Problems for the mining industry
Presidential Address

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As is usual when preparing for this type of occasion, I looked back at the subjects covered by my predecessors when they assumed the presidency of this Institute. You will appreciate that, in the eighty odd years since the Institute was founded, the diversity of subjects has been very great. In almost all cases it is quite natural that the speaker should have chosen a topic of special interest to him and one in which he was particularly knowledgeable. Less obvious, though, is another factor that is quite apparent once it has been recognized: that the tone and emphasis of a paper is very often heavily coloured by conditions prevailing outside the mining industry at the time. Wars, strikes, depressions, and booms all leave their mark, and this is to be expected. In the recent past, it is therefore understandable that emphasis has been laid upon the increasing problems facing Southern Africa. These do not seem to me to be becoming less pressing or depressing. On reflection, however, I do not believe that I have anything to contribute in this area that has not already been said very adequately. I have therefore looked elsewhere, and shall attempt to cover a broader canvas. Certainly, many of the technical problems in the mining field are present in South Africa, but it is my conviction, deeply held, that the real problems of the mining and metallurgical industry are common throughout the world. So, for that matter, are all the major fundamental problems confronting mankind. My aim in this address is to consider how the international mining industry in general and, where appropriate, our South African mining industry in particular can help in overcoming and solving the world's real problems. Perhaps this may explain the use of the word *for* in the title of this address, which may have puzzled you.

Problems for the Mining Industry

When we refer to the mining industry, we are really thinking of the people working in the industry. Often overlooked because their part in the safe, effective recovery of metals and minerals is not obvious are the many specialists, on and off the mines. They have always been important and are now essential in what is becoming perhaps the most difficult industrial activity there is, and I shall refer many times to their potential for broader problem-solving. The old concept of the producer being all-powerful because he had the most important job (which incidentally he still has) and because he was a specialist, is no longer valid. Everyone has had to become much more of a generalist simply to remain reasonably proficient in his own speciality, let alone to understand and manage the special skills of others. If the world's technical problems are worth solving, it will involve pure and applied sciences, engineering and other technologies, and semisciences such as sociology, psychology, and politics with its hand-maiden bureaucracy.

Perhaps I might at this stage be forgiven for quoting a handy guide to the modern sciences to put the disciplines in perspective:

If it's green or wiggles, it's biology.
If it stinks, it's chemistry.
If it doesn't work, it's engineering.
If it's green and wiggles and stinks and still doesn't work, it's psychology.

I have compiled my list of problems but before projecting it, some explanation might be useful.

By convention, party politics, which vary from place to place, are excluded along with the other taboo subjects, religion and sex, although they all cause problems. However, all the fundamental problems that we have to face are in essence political, and there is no way of avoiding this. Not only are they problems politically produced in many cases, but their solutions are all too often conditioned by the art of the politically possible. Also, you will certainly feel that my list is biased, and of course it should be since it is concerned with my worries for the world. It could not correspond exactly with any other person's list because he would have his own worries, but I would be very surprised if there was not a considerable degree of overlap between any two lists. Finally, I make no attempt to rate the relative importance of these problems, but all of them are urgent.

The List

1. Food for All
2. World-wide Health Services
3. Population Increase
4. Drug Addiction
5. More Clean Energy
6. Misuse of Raw Materials
7. Water
8. Environmental Degradation
9. Product Pollution
10. Safe Disposal of Radio-active Waste
11. Urban Renewal
12. World Education including Worldwide Open University
13. Training
14. Prediction of Earthquakes and Other Natural Disasters
15. Speedy Amelioration and Relief of Disasters
16. Genetic Engineering
17. Bureaucracy.

Now to take the problems individually.

