ERRATA — August Issue
p.100 last line
nucleus read nucleon
p.102 line 16
kWh read GWh
EDITORIAL

PUTTING PEN TO PAPER —

It is my habit, like so many other people, to pin up on the walls of that small room, I fondly think of as a study (my nearest and dearest for many reasons refer to it as a den), articles clipped from newspapers and journals. There they stay, yellowing witnesses of promises once made to do something — to write, to check, to complain, etc. Few of these promises are kept. One such article came from The Times Higher Education Supplement in 1975. Written by an academic, Ivor Crewe, it is entitled “Why writing it down is the Scholar’s dilemma”, and it stays there a challenge to do more writing and less reading.

The challenge is there because in the article Ivor Crewe muses on the puny output of the majority of academics. A mere page per day would produce a substantial book each year, but few of us do anything like this. He recognises that “writing is hell” but thinks “it is better to write what you think is not absolutely worthy than write nothing at all”, making a distinction between publication and writing. “Better to lower one’s ambitions a little than to retire into silence out of over-perfectionism.”

I hand the challenge on to readers of this Journal for there are many who could write for members of their profession rather than for their specialist confrères. Writing of this kind may expose us to our colleagues and bring on agonies of self doubt but the smallest contribution, complete with all those imperfections to which the author alone is sensitive, does lift us from a comfortable obscurity and may start a new intellectual enterprise — Be in it.

All this has arisen because in this issue we find the second prize winning contribution to our competitive essay on “The Nuclear Debate”. Both Dr Graham and Dr Thompson (whose essay was published last month) are to be congratulated on their responses to the problem of writing to a definite set of conditions. I have no doubt that all entrants found this trading off between the demands of scholarship and the conditions of the essay a very difficult and demanding task.

Our thanks then to these authors, for they are making a permanent statement on our behalf and as members of the Institute, though we may not agree with them, we should see that these essays reach the people for whom they were produced. In this way the essays will become an AIP contribution to an ongoing educational programme and perhaps in their turn they may inspire some new writing.

Bill Boundy

A LETTER TO THE EDITOR FROM ASTEC

SIR,

I read with interest your column in the June issue of the Australian Physicist regarding the Report of the Inquiry into the CSIRO and the subsequent decisions of the Government. You remarked on the decision not to include the Directors of the six Institutes in the Executive and intimated that ASTEC was not an appropriate body to comment on the Inquiry’s recommendations. I certainly agree that “ASTEC can hardly be thought of as a disinterested party.” It has been specifically established to “investigate, and to furnish information and advice to the Commonwealth Government in respect of, matters relating to science and technology”. With that as its function, ASTEC had better be interested! However, this surely does not imply vested interest or bias, which might be imputed from your statements.

In case you have not read the advice provided by ASTEC to the Prime Minister, I attach a copy; the Prime Minister tabled the ASTEC document when he announced the Government’s decisions on 11 May. In relation to the composition of the CSIRO Executive, ASTEC stated its belief that CSIRO should be allowed to make its own arrangements for its new Executive structure. ASTEC went on to recommend an Executive of three full-time and three part-time members appointed by the Minister, and six associate (non voting) members drawn from among the staff of CSIRO and appointed by the Executive. ASTEC considered that the Directors of Institutes normally would be the associate members but that it was inappropriate for Directors to be voting members because of possible conflict of loyalties. Surely such an arrangement does not “divorce” the Directors from the Executive.

Expressing a purely personal view, I would be an advocate for a Parliamentary & Scientific Committee as a useful forum for developing a better understanding between Parliamentarians and scientists and you may be interested to know that the Minister for Science has initiated a program in which scientists are invited to Parliament House to address Members on topics of interest in science and technology. However, I am doubtful if a committee of this nature would be an appropriate group to provide the sort of advice you suggest. Be that as it may, the Government obtains advice from many quarters, and I feel sure ASTEC was not the only source of advice in this case.

R. M. GREEN (Secretary)
In view of:

(a) The vital role that contact with overseas workers plays in the planning and execution of research and teaching in physics in Australia,

(b) the importance that the physics community places on overseas visits to perform adequately its professional duties, and

(c) The necessity for physicists to be able to work for periods of the order of a year in overseas laboratories so that they can perform their duties at the highest international standard.

The council of the Australian Institute of Physics recommends that:

(1) The limit of expenditure on overseas travel be increased above the figure of 0.5% of the total cost of academic salaries recommended by the Working Party (see Recommendation 2(h) of the Draft Report), to a level comparable with that granted at present.

(2) The restriction on release from teaching and administrative duties to 13 weeks in any three year period (recommendations 2(e) and 7(e) of the draft report) is unrealistic and unnecessarily restrictive, and should not be implemented. The Institute is absolutely opposed to any attempt to put academic staff into a straight jacket of a specified leave period.

(3) The limits on the total amount of release from teaching and administrative duties granted each year to academic staff in aggregate, to 7% of the available teaching man-weeks for university staff and 5% for college staff (Recommendations 2(c) and 7(c)) are too restrictive, and should be eased. Brief absences from the home institution to attend conferences, or to visit other institutions on academic duties should not be included as leave granted as part of the special studies and professional experience programs.

The AIP Council supports the Working Party's recommendations that staff released from teaching and administrative duties under the special studies and professional experience programs be required to submit reports (Recommendations 2(k) and 9(b)), and that the University or College publish information on the operation of these programs (Recommendations 3 and 9(a)).

The position paper on which these recommendations are based follows.

The severe restrictions on overseas travel by academic staff recommended in the Tertiary Education Commission's Draft Report on Study Leave will lead to a deterioration in the quality of research and teaching in physics conducted in Australia. It appears that the Working Party which prepared this Report has not appreciated the vital role that contact with overseas researchers plays in the planning and execution of scientific research in Australia. The rigid control on overseas travel applied to scientists employed by the Commonwealth Public Service has reduced the ties which keep the Australian scientific community in touch with developments in overseas centres of excellence. The proposed permanent reduction in opportunities to work overseas by academic staff will further isolate Australia from the mainstream of scientific research.

The advantages that accrue from Australian based academics working for an extended period of time in overseas institutions are discussed in detail in the Draft Report (see, in particular, Section 4.6). This paper presents additional information to justify the retention of adequate overseas study leave as a valuable means of allowing physicists to keep abreast with latest developments in their field of specialization or gain experience in new areas of importance to Australia. Attention is also drawn to a survey of physicist's attitudes to their research conditions, which indicates that the profession regards opportunities for working in and visiting overseas research institutions as playing an important part in allowing them to fill satisfactorily their professional role.

It is difficult to envisage how the proposed restriction on the fraction of aggregate teaching man-weeks which can be made available for study leave, or the restriction on the absence of individual staff members to 13 teaching weeks in any 3 year period, will improve the efficiency of either the teaching or research undertaken in Australian tertiary institutions. In all tertiary institutions study leave, conference leave and leave for carrying out research work at other institutions is a matter of mutual agreement among the staff concerned. This is at no extra cost to the institution, but a matter of staff agreeing to accept teaching loads which will allow the institution to function most efficiently. This system has worked very well in the past, and the freedom to carry out these activities has resulted in improved teaching and research.

What can be gained from overseas study leave?

The Working Party has apparently not appreciated the importance to physicists of close association with overseas workers and institutions in keeping informed of recent developments in their subject. The following information is intended to provide additional justification of such contact for physicists. Similar comments no doubt apply to scientists in other fields.

(1) The number of papers in Physics published annually has increased from about 9,200 in 1950 to 94,900 in 1976 (Source: Physics Abstracts). In spite of the appearance of journals that list the title of scientific papers currently in the process of publication, journals that comment on progress in various fields, and of the development of computerized literature searching techniques the number of papers published makes it extremely difficult for an isolated physicist, or a small...
group of isolated physicists, to assess the thrust of developments in their field of specialization. Communication with overseas colleagues is necessary if research efforts are to be directed into the most fruitful channels, and unrewarding lines of research avoided.

(2) The nature of papers published in Physics journals has changed drastically over the last few decades. Long papers with detailed discussions of procedures, techniques and apparatus have been replaced by much more abbreviated papers that concentrate on results and their consequences, not on how these results are achieved. This change in the nature of physics publications is probably a consequence of the fragmentation of physics into a number of specialties, and the pressure to publish. In order to take proper advantage of the results published it is necessary to know the background to the publication, and this can be achieved only by having contact with overseas workers in the field. The absence of experimental detail can result in inappropriate techniques or apparatus being used unless researchers are familiar with techniques used elsewhere.

(3) The details that have been eliminated from scientific papers appearing in recent years are now communicated by personal contact - at conferences, by laboratory visits, or by mail or telephone. These personal contacts are a particularly prominent feature of US physics. It is particularly difficult for Australian scientists to maintain this type of contact.

