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TREADING THE THORNY PATH FROM FUNDAMENTAL RESEARCH TO INDUSTRIAL DEVELOPMENT

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Abstract

As a contribution to the discussion of the research and development process in publicly funded institutes working in the pulp and paper field, the effort in the CSIRO division of Chemical Technology, Melbourne, is described under the following headings: function: the Division as part of CSIRO: staff: research programmes: research administration: funding: career structure and remuneration: interaction with industry and other outside bodies: and achievements. Brief reference is made to pulp and paper laboratories in neighbouring countries, which are usually part of a Forest Research Institute.

In connection with the theme of this Symposium, it appears that the relationship between fundamental research and paper-making can be traced through the Proceedings of previous Symposia, as shown for example by the impacts of the hydrogen bonding theory on paper strength, the theory of electrokinetic interactions on paper formation, the theory of glass transitions on high yield pulping, the understanding of fibre morphology on resource extension and the theory of hydrodynamics on wet end improvements.

Introduction

The purpose of this Session, as I understand it, is to discuss the management, funding and co-ordination of research in paper-making in publicly funded institutes. As far as Australia

is concerned, the Division of Chemical Technology of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is the main publicly funded laboratory in this field, so it will receive most attention. The interpretation of paper-making adopted here is a very wide one, including such topics as pulping, assessment of forest and agricultural resources for paper manufacture and those aspects of the chemistry and physics of wood and other plant materials which are relevant to their conversion to pulp and paper. Particular attention will be given to problems associated with the path from research to development.

The CSIRO Division of Chemical Technology

Function

The Division is concerned with the application of chemical technology and biotechnology to the utilisation and processing of renewable resources such as forests, residues from forest and agricultural industries, algae, water and wastewater. Research areas include: fibre separation and pulping, development of pulpwood resources: cellulose-based composite materials: the use of biological systems for the production of chemicals and energy: the development of agro-industrial systems: and technologies for purifying and recycling water. About half of the Division's activities are related in some way to the pulp and paper industry.

The Division as Part of CSIRO

The 38 Divisions of CSIRO and a few smaller units are now grouped into five major research Institutes, and Chemical Technolgy is a component of the Institute of Industrial Technology. Other Divisions within this Institute are Applied Organic Chemistry, Building Research, Manufacturing Technology,

Mechanical Engineering, Protein Chemistry, Textile Industry, and Textile Physics. Since the introduction of the Institute system at the end of 1978 the Institute Committee, on which the Division is represented by the Chief, has met at monthly intervals and at this level a close relationship has developed between the constituent Divisions of the Institute and between the Chiefs and the Institute Director and Secretariat. At other levels inter-Divisional collaboration is now being improved by the setting up of research working groups in areas of common interest, e.g. noise, printing, interfacial bonding, alloys and composites. There are many other points of contact and co-operative research with other Divisions, both within the Institute and on other Institutes.

Staff

The total staff of the Division is about 135, including 57 professional officers (34 Research Scientists, 18 Experimental Officers, 1 Engineer, 2 Scientific Service Officers, and 2 Scientific Librarians). The age distribution of Research Scientists shows a peak in the 40-45 group (mean 44), and of Research Scientists plus Experimental Officers in the 35-40 group (mean 43 - a skew distribution).

Research Programmes

The same research effort of the Division is pursued in six major Programmes and a support Research Programme, with a total of 27 Subprogrammes, which tend to rise and fall on a shorter time-scale than the major Programmes, with their broader objectives. The present Programme and Subprogramme structure is as follows:

CELLULOSE TECHNOLOGY

-Siropulper explosion process
-Fibre-cement composites
-Applications of composite yarns
-Processing of cellulosic materials
-Fibre and composite science

ASSESSMENT AND UTILISATION OF PULPWOOD RESOURCES

-Pulpwood assessment
-Pulp treatment
-Scientific methods

PULPING AND LIGNIN TECHNOLOGY

-High yield pulping
-Chemical pulping
-Lignocellulosic feedstock

BIOTECHNOLOGY

-Biomembranes
-Fermentation processes
-Algal technology
-Bioenergy development
-Chemical conversion

AGRO-INDUSTRIAL SYSTEMS

-Agro-industrial assessment
-Process and technical analysis

WATER AND WASTE-WATER PURIFICATION

-Sirotherm desalination
-Continuous magnetic ion-exchange and adsorption system
-water clarification and decolorisation by the Sirofloc process
-Collodial system
-Treatment of sewage
-Environment and public health

SUPPORT RESEARCH

-Technical and engineering services
-Research services
-Spectroscopy services

Research Administration

Administration of the programmes is effected through Programme and Subprogramme Co-ordinators, who thus exercise both research and administrative leadership. A matrix type of organisation was tried soon after the Division was established in 1973. The scheme has much to commend it, particularly in respect of the flexibility of research programmes, but in our situation the dual structure comprising an administrative framework based largely on scientific and technological disciplines, and a superimposed research programme structure, was found by many people to be too complicated and confusing, and it has now been abandoned in favour of the single structure.

The philosophy of the Division, insofar as it can be generalised, has developed in line with contemporary ideas regarding the value of strategic mission-orientated research. As is appropriate to a component of the Institute of Industrial Technology, we look to the development of processes to help industry provide products and services of value to the community, but equally we are conscious that our concern is to develop a

particular set of natural resources in the most effective way. These resources include water, in diverse states, and the products of photo-synthesis in field, forest and the sea.

The work of the Division revolves around the Research Programmes. In CSIRO these Programmes arise either through an initiative of the Executive or more usually by formulation by the Chief in conjunction with the Divisional scientists. External sources of advice and information are constantly taken into account. For example, the deliberations of bodies such as the Australian Forestry Council and its Standing Committee, the Australian Water Resources Council, and Industry groups are of considerable importance in our case.

