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THE ROLE OF FUNDAMENTAL RESEARCH IN PAPER-MAKING: ASKING THE IMPORTANT QUESTIONS

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About five years ago, signs began appearing that economic growth in the United States was losing its vitality. In an economy as complex as that of the US it is not always easy to distinguish symptoms from causes. Industrial innovation has long been recognised as the engine of the American economy, and it was clear that this loss of power could not be explained simply in terms of OPEC and the rapid rise in the cost of energy. Many measures of the "State of Innovations" have shown signs of a downturn. President Carter initiated a cabinet-level study of the extent to which government regulation might be to blame, and numerous other groups have analysed the extent to which other factors have contributed to the decline.

The picture is complex but a concensus has emerged that, in many sectors of the economy, government policies and intervention have biased the odds against the entrepreneur prepared to pursue a high risk, long-term opportunity in expectation of achieving a major breakthrough and high financial return, and in favour of those satisfied with projects of low risk and modest but short-range pay out. The national debate has served to increase the level of public understanding of the nature of industrial innovation and of the important role that technology plays in an industrial society. With it has also come a rediscovery of the underlying role played by basic or fundamental research as the reservoir from which we derive our new insights and solutions to market needs. In many sectors of our economy, neglect of basic research has allowed the reservoir to run dangerously low.

On the occasion of the 50th anniversary of The Institute of Paper Chemistry two years ago, Dr. Nissan recommended that the time was ripe to re-evaluate the state of innovation in the paper industry. There were signs that for the previous 25 years we have been guilty, as an industry, of liquidating our technological resources without an adequate commitment to developing the basic knowledge that will be needed to serve the industry over the next 25 years. He contrasted this situation with the state in the two industries that are emerging as our future competition, chemicals and electronic communications, both of which continue to support much higher levels of investment in research.

Webster's dictionary defines technology as "The totality of means employed to provide objects (or services) necessary for human sustenance and comfort." This definition closely parallels the function played by innovation in our industrial society, which is the successful introduction of new products or services, or processes for providing them, and their development into widespread commercial use.

You will note that neither definition includes a specific reference to scientific discovery, invention or to basic research. The emphasis is rather upon successful application, on useful products or needed services, and upon improved methods of providing them. The success of technology or innovation is measured by the degree of acceptance received in the market-place. Occasionally, a new piece of scientific research or a breakthrough invention provides the initial idea for a new product or process, but even in these cases it requires the "totality of means" within a business to make a commercial success of it. Indeed, it has been suggested that 80 percent of all successful innovations start out from a perceived need in the market-place: only 20 percent are the outcome of a new scientific breakthrough in the laboratory which then goes looking for a commercial application.

Both types of innovation are important and have a place. The one tends to produce evolutionary product changes and can be reasonably planned for. The other leads to revolutionary changes and is less predictable. Statistics such as these involve degrees of judgement to a certain extent, but there is growing recognition today of the importance of the very close coupling that should exist between recognition of what the market needs, and managing the technological, financial, material and human resources that a company can bring to bear on meeting these needs. Nevertheless, underpinning the commercial success of the industrial innovative process is the important role played by fundamental or basic research, whether it be carried out by private industry, in public universities, or at co-operatively funded research institutions.

It is very difficult for scientists living in ivory towers to respond to the subtle colorations of market needs, especially when the marketing specialist frequently has only a partial understanding of them himself. This suggests to me that the most important roles of an industrial research manager today are to develop channels through which the needs of the market-place can be understood, and to translate these needs into appropriate research objectives. The way in which these needs are defined will determine the kinds of skills that are assigned to the problem and, indirectly, whether the end result will be what is needed in the market-place. The way the questions are posed will determine the way they are answered.

In the past, some of the most important innovations have occurred when the innovator recognised broader future needs than the market-place itself was then asking for. Two good examples come to mind.

The way the old Haloid Corporation developed the commercial uses of xerography went far beyond meeting the limited needs which xerography's inventor, Chester Carlson, started out to address. Carlson, a patent attorney, originally wanted a quicker way to copy references in the library. Xerox, as Haloid is called today, saw a much broader need for copying and ended up revolutionising office paper-work.

Likewise, the Bell Laboratory, seeking ways to improve the telecommunications systems in use in the late 1930's, looked beyond their immediate need to up-grade the reliability of the vacuum tubes and mechanical relays then in use, and sought instead to develop a brand new approach that would supply the expanded capabilities and reliability that they foresaw would be needed in the future. In so doing, they expanded the knowledge on semiconductors and opened up the field of transistors and integrated circuits for commercial exploitation.

As J.A. Morton, late head of Bell Laboratories, recalled in looking back over the history of the transistor development, their success was a direct result of posing the research question in terms of what new technology might be developed to meet the greatly expanded needs of communications in the future rather than seeking incremental improvement to their existing methods. It is only when you "ask an important question" Morton stated, "that you get an important answer."

All too frequently we look at the symptoms of an existing problem and attempt to fix it with a Band-Aid (Elastoplast) instead of spending the necessary time to define accurately the problem in terms of tomorrow's needs. Millions of R & D dollars and hours of creative peoples' time have been wasted developing brilliant solutions to poorly defined problems, only to find they are solutions to needs of the past rather than of the future. When this occurs, the result is a costly failure and disappointment.

In the past decade, the structure and aspirations of our society have undergone a dramatic revolution. In today's environment, assumptions about market needs, based on experiences of the past, provide an insufficient basis for guiding technological development in the future. There is today a need carefully to research the problem itself before we rush to develop the solution, to pause long enough to gather sufficient information to be able to pose the appropriate questions.

A research and development programme that places a priority on market needs is often called "focussed" or "mission-orientated." It's an approach in general use today in US industry, though it was not always so.

Indeed, you have only to look back about 20 years to find a very different philosophy in vogue. That was the golden era of rustic research parks, remote from town and market-place and contact with reality, of freedom for researchers to pursue their own individual scientific goals, of research groups probing the frontiers of cellulose chemistry, without a clear commercial goal in mind. There was approval of the long-range view, tacit encouragement of basic research, and a search for scientific breaks-through on new frontiers.

