AUGUST 1978 NUMBER 262

# ATOM

LOW LEVEL EFFECTS OF RADIATION

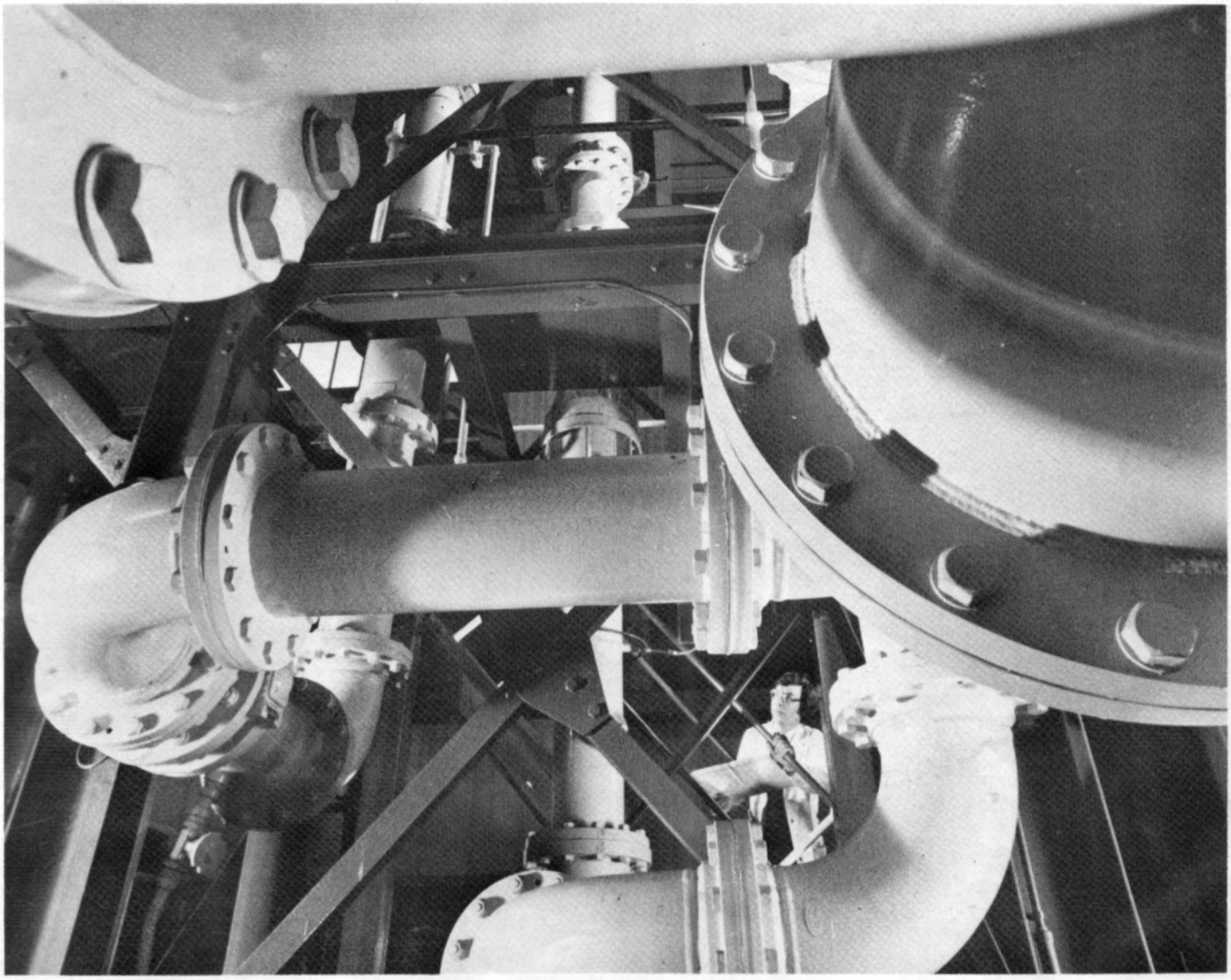
VIBRATION IN NUCLEAR PLANT

'ENERGY 2000'

UNDERGROUND WASTE DISPOSAL

ALTERNATIVE SOURCES OF ENERGY





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# ATOM contents

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Front cover: Risley vibration rig used to examine vibration in fast reactor fuel element assemblies under simulated reactor flow conditions in water.

# LOW LEVEL RADIATION EFFECTS: THE MANCUSO STUDY

Experimental evidence of the effects of radiation on man has been obtained from such groups as Japanese bomb survivors, luminous dial painters, radio-therapy patients, and early radiographers. In all these cases quite substantial doses of radiation were accumulated, and an unambiguous correlation is found between dose and the incidence of various types of cancer.

The magnitude of the effect is roughly $10^{-4}$ deaths per rem. That means that if 10,000 people each are given a dose of 1 rem, then about one of them can be expected to die as a result of radiation during the following few decades. In recommending dose limits for radiation workers and the general public, the International Commission on Radiological Protection (ICRP) assumes that this incidence applies at all dose levels, even though the observations relate to substantial doses. Known as the 'linear hypothesis', this assumption is widely believed to be pessimistic, because natural repair mechanisms are expected to be more effective at low doses. If the same assumption is applied to animals, where more extensive data is available, the effects at low doses are over-estimated by up to a factor of four.

At the much lower dose levels of interest for radiological protection purposes, no accepted measurement of radiation effects in man has been achieved. This is not surprising since the limits on radiation dose recommended by ICRP are set at such a low level that the effects expected on the assumption of the linear hypothesis are very small compared with other hazards of life.

This view has been disputed in a recent paper by Mancuso, Kneale and Stewart, on the basis of an analysis of the radiation and mortality records of workers at the Hanford plant in the United States. The total dose received by the 25,000 men in the study was about 3800 rems. On the basis of the linear hypothesis, less than one death from radiation would be expected among the 670 deaths from cancer observed in this population. The new study claims to have detected effects a factor of 10-100 greater than the linear hypothesis predicts. It has been widely criticised for its defective methodology. The following critiques explain the objections. The first of these appeared in the April 1978 issue (No. 23) of the Quarterly Bulletin of the National Radiological Protection Board (NRPB); the second was published earlier this year by the US Atomic Industrial Forum as part of their Public Affairs and Information Programme.

## A REVIEW OF THE STUDY OF MORTALITY AMONG RADIATION WORKERS AT HANFORD

by Dr. J.A. Reissland and Dr. G.W. Dolphin,
National Radiological Protection Board, Harwell

In a study* of 24,939 males and an unspecified number of females who have worked or are working at Hanford (Washington, USA), so far there are 3520 certified deaths of males and 412 certified deaths of females. Of the 3520 males, 2184 were classified by the authors as "exposed", with an average life-time radiation dose of 1·72 rads. There were 670 deaths of males due to cancer, 442 in the exposed group, and on a proportional basis only 416 were expected; hence, there is an apparent excess of 26 cancers among the exposed males. There were 123 deaths of women exposed to radiation among the total of 412 and the deaths due to cancer were 127, of which 38 were in the exposed group and on a proportional basis 38 were expected. The average dose to the exposed women was 0·89 rads. There is little analysis of the data on females in the paper; the discussion mainly concerns the males.

An "exposed" worker is defined as someone who accumulates a lifetime dose greater than 0·01 rads. This is a particularly low level for natural background radiation delivers a dose of 0·1 rads per year, so that many of the so-called "exposed" workers will have accumulated larger and more variable amounts of radiation dose from background than from occupational exposure.

The paper contains 26 tables and 4 figures which, together with the style of presentation, makes it difficult to understand at the first reading. The most important data are contained in Table 11, where the correlation between the percentage of cancer deaths and the accumulated radiation dose is tested.

From this test of the proportional mortality data for cancers it is concluded that a correlation does exist. The most remarkable data are in Table 22, where 27 separate values are given for the doubling dose at various ages for two groups of cancer, namely, RES neoplasms and other selected cancers (pancreas, lung, brain, kidney and the large intestine). The radiation doubling doses for these two categories of cancer vary with age at which the dose has been accumulated; for example, the doubling dose is 30 rads for RES neoplasms at 45 years of age but is only 0·1 rads at 70 years, and before the age of 45 the doubling dose is infinite.

*Radiation Exposures of Hanford Workers Dying from Cancer and other causes by T.F. Mancuso, A. Stewart and G. Kneale, Health Phys., **33,** *369 (1977)*

**Comments**

It is known that the average accumulated dose for all Hanford workers, both living and dead, is about 3 rads. As the average dose to the 3520 who have already died is 1·07 rads, the average dose among the dead will increase as more workers die; hence, the average dose in the survey will increase with time. Total cancer mortality rates are not constant and are also increasing with time. However, certain types of cancer are decreasing, such as those of the stomach and rectum, whereas other types, such as myeloma and pancreatic cancers, are increasing. Since both accumulated dose and total cancer death rate increase with time, there will be an apparent correlation between dose and percentage deaths due to cancer in this survey. Certain individual cancers will correlate positively, that is, those increasing with time, and certain cancers will not correlate, that is, those decreasing with time. In Table 4, where 18 types of cancer are ranked in order of association with mean cumulative radiation dose, all those cancer types listed above the mean dose are increasing with time and those below are decreasing with time.

Dr. Land of the National Cancer Institute, USA , has carried out an analysis on the same data as used in this report. He corrected certain artefacts in the analysis and took into account calendar date of death. He found that the apparent relationship between accumulated dose and the percentage of deaths from cancer did not survive except for two types of cancers, myeloma and cancer of the pancreas.

From the estimates of doubling dose the authors conclude that radiation dose accumulated before the middle years of life is less likely to produce a cancer at later times than doses accumulated at older ages. It would probably be misleading to apply these doubling doses, which have been abstracted from the Hanford data, to other situations. For example, a radiation worker who has accumulated 30 rads before the age of 45 appears to have doubled his chances of developing an RES neoplasm according to the analysis of the Hanford data, but if he survives without further radiation exposure to the age of 70, the doubling dose has been reduced to 0·1 rads and, hence, his chances of developing an RES neoplasm have increased by 300 times. Furthermore, at the age of 70 years, even a person without occupational exposure will have accumulated about 7 rads from background radiation and, consequently, it is not possible to reconcile this background dose with a doubling dose of 0·1 rads unless the authors have ascribed a meaning to doubling dose different from that given in the text: "A radiation dose which is just sufficient to double the normal risk of cancer death". Maybe the significance of the doubling dose values given in Table 22 could be more fully appreciated if the uncertainties in the values were also given; it is suspected they would be very large.

From the values of doubling dose it is clear that the risk coefficients associated with the radiation at Hanford are between 1 and 2 orders of magnitude greater than previous estimates made from analyses of the cancer mortality in the Japanese atomic bomb survivors, radiotherapy patients and other groups of irradiated persons. If proven, the Hanford findings have serious implications for radiological protection and it is a pity that the text and tables are of such obscurity that any association between cancer deaths and radiation exposure has been buried rather than extracted. Without access to the raw data which is not given in this paper, the findings cannot be checked but they do appear to be related to the statistical methods employed.

In summary, this is an important survey which indicates the necessity to continue studies on the causes of death among radiation workers and that myeloma may have a greater association with radiation than hitherto supposed. However, the quantitative relationships between cancers and radiation dose derived in the paper must be regarded with caution and, for the present, as unproven.

**Note**

At the request of ATOM Dr. Reissland has up-dated this critique as follows:

More recently the authors (IAEA, Int. Symp. on Late Biological Effects of Ionising Radiation, 1978) have extended their data to include 4694 males who died between 1944 and 1977. Their analysis is concerned with the 3742 males who were monitored for external radiation, among whom 743 died of cancer compared with 670 in the first report. As we predicted in our commentary on the Health Physics article, the inclusion of later deaths has increased the mean doses of all groups, for example, for all males 1·66 rads (from 1·07 rads) and for all cancers 2·03 (from 1·38 rads). Detailed comparison is difficult because in the second analysis the workers are not clearly divided into exposed and non-exposed. However, the new estimates of doubling dose are strikingly different from the earlier ones. Based on 25 cases, the authors estimate a doubling dose of 3·6 rads for myeloma and myeloid leukaemia. Their previous estimate was 0·8 rads from 22 cases (14 exposed). The reduction of their estimated risk by more than a factor of four when so few extra cases are included undermines any confidence in the methods adopted by Mancuso, Stewart and Kneale. Even the 10 per cent more all-cancer deaths changed their calculated doubling dose from 12·2 rads to 33·7 rads. Thus this extension of the analysis does nothing to strengthen their claim that ICRP malignancy induction rates substantially underestimate the true rates.