To advise on research activities related to the pulp and paper field, the Divison has set up an Advisory Committee of 14 members drawn mainly from industry. This is known as the Pulp and Paper and Allied Industries Research Liaison Committee and it meets about every six months.

The aims of Programmes and Subprogrammes are specified as clearly as possible. From time to time revision is required, particularly in Subprogramme objectives, as new results point to more expeditious ways of attaining the overall Programme objective.

It is the responsbility of the Programme Co-ordinator to guide and control the research, in consultation with the Subprogramme Co-ordinators and the members of the Programme, to formulate specific projects and decide on participants, to conduct review meetings, to set up appropriate collaborative arrangements outside the Division, if required, and generally to see that the work progresses towards the stated objectives.

The overall direction of Research Programmes is the responsibility of the Chief, acting on the advice of the Programme Review Committees. The terms of reference of each Committee are to specify and issue Subprogramme objectives, to allocate responsibility for these objectives, to allocate staff resources within the Programme, to predict future requirements, to review the progress of the Programme, to initiate and terminate Subprogrammes as required and to plan collaborative

development with other Divisions, industry, etc. The Review Committees meet formally about once per year. However, ad hoc meetings are arranged to meet specific circumstances. All members of the Programme participate in the formal reviews.

A guiding role in the Division is exercised by the Resources Committee which consists of the Chief (Chairman), the Assistant Chief, all Programme Co-ordinators, and the Assistant to the Chief (Secretary). The main function of the Committee is to assist the Chief in the disposition of staff and financial resources within the Division, but it also considers a wide range of other activities germane to the running of the Division, such as publications, travel, laboratories and offices, sources of funds, budgeting and workshop priorities. The Divisional Administrative Officer, the Technical Secretary and the Divisional Engineer attend meetings of the Committee for specific items.

The Divisional Services Committee consists of the Divisional Administrative Officer (Chairman), the Divisional Engineer, the Librarian, and a representative of the scientific staff. The main function of the Committee is to ensure the smooth running of the service activities of the Division, and to this end it consists of the persons who are in a position to take immediate action if services are not being provided in the proper manner. The representative of the scientific staff is the focal point for complaints from that quarter. The Committee reports to the Resources Committee through the Divisional Administrative Officer.

Projects which have reached the stage of commercial development, and other projects involving participation by outside organisations, are normally managed by a Committee of representatives from the Division and the other organisations involved. The Chief is normally the Chairman, but this function may be delegated to another senior officer in the Division. At present ten such management committees are active in project development.

Funding

The main source of funds is the Australian Government through appropriations to CSIRO from the Department of Finance. The Division's funds are allocated either directly by the Executive or through the Director of the Institute of Industrial Technology.

Substantial contributions, which amounted to 9.0% of the total funds in 1979-80, are also received from outside bodies, including industry and other Government agencies.

In the financial year 1979-80, the total expenditure was $3,233,000 Australian of which $2,941,000 was provided through CSIRO and $292,000 by outside sources. Of the Government contribution through CSIRO, $1,990,000 was for salaries, $732,000 for operating expenses, $132,000 for capital items and $87,000 for other purposes.

Career Structure and Remuneration

In CSIRO the scientific staff is channelled into two streams - Research Scientists and Experimental Officers. These are divided into a hierarchy of classifications with the following salary ranges (Australian dollars per annum) as at 30th April 1981:

RESEARCH SCIENTISTS

Research Scientists (RS) (7 steps with one efficiency bar)	$17,972 - $22,029
Senior Research Scientist (SRS) (5 steps with one efficiency bar)	$22,807 - $26,109
Principal Research Scientist (PRS) (5 steps with one efficiency bar)	$27,091 - $30,727

Senior Principal Research Scientist (SPRS) (2 steps)	$32,384	-	$35,577
Chief Research Scientist Grade 1 (CRS1); Chief of Division Grade 1			$38,063
Chief Research Scientist Grade 2 (CRS2); Chief of Division Grade 2			$41,658
Chief of Division Grade 3			$45,258
Chief of Division Grade 4			$49,481

EXPERIMENTAL OFFICERS

Experimental Officer Class 1 (EO1) (7 steps)	$12,350	-	$17,266
Experimental Officer Class 2 (EO2) (4 steps)	$18,001	-	$19,862
Experimental Officer Class 3 (EO3) (4 steps)	$20,743	-	$22,917
Experimental Officer Class 4 (EO4) (3 steps)	$23,822	-	$25,289
Experimental Officer Class 5 (EO5) (3 steps)	$26,043	-	$27,555

The minimum qualification for RS is a PhD degree, or equivalent, plus satisfactory research experience. Promotion to SRS and PRS requires fulfilment of increasingly stringent criteria, and the top of PRS is regarded as a normal career maximum. Promotion to SPRS and beyond requires a clear

demonstration of exceptional ability and achievement, and its recognition by independent persons of scientific eminence. A senior Doctorate (DSc or equivalent) is not regarded as a sufficient qualification in itself for the transition from PRS to SPRS. It is possible in theory to progress to CRS2 without responsibilities for administration or leadership of research groups, but this is extremely rare. Election to Fellowship of the Royal Society, the Australian Academy of Science or the Australian Academy of Technological Sciences would be regarded as the sort of qualification which would assist in the transition from SPRS to CRS. Chiefs of Divisions are not normally appointed below Grade 2.

