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The National Educational Trust of the Australian Forest Products Industries

GOTTSTEIN TRUST

ADVANCES IN PAPER COATING

STEVEN LOFFLER

2003 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.

Further information may be obtained by writing to:
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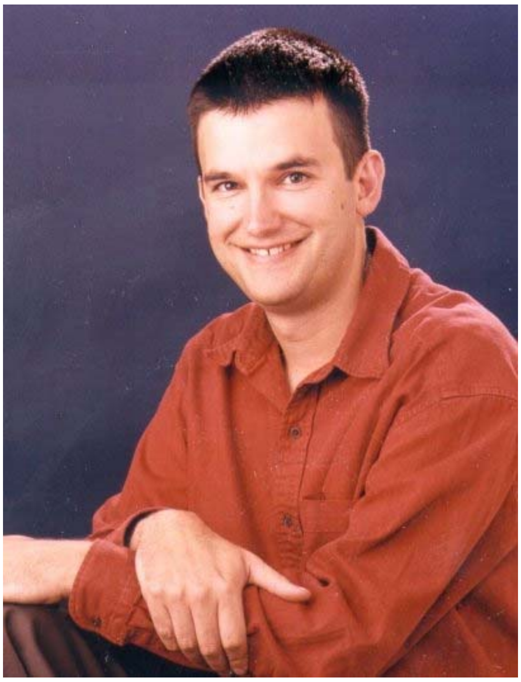

Steven Loffler currently works as a Senior Research Scientist in the Mill to Market Centre of Excellence in the CSIRO Division of Forestry and Forest Products.

His research centres on the adding value to paper products through coating and printing applications. He has leadership for two projects in the Cooperative Research Centre for Functional Communication Surfaces, and has involvement in a number of other projects within the CRC.

Prior to joining CSIRO, Steven worked as a post-doctoral fellow at the University of Melbourne, and as an engineer in the oil and gas industry.

Steven has a PhD from the University of Cambridge in the UK and a BE (Hons) in Chemical Engineering from the University of Adelaide.

Executive Summary

This report details the findings of a visit to a number of research institutions in North America and Europe in May 2003, as well as to the 8th Tappi Advance Coating Fundamentals Symposium held in Chicago.

The research discussed at the Tappi Advanced Coating Fundamentals Symposium, and being undertaken at the organizations visited, covers a wide variety of areas encompassing coating formulation rheology, fundamentals of coating application, coating structure, and surface evaluation techniques. The majority of work being undertaken appears to be focussing on making incremental improvements to existing coating processes and grades. Comparatively little research is being undertaken in novel coating processes or in novel formulation development.

After reviewing the state of international research in paper coating, it is that in order to best serve the Australian paper industry, it is recommended that Australia's fundamental paper coating research concentrate on the following areas:

- New formulations incorporating **new chemical components** with the aim of developing multifunctional printing options such as simultaneous offset and digital printing capability
- **Emerging Processes –** spray and plasma coating
- **Active Involvement** in the development of an ISO standard for colour inkjet printing.

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Introduction

Despite having abundant plantation hardwood and softwood fibre resources, Australia imported over $1 billion of printing and writing and newsprint paper grades in 2000-2001. A large proportion of this was in areas of value-added paper grades, including coated grades for conventional printing, and specialty grades for digital printing and other new applications. Most of the process chemistry associated with the processes needed to manufacture these paper grades is highly proprietary and not available to the local industry. The only real way to address the significant balance of trade deficit in this area is therefore through local research and development of new coating chemistries that will assist Australian paper manufacturers.

CSIRO Forestry and Forest Products has invested heavily in paper coating research over the last few years, and has built up the only publicly available research facility in Australia for research into paper coating and surface enhancement.

The objective of the studies undertaken within this Gottstein Trust Fellowship was to benchmark our own studies and facilities within CSIRO Forestry and Forest Products with world's best practice and to incorporate the latest learnings and techniques from overseas laboratories into our own. By doing so, CSIRO will be able not only to enhance the services provided to Australia's paper industry in this important area, but also to influence positive changes in our Forest Products Industry and the contribution it makes to the national Gross Domestic Product.

The specific objectives of the visits to similar institutions to CSIRO in Europe and North America working in this field was to see how they:

Evaluate products by:

- Chemical and rheological assessment of coating formulations
- Assessment of print performance
- Use of standard testing instruments
- Development of in-house techniques

Develop a balanced research portfolio of

- Research into base paper smoothness (important to minimise coating costs)
- Research into improved manufacture of conventional products (e.g. lightweight coated paper grades)
- Research into novel products (e.g. multi-purpose papers for inkjet and offset printing)

Assess the state, and future direction of the industry by

- Forecasting the major growth products, and those about to decline
- Predicting what surface enhancement can be done on the paper machine at the size press

Develop partnerships with

- Paper companies
- Chemical supplier companies
- Ink manufacturers
- Printing equipment manufacturers
- Other research enterprises

Why Coat Paper?

Coating improves the printing properties of paper. Typically, coating is applied to one or both sides of paper using an aqueous suspension, referred to as the coating formulation or the coating colour.

Coating will fill the cavities that form in the fibre web, but for consistent printing properties the highest fibres on the base paper must also be covered in coating. Some methods produce a relatively uniform thickness of coating on the uneven base paper surface, whereas other methods preferentially fill the cavities and low areas of the sheet.

The coating formulation generally consists of a pigment, small particles with particle sizes less than 10 μm; the binder, which assists in the attachment of the pigment to the base sheet; and assorted other additives included for functional properties in the suspension (such as thickeners, dispersants, pH modifiers, lubricants and biocides). These components are dispersed in water, with the water content being as low as 30% w/w in some formulations.

As well as improving the look of the paper, the coating must be strong enough to withstand the printing process. The ratio of the binder to the pigment is therefore critical – too little binder can lead to detachment of the pigment in printing, whereas too much can cause low opacity or gloss.

Coated papers have the following properties relative to uncoated papers:

- Improved smoothness
- Increased surface strength
- Increased opacity
- Decrease ink absorption
- Lower mechanical strength

Coated Paper grades

The key classification criterion in printing and writing grades is the nature of the raw material, pulp. Grades from mechanical pulp dominated the lower end of the price and quality graph, whereas those at the upper end of the scale tend to be made from chemical pulps.

Mechanical pulp dominated grades

Mechanical pulp dominated grades, also known as wood-containing papers comprise newsprint grades, supercalendered grades and coated mechanical grades. They have good opacity and good printability even at low basis weights, and as the price of mechanical pulp is lower than chemical pulp, are less expensive to produce than chemical pulp grades. The tendency of mechanical pulp papers to yellow when exposed to ultraviolet radiation means that they have limited use for products with a long life cycle.

Coated mechanical grades

Coated mechanical grades consist mainly of high-quality mechanical pulp where long fibre chemical pulp is used to give it strength.

Light weight coated (LWC) grades

LWC papers have between 5 and 12 g/m^2 coating per side. Typically, the end use of these grades is in magazines, catalogues, inserts and commercial printing. Basis weights are typically anywhere from 35 to 80 g/m^2, of which 6-12 g/m^2/side is coating. Important properties for these grades are good smoothness with minimal roughening tendency when drying printing ink as well as print gloss. Fibre furnish is typically 50-70% mechanical pulp with 30-50% chemical pulp. The most common coating pigments are clay, calcium carbonate and talc.

LWC paper is printed typically by offset or rotogravure methods, which have different quality demands on the paper. Papers printed with offset printing need good surface strength to avoid accumulation of debris and dust on the printing blanket. Consistency of z-directional strength and porosity is also important. Rotogravure printing inks are of a lower viscosity, and thus paper density needs to be sufficient to stop excessive penetration of ink through the sheet. Smoothness and compressibility are also important.

The most frequently used coating technology for LWC papers is blade coating.

Medium weight coated (MWC) papers

MWC papers have coat weights between 12 and 25 g/m^2 per side. They are used for high-quality special interest magazines. The basis weight varies between 70 and 130 g/m^2 with 70-90 being the typical weight. Base paper is made from 40-55% mechanical pulp with 45-60% chemical pulp.

