Ceramics and Society
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COMPETITIVENESS AND QUALITY OF LIFE

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The belief that a change is needed in the contract between society and the scientist has already been well stated at this meeting. The argument has been made that scientists have in recent years enjoyed an unparalleled degree of freedom in the choice of problem which they can tackle with the help of public funds; this freedom has been such that scientists have come to resent as intrusion and certainly as potentially deleterious to the effectiveness of their work any enquiry from the wider society which may question the value of the research in progress. If indeed there is now to be a move towards a more utilitarian style of research where favour is to be given to those projects which may claim to be of greater relevance to the needs of society (assuming that the link between research and the resulting benefit can be so strictly drawn) then it is reasonable to ask which of these two conditions, namely that of freedom or that of the utilitarian requirement, may correspond the more to the steady-state condition.

Some indication of the long-term vitality of the utilitarian view can be gleaned from two early quotations. The first is to be found in the third book of Gulliver's Travels (1727) in which Gulliver meets a scientist working at a research institute "He had been eight years upon a project for extracting sunbeams out of cucumbers which were to be put into vials hermetically sealed and let out to warm the air in raw, inclement summers. He told me he did not doubt in eight years more that he should be able to supply the Governor's gardens with sunshine at a reasonable rate; but he complained that his stock was low and entreated me to give him something as an encouragement to ingenuity especially since this had been a very dear season for cucumbers." The view is that a scientist left to his own devices will cost more than he expects, will take longer to deliver results than he expects, and indeed may deliver something of marginal merit. An earlier view (1637) is given by Descartes in his estimation of the conditions under which work of merit is to be expected. "It seemed to me that I would be the more likely to find truth in the work of someone who had an interest in the results and who would bear the consequences of any failure than in that performed by a scientist bearing upon hypotheses which cannot be tested and which have no other consequence than that he would draw the more credit from the work the more it was removed from commonsense because he would have to use more wit and cunning to make it seem probable." The suggestion from such quotations is that the need for a utilitarian dimension had been recognised at an early stage and that apart from a limited period in the middle of the twentieth century (perhaps as a consequence of the progress made in nuclear science and technology) the scientist must join the medical practitioner in enjoying the scepticism of the thinking public. The view of Belloc perhaps reflects the norm: "Physicians of the utmost fame were called at once; but when they came they answered as they took their fees, there is no cure for this disease".

If, therefore, ceramics are to enjoy the research attention which those in the subject would wish then it becomes important to identify the grounds for thinking that a utilitarian requirement can to some extent be met. In looking for such a requirement it is helpful to distinguish between the direct contribution which ceramics can make to industrial strength - national competitiveness - and the less direct impact which they can make upon the wider range of social and cultural activities - quality of life.

In turning to the industrial aspect, it is important to emphasise that ceramics have for many centuries fulfilled important industrial needs. The hardness, wear resistance and corrosion resistance, coupled with high compressive strength, have caused them to be seen as model building materials. The qualities of impermeability and transparency/translucency , not to mention colour, have made them readily marketable where an aesthetic dimension is sought in articles ranging as widely as porcelain and stained glass. These industries are, however, in a highly mature condition and there is little call for an especially intensified research effort in order to advance matters.

The requirement for research has arisen as a consequence of the wish to extend the use of ceramics into a much broader portfolio of activity. This would include the use of mechanical components for load-bearing parts of high temperature heat engines. It would include the set of devices which can be established on the basis of particular ceramic properties such as piezo-electricity, superconductivity, ionic conductivity or sensing discrimination. The aim has thus been to introduce ceramics either into a set of applications where they have been of negligible or marginal significance or alternatively into a set of new applications which can be identified on the basis of the properties that are only now becoming available. For both of these, namely for substitution on the basis of property improvement or for niche penetration on the basis of new phenomena, structural reliability remains a requirement. For this reason, the mechanical fragility which ceramics display under impact or in the presence of small manufacturing faults has proved to be a major impediment to their uptake into the anticipated markets. If one is to reach a degree of acceptance among the wider engineering community, then it will be necessary for the researcher to find convincing ways of overcoming this challenge which has been thrown down by nature. In summary therefore, we have a promised land of applications which lies tantalisingly before us; to reach this land we have to modify in a dramatic manner one of the principle properties of ceramic systems, namely their brittleness, and we must do this furthermore without incurring the high costs which are often associated with sophisticated solutions. This problem of removing brittleness by cost-effective measures has remained the central issue for some 50 years of intensive research.

