J. W. GOTTSTEIN MEMORIAL TRUST FUND

The National Educational Trust of the Australian Forest Products Industries

GOTTSTEIN
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ADVANCES IN PAPER SCIENCE

MICHAEL WEDDING

2007 GOTTSTEIN FELLOWSHIP REPORT

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Joseph William Gottstein Memorial Trust Fund

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are:

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry group study tours are arranged periodically and have been well supported.

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His research centres on new ways of adding value to the paper and packaging industry as a whole. He has leadership of one project in Ensis Papro and has involvement in a number of projects for the SmartPrint Cooperative Research Centre.

Prior to joining Ensis, Michael worked as a Project Chemist for AorTech Biomaterials and as an Experimental Scientist for CSIRO Division of Molecular Science.

Michael has a Bachelor of Science from the University of Melbourne, majoring in Chemistry.

Growing up near Hamilton in the Western District of Victoria, Michael spent six years working as a farm tradesman before he embarked on a career in Science.

Executive Summary

This report details the findings of a visit to five research institutes in North America in March 2007, as well as the 2007 TAPPI Papermakers and PIMA International Leadership Conference held in Jacksonville, Florida.

The research areas discussed at the conference and underway at the institutions visited covered a wide variety of areas incorporating paper machine wet-end chemistry, pulp flow dynamics, new analysis equipment, improved energy efficiency, biofuels, wood chemistry and novel forest-based products. With the North American pulp and paper industry in decline, there is a need for the introduction of new technical innovations to save it, as is the case for the Australian industry.

All the institutions visited were researching biofuels from vegetable sources, mainly corn. This area of research has become more important over the past few of years due to the increasing demand for and the rising cost of crude oil.

The Ensis-Papro pilot sheet formers are seen as useful complements to the larger pilot formers located in North America, requiring significantly less pulp for operation.

After reviewing the state of international research in paper making, it is recommended that Australia's forest product research devote increased resources on the following areas to:

- Assess new-generation wet-end retention systems (such as Bufloc 5521 and 5567 and TELIOFORM™)
- Research surface chemistry at the paper machine wet-end to resolve issues around retention and water reuse
- New novel forest-based products (such as the Biofine process)

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Introduction

In 2004 the annual production of paper and paperboard products in Australia was approximately 3.0 million tonnes (Mt) [1]. Australian paper production currently employs 26 paper machines that differ in size, speed and complexity. While every attempt is made by the paper producers to optimise machine efficiencies, it is generally accepted that breaks at the wet-end are responsible for 4 % of down time which equates to a lost opportunity in excess of $ 200 million. Understanding the reasons for this down time therefore offers significant cost savings to the Australian industry. The development of closer links with institutions who are world leaders in papermaking research and attending the combined TAPPI Papermakers and PIMA International Leadership Conference in Jacksonville in March 2007 offers the opportunity to learn of recent progress in both resource utilisation and fibre processing methods.

Over the last few years, CSIRO Forestry and Forest Products and now Ensis has developed the Ensis Papro Pilot Scale Former (PSF) which is a unique facility capable of producing sheets that span the basis weight range from tissue grades (18 to 25 g/m^2) to copy paper (65 to 105 g/m^2) through to heavyweight two-ply linerboards (up to 250 g/m^2). Its major advantage is in being able to produce paper sheets with directionality properties similar to those achieved on commercial paper machines. The PSF has been used on various projects, both appropriation-funded fundamental studies and co-investment research for paper companies, equipment vendors and chemical suppliers to the paper industry.

The overarching aim of the studies undertaken within this Gottstein Trust Fellowship was to investigate advances in pilot paper forming, wet-end chemistry and surface enhancement technologies, in order to assist the Australian pulp and paper industry improve its processing efficiency. By doing so, Ensis will be able not only to enhance the services provided to the Australian paper and packaging industry in this important area, but also assist our forest product industry make a positive contribution to the national gross domestic products of Australia and New Zealand.

The specific objectives of visiting both tertiary and public research institutions in North America with technical programs similar to our own and attending a major papermaking conference specific to the study area are several fold:

1. To learn of progress in the areas of paper forming and surface treatment
2. To visit other groups with pilot facilities in papermaking
3. To look for opportunities in the field of emerging paper making technologies
4. To pursue the possibility for joint collaboration with overseas research institutions working in areas of common interest
5. To identify practical pathways that would assist in new product developments utilising the Ensis Papro PSF
6. To use the knowledge gathered from the visits to provide a better service to the Australian forest products industry

The prime reason for visiting these institutes was to pursue opportunities around value-added paper products via both on-machine and off-machine processes. Such products, notably printing and specialty grades, are largely imported into Australia. The development of high value-added products through the application of surface enhancement technologies has been identified by the industry as being critical to its long term survival.

About Paper

The History of Papermaking

Paper has been around for nearly 2000 years [2]. The papermaking process has come a long way since 105 AD when Ts'ai Lun, a Chinese court official, invented paper. In all likelihood, Ts'ai mixed mulberry bark, hemp and rags with water, beat it into pulp, pressed out the liquid, and hung the thin mat to dry in the sun. Thus began humanity's greatest revolution in communications.

Chinese papermakers captured in battle with Arab armies in Samarkand, passed their skills to the Islamic nations around 750 AD [3]. It was in Baghdad in 795 AD where the Islamic paper industry was established. All paper was made by hand, from old cloth rags consisting of mainly hemp and linen, with some cotton. Significantly, the lignocellulosic fibres in the rags were softened by fermentation followed by boiling in wood ash (largely potassium carbonate) a practice that led directly to the invention of alkaline pulping in Britain and the US almost exactly 1100 years later.

Paper was first reported in Europe early in the 12th century. War was again responsible for introducing paper to another part of the world with the crusades and the conquest of Spain by Christian armies. Trade between Venice and the area that is now Lebanon also transferred early knowledge of the craft of papermaking into Italy in the 13th century. The development of paper in Europe signalled the beginning of reliable and widespread dissemination of scientific and other knowledge. A vital later innovation that was dependent on the availability of paper was the development of the Gutenberg printing press, which allowed for mass production of printed materials thus increasing the demand for and production of paper.

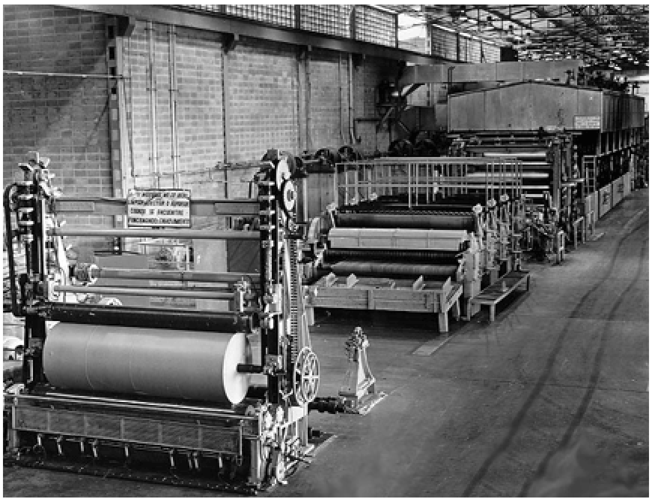

Figure 1: Early Fourdrinier paper machine

Hand making paper continued until 1750, when the Hollander beater was invented in the Netherlands to break down the rags to fibre using water power. In the early 1800s, Frenchman Nicholas Louis Robert invented a process for continuous production of paper that was subsequently taken to England (as a result of political instability following the French Revolution) where Robert's patents were purchased by the Fourdrinier brothers in 1801. Almost all modern paper machines are direct descendants of the later Fourdrinier patents, being based on a rotating endless wire screen that makes a continuous web that is subsequently pressed, dried and wound into continuous rolls of paper weighing up to 40 tonnes each.

The Industrial Revolution saw the need for paper outstrip the available rag supply. The rapidly growing need of new industries for paper was a major incentive for papermakers to look at other sources of papermaking fibre, wood being the great challenge of the day. In 1840, a German named Keller invented a mechanical pulping process for grinding logs into mechanical pulp. Today Keller's mechanical process has evolved into the many thermo-mechanical and chemi-thermomechanical pulping processes that are used to make newsprint and other lower-priced printing papers.

In 1867 an American chemist, Benjamin Tilghmann was granted a patent for treating wood, or other vegetable matter under conditions in which the lignin fraction of the wood was dissolved in sulphurous acid. This discovery led to commercialisation of acid sulphite pulping.

In 1853, two British inventors, Hugh Burgess and Charles Watt were granted a patent for separating the fibres in wood using sodium hydroxide, followed by calcium hypochlorite. The patent was offered for sale to the British Government who refused the offer because of the lack of a cost effective means of recovering the spent chemicals. Burgess emigrated to the US where he teamed up with another American inventor, Morris Keen. These two men jointly patented a process in 1865 that used sodium hydroxide alone, which enabled 85 % of the pulping chemical to be recovered. The first 'soda' pulp mill was established by Burgess at Manayunk in Pennsylvania with an output of 15 tonnes of pulp per day.