Heavy weight coated (HWC) papers

HWC papers are traditionally produced at a basis weight level of 100-103.5 g/m^2, and can be double or triple coated.

Figure 1 shows the relationship between basis weight and brightness for the range of coated mechanical paper grades, showing the progression from the light to heavy weight grades.

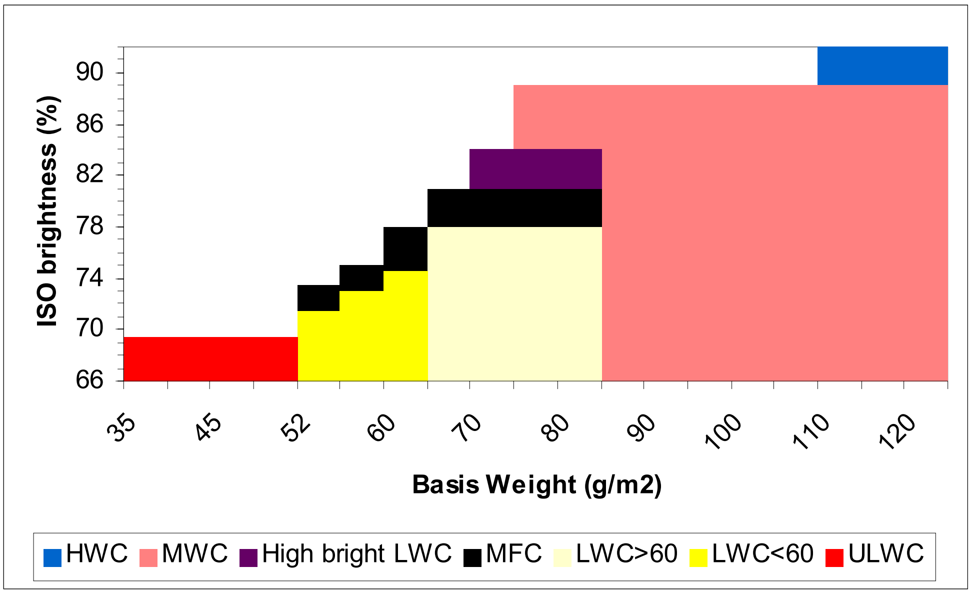

Figure 1 – Relationship between ISO brightness and Basis Weight *[Paulapuro, 2000]*

Film coated offset (FCO) papers

Film coating technology was introduced in the mid 1990s to produce papers that are primarily used for special interest magazines and catalogues. FCO papers typically have a basis weight between 45 and 65 g/m^2, and have high bulk, and good surface strength, but have higher roughness than LWC grades.

Coated Woodfree Grades (WFC)

Woodfree paper (i.e., grades containing less than 10% mechanical pulp) are coated in basis weights from 55 to 170 g/m^2, and with coat weights between 3 and 14 g/m^2 per side. They compete in the marketplace with high brightness LWC and MWC grades.

Table 1 shows the coating techniques typically used to generate the range of coated paper grades described in this section.

Table 1 – Coating techniques used for different paper grades *[Paulapuro, 2000]*

Coating Technique	Coated Paper grade(s)	Basis weight g/m^2
Film	ULWC, LWC, FCO	<60
Short dwell blade (SDTA)	LWC	40-60
Long dwell blade (LDTA)	LWC	35-70
Film + LTDA	MWC, WFC	70-100
SDTA + LDTA	MWC, WFC	75-120
LDTA + LDTA	MWC, WFC	80-150
Film + LDTA + LDTA	WFC	100-170

Coated Paper Grades – Markets and Growth

Coated paper grades make up approximately 20% of total world production of paper grades. As figure 2 shows, the biggest percentage growth of any paper grade is for coated woodfree sheets, with a 10% annual growth rate.

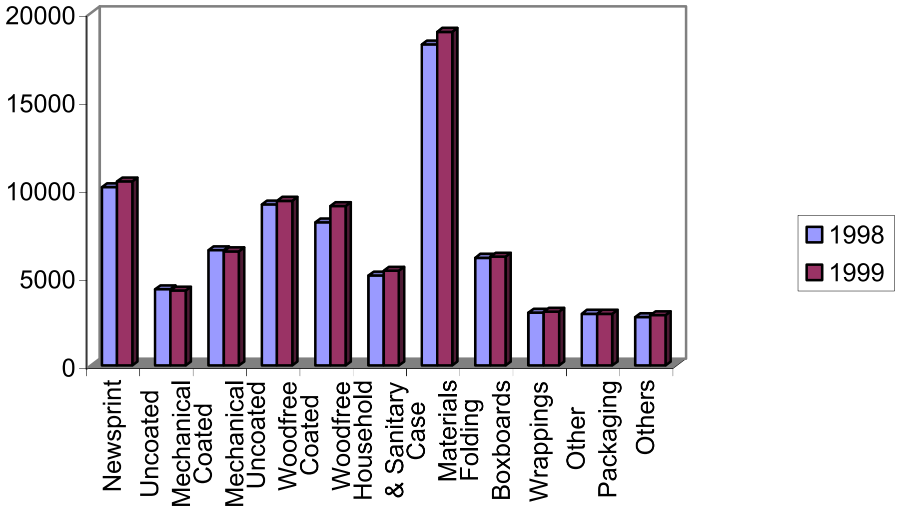

Figure 2 – World production of paper grades (from www.cepi.org)

ABARE statistics (Figure 3) show the dominant position of printing and writing grades in the import of pulp and paper products into Australia. Coated papers, being high value printing and writing papers, comprise a large fraction of the over $1 billion annual imports in these grades.

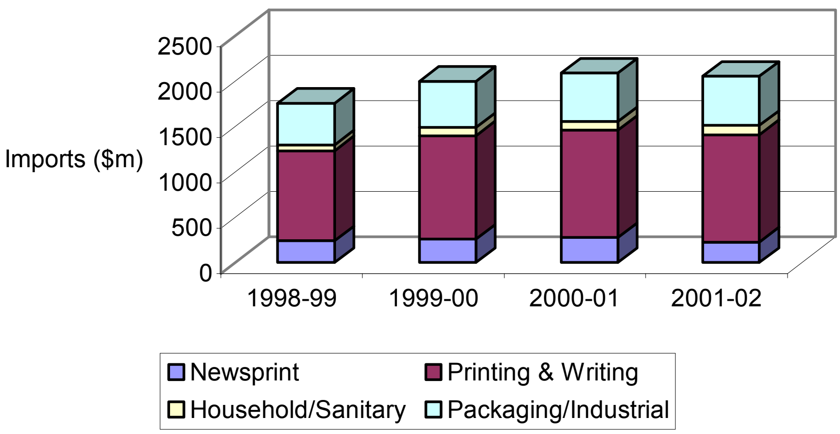

Figure 3 – Importation of paper grades into Australia *[ABARE, 2002]*

Pigments and Binders for Paper

Efforts to coat paper with pigments date back several hundred years. Early coaters (in the late half of 19^{th} Century) used a brush to apply a coating and several brushes to smooth the coating prior to drying.

By 1920 pigment coated paper was a commercial commodity, with approximately 100,000 tones/year produced in the USA. The dominant pigment was coating clay, and common binder was animal glue.

Pigments

Desirable pigment properties for inclusion in paper coating formulations include:

- Low solubility in water
- Chemical solubility
- Brightness
- Opacity
- Dispersability in water
- Good properties as an aqueous suspension
- Chemical stability and compatability with other formulation components
- Inexpensive

The three primary pigments used in paper coating that meet most of these demands are kaolins (clays), ground calcium carbonate and talcs.

Kaolin

Kaolin has been used in the paper industry since the 18^{th} century, and in paper coating since the 1870s. As a widely occurring mineral, it is relatively cheap to produce, and has advantages in terms of good whiteness, ease of processing to a fine particle size, and it's platey particle shape, which enables particles to pack in an ordered structure. Kaolin suspensions of up to 60% can be achieved.

Ground Calcium Carbonate

The use of ground calcium carbonate in coating formulations commenced in Europe in the 1960s. Ground calcium carbonate has good rheological properties in suspension, and can be run at higher solids content than can kaolin. It also produces higher brightness properties than does kaolin, and thus is preferred for higher quality product.