# THE MANCUSO STUDY: A COMMENT

**by Dr. Leonard A. Sagan, Manager of the Electric Power Research Institute, Biomedical Studies Program, Palo Alto, California. This paper was first delivered to the INFO '78 Conference organised by the US Atomic Industrial Forum and held in Los Angeles earlier this year.**

The AEC/ERDA Health and Mortality Study was initiated in 1964 with Dr. Thomas Mancuso, a Professor of Occupational Health at the University of Pittsburgh. The objective of the study was to investigate the health of workers in the nuclear industry, with special attention to the possible effects, if any, of radiation exposure. Mortality was selected as the most feasible measure of health experience with ascertainment of death to be determined from Social Security Administration records. Barkev Sanders, a statistician, recently retired from that agency became part of the project, as did Dr. Alan Brodsky, a health physicist. After an early exploratory period, Hanford and Oak Ridge Laboratories were selected for study, the intention being to recreate records of all persons employed from 1944 to the present. Three control or comparison groups were chosen: persons hired at these two laboratories but not subsequently employed; siblings of employees; and a national sample drawn from Social Security rolls.

In spite of an enormous expenditure of funds (6 million dollars) over the past 14 years, no publications were generated by the project. Annual progress reports suggested that preliminary analyses indicated no detectable radiation effect, a not surprising outcome in view of the very low radiation exposures experienced by employees at those laboratories.

One oral presentation by Dr. Mancuso at an annual Health Physics Society Meeting (published in the proceedings, Richland, Washington, Nov. 2-5, 1971) also suggested the absence of a radiation effect, although he cautioned that this tentative conclusion was preliminary.

In March of 1975, Dr. Mancuso was informed that his contract was to be terminated within the following year. Alan Brodsky had already left the project. Barkev Sanders was informed by Dr. Mancuso that he was to be dropped from the project. He was replaced by Dr. Alice Stewart, a British epidemiologist and her colleague Dr. George Kneale. Within a matter of months a new analysis limited to Hanford data was prepared and presented at the Saratoga Springs meeting of the Health Physics Society (October 11-13, 1976). This new material, with some changes, was recently published in the journal, Health Physics (**33,** 369-385, 1977). In this publication, it was concluded that occupational radiation exposures at Hanford were associated with an increase in cancer.

This unexpected finding aroused national attention, not only in scientific circles but among governmental agencies as well. Occupational radiation protection standards have been thought to be well below levels where health effects could be detected. It was said that the nuclear industry was extremely safe and studies of radiation workers at other laboratories supported that conclusion. Radiation exposure levels at Hanford were well below permissible levels. These were levels so low that on the basis of all other human exposure data, no detectable effects would be expected.

Following publication of the Hanford study, Representative Paul Rogers, Chairman of a House Subcommittee, charged that Federal Energy officials had attempted to cover up the report and that the ERDA contract had been taken away from Mancuso in order to prevent publication of his findings. Dr. James Liverman, who had ordered termination of the contract, testified that there was no attempt to cover up but that the contract had been terminated for other reasons, namely:

(a) "A clear lack of substantive publications appearing in referenced journals, even papers on his methodology for analysis, would have been highly useful".

(b) "A reluctance to initiate any analyses until all data collection was complete — a clear difficulty in studies requiring massive data bases which take a long time to compile. The reason given was that the results might be misleading; however, generally in studies like this, it is crucial that even trends — positive or negative — get identified early so as to guide studies more directly. Related to this point is the accusation voiced by some of suppression of data. As far as I, personally, am aware, no results of any project supported by BER funds have been suppressed by management of BER programmes".

(c) A judgment by his scientific peers that the work should be limited, terminated, or another investigator selected to be the principal investigator".

(d) "The need from the Agency's standpoint to insure that the records constituting this study could be preserved for posterity and be readied for transfer to new programme management".

Not only in its authorship and its conclusion but in other respects too, the Health Physics paper represented a divergence from the previous style and methodology of the project. In his annual reports and in private conversation, Dr. Mancuso had emphasized the need for caution and warned against the danger of premature judgements. He had stressed the requirement that all environmental factors be carefully studied so as to remove the confounding effect of other variables. Three separate control groups were developed in order to overcome the possible errors inherent

**TABLE 1**

**Employees with recorded radiation exposure at Hanford who later worked at Oak Ridge where there is no record of their prior radiation exposure at Hanford*.**

| | Occupational radiation in millirem |
|---|---|
| Year | % of Offsite Radiation |
| 1944 | 96.1 |
| 1945 | 55.3 |
| 1946 | 29.9 |
| 1947 | 27.6 |
| 1950 | 100.0 |
| 1951 | 100.0 |
| 1952 | 100.0 |
| 1953 | 100.0 |
| 1954 | 9.8 |
| 1955 | 65.2 |
| 1956 | 96.6 |
| 1957 | 100.0 |
| 1958 | 99.3 |
| 1961 | 80.5 |
| 1963 | 100.0 |
| 1965 | 86.8 |
| 1966 | 100.0 |
| TOTAL | 61.5 |

*Prepared at Oak Ridge partly from magnetic tape supplied by Hanford.

in choosing an anomalous comparison group. He had been criticized for his cautiousness and unwillingness to begin analysis until all data at all laboratories has been weighed and considered. That had in fact been his defence for the long delay in publishing analyses.

The Health Physics paper as published shows none of this caution. None of these control groups were used. Nowhere are there the usual caveats about possible unrecognised confounding variables. Scholarly references to the existing literature and to the contrary findings of others are absent. There are only 6 references, two to his own work and no references to the enormous body of radiobiological literature. One has the feeling of haste in the writing of the report. Criticism of the paper falls into two categories.

1. *Dose estimates.* Comparisons are made between the "exposed" and "non-exposed" populations, yet the paper does not provide information on the level of radiation which would be considered "exposed". Commonly 10 millirads above background would be sufficient to produce a positive reading. Therefore, the "exposed" population is swollen with a very large number of persons who have experienced trivial exposures and a very small number of persons with considerably higher exposures, i.e., an extremely skewed distribution. The paper lacks information on the exact distribution of dose within the exposed population or among the persons with cancer and/or other causes of death. Only mean values are presented, giving the false impression that exposures were fairly uniform. One reviewer compared this usage of statistics in this way: if a population of 10 persons one of whom has an annual income of one million dollars and 9 of whom earn 100 dollars a year, the mean income of the group is $10,100 a year. The mean alone gives no indication of the disparity here.

Secondly, Dr. Mancuso had previously stressed the fact that Hanford occupational exposures are a poor reflection of total radiation exposure. Medical exposures to the work force, the subject of a publication* is not mentioned in this Health Physics paper. Nor is there any mention of occupational radiation exposures prior to or subsequent to

*D. Norwood, F.L. Rising, C.W. Kirklin, A. Brodsky, B.S. Sanders, and T.F. Mancuso, "Cumulative Dose from Diagnostic Radiation", Am. J. Roentgenol, Radium Ther., Radium Ther., and Nuclear Med. CXV, 644-648, 1972.

**Table 2**

Certified Deaths among Hanford Males

| | % Cancers | % Non Cancers |
|---|---|---|
| Exposed (2184) | 20.2 (442) | 79.8 (1742) |
| Non Exposed (1336) | 17.1 (228) | 82.9 (1108) |

(taken from Mancuso *et al)*

Hanford employment, a subject which had previously been of concern to Dr. Mancuso and the subject of a previous study which had shown occupational exposures elsewhere to be as great as those at Hanford for those employees who had transferred from one laboratory to another. (Table 1).

2. *Methodology:* The cancer epidemiologist wants to know whether radiation exposure increases the risk of cancer and the magnitude of the risk if it exists. He knows that he must be cautious in excluding the effect of other variables which may influence the risk of cancer. Since the risk of cancer rises steeply with age, age is a factor which requires careful control. In the Mancuso publication, there are no details of the ages of the living or deceased members of the exposed or non-exposed populations.

Typically, the population under study is also carefully matched by all variables known to influence cancer (such as socio-economic status, education, smoking habits) with a similar population. If exposures varied then the exposed group might be categorized by dose level on the logical assumption that a radiation effect if present would reflect a gradient from highest exposure to least. None of this appears in the Mancuso report.

Although the strategy followed in the original Mancuso proposals would have provided such adjustments, the recent Health Physics paper shows use of a weaker technique known as proportionate mortality normally used when the characteristics of the population at risk are not known. The problem with proportionate mortality is that, if one cause of death is reduced, other causes will appear to be increased. One can never be certain whether any single cause of death is increased, unchanged or decreased on an absolute scale. Table 2, taken from the Mancuso study, apparently shows an increase in cancer deaths as compared with the percentage cancer deaths among non-exposed persons. The questions then are:—

1. Is this difference in the *proportion* of cancer deaths due to radiation or some other factor, and 2. Is the *rate* of cancer among exposed Hanford workers increased, decreased or unchanged.

The first question is impossible to answer from the data available in the Health Physics paper since the age and occupational distribution of the two populations is not given. There is some reason to believe that the exposed population is older than the non-exposed population since the rise of radiation exposure increases with the length of employment. Furthermore, there are occupational differences between the exposed and non-exposed groups — craftsmen and operators being more common in the former group, and managers more common in the latter group. These differences could well explain the slightly greater frequency of cancer among the deaths in the exposed group.

As to the second question of whether cancer is increased or decreased on an absolute basis in exposed Hanford workers, we are fortunate in having another analysis to which we can turn, that of Dr. Ethel S. Gilbert of Pacific Northwest Laboratories (Table 3). This table shows that when Hanford employees are carefully matched for age and years of exposure they have lower risk of death than do all US males (the "healthy worker" phenomenon). We also see here that circulatory and all other diseases are even more reduced than cancers, a likely explanation of the relative increase in cancer seen in the Mancuso paper.

**Table 3**

Standard Mortality Ratios (SMR) for White Males by Length of Employment (Number of deaths is given in parentheses)

| | *Length of Employment* | |
|---|---|---|
| | <2 Years | 2 + Years |
| Number of Workers | 7767 | 13,075 |
| *Cause of Death* | | |
| All Causes | 86 (1905) | 75 (2089) |
| All Malignant Neoplasms | 88 ( 319) | 85 ( 414) |
| Circulatory Diseases | 87 ( 839) | 76 ( 955) |
| Accidents, Poisonings & Violence | 109*( 243) | 75 ( 216) |
| All other causes | 74 ( 423) | 65 ( 455) |
| No Death Certificate | (81) | (49) |

*This is the only SMR presented in this table which is *not* significantly different from 100. All other SMRs are significantly lower than 100 at the .01 level.

This material was presented by Dr. Gilbert at the AAAS meeting in Washington.

In examining specific cancers, Dr. Gilbert did find two sites where cancer did appear to be increased with radiation exposure, pancreas and multiple myeloma (Table 4). Neither of these cancers have been found increased in studies of other exposed populations and the meaning of this observation remains unclear, but deserves further attention.

As is often the case with radiation, these scientific issues have now become widely publicised and politicised. Dr. Mancuso has charged that his ERDA contract was terminated because of his scientific findings (his contract was terminated prior to his recent publication). Others assume the opposite, i.e., that his scientific conclusions were influenced by "sour grapes" at his contract being ended. In any case charges have begun to fill the air. One former collaborator of Dr. Mancuso, Dr. Brodsky, has written a critique in which he attacks the "many scientific absurdities" of the Health Physics paper. The other former colleague, Barkev Sanders, has written a rebuttal, also to be published soon in Health Physics in which he concludes that no radiation effect can be detected at Hanford. Those who are anti-nuclear will adopt Mancuso as a hero, and those who support nuclear power will raise their eyes to heaven and prepare for the worst. And so it goes.

**TABLE 4**

Standardized Mortality Ratios (SMRs) for craftsmen and operators employed for at least 5 years (Number of deaths is given in parentheses)

| | OCCUPATIONAL CATEGORIES | |
|---|---|---|
| | High Exposure | Low Exposure |
| Population Size | 1844 | 1975 |
| Percent with Total Doses >5.3 Rems | 67.9 | 15.7 |
| SMR FOR | | |
| All causes | 0.65 (185) | 0.76 (316) |
| Diseases of the Circulatory System | 0.67 (83) | 0.78 (148) |
| External Causes | 0.65 (20) | 0.72 (26) |
| Malignant Neoplasms | 0.92 (46) | 0.92 (68) |
| Cancer of | | |
| Stomach | 0.32 (1) | 0.98 (5) |
| Large Intestine | 1.17 (5) | 0.45 (3) |
| Pancreas | 2.09 (6) | 0.46 (2) |
| Lung | 0.87 (13) | 1.13 (24) |
| Prostate | 0.46 (1) | 2.39 (10) |
| Res | 1.27 (7) | 0.81 (6) |
| Myeloma and certain Lymphomas | 3.40 (3) | 2.34 (3) |
| All Leukemias | 0.00 (0) | 0.65 (2) |

None of the differences in SMRs between the two groups are statistically significant.

# VIBRATION IN NUCLEAR PLANT

A major conference with this theme was held in Keswick in May and attracted 230 participants from 16 countries, half of the delegates coming from overseas. This response stems from the success of a more general Conference on vibration studies organised by Windscale Nuclear Power Development Laboratories (WNL) in 1973. This time, papers were strictly confined to vibration in nuclear plant and it was clear that another Conference with the same subject and format would be welcomed by the great majority of participants in three years' time, when progress will have been made in many of the areas discussed. This report is by M.E. Ginniff, Research Manager, Engineering Group, at the Authority's Windscale Laboratories and C.H. Jones of the Authority's Springfields Laboratories (SNL).

