SOME THOUGHTS ON R&D, CREATIVITY AND NEED FOR INDUSTRY-UNIVERSITY INTERACTION

by

Arun S. Mujumdar
Singapore

1. INTRODUCTION

In this chapter a collection of my thoughts on R&D, creativity and need for academia-industry collaboration to promote advances in drying technology is presented. Most of them are philosophical and present views on diverse subjects of interest to any serious researcher or scholar as well as the industrial practitioner.

Among the various topics discussed are research models for academic R&D, need for innovation, significance of R&D as well as need for industry-university interaction in applied discipline such as drying. Newly coined phrases *"closed-loop model of academic research"* as well as *"academic research for academics and by academics,"* both of which are now in wide circulation, indeed resulted from this thinking process. The application of Foster's "S" curves to define when R&D on a given product or process should be discontinued as the incremental gain in performance will not justify continued allocation of scarce R&D resources (see Chapter 6) also originated from these thoughts.

Some of these ideas were selectively published as Editorials in *Drying Technology – An International Journal*, the only archival journal devoted solely to the science and engineering of drying. Slight variations can be noted in these two places, however.

For the convenience of the reader this chapter is divided according to different categories of ideas and viewpoints presented. Some overlapping is inevitable, of course.

2. RESEARCH MODELS: UNIVERSITY-INDUSTRY INTERACTION

A.

It is well known that academic researchers are facing severe compression of funding from public sources in almost all parts of the world – there are exceptions, which only serve to support the rule. Yet, high quality innovative research, both basic and applied, must go on to push the frontiers of knowledge and technology in this era of global competitiveness. Further, research in academia serves another valuable purposes viz. to train highly skilled researchers for academia as well as industry. This key element of training often results in a longer time scale for accomplishment of research in universities. Also, academic research results are generally expected to be open and disseminated widely. These two distinguishing features of academic research are often in conflict with the goals of most industries, leading to poor interaction between the generators of knowledge and the potential users thereof.

I believe that special effort must be made so that the two parties can meet halfway for mutual benefit. In a field such as drying (or applied heat and mass transfer) close interactions between university researchers and industry are essential to make the research relevant and worthwhile.

Figure 1, which is clearly a simplistic model of most academic research, shows essentially its “closed-loop” nature; this is undesirable, especially in engineering and technological fields. Research in academia, by academics and for academics is unlikely to lead to technological advances of benefit to the society. Since, in most parts of the world, much of the funding for university-based research currently comes form government sources there is little incentive for academics to seek partnerships with industry. Publication and desire for increased citation of their research papers often becomes the primary goal of such research since these criteria are applied by granting agencies in their evaluation of grant applications. Obviously, this is not a good model for engineering or applied scientific research in universities.

Figure 1 A “closed-loop” model of academic research

Figure 2 presents a model for engineering research in academia, which portrays how industry-university cooperation could lead to useful technology transfer. Aside from tangible research support from industry as well as public sources, it is necessary to maintain interaction between academic researchers and industry personnel throughout all phases of research. If the academic researcher is not included in the final technology application it is unlikely that further interactive research will take place. It is also reasonable to expect that the beneficiary of the R&D results should plough back a part of the benefits received directly or indirectly to promote further research training in academia.

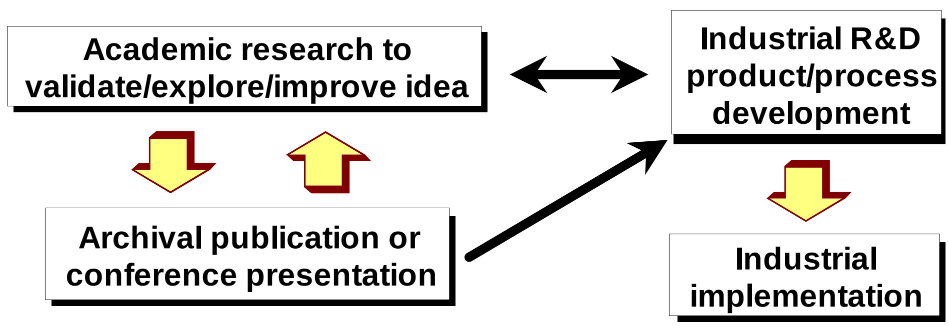


Figure 2 A desirable model for engineering research in academia

As drying is a truly inter- and multi-disciplinary field, without eventual industrial exploitation, engineering and scientific R&D results are of marginal value and often difficult to justify. I hope that many more of the papers published by academic researchers will be read and "used" by engineers, technologists and scientists in industry rather than only by other academics to make incremental advances by extending the reported results. Unfortunately, the current system of evaluation of university-based research places excessive emphasis on "citations" (rather than utilization) of research papers by other researchers (which is almost exclusively in the academic domain) and does little to evaluate the impact on industrial applications or their pertinence to industry.

B.

Evaluation of research carried out in academic institutions has been a topic of considerable discussion and disagreement over the years, especially as resources devoted to R&D – basic as well as applied – continue their downward movement almost in all parts of the world. Numerous organizations and publications continue to evaluate academic institutions according to some transparent and some not-so-transparent criteria and often arrive at widely divergent ranking results. The criteria used for the ranking exercise and the relative weight given to such criteria decide the ultimate ranking obtained. These results can and do have appreciable impact on the reputation and hence ability to attract high quality students as well as research funding and alumni support.

Probably because of its simplicity, the dollar value of the research expenditure is often used as a convenient indicator of the level and quality of the research effort. This criterion, of course, does not properly account for the effectiveness with which the funds are used to conduct research. It is obvious that an appropriate indicator would be the productivity and impact of the research accomplished. The number of publications itself can yield a false indicator of the value of the research results produced.

It is generally recognized that the impact of the research on its particular field should be a reliable indicator of research productivity. Publication in a journal with a high impact factor is therefore taken as a measure of the value of the research output since this is a quantifiable (within some limits) number that is useful for numerical manipulation in arriving at rankings. Basically, a high impact factor implies a larger number of citations of the work by other researchers in their own research publications. Implicit in this logic is the assumption that the purpose of a research publication is to help produce other publications. Furthermore, a large fraction of technical literature produced around the world is not yet included in the databases used for computing the impact factors for journals as well as individual papers. What is even more troubling is that if the paper produces a result that is actually applied in an industrial process, it does not enhance the impact factor for that publication. For many engineering and applied scientific publications their true value is in utilization rather than mere citations of the work published. While the impact factor certainly has clear merits for primarily academic journals servicing research in academia by academics and for academics, its application to technology-oriented publications must be called into question.

C.

Nature does not compartmentalize itself into the manmade pigeonholes of chemistry, physics, biology, engineering, etc. The real world crisscrosses our artificial disciplinary boundaries with increasing intensity as the complexity of the problem and our knowledge thereof increase. It is only recently that the significance of inter- and cross-disciplinary education and research has been recognized in a tangible manner by major granting agencies like the National Science Foundation (NSF) of the USA. Communication skills, teamwork skills, multi-disciplinary and applied research experience are important elements of training, especially at the post-graduate level. NSF has also identified international awareness and need to build on the strengths of different disciplines and different institutions along with exposure to industrial practice as some of the key elements for engineers and scientists of the next generation.

Drying has naturally evolved as a multi- and cross-disciplinary area of R&D right from its inception. It is no longer a subject area only in the chemical engineering curriculum. Indeed, fewer than ten percent of the research contributions published in *Drying Technology – An International Journal* come exclusively from chemical engineering; even a cursory look at the affiliations of authors shows a definite trend toward interdisciplinary and even international collaboration. This is a natural by-product of globalization but also an essential feature of a truly cross-disciplinary area of R&D. I hope that in the future we will see more interactions between industry and academia as well. Personally I have found it extremely beneficial for my graduate students as well as for my research objectives to actively collaborate with academic and researchers from R&D Centers nominally belonging to agricultural engineering, food science, mechanical engineering, pulp and paper technology as well as electrical engineering disciplines. What has been an even more interesting and rewarding experience is the international scope of such collaboration which included researchers from (in random order) Canada, USA, Finland, China, Japan, Hungary, Spain, Czech Republic, Poland, Russia, Singapore, Hong Kong, Jordan, Brazil, Norway, etc.