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Food for All

Nitrogen, one of the essential constituents of fertilizers, was at one time mined and processed from caliche, saltpetre, and guano, and, had the prophets of doom been right in assuming that these along with nitrogen-fixing bacteria in the soil were the only sources of nitrogen, population restriction would by now have been severe and we would be in a very different world. The remarkable statement made by a world-renowned scientist in the 1890s that mankind was doomed because of the lack of nitrogen resources must be one of the most short-sighted predictions ever to have been made. Mining cannot claim any credit for the production of fixed nitrogen, but the uninterrupted and adequate supply of the two other main plant-food components, potassium and phosphorus, stands considerably to its credit. All resources will have to be harnessed if we are to have any chance of meeting the ever-increasing need. The most obvious way will be by the discovery and exploitation of new ore deposits, coupled with an extension of those already known; also, in the case of phosphates, supply from shallow under-sea deposits. Of prime importance, though, is to increase recoveries, which are very low at present, by substantially improved, or even new, mining and processing techniques. In the case of potash, poor recovery is now defended on the grounds that not only is the dry mining of sylvite deposits difficult because of water problems and lack of integrity of the host rocks, but also that the minerals are intermixed and mining must therefore be very selective. This may be so with relatively inexact processing techniques, but the result is that large quantities of sub-grade sylvite are left in place, where it is lost permanently. In the case of phosphate, where mining extraction may be better, large proportions of the phosphorus present are lost to tailings because of inefficient processing. Again, there is a good excuse in that high-grade concentrates are preferred to facilitate further treatment, and very fine material is not easily recovered. This is a most important and widespread processing problem, in which success has not yet been attained. We in this country have no special skills in this field, and many other places have worse problems. However, we do pride ourselves on being rather good producers of mineral concentrates and so should probably be doing more than we are.

In the case of essential trace elements for plants and animals such as cobalt, zinc, manganese, boron, and some rare earths, the world is completely dependent on the mining industry, and, once the scientists have determined the trace elements needed, it is our duty to provide them. In some cases, considerable problems confront us. Boron supplies are limited. As for cobalt, you probably noticed how sensitive the market is to any shortage, real or threatened, when, on the invasion of Zaire recently, the price rose from around $6 per pound to about $30.

Equally essential for food production is an increase in the supply and better utilization of water resources, but this is a much broader problem. Naturally, also not to be forgotten are the improvement of species and the development of hybrids for greater-yielding crops such as 'super rice' and animal protein sources. While not related to food production, the recent announcement of a hybrid poplar bush capable of being grown in areas not suitable for normal agriculture is of interest. It is claimed that the foliage produced can, in certain parts of the U.S.A., compete with coal for the production of energy. Presumably, the ash would also have fertilizing properties, which would be an additional factor to its advantage. It might even represent a renewable resource of liquid fuel.

Worldwide Health Services

We know a great deal about First Aid, mine health, and environmental problems in closed communities, including accidents and how to handle them, not forgetting rescue activities. We must make perfectly sure that this knowledge is shared at all times and in all places with those less skilled and more ignorant than we are. Perhaps sporatrychosis may be largely confined to our world, but heat exhaustion is certainly known elsewhere. This is also true of other environmental hazards such as the toxicity of heavy metals, as well as occupational diseases like pneumoconiosis and asbestosis. If a very recent article in the authoritative journal *Nature* is anything to go by, there is evidence to suggest that some United States operators are actually doing the reverse and indulging in 'hazard export' by offshore relocation of hazardous operations without adequate safeguards. The international mining community should have something to say about this.

Population Increase

With this additional food and increased life expectancy, population levels will increase drastically, and population regulation will become a most urgent priority. This has been, and will remain, an economic, religious, educational, and chemical problem, and we have no significant contribution to make, although the prophets of gloom would have us believe that the Malthusian bogeyman will in any event solve it without any help from man.

Drug Addiction

It is certain that this is an ever-increasing problem throughout the world. I mention it only as a reminder that we do not have a monopoly on problem-solving, and that there are very many areas in which we would do well to acknowledge the efforts of others.

More Clean Energy

Perhaps the hybrid poplar bush mentioned earlier should have been included here, since the energy could, presumably, be rendered clean. Of much greater importance, though, is the potential energy from the harnessing of geothermal, fusion, wind, tidal, and solar sources. Our contribution would seem to me to be predominantly in the geothermal and fusion areas, with fusion of less importance as far as the magnitude of our industries' contribution. The generation of geothermal energy, perhaps from great depths, will have to be developed. It should not be difficult, and the heat recovered will be clean and available in great quantities. We know how to drill holes and sink shafts. The transfer of heat from the atmosphere and surroundings of these

to a fluid that can be removed is standard practice in mine ventilation.

If we do this well, and I believe we do it better than anybody else, the reverse process of using the heat content of the fluid should also be feasible. This would not be economically attractive with ventilation systems, but could be very effective using the heat pump principle in specially drilled deep holes. It could be applied in our own industry by the use of a deep U-shaped hole for the natural pressure-leaching of ores. Within the U-tube, not only would the slurry temperature be substantially increased from the surroundings, but, because of the increased pressure due to the height of the slurry column, the dissolution reactions would become more rapid and complete.

