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Quality Developments in Pulp Fibers using Conventional Papermaking Laboratory Beaters and an Industrial Pilot Refiner

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ABSTRACT

The research focused on the examination of quality developments of bleached kraft softwood pulp in the papermaking process. The pulp was mechanically treated using conventional papermaking laboratory beaters and an industrial pilot refiner. The conventional laboratory devices studied were a PFI mill and a Valley beater, while a Voith LR 40 industrial pilot refiner was used to represent a mill refiner. The results showed that the pulp fibers developed in different directions depending on the testing devices. The pulp samples treated using the laboratory equipment were found to contain a higher ratio of long fibers, a higher coarseness and a greater internal change of fiber structure, while the pulp samples refined using the industrial pilot refiner consisted of a shorter fiber, a lower level of internal structural changes in the fiber walls and a higher content of fines. The paper made from the pulp manipulated using the laboratory equipment had a superior strength, while the paper made from the pulp treated using the industrial pilot refiner had a poorer strength and a lower density, but had a higher light scattering value. The results of this study indicated that laboratory pulp cannot be used directly to examine fiber actions under industrial operations. Further research should study pulp characteristics and their effects on the papermaking process with regard to the correlation between laboratory work and industrial performance.

Keywords: refining, pulp fibers, fibrillation, fiber walls, paper

INTRODUCTION

Manipulation of pulp fibers to obtain the desired quality for making paper is basically carried out using a mechanical treatment on the wet fibers called beating or refining. The refining produces external fibrillations of fibers, internal structural changes in the fiber walls and the fines in pulp suspension, and reduces the length of fibers (Page, 1989). In the pulp and paper laboratory, conventional refining equipment, such as a Valley beater and a PFI mill, are commonly used to produce the desired pulp fibers. These devices are operated differently from an industrial refiner and do not reflect what happens in the industrial operations including the way the machinery is operated and the resultant pulp characteristics. Therefore, some advanced research centers now use pilot industrial refiners as a modern laboratory device operating in a similar manner to the mill refiners and providing pulp and paper results close to those from industry. However, most papermaking laboratories are still working with conventional laboratory devices. The use of

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laboratory-treated pulp to interpret fiber performance characteristics under industrial processes such as chemical applications and web forming produces an ambiguous result. Therefore, this study aimed to develop a deeper understanding of the differences in the development of pulp from conventional pulp and paper laboratory equipment compared to an industrial pilot refiner. The knowledge obtained could be further used for studying the correlation of fiber action between the laboratory and industrial papermaking processes and finally could be applied to optimize papermaking processes and to predict the quality of final paper products from industrial processes.

A Valley beater is the most common beating equipment used in pulp and paper laboratories worldwide. The beater is normally used to evaluate the fiber quality produced from various pulping processes. Beating is performed under a beater roll and a bedplate with a load lever arm. The testing pulp is prepared at a low consistency of 1.57% and circulated through the beater roll. The degrees of beating are controlled using a beating time in a range of 0.5–1.5 hr depending on the quality required. This equipment has been found to produce strong breaking of the fiber walls and creates external fibrillations (Hiltunen, 1999).

A PFI mill is operated using testing pulp with a medium consistency range of 10%. The pulp is treated under a compressive shear force at different speeds between a bar roll and a smooth housing (Mckenzie, 1981). The levels of treatment are controlled using the number of roll revolutions in a range of 1,000–15,000 revolutions depending on the desired quality. This device principally provides higher internal structural changes in the fiber walls than in the external structure and maintains the length of fibers (Hiltunen, 1999; Kerekes, 2001).

A pilot refiner is a small industrial refiner having operating parameters and equipment using a similar design to that of mill refiners. This device is generally a modern laboratory refiner such as a Voith Sulzer laboratory refiner or a Metso Prolab^{TM} laboratory refiner . The pilot refiner has control parameters such as the intensity, the refining energy and the rotational speed corresponding to the industrial operations and produces pulp and paper qualities close to those obtained from mill production (Sepke, 1991; Soini *et al.*, 2001).