(4) One aspect of the publication of the result of an experiment, or a theoretical calculation, that is of concern is the delay between the receipt of a paper by a journal, and the receipt of that journal in Australian libraries. The results of an analysis of this delay for 5 major journals appears in Table I. The journals chosen are all sent to Australia by accelerated air post; most of this delay occurs in preparation of the paper for printing, and printing of the journal. These delays are only a few weeks for "letter" journals or "Letters to the Editor", which briefly summarize preliminary results, or establish priority in an area of research, and which are not very informative to those unfamiliar with the field. For longer papers the delay is frequently six months to a year.

TABLE I
Delays from Receipt of a Paper to the Appearance of the Journal in an Australian Library
(Standard deviation given in parentheses)

<table>
<thead>
<tr>
<th>Journal</th>
<th>Mean Delay prior to appearance of paper (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Review A</td>
<td>42 (11)</td>
</tr>
<tr>
<td>Journal of Physics B</td>
<td></td>
</tr>
<tr>
<td>Letters to the Editor</td>
<td>15 (4)</td>
</tr>
<tr>
<td>Regular papers</td>
<td>38 (8)</td>
</tr>
<tr>
<td>Physics Letters</td>
<td>18 (5)</td>
</tr>
<tr>
<td>Journal of Scientific Instruments</td>
<td>42 (8)</td>
</tr>
<tr>
<td>Review of Scientific Instruments</td>
<td>40 (12)</td>
</tr>
</tbody>
</table>

TABLE II – AIP ATTITUDES SURVEY
Mean Responses to Questions on Leave and Travel
(standard error in the mean shown in brackets)

A response of less than 3 indicates agreement; a response of greater than 3 indicates disagreement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>University Respondents</th>
<th>Other Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>To be able to go to other laboratories for a sabbatical year or the equivalent should be a routine practice</td>
<td>1.37 (0.05) (Strongly Agree)</td>
<td>1.69 (0.05) (Agree)</td>
</tr>
<tr>
<td>You are able as a matter of routine to go to other laboratories on sabbatical leave or its equivalent</td>
<td>2.26 (0.12) (Agree)</td>
<td>3.97 (0.07) (Disagree)</td>
</tr>
<tr>
<td>Attendance at overseas conferences or visits to overseas Institutes should be possible n times per year</td>
<td>0.71 (0.05)</td>
<td>0.63 (0.03)</td>
</tr>
<tr>
<td>You are able to make frequent visits overseas</td>
<td>3.51 (0.12) (Disagree)</td>
<td>4.03 (0.07) (Disagree)</td>
</tr>
<tr>
<td>Attendance at conferences in Australia or visits to other Institutions in Australia should be possible n times per year</td>
<td>1.88 (0.14) (Neutral)</td>
<td>2.05 (0.11) (Neutral)</td>
</tr>
<tr>
<td>Frequent attendances at conferences and visits to other laboratories or Institutions are possible</td>
<td>2.85 (0.11) (Neutral)</td>
<td>3.12 (0.08) (Neutral)</td>
</tr>
<tr>
<td>The optimum length of a short term overseas visit involving participation in collaborative work is n weeks</td>
<td>15.26 (1.27)</td>
<td>17.07 (0.99)</td>
</tr>
<tr>
<td>Your overseas visits are of sufficient duration considering the amount and type of work to be completed</td>
<td>2.92 (0.12) (Neutral)</td>
<td>3.52 (0.09) (Disagree)</td>
</tr>
</tbody>
</table>
These comments indicate that an “invisible college” is an important channel for the communication of ideas, and the stimulation of new lines of research, within the physics community, and no doubt in other scientific fields. Restriction of opportunities to communicate with, and work with, colleagues overseas by changes in study leave conditions, or by economy moves by the Federal Government, will cause Australian physicists to become second class members of this “college”, with the consequence that Australian physics will become second-class physics.

How do Physicists regard overseas travel?

In 1973 the Australian Institute of Physics conducted a survey of the attitude of physicists to various aspects of their career. One series of questions probed the attitude of physicists to the provision of support staff and facilities, including provision for travel. This survey showed a great discrepancy between what the respondents considered necessary in the way of local and overseas travel, and the provisions made by their employers for travel.

The number of useful responses received from Australian Institute of Physics members was 372, made up of 51 CSIRO employees, 59 from other Australian Government employees, 110 from Universities, 44 from CAE’s and 60 from State Government employees, Industry and Schools. For most questions respondents were asked to state whether they agreed or disagreed with a short statement. Their degree of agreement was ranked on a scale from 1 to 5, corresponding to “Strongly Agree”, “Agree”, “Neutral”, “Disagree” and “Strongly Disagree” respectively. On such a scale a mean response of 3 would indicate that the respondents took a neutral stance toward that particular statement. A smaller mean response would indicate agreement; a larger mean response, disagreement. Table II summarizes the results of questions relating to local and overseas travel. Further details of this survey, and a discussion of these and other results, appear in The Australian Physicist (T. M. Sabine and C. J. Howard, “The Attitudes Survey”, Australian Physicist, pp. 73-77, Vol. 12, No. 5 (May 1973)). Table II is adapted from a table which appears in this paper.

This survey was made at a time when study leave was regarded as a permanent feature of Australian academic life. The respondents agreed that it should be routine practice to be able to spend periods of time of the order of a year in other laboratories. The dissatisfaction expressed by non-University respondents regarding provisions for gaining overseas experience, when opportunities were more freely available than at present, show that even these provisions did not fulfil physicists’ expectation of what was necessary to perform adequately their professional duties. The recommendations of the Working Party have stimulated a similar response from University physicists.

The New Zealand Physicist

In April this year there appeared “The New Zealand Physicist” edited by John Campbell, Physics Department, University of Canterbury, Christchurch, NZ. The second issue appeared in June and the third is promised for August.

This is the first attempt to provide a newsletter and forum for discussion for all physicists and people interested in Physics in New Zealand. Airmail subscriptions are available at a cost of $6 for the six issues which will appear each year. It is intended to hold $1 of each subscription in trust to help support an overseas speaker of note at the next National Physics Conference which is due to be held in Christchurch in August, 1980. Subscriptions may be sent to the editor. Some items of interest in the first two issues are mentioned below.

On May 8, this year, the first supernova reported this year, and the first ever discovered in New Zealand was detected at Mount John Observatory, which is jointly run by the Universities of Canterbury, Pennsylvania and Florida. As part of a systematic study of the optical intensity variations of southern quasars, Gerald Gilmore, a PhD student had been taking many photographs. On one plate, showing a 16th magnitude distorted spiral galaxy designated MCG-4-32-23 appeared the supernova. It appeared at a magnitude of 17.5 and was confirmed on another plate taken the following night. The next observation was with the UK 48 inch Schmidt telescope at Siding Springs on May 25th, the magnitude was then 20. The supernova is a Class 1 type and the galaxy MCG-4-32-23 is approximately 750 million light years away.

Professor N. Gell-Mann will visit Canterbury and Stewart Island during September this year.

The publications also provide a list of recent New Zealand PhD theses together with a short summary of each. In 1978 there are 48 PhD or DPhil students in the country.

The Education Committee of the Institute of Physics in New Zealand has produced a pamphlet for schools entitled “Why Take Physics”. Ten copies have been sent to every school in New Zealand. The total cost of the pamphlet was $2.00. It details job opportunities in physics, the sorts of interesting everyday observations that a knowledge of physics can explain, the attributes required of a scientist and a flow diagram of training in physics from school to a professional career.

The editorial committee of the Australian Physicist can only wish our New Zealand “relatives” well. (We nearly wrote brothers but hesitated at the sexist connotations). [The New Zealand Physicist, Vol. 1, Nos. 1 and 2]
As in any new technology it is possible to be a technical expert without understanding the wider implications of the nuclear debate. Even the non-expert may grasp the issues involved if he has access to reliable information when such exists, and if there is open discussion of the probable consequences where no data exists. It is the purpose of any serious debate to sort out the important from the unimportant, the correct from the incorrect, and to attempt a cost-benefit analysis of the use of nuclear energy as compared to currently known alternatives. That is not easy.

Included in both costs and benefits are many long-term items which will affect not only our children's children, but possibly all future life on earth. This situation is new only in degree, not in kind. Man's inventions, from the first primitive weapons, through the wheel, the spinning jenny and the aeroplane, have brought about radical changes in life-style which most of us believe to be advantageous; but most inventions have been misused at some stage in history, and most have produced problems of a sociological, political or medical character which we are just beginning to appreciate. Even ideas have far-reaching effects for good or evil; everyone knows the catastrophic results of misinterpreted Christianity or socialism. Who can doubt that man is his own worst enemy? At times one despairs that man does not learn from his past mistakes, and at times one wishes that knowledge, once gained, could be erased.

