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BELOIT GROUP R & D PHILOSOPHY AND PRACTICE

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Technical Research as a formalised departmental activity at Beloit was begun in approximately 1957, with instructions from Mr. Lloyd Hornbostel, Vice-President of Engineering, to set up a Research Department.

Prior to that time, Beloit Iron Works had been a very progressive company in their policy toward technical innovation by their engineers. It had been for a long time, and continued to be, the policy of the company to pay substantial royalties to those within the company who were able to develop economically viable products, with patent protection. The policy of paying royalties to employees was quite different from the policy followed by most companies, wherein all patent rights were automatically assigned to the company. It is believed by some that this very significant monetary recognition of patentable ideas was important for the early growth of the Beloit Iron Works.

Beloit, Wisconsin, is essentially in the middle of the cornfields in Southern Wisconsin and some distance from any significant paper-making area. Their early reason for growth had to be the high quality of labour in the area, which was largely German and Scandinavian, plus enlightened sales and technical policies.

With the beginning of the formal Research Department, objectives were set to bring a higher level of technical understanding of the different mechanisms of paper-making to the R & D approach at Beloit. Young men with advanced degrees were hired, whereas, previously, almost no one had an advanced technical degree. Areas such as fluid mechanics, paper forming, heat transfer, drying, pressing, and coating were identified and

set up as separate sections.

The philosophy at Beloit is to spend practically all of the research effort and money on the products that Beloit sells. In other words, we do not set up programmes to develop improved lathes and milling machines within the Research Department. We feel that we could buy machine tool development with our machine tools. We have noticed that some paper companies tend to spend much more of their development effort on the machinery that they buy, or might buy, than on the paper products that they sell. It has been our observation that those R & D programmes in the paper industry which are really successful, are primarily those which focus on the improvement and expansion of the paper products or the pulping process. There is a tendency when R & D works on those items which are purchased by a company to favour unduly the in-house development, quite often to the detriment of the paper company.

Beloit has emphasised certain areas of investigation, such as fluid mechanics, which includes fibre dispersion, paper forming, pressing and drying. These are areas in which the company cannot afford to be outflanked. R & D work is carried on in basic areas with the training and advancement of expertise of the personnel in those areas on a continuous basis. Such work is not just primary "project" orientated, but is expected to be an investigation into the best use of existing technology and the generation of such new technology as is required for the improvement of the area of investigation.

An example of this approach was the development of the Venta-Nip, or grooved, press. In the `50's, almost all high-speed presses were suction roll presses. But in attempting to define the mechanism of pressing and the removal of water from paper and felts, we tried to go back to as fundamental an analysis as possible.

As young engineering students, we were taught that the basic driving force for moving water or other fluids was a pressure gradient. In pressing,therefore, it appeared desirable to achieve the maximum pressure gradient. To increase the pressure gradient, it was necessary to shorten the flow path and reduce the fluid

pressure on the side of the felt away from the sheet. In numerical analysis of this mechanism, the question was raised as to what effect the vacuum had, and it became apparent that the maximum vacuum is equivalent to approximately 10 psi, whereas the unit pressure developed by the nip could be in the order of 400 to 500 psi. From these conclusions, it would appear that vacuum had very little to do with the actual removal of water or establishing the flow of water from the paper to the felt. A further investigation of the method of venting the back side of the felt indicated that certain suction roll hole patterns created a much longer distance for water to flow in the plane of the felt than a fine grooved pattern. Further analysis of the vent patterns available, such as holes, blind-drilled holes, and grooved patterns, indicated that the perimeter around the vent on the back side of the felt was greatly increased by the use of linear grooves rather than holes.

An experimental programme was set up to investigate these concepts and see if they worked as the basic analysis said they should. After some experimentation, an optimisation was arrived at in 1963, and this information was announced to the trade. At that time there were no grooved presses operating at high speed on paper machines. Today, there are approximately 10,000 rolls operating as grooved presses with grooving patterns not unlike those developed at Beloit. The savings in costs of vacuum pumps and suction rolls have been literally into tens of millions of dollars.

