Chapter 7
Project conclusions and recommendations

7.1 Project evaluation based on objectives

In order to establish the success of this research project, the experimental data, as well as the results and discussions considered in the individual chapters were evaluated against the six objectives set out in Chapter 1. In the following paragraphs, the project objectives are denoted as item (i) to (vi) and the evaluation of each objective is given in italics.

i. Obtaining CTP samples from several different producers that produce CTP specifically for Söderberg electrode paste production. Having a range of CTP samples, with different composition and properties, will aid in testing the hypothesis put forward on a broad spectrum of CTPs.

In this study, 12 different CTP samples were sourced from South Africa, Europe, Asia and South America. Formal agreements had to be signed between the NWU and some CTP suppliers in order to facilitate obtaining these samples. These formal agreements enabled the candidate and study leaders to negotiate with the CTP suppliers, in order to ensure that the CTPs received covered the widest possible range in terms of composition and characteristics. This ensured that the hypotheses proposed in this study could be tested against CTPs with a wide range of compositions and characteristics, which gave credibility to the study. In this regard, it can therefore be concluded that the objective was met successfully.

ii. Establish the fundamental chemical and physical properties of the CTP samples obtained. Proximate and ultimate analyses, as well as the determination of the softening point (SP), coking value (CV), and quinoline (QI) and toluene insoluble (TI) contents will determined.

In this study, proximate and ultimate analyses, as well as the softening point (SP), coking value (CV), quinoline (QI) and toluene insoluble (TI) contents were determined for all 12 CTP samples received. These results were presented in Chapter 4. As an example of the wide range in composition and characteristics of the CTP samples received, it can be mentioned that the SPs ranged from 65.4 to 134.2 °C. According to the knowledge of the candidate, this is one of the most comprehensive sets of CTPs ever considered in a study that was published in the peer-reviewed public domain. The above-mentioned objective was therefore met.

iii. Use multi-linear regression (MLR) of relatively commonly determined characteristics of CTP (e.g. proximate and ultimate analyses, as well as SP) to compile mathematical equations that can be used to calculate less commonly determined characteristics (e.g. CV, TI and QI).

MLR was successfully used to calculate less commonly determined characteristics from more commonly obtained parameters. By making use of only the proximate and ultimate analyses, as well as SP, the CV and TI could be predicted/calculated. These results were also presented in Chapter 4. Although the prediction/calculation of QI was also successful, it could not be calculated as accurately as the CV and TI values. This was ascribed to the fact that CV and TI can be considered as systematic parameters, which remain comparable between different CTP production facilities. In contrast, the QI content of a CTP is a non-systematic factor, i.e. it depends on the carry-over of insoluble particles during the distillation process that will be highly variable between different CTP production facilities. According to the knowledge of the candidate, a systematic method of prediction of CV, TI and QI values has not yet been published in the peer-reviewed public domain. This method will assist Söderberg electrode paste producers that do not get the CV, TI and QI analyses from their CTP suppliers to determine these important

parameters without performing actual laboratory analyses. Additionally, this method can be used to verify CV, TI and QI analyses received from CTP suppliers. This can further assist in improving the quality of Söderberg electrode paste produced. Considering the above-mentioned discussion, it can be stated that this objective was successfully met.

iv. Determine the Söderberg electrode baking isotherm temperature of the above-mentioned CTP samples. Thermal pre-treatment under an inert atmosphere, followed by TMA analysis, will be used to determine this transitional temperature more accurately than what has previously been indicated in literature.

In Chapter 5, it was demonstrated with TMA analysis that the baking isotherm temperature of all 12 CTP samples used as binders in Söderberg electrode pastes lies between 450 and 475°C. It was found that this temperature is independent of the initial physical and chemical composition of the CTP. These results were very novel and certainly reduced the uncertainty associated with the baking isotherm temperature. The narrower range of the baking isotherm temperature can assist operations personnel to further improve the electrode management procedures on operational level. This objective was therefore also successfully met.

v. Relating the observed baking isotherm temperature to fundamental properties and changes of the CTPs taking place during thermal treatment. For this purpose, FT-IR analysis will be conducted on CTP samples to determine how the functional group composition of the CTP samples changes during thermal treatment.

Qualitative FT-IR analysis was successfully performed to identify the different functional groups in the as-received and thermally pre-treated CTP samples (Chapter 5). The results indicated that the as-received/raw CTP samples were similar in composition, only differing in terms of the

fractional composition of the various functional group compounds as was confirmed by NMR analysis. Thermal pre-treatment of CTP resulted in structural changes of the organic functional groups present, but again similar changes occurred in all CTP samples with the only difference being the fractional composition of the various functional group compounds. These results explained why the baking isotherm temperature was found to be independent of the initial composition and characteristics of the CTP (Objective iv). The knowledge gained made a significant contribution to the fundamental understanding of the baking isotherm temperature and the objective was therefore met.

vi. Use XRD analysis to study the graphitisation/structural ordering of the CTPs that result from the thermal treatment.

The structural ordering of CTPs thermally treated was evaluated using XRD analysis (Chapter 6). The as-received CTPs had a wide XRD peak, while this peak become progressively narrower as the thermal pre-treatment temperature was increased. This was an indication of structural ordering within the CTP. Fully graphitised electrode paste, received from a prebaked electrode producer, had a very narrow/sharp peak with a calculated DOG of 81%. XRD was used to follow the graphitization process, at least semi-quantitatively and qualitatively (therefore by looking at peak intensities).

7.2 Future perspectives

The field of study of Söderberg electrodes and CTP is quiet broad and several other research aspects related to the above-mentioned field could be considered in future research efforts, include the following:

i) Quantitative FT-IR should be performed to establish the exact quantities of major functional groups compound in as-received and thermally pre-treated CTPs. This could be used to establish the transformations in chemical composition that occur during the determination of the baking.

ii) Solid fillers, i.e. calcined anthracite and coke, could be evaluated in a similar fashion as was done for CTP in this study. This could enable the identification of optimal fillers for the production of Söderberg electrode paste that would reduce thermally-induced stress in these electrodes.

iii) If industrially-produced Söderberg electrodes can be obtained and sampled by means of core drilling, XRD analysis could be used to quantify the degree of graphitization as a function of electrode length below the contact shoes, as well as differences between the delta and other sections of such electrodes. This would enable operational personnel to better understand the mechanical strength and thermal stress characteristics of Söderberg electrodes.