THE INFLUENCE OF CELL TEMPERATURE ON THE EFFICIENCY OF COMBINED FUEL CELL AND POWER CYCLE SYSTEMS

S.F. Au[a,b], K. Hemmes[a] , N. Woudstra[b]

[a] Delft University of Technology, Faculty of Applied Science, Materials Science and Engineering, Rotterdamseweg 137, 2628 AL Delft, The Netherlands.
[b] Delft University of Technology, Faculty of Design, Engineering and Production, Laboratory for Thermal Power Engineering, PO Box 5037, 2600 GA Delft, The Netherlands.

Fuel cell technology is about to become available as an alternative for the theoretically less efficient combustion technology. Especially the MCFC and SOFC are interesting technologies for the stationary power supply due to their high operational temperatures. The exergy of the waste heat is high enough to make further conversion into electricity possible. As a newcomer, these fuel cell technologies have to compete with conventional combustion technology, which on his hand already has a century to mature. In order to be competitive, reduction of costs and extension of lifetime have been the subjects where recent fuel cell developments have been focused on. Although these developments are essential in order to make the fuel cell economically attractive, some of them also have resulted in loss of efficiency. Unfortunately, the high conversion efficiency is the main advantage of fuel cell technology. It is therefore now necessary to change our focus back on the main advantage of fuel cell technology, that is: convert chemical energy in electricity as efficiently as possible.

This paper presents an investigation on the electrical efficiency of fuel cell systems consisting of a hydrogen fuel cell and a bottoming power cycle in which the exergy of waste heat is recovered. The aim of this work is to obtain insight in the thermodynamics of fuel cell systems with which we can fully exploit the fundamental advantages of fuel cells.

This study starts with the thermodynamics of reversible systems with which we examine the temperature dependence of the reversible limit. The effect of fuel utilization and the Nernst loss associated with that is explained and as example elaborated for an MCFC. Its shows that in both cases the reversible limits are temperature independent. The influence of Nernst loss on the total system efficiency is small, even for the MCFC, which from all types of fuel cells, its cell voltage suffers the most from this effect.
The study continues with practical fuel cell systems where irreversible losses are introduced by using simple assumptions for the loss functions. These simple assumptions are polarization losses for the fuel cell and intrinsic efficiencies for the power cycle. Both losses are first assumed to be temperature independent The results are shown by figure 1.
This study is further elaborated for situations that are more realistic by introducing temperature dependent irreversible losses. The losses are refined by using experimentally determined performance equations for an MCFC stack [1,2] with which the temperature dependency of a total MCFC system efficiency is predicted and analyzed.

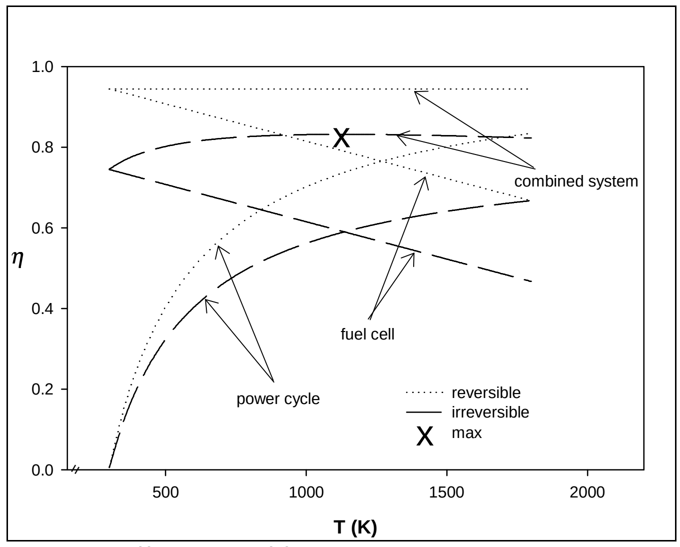

Figure 1: Efficiencies of fuel cell, power cycle and combined system operating reversibly and irreversibly

[1] F. Yoshiba, N. Ono, Y. Izaki, T. Watanabe and T. Abe, *Numerical analyses of the internal condition of a molten carbonate fuel cell stack: comparison of stack performances for various gas flow types*, p328-336, Journal of Power Sources 71. (1998).

[2] Y. Mugikura, H. Morita, M. Yoshikawa and T. Watanabe, *Modification of cathode performance equation and reaction mechanism of MCFC*, Proceeding of the 7th FCDIC Fuel Cell Symposium, Tokyo (JP) (2000).