Reconciliation of Performance Test Results at LADA Unit 4 and BESOS Unit 2 (Spain) Using PEPSE®

Nuria Lopez

UITESA Grupo Iberdrola
Madrid, Spain

ABSTRACT

The fossil thermal plants are tested periodically to determine plant efficiency losses and system malfunctions. These tests result in design improvements and verification of the effects caused by the modifications in the plant.

The availability of a plant thermodynamical model is an essencial aid, to learn in a reliable way about of the plant components and whole system behaviour. In this way, the performance deviations from the design values and their causes are determined.

During years, UITESA, has given technical support to the Spanish utilities for the optimization of the thermal plants efficiency.

This papers shows the UITESA experience in the development of models and procedures for the thermal efficiencies with the PEPSE code for the LADA Unit 4 and BESOS Unit 2 Spanish thermal plants.

We had the following targets:

- The determination and the evaluation of the efficiency losses relative to the target values.
- The evaluation of the impact in the heat rate of plant parameters variations.
- The evaluation of the supplier turbine tests.

Besides to the capabilities to analize the on-line efficiency and to determine improvements to the plant operating conditions, UITESA has decided to incorporate to his know-how, the PMAX software for the Spanish utilities and its first aplication will be for the VELILLA Unit 2 thermal plant.

FOREWORD

Unión Iberoamericana de Tecnología, S.A. (UITESA), is a Technological Consultancy and Advanced Engineering Services company specializing in high technology sectors, fundamentally in the energy area.

In the field of Nuclear Thermal Engineering, UITESA has gained extensive know-how centred on specific technological fields related to thermal and nuclear power plant design and operational support.

UITESA is entirely owned by IBERDROLA Industrial Group (Iberdrola is a private Spanish electric company) and is the leading firm in the area of engineering, and thus actively participates in the Group's diversification policy.

INTRODUCTION

The need of a periodic control in power plants efficiency has been detected in order to improve and to optimize the energetic resources.

For this reason, UITESA has developed a procedure for analizing the plant efficiency and evaluating losses. This procedure is the following:

- Optimum perfomance plant model elaboration.
- Sensitivity studies of the equipment perfomance parameters, to know their effects in the heat rate.
- Measurement data adquisition.
- Efficiency analysis with identification and evaluation of the possible efficiency losses.

This paper presents the thermodynamic models employed by UITESA in order to simulate the LADA Unit 4 and BESOS Unit 2 Spanish thermal plants, with sensitivity and efficiency analysis, using PEPSE code.

Spanish utilities have decided to install in their thermal plants a real time efficiency analysis program to cover the operation needs. Actually, UITESA has decided to used the PMAX software, with a good degree of aceptance among its customers.

PEPSE THERMODYNAMIC MODEL OF THE BESOS UNIT 2 THERMAL PLANT

From 1989 to 1990, UITESA developed the OTRO project, " Real Time Optimization of the Thermal Plant Operation ". The PEPSE code was used in the phase of thermodynamic models elaboration, used later in the experience cases generation for the expert system. Besos Unit 2 a 300 Mw thermal plant was selected as a base for the development.

The Figure 1 shows the thermodynamic model of the plant.

The sensitivity of the Group Net Heat Rate (GNHR) was studied. The model was verified in every possible and reasonable state in which the expert system could be demand to search the optimal perfomance or the minimal GNHR.

The tests analysed were divided in two groups:

- Tests of normal conditions: These are expected plant states whose parameters remain in the nominal values except the analysed variable.
- Tests of abnormal conditions: These are the possible situations of the plant that modify some component perfomance (e.g: Feed water heater out of service).

Three load were used: Full load (305.7 Mw), Medium load (179.13 Mw) and Low load (102.56 Mw). Several tests were run for each variable, covering all the expected ranges.

The Figure 2 shows the matrix tests ran. The symbol (*) shows the normal tests, the symbol (+) the abnormal tests and the symbol (-) the tests that didn't run. In these last cases the Simulator was unable to run or the test result was a conclusion from another test.