Vibration is inevitable in all plant which involves moving fluids or machines. Its nature depends on the vibration characteristics of the plant and on the mode of operation so that attention must be given to the whole range of possible operational conditions from commissioning and through part power, to full power, under refuelling and also under fault and earthquake conditions. Vibration signatures can also be used as a means of health monitoring or non-destructive testing (NDT). All these aspects were included bringing together specialists in the different areas and enabling them to appraise the state of the art as it is applied in the nuclear industry.

Under steady operating conditions, plant is subject to forced vibration caused by the unsteadiness of the flow, or by sound generated by flow disturbances or by rotating machines. The problem is to show that component life will not be impaired by fatigue, fretting or wear, so it is necessary to discover the most onerous conditions for each part of the plant, compare them with acceptable limits and, if necessary, inhibit the vibration or find ways of relaxing the acceptance limits so that satisfactory life can be assured.

There are also many instances where the steady component of the fluid flow couples with vibration of the structure so that energy can be extracted from the fluid kinetic energy and converted into vibration which can then grow exponentially until failure occurs or until some other factor or restraint is brought into play. A common example is the motion of a flag in the breeze. However, because of the potentially destructive nature of these phenonema, (to which both fuel stringers and heat exchanger tubing may be prone) it is necessary to show that a substantial margin exists between the velocity of fluid flow in the plant and the velocity at which "self-excited" instability may set in. Some cases arise in which a three-fold coupling can be significant, that is between the fluid flow, vibration of the structure and acoustic vibration of the fluid.

Transient vibration caused by faults, accidents or earthquakes must be studied to ensure that the resulting motion of the plant or its internal components or fluids does not compound the incident by any further structural failure, or by interference with the reactor control or essential services and safety features.

The recent developments in using vibration to monitor plant health or integrity also holds promise of substantial economic benefit to operators.

Nuclear plant poses some particularly challenging problems because of the combination of the harsh environment, limited accessibility and the emphasis on safety and reliability. There are now a large number of instances throughout the world where vibration problems have caused expensive delays or outrages. They provide a strong incentive to improve confidence in mastering these problems and in doing so at a suitably early stage in the plant development.

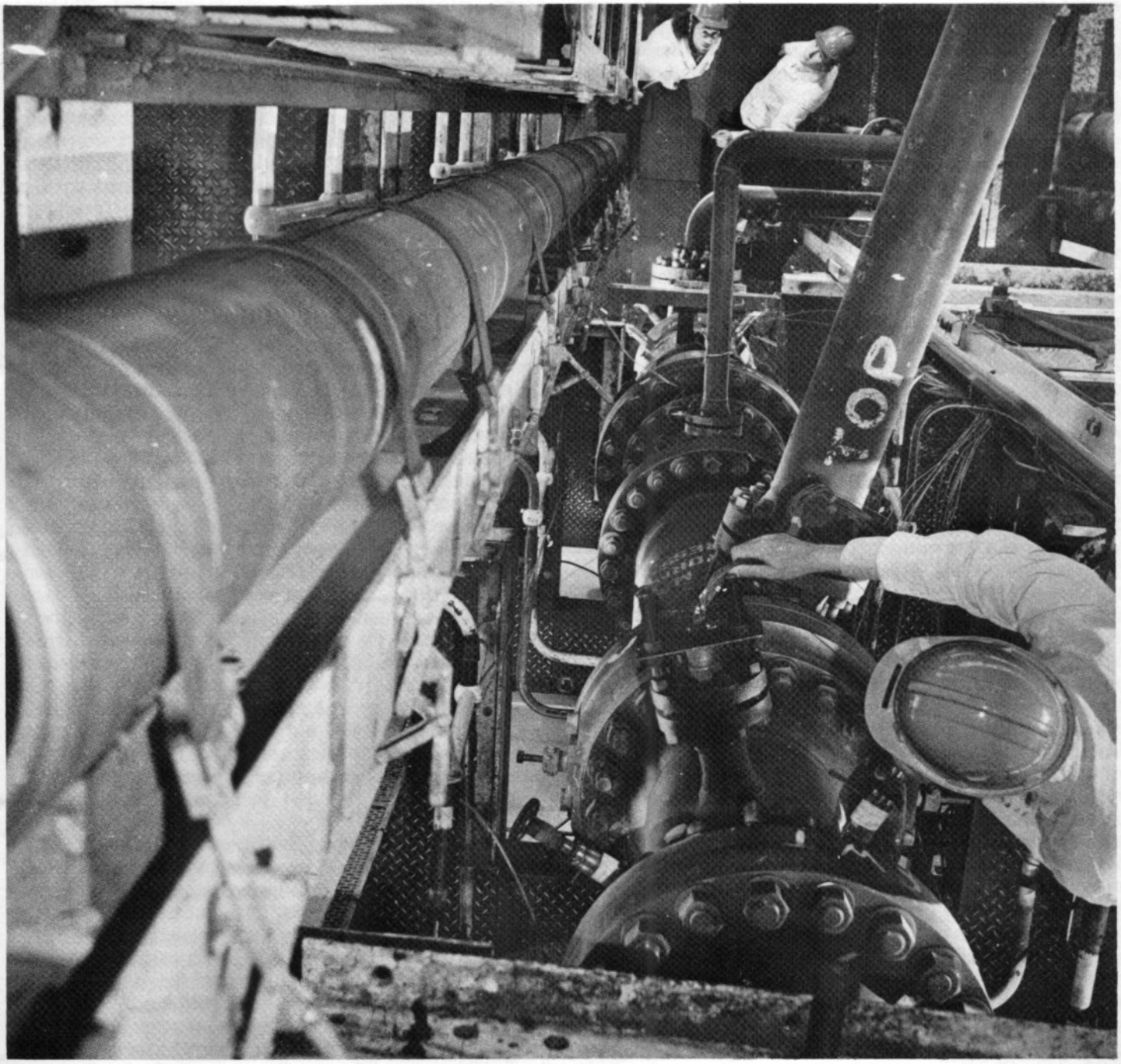
**Fuel**

Undoubtedly, the Canadians have adopted a more thorough approach to the penetration of fuel vibration problems than any other country. Canada is now concentrating on CANDU reactors which have horizontal channels with separate fuel bundles and on-power refuelling. Only Gentilly has vertical fuel channels. Its successor BLW was cancelled. (There are still a number of vertical interstitial holes occupied by instruments and control rods.)

For the horizontal channels, a computer programme has been developed which calculates the forced vibration of each fuel bundle in each mode then sums these responses to give the frequency spectrum of vibratory motion at each wear pad. It is necessary to measure the fluid loading in a water/air rig to account for the unpredictable effects of grids and entry geometry. Data on the fretting of Zircaloy has been obtained from mechanical tests, but it has not been possible, so far, to make the final step of relating the vibration with fretting.

A corresponding programme, DYNMOD, has been written for vertical fuel (primarily by V. Mason of Springfields Nuclear Power Development Laboratories (SNL) on detachment at Canada's Chalk River Laboratories). Good agreement is found between measured and predicted vibration and the programme has been used to calculate the dynamic stability of reference design CSGHW fuel stringers, showing a flow margin of 200 per cent to instability. However, the stability margin is very sensitive to bending stiffness of the fuel cluster, implying that this margin would be significantly reduced by a change to the back-up design with sloppily located spacer pads. This work also explains why the Italian CIRENE fuel stringer buckles into a helical shape and rattles in its pressure tube, causing unacceptable fretting.

It was noteworthy that Interatom (Germany) found similar, but not identical, vibration of a liquid metal fast breeder reactor (LMFBR) fuel element when subjected to cool water and then to hot (500°C) sodium flow. Differences were attributed to the different structural vibration and upstream flow turbulence spectra for the two loops. The use of water loops for development work was advocated, leaving sodium tests just for final confirmation. This confirms the UK project view.



**The 'SCOT' Environmental Test Loop at the Reactor Fuel Element Laboratories, Springfields.**

A full description was presented, in a total of five papers, introduced by G.M. Emsley of the Nuclear Power Company (NPC) of the work done by SNL and WNL and also by the Central Electricity Generating Board (CEGB) at Marchwood and NPC in overcoming the problems with dynamic instability of the Hinkley Point 'B' gag and plug stringer bellows.

In contrast to the Canadian approach, the CAGR work relies on full-scale *ad hoc* tests extending to flows only just beyond those obtained in the reactor. The effect of tolerance variations in component manufacture or embodiment compared with those actually tested was then found to be so significant that a sizeable proportion of production components behaved in an unsatisfactory way, some failing quite dramatically. These presentations underlined the value of the large loops used in the UK but also highlighted the need to establish greater margins between operating conditions and those where the limits of acceptable behaviour are transgressed than has been traditional in the UK industry.

Attention was also focussed on the pertinent question of the extent to which it will pay to invest in a more thorough analytical approach to complex and slightly non-linear vibration of rattling components. The hope is that by such an investment, a more direct approach could be made to diagnosis and cure of vibration problems with these components and that a great deal of confirmatory testing needed in the wake of minor changes could be avoided. Such a course would involve rationalisation of current CAGR and SCOT Rig programmes, together with additional work of a more erudite nature. Would a radical reappraisal save scarce resources in the longer term? We cannot be sure. There is no doubt that limited scope exists for this type of approach.

**Heat exchangers**

The vibration of the tubes, heat exchangers and steam generator has taken on great importance with the arrival of the nuclear power reactor. Prior to 1970 little, if any, research seems to have been devoted to problems like liquid cross

flow induced vibration of heat exchanger tube bundles and most of the limited experimental work performed prior to that time was conducted with gas flows and with single or a limited number of tube rows.

The result of the vibration is usually tube failures due to fatigue or fretting. While such failures were apparently acceptable in the pre-nuclear age the present day designer of nuclear plant finds himself in a situation where this is no longer the case. Failure of tubes in nuclear plant heat exchanger equipment can lead to a range of unacceptable situations such as intermingling of expensive heavy and light water or of sodium and water and in most cases to expensive down time for remedial work with conseqential radiation doses to operators. The AEA have had direct experience of these problems in their prototype reactors and in addition to work in their own establishments have encouraged and assisted other organisations in their R & D programmes on heat exchanger vibration.

During the current decade in particular a large number of publications describing good experimental and/or theoretical work have appeared in the literature and a number of conferences have provided excellent forums for discussion of the subject. Vast advances have been made but some of the basic fluid phenomena are still not well enough understood. The designer is much better equipped with design data than he was a decade ago but further information is required to ensure 30 year life factors for heat exchangers.

The Keswick Conference brought out general agreement that turbulence and hydro-dynamic instability are the main excitation mechanisms for vibration excitation at the interior of tube bundles subjected to cross flow with pitch-to-diameter ratios of 1:5 or less. It was also clear that the first and second tube rows will generally differ from the behaviour of tubes at the interior of the bundle. There was, from a limited amount of work, agreement that dynamic lift coefficients in the range 0·10 to 0·12 for resonant vortex excitation were appropriate. Some other areas require further work. For example, for tubes in a narrowly spaced tube bundle operated with a very dense fluid, eg water, the predictions of the natural frequencies of the tubes include an allowance for the fluid around the tube and this added mass allowance is usually based on the hydro-dynamic added mass values obtained in tests without flow. Recent work has shown that with the onset of flow these frequencies increase and hence the added mass concept needs some further sorting out. Similarly further work is needed to improve the understanding of damping factors. The difficulty of experimentally determining damping factors was generally accepted and a reference to a method used in space engineering was to be followed up.

Two papers were presented dealing with acoustic resonances in heat exchanger systems. It is clear that the acoustic resonances may considerably influence the nature of the flow but the theory is in an early development stage and the experimental work requires sophisticated acquisition and analysis techniques.

**Flow-induced vibration of plant components**

The concern of LWR vendors to avoid the recurrence of expensive plant outages because of damage resulting from flow-induced vibration was illustrated by papers from the United States, France and Czechoslovakia. Vibration of piping caused by the internal flow was discussed in contributions from the UK and France in relation to normal operation of LMFBRs and PWRs; from Germany for HTRs. UK authors presented two papers on the vibration of cover plates for thermal insulation of AGRs, one on the avoidance of vibration problems with instrument cables.

The significance of flow-induced vibration was highlighted in a paper describing the joint DOE, GE and ANL National Programme. Some twenty different problems which had caused expensive shut downs of LWR plant up to 1977 were listed. Because of this experience, the US intends to obtain an in-depth understanding of phenomena which may limit the reliability of components subject to flow-induced vibration. Attention was focussed on mechanical-hydraulic features where there are high flow velocities, sharp changes in pipe direction or flow paths, splitters, jet flows entering confined spaces or diffusing in surrounding fluid, sliding joints and seals. The jet pump used in BWRs was singled out because of the high cost of unreliability. The seriousness of this programme was underlined by the illustrations of the very large full scale GE rig representing one loop of an LWR with the corresponding core sector. This rig was being commissioned at the time of the conference.

