Test Procedure

8.2 Gross Turbine Cycle Heat Rate Test (GTCHR)

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8.2 GROSS TURBINE CYCLE HEAT RATE TEST

8.2.1 Introduction

This procedure provides a systematic method for conducting Gross Turbine Cycle Heat rate (GTCHR) test on steam turbine.

8.2.2 Objective

The objective of the Gross Turbine Cycle Heat rate (GTCHR) test is the measure of efficiency of a Steam turbine cycle. It is defined as heat energy used by the turbine cycle to generate one unit of Electrical energy.

8.2.3 Test Procedure

This method determines the overall efficiency of Turbine cycle along with the auxiliaries. The unit is to be operated at steady conditions at constant load with feed water heaters in service at normal cascading.

To ensure accuracy, each independent variable must be controlled, such that all subsequent tests may be related to all previous tests.

8.2.3.1 Station Instrumentation Required

Measurement	Temperature	Pressure	Flow	Electric Power
Feed water (At Eco inlet)	Yes	Yes	Yes	
Feed water (At HPH Inlet & Outlet)	Yes	Yes		
Reheater Attemperation	Yes	Yes	Yes	
SH Attemperation (as applicable)	Yes	Yes	Yes	
Main Steam (L&R) Before ESV	Yes	Yes		
HPT Exhaust (L&R)	Yes	Yes		
Hot Reheat Steam (L&R) Before IV	Yes	Yes		
HP Turbine Extraction to HPH at Heater end	Yes	Yes		
HPH Drip	Yes			
Gross Generator Output				Yes

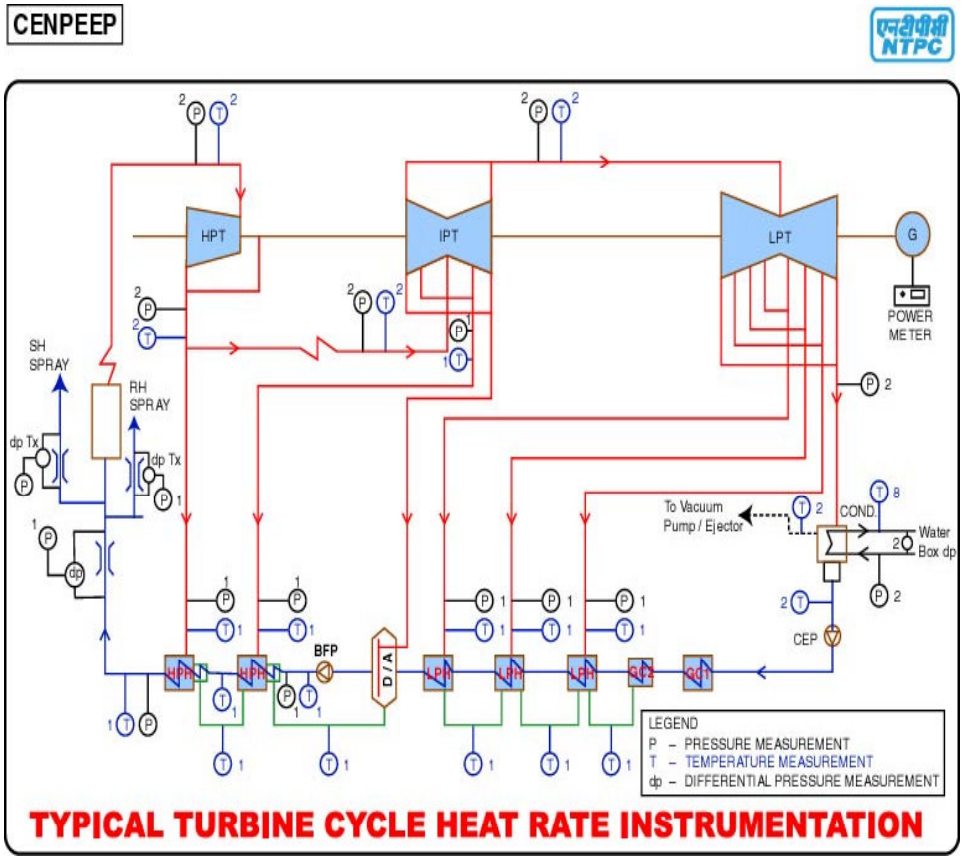

Fig-8.2.1

8.2.3.2 Operating Conditions for Each Test Run

i. Unit Load Control on manual mode and Steady

ii. Main Steam and Reheat Steam Temperatures at Current Expected Value

iii. All Feed water Heaters in Service, Normal Drain cascading,

iv. No Auxiliary Steam supply to Other Units.

