POLITICAL AND SOCIAL DECISION MAKING IN RELATION TO FRACTURE, FAILURE, RISK ANALYSIS AND SAFE DESIGN

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The main theme of this meeting is purely technological but it is a sign of our times that the proceedings should include consideration of the theme in political, social and educational terms. Politics and public opinion now play a major role in deciding the level of support that can be given to technology, and while this may be somewhat unpalatable to research engineers and scientists, it is not wholly unreasonable that he or she who pays the piper should call the tune. At any rate, for better or worse that is the reality of politics.

It is proper therefore, that I should address the question in my capacity as a politician. It is not my purpose to be political but rather to try to give you a politician's view on technology in general, and fracture in particular.

First a disclaimer, like the disclaimers put forward by writers in their prefaces of books. They thank those whom they have consulted, but at the same time, assure the reader that they and they alone bear the responsibility for error. My preface is somewhat similar, but in reverse as regards this paper.

Lest you come to the conclusion that politicians have learned too much about science, I must say that most of the factual information was put together by Dr. F. R. Thurston, Director of the National Aeronautical Establishment of the National Research Council, to whom I ran in humble supplication after committing myself to speak and only then realizing what I had done. A kind of fracture strikes the politician confronted by facts. Dr. Thurston helped me out.

And to show my gratitude to Dr. Thurston for his generous response, I hold him totally responsible for all errors of fact. The political parts are my own and I accept their paternity, particularly since they can't be verified or checked out on a slide rule.

In Canada, fracture is always on our minds. Even the Prime Minister when addressing a joint session of the U. S. Congress and Senate, used the word to describe the Canadian dilemma. Canada has lived with the problems of fracture from its very beginnings.

Not just the fracture of politics of English-French, Catholic-Protestant, farmer-manufacturer, but the fractures that we have had to overcome from the nature of the Canadian geography.

We have been essentially a resource based economy, living off the bounty and hazards of nature, and to conquer nature, we have fractured nature

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herself and learned to overcome nature's angry responses. The mountains were fractured to build the railways - and mountains wait to break the tracks and the vehicles that race the wounded passes. The earth was fractured by drills and shovels to move the Antediluvian sleeping hydrocarbons to machines that are then operated by the oil, gas and coal that we had extracted.

In return, the heat, pressure and conveyances to accomplish these purposes are a Damoclean sword over our impertinent scientific heads. Some of these energies are used to further fracture the earth for its riches of copper, potash, nickel, iron, etc. The very chemicals in the air are separated or transformed in the course of turning the rich rocks into tools, shelter and machines for man.

We live surrounded by an ever ready retaliation for our acts and just as disease moves man to value his physician, Canada needs and cannot live without its fracture specialists.

As an example of current concern, Mr. Justice Thomas Berger, conducting an inquiry for the Government of Canada, had this to say: "One of the important technical problems that needs to be resolved, is designing pipelines that are capable of withstanding frost heave. The Russians have been able to avoid permafrost areas in building their pipelines, while the Americans elevate their northern pipelines. The gas pipeline that Arctic Gas and Foothills Pipeline propose to build, on the other hand, because of costs, will be buried. Chilling the gas, because permafrost areas are discontinuous, creates the problem of frost heave. Arctic Gas says that the heave can be negated by covering the pipe with mounds of earth. But dissenters assert that the amount of earth needed for this is too great to be feasible. The concern here is that the largest civil engineering project ever to be considered for Canada has left a fundamental scientific/engineering question unexamined by any department or agency of government. It is not appropriate that such questions are left entirely to industry."

In elaborating on this problem, Mr. Justice Berger emphasized that Canada is a northern country, that the North is part of the Canadian psyche, that the North is a kind of window "opening on to the infinite". Despite this and despite the obvious need for the sort of scientific work which would have resolved the frost heave question, no agency of government has undertaken or supported the necessary research.

As industrialization moves farther and farther into the North, we will encounter other unique scientific and technical questions that Canada should be looking into now.

Another example was given by Dr. J. J. Shepherd of the Science Council of Canada. He said, "an emerging major programme is the transportation by marine mode of gas and oil from the Arctic to our eastern seaboard. Northern based control systems, ship and containment design and construction, *en route* and terminal navigation systems - all pose special problems." He might have added special problems in *fracture*.

The worry about resource energy shortages and escalating costs calls for the preaching of a doctrine of greater durability, safety and conservation. History can teach us many lessons and perhaps one of the best examples of a long life structure is to be found in Egypt. While we can all marvel at the long life of the Pyramids and still admire their beauty and proportions after so many generations, we must question their cost and purpose. I doubt that they did much to improve the quality of life of the slaves who built them although undoubtedly they did a great deal for the quality of death of the Pharaohs. Equally certain, they must have had a big impact on the unemployment rate.

The great difference between the Pyramids and modern construction is that the Pharaohs' builders didn't have to worry about zoning by-laws, spills, radioactivity, explosions or what the effect of these disasters would have on the environment or the people about them.

