LOAD OPTIMISATION BY BLADE & STEAM WASHING-CASE STUDY OLKARIA II

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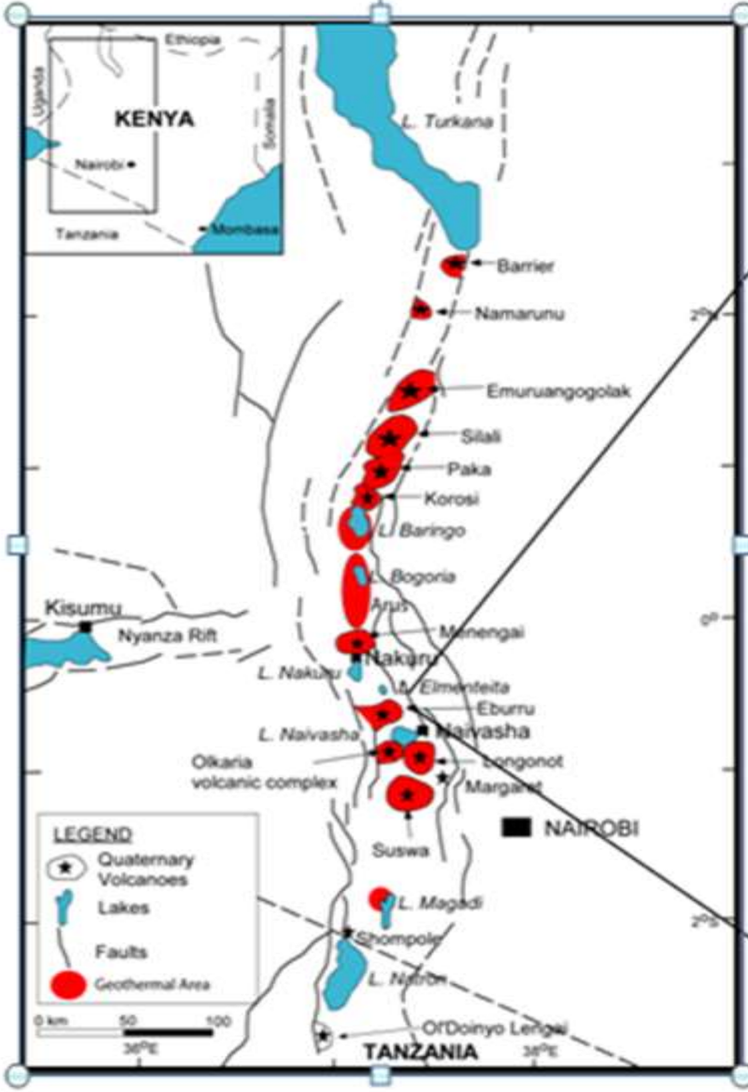
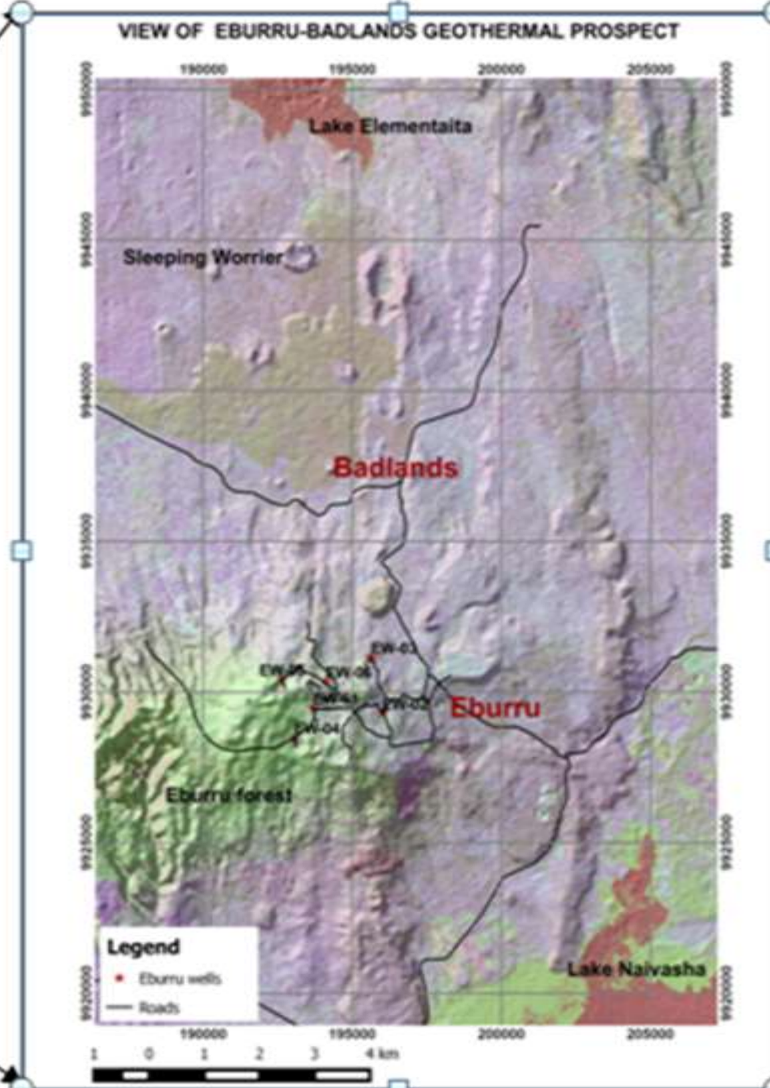
GEOTHERMAL MAP IN KENYA