Talc

Talc was first used as a coating pigment in Finland and France in 1982, and since then has been widely used in LWC grades. The major advantage of talc coated grades relative to other pigmented grades is increased smoothness

Other Pigments

A range of other pigments, including titanium dioxide, gypsum, aluminium trihydrate, silica and precipitated calcium carbonate all have application in pigment coated papers. High glass transition point organic polymeric latexes based on styrene have also been successfully used to improve optical and print properties of paper and paperboard.

Binders

Binders are required to bind the pigment particles to the base paper; to bind the pigment particles to each other; and to partly fill the voids between the pigments in the coating structure. The ideal binder would have many of the following properties:

- Good binding capacity
- Good water retention
- Water soluble or miscible
- Compatability with other coating components
- Good optical and mechanica properties
- Chemical and mechanical stability and durability
- Non toxic, odourless
- Low foaming characteristics
- Inexpensive

The most common binders used are natural polymers (starch, protein, cellulose derivatives), latexes (styrene butadiene, styrene acrylate, polyvinyl acetate), and synthetic (polyvinyl alcohol).

As the paper industry moves to increase both the range of use of existing paper grades and to develop new grades, there has been increased interest in developing the functionality of the pigments and binders used in the coating formulation. Rather than just being used to increase opacity or to enhance pigment – fibre binding, coating components are being sought that provide extra hydrophobicity (for barrier coating applications) or other functional advantages.

The Paper Coating Process

Paper coating can be divided into four phases.

- **Application** of the coating formulation onto the base paper
- **Metering** the coating (removing excess coating to a desired level)
- **Drying** the coating
- **Finishing** phase – usually supercalendering

The following section will deal with the technologies routinely used to apply and meter the coating onto the surface of the paper. Although both drying and finishing are areas of research and development, they will not be dealt with in this report.

Coating Technologies

Blade Coating

Blade coating processes for paper date back to the 1940s, although related patents can be found as early as 1906. Blade coating is still the dominant process in producing a range of paper grades.

Most blade coating processes involve the application of an excess amount of coating to the paper web, typically using an applicator roll, followed by removal to a set coating weight with a metering blade. Pneumatic pressure is used to force both the applicator roll and the blade against the moving web. The pressure in the nip between the applicator and backing rolls promotes good adhesion of the coating to the paper web. The blade material is usually steel and the blade thickness ranges from 0.3 to 0.6 mm. Figure 4 illustrates the basic mechanism of blade coating. Changes in the basic configuration shown at the applicator roll (fore example, by the use of a contact shoe rather the applicator roll) can increase the dwell time and change the amount of coating applied to the sheet.

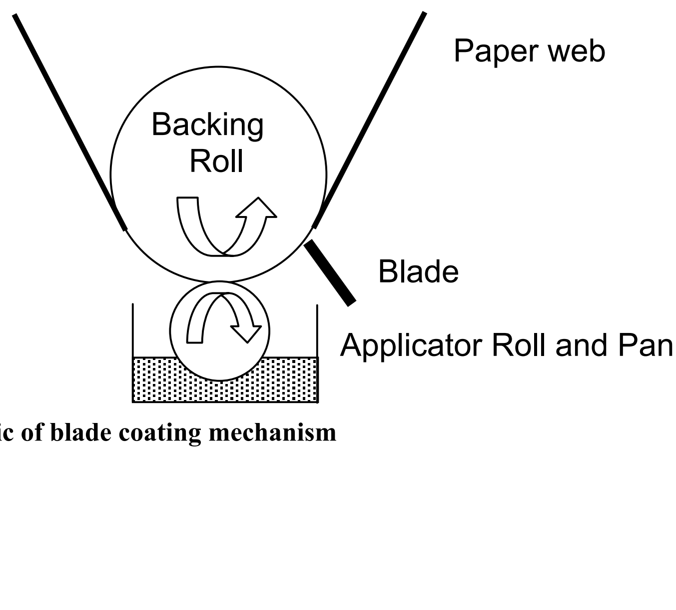

Figure 4 – Schematic of blade coating mechanism

By the nature of the process, blade coated papers tend to produce a sheet in which the coating thickness may vary but the end product has a relatively smooth surface.
The blade runs on the top of the highest peaks of the paper. The higher the roughness of the paper, the more coating colour stays on the paper for a given blade pressure.

Air Knife Coaters

In air knife coating, a jet of moderate to high velocity air impinges on the coated substrate at an angle of the order of 45^o opposed to the substrate movement. The jet shears the liquid coating film and removes the excess as a liquid mist, which is then collected and reused.

The application of the coating is in a similar manner to blade coating, an excess of coating is applied to the sheet in the applicator. Water begins to migrate from the coating to the web, and the coating begins to dry. The air knife acts to split the coating at the point between the dried section of the coating layer adjacent to the paper web and the wet section at the surface. The exact point at which this split happens is a function of the energy in the air jet – a higher velocity jet will penetrate further in to the coating layer and remove more coating, leaving a lower coat weight on the sheet.

Roll Coaters and Size Presses

Roll coaters are often used in the paper manufacturing process as part of "sizing", or pre-coating the paper on the paper machine. As illustrated in Figure 4, the paper web runs between two cylinders, and the nip in between the cylinders is flooded with sizing solution. The cylinders act as the metering part of the size press. Size presses can be configured with the primary cylinders arranged vertically, horizontally or inclined (as shown in Figure 5).

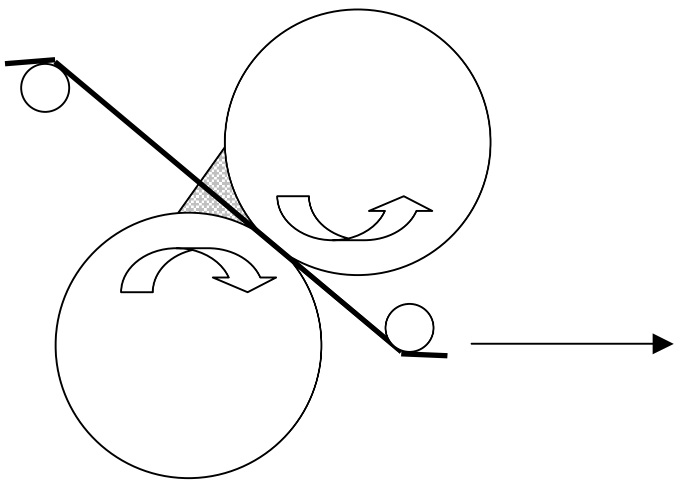

Figure 5 – Inclined size press with puddle at entry point to nip.

A major operational limitation in size presses is the phenomenon of film splitting. Although most of the size solution in the nip is absorbed into the sheet, some solution remains on the surface of the sheet between the paper and the roll. This excess is split into two layers, with some remaining on the roll and some being transferred to the sheet. A characteristic orange peel pattern emerges on the sheet as a result of the split of this layer, the magnitude of which is dependent on the rheology of the size and the absorptive characteristics of the paper web.

An alternative configuration for size press involves metering the size onto the roll, rather than using a puddle at the nip. This configuration is illustrated in Figure 6, and gives greater control of wet film thickness and solids content on the sheet.