In PWRs, the specific problems to which reference was made included the fatigue of the core barrel, its attachments and of the thermal insulation sleeves between the barrel and the outlet nozzle. The Czechs had studied vibration of the hemispherical bottom closure of their PWR core barrel. In each case, the flow into or out of the confined annular space between the pressure vessel and the barrel caused turbulence which excited some of the lower frequency modes of the structure. The procedure adopted in each of the investigations presented was to calculate the natural frequencies of the vibrating component, confirm this experimentally, measure its damping and also the fluctuating fluid pressure at selected positions. From this, the expected vibration response was calculated and compared with experimental observations, for instance the French ⅛ scale 3 loop SAFRAN 1 loop. The accuracy of these calculations depended on the choice and extent of the simplifying assumptions which were made and on the accuracy with which damping could be measured. None of the papers presented utilised the latest state of the art. They did underline the need for thorough analysis to understand the reasons for observed behaviour and give confidence in proposed solutions.

Reactor plant inevitably contains many examples of pipes and ducts in which the flow is far from the classical fully-developed turbulent flow of long straight pipes. The loads exerted on sections of pipe by upstream bends or discontinuities were reported from RNL work related to LMFBRs and from Germany for HTRs. Again, the fluid loading can only be found experimentally, but the intention is to use this together with an analytical description of the structure dynamics to calculate the resulting vibration response. Theoretical methods are unlikely to suffice for a very long time ahead and it will still be essential to confirm design calculations experimentally and at full scale.

UK papers on the design of cover plates for the Dungeness 'B' insulation to resist low frequency flow-induced vibration were well received. One could not avoid the very obvious comparison between the confidence level that has been achieved with these vulnerable components and the extensive development and service experience with "standardised" PWR components.

In BWRs, pressure increases in the primary containment which occur under some normal operation or fault conditions are suppressed by condensing steam dumped into the pool. An analysis, borne out by experiment at Brunsbüttel, showed that, to avoid excessive stresses in the containment vessel, it was necessary to guarantee a satisfactory separation between the natural frequency of the vessel and of the coupled motion of the contained air and of the water pool.

**Acoustics**

The more detailed components of reactor plants were considered for acoustic excitation. Pipework systems for

example were studied and in one case it was shown that it is important to take account of the flexural modes of vibration of the pipe cross section which are acoustically generated as the frequencies above which these modes exist have a strong influence on the vibration response of the system. In the other case a method was described of predicting the response of general pipework systems to acoustic or mechanical excitation. A transfer matrix approach was used which took account of the usual radial stretching of the pipe and tension waves in the pipe walls, but additionally extended the gas-filled pipe acoustic method to embrace all fluid-structure interaction.

Thermal insulation is an important feature of concrete reactor containment. The thermal duty which involves gradients of up to 500°C in advanced gas-cooled reactors is a severe constraint on the design and imposes a need for flexible structures to minimise thermal stresses. There is then a conflicting requirement of stiffness to prevent excessive vibration. Both gas flow and sound generated primarily by the circulators provide strong dynamic exciting forces. The designs used in AGRs consist of about ¼" thick retaining cover plates over fibre or foil and mesh insulant supported at a number of points by studs welded to the pressure vessel liner. Experimental and analytical studies of the acoustic performance of cover plates systems were reported. In one case simple mathematical models had been developed to provide design guidance and also to provide a method of distributing instruments during reactor commissioning to measure insulation response. An important conclusion from this work was that irregular cover plate shapes or stud positioning increased radiation resistance. In the discussion of this work it was pointed out that the benefit of the irregular stud positioning had been used to relieve the need for accurate stud location for the Dungeness 'B' AGR and test work had confirmed that the advantage existed.

Turning to fast reactors it was noted that acoustic excitation is a principle source of vibration in PFR. The pumps produce acoustic pressures of up to 2·2 psi at twice blade passing frequency which excite structural resonances with significant but small stress levels. It is important to avoid coupling of acoustic energy in components and this requires attention to the details of the design. In general acoustic vibration is not expected to be a serious problem in fast reactors and this was confirmed by information from model studies extrapolated with some uncertainty to full-scale situations and from PFR commissioning tests.

The Conference heard a description of a study of the consequence of a molten fuel-coolant interaction in a Liquid Metal Cooled Fast Breeder Reactor. This can generate a large amplitude pressure pulse which in turn, according to this study, is rapidly attenuated by plastic deformation of the ducts in which the event occurs to the extent that the on-going pressure pulse does not cause plastic yielding of the further duct walls.

It was interesting that the major contributions to fast reactor acoustic studies were British and in particular from the UKAEA.

**Remote vibration monitoring of plant**

The participants agreed that a particular weakness in current vibration understanding is the change in vibration amplitude during operation consequent upon wear, changes in material properties, corrosion and sometimes even unexpected changes in operational parameters.

Test work rarely, if ever, covers these variables which are both difficult to specify and difficult to reproduce. Wear is a typical case. Wear data is sparse and there is an interrelationship between degree of wear, vibration amplitude and wear rate. Consequently life predictions are subject to uncertainties which demand conservative safety factors, with an economic penalty additional to that already imposed by basic vibration design uncertainties.

The participants could not recommend a design stage approach which would overcome this difficulty, the general feeling being that the acquisition of more wear data or more endurance testing would offer, certainly in the short term, only a modest reduction in this particular uncertainty. The Conference delegates were therefore interested in operational monitoring as a safeguard against this uncertainty. Monitoring for practical reasons means remote, external monitoring.

The various papers can be conveniently divided into vibration monitoring of non-rotating and rotating plant. This is supported by inspection which, as will be mentioned later, can provide more information than just that of plant condition.

Monitoring of PWRs shows promise in that some success in computer modelling has been obtained and, coupled with measurements made with imposed mechanical excitation and, later, during flow tests, an understanding of the vibrational behaviour of major components is being obtained. The particular example reported from France indicates progress towards a triple objective of detection of abnormal operation, diagnosis of the particular fault and finally some estimation of the life of the component involved.

From the United States came an interesting alternative approach, again applied to PWRs. In this case vibration measurement of the core support barrel appears practical by analysis of neutron flux perturbations as detected by flux detectors mounted outside the pressure vessel. Since these detectors are affected by a number of different sources of flux perturbation a major task is separation of these from those induced by structural vibration. The authors have found this possible by examination of the coherence, phasing and frequency characteristics of diametrically opposed detectors. Having identified that part of the neutron signal related to structural vibration the authors treated the quantification as a shielding problem with a dynamic component. Amongst a number of recommendations for further work the authors list the need for experimental verification of the vibration/neutron flux relationship. Experimental variation was regarded as essential by all workers in this field, irrespective of the detection method in which they were involved.

Two papers dealing with gas-cooled reactor problems, one the Wylfa boiler and two the Hinkley Point 'B' gag illustrated further variants of the monitoring technique. The former showed how coherence techniques made use of the fact that groups of interleaved boiler tubes came out through adjacent headers, the coherence between signals from two such headers being used to define the vibration of a group of tubes. The second paper illustrated a rather unusual calibration of monitoring in that one component under surveillance, the Hinkley Point gag, was pre-set in a known unstable situation to provide a fault signal. In this case the fault condition was impacting, not vibrating, and detection proved effective on a signal amplitude distribution basis. This system has been adopted as an operational aid and is now installed as fully-automated equipment.

Monitoring of rotating machinery is more advanced, having been stimulated by costly turbine failures. Papers at this Conference dealt with this topic using frequency analysis as the basic approach. It was of interest to hear a plea from the author of one of these papers for more attention to inspection as a means of obtaining further information. He illustrated this with wear scar data showing evidence of modes of vibration.

The present status of monitoring can be summarised from the Conference papers and discussion as follows. A diverse approach to the various problems has shown the existence of many useful techniques though there is still much work to

be done, particularly of an experimental nature. Some operators welcome remote monitoring, but this interest is by no means unanimous. However, more may be forced to adopt it by the likely US NRC statutory requirement for monitoring. Consideration of the problems which formed the background to these monitoring papers shows the value of detection of incipient failure to be enormous.

## Earthquakes

The final session of the conference was devoted to effects of earthquakes on nuclear plant. The effort to study these effects is increasing, firstly, because it is realised that even in non-seismic areas there could be a significant risk to the safety of the plant and secondly, because there is a significant reactor market in active earthquake areas. The majority of the work being performed is analytical rather than experimental and this emphasis was reflected in the proportion of conference papers devoted to each aspect.

Finite element techniques are commonly used to predict structural motion. The earthquake spectra are derived from typical ground motion time histories measured during actual events. The ground motions recorded during a single earthquake are particular to that event and in addition are not representative of bedrock motion. Scanlan and Klaus-Sacho proposed a design method based on energy density techniques and claimed that it was independent of particular time histories.

The French are building a reactor in a seismically active area of South Africa. The reactor hall is isolated from the effects of earthquakes by soft mounting so that only reduced forces will be transmitted into the building. Denham and Kelly presented the results of an experimental study of a similar system in which natural rubber blocks were used to provide the soft mounting. The reduction in acceleration was significant, although this advantage was countered to some extent by the increased displacement. The experimental facilities, at the University of California, which were used to apply representative ground accelerations to the large model were impressive.

## Final Discussion

The final discussion of the conference turned out to be a good opportunity for seeking comments on the general international position of the subject. The discussion was focussed by seeking answers to questions as follows:-

Q1 What components are not receiving sufficient vibrational assessment?

There was divided opinion on this question. A number of delegates agreed that fuel as the heart of the reactor required more vibrational assessment and almost as many delegates countered with the argument that fuel had been covered in all aspects and although more data was always an advantage, the other permanent components of the system, particularly those which were irreplaceable should receive increased consideration.

Q2 What tools of the trade need more attention?

eg Theoretical assessments
Model studies
Fatigue and wear studies
Environmental test facilities
Instrument techniques–in-reactor
Data collection from operating plant

Many delegates emphasised the need for more wear, fatigue and fretting information, particularly under some of the more unusual motions encountered during vibration like impact scuffing. It had been a conscious decision of the Papers Committee for the Conference to exclude subjects like fretting and wear not because they were unimportant but to contain the technical content: however, in the light of the facts of the discussion this decision would require review for any future Conference.

There was a range of views on the adequacy of the tools available but what clearly emerged was the need for assessments for more difficult situations than just the normal design geometry in its idealised form and also for the distorted and worn part life state. Also the less common parts, for example in heat exchangers the associated bends, U-tubes and helical tubes. For those more demanding situations the tools would require sharpening at least.

Q3 Has the vibration subject reached a stage where a manual could be prepared for designers and operators of nuclear plant?

There was clearly a desire by many to create some form or advice document but also much reservation was expressed about how this should be done. The emphasis was on not replacing the 'thinking' that was essential for a vibration assessment. Hence the form of the document should be such that information and guidance were available which prompted the correct approach, encouraged the reader to apply the necessary depth of assessment and to seek the guidance from specialists.

Q4 What vibrational subjects have we forgotten?

This had a limited response but brought out the important point of assessments at unusual conditions like part-load or other than the fully assembled state of the reactor, eg during refuelling.

It was pointed out during this discussion period that more information should be available from reactor operators about the vibrational performance of their plants and about the results of work carried out during reactor commissioning.

## Conclusions

Vibration is an important subject in nuclear plant, in fact there must be few cases where there is zero vibration. Vibration leads to wear fretting and fatigue of components which are life or power limiting factors and in the case of permanently installed components, early failure can be a major economic problem.

Little work on vibration in nuclear plant was done before 1970 but during the current decade the recognition and understanding of the subject have broadened rapidly. Much useful work has been done on the more common geometries under normal design conditions and the prime causes of vibration are now known and generally avoided. Much work remains to be done on common components under the more unusual operating conditions, on the less common components and particularly on permanently installed components. For the latter particularly, the work must be sufficiently refined to ensure a 30-year life span.

Theoretical predictions and theoretical design assessments of the vibrational characteristics of plant are improving in accuracy but in the majority of cases experimental confirmation is still necessary. In fact the theoretical approaches are being limited in many instances by lack of experimental data particularly from operating plant.

There is a need for an improved co-ordination between the vibration and the fatigue and wear subjects. Data often does not exist to allow the translation of the more complex vibration movements to lifetime assessment because the fatigue or wear characteristics of the material are not known.

A need exists for an advice document on vibration for designers and operators, but such a document will need a balanced presentation to ensure that guidance does not suppress the thinking of the reader.

The 1978 Keswick Conference organised by the UKAEA on behalf of the BNES was a successful follow-up to the 1973 Keswick Conference and the delegates requested a third conference in about three years' time.

# ENERGY 2000

**The British Institute of Management organised a one-day Conference on 20th June, 1978, to present to top managers the views of the heads of a complete cross section of energy sector organisations and the views of industrialists concerned with the use of energy. The themes of the Conference were the need to adopt a more rational use of energy and to discuss what strategy should be followed in the next couple of decades to cope with the uncertainties and likely shortages of currently available energy sources in the future. This report is by John Sargent of the Authority's Economics and Programmes Branch.**

This was just one of the many conferences, debates and seminars which have used as their source material the Government Green Paper on Energy Policy. It was not surprising, therefore, that there was a large measure of common ground among the speakers to the Conference and the contributions from the floor. The value of the Conference lay in its discussion of the role and special problems faced by industry, which could not only make a vital contribution to the country's energy policy, through conservation, but also stood to improve its own financial position in this way.