Misuse of Raw Materials

Some of my earlier examples may seem tenuous, but here we are on firm ground and very culpable. It is unbelievable that there is still a lack of understanding about the impossibility of replacing many raw materials, coupled with a prodigal misuse of them. Foremost among these are the fossil fuels, particularly oil. In this case, though, the misuse tends to be literally that and not mis-mining; but, in other materials, mis-mining has for centuries resulted in the discarding of tailings, or semi-tailings, often too low in value to be worthy of re-treatment but still containing considerable proportions of the minerals originally present in the ore.

It is well known that low recoveries were tolerated in the past under certain mining conditions. At the other end of the scale is diamond mining, where a recovery of 99,9 per cent is not considered good enough. In between are tin deposits, some of which have been dredged four times, presumably at a profit. Although there may occasionally be special circumstances, it all boils down to economics, but short-term economics.

Recycling will have to be intensified, not only for the purpose of stretching existing known reserves, but also for environmental reasons. Not only is there the scrap-heap difficulty, but also the air-pollution problem. It is far cleaner to recycle copper or any other metal than to make virgin metal by the treatment of sulphide concentrates. An extension of that principle would be to procure increasing proportions of metal requirements from off-shore primary producers, where environmental and other standards might be lower. This would please the local environmentalists and infuriate the international ones, who seek to protect the less developed. In either case mining can't win.

For almost all the metals that are produced, there are from time to time thoughts and nightmares about substitution. Sometimes, this is the substitution of one metal for another, a hardy perennial being copper versus aluminium, although this involves talk rather than action, irrespective of relative process.

Another classic case is lead. Technically, talk of substitution has been out of date for a hundred years, but it is amazing how the idea continues to flourish in spite of this. More in the public eye perhaps is the substitution of metals by non-metallic synthetics, for instance quartz-fibre optics to replace copper conductors in communication systems. The total expenditure on this single development cannot be calculated accurately, but it certainly amounts to some hundreds of millions of dollars annually. One wonders whether this is justified when cheap copper is readily available. Be that as it may, aggressive attacks on traditional metallic applications will continue. There may sometimes be merit in joining the attackers rather than trying to lick them. However, if we do, we should remember that our prime function as an industry is to improve our competitive position by producing metals efficiently and to market the materials as effectively as possible. The self-wounding that the mining industry sometimes indulges in cannot be encouraged or justified. Witness the disarray in which the copper producers find themselves or have put themselves. Mismarketing is as bad as mismining.

Although not quite the same, one area of misuse, or rather non-use, of raw materials needs special attention. There are many deposits whose metal contents are well below economic recovery grades and are likely to remain so, even with technical improvement in the future. However, the deliberate sacrifice of efficiency for effectiveness may make their recovery possible. An example is the *in situ* leaching of very low-grade uranium ores, in which values in the parts-per-million range can be recovered economically, with the full knowledge that much of the valuable content will be left behind. This is different from the shoddy extraction of values from ores of respectable grade, since, unless this compromise is made, the mineral will never be recovered; in addition, by the acceptance of such a compromise, vast additional resources may be made available.

Water

This is also a raw material — the only universal one — and, as a result, perhaps deserves special mention. In an overall sense there is no shortage of water, and it is of course the least destructable of raw materials. The real-life problem is always localized. For example, Africa and other areas of the Southern Hemisphere are deeply conscious of the need for major conservation works and the sparing use of available supplies, while Europe applies itself with equal diligence to drainage to get rid of its persistent surplus!

The urgent problem is to maintain as far as possible the quality of the available water. The activity that gives rise to the need for treatment to protect the quality of water does not really matter. It might be poor performance in a flotation plant on wash day, or the accumulation of residual steroidal hormones with their long-term ill effects. Pollution may even result in the short-term poisoning of people who have eaten fish that have most efficiently concentrated minute quantities of toxic metal salts from industrial effluents. What does matter is to continue to develop simple cheap methods of treatment that are generally applicable. Two routes of help in the three examples mentioned, carbon adsorption and electrolytic removal, are already in use in the mining industry. Other methods are also being developed, and we are among the world's leaders in treatment techniques. The reason, of course, is that we have the

problems now and cannot delay. Others will be forced to follow. Our contribution to the solution of their problems will be very great.