As noted above, the applications areas themselves fall into two broad categories, namely one of substitution where war parts, cutting tools and engine components would all provide examples and one of niche markets where biomedical materials, sensing components, vibration control systems and indeed the vast array of functional ceramics would be found. Here a distinction can be made in the development of the markets for the two types. Substitution must be performed against a steadily developing competitor; it must be performed under conditions of extreme cost-effectiveness. For these reasons the rate of substitution of one material for another can be prolonged. The set of half a dozen or so of material substitutions that have taken place over the 250 year life time of cutting tool systems can perhaps serve as an example.

The assumption is often made in contrast that the development of niche markets can occur quite promptly. The discovery of high temperature superconductivity over some few weeks did lead to frenzied research work internationally on the basis that applications were likely to emerge rapidly. The true pace has been somewhat more pedestrian in that these materials are still looking for a substantial product sector some years after their discovery. Even for niche markets one has to recognise that materials developments require time; the material must often be introduced into a device which in turn must often form part of a system which then often forms part of some final product for the end purchaser. This long chain is itself an indicator of the delays which are likely to arise when materials seek new markets.

In the light of these difficulties, it is important to emphasise that the opportunities for progress remain correspondingly large. In general, the paths are two, namely we can seek to improve our manufacturing skills so that materials relatively free from defects are produced and produced at attractive price levels or we can seek to enhance the design of the material, both in terms of its composition and in terms of its microstructure (and indeed macrostructure) so that remarkable fitness for purpose is achieved. In the first of these it is important to record the progress which has been made in enhancing the quality of ceramic powders over the last decades. Levels of perfection are now available in the finished component which would have been unthinkable prior to this powder revolution. The enhancement of powder quality has been accompanied by a general recognition that higher standards of cleanliness and precision must be adopted throughout the processing sequence; the combination of the two factors has led to dramatic progress. The second aspect namely that of design is also one which has made notable advance. The earlier trend towards the simplification of microstructures with a view to avoiding accidental faults has now been replaced by a trend toward purpose-designed more complex, microstructures whose complexity has been deliberately chosen with a view to achieving identified property groupings. The sequence of highly engineered microstructures which has been proposed to exploit the phenomenon of transformation toughening is a case in point. The design of microstructures to the nanometer level found in nanocomposites is a further example. There is no doubt that this avenue is one where major advance can continue to be expected.

The design aspect has been emphasised in terms of ceramic microstructure. It is important, however, to acknowledge the merits of extending our processing capabilities to the point where components can be manufactured also with the correct macrostructures i.e. where, as in a fuel cell or as in a multilayer electronic component, the distribution of active phases can itself be engineered during the ceramic fabrication processing.

The general picture is one where ceramics possess a range of properties which are of undisputed significance for the industrial sector. The problems posed by brittleness and by cost comparisons are well recognised and have acted as brakes upon the rate of development. The opportunity provided by meticulous science-based manufacture and by imagination and understanding in design is, however, an appealing one. There is no reason to question the ability of ceramics to survive in a research framework where the utilitarian requirement is once again recognised as a significant criterion.

When one turns to the aspect of quality of life then its very subjectivity makes judgement difficult. It is an attractive and perhaps fortunate aspect of life that different people find their solace in different patterns of behaviour. Nonetheless, as has been indicated earlier in this meeting, certain minimal and readily specified requirements can be identified such as shelter, warmth and sustenance. It is only after we are past this point that we can allow ourselves the luxury of debating whether life's quality is better found in a library or in a Pachinko parlour. The risk here is that the nebulous aspects of the target become an excuse for failing to recognise the obvious, nakely that basic minimal levels of prosperity are required and that these are often linked to basic levels of competence in industrial performance.

The good fortune of the ceramist is precisely that work of high scientific interest can be performed on materials which possess an alluring array of properties ranging from the aesthetic to the exotic. That ceramics will in the future be used in a much wider range of applications than at present is certain; the task for Academy member is to identify the most rewarding and effective means for passing from the present state of affairs to that eagerly anticipated future.