MATERIALS AND METHODS

Pulp refining

Bleached kraft softwood pulp was used as the raw material in this experiment. Pulp refining was performed using a Valley beater, a PFI mill (Figure 1) and a Voith refiner-LR40 (Figure 2). Pulp treatment on the Valley beater was carried out according to the ISO 5264-1 standard method. The pulp was prepared at consistency of 1.57%. The beating times were 0, 15, 30, 60 and

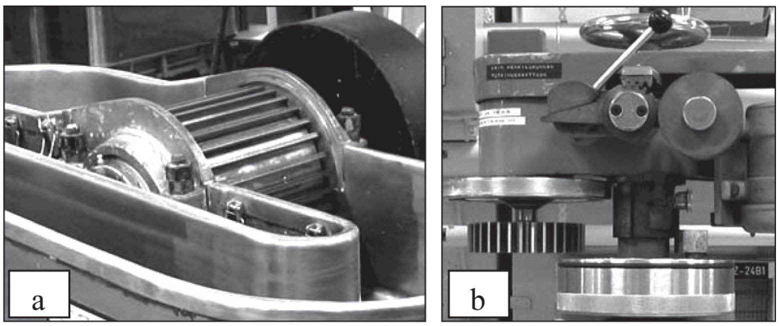

Figure 1 Conventional laboratory beaters: (a) Valley beater; and (b) PFI mill.

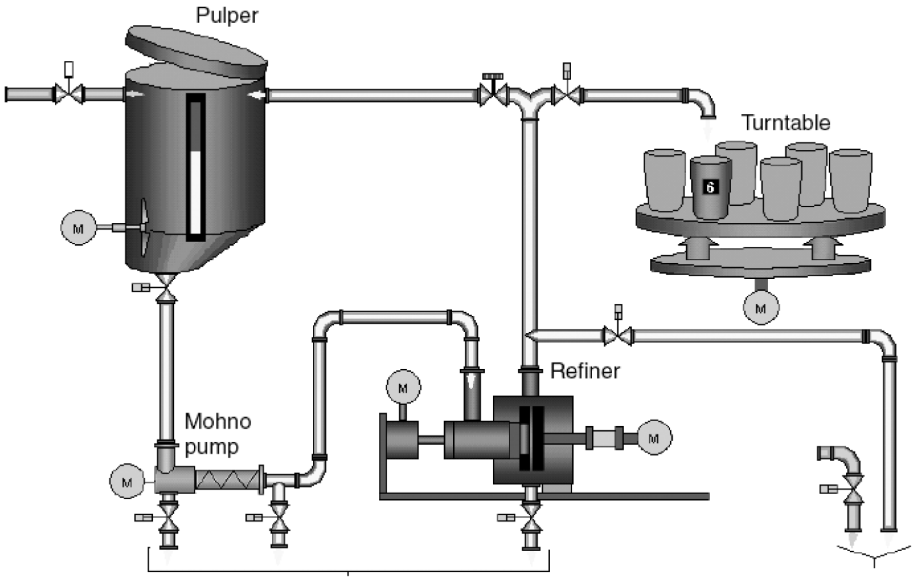

Figure 2 Industrial pilot refiner (Voith refiner-LR40).

80 min. Pulp treatment using the PFI mill was carried out according to the ISO 5264-2 standard method in which the pulp was refined at a consistency of 10% under 0, 2000, 5500, 9000 and 12000 revolutions. Pulp refining on the Voith refiner-LR40 was performed at a pulp consistency of 4%. The refiner was equipped with a standard plate filling for softwood pulp and operated at a rotational speed of 2000 rpm. The refining intensity was controlled at 2.75 J/m. The pulp was refined under specific refining energies of 0, 50, 110, 200 and 280 kWh/t.

Pulp and paper testing

Pulp quality was determined using the drainability of the pulp suspension measured by a Schopper-Riegler apparatus. The measurement and correction were based on the ISO 5267-1 standard method. The fiber length was carried out by an automated optical analyzer and the calculation of average fiber length was based on the length weighted average according to the TAPPI T271 standard method. The fiber saturation point (FSP) was measured using the solute exclusion method (Stone and Scallan, 1967). Laboratory sheets of 60 g/m^2 were made according to the ISO 5269-1 standard method. The measurements of paper properties including physical and optical properties were measured according to the ISO 5270 and ISO 2470 standard methods.