This atmosphere produced a lot of creative research. If the laboratory was also fortunate enough to have someone on board interested in applying these findings commercially, the approach was successful. But it was not always so. Since that time, partly as the result of the recessions that hit our industry in the late `60s and again in 1974, we have seen moves towards R & D budgets controlled by product-line managers, and an increased reliance on marketing people to generate and fund specific development projects.

Financial support has very easily slipped over into product control.

In addition, rampant inflation, through its effect on discounted cash flow analysis, has inevitably shortened planning horizons, and in times of economic uncertainty any long-range project automatically assumes a higher risk. Much of our research today has switched to short-range projects which carry lower risk and almost certain but lower return: usually these can be carried out with readily available technology.

The area of pollution abatement is a good example. In order to meet the tight compliance schedules established by the law, and avoid the stiff penalties if the technology doesn't work as planned on time, there has been a strong incentive to stay with well-proven technologies. With the falling profitability in the `70s, management could hardly afford the risks involved with investments in novel but untried pollution control techniques.

The concept of industrial research that I have just outlined places a heavy emphasis on the end use of the development, and makes it a primary factor in the management of the project.

Where, I am sure you are asking, does all this leave the pursuit of basic research within our industry? Aren't we in imminent danger of depleting another natural resource, our scientific knowledge data base, unless we also take appropriate steps to replenish it as we go along? This must become a legitimate concern of our industry leaders and scientists in the `80s. Perhaps we have allowed the difficult economic conditions of the `70s to over-shadow the important role which basic research can play in mission-orientated industrial research. The question we should be asking is not "Who shall control the industrial technical efforts, the general manager, the research director or the marketeer?", but rather "What is the proper role for each in this effort?"

Management has two important roles to play: it determines the mix of scientific talents available to work on its problems through its hiring and personnel programmes; and it manages the relevance of the research programme to its business objectives through the planning and budgeting processes. Diversity of talent and of work activity within a research group has been shown to be a critical element in stimulating the creativity and productivity of scientists and engineers, and both factors are under the control of management.

Marketing people should play an important role at all phases of a project, from helping in the identification of market needs, providing market intelligence during development and, finally, to participation in commercialisation efforts.

Management of research is a specialist role, and marketing skills alone are not appropriate qualifications for directing the research effort. The R & D manager must be responsive to inputs from both general management and marketing, and engage in open communication with both groups, though his responsibilities do not stop there.

It is the scientist's and engineer's responsibility to decide what are the most appropriate technologies to use, and also to be creative in their use. He must ensure the timely replenishment and extension of his scientific knowledge base, which is after all his most important, indeed perhaps only, stock-in-trade. To do this not only requires familiarity with the newly-emerging fields of science and engineering, but also the support and encouragement of basic research in those areas of special interest to the company, either within the laboratory or through financial support of universities and other research organisations with whom he maintains close contact. It requires effort and encouragement to promote communication between scientists who are not in close daily contact with one another. It will not happen unless it is given priority by research management.

At Mead, we have a research programme today that has evolved with time, corporate growth, and management philosophy. Starting as an offshoot of the technical service department in a small paper manufacturing company, it has evolved into a multi-levelled effort serving the diverse needs of a multi-divisional corporation. Technical programmes are carried out, sponsored and managed at three levels in the company: by the individual operating division; by the business groups; and at the corporate level.

At the divisional level, they serve divisional needs, where the emphasis is on new products, product modification and technical and customer service.

At the group level, projects are funded that serve the needs of several divisions or that address future needs of the group which would not fit well into an individual division's charter. The work sponsored at group level may be carried out at the corporate R & D laboratories or by outside institutions under corporate management.

At the corporate level, programmes usually cross several groups' interests or are aimed at exploring new business opportunities for the future. Sponsored work is also carried out for divisions, especially when special expertise or equipment is required that is only available at the corporate level. Budget planning and management review are integrated into the normal business planning and review processes.

Divisional projects are generally evolutionary, shorter range, related to present business, and closely tied to the market-place.

The corporate viewpoint tends to be longer range and broader in scope, and with a heavier emphasis towards the basic side. It does, however, cover the entire spectrum from basic research to limited technical service. Basic research is also supported by involvement in and financial support of several outside academic programmes working in areas of general interest to the company's long-range objectives.

The Advanced Systems Group was originally formed to exploit technologies developed in two of the corporate R & D laboratories in two completely new fields for the company. One development, digital ink-jet printing, was the outgrowth of a corporately sponsored study of the potential impact of computer technology on one of our major markets, commercial printing. The other, a computerised legal information retrieval and search service, was an offshoot of a government defence contract by a corporate R & D division.

Today, the Advanced Systems Group has its own group research department and separate development departments in each of its divisions. In contrast to earlier stages in its development, the R & D effort today is well integrated with the corporation at many levels, and every effort is made to make it an integral part of the total business planning and management structure, rather than a separate activity.

Sponsoring and funding, therefore, rest at those levels in the company at which the business responsibility resides. Research management of individual programmes and projects resides with the managers of the laboratory to which the work is contracted. Overall co-ordination with the business objectives is provided through the corporate business planning processes and the overall functional direction by the corporate vice-president of technology.

My personal judgement is that in recent years the US paper industry has made a major effort to increase the relevance of its research efforts to the needs of the market and, in its enthusiasm to do so, has neglected to provide the necessary support for updating its basic research base. Part of the responsibility for this neglect lies with the scientists themselves. Perhaps it is time to re-examine what the important areas of basic research should be for our industry in today's environment. I suspect they are quite different from those that were important 25 years ago. Our basic research efforts may not have died from lack of nourishment, but rather from old age and irrelevance. We may be in need of new directions and ideas to restore enthusiasm and new growth to our basic research stock.

One of the major developments of the past 25 years has been the emergence of systems analysis as a major area of technology. Its growth has been largely a result of the major strides in computer technology which have enabled large quantities of data to be handled rapidly and accurately so that control actions can be determined and implemented in real time. It has also forced the use of inter-disciplinary teams because of its blending of the traditional sciences, economics and system analysis. There is need for a better understanding of the role which systems play in our industry, and the need for system analysis in our research efforts. The manufacturing process and the conversion and use of our products in the market-place both involve very complex systems. Our raw materials come from forests, quarries and farms; in their processing large amounts of energy and water are consumed, and the ultimate uses of our products are as components of larger systems that satisfy the general public's needs for information, communication, food, housing, and conveniences. There is considerable interaction between one stage of these processes and another. Changes made in one stage affect operations in many others and often in a way that is not intuitively predictable.