With the dawning of the new century, I am optimistic about acceleration in drying R&D, both at the fundamental and applied levels, preferably with active industry participation and guidance.

D

Researchers in academia as well as industry along with granting agencies consistently agree on the need for more R&D funds. They argue that R&D funds should be rightfully considered as investment rather than expenditure. In either case it is necessary to account for the outlays on R&D in terms of its economic and/or social benefits. It is essential to look critically at the cost/benefit ratio for R&D funds in general and provide appropriate justification for such expenditures or investments. This is more readily – not necessarily easily or reliably – achieved in the business or industrial world. When public funds are used for R&D – a major source for most nations – it is a much more difficult task.

There is much scholarly literature on the economic returns on publicly funded basic research (e.g. A.J. Salter and Ben R. Martin, Research Policy, Vol. 30, 2001, pp. 509-532). As these authors point out research output may be information or knowledge that can be used to economic advantage; they postulate that much of the publicly-funded R&D output is of informational nature and the knowledge created is “non-rival” and “non-excludable”. Non-rival knowledge is defined as that which others can use “without detracting from the knowledge of the producers”. Non-excludable implies that no one can be stopped from using this knowledge – even competitors have free access to it although they did not pay for it directly. This is also the nature of information and knowledge disseminated by journals such as Drying Technology.

Utilization of “free” informational knowledge requires significant investment to understand and use it to advantage. Thus, scientific knowledge is really not available “freely” but only to those who have the necessary expertise to access it. An OECD Report (1996) states: “Knowledge and information abound; it is the capacity to use it that is scarce”. Information is available to all but only those with the right capabilities can convert it to knowledge and use it to innovate.

I propose that the rate of technological innovation depends directly on the rate of generation of informational knowledge and the effectiveness in its utilization; the latter is a measure of the ability to assimilate or exploit the knowledge. Efficient dissemination of knowledge is important but it is equally important to develop the ability to utilize it. Academic institutions are responsible for developing such ability. If they can also make a valuable contribution to generation of new knowledge as well then they are very effective in enhancing the rate of innovation, which drives economic growth of nations.

E

The central theme of this editorial is the role of academic research per se. Diverse demands are being made of academic institutions of higher learning practically all around the world. All wish to be world class – a label that is very ill-defined but extensively used term. This is often interpreted to mean that they must excel in teaching, research and in providing service to the academic community at the university, the profession, the society and indeed the whole world. Various criteria have been established in good faith by the various administering and governing as well as financing bodies to ensure that these institutions do their perceived jobs well and become internationally recognized.

I will focus only on what I think is the university's role as far as research is concerned. There is little or no controversy regarding the teaching or educational function of such institutions. The service component, while important, also can be interpreted flexibly and thus lead to minor dissent among peers. Research, on the other hand, is a difficult topic since it also tends to be expensive. Basic research, as commonly defined and understood, does not produce perceptible benefits in the short term. Thus, it may be considered a luxury. Applied research may produce short term economic fallout which may or may not be of enough general interest and archival value. The more affluent institutions, regardless of their geographic location, can afford basic research in science and engineering (some scientists may legitimately label all engineering or technical research as applied.) The primary question remains: what is the purpose of academic (or university) research?

Simplistically, academic institutions should provide a fertile training ground for researchers of the future by fostering creativity and innovation. The short stay of 3-5 years that a typical PhD student gets in residence at a university is barely adequate to prepare him for a research career. Professors are constantly provided with novice researchers whom they must train from ground zero and hopefully make them good enough researchers so that they can be awarded the PhD degree as a stamp of approval. Thus, professors in most parts of the world - there are of course welcome exceptions - are asked to train or educate researchers. Their research output then is a valuable by-product of the training process. If the focus is only on the output of papers, then the researcher will become more of a technician adept at producing repetitive results with little insight, creativity or innovation. The research training aspect of university professor's job must not be underestimated. Thus the current emphasis on producing research papers in journals of so-called high impact factor (not necessarily of high impact) is counter-productive to the main theme of academic research. I believe that the true research career of a PhD starts once he becomes a researcher on his/her own in academe or industry.

Can academic research in most institutions compete successfully against industrial R&D laboratories of large multi-nationals? The short answer to this question is No! Some of the really ground-breaking research of today requires human and financial resources which are way out of line of what academic research granting agencies can afford perhaps all over the world. The latter may be able to devote orders of magnitude greater resources to a truly epoch-making discovery. What academics can strive and hope to do is provide industry with well trained researchers so that they can actually accomplish the mammoth tasks ahead. If they can do this successfully, I feel they have done their job and they should feel proud of their accomplishments.

To sum, I feel academic research should focus on producing high quality researchers (where research output is a valuable by-product), while industry and government laboratories should utilize this valuable resource to produce R&D that drives the national economic engines competitively. This will be a true win-win situation for both parties. Universities trying to commercialize research are unlikely to get rich producing results that cannot match what major industry partners can do on their own. Also, making conflicting demands on academia can only have demoralizing effect on their performance especially in resource-challenged institutions of today.

F

Globalization has become the *mantra* in all spheres of life in the modern day. This has increased competition in all spheres of the economies of nations. R&D is recognized as the engine of knowledge-based industries. It is well known that the objectives and methods of assessment of success are different for industrial R&D and for academic research. Yes, universities are expected to educate and train researchers for industry although they are expected to follow a different line of objectives once they are in the industrial sector. An obvious question then is: are universities are doing a good job of meeting the industrial needs? Indeed, one may go further and question of academic research training can produce outstanding industrial researchers. My short answer to these questions is a definite yes, provided academics take into account the needs of industrial R&D.

As I have noted in an earlier editorial in this journal, I believe that one of the objectives of academic research is to train researchers while the research output itself can be maximized as a by-product of this effort. University professors are expected to initiate graduates with no prior research training or experience and convert them into able researchers in a relatively short period of three to five years. This must also be done with very limited and continually shrinking financial and other resources. As the dynamic frontiers of knowledge keep expanding at a hefty clip, this is a daunting task for both the research student and his/her mentor. Hence it is too much to expect that researchers-in-training can produce truly cutting-edge research that will make a massive impact on the state-of-the-art. One should consider academic research to be successful if it produces outstanding researcher and useful research in the process.

Industrial and academic research approaches differ in several ways: industrial research is driven by the bottom-line of the company- the need to make profit by overcoming (even destroying) competition. Hence the time scale of R&D is shorter and it must be confidential to keep the competitive edge. The focus is on *know-how* and not *know-why*, which is the key focus of academic research. Academic research also must be in the public domain and peer-reviewed publication is central to recognition of such research and institutions where it is carried out. It is supposed to expand the global reservoir of knowledge while industrial R&D must aim at tapping this reservoir for economic benefit to the company concerned and eventually to the society at large. Originality and scientific quality, which are yardsticks to measure academic research, do not apply for industrial R&D.

Although the objectives and assessment criteria for academic and industrial research are understandably different, I believe that cooperation between the two is essential in engineering research in academia. Industry can identify generic problems requiring a fundamental knowledge base which is the ideal realm of academic research. Unless academics are made aware of current and future industrial problems in new areas, industry cannot reasonably expect to find trained researchers who can help them grow via innovation in the future. They also cannot expect to have someone develop the necessary basic reservoir of knowledge that is potentially useful to industry. Finally, if industry has a stake in the research they collaborate in then it is a true win-win situation for both academia and industry.

In the interdisciplinary and multi-industry field of drying there remain formidable challenges in need to fundamental research. Industry can help identify them clearly and also support academics in their search for solutions in a generic manner. Without sacrificing the understandable requirement of secrecy, it is possible to help expand the knowledge reservoir that may be profitably tapped in the years to come. I do hope that we will see much more industry-academe collaboration in coming years that will accelerate the development for drying technologies in all industrial sectors. Furthermore, such cooperation can be global as well.

3. SIGNIFICANCE OF RESEARCH AND DEVELOPMENT

A.

Although it has been widely recognized that research and development activities are central to the rising standards of living, in recent years, only a few countries from among the developed world have actually continued their support of R&D and education at the advanced level at the same clip. There are notable exceptions, of course.

