure	λ 1	β 1
Inlet Steam Temperature	λ 2	β 2
Exhaust Pressure	λ 3	β 3
Product of Correction Factors	X	Y

d) Test for Auxiliary Power consumption

This test will be conducted to check the power consumed by the auxiliary power equipment at 100%MCR condition for STG Auxiliaries which is 174.0 KW and cooling water temperature of 32 °C & power factor of 0.8.

Equipment, which are guaranteed for aux. Power consumption are;

Sr.No.	EQUIPMENT
1	CONDENSATE EXTRACTION PUMP
2	DRAIN TRANSFER PUMP
3	LUBE OIL TANK VAPOUR EXTRACTOR FAN

Power consumed at each feeder shall be measured in TG MCC for above equipment.
Duration of test shall be two hours. Frequency of readings shall be every fifteen minutes. Average power consumption will be taken for performance.

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D. Minimum measurements required for Heat Rate

Sr. No.	Parameter to be measured	Tag No.	Unit
1	ELECTRICAL POWER AT GENERATOR TERMINALS	*	MW
2	TURBINE SPEED	-	RPM
3	POWER FACTOR	-	-
4	MAIN STEAM FLOW	FT-0701	TPH
5	INLET STEAM PRESSURE	PT-0701	Kg/cm²
6	INLET STEAM TEMPERATURE	TE-0701	°C
7	STEAM PRESSURE AFTER GOVERNING STAGE	PT - 101	Kg/cm²
8	STEAM TEMPERATURE AFTER GOVERNING STAGE	TE - 105	°C
9	1ST EXTRACTION TEMPERATURE AT HP HEATER-1 INLET	TE-0705	°C
10	1ST EXTRACTION PRESSURE AT NOZZLE (DTC SUPPLY)	PT - 106	Kg/cm²
11	1ST EXTRACTION PRESSURE AT HP HEATER-1 INLET	PT-0706	Kg/cm²
12	2ND EXTRACTION TEMPERATURE AT HP HEATER-2 INLET	TE-0706	°C
13	2ND EXTRACTION PRESSURE AT NOZZLE (DTC SUPPLY)	PT-107	Kg/cm²
14	2ND EXTRACTION PRESSURE AT HP HEATER-2 INLET	PT-0707	Kg/cm²
15	3RD EXTRACTION TEMPERATURE AT DEAERATOR INLET	TE-0707	°C
16	3RD EXTRACTION PRESSURE AT NOZZLE (DTC SUPPLY)	PT-108	Kg/cm²
17	3RD EXTRACTION PRESSURE AT DEAERATOR INLET	PT-0708	Kg/cm²
18	4TH EXTRACTION TEMPERATURE AT LP HEATER-3 INLET	TE-0708	°C
19	4TH EXTRACTION PRESSURE AT NOZZLE (DTC SUPPLY)	PT-109	Kg/cm²
20	4TH EXTRACTION PRESSURE AT LP HEATER-3 INLET	PT-0709	Kg/cm²
21	5TH EXTRACTION TEMPERATURE AT LP HEATER-2 INLET	TE-0709	°C
22	5TH EXTRACTION PRESSURE AT NOZZLE (DTC SUPPLY)	PT-110	Kg/cm²
23	5TH EXTRACTION PRESSURE AT LP HEATER-2 INLET	PT-0710	Kg/cm²
24	6TH EXTRACTION TEMPERATURE LP HEATER-1 INLET	TE-0710	°C
25	6TH EXTRACTION PRESSURE AT NOZZLE (DTC SUPPLY)	PT-111	Kg/cm²
26	6TH EXTRACTION PRESSURE AT LP HEATER-1 INLET	PT-0711	Kg/cm²
27	EXHAUST TEMPERATURE	TE-0711	°C
28	EXHAUST PRESSURE	PT-0712	Kg/cm²
29	COOLING WATER INLET TEMP. AT CCONDENSER	TE-0804/0806	°C
30	COOLING WATER OUTLET TEMP. AT CCONDENSER	TE-0805/0807	°C
31	CONDENSATE FLOW TO LP HEATER-1	FT-0801/0801A	TPH
32	CONDENSATE INLET TEMPERATURE TO LP HEATER-1	TE - 1201	°C
33	CONDENSATE INLET PRESSURE TO LP HEATER-1	PT-1201	Kg/cm²
34	CONDENSATE INLET TEMPERATURE TO LP HEATER-2 FROM LP HEATER-1	TE - 1202	°C
35	CONDENSATE INLET PRESSURE TO LP HEATER-2 FROM LP HEATER-1	PT-1202	Kg/cm²