A research approach which optimises the performance of individual unit processes within a system is not necessarily the way by which the best performance of the entire system can be achieved. In particular, research that focusses on unit operations alone rules out the possibility of substituting an entirely new system of technology for meeting the market requirements if either available technologies or the market needs undergo a revolutionary change.

In the past 10 years, our understanding of the industrial innovation process has been greatly increased by the studies of researchers like Roberts and others at MIT. One of the interesting findings that has come from this work is that the frequency and the significance of innovations in the fields of process and of product development are quite different from one another. They also change in quite different ways at different stages of the life cycle of a new product or in the period following the introduction of a radically new technology into an established market.

In the case of products, the introduction of a new line or technology usually leads initially to a rapid rate of product innovation. During this early phase, uncertainty of the market requirements encourages many product modifications, and rapid feedback from the market is essential to guide the evolving product development. Eventually the product specifications tend to stabilise with only infrequent and incremental modifications occurring thereafter.

Process innovation on the other hand initially starts more slowly. In fact, there is a tendency initially to adapt existing processes wherever possible in order to cope with the frequency of product changes. As the product stabilises, efforts are made to develop new processes of manufacture and the rate of process innovation begins to rise. Indeed, it is frequently at a peak when the product itself has alrady reached maturity. Cost reduction then becomes the primary focus of process development.

The kind of innovation strategy that is appropriate in an industry at any given time period, therefore, has a lot to do with the evolutionary stage of its technology.

In the 1960s, the market environment for paper products had been relatively stable for a number of years. We had well established product lines, serving well established needs. Our industry showed all the characteristics of maturity; heavy capital investment with low rates of capital obsolescence, major emphasis on capital productivity, and the development of many commodity-type product lines. Product innovation was low and incremental process innovation was the major game in town. Our processes were optimised to make full use of abundant supplies of cheap water and very cheap energy, and to minimise the use of labour. Only incremental modifications of process or product succeeded economically since the high risk of major innovation did not offer sufficient rewards or benefits to justify premature obsolescence of already committed capital investments.

In this environment it is perhaps to be expected that many of the new technological developments which occurred came from outside our industry from people with no investment in the status quo and that the established companies were very slow to adopt or react to them.

Well known examples of innovations that came from outside during this period include product innovations such as carbonless paper by NCR, milk cartons by the Excello Corporation, a manufacturer of shoe-making machinery, and xerography. On the process side, innovations such as plastic wires and computer process control came from felt makers and computer manufacturers respectively.

Several events occurred in the `70s that have changed the stability of the status quo. They have so changed the basic economics of our manufacturing processes and the nature of the markets we serve that the technologies most useful in the future may well be different from those we have used in the past. In the future, I suggest that we will make better decisions about the direction of our industry′s R & D if we begin to pay more attention to some of the factors that up to now have been of little interest. Recent happenings in areas outside our industry and its markets may well be the most influential factors in determining the future direction of our industry′s technology.

Let′s take a look at some of them and their possible consequences.

First, consider the paper manufacturing system itself. Some of the areas in which major changes have occurred over the past few years are:

Energy Supply and Costs;
Raw Material Supply and Costs;
Environmental Requirements;
Human Health Considerations;
Capital Cost of Economically-Sized Production Units.

These changes have affected all paper producing countries but to quite different degrees. Some of these differences are sufficient in themselves to have far-reaching effects on future world trade in pulp and paper, and in traditional fibre types and sources.

Here are a few facts. The pulp and paper industry is one of the most energy intensive of the major commodity industries in terms of energy use per dollar of value added, being second only to aluminium. Over recent decades the convenience and availability of cheap oil and natural gas have made these fuels our industry's primary power source. In addition, the added complexities of our processes have increased our use of electrical power, and in turn, our dependence on public utilities for this power because of their very favourable financing structures. Finally, in a perverse twist of regulatory intervention, the initial impact of air pollution controls in the early `70s caused many mills to convert from coal to oil or gas.

In 1973, the oil exporting countries were able to establish an oil monopoly. Having done so, they began a dramatic upward revaluation of oil in the world market. There is every reason to believe that this upward revaluation has not yet been completed, and that it will continue until a new balance of energy supply and demand is achieved in which the leverage of the OPEC nations is diminished. This process will take a long time, unless the world economy collapses, because it requires the development of a complex mix of conservation measures, installation of new plant and equipment designed for increased energy efficiency and the development of new sources of alternative fuels. In many cases, existing equipment will have to be replaced and to do so will require large capital investment.

asking the important questions in fundamental research

Since 1973 the price of oil has increased tenfold, which is a 30 percent annual compound growth rate. Fortunately, we are not entirely dependent on oil, and other fuel prices have not increased at the same rate. Even so, if we look at the impact this has had on the energy used in our manufacturing processes, we find that direct costs attributable to energy have risen from approximately $14 per tonne of product in 1972 up to around $60 per tonne in 1979.

But that is only the merest tip of the energy iceberg. Transportation costs from the forest to the mill and from the mill to the customer are also sensitive to oil costs: some of the chemicals used in our pulp mills, especially chlorine, caustic, chlorate and lime also require large amounts of energy for their production. The impact of increased energy prices on our final product is, therefore, even greater than it at first sight appears. It is clear, I think, that for at least the next 20 years the cost, availability and rate of consumption of energy must be major factors to be considered when we begin to plan new technological innovation in our industry.

Until recently there was a relatively world-wide surplus of timber growth over demand. It is true that in some countries shortages have existed for many years, but elsewhere surpluses and low transporation costs have allowed these regional difficulties to be overcome. For most commercial purposes, softwoods are the preferred species. In the free world today, only North America has a surplus of softwood growth over demand. Japan has experienced a major deficit since early in its post-war boom, and Scandinavia, in the past a traditional exporter of timber, is today an importer of wood and wood residues. Major efforts have been made in the past 20-30 years to increase softwood productivity from our commercial forests by improved silviculture. We are just beginning to reap the benefits of those man-made plantations. However, if the world-wide demand for timber and paper products continues to grow as expected, we will remain in a largely supply-constrained situation into the foreseeable future.