Contents

KenGen

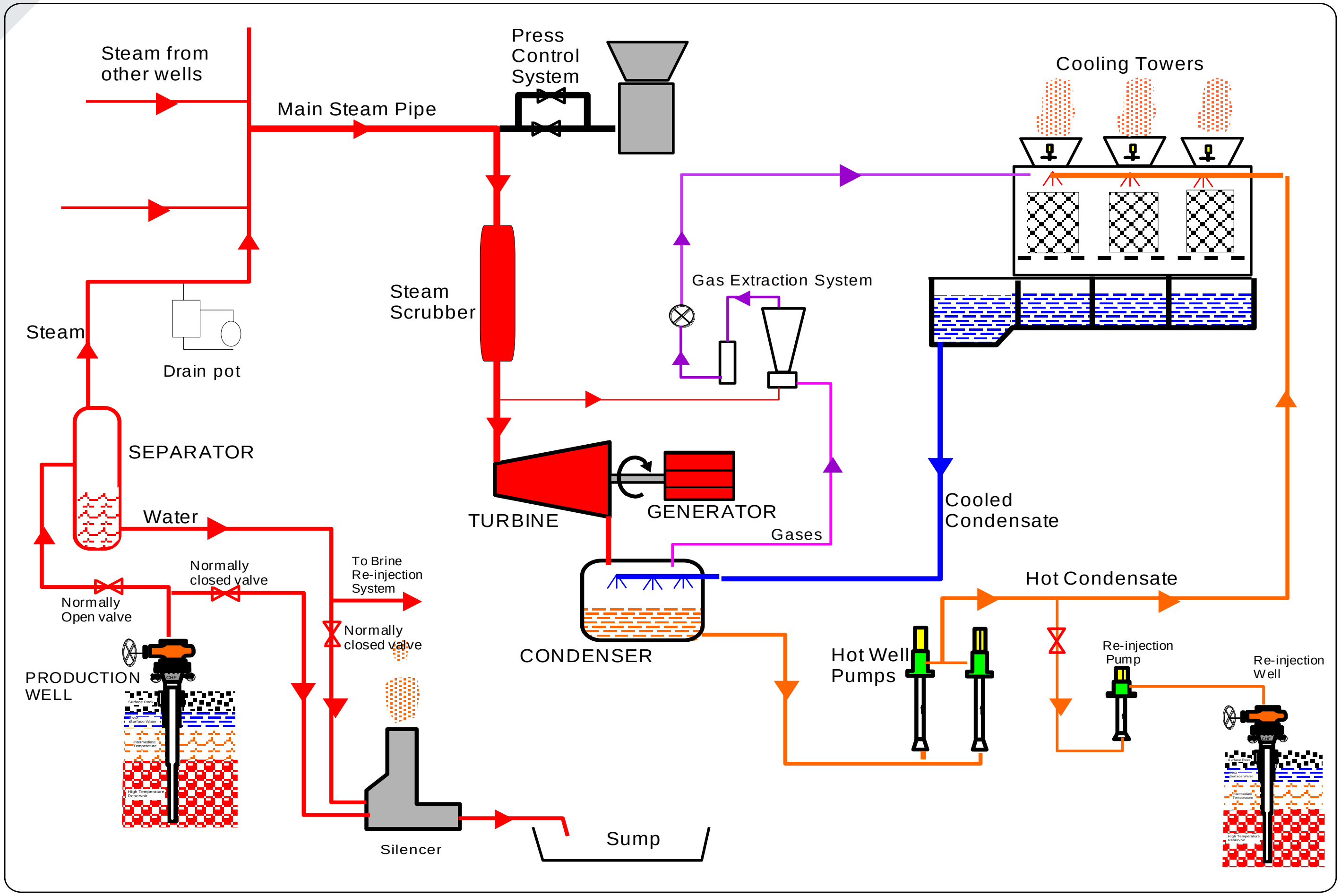
INTRODUCTION

- Olkaria II power station receives steam from olkaria North east field which measures about 6km square.
- The field has 20 production wells,4 hot re-injection wells and two cold re-injection wells.
- It has three shallow wells,M1,M2 and M3 which were drilled as monitoring wells.
- The steam field has further been divided into eastern and western fields for better operation and management.
- The well casing program consists of 20” diameter surface casing;13.375”,anchor casing 9.55”,production casing, and 7” slotted liners.
- The production casing usually extends to between 600m and 900m while the drilled well depth ranges from 1800m to 2500m.

INTRODUCTION……

- Scales are hard mineral coating and corrosion deposits made up of solids and sediments that collect in the distribution systems.
- The reduction in power generated and increased operating costs from scaling impacts a plants financial outcome.
- Geothermal fluids from different wells have differing chemistry even within same field.

OLKARIA II PROCESS FLOW DIAGRAM



INTRODUCTION

Generator load is the key focus of every power plant output.

The parameters of interest for this study were turbine inlet pressure, steam flow rate, steam chest pressure and Load.

After operating for two years, steam chest pressure increased from **3.5 bar-a** to **4.1 bar-a** and steam consumption increased to **82.2 kg/sec**.

This led to decline in turbine overall rated capacity of 35 Mw and hence Efficiency.

INTRODUCTION………

- After dismantling and inspecting for the purpose of this study, significant sulphur deposition and silica scaling deposits.