The basic questions being asked concerning nuclear power seem to be as follows:-

Is it necessary?

How unsafe are the wastes, and can they be disposed of?

Are the generating plants safe?

Is the breeder reactor necessary?

How unsafe is the "plutonium economy" which the breeder requires?

In addressing these questions we become involved in forecasts of energy requirements, the nature of radiological hazards, the possibility of nuclear terrorism, proliferation of international nuclear armaments, economics, the likelihood of possible break-throughs in physics and medicine, as well as trying to assess the various risks involved in living in society today. In the end our decision will depend on value judgements and compromise, no matter whether we give the red or the green light. Despite the fact that most decisions worth taking involve similar uncertainties, I believe it is the necessity for compromise which gives rise to the suspicion and animosity so intimately associated with the debate.

Energy Demand

Today's civilized society depends on a cheap and convenient energy supply. It might be argued that warmth and the preparation of food are the only essentials involved, but that takes us back to the stone age. Clothing, building materials, metals, household furniture and utensils, lighting, machinery and transport all consume large quantities of energy in their manufacture or operation, and we have not mentioned air-conditioning or health services. The provision of energy itself consumes some of our resources; for instance 70% of all mining and quarrying and 50% of all ocean traffic is generated by the energy industry.

The availability of energy-derived goods and services has changed our life-style to such an extent that we appear to depend on expansion for employment. Labour-saving devices seem to breed material goods, all requiring more energy for their manufacture and operation. And added to this is the inexorable increase in population brought about by improving food supplies and medical technology. Even if we cry "Enough" in our privileged Western Societies, the World's energy consumption must increase many times if all mankind is to enjoy the same benefits. In a sense the energy problem and the problem of over-population are the same.

Expansion of energy use (or of population) cannot continue indefinitely, as any kind of growth law leads to ridiculous predictions if continued over long periods of time.

As an example,* consider the thirty pieces of silver (call them dollars) that Judas threw at the feet of the Jewish High Priest about AD 30. If they had been

*After G. Hardin
invested at 2% per annum, they would now form a fund of such magnitude that it would provide an annual income of a third of a million dollars for every man, woman and child on earth. That much money does not even exist at present.

The plain truth is that there is a limited supply of fossil fuels (coal, petroleum, natural gas) which on any reasonable forecast of energy use will be completely exhausted within a few centuries. Petroleum, indeed, is not expected to be freely available for even twenty-five years, and its cost must increase markedly as it nears exhaustion. When one considers its value as raw material for the manufacture of plastics and chemicals, it seems immoral even to talk of its exhaustion by burning. Even current rates of usage are far too high for the good of the world.

Because energy is cheap, it is not always used in the most effective way, and it is possible by taking conservation measures to marginally extend the period for which fossil fuels will be available. Decisive government regulation of energy use would be needed for a significant improvement, but the future is still strictly limited. If coal reserves are to last for ever, it is obvious that a continuing reduction in use is necessary, and an interesting calculation by A. A. Bartlett for the United States shows that a rate of decrease greater than 3.3% per annum is required to prevent exhaustion of that country’s coal reserves. At present, world consumption of coal is increasing by more than 3% per annum.

It is difficult to over-estimate the importance of costs in any future energy scenario. Thus it has been said that the deciding issue in the Windscale enquiry into whether it is desirable to reprocess nuclear fuels is money. While increased cost of power may provide an incentive to conservation in the developed countries, it leaves less money available for investment in industry and research, and in underdeveloped countries results in an even slower approach to a reasonable standard of living. There is a body of opinion, however, that disputes the connection between energy usage and standard of living.

An interesting point made by L. G. Brookes is that if we leave the development of new energy resources until we need them, we will not be able to afford them. It is only by planning and building now that low-cost energy can be guaranteed for the future.

Of the possible alternative courses of energy, solar energy has the greatest popular appeal because it is familiar and non-polluting. Solar water heaters are common in Australia and solar cookers are in use in three world countries. Solar electricity, on the other hand, is only used for isolated or specialist applications because of its high capital cost. It is a hard fact that any form of solar electricity supply must be costly because of the large area of absorbers required, and the necessity for electrical storage to provide at least a fraction of the peak load when the sun is not shining. Some of the inefficiencies can be reduced by schemes such as orbiting power stations in space, but these substitute one cost for another. Direct use of solar thermal power through a central receiver is considerably more efficient, but cannot compete with conventional sources of power on economic grounds.

I should point out here that even on simple economic comparisons like this there is considerable disagreement. Although all agree that solar power will be more expensive than power from coal or nuclear stations, there are order of magnitude differences in the margins expected. Those like R. S. Caputo who expect the lower range of prices for solar energy, point to advantages in terms of pollution and freedom from accidents for which a small increase in costs is acceptable payment. Caputo rightly or wrongly expects the differential in costs between solar and conventional installations to decrease as time goes on.

Other alternatives like wind, wave and tidal power are intermediate in costs in the right environment but can only provide relatively small amounts of energy on a national scale. Much interest has also been expressed in the indirect use of solar energy via organic materials — the “biomass” experiments in which useful fuels such as methane, methanol and hydrogen are prepared. These techniques provide a direct route to fuel for transport. As with most farming, they are rather hard on the environment, and they constitute direct competition for food production. Significant amounts of energy can, however, be derived from organic wastes, even in low-technology societies.

Nuclear fusion has been described for many years now as “promising”, and that is all it is. Although its fuel is abundant and the process is not likely to be highly polluting, it doesn’t yet work. Even if we buy a few years’ respite by expanding our use of coal, there is no guarantee that solutions will be found to the grave problems that still exist in this area; and coal has its own problems, as we shall see.

We have uncovered a rather depressing energy picture and there is a good measure of agreement that conventional fission power is inescapable as a supplement to coal if we are not to suffer a dramatic shortage of power by the end of the century. The opposite view, although well put by the Friends of the Earth, is not convincing.

Nuclear Power

Certain types of atoms of heavy elements are capable of absorbing a neutron and breaking down into two or more “fission fragments” of other elements. In the process, energy and radiation are released. More neutrons appear in the radiation, and these are available to cause the reaction in other “fissile nuclei”. Natural uranium contains a small amount (0.7%) of 235U, the isotope of mass 235, which has these properties. For the reaction to occur efficiently, the neutrons must be slowed down by a “moderator”, usually water or graphite, which must not be an absorber of neutrons, and we also need a way of stopping the reaction if the power output becomes too high. This is done by means of “control rods” of highly absorbing material such as boron steel which soak up any unnecessary neutrons.

Heat must be removed from the reactor “core” by means of a coolant which must also be non-absorbing, and which is used for generating electricity in a conventional manner. Different choices of moderator and coolant necessitate different designs of reactor, and there is an additional choice of type of fuel which is partly dependent on the other decisions. With metallic fuel elements and efficient moderation it is not necessary to enrich the fuel in 235U because enough fissile nuclei are present to sustain the reaction. Some reactor designs choose to rely on “enriched” fuel (containing up to 3% 235U) because the heat-exchange system is thereby simplified and some design problems avoided.
The bulk of the uranium consists of the isotope $^{238}\text{U}$, which is not fissile. However, it can react with neutrons (especially fast neutrons) to form plutonium of mass $239$ which is fissile. A significant part of the energy developed in a conventional reactor actually comes from fission of $^{239}\text{Pu}$, and we say that the $^{238}\text{U}$ is “fertile”. If we wish to use more of the energy potential of $^{238}\text{U}$ a change in design of the reactor is necessary; no moderator is used, and a “breeding blanket” of natural uranium (or $^{238}\text{U}$ remaining after the preparation of enriched fuels for conventional reactors) is placed around the reactor core. The core contains the fuel, which may be plutonium or enriched uranium. Neutrons absorbed by the blanket gradually convert the $^{238}\text{U}$ to $^{239}\text{Pu}$, which can later be separated chemically and used as a fuel in its own right. It is possible for such a reactor to produce more fuel than it uses, and it produces about 50 times more energy for every tonne of uranium mined than a conventional reactor. It is called a “fast breeder” reactor, and figures prominently in discussions on nuclear power.

Many countries in the world operate conventional reactors which have worked satisfactorily for many years. In Great Britain, Calder Hall was commissioned in 1956—twenty one years ago—and 15% of the country’s electricity supply is now generated by nuclear energy. The world has 1,200 reactor years of commercial nuclear power experience involving 192 reactors and the cost of nuclear power compares favourably with that from coal and oil plants. The industry has been remarkably safe; the fatalities that have occurred have been during mining operations, or mainly in the early days (prior to 1961) of reactor development. To date, no member of the public has suffered from a nuclear accident, and even accidents due to normal industrial-type causes have been very low.