A wealth of valuable information is available on the website of the National Science Foundation (NSF) of the USA regarding R&D support by the US government and the R&D activity of the US industry. The interested reader is referred to www.nsf.gov for details. It is encouraging to see that the support of R&D by both the government and industry show increases, albeit small in constant dollar terms. The combined government and industrial R&D represents 2.8% of the Gross National Product (1999 figure for the USA) – a 5% real increase over 1998. This represents $247 billion of which only 15.3% went to basic research (mostly carried out by universities and government R&D laboratories), 22.9% to applied research and a whopping 60.9% to development. Another interesting statistics is the fact that the lion's share of R&D in the USA is carried out by industry – $169.3 billion or 68.5% of total R&D in 1999. This amounts to a gain of 10% in real terms for industrial R&D. Government contribution was only 26.6%, which is very significantly down from the earlier decades. The drop in government R&D support comes mainly from the reduced defense expenditures. For comparison, Japan allocates about 2.92% of its GDP to R&D.

As the share of the government support of R&D drops, basic research activity as well as applied research of a non-proprietary or unclassified nature will necessarily decline over the next decade. Since our knowledge-based scientific as well as technology depends on our ability to access results of R&D, this is a somewhat worrisome development in the global context. I hope that industry will contribute its fair share to promote basic and applied research at universities and also encourage its own staff to disseminate results of their R&D whenever it is justified. So far the transfer of scientific knowledge has been in one direction – from academia to industry. In future we will need a new model for knowledge transfer that is bi-directional. The ultimate beneficiary of both academic and industrial R&D is the society at large. I hope there is adequate justification for greater involvement of industry around the world in both the production and dissemination of knowledge across geopolitical boundaries via peer-reviwed publications.

B.

The link between R&D and corporate profitability has been established time and again. It is well known that countries devoting larger fractions of their GNP to R&D have competitive advantages over those that do not or cannot in international trade. Yet, many companies – not unlike countries – view R&D as an overhead expenditure rather than investment in the future profitability – indeed even survival – of their business. Many countries have elected to cut down their R&D budgets in a desperate attempt to reduce expenses in the short term. Unfortunately, the time scales of basis as well as most of the innovative applied research do not fit the inherently shorter time scales which are considered politically correct.

Richard N. Foster (author of the book "Innovation – The Attacker's Advantage, Summit Books, N.Y., 1986) has noted numerous cases of seemingly profitable companies that eventually lost major fractions of their primary business – or even went bankrupt – since they did not anticipate when their present products would become unprofitable. Foster shows that successful companies constantly attack both the competition – and often themselves – via constant innovation fuelled and support by relevant R&D. Holding on to the current technologies for too long and abandoning (or not accepting) new technologies because they do not recognize their long terms benefits, can lead to disastrous results.

R&D effort in drying and dewatering must necessarily lead to improved processes and products and enhanced profitability if it is to be justified. Basic research in drying is expected to yield innovative concepts that applied R&D may convert into viable products and processes. A key link in this transition is better communication between academia and industry. Ivory tower basic research with no long term goal (or vision) will not find an industrial partner to utilize the results effectively, eventually casting doubt on the value of the academic effort. On the other hand, without such research it is unlikely that we will see the development of innovative concepts for industrial exploitation in the future. I believe that fruitful innovation in drying – as in other engineering fields – can only emerge as a result of effective industry-university interaction.

C.

A cynic, said Oscar Wilde, knows the price of everything and the value of nothing. Unfortunately, while it is easy for managers in government and industry to calculate the price or cost of R&D quite readily, it is much more arduous, if not impossible, to establish the value of the results of R&D for several reasons. One key mitigating factor is the time scale associated with returns on R&D expenditures (or investments). Since the returns, if any, are realized in future, current accounting practices make it impossible for managers to fully appreciate the value of R&D. One may short-sightedly "reengineer" an operation to cut expenditures at the cost of value; this can happen especially easily if the output of research has no directly salable product, e.g., academic research and industry exploratory investigations.

Appropriate R&D must eventually increase the value of the output or decrease costs of a company. The components of cost in a product today are R&D costs, intellectual assets and services. However, old accounting practice is based largely on costs of materials and labor. Clearly, it cannot account for the value of the intellectual capital and such intangibles as skill, knowledge and information. Charles Handy, the author of "The Age of Unreason," estimates that the intellectual assets of a corporation are usually worth three or four times its tangible book value and even more for a research-intensive company. In the emerging knowledge-based economies "soft" assets can be far more valuable than "hard" assets (like buildings). As long as CEOs and their subordinates are rewarded financially on the basis of quarterly bottom-line income, little attention and resources are devoted to long term expenditure, particularly where depreciation cannot be charged (such as for buildings).

If one views the current costs of R&D in the light of its future value, it is clear that the current trend of cutting R&D budgets is at best short sighted. R&D enhances the "soft" assets of an organization, which, in the long run, may outweigh the "hard" ones. In some rapidly evolving industrial sectors it will also help the very survival of the organization.

D.

Drying is one of the oldest and most commonly encountered operations in industry. It is naturally considered to be a mature technology although from the scientific and engineering points of view a lot remains to be understood about this complex operation. To a novice to the field it might not be obvious why drying technology remains an area in need of much R&D effort.

Based on the hypothesis that the number of patents issued in a given area is a measure of the industrial R&D activity and interest in the subject area, we carried out a simple analysis of the patent literature. Specifically, we focussed on patents issued in the USA over the last decade (1990-1999). Figure 3 shows the number of patent titles that include the words dryer, drying or drier. Almost 240 patents issued in the USA per year have a direct bearing on dryers (equipment) or drying (process). The European Patent Office issues about 80 patents per year. In absolute terms it is difficult to state categorically whether this number is small or large or in between as a reflection of industrial interest and activity in the field of drying. Non-thermal dehydration (dewatering) was not included in this study.

In order to assess the relative significance of drying to other unit operations of major industrial interest, we obtained similar data for adsorption, crystallization, distillation, evaporation and membrane separations. Figure 4 shows the results of these searches for the 1990-1999 period. It turns out to be that the activity in drying exceeds the total activity in all other unit operations listed. While the low number for evaporation is expected the academically active research area of membrane separations has attracted fewer than 20 patents per year, i.e., under ten percent of drying/dryers. Thus, it appears that drying R&D remains and will remain an economically attractive and viable area.

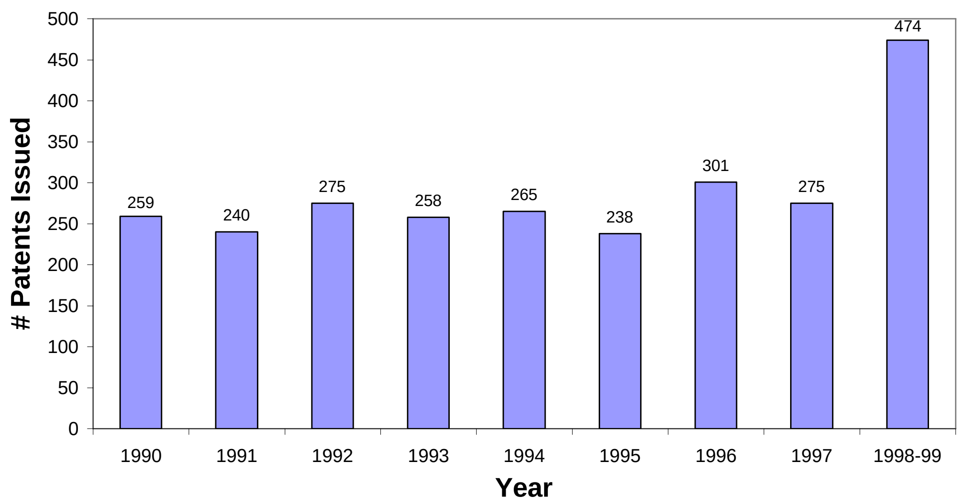


Figure 3 Number of US patents issued in drying (1990-1999)

