Applied Thermal Engineering 31 (2011) 119–128

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

# Improvement of chemical control in the water-steam cycle of thermal power plants

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A R T I C L E I N F O

*Article history:*
Received 26 July 2010
Accepted 30 August 2010

*Keywords:*
Chemical control
Analytical measurements
Thermal power plant
Water-steam cycle

A B S T R A C T

A more effective chemical control in the water-steam cycle (WSC) of thermal power plants (TPP) is proposed in this paper. Minimization of corrosion effects by the production of ultra pure water and its strict control is the basis of all the investigated processes. The research involved the analysis of water samples in the WSC through key water quality parameters and by the most convenient analytical tools. The necessity for the stricter chemical control is demonstrated through a concrete example of the TPP Nikola Tesla, Serbia. After a thorough analysis of the chemical control system of the WSC, diagnostic and control parameters were chosen for continuous systematic measurements. Sodium and chloride ions were recognized as the ions which indicate the corrosion potential of the water and give insight into the proper production and maintenance of water within the WSC. Chemical transformations of crucial corrosion elements, iron and silica, were considered and related to their quantitative values.



## 1. Introduction

Chemistry and energy sciences pervade many topics, nowadays they are invited to give new contributions in the task of energy efficiency, water quality and rationalization of water consumption. The efficient production of electric energy, the effective production of ultra pure water and the minimization of corrosion effects are at least three aspects which can not be considered without the expertise of analytical chemists [1]. Assembling the scientific and professional work which in the last ten years was devoted to the quality of the analytical tools and methods applied in thermal power plants (TPP) gave rise to the results presented in this work. In order to maintain high reliability of TPPs and to realize their expected lifetime, high water quality in all the water systems within a TPP have to be achieved which was elaborated in applicative guidelines and scientific reports [2–9]. The main water systems in TPPs for steam generation can be recognized as: raw water, demineralised (demi) water, condensate, boiler feed water and steam. The measurement of impurities throughout the power generation process can provide valuable information regarding the source of contamination, the rates of contaminant build-up and the probable rates of corrosion, as well as the data collected during the start-up and shut-down of power plants. Chemical control in TPPs has been studied partially in some papers. In advising operators some useful tools were proposed for the identification of a chemical problem, which was particularly valuable when laboratory staff is not available at the power plant [10]. In some papers wastewater reuse was proposed as potential improvement in a fossil unit [11]. A very important issue concerning energy policy [12] and large water consumption [13] was also considered. The origin, composition and rate of built-up were analyzed [14] and a review of the common corrosion phenomena were described taking in account the predominant corrosion mechanisms in high temperature and supercritical water [15]. The research about long-term impact of common ions (especially sodium and chlorine ions) in a real thermal power plant which demonstrate the corrosion effect in water–steam system are still neglected.

The presence of corrosive ionic species in water/steam even at low μg $L^{-1}$ levels can make the components of a TPP susceptible to corrosion [6,8,16]. The production of electrical energy, mechanical problems and economy are usually the main concern in TPPs. However, the water chemical control is incorporated in and has an influence on all these aspects; it is also a high priority issue.

## 2. Chemical control in water–steam cycle (WSC)

A chemical water treatment plant (CWTP) for demi water production and a polishing plant (PP) for condensate purification are the systems for ultra pure water production. The PP is a system

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doi:10.1016/j.applthermaleng.2010.08.028

for the make-up of feed water and it is a part of a WSC, as presented in Fig. 1.

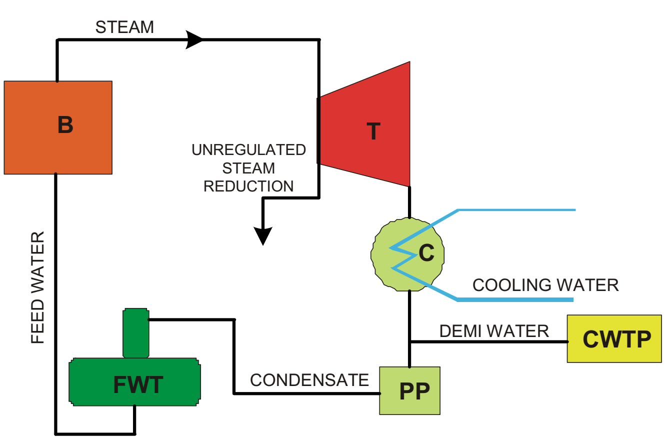
The WSC consists of: a PP, a feed water tank (FWT), a boiler (B), a turbine (T) and a condenser (C). Conditions within the WSC are extreme, with high pressures, high temperatures and various other features of steam. Due to the loss of the condensate (caused by evaporation or leakage) in the WSC, demineralised water from the FWT is continuously added. Deaerated water in the FWT is the source for steam generation, produced in boiler. Steam, with an adequate temperature and pressure, enters the turbine. A more detailed scheme of the WSC in the TPP Nikola Tesla, which was the subject of this work, is presented in Fig. 2. In addition to the main parts of the WSC, which are explained in the legend, the sampling points, which were the basis for the experimental work, are also indicated and listed in the legend.