The minimum qualification for EO is a pass degree or its equivalent. The normal career maximum is E03. Promotion to E04 requires special abilities or achievements, either in individual experimental or research contributions or in group leadership. E05 is extremely rare, being reserved for persons with very wide responsibilities in scientific management. It is possible for persons who have demonstrated a suitable level of research ability to be transferred from the EO to the RS stream, even without the basic RS qualification of a PhD degree. However an extremely competent EO, who is a master of experimental techniques and who may be capable of planning and carrying out substantial portions of a research programme, may still not be regarded as possessing the capacity to operate as a research scientist in respect to formulation of problems, interpretation of results, development of hypotheses, and so on. The distinction between RS and EO functions is by no means crystal clear, and there is considerable support for the merging of the two streams into one professional category. It will be seen, however, that the EO and RS salary ranges overlap considerably (between $17,972 and $27,555 pa), so that for a substantial proportion of the professional scientists the distinction is more a matter of prestige than of remuneration, at least in the short term.

Interaction with Industry and other Outside Bodies

In common with other Divisions of the Institute of Industrial Technology, the Division interacts with industry in various ways, some specific to problems with well-defined objectives, others of a more general nature. The modes of interaction may be listed as follows:

SPECIFIC

- CSIRO research on specific industrial problems or technological developments
- Industry-funded research by CSIRO staff
- Industrial development of CSIRO innovations
- Research contracted to industry by CSIRO
- Research by industry personnel within CSIRO
- Research by CSIRO personnel within industrial premises
- Joint development company involving government and industry
- Research contracted to CSIRO by industry.

GENERAL

- Short term trouble-shooting
- Consulting
- Information transfer
- Seminars, etc
- Publicity
- Interactions with industry committees and associations
- Interactions with standards organisations
- Interactions with service industries
- Interactions with industry research groups
- Advice to Government-owned industries.

In recent years we have been increasingly concerned with the complexities associated with the transfer of technology from the laboratory bench to the pilot plant and thence to industrial practice. There is nothing automatic about this process, which,

in the view of many people well qualified to make the comparison, is beset with just as many difficulties as the applied scientific research preceeding the development phase. Technology transfer may involve the consideration of profound questions of a scientific, engineering and economic nature, as well as the setting up of suitable administrative and financial arrangements which may draw together industrial companies and sectors of Government around a common objective. There seems to be no set pattern for these arrangements, which vary greatly according to such factors as the nature of the scientific advance or invention, the possibilities for its exploitation in Australia or overseas, the patents position, the capacity of existing industrial or Government service organisations to absorb the proposed developments, the size of installation needed for economic operation, the size and distribution of the natural resources to be developed, and the availability and location of suitable markets for the end products.

Some of the particular areas in which we have been engaged in technology transfer include: SIROPULPER (explosive defibration): multi-ply starch applicator (paper and board manufacture): fibre board waxing: Hover dryer (paper-making): SCRIMBER (reconsolidated wood): novel bales (with CSIRO Division of Textile Industry): energy absorbing composites (with CSIRO Division of Textile Industry): SIROTHERM (water desalination): SIROFLOC (removal of colour and turbidity from water): methane from pig waste: ethanol from sugar beet: wood-chip export developments (particularly New South Wales and Western Australia): utilisation of tropical forests: high-yield pulping.

Over a period of seven years from 1973, the Division entered into 32 formal agreements for technology transfer and development. The types of agreement correspond to the specific modes of interaction listed above.

Over the same period the Division also entered into 12 formal agreements with universities and other tertiary institutes and 13 with various Governments, Government agencies and statutory corporations.

Patent applications are submitted in accordance with the usual legal requirements, and in consulation with the CSIRO Bureau of Scientific Services in Canberra. Agreements with industry may assign exclusive patent rights, with the right to sublicence, or non-exclusive rights, grant an option on exclusive or non-exclusive rights, or involve no transfer of patent rights, according to circumstances.

Technological Change in Relation to Research

As a background to the formulation of our Research Programme, some consideration has been given to the way in which industries related to our activities are changing, and how desirable changes can be stimulated by research, and by appropriate Government action. Three areas of relevance to the Division are briefly examined below in these terms.

Pulp and Paper Industry

Recent changes. The past ten years have seen the development of export markets for wood chips, mainly for conversion into printing and writing papers in Japan. There has been a distinct trend towards better utilisation of forest-based resources, e.g. in the use of sawmill and forest residues, and through developments in high-yield pulping. Improvements have taken place in environmental control, e.g. the introduction of the Sonoco process for recovery of chemicals in neutral sulphite pulping and oxidation of the kraft black liquor to reduce air pollution. Technological developments appear to be contributing towards employment opportunities, although there may be other sectors of the industry where, for example, the introduction of computer control systems has reduced the need for manual testing.

Imminent changes. In the next ten years we may see a development of export markets, based on a greater degree of processing of raw materials, e.g. high-yield pulps from pine

thinnings. Recent research has emphasised the potentials of new pulp-types which could provide the basis for new industries based on forest plantations. Internationally, the cost of energy, the availability of resource and further developments in computer technology are likely to have an increasing influence on the industry, the first two restrictive and the last possibly leading to reduced costs, but accompanied by reduced employment opportunities.

Government influence. Tariffs clearly have a great influence in this industry and have had a stimulating effect in a period when the local industry has been establishing its competitiveness. The relative smallness of the industry in Australia, compared to countries such as USA, Canada, Japan and Sweden, and the number of different products it is necessary to manufacture to satisfy local markets, lead to serious difficulties in open competition. In the long run, however, it is possible that the tariff structure removes the strongest incentives to increased efficiency. In respect of exports, the guidelines set up by the Australian Government, e.g. in respect of the fob price of wood-chips, appear to be wholly desirable and in the national interest.

Composite Materials

Recent changes. The rising cost of petroleum, and hence petro-chemicals, coupled with greater concern for health and the environment, and the need to conserve energy, have been major factors promoting the development and use of composite materials over this period. Advances in polymer technology have enabled composite structures to be produced which use materials more efficiently, as, for example, in glass-reinforced plastics. However, cost escalation and energy considerations are stimulating greater interest in the development of composites using natural fibres from renewable resources as the reinforcing elements. Added pressure in this direction has come from the need to find substitutes for asbestos.