- Significant scaling on the circulating water line, Turbine shroud and nozzles.
- Real time data analysis of the de-scaling of turbine blade nozzles to improve on the Olkaria II power plant performance.
- The study realized that steam and blade washing had an overall decrease of steam chest pressure.
- The decrease in steam chest pressure improved turbine efficiency by up to 10%.

PROBLEM STATEMENT

- Geothermal fluids contain varying concentrations of dissolved solids and gases.
- The dissolved solids and gases often provide highly acidic and corrosive fluids and may induce scaling and corrosion.
- Silica scaling is a major problem in most geothermal fields in olkaria.
- Therefore it is for this silica phenomena in geothermal equipment that this paper has been developed.

OBJECTIVES

- To explore blade washing and steam washing procedures for de-scaling of turbine blades and shroud.

- Real time experimental data analysis from Olkaria II Power station for load optimisation.

- Improving the geothermal power plant efficiency by way of silica de-scaling.

GEOTHERMAL EQUIPMENT WITH SILICA ATTACKS

- Main Condensers.
- Inter-Condensers.
- Hot well pumps and pits.
- Turbine nozzles and blades.
- Steam scrubbers and pipelines.
- Brine separators.
- Steam ejectors
- Main stop valves and control valves.

TURBINE BLADES & SHROUD

DESCALING OF TURBINE BLADES DURING AN OVERHAUL

PRESSURE LET DOWN VALVES SCALING

SILICA ATTACKS

Turbine nozzle without silica

Turbine nozzle with silica

DISCUSSION-TURBINE

- The Turbine is the most important and costly equipment in a geothermal power plant.

