Due Diligence: Efficiency Increase in Existing Power Stations

- a Practice Report-

Nick Peters, Dr. Wolfgang A. Benesch

Steag Energy Services Germany

1 Background and methodology

Steag owns and operates some 9500MW own and related power stations. Beside this SES (Steag Energy Services) operates another 2500 MW for third parties. As well engineers of STEAG Energy Services have been permanently active in Turkey over the last 30 years and thus are very familiar with the local developments and particular business environment. As a consequence to this familiarity STEAG GmbH was successfully able to commission the SUGÖZÜ Power Plant. STEAG Energy Services has been involved from the initial steps of project development up to implementation, providing services as the Owner's Engineer in project development, elaboration of concept, layout and design, permitting procedures, specification and contracting, site supervision and quality assurance, commissioning support and operation optimization. A value-added service for our customers is the close contact with STEAG's operations: we plan and design through the eyes of the engineer and operator.

Efficiency is a permanent goal of every power plant owner and operator. Environment and economics ask more and more for high efficiency or in other words low heat rate. Efficiency is governed by parameters like steam pressure and temperature or flue gas exhaust temperature. These can be clearly seen in the control room. But reaching high efficiency typically asks for more detailed analysis. Secondary parameters have to be monitored that cannot be easily derived from control room information.

There are two steps to mitigate this deficiency:

0. Special investigations of a so called "efficiency team" which is subject of this paper.
1. Use of additional online tools which could be installed afterwards to keep the reached efficiency values on a constant high level.

Such efficiency team worked recently quite successful in South Africa. This country has an installed capacity of more than 40.000MW based on coal as a dominant fuel. Beside continuous efficiency monitoring methods ad hoc off line investigations are quite helpful to increase efficiency. It is the task of the "Steag efficiency team" to visit several power stations looking for possibilities of efficiency improvement and as a side effect increase power output. The goal is to improve the station heat rate and to indentify capacity increase opportunities. In this paper the work of the efficiency team should be described and some examples of typical findings should be given. We can clearly imagine that such kind of method could be adapted also to Turkish power plant fleet.

The procedure includes plant visits, document review and discussions to evaluate key performance parameters to establish current and target plant performance. In addition the carbon footprint will be reduced.

The following important steps are part of the work:

- Creation of a database collecting the key information for the regarded power station
- Check of the current coal quality and comparison it with the design coal based on the performance acceptance test.
- Based on the as built geometrical boiler drawings the theoretical boiler performance and the performance acceptance tests are compared
- Check of every load case of the boiler and the current efficiency of the boiler
- With the boiler calculations and the current performance data it is also possible to evaluate the heat absorption in the different boiler parts and the air and flue gas temperature of the air pre heaters.

- Among others the auxiliary power consumption, the air ingress, the milling system and the soot blowing system are monitored.
- The turbine side will be evaluated as well. Based on the station benchmarks (the performance acceptance tests) the impact of the main turbine issues on the electricity output and the heat rate can be shown. These main issues are for example the live steam parameters, reheat steam parameters, cooling system, final feed water temperature, make up water consumption, steam losses and turbine efficiency.
- After a plant inspection and detail discussions with plant personal the"efficiency team" will give an overview of the current situation.
- The results are shown in a summarizing table. Additionally the "efficiency team" will provide different diagrams which will describe the current situation of the main components. For example the steam turbine efficiency, backpressure and terminal temperature difference of the condenser, cooling tower range and approach, terminal temperature differences of the pre heaters, current heat rates (full and part loads) and impact of the main issues on the heat rate
- Based on this it is at least possible side to show the current carbon foot print in comparison to the benchmark based on the performance acceptance tests.

In the following some examples of these activities are described.

2 Coal quality

Coal quality is forming the basis for boiler design and the related equipment like: conveyor belts, coal feeders, dust precipitators and ash handling system. Comparison of current NCV (Net Heating Value) and that during performance tests establish the foundation for any further statements on station heat rate. The checks can be performed by the use of an ultimate analysis as well as by applying the elementary analysis.

After the check of the specified coal the efficiency team makes the same investigations for the actual coal supply of the power station. Possible deteriorations of the heating value, the ash content, the abrasiveness or the volatile matter will have a huge impact on the combustion, the milling performance or the ash handling system. If this is the case the result will be load reductions and consequential damages can occur.