The main Australian industry based on composite materials, the fibre-based panel products industry, has declined markedly in recent years as the result of depressed building activity and a severe drop in exports resulting from lower prices overseas.

Imminent changes. Greater utilisation of composite materials is expected as the world's oil reserves become further depleted, with increased emphasis being placed on products derived from renewable resources. Development of new composite materials will accelerate as better understanding of the properties and behaviour of composite systems is obtained.

Three CSIRO developments, if successful, are likely to have a significant effect on the Australian economy. These are

(1) a composite paper/nylon wool pack to replace the rather unsatisfactory polyolefin bale used at present,

(2) a reconsolidated wood product (Scrimber) derived from young trees or thinnings to supplant sawn timber from mature trees in some specialised uses,

and (3) an energy-absorbing composite with considerable potential, particularly in the automotive and highway engineering fields.

Government influence. A major factor inhibiting technological innovation in Australia is the high level of risk involved. This leads to only the largest companies being in a position to support major technological developments. The relatively small size of most Australian companies limits the number of technological innovations that can be introduced at any one time.

The funding of technological development in this area by the Department of Productivity should be wholeheartedly encouraged as a means of relieving the risks involved.

Consideration might be given to encouraging production of composites based on Australia's natural resources by waiving duty on ancillary imported raw materials not locally manufactured, e.g. nylon yarn for the nylon/paper wool pack.

Energy in Relation to Agriculture

Recent changes. There has been a general decline in agriculture, despite the recent partial recovery, leading to a loss of infrastructure for development. The establishment of agro-industries could lead to a revival, with beneficial effects in relation to employment, decentralisation, defence and stable industrial relations. The production of food, fibre-based materials, energy and possibly other products such as industrial chemicals could fall into a new pattern of agro-industrial development.

Imminent changes. The worldwide shortage of oil, and the running-down of Australia's resources, will have an increasing effect on the capacity to deliver oil, which will be subject to both technical and political restraints. The significance of conversion of biomass to liquid fuels opens up the possibility of a large increase in agriculture, or agro-industrial, employment. The land area involved could be of the same order as that used in the present wheat industry. The provision of 60% of our present fuel use would lead to a doubling in agricultural area and activity. Energy derived from agricultural activity could thus contribute to a substantial proportion of our total energy use, with the advantages already mentioned in respect to decentralisation, employment (increased labour-intensity), etc.

Liquid fuels from biomass may be produced in a variety of ways, e.g. production of methanol and ethanol and, in the longer term, the production of volatile fatty acids by anaerobic fermentation. Oil seeds are a possible source of diesel substitute.

Government influence. The effects of the abolition of the superphosphate bounty, tariff reduction, export incentives, taxation policies, etc., would be considerable. It has been contended that the reduction of tax benefits to primary producers has limited the use of land, led to bad management, and discouraged the inflow of new ideas and capital from small

operators. The transfer of technology should be encouraged by financial incentives. Energy farming will require such encouragement in relation to other farming activities. The uncertainties and risks should be recognised by Governments.

Achievements of CSIRO

Recent work of relevance to the pulp and paper industry includes the following projects which have come to some degree of fruition:

1. Acceptable paper-making pulps have been produced by the explosive defibration process, and the technology has been applied to waste-paper recovery and pulping of agricultural residues and in a number of other ways:

2. Asbestos-free cellulose fibre reinforced cement sheets are being introduced to the Australian market:

3. Composite paper-wrapped yarns with special properties have been developed in association with the CSIRO Division of Textile Industry and are well on the way to finding practical application in a new type of wool bale and in energy-absorbing materials:

4. A new consolidated wood product has been invented, which is based on the use of small trees such as thinnings, and process development is taking place in collaboration with industry:

5. A new high-speed process for waxing corrugated fibreboard containers was developed in collaboration with an engineering firm, and is now well established commercially:

6. A technique has been developed for the application, at the wet-end of the paper machine, of starch and/or pigments between the plies of multi-ply liner-board, thus eliminating size-press application and increasing possibilities for greater use of waste-paper:

7. A surface-effect air impingement device for drying paper has been invented, and is being developed commercially in association with a Swedish company:

8. The development of the magnetic resin concept was a fundamental discovery which permitted finely-divided resins with high reaction rates to be handled in a continous way. It has been applied in water purification, but new applications may well emerge in other fields:

9. A new process for removing colour and turbidity from water has been developed and has successfully passed through the pilot stage: a full-scale plant has now been commissioned. The use of magnetite to replace alum or iron floc formed the basis of the process:

10. An instrument has been developed for monitoring organic materials in water, based on chemiluminescence induced by ozone. New analytical procedures may be an important spin-off from this work:

11. A novel principle has been devised for the separation of ethanol from fermentation liquors and is being studied in the laboratory:

12. The potentials of mixing tropical hardwoods as a pulpwood resource have been demonstrated:

13. The Division has contributed to the development of various Australian forest resources for pulpwood production, including species previously considered to be unmerchant-

able, sawmill and forest residues, hardwood thinnings and branches and tops with bark included, and has played a considerable part in assisting the establishment of export industries, particularly in New South Wales and Western Australia, but also in Victoria and Tasmania. Underpinning the practical achievement has been a long series of studies on the relationship between wood and paper properties, e.g. the effect of basic density, accompanied by parallel work on the establishment of appropriate sampling procedures and on new aspects of pulpwood evaluation:

14. An instrument for the measurement and control of temperature and relative humidity in paper testing rooms has been designed, constructed and released for commercial manufacture:

15. Fundamental studies on the behaviour of wood and lignin as a function of temperature, moisture content, chemical pretreatment, refining frequency and other factors have been applied in the preparation of new types of high-yield chemi-thermomechanical and chemi-mechanical pulps from young eucalyptus, pines and other species. In particular recent work with oxidative pretreatments has provided pulps with a very good balance between yield, strength and brightness:

