SUMMARY

This work was undertaken to investigate how different additives and modified cooking conditions in kraft pulping of softwood influence the delignification rates, the yield, the carbohydrate composition and the papermaking properties of the pulps. Other objective was to determine the optimum combinations of kraft or modified kraft pulping with oxygen/alkali delignification.

The first part of the work studied the effects of black liquor impregnation alone or in a combination with anthraquinone as well as addition of anthraquinone and/or methanol in conventional batch kraft cooking of pine chips. Two-stage kraft cooking of pine chips with green liquor impregnation was also investigated. Black liquor impregnation before kraft cooking at a given effective alkali charge as well as additions of 10% methanol or 0.5% anthraquinone increased the delignification rates. When anthraquinone was combined with either black liquor impregnation or methanol addition, the delignification effect appeared to be additive. The pulp yield was increased only by the addition of anthraquinone. The pulp yield-kappa number relationship seems to follow a straight line correlation as reported in the literature for conventional kraft pulping in the region of kappa numbers 30-90 with the change in yield per change in kappa number of about 0.14. The black liquor impregnation and the addition of methanol did not influence this correlation. The yield-kappa number relationship for pulps produced by the addition of anthraquinone showed a slope of 0.16 for kappa numbers above 30.

The intrinsic viscosity of the pulps at a given kappa number was unaffected by the addition of anthraquinone, improved by the addition of methanol and reduced by the black liquor impregnation. The tensile strength development by beating of the pulps was unaffected by the addition of methanol, but improved by the black liquor impregnation and the addition of anthraquinone. None of the said changes in the cooking conditions by pulping of pine chips to kappa numbers in the range of 19-26 altered the response of the residual lignin in the pulps regarding oxygen/alkali delignification or significantly influenced the pentosan content of the pulps.

A two-stage kraft pulping process with green or white liquor impregnation in the first-stage showed that the green liquor impregnation did not influence the pulp yield or the pulp yield-kappa number relationship in the kappa number range of 30-90, when compared to the white liquor impregnation. However the green liquor impregnation resulted in a somewhat improved delignification rate when cooking to kappa numbers below 40 and also a slightly higher consumption of effective alkali.

In the second part of the work, simulated Iso-Thermal Cooking (ITC) with split alkali addition as well as conventional kraft cooking of spruce chips was carried out in a pilot plant. Kraft liquor; soda liquor; and different polysulphide liquors were used in the pulping experiments. A small amount of AQ was added to most of the polysulphide liquors. Different types of high kappa number linerboard grade pulps and low kappa number bleachable grade pulps were produced. Oxygen/alkali delignification studies were made on selected pulps of different kappa number in order to determine the best combination of pulping and oxygen delignification for obtaining optimal pulp yield.

Linerboard grade pulps produced by conventional pulping techniques: Mixing 10 and 20%, by volume, green polysulphide liquor into regular polysulphide liquor of equal polysulphide content resulted in a savings of 4 and 9% regular polysulphide liquor by production of 80 kappa number pulp. However, the addition of green polysulphide liquor had a negative effect on the yield increase attained by PS/AQ pulping with the addition of 0.05% AQ and about 1% PS. The yield increase compared to conventional kraft cooking was decreased from 4.4 to 3.5% when 20% green polysulphide liquor was mixed with the regular PS cooking liquor. The replacement of some of the conventional PS cooking liquor with green polysulphide liquor did not influence the rate of delignification. Compared to conventional kraft pulping the rate of delignification was increased by PS/AQ pulping, resulting in a pulp with 10 units lower kappa number at equal H-factor. The linerboard grade PS/AQ pulps made with or without the addition of green polysulphide liquor showed similar beatability, tensile stiffness and tearing strength potential as the conventional linerboard kraft pulp. The papermaking properties of the PS/AQ linerboard grade pulps were generally not different from comparable kraft pulps.

Bleachable grade pulps: Pulping of air-dried spruce chips with 2.2% polysulphide (PS) sulphur and 0.05% AQ according to a simulated ITC procedure and using soda or kraft white liquor as the major alkali source in the cooking stages gave the following results compared to ITC kraft pulping:

1. a yield increase of about 3% (based on o.d. wood) was obtained with soda liquor as the major alkali source but without AQ addition to the PS impregnation liquor no significant yield increase was observed,
2. a yield increase of about 3.5% was obtained by using kraft liquor as the major alkali source,
3. A 50% split in the AQ addition between the PS impregnation stage and the counter-current cooking stage did not influence the yield increase or the delignification rate,
4. impregnation of chips with PS liquor prior to ITC with soda or kraft white liquor as the major alkali source increased the effective alkali consumption significantly,
5. the beatability and TEA strength of the polysulphide ITC pulps were very similar to those of conventional PS/AQ pulps of equal kappa number. The tearing strength of the ITC kraft and ITC kraft PS/AQ pulps were slightly higher than that of the ITC soda PS/AQ and conventional PS/AQ pulps.

Conventional PS/AQ pulping of air-dried spruce chips with 1% sulphur and 0.05% AQ gave a kappa number 40 pulp with a yield increase of 2.2%. The yield increase was improved to 4.2% by using undried chips. It was thereby demonstrated that air-drying of wood chips before PS/AQ pulping can have a very negative effect on the yield increase, even when the chips were properly steamed. Soaking of the air-dried chips overnight did not give any significant yield improvement.

The carbohydrate composition of the different pulps analysed according to our own modified HPLC method, showed that the yield increase by the PS/AQ pulping, as reported in the literature, is caused by higher retention of glucomannan and cellulose. It was also demonstrated that conventional kraft pulping results in pulps with higher xylan content than kraft ITC.

The response of PS/AQ pulps to recycling compared to a kraft pulp was investigated. The results showed that PS/AQ fibres with relatively high content of glucomannan preserves the papermaking properties somewhat better than kraft fibres by recycling (drying, heating and repulping).

The pilot plant ITC studies on spruce confirm the findings by conventional kraft and kraft/AQ pulping of pine, that extension of alkaline pulping below kappa numbers 27-28 results in considerable loss of pulp yield per kappa number reduction, 0.3% by kraft and 0.4% by PS/AQ pulping. In the kappa number range from 30-90 the yield loss per kappa number reduction by kraft and PS/AQ pulping of spruce was as found earlier for pine chips, 0.14 and 0.16% respectively. Changing from conventional kraft pulping to kraft ITC did not influence the pulp yield obtained at a given kappa number. Oxygen delignification up to about 55% reduction in kappa number preserves the yield increase attained

by PS/AQ pulping and a yield loss of about 0.1% per kappa number reduction was obtained as for kraft pulps. Extending the oxygen/alkali delignification beyond 55% may increase the yield loss considerably. It can be concluded that optimal yield for bleached pulps can be reached when cooking to kappa numbers between 40-45 followed by oxygen delignification to kappa numbers 20-22 before final bleaching.