PEPSE TURBINE MODEL, BESOS UNIT 2

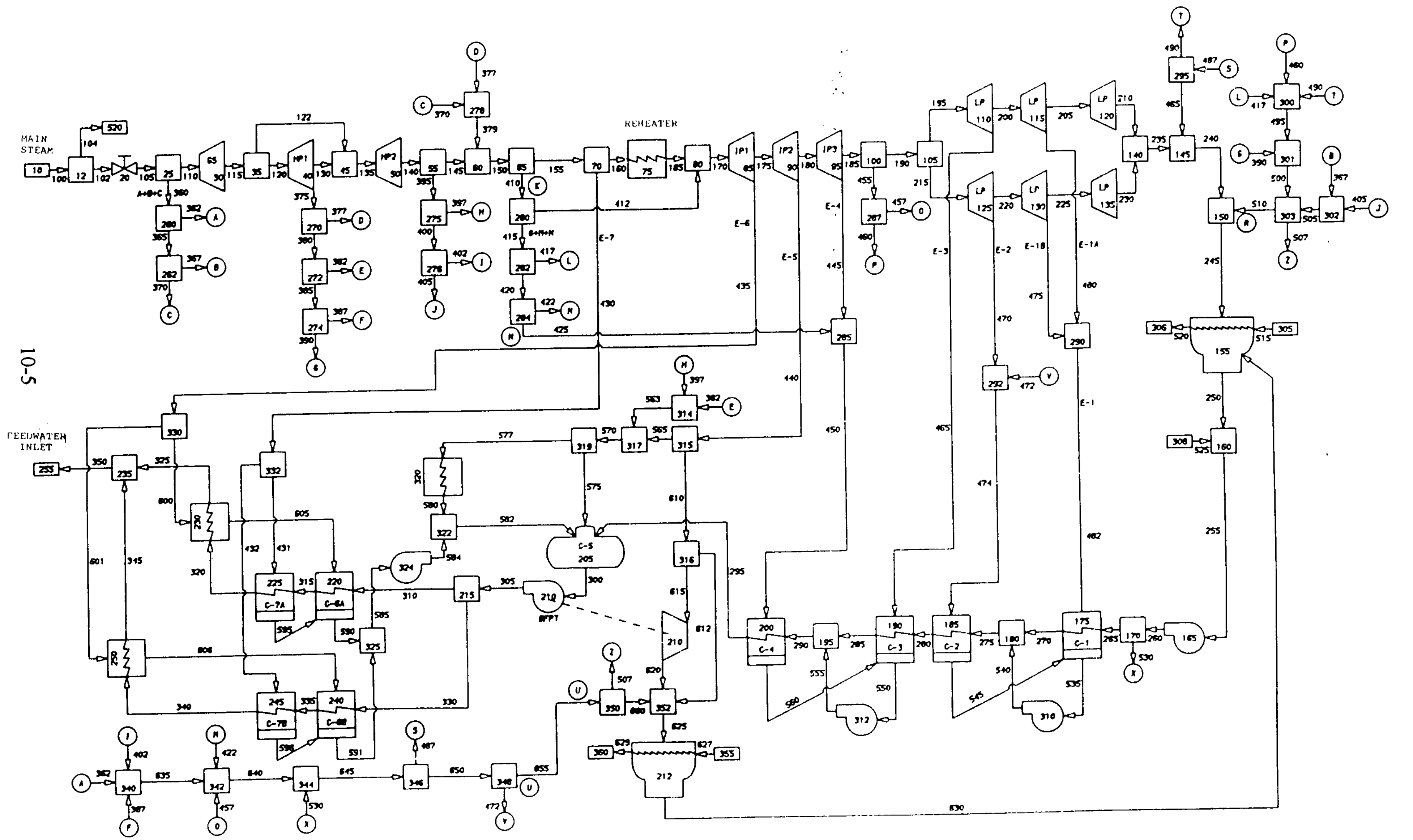


FIGURE 1

MATRIX TEST PEPSE MODEL BESOS UNIT 2

	GENERATOR GROSS		
	305.71 Mw	179.13 Mw	102.56 Mw
OPERATE VECTOR VARIABLES			
Main steam pressure	*	*	*
Main steam temperature	*	*	*
Hot reheat temperature	*	*	*
Excess air	*	*	*
Boiler inlet air temperature	*	*	*
Boiler outlet flue gas temp.	*	*	*
CO in combustion gas	*	*	*
Injection steam flow	*	*	*
Injection reheat flow	*	*	*
Ejectors condenser in service	-	-	-
Burners in service	-	-	-
1 Forced draf fan in service	-	-	-
Boiler soot blowing	-	-	-
1 Induced draf fan	-	-	-
Air heater soot blowing	-	-	-
1 circulating water pump	-	+	-

OPERATION VECTOR VARIABLES			
Generate power	*	*	*
Power factor	*	*	*
Index charge	-	-	-
%carbon fuel	-	-	-
%fuel oil	-	-	-
%natural gas	-	-	-

INSTALLATION VECTOR VARIABLES			
Heat rate	*	*	*
Circulating water temperature	*	*	*
Ambient temperature	*	*	*
Ambient air moisture	*	*	*
Barometric pressure	*	*	*
Condenser backpressure	*	*	*
Auxiliar condenser backpressure	*	*	*
Condenser cleanliness	*	*	*
Auxiliar condenser cleanliness	*	*	*
Condenser effectiveness	-	-	-
Auxiliar condenser effectiveness	-	-	-
Pressure drop reheater	*	*	*
Boiler cleanliness	-	-	-
Auxiliar power	*	*	*
Make up rate	*	*	*
Auxiliar steam rate	*	*	*
HP Feedwater heaters out of service	-	+	+
50% HP heaters out of service	-	+	+
LP1 heater out of service	-	+	+
LP2 heater out of service	-	+	+
LP3 heater out of service	-	+	+
LP4 heater out of service	-	+	+
HP-a cond.rht.pump out of service	-	-	-
HP-b cond.rht.pump out of service	-	-	-
LP1 cond.rht.pump out of service	-	+	+
LP2 cond.rht.pump out of service	-	+	+
Turbopump in service	-	-	-

(*) normal test
(+) abnormal test
(-) not run test

FIGURE 2

Some conclusions from these studies are the followings:

- Main steam and reheat steam temperature have a significant effect on the heat rate. See the Figures 3-A and 3-B.
- The environmental conditions have a smooth effect on the heat rate. The cold side temperature, the sea in this case, has an important effect through the condenser backpressure. See the Figures 4-A and 4-B.
- A general linear behaviour of the GNHR on the main variables can be observed, in the range analysed and with the hypothesis of the studies. When some variables are changed at the same time from their nominals values, probably the real plant won't response linearly. However, individual changes in each variable produce linear behaviour. The condenser backpressure variables haven't a lineal trend. This is explained by the different causes or origins of the turbine exhaust losses. See the Figures 5-A and 5-B.

The Figures 6-A and 6-B show the heat rate behaviour called " abnormals states " of the plant.