With such an array of personalities the proceedings could have drifted along on a purely theoretical plane, but the conference had its feet firmly on the floor. The contributions from the energy industries themselves alongside plans for justifiable conservation emphasised that conservation alone would not solve the long-term energy problem since, as one questioner pointed out, it simply postpones the problem for a few years. Moreover without the exploitation of the new low cost sources of energy the country cannot hope to break out of the strong hold of a few monopoly suppliers of fossil fuels.

The main points of the Green Paper were summarised in an introductory speech by Sir Jack Rampton, Permanent Under Secretary of State at the Department of Energy. Rather than dwell on the mass of data provided in the paper he brought out a number of important points. The figures presented in the Green Paper were projections, not forecasts, and although no one could foretell the future exactly they were essential as a basis for policy decisions. Moreover the Green Paper put forward plans which should cope with a wide range of energy futures. Energy policy should be flexible, but that was not the same as an indecisive policy. This flexibility had been one of the hallmarks of the ACORD study on energy research and development under Dr. Walter Marshall.

The UK had a temporary glut of fuels of all types. As a result it was difficult to engineer the proper price signals, for instance, to bring about a sensible depletion policy for the North Sea and similarly to ensure that the electricity construction industry was maintained to cope with the large requirement for new plant in a few years' time to replace retired plant. Energy policy had an impact on many other policies which concerned Government, notably care of the environment; the UK would become less competitive if other countries neglected environmental issues in the production of fuels in order to reduce costs. He concluded that the energy problem was a world problem and that the UK could not insulate itself from world prices. The US held the key to world oil prices; he wished President Carter every success with his energy policy.

In the second section Dr. Austin Pearce, Chairman and Chief Executive of Esso and Sir Dennis Rooke, Chairman of the British Gas Corporation addressed the question: How should we make the best use of North Sea oil and gas? The Green Paper shows that our North Sea reserves of gas and certainly of oil may be running down at the end of the century. However, management of these reserves would be of vital importance to the capacity of UK fuel supplies in 2000. Dr. Pearce saw that the benefits from our oil could be expressed in different ways — as a bonus to the balance of payments, a secure source of fuel, or hydrocarbons for industry, as a means of taxation or a competitive consumer fuel. But in each case the best policy for oil suggested the need for flexibility. For instance the rate of depletion, the split between refinery products and export policy would depend upon world demand for the many different products obtainable from crude oil. The highest valued-added uses of the oil should be adopted and bearing in mind the low sulphur, high quality nature of UK oil there would be a case for exporting some to countries where these qualities commanded a high premium while continuing to import heavier crudes required in this country.

Sir Dennis Rooke emphasised the scale of natural gas reserves and that exploration was still going on. Extension of the reserve base would, however, permit a lengthier period of natural gas production rather than an increase in annual rates. Looking to the very long-term, British Gas were conducting research into synthetic natural gas (SNG) from coal. In the meantime they were following pricing policies which should maximise the premium use of fuel, ie. providing gas to those people who valued it the most, whilst evening out their offtake from the North Sea by some interruptible sales to non-premium users. Prices were not so low as to encourage the wasteful use of fuel, especially in view of the likely increase in future gas prices as more expensive reserves were exploited.

This point was taken up by Sir Francis Tombs, Chairman of the Electricity Council. Electricity was expected to substitute for other fuels in the future since it could use low value inputs like coal and uranium to produce the high valued electricity, thus sparing valuable oil and gas for premium uses. But the industry would be severely hampered in that task if it continued to be charged four times more for its primary fossil fuels than the gas industry. He was not asking for parity pricing of gas and electricity to consumers; indeed because of its many special applications and the high degree of control which it allowed, electricity was able to command a price substantially higher therm for therm than gas without losing its market share. In the last year, when economic output had been static, the index of industrial production had fallen and 1½ million people were unemployed, electricity production had risen by 2 per cent.

Sir Francis also echoed Sir Jack Rampton's remark that the UK possessed supplies of depleted uranium which, if burned in fast reactors, would

**At the Energy 2000 Conference (left to right) Sir Derek Ezra MBE, Chairman, National Coal Board, Dr. Austin Pearce CBE, Chairman & Chief Executive, Esso Petroleum Co. Ltd., Sir Francis Tombs, Chairman, The Electricity Council, Sir Jack Rampton, Permanent Under-Secretary of State, The Dept. of Energy, Sir Ronald McIntosh KCB, Chairman of the Conference, Sir John Hill, Chairman, UKAEA, BNFL, Dr. F.J.P. Clarke, Research Director (Energy) AERE Harwell, Sir Dennis Rooke, CBE, Chairman, British Gas Corporation.**

provide as much electricity as our entire known coal reserves.

Sir Derek Ezra, Chairman of the National Coal Board, emphasised the large amount of new mining capacity required simply to replace those pits which would be retired in the coming years. Of the 150 million tons of deep mined capacity in 2000 envisaged by NCB, 100 million tons would be new capacity. This called for a commitment to a large construction programme. He summed up the views of many speakers, that the country required a flexible energy policy but this entailed commitment to steady programmes to increase coal capacity, develop the nuclear industry and further conservation schemes.

Sir John Hill felt it was axiomatic that the least abundant fuels should be used with the greatest care. Uranium provided a source of fuel which, though the least convenient to burn, offered the largest and cheapest energy supplies. There was no limit to the amount of nuclear plant we could have and no reason why smaller nuclear plant should not be used for specific applications if we wished. However, nuclear power for electricity generation required up to ten years between the decision to build a station and the commissioning date, and therefore timing was very important. There was a strong case for moving quickly to series ordering of nuclear plant, especially to reduce our dependence on oil as was happening in France.

Sir John drew a distinction between the problems of nuclear power as seen by the public and by the industry. In the public eye, safety, management of nuclear waste and the proliferation of nuclear weapons had been the important issues. Safety and waste management were steadily being demonstrated. Proliferation was a more serious threat which should be the concern of the politicians rather then the nuclear industry. Nuclear weapons did not require a civil nuclear programme; the necessary knowledge on these matters had been widely published and thousands of people from the less developed countries had been trained in nuclear technology in order to benefit their economies. Many countries now had the necessary industrial capability for nuclear weapons manufacture and only by continued international agreements would the threat of proliferation be reduced.

The nuclear industry itself was confronting the more practical problems. Sir John identified an item of common concern when he noted that poor productivity affected progress on large construction sites including those in the nuclear industry.

Dr. Freddy Clarke, Energy Research Director at AERE, Harwell, reviewed the prospects for energy supply from the alternative sources to the year 2000. He concluded that if research and development went well we could hope for some 10 million tons of coal equivalent from all these sources by that time. Geothermal energy similar to that now utilised on a small scale near Paris might be available in certain areas of the UK. The question was whether this could be developed near a market able and willing to use it, eg. for space heating in flats. Solar power in the form of solar furnaces appeared to be quite uneconomic in the UK but solar panels were more hopeful for the future. But at present for an outlay of £500-£600 on panels, an annual return of only £30 could be expected.

Other renewable energy sources were associated with electricity production. Dr. Clarke was most impressed by wind energy despite the environmental drawbacks. It was already economic for some small scale applications. But substantial generation from wind was perhaps best suited to offshore siting. Wave power, although in some senses the most promising, was furthest from commercial exploitation and many formidable problems remained to be solved. Tidal power was limited to a potential supply only from the Severn estuary.

Work was in hand on all these projects by the Department of Energy to increase the state of knowledge and identify those projects where larger development costs were appropriate. Dr. Clarke said that the alternative sources required back-up capital plant and storage facilities to allow for their variability in supply.

Dr. John Cunningham, Parliamentary Under Secretary of State at the Department of Energy, emphasised the need for conservation despite the apparent glut of energy at present. There was a nominal 30 years' supply of oil left in the world, at current rates of production for example, but these rates were liable to rise. One speaker likened the current world oil position to that before the 1973 oil crisis, when demand came up against production potential. Moreover, as Dr. Cunningham pointed out, even if all of President Carter's energy policy is as successful as planned, this will merely slow the US growth in oil consumption (which currently accounts for 25 per cent of world-traded oil) from 4 per cent to 2 per cent. All the recent major international studies on the subject pointed to a shortfall of supply, below what would otherwise be demanded, well before the end of the century, perhaps in the mid-1980s. Faced with this prospect it

made more sense than ever to use fuel as effectively as possible. He listed specific companies where large savings had been achieved and estimated that £350 million worth of energy could be saved by industry every year given capital investment which would have a pay back period of less than two years in most cases.

Commenting from the floor, Dr. Chesters, Chairman of the Watt Committee, felt the Government's aims for conservation were too timid. Thirty per cent reduction should be the target. Dr. Cunningham reminded the conference that the Government had earmarked £400 million for conservation investment over the next few years.

Mr. Robert Malpas, Main Board Director of Imperial Chemical Industries saw the period to 2000 as a breathing space in which the country should adapt its energy habits to changing circumstances. Much of the post 2000 energy supply would rely on coal for SNG plants which he showed had a poor conversion efficiency at present. Indeed he felt that the Green Paper underestimated the amount of fuel required for the SNG programme it envisaged. This detracted from his hope that a zero energy growth was possible in the long run without terminating economic growth.

Mr. Malpas challenged industry to examine itself carefully, to think far ahead to the kind of energy supply it was likely to face around 2000 and develop in the way best suited to the energy environment. He came with no answers but many problems requiring solution. Most importantly he tried to discuss what the projections of the Green Paper meant to UK industry.

Mr. Morris, Deputy Chairman of the National Enterprise Board, posed other important questions for the audience as industrialists and consumers. He was particularly concerned that industry should prepare in advance for much higher energy prices. In practical terms this suggested extensive conservation measures, which must be taken voluntarily or the Government might have to force them through by financial measures.

Mr. Malpas had showed that industry had been conserving fuel — using it more efficiently — long before the oil crisis, as plant became more productive and industry switched to more efficient fuels. This suggested that the 'oil crisis' was not necessary to make it worthwhile for industry to invest in conservation but the crisis had a dampening effect on expectations, incomes and output. A further energy price rise could be expected to further reduce the prospect for expansion.

Mr. Lambert, Director General of the Automobile Association, emphasised that there was a clear preference for personal mobility. Indeed 67 per cent of working adults drove their cars to work and 13 per cent of non-working adults drove another member of the family to work. People in new towns relied to a very great extent on cars for all mobility. He foresaw a growth of two-car households judging by recent Government statistics. It was therefore no use to try and tax away the motor car — it was here to stay and there was no disgrace in the preference for private motoring.

Mr. Michael Shanks, Chairman of the National Consumer Council, and like many of the other speakers, a member of the Energy Commission set up by Mr. Tony Benn, put the consumer's point of view. He was not convinced that there would be a large increase in energy demand as economic output rose but he did stress the importance of availability of adequate heat and light for all with a high security of supply and an overall policy of "minimum regret". It was in the consumers' interest to insulate homes sufficiently and, taking a long-term view, they would benefit from a pricing structure which reflected long-run marginal cost which would also help them to choose between fuels. The public and the energy industries benefited from wide participation in energy decisions and in particular the Windscale Inquiry had widened the debate on one particular energy issue — the merits of reprocessing thermal oxide fuels — making it easier to carry through the decision.

## New appointments at IAEA

The Director General of the International Atomic Energy Agency (IAEA) announced in May the appointment of five new directors:

Vitaliy Frolov (USSR) as Director of the Division of Research & Laboratories. Born in 1927, Mr. Frolov gained his diploma as physicist at the Engineering and Physical Institute in Moscow, where he worked as senior engineer from 1956-1959. Between 1959 and 1962 Mr. Frolov worked as Director of the Research Department at the same Institute and in 1962 he became Vice-President for Science.

Hans Juergen Laue (Fed. Rep. of Germany) as Director of the Division of Nuclear Power and Reactors. After his studies at the Technical University in Munich, Mr. Laue (born in 1931) worked as scientific assistant at the Institute of Metallurgy and Metallography at the Technical University at Munich, later became Project Manager at the Institute for Applied Reactor Physics on the Fast Breeder Project in Karlsruhe (from 1964-1969) and since 1970 he has been Head of the Division on the planning, implementation and co-ordination of co-operation projects within bilateral contracts at the Gesellschaft für Kernforschung in Karlsruhe (FRG).

Georges B. Le Guelte (France) as Secretary of the Policy-making Organs. Born in 1935, Mr. Le Guelte gained his doctorate of international law at the University of Paris on "Safeguards on the Peaceful Uses of Nuclear Energy". Between 1962 and 1964 he was recruitment officer at the Commissariat à l'Energie Atomique in Paris, where he worked from 1964-1975 as Special Adviser for the Far East/Australia section. Since 1975 Mr. Le Guelte has been responsible for the development of co-operation for peaceful uses of nuclear energy, co-ordination, preparation and application of bilateral agreements and to control their effectiveness.