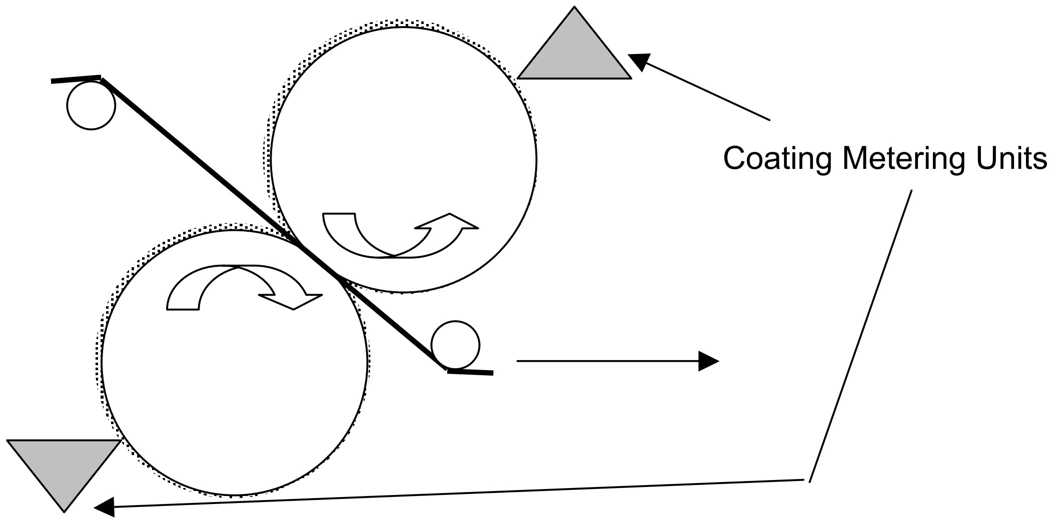

Figure 6 – Metered size press configuration – metering units apply a controlled amount of coating to the applicator rolls.

There is great interest internationally in developing coating formulations compatible with size press application. This prevents an additional production step in the transfer of the uncoated paper from the paper machine to the paper coater, with corresponding cost savings and reduction in waste.

Basestock Characteristics

Because anywhere up to 90% of coated paper content is the base paper, the properties of the base paper are important in determining the characteristics of the final coated product. Despite this, very little research appears to be undertaken into basestock qualities for optimal printing.

Some of the most critical properties of the base paper are:

- Strength (tensile, tear)
- Profile (basis weight, caliper, moisture)
- Good formation
- Opacity, brightness
- Porosity and pore size distribution
- Roughness
- Stiffness
- Compressibility

Runnability and the ability to achieve consistent coating coverage are the two major concerns of the paper coater. Runnability is a measure of the ability to get the paper through the coating process at maximum rates with minimum production downtime due to mechanical failure of the paper web, or due to the need to clean the machine if fibres or defects detach from the web.

Consistent coating coverage, particularly for blade-coated grades, relies on a smooth base paper. The blade runs of the highest peaks of the paper, and therefore the higher the roughness, the more coating is forced into the valleys of the fibre web. However, if the paper is too smooth, there blade pressure is low causing poor coating profiles. Bad formation can also cause uneven binder distribution, which can manifest itself in mottled print images.

International Research in Paper Coating

Comparison of Coating Equipment

The research institutions visited had a wide variety of coating equipment, ranging from drawdown units able to coat a single sheet of paper at very low rates, up to full scale pilot facilities rated at over 3000 metres/minute available in a number of configurations. The equipment available at each institution is detailed in Table 2.

The use of drawdown coaters in quickly assessing formulation viability is widespread. Drawdown units have the advantage of being easy and inexpensive to operate, and require very little in the way of paper or coating colour for testing. Their speed of operation is of the order of 1-2 metres/minute, which makes them an order of magnitude slower than laboratory coater, and two orders of magnitude slower than a pilot coater or on-machine coating. A typical drawdown coater is shown in Figure 7.

Figure 7- Drawdown coater for low speed coating of individual paper sheets.

The CLC-6000 helicoater (see Figure 8) is present in a number of the institutions visited. Able to operate at a speed of up to 2000 metres per minute, it replicates on-machine speed well. However, the coater has been reported by some users to be difficult to operate at maximum speeds, and some of the research institutions visited (notably STFI) have reported difficulties in comparing results obtained on the CLC-6000 with those from pilot coating studies or mill trials. It would appear that the helicoater finds its best use in understanding how problems develop with coating consistency under the types of shear rates found in industrial applications. The new paper coater at APPI launched this year will be similarly useful in understanding these issues.

Table 2 – Comparison of coating facilities at research institutions visited

	CSIRO FFP	Western Michigan University	Paprican	University of Maine	STFI	HUT	KCL	CTP
Drawdown	√	√	√	√	√	√	√	√
Laboratory Coater	√ 100 m/min blade, rod, MSP modes	√ 250 m/min blade, rod, air-knife modes				√ 100 m/min blade, rod, MSP modes		√
CLC-6000 Helicoater		√	√	√	√	√	√	√
Pilot Plant coater		√ 1220 m/min 1 m web width blade, rod, MSP, pond size press					√ 3000 m/min, 550 mm, blade, rod, MSP	√
Other		Impregnator		Size press on pilot paper machine			Rapid Sheet Coater (100 m/min)	

Figure 8- CLC-6000 Helicoater at the University of Maine

A number of institutions (including CSIRO) have laboratory coaters operating typically at speeds of 100 metres per minute. The CSIRO laboratory coater (made by ENZ technology in Switzerland under licence from Dow Chemical) can be converted in a few minutes from a metering size press mode to a blade or rod coating mode, and can coat weights from 0.5-20 g/m^2 on base stock from 20-250 g/m^2, at web speeds up to 100 m/min. Such coaters can be used to rapidly assess a number of different chemical formulations on the same paper web, at a much lower cost than using a full scale pilot plant.

Figure 9 – Helsinki University of Technology's paper web coater

Figure 10 – CSIRO's paper web coater

Full size pilot coaters were visited at Western Michigan University, KCL and CTP. These machines are able to operate at web speeds up to 3000 m/min, and can usually be configured in a range of operating modes, including blade, rod, metering and pond size press operations. Although the speeds of operation replicate those of mill machines, and although Western Michigan University's plant is brand new (donated by International Paper Company to the University), the high daily operating cost (from US$15000 to 20000 Euro per day) and the large consumption of paper and chemicals means that these machines are infrequently used.

Figure 11 – Paper Coating Pilot Plant at Western Michigan University

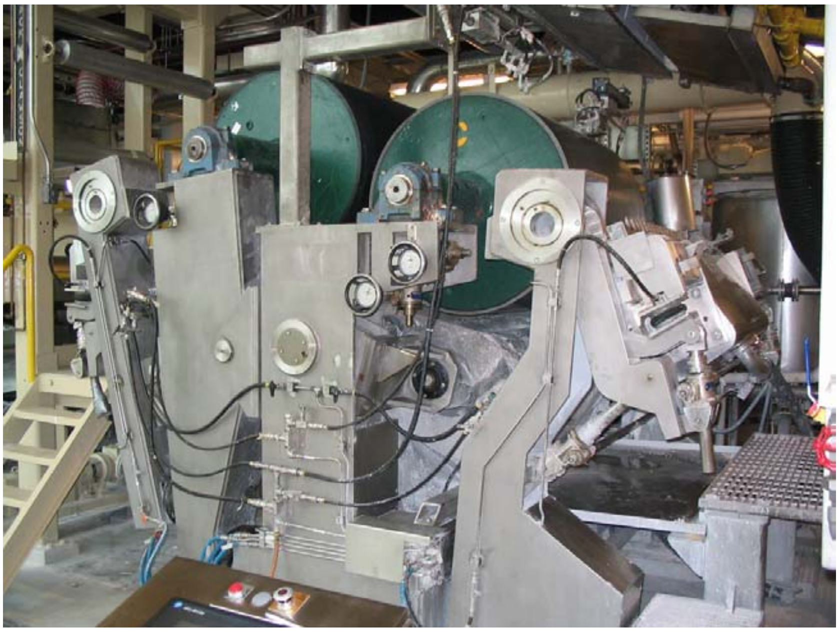

Figure 12 – Detail of coating applicator unit on Paper Coating Pilot Plant at Western Michigan University

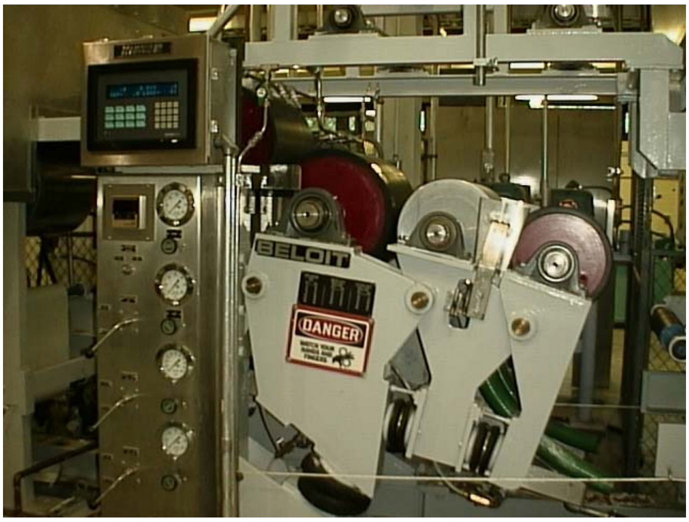

Figure 13 – Size Press Unit on Pilot Paper Machine at the University of Maine

Other coating operations worthy of mention are the Impregnator unit at Western Michigan University, and the Plasma Enhanced Chemical Vapour Deposition (PECVD) used by Phillipe Tanguy's group at Ecole Polytechnique in Montreal. The Impregnator unit uses an adjustable pressure shoe to implant coating into the paper, and research has proved that it can be used to control the depth of penetration of coating into the fibre web. It has been used to impregnate lignosulphates into linerboards, allowing the fibre usage to be decreased by one third, while still providing increased stiffness without decreasing gluability. The PECVD unit is used to apply thin films of substances such as silicon dioxide for barrier coatings.