16. Extensive studies have been made on novel effects of a chip "destructuring" process, first studied in Europe to improve penetrability in oxidative pulping processes. Possibilities exist for bringing into use a much wider range of hardwood resources for both high-yield and chemical pulping than has hitherto been possible:

17. Ethanolamine pulping has been quite extensively studied and found to yield good pulps from eucalypt wood while allowing recovery of the residual ethanolamine and the lignin:

18. Technological and economic assessments have been made of various agro-industrial systems, in some cases in association with appropriate experimental work. These include: the potential for drying and briquetting sugar-cane bagasse as an exportable raw material for pulping: the potential of pulp from Kenaf grown in northern Australia as an exportable product: and the potential for production of ethanol and methanol from residues at present available, and from energy crops on land not used for crops.

Associations with adjacent countries

In the following countries, a significant amount of Government-funded pulp and paper research takes place at the locations shown in Forest Research Institutes, which form part of the national forest services:

India	Dehra Dun
Japan	Ibaraki
Malaysia	Kepong
New Zealand	Rotorua
Phillipines	Los Banos

In Indonesia, the Cellulose Research Institute at Bandung, Java, does not form part of the Forest Research Institute, located at Bogor, but it is part of another Government department.

Close association with forestry research, as part of a Forest Research Institute, probably has certain advantages in that the nature of the resource to be developed is constantly in view when considering priorities. However, on a world scale, I believe there are arguments in favour of organisations which have developed in a sophisticated environment of chemistry, physics, biology and technology.

Fundamental Research and Practical Consequences

I should like to conclude with a few observations directly relevant to the theme of this Symposium: the role of fundamental research in paper-making. Among many examples of this relationship which have emerged during the last 25 years it will suffice to mention five:

- Fibre morphology and resource extension
- Hydrodynamic theory and wet-end improvements
- Electrokinetic interactions and paper formation
- Glass transitions and high-yield pulping
- Hydrogen bonding and paper strength

The evaluation of these effects can usually be traced, at least in the initial stages of application, through the Proceedings of the Oxford and Cambridge Symposia, of which this is the seventh.

Fibre morphology appeared at the first Symposium in 1957, and the fundamental ideas presented then and in subsequent Symposia have greatly influenced the technology of assessing the suitability of diverse and agricultural resources for the manufacture of pulp and paper.

Hydrodynamics first appeared in 1961, and the basic consideration of what happens at the wet-end of a paper machine has led to a variety of new forming systems.

Electrokinetic interactions were first discussed in these Symposia in 1965, and their study has contributed greatly to the correct formulation and use of additives in paper-making, with beneficial effects on formation and other properties.

The concept of glass transition also appeared at the Cambridge Symposium in 1965, and is now a household phrase among those attempting to improve the quality of high-yield pulps.

And running right through the Symposia has been the theme of the hydrogen bond, originally viewed mainly as a means of maintaining the crystal structure of cellulose, but gradually taking its rightful place as the basis of paper strength.

Acknowledgements

In preparing this contribution I have drawn freely on the work of my colleagues in the CSIRO Division of Chemical Technology. I should also like to acknowledge the stimulating effect on our Research Programmes of the contributions made to the Oxford and Cambridge Symposia.

Discussion

Prof. H. W. Giertz, University of Trondheim, Norway

Having discussed the importance of fundamental research and having heard at this symposium of how many practical achievements and industrial applications have been engendered by fundamental research, I would like to know if anyone has gone over his files to see what proportion of fundamental research projects has actually given rise to useful results? In the research organisation at Trondheim we did analyse the useful returns on fundamental research and concluded that only 15% of projects that began as fundamental research had any ultimate practical use.

Mr. H.A. Posner

We have tried to check back, as you suggest, on several occasions. However, it has always turned out very difficult, for two reasons. Firstly, the records often aren't very good. It is very often the case that to unravel the course of a particular development is impossible without the assistance of the personnel involved. Secondly, we find that much of the research we do has to be considered as building blocks, not of direct relevance to an identifiable end, but nevertheless very important to it. Combinations of apparently unrelated building blocks can, sometimes and in the right hands, be the correct combination for a technical breakthrough. For these reasons we think it very difficult indeed to try to perform the sort of analysis Prof. Giertz mentions.

Dr. J. Mardon, Omni-Continental, USA

Please forgive me if I phrase this question a little tactlessly, but I want to ask about what happened at IPC when it went through its difficult period some ten years ago. At that time, as many people in the industry know, its reputation diminished, so that it made a substantial effort to reverse this change. Could you identify what aspects of IPC's work or organisation you found inadequate, and how you changed your planning in order to remedy the deficiencies?

Mr. H.A. Posner

It is a very long story. Most people are aware that the sticky patch IPC went through in the later sixties-early seventies was partly a reflection of the mood of the times. There were however, some particular factors which contributed more than most to the problems at that time. They were quite easily identified, and all were important.

The institute at that time was trying to support its non-educational faculty on a contract research basis. This is a tough way of supporting yourself under the best circumstances. It seems to me that efficient and successful contract research organisations work very differently from most governmental research institutes. They, like everyone, have good people, and then leave them to make their own contacts and build their own organisations, subject only to the condition that they continue to turn in a profit. As soon as that condition is not met, then they are out.

At the IPC it is difficult to do that, partly because of our educational role. Thus, the use of contract research as a way for university staff to support themselves outside their academic life was one of the factors which led to the institute's difficulties.

A not-unrelated factor was our losing touch with the outside world. As is always the case, researchers would rather talk to one another than to anyone else, being quite capable of concocting enough interesting problems for one another to work on, with absolutely no reference to anyone else. So why go out to find problems? Thus I think the institute had become very much too introspective.