A German chemist, Carl Dahl, developed the kraft (from the German word meaning "strength") pulping process between 1879 and 1884. He was granted a patent describing how the addition of sodium sulphate to the chemical recovery cycle resulted in generation of sodium sulphide in the regenerated sodium hydroxide. The combination of these two chemicals allowed the time required for removal of lignin to be reduced, resulting in stronger fibres and stronger paper. This process became known as the kraft process in America and the sulphate process in Europe. The first mill based on Dahl's patent was built in Munskjo, Sweden in 1885, based on spruce wood chips. Today, after many refinements to the ways in which the kraft cooking chemicals are added to the chips and much improved methods for collecting and destroying the malodorous sulphide gases that the process generates as unwanted by-products, the kraft process is used to produce around 75 % of the world's 345 million tonnes (Mt) of virgin fibre. In addition to the strength of the pulps produced, the kraft process has several distinct advantages: the chemicals used to dissolve the lignin are recoverable with over 95 % efficiency and sufficient energy is produced from combustion of the dissolved lignin during the recovery process to make most kraft mills energetically self-reliant with a small excess normally sold to the local power grid.

Australia has played a significant role in the development of pulp and paper making technology. On the international scene until the mid-1930s it was generally accepted that high proportions of softwood fibre were necessary in the paper making furnish in order to make strong uniform papers that were acceptable to world markets. By the late 1920s concerns were being raised by many experts that the demand for paper was rapidly outstripping the supply of softwood fibre. As late as 1935, Mr. W. Raitt, cellulose expert to the Colonial Government of India was advocating the use of bamboo of the genus Melocanna as the only viable source of additional fibre suitable for paper making. His derogatory comments regarding the potential of hardwoods, such as eucalypts are worth quoting at length:

> *'It is significant of the apprehension felt regarding the continuity of wood-pulp that a considerable amount of attention has been given in recent years to so unpromising a subject as deciduous and hardwood trees. …But the hardwoods are all of extremely short fibrous structure, and highly lignified and therefore expensive to convert to pulp, and it is questionable whether the paper-maker can establish any economic right to them. …At the time of writing [1933] there is a strong movement in Australia (Tasmania) to bring certain species of eucalypti into use. These do appear to have some claim to be considered in the short period required for production to pulp – wood size – said to be fifteen years – but they are all short fibred species, and the most that their advocates can say for them is* ***that in considerable admixture with better pulps*** *[Raitt's emphasis] they produce a fair newsprint. That does not seem a very sound foundation for a new industry.'*[4]

From Raitt's comments it can be seen just how visionary was the 'movement in Australia' aimed at using eucalyptus fibre for paper manufacture was. The inventions that were being made in Australia as Raitt wrote his book were indeed prompted by necessity. Geography had not endowed the Australian continent with vast areas of softwood forest that exist in the northern hemisphere. Given the almost exclusive reliance of the early wood pulping industry on softwoods, the shipping restrictions during the First World War came as a great shock to the Australian governments. Not only did the softwood pulps imported from Europe and North America become in short supply for papermaking, but so did the dissolving pulps that formed the main raw material for production of cordite and other explosives that were essential for the war effort and for the defence of Australia.

One clear and sensible remedy was the selection of exotic species of softwood trees (notably *Pinus radiata*) in the 1920s by many state forestry agencies to form the basis of Australia's wood and wood-fibre supplies for future decades. Major plantings of these trees started in the 1930s after field trials to test a wide range of exotic species had been conducted in the 1920s. Australia's need for a local source of virgin paper-making fibre was more urgent than the 20 to 30 year maturation periods characteristic of even the fastest growing exotic softwoods. So it was that a parallel stream of research and development was instigated by the Western Australian government in 1917 – aimed firmly at devising new pulping and papermaking methods that would permit Australia's huge resources of native eucalypt wood to form the basis of an economically viable pulp and paper industry.

It was a team under the leadership of Ian Boas, with his chief scientist, the young Louis Benjamin, who accepted the challenge. Initially they worked within the WA Department of Forestry and later in the new Federal Council of Scientific and Industrial Research (CSIR) the forerunner of today's CSIRO. They demonstrated that 50:50 mixtures of eucalypt pulps with imported softwood pulps could be successfully converted to paper on a 15 cm wide laboratory paper machine that is today proudly preserved in the foyer of Ensis' Clayton laboratories. It must have taken enormous courage and vision for the management of the newly incorporated Australian Paper Manufacturers (founded 1926) and Papermakers Pty Ltd (founded 1926 – later Associated Pulp and Paper Mills) to start planning fully commercial-scale pulp and paper mills in the early 1930s in the depths of the most catastrophic economic depression that the world had ever seen. Australian Paper Manufacturers chose the kraft process as the basis of its manufacture of packaging papers from eucalypt wood, whereas Associated Pulp and Paper Mills were satisfied that the slightly lower strengths of the soda pulping process were compatible with its manufacture of printing and writing papers at Burnie.

How is Paper Made?

Today paper is generally made from either wood, or recycled paper and paper board. Small amounts of paper (around 10% globally) are made from cotton, flax and other fibrous cellulose based materials.

About 75 % of the world's requirement for virgin fibre is made from wood chips using the kraft process. Firstly the trees are harvested, transported to the mill and chipped. The woodchips are pulped using an aqueous solution of sodium hydroxide and sodium sulphide under pressure at 160 to 170 ^oC in order to make about 90 % of the lignin in the wood soluble in alkaline pulping medium. The residual lignin in the kraft pulp gives it a brown colour, so if a white pulp is required a series of bleaching processes are employed using oxygen, sodium hydroxide, chlorine dioxide and hydrogen peroxide. About 75 % of the bleached kraft pulp produced in the world uses these chemicals in four or five-stage bleaching sequences that have become known as elemental chlorine free (ECF). Alternative bleaching sequences that do not use chlorine dioxide, or any other form of chlorine-containing chemical are called totally chlorine free (TCF). These pulps are more expensive to produce and do not result in discharge of effluents from the pulp mill that are environmentally more benign than ECF pulps. TCF pulps account for about 6 % of bleached kraft pulps produced and TCF pulping capacity has plateaued since 1995, whereas production capacity for ECF pulps continues to grow strongly. Both technologies have been accredited as environmentally acceptable by the United Nations Environmental Program.

Once a pulp has been produced it must be subjected to further processing before it can be used to make paper on a paper machine. This process is called refining (or beating) and it is a mechanical treatment that increases the flexibility of the fibres in the pulp which results in an increase in the bonding area between each fibre in the paper web. Refining of pulps gives papers with higher tensile strengths, however, it also decreases the rate at which water can be removed from the sheet (the rate determining step in commercial papermaking) and other adverse effects such as lower dimensional stability in humid atmospheres. So there is a trade-off in properties and an important task for the paper manufacturer is to optimise the degree to which each pulp is refined before papermaking commences.

After refining the suspension of fibre in water (called 'stock') is diluted to the desired concentration. The pulp is combined with any chemical additives that are necessary to improve the properties required in the type of paper being made and then pumped on to the forming section of a paper machine. In the forming section the fibres are formed into a uniform flat sheet and water is drained away to the point where the sheet has sufficient strength to be fed forward into the second section of the paper machine. The sheet is sandwiched between thick felted fabrics and water is physically pressed out of the sheet by passage of the felts and the sheet through the nip of two co-rotating cylindrical metal, or granite rolls. Often two, or three sets of nips are used in this 'press section' of the paper machine and one or more rolls may be replaced with a moving belt arrangement that extends the period during which the sheet is under pressure. The latter device is called an 'extended nip press' (ENP), or a 'shoe press'. After the pressing of the sheet, the moisture content has normally been reduced to 40 to 50 % and this final proportion of water is removed by passing the sheet over polished steel cylinders that are heated with steam internally to temperatures between 110 to 160 ^{o}C. Further felted fabrics – 'dryer felts' may be used to hold the paper sheet against the dryer cylinders.

Once the paper has been dried, it can be subjected to further 'on-machine' processes that include impregnation with starch suspension (in a device known as a size press), surface coating, glazing, creping and/or calendering, or embossing. If a smooth surface is required on the final paper, generally a size press and calendering are used in succession with an extra train of dryer cylinders removing the water that was added at the size press. This is normal practice for high quality printing and writing papers. If bulk and water absorption are important, as in tissue and towelling grades, then creping without calendering is the norm. After these final treatments the paper sheet is typically wound onto a large 'machine roll' weighing many tonnes and up to 10 metres in width. The final moisture content of the paper is usually controlled so that it lies in the narrow range of 5 – 9 % depending on the end use. 9 % is the equilibrium quantity of water absorbed onto most papers under ambient atmospheric conditions.

