Abstract of Doctorate Thesis

CONTRIBUTION TO THE STUDY OF DEPOSITION AND SLAGGING REDUCTION METHODS IN THE FURNACES OF STEAM BOILERS ON LOWER SOLID FUEL

The component of capital economic, social and strategic importance, energy, constitutes to each nation an element of welfare and progress.

Durable development of Romania will be directly influenced by the evolution of the energy generating sector. On the way of developing availability, accessibility and acceptability of energy will depend further evolution of economy and therewith the entire Romanian society.

Romania, with electrical and thermal energy generation based in proportion of 35% on coal and especially on lignite, will be able to utilize this resource without major constraints, in the context in which the international community was required to accept the idea of keeping open all energy opportunities. Not any energy generation technology has to be refused or impeded in development, but the efficiency in generation and especially in utilization has to be increased. All energy sources have to be considered open, including the advanced systems which use fossil and nuclear resources.

It necessitates in turn increasing utilization efficiency, adoption of efficient, innovative solutions for improving generation efficiency and reduction of the harmful effect upon the environment.

Due to the fact that the Romanian electrical energy generation sector based on solid fuel was having at disposal preponderant low quality coal, with high percentages of mineral mass and humidity, in over 50 years of utilization, it was created considerable domestic experience with regard to their combustion in steam boilers.

It was therewith developed also theoretical and experimental research which has emphasized the combustion particularities of these fuels. Humidity of over 40% and mineral mass in proportion of 20-25% have forced the scientific research and design world and the constructors as well, to find solutions for improving the thermal condition, by adding supporting fuels, or by combustion with reduced air coefficients.

All these led systematically to increase of temperatures in the combustion area and to outgrowing of the ash softening temperatures, with other words, to initiating and development of slagging phenomenon. This phenomenon has one of the most unfavorable influences upon the boiler unit. As slagging progresses, the electrical power decreases and therewith the economic operation of the cycle is seriously disturbed, the specific consumption increasing by 10-12%.

The suppliers of such combustion equipment have not made available to the beneficiaries detailed information and formulas for reduction of the slagging processes, such as this important factor of inefficiency and waste of resources be diminished. The reply consists of the fact that the phenomenon was never seriously studied.

The present work tries to put a “brick” to fill this gap.

The originality of the work consists in exposure of the conclusions resulted following carrying out experiments with a special additive, injected in the furnace of the boiler of 1035t

steam /h. In fact, this method can be applied to any boiler which uses coal as basic fuel, no matter the quality and composition, associated or not with an ancillary fuel.

Chapter 2 of the work is made up by presentation of the steam generators, as well as the fuels use by them. The waterpipe type generator has in its composition relatively large ducts in which are immersed pipe systems. Flue gas, resulted following fuel combustion flow through the ducts, at the outside of the pipes, delivering heat to the heat carrier (water and steam) which is transported through these. Combustion of fuels takes place in an area situated at the basis of the ducts, called furnace. The duct walls can be made of ceramic heat resistant material (fire resistant bricks), or of metal membranes cooled inside with water and/or steam. Fuels used are diverse, but in the case of large plants the most common are coal, heavy fuel oil and natural gas. The chapter includes also a general presentation of the main types of boilers, respectively those with natural flow and pump circulation.

Contamination of the heat exchanger part in the composition of these flue gas driven generators is registered wherever heat is recovered from the flue gas flow which contains corrosive or reactive particles, accumulation of depositions on the exposed surfaces, not only on the surfaces of the heat exchangers, may create problems.

As result, unwanted accumulations of solid matters may occur on pipes or armatures, in equipment as dryers or reactors, as well as combustion chambers and stacks.

Extension of the harmful effects depends on a multitude of factors. Operation temperature, fluid speed, dimensions of particles and concentration of any solid matters driven by the gas flow, as well as the chemical composition of the components which are included in the composition of the fuel blend, are meant to contaminate the heat changers surfaces. Starting from here are defined the terms of “contamination” and “slagging”.

Different types of fuel, as well as the combustion modes, will affect the deposition potential. Therefore are also presented and analyzed the combustion methods, as well as the combustion plants; connected to this is made a presentation of several types of burners.

The general principles of the deposition process involve:

(i) Transport of particles or components chemically reacted on the heat exchanger surfaces.

(ii) Adhesion of particles (or particle agglomerations) at the heat exchanger surfaces by physical processes or by chemical reactions.

(iii) Possible exfoliations of the constituting materials of the heat exchangers.

The result of this process is net accumulation of solid matters on the surface of the heat exchanger, as a result of balance between depositions and their removal, the later being very much dependant on the nature of deposition from the viewpoint of its cohesion and adherence to the surface.

There are also exposed the negative consequences of depositions.

In the attempt to understand the effect of different variables regarding depositions in a combustion system, it is useful to get a general concept of the involved mechanisms, such as be possible to appreciate the needs and requirements for a good design and operation of equipments.

The involved mechanisms will differ depending on the type of deposition particles, on diffusion of vapors or chemical reaction. Basically, the main mechanisms aim particle depositions, which are realized by convective molecular diffusion and by diffusion of vapor.

Molecular diffusion is the result of individual and disordered movement of molecules, determined by thermal agitation movement and elastic collisions with the other molecules of a blend formed of several molecular species. Accordingly, molecular diffusion is a mechanism which takes place at molecular level and consists in transport of a molecular species inside the blend, when in the blend exist a potential difference, which can produce imbalance inside the blend.