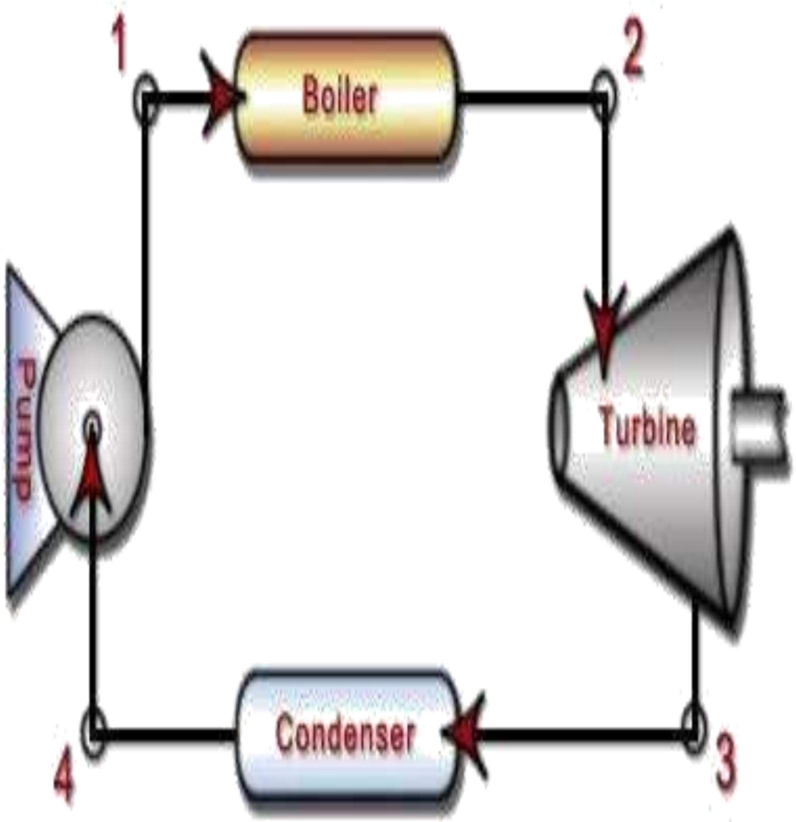
- After steam is expanded through a turbine ,it is exhausted into the condenser.

- In binary plants, geothermal fluid heats a secondary fluid in a heat exchanger and the secondary fluid is expanded through a turbine (organic rankine cycle).

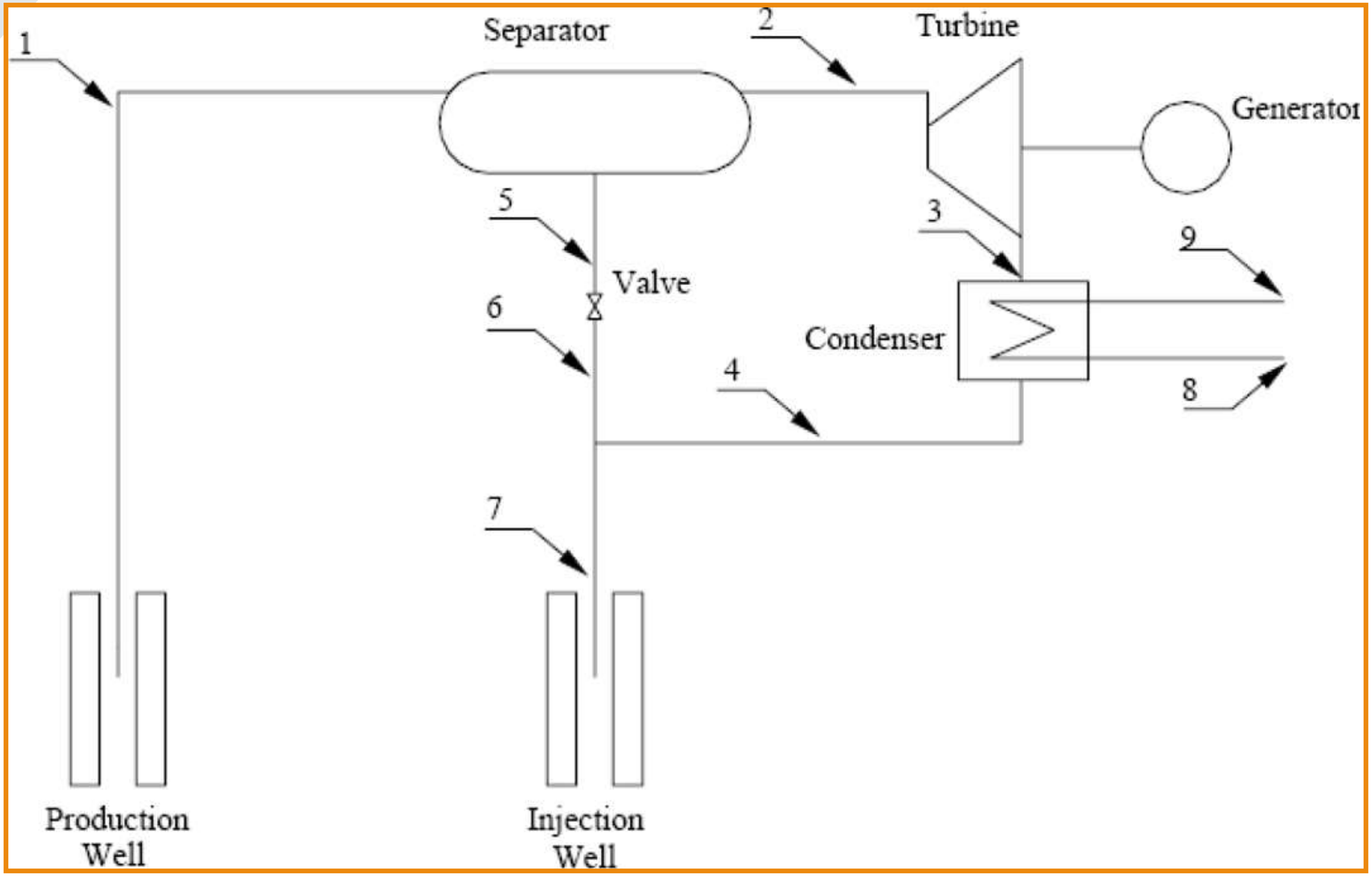
TURBINE…….