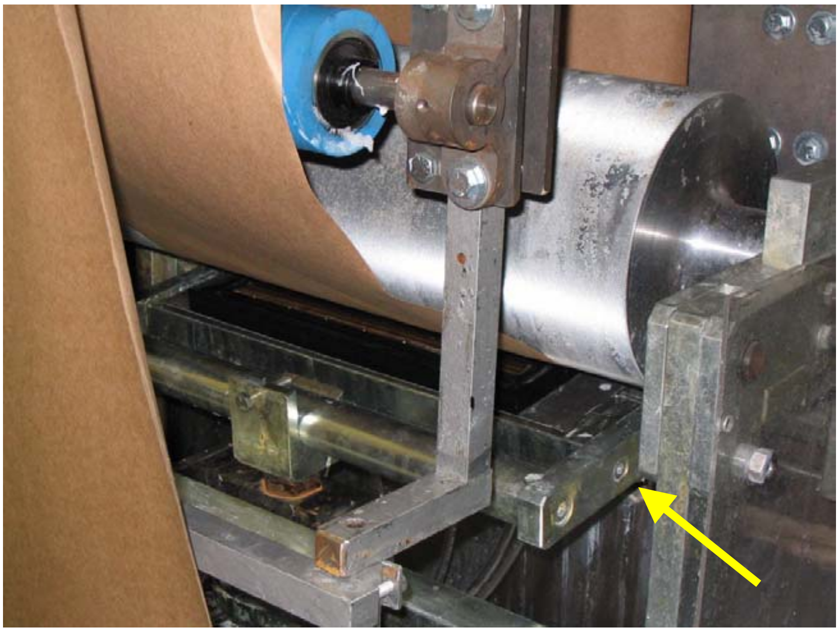

Figure 14 - Detail of Impregnator Coating Unit at Western Michigan University, showing adjustable pressure shoe

Chemical and Rheological Assessment

A range of assessment techniques are used to look at both the deposition of coating on the fibre web surface, and also to characterise the rheology of the coating formulation to be applied. Most of these techniques would be considered standard for surface studies, including:

- Scanning Electron Microscopy (SEM), including environmental SEM
- dynamic Contact Angle measurement
- mercury intrusion porosimetery
- nitrogen adsorption
- Atomic Force Microscopy
- XPS (ESCA)
- Scanning UV-Visible spectrophotometry
- FTIR analysis

All of these techniques are available either at CSIRO, or at collaborating organizations, and are widely used in analysing uncoated and coated substrates. There appears to be no area to dramatically improve the scope of characterization techniques available to CSIRO FFP at this stage.

Rheological research is being widely undertaken at a number of the institutions visited, although it is noteworthy that at least one organization (CTP) is withdrawing from research in this area. The papers presented on the session on rheological research at the Tappi Advanced Coating Fundamentals Symposium in Chicago (by speakers from Stora Enso Research, the University of Toronto and Ecole Polytechnique, Montreal) were focussed either on looking at very specific coating formulations (calcium carbonate with a narrow pore size distribution), or under conditions that are believed to correlate to a specific geometry or set of strain conditions.

Many researchers mentioned the importance of mimicking the geometry of the process in measuring rheological properties during that process, and the research carried out (notably at Ecole Polytechnique and Helsinki University of Technology) would appear to be concentrating on replicating these conditions.

Given the amount of research already being carried out internationally in the rheological characterization of coatings, and the strength in this area already present at both Monash University and the University of Melbourne, it would not appear worthwhile for CSIRO to carry out fundamental work in this area.

Standard Testing Instruments

Most of the laboratories visited had what would be considered a standard set of laboratory instruments for measuring printability and for spectrophotometric assessment of print quality. Image Xpert appears to be the tool of majority choice in assessing digital print quality.

In House Techniques

Some organizations, particularly STFI, are developing a significant range of both software and hardware tools and techniques in assessing both coated paper quality and printed paper quality. Of particular interest are the psychologists employed by STFI, and used by Paprican (from McGill University) to help correlate subjective print analysis with objective parametric measurements. It is recognised within the Australian Paper Industry that the consumer perception of print quality is vitally important in the uptake into the marketplace of products produced for printing and writing, and research effort has already gone in to understanding the drivers for consumer preference. In order to help the papermaker and the producer of coated paper, these preferences need to be correlated with either on machine or laboratory measured parameters of print quality, so that controls in the production process can be implemented to ensure that these parameters are met.

KCL have also developed a modified Xerox Docufeeder 40 with 2 printing transfer units, a variable transfer voltage between 0 and 10 kilovolts, and a variable speed between 100 and 160 mm/sec for assessing electrophotographic transfer of toner to paper. There was surprisingly little research being done elsewhere in toner transfer or ink-jet droplet production and deposition. Although most research groups appeared to take these two areas as areas that are set by the manufacturers of digital printing equipment, development of a fundamental understanding of inkjet ink/paper and toner/paper interactions would appear to be critical in designing papers to best meet these needs.

Coating Structure Research

Some significant papers were presented at the Tappi Advanced Coating Fundamentals Symposium on the simulation of particle packing and subsequent pore network formation in pigment coating processes. This research appears to be conducted largely by two pigment suppliers (IMERYS and OMYA, via their sponsorship of research at the University of Plymouth), and by a small group at Paprican.

This research area has evolved rapidly over the past two years, from considering random packings of spheres to looking at ellipsoidal particles (used to represent platelets of clay) and hyperellipsoidal needle-like structures (used to represent precipitated calcium carbonate). Although this is a major advance, to move further into more complex geometries (such as polyhedra) or into other than mono-sized particles using current Monte-Carlo simulation methods would be prohibitively difficult in terms of the demand on CPU capability.

Research Portfolios

The balance of research being carried out internationally appears to be biased towards making incremental improvements in the current range of coated paper grades, rather than in the development of novel grades such as multifunctional papers for multiple serial printing (e.g. offset and digital on the same print run). This may be a function of the ownership models of the organizations visited, in which the involvement of more than one owner company on any given project may mean that the companies prefer to keep the ground breaking research in-house rather than potentially losing their competitive advantage.

Nevertheless, CTP in particular appear to be moving down the path of developing new products, having spent time looking at starch and pigment coatings for enhancing newsprint, as well as conducting research into novel coating techniques. Paprican also are looking at multi-printable papers, but are approaching this from the perspective of modification of the printing process in preference to modification of the paper. This approach would appear to have limited possibility, as modification of a single substrate would appear to be a simpler task than the modification of a number of printing processes.

Most of the research groups appear to take the quality of the basestock as a given, a parameter at the start of the coating process that must be dealt with. KCL in Finland appear to be the organization closest to taking the step to “design” the surface of the basestock to best facilitate high quality coating, although other organizations (notably Paprican and the University of Maine) would be in a position to take such a holistic approach to developing coated paper products.