3 Boiler

The efficiency team evaluated different kinds of boilers like drum type boilers, once through boilers with and without dividing wall or boilers with two pass and tower type design. For the boiler efficiency calculations, our own boiler calculation program is used. The flue gas temperatures are calculated, based on the handed over O_2 concentration upstream and downstream the regenerative air pre heater. The calculation program is based on the geometrical input of the boiler Again current values are compared with design parameters and performance test results.

With this model and the current coal quality it is possible to derive the current boiler efficiency. Beside the boiler efficiency the detailed heat absorption of the different heating surfaces can be calculated. The boiler performance in comparison to the acceptance test will be illustrated in a h-p-diagram (Figure 1).

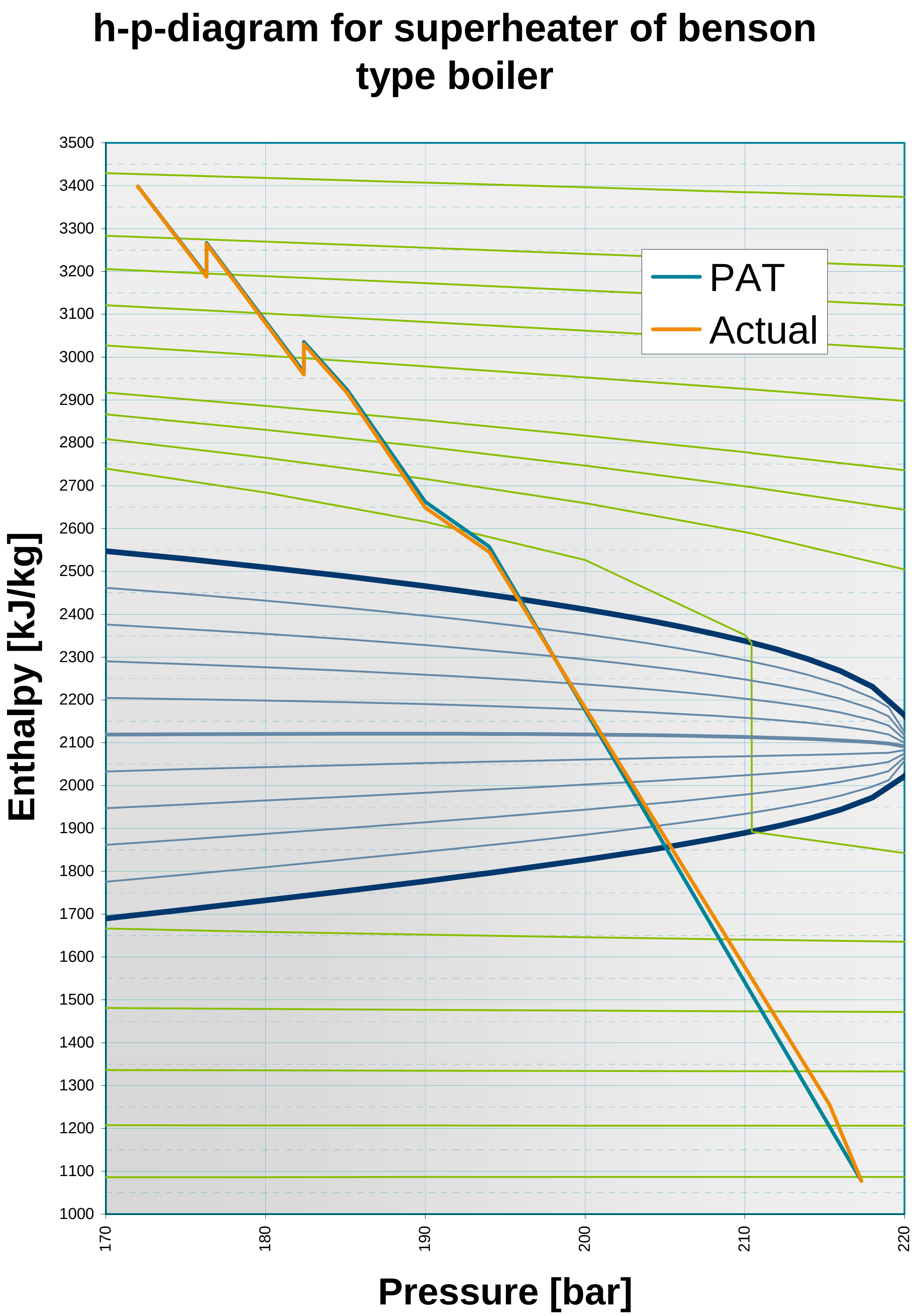

Figure 1: Example for the evaporation line for the super heater of a once through boiler

The energy efficiency team is also focussing on the auxiliary power and steam consumption, the air ingress, the air and flue gas temperatures of the air pre heater, the milling system and the soot blowing performance.