Undoubtedly in very many cases, durability and safety can be bought; in other words we can have long lives and high reliability if we are prepared to pay the added costs. The questions now are what should our proper goals be in both product lives and costs. These are very important and difficult questions to resolve and, in fact, they can make or break an industry. If either the life is too short or the price too high there will be no public acceptance and no sales. We may also enter the realm of planned obsolescence in which a manufacturer deliberately designs in a limited life to his product in order to obtain repeat orders. In such a case, the benefits of increased employment must be carefully balanced against the costs to the consumer.

The price that we are prepared to pay for durability and safety will depend on both our ability to pay and on the consequences of failure. The risks that we can accept in consumer products are many orders of magnitude greater than those that we can even contemplate in an atomic power plant. In fact, to a politician, to the general public, or to the scientist, there is no "acceptable" risk of failure of an atomic power plant if it would result in the release of radioactive material. This is a major dilemma in our growing needs for energy.

It is, as I am sure you will all agree, impossible to design anything or develop any material that will not crack, degrade or otherwise fail under some set of circumstances. Unbreakable houseware is a salesman's illusion and as fictitious as the irresistable force meeting the immovable body. This is why it is, in my view, essential that materials scientists and engineers work closely together at meetings such as this. The materials man must be able to say clearly when, how and why his material will fail and the engineer and designer must be able to produce designs that will minimize or eliminate the consequences of the failure.

The spread of information about failures within the technical community is essential and it is a sad reflection on society that legal and political constraints are doing so much to prevent this spread.

History contains many excellent examples of the benefits of freedom of information about failures. In Canada, we can have cause to be proud of the Report of the Royal Commission on the failure of the Quebec Bridge that was published in 1908. This report, which I might add was produced by a Commission of three Engineers and no lawyers, contains a frank and exhaustive analysis of the failure, which was attributed largely to the then poorly understood buckling failure of a compression member. The work of the Commission led to a large number of experiments and studies that, to quote Steinman and Watson in their book "Bridges and their Builders" - "-more than any other occurrence in the evolution of bridge-building, revolutionized the art by bringing it to a new high level of scientific analysis and design".

Similar benefits have accrued in more recent times from the information that was released in the United States following the Polaris and the F-111 difficulties.

The subject of freedom of information on failures inevitably leads to a discussion of legal issues. While there can be little question of the technical benefits of making information on failures freely available within the technical community, this is only possible if the legal profession and the laws of the land take an enlightened attitude. No manufacturer likes to take the risk of exposing himself to lengthy court cases and possibly punitive damages because of a genuine error on his part. By the same token, no regulatory agency would willingly expose itself or a manufacturer to this risk. There are, of course, many legal defences available; notably that the product was designed and manufactured according to the state of the art - the legal doctrine of the "reasonable man". Unfortunately however, the mere act of defending oneself against court charges is expensive and will tie up technical experts over a lengthy period in which they might well be better occupied with more profitable exercises. The principal difficulty is that of interfacing between the legal and technical communities to ensure that technical matters are fully understood by lawyers before lawsuits are commenced. Indeed, with all due respect to the legal profession, there is in my view, a need for more lawyers with a technical background. These problems can only become more acute as technology advances and perhaps we should be taking a fresh look at the whole question of the interactions of the law and technology - if we have accepted the idea of a Family Court to deal with one class of legal problem, why not a Technical Court for another?

What do we mean by durability? This is an all-encompassing term that simply implies that a product must be capable of performing its designed function for an appropriately long time. While we recognize that nothing will last forever, a product must serve a function that justifies its initial cost and, perhaps equally important, justifies the costs of maintaining and repairing it. We should then examine the factors that limit the lives of products.

First and foremost, a product must be capable of sustaining all of the loads that it sees in service without breaking. This implies that the designer, and frequently the customer, must have a complete knowledge of both the strength and of the loads and environment that the product will see in service. The strength will be determined by technologies such as those discussed at this meeting, by considerations of fatigue, fracture toughness, creep and other forms of what are perhaps improperly referred to as material failures. The loads are usually estimated from a knowledge of the task that the product must perform and on a judgement based on past experience, of future use. The environment is all too often ignored but a wise designer will always attempt to take into account the effects of extremes of temperature and of corrosive surroundings.

From the titles of the papers to be presented at this meeting, I would have judged that you have made a great deal of progress in understanding the processes of material failures. I am sure, however, that much remains to be done and it is regrettable that the level of support for research in this important area, in Canada, is so low. In spite of your progress I am concerned that the fruits of your efforts do not always reach the audience that they should. The literature is full of examples of costly design errors that could have been avoided had the designer been properly aware of the current knowledge. A good Canadian example was the failure of the Duplessis Bridge at Three Rivers in Quebec in 1949. This failure occurred when the temperature was 230 K and was largely attributed to the use of a steel which became brittle at such temperatures, a fact that should have been known to the designers. It is almost astonishing to learn that in July 1962, the Kings Bridge at Melbourne, Australia, also suffered a brittle failure, albeit at a much higher temperature. In this case it was reported that no adequate impact tests were made on the material. The lesson had apparently still not been learned.