Five technological developments must be taken into account when considering the future supply of fibre:-

- Lumber and pulpwood integration;
- Increased use of wood as a fuel;
- Growing differentiation between timber availability and economic accessibility;
- Greater exploitation of hardwood species;
- The emerging importance of plantation forests as future sources of commercial lumber.

Because of the international character of forest products, and the well-established patterns of international trade, it is essential to consider not only developments in North America but also those taking place in the other producing countries.

Until 10 years ago, some forests were harvested for lumber production and others for pulpwood. Indeed, corporations tended to be in one business or the other. About that time, environmental regulations outlawed tepee burners for disposal of lumber residues, and a developing shortage of softwood stumpage increased the competition between lumber and pulp mills for the available supply. In this situation the rapid development of lumber residues as a source of pulp chips became a natural response. Thus, economic pressures accelerated the process of forest use integration. Today, competitive bidding ensures that most forestland is cut to provide the highest value mix of products; poles, plywood, lumber and pulpwood chips. In the next decade economics will force the wide-spread adoption of one more level of use integration, that of limbs, roots and weed-tree species as industrial fuels. Coupled with this greater utilisation of softwoods, we will also see the increased use and substitution of hardwoods in many new areas. The Japanese today make several bleached paper grades entirely from hardwood pulps.

The fourth development is, however, a relatively new one, and is a result of rapidly increasing energy prices. As fuel costs increase so do the costs of harvesting and transporting timber from areas of difficult terrain or isolated location to the pulp- and saw-mill. Forest economists are beginning, as a result, to differentiate between standing timber and that which is economically available. This distinction recognises that at a given level of world pulp or lumber price, it will cost more to get some trees to market than they are worth either as pulp or lumber, that is they have a negative stumpage value. They are, therefore, unavailable economically unless their harvesting is subsidised. It has been suggested that as much as 15 per cent of Sweden's present productive forestland falls into this category; much of Canada's remaining virgin forests are probably in a similar state, and it is certainly true of much of Siberia's vast forestlands. It has been customary in the past to include these forests in world forest inventories, thereby over-estimating the economically available reserves. Note that if energy costs increase faster than pulp prices, the size of the economically available forest reserves shrink. In the past, some governments have been willing to subsidise the harvesting of these marginal forests for social purposes, but the practice will become increasingly costly to maintain as fuel prices rise.

The bottom line of all these changing factors in forest supply will be to increase the economic incentives for man-made plantation forests, growing carefully selected species and designed for economical harvesting techniques. They are an increasing factor not only in traditional supply regions, but also in new ones such as Brazil, Chile, and Australasia. The impacts of higher transportation costs will be further amplified as forest residues become an increasing element of our industry's fuel supply. This trend may lead to the reversal in the growth of the ocean shipping of chips, since it's cheaper to ship one ton of pulp than four tons of wood fibre and a ton of oil.

A recent Swedish energy study has shown that using currently available technology it is technically possible today to design a bleached pulp mill that would provide all its own steam requirements from the normally available forest wastes, and could generate an excess of electrical power in the process. Its only reliance on oil would be in the lime kiln, and wood residues may be usable even there. Such a mill would certainly be as independent of oil economics as it is possible to be. A liner-board mill could also be designed to be self-sufficient in steam and power, and the consumption of fossil fuels dramatically reduced in other, non-integrated mills.

What new directions for research and technology development does this analysis suggest? Perhaps the following as a start:

Genetic improvements for stocking plantation forests;

New harvesting techniques to get maximum fibre and fuel yield from the biomass;

Improved debarking and screening methods to segregate pulp chips from fuel residues, removing dirt and low fibre-yielding portions of the tree before the digester instead of after it, so we can burn it directly instead of cooking and evaporating it first, consuming energy and chemicals in the process;

Improved recovery boiler design, especially with respect to corrosion so that high pressures and maximum back-pressure generation can be safely practised;

Improved re-use of water and heat throughout the system, and resolution of constraints on the process caused by chemical and heat build-up as the systems are closed.

When examined from a systems viewpoint, it quickly becomes apparent that most of the energy we use in a pulp and paper mill is used for warming water, thickening and diluting stock, and pumping stock up and down hill, with very little energy directly entering into the transformation of the fibres from wood chip into paper web. Water and energy conservation force us, therefore, to consider the entire system rather than individual unit operations since it is often in the connections between the unit processes that the changes must be made.

asking the important questions in fundamental research

With the tenth anniversary of the environmental movement behind us, it should be unnecessary to remind you of the importance that pollution control continues to assume in the future development of paper technology. It seems to me that the issues arising from environmental concerns are now being differentiated into two distinct lines: concerns about conventional pollutants on the one hand; and about toxic health-related pollutants on the other. The evidence today suggests that we can reach an adequate level of environmental protection for our manufacturing operations in both categories with currently available add-on technology. Future developments should focus, therefore, on economic optimisation, and on improving the margin of safety for the potentially hazardous and toxic pollutants we must deal with. There is a significant commonality betwen the approaches to optimise the economics of conventional pollutant control and those of energy conservation. In the case of potential toxic pollutants, it now appears that chlorine is the common thread through our potential problems: it runs through chlorophenols and chloroform in our bleach plants and chlorinated biocides in our paper mills. While they are controllable within acceptable levels with currently employed technology, the fact that chlorides also require expensive metallurgy in our process equipment to minimise corrosion suggests to me that alternative forms of bleaching may provide overall economic benefits, at least in new plants. There is much to learn of the reactions between active forms of oxygen and lignin or cellulose.

The remaining major element in our product is the capital equipment, whose costs have also risen faster than general inflation. Part of this has arisen because of the added equipment required for controlling pollution. The addition of heat recovery equipment and back-pressure electrical generation also increases capital costs without increasing production of paper. Changes such as this once again force us to examine how to optimise the total system, including capital costs, in our evaluation. In doing so, let's keep in mind the capital costs involved in making electricity and chemicals; costs which we usually tend to ignore because they are external to our plants.