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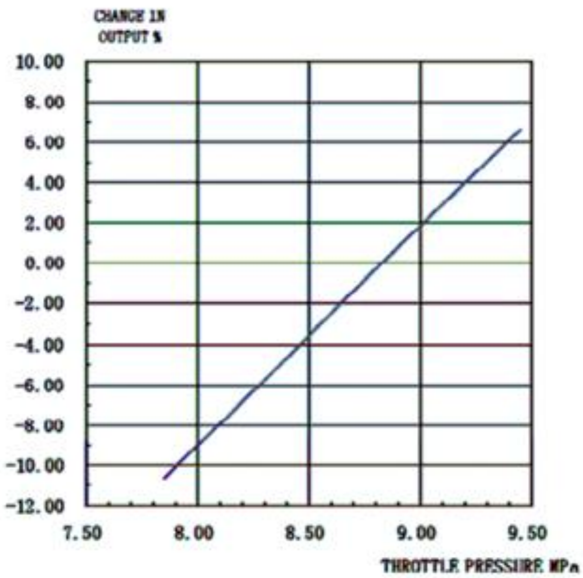
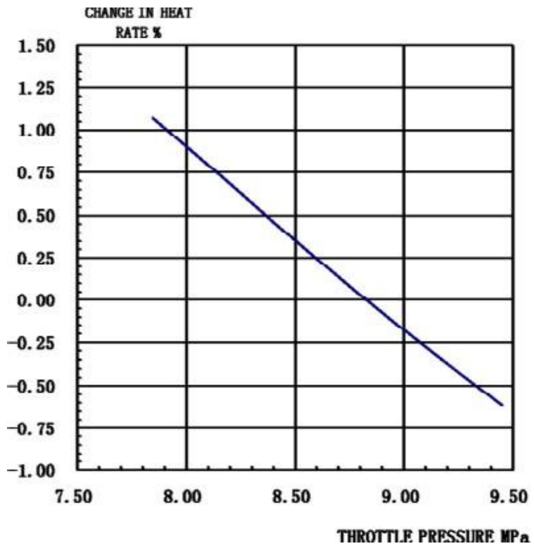
36	CONDENSATE INLET TEMPERATURE TO LP HEATER-3 FROM LP HEATER-2	TE - 1203	°C
37	CONDENSATE INLET PRESSURE TO LP HEATER-3 FROM LP HEATER-2	PT-1203	Kg/cm^2
38	CONDENSATE OUTLET TEMPERATURE FROM LP HEATER-3	TE - 1204	°C
39	CONDENSATE OUTLET PRESSURE FROM LP HEATER-3	PT - 1204	Kg/cm^2
40	DTP DISCHARGE PRESSURE	PT - 1205	Kg/cm^2
41	DEAERATOR STORAGE TANK TEMP	TE - 0302	°C
42	DEAERATOR STORAGE TANK PRESSURE	PT - 0302	Kg/cm^2
43	FEED WATER TEMPERATURE AT BFP SUCTION HEADER	TE - 0303	°C
44	FEED WATER TEMPERATURE AT BFP DISCHARGE HEADER	TE - 0304	°C
45	FEED WATER PRESSURE AT BFP DISCHARGE HEADER	PT - 0303	Kg/cm^2
46	FEED WATER INLET TEMPERATURE TO HP HEATER-2	TE - 1101	°C
47	FEED WATER INLET PRESSURE TO HP HEATER - 2	PT - 1101	Kg/cm^2
48	FEED WATER INLET TEMPERATURE TO HP HEATER-1 FROM HP HEATER-2	TE - 1102	°C
49	FEED WATER INLET PRESSURE TO HP HEATER - 1 FROM HP HEATER-2	PT - 1102	Kg/cm^2
50	FEED WATER OUTLET TEMPERATURE FROM HP HEATER-1	TE - 1103	°C
51	FEED WATER OUTLET PRESSURE FROM HP HEATER - 1	PT - 1103	Kg/cm^2
52	FEED WATER FLOW FROM HP HEATER- 1 TO BOILER ECONOMISER INLET	**FT-0001/0001A**	TPH

IV. OPERATING CURVES

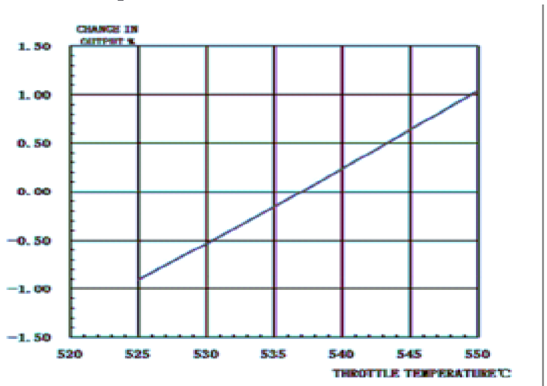
1. Correction curve for Inlet Steam Pressure v/sOutput.