Impact tests are easily understood and there can be little excuse for them not being required by designers in this day and age. There are more sophisticated tools, such as fracture mechanics, that pose an entirely new set of problems. These tools all too often demand of the designer a high level of knowledge of mathematics and I suggest that a major problem confronting research workers is that of simplifying their concepts so that they are less demanding in expertise and can become everyday tools.

I have referred to the needs for knowledge on loads to enable designers to produce goods with the appropriate durability. It is surely not good enough for a manufacturer to defend the failure of his product by the claim that it was abused. It is almost an aphorism that if a product can be abused it will be. One might cite as an example the recent introduction of high performance glass or carbon fibre reinforced composites into the manufacture of fishing rods. The stiffness and strength of these are ideal for the sporting fisherman but the strength when loaded across the diameter of the tubular rod is lamentable and what fisherman has not accidentally sat on his rod?

The hazards of an incomplete understanding of loads and environment were demonstrated only too clearly by the unfortunate experiences of Rolls Royce in the U.K. You may remember that this company was responsible for the development of turbine engine carbon fibre composite compressor blades that had remarkable strength and fatigue properties. Unfortunately, their resistance to impact and erosion damage was inadequate and these facts were not appreciated until far too late in an engine development programme. The economic consequences played a major role in the subsequent bankruptcy of the company, and had profound political repercussions.

So far in this discussion, I have referred to fracture as though it implied failure. I am sure that many of my audience would wish to correct this impression and I hasten to do so myself. Fracture is of course, an essential part of any manufacturing process as many forms of cutting are nothing more than controlled fracture. Thus, there are times when the need is to produce fractures rather than prevent them. We might even refer to the production of jewellery in which the fracture surfaces of precious stones provide one of the oldest art forms.

In terms of our current needs, I would draw your attention to the enormous expenses that are incurred worldwide in tunnelling and in excavating. The search for oil and gas is paced by man's ability to bore holes in the ground, a technology that has changed little in past decades. The congestion of our cities can only be relieved by underground tunnelling to provide route for rapid transit and in many cases this is prohibitively expensive. I suspect, too, that as the energy crisis grows, we shall find that we would be better to revert to being troglodytes by burying our housing underground where we can find more stable and comfortable temperatures than we have on the surface.

While research workers have protested at the lack of adequate funding for their efforts, they have done little to provide quantitative support for their case. Most of the protests that have been heard by the politician are based on arguments to the effect that support of research activities should be based on some fixed relationship with the gross national product or that there should be some other international comparison. On any of these grounds, support of research in Canada is clearly inadequate but it is my impression that the significance of this inadequacy has not been properly brought to light. In preparing this paper, I have tried to obtain statistics on the cost of lack of knowledge on durability that might be used to provide arguments for or against greater support for research on fracture or on durability. Appropriate statistics seem to be lacking. To quote from H. E. Morgan from National Bureau of Standards Publication 423 "Comprehensive statistical data on the economic cost of mechanical failures do not exist. Sellers do not wish to publicize their mistakes; this may account for the fact that we have only anecdotes rather than aggregate data on failures". Morgan then goes on to discuss personal injury and fatality rates in the U.S. due to accidents and suggests that the total cost of personal injuries in 1963 was of the order of $9.9 billion. Fishlock in his book "The New Materials" quotes a British chemist as having estimated the cost of corrosion to the British economy as being 600 million pounds a year. A related statistic given by Jost in the August 1975 issue of "Mechanical Engineering" is that increased attention to tribology could save the U.S. economy as much as $16 billion per annum.

These are all very large sums of money and, as a politician I am particularly anxious to know more about them. I think that you will agree that as they have been presented, they are not particularly useful. We need to know not merely the cost of corrosion, but also the costs and effects of preventing it. In this context I must remind you that costs cannot be measured simply in dollars, we also need to know the effects on things like employment and on energy conservation. As far as accidents and personal injuries are concerned, we must accept that all accidents are preventable, human beings are fallible. What we need are reliable figures for the costs of preventable accidents and the costs of minimizing these.

The politicians and society at large, are very well aware that the modern world is critically dependent on technology, but they are not prepared to buy technological solutions to contemporary problems at any price. There is a prevailing tendency to accept solutions that may be socially retrograde, unless proposed technological solutions are proved to be economically and socially superior beyond all reasonable doubt.

It is in this context that conferences such as this can serve a major purpose. Although the primary benefit is to the scientific community dedicated to the study of Fracture, the politician hopes that he will obtain some authoritative guidance in terms of the durability, cost and safety of consumer products and of certain engineering works costing millions of dollars.