GROUP NET HEAT RATE
Boiler outlet Temp.=1202 F
2 Heater trains

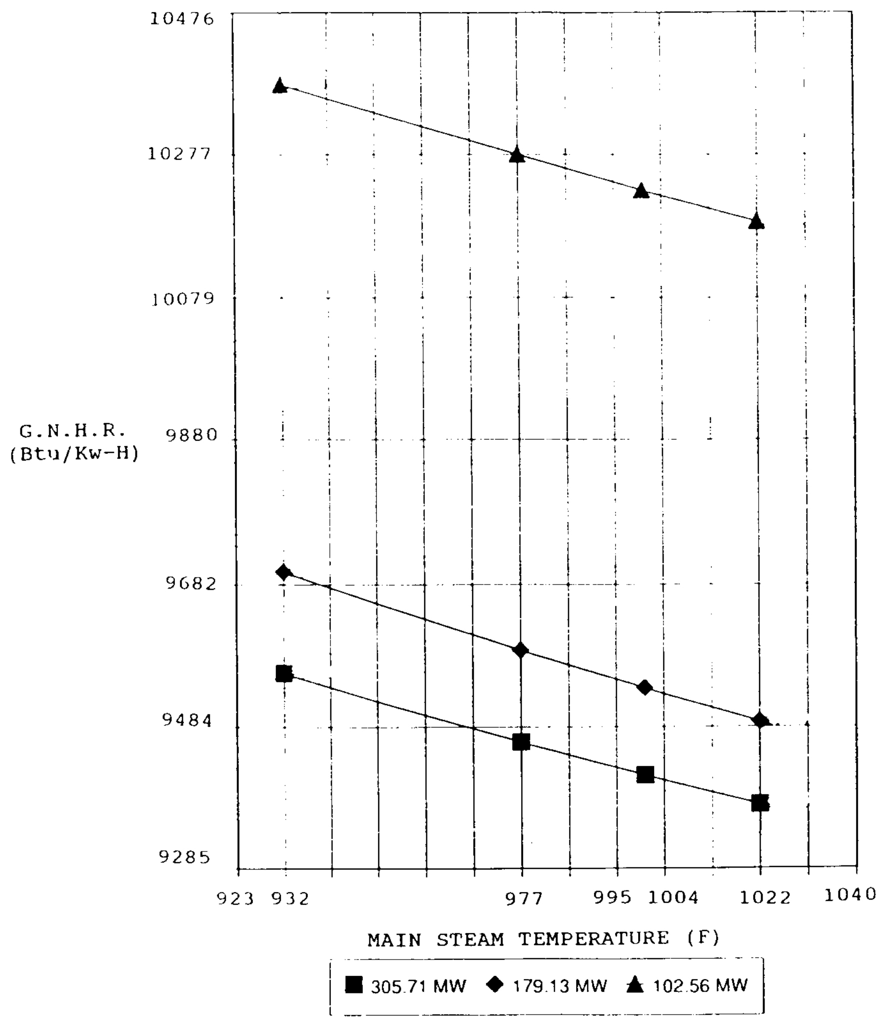


FIGURE 3-A

GROUP NET HEAT RATE
2 Heater trains

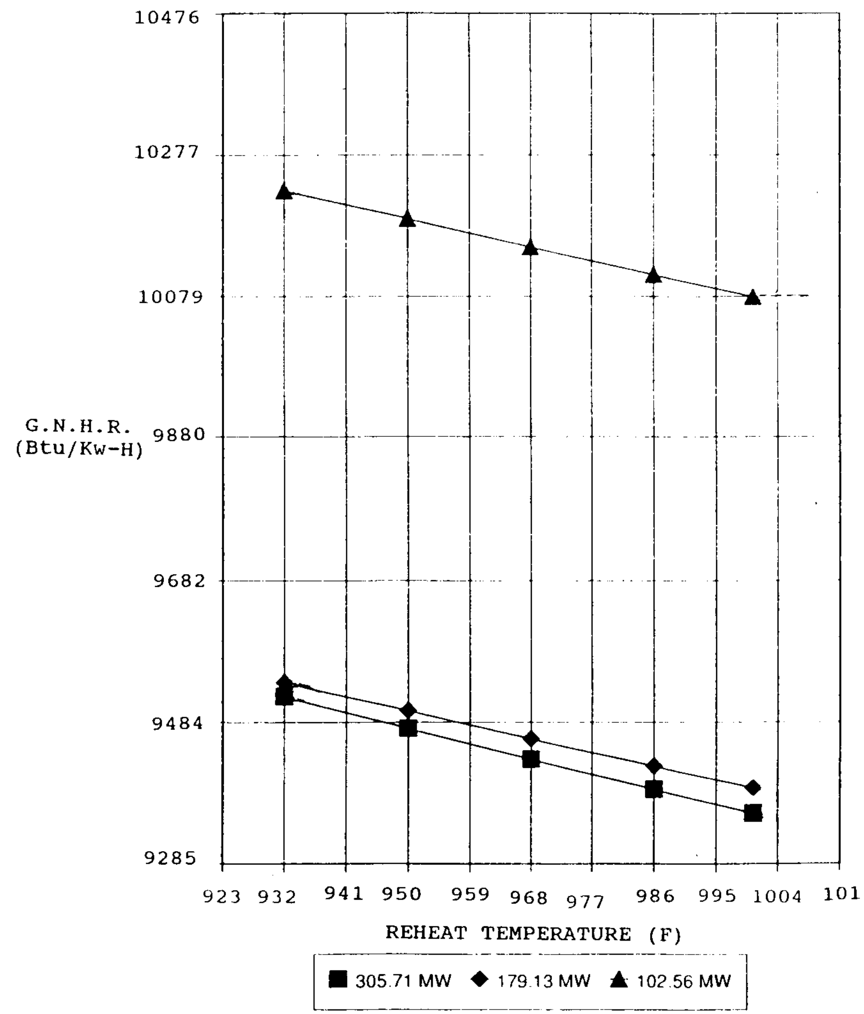


FIGURE 3-B

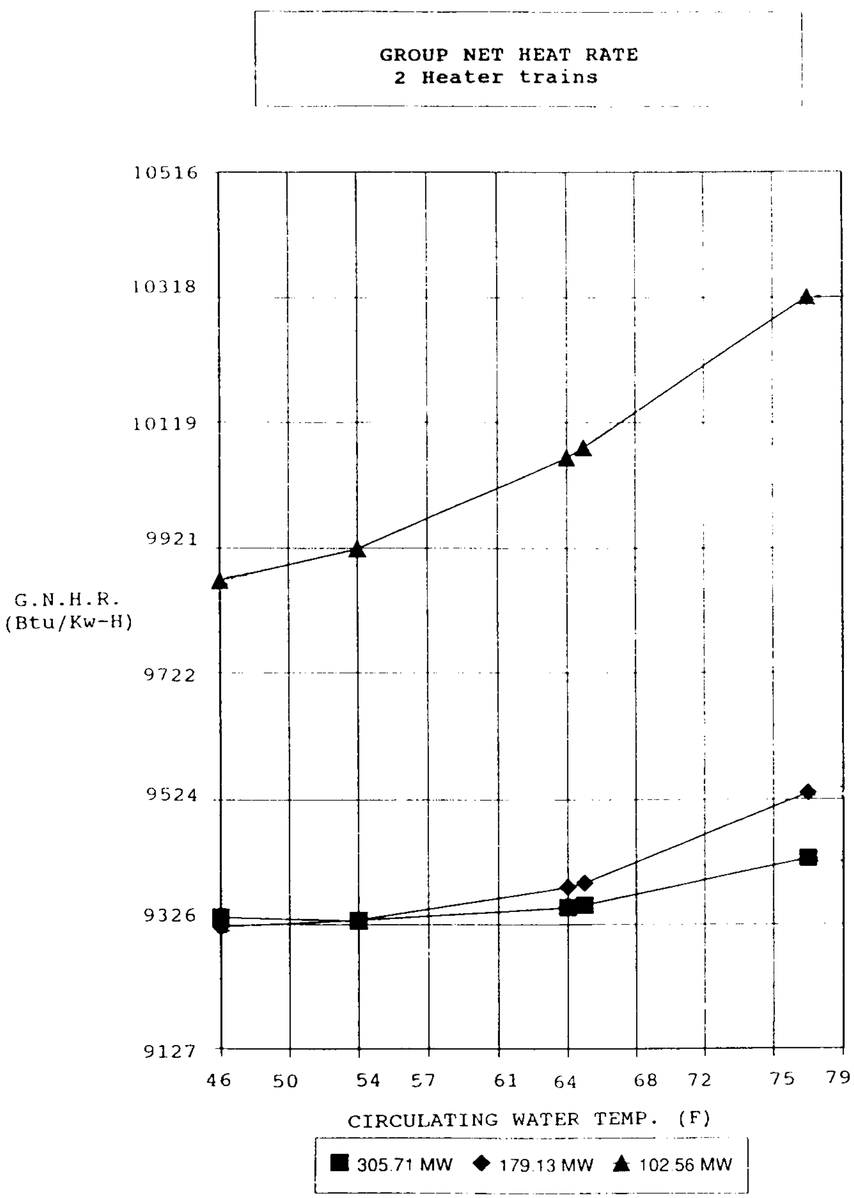


FIGURE 4-A

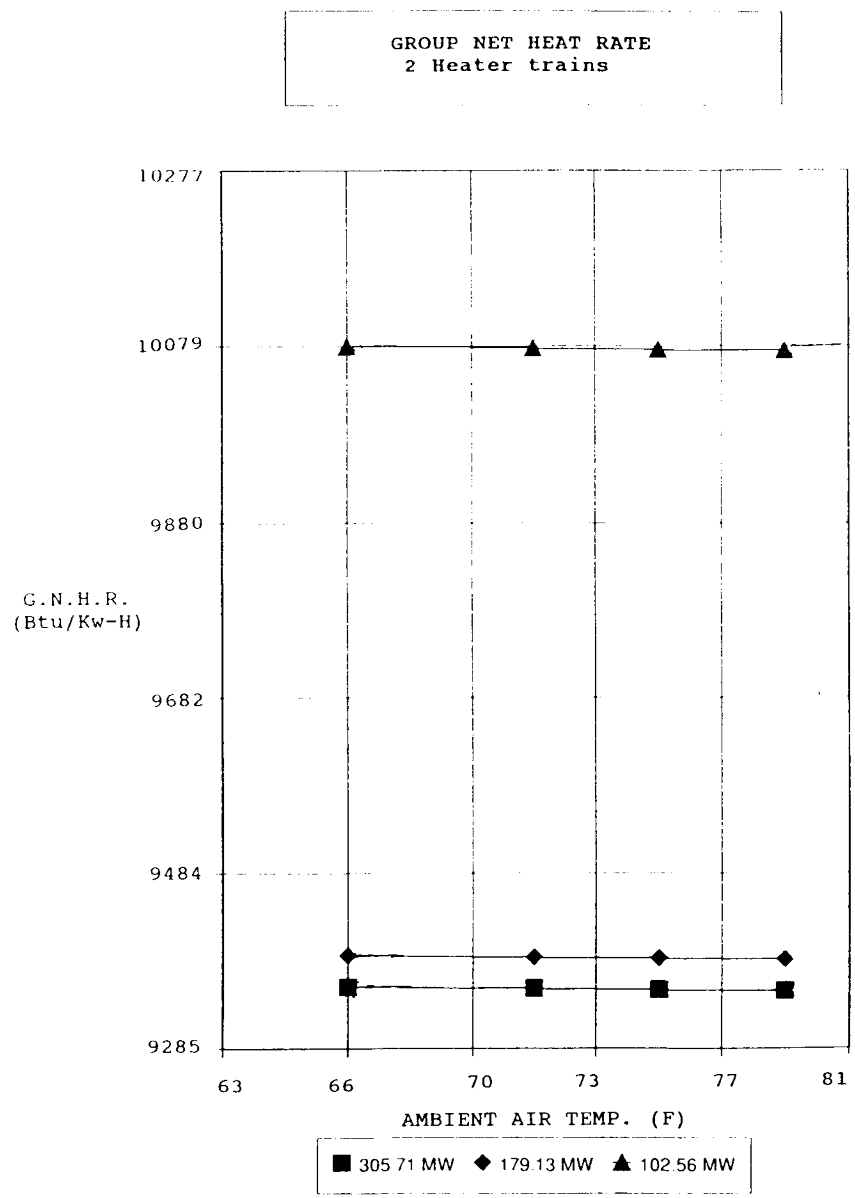


FIGURE 4-B

GROUP NET HEAT RATE
2 Heater trains

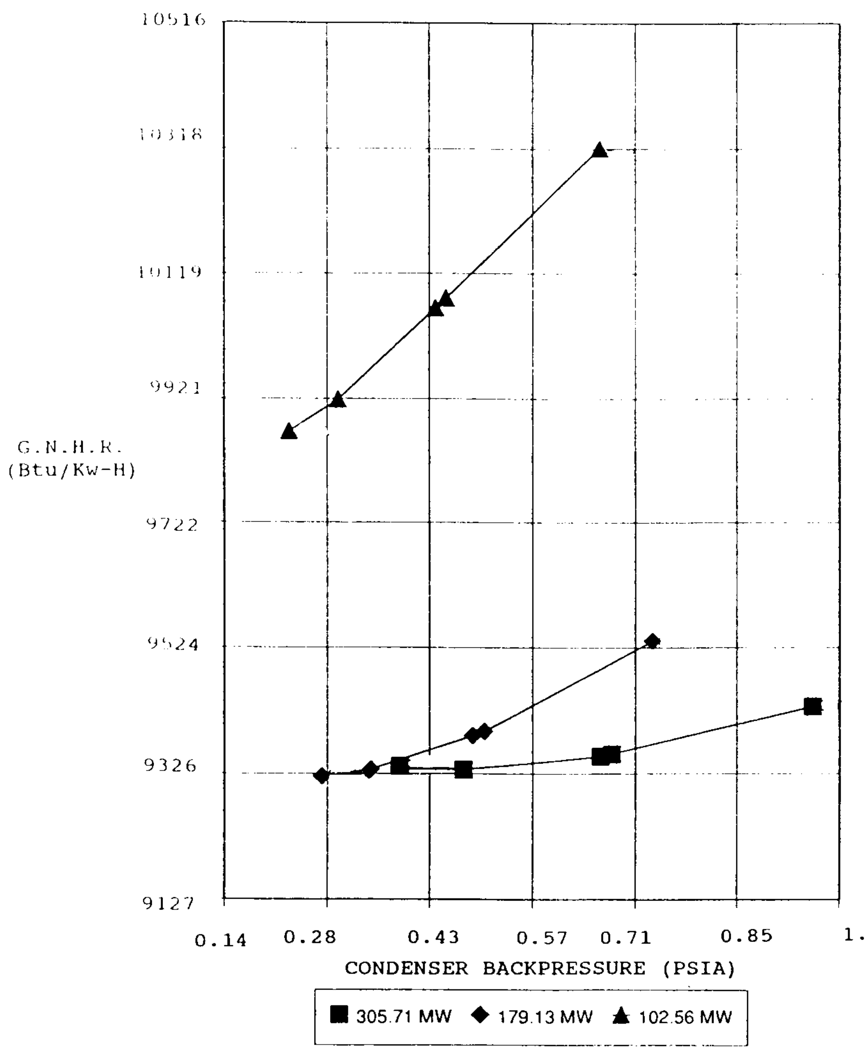


FIGURE 5-A

GROUP NET HEAT RATE
2 Heater trains

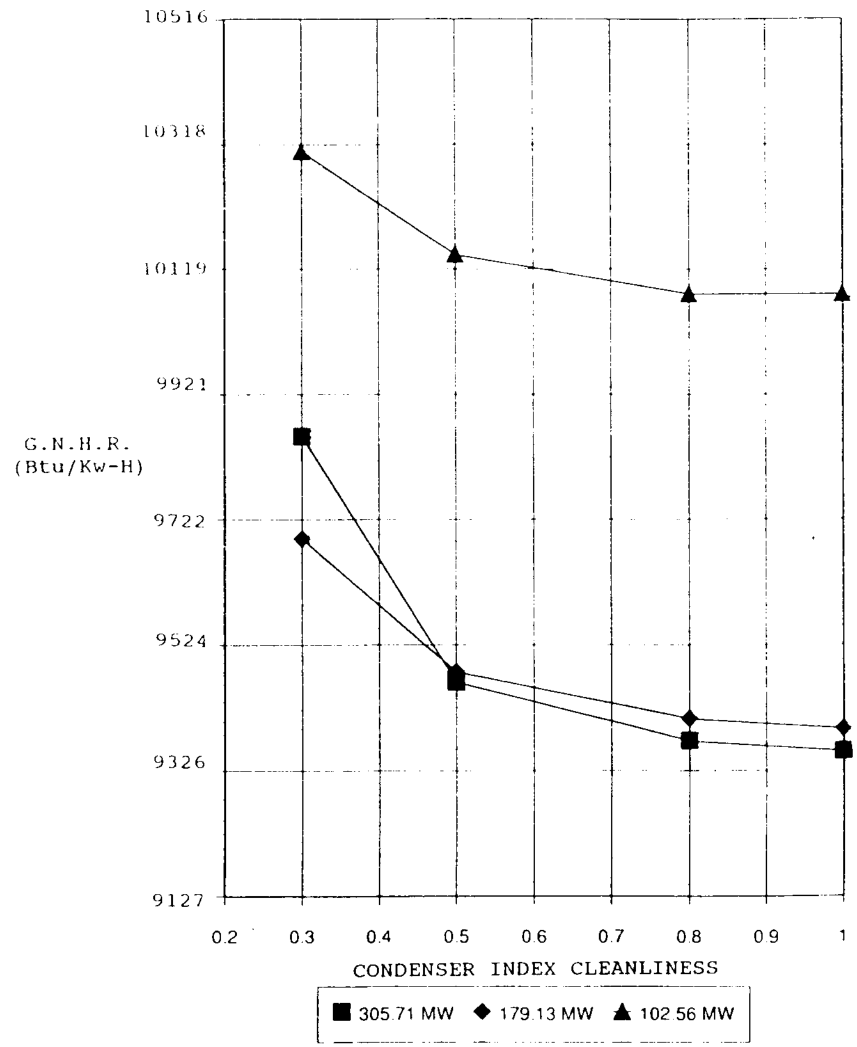


FIGURE 5-B

GROUP NET HEAT RATE
HP HEATERS OUT OF SERVICE
50% HP HEATERS OUT OF SERVICE