What areas of new basic research do these changes seem to indicate? I'm not sure that anyone has yet really thought this through. The primary function of pulping is the dissolution of the inter-fibre bonds by either chemical or mechanical forces, and for many products, the removal of the lignin portion of the wood without serious degradation of the cellulose fibre.

Dr. Tucker has suggested that if this process were done in a thermodynamically efficient manner, it would use only 1 per cent of the energy typically used today. We are substituting brute force for science to get acceptable reaction rates.

The excitement which the recent work with anthraquinone has created suggests that much is still to be learned about the chemistry of our basic materials and, in particular, the mechanisms that can affect the kinetic rates and selectivity of the chemical reactions of lignin and cellulose. The problem is not an easy one, especially since we are dealing with natural materials of varying chemical composition. But, if we are to increase the productivity of our processes in the future, we must find a way to reduce energy consumption through a greater understanding of the inter-molecular forces we are working with.

A word of warning, however, may be in order. An early response to the environmental problem was to jump to the conclusions that if a chemical gave a problem, find a way to eliminate it. I believe this was the reason for the once fashionable trend to non-sulphur pulping. It seems to me, however, that this approach ignores the economic advantages of sulphur in kraft pulping, namely faster reactions, wider tolerance of raw materials, stronger pulp, and reduced lime demand. To my knowledge, there is no evidence that sulphur is responsible for the production of carcinogenic materials and anyway, adequate control technology is available. If we ever replace sulphur in our pulping systems it ought to be because we have found a more cost efficient pulping reagent, not because it has an odour.

asking the important questions in fundamental research

With the emphasis I have placed on the importance of viewing the manufacturing process as a system, it should come as no surprise that I believe that the potential for computer process control has barely been scratched to date. So far we have emphasised optimising unit operations, and the rapid development of mini- and micro- computers has made this cost-effective. The next stage, and the one that offers to increase the overall productivity of our plants, is the integration of these unit controls into a hierarchy that optimises the efficiency of the total process from wood-yard to shipping bay: in this area the Swedes and Finns are already active.

Let us now leave the process and look at the future markets for our products. In the time available, we can only look at two examples: Communications and Food Distribution.

One of the earliest uses of paper was to replace skins and papyrus as a medium for written messages. For many centuries, storing the written word was paper's primary function so that ideas could be transmitted from one place to another or from one generation to another without fear of being lost of confused in the process. It was effective because paper was cheap, relatively permanent and it was easy to store or carry around. Its only limitation, and that not a serious one until recently, was that it had to be physically transported from sender to receiver. The speed of communication was limited to the speed with which man could travel. Today, large-scale integrated memory circuits are also cheap, permanent, easy to store or carry around, and they can transmit their contents without limitation and at the speed of light. Well, almost all those things. The only limitation at present is that it requires auxiliary equipment a little more complicated than a pencil to load them or a human eye to read them. We cannot expect the role of paper in communication, however, to be unaffected by these new developments in electronics and digital computers.

A bank in Chicago has already eliminated inter-office correspondence and individual files. It's done by a computer and personal terminals at executive work stations. No more need for multi-copies. Once entered into the system, anyone can ask for a display of the memos on file for his attention recorded since his previous inquiry. He can be advised by a warning light at his desk when a new one is added.

The telephone company in France has replaced individual telephone books in one community with an electronic inquiry system that is kept up-to-date at all times.

And Mead is offering a full text information retrieval system that allows a lawyer in New York, London or Paris to consult all aspects of the law directly from his desk, without the intervention of the keyword abstract, or a news researcher to locate and retrieve electronically news items on any subject from a growing list of international news publications, with greater accuracy and speed than is possible from a conventional library system. Both services are provided by satellite from a computer-based library in Dayton, Ohio.

In the publication field, methods of editing, composition and of printing itself are undergoing an electronic revolution.

When you stop and think, we do three things with information:

- store it;
- rearrange or manipulate it; and
- communicate it to others.

We have already noted that storage and manipulation of textual material can now be done very efficiently with computers, using digital techniques. In the past, telecommunications by telephone or radio have tended to use analogue techniques, using variable amplitude or frequency to transmit information. This is changing and by the mid-`80s it is anticipated that telecommunications will also have switched to the digital form. When this occurs, the language barriers between computing and communications will have disappeared. Information storing, communicating and manipulating already share a common digital technology, and the generation and transmission of sound and pictorial information by digital means is close at hand.

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I think it is a safe bet to say that 10 years from now many of our customers will use paper differently in their communication processes than they do today. In some cases, they may not use it at all.

Very few secretaries use carbon paper today, and pink file copies may quickly become a thing of the past. To survive in the market-place, paper will have to adapt to meet new end-use requirements, and these will most certainly be set by the needs of the market-place.

Still, I suspect that for a number of years paper will continue to be the most economic and convenient way to allow an individual to carry personally selected material around for easy access, away from computer terminals.

Digital encoding of high quality graphical material is much further away in time, particularly in colour, so it is likely that there will continue to be a market for quality pictorial magazines for many years. They may well be produced however, by a different printing process than is used today. Changes will come gradually, that is clear, but no less inevitably. And in the near future, the customer will have a cheap alternative to paper available.

Food packaging is only part of the larger packaging field, but the major changes that are taking place in food distribution are an example of how paper products must be sensitive to new market demands. Part of our high standard of living is the variety and quality of the food that is available in the stores year-round, the convenience with which it can be prepared and, in recent years, the rapid growth of eating out in convenient fast food outlets.

Consider the example of fresh meat. Originally it was butchered and quartered by the local butcher who handled all the different cuts and disposed of the waste. We already have most of the butchering done at locations near the cattle-finishing stations, where the carcasses are pre-trimmed and quartered for transportation to the local market. Packaging systems are required to protect the sections in shipment and to meet the requirements of refrigeration, etc.