I offer this as an example of a basic technological re-look at one of the mechanisms of paper-making. It is a Beloit premise to go back as far as possible to basic technological understanding of a process before getting into the experimental or developmental stage.

One of the most important technical papers which we utilised over the years for the development of headboxes and forming systems was that given by Dr. Stan Mason on the network strength of paper fibres. I think that I first heard this paper given at the Institute of Paper Chemistry in Appleton in approximately 1954. Study and attempted understanding of the basic concept

pointed the way to the development of the new design of headboxes and new forming zones, and without such basic understanding of fibre network strength, headbox development and forming zone development is much more of a guessing game.

The development of the Converflo headbox was a long-term programme instituted to make a static element headbox which would give maximum fibre dispersion by breaking up fibre networks and rejoining the fibres into a more uniformly dispersed flowing mass. The use of static elements rather than rectifier rolls to accomplish this function was necessary to contain the forces resulting from the high pressures within the headbox and to eliminate the associated cross-machine deflection problems.

Here, again, a rather long-term programme with the attempt to utilise and develop the best fundamental knowledge of fibre dispersion along with a mathematical and electrical approach to flow distribution was carried out. The result at the present time is over 200 installations of Converflo hydraulic headboxes. I would like to acknowledge the major contributions of Dr. Joseph Parker, now deceased, author of the TAPPI monogram on sheet forming, to this endeavour.

Back in 1957, when I was a much younger engineer, I made a request for something over a million dollars for a new research facility at Beloit. Mr. Neese, who was the owner of the company, asked me one day at lunch,

"Justus, how can you justify spending over a million dollars of my money to build a Research Department?"

I was very much taken aback, and after thinking a moment, the best answer I could give was,

"Mr. Neese, if you decided ten years from now that you wish you had a Research Department, it will already be too late. Research is an act of faith; a casting of bread on the water."

Mr. Neese, being the son of a preacher from the West Virginian Mountains, thought for a moment and said, "That was the best answer I could have gotten. When can you get started?" We moved into new facilities in less than one year and now have a corporate R & D budget approaching nine million dollars.

There has always been strong financial support by the management of Beloit for R & D, and no R & D operation can function effectively and well without the enthusiastic support and backing of management.

R & D people, by definition, should be the equivalent of patrols and no army unit advances without active and persistent patrol activity: patrols represent R & D. No patrol can operate well if it is being "shot at from behind."

So, in conclusion, Beloit R&D has attempted to improve the machinery of the paper-making process. They have attempted to go back to basics and to utilise fundamental and basic technologies wherever possible. They have had strong support from the management.

I would be pleased to try to answer any questions regarding our past developments and our philosophy towards different aspects of the paper machine that you may ask.

Thank you.

Asked about the organisation, decision-making and career structure of Beloit Corporate R & D, Mr. Justus writes:

a. The organisational structure of the Beloit Coporation Research is essentially a simple line organisation. There are three facilities: one in Rockington Illinois; one in Pittsfield, Massachusetts; and one in Bolton. All report to the Corporate Vice-President of Research.

Within each of these facilities there is an R & D Director, and the internal structure is again basically simple line organisation, with a director of each of the areas of investigation reporting to the director of the facility. There is also a function which we term R & D support, which handles mechanics, secretarial services, and cost reporting, which are used by all of the areas of investigation.

In other words, the Beloit R & D philosophy on organisational structure is to keep it simple and direct.

b. The decision-making process to determine which projects on which to work and the general areas of investigation are again quite simple and straight-forward. R & D in the past has had the ability and the authority to make the decisions about the areas of investigation and the projects. The R & D management has always tried to listen and ascertain from the sales organisation and from the technical literature, guidance as to what projects should be pursued. We try to balance need against probability of success, need against cost, and advantage to the industry against overall cost. I suppose it must be admitted that the final decisions are somewhat subjectively arrived at. We do not have a rigorous numerical formula and have resisted all attempts to create one.

c. With respect to career structure, many of the young engineers assigned us who come into R & D migrate to the rest of the Beloit Organisation and even to the rest of the paper industry for that matter. We try to pay salaries which are commensurate with the contribution.

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.