Figure 2 illustrates the impact of the selected source for soot blowing. Within the upper diagram the danger of not sufficient heated soot blowing steam is shown. The lower diagram for selection the soot blowing steam source shall be considered to avoid wet areas in the blowing ambient leading to erosion of the heating surfaces by droplets.

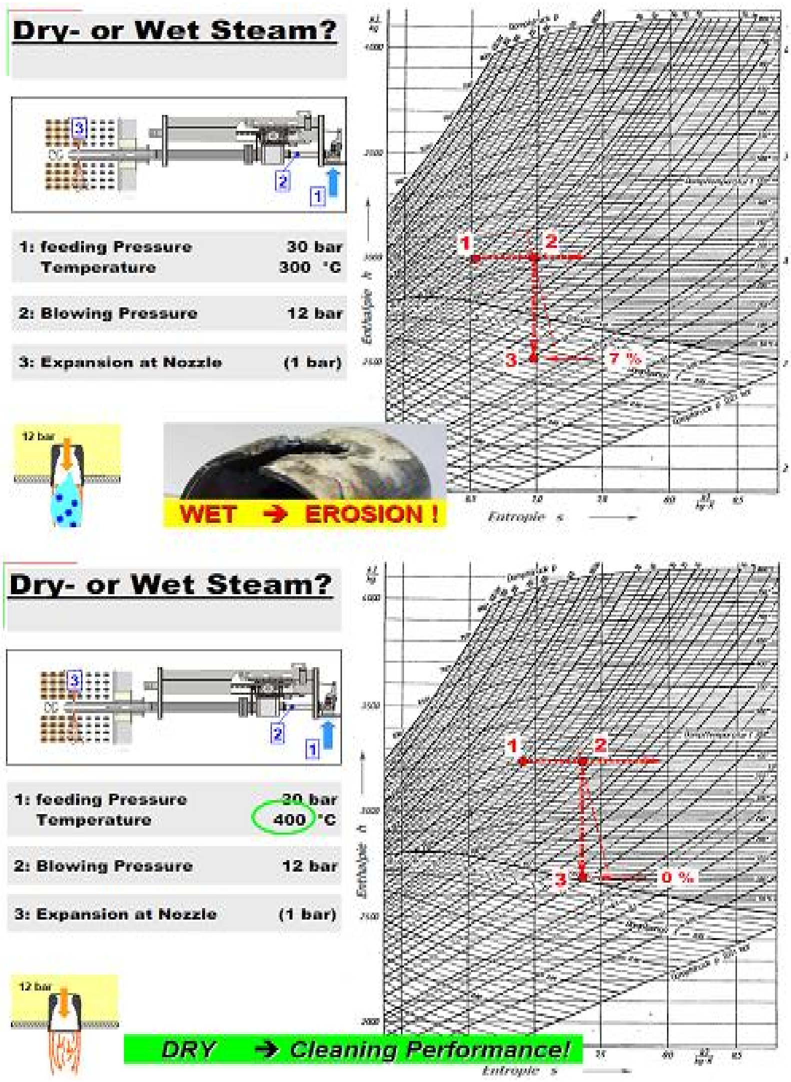

Figure 2: Steam source for soot blowing

4 Turbine and water steam cycle

In general the heat rate (HR) of a power plant is varying with the load, ambient site conditions and deviating process parameters.

Among others, the ambient conditions have an impact on the main cooling water (CW) temperatures. At constant load, the warm cooling water temperature and the condenser thermal temperature difference (TTD) determine the backpressure and therewith the HR.

Deviations of condenser backpressure and several other process parameters compared to the design values have an impact on the HR.

Deviations from the design values can be judged based on correction curves of the original equipment manufacturer (OEM). If they are missing appropriate correction curves have to be derived.