Today in the restaurant business, as a result of the introduction of micro-wave cooking, the process is being taken one stage futher with the pre-manufacture of uniform, pre-weighed individual portions of steak or roast beef. Here there is no margin for spoilage or loss of appearance, flavour or weight: this trend is continuing despite increasing public concern with the use of chemical preservatives in the product or packaging materials. The technical specifications required of the package have increased considerably. This may be an extreme example today, but with our growing knowledge about carcinogens and food chemistry, I believe that manufacturers of food packaging of the future will require a much greater knowledge of barrier properties, migration of trace chemicals and the biological activity of the additives we incorporate in our products than we ever dream of today. The new laws and regulations that have appeared on the books in the past five years are certainly internalising for the packaging industry the public's concern for health protection.

In summary then, we have moved away from a period in which the industry and its markets were mature, stable and predictable. Factors we previously ignored as unimportant have become, in some cases, controlling: political, environmental and technological changes that are largely outside our direct control are affecting many of the elements of our manufacturing processes and of our market-places. Adaptation of our existing systems was the response of the `70s. The technological challenge facing our industry in the `80s is the redesign of our processes and products to suit the changed circumstances. In the past, we solved our problems with abundant natural resources, cheap energy and cheap capital equipment. In the future, we will have to rely more on knowledge; knowledge of our markets, knowledge of how better to utilise our raw materials and manufacturing processes, and knowledge of the impact our processes and products have on health and on the environment.

While the emphasis in commerical enterprises will continue to be on application, I think it is clear that there is an equal need to expand our basic scientific knowledge in many areas,

asking the important questions in fundamental research

some of which we have ignored in the past. If we don't make this effort, we may find, as the papyrus cutter before us, that a new product has replaced ours in the market-place.

Transcription of Discussion

Discussion

Discussion following prepared discussion contribution from Dr. J. Mardon.

Mr. D. Attwood, PIRA, UK

Dr. Asaoka, in your preprint you discuss Japanese government subsidies to your institute. Can you tell us please a little more about this, in particular, what ratio of funding you expect from industry and from government?

Dr. H. Asaoka, JPRI, Japan

The Japanese government gives no subsidy to any industry. If the government wants work done in a particular field, it discusses this with the appropriate companies, who put up the necessary money. Thus, in general, the government doesn´t subsidise any industry.

Mr. A. Ibrahim, AccuRay Corporation, USA.

Mr. Justus, references to the concept of the extended nip press can be found as long ago as 1967-68, where Wahlström and others showed that the applied pressure and its duration could be varied to achieve optimum pressing of a specific grade. This work was supported in publications of Beloit´s own research. I see Beloit´s development of the extended nip press as the first stage in the practical application of these results. Does your Corporation have any plans to go to a second stage, in which the applied pressure and the drainage flow are under operator control, and variable to suit the product?

Mr. E. Justus, Beloit Corporation, USA.

The extended nip press is a project on which Beloit have been working for over ten years. On a three dimensional plot, showing sheet moisture as a function of both nip residence time and nip pressure, the area of practical interest can be enlarged with the extended nip press to include nip residence times of up to 30 ms, at pressures up to about 600 psi, leading to increases in sheet dryness of some 25% over conventional presses.

Physically, the heart of the extended nip press is a curved shoe fitting beneath the press roll. It is about ten inches long in the machine direction, and loaded hydraulically to about 600 psi, equivalent to about 6000 pli in a conventional nip. There is a belt adjacent to the shoe, and the two felts and the paper sheet run between the belt and the Venta-nip press roll.

Lubrication is by oil applied between the belt and the shoe, whose mechanics are the same as those of a crown-controlled roll. The first commercial unit was assembled and run in the shop, and has been running on a paper machine some nine months. A full report will be given on it at the Tappi meeting shortly.

It is imagined that an extended nip press could be used in a liner-board machine as second after a double felted first press. This combination should give drynesses into the dryer section of above 45% dry. The advantages of the extended nip press seem to include a reduction of about 25% in the amount of water to be evaporated, and an approximately 15% increase in sheet density.

Mr. S.F. Brailsford, Reed International Consultants Ltd., UK

Mr. Justus, you implied that it was best for machinery development to be left to the manufacturers. However, surely the interests of the paper and board machinery suppliers are diametrically opposed to those of the paper manufacturers? We, the paper producers, prefer to use the least quantities of chemicals and the cheapest machines possible, which must surely be against the interests of the chemical suppliers and machinery builders. Thus I put it to the panel that the paper manufacturers find it hard to believe that it is in their own best interests to leave all R & D to the suppliers.

Mr. E. Justus

I don't want to travel with an airline that designs its own aircraft and I don't believe that in the long run it would be economical for airlines to do so. Machine building is a specialised trade, and the builders are to be commended for eliminating expensive and difficult to maintain, but very profitable, items from machinery (e.g. suction rolls).

Machine speeds have doubled on almost every grade of paper over the past twenty five years, and the cost of machinery per unit of production has increased less in the paper industry than in almost any other.

Dr. A. Mawson, Wiggins Teape, UK

Many people in paper-making argue as Mr. Brailsford, but I believe that competition forces suppliers to continue improving the performance and productivity of machinery. While I believe that discontinuous innovation is most likely to arise outside the industry, I am sure that incremental technical improvements will always come from within.

Mr. B.W. Burgess, PAPRICAN, Canada

The position isn't at all clearly defined. No organisation has a monopoly of expertise, so I don't agree with Mr. Justus that all machinery development should be left to the manufacturer.

Dr. D.A.I. Goring, PAPRICAN, Canada

Mr. Justus, is your Corporation working on air-forming for high speed machines?

Mr. E. Justus

No, and there is a reason. It seems to us that what gives paper its particular characteristics, is the hydrogen bond. Dry-forming is for speciality products, while my Corporation is in the business of supplying machinery for making commodity grades. We intend leaving dry-forming to the speciality machine builders.

Dr. A.H. Nissan, Chairman

This issue doesn't need to be polarised, and while I would hate to suppress inventiveness amongst users, I think that I am in favour of most of this development being done by machinery builders. The cost of research by suppliers can, except for royalties, be distributed over a large number of units if it is successful, whereas this is not the case of research by users.