Steam and Turbine generator

Organic rankine cycle.



TURBINE……



Separator
Turbine
Generator
Valve
Condenser
Production Well
Injection Well
1
2
3
4
5
6
7
8
9

TURBINE….

- These changes can be calculated as the average fluid enthalpy is constant (adiabatic flashing).
- The fraction to steam can be calculated by the equation:
- $h1\dot{m} = h_f \dot{m}_f + h_g \dot{m}_g$
- $x = (h_1 - h_f)/(h_g - h_f) = (h_1 - h_f)/h_{fg}$
- Where;
- **H_5=H_6=697 KJ/kg (Brine for hot re-injection)**
- **H_2=Enthalpy of steam to turbine blades (useful energy)**
- **H_1=Total heat flow from production wells.**
- **$\dot{m}$=Mass flow rate in Kg/seconds.**
- **X =Dryness fraction of steam.**

WORK DONE AT THE TURBINE

- Under isentropic expansion (constant entropy), point 4 to 5s, the work extracted from a steam flow rate of 1 kg/s is given as:
- $W = h_4 - h_5s$

- Where W = Work output from turbine (kJ/kg);

- h_4 = Steam inlet enthalpy (kJ/kg);
- h_5s= Steam exit enthalpy (kJ/kg).

STEAM WASHING

- Steam washing is a basic steam scrubbing technique of injecting steam condensate into the steam flow up-stream of a final scrubber.
- This will collect unwanted substances entrained and dissolved in the steam into the wash water.
- This is followed by separation of the liquid fraction from the flow.
- Silica, boron, and arsenic can all be removed readily in this manner.
- Scrubbers can also be used to remove ammonia, however other non-condensable gases such as carbon dioxide and hydrogen sulfide cannot be removed readily by scrubbing.