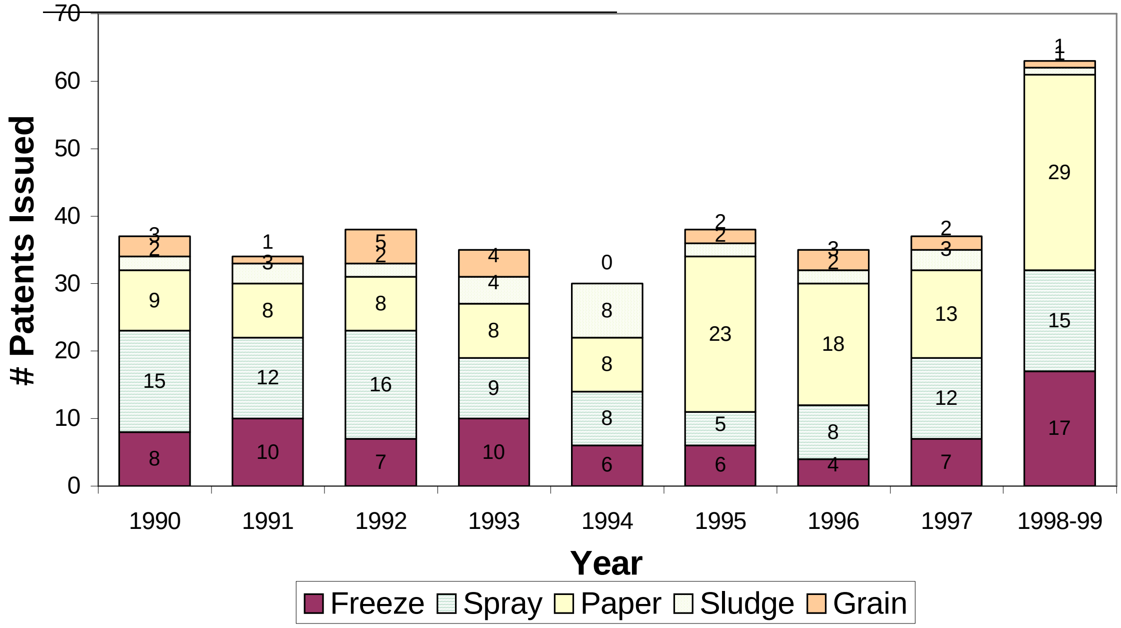
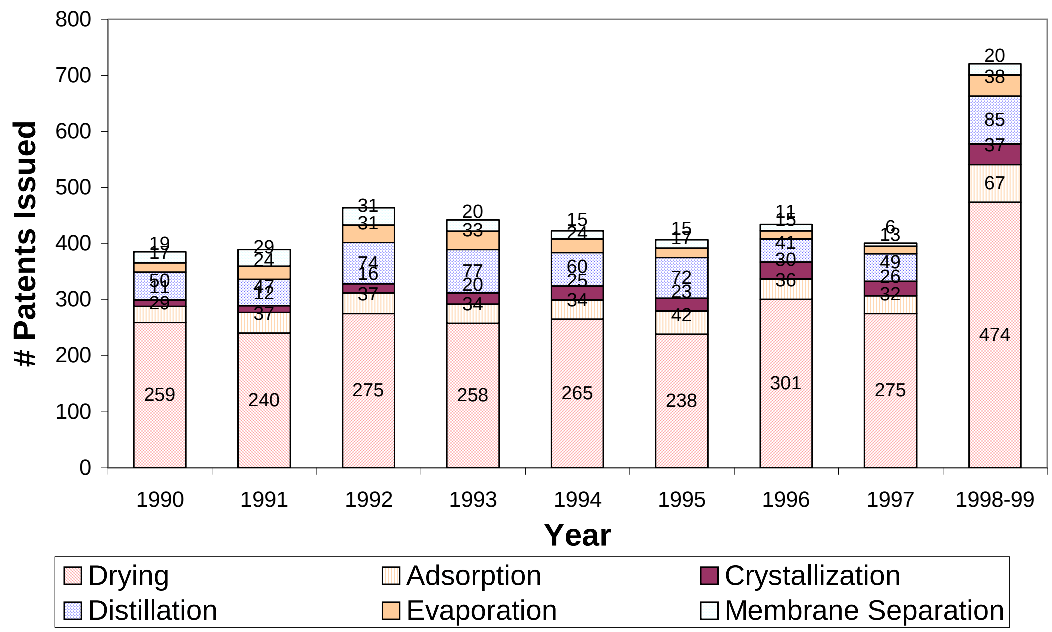


Figure 4 Distribution of US patents among various unit operations

Finally, within the general area of drying we found that paper drying, spray drying and freeze drying remain active areas for inventors seeking patents while such activity is rather low in the field of grain and sludge drying. Figure 5 displays the results, again, covering the same period viz. 1990-1999.



. **Figure 5** US patents issued in different areas of drying

E.

In the 21st century it is innovation that will drive the economies of the world. A pro-innovation policy that earmarks increased resources for R&D – both basic and applied – will rich dividends to those that adopt it. Research investments are often considered risky. However, according to Business Week (August 24-31, 1998) investment in R&D has yielded at least a 30% annual return to the society (in USA) compared to 8-10% on investments in new physical capital such as new machines. Some $200 billion are being spent on public and private R&D annually in the USA. Some economists believe that the right level should be about four times this figure. Perhaps this is overly optimistic. On the negative side, resources for basic research – largely and most effectively carried out in universities – are lagging at about 3.8% of the GDP for USA in 1997. This is down from 4.1 % in 1991. The trend is disturbing if not serious.

Studies show that R&D spent in the private sector and in academia have a much bigger payoff than research done in government organizations. Naturally, industrial R&D are necessarily shorter term and focused on specific products and processes. Fundamental research, which is often the breeding ground for breakthrough technologies, is best carried out in academic environment since it is long term, open-ended and cost-effective. It is well known that government-funded research has resulted in such seminal technologies as the transistor, semi-conducting devices, satellite communications as well as the Internet. The outcome and potential impact of such research results are generally not known or even anticipated at the time such research was initiated. Trying to speculate on what areas or what specific projects will have big payoffs is in itself a risky business that may nip potentially breakthrough technologies in the bud. It also certainly stifles creativity in areas that are not so chosen for enhanced research funding. To quote Dr. M.J. Mandel – the Economics Editor of Business Week – granting agencies (and even peer review committees) should concentrate on nurturing a diversified portfolio of research grants in a wide range of areas – from cutting edge to so-called mundane. He also suggests that funding of research students should not be tied to specific projects and let the market determine the selection of projects and research areas.

A new era of innovation is upon us. How we respond to it in this age of true global competitiveness will determine economic survival. We need to enhance the pool of people involved in activities designed to generate new ideas. Of course, the quest for relevance in research must continue for the effort to pay off. For creative minds there is scope for innovation even in one of the oldest of unit operations – drying! I hope that with effective interaction between industry and academia we will see significant improvement in drying and dewatering technologies so vital to industrial success.

F

The trend towards application-oriented research is evident in all parts of the world. The economic and social benefits of basic research are being re-evaluated and debated.

One question that comes to mind is whether science pushes technology. Recently, M. Meyer (Research Policy, vol. 29, No. 3, pp. 405-434, 2000) carried out a study of the front pages of US patents in the field of nanoscale technologies (which are most likely to be linked to latest basic research). Surprisingly, he concluded that there appears to be no direct link between the cited papers and the citing patent. This seems to contradict a 1995 report, which observed a growing linkage between US technology and public science. One of the possible reasons for such discordant conclusions could be that authors often do not necessarily cite or are fully aware of the prior work that is most relevant and sometimes cite peripheral works instead. So, no definitive conclusions can be made.

With the cost of patenting in terms of R&D dollars spent per patent in the neighbourhood of US$2.5 million, it is not surprising that the university share of all patenting activity in the US has been just under five per cent in 1999 – ranging from a low of two per cent in information technology to about 15 per cent in the health sciences and technologies.