Water for the WSC is provided either from groundwater sources (wells) or surface water (rivers). Water is chemically prepared in the CWTP. Ion-exchange (IE) is no longer the only reliable method for the production of high-purity water. Other techniques, such as reverse osmosis (RO) and electrodialysis, are available for this process. Often a combination of these techniques, such as RO and IE, may be the most economic arrangement [17]. The final result should be ultra pure water convenient for the WSC.

The path and conditions of the water and steam in a WSC could be explained in a simplified way using Fig. 2 and the *T*–*s* diagram for steam transformation in the WSC of the TPP Nikola Tesla B, which is presented in Fig. 3.

Demineralised water from the CWTP, which is the starting point in Fig. 2, goes to the DWT situated in the main building (MB). Water from the DWT is used as a substitute for the loss of condensate in the system and together with condensate is treated in the PP.

The make-up water polished with ammonia ($NH_3$) and hydrazine ($N_2H_4$) goes to the LPH and FWT, where the water temperature, $t$, is $\leq 180$ °C and pressure, $p$, is $\leq 12$ bar. In the FWT, the deaeration process is accomplished. After a second polishing with ammonia and hydrazine, the feed water goes to the FWP. The further path of fluid can be described with the process conditions on the *T*–*s* diagram presented in Fig. 3. After the FWP (the line




| Legend | |
|---|---|
| Chemical Water Treatment Plant | **CWTP** |
| Polishing Plant | **PP** |
| Feed water tank | **FWT** |
| Boiler | **B** |
| Turbine | **T** |
| Condenser | **C** |

**Fig. 1.** Water Steam Cycle (WSC).

between 5 and 6 in Fig. 3.), the pressure reaches 250 bar. The water goes to the HPH (6–7 in Fig. 3), where it is heated to a temperature of 250 °C. From the HPH, the water goes to B and to $E_c$, where it is heated to 330 °C, close to the boiling temperature. From $E_C$, the water goes to $E_V$, which is used for the transformation of water from liquid to vapour state (point 7 in Fig. 3). From $E_V$, the water–steam goes to SS, where isentropic expansion of the steam occurs and water is separated from steam. The steam goes to SH (8–1 in Fig. 3) and to HPT (1–2 in Fig. 3). Steam after HPT is reheated to $t = 543 \pm 5$ °C, $p = 37$ bar (2–3 in Fig. 3) and it goes to MPT, where it expands (3–4 in Fig. 3) to $t = 256$ °C, $p = 3.6$ bar. Steam continues to expand to LPT (up to point 4 in Fig. 3) as wet steam. In LTP, the steam expands up to $t = 34$ °C, $p = 0.05$ bar and it goes to condenser (4–5 in Fig. 3).

In order to monitor the quality of ultra pure water, two groups of parameters were introduced: control and diagnostic parameters. The control parameters are: pH, conductivity, oxygen, sodium, chloride and silica. The diagnostic parameters are: iron, copper, organic matter and oil (traditionally water hardness is also controlled). These water quality parameters need to be measured precisely and quickly in order to estimate the water quality at critical working and operational points.

The main characteristics and the reason for their measurements as control and diagnostic parameters of water–steam quality in the WSC are highlighted in Tables 1 and 2.

In Table 3 the characteristic and limiting values for the control and diagnostic parameters for the proper functioning of the WSC are listed in Table 3, together with sensitive analytical tools which could be applied for the measurements. Control parameters are measured on line, continuously (C), and they give information on the current status of the WSC. Diagnostic parameters are measured daily (D) and weekly (W) and they give wide and basic information on the water quality in all segments of the cycle. Analytical tools and techniques for the measurement of the control and diagnostic parameters are on line analyzers and/or sophisticated instruments of high precision and sensitivity.

The water and steam are of high purity but in the case of failures, a TPP should operate with adequate actions and improvement of water quality. Usually three levels of action are defined based on the experience and failures resulting from inadequate chemical control. A target range (TR) and three levels of action are usually defined as guidelines in TPP [2]. The TR covers the optimal values which plant managers will normally achieve without excessive cost. Action level 1 implies minor disturbances requiring investigations, diagnosis and optimization, and correction within two weeks. Action level 2 implies serious disturbances in chemical control requiring not only diagnosis but also action to eliminate the cause within two days. Action level 3 implies very serious disturbances requiring substantial interventions, such as load reduction, within 8 h, or plant shut-down.

Impurities in water and steam are closely related to deposits on tubes and all segments of a WSC. Deposits not only impair heat transfer, they also increase the risk of corrosion processes. Purification of water and consumption and the wastage corrosion mechanism in the WSC provide an incentive to improve water chemistry control, which has to be in balance with mechanical and electrical operating conditions [13]. Chemical control is a very important factor for the daily operation and for the future life of a power plant. Chemical control should guarantee the maximum purity of the water. Any deviation of a parameter must be detected and explained, in order to prevent or to correct its causes. Although in the last decades chemical control has received certain attention [18], there is still a need to monitor a set of parameters reflecting the chemical status of the water at key sampling points.