DATA ANALYSIS AND INTERPRETATION

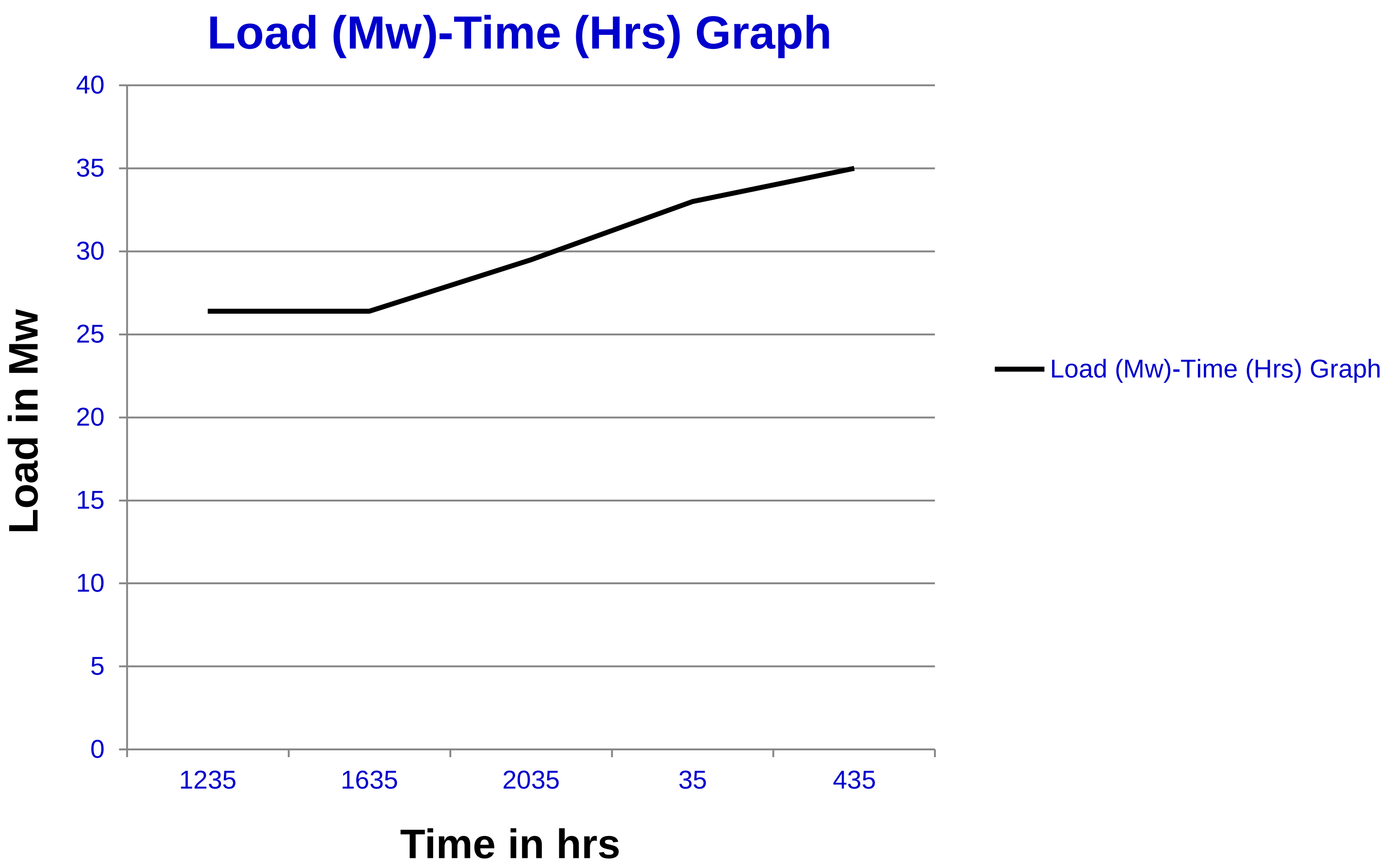
- ❖ Samples of two-phase brine-steam mixture, steam, scale deposits, and condensate were taken for analysis in the geochemistry laboratory.
- ❖ Also, well production flow rates at 6 bar-a were compared with separator design capacity to discover whether there was brine carry-over to steam pipelines.
- ❖ Four samples collected from inside the turbine shroud and turbine blades were analysed using X-ray diffraction (XRD) in Olkaria geochemistry laboratory.
- ❖ X-ray fluorescence was also done for element composition analysis in Japan by Mitsubishi Heavy Industries.
- ❖ Other samples were analysed for calcite scaling, silica scaling and corrosive components in the local laboratory.