Furthermore, Meyer's study showed in a quantitative fashion what is intuitively well recognized, viz. technologies in some industrial sectors lag behind relevant science while in others they lead science. Technology moves faster than science in the fields of telecommunication, semiconductors, medical electronics etc. while the reverse is true in the fields of paper, wood and textile technologies, food processing, agriculture etc. The average annual growth rate in the number of patents in areas where technology leads science is reported to be greater than five per cent.

In the case of drying technologies it appears that technology leads science in that we still depend on empiricism in the design and operation of dryers in most industrial sectors. On the other hand a number of innovative drying technologies have yet to find their rightful place in industrial practice. The number of patents granted annually in the subject area of drying or dryers is almost unchanged over the past decade while the archival literature shows a definite upswing over the past decade. It will be some time before drying science will catch up with drying technology.

It is obvious that the synergistic relationship between technology (or engineering) and science will yield significant economic and social benefits with a good balance between basic research and applied R&D. Scientific advances in drying will eventually provide new and improved drying technologies that will cost-effectively replace the conventional ones.

G

Although undoubtedly one of the oldest unit operations, thermal drying has emerged as an important discipline worthy of R&D in its own right. Spurred by the need to reduce energy consumption, to enhance product quality, to reduce environmental impact, and often to produce new products using new processes, numerous attempts are under way around the world to develop innovative drying technologies. Definitive research linking the impact of R&D to economic benefits remains to be carried out, however. In some industrial sectors and for drying of some specific products, new drying technologies have replaced or, in some cases, even supplanted conventional drying technologies. Much remains to be accomplished, however.

Recently, Robert J.W. Tijssen (Research Policy, volume 31, 2002, 509-526) has examined the issue of science dependence of technologies by articulating evidence from inventions and their inventors. Although limited to The Netherlands, the results of this comprehensive study are likely to be more generally valid. Interestingly, some 20 per cent of the private sector inventions were found to be based on publicly funded scientific research. Another interesting finding: citations in patents referring to research literature are invalid indicators of a technology's science dependence. Often the patents do not cite relevant literature, or the patentees are simply unaware of the existence of related published work, especially if it is not archived by one of the indexing services. Papers published in conference reprints or in languages other than English, unfortunately, may suffer from lack of appropriate credit for their contributions.

Many empirical studies have shown that knowledge interaction between industry and university researchers are valuable in improving or innovating new technologies regardless of whether the industrial sector is classified as high technology or low technology. Indeed, many of the new drying technologies can easily be classified as high technology. When it comes to modelling some of even the traditional dryers e.g. spray dryers, the problem is more complex and difficult to resolve, when both transport phenomena and quality parameters are included, than computing the flow over an aircraft, for example. Thus, there are major challenges open to young researchers who wish to contribute their talent and effort to improving the knowledge base and technology performance of various dryers.

I believe that recognition of drying R&D as an important area that provides major challenges in a true multi-disciplinary arena is the first step towards development of new innovative technologies. Industry –both users of drying equipment and vendors of such equipment- can make a significant contribution to this area by direct and indirect support of cutting-edge research and new concepts which will yield economic pay-offs to all concerned in the short as well as long term. Let us hope that such interaction will increase over this decade.

H

Sustainable development has become a buzz word, especially following the Johannesburg Summit held last year. This century may well be labelled the "Green Century", as we seek green industry, green transportation, green energy etc. Although a disarmingly simple concept, implementing the concept is fraught with serious challenges. It is estimated that it takes over 14 months for the earth to regenerate what 6.1 billion people consume every year in terms of bio-matter. About 2.5 billion people have no access to modern energy resources; energy needs will increase at about 2.5% per year in the developing world alone. If this energy need is met by burning fossil fuels like oil, gas, bio-mass etc. additional greenhouse gases will enter the atmosphere causing further global warming and disastrous climate changes. Clearly, there is need to re-visit renewable energy sources as many countries are doing already.

We all know that drying is a highly energy-intensive operation, consuming from 10-25% of national industrial energy in the developed world. We also are painfully aware of the low energy efficiecy at which a majority of industrial dryers operate currently- from an appalling 10% to a respectable 60%. There is clearly scope for improvement. Designing better dryers and operating them optimally is a part of the solution. However, we must also evaluate, where possible, the opportunities for use of renewable energy sources e.g. solar (including photo-voltaics), wind, geothermal etc). De-carbonization will be the catch phrase of the coming decades as attempts are made to switch from fossil fuels to "green" sources. The car industry is making rapid inroads in this area. The "well-to-wheel" overall efficiency of car engines is being studied critically. The result is a new breed of "hybrid" car engines with remarkably high efficiency compared to the current engines. Can we think of a new breed of eco-friendly dryers that can legitimately be called "green dryers"? This will be the truly "disruptive" technology we really need.

With fossil fuel costs at current levels it is unlikely we will see any revolutionary changes to drying technologies. However, with legislative support by governments around the world clean energy will come in vogue within the next decade or two. Worldwide solar and wind energy output is growing at 30% per annum but that is because of the low base rate. One clear indication of the coming age of renewable energy sources is the massive influx of funds being devoted to renewable energy resources by some of the world's largest oil companies. The trend towards lower-carbon world is expected to grow. I hope that we try to do our modest share of effort towards sustainable development by improving drying technologies and making them more eco-friendly. Also, perhaps there is need to develop equipment standards against which various designs can be compared so the clients or users of drying equipment have a benchmark to compare against.

I

Innovation has become order of the day in academia and industry alike. Drying R&D and technology is no exception. Indeed, I have had the distinct privilege of promoting innovation in drying for over two decades via the IDS series as well as this journal with some success. However, quantitative measurement of innovative performance remains an elusive task. There are no widely accepted indicators of innovative performance or a common set of indicators. Such an indicator or set of indicators is crucial to managing innovation. As noted by Hagedoom and Cloodt (Research Policy, Vol.32, pp. 1365-1379, 2003), literature studies have used R&D inputs, number of patents, number of patent citations, counts of new product launches, etc., as indicators of innovative performance in industry. The task is harder for academic institutions, however.

Hagedoom and Cloodt have developed a composite indicator based on R&D input, patents and patent citations as well as new product announcements and applied it to some 1200 companies in defense, aerospace, computer, electronics and pharmaceutical industries.. They believe this composite index captures the innovative performance adequately. Interestingly, they also find that the result overlaps with what one would observe with just one of these performance indicators in high technology industries. On a

Venn diagram representation of the relationship between R&D expenditures, patents and new products, the degrees of overlap depends on the industrial sector. For high degree of overlap it is clear that one of these three indicators would suffice. Perhaps for more traditional industries with longer shelf-life products and processes the results may differ from the above conclusion.

J

Drying has been a particularly important and active area of research in the agricultural and food sectors all over the world. Indeed, a majority of papers published in Drying Technology have a direct or indirect relevance to drying in these sectors, which are also perhaps the most important economic sectors for most countries of the world. They will necessarily remain so over the current century as well. Past century saw remarkable contributions by engineers and scientists to mechanization leading to lowering of animal and human labor requirements in agriculture, to enhancement of productivity of foods in a variety of environmental conditions and effective use of chemicals to stimulate growth in food production to feed the rising population of the globe. As noted by Professor Vincent. F. Bralts of Purdue University (IACS2002, Shanghai, China, November 2002), there is need to open up new opportunities in the current century through the application of science and engineering in the arena of what he calls ***Extreme Engineering (EE*).** This arena encompasses subjects that have attracted extreme attention of researchers and media alike, e.g., nanotechnology, proteomics, GMOs, etc. Developments in information technology and telecommunications will have their impact on agriculture and food supply for the world's population. Developments in biosensors, biomaterials, bio-processing and their applications to agriculture as well as other industrial sectors will make dramatic changes to the quality of life on earth providing the geopolitical situation permits it. Clearly, science, engineering and technology are poised to take huge leaps ahead and thus make massive positive impact on the current quality and standard of living. However, it is just as critical to develop the right kind of global environment which will permit application of the EE-based discoveries to benefit humanity as a whole.