What then is all the fuss about?

Hazards

The hazards due to nuclear power generation can be grouped into two categories, those due to the radiation and toxicity and those due to accident or misuse involving fissile material. Both have caused concern of a grave nature, and much effort has been expended in trying to evaluate and minimize the risks.

The dangers of nuclear explosions are understood by everyone; we have all heard of the nuclear arsenals stockpiled by the USA and USSR and the nuclear capabilities of Great Britain, France, China, India, and now perhaps Israel. Nuclear proliferation is already a fact, and the story of Israel’s plutonium suggests that any determined country can join the club without too much effort. Bombs are made from $^{235}\text{U}$ (obtainable from a uranium enrichment plant) or $^{239}\text{Pu}$ (produced in a conventional nuclear reactor or in a fast breeder reactor, and obtainable from a reprocessing plant). If pure, these two metals can be handled with reasonable safety, and converted to a crude bomb with ease, so the fear has been expressed that individuals or small groups of terrorists might be able to obtain sufficient material to hold a whole country to ransom, if the fissile material becomes a common article of trade. This is the reason for the current anti-pathy towards waste reprocessing and fast breeder reactors, both of which otherwise have a great deal to be said for them.

Radioactivity and toxicity are less easily comprehended and the degree of danger from low levels of radiation is not completely understood. The carcinogenicity of radioactivity is inferred from the case histories of people who work with radium, uranium or have been treated with medical radiation. Radiosensitive tissues (bone marrow, lymph tissue, thyroid gland) are especially susceptible. The survivors of the atomic bomb blasts on Hiroshima and Nagasaki also suffered an above normal incidence of cancers of various kinds, but there has been no evidence of genetic effects. Such effects seem to be present, however, in areas where natural radiation levels are very high (about ten times normal). In Aberdeen, although its background radiation level is 50% higher than the national average for the UK, there are no detectable genetic or somatic effects.

A typical background population dose from all sources may be of the order of 165 mrem per annum. In various suburban areas of Perth, due solely to differences in soil, rock and building materials, the figure could range from 125 mrem per annum to 200 or even 250 mrem. Aircrew could double their normal exposure by spending 1% to 4% of their time in the air. Such differences in exposure cannot be shown to have any deleterious effects on health, and they are much greater than the 6 mrem per annum increased exposure expected to be produced by a world dependent on nuclear power.

The “Flowers Report” estimated that radiation workers exposed to an annual dose of 1000 mrem ran a risk of one in 10,000 of dying of cancer as a result of this exposure—equivalent to the risk of smoking three cigarettes a week.

In calculating possible effects from leakage of radioactive wastes, or accidental discharge of contaminants into the air, the worst possible assumption is usually made, that there is no threshold below which the waste becomes harmless, but that harmful effects are cumulative and proportional to the amount of radiation down to very low doses. This “linearity” hypothesis does not hold for common poisons such as arsenic (which in small doses is used in some tonics or fluoride used to improve our teeth). By analogy with chemical carcinogens, it seems likely that damage induced in a few cells by ionizing radiation can be repaired by normal body mechanisms, but that the repair process can be overwhelmed as more cells are damaged. If this is so, the linearity hypothesis is not true, and low levels of radiation are not toxic unless in the form of “hot particles” lodged in the body. $^{90}\text{Sr}$ may be rather nasty in this respect, as it is highly concentrated in bone, especially growing areas.

Besides the possible absence of threshold, radioactive toxicity differs from chemical poisons in two ways.

1. Its effects occur at some time long after ingestion, and the connection between the toxic effects and the source of exposure may not be obvious (compare cigarettes and lung cancer or heart disease).

2. Its toxicity decreases with time. For example the radioactivity of wastes from a pressurized water reactor has decreased by a factor of 1000 after 500 years, largely because of the elimination of $^{90}\text{Sr}$, which has a half life of 28 years.

Cohen has shown that the most important source of concern is in ingestion with food or drink, and that inhalation of dusts is a minor concern in waste disposal. Although fresh wastes are quite poisonous (a dose of...
½ gram gives a 50% probability of death) after 500 years you would need to eat about 250 grams for the same probability of death. The new chelating agent “pucler”, discovered at Harwell, promises to be an effective decontaminant or antidote which renders plutonium and perhaps other actinides, less frightening.

Although the risks associated with the nuclear program have been widely publicised, those associated with conventional power have been largely ignored until very recently, although controls affecting particular emission from smoke-stacks have been in existence for some years. How can we put such risks in perspective?

Life is risky, and always ends in death. With the progress of civilization the risks have changed and where figures are available it can be shown that expectation of life is increasing. (In fact this is a contributing factor to the present energy shortage.) Some people find risk the spice of life, and others accept known, unnecessary risks to themselves or their neighbours purely in the interests of self-gratification (tobacco, alcohol). As civilized people, we have traded a degree of safety on the roads for convenient transport — and we value our energy supplies more highly than the lives of miners and an unspoiled environment.

Bernard L. Cohen has said16 “We kill 10,000 people (in USA) per year with air pollution, 1,000 per year from coal-mine accidents and disease, 500 per year with asphyxiation by natural gas, 300 per year from fires started by leaking oil and gas, and 1,200 per year by electrocution, all in the name of providing energy”.

J. J. Devaney, with general support from many quarters says17 “The total ratio of fatalities from mining and milling of the two fuels, coal to uranium, are somewhat uncertain, but are approximately 60 to 1 for the same electric power produced. The ratio of disability days, coal to uranium, is 10 to 1. Of the fatalities in uranium mining and milling noted above, the fraction caused by radioactivity is only 1 part in 174. One estimate for the ratio of fatalities for the total generation cycle gives numbers in the range 60 to 1 to 220 to 1 for coal power-generation fatalities to fission power-generation fatalities for the same electric power generated. The ratio for the general public has been put as high as 18,000 to 1, coal to nuclear, a ratio which could be increased by considering new evidence”. We have not even begun to consider the effect of 20 x 10⁹ tonnes of carbon dioxide added to the atmosphere each year by burning coal and oil; this is one of the many factors which affect the climate of the earth. The other hazards from coal include carbon monoxide, sulphur and nitrogen oxides, heavy metals, dusts (causing “black lung disease”) and organic carcinogens and genetic poisons. There is also a long-lived radioactivity hazard associated with coal which is only ignored because it is diluted with a large volume of ash. In fact, if 239Pu is recovered from nuclear wastes for recycling, after 500 years coal ash contains greater total radioactivity than nuclear waste produced for the same electric power output17.

The argument is sometimes heard that wastes from the commercial nuclear program are overwhelmed by those from the military program to such an extent that they are almost negligible. This does not seem to be the case18, and waste disposal is a substantive issue in civilian nuclear use.

Nuclear Wastes

We have spoken in a general way about the wastes from nuclear reactors, and it is not possible to be completely specific without focussing attention on a particular reactor design. The ratio of the various fission products formed depends not only on the reactor design, but on the way in which it is used. The percentage of plutonium 239 in the spent fuel rods, for example, depends strongly on the degree of “burn up” — how long the rod has been in the reactor. A normal life would be about three years.

After removal from the reactor the spent fuel rods must be stored under water until the intense short-lived radioactivity decays. One of the most dangerous fission products in this category is iodine 131, with a half-life of eight days. After storage for a typical 120 days, this isotope has been reduced to less than 1/100th of a percent of its original concentration. At this stage, several options are open, but at present the majority of spent fuel elements are stored without further processing. Radioactivity and heat production can both decay during this storage (it may be surprising that 7.5% of the reactor’s thermal output is due to radioactive decay of fission products rather than the fission process itself).

Fuel reprocessing to extract plutonium for recycling is not at present carried out for commercial reactors in America, for three reasons —

(1) The process is only marginally economic in terms of the 239Pu recovered as a potential fuel. (This evidently depends on the price of enriched uranium).
(2) The handling and transport of 239Pu is seen to be an unacceptable security risk because of the possibility of nuclear proliferation and terrorism.
(3) The remaining wastes are converted into the much less convenient liquid form and require more complicated storage and treatment.

Reprocessing, however, does occur for military reactors in the US and for military and commercial purposes in the UK, France, Germany, India, the USSR and probably China. Further plants are projected for these countries and Japan, Brazil, Italy and Pakistan19. A very large-scale public enquiry has just been conducted in Great Britain to determine whether reprocessing facilities at Windscale should be expanded. The proposal is that Britain should supply and reprocess fuel for Japan and other countries, and even if Windscale does not go ahead, Britain will accept and store Japan’s spent fuel rods for some years.