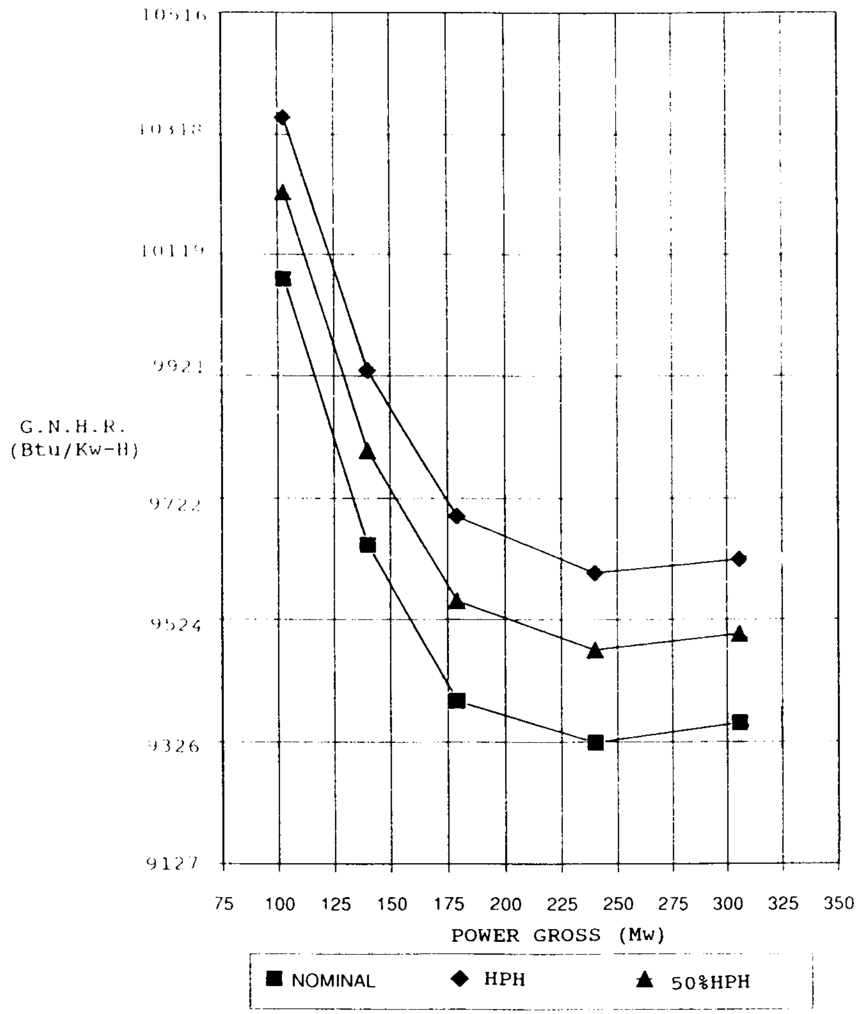


FIGURE 6-A

GROUP NET HEAT RATE
1 CIRCULATING WATER PUMP IN SERVICE

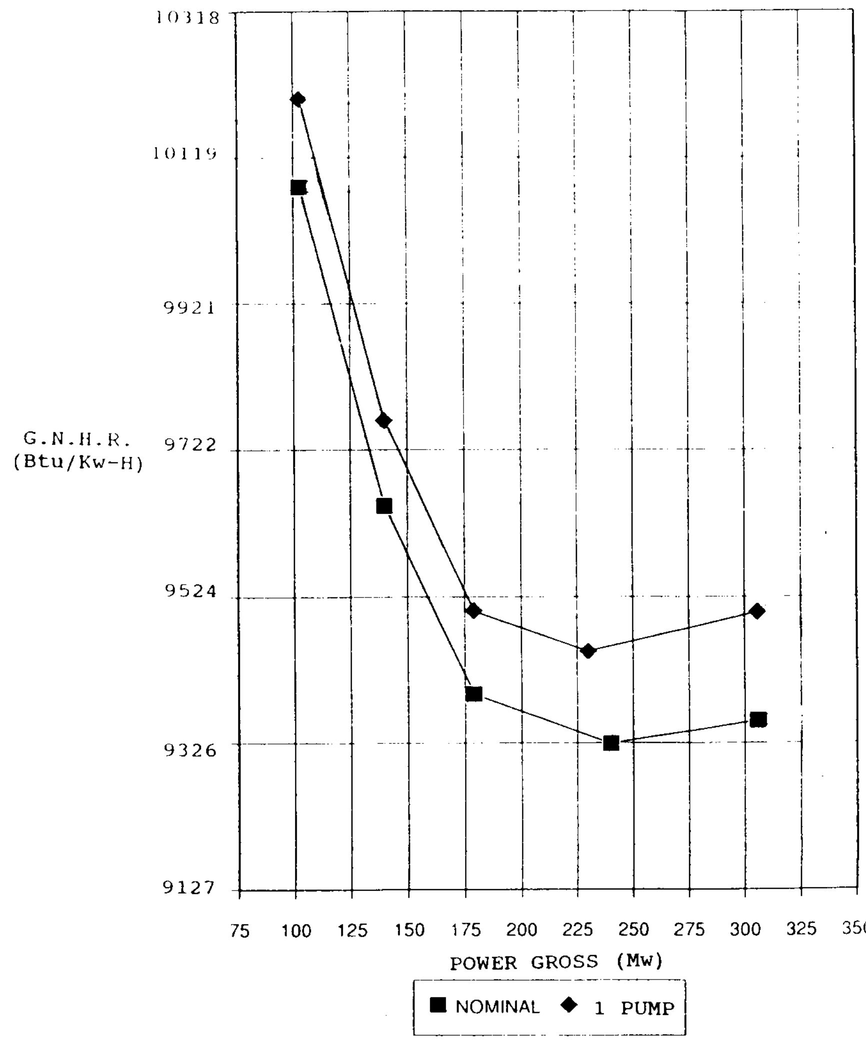


FIGURE 6-B

PEPSE THERMODYNAMIC MODEL OF THE LADA UNIT 4 THERMAL PLANT

LADA Unit 4, a 350 Mw unit, was used in 1990 by UITESA to study heat balance, identify degradation of components and propose improvements in the efficiency of plant thermal cycle. The PEPSE model is shown in Figure 7.

A representative model of the best operating condition of the plant (Benchmark model) was developed. The Benchmark model provides, through sensitivity studies, the knowledge of the most influential parameters on the heat rate. Several fundamental variables are feedwater flow, condenser backpressure, reheat outlet temperature and pressure.

Sensitivity studies on the feedwater heaters and circulating water circuit parameters, were done to analize the measurement uncertainty. The cooling towers and circulating water pump were added to the PEPSE model.

Some conclusions from this studies are the followings:

- The model has not much sensitivity when the feedwater heater variables are changed. The most significant effect is the high pressure feedwater heater outlet temperature (tube side), component number 6 in Figure 7. Turbine extraction pressure to low pressure feedwater heater haven't measurement problems if a pressure instrument of narrow range is available.
- In the circulating water system, the most significant variable is the condenser circulating water inlet temperature. The circulating water flow have low importance when the direct measurement error or the indirect calculated value of it, isn't large.
- In the feedwater turbopump, the most significant variable is the discharge temperature.
- The model is sensitive to the changes in the feedwater flow.