Environmental Degradation

This heading is self-explanatory. A substantial contribution has been made to the ugliness of the world by thoughtless or deliberately destructive methods of mining and metal recovery. One has only to look at the traditional coal-mining areas of the world. It should, however, be borne in mind that it is not only mining that causes damage. Inefficient agriculture has done far more to destroy the environment, very often so completely that there is little or no possibility of rehabilitation. The same is true of many other industries and public authorities, who have cheated for as long as unscrupulous miners have cheated and in many cases still continue to cheat. The miner, though, is under such close scrutiny that it is no longer possible for him to cheat even if he wants to.

Strenuous efforts are now being made, not only to plan new projects and mines so as to take account of the surrounding environment, but also, where possible, to improve the areas worked out in earlier operations. There are three main problems in this restoration work.

The first is that somebody has to pay for it. There is no possible way that the terrain can be restored exactly, or even close to its former condition, at no cost. It is only by accepting that there is a cost, which may be considerable, and that it will be borne eventually by you and me as tax payers or consumers, that constructive progress can be made. We have been extremely lucky in South Africa in the acceptance by the authorities and local people the concept of doing the best we can with the resources available.

The second problem is the difficulty of predicting what the very long-term effects of mining activity will be. However, considerable progress is now being made in the ameliorization of chemical problems arising from the combined effects of water and air on the remaining minerals in old worked-out areas. Important work has now also begun on the determination of any possible long-term environmental effects of the large quantities of ash from coal burning, and to plan for the best possible method of storage of the ash. No great difficulty is anticipated in this area.

The third problem in restoration work, which is quite beyond our control, is the weather. Much of the rehabilitation work, short and long term, is at risk owing to unforeseen and variable weather conditions, and I have been associated with one programme in which literally days separated a very successful effort from a potential disaster through lack of rain.

In South Africa we shall also need to be extremely careful to ensure that the excellent work previously done on the Witwatersrand gold mine dams and dumps is not allowed to deteriorate in the long term. I wonder whether sufficient attention is being paid to this aspect. Superficially, there are areas where the cover does not look as good as it once was, and here again there is no substitute for effort and expenditure to ensure permanent stability.

Product Pollution

This is rather different from degradation of the environment on a large scale, and can perhaps best be described as the effect on the local surroundings of any manufactured article.

First and foremost are unsightly plastics. For a long time these were deliberately made to be resistant to perishing, and man, being basically an untidy beast, has allowed them to accumulate. By some defence mechanism, he now seems able to avoid seeing them and therefore to tolerate them. The same is true of metal objects, such as motor wrecks, old refrigerators, and cans. Lastly, there is glass; development of the dumpy or non-returnable bottle has meant that not only unsightly but potentially dangerous materials can accumulate at a great rate. The negative approach, which is better than nothing, is to discourage this pollution by legislation or taxation.

A positive method of coping with the problem is to attempt the profitable collection, separation, and recycling of these materials. This is an area in which our industry is already taking a lead, particularly in the Northern Hemisphere, where the quantities are large. The techniques used are those developed for the sorting of ore, which is fair enough since this is an alternative ore reserve and an ever-increasing one. Biodegradable plastics are now being produced, and it has been suggested that a spot of fluorescent dye incorporated in other plastic materials would enable them to be sorted for profitable recycling. The sorting unit would use the same sensor as in the X-ray diamond sorter.

Materials that are difficult to place in this or the 'environmental' category are gaseous emissions, sulphur dioxide being by far the largest, although most hysteria is generated at the moment by the fluorinated hydrocarbons used as aerosol propellants. Some most interesting and highly pessimistic calculations have been made on the effect of these stable materials on the ozone layer of the upper atmosphere, and the consequential effect on the incidence of skin cancer. It has also been seriously proposed that, in order to determine whether there is a significant problem, some hundreds of years of testing will be necessary. Scientific bureaucracy rides again. It might be argued that, if we have not succeeded in curing skin cancer in the same time span, we will have failed completely in any case.

As previously mentioned, the surreptitious disposal of trace quantities of soluble salts into areas where they may accidentally become concentrated is only one of many other possible examples, valid or ridiculous. We, as an industry, have a prime responsibility for this, since not only is it environmentally important, but the recovery of metals from very dilute solutions is an area of technology in which we have still to make great progress, particularly in cost reduction.