Based on current process data the efficiency team is calculating performances of several main components of the water steam cycle like:

- Inner efficiency of the HP- and IP-Turbine
- Expansion lines of the HP- and IP-Turbine (Figure 3)
- Boiler feed water pump and if applicable the boiler feed water pump turbine
- Cold end of the turbine including backpressure, cooling tower, condenser and cooling water mass flow
- The TTD of the pre heaters
- The results of the main issues on the heat rate are presented in a summarising template.

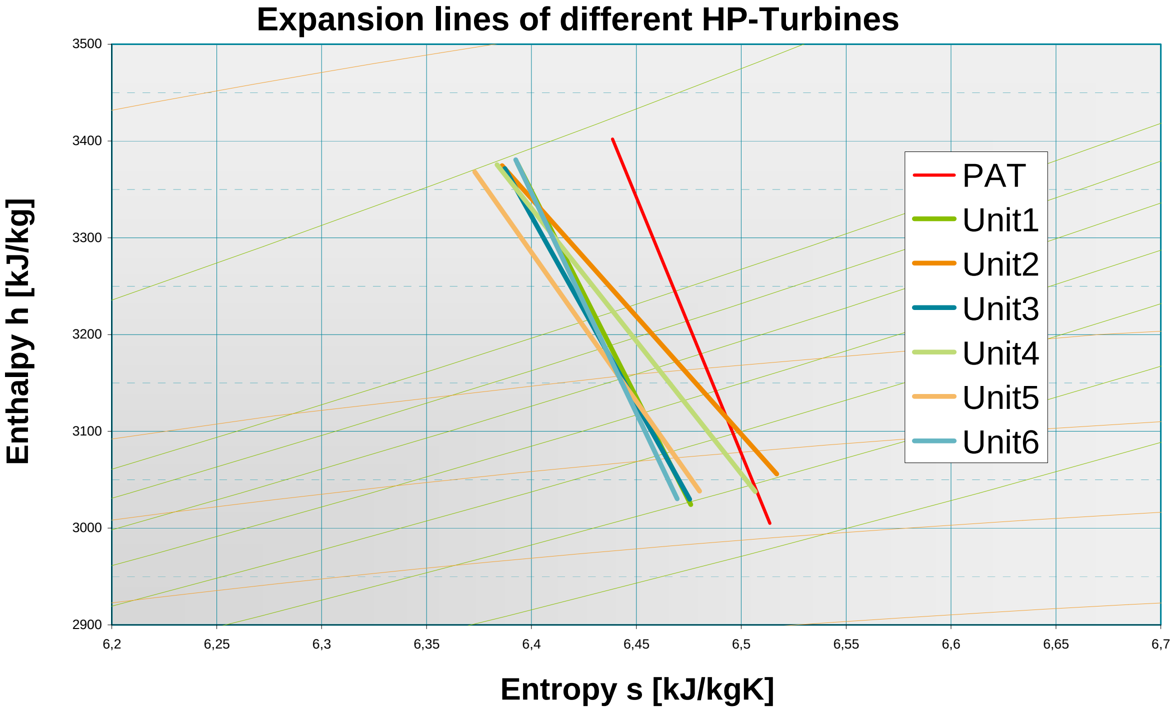

Figure 3: Example comparing expansion lines of different HP-Turbines

The energy efficiency team is also looking after the plant operation and maintenance of the water steam cycle. For example the drain system of the pre heaters, the economical keeping warm of the HP- and LP-bypass valves, leaking steam and safety valves or the steam source for the steam air pre heater. Based on valve characteristics and specific steam losses it is possible to calculate corresponding losses.

Recommendations for a safe and sustainable power station performance are also part of the report of the energy efficiency team.

5 Monitoring and measuring

The results of the investigations are highly depending on the quality of the measured values. Therefore calibrated measuring devices for example temperature, pressure or mass flow measuring points are absolutely essential for a proper evaluation.

STEAG is using in their own power stations software tools which are able to show performance trends of the main equipment. Additionally these tools are able to show the operator which operation mode for different parts of the power station is the most efficient one.

6 Recommendations and typical findings

The most difficult part on the boiler side are the unknown current situation or performance for example of the combustion, the air preheater or the air ingress. Additional measuring points and key performance trends are necessary to show the operator when and where problems arise.