We also had staffing personality problems, of delayed decisions and insufficient flexibility.

Mr. G. Place, Proctor and Gamble, USA

You mentioned that the IPC targets about 50% of its resources in basic research. I believe that the paper industry is going to change its technology radically within the next two decades. What percentage of your institute's research effort is devoted to

major technological changes, discontinuous with existing methods, as opposed to evolutionary upgrades of what we are doing now?

Mr. H.A. Posner

A relatively small percentage, at a guess about 15%, but not more than that.

Mr. G. Place

Is that because you are interacting with an industry that already exists?

Mr. H.A. Posner

Yes, and it is very understandable. The IPC is not looking at things beyond the realms of current paper-making technology, because its emphasis must be on the realistically practicable. We can and do bring up questions of discontinuous change sometimes, but they must be couched in terms of existing practicability. I don't believe it is the role of IPC to undertake that type of research except when an identifiable need for it arises. We must always be aware of what industry sees as the priorities.

Mr. L. Rodes, São Paulo, Brazil

Some years ago you ran a strategic planning exercise in your institute. Would you say it was successful, and, if you were to repeat it, how would you change the way you conducted it?

Mr H.A. Posner

As a matter of fact we are conducting a similar exercise now. There is a wide variety of possible methodologies for such investigations. The one we at IPC selected is that which seems most appropriate to the collection of people involved, not only within but also outside the institute. Even the selection of the methodology has involved not only members of the institute, but also a number of people from industry.

Dr. A.H. Nissan

People have been asking how much of the fundamental research effort in the various institutes has a useful outcome. One study mentioned suggests 15%, which I consider surprisingly high. To understand how this figure comes about, I think perhaps we must appreciate that the term "fundamental research" has two connotations. Thus Sir G.I. Taylor's work on the instability of rotational flow, published in the Royal Society transactions, was pure fundamental research. Studying what happens on a table roll, even when it is the same problem as Sir G.I. Taylor's, should properly be called "Paper Science fundamental research". This is therefore an application of a deeper level of fundamental research, and I presume that this is why such a relatively high proportion of what is understood in the research institute as fundamental research has a successful outcome. Now may I ask Professor Giertz to repeat his earlier question to Mr. Posner, so that others may have a chance of answering it.

Prof. H.W. Giertz

My question to Mr. Posner was, has anyone in your institute looked back through the last fifteen or twenty years' files to try to follow up lines of research, to establish whether or not they led, eventually, to useful results? This is to some degree the matter to be covered by Dr. Scheuring in his paper later today. He will show the technical leader always goes over a project after its completion to try to show what it has led to.

Mr. B.W. Burgess

We find that applications of our work can surprisingly often be traced back to fundamental research. Though we have never conducted an exhuastive examination, it is surprising how often the comment that some piece of work is clearly traceable to such and such past fundamental research is heard. Consider these examples, which all began as fundamental and basic studies: our study of pitch fouling, now being applied in the majority of Canadian mills: similarly our corrosion research, resulting in the Papritection system which greatly extends the life of bleach

plant washers. Dr. Tabor earlier this week mentioned the work of Dr. Atack, whose study of sliding friction gave us a very useful insight into the mechanism of fibre removal in all forms of mechanical pulping. There are other examples too, where fundamental studies at our or other institutes have resulted in significant improvements to industrial processes.

Mr. G. Place

I am concerned that the paper industry must soon face serious changes, and I am trying to discover what role the various institutes are playing in identifying and forcing our attention on these changes. The structure of the funding and managerial control of these institutes suggests, in my experience, that they will be the last places to discover the discontinuities that must occur.

Mr. D. Attwood, PIRA, UK

PIRA is at present involved in pursuing such a discontinuity as those of which you speak, though it is of no help to paper-making. I am speaking of the new electronic information laboratory. This is a discontinuity that will affect us all, though it can only harm the paper industry, which will have to struggle on, trying to compete and think up different uses for paper.

Mr. B.W. Burgess

Mr. Place's question is very important. Part of the brief of our institutes must be to lead the industry, to try to determine what is going to happen in twenty year's time, so as to prepare the industry for it. We spend a lot of time on this. We have a future awareness committee engaged in technological forecasting and we make use of every device we can think of to try to anticipate future technical needs. This committee works alongside our Research Programme Committee, where the summary organisation of our research effort is done. We believe that one mechanism for initiating action on these technical step jumps is to encourage research by our staff on which they do not have to

report. We are concerned that the level of this exploratory research in our institute has declined recently and moves are in hand to reverse this. We believe it to be of the utmost importance that a scientist can retire into a corner to try out his screwy idea before it is exposed to the harsh light of reality.

Dr. R. Martin-Löf

I agree very much with what Mr. Burgess said, with the addition that I believe the government support for our institute adds to the freedom of the scientists to explore less immediately useful directions. Thus a project doesn't have to convince industry of its viability too early.

Dr. A.J. Michell

Perhaps the best example of a discontinuity, though not a very great one, in CSIRO, was the move into composite materials. It required a completely new start by us, with initially no enthusiasm from industry. This has now changed, since we have come up with several interesting inventions and patents.

In CSIRO, being a government body, the advisory committees are purely advisory. All the decision making power lies in the hands of the senior executive, who can see a project started if he feels sufficiently strongly about it.

Mr. E.J. Justus, Beloit Corporation, USA

Discontinuities, doing things differently, always need one or two dedicated people, backed by a courageous organisation, to come to fulfilment. The onus of responsibility for adopting a new idea lies with the paper industry itself. The problem of the transfer of good ideas from laboratory to mill makes demands as great on individual courage as on technology.