v. No Soot Blowing.

vi. No DM make up

vii. Other aspects as given in sample Check Sheet enclosed (Format- 8.2.1).

viii. The Test Engineer is responsible for ensuring that the unit has reached steady state before beginning a test data collection

8.2.3.3 Data Collection

i. Form a data group in the DAS for Data collection during the test (See Format –8.2.2)

ii. Each test must be conducted for about 30 min for the purposes of data collection.

iii. The frequency of data collection in DAS should be 1 min or minimum possible to achieve, depending upon the data collection rate of DAS.

8.2.3.4 Turbine Cycle Heat Rate.

Turbine Cycle Heat Rate (kcal/kWh) =

= (Heat Added to Feed Water + Heat added to SH Attemperation + Heat Added CRH + Heat added to RH Attemperation) / Gross load

$$= \frac{Q_f (H_1 - h_1) + Qs\,(H1\text{-}hs) + Q_2 (H_3 - H_2) + Qr\,(H3\text{-}hr)}{Gross\ Load}$$

Where

Main Steam Flow	t/hr	(Q1)
Feed Water Flow	t/hr	(Qf)
CRH Flow	t/hr	(Q2)
S/H Attemperation Flow	t/hr	(Qs)
R/H Attemperation Flow	t/hr	(Qr)
Enthalpy of MS at HPT inlet	Kcal/Kg	H1
Enthalpy at HPT Exhaust	Kcal/Kg	H2
Enthalpy at HRH at IPT inlet	Kcal/Kg	H3
Enthalpy of FW at Economizer inlet	Kcal/Kg	h1
Enthalpy of HPH Extraction Steam	Kcal/Kg	Hext
Enthalpy of FW Entering HPH	Kcal/Kg	Hin
Enthalpy of FW Leaving HPH	Kcal/Kg	Hout
Enthalpy of HPH drain	Kcal/Kg	Hdrain
Enthalpy of S/H Attemperation	Kcal/Kg	hs
Enthalpy of R/H Attemperation	Kcal/Kg	hr

8.2.3.5 Calculation of Main Steam Flow

Total steam flow (Q1) = Feed Flow (Qf)+ S/H Attemperation Flow (Qs)
Note: Care to be taken in computing Main Steam flow depending upon SH /RH Attemperation tapings.

8.2.3.6 Calculation of Reheat Steam Flow

CRH Flow (Q2) = Steam Flow (Q1) – Extraction Steam Flow (Qe) to HPH
- HP Leak Off Steam flow

a) Leak off steam flow derived from design leak off flow as per load from HBD)
b) Extraction flow to all HP Heaters having Extraction From HP Turbine to be considered for computing CRH Flow

8.2.3.7 Calculation of Extraction Steam Flow

$$(Q_e) = \frac{Q_f\,(h_{\text{fw out}} - h_{\text{fw in}}) + Q_{\text{drain in}}\,(h_{\text{drains out}} - h_{\text{drains in}})}{(h_{\text{ext}} - h_{\text{drains out}})}$$

Where:

Q_f	= Feed Flow
$h_{\text{fw out}}$	= Feed Water Enthalpy at HPH Out.
$h_{\text{fw in}}$	= Feed Water Enthalpy at HPH in
Q_e	= Extraction Steam Flow
h_{ext}	= Enthalpy of Extraction Steam
$h_{\text{drains out}}$	= Enthalpy of Drain Out
$h_{\text{drains in}}$	= Enthalpy of Drain In
$Q_{\text{drain in}}$	= Drain Inlet flow

Sample test report format is given in Format-8.2.3

8.2.4 References

ASME Performance Test Code 6 – 1996, Steam Turbines.