PEPSE TURBINE MODEL, LADA UNIT 4

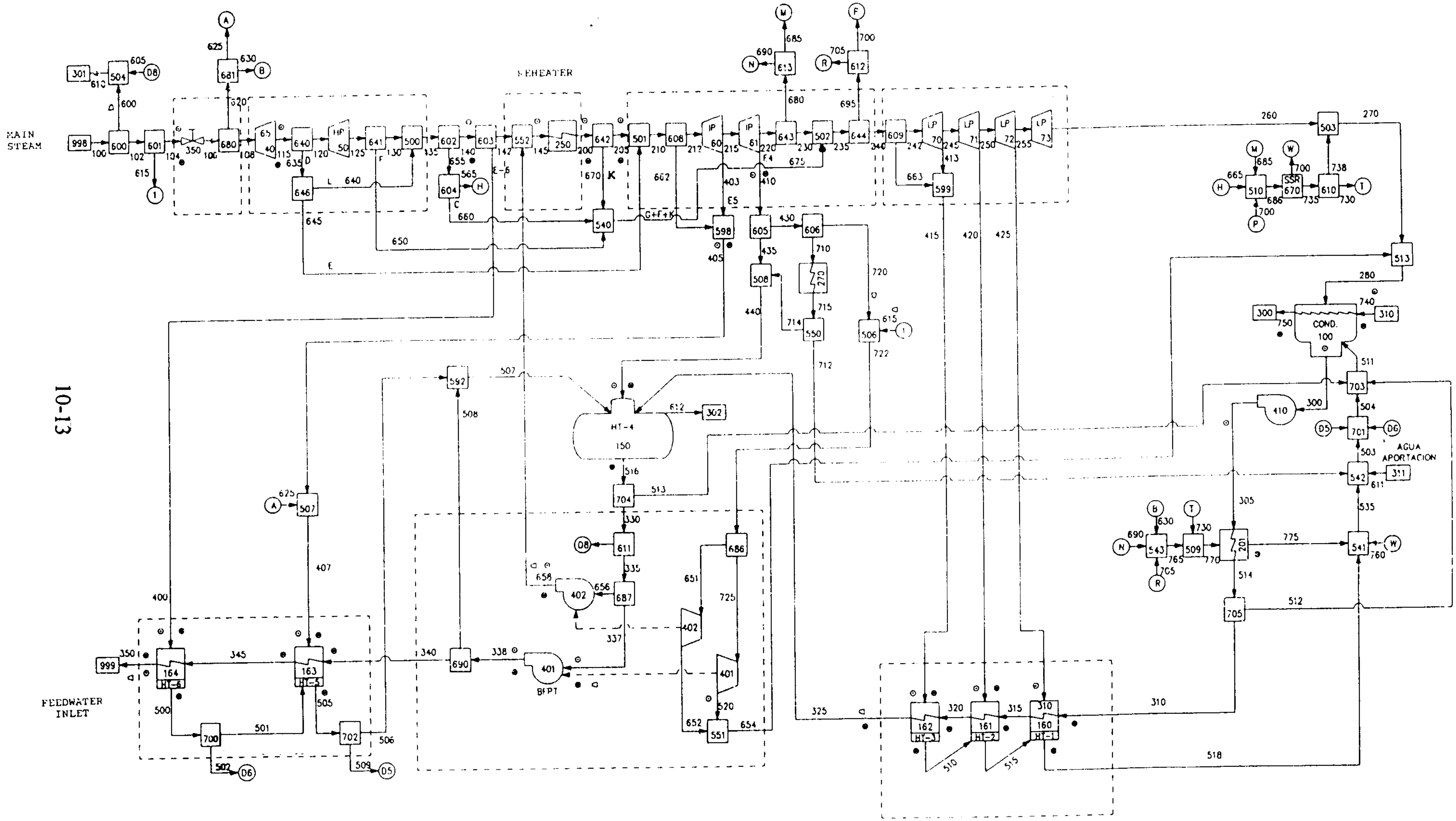


FIGURE 7

⊙ PRESSURE

⊗ TEMPERATURE

▷ FLOW

The determination of the measurement point is fundamental: The more is the number of the measurement points, the better will be the accuracy in the real plant model but the efficiency test will be more expensive.

The variables are classified in three groups depending on their effect in the plant efficiency:

- Primary variables: Are fundamental for a correct calculation of the efficiency. Some of them are; turbine extraction pressures and temperatures, condenser backpressure, reheat outlet pressure and temperature, heater shell inlet pressure, feedwater heater tube outlet temperature, heater drain outlet temperature, feedwater flow, generator power, power factor, generator hydrogen pressure, pump parameters ...
- Secondary variables: Their measurements are recommended, although can be replaced by historical or design values. Several are; intermedate pressure and low pressure turbines section bowl pressure and temperature, leakages flows, heater shell inlet temperature ...
- Variables of minor importance: The lack of measurements for these variables implies small changes the heat balance. These include; circulating water inlet pressure, feedwater heaters tube inlet pressure and temperature ...

After having done a statistical check of the measurements, a real perfomance plant model was elaborated.

Efficiency losses evaluation was done after correcting all boundary real model to design conditions. An efficiency losses in several components can be seen.

PEPSE Special Option Number 6 was used to calculate the deviation from design for every component of the subject unit.

The Figure 8 shows the efficiency losses identified in the following equipments:

- Condenser and circulating water system
- Condensed heaters and feedwater
- Turbopump feed water
- Turbines

Most of the efficiency losses were identified in the condenser and circulating water circuit. The measurements and model uncertainties are added in the low pressure turbine. An increase of 0.5 percent in feed water flow, which can correspond to flow measurement uncertainty, provides analysis results more realistic for the low pressure turbine. This change in the flow has low influence in others systems. See Figure 9.

Due to these results specific check and tests were requested by the plant to the suppliers of the equipment. Relative leakages rates to the condenser in the plant cycle isolation valves were detected.

During 1993 through 1994, UITESA has updated the LADA Unit 4 thermal plant model. Leakages and drains have been added. Also, a boiler model has been done using input/output method. See Figure 10.

The PEPSE model has been successfully used to evaluate recent supplier turbine tests. The calculated heat rate compared to the supplies results are:

CASE	GENERATOR POWER (Mw)	POWER INCREMENT (Mw)	HEAT RATE (Btu/Kw-h)	HEAT RATE INCREMENT (Btu/Kw-h)	%
benchmark	346.851		7864.		
test data	345.141		8210.		
standar+atemp.	347.240	0.389	8164.8	301.2	
standar	340.244	-6.607	8133.	269.	3.42
upgrate					
condenser	346.521	6.277	7985.8	-146.8	1.87
reheater 1	346.438	-0.083	7987.	1.2	0.01
reheater 2	346.516	0.078	7985.8	-1.2	0.01
reheater 3	346.672	0.156	7981.8	-3.97	0.05
desaireator	346.743	0.071	7979.8	-1.98	0.03
reheater 5	346.803	0.06	7979.1	-1.19	0.01
reheater 6	344.572	-2.231	7966.	-13.1	0.17
no feedwa.flow	345.162	0.59	7933.8	-32.14	0.41
feedwater pump	345.667	0.505	7922.	-11.9	0.15
aux.turbine	347.136	1.469	7887.8	-34.13	0.43
HP turbine	350.136	3.0	7848.1	-40.08	0.51
IP turbine	349.124	-1.012	7835.	-13.1	0.17
LP turbine	349.109	-0.015	7858.	23.	0.29
optimum state	346.851	-2.258	7864.	5.95	0.08