All described possible deficiencies will decrease the efficiency of the power station. The energy efficiency team is able to explain a part of the gap between the heat rate during the performance a test and the currently achieved heat rate. On the turbine and water steam cycle side the following issues have a main impact on the heat rate:

- Main steam temperature and pressure

- Reheat temperature and reheat spray water mass flow
- Cold end (including cooling tower, air cooled condenser, condenser, backpressure)
- Final feed water temperature to economiser
- Make up water consumption
- Steam losses
- Inner efficiency of the turbine

For a better understanding the results of the deficiencies of different power stations (units) are plotted (Figure 4). Therefore the gap between the performance test and the actual heat rate can be partly explained by the energy efficiency team.

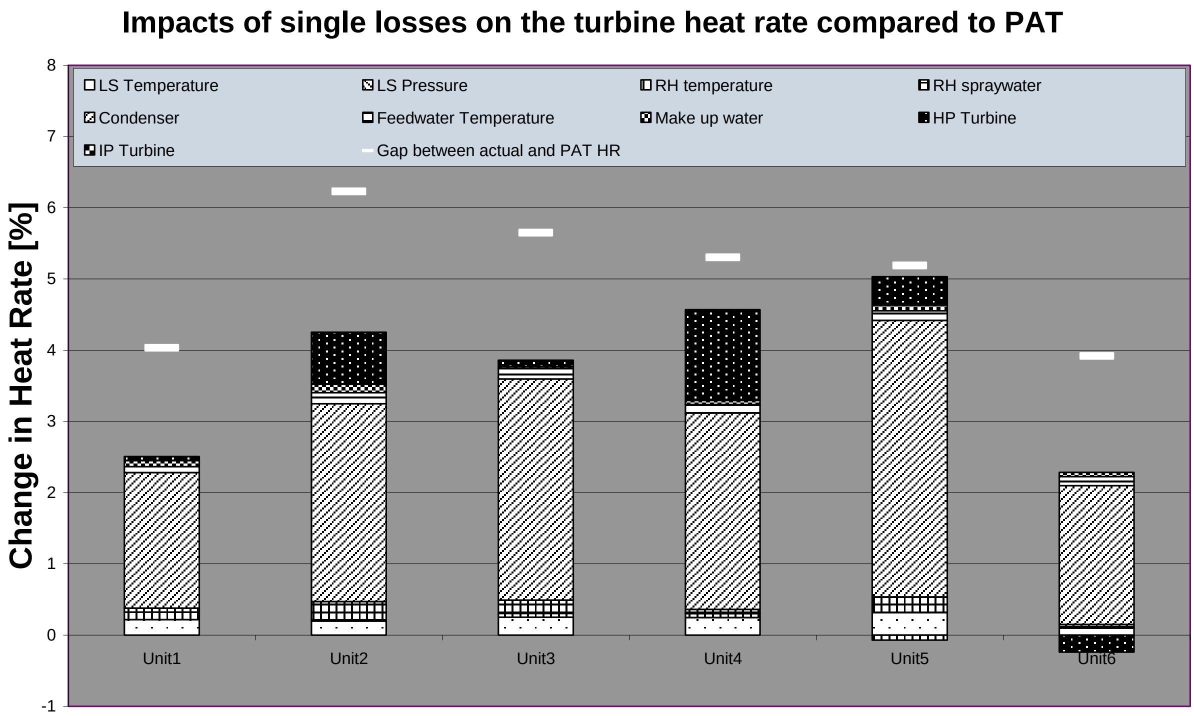

Figure 4: Impact of single losses on the turbine heat rate compared to PAT

Some of the deficiencies of a power station are based on the different requirements between the performance test and the actual power station operation. For example the different coal quality, changed water treatment or decommissioned areas in power station. The station personal is sometimes living with these problems instead of deleting the root causes.

7 Summary

Efficiency, economy and environmental friendliness are major goals of state of the art power plant operation. In day to day operation, several years after commissioning, deficiencies increase unnoticed. The Steag efficiency team shows how to monitor these deficiencies which offers a solid foundation for improvements.

This kind of monitoring is a first step of efficiency improvement. In a second step online tools (like SR EPOS) could be installed to have a permanent view on this important aspect. Both is done and realized typically in our Steag power plants.