Prof. N. Hartler, RIT, Sweden

I think that the industrial committees play a very useful role in directing the institutes' research programmes, but that it is unreasonable to expect them to take much part in

identifying the long range changes, the discontinuities. The reponsibility for this must be with the individual institute staff, who must be sufficiently strong to resist following completely what the industry committee says. They must be forceful enough to be able to see their own ideas through, and good enough that these ideas will be of value. But the responsibility for step changes must be with individuals in the institutes.

Mr. S.O. Dillen, Stora Kopparberg, Sweden

I think there are two aspects of the discontinuity subject, and the answers so far given don't match the question put. The answers tend to have been concerned with the difficulties of adaptation, of the individual effort needed to force changes through, which is indeed one aspect of the matter. But I think that the questions have been asking to what extent research in institutes can hope to recognise the discontinuities: quite another matter. It is by no means self-evident that it is in the institutes' interests to make discontinuous discoveries, because of the drastic effects they would have on the industry.

Dr. A.H. Nissan

That is why they are called discontinuities: some companies discontinue. I have not found a single instance in history of an important or novel idea being born in the mind of the majority. The ideas from which discontinuities stem invariably occur to a minority of one, and they are almost never welcome. We shouldn't be concerned about that, as one of their strengths is their ability to withstand criticism. They will not be valuable if they can't. Anyone with suggestions of how to foster such ideas should please speak up.

Prof. D. Wahren, IPC, USA

On what criteria do the members of the panel believe that a research director should work when trying to judge whether or not to support a new idea, such as might give rise to a discontinuity?

Mr. B.W. Burgess

With difficulty. There are no rules, and such decisions can only be made with support, advice, and, ultimately, courage. Our institute recently moved into bio-technology. We don't know what will result, though we hope it will be useful. We do expect, however, to have to support that work for a good number of years with no returns. The initiative to move into this field came entirely from within the institute, and has had nothing to do with the industry.

Mr. J. Adams, BPBIF, UK

Nothing has been said here about the role of universities in fundamental research. I suggest that they have a much greater likelihood of provoking the development of discontinuities than do the research institutes, because of their greater potential for cross-fertilisation from different disciplines.

And now I would like to ask Professor Göttsching whether he, in view of recent EEC bureaucratic intervention in the matter of the amounts of waste paper to be included in pulp, believes that the European research institutes should work more closely with the industry federations, the better to resist bureaucratic pressures?

Prof. L. Göttsching

You are asking for better co-operation between the research institutes and the industry federations in the various countries of the EEC. This you think would be the way to improve communication between the research institutes and the EEC bureaucracy. But I think that they work very closely together already, at least in West Germany. And then there is the question of who should try to improve this communication, the federations or the institutes. I think it would be a matter for the federations, as they have the necessary power.

Dr. A.H. Nissan

I draw a different conclusion from the recent EEC experience mentioned. I believe there are problems faced by all industries, particularly paper, which are not purely political or commercial, but have also a technological content, such as this one regarding the inclusion of a greater proportion of waste paper in new pulp than hitherto. These problems must be studied within the industry, even at the risk of a disquieting result. It will be impossible to stop that study; so surely it is better that it shouldn't be conducted by outside amateurs, who may well fail to take important technical aspects into consideration. I am certain that it is better in the long term for the industry's research institutes to investigate responsibly and fully the fringe problems such as conservation, pollution and safety.

Dr. R. Martin-Löf

The Swedish experience in the environmental debate was that by taking the lead and the initiative, industry could so improve its relations with the government that its point of view is much more fairly heard. I think the outcome has been greatly more satisfactory to us than it would if the initial study had been left to the National Environmental Board. I think industry must vigorously study its own problems because that is the only way of ensuring that proposed solutions fall within practical technology, and that end products meet the customers' requirements without being hazardous.

Dr. J.E. Luce, International Paper, USA

Returning for a moment to the question of discontinuities, I am sure no-one here believes they are spontaneous. Discontinuities result from the combination of two processes. Firstly, there must be the recognition of a need, that is to say, an overall need, which might be defined by asking "What busines are we in?". Thus in the paper industry we are in the business of substrates, communication, wrapping or cleaning up mess. Secondly, one has to ask oneself what alternative ways are available for satisfying those needs, other than those in current

use. Generally, scientists aren't very good at asking these overall questions, but one thing fundamental researchers are good at is recognising opportunities for satisfying these needs. I suggest that even the largest companies are not able to support truly fundamental research, but they are aware of the needs. Thus the combination necessary for a discontinuity to result can occur if the links between the large company, with its knowledge of the needs, and the fundamental research institute can be strengthened. This I see as the weakest link and one that must be reinforced even if it involves considerable retraining of the people involved.

Mr. G. Place

Dr. Goring said that the greatest ideas can only arise from mountains of solid background work, and I agree with him. But my experience suggests that they usually occur only at interfaces between displines, not within the core of a single discipline. Thus, for them to arise there must be interaction between several sciences besides the one of need. Having created a climate in which there is this required interaction, then the exploratory team investigating it should, I think, be fairly small: one or two of the right people is probably the correct size: with any more it is likely the team would come apart. Thus I think it is worth keeping the number of people involved in the early stages small, at least until they begin to produce some results: then it becomes sensible to increase the effort. One of the roles I believe could be usefully fulfilled by the research institutes is the bringing together of the various disciplines from the universities, with whom they often have closer ties than industry does. The resulting interactions I believe, as I have said, would provide the groundwork for Dr. Goring's flags of achievement.

Mr. P. Waern-Bugge, Stora Kopparberg, Sweden

According to the figures given in the preprints, Europe manufactures some forty million tonnes of paper annually. The larger part of this goes forward to converting in one way or

another, and yet almost all the research funds are spent in the paper industry, and very little on converting. In fact there is an appalling lack of basic research on the downstream side of our industry, which I think reflects a lack of innovative thinking on the part of the end users. If any of the panel would care to elaborate on that I would be the most interested.