RESULTS AND DISCUSSION

Pulp quality developments

Classical characterization of pulp quality in the refining process is normally carried out at a given applied energy or a given drainability of pulp suspension. These parameters are basically used as the controlled variables in industry, correlating to the degrees of pulp treatments and the controlled qualities of the paper. In this experiment, the refining energy consumption of the conventional laboratory devices could not be measured. Thus, the comparison of pulp quality was carried out at a given drainage of pulp suspension based on the Schopper-Riegler value.

The study found that the pulp fibers developed in different directions depending on the equipment used in the process. The conventional laboratory equipment was found to provide a gentle treatment of the pulp fibers, while the pilot refiner provided a harsh treatment as shown in Figures 3 and 4. Figure 3 shows the treated pulp produced from the conventional laboratory devices contained longer fibers and a lower fines content. Figure 4 shows the coarseness values, indicating the removal of outer fiber walls, and the fiber saturation point (FSP) values, indicating internal structural changes in the fiber walls. These results from Figure 4 indicate that the industrial pilot refiner predominantly removed the outer layer of fibers resulting in lower fiber coarseness, while the PFI mill predominantly produced internal structural changes in the fiber walls with a higher FSP value.

Industrially, softwood pulp is refined to a target specific refining energy of about 150–200 kWh/t corresponding to a drainability of about 30 °SR. At this drainage value, the characteristics of treated pulps obtained from the industrial pilot refiner and the laboratory devices were obviously different. This indicated that the performances of these treated pulps in the papermaking processes

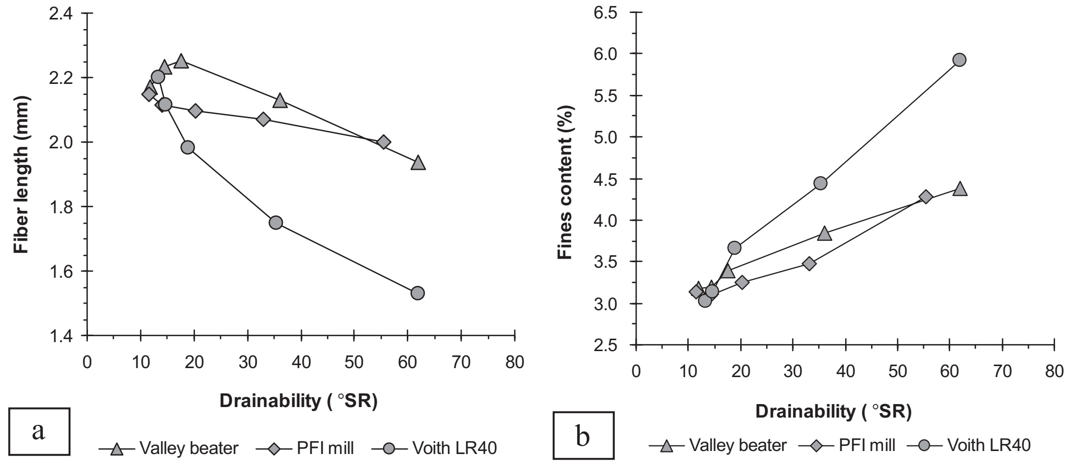

Figure 3 (a) Length weighted average fiber length; and (b) fines content-P200.

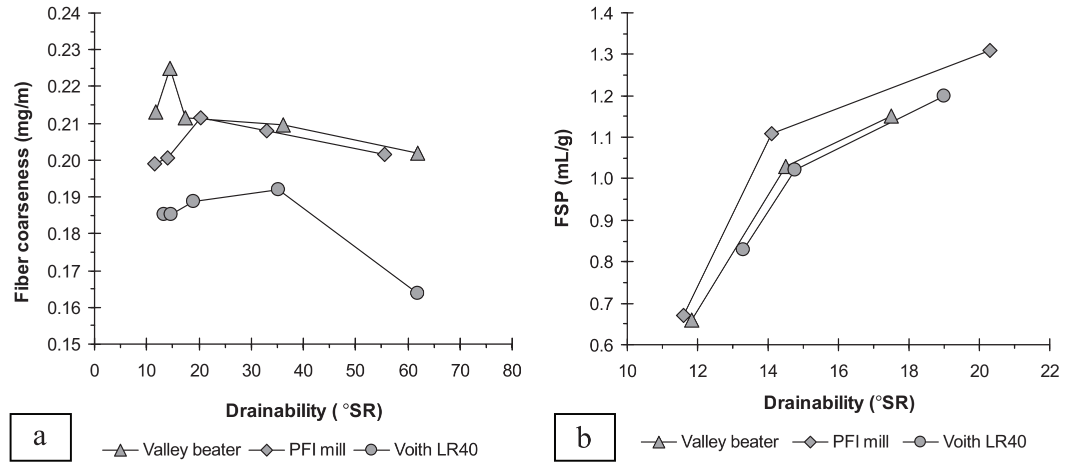

Figure 4 (a) Fiber coarseness; and (b) fiber saturation point (FSP).