EXPERIMENTAL DATA

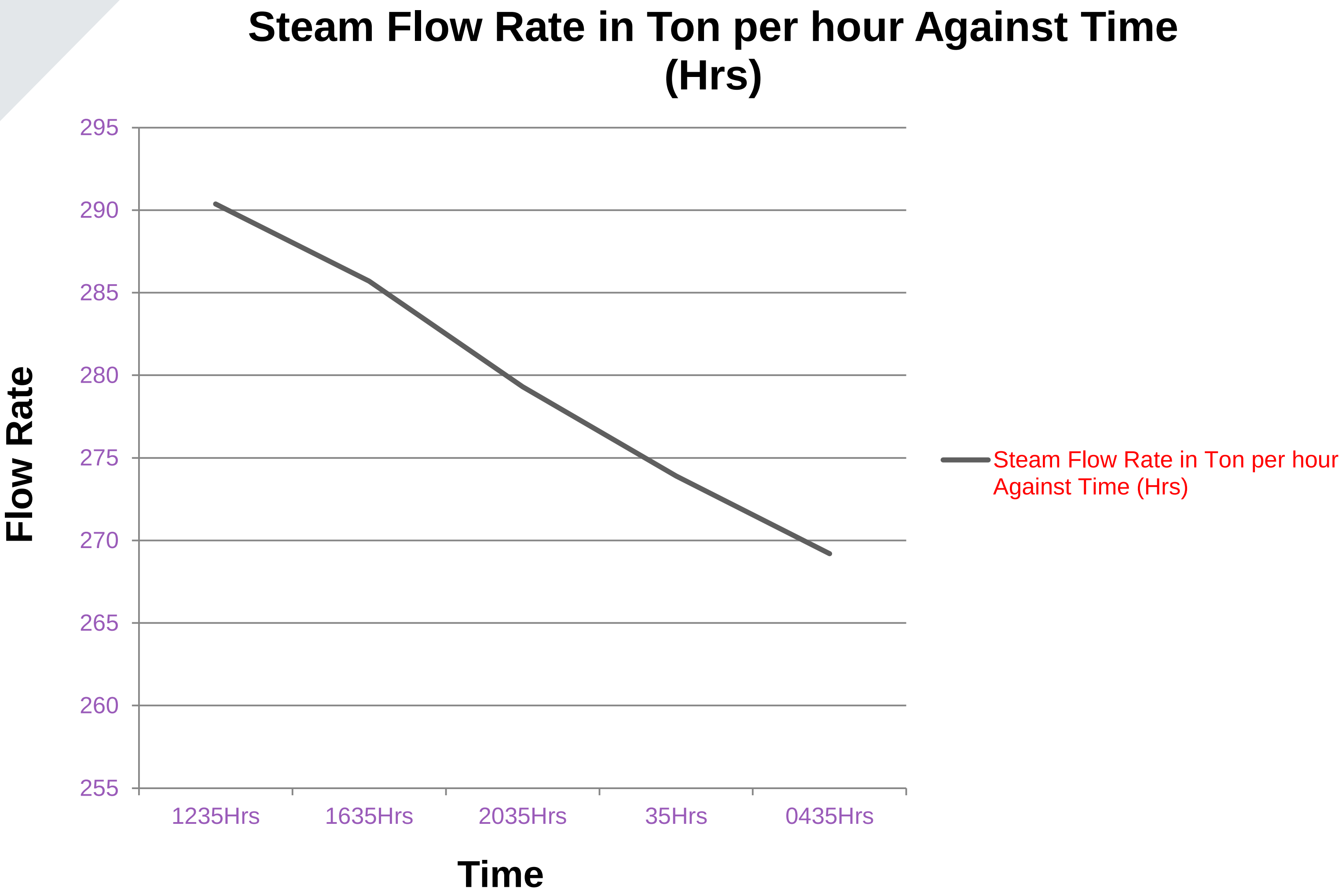
		ITEM TO BE MEASURED			UNIT	BEFORE	DURING BLADE WASH 1	AFTER BLADE WASH 1	DURING BLADE WASH 2	AFTER BLADE WASH 2
BLADE WaSH		Time hours				1235	1635	2035	0035	0435
	1	Generator load			Mw	26.4	26.4	29.5	29.0	33.0
	2	Blade wash water flow			T/H	0	4.0	0	4.5	0
	3	Main steam flow			T/H	290.38	285.7	279.3	273.9	269.2
	4	Main steam pressure		interface	Barg	4.42	4.35	4.31	4.28	4.24
				LH		4.03	4.06	4.07	4.07	4.07
				RH		4.01	4.04	4.05	4.05	4.06
	5	Main steam temperature		interface	C	151.34	151.5	151.6	151.7	152
				LH		150.1	150.1	150	150	150.2
				RH		150.16	150.4	150.1	151.1	151
	6	Steam chest pressure			Barg	3.638	3.642	3.534	3.509	3.47
	7	Condenser vacuum			Bara	0.077	0.079	0.077	0.075	0.07
	8	Gv position		LH	%	61%	60.5	55.3	52.2	50.4
				RH		59%	58.5	52.9	51.8	50.3
	9	Bearing metal temperature		#1	C	66.5	66.7	66.4	66.3	66.2
				#2		63.5	63.6	63.4	63.2	63.1
				#3		62	62.3	61.9	61.8	61.6
				#4		60.8	60.9	60.6	60.5	60.3
	10	Bearing vibration	#1	X	Micron P-P	18	17	14	14	14
				y		19	18	15	14	14
			#2	X		24	23	17	17	17
				y		24	24	19	18	19
			#3	X		32	32	31	31	33
				y		20	21	20	20	21
			#4	X		24	24	25	24	26
				y		29	29	29	29	32
	10	Rotor position			Mm	-0.09	-0.09	-0.11	-0.11	-0.11
	12	Differencial expansion			Mm	1.11	1.11	1.15	1.16	1.24
	12	Thrust bearing metal temperature (gov side)			C	58.2	58.3	57.6	57.4	57.3
	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ANALYSIS OF RESULTS