Many chemicals and additives are used to enhance the papermaking process and the final product produced:

- Cationic starch is added to the stock to increase the strength of the sheet
- Polyelectrolytes, sometimes referred to as retention or drainage aids, are added to improve sheet drainage rates and to retain fine material
- Nanoparticles, such as bentonite and colloidal silica can be added to enhance retention of fines
- Alum can be used to lower the pH
- Size can be added to give the sheet some hydropobicity
- Fillers, such as kaolin, calcium carbonate, talc and titanium dioxide can be added to enhance the appearance and print performance of white grades
- Dyes and fluorescent whitening agents can be added to enhance colour or whiteness, brightness and appearance of the sheet
- Biocide is added to kill bacterial growth in the recycled water system
- Defoaming agents are added to eliminate foam from the forming section

All these additives in the paper making process can give it the appearance of alchemy or a 'witch's brew' rather than a scientifically-based formulation. In some paper mills the 'craft' can dominate over the science, because papermakers know that particular additives work to their advantage but do not necessarily understand the underlying science, or what has happened when the system fails for some reason.

Paper Products and Everyday Life

Most people take it for granted that paper allows them not only to enjoy their lives but also to go about their daily routines with greater efficiency [5]. From the thinnest tissue, to the most absorbent diaper, to the toughest corrugated box, there are almost as many different kinds of paper as there are uses for it.

Most of us begin our mornings by enjoying the comforts of paper products - from facial tissue and toilet paper, to the morning newspaper, to the carton that holds our orange juice or milk, and the paperboard packaging that holds our breakfast cereal.

Our children benefit from paper at school, from classroom drawings and notebook paper, to text books that students read and from which they learn.

Figure 2: School book

At work, office papers help us communicate. Even in this digital age, despite promises of a 'paperless office' as early as the late 1980s, paper consumption has increased. Office papers are essential for copiers, laser printers, brochures, notepads, and other uses. Storage of information on paper lasts much longer and is more reliable than storing the data digitally. Experience over the last two decades has demonstrated that every personal computer on every desk creates a need for more, rather than less, office paper. Office paper usage in the western world has grown at rates as high as 6% per annum in many countries over this period.

Wherever we go, paper is there to help us. It's the bags that we hold our food or latest clothing purchase. It's the cards, letters and packages we receive, the cup that holds our coffee, and the album that holds our photographic memories.

Even while we sleep, paper is still hard at work providing a host of innovative paper products that help hospitals deliver cleaner, better patient care and which protect healthcare personnel. Paper is at work in thousands of industrial and manufacturing applications helping keep the air clean, and providing protective apparel and innovative sterile packaging.

Grades of Paper

There a literally thousands of grades of paper products for just as many end uses. Different processes of manufacturing are often coupled with differing raw materials that are available in different parts of the world to widen the number of types of paper still further. The early adoption of eucalypt woods and the modification of pulping process conditions in Australia where softwoods suitable for pulp manufacture were in short supply until 1980 is a classic example of how pulping and paper making have been widely adapted in order to suit local conditions. Papers can be classified in many ways. Some of the major grade classifications are [6]:-

1. **Based on basis weight or 'grammage' –** the mass in grams of a square metre of paper (in the USA basis weight is the mass in lb of a 500 sheet ream of paper with dimensions that apply to the standard cut size for the grade in question, so there is

no universal relationship between metric ‘grammage’ and US basis weights measured in imperial pounds):

- Tissue: Low weight, < 40 g/m^2
- Paper: Medium weight, 40 to 120 g/m^2
- Paperboard: Medium-high weight, 120 to 200 g/m^2
- Board: High weight, > 200 g/m^2

2. **Based on Colour:**
   - Brown: Unbleached
   - Grey: Recycled
   - White: Bleached
   - Coloured: Bleached and dyed or pigmented
3. **Based on Usage:**
   - Industrial: Filter papers, electrical, label release, backings for abrasive sheets, interleaving papers, tube-winding boards, paster boards, saturating papers, grease proof papers, anti-corrosion papers and blotting papers
   - Packaging papers: Corrugating materials (linerboards and corrugating mediums), carton boards (coated and uncoated), sack papers, bag papers, wrapping papers, ‘butchers’ papers, cup papers and laminating papers
   - Printing and writing: Lithographic printing papers (coated and uncoated), copy papers, laser printing papers, inkjet printing papers, envelope papers, form printing papers, note papers, writing papers, ‘bond’ papers, ‘bank’ papers, cheque papers and cartridge papers
   - Newsprint: Newsprint, gazette papers, directory papers, coated mechanical papers and paperback papers
   - Health care: Toilet and facial tissues, towelling, paper napkins, disposable table cloths, overalls and surgical gowns
   - Specialty papers: Security papers (including bank note and passport papers), embossed papers, crepe papers, photographic papers and artists’ papers
4. **Based on Raw Material:**
   - Wood-containing (also called ‘mechanical papers’): Contain mechanical pulp fibres from wood, or non-woods
   - Wood-free: contain greater than 90 % bleached chemical pulp in the fibre fraction (typically uncoated wood-free (UCWF is an international customs classification term) ‘office’ papers typically contain 20 % $CaCO_3$ and 75 % bleached hardwood kraft pulp and 5 % bleached softwood kraft pulp)
   - Agricultural residue: Fibres from straw, grass or other annual plants
   - Rag papers: Contain more than 98 % bleached cotton fibre
   - Recycled: Recycled or ‘secondary’ fibres that may or may not have been subjected to deinking depending on the end use. Mixtures of recycled and virgin fibres in the same sheet are common, e.g. 35 % recycled copy paper
5. **Based on Surface Treatment:**
   - Coated: Usually coated with clay, or other mineral suspended on a polymeric ‘binder’ – coated mechanical and coated woodfree are two major categories of printing papers. Coating with molten low-density polyethylene (LDPE) is also common in liquid packaging boards that are converted into milk and juice cartons, and in copy paper wrappers that are designed to slow the absorption of water by the copy paper, so that the paper feeds smoothly through the copier without jamming

- Uncoated: No coating (other than starch applied using a size press) applied to the paper
- Laminated: A layer of synthetic polymer (LDPE) sandwiched between two sheets of paper, or paperboard, or between one sheet of paper and a sheet of aluminium foil

6. **Finish:**
   - Fine/ course
   - Calendered/ supercalendered
   - Machine finished (MF)/ machine glazed (MG)
   - Cast coated, gloss, semi-gloss, satin, matte, embossed and textured

World and Australian Production

World production of pulp in 2003[a] was 345 Mt with Australasia (Australia and New Zealand) producing 4.6 Mt equating to 1.3 % of world production and North America being the biggest producer with 36.4 % [1]. See production and consumption data by region in Figure 3.

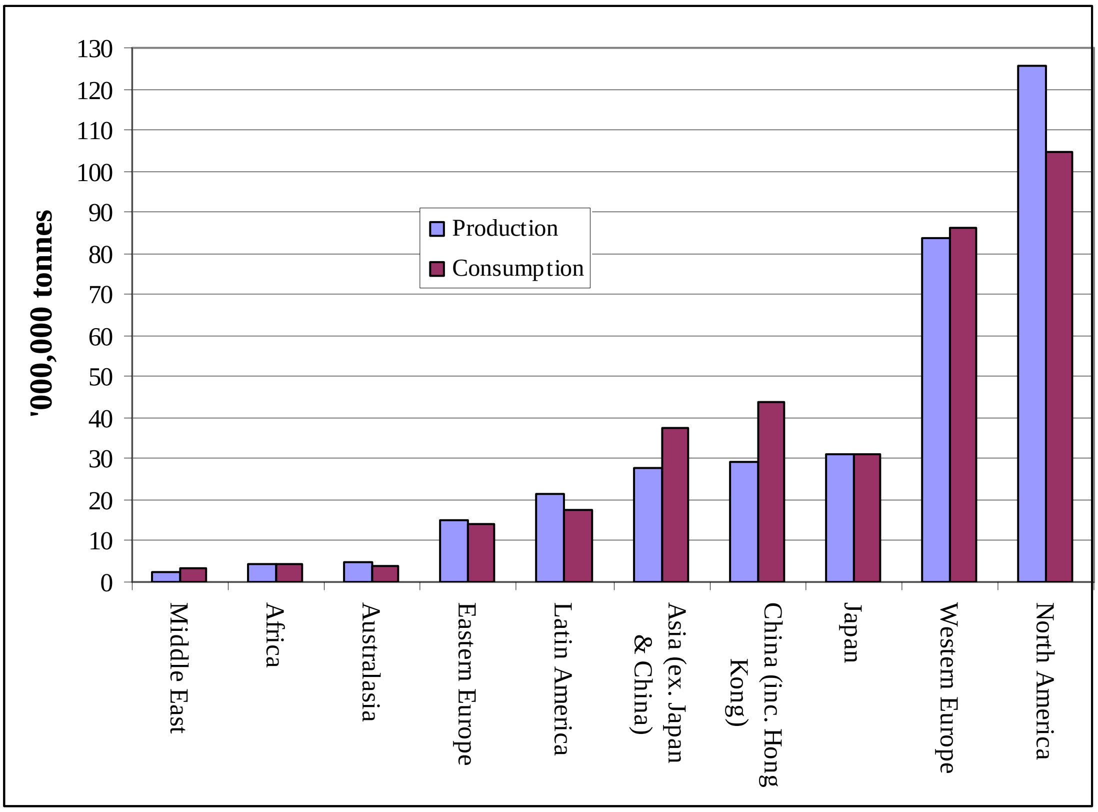

Figure 3: World pulp production and consumption in 2003 [1]