(for example, during chemical application in the wet end process, and filler retention during forming, wet pressing and web drying) would be different between the laboratory process and industrial operations.

Paper quality developments

Changes in fiber morphology and the fiber wall structure affect the optical and mechanical properties of paper as shown in Figures 5–8. Paper sheets made from pulp produced using the conventional laboratory equipment had higher density as shown in Figure 5. The dense sheets resulted from the broken structure of the fiber wall (Figure 4(a)) and the consequent collapse during the drying process. This reduces the scattering of light in the paper structure (Figure 5(b)), which consequently lowers the opacity and brightness of the paper sheets presented by Pauler (2002).

The mechanical properties of paper sheets in this study are described using the tensile strength and tear resistance. The tensile strength of paper corresponds to the bonding area of the fiber matrix, which is approximately determined

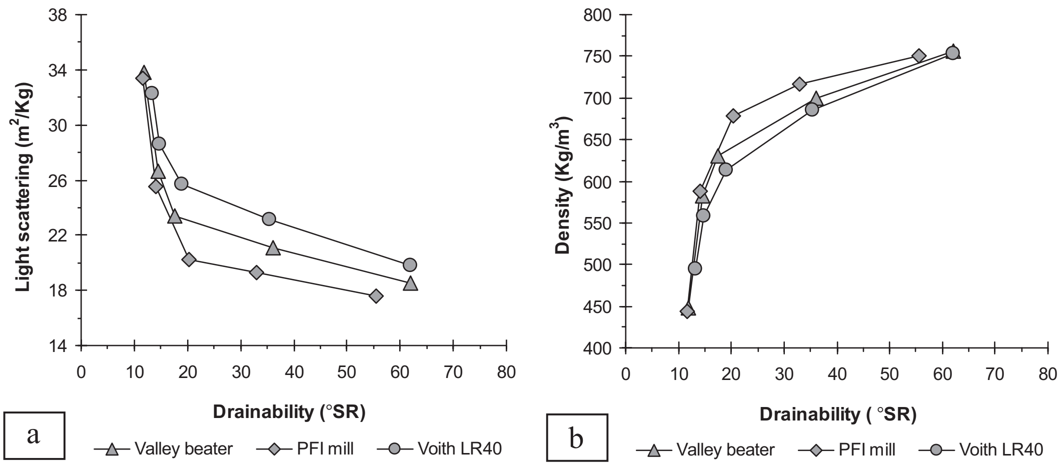

Figure 5 (a) Light scattering coefficient; and (b) sheet density at a given drainage value.

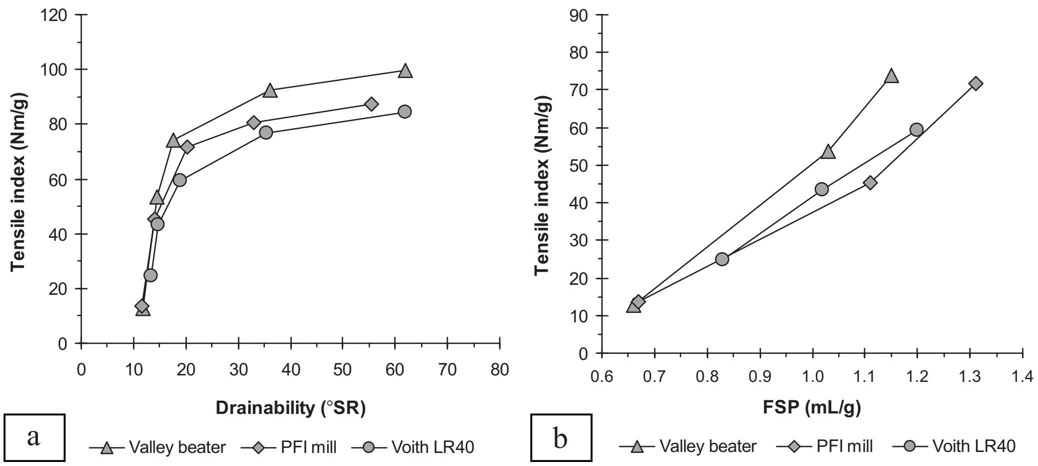

Figure 6 Tensile strength at a given (a) drainability; and (b) fiber saturation point (FSP).

