SIMULATION OF EUCALYPTUS KRAFT BLACK LIQUOR COMBUSTION IN INDUSTRIAL RECOVERY BOILERS

M. CARDOSO†, G. A. AVELAR COSTA†, E. D. DE OLIVEIRA† and S. P. RAVAGNANI‡

† Departamento de Engenharia Química – Escola de Engenharia – Universidade Federal de Minas Gerais (UFMG), Rua Espírito Santo 35 – 6º andar Belo Horizonte – MG – Brasil CEP 30160-030. mcardoso@deq.ufmg.br
‡ Faculdade de Engenharia Química, Universidade de Campinas (UNICAMP), Caixa Postal 6066 – Campinas – SP – Brasil CEP 13083-970. ravag@feq.unicamp.br

Abstract — In this study, the performance of a “kraft” black liquor recovery boiler was analyzed using WinGEMS, a commercial simulator software. The operational variables and design parameters of a pulp industrial unit in southeastern Brazil provides the input data used in setting up the material and energy balance equations in the simulator program. The simulations allowed the prediction of thermal efficiency as a function of solid content in the liquor, in which an increase of 10% in steam generation was obtained when dry solids were increased from 72% to 100%, the latter being a hypothetical operational condition. This study also determined that in spite of making accurate predictions about the temperature profile along the recovery boiler, WinGEMS does not correctly predict the profile of combustion gases when burning eucalyptus black liquor.

Keywords — Black Liquor, Recovery Boilers, Combustion and Simulations.

I. INTRODUCTION

The aim of this work is to perform an analysis of the impacts of increasing dry solids content of the black liquor burned in a kraft recovery boiler by using a commercial process simulator.

A – RECOVERY BOILER DESCRIPTION

Figure 1 shows the general layout for the kraft recovery boiler studied (Cardoso, 1998). The boiler consists of a furnace, where black liquor combustion takes place, and auxiliary equipment to generate superheated steam that is further used in the plant. Among the auxiliary equipment, economizers, boiler bank, and superheaters are noteworthy.

Black liquor is usually pre-heated before being injected into the boiler, turning it less viscous and more easily atomized into the furnace. In the case of the industrial unit analyzed, the concentrated liquor that leaves the evaporator unit passes through a shell and tube heat exchanger reaching temperatures of 110 to 120 °C. This liquor is then sprayed into the furnace, forming droplets that are dispersed and descend counter currently to the hot air and combustion gases causing the drying, devolatilization, and combustion reactions.

Combustion takes place in three different furnace zones (Fig 1), namely, the zones of oxidation, drying and pyrolysis, and reduction of the inorganic compounds with formation of a char bed (Green and Hough, 1992). The oxidation area, located above the liquid injection system, is characterized by the burning of volatile substances produced during the pyrolysis of the liquor. The predominant reactions involve the oxidation of carbon monoxide and sulfur gases, with formation of carbon and sulfur dioxide, respectively. These reactions occur at high temperatures (1400 to 1500 °C) and are extremely fast. The introduction of tertiary air (in excess), in a highly turbulent flow together with the volatile compounds, assure their complete burning. Liquor droplets usually have an initial water content of between 20 and 40% in mass and they generally dry in the region closer to the liquor guns. The size of the droplets, which strongly affects their heat and mass transfer properties, has to be well controlled to guarantee the complete drying of the liquor, otherwise, the char bed will get in contact with water in excess, resulting in its blackout or even explosion. The pyrolysis reactions that take place in the furnace represent the thermal degradation of the solids contained in the liquor. These reactions occur at temperatures above 200ºC (Green and Hough, 1992) producing combustion gases (H₂S, CO, H₂) and a particular porous solid material, with average diameter of 12 mm. This material descends to the floor of the boiler forming the char bed. The residual fixed carbon, contained in this material, burns in the top layer of the bed (conversion of the fixed carbon to CO and CO₂), supplying the necessary heat for the reduction reactions of the inorganic compounds - the reduction region. The final solids, containing mainly sodium carbonate, sulfate, and sulfide are melted and flow to the smelt dissolving tank through water cooled spouts, located in the base of the boiler. Some of this material, however, is partially dragged by the flue gases to the top of the furnace.

Primary air is introduced at the base of the furnace (Fig 1), where it partially oxidizes the organic compounds, supplying heat for the reduction and melting of the inorganic compounds in the char bed. Secondary air is introduced at 1.5 m above the primary air feed line. This air controls the combustion temperature as well as the height and pyramidal shape of the char bed. Tertiary air is necessary to complete the burning of the liquor in the upper part of the furnace. The addition of air in three different levels provides better temperature control in all combustion areas and assures greater boiler efficiency (Vakkilainen, 2005).