Of this 345 Mt of paper and paper board products produced world wide, 37 Mt was newsprint, 104 Mt was printing and writing grades, 23 Mt was health care products, 105 Mt of corrugating materials and 37 Mt of carton board and the residue of 39 Mt being other grades [1]. As is evident from this data, corrugated boxboard, newsprint and printing and writing grades together make up over 70 % of all of the paper produced. Global rates of usage of recycled paper are not easy to calculate, but are

[a] At the time of writing this was the most recent data available to the author.

arguably in the 50 to 55% range based on published figures for North America and Europe [7,8]. Over 30 % of waste paper collected in the US is currently exported to Asia because of the lack of softwood resources needed for manufacture of boxboard. In Australia a similar figure is believed to apply. The major paper product grades produced by major supplying regions are shown in Figure 4.

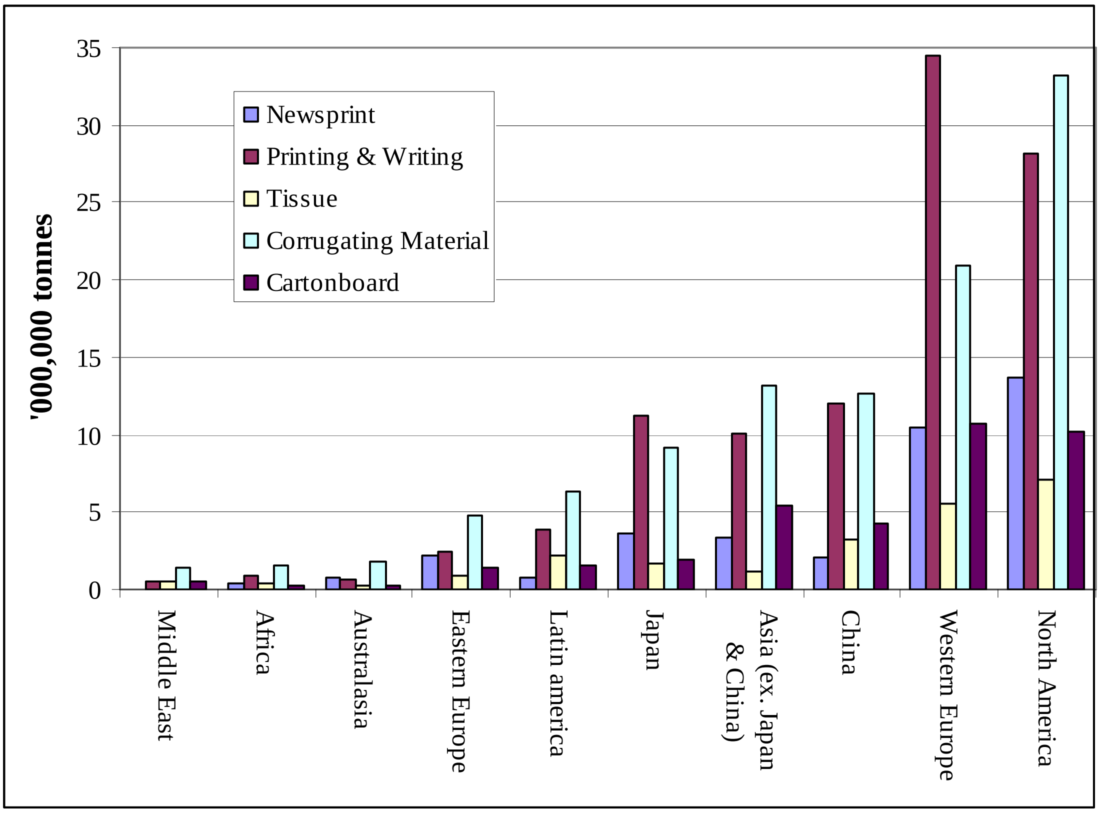

Figure 4: World paper and paper board production by grade 2003 [1]

The Australian paper and paper board industry had a turnover of $ 2.1 billion in the 2003-04 financial year [9]. Paper and paper board production and consumption data shown in Table 1, shows that Australia was a net importer of these commodities, importing 658 and 840 kt in 2002 and 2004 respectively. Australia was a net exporter of packaging and industrial products. However it was a net importer of printing and writing grades, newsprint and tissue. Somewhat ironically, Australia also exports over 4.6 Mt of 'bone dry' woodchips (77 % eucalypt) with a value of around $ 860 million. These chips are exported wet with 50 % water content meaning Australia (the driest continent) exports 4.6 Mt of water to Asia (the wettest continent). If converted to bleached eucalypt kraft pulp in Australia the export value would be close to $2.1 billion. And if converted to uncoated woodfree office papers the export value would be around $5.5 billion.

Potential for Growth

The data presented above shows that Australia has a potential to grow its markets. It is one of the world's smallest producers which imports a significant amount of its printing, writing and newsprint grades. While Australia is a net exporter of packaging and industrial grades there is also the potential to grow production and export of these commodities too.

Table 1: Paper and board production and consumption in Australia (‘000 tonnes) [1]

	Production			Imports			Exports			Consumption			Net Importation		
	2002	2004	% Change	2002	2004	% Change	2002	2004	% Change	2002	2004	% Change	2002	2004	% Change
Printing & Writing	624	624	0.0	681	912	33.9	140	167	19.3	1,165	1,369	17.5	**541**	**745**	37.7
Newsprint	395	424	7.3	224	301	34.4	2	1	-50.0	617	724	17.3	**222**	**300**	35.1
Tissue	198	205	3.5	50	63	26.0	26	46	76.9	222	222	0.0	**24**	**17**	-29.2
Packaging & Industrial[b]	1,679	1,796	7.0	260	254	-2.3	389	476	22.4	1,550	1,574	1.5	**-129**[c]	**-222**	72.1
Total Paper & Board	**2,896**	**3,049**	**5.3**	**1,215**	**1,530**	**25.9**	**557**	**690**	**23.9**	**3,554**	**3,889**	**9.4**	**658**	**840**	**27.7**

[b] Combined corrugating and carton board material

[c] A negative value indicates net exportation of commodity

Report on North American Institutes Visited

All the research institutions visited in North America had interesting and stimulating research programs investigating papermaking challenges and novel forest-based products. All of the institutes were aware of many complex issues facing the North American pulp and paper industry and are looking at ways to make a step change improvement for the industry as well as new forest based products and technologies.

Comparison of Pilot Paper Machines

The prime objective of my Visits was to learn about the pilot paper machines that are operated in a number of American and Canadian research institutes. The knowledge gained would be used to enhance the value of the PSF, a much simpler and far less expensive device that attempts to mimic as many of the features of a pilot paper machine, but on a smaller scale. The pilot paper machines located at North Carolina State University, Western Michigan University and The University of Maine were all Fourdrinier configurations and were quite similar to each other in speed and size, as shown in Table 2. The Paprican machine was a gap former and operated significantly faster than the other three, which is consistent with the high focus on production of newsprint by the Canadian paper industry. All the pilot paper machines inspected in North America produced paper in a continuous sheet, whereas the two pilot paper machines at Ensis Papro produce one sheet at a time. The large North American pilot machines require many hundreds of kilograms of pulp to operate successfully, while the Ensis machines can both perform comprehensive meaningful investigations with less than 5 kg of dry pulp.