Safe Disposal of Radio-active Waste

Quite different is the 'product', or at least the waste product, from the reprocessing of nuclear fuels. This is almost the last refuge of the anti-nuclear faction, and it is

of the utmost importance for all mankind that the development, proving, and public acceptance of long-term, safe storage methods should be achieved. So far there have been no real difficulties with the interim methods used, and it may be that improvements will render them sound in the long term. One of the problems that will have to be overcome is the generation of heat: the wastes, however encapsulated or rendered insoluble by incorporation in solid supports, can during initial storage produce heat that is capable of increasing corrosion rates and breaking down the support. This has so far always proved to be physical rather than chemical, and therefore not hazardous. One serious suggestion is that the wastes should be enclosed in rather thick gold capsules before being placed in deep water for permanent storage. This would undoubtedly reduce corrosion rates and would also be a very excellent permanent use for large quantities of gold. It may be, however, that new methods involving mining in its broadest sense will assume increasing importance. It is impossible to predict that a particular area of the earth's crust, however small, will always be unusable or completely isolated, but there must be places where, with insignificant loss of amenities, deep shafts could be sunk and then resealed so that no solid, liquid, or gaseous effluents from the wastes would ever escape. South Africa's expertise in deep-level mining and the remote assessment and control of mining environment must give us a very major part to play in this approach to the solution of the problem.

Urban Renewal

The developed world is undoubtedly suffering from revulsion at the increasing urbanization of its people. Man is a gregarious beast, and not many individuals are capable of appreciating isolation, but it is obvious that urbanization has gone too far, as the problems of tatty, rundown, uneconomic New York City show. Perhaps one way in which urban renewal might take place is by a concerted effort in the development of communications. This will mean carrying the message, whatever it may be, to people where they are, rather than have them congregating physically, with all the congestion, frustration, and travelling problems that this involves, not to mention the cost of subsidizing uneconomic facilities. Perhaps our ability as an industry to contribute in this field may be underestimated. The development of remote communities by the mining industry is taken for granted, and South Africa is among the world's leaders in fact, although some others may be more vociferous in their claims. We should be able to build upon our accumulated experience and ensure that, as we develop our systems of communication, their possible application to other environments should not be lost sight of. There is a more general principle here, which is that the mining industry of the world — and I stress the word *world* — will need to learn to think instinctively of the effect of major new developments on others. Activity must be aimed directly at the mine's problems, but possible adaptation to improve the lot of others outside this environment will need attention. Let it be stressed that this is not 'do-gooding' — there is a large element of self-interest involved.

World Education Including a Worldwide Open University

In its more general aspects, world education — another problem in communication — is a task of such magnitude that governments and power blocks are really the only units that have adequate resources to begin to cope with it. The concept of a worldwide open university does have very much to recommend it. It could help diminish differences and misunderstandings, but, even more important, it would provide the incentive for great numbers of people to seek access to additional learning, which conventional means of instruction could never support. Teaching at such a university would be more difficult than with personal contact, but, wherever it has been possible to introduce those who want desperately to learn to those who are prepared to make the extra effort to teach in this way, it has succeeded. Let me immediately pay tribute to the pioneering and continuing effort of UNISA. Its national and international activities, against great odds, are very widely appreciated by many elements of the mining industry.

We have no special position in teaching, except perhaps to consider it our duty as an industry, and more particularly as individuals who have gained considerable experience in that industry, to make some contribution, however small, to this educational programme. I think here of the 'dollar-a-year man' who is prepared to pass on his knowledge to others at no cost. Perhaps we as South Africans could participate in this in three main ways: by part-time lecturing at universities and technical colleges, by teaching during sabbaticals in our professional careers, and, most important, by teaching during our retirement, when the financial need is perhaps not great but the desire to contribute remains strong. I am convinced that this would be worth while, not only in South Africa but in other countries in Southern Africa and even further afield.

Training

Because of the way it has developed over the centuries, the mining industry has a much more direct and easily understood role to play in the solution of the next problem, which is applied education related to training, directed both towards better job performance and leisure utilization.