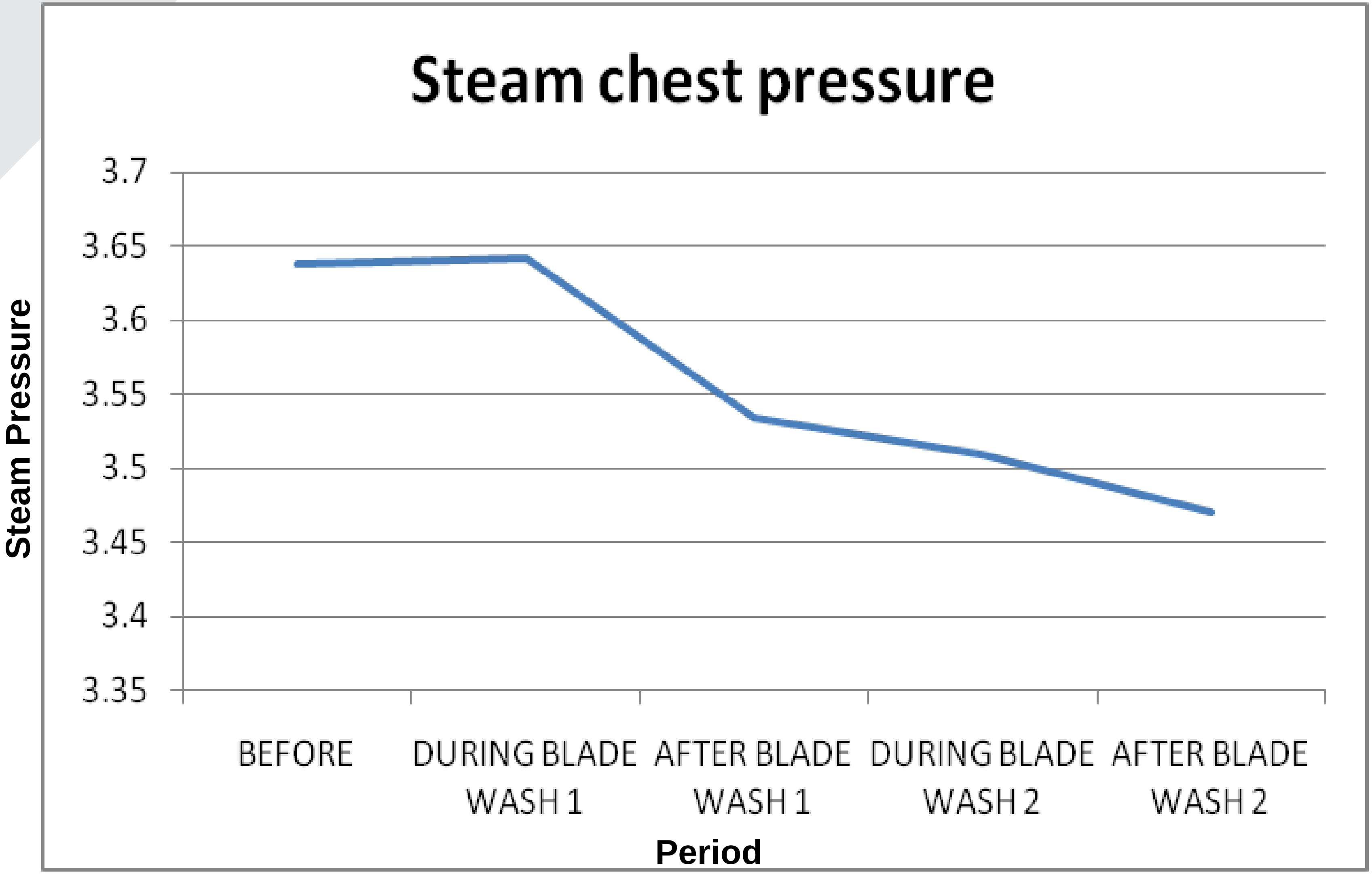
❖Generator load.



MAIN STEAM FLOW



STEAM CHEST PRESSURE



CONCLUSION

- The scaling has been identified to be chemically formed and this would also require chemical inhibitors to clear.
- The study has also realized that there is significant load optimization through steam and blade washing.
- The generator Loading in a geothermal power plant is mainly affected by the steam chest pressure, main steam flow rate as well as the Condenser vacuum.
- Steam washing should be regularized in every power plant that exhibits silica scaling.

RECOMMENDATIONS

- Geothermal plants in Olkaria should establish a comprehensive steam wash and blade wash system for mitigation in its future plants.
- A well designed steam washing and blade washing system to be designed as a least cost mitigation measure to augment on optimal generator loading design.
- The steam wash system should be combined with other chemical methods such as the use of chemical inhibitors to minimise silica scaling right at the well head.
- The use of pH variation as well as separation pressure method to be be employed as well to maximise on the benefits.

THE END