The potential difference can be determined by several causes:

- **existence of a concentration gradient in the blend**
- **existence of a temperature gradient in the blend**
- **existence of a pressure gradient in the blend**

Transport of particles towards the cooling surfaces in a combustion system may result from vaporizing of the inorganic ash components and their ulterior diffusion towards the cooling surfaces of the equipment. Volatilization in the flame of the inorganic components is the common source of these vapors.

The mechanism by which the heat exchanger surfaces get contaminated is explained by the chemical reactions which take place during combustion and by corrosion, as it is shown in Chapter 3.

In Chapter 4 are analyzed the principles of combustion, analysis being made at relatively different types of fuel, such as – for example – coal, heavy fuel oil, natural gas or waste, by making express reference to contamination of heat exchanger surfaces. During combustion of fuels may prevail oxidation or reduction conditions, at local level, or at the level of the entire system, depending on the operation mode of the equipment. Increasing the air excess coefficient will ensure in general oxidation conditions, while registering O_2 values close to those resulted from stoichiometric calculations could mean that in certain areas are accomplished reduction conditions. By loose control of the burners and the referring equipments may be created involuntary reduction conditions within the system. The nature of reactions – oxidation as well as reduction – will affect the chemical composition of the depositions, by forming compounds present in the flue gas, as suspension, or on the surfaces exposed to deposition.

The chemical reactions responsible for their contamination are presented for different types of fuel. Also are presented evaluation techniques of the contamination and slagging trend.

In any evaluation process of slagging and depositions it is imperative required performance of an ash analysis, as the chemical nature of the ash determines its deposition properties. Due to that fact that the available techniques for quantitative evaluation of the slagging and deposition trend of different types of fuel developed over the years, very many terms being included in the usual vocabulary, e.g. *index*, *factor* or *indicator*. In many regards these terms can be seen as incompatible and without logic basis, but, despite these, they are used, being accepted and understood in the language used in the respective industry.

Based on analysis of mechanisms and trends, some of the techniques for limiting these phenomena in combustion plants are shown in Chapter 5. These include fuel blends, combustion conditions and the use of additives. Additives were also proposed and used in combustion plants of fossil fuels for fighting against deposition problems. They were also used for resolving matters related to corrosion and acid emissions, allowing improvement of the control with regard to electrostatic precipitator overheating, despite these applications are outside the application area of this element.

The additives utilization method was initially developed in the heavy fuel oil combustion process, due to the easiness of application but at present this concept was also used in coal combustion. Utilization of additives in combustion of waste is under development.

It is true that in the case of many applications the basic mechanism and the factors which affect efficiency of the additive are less understood and reference to empiric evaluations is required. In general, the effect of the additive is to modify the structure of depositions, such as these be easier eliminated by mechanical techniques.

Chapter 6 treats cleaning techniques of the heat exchanger surfaces which can be applied during operation as well as during boiler shut down. There are debated involvements of contamination and slagging on designing combustion equipment, being also added experimental recommendations among good design practices.

Thus, during operation, the purpose of the cleaning methods is to keep the heat exchanger surfaces in a reasonable status of cleanness in order to ensure high efficiency and availability of the plant. There are used air, steam of water blowers, retractable or not, depending on their positioning on the gas track. There are also used acoustic blowers, as well as methods for removing depositions with shots.

Completely dry cleaning by manual or mechanical means has to be used in cases in which cleaning of heat exchange surfaces with water or steam is not possible or is considered undue based on design reasons.

In Chapter 7 are presented evaluation and quantification of efficiency increase at 1035 t/h boilers by applying a new technology using a special additive which determines diminishing of the slagging phenomenon and maintain the heat exchanger surfaces in a clean status.

Starting with the problems the CET-Turceni lignite boilers face during long term operation, problems which lead to decrease of the boiler efficiency, by reducing the heat exchange transfer between flue gas and the heat exchanger surfaces, as well as by increasing the pressure drops on the flue gas track, decrease of boiler efficiency by increasing the flue gas temperature at the stack, decrease of the availability periods of the boilers and increase of the maintenance costs – caused by high temperature corrosion in the area of superheaters, and low temperature corrosion in the area of air preheaters and flue gas ducts, it was studied in the plant their behavior in the case of injection of an additive which reacts with the components of the heat exchanger depositions, resulting mainly neutral compounds.

The study was accomplished in two steps: a reference step and an implementation step, comparable as time and conditions, the results obtained being analyzed by:

- drawing diagrams which represent the curves referring to the considered representative operation parameters
- effective interpretation of the data and curves
- review and interpretation of the results of chemical analysis of the depositions
- economic calculation

Following the study were drawn the following conclusions.

1. By applying the cleaning treatment in the flue gas area of boiler No.4 were reduced the amounts of depositions by reactions between the cleaning product and the boiler depositions.
2. The remained depositions show no more corrosion risk to the cold area of the boiler
3. The remained depositions show no risk to forming eutectics which generate melting, these were removed and in this way the heat transfer at pipe wall level is better.
4. Referring the environment it was reduced the risk to forming acid powders and the concentration of sulfates decreased.

The obtained results substantiate the real and huge potential of their using in the control of depositions, but in the same time it still remains to be researched the evaluation process of the value of compounds and the individual blends.