Drying is an energy-intensive process. Therefore, the need to develop more efficient drying processes will remain important along with the use of renewable resources that will reduce dependence on the limited fossil fuel reserves. Extreme engineering will generate new, as-yet unknown opportunities for those of us interested in drying R&D. We need to expand our horizons and look beyond the current needs to identify novel and challenging opportunities. Future researchers in the inter-disciplinary field of drying will need to collaborate more actively than heretofore required to make truly impactful contributions that will have a lasting value to fundamental science as well as commercial application. In fact, they will need to have a more diversified portfolio of knowledge in sciences (e.g. physics, chemistry, biology, etc.) as well as engineering (including information systems, computer applications, etc). Curricular changes taking place in many parts of the world will provide the necessary background for the future generation of researchers in drying to be armed with a bigger arsenal of knowledge tools to tackle more challenging problems they need to face in coming years.

4. CREATIVITY AND INNOVATION

A

Creative original thinking is the key to all breakthrough research in sciences, engineering as well as in the liberal arts and business. Much has been written about it but little appears to be known about it except in an empirical way. We know, for instance, that intelligence and creativity are not directly correlated. Reproductive thinking, which permits some students to score high marks in many examinations, is different from productive thinking. Creativity is clearly central to innovation and successful R&D.

Some of the key characteristics of "geniuses" have been enumerated. Among these one may cite their ability to think laterally (rather than vertically), metaphorically and even in opposites. Also, they are prepared, intellectually and otherwise, to benefit from serendipity. A further trait identified of geniuses is that they are prolific in their output of art, music, scientific or technological accomplishments. Immense productivity is a hallmark of most geniuses. For example, Thomas Edison held 1093 patents while Mozart produced some 600 pieces of outstanding music. They are also great mentors. Enrico Fermi and six of his students won Nobel Prizes. Between J.J. Thomson and Ernest Rutherford, seventeen of their students received the Nobel Prizes. Niels Bohr and four of his protégés as well as S. Chandrasekhar and two of his students became Nobel Laureates. The productivity of creative individuals is thus very extensive as well as intensive.

It is very important for the future of technological and social development of the world that efforts be made to identify, instill and nurture creativity and to encourage excellence at all levels. The role of the teacher or mentor in this process must not be underestimated. I believe that the success of the society depends on how well it treats its institutions of learning. Education and research are key to the future prosperity and development of the world. As the world economies become more and more knowledge-based, creators of knowledge must be duly recognized; the focus should not be only on dissemination and transfer of knowledge (often confused with information in light of the Internet revolution). Without the generation of knowledge it is obvious that there will be no knowledge to be disseminated however rapidly.

The upshot of the above discussion is that support of R&D by creative individuals is essential to future developments in any field – drying technologies included!

B

An article in Mechanical Engineering Design (2004) caught my attention recently. It was about a species of beetle called the Bombardier beetle, which squirts its predators with a high-pressure pulsed spray of a boiling hot toxic liquid. The chemistry of the liquid and the mechanism of the pulsed spray have been studied in depth by biologists and biochemists for over two decades.

Research by Professor G. Eisner of Cornell University discovered that the Bombardier beetle produces hydrogen peroxidase and hydroquinone, and when attacked by a predator, it can mix the two in a tiny heart-shaped combustion chamber to produce benzoquinone and steam; the mixture is then emitted as a pulsed jet at temperatures in the order of 100°C. Recent research at the University of Leeds by Professor McIntosh has already found that the unique shape of the beetle's reaction chamber is critically important in maximizing the mass of ejected spray for each "explosion" which can occur at about 300 times per second. The shape of the nozzle, which can swivel in any direction, is also important. An in-depth study of this unique creature is expected to yield a solution to the occasional but serious problem of re-igniting a gas turbine aircraft engine which has cut out at high altitudes and extremely low temperatures. Clearly, study of natural engineering marvels can help us with arriving at novel engineering solutions to complex problems.

Copying such natural mechanisms is a feature of the field of biomimetics in which scientists and engineers learn from the intricate design ideas that nature uses. Indeed, the pulsed combustion-based self defense mechanism of the Bombardier beetle is an extremely complex design. Such a study will require sophisticated research techniques and multi-disciplinary teams involving biologists, biochemists, chemists as well as engineers. I believe that improved design of the pulsed combustion process could also lead to improved design of novel pulsed combustion dryers for liquid feedstocks.

C

Innovation is central to any R&D activity aimed at improving products and/or processes and making them competitive and more cost-effective. Indeed, several hundred innovative (and not-so-innovative) ideas have already been proposed in the literature, which claim to offer significant advantages over convectional drying techniques. Most of these come from academics, who are not much concerned about cost performance and yet are discouraged by the lack of industry interest in utilizing their novel ideas in practice. Often product quality is not even considered as an important criterion. Clearly, close industry-academia collaboration is needed to define the specifications for new designs and to evaluate the potential for their implementation. Novelty *per se* is not justification for adoption of new technology; the bottomline is.

After examination of several hundred new drying concepts available in the patent and technical literature (mainly in the Proceedings of IDS and several sister conferences as well as Drying Technology) I have attempted to summarize here what I call the inventive principles for dryers. This terminology is taken after that used in the well known Triz method originally developed in Russia. Briefly here is a list of actions that can be taken on the wet feed material, the material within the dryer, the dried product, and/or the drying conditions (e.g. pressure, temperature, air flow rate, humidity, energy input, mode of heat transfer, etc.).

- Wet feed: Dewater, filter, centrifuge, mix with dried product or inerts
- Material in dryer: Disperse, agitate, vibrate, convey

- Drying Conditions: (a) Drying medium (air, flue gas, superheated steam) pulsate, turn on/off; (b) Temperature: steady, cyclic or on/off, below freezing, above critical temperature; (c) Pressure: low, high, cyclic; (d) Humidity: low, high; (e) Heat transfer mode: conduction, convection, radiation, steady, cyclic, on/off; (f) Fields: sonic, ultrasonic, MW/RF, continuous, intermittent
- Dried product: Mill, agglomerate, granulate

It is easy to see that hundreds of variants of dryers will emerge as a result of the application of above Inventive Rules for Drying. I would be pleased to hear from our readers about new drying concepts that are not covered within the framework of the above inventive rules for drying.

D

At the cutting edge of technological innovation it is often believed that inventiveness approaches an art form rather than science. Individual creativity is thus the primary engine driving innovation - coupled with the willingness to take risks. Collective effort is necessary to succeed in implementation of complex projects requiring cross-disciplinary expertise, however.

While many novel ideas are generated, researched and published in the archival literature only a few of them are ever exploited commercially. Large investment in R&D and pro-innovation public policies have helped the United States of America, for example, to lead the world in inventiveness and economic prosperity. R&D in several scientific disciplines and engineering is essential to bring scientific discoveries to commercial realization. Basic research is essential to fuel new and truly innovative ideas. There is an unfortunate trend worldwide to short-circuit fundamental research and seek short-term economic returns even on scientific research carried out in academic institutions. Further, funds are being diverted into life sciences at the expense of other sciences and engineering. In recent years the information technology (IT) revolution caused diversion of research funds to computer science and closely related fields focusing more on compilation and transfer of knowledge rather than on generation of new knowledge in a wide range of disciplines. There has been widespread confusion about the differences between information and knowledge – the words are often used synonymously. Clearly, there is a major distinction between the two.

Depending on local policies with regard to R&D support the pecking order of nations in the area of technological innovation will eventually change in favour of those countries that invest in engineering and scientific R&D. Many countries are now recognized as “top-tier innovators”, while several others are “emerging innovators”. Highly educated technical personnel will be needed to support the innovation-driven economies at a time when the trend appears to be swinging away from technical and scientific education. I hope the situation will rectify itself in due course.

In summary, research and development in all sciences and engineering should be priority in a global economy. It is my hope that this journal will continue to provide a forum for the dissemination of truly innovative scientific and engineering ideas at least some of which will lead to commercialisation and economic fallout.