using the sheet density and light scattering values. The tensile strength is also influenced by the degree of fines content, the long-fiber fraction and external fibrillation (Niskanen and Karenlampi, 1998). The results of the present study show that the pulp manipulated using the conventional laboratory equipment produced a denser paper with lower light scattering in the sheet structure indicating a higher bonding area (Figure 5) that resulted in superior tensile strength (Figure 6). In addition, the tensile strength can be evaluated at a given level of the FSP value, fines content and long fiber fraction in order to determine the influence of external fibrillation on the tensile strength, as shown in Figure 6 and 7. The results indicated that the pulp treated using the Valley beater possibly had a higher degree of external fibrillation that strengthened the paper sheets.

The tear resistance of the laboratory sheets principally corresponds to the length, the strength and the bonding of fibers (Levlin, 1999). In the present study, the tear resistance was found

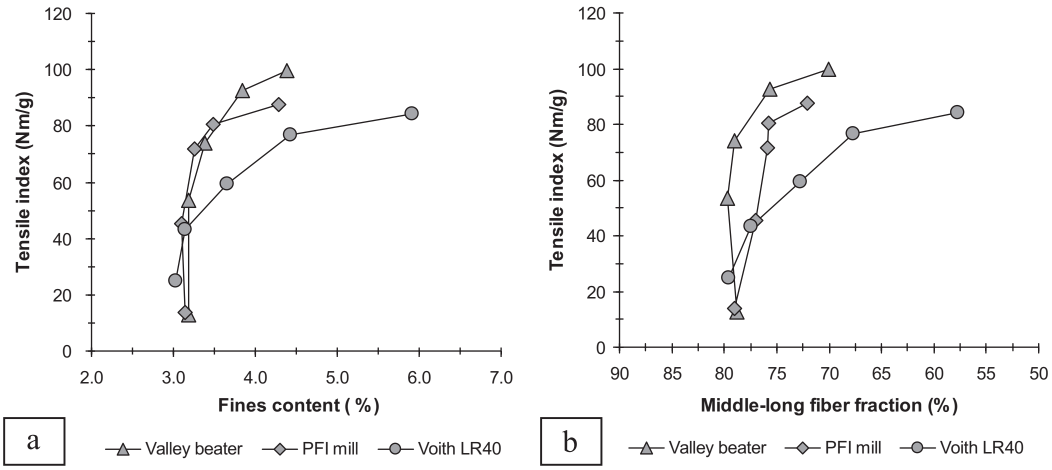

Figure 7 Tensile strength at a given (a) fines content; and a given (b) middle-long fiber fraction at fiber length > 1.2 mm.