Harold E. Pryor (USA), as Director for the Division of Scientific and Technical Information. Born in 1926. In 1964-1965 he worked as Executive Assistant to the Director of Manned Space Flight Management Operation in Washington DC, and became Director of the NASA/DOD Contract Administration Services Office. Between 1971 and 1973 Mr. Pryor worked as Director of the Management Systems Office in Washington, and between 1973 and 1976 as Director of the Scientific and Technical Information Office. Since 1976 he has been Deputy Assistant Administrator for Industry Affairs and Technology Utilisation.

Krishna Sundaram (India), as Director of the Division of Life Sciences. Born in 1926, Mr. Sundaram received his M.D. (Doctor of Medicine) at the G.S. Medical College in Bombay. Between 1957 and 1967 he worked at the Bhabha Atomic Reseach Centre in Bombay where he became Head of the Medical Division. Since 1972, Mr. Sundaram has worked as Director of the Biomedical Group at the Bhabha Atomic Research Centre, where he deals with projects in the area of basic and applied research, a substantial part of the research being related to effects of radiation and other radiomimetic chemicals in the elucidation of basic mechanisms of radiation damage.

# UNDERGROUND WASTE DISPOSAL

**Dr. J.B. Lewis, Head of the Industrial Chemistry Group at AERE Harwell, reviews a recent report — Preliminary Assessment of the Radiological Protection Aspects of Disposal of High Level Waste in Geologic Formations — by M.D. Hill and P.D. Grimwood, National Radiological Protection Board Report (R69)**

This assessment was commissioned by the UKAEA as part of an EEC study into the feasibility of disposing of vitrified high-level wastes into deep geological strata. The authors examine the potential radiological consequences of a failure of the geological containment which allows ingress of ground water and the eventual contamination of potable water supplies. They review the type of events which could conceivably lead to the breach of the containment and use a mathematical model to predict the subsequent migration of radioactivity. The individual and collective doses which could be received by using the contaminated water and by eating fresh fish etc. are evaluated. For the purpose of these calculations it is assumed that the hypothetical repository contains all the high-level wastes produced in the UK up to the year 2000. The absence of some necessary data meant that a number of conservative assumptions had to be made and the numerical results cannot be used to draw any detailed conclusions. Areas where further studies are needed have been identified. Notwithstanding the uncertainties the results are encouraging and indicate, for example, that contamination of potable water might be comparable with that caused by existing natural radioactivity.

The assessment does not consider a particular design of repository nor, in general, any one type of rock. For convenience, however, when specific assumptions had to be made the properties of typical hard crystalline rocks were used and the repository was considered as consisting of a matrix of holes drilled to depths between 300 m and 1 km. This type of repository lies between the two extremes of emplacement in a large mixed cavity on the one hand and burial in a single very deep hole on the other.

The authors divided the barriers which prevent the return of radioactivity back to the environment into four types:

(i) geologic containment of the waste in the rock formation,

(ii) the waste form itself and its container,

(iii) retardation of activity by sorptive processes during transport through geologic media.

(iv) dispersion and dilution of activity in the biosphere.

The nature, and probability, of the events which might cause failure of the geological barrier are first considered and a mathematical model is then used to predict the behaviour of the radioactive species in the geological media and the biosphere.

Events which might lead to a breach of the geological containment may be divided into four groups:

(a) natural rapid events, eg. meteorite impact or volcanic activity,

(b) natural geologic processes, eg. erosion, subsidence or faulting,

(c) processes caused by the waste itself, eg. thermal or radiation effects on the rocks,

(d) human actions, direct or indirect, eg. war or sabotage on the one hand and mineral exploitation or reservoir construction on the other.

The probabilities of meteorite impact or volcanic eruptions are low, say one in $10^{13}$ or $10^{10}$ years respectively. Earthquakes have a somewhat higher probability although the effects produced are mainly on the surface and diminish with depth and are more likely to open up existing fissures and cracks rather than produce new ones. Erosion down to the waste itself can be avoided by selecting a site that would be unaffected even if there was a major climatic change such as a new ice age. However erosion might affect the material used to backfill and seal the repository.

The maximum temperature produced in the rock will depend on the concentration of waste in the emplaced blocks and the period for which they will have been stored prior to disposal. After fifty years of predisposal storage for example, the heat output of a HARVEST block will have fallen to 1kW which will give a maximum rock temperature of about 77°C. It is not possible, yet, to make a reliable prediction of the effect that this will have on the rock, but some fracturing is assumed. Again, it is not possible to predict accurately the effect of radiation on the rock but it is unlikely to be very important.

The authors show that neither nuclear warfare nor sabotage are likely to cause significant damage to the repository. Some release of radioactivity might occur if there was mineral exploitation or dam building in the vicinity of the site, but these possibilities can be largely eliminated by suitable location.

It is concluded that the most likely way in which ground water could enter the site would be damage to the rocks by seismic action or by thermal effects from the waste. There is also the possibility that processes such as erosion, geological uplift or subsidence due, for example, to a new ice-age could damage the sealing material sufficiently to allow water to enter.

The authors make the arbitrary assumption that ground water would enter the repository about 1000 years after disposal, at which time the waste canister has corroded away and the waste matrix has broken up and is subject to direct leaching. Factors controlling the latter process are examined and a value of $10^{-5}$ g $cm^{-2}$ $d^{-1}$ is considered to be appropriate.

The major processes which take place to the radionuclides when they are being transported by ground water are convection, dispersion, sorption and radioactive decay. Axial convection and dispersion are more important than the corresponding transverse processes so that a one dimensional flow path can be used. The 'sorption' process includes adsorption, ion exchange, precipitation,

colloid filtration and irreversible mineralisation. It is assumed that the nuclides are soluble, present in trace concentrations only, and in sorption equilibrium everywhere. A retardation coefficient is then derived. Calculating the migration of nuclides with a single stable daughter is relatively simple, but the modelling of actinides with long decay chains is more complicated and a numerical solution is needed. It is necessary to use a realistic dispersion coefficient and ground water velocities, and the appropriate sorption equilibrium, or retardation coefficient and the radioactive decay constant; the first three terms depend on the nature of the rock or soil. A value of 10 $m^2$/day was used for the dispersion coefficient and a high figure of 0·3 m/day for the water velocity. A path length of 10 km was used as a conservative estimate of the distance ground waters need to travel to reach surface water. There are considerable uncertainties in applying laboratory sorption data to geological conditions, but a range of representative values have been worked out. These are generally in the range $10^2$ to $10^4$ except for tritium, technetium and iodine which are not significantly adsorbed.

The results of the calculation are expressed as discharge rates in curies per year at the end of the 10 km rock column. The first nuclides to discharge are Tc-99 and I-129, which peak at 200 years after ingress of water. Subsequently after $10^4$ - $10^5$ years Np-237, Se-79, Cs-135 are discharged then Zr-90, Pd-107 and Sn-126. After a million years the highest discharge is from Ra-226.

Leach rate is important in determining the peak discharge rate of poorly sorbed nuclides, but much less so for strongly sorbed species. Its effect on actinides is slight. The dispersion coefficient is not critically important, but the ground water flow-rate and flow-path length are.

The authors discuss the mechanisms by which the radioactivity in ground water can get into potable water and foodstuffs. The most important nuclides are Np-237, Ra-226, Tc-99 and I-129 which could give doses from drinking water of 3, 2, 5 and 8 per cent of the appropriate ICRP dose limits. The peak annual collective doses in the UK would then be 10 man rem to the bone, by Np-237 and Ra-226, $10^4$ man rems to the GI tract by Tc-99, and $3 \times 10^4$ man rems to the thyroid by I-129. Somewhat similar individual doses could arise from the consumption of fresh water fish but the collective doses will be less because the total consumption is small. Lower individual doses would be obtained from drinking cow's milk and by eating sea food.

It should be noted that Ra-226 occurs naturally and the calculated peak concentration in fresh water, 0·2 pCi/litre, should be compared with the range of 0·01–1·0 pCi/litre found naturally (although exceptionally, 10 pCi/litre is found).

The main result of the preliminary study is the better identification of areas where more research is needed, especially the need for a better knowledge of relevant geological and hydrological processes and the sorptive properties of rock. Work is already in progress to obtain such information. However, despite the absence of some of the data, conservative estimates being used instead, it is clear that the unlikely failure of a geological depository would not lead to a catastrophic situation.

# 25 YEARS OF MEASURING FALL-OUT

In 1976 the concentration of caesium 137 from nuclear weapon tests measured in surface air over the United Kingdom fell to the lowest level, since sampling began in 1953. Although the concentration rose again in 1977, in response to a Chinese test in the previous year, the current levels are only 2 per cent of the maximum reached in 1963-4. The latest report in the Harwell series has been published recently; it includes a record of caesium 137 concentration spanning 25 years.

The Harwell network of stations sampling airborne dust and/or rainwater includes seven in the United Kingdom and 19 overseas, stretching from latitude 70°N to Antarctica in the south.

The fallout programme was designed principally to provide a regular inventory of radioactivity from nuclear test explosions so that the effect on the general population could be assessed by establishing correlations with the radioactivity in food (Agricultural Research Council) and in man (Medical Research Council). Early warnings have been obtained of potential dietary contamination and also it has been possible to monitor the external radiation dose to the population-at-large.

The radioactive debris that has been injected by each explosion into the troposphere and above into the stratosphere has served as a valuable meteorological tracer to discover important atmospheric mechanisms and transport processes that have helped to elucidate the immediate and protracted behaviour of the radioactive debris. Thus the concentrations of radioactivity in the troposphere rise to maximum values in the spring of each year; globally there is a minimum at the equator and maxima at latitude about 35° (N & S). The residence half-time in the lower stratosphere is one year — in the troposphere about one month. The interhemisphere exchange has been studied as has the zonal circulation of tropospheric clouds from individual explosions. The total global deposition has been estimated year by year and good agreement found with the amounts thought to be injected progressively into the atmosphere.

The techniques of sampling, analysis and interpretation have been applied to a separate programme of non-nuclear environmental pollution, in particular to the determination of (stable) trace elements in air, rain and the terrestrial environment generally. This has included the retrospective analysis for trace elements of filters stored after initial analysis for radioactive fallout.

The highest rates of injection by nuclear weapon tests occurred in the late 1950s and again more sharply in 1961-2. Since that time there has been a gradual decrease in the concentrations observed: the present comparatively low levels have been maintained during the 1970s by only occasional testing. However the cumulative global deposition after decades of nuclear weapon testing is estimated to be nearly 20 megacuries of caesium 137 and corresponding quantities of other fission and associated products including plutonium.

This means that the natural radioactivity of the environment has been overlain by small but detectable quantities of radioactive material produced by the fission process. Therefore the weapon fallout sets a "baseline" of radioactivity, against which the effects of nuclear reactor and similar operations may be measured.

Further information about the Harwell fallout programme may be obtained from Mr. Roger Cambray (extension 4883), Environmental and Medical Sciences Division, AERE Harwell.

*Reference* "Radioactive Fallout in Air and Rain: Results to the end of 1977" by R.S. Cambray, Miss E.M.R. Fisher, K. Playford and D.H. Peirson. AERE-R9016 (1978) (HMSO).

# IN PARLIAMENT

## Torness

A REPORT BY A PARLIAMENTARY CORRESPONDENT

An advanced gas-cooled reactor power station is to be built in Torness, East Lothian, without any further public inquiry.

This was announced by Mr. Bruce Millan, Secretary of State for Scotland, in the Commons on 24th May. In a written reply, he said: "I have received representations from several organisations and individuals to the effect that there should be a further public inquiry into the South of Scotland Electricity Board's application to construct a nuclear power station at Torness in the light of the decision to adopt the advanced gas-cooled reactor system in place of the steam generating heavy water reactor system for which the board have approval at present.

"After careful study of these representations I have concluded that they raise no relevant considerations materially different from those discussed at the public inquiry in 1974 which led to the Reporter's conclusion that Torness is a suitable site for a nuclear power station of any one of the four types, including the AGR system, considered at the inquiry.

"I have therefore today granted consent under section 2 of the Electric Lighting Act, 1909 for the construction of an advanced gas-cooled reactor power station at Torness."

The Leader of the Liberal Party and two of his colleagues have protested in the Commons about the decision to build a nuclear power station at Torness in Scotland without holding a second public inquiry.

The motion, tabled by Mr. Steel whose constituency is Roxburgh, Selkirk and Peebles, and Mr. Russell Johnston (Inverness) and Mr. Alan Beith (Berwick upon Tweed) on 25th May, says: "That this House regrets that the Secretary of State for Scotland has declined to hold a public inquiry into the proposed Advanced Gas-cooled Reactor project at Torness; believes that a second inquiry is justified into this specific choice of nuclear reactor and because of the lapse of time since the last inquiry in 1974; and calls for a greater recognition on the part of Her Majesty's Government of the need to carry public opinion on such developments."

The motion has little chance of ever being debated and is little more than an expression of opinion. However, further names are likely to be added to it.

QUESTION TIME

### Radionuclides

*22nd May, 1978*

Mr. Skeet asked the Secretary of State for the Environment as he proposes to set specific discharge limits for each significant radionuclide, if he will list those for which limits have already been set and those to which the provision will now be extended.