The output from a reprocessing plant consists of plutonium, depleted uranium (i.e. uranium containing less U²³⁵ than natural material) and high level wastes which from the British Magnox fuels amount to 5-7% of the material in the fuel element in acid solution. A consensus seems to be being reached that the best means of disposal of the waste is to solidify it in the form of glass blocks cast into stainless steel canisters which are buried deep in the earth in a favourable geological environment. The reason for deep burial is not because the canisters are dangerous so much as to ensure that when the canister dissolves and the radioactive elements begin to leach away in the groundwater over very long periods of time, sufficient delays are introduced that the activity reaching the surface has decayed to an acceptable level. At least two serious attempts have been made to determine the factors involved in migration of the ions.
to the surface. Transport of wastes from the burial site to the surface requires –

(1) Access of groundwater to the canister, which involves fracture or dissolution of the rock if the site is carefully chosen;

(2) Leaching away of the canister and contained glass;

(3) Movement of the water to the surface.

Each of these steps introduces a delay, although of course the last two processes occur concurrently. This merely means that only a small fraction of the total radioactivity is found at any one point once leaching has begun. It is interesting that no radioactivity could be detected in groundwater surrounding a glassified block of waste at Chalk River after 15 years, and from a block of poor quality glass leaching is barely detectable.\(^2^0\)

Cohen\(^2^1\) has worked on the assumption that the wastes will escape into the environment in a way similar to the escape of radium atoms from the surface layers of the earth due to natural causes (weathering and leaching by groundwater). There are approximately 12 x 10\(^7\) gm of radium in the top 600 metres of ground in the USA, of which about 300gm finds its way into all the rivers annually. That is, about 1 part in 40 million escapes each year into the surface water, of which 1 part in 10,000 is ingested by humans (purification processes reduce this amount). Knowing the number of fatal “doses” of radiation in the wastes, one can easily find the number of such doses released into the population annually. The result is much less than 1 death annually for the waste from a year’s all-nuclear power generation in the United States, and when the time delays described above are taken into account the number becomes so small as to be meaningless. Cohen believes even this to be an overestimate, because the wastes are to be buried at twice the average depth assumed for the radium.

Marsily \textit{et al}\(^2^2\) have pointed out that the Cohen analysis does not apply to local areas near the highly concentrated waste repository. They have worked from the point of view of transport in groundwater. Even though the burial site is carefully chosen for its stability and lack of groundwater, one must assume that groundwater will eventually gain access to the burial site and a hydraulic flow will be established. Both their theoretical analysis and a study of the “natural reactor” at Oklo, Gabon, show that many of the fission products are effectively confined under these conditions; this is because these elements are trapped by adsorption as they move through the porous rock, and so move many times slower than the water that is transporting them. On the other hand, some isotopes such as iodine 129 are not readily absorbed, and will travel at the same speed as the water stream. There is also a slight possibility that plutonium 239 will not be absorbed. In this case virtually no delay is incurred in the transport of the waste to the surface and Marsily \textit{et al} have calculated that the water may contain many times the permissible dose under certain circumstances. High values are obtained if the glass containing the waste devitrifies, increasing the access of water to its interior, and the calculation suggests that maximum values occur between 10,000 and 20,000 years after water flow begins and the stainless steel canister has corroded sufficiently to allow leaching to begin. This would be hazardous to any local population if the groundwater was used for drinking purposes, and would affect crops and pastures, but would not be hazardous on a national or world scale. In addition I believe that a dilution factor of 100 should be introduced into the calculations because each cylinder of cross-sectional area approximately 1 sq. metre occupies an area of 100 sq. metres in the proposed repository. Groundwaters are then only marginally hazardous to certain types of geological strata even if leaching begins immediately.

The conclusions from both the general and specific approaches therefore agree that the proposed method of waste disposal by burial of glassified wastes at a depth of 5 - 600 metres provides satisfactory safeguards. If indeed the local environment is protected, the nuclear program can be regarded as beneficial from the point of view of world radiation hazards, since after a few hundred years the radioactive toxicity of the wastes is considerably lower than that of the radium in the ore from which they were derived.\(^2^3\) The release of radon from poorly managed tailings dumps can only delay the time at which such “cleansing” occurs.\(^6\) There have been even suggestions that the glassified wastes are not dangerous enough to warrant expensive burial, and may in future years be a valuable source of otherwise rare materials, so they should be stored in surface repositories.\(^2^4\)

Other “low level” wastes are produced during operation of the reactor due to slight leakages, contamination of clothing etc. Although they constitute a relatively minor hazard, their management has not always been as responsible as one would like. They are now subject to strict control, and are released into the environment only if the effects can be shown to be negligible.

Disposal of the core of a reactor after its useful life is over may also pose a problem because of the long-lived radioactivity involved. The best solution may be simply to seal the containment building.

\textbf{Generating Plants}

A valiant attempt was made by a committee under the chairmanship of Norman C. Rasmussen, set up by the US Atomic Energy Commission (now the Nuclear Regulatory Commission) to determine the risks associated with the operation of a light water reactor, and the likely consequences of any failure. Before their preliminary report was published in August, 1974, the American Physical Society set up a Study Group on reactor safety whose findings released in April, 1975, differed substantially from those of the Rasmussen study. The final version of the Rasmussen Report took the APS study partly into account, but has been facing a barrage of criticism since on many fronts.\(^2^5\)\(^2^6\). Although the studies have identified some of the weak links in the chain of reactor safety, and suggested areas where research could profitably be carried out, they do not appear to have produced a reliable comparison with other risks in the community. They calculate also that if the worst nuclear accident does occur, it is likely to cause few fatalities in the short term, whereas long term deaths from the effects of radioactive debris could be of the order of 7,000 with perhaps ten times that number of major health effects over the 20 years. When compared with deaths attributable to natural radiation, this is an increase of only a few percent.\(^2^5\)

Calculations by the British National Radiological Protection Board commissioned by the Nuclear Installations Inspectorate\(^2^7\) extend risk analysis to fast breeders and indicate again a low risk. It is not only difficult to
calculate the risk reliably, however, but also to visualize it. We are told that an "extreme" accident in a fast breeder nuclear reactor could be as serious as the toll of cigarette smoking. In Britain, fatalities from cigarette smoking are four times as numerous as those from traffic accidents and if we are considering a 30-year time period, as suggested by the New Scientist discussion of the report, actual numbers could be quite large. A release of 10% of the reactor's core in a semi-urban site is expected to increase the number of cancer deaths over a 30 year period in an area up to 250km from the site by about 20%. But the probability of such a release is very low and we still haven't stopped smoking!

The uncertainty in these estimates is unfortunate, but you will appreciate that true risk probabilities can only be derived by hindsight from actual experience. The current interest in safety is entirely commendable, but it should be critically directed so that emphasis is placed on areas of greatest risk. Efforts to improve safety in low-risk areas will not then affect the viability of nuclear energy, which otherwise could be priced out of consideration by unrealistic safety codes.

There has been considerable discussion concerning the actual costs of nuclear power both in terms of money and energy input, and the situation has been complicated by escalating safety requirements and increasing delays in licensing and construction schedules. There is no doubt, however, that in Europe at least, nuclear power is still very much an economic proposition. In terms of overall energy balance, nuclear electricity seems to be much more efficient than coal-generated electricity.

The Fast Breeder Reactor and the Plutonium Economy

If power from nuclear fission is to contribute significantly to the world's energy supplies in the future, the breeder reactor is a necessity. We have already seen that it is at least 50 times more efficient than the conventional reactor in utilizing natural uranium with its preponderance of $^{238}$U. The fuel component of the cost of nuclear energy is thus reduced, so that much lower grade ores can be utilized without significantly increasing the price of power. So great is this effect that many of the world's granites become suitable sources of uranium, and nuclear fission becomes an almost inexhaustible source of energy. Without the breeder, the world's uranium can only last a few years; at a pinch some centuries.

Another advantage of the breeder reactor is the fact that it can be fuelled with the plutonium derived from spent fuel elements of conventional reactors, thus reducing the long-term toxicity of the wastes. Other actinides transferred to the core of the fast breeder can also be broken down into less harmful products, so the fast breeder acts as an incinerator, burning up many of the more difficult waste products of thermal neutron reactors.