Significant steps are being taken by both KCL and CTP to develop their research into calendering, with almost industrial scale calendering equipment being recently installed at both institutions. Both organizations have a number of smaller scale test units for calendering of individual sheets, or for control of the process at a single nip to understand the web compression processes happening at that nip.

Collaborative Research

The range of internationally collaborative research happening in paper coating was impressive. The University of Maine appears to be an exceptionally strong hub of paper coating research internationally, with collaborative projects with Universities and research organizations in Canada (Paprican), Great Britain (The University of Plymouth), Sweden (STFI) and Finland (Abo Akademi, KCL, HUT and Tampere University).

Some of the research organizations appear to be inhibited somewhat either by the possibility of a conflict of interest in serving their member companies and developing collaborative programs with other research groups that may have competitive sponsors, or in the case of government owned or funded organizations, a conflict between serving the needs of the nation and developing partnerships with competing nations. The fact that the University of Maine with its 18 sponsoring organizations is able to balance these tensions is a reflection partly of their excellent attitude to collaborative work, but also to the nature of their research, which largely concentrates on fundamental understandings of the mechanism of coating transfer to the paper web and of ink-coating interactions, particularly for offset printing.

There also appears to be excellent collaboration between some chemical supply companies (particularly pigment suppliers)) and research institutions – notably between OMYA and the University of Plymouth. There is little collaborative work between the organizations visited and ink manufacturers, or printing equipment manufacturers, again largely due to the tension that the suppliers they may choose to partner with may not be the partner of preference for one or more of the sponsoring companies for these organizations.

Opportunities in Paper Coating Research

Paper Coating Formulations

Perhaps surprisingly, little work is being carried out within the research institutions visited on the development of new coating formulations. This is probably a reflection of the chemical engineering background of the university departments, and the associated engineering tendencies of the other research institutions. This background manifests itself in research into film splitting in metering size press coating, misting and filament formation in blade and rod coating, and transfer of coating onto the paper web from the applicator roll. While these areas are of fundamental importance in the development of high quality coated paper products, this does leave opportunities to develop new or improved chemicals for formulations – a province largely left to chemical supply companies at this stage.

This may also be related to the equipment used. It would appear that the CLC-6000 helicoater, which appears to be a staple research tool in Northern Hemisphere paper coating research laboratories, provides coated paper products that bear little or no resemblance to that made on the paper machine. The helicoater finds more use in developing understanding of rheological issues and the development of instabilities. Pilot paper machines are extremely expensive to operate and thus are suitable primarily for troubleshooting of on-machine problems by simulation in a controllable environment, or for the final proof of concept prior to full production of a new product. It would appear that the use of moderate speed laboratory coating equipment is the best way to assess rapidly a range of formulations with different chemical or physical (e.g. pigment size distribution) properties in a comparative way.

Strong opportunities exist for CSIRO Forestry and Forest Products in this area. By forming a “critical mass” of research effort, and including researchers from a combination of CSIRO’s Division of Molecular Science, and from Chemistry Departments in Australia (particularly at Monash University and the University of Wollongong, with which collaborative research programs already exist), new chemical formulations can be developed. These could prove useful either for specific niche products, or to introduce new functionality to existing products – such as digital printability or barrier coating.

Novel Coating Techniques

Although much interest was expressed in non-contact coating techniques, relatively few institutions are actively involved in research in this area. This may partly be because the nature of the funding of the institutions who operate under an industry level model may mean that they tend to work on incremental improvements to existing processes used by their member companies.

The two main novel coating techniques worth further investigation are spray coating and plasma deposition. The advantages of both these techniques is that it may be possible to more uniformly deposit the active chemical ingredient in the formulation in a thinner layer than is possible with conventional techniques. By doing so, the possibility of using more expensive chemicals, whose cost may be prohibitive in a thick (multi-micron) coating, may be explored. Further, chemicals that would be unsuitable for application in an aqueous solution may also find application. VO_2 has been suggested as a pigment for use where thermo chromatic properties are desirable, and titanium dioxide and silver, if coated on in mono-molecular levels, may prove cost effective in providing anti-microbial properties to paper products.

Abo Akademi and Tampere University in Finland are amongst the few groups doing research in the area of spray coating of paper webs, and Philippe Tanguy's group at Ecole Polytechnique in Montreal are the only group encountered working in the area of plasma deposition.

There is also some interest in using digital printing techniques to apply very thin films of coating in a non-contact way. In the same way that roller coating evolved from the printing industry, it has been suggested that inkjet printing could be used to apply dispersions of nanopigmented coating in the same way that the technique applies dispersions of nanopigmented ink currently. By combining such a method with evaluation of the surface topography of the sheet being coated, it should be possible to target the "printing" of the surface coating to the regions of the sheet that most need it. Inkjet printing techniques currently have the disadvantage of speed relative to conventional coating, but evolution in the development of print heads would be expected to overcome these issues in the near future.

Assessment of Print Quality

As discussed earlier, the assessment of print quality whether by the consumer or the printer is a highly subjective process, and correlation between this assessment and measurable parameters is critical in the production of quality paper products for printing.

In 2001, The International Standards Organization (ISO) released a standard (ISO 13660) for the assessment of monochrome inkjet print quality. The ISO has also set up a number of sub-committees looking at the various critical parameters in determining colour inkjet print quality, with the aim of producing an ISO standard for the assessment of colour inkjet print quality.

Australia has no current representative in this process, and there is an opportunity to be involved in determining what this standard should be. The opinions of the technical representatives of the Australian paper industry need to be communicated to the ISO committee, and the Australian paper industry also need timely feedback as to what parameters will be important in determining colour print quality, so that changes can be made in the papermaking and coating processes if appropriate.

Collaborative Opportunities

All of the institutions visited expressed an interest in developing collaborative links with CSIRO on mutually beneficial projects. As highlighted earlier, CSIRO Forestry and Forest Products is in a strong position to develop a range of novel coating formulations through linkages with the Chemistry Departments of Australian Universities, and employing the paper web coater in the division to rapidly assess the feasibility of a number of formulations.

In order for collaborative research to be beneficial to CSIRO and to the Australian paper industry, expertise must be brought in from the partner organization that complements rather than replicating locally available skills. The areas that would appear to be a weakness for local research are scale up to industrial scale from the laboratory level, and understanding of fundamental issues such as film split in metered size press coating.

Pilot scale coating trials are likely to be prohibitively expensive for Australian paper companies to run in the Northern hemisphere. The opportunity for local research to scale up to pilot levels would be limited.

The work of Paprican, particularly through its linkages to Ecole Polytechnique in Montreal, would appear to best dovetail with the second objective. However, until research into novel formulations has been advanced to a level where understanding the fundamental coating issues for these particular formulations is of concern in developing new products, pursuing active collaboration is probably premature.

Conclusions

The research discussed at the Tappi Advanced Coating Fundamentals Symposium, and being undertaken at the organizations visited, covers a wide variety of areas encompassing coating formulation rheology, fundamentals of coating application, coating structure, and surface evaluation techniques.

The majority of work being undertaken appears to be focussing on making incremental improvements to existing coating processes and grades. Comparatively little research is being undertaken in novel coating processes or in novel formulation development.

Concentrating the research effort for the Australian paper industry into developing new products either by emerging processes (such as spray coating or by plasma deposition) or novel processes (such as adaptation of digital printing techniques to apply nanopigmented coating particles), or by the design and use chemical systems with enhanced functionality for specific purposes (such as improved toner adhesion, ink receptivity or barrier properties) will give the local industry the best chance of producing breakthroughs that will help international competitiveness.

Appendix A – Notes from organizational visits

Western Michigan University (12 May 2003)

Key Contact: Dr. Margaret Joyce

Margaret Joyce is an Assistant Professor for the Department of Paper and Printing Science and Engineering at the University of Western Michigan. Her research interests include coating and ink rheology, water soluble polymers, surface chemistry, paper and ink interactions, paper coating processes, paper coating formulations, surface sizing and wet-end additives.