Mr. B.W. Attwood, Consultant, UK

Mr. Justus must realise from his own experience that machinery innovation can be a two way process. His corporation has made use of ideas developed by paper-makers and developed them to levels unattainable by their originators.

On the subject of air-forming, it is important to bear in mind that it is a speciality process, not for general application. I am concerned that, unless it is being done in secret, none of the major machinery manufacturers is investigating either this or any other of several new ideas, which may be the precursors of technology discontinuities. It looks very much to me as though the main research effort at this time is into evolutionary modification.

Dr. N.K. Bridge, PIRA, UK

A report on innovation and the factors influencing it has been prepared by the Science Policy Research Unit at the University of Sussex. One of the conclusions presented there was that innovation is often initiated by users, then further developed by the suppliers. This seems very natural, and I am sure that Mr. Justus recognises the approach.

Mr. F. El-Hosseiny, Weyerhaeuser, USA

I think that the development of machinery should be left to anyone who wants to do it, though I agree that the manufacturers are likely to make a better and cheaper job of it. But paper-makers have to be careful not be inveigled into buying extremely expensive equipment that they neither understand nor need.

Dr. J. Colley, APPM Ltd., Australia

Development and innovation doesn't stop as soon as equipment is delivered to the paper mill machinery house. Most installations have an element of speciality about them, and no manufacturer can expect his machines to suit every application straight away. The last stage of development, in the paper mill, is usually conducted by the paper-maker, though with the manufacturer usually present too.

Dr. J. Mardon, Omni-Continental, USA

Dr. Justus has a valid point, from one particular viewpoint. The key to managing R & D lies not in knowing what to do, but in knowing what not to do. By tying up a lot of limited resources of expertise and equipment in machinery research you are not equipped for, your research operation will be very ineffective and you would have done better leaving it to the manufacturers. I am sure that is what Mr. Justus was referring to, as both he and I have seen many examples of it. If a paper-maker has an innovative idea, then his most effective way to exploiting it, is to develop it himself as far as he reasonably can, before taking it to the machine builder for further improvement. But to try to produce large scale pilot plant is a mistake.

Dr. A.H. Nissan

Without wishing to take sides, I will just mention that Tsai Lun, M. Robert, and the Fourdrinier brothers were all users. The twin-wire was a user development, and I think George Tomlinson was a user. But machinery builders have produced revolutionary changes also. Dr. Mardon's point about when to take a developing idea to a machine builder is important, because, whatever else, the builder does have experience of how to design and make pieces of machinery that work, and the outcome of the idea will be much influenced by whether or not it works. There isn't however a god-given law about this.

Mr. G. Place, Proctor and Gamble, USA

I believe there is a god-given law on this subject, which is that the R & D management and the general management of a company must have a very clear view of what business they are in. What I hear from Mr. Justus is a very clear view of his business, and therefore a very clear view of the research his company will undertake. If a revolutionary change does come about then Beloit either will have to have made arrangements with their research group to switch to the new technology, or go out of business. Thus the primary strategic question for a company is to resolve what business they are in, and for both R & D and general management to see it the same way. This view of the business can be as narrow and specialised as you like, provided there isn't some discontinuous change of technology. As soon as one occurs, the view will have to be widened if the company is to remain in business.

Mr. E. Justus

A lesson I saw illustrated very well the other day during a visit to the Imperial War Museum is that the simplest way of doing a thing is the best. The example I saw was of World War II aero engines, amongst which the successful ones stood out by virtue of their simplicity and cleanliness of design. I thought this example one of the best of the artistry and rightness of design that I have ever seen.

Dr. A Mawson

The similarity between two of the engines you looked at, the Rolls and the Daimler Benz, probably illustrates a point we are overlooking, namely that we learn much from our competitors.

Dr. A.H. Nissan

Before bringing the discussion back to paper-making, I must just say that the most successful aero-engine design has been the turbine, developed by an RAF engineer, a user.

Mr. B.W. Attwood

What happens to an innovator from a paper mill who has a idea, but who can't interest anyone, either machinery builders or other paper-makers, in it? He must have something material to show them, because innovation is concerned with doing things differently.

Mr. P.E. Wrist, Mead Corporation, USA

I see a difference between invention and innovation. The innovation mentioned by the previous speaker was not in widespread, successful, commercial use and therefore was not, as I understand it, an innovation. It was only at the stage of invention. To qualify as an innovation, as I see it, an invention has to be in commercial use.

Mr. J. Gough, Wiggins Teape, UK

Mr. Wrist, in the last diagram you showed in your presentation, demonstrating the relationship between the research resources required and the rate of growth sought, what was the scale of the x axis, the research resources? If it was percentage annual sales, then it implies that for a major breakthrough, it is necessary to spend around 6% of annual sales revenue on R & D. This is an unheard-of figure in our industry.

Mr. P.E. Wrist

Those figures were drawn from the examples firstly of a number of companies undertaking minor product development, who seemed to be spending, on average, rather less than 1% of annual sales: secondly, those who, while doing good development work, were remaining within their industries, spending 1-3%: thirdly, some examples of companies breaking into new markets. I would be the first to agree that present annual sales is a poor way of quantifying expenditure. For a conglomerate, with enormous sales, the amount required to penetrate a new market is a rather small percentage. My main point in that diagram was, to make a major breakthrough a company must spend on R & D at far higher rate than it need just to maintain market position.

Dr. A.H. Nissan

If, in a business with annual sales of $1 m, a product improvement is introduced that increases sales to $2 m, then it doesn't follow that R & D spending should double. So, this annual sales percentage issue is very misleading. I have seen only one article, many years ago, where an attempt was made to calculate, accurately, recommended levels for R & D expenditure. The calculations were involved, and required taking account of product life and profitability, amongst other things.

Mr. D.G. Croxon, Kimberly-Clark

Mr. Wrist, would you think it advisable to involve research workers in discussions of profitability, or do you believe they should be left totally in isolation, not even allowed telephones?