Dr. R. Martin-Löf

To a large extent I think rectifying this deficiency should be the responsibility of the paper industry. Converters are the paper industry's customers and as such should be encouraged to develop their uses for paper. Any rapprochement must also include the converting machinery manufacturers, and will take courage and determination. There is every reason for the paper industry to take the initiative in this, and to try to get as much as possible out of the contact. There should be two-way communication, so that, for example, paper can be matched to ink rather than, as is usually the case, the reverse.

Mr. D. Attwood

The paper industry has sometimes been very bad at recognising discontinuities when they occur in the downstream industries. For example, when web offset printing for newsprint was introduced,the paper industry failed to take notice, and all the research had to be done afterwards, at great expense. There are now new developments taking place in packaging, which the paper is not good enough to handle. We seem again to have been caught unawares by these developments, and I suggest that we should spend more time talking to downstream equipment manufacturers in future, to try to be aware of what changes are in the offing.

Mr. E.J. Justus

I want to say a few words in support of Mr. Posner. The strength of the Institute of Paper Chemistry, and the other institutes, lies primarily in their education role. The outstanding young people from these institutes who enter the

industry give it its great strength. Our company does not look to these institutes to do our research work for us. We are interested in the Ph.D. and other research work that is done, but the primary function of these institutes is as centres of educational excellence.

Mr. P. Wrist, Mead Corporation, USA

Mr. Posner described some of the changes that were made in the re-organisation of the IPC. In particular he mentioned that changes were made to the mixture of personalities, which, it was felt, had become too homogeneous. Probably one of the essential ingredients in furthering a discontinuity is a mixture of personalities and disciplines.

The Advisory Committee felt that further re-organisation was still needed, so they tried to advise the institute management of the direction in long-term research where they felt there was need for knowledge. I believe it is in supplying essential understanding that an institute's main purpose lies, rather than the development of this understanding to useful applications.

After considerable discussion, five areas in need of long term investigation were identified. The emphasis on the long term was felt to be important because of the institute's one step removal from the market place; it was felt that the institute should not chase after every short term development of the market, which it couldn't possibly hope to follow because of this position of remove. The five areas have continued important over the past eight or nine years.

The first was the supply of raw materials, the concern being to maintain adequate supplies to ensure the healthy future of the industry. Within this overall title investigations ranged from genetics to pulping yield improvements. The continuing recommendation from this branch of the work has been that the productivity of our eventually finite land resource must be continuously improved.

The second area investigated was energy consumption. It was recognised that the paper industry is highly energy intensive, second only to aluminium smelting. Thus here too, there must be

continual pressure to improve the energy efficiency of the process.

The third area was that the popular view of the environment had seen a discontinuous change, so that many actions acceptable before 1970 were no longer so after 1970. This has created the opportunity for a considerable re-evaluation of the economic factors in decision making in our industry. The initial reaction from the industry was to patch up, and reduce the impact of the waste produced. This approach has been replaced over the years by one in which the total amounts of waste are reduced, which of course has benefitted the first two fields of study.

The fourth area concerned the capital intensiveness of the industry. It is becoming increasingly more costly to introduce a new unit of production in paper-making, and, even without revolutionary change, it is important continuously to improve the process of productivity. This of course involves further investment, and so the process was thoroughly examined to try to reduce some of the capital intensity.

The last area chosen for investigation concerned the fact that very little account of intended end use is ever taken in the design or testing of our products. Q.C. tests tend to be limited to what is easy, without any real evidence that these have much relevance to properties important in the market place. So effort has been spent trying to discover what properties are of importance to end users, to try to optimise the product without excessively increasing raw material demand.

Dr. A.H. Nissan

I appreciate your having made this contribution at this juncture, where I am sure it is appropriate, and thank you for having made it at such short notice.

Dr. A. Mawson, Wiggins Teape, UK

I wish to return to the question of revolutionary change, discontinuities, that we began discussing. It has been proposed that the universities might be the ideal germinating ground for the seeds of such changes, and also that collective

government funding actually acts against the stimulation of revolutionary change. It is indeed true that large government finance (e.g. the EEC) tends to go into the collective interests of the industry, where collaboration presents no threat, and that this tends to promote the status quo. But in the U.K. money for R & D is being put increasingly into specific companies within an industry, which by helping to avoid the problems of confidentiality, opens the possibility of more revolutionary changes. This approach can, of course, give rise to products like Concorde, for which the primary need was never properly identified, and whose spin-off products weren't sufficiently immediately useful to be widely adopted.

The question of whereabouts to find the most fertile ground for revolutionary change has concerned several speakers here, and surely the need for cross-fertilisation must be apparent. But if this cross-fertilisation is to occur within a committee, it must be a committtee of one only, and of course modern specialisation renders such committees very unlikely to have the necessary range of experience. The main problem, therefore, I see as being one of tapping existing sources of knowledge, mainly in universities, which is a slow, laborious job. I myself am trying to undertake it and I seek suggestions as to how I can improve my technique

Dr. J. Colley, APPM Ltd., Australia

Yesterday Professor Judt called upon the Research Institutes of the developed countries to do more work for the benefit of the developing countries. Could you briefly outline the extent to which the CSIRO Division of Chemical Technology answers this call.

Dr. Michell

The CSIRO Division of Chemical Technology has been engaged for some years in the assessment of the pulping qualities of woods from Papua New Guinea and Malaysia and in advising these countries in their negotiations of chip export contracts with pulpwood buyers from the developed countries. The work has also included assessments of the potential of possible re-

afforestation species. The work is being done in collaboration with the forest departments of the countries concerned and has included training programmes for their personnel.

The work was funded initially by the Australian government through the Australian Development Assistance Bureau but more recently funding has been provided by the governments of the participating countries.