Table 2: Comparison of pilot paper machines

	Ensis Papro		NCSU	WMU	UoM	Paprican
	PSF	PDF				
Forming Section	Simulated Fourdrinier and twin wire	Sprayed on to a wire in a rotating drum	Fourdrinier	Fourdrinier	Fourdrinier	Gap Former
Speed	One 28 cm square sheet per 3 min	One 90 x 29 cm sheet per 15 min	Up to 120 m/min	30 to 120 m/min	Up to 50 m/min	1,000 m/min
Machine Width	28 cm	29 cm	30 cm	58 cm	30 cm	40 and 30 cm

Ensis Papro

The PSF shown in Figure 5, is located in Clayton, Victoria, Australia and is a modified M/K former. Its key features are:

- Computer controlled automatic forming, couching and drying
- Forming section is:
  - Simulated Fourdrinier
  - Simulated twin wire (under development)
  - Grammage range 20 to 250 g/m^2

- Produces 28 cm square sheets of which a 20.5 cm square region of interest is analysed

- Variable flow rates (to produce orientated sheets)
- Permits chemical addition
- Requires small amounts of pulp

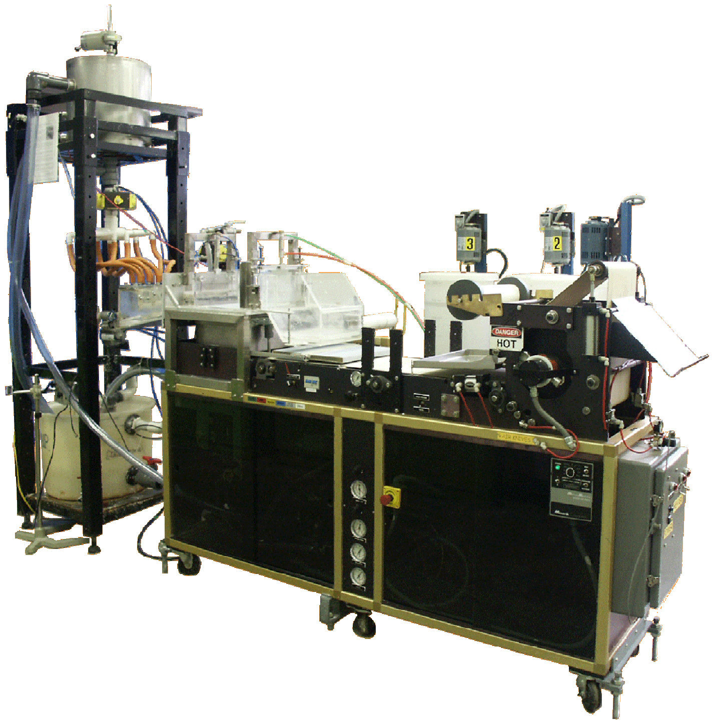

Figure 5: PSF located at Ensis Papro – Clayton, Victoria, Australia

The Pilot Dynamic Former PDF shown in Figure 6, is located in Rotorua New Zealand. It is a modified French CTP Formette Dynamique. The sheet is formed by spraying the stock on to a wire in a rotating drum as the nozzle transverses the height of the drum. Key parameters are:

- Produces 90 x 29 cm sheets (MD/CD) of near perfect formation
- Permits chemical addition
- Requires small amounts of pulp

Figure 6: PDF located at Ensis Papro – Rotorua, New Zealand

North Carolina State University

The Fourdrinier pilot paper machine shown in Figure 7, is located on the NCSU campus at Raleigh. It is capable of making 12 inch (30 cm) wide paper at a speed of up to 120 m/min. Also available at NCSU are pulp and paper testing, and environmental laboratories [10].

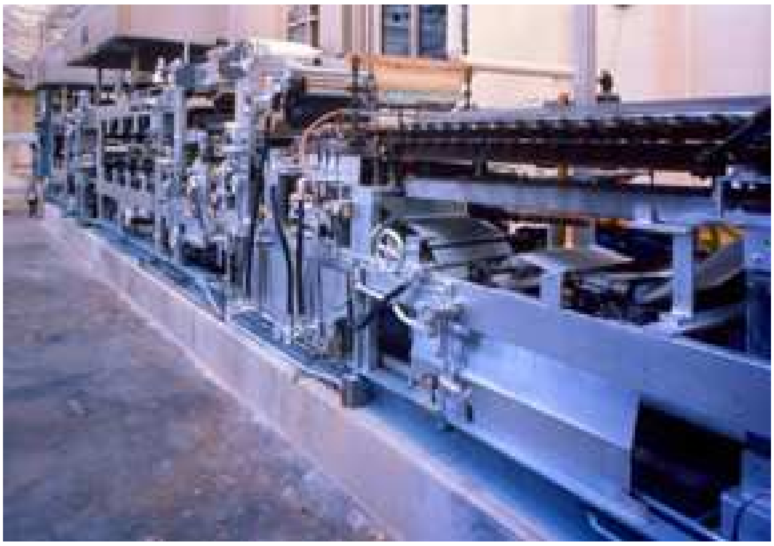

Figure 7: NCSU pilot paper machine

Western Michigan University

The paper machine shown in Figure 8, is located at the WMU campus at Kalamazoo. It is capable of making 23 to 590 g/m^2 paper with stock and additive preparation facilities sized to make extended continuous operations practical at production rates up to 70 kg/hr. The cost of operating the pilot paper machine is US $4,500/day [11].

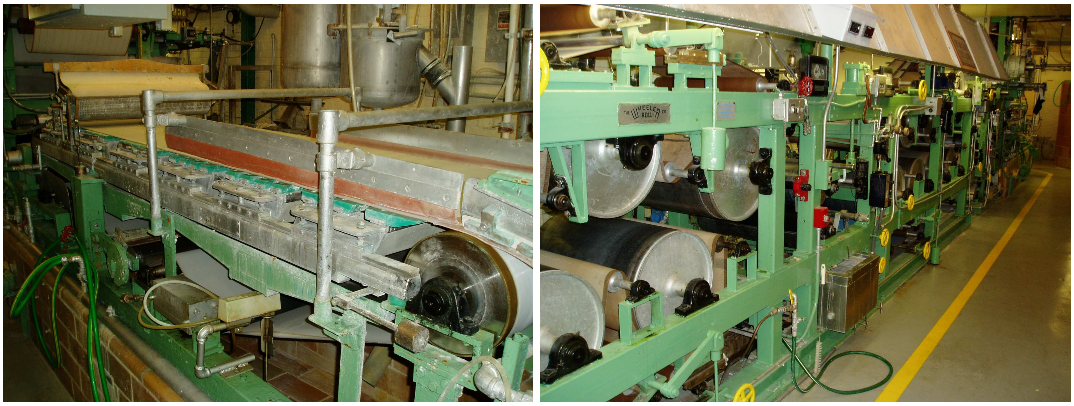

Figure 8: WMU pilot paper machine; *left* wet end and *right* drying section

The University of Maine

The Fourdrinier pilot paper machine shown in Figure 9, is located on of The UoM campus at Orono. It is 12 inch (30 cm) wide, can operate at up to 50 m/min and is equipped with gate roll size press. The machine cost US $6 million to construct, with the money being raised through government bonds. Currently the University receives about US $ 1 million per year in payments for contract work on the machine [12].

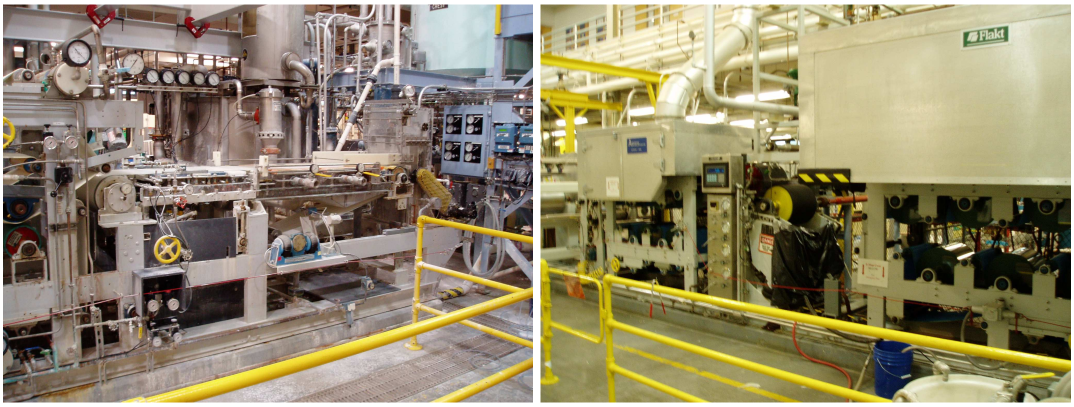

Figure 9: UoM pilot paper machine *left* wet end and *right* dry end

Paprican

The Paprican pilot paper machine shown in Figure 10, is located on the campus at Montreal. It operates as a gap former and was the biggest and fastest of the four machines inspected. It has a trim width of 40 or 30 cm and can operate at 1,000 m/min and will soon be upgraded to run at 1,500 m/min. The current speed is too fast to dry the paper produced so it is put through the dryer a second time to complete the drying process. This equipment was completely designed and constructed by Paprican's engineers and scientists, providing Paprican staff with the advantage of complete knowledge of operation and maintenance of the machine and obviating reliance on outside contractors and consultants [13].