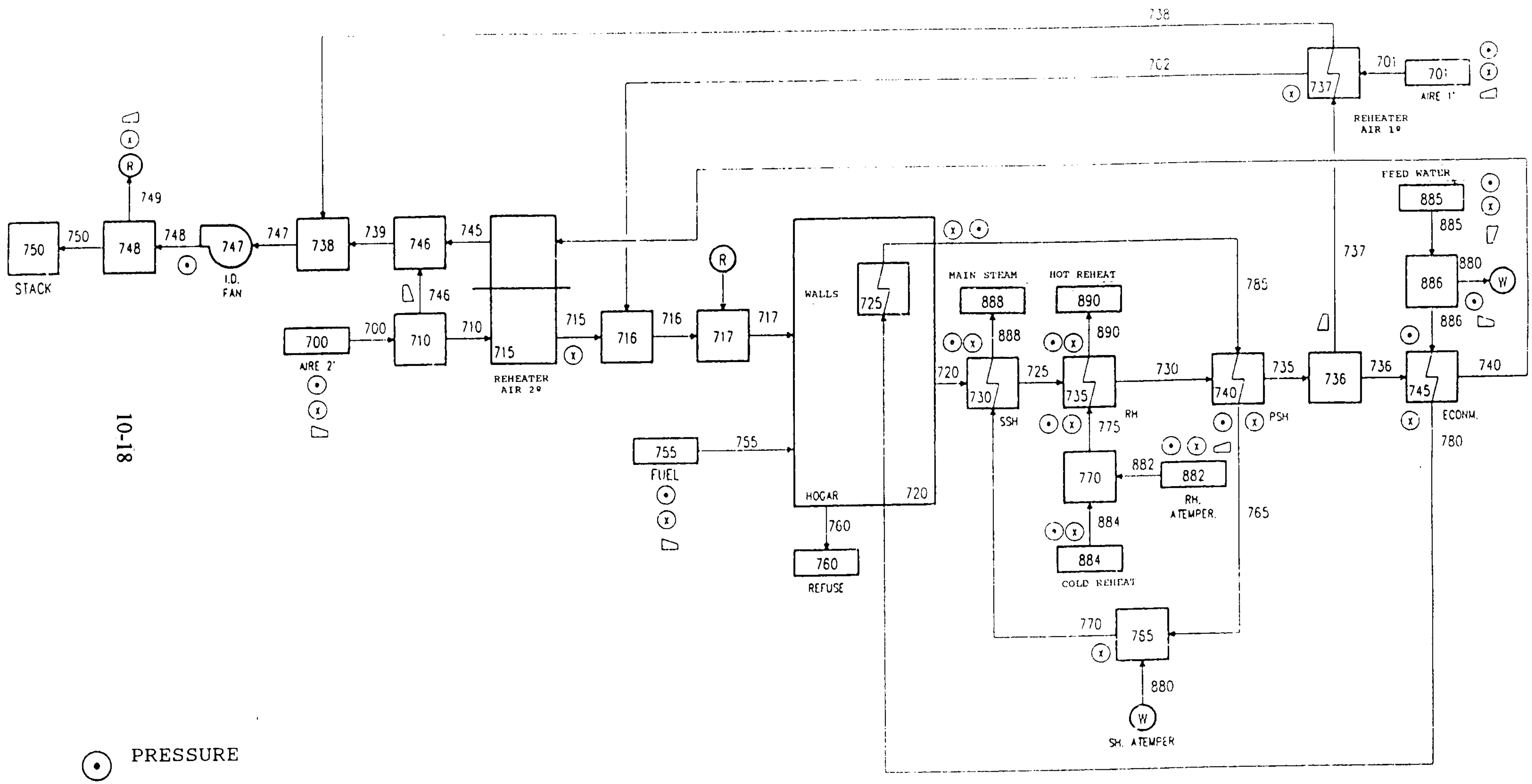
FIGURE 8

FEEDWATER FLOW, 1.005*TEST FLOW

CASE	GENERATOR POWER (Mw)	POWER INCREMENT (Mw)	HEAT RATE (Btu/Kw-h)	HEAT RATE INCREMENT (Btu/Kw-h)	%
benchmark	346.851		7864.		
standar	340.317	-6.534	8173.1	309.13	3.93
upgrate					
condenser	346.590	6.273	8025.1	-148.0	1.88
reheater 1	346.510	-0.080	8025.9	1.2	0.01
reheater 2	346.570	0.060	8025.1	-1.2	0.01
reheater 3	346.712	0.142	8021.1	-3.97	0.05
desaireator	346.802	0.090	8019.1	-1.98	0.03
reheater 5	346.881	0.079	8018.	-1.19	0.01
reheater 6	344.665	-2.216	8004.8	-13.1	0.17
no feedwa.flow	345.230	0.565	7974.	-30.95	0.39
feedwater pump	345.730	0.500	7962.	-11.9	0.15
aux.turbine	347.185	1.455	7928.	-34.13	0.43
HP turbine	348.752	1.567	7985.8	-42.06	0.53
IP turbine	348.521	-0.231	7872.	-13.9	0.18
LP turbine	349.124	0.603	7858.	-13.9	0.18
optimum state	346.851	-2.273	7864.	5.95	0.08

FIGURE 9

PEPSE BOILER MODEL, LADA UNIT 4



PRESSURE
TEMPERATURE
FLOW

FIGURE 10

Heat losses

	Supplier test	PEPSE test
HP turbine	54 Btu/Kwh	54 Btu/Kwh
IP turbine	71 Btu/Kwh	65 Btu/Kwh

The difference seen in the IP turbine is due to news leakages no represented in the PEPSE model (e.g; leakage from HP turbine to IP turbine).

CONCLUSIONS

A procedure which systematizes the measurement and the metodology for the efficiency analysis in thermal plants must be developed. This provides a knowledge to make correction of the working plant parameters for the different equipments during the plant life cycle.

This metodology has been developed, to produce new strategies and to improve the relationship betwen plant investment and rentability.

The periodical efficiency analysis will allow us to elaborate a operation historical data bank of the plant. With this data we can detect not only punctual anomalies due to equipment deterioration but also we can foresee the repair and maintenance of the components avoiding their fast degradation.

PEPSE models have been developed for the different possible steady states in LADA Unit 4 and BESOS Unit 2 thermal plants. Wide types of cases have been run to verify the behaviour of the models for different working conditions.

This results have been the key for taking decisions to optimize the plant operating conditions.

REFERENCES

1.-"Proyecto OTRO. Validación del modelo termodinámico de la central térmica de BESOS-II". UITESA, Octubre 1989.

2.-"Proyecto OTRO. Generación de los casos de experiencia con el simulador de la central térmica de BESOS-II mediante el código PEPSE". UITESA, Noviembre 1990.

3.-"Mejora en el rendimiento del ciclo térmico de la central térmica de LADA-IV". UITESA, Febrero 1990.

4.-"Procedimiento de cálculos de rendimiento off-line para la central térmica de LADA-IV". UITESA, Mayo 1993.

5.-"Modelo de caldera para la central térmica de LADA-IV con PEPSE". UITESA, Noviembre 1993.