Western Michigan University has a number of distinct coating facilities over a wide size range:

- Benchtop Drawdown Coater, for individual sheets at slow speeds
- CLC-6000 Laboratory Coater, able to operate at speeds of up to 2000 m/min
- Laboratory coater, which can operate in either airknife, blade or rod configuration at speeds of up to 250 m/min on webs up to 26 inches in width.
- Impregnator, which uses an adjustable pressure shoe to control depth of penetration of coating into the sheet
- Full scale pilot plant

The CLC coater is mainly used in blade applicator mode. Most use of the CLC coater and faster units is done to understand either coating rheology effects or application issues. Coating rheology is typically characterised with one or more of an Eklund High Shear Capillary Viscometer, a Rheometrics Dynamic Stress Rheometer, and a Hercules High Shear Viscometer, and then the coating formulation is run on the CLC coater at up to 5 speeds to understand correlations between coat application weight and physical formulation properties, and to see when problems develop with coating consistency. Very little research is carried out in new formulation development.

The pilot plant works on a 1 metre web operating at speeds up to 1220 m/min, on a full range of basestock basis weights. The plant can be configured to run as a metering size press, in blade or rod configurations or as an inclined pond size press. The plant is equipped with infrared dryers and air flotation dryers, with one bank of infrared dryers being used to preheat the basestock prior to the size press. The pilot plant also has a hot soft nip calender with 4 nips, that can be operated in series to the coater or separately. There is a full coating kitchen, able to cook starch continuously, provide high shear mixing of pigmented coatings and provide three feed tanks for the coater.

The University is also well equipped with printing presses (rotogravure, offset and flexography) and a well equipped digital printing laboratory. The primary tool for measuring print quality is Image Xpert.

Surface characterisation of coated papers is carried out with dynamic Contact Angle measurement, mercury intrusion porosimetery, nitrogen adsorption, Atomic Force Microscopy and Scanning Electronic Microscopy.

80% of the use of the new pilot plant's time is expected to be devoted to contract research from industry (with a charge out rate of the order of US$10k per day). The balance will be used for student projects; however, this will be indirectly funded by industry, as the charge out cost of operating the pilot plant will mean that it will be unlikely that unless the student project is generously funded that the pilot plant will be run. The mix of usage for the pilot plant is approximately 50/50 between paper chemical suppliers and paper manufacturers.

PAPRICAN (13-14 May 2003)

Key Contacts: Ron Crotogino, Joe Aspler, Philippe Tanguy (Ecole Polytechnique, Montreal), Alfa Arzate (Ecole Polytechnique, Montreal)

Paprican's funding model (80% coming from an industrial levy, 12% from directly funded projects for industry and 8% from various other government grants) gives them flexibility in pursuing a good range of fundamental research. However, this causes them some conflicts in pursuing partnerships with chemical suppliers, ink suppliers or printers as the suppliers they may choose to partner with may not be the partner of preference for one or more of their 33 member companies.

Paprican have developed strong lings with universities, particularly McGill and Ecole Polytechnique, and appear to have good working relationships and exchange with the universities. McGill University have worked closely with Paprican to develop principal component analysis models to correlate subjective measurements of print quality with instrumentally measured parameters.

Paprican have particular strengths in modelling and numerical simulation. David Vidal, who presented at the Advanced Coating Fundamentals Symposium in Chicago (and previously in San Diego), has done some excellent work in developing Monte Carlo simulations of coating structure for pigment coatings, and they have brought in two recent postdoctoral fellows to develop models of consolidation of the paper web during the paper making process.

Most of the work Paprican is undertaking appears to focus on existing processes and products, rather than considering new processes. Their research direction appears to have some application towards multifunctional paper – however, rather than trying to produce a paper to work on any printing system, their preference appears to be to modify printing processes somehow to make them work on any paper. They are keeping a watching brief on new printing developments and see great potential in flexographic printing of newspapers.

Phillipe Tanguy and his PhD student Alfa Arzate from Ecole Polytechnique came to visit Paprican during my time there to discuss their work. Philippe has had a collaboration with Paprican for 10 years, and in that time his research has moved from looking at jet coating, to metered size press coating, and he is also developing some work in non-contact coating (jet coating).

Tanguy's work on metered size press coating has been to develop a high speed testing rig capable of running at up to 2000 metres/min. He does not use a paper web in his test rig, instead using a metering rod to apply an application of coating directly to the backing roll and then using a doctor blade to remove the coating. Instrumentation includes a pressure sensor on the metering rod. The rheology in the nip is a topic of interest, though this is critically dependant on the deformation in the nip, which is a difficult process to reproduce in standard rheometric testing.

Tanguy's group also uses Plasma Enhanced Chemical Vapour Deposition (PECVD) to apply thin films of substances such as silicon dioxide for barrier coatings. They are also employing high speed digital video photography to look at a number of phenomena, including formation of coating filaments between the metering rod and the web, drop formation in jet coating and formation of ribs and other defects in metering size press applications. The lighting demand for looking at these small scale issues at high speeds is quite demanding (600 kW was the figure given).

The University of Maine (15 May 2003)

Key Contacts: Prof. Doug Bousfield, Yang Xiang, Joe Gresco, Prof. Bill Unertl, Prof. Carl Tripp

The University of Maine has extremely strong cross disciplinary links, not least between the Department of Chemical Engineering and the Laboratory for Surface Science and Technology (LASST). They also have a number of strong external linkages (with Abo Akademi, STFI, KCL, and PAPRICAN amongst others).

They have a wide range of industrial sponsors, who provide approximately 50% of the income to the Department:

- Armstrong World Industries
- BASF Corp.
- Dow Chemical Company
- ECCI IMERYS
- Finnish Pulp & Paper Research Institute
- Heidelberg Web Press
- International Paper
- J.M.Huber Corp.
- MEADWESTVACO
- M-REAL
- NIPPON PAPER
- OMNOVA
- Rohm and Hass Corp.
- SAPPI Fine Paper North America
- SCA Graphics Research Lab
- Speciality Minerals Inc.
- Stora Enso Research
- Sun Chemical Corp.

Most of the research carried out appears to focus on coating structure, binder migration and pore structure.

Coating equipment consists of a 300 mm pilot paper machine, equipped with Gate-roll size-press; a CLC Pilot coater and laboratory super- and soft-calenders.

Analytical equipment includes

- Atomic Force Microscope
- Environmental Scanning Electron Microscope equipped with EDX
- XPS (ESCA)
- Scanning UV-Visible spectrophotometer with diffuse reflectance attachment
- Fourier Transform Infrared Spectrometer
- Mechanical Tester for compression or tensile strength (Instron)
- Mercury Porosimeter
- BET Analyzer for surface area

- Video equipment for observing spreading and absorption of liquids into paper
- Wilhelmy apparatus for dynamic contact angle determination Image analyzer
- Rheometers (Rheometrics, Haake, Hercules, Brookfield, Bohlin constant stress device)
- Bristow Absorption Tester
- Gonioreflectometer
- Blade Deflection measuring device on the CLC coater
- Ink gloss dynamics attachment on KRK print tester

STFI (19 May 2003)

Key Contacts: Michael Karanathasis; Goran Strom

Pilot coater trials are done offsite – typically at CtP in Grenoble or KCL in Helsinki. STFI have a CLC-6000 helicoater, but Michael doesn't think this is a particularly useful piece of equipment, as it doesn't replicate pilot coating or industrial scale coating satisfactorily. Michael also commented that the CLC-6000 is difficult to operate at the maximum speed (2000 metres/minute).

STFI have approximately 220 research personnel, and recently merged with a packaging research organization to give themselves an extra 60 staff.

STFI's operational model is now that of a "research business". One third of the organization is owned by the Swedish Government, and the rest by operating companies. Income comes from contract research and European Union grants.

STFI spend little time on product development other than for contract research. The owner companies have expressed an explicit preference for STFI to concentrate on "more fundamental" research.

Two full time psychologists are employed to help correlate subjective print analysis with objective parametric measurements. For subjective evaluations, subjects are asked to pick one area to focus on (e.g. colour bleed or mottle) and rank the samples accordingly. The panels vary, some being experts in printing and other being a random population sample. Observation conditions (such as lighting, reflections from walls) are strictly controlled. They have found key parameters to be colour gamut, black/yellow bleed and mottle.