8.2.5 SAMPLE COMPUTATION: GROSS TURBINE CYCLE HEAT RATE

S.N	PARAMETER	UNIT	Test Data
1	Generator Load	MW	500
2	MS Pressure Before ESV	kg/cm^2(abs)	169.79
3	MS Temperature Before ESV	^0C	538
5	HP Turbine Exhaust Pressure	kg/cm^2(abs)	42.45
6	HP Turbine Exhaust Temperature	^0C	340.8
7	HRH Press at IP Turbine Inlet	kg/cm^2(abs)	38.2
8	HRH Temp at IP Turbine Inlet	^0C	538
9	FW Press. At eco in / HPH outlet	kg/cm^2(abs)	200
10	FW Temp at Eco Inlet	^0C	251.1
11	Feed Flow	t/hr	1502.76
12	S/H Attemperation Flow	t/hr	0
13	R/H Attemperation Flow	t/hr	0
14	S/H Attemperation Temperature	^0C	154.3
15	R/H Attemperation Temperature	^0C	154.3
16	HP Leak off flow	t/hr	16.92
17	HPH Ext. Steam Temp (Heater End)	^0C	340.8
18	HPH Ext. Steam Press (Heater End)	kg/cm^2(abs)	42.45
19	FW Temp at HPH Inlet	^0C	194.3
20	FW Temp at HPH Outlet	^0C	251.1
21	Drain out temperature	^0C	206
22	Drain Inlet Flow	t/hr	-
23	Inlet Drain Temperature	^0C	-
24	Enthalpy at HP Turbine Inlet	kcal/kg	811.47
25	Enthalpy of HRH at IP Turbine Inlet	kcal/kg	844.04
26	Enthalpy at HP turbine Exhaust	kcal/kg	732.71
27	Enthalpy of FW at Eco. inlet.	kcal/kg	260.78
28	Enthalpy of S/H Attemperation	kcal/kg	158.27
29	Enthalpy of R/H Attemperation	kcal/kg	158.27
30	Mean Enthalpy of FW leaving HPH	kcal/kg	260.78
31	Mean Enthalpy of FW Entering HPH	kcal/kg	199.47
32	Mean Enthalpy of Extraction Steam	kcal/kg	732.71
33	Mean Enthalpy of drain Out	kcal/kg	206.56

Calculation of Main Steam Flow:

Total steam flow (Q1) **=** Feed Flow (Qf)+ S/H Attemperation Flow (Qs)
= 1502.76+0 =1502.76 t/hr

Calculation of Extraction Steam Flow:

$$(Q_e) = \frac{Q_f (h_{fw\ out} - h_{fw\ in}) + Q_{drain\ in} (h_{drains\ out} - h_{drains\ in})}{(h_{ext} - h_{drains\ out})}$$

Where:

Q_f	= Feed Flow
$h_{fw\ out}$	= Feed Water Enthalpy at HPH Out.
$h_{fw\ in}$	= Feed Water Enthalpy at HPH in
Q_e	= Extraction Steam Flow
h_{ext}	= Enthalpy of Extraction Steam
$h_{drains\ out}$	= Enthalpy of Drain Out
$h_{drains\ in}$	= Enthalpy of Drain In
$Q_{drain\ in}$	= Drain Inlet flow

$$= \frac{1502.76^* (260.78-199.47) +0}{732.71- 206.56} = 175.11 \text{ t/hr}$$

Calculation of Reheat Steam Flow:

CRH Flow (Q2) **=** Steam Flow (Q1) – Extraction Steam Flow (Qe) of HPH – HP Leak Off Steam flow

= 1502.76 – 175.11 – 16.92
= 1310.73 t/hr

Turbine Cycle Heat Rate:

Turbine Cycle Heat Rate (kcal/kWh)

$$= \frac{Q_f (H_1 - h_1) + Q_s (H1-hs) + Q_2 (H_3 - H_2) + Q_r (H3-hr)}{\text{Gross Load}}$$

$$= \frac{1502.76^* (811.47 - 260.78) + 0^* (811.47-158.27) + 1310.73^* (844.04 - 732.71) + 0^* (732.71-158.27)}{500^*1000}$$