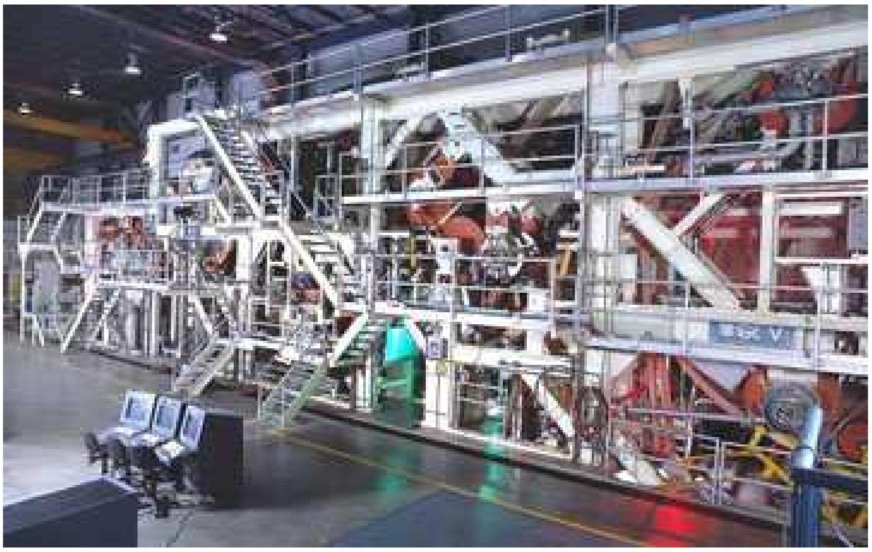

Figure 10: Paprican pilot paper machine

Opportunities in Pulp and Paper Research

Comments on the North American Paper Industry

The North American pulp, paper and packaging industry is very much in decline due to competition from Asian and South American countries; namely China, Indonesia, Korea, Brazil and Mexico, where raw material, labour and regulatory costs are significantly less. Many North American paper mills (along with other industries) have closed due to competition from cheap Asian imports or relocated to Mexico and Brazil. Import dumping is such a cause of concern to the pulp and paper industry that there have been calls for greater tariff protection to save the industry. This problem is not limited to the paper industry, as most other manufacturing industries face similar difficulties. Many of the paper scientists to whom I spoke believe that the North American industry needs more than just incremental improvements to compete on the world market and that a 'step change' in technology or market focus is required. In my opinion, the same could be said for the Australian and New Zealand Industries.

However there are pockets of optimism, with companies such as the Sinclair Group and FedEx Kinkos looking for unconventional ideas and inspiration. These companies seem to be progressive and have a success culture. They are very customer focused, both internally and externally, and see the customer not just as a source of revenue, but a partner who they can't do without.

The technical content of papers presented at the 2007 TAPPI Papermakers and PIMA International Leadership Conference were excellent. The main focus was on methods to improve the paper machine via better wet-end retention, higher machine speeds, improved product quality, new instrumentation and unlocking environmental and economical efficiencies. It should be noted that while the North American paper industry is declining, the Asian and South American industries are experiencing significant growth and consequently this is where much investment in new machines and equipment is being directed.

During my visit I found a great fondness in America for Australia and its people, and many American paper scientists and engineers expressed a desire to visit our country. Such visits would provide valuable opportunities to gain knowledge and expertise through collaborations, short term consultation or longer term secondment.

Highlights from 2007 TAPPI Papermakers and PIMA International Leadership Conference

The papers that I found to be of greatest interest and value to me were:

***Pitch Control** - Matthew Blazey of Ciba Speciality Chemicals*

The Ciba Contaminant Analyser (CCA) is an instrument designed to characterise the amount, source and chemical composition of pitch in mill stocks [14]. This equipment has advantages over conventional pitch measurement methods, such as turbidity and pitch counts, which cannot differentiate between fixation and agglomeration of hydrophobic species. The CCA provides size and size distribution data, and differentiates pitch and stickies from fines and fillers. Portability of the CCA allows for mill testing of fixatives under actual operating conditions.

***Fractionating Fines from Fibre** - Donald Guay of the University of Wisconsin*
A fractionating save-all manufactured by Whitewater Solutions Corporation was able to achieve in excess of 80 % removal of fines from a recycled newsprint stock [15]. The technology has advantages over conventional equipment such as a vibrating 200 mesh screen, disk filter, drum filter and dissolved air flotation (DAF) as it provides better separation of fines and filler from fibre. The equipment improved the freeness of recycled newsprint from 230 to 450 mL CSF and deinked the stock. Ensis Papro should contact Dr. Guay to either commence collaboration or obtain a costing of the equipment.

***New Organic Coagulant (Bufloc 5521 and 5567)** - Gary Headrick of Buckman Laboratories*
Bufloc 5521 and 5567 were reported to increase retention of fillers, OBA and FWA [16]. They were claimed to reduce chemical costs and improve sheet strength and print properties. It is epichloroihydrin (EPI) free, FDA approved and does not quench OBA or FWA as conventional coagulants do. Ensis Papro should consult Australian industry to ascertain if there is any interest in the coagulant and if so, initiate a laboratory trial to asses the potential of the product.

***Periodic and Pseudo Periodic Marks in Paper** - Roland Trépanier of OpTest Equipment*
A new software package was reported to detect periodic and pseudo periodic marks in paper [17]. The software uses a 2-D FFT to detect patterns within paper. It can quantify size, orientation and intensity of the periodic marks. Applications of the package include quality control, paper machine control, troubleshooting, maintenance optimisation and sheet ‘finger print’ identification. Ensis Papro should consider acquiring this software package, which can be installed on the OpTest PPF formation analyser, to assist in projects requiring formation analysis.

***Headbox Flow and Fibre Orientation** - Paul Krocha of the University of British Columbia and Cyrus Aidun of Georgia Institute of Technology*
Both authors used a Fokker-Plank type equation to model headbox fluid flow and the effect it has on fibre orientation or anisotropy of the sheet [18,19]. The authors reported studies on fibre-fibre interactions and the effect these have on curl, cockle, lean and other defects in the physical properties of the paper produced. These interactions are particularly important in paper forming, for example high speed printing requires strength in the feed direction and sack paper must be strong in all directions.

***Drainage Coefficients** - Joseph Genco of The University of Maine*
Drainage coefficient measurements were modelled using an internally developed apparatus for measuring the effect of shear on drainage properties of various stocks [20]. The apparatus was used to measure the effect of shear on retention, retention aid performance, drainage, vacuum under the sheet and mat formation. The drainage coefficients have the potential to be adapted to model drainage on the PSF.

Three Component Retention System (TELIOFORM®) - *Philip Ford of Ciba Speciality Chemicals*

The TELIOFORM® three component retention system has the potential to be the next generation in retention systems [21]. The technology consists of a cationic or anionic polymer, inorganic microparticles and organic micropolymer in a retention program, resulting in improved formation, smoothness, porosity and pore size distribution and enabling the efficient production of high and very high brightness paper grades. Ensis Papro should consult Australian industry to ascertain if there is any interest in the system and if so initiate a laboratory trial to asses the potential of the product.

New Research Opportunities

There was a large amount of paper research presented at the 2007 TAPPI Papermakers and PIMA International Leadership Conference [22] that I found particularly valuable. Many speakers presented technologies that improved the paper machine wet end process. Some of these technologies have potential to improve retention, properties of the final product and running speeds. A number of new instruments to measure the final product quality were also described.

All the research institutions visited were looking at ways new of extending the use of wood products into non-paper related areas. Significant among the non-paper areas were novel methods for producing biofuels. This area of research has obviously become quite popular over the past few of years due to the increasing demand for and the rising cost of crude oil. Most institutions were investigating the production of biofuels from vegetable sources, mainly corn syrup and vegetable oils, whereas we at Ensis believe that if the Biofine process [23] could be developed to a commercial viability, it would have compelling advantages, not least of these being the utilisation of waste streams rather than food crops. None of the institutions visited indicated that they were researching the Biofine Process.

Potential Collaborative Research

A number of organisations visited expressed interest in collaborating or working with Ensis and efforts should be made to develop closer links with them.

North Carolina State University had a very interesting wood science group researching the structure and chemistry of wood. Efforts should be made to find an area of common interest with this university.

Western Michigan University are interested in collaborating with Ensis in printed circuits and biofuels. Also they may be able to provide us with students to undertake short term projects and Dr. John Cameron has expressed an interest in a six month sabbatical with Ensis.

The University of Maine expressed an interest the odour measurement station developed by Ensis as well as collaborating in biofuels. One masters student, Ms Emilia Vänskä, expressed a desire to work for Ensis Papro.

McGill University were very interested in the PSF, in particular the ability to control production of poorly formed sheets with interesting fibre orientations and three dimensional structure. Dr. Gray expressed interest in receiving sample sheets produced outside normal operating conditions.

Conclusions

The research discussed at the 2007 TAPPI Papermakers and PIMA International Leadership Conference and being undertaken at the research organisations visited covered a wide variety of papermaking and forest product products. Topics of interest were technologies that improved the paper machine wet-end process, instruments that measured stock and product quality and mechanical performance of the paper machine.