The argument against the use of the fast breeder on a large scale essentially rests on the dangers of the plutonium economy. Can we afford to produce and trade in such a dangerous material as plutonium, with its potential for making an atomic weapon? This is a curious one, and it is not reassuring that a good deal of plutonium is already in existence in Eastern and Western camps. We have previously mentioned the Windscale enquiry in Britain which has received evidence on this theme; that will be followed by an enquiry into the desirability of breeder reactors, and was preceded by a Royal Commission on Environmental Pollution, whose 6th report (the "Flowers report") on Nuclear Power and the Environment was published in September, 1976, and pointed to terrorism and nuclear proliferation as an area of special concern. President Carter's initial stand against the fast breeder reactor and reprocessing has had to be modified somewhat since it was shown that it could be counter-productive; he has now convened an international Fuel Cycle Evaluation Conference (INFCE) to determine the feasibility of safe international control on these matters. Australians know that the Fox report on the mining of uranium stressed the need for strict safeguards in its use. The announced government policy almost amounts to an "atoms for lease" idea, which does not seem consistent with President Carter's latest suggestion of an international "fuel bank".

The arguments are long and involved, and various ideas have been put forward which would make the fueling and reprocessing of nuclear fuels less vulnerable to abuse. These include the spiking of fuels to make them too dangerous to handle or to make them unsuitable as bomb material; the use of alternative fuels such as thorium; the clustering of nuclear facilities so that transport of dangerous materials is avoided; limitation of the breeding charge of reactors so that only sufficient material is produced for immediate needs. These are called "technical fix" options.

It is obvious that no solution can be completely safe, and in any case it seems to me too late to worry about nuclear proliferation when the technology is widely known. Any determined government could already gain control in one way or another, of the making of a number of atomic bombs. China, India and probably Israel and South Africa, have already done so.

Conclusion

This may seem a pessimistic note on which to end, but I believe there is no point in crying over spilt milk. If nuclear power is not economically viable compared to other options, as some allege, its use should be terminated. If, on the other hand, it can provide economical power for the future, as those most closely involved in its commercial development believe, I think it should be given every encouragement as the only long-term basic energy source in prospect. Coal, and especially oil, have a limited future, and should be conserved for specialized uses. Relative to present energy sources nuclear power is clean and safe in operation, and the nuclear proliferation issue, while a major concern for the world, is almost irrelevant to the question of our power supplies, since the problem exists whether we proceed or not.

It will be evident that our assessment of the benefits of nuclear power is coloured by our attitude to standards of living and quality of life, as well as by our understanding of human nature and our estimate of the technical capacity of mankind. We have not thought sufficiently about the consequences of processes we use every day. It is unfortunate that men seem to perceive only black or white in areas which in reality are various shades of grey. Familiar paths are easy to travel even when the light is poor, but a few shadows can be fearsome in new surroundings. The incentives to travel that way need to be obvious.

I believe we have little option and nuclear power is
here to stay. Despite its problems, the nuclear way will almost certainly reduce pollution and improve industrial safety. Its increased efficiency may be a factor in the continuing change in the way of life of mankind.

REFERENCES

2. Ian Breach, New Scientist, 8th September, 1977, p.4. Economics are the deciding issue.

Dr Jim Graham became interested in the Nuclear debate in the middle of last year and finally sick of hearing claims and counter claims that could not both be true went to a lot of trouble to become informed. This essay is the result and he believes he can see why most of the conflicts arise.

Dr Graham graduated in physics from the University of Western Australia and received an MSc for research in clay minerals and soft X-rays. Brillouin zones and structural transitions gave him a PhD from Birmingham and unable to avoid clay minerals he came to CSIRO and is now a principal research scientist in the Division of Mineralogy in Perth. Most of his work has been of a crystallographic or structural nature and his publications have ranged over a variety of disciplines. Currently he is using thermomagnetic methods for the study of minerals and is attempting to improve the quantitative results obtained from the electron micro-probe. This work seems a far cry from nuclear physics.

Dr Graham has served the WA branch of the AIP as a committee member for many years and has been Chairman and Secretary. His outside interests include singing in the University Choral Society and his church choir. His wider church interests can be seen in his membership of the Graduate Fellowship of the Australian Fellowship of Evangelical Students and he has been Chairman of both the Victoria and the WA Branches.

He does have a nuclear family in the social sense. His wife is a radiologist and two of his three daughters are doing medicine at the University of Western Australia.
Science Policy Report
Commentary on the Birch Report
on CSIRO and the Australian Government's Response, May 1978

In a statement in the Senate (Senate Hansard, 11 May 1978, p.1677) the Minister for Science, Senator Webster, announced the Government's response to the report of an independent committee of inquiry into CSIRO. This inquiry was established in 1976; the members were Professor A. Birch, Professor of Organic Chemistry at the Australian National University, Sir Cecil Looker, former President of the Australian Associated Stock Exchanges, and Mr. R. Madigan, Chairman of Hamersley Holdings. The report was tabled in Parliament on 6 October 1977. At the same time the Prime Minister made the same statement in the House of Representatives (Hansard, 11 May 1978, p.2244) leaving out some of the details.

The inquiry's report was long and comprehensive and included 122 recommendations; since much of the Minister's statement was concerned with these recommendations, a brief list is given of those that seem to be important for physicists. The recommendation is given first and then a comment follows on the minister's response. All quotations are given in inverted commas. It is appropriate to quote from the Resumé of the report.

"The principal role of CSIRO, as we see it, is to fill a gap in national research, with what we call strategic mission-oriented work, which would otherwise remain unfilled. This is the kind of rather long-term work for the community benefit which cannot be, and is not being, carried out by industry or other organisations."

"The particular requirements of research, which need great organisational elasticity for a variety of reasons, lead us to conclude that CSIRO should remain a statutory authority. Its existence as one organisation has been beneficial and we do not recommend splitting it into separate entities."

"However, for reasons concerned both with scientific programming and ease of administration, we do recommend grouping its Divisions, possibly re-ordered, into not more than six Institutes. These Institutes are organisational groupings, not buildings. Their Directors should be members of the Executive."

Recommendations and Responses

"3 The Main Role for CSIRO
The main role should be scientific and technological research in support of Australian industry, community interests and other perceived national objectives and obligations."

"6 Research into economics and the other social sciences should not be undertaken, but steps should be taken to utilise the requisite expertise from these fields in program conduct, evaluation and planning."

"8 The principal type of research should be strategic mission-oriented, but fundamental and tactical problem-oriented research should be undertaken when related to the role of CSIRO."

"9 Research for Australian industry should include work in support of primary, secondary and tertiary industry."

The Minister accepted these. He also said that as part of the improved service to industry, the Government has directed that CSIRO compile an up to date directory of current programs in CSIRO and the people associated with them. This is an important statement. There is a great shortage of small, tertiary-industrial firms in Australia and CSIRO can be seen to be acting as a research organisation for them.

"23 Research program objectives, and the emphasis to be given to them, should be determined by CSIRO subject to the criteria and the consultative, advisory and review mechanisms suggested elsewhere in this Report. Current research programs should be reviewed and, where judged to be inappropriate, terminated."

"27 Overall Organisation Structure
CSIRO should as a matter of priority modify its internal structure by grouping Divisions into Institutes, the number of which should not exceed six."

The Minister accepted these. It is not clear that this recommended grouping of Divisions into Institutes is to be welcomed. In the summary of the Report, as quoted above, the key words seem to be "scientific programming and ease of administration." It could occur that the autonomy of the Division and its scientists would be reduced in these new Institutes and that the native creative vigour of the individual would be lost in an increasing demand for reports leading to remote control from above. It is not enough to note that the Institutes are organisational groupings, not buildings; such a structure added to a scientific organisation will, with the passage of time, become resistant to change. The present arrangement in which the Division has its freedom to work on its own problems and yet to have direct responsibility only to Head Office, seems to have so many advantages that the Government ought to reconsider this recommendation.

"35 The Advisory Council mechanism should be modified and strengthened. It should be fully independent of the CSIRO Executive and be appropriately serviced."

"38 Advice on policies and program priorities should be developed at Institute level, but initiatives of scientists in Divisions in regard to consultation, inside or outside CSIRO, should be encouraged."
45 The Personal Classification System
The personal classification system applying to all except clerical-administrative staff should be retained.

46 Criteria for assessment in relation to promotion at various levels of the classification structure should be clearly defined, and be made available in printed form to all staff. Such criteria should be reviewed from time to time with changing circumstances.

48 Experimental Officer-Research Scientist Classification Structures Consideration should be given to the establishment of a vestibule grade of Scientific Officer (or similar appropriate title) to which all potential tenured Research Scientists and Experimental Officers should be appointed.

This seems to have much merit, especially at the present when there are few tenured jobs for physicists and for most advertised jobs many recent doctoral students are applying. It is not specifically mentioned in the Minister's statement but he mentions that there are "some matters" requiring "further consideration to bring about their implementation."

51 Voluntary retirement at age 55 should be introduced.

The Minister said that he would be looking at the question of voluntary retirement of research staff at age 55 in the context of the Government's consideration of redeployment and retirement policies.