Our record in training at all levels is now a proven and proud one, encompassing not only the unskilled labourer, who has to be taught basic skills before being able to contribute and receive reward for his labour, but also the supervisor, the engineer, and the manager at all levels and the specialist. It is in these latter categories that poor training causes the greatest damage, whether in terms of safety, productivity, the environment, or overall achievement. Because of the great differences at present in the backgrounds of the potential labour force available to the mining industry in Africa, special techniques have been developed to allow a man to achieve results as soon as possible. These differences will disappear in time — and one hopes not too much time —

and the present techniques may then become outdated. On the other hand, there is no doubt that in the meantime they can be used in many other parts of the world, not only in the mining industry but in other primary and secondary industries as well. Different, but of no less importance, is the need to publicize the success that the mining industry has had in assisting people to make more rewarding use of their leisure. Almost by definition, mining takes place in remote and sometimes inhospitable areas, and the way of living of the staff, not least in South Africa, is unnatural. If there is to be any worthwhile attempt to maintain morale and standards, great care must continue to be taken to help guide people in the use of their leisure. One aspect that is essential but is sometimes frowned upon is further education; *further*, that is, than the stage man had already reached. The old idea that it is dangerous to 'over-educate' people cannot be sustained. It is only by educating them first that the opportunities for fuller living and more effective job performance become a possibility. Put differently, this means that non-physical achievement is just as important as physical activity to man.

Prediction of Earthquakes and Other Natural Disasters

Fear of unexpected and unpredicted natural events still concerns man almost as much as does the worry about man-made calamities, although in many cases emotion has tended to make him think that a nuclear explosion is far more dangerous or frightening than an earthquake or volcanic eruption. However, man has not yet succeeded, and God willing he will never suceed, in manufacturing events with the same sheer intensity as some of these natural events.

Much detailed and important work has been undertaken over many years in the monitoring of ground instabilities of different kinds. Research concentrating upon very highly sophisticated and sensitive measuring systems vies with a more unconventional approach in Japan, where the agitation and nervousness of fish before earthquakes are used as a measure for forecasting.

It is apparent that the massive sustained effort being devoted to mining rock mechanics is, and will continue to have, a very major influence in this area. There is some doubt, though, that this effort has been sufficiently appreciated by workers in non-mining spheres. They should be encouraged to give it the recognition it deserves. If this kind of natural disturbance can be predicted with great accuracy, with or without the help of the mining industry, it will be possible to save many lives and reduce material damage. Contemplate, however, the dilemma that this accurate prediction poses.

Speedy Amelioration and Relief of Disaster

We have warning of the calamity and certainly we are capable of helping in an accident situation after it has happened, but do we know enough about reducing its overall devastation by moving people and goods with very great speed to a safe area before the disaster occurs? Do we in fact know enough about this in our own mining and processing environment?

Genetic Engineering

It has been said that, within the next fifty years, the great technical advances are more likely to be made in the biological than in the physical sciences. I am inclined to agree, if only because the physical sciences are at least fifty years ahead of their biological counterparts at the moment. A fundamental development in these biological sciences will be genetic engineering. Provided genuine attempts to adapt and optimize organisms with microbiological activity can be pursued without hindrance, we can expect that it will be possible to convert many organic materials to clean fuels and other useful chemicals or foods at high efficiencies. This would be one of the greatest technological achievements of all time. Of more direct importance to us may be the development by similar techniques of organisms capable of extracting metals and other salts from materials that we would not now regard as ores. It is worth remembering that this is already being done quite effectively by nature, with copper and iron. Again, as we are already in the business, even if by chance, we should continue with the development that will undoubtedly prove to be attractive in the long run to the mining industry and probably to many others as well.

Bureaucracy

There is no doubt that, if growth rate is used as the only criterion, by far the most successful industrial activity is bureaucracy. If any other criteria are added, its adverse effects on people and progress are increasingly exposed. Repeated mention has been made of the breadth of knowledge and skills needed by those who contribute to the production of mined products and their profitable disposal. Despite this breadth, all the disciplines are linked by a basic principle, which is that mining is risk business. It is because of this and the challenge it creates that there is a tendency for the industry to weigh the risk and, judging it reasonable, to take it rather than to refuse it. This, I suppose, is a form of gambling, but it is only this gambling instinct that has made possible much of the contribution we have made to the general problems I have chosen, and it is a built-in need to continue to take these risks that will enable us to contribute as greatly in the future.

Having said that, I think it important to determine what might make us lose our adventurous approach and, short of a specially tailored virus — perhaps genetically engineered — the biggest danger may be bureaucracy. Bureaucracy and risk are basically antipathetic, and this is true in problem-solving as well as in anything else. When I refer to bureaucracy, I mean not only petty bureaucracy, but also major bureaucratic restraints imposed from whatever quarter — and there are many.