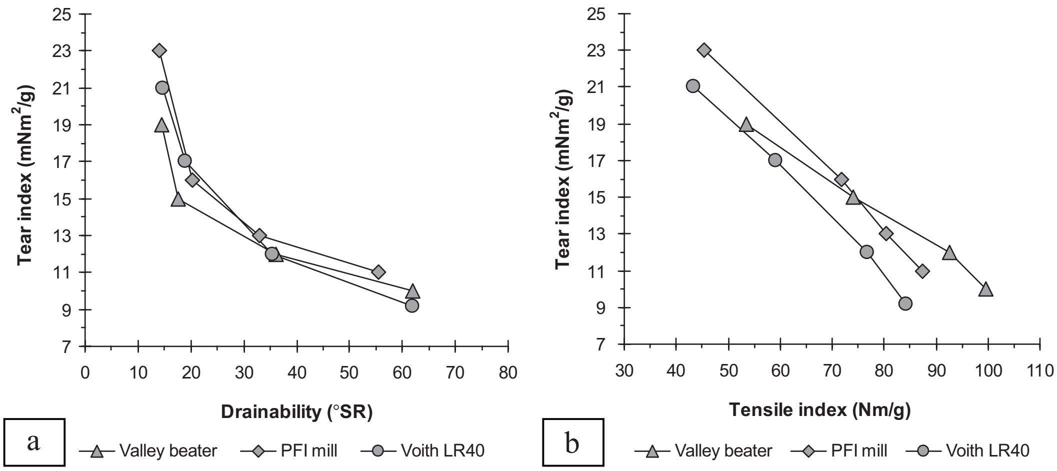

Figure 8 Tear resistance at a given (a) drainability; and (b) tensile strength.

to be not clearly different at a given drainability level of the pulp as shown in Figure 8. However, when this property was evaluated at a given tensile strength, the pulp obtained by the conventional laboratory process provided the better tear strength. This indicated that the pulp produced using the conventional laboratory equipment had lower damage to the pulp fibers, and had better reinforcement properties.

CONCLUSIONS

The quality developments of bleached kraft softwood pulp produced mechanically using a conventional laboratory equipment with a Valley beater and a PFI mill were found to be different from the pulp produced using the pilot industrial refiner Voith LR40. The treated pulp from the conventional laboratory refining equipment had a longer fiber length, a lower fines content and a higher internal structural change in the fiber walls. The sheets made from this pulp had a higher sheet density, a lower light scattering value, a superior tensile strength and a higher tearing resistance, while the refined pulp obtained from the industrial pilot refiner had a shorter fiber length, a higher fines content and a higher removal of fiber walls. The paper sheets made from this pulp had a lower sheet density, a higher light scattering value and a lower strength property. Differences in pulp characteristics were found to affect the paper properties and potentially could also affect the chemical application on the pulp suspension and the web-forming process. Therefore, the pulp manipulated using the conventional laboratory equipment could not be directly used to replicate the performance of pulp under industrial operational conditions. Further study is required into the correlation between the pulp properties obtained from the laboratory work and from the industrial process.

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LITERATURE CITED

Hiltunen, E. 1999. Papermaking properties of pulp, pp. 39–61. *In* J.E. Levlin and L. Soderbjelm, (eds.). **Pulp and Paper Testing.** (Paper making science and technology, Book 17). Fapet Oy, Finland.

Kerekes, R. 2001. Characterising refining action in PFI mills, Paper 11. *In* **Proceeding of the 6th Pira International Refining Conference,** 28-29 March 2001. Toronto, Canada. Pira International, UK.

Levlin, J. 1999. General physical properties of paper and board, pp. 138–160. *In* J.E. Levlin and L. Soderbjelm, (eds.). **Pulp and Paper Testing.** (Paper making science and technology, Book 17). Fapet Oy, Finland.

Mckenzie, A.W. 1981. The beating action of a PFI mill. **APPITA** 34(4): 293–297.

Niskanen, K. and P. Karenlampi. 1998. In-plane tensile properties, pp. 139–187. *In* K. Niskanen, (ed.). **Paper Physics.** (Paper making science and technology, Book 16). Fapet Oy, Finland.

Page, D. 1989. The beating of chemical pulps-the action and the effects, Volume 1, pp. 1-38. *In* **Proceeding of the 9th Fundamental Research Symposium (Fundamentals of Papermaking),** 17-22 September 1989. Cambridge, UK. Mechanical Engineering Publications Ltd.

Pauler, N. 2002. **Paper Optics.** AB Lorentzen & Wettre. Sweden. 93 pp.

Sepke, P.W. 1991. Mill oriented lab refining for routine furnish control and development, Paper15. *In* **Proceeding of Current and**

Future Technologies of Refining Conference, 10–12 December, 1991. Birmingham, UK. Pira International, UK.

Soini, P., K. Harju and M. Cox. 2001. Advance laboratory refining system for optimization of mill refining, Paper 5. *In* **Proceeding of the 6th Pira International Refining Conference,** 28–29 March, 2001. Toronto, Canada. Pari International, UK.

Stone J.E. and A.M. Scallan. 1967. The effect of component removal upon the porous structure of the cell wall of wood, II. Swelling in water and the fiber saturation point. **TAPPI** 50(10): 496–501.