Mr. Shore: The existing authorisation under the Radioactive Substances Act 1960 for the discharge of liquid radioactive wastes from the Windscale reprocessing plant sets specific limits for the discharge of ruthenium 106 and strontium 90. There are also limits on total discharges of all beta and of all alpha emitters. This authorisation is currently being reviewed. Amongst the radionuclides for which the authorising Departments are considering setting limits are:

Plutonium 239
Americium 241
Iodine 129
Ruthenium 106
Strontium 90
Zirconium 95/Niobium 95
Caesium 134/137 and
Tritium

Limits will continue to be placed on the total discharges of all other beta emitters and all alpha emitters.

A further revision of the authorisation will be necessary in due course to take account of discharges from the proposed THORP plant.

### Radioactive Waste Management Advisory Committee

*22nd May 1978*

Mr. Skeet asked the Secretary of State for the Environment, since he proposes to establish a non-statutory radioactive nuclear waste management advisory committee (H.5/5/78, W.A.304 and Cmnd. Paper No. 6820) how he proposes to make the body accountable to Parliament.

Mr. Shore: As announced in the White Paper "Nuclear Power and the Environment" (Cmnd. 6820), the Radioactive Waste Management Advisory Committee will submit an annual report for the Secretaries of State for the Environment, Scotland and Wales, who will lay it before Parliament.

### Krypton

*22nd May, 1978*

Mr. Skeet asked the Secretary of State for the Environment whether there is a commercial plant or process available suitable for the removal of krypton gas from nuclear plant discharges.

Mr. Shore: Although at present there is no commercial plant or process for the removal of krypton gas available in the United Kingdom, small-scale processes for krypton 85 extraction have been tested here, and a pilot storage plant is in operation. Plant for the extraction and retention of the small amount of krypton arising from reactors is being used in the United States, and larger-scale processes are being developed and tested in pilot reprocessing plant in several other countries. The oxide reprocessing plant (THORP) is to be designed so as to enable a krypton removal plant to be incorporated.

### Radioactive substances

*22nd May, 1978*

Mr. Skeet asked the Secretary of State for the Environment whether he proposes to seek to amend the Radioactive Substances Act 1960 to align it with his response to the Parker Report proposals contained in H.8/5/78 W.A. 335-338.

Mr. Shore: My statement of 8th May explained that my Department had begun an examination of the provisions of the Radioactive Substances Act 1960 relating to inquiries into proposed discharge authorisations. This review will consider whether any legislative changes are needed.

### Waste disposal

*22nd May, 1978*

Mr. Skeet asked the Secretary of State for the Environment whether he has reached any further conclusions on paragraph 20 (Nuclear Waste Disposal Corporation) of Command Paper No. 6820.

Mr. Shore: The Government are still reviewing the current arrangements for controlling radioactive waste. We shall seek the advice of the Radioactive Waste Management Committee before reaching a decision on the establishment of a Nuclear Waste Disposal Corporation.

Mr. Skeet asked the Secretary of State for the Environment whether the Government propose to contribute to the cost of a pilot plant for the vitrification of highly radioactive nuclear waste to be constructed by British Nuclear Fuels Ltd., at Windscale; and whether the Central Electricity Generating Board and South of Scotland Electricity Board will be called upon as operators of nuclear power stations to provide a percentage of the capital and operating costs.

Mr. Eadie: I have been asked to reply. British Nuclear Fuels Ltd., the generating boards and the AEA are putting forward proposals for financing the vitrification programme up to the point at which a full-scale plant is constructed at Windscale. These will be considered.

Mr. Skeet asked the Secretary of State for the Environment whether he has decided to seek to amend the Radioactive Substances Act 1960 to carry out its responsibility on nuclear waste.

Mr. Shore: The Government are still reviewing the current arrangements for controlling radioactive waste. They will consider in due course whether changes in the Radioactive Substances Act 1960 are needed.

**Desalination**

*25th May, 1978*

Mr. Jim Spicer asked the Secretary of State for Industry if, bearing in mind the size of the overseas market for desalination plants, he will set up a desalination working party to consider research and development as related to possible overseas projects.

Mr. Cryer: I am very conscious of the opportunities in overseas markets for United Kingdom manufacturers of desalination equipment. My Department has, of course, supported a number of R and D programmes in the desalination area over a considerable period of time. During the past five years the Department's Chemicals and Minerals Requirements Board (CMRB) has approved expenditure on four United Kingdom Atomic Energy Authority programmes, namely, the background and exploratory technical assistance — BETA — programme and three others directed at multiple effect flash distillation, additives — for prevention of scale formation — and reverse osmosis — on which Board funding has only just ceased. The CMRB withdrew its support for BETA in 1974, largely due to the lack of industrial support for the programme. Indeed, the view has been taken that continued departmental funding in this area is only justified if industry itself is prepared to make a substantial contribution. There is, nevertheless, a need to keep a close and continuing eye on the situation, and my Department is currently reviewing the need for Government support for research and development in this sector. Any further action will depend upon the outcome of the review.

**IEA Review**

*6th June, 1978*

Mr. Spearing asked the Secretary of State for Energy if he will make a statement about the International Energy Agency's reviews of the United Kingdom's energy programme, including energy research, development and demonstrations,

Mr. Benn: The International Energy Agency's reports on the United Kingdom are part of the Agency's annual review process designed to provide a thorough and systematic assessment of all IEA member country national energy programmes and policies on the basis of common criteria and to identify areas in which programmes might be improved. The reports are based on information provided by the United Kingdom and discussed in committee under rapporteurs who are responsible for producing the final report. The recommendations made in the reports are those of the rapporteurs alone and while we have agreed to study them with care as a helpful contribution to our thinking, they do not involve any commitment for Her Majesty's Government either as a whole or in details.

The Standing Group on Long-Term Co-operation report assesses the United Kingdom's contribution to the achievement of the overall IEA objective to hold oil imports to not more than 26 million barrels per day in 1985. Although we are not entirely happy about the balance of the report on the United Kingdom we accept that it is difficult to cover the complex issues fully within such short documents. The report generally represents the position at the end of 1976, although some account has been taken of measures in force by mid-1977. In particular, certain new measures have been introduced which overtake some of the comments in Section III (Policy Recommendations). These include the energy conservation measures announced in the House on 12th December, 1977, and the further conservation measures announced in the April 1978 Budget speech. In addition, the sixth licensing round has now been announced, opening about 40 new blocks to application.

The review of national energy research and development programmes is the first to be undertaken under the auspices of the IEA. The report on the United Kingdom is based on statistics which are now nearly 12 months old and a number of new research and development programmes have been initiated since it was prepared.

**Radiation Hazards**

*8th June, 1978*

Mr. Hooley asked the Secretary of State for Social Services

(1) what progress is being made by the National Radiological Protection Board with the survey of former radiation workers, arising from the recommendations of the Flowers report;

(2) if he is satisfied with the progress of the National Radiological Protection Board with the pilot study of workers of British Nuclear Fuels Limited involved in radiation hazards; and if he will make a statement;

(3) if steps are being taken to maintain a permanent central register of all workers involved with radioactive substances;

(4) if steps are being taken to follow up the health records of ex-radiation workers to ensure that epidemiological information vital to the long-term assessment of radiation risks is not lost nor allowed to become irrecoverable.

Mr. Moyle: The White Paper "Nuclear Power and the Environment", Cmnd. 6820, responding to the Sixth Report of the Royal Commission on Environmental Pollution — the Flowers Report — announced — Annex A, paragraph 9 — that the National Radiological Protection Board had set up a central register of radiation workers. I understand that negotiations have been completed by the Board for the inclusion on a voluntary basis of the dose records of all workers engaged in radiation work for the main nuclear employers and that steady progress is being made in adding these to the register.

The Board has also discussed with the main nuclear employers the feasibility of a study of ex-radiation workers but agreed that a final decision on the inclusion of their records should depend on the results of the pilot study currently being carried out by British Nuclear Fuels Limited. I am informed that the results of this study will be available within the next few months, which is within the time-scale originally anticipated.

Employers of radiation workers are required to retain health registers and radiation dose records in respect of radiation workers for a period of 30 years after the last entry.

Mr. Hooley asked the Secretary of State for Social Services what evaluation is made by his Department of the findings of studies carried out in the United States, or elsewhere, concerning the health of workers involved with radiation hazards.

Mr. Moyle: No evaluation has been made by my Department. The subject is being carefully reviewed by the National Radiological Protection Board and, the Protection against Ionizing Radiations Committee of the Medical Research Council has been asked to assess the relevant publications and prepare a report for my right hon. Friend on the scientific aspects of the studies.

*8th June, 1978*

Mr. Hooley asked the Secretary of State for the Environment whether the Royal Commission on Energy and the Environment will have access to the records and research of the National Radiological Protection Board to determine the long-term hazards to workers involved with radioactive substances.

Mr. Shore: If the Commission on Energy and the Environment should ask for access to this information, I am sure this would be arranged.

**Radionuclides Limits**

*12th June, 1978*

Mrs. Kellett-Bowman asked the Secretary of State for the Environment, in view of the fact that caesium isotopes currently contribute more radiation to the public than any other from Windscale, if he will seek to put an immediate specific limit on the amounts of caesium 134 and 137 that the plant may put out.

Mr. Shore: I and my right hon. Friend the Minister for Agriculture, Fisheries and Food are considering what radionuclides should be specified in new limits on emissions from the Windscale plant and we shall in due course be issuing a new authorisation under the Radioactive Substances Act 1960. The authorisation will specify limits for all the most significant radionuclides, including caesium.

Meanwhile, British Nuclear Fuels Limited is designing a plant to reduce the discharges of caesium and other radionuclides from the Windscale works, and has been requested to submit the design to authorising Departments for examination.

Mrs. Kellett-Bowman asked the Secretary of State for the Environment if, in order to ensure compliance with any recommendations which the new inspectorate proposed under recommendation 6 of the Parker Report may make, he will seek to give the inspectorate the power to restrict plant working or enforce temporary closure if permitted limits are exceeded, until improvements have been made to bring the emissions within the limits.

Mr. Shore: As I told the House on 18th May, the Government have not yet reached a decision on the unified pollution inspectorate for England and Wales recommended in the Fifth Report of the Royal Commission on Environmental Pollution.

Meanwhile, the Radiochemical Inspectorate of my Department will, in collaboration with the Ministry of Agriculture, Fisheries and Food, be responsible to Ministers for carrying out Mr. Justice Parker's recommendations that an overall view be taken of the level of discharges to be authorised to all sectors of the environment, and each authorisation should take account of the advice of the National Radiological Protection Board on the total radiation dose from all sources of discharge.

The Government have already indicated, in their response to the Royal Commission's Sixth Report, that they are considering whether further statutory powers are needed to enable the Secretaries of State for the Environment, Scotland and Wales to carry out their new responsibilities for radioactive waste management.

**Decommissioning Nuclear Power Stations**

*12th June, 1978*

Mr. Hooley asked the Secretary of State for Energy what studies or research are in train on the problem of decontamination during decommissioning of a nuclear power station.

Mr. Benn: Decontamination of wide varieties of nuclear plant, buildings and equipment has been carried out as part of routine operations for many years. Decommissioning studies by the United Kingdom Atomic Energy Authority and the generating boards are reviewing the application of existing techniques. The development of new techniques will be undertaken if required. In addition, methods of "fixing" contamination are being considered so as to reduce the need for decontamination which itself produces active effluents requiring disposal. Close liaison is, of course, maintained between the Authority and the boards.

Mr. Hooley asked the Secretary of State for Energy what features of nuclear power plant design have been built in to facilitate the eventual decommissioning of the reactor.

Mr. Benn: Decommissioning is facilitated by features of reactor design which have the immediate purpose of facilitating the repair and maintenance of nuclear power plants. Important among these features are the easy removal of the fuel and the confinement of radioactivity to the central region of the plant with a very substantial concrete shield. Specifications for new nuclear power plants require the designers, having regard to the consideration that safety and performance should not be impaired, not only to improve access for repair and maintenance, but also to pay further attention to the ultimate need for decommissioning.

Mr. Hooley asked the Secretary of State for Energy what estimates have been made of the quantities of radioactive waste which will arise from the decommissioning of a Magnox or advanced gas-cooled power station.

Mr. Benn: Amounts will depend on the method of decommissioning adopted, and in particular the period that is allowed to elapse between shutdown and decommissioning. Calculations that have been made indicate that there is advantage in allowing radioactivity to decay before decommissioning is undertaken.

Mr. Hooley asked the Secretary of State for Energy whether any trial dismantling techniques have been evolved for the eventual decommissioning of nuclear power stations.

Mr. Benn: Basic techniques which are required for decommissioning are already available. Practical experience has been gained, for example, in maintenance and repair operations and also in the carrying out of large scale decontamination and dismantling the chemical reprocessing plant which had been in service at Dounreay for 17 years. Work is also in hand on the decommissioning of the experimental fast reactor at Dounreay, and a scheme is being prepared for the Windscale AGR.

**Uranium for Brazil**

*12th June, 1978*

Mr. Hooley asked the Secretary of State for Foreign and Commonwealth Affairs what discussions have taken place with the United States Government about the supply of enriched uranium to Brazil.