The control mechanism actually comes into being as a result of pressure by a body of opinion — often public opinion. If this is well-informed and balanced, well and good — worth-while results can be expected in due course. If opinion is ill-informed, hysterical, or politically biased, the agency will be forced to adopt a protective, negative attitude. The real problem, though, is that the control agency cannot cease to operate because then it

would be disbanded; and it cannot afford to say yes because that would be nonsense!

Two examples from the drug industry may be of interest, one because it makes an attempt to calculate the hidden cost of saying no.

The cost of developing a new chemical birth-control agent has been estimated at $40 million, expended over seventeen years, at any time during which one adverse report may result in the abandonment of the effort. This is not risk business, it is lunacy. Of course, there have to be standards, but couldn't they be less smug and comfortable and more courageous, even if politically less popular?

The second example I have chosen concerns that most wonderful and cheapest of drugs, aspirin. With present restrictions, if aspirin had just been invented, even its minimum side effects would probably be enough to disqualify it for all time.

The cost of comfortably saying no, or of creating sufficient obstacles so that everyone has to say no, can be very high indeed. Other bureaucratic restraints that might be mentioned are the American objections to supersonic aircraft and the damning of certain types of nuclear reactors on highly emotional grounds. At the time, the reasons put forward may be compelling, but their persuasiveness depends on the acceptance by those in authority of confident predictions of the future by political technocrats. Their negative reasoning often fails totally, as illustrated by the complete change in the ball game brought about in a very short time by the 1973 oil play.

I should now like to draw attention to a very fashionable bureaucratic concept that I believe we do not yet fully appreciate. This lays down that anything which permanently affects the environment should not be allowed to take place. Let it immediately be said that the selfish devastation of large areas of the environment in the nineteenth and twentieth centuries can in no way be defended. A brave Rachel Carson and others performed a very necessary, and at the time unpopular, task in persuading people to count the hidden costs of saying yes to irresponsible industrial developments. As a result, careful public accounting of these costs is in many cases now prescribed by law, which is sensible. However, because it is fashionable and popular, the 'nature knows best' ecological 'law' has gained a considerable following, and its spokesmen have assembled a great number of horror stories to reinforce the opinion that eternal vigilance must be applied to prevent human alteration of a natural environment. In their view, human intervention inevitably leads to deterioration and disaster (shades of the Alaska pipeline). This is enthusiastically endorsed by those who believe that, if nothing happens, no mistake is possible. Persuasive anp comfortable perhaps, but it is nonsense. To accept this idea would be to say that we should return almost to prehistoric times, since a great deal of the best environment in developed countries is entirely manmade. In undeveloped countries, where equal hysteria can be whipped up, who indeed can say that some change in the environment might not improve the living conditions? If it were possible, and there is evidence to suggest that it might be, would a wetter Sahara desert or a warmer Siberia necessarily be a bad thing? A hungry world should count the cost before saying no to such possibilities.

Finally, in the same context I should like to return to genetic engineering. Great protests are mounted to prevent evil man from acquiring the knowledge that would enable him to modify the characteristics, and presumably the characters, of human beings. Some cynics might say that there is considerable room for improvement in this field! There is also the related idea that particularly evil genes could be grafted into the genetic apparatus of bacteria that could deliberately or accidentally escape from control and affect human and animal populations. Not being a biologist, I am willing to accept that the danger is real and serious. However, there are many areas, not least in mineral processing, where related changes to other bacteria could immeasurably improve the lot of man if known reactions could be optimized by this means. Do we therefore have any right to automatically say no to experiments when the potential for doing good may be so great? It will be a lengthy battle before sense prevails, but these and many other difficult questions will eventually have to be faced. They will most probably be faced by those who are prepared to stand up to the bureaucrats and, having assessed the risks properly and responsibly, decide in some cases to say 'yes'. This is why I believe that we in the mining industry have a very great responsibility to persist in our ability to live with risk and to capitalize on it, and indeed exploit it when this seems possible.

Epilogue

I should like to leave one last thought with you. It is a plea for the acceptance of open-mindedness. Without it and the realization of the need to seek change, which will involve having to give up hard-won, preferred, and entrenched positions, nothing will be achieved. Perhaps this may appear to be an unrealistic goal. I do not believe it to be so, and it is worth remembering that it was done very effectively during wartime, when we saw the unlikely situation of cabinet ministers and technologists working together and even in rare cases enjoying it! Could it possibly happen in peacetime?