= 1946.95 kcl/kwh

Turbine Heat Rate Test

Pre – Test Check Sheet

Station : _____ **Unit No:_____**
Date: ____/____/____

Checks Made By:_____

Description	Status	Initials
Control Valve Position "A" & "B"	%	
Auxiliary Steam Feed	Isolated	
Both NRVs to No ----- HP FWH:	Open	
Both NRVs to No ----- HP FWH:	Open	
Both NRVs to No ----- HP FWH:	Open	
Both NRVs to Deaerator:	Open	
Both NRVs to No ----- LPH	Open	
Gland Steam Pressure Controller:	Auto and set to ---- kg/cm^2	
HP Bypass Valves "A" & "B"	Closed	
LP Bypass Valves "A" & "B"	Closed	
Main Steam Line Drains (total)	Closed	
Hot Reheat Drains (----No. total)	Closed	
Cold Reheat Drains (---- No. total)	Closed	
HP Steam Chest Warming (---- No. total)	Closed	
HPH Drain Cooling Zone Steam Vent	Closed	
HPH Drip to Condenser	Closed	
HPH --- Extr. Drain to condenser (----No. total)	Closed	
HPH --- Extr. Drain to condenser (---- No. total)	Closed	
DA High Load Extr. Drain to Condenser (---- No. total)	Closed	
DA Low Load Extr. Drain to Condenser (----- No. total)	Closed	
LPH --- Extr. Drain to Condenser (----No. total)	Closed	
Trap Bypasses	Closed	

Notes / Special Conditions:

Format-8.2.1

Turbine Heat Rate Test

DATE- **Unit-**

S. N	Description	Unit	Readings
1	Avg. Unit Load (From Energy Meter)	MW	
2	MS Pressure Before ESV	kg/cm^2(abs)	
3	MS Temperature Before ESV	^0C	
4	HP Turbine Exhaust Pressure	kg/cm^2(abs)	
5	HP Turbine Exhaust Temp	^0C	
6	HRH Pressure at IP Turbine Inlet	kg/cm^2(abs)	
7	HRH Temperature at IP Turbine Inlet	^0C	
8	FW Press at Eco In / HPH outlet	kg/cm^2(abs)	
9	FW Temperature at Eco Inlet	^0C	
10	Feed water Flow (Excluding S/H & R/H Attemperation)	t/hr	
11	SH Attemperation Flow	t/hr	
12	RH Attemperation Flow	t/hr	
13	SH Attemperation Temperature	^0C	
14	RH Attemperation Temperature	^0C	
15	HP Leak off flow	t/hr	
16	HPH-7 Ext. Temp (Htr end) If applicable	^0C	
17	HP H-7 Ext. Press. (Htr end) if applicable	kg/cm^2(abs)	
18	FW Inlet Temp at HPH-7 (if applicable)	^0C	
19	FW Outlet Temp at HPH-7 (If applicable)	^0C	
20	HPH-7 Drain Temperature (If applicable)	^0C	
21	HPH-6 Ext. Temp (Htr end)	^0C	
22	HP H-6 Ext. Press. (Htr end)	kg/cm^2(abs)	
23	FW Inlet Temp at HPH-6	^0C	
24	FW Outlet Temp at HPH-6	^0C	
25	HPH-6 Drain Temperature	^0C	

Format-8.2.2

Gross Turbine Cycle Heat Rate -Report

Station: **Date :**

S.N	PARAMETER	UNIT	Unit-1	Unit-2	Unit-3	Unit-4	Unit-5	Unit-6
1	Unit Load	MW						
2	MS Pressure Before ESV	$kg/cm^2(abs)$						
3	MS Temperature Before ESV	^0C						
4	HRH Press at IP Turbine Inlet	$kg/cm^2(abs)$						
5	HRH Temp at IP Turbine Inlet	^0C						
6	HP Turbine Exhaust Pressure	$kg/cm^2(abs)$						
7	HP Turbine Exhaust Temperature	^0C						
8	FW Temp at Eco Inlet	^0C						
9	Feed Flow	t/hr						
10	S/H Attemperation Flow	t/hr						
11	R/H Attemperation Flow	t/hr						
TURBINE HEATRATE		**kcal/kWh**						
PG Test TURBINE HEATRATE		**kcal/kWh**						

Test Condition

Remarks

Format-8.2.3