Mr. Judd: The safeguards and non-proliferation arrangements to be attached to the Urenco contract to supply low enriched uranium to Brazil have been discussed on a number of occasions with the United States Government in the course of exchanging views on international non-proliferation matters generally.

Mr. Hooley asked the Secretary of State for Foreign and Commonwealth Affairs what safeguards will be

required from the Brazilian Government in return for the supply of enriched uranium from Capenhurst; and how these safeguards will be monitored.

Mr. Judd: Exports of low enriched uranium from the United Kingdom supplied under the Urenco contract, and any nuclear material derived therefrom, will be subject to International Atomic Energy Agency safeguards, including inspection and monitoring by the Agency, to ensure that they are used only for peaceful purposes. In addition, the Brazilian Government agreed in January that any plutonium derived from the reprocessing of low enriched uranium supplied by Urenco shall be stored under an IAEA plutonium storage regime if such a regime is available, or under an ad hoc regime based on the principles of Article XII(A)5 of the IAEA statute to be agreed by the three Centrifuge Governments and Brazil if by that time an international storage regime has not been set up under the IAEA statute. A copy of the text of this agreement was deposited in the Library of the House on 22nd March.

### Fast Reactor Inquiry

*15th June, 1978*

Mr. Charles Irving asked the Secretary of State for the Environment if he will give details of the procedures to be adopted at the proposed inquiry into the commercial fast reactor, stating how members of the public will be able to take part in the inquiry, how evidence will be accepted and whether he envisages some financial help will be available for the main objectors.

Mr. Shore: Any proposals to build a commercial scale demonstration fast breeder reactor will be subject to a public inquiry. The inquiry would not be limited to local planning issues but would allow wider relevant issues to be examined. The Government are considering what might be the most appropriate arrangements for such an inquiry.

### Radiological protection

The Society for Radiological Protection will hold a meeting on personal protection against air and surface contamination, at the Middlesex Hospital, London, on Tuesday, 23rd January, 1979.

Enquiries should be addressed to the Programme Committee Secretary — Professor J.H. Martin, Department of Medical Biophysics, Blackness Laboratory, University of Dundee, Dundee. DD1 4HN.

# THE RISKS OF ENERGY PRODUCTION

**Dr. P.M.S. Jones of the Authority's Economics and Programmes Branch comments on a recent report by Dr. Herbert Inhaber of the Canadian Atomic Energy Control Board (Report AECB 1119, March 1978)**

This report, a short version of which appeared in New Scientist (18th May, 1978) sets out to compare the risks to health and life of employees and the general public from a range of energy technologies. It breaks new ground in its attempt to apply the same criteria to conventional (including nuclear) and non-conventional technologies. The latter cover solar thermal electricity, solar voltaic, solar space heating, wind power, ocean thermal gradients, and methanol from vegetation.

The risks are calculated on a full systems basis, taking into account material acquisition and construction, emissions caused by material production, operation and maintenance, energy back-up systems, energy storage and transportation. The 'risks' associated with construction are spread over the system life. The concept is good and draws attention to the fact that the risks associated with non-conventional sources are hidden because they are associated with the extraction, production and fabrication of material in quantities that significantly exceed those needed for the centralised conventional systems.

The data and conclusions are not, however, directly transferable to the United Kingdom. The statistics for risks in mining and manufacturing are based on North American figures and the natural gas and oil data relate to land-based rather than North Sea operations. For comparison/occupational risks between fossil and nuclear sources the data produced by the Health and Safety Executive in 'The Hazards of Conventional Sources of Energy' (HMSO, 1978) are therefore preferable. They omit risks in construction and those associated with materials of construction, but these are comparatively small for conventional and nuclear electricity as the Canadian report points out. The HSE figures limit themselves to accidents and exclude occupational illness because of the 'uncertainties'.

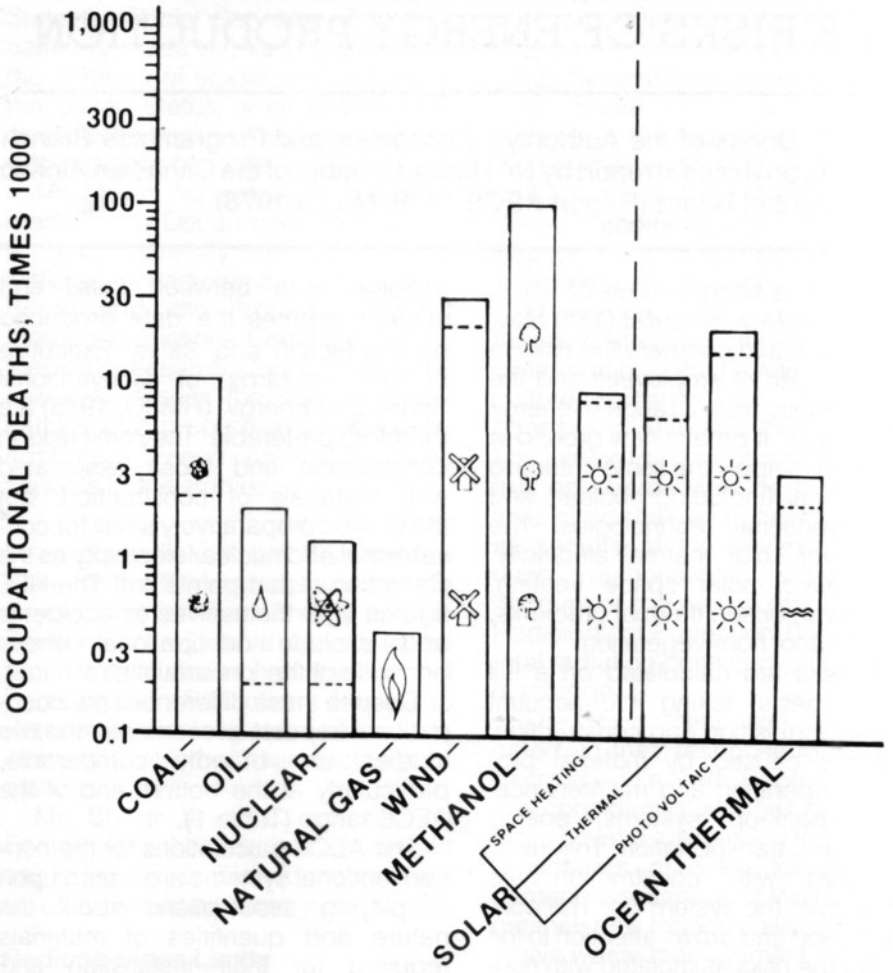
Despite these differences the occupational impacts presented in the two studies are broadly comparable, particularly at the bottom end of the AECB range (Table 1).

The AECB calculations for the non-conventional systems are based upon simplifying assumptions about the nature and quantities of materials required for their installation and properly include allowance for back-up systems and storage, both of which tend to be neglected by their protagonists. The general *ranking* of the systems and their relationship to the conventional systems is probably reasonable though the numbers themselves could not be accepted until the calculations have been confirmed for the UK (See figs 1 and 2 reproduced from AECB 1119).

The calculations of public risk are not transferable to the UK environment. They are based on air pollution

**Table 1 — Comparison of occupational deaths per GWy of electrical energy sent out.**

| | *HSE (UK conditions)* | | *AECB (N. American conditions)* | |
|---|---|---|---|---|
| **Primary Source** | **Operation** | **Deaths** | **Deaths** | **Man days lost** |
| Coal | Extraction | 1.4 | | |
| | Transport | 0.2 | | |
| | Generation | 0.2 | | |
| | Total | 1.8 | 2.2-10 | 70,000 |
| Oil and Gas | Extraction | 0.3 | | |
| | Transport | Insignificant | | |
| | Generation | None reported | | |
| | | | oil — 0.2-2 | oil 2,000-19,000 |
| | Total | | gas 0.4 | gas 6,000 |
| Nuclear | (USA) Extraction | 0.1 | | |
| | Transport | Insignificant | | |
| | Generation & reprocessing | 0.15 | | |
| | Total | 0.25 | 0.2-1.3 | 1800-9,000 |



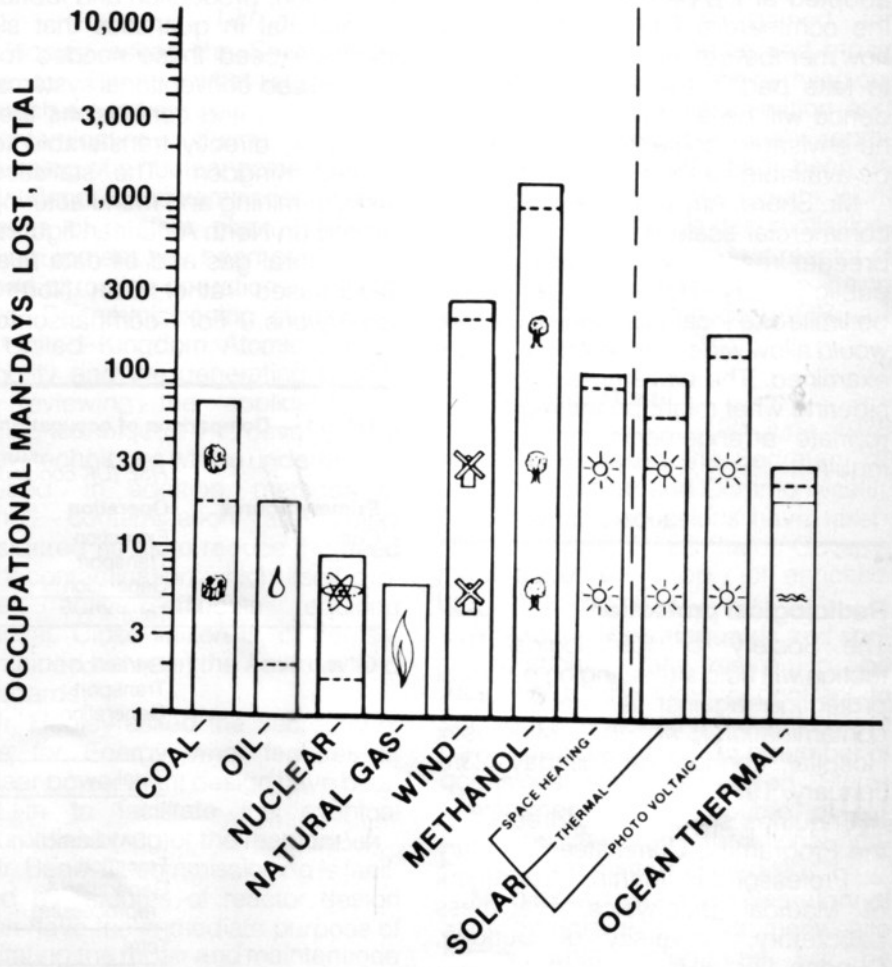

effects arising from the combustion of fossil fuels for direct electricity production or in producing the materials to manufacture non-conventional systems. To these figures are added estimated effects of potential accidents. The principal contributions are estimated to arise from emissions in material production and the production of back-up energy using coal as fuel. Nuclear risks to the public are based on the Rasmussen report and other publicised works.

Whilst there are correllations between fossil fuel combustion and morbidity and mortality the issue is a complex one with the effect of pollutants on population dependent on emission levels, temperature and height of emission, weather, topography and population density, as well as the chemical nature of the pollutant. Discharge of sulphur dioxide and particulates from a 200ft. power station chimney is very much less damaging than emission of an equivalent quantity from a domestic coal fire. (See for example P.M.S. Jones *et al* 'An Economic and Technical Appraisal of Air Pollution in the UK', HMSO, 1972).

For these reasons figures for public risk in the UK could differ radically from those estimated by AECB for N. America.

**Above**

*Figure 1. Occupational Deaths, times 1000, per Megawatt-year, as a Function of Energy System. The values refer to one megawatt, net output, over the life of the system. For example, coal would have a maximum of 10/10,000 = 0·010 deaths per megawatt output per year over the 30-year system life. The top of the bars indicates the upper end of the range of values; the dotted lines within the bars, the lower. Where no dotted line is shown, the upper and lower ends of the range are similar. Those bars to the right of the vertical dotted lines indicate values for technologies less applicable to Canada. Most of the non-conventional technologies have higher values than the conventional systems.*




**Right**

*Figure 2. Occupational Man-Days Lost per Megawatt-year Net Output over Lifetime of System. As in the previous graph, these values refer to the risk incurred in particular activities related to gathering and handling fuels, acquiring material and equipment, and operation and maintenance of power plants. Risk incurred by the public is not included. For calculational purposes, each death is counted as 6000 man-days lost. Methanol has by far the greatest values, a factor of about 3 greater than windpower.*

# CEGB CORPORATE PLAN 1978

**This important document was published in April of this year: The review which follows is by John Sargent of the Authority's Economics and Programmes Branch.**

The Central Electricity Generating Board's (CEGB) latest Corporate Plan is the third such plan to be prepared and is considerably larger than in previous years. It includes not only their own thinking on electricity supply and demand but a comparison with the reference assumptions and policies of the Government's Green Paper on Energy Policy (Cmnd