Mr. P.E. Wrist

I don't think taking their telephones away will much improve profits. There is an advantage in having at least the research managers know something about business and the factors that influence profit. However, that isn't their primary concern, which must be the identification of new technical opportunities to be brought to the main management's attention. They must point out the advantages, while recognising that the company is a team effort in which there are others more skilled in making financial judgements. This way lies the course to a true corporate decision on the viability of new projects. Profitability is very difficult to relate to R & D, and by loading such matters onto R & D personnel, the risk is of giving them too much to worry over, such that their performance is impaired. Still, they should be aware that making a profit is one of their company's objectives.

Dr. J.L. Brander, Wiggins Teape, UK

Expenditure on R & D is sometimes believed to be a function of what industry you are in. In other branches of machinery building 6% of annual sales is considered adequate to keep market position, without expecting any breakthroughs. I would like to ask Mr.Justus if the same is true in paper machine building?

Mr. E. Justus

6% is a lot and we would like to have a budget like that, but we don't.

Dr. M. Hussain, Abitibi-Price, Canada

From one of the charts in Dr. Asaoka's paper, I see that Japan consistently spends less as a sales percentage on R & D than we do in USA, in every industry except iron and steel.

Since we all recognise that the Japanese economy is doing better than that of the US, is there something significant in that? Also, I would like to ask Mr.Justus if he would care to comment on the suggestion I have heard, that Beloit deliberately held the extended nip press back in order to protect their foundry business?

Mr. E. Justus

The reason for the extended nip press' long development period, was arriving at a suitable mechanical arrangement that would survive in a paper mill. The belt was the most difficult part of the assembly. Our first design made use of hydrostatic rather than hydrodynamic bearings. The development has been hard work, and if you were to see our annual expenditure figures you would see that we weren't trying to hold back on it. We are in competition with the world in machinery production and if we have a development that will make more paper at lower cost, we won't hold back on it.

Dr. A.H. Nissan

The development time of the extended nip press was not unusually long.

Mr. A.G. Marriott, BPBIF, UK

There has been very little discussion about the financial justification for R & D, though it has been suggested, especially by Mr. Wrist, that it is essential for a company's survival. Would anyone of the panel like to comment on the quite widely held belief that it doesn't pay to be market leaders in an innovation, and that the second group in, the copiers, stand to do much better? The Japanese at one stage of their post-war development seemed to illustrate the truth of this.

Dr. A. Okagawa, JPRI, Japan

Japanese industry spends roughly 0.3 to 0.4% of sales on R and D, which is comparable with what is found in other countries, not less as has been suggested.

Dr. W. Adams, AccuRay, USA

We have discussed to some extent how inventions come about, before being developed into innovations. I think they usually come into being wherever a problem is well identified, and where there is stress. The greatest inventiveness is shown in time of war, or when companies are in trouble. So if people of inventive minds are subjected to stress, then inventions result. To develop further, to the innovation stage, using Mr. Wrist's definition, involves people with marketing skills. So, bearing in mind what I've said, I would like to ask anyone on the panel if they have ever tried taking their problems to their suppliers in a stressful way?

Dr. A.H. Nissan

Can anyone on the panel define "a stressful way"?

Mr. P.E. Wrist

The big thing that helps change an invention into an innovation is an identifiable market need. The chance of rapid adoption of an invention when there is a need for it are great. This shows in statistics too, such that some 80% of innovations can be shown to be in response to previously identified market needs, whereas only 20% arise without a market need. That doesn't mean that the latter group is unimportant, because when such inventions finally gain acceptance they often provoke change, revolutionary rather than evolutionary.

Lasers are a good example. For years after their development they were virtually unexploited, yet now we see that they will probably be at the heart of the next revolution in communications technology. We need both kinds of inventions, but in an industry where it is important to make a profit every year, it is probably better to look for inventions that meet market needs, rather than the other sort.

Mr. E. Justus

If a customer with an invention wants to provoke a response from us, then his best chance is to spell stressful "M-O-N-E-Y".

Dr. A.H. Nissan

On that, which defines the essence of all our involvement in the industry, I think we should call a halt.

Today we have had fourteen panelists give their views on various aspects of R & D, and I think that the fact that I have had to cut short the discussions must testify to the high standard of their various presentations. Thank you for putting such efforts into the preparations.

Concluding Remarks

Mr. M.I. MacLaurin

Firstly, I want very much to thank Dr. Nissan for so ably chairing today's proceedings. It required much preparation and hard work, but the results have well justified the effort. So, on behalf of us all, Alfred, thank you.

Thank you, also, the Engineering Dept. Staff who have been working behind the scenes, handling the audio equipment and projectors, as well as the very efficient people, Sandra and all the UMIST students, who have been doing all the microphone work, and the two girls, Katherine and Dawn, who have been manning the front desk.

I will be brief in closing this symposium because many people have a lot of travelling to do this evening, and I want to sustain our reputation for being on time. But I shall speak for a few minutes about the next, the eighth, to be held in 1985.

Firstly, a large number of delegates has in fact responded to my request for opinions yesterday, and it is quite clear that we shall be at Oxford unless some compelling difficulty arises. We shall start investigating right away, to see how things can best be arranged to overcome some of the problems we have had here. But is does seem that a majority would prefer being at Oxford.

Secondly, this particular meeting in its first morning and its last day, has departed somewhat from the tradition of these symposia, and I think that format has been timely for 1981, especially as regards todays discussions. However, I think it is not something we shall repeat too soon, and the 1985 meeting will be essentially scientific throughout, with a return to the format of previous symposia in the series.

Thirdly, you may recall that, in my opening remarks on Monday, I suggested we didn't need a theme for 1985. Well, even before the first working session Dr. Rance had put his disagreement on record, and it has become clear during the week that most people here disagree with me on that. So I am now persuaded of my folly and publicly repent.

What really convinced me was the emergence during the week, based upon a lot of help from everyone, of an idea for a theme, endorsed by the committee. We shall have to sort out the wording of it, but, as we all know, the paper-making processes and the properties of paper products depend very much on the properties of the pulps we use and the processes by which we prepare them. In 1985 we intend to bring those relationships together as the theme for the symposium. If anyone has ideas about this, even if you think it is utterly wrong, I would like you to write to one or other of the committee.

Now, all that remains to be said is thank you to everyone for taking part in the week's events. Travel home safely, and let's all meet again in 1985.