Other than a typical range of SOHO ink jet printers, STFI do not have printing facilities on site. However, they do have reasonably good access to Stora Enso's four colour printing unit.

STFI have developed a significant amount of printing equipment on site, such as their dynamic force analyser, fibre analyser and in-house image analyser for measuring gloss development during printing and ink jet print quality.

Recent work has focussed on mylar coating. Although STFI did not elaborate on why they are working in this area, it would be expected that it is for matte to gloss finishes on products for book and brochure covers, postcards and related applications.

STFI has partnerships with a number of universities, such as KTH, Karlstad and the University of Maine.

Helsinki University of Technology (20 May 2003)

Key Contact: Jouni Palkatari

Helsinki University of Technology have research units in Fibre and Paper Physics; Paper Chemistry; Unit Operations; Pigment Coating; Converting, and Printing.

Within the pigment coating group, most current research is being undertaken in coating rheology. Rheological studies of pigment coatings employ a "gap" geometry rheometer as well as a capillary viscometer. As Phillipe Tanguy from Ecole Polytechnique in Montreal mentioned, the geometry at the nip is critical in determining rheological behaviour, and the gap rheometer is believed by HUT to realistically simulate the coating head geometry.

HUT is spending more time on paper formation (e.g. the moving belt drainage former, as used by the Australian Pulp and Paper Institute) than on coating studies. They are also developing an air dynamic former (ADF), which attempts to form paper sheets from a 50:50 fibre:water mix.

They are using thermoporosimetry to look at pore network structure. Thermoporosimetry is a very low rate Differential Scanning Calorimetry method. Water is frozen in the paper pores, and the temperature is increased extremely slowly and allowed to equilibrate. The pore size distribution is inferred from the amount of water melted at each step.

KCL (21 May 2003)

Key Contacts: Jukka Ketoja

KCL's funding comes its four owner companies – Metsäliitto; Myllykoski; Stora Enso and UPM-Kymmene Corporation.

Structurally, they are split into a research unit (which includes consulting services), paid for by their four owner companies. The owner companies are prevented from specifying particular projects until the fundamental research is advanced to a level where case studies are required. They report some tension between producing work useful to their owner companies while not being able to do company specific work.

Most of the paper coating research at KCL is on LWC grades, especially fundamental issues such as film split and deaeration of coating colours. This reflects the primary interests of their owner companies.

KCL has a number of distinct coating facilities over a wide size range:

- Benchtop Drawdown Coater
- CLC-6000 Laboratory Coater
- Laboratory Coater (able to coat at 140 m/min on a 350 mm web)
- Full scale pilot plant (3050 m/min), cost to operate approximately 20000 Euro per day depending on the options chosen (such as calendering).

They are doing a significant amount of research on electrophotography, using a modified Xerox Docufeeder 40 with 2 printing transfer units, a variable transfer voltage between 0 and 10 kilovolts, and a variable speed between 100 and 160 mm/sec. Most of the testing is on the transfer of toner on to the paper, and looks at unfused printed samples, precluding image analysis (which would cause problems due to toner transfer to the scanner. They use an Epson Expression 1680 Pro scanning unit for assessing digital printing quality.

They do very little work on product development. The companies are very secretive about formulation chemistry, and use the facilities such as the pilot plant on a contract services basis.

KCL are probably best positioned out of the organizations visited to offer a fully integrated service, from pulping through refining, papermaking, coating, calendering, converting and printing.

They use laser profilimetry for surface analysis, and an abrasion technique to remove 2 μm layers of coating to look at latex distribution and ink penetration.

Centre Technique du Papier (CTP) (22 May 2003)

Key Contact: Jean-Pierre Maume

CTP have approximately 135 staff spread across 3 research departments – pulping, environmental chemistry and surface treatment and printing. They also have a group developing on machine sensors.

The surface treating and printing department concentrate their current research work on dewatering coating colour, calendering and barrier coatings. Most of the printing research looks at offset and digital printing. They have developed specific patterns for assessing different aspects of print quality such as mottle and gloss.

The funding for CTP comprises 40% of French Government funding, 40% from the French paper industry, and 20% from the European Community. Although they are geographical neighbours to the Engineering University in Grenoble, they report more competition than collaboration with the University.

Unlike most of the other research institutions visited, CTP are developing a large amount of research in new and developing areas. They have a particular interest in adding value to newsprint by coating with either starch or starch/pigment combinations.

Also unlike other research institutions, they are carrying out very little research into rheology anymore. They maintain a rheology laboratory, and perform rheological characterization of coating formulations applied on the laboratory coater and pilot plant, but do not consider rheology research as important at this time.

They are doing significant amounts of work on digital printing, both inkjet and electrophotography, and are also conducting large amounts of work in barrier coating.

CTP have the following coating facilities:

- Benchtop Drawdown Coater
- CLC-6000 Laboratory Coater
- Laboratory Coater (able to coat at 100 m/min on a 300 mm web)
- Full scale pilot plant (3050 m/min, cost to operate approximately 20000 Euro per day depending on the options chosen (such as calendering).

They report that the pilot coater is rarely used anymore, and believe this to be a Europe wide trend. Given that an asymptotic limit in solids content (~70%) appears to have been reached, they believe that to get a major improvement in coating a step change to a new technology is needed, and they believe spray coating is the most likely candidate.

Jean-Pierre Maume recommended the bi-annual coating research conference held in Germany as a better conference than Tappi for finding out the state of the art in coating research.

Appendix B – Itinerary

Date	Venue	Visit
Tuesday May 6		Depart Australia
Wednesday May 7	Chicago	Maine - Chicago
Thursday May 8	Chicago	Tappi Coating Conference
Friday May 9	Chicago	Tappi Coating Conference
Saturday May 10	Chicago	Tappi Coating Conference
Sunday May 11		Chicago - Kalamazoo
Monday May 12	Kalamazoo, Michigan	University of Western Michigan
Tuesday May 13	Montreal	PAPRICAN
Wednesday May 14	Montreal	PAPRICAN
Thursday May 15	Orono, Maine	University of Maine
Friday May 16		Orono-Stockholm
Saturday May 17		Orono-Stockholm
Sunday May 18	Stockholm	
Monday May 19	Stockholm	STFI
Tuesday May 20	Helsinki	Helsinki University of Technology
Wednesday May 21	Helsinki	KCL
Thursday May 22	Grenoble	Centre Technique du Papier
Friday May 23		Return to Australia

Appendix C – Abbreviations and Glossary

APPI	Australian Pulp and Paper Institute (http://www.eng.monash.edu.au/chemeng/appi.html)
CSIRO	Commonwealth Scientific & Industrial Research Organisation (www.csiro.au)
CTP	Centre Technique du Papier (www.webctp.com)
FFP	Forestry and Forest Products Division, CSIRO (www.ffp.csiro.au)
HUT	Helsinki Institute of Technology (www.hut.fi)
ISO	International Organisation for Standardisation (www.iso.ch)
KCL	Oy Keskuslaboratorio – Centrallaboratorium Ab (Finnish Pulp and Paper Research Institute) (www.kcl.fi)
PAPRICAN	Pulp and Paper Research Institute of Canada (www.paprican.ca)
STFI	Swedish Pulp & Paper Research Institute (www.stfi.se)
TAPPI	Technical Association of the Pulp and paper industry (www.tappi.org)

ADF	Air dynamic former
BET	Brunauer-Emmett-Teller method for surface area from gas adsorption
CLC-6000	Cylindrical Laboratory Coater (www.clc6000.com/index.htm)
EDX	Energy dispersive X-ray analysis
ESCA	Electron Spectroscopy for Chemical Analysis
FCO	Film coated offset
FTIR	Fourier Transform Infrared Spectroscopy
HWC	Heavy weight coated
LDTA	Long dwell time application
LWC	Light weight coated
MSP	Metered size press
MWC	Medium weight coated
PECVD	Plasma Enhanced Chemical Vapour Deposition
SDTA	Short dwell time application
SEM	Scanning electron microscopy
SOHO	Small office / home office
WFC	Woodfree (contains less than 10% mechanical pulp) coated grades
w/w	weight fraction (weight of component/total weight)
XPS	X-ray photo-electron spectroscopy

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