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In the name of God, Most Gracious, Most Merciful

ABSTRACT

A technical, economic and environmental assessment of oil shale utilisation, as an energy resource in Jordan, has been reported in this thesis. The experimental work was performed (using representative oil shale samples from Jordan) by employing a thermogravimetric analyser, fixed bed (static batch) retort and fluidised bed (continuous) gasifier.

As an introduction, the investigation starts with an overview of the energy, water and environmental background in Jordan. Based on the historical developments and the general trends for the energy sector, such as supply and demand, indigenous resources, imports and energy-economy relationship, a simple mathematical model has been established to forecast energy consumption on annual basis. Also, the reserves of oil shale resources in Jordan and their importance to the local economy are discussed. In order to utilise such a resource wisely, an oil shale integrated tri-generation system has been proposed, with the main aim of increasing the conversion efficiency and reducing negative environmental impacts.

In the experimental part of the thesis, the kinetics of oil shale during pyrolysis or gasification processes were investigated. Among the most important relationships, which were studied, the influence of particle size, final temperature and heating rate on the qualities and quantities of the final products. It was found that the Ellujjun oil shale has higher carbon and nitrogen concentrations as well as lower contents of ash compared with those obtained from the Sultani shale. Thus, oil shale from the Ellujjun is considered to be of a higher grade than that obtained from the Sultani deposit. This was confirmed through the pyrolysis of the two oil shale samples, carried out in the fixed bed reactor and thermogravimetric analyser; the Ellujjun shale gave higher oil yields than the Sultani shale. Also this study concluded, within the limits of experimental error. that particle size has a little effect on the conversion of organic content during oil shale pyrolysis and gasification. Both shales exhibited a single step thermal decomposition. and the total weight loss was directly dependent on the final temperature: the higher the temperature the greater the weight loss. But results from the fixed bed tests showed that the maximum shale oil yield was obtained at a temperature of 480 (±30) °C.

The results of oil shale gasification tests, using a thermogravimetric analyser and a fluidised bed gasifier with a mixture of CO_2 and steam (at various ratios) as the reactant and fluidising gas. implied that it is possible to produce gaseous fuel with an acceptable calorific value and it could be used to fuel heavy-duty gas turbines or combined-cycle power plants. Analysis of the generated gases showed that they were dominated by carbon monoxide, hydrogen and hydrocarbon gases. Again, gasification tests, employing thermogravimetric analyser, have successfully demonstrated that the weight loss from the Ellujjun specimen is higher than that for Sultani oil shale under similar conditions. But the thermal decomposition rate and reactivity were almost similar for both shales. Heating rate has little effect on the weight loss from the sample as well as insignificant difference in the apparent activation energy during the gasification process. However, as in the case with oil shale pyrolysis, the maximum reaction rate increases with higher heating rate, and there was a sharp increase in the reactivity over the studied range.

The impact of employing a low calorific value fuel gas, which is evolved from oil shale gasification, on the performance (i.e. detailed design-point for a selected actual case study) of industrial gas turbines and combined cycle power systems is studied using computational thermal models. The simulation results showed, when such gases (with an average calorific value of between one fifth and a quarter of that of natural gas) are used to fuel heavy-duty industrial gas turbines, would provide the possibility of achieving higher efficiencies without any change in the gas-turbine's geometry or the compression ratio.

Preliminary predictions suggest that the proposed integrated plant will be financially attractive, as well as an environmentally-acceptable technique for producing synthetic fuels and electricity from oil shale, compared with conventional utilisation methods provided the price of crude oil exceeds 20 US$ per barrel. Based on an introductory analysis, it can be said that the operation of the integrated plant implies that the generated electricity would compete commercially with electricity generated from large-scale coal or heavy fuel-oil fired power stations in some countries (such as Jordan), who are at present heavily dependent on imported fossil-fuels. If the benefits of self-sufficiency and lower pollution rates were taken into account, the produced final energy unit price would be reduced and so the plant could be economically attractive now. But significant information gaps exist, so inhibiting the making of accurate financial and environmental assessments concerning the behaviour of the proposed integrated system at this time. Also, the expected complexity and relatively high capital-cost together with prevailing low unit prices crude oil (in the international market) may discourage its development in the near future for commercial applications.