A lot of the research being undertaken appears to be making incremental improvements in paper making technology. However the state of the North American industry requires a step change to bring it to a level where it can compete in the world paper and packaging markets and the same is the case for the Australian industry.

The pilot paper machines located at North Carolina State University, Western Michigan University and The University of Maine were all Fourdrinier configurations and were quite similar to each other in speed and size. The Paprican machine was a gap former and operated significantly faster than the other three. All the pilot paper machines inspected in North America produced paper in a continuous sheet, whereas the two pilot paper machines at Ensis Papro produce one sheet at a time. The large North American pilot machines require many hundreds of kilograms of pulp to operate successfully, while the Ensis machines can both perform comprehensive meaningful investigations with less than 5 kg of dry pulp.

For the Australian industry to compete in the world market there is a need to develop new technologies and products, something many of the institutions visited were working on. All the institutions visited were researching biofuels produced from vegetable oil and corn starch. A Biofine-type process for the production of biofuels from wood (for example from forest waste) and other forms of lignocellulose has merit. Its advantage is being able to produce fuel from cellulose and hemicellulose (major components of wood) using the whole plant and not just a small amount of extractable oils.

Among advances in papermaking there were:

- New retention systems presented (such as the Bufloc™ and TELIOFORM™) that have the potential to improve the papermaking process
- Models being developed that describe pulp flow and drainage and the effect these have on sheet quality

However much work is still required to understand the surface chemistry at the paper machine wet-end to resolve issues around retention and water reuse.

## Acknowledgements

The author would like to acknowledge the support of the following organisations and individuals:

- **J. W. Gottstein Memorial Trust –** for providing me with a fellowship to conduct this research
- **Ensis –** for providing extra funding to conduct the research
- **Appita –** for providing complementary registration to the 2007 TAPPI Papermakers and PIMA International Leadership Conference
- **Dr. Nafty Vanderhoek and Dr. Warwick Raverty –** for their encouragement and support
- **The research institutions visited** and key contacts were:
    - **North Carolina State University** – Dr. Martin Hubbe
    - **Western Michigan University** – Dr. John Cameron and Dr. Said AbuBakr
    - **The University of Maine –** Proserfina Bennett and Dr. David Neivandt
    - **Paprican –** Dr. Ivan Pikulik and Dr. Lawrence Allen
    - **McGill –** Dr. Derek Gray
- **Louise, Georgia and Holly Wedding –** for support of their husband and father who they missed for 16 long days

Appendices

Appendix A - Notes from Organisational Visits

North Carolina State University *(Monday 19 March 2007)*
Department of Wood and Paper Science
Box 8005, Raleigh NC, 27695-8005
Telephone: +1 (919) 515 5807
Fax: +1 (919) 515 6302
Email: hubbe@ncsu.edu

People met**:** Dr. Martin Hubbe, Dr. Stephen Kelley, Dr. John Heitmann, Dr. Richard Venditti, Dr. Dimitris Arygropoulos, Dr. Orlando Rojas and Dr. Joel Pawlak

The Paper Science and Engineering program located at NCSU has research programs in pulping and bleaching chemistry, fibre recycling, environmental engineering, fibre physics, wood chemistry and papermaking [10].

Papermaking
The NCSU has research programs investigating the fundamentals of papermaking and has a lot of internally designed and constructed equipment for studying specific aspects of papermaking. The major areas of research are:

- Wet-end chemistry
- Wood chemistry, including lignin chemistry, carbohydrates, and pulping;
- Bleaching chemistry and its consequences
- Enzymatic treatments
- Mechanical aspects of paper drying and tissue production
- Recycling and de-inking
- Other aspects of papermaking technologies

Forest Biomaterials Laboratory
NCSU has extensive forest biomaterials research interests, investigating a wide variety of topics including adsorption behaviours of surfactants and polymers. The interfacial properties of adsorbed layers were being investigated using light scattering, piezoelectric sensing, spectroscopic and AFM techniques. Some research was focused on adhesion forces in model cellulose surfaces, adsorption of synthetic and natural polymers in lignocellulosic systems, boundary layer lubrication, enzyme activity and surface phenomena. Some areas of research are:

- Ionic liquids as novel wood solvents (see Figure 11)
- Membranes, fibres and composites from wood
- Developing and understanding new wood pulping methods based on green liquor technologies
- Use of ionic liquids as pulping and oxidative catalysis
- Fundamentals and catalysis of oxidative delignification
- Activation of oxygen delignification and lignin degrading enzymes

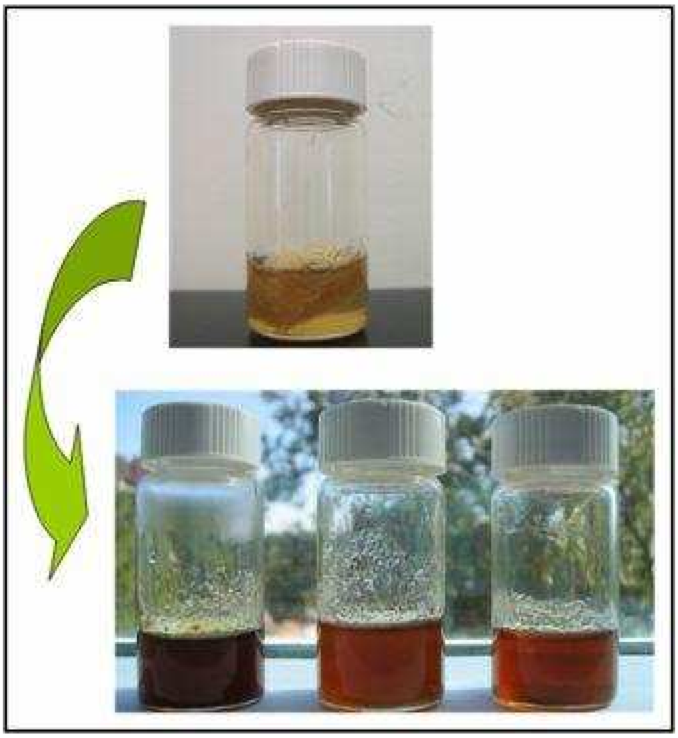

Figure 11: Wood dissolved in an ionic solvent

Further research effort at NCSU was focused on wood chemistry with emphasis on the fundamental structural and polymer chemistry of wood biopolymers. A major thrust of their effort was focused on developing novel chemicals and materials from a variety of renewable resources. To do this, the fundamental organic chemistry of oxidations as applied to the lignocellulosic substrate was being closely examined. In addition, they were developing novel NMR techniques for probing the structural transformations induced on such polymers during processing. Other topics included oxygen compound bleaching of chemical pulps, biomimetic catalysis in oxidations of aromatic substrates, solvents for green chemistry, detection and determination of chromophores induced during yellowing and aging of mechanical and chemical pulps. Some areas of research are:

- Structure and property relations of ionic liquids
- Novel chemicals and materials from renewable resources
- Reaction mechanisms
- Catalysis and biomimetic systems for oxidations
- Lignin oxidative enzymes
- Heteronuclear and multidimensional NMR including phosphorus 31 and fluorine 19
- Yellowing of paper
- Lignin analysis and isolation methods

The Paper Science and Engineering program at NCSU are an exciting group and Ensis should make efforts to built collaborations with this institution.

Western Michigan University (Tuesday 20 March 2007)
Department of Paper Engineering, Chemical Engineering, and Imaging
A-217 Parkview Campus, Western Michigan University, Kalamazoo MI 49008-5462
Telephone: +1 (269) 276 3500
Fax: +1 (269) 276 3501
Email: said.abubakr@wmich.edu

***Key Contacts*:** Dr. Said AbuBakr, Dr. Fohn Cameron, Dr. Dewei Qi, Dr. Thomas Joyce, Dr. Margaret Joyce, Dr. Peter Parker and Joel Kendrick

The Paper Engineering, Chemical Engineering and Imaging group at WMU is a large institute with well equipped laboratories. The facility provides research solutions for product development, nanotechnologies, printing and ink development, recycling, paper mill engineering and operation, process control and instrumentation and allied industries [11].

Papermaking
WMU has an extensive paper engineering group researching many areas of papermaking, such as:

- Paper making chemistry and formation
- Pressing and drying
- Energy and mass transfer balances
- Calcining
- Causticising
- Black liquor evaporation and kraft recovery boilers
- Pulp Washing

The University has a recycling facility that can recycle and re-pulp a wide variety of post consumer products. The facility is a certified pilot plant for the Fibre Boxboard Association's repulpability and recycleability test protocol for wax replacement corrugated containers.

Paper Coating
WMU appeared to be a leader in the field of paper coating research and applications with a comprehensive research program in this area. The pilot coater, as shown in Figure 12, is 1 m wide, can operate at a maximum speed of 1,200 m/min, with a variety of application methods and can coat one or both sides of the paper during a single pass. It costs US $12,000 per day to operate.