52 The proportion of fixed term to indefinite tenured appointments should be raised, and a high proportion of all new appointments should be made as Research Fellows.

The question of fixed term appointments is controversial in any laboratory; it is a sign of the difficulties that younger scientists are having in getting permanent positions.

76 Bureau of Mineral Resources, Geology and Geophysics
CSIRO should continue to carry out strategic mission-orientated work in the mining area, of the type already pursued by the Mineral Research Laboratories. However, this research effort should be rationalised with the appropriate role of the Bureau of Mineral Resources, Geology and Geophysics.

Minister - "I shall also be following up with my ministerial colleagues ways of rationalising with the Bureau of Mineral Resources, Geology and Geophysics the strategic mission-orientated work CSIRO does in the mining area which is of immense importance to the national economy. The Government has decided that CSIRO should be encouraged to contract out appropriate work to organisations such as the Australian Mineral Development Laboratories and the Australian Coal Industry Research Laboratories as part of this new impetus to bring CSIRO and industrial implementation expertise closer together."

88 Consideration should be given to using the new National Measurement Laboratory buildings and equipment as a national facility for engineering research.

89 Universities
A joint committee of CSIRO and the Australian Vice-Chancellors' Committee should be established to investigate means of collaboration.

90 Initiatives aimed at forging closer links between tertiary institutions and CSIRO Institutes, especially in research, but also in teaching, should be encouraged.

The Minister accepted these.

91 Close consideration should be given to siting new CSIRO laboratories adjacent to tertiary institutions.

Minister - "... the Government has directed CSIRO to give close consideration to siting any new laboratories adjacent to tertiary institutions and it agrees with the inquiry that secondment of staff between CSIRO and universities should be more actively promoted."

Many readers will agree with the Minister who, in a News Release from the CSIRO (PR. No.14 of 11 May 1978), said -

"It is to the credit of CSIRO's scientists and administrators that the CSIRO of today has, under critical scrutiny, proved to be equal to the expectations its founders and subsequent supporters placed on it."

The Minister, in his Hansard statement, also said -

"If any reminder were needed of the great contribution which CSIRO has made, it is sufficient to refer to the decision last month of the International Civil Aviation Organisation Air Weather Operations Division to adopt internationally the INTERSCAN microwave aircraft landing system developed by CSIRO in collaboration with the Department of Transport."

On the same day, the Chairman of the Executive of CSIRO, Mr. V. D. Burgmann, said (CSIRO News Release PR. No.13), and again many will agree -

"I am confident that I speak for most of the 7000 people who work for CSIRO in saying that we regard the Inquiry's report and the Government's reaction to it as an endorsement of the Organisation's past performance and a vote of confidence in the continued relevance of CSIRO to Australia."
Physics Roundabout

New Director for RSPhys Sciences
Professor J. H. Carver, Elder Professor of Physics at the University of Adelaide, has been appointed Director of ANU's Research School of Physical Sciences.

The directorship of the Research School became vacant in mid-February with the resignation of Professor Robert Street to take up appointment as Vice-Chancellor of the University of Western Australia.

Born in Sydney in 1926, Professor Carver began his research career as a Commonwealth Research Student at Sydney University in 1948-49. From 1949 to 1953 he was an Australian National University Scholar at the Cavendish Laboratory in Cambridge.

Following that, he has been: Research Fellow, Fellow and Senior, Research School of Physical Sciences, ANU, 1953-61; Bursar, University House, 1953-58; Visiting Scientist, Division of Nuclear Physics, AERE, Harwell, England, 1958-59, Visiting Scientist E. O. Hulbert Centre for Space Research, US Naval Research Laboratory, Washington, 1968-69; Chairman, Australian National Committee for Space Research. Chief Australian delegate to COSPAR; Chairman, United Nations Scientific and Technical Sub-Committee on the Peaceful Uses of Outer Space, 1970; Chairman of the Radio Research Board of Australia, Member of the Clean Air Committee of South Australia, Chief Examiner in Physics and Member of the Public Examinations Board of South Australia, 1961-71; Dean of the Faculty of Science, Adelaide University, 1971 – and Chairman of the Education Committee (Professorial Board), Adelaide University, 1973-74. [ANU Reporter, June 1978]

Retirement of Dr Roy Muncey
‘Think Change’ – those two words displayed prominently in the office of Dr Muncey represent a personal belief that guided him through his 34 years with CSIRO.

When he joined the Division of Tribophysics in 1944 he undertook a war time task of measuring the muzzle velocity of shells fired from battle ships.

In 1946 he was appointed to the Division of Building Research and led the Architectural Physics Group for 20 years where his research included thermal investigations and room acoustics. His research reports on this work formed the basis for his degree of Doctor of Applied Science conferred in 1969.

Dr Muncey believes that the Division's research should be oriented towards a practical application and in line with these thoughts he has been responsible for encouraging the Division to study human factors in building as well as the more traditional areas such as materials, heat and sound.

His appointment as Chief of the Division of Forest Products in 1966 started his involvement with the timber industry.

In 1971 when much of the Division of Forest Products and the Division of Building Research were amalgamated, Dr Muncey was appointed Chief of the newly formed Division of Building Research.

Appointment as a member of the Standing Committee of the Australian Forestry Council preceded his appointment as Chairman in 1975.

He has also been a member of the Timber Promotion Council of Victoria since 1969.

He is also a member of the Australian Housing Research Council and the Building Research and Development and Advisory Council.

Besides his scientific achievements, Dr Muncey has distinguished himself in several extra-curricular activities. [Coresearch, 1978]

Fusion
"If we cannot make fusion work satisfactorily, there is no alternative major source of energy for next century apart from a proliferation of fast breeder nuclear reactors", says Dr Sydney Hamberger, the recently appointed Head of the Plasma Research Laboratory at ANU.

Dr Hamberger hopes and expects that other forms of renewable energy sources, such as solar, wind and tidal, will be developed but he asserts that all proper studies show that these put together will be able to supply only a fraction of the world's needs. Fusion, he says, can in principle supply clean, safe energy in abundance. Already billions of dollars are being spent overseas on fusion research aimed at making thermonuclear power man's principal energy source in the 21st century.

Formerly Head of the Stellarator and Plasma Physics Group at Culham Laboratory, in the United Kingdom, Dr Hamberger joined ANU as a Professorial Fellow in December last year to lead the plasma physics work at Canberra. The Plasma Research Laboratory with departmental status in the Research School of Physical Sciences, was established by Council earlier this year. A graduate of the University of London, Dr Hamberger was associated with Culham Laboratory from its formation in 1962, having worked in the same field at Harwell since 1958.

He concedes that ANU, or Australia for that matter, does not have the resources to compete with USA, USSR, EEC and Japan in developing fusion processes. 'Nevertheless we can do very useful research on the fundamental properties of high temperature plasma to help solve outstanding problems, devise new measurement methods, and influence progress by adding to the general pool of international knowledge on the subject', Dr Hamberger says.

'The Australian Atomic Energy Commission is now interested in fusion and has set up a Fusion Advisory Group including heads of university plasma research groups. There is increasing collaboration between universities and Lucas Heights. Two members of the Lucas Heights staff are now attached to ANU as Visiting Fellows and one or two more are expected to follow.'

Having come from a large laboratory, Dr Hamberger regards it as a challenge to help build up a small but influential one at ANU. However, he adds, the laboratory has an enormous asset in having the large homopolar generator which is uniquely capable of generating vast amounts of electrical power – an essential requirement for experiments on magnetic confinement of plasma.

Dr Hamberger is keen to bring home several Australian plasma physicists who are working overseas because of lack of facilities in Australia – he believes the laboratory has the potential of becoming a major national facility and will help to keep Australian talent here. [ANU Reporter, 14 July 1978]
Dr Paul Wild
Internationally recognised radio-astronomer and solar physicist, Dr J. Paul Wild, 55, is the new Chairman of CSIRO.

The seven-year appointment was announced on 30 June by the Minister for Science, Senator J. J. Webster.

‘Dr Wild’s appointment is a keystone of the wide-ranging new measures being introduced following the Government’s consideration of the report of the Independent Inquiry into CSIRO earlier this year’, Senator Webster said.

‘His seven-year term of office will provide the necessary stability in top management to enable CSIRO’s strengthened links with industry, the community and Government to be put into effect and sustained.’

He said Dr Wild was elected a Fellow of the Royal Society of London in 1970, has been a Fellow of the Australian Academy of Science since 1962, and this year (1978) became a Fellow of the Australian Academy of Technological Sciences and was created Commander of the Order of the British Empire for his services to radiophysics.