2. Correction curve for Inlet Steam Pressure v/s HeatRate.



3. Correction curve for Inlet Steam Temperature v/sOutput.



4. Correction curve for Inlet Steam Temperature v/s Heat Rate.

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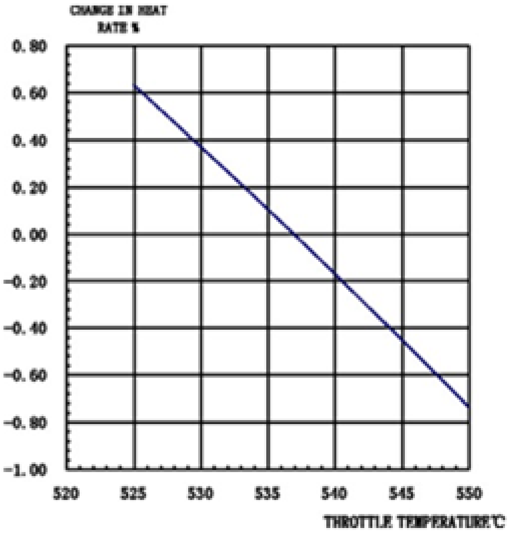
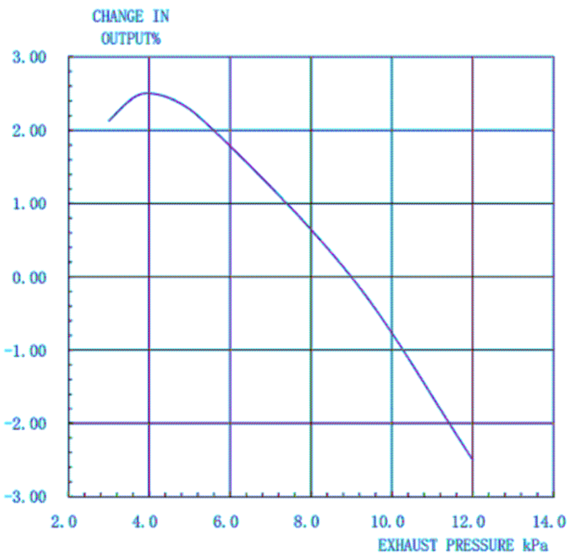
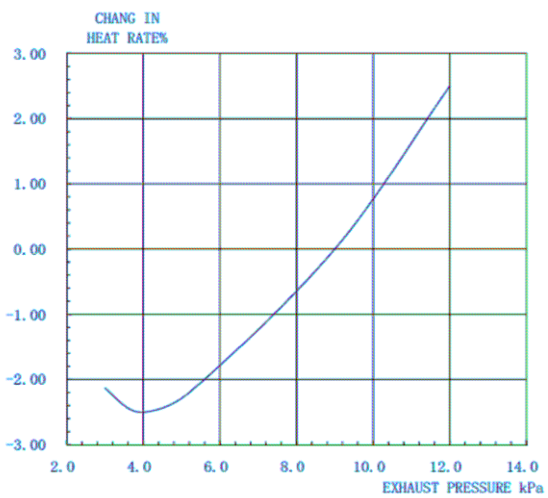


5. Correction curve for Exhaust Pressure v/sOutput.



6. Correction curve for Exhaust Pressure v/s



HeatRate.

V. CONCLUSION

The performance guarantee test was successful completed and the various parameters and readings were found of 250 TPH CFBC boiler and 4X61.5MW condensing Turbine and based on the readings found, various operating curves are prepared which gives the pictorial representation of the various parameters. The correction curve for Inlet Pressure and output represents that as the throttle pressure increases the output also increases. The correction curve for Inlet Pressure and Heat rate represents that as the throttle pressure increases the Heat rate decreases. The correction curve for Inlet Temperature and Output represents that as the throttle temperature increases the output increases. The correction curve for Inlet Temperature and Heat rate represents that as the throttle temperature increases the Heat rate decreases. The correction curve for Exhaust pressure and output represents that as the Exhaust pressure increases the output also increases up to 4 KPa, after that it decreases continuously. The correction curve for Exhaust pressure and Heat rate represents that as the Exhaust pressure increases the Heat rate decreases up to 4 KPa, after that it increases continuously.

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He received his Diploma in Mechanical Engineering, B.E in Mechanical Engineering and M.Tech in Heat Power Engineering and pursuing PhD. He has published one reference book on Fluid Mechanics.

He has 3 Copyrights under Copyright Office, Government of India, New-Delhi and has published more than 20 Research Papers in National and International Journal and Conferences. He awarded certificate of Meritorious contribution towards successful and ahead schedule of commissioning of Prestigious "4X61.5 MW Mihan Power Project."

He is a life member of Indian Society of Technical Education (I.S.T.E), International Association of Engineers (IAENG) and Individual member of Solar Energy Society of India (SESI).

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International Journal:8
International Conference: 4
National Conference :4

Projects guided to U.G:
1.Design and fabrication of biomass pellet burner
2.Development and enhancement of 4-stroke I-C engine to use acetylene as an alternative fuel.
3.Design and fabrication of river trash cleaning mechanism

Achievements:
1)BEST PAPER AWARD IN international conference on science, Engineering &Technology ICSET- 2019, HELD AT TASHKENT, UZBEKISTAN
2)Won 1st prize in national level paper presentation
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International Conference:2
National Conference:1

Projects guided to UG:
1)Design & Fabrication of material handling system using E-vehicle.

Achievements:
1)Won 1st prize in Power point presentation conducted by RAHE, GHRCE in Nagpur national level paper presentation
2)won first prize in state level competition conducted by ABVP in Latur.
3)Won second prize in national symposium conducted by SRKNEC Nagpur.

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