5. ON IMPACT FACTORS AND MEASURING RESEARCH IMPACT

A

In recent years researchers and their employers have come to use the ISI JCR impact factors for journals as a sole quantitative measure of the quality of journal and its impact on the field it serves. Amin and Mabe (2000) (www.elsevier.com) of Elsevier Science have recently published a quantitative evaluation of the statistical and sociological significance of the impact factor. It is strongly recommended reading for anyone who is even remotely concerned with the JCR impact factor. First of all, it spells out exactly how the factor is computed. Secondly, it shows quantitatively the wide variability between journals in different subject fields; the large variability from year to year for a given journal and its dependence on the size of the journal itself. Even the average number of authors per paper affects the impact factor. Journals in fundamental sciences have higher citation rates than those in engineering and technology as expected. To make matters even more complex, this study clearly demonstrates that the fluctuation in the impact factor can be as high as ±50 per cent for journals publishing under 35 papers per year and up to ±25 per cent for a journal like this one which publishes about 120-150 articles per annum.

Finally, since the JCR impact factor for a given year is computed based only on the number of citations within the two-year window following the publication, its numerical value can change depending on the size of the "window" used. For example, of 30 chemistry journals examined, 24 changed in rank by up to 11 positions when the two-year window was extended to five years in computation of the impact factor. The choice of a two-year window is clearly arbitrary. Given the one to two year delays in publication for most journals these days perhaps a case can be made for a 3-year window. In fact, the window size should depend on the field the journal serves.

One point the authors of this study did not make is that the factor must also depend on the subject field itself and the distribution of its readership. For example, a distinction can be made between journals in engineering sciences versus those in engineering technology. This journal, for example, may have an even split between academic and industrial readership; only the former are likely to publish archival papers which may cite what they read in the journal. In fact, application of the knowledge archived is perhaps more valuable than citation of the paper in a subsequent publication which is the domain primarily of the academic researcher.

B

When Eugene Garfield made his seminal contributions to quantitative studies of scholarly journal publication (*Citation Indexing – Its Theory and Applications in Science, Technology and Humanities,* New York; Wiley, 1979), I am sure he did not anticipate the dominant influence it will have on the publication process. His concept of the journal impact factor (IF), published by the Institute for Scientific Information (ISI) and published in the Journal Citation Reports (JCR) is commonly used to evaluate journal status as well as the productivity of researchers. More recently even non-bibliometric scholarly journals have discussed the use, misuse, disuse as well as possible abuse of the numerical values of the IF. At first glance IF appears to be a perfectly objective numerical tool to judge both the quality and quantity of research output regardless of the discipline. As has been shown with abundant evidence this is not indeed true, namely, the short term (two years) IF does not necessarily reflect the quality of publication correctly. The interested reader may wish to refer to the extensive, scholarly literature on this subject. A selection of relevant references is posted on the website www.geocities.com/AS_Mujumdar.

In my earlier series of Editorials, I have pointed out the weaknesses of the IF on simplistic terms without the benefit of any major statistical studies. In particular, I have pointed out the fallacy of comparing IF values for different types of journals, e.g. science cannot be compared with technology in terms of the IF alone. There are major differences in the nature of authorship, readership as well as the citedness of these different classes of journals. Science journals typically have papers with very large listing of references, often requiring elimination of paper titles and even use of a finer font to save space. Engineering and technology journals on the other hand typically have a smaller citedness number (i.e. fewer references cited) and demand full reference citation including the title for the benefit of the reader. This can influence the citation frequency for the journal, for the author and also result in a lower impact factor. For those who are not familiar with the impact factor definition, here it is. *The IF of a journal in year T is the number of citations in year T to documents published in that journal in years T-1 and T-2* (Garfield, 1979). If a journal reaches its maximum citation in the third or subsequent year it has a lower IF than one that reaches the peak in the second or first year after publication. The so-called citation half-life does not correctly remedy this situation as been demonstrated by several published studies.

Finally, a new or corrected journal impact factor is needed. One such attempt, which appeals to me as being reasonable is that of Moed et al. (Scientometrics, Vol. 46, No. 3, 1999, pp. 575-589). He proposes a normalized impact factor depending on the subject category of the journal. In fact a single journal can be placed in two or more sub-fields as defined by ISI. A normalized impact factor ratio of one implies that the impact of the journal is "as expected", given the average in the sub-field to which it belongs. In a given sub-field, citation characteristics and types of articles may be expected to be similar. Thus apples are compared with apples and not with oranges or pineapples! Thus a scientific journal with IF of 30 may be compared with journals of the same class. Its normalized IF may drop to just 3 if the average IF of the sub-field is 10. In another sub-field the same journal may have a different normalized IF for this reason.

C

The objective of this archival journal is to disseminate high-quality original R&D results to a wide audience consisting of academic researchers, academic educators and industrial researchers and practicing engineers. The peer review process is crucial to assuring quality of what we disseminate. As an engineering technology journal we aim to serve both industrial and academic communities; it is hard to pinpoint the precise distribution, but we can reasonably assume it is about even. We strive to publish "impactful" R&D results that can benefit industry and eventually the society at large in a number of ways, e.g., higher quality products at lower cost, reduced consumption of fossil fuels, reduced environmental impact, safer operations etc.

While the authorship of most contributions we publish has academic affiliations, the readership is probably evenly distributed among academic and industrial sectors. The producers of the results are not the only consumers of the outcome of the research effort. As is obvious, some of the papers published lead to further extension or diversion and lead to archival publications in this or other journals. However, it is equally likely that the results are applied in practice and no publications appear from this extremely important activity. The former leads to journal citations, which the academic community is particularly fond of, while the latter leads to real impact and yet no measurable credit accrues to the authors or the journal. The former may be classified as "high-impact-factor research" while the latter is truly "impactful" research. The impact factor computation thus ignores a key contribution of an engineering technology-oriented journal and its authorship. Engineering science journals, on the other hand, have both authorship and readership firmly placed in academia. A reader is potentially an author as well. One need not be a rocket scientist to predict that engineering science should have higher impact factors and science journals should have even higher ones. Even a cursory analysis of the impact factor data indeed attests to this hypothesis. Without divulging the identities of the journal concerned, the following tables substantiate this thesis quite clearly.

Tables 1 and 2 provide some quantitative data to substantiate the thesis that the numerical value of the impact factor depends on the category of intended readership. When the readership is primarily that which is actively involved in research and publication, the impact factor should be high; indeed it is of the order of 25 for the most recognized scientific journals. On the other hand, if the readership is primarily users of the results published, as is the case for engineering practice-oriented journals, the impact factor calculated in the same manner must be low or even very low. Engineering science and technology journals should stack between these limits since their readership is mixed and, depending on the journal, maybe slated towards practice. This is also borne out by the data in Table 1. Of course, an extensive analysis could be undertaken to further assess this hypothesis but perhaps it is more important to look at the impact factor in proper perspective since it most certainly serves a useful role if interpreted correctly.

Interestingly, high impact factors may be associated with shorter cited half-lives in some cases.

Table 1 Impact factors for selected standard journals in four categories.

Journal	Area	Impact Factor		
		1998	1999	2000
S-1 S-2 S-3	Science Science Science	25.8 24.4 3.3	29.5 24.6 4.1	28.8 23.9 3.9
ES-1 ES-2	Engineering Science Engineering Science	1.42 0.99	1.54 1.21	1.65 1.05
ET-1 ET-2 ET-3	Engineering Technology Engineering Technology Engineering Technology	0.61 0.40 0.45	0.58 0.40 0.45	0.61 0.40 0.57
EP	Engineering Practice (very high circulation)	0.130	0.165	0.104

Table 2 Approximate distribution of readership and authorship of different categories of journals.

Journal Type	Authorship	Readership	Impact Factor Range (numerical value)	Remarks
Pure Science	Academic	Academic	High	Readers are potential authors
Engineering Science	Academic	Academic + Industrial	Medium	Smaller fraction of readers are potential authors
Engineering Technology	Academic + Industrial	Industrial + Academic	Low	Very small fraction of readership is potential authors
Engineering Practice	Industrial	Industrial	Very Low	Almost no authors among readership

High: > 20 Medium: ~ 1-2 Low: ~ 0.50 Very Low: ~ 0.10

Until a new true measurable impact factor can be defined it is hazardous to make judgements based on the “academic” impact factor, which does have useful purpose but only when both the authorship and readership belong to the same category viz. academic researchers. True impact of applied research cannot even be measured in terms of patents resulting there from since a minute fraction of patents actually see real adoption in practice. The not-so-infrequent trend among some authors to avoid citing the most relevant papers and of citing peripheral papers also clouds the impact factor calculation. High quality papers published in other than the English language also get sidetracked in this computation. Also, citations in textbooks, handbooks and encyclopaedias, which have much more extensive readership than a typical journal article would have are excluded from computation of the impact factor.