Figure 12: WMU pilot scale paper coater (looking from the coater end toward the dry end)

WMU were very interested in collaborating with Ensis. Potential projects are printed circuits and biofuels as well others may emerge as a relationship develops. Also they may be able to provide us with students to undertake short term projects and Dr. John Cameron has expressed an interest in a six-month sabbatical with Ensis.

University of Maine *(Thursday 22 March 2007)*
Paper Surface Science Program
5737 Jenness Hall, Orono, ME 04469-5737
Telephone: +1 (207) 581 2277
Fax: +1 (207) 581 2323
Email: pbennett@maine.edu

Key Contacts**:** Proserfina Bennett and Dr. David Neivandt

The objective of the Paper Surface Science Program at The UoM is to develop fundamental and applied knowledge about paper surface treatment processes (sizing, coating, printing, gluing, etc.) and structure performance relationships in the materials [12].

Research Program
The research is performed by graduate students (MSc. and Ph.D.), postdoctoral fellows and visiting scientists under the guidance of the faculty. The research program covers paper surface treatment from process improvement to product development and is centred around two main areas:

1. Fluid-paper interactions in surface treatments
Current projects include investigating the rheology of non-Newtonian fluid suspensions, modelling the setting of coatings and adhesives on paper, interactions between coating and base stock and ink film levelling. Attention is given to the effect of water, particularly, the roughening phenomenon examined in the Environmental SEM and with special equipment designed and constructed for this purpose.

2. Physics and chemistry of paper surfaces
Projects in this area investigate the mechanisms involved in:
- Development of the porous structure of pigmented coatings during drying
- Relationships between bulk and surface structural characteristics and optical properties of gloss and light-scattering
- Processes of wetting and spreading of latexes on pigment and cellulosic substrates
- Factors determining adhesion and cohesion in coated papers
- Influence of pigmentation and of the type of binder on surface chemistry
- The surface energy of pigmented coatings

The University has an extensive pulping and bleaching research capability investigating new pulping methods as well as commercial analysis for industry.

The University of Maine was very interested in Ensis and potential collaborations in biofuels and the odour measurement station. A master's student, Emilia Vänskä, expressed a desire to work for Ensis Papro.

Paprican *(Friday 23 March 2007)*

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Fax: +1 (514) 630 4134
Email: IPikulik@paprican.ca

Key Contacts**:** Dr. Ivan Pikulik and Dr. Lawrence Allen

Research Programs

Paprican's programs are driven by high priority technical issues of the industry such as product quality and value, cost competitiveness, environmental performance and sustainability [13]. They strive to meet the needs of their members and partners within the following areas of research:

- **Fibre Supply and Quality:** Capturing more value from fibre resources and enhancing performance of market pulps
- **Chemical Pulping:** Producing superior kraft pulps and the next generation of bleaching technologies
- **Mechanical Pulping:** Developing the next generation of superior performance thermomechanical pulps
- **Papermaking:** Improving wet-end chemistry, designing and developing highly filled printing papers
- **Product Performance:** Delivering state of the art end use properties from advances in surfaces, coatings and web structures
- **Sustainability and Environment:** Minimizing environmental impact, reducing total emissions, optimising energy efficiencies in response to climate change and economic drivers
- **Analytical Services and Standards:** Provide customised technical services, resolution of process and quality related problems, support in development of new products and quality assurance programs and training

Paprican Merger

Currently Paprican are undergoing a merger with FERIC and Forintek Canada Corporation to form a new single institute named FPInnovations. The staff were very interested in Ensis and how CSIRO and Scion functioned together in an unincorporated joint venture, and the potential issues that Paprican may face in their merger.

Again it was obvious that the paper and packaging industry in North America (Canada) is declining and Paprican was very aware that a step change in the paper making process is required to save the industry. They are busily working on new products and are researching biofuels, namely ethanol. Paprican is very committed to its members, partners and clients and are looking forward to the creation of more innovative projects in the future to meet the emerging technology needs of the industry.

McGill University *(Friday 23 March 2007)*
Department of Chemistry
Otto Maass Chemistry Building, 801 Sherbrooke St. West, Montreal, QC, Canada H3A 2K6
Telephone: +1 (514) 398 6999
Fax: +1 (514) 398 3797
Email: derek.gray@mcgill.ca

***Key Contact*:** Dr. Derek Gray

Most of the time during the short visit was spent with Dr. Derek Gray. He is researching a number of interesting projects involving [24]:

- Physical chemistry of cellulosics and wood polymers
- Surface properties of fibres and paper
- Preparation and properties of novel cellulosics
- Liquid crystalline phase separation of cellulosics, and chiroptical properties in dilute solution and in the liquid crystalline state
- Chiral nematic order in solid cellulosics, and in the plant cell wall
- Relation between chiral properties at the molecular fibrillar and macroscopic levels, including effects on paper curl
- Studies of the chemistry of brightness, reversion and luminescence spectroscopy of pulp and paper

Dr Gray was very interested in the PSF, in particular poorly formed sheets and would like receive sheets produced out of the normal operation (i.e. sheets formed during a malfunction with a 'poor' but interesting 3-D structure).

During the visit Dr. Murray Douglas who was involved in the invention of the OpTest PPF formation analyser (an instrument owned by Ensis Papro) was briefly met. His areas of research are:

- Formation, coating, drying, calendaring and paper quality
- Novel drying technologies including transport phenomena and superheated steam or air as a drying medium
- Improvement of uncoated and coated paper
- Simulation of pressing and drying of paper and drying non-uniformity
- Printability and mechanical property control through formation and drying
- Image analysis based partitioning of formation non-uniformity into components as a function of scale (or size) of formation
- Papermaking parameters, paper formation and property relations; and the rheological behaviour of paper in the nip at high speed for development of predictive CD control of calendaring

Appendix B - Itinerary

Table 3: Trip Itinerary

Date	Venue	Visit/ Activity
Saturday March 10		Depart Australia
Sunday March 11	Jacksonville, FL	2007 TAPPI Papermakers and PIMA International Leadership Conference
Monday March 12	Jacksonville, FL	2007 TAPPI Papermakers and PIMA International Leadership Conference
Tuesday March 13	Jacksonville, FL	2007 TAPPI Papermakers and PIMA International Leadership Conference
Wednesday March 14	Jacksonville, FL	2007 TAPPI Papermakers and PIMA International Leadership Conference
Thursday March 15	Jacksonville, FL	2007 TAPPI Papermakers and PIMA International Leadership Conference
Saturday March 17		Travel to Raleigh, NC
Monday March 19	Raleigh, NC	North Carolina State University
Tuesday March 20	Kalamazoo, MI	Western Michigan University
Thursday March 21	Orono, Maine	The University of Maine
Friday March 22	Montreal, Canada	Paprican
Friday March 22	Montreal, Canada	McGill University
Saturday March 23		Return to Australia
Monday March 26		Arrive in Australia

Appendix C - Glossary

2-D	Two dimensional
3-D	Three dimensional
AFM	Atomic force microscope
CCA	Ciba contaminant analyser
CSF	Canadian Standard Freeness
CSIR	Federal Council of Scientific and Industrial Research, the forerunner to CSIRO
CSIRO	Commonwealth Scientific and Industrial Research Organisation (www.csiro.com.au)
DAF	Dissolved air flotation
ECF	Elemental chlorine free
ENP	Extended nip press
Ensis	Unincorporated joint venture between CSIRO Division of Forestry and Forest Products and Scion (formerly New Zealand Forest Research) (www.ensisjv.com)
EPI	Epichloroihydrin
FDA	U.S. Food and Drug Administration (www.fda.gov)
FERIC	Forest Engineering Research Institute of Canada (www.feric.ca)
FFT	Fast Fourier transformation
FWA	Fluorescent whitening agent
gpm	US gallons per minute
kt	kiloton
LDPE	Low density polyethylene
MF	Machine finished
MG	Machine glazed
Mt	Millon ton (or Megaton)
NCSU	North Carolina State University (www.cfr.ncsu.edu/wps/)
NMR	Nuclear magnetic resonance
OBA	Optical brightening agents
PAM	Polyacrylamide
Paprican	Pulp and Paper Research Institute of Canada (www.paprican.ca/wps/portal/paprican?lang=en)
PDF	Papro Dynamic Former
PIMA	Paper Industry Management Association (www.pima-online.org)
Pitch	Sticky organic deposits on surfaces of paper machines
PPF	Paper PerFect
PSF	Papro Sheet Former (www.ensisjv.com/Portals/0/Tier7-PilotScaleFormer.pdf)
TAPPI	Technical Association of the Pulp and Paper Industries (www.tappi.org)
TCF	Total chlorine free
UCWF	Uncoated wood-free
UoM	The University of Maine (www.umche.maine.edu/pssp/)
WMU	Western Michigan University (www.wmich.edu/pci/)
US	United States of America
WA	Western Australia

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