‘Dr Wild is the man who led the CSIRO Interscan microwave aircraft landing guidance system research team to success in collaboration with the Australian Department of Transport, Senator Webster said.

‘He has worked in the Organization for 31 years and is recognised internationally as one of Australia’s most outstanding radio-astronomers and possibly the world’s foremost solar physicist.

‘His many abilities should fit him well for the demanding job of leading CSIRO — one of the world’s leading Governmental scientific research bodies whose innovative work is of such national and, increasingly, international significance. [Coresearch, 1978]"

Dr Lloyds Rees Retires
The man who developed the Division of Chemical Physics from a small section within the Division of Industrial Chemistry to one of the world’s leading research centres in this field has retired from CSIRO.

In a recent tribute, the President of The Royal Society, Lord Todd, said he believed Dr Rees had done more than anyone else to establish Australia as a force on the international scientific scene.

In 1944, Sir Ian Wark, Chief of the Division of Industrial Chemistry, asked Dr Rees to return from the UK to Australia to set up a Chemical Physics Section in the Division, the first chemical physics group to be set up in any government-financed laboratory in the world.

The function of the Section was to meet the urgent demand for the introduction into Australia of a number of major chemico-physical methods including electron-microscopy, electron diffraction, X-ray structure analysis, mass spectroscopy and infrared spectroscopy.

A chemist by training and a physicist by inclination and adoption, Lloyd Rees was the ideal man for the job.

In 1958 the Section that he had built up became the Division of Chemical Physics with Dr Rees as its Chief.

A firm believer that the best way to help industry is through fundamental scientific research, Dr Rees has seen many of his Division’s inventions become commercially viable, not the least of which is the atomic absorption spectrophotometer.

Active in the affairs of both national and international scientific organisations, in 1969 Dr Rees became the only Australian to be elected president of the International Union of Pure and Applied Chemistry, the largest of all international scientific unions. He held the post until 1972.

Dr Rees was awarded a CBE in 1977 ‘for services to the science of chemical physics’. [Coresearch, 1978]

CSIRO
The Budget session of Parliament beginning in August is expected to provide a green light for fundamental changes recommended for CSIRO by the Birch Committee.

Amendments to the Science and Industry Research Act 1949 under which CSIRO operates cannot be made until Parliament reconvenes, but meanwhile groundwork for change is being laid.

However, many of the Government’s recommended changes are not dependent on legislation being amended.

A Steering Committee has been formed to study the Government decisions on the Birch Committee Report.

The Committee has already sought the views of Chiefs and interested staff on what many regard as the most radical proposal of the Birch Committee — the grouping of research Divisions into Institutes.

Staff are understandably keenly interested in the composition of the proposed Institutes, but no information is available.

For speculators, some clues may be found in the number of research Institutes recommended — a maximum of six — and the present mainstream of research in CSIRO. Rough groupings can be arrived at in this way, but it will remain a guessing game at least until August, and probably longer. [Coresearch, 1978]

Australian’s study Florida Lightning
Dr M. Darveniza, reader in electrical engineering at the University of Queensland and two of his graduate students have been invited to join an American research team studying lightning.

The aim of the work is to combine Darveniza’s expertise on lightning effects on power systems with Dr Uman’s knowledge of lightning Physics. Dr Martin Uman is Professor of Electrical Engineering, University of Florida.

Stroke-by-stroke characteristics of lightning will be studied and the data used to develop advanced analytical models of lightning and its effect on power systems. [Engineers Australia, July 14, 1978]

There is no hint in its title that this book deals largely with applications of CO₂ lasers as high-intensity sources of heat only. The author is an authority on laser drilling, welding and machining and these subjects are dealt with in detail in two chapters containing many of his own photographs and experimental results. As a background to these there is a chapter containing a useful collection from the literature, of solutions of the heat diffusion equation for a variety of experimental situations. Together these three chapters portray the state-of-the-art in laser drilling, welding and machining in 1976. To enable the relative newcomer to apply the equations to practical problems there are numerous tables of relevant thermal properties of metals and non-metals and three useful appendices showing the variation of some properties with temperature. However there are two shortcomings here. Firstly, the data relating to infrared absorbances of materials is limited to a table of resistivities of a few pure metals and steel alloys, and a formula which leads to the ideal absorbance of clean polished surfaces only. There is no discussion of the effects on absorbance of surface roughness, change of conductivity on melting and oxidation before and during heating. Secondly there is, in places, a lack of clarity in the definition of symbols and units. There are also a few inevitable typographical errors in equations. Users of the equations should refer to the original sources, which are well cited throughout the book.

The treatment in the rest of the book is more superficial. At the beginning there are three introductory chapters on lasers in general, CO₂ lasers in particular and detectors and optical components for use with CO₂ lasers. The sections on types of high-power CO₂ lasers are very comprehensive. These chapters give a quick review for the newcomer but the presentation of physical arguments is not always completely clear. Better introductions can be found in the many books now devoted entirely to lasers. Those introductory chapters are followed by the specialist chapters discussed above. Then there are four chapters entitled "Applications of Laser-Induced Evaporation", "Spectroscopy of Laser-Induced Reactions", "Thermal Effects" and "Propagation, Atmospheric Monitoring and Communications Links at 10.6 μm". The coverage in these chapters is not comprehensive but a good overview is given and there are plenty of references right up to 1975, one thousand of them in all.

In summary, this is a quite readable review of the varied applications of laser heating of solids with sufficient introduction to high-power CO₂ lasers for an undergraduate or newcomer to lasers. In addition there are three detailed chapters which are essential reading for anyone intending to specialize in laser drilling, welding or machining. The book is a worthwhile addition to the scant literature on the effects and applications of high-power laser radiation.


Although this monograph is aimed at promoting interest in the varied aspects of nuclear reactor safety technology it also provides a most useful and timely volume on the quantitative approach to the nature of risk in an industrial society. The contributors to this volume are all from the Safety and Reliability Directorate of the United Kingdom and enjoy considerable reputations in their fields of Nuclear Safety, and therefore make this monograph a most desirable addition to the shelves of one's Technical Library.

Chapter 2 deals with the quantitative assessment of fission product release from fuel elements and their migration through the reactor circuitry and filter systems and Chapter 3 compares the likely quantitative effects on man and the environment of completely uncontrolled release of such fission products under hypothetical accident conditions. Although a numerical risk criterion is proposed in Chapter 4 the author also notes "that the licensing of reactors for power generation has not so far been based on an explicit quantitative criterion, but rather upon a detailed examination of possible fault sequences defined in a more deterministic manner".

The main thrust of this book is to demonstrate the need to establish the real engineering reliability of the various reactor sub-systems by quantifying the technical arguments which go to make up a safety assessment of a nuclear reactor.

For those wishing to enlarge their reading on the quantitative approach to nuclear reactor safety there is a very good list of references at the conclusion of each chapter.

MULTIPLE HYPERGEOMETRIC FUNCTIONS AND APPLICATIONS, Harold Exton (312 pages) in the series "Mathematics and its Applications". Australian Distributor: John Wiley & Sons.
Reviewed by D. G. Lampard, Monash University, Clayton, Vic.

In this book Dr. Exton has collected together virtually all the known work on hypergeometric functions of more than one variable. The classic functions of Appell and Kampé de Fériet are of course treated as well as more generalized functions of Lauricella. Other more recently introduced hypergeometric functions of several variables are dealt with including, for these and for the more classical cases, their integral representations, convergence properties, transformations, partial differential equations, generating functions and recurrence relations.

Finally two major chapters review applications in statistics, physics and other fields.

The reviewer finds the book very clearly written and a mine of information.

The book contains a bibliography of 168 references and two computer programs for calculating the Lauricella functions Pₐ and Pₕ.

It will certainly dwell happily on this reviewer's bookshelf next to W. N. Bailey's Cambridge tract "Generalized H.G. Series" and together with Dr. Lucy Slater's two important books on H.G. functions.

This reviewer believes that it will be an extremely useful book for those applied mathematicians whose work involves them in dealing with H.G. series in more than one variable.
Books Received

The following books have been received for review. Space limitations will probably not permit the publication of review or notices of all of them. Would anyone interested in reviewing a particular book please communicate with the Book Review Editor, G. A. Bell, National Measurement Laboratory, Chippendale, NSW. 2008.


The Australian Institute of Physics

EXECUTIVE
Prof T. M. SABINE, President
Prof H. C. BOLTON, Vice-President
Dr J. R. BIRD, Hon Secretary (02-531-3447)
Dr C. J. HOWARD, Hon Treasurer (02-531-3609)
Dr J. G. COLLINS, Hon Registrar (02-467-6211)

ADDRESS:
Science Centre,
35-43 Clarence St.,
Sydney, NSW 2000.
Telephone: 02-29-7747