What is the main point of all this discussion and analysis? It is simply that due diligence and care is needed to make informed decisions about the true value of applied engineering R&D. Unless academic researchers conduct applied research and publish it in technology-oriented journals the development of innovation in industrial operations and processing will suffer. Purely scientific research has long lead times before it can be adopted by industry. Someone must make the path from discovery to application a little bit clearer and smoother, which is the role of engineering researchers. This path may, however, lead to lower "impact factors" but significant "impact," which should not detract, but inspire the researcher as it improves the lives of the people around the world in a variety of ways.

D

To cite or not to cite is often the question most authors face while preparing their manuscripts. It is essential to give credit to prior work that has motivated or in some manner guided the authors' work. This is necessary not only to put the new work in proper perspective but also to be professionally ethical. In engineering journals it is customary not to include an excessive number of references. Hence, choice of the literature cited is important. This is helpful to the readers but it also has an unexpected effect on the perceived quality of the authors' research and the journal itself. The citation count for the authors and journal impact factor are affected by the selection of references. A recent study has shown that often authors simply copy lists of references from an earlier paper. This is clearly in conflict with the expectation by the reviewers as well as editors that the references are really pertinent; at the same time it is necessary to be sure that the most relevant references are actually cited.

The impact factor for journals and citation counts of research papers have become generally accepted as quantitative measures of quality. There is much bibliometric archival literature that clearly demonstrates the weaknesses of such measures in making objective judgments about both the quality of research and the journals. What started as an administrative measure for convenient appraisal of research output has ended up becoming researchers' goal. Evaluation of research quality and its impact are difficult tasks. As Peter Lawrence points out (Nature, vol. 422, March 2003), the result of this "audit society" has been to compromise the objective presentation of research, its accessibility and quality. The primary goal of archival peer-reviewed journals is to disseminate selectively high quality research results to the right readership as expeditiously as possible. Reducing an essentially qualitative task to a quantitative measure is bound to be fraught with errors.

We depend on conscientious and expert referees to ensure quality of papers accepted for publication. The editors need to exercise their own judgment after the review process. Aside from the intrinsic merits of the paper, we also try to judge the value of the work to our readership. Not infrequently we must advise authors of excellent articles to seek an outlet in another journal as the reported work is not likely to be of interest to our readers. The manuscript flow to this journal has risen steadily over the past decade to a point where we may have to forewarn the authors about potential long delays prior to publication. On the other hand, this allows for better selectivity and enhancement in quality of the journal via the evolutionary process.

E

A literature search on the subject of Impact Factor has unearthed a large number of scholarly articles attesting to the various shortcomings of the IF even within a single discipline. Interested readers can refer to www.geocities.com/AS_Mujumdar for a selection of literature citations. Most deal with scientific and medical disciplines but not with engineering. The high volume of IF are shown to be correlated to the "degree of citedness" or the practice of a given discipline to cite a very large number of references (e.g. science and medicine) or only cite few references (e.g. engineering and technology journals). This clearly influences the volume of IF the way it is computed. Also, IF covers only those papers that appear in a two year span following the publication year; this has further implications on the true value of the real impact of the published work.

The published IF values have also been shown to be affected by typographical errors in author's citations. At least in one case one journal had an inflated IF as citations for a similarly titled journal were incorrectly credited to it over nearly two decades before the error was discovered!

What is the conclusion? Simply that IF values should be used with caution. Do not confuse IF values between disciplines – it is worse than comparing the proverbial apples and oranges! Some have proposed new measures to assess journal impact since they consider IF as a misnomer. (See, for example, S.P. Harter and T.E. Nisonger, Journal of the American Society for Information Science, Vol. 48, No. 12, 1997, pp. 1146-1148).

Journal quality assessments perhaps needs a combined subjective and objective approach as proposed by D. Zhou, J. Ma and E. Turban (IEEE Trans. on Engineering Management, Vol. 48, No. 4, 2001, pp. 479-490). Suitably computed IF could provide the objective input while expert judgements provide the subjective input. Zhou et al. propose a fuzzy set approach, which can also consider incomplete and imprecise information often inherent in any evaluation process.

The critical comments of Van Leeuwen et al. (Journal of Information Science, Vol. 25, No. 6, 2000, pp. 489-498) are particularly illuminating as they address a number of problems with conventionally accepted two-year IF. They conclude that often IF is used inappropriately by researchers for their publication strategy (e.g. engineering papers in applied physics or chemistry journals), by decision-makers to evaluate research and by libraries to evaluate their journal collections. Short term IF favors journals that reach their maximum citations in two years; there are important journals that achieve the peak between four to eight years after publication.

6. GENERAL TOPICS

A - Engineering Education

Engineering education has been undergoing rapid changes around the world. As usual US universities lead this rapid change and others around the world, including developed nations in Europe and Asia tend to follow the trend. While much of it is highly desirable in view of the increasing science base of new technological revolutions taking place, it must not be forgotten that the USA is a giant economy with room for all types and levels of education. The tremendous diversity of its economy permits and indeed benefits from the wide variation in educational experiences one can find there. Small economies do not permit this possibility. Local environment and conditions must therefore be taken into account to really derive optimal benefit from experiences of others. The adage" *think global but act local"* is particularly apt in this context.

One definitive trend that can be noticed today is the increased focus on science in all engineering disciplines. This is highly desirable if the focus on engineering itself is not side-tracked. If that happens then we will have neither good engineers nor accomplished scientists. It is also important that engineers of today have multi-disciplinary training and ability to work in teams that are multi-cultural as the global village requires this ability. Engineers today must also be able to think critically and analytically and have soft skills of being able to communicate effectively, be creative and innovative, enterprising and be able to appreciate societal needs. Thus the new engineer needs to learn a lot more that what the earlier generation needed to. To make matters harder, the half-life of engineering education today is probably less than 5 years and it will get shorter. This implies we must have engineers to know the importance of life-long learning and self-study. They must be ethical as well. Since the period within which institutions must impart this additional training and education cannot be increased for economic reasons, we just need to be more efficient, selective and productive. Clearly, there is need to attract talented youth to engineering for the benefit of society and for the creation of wealth needed to raise the standard and quality of living around the world.

B - Globalization of R&D Capabilities

One of the by-products of globalization is the diffusion of R&D culture across geo-political boundaries at an increasingly rapid rate. This process is accelerated by the lightening speed of advances in telecommunication and internet technologies as well as the continual drop in cost of computing. With improvements in the quality of living due to developments in agriculture and health sciences, now many developing nations of the world can are and, indeed do, make noticeable contribution to the knowledge reservoir of the world. Educational standards and emphasis on sciences have improved in the emerging world. Recent reports from the National Science Foundation attest to this trend in concrete terms with appropriate statistical data. Just about two decades ago western world dominated the science and innovation fields with lion's share of peer-reviewed publications in scientific and engineering journals (as a measure of R&D effort) as well as the number of patents grated in the US, for example. Researchers from Japan, Korea and Taiwan now account for over a quarter of patents issued in the USA. Their growth rate is also significant although it can be expected to level off as China and India begin to make a dent on these statistics in the near future. The prestigious journal Physical Reviews now has under 30 per cent of its papers from the USA; a drop from over 60 per cent two decades earlier. Over 1000 papers per year arrive from Chinese laboratories alone. There is also a decline in the number of PhD's awarded in the sciences in North America. The corresponding numbers in emerging countries are rising as is expected.

I believe that these statistics are really not alarming in the global sense. It is good that all parts of the world are making their fair share of contribution to the world intellectual resources. As the gradients in wealth and per capita resources try to level off as a natural result of diffusion across boundaries, there should be some major social benefits as well e.g. reduction in poverty, tension between nations and better chances of achieving peace in this Globe. If this can occur in the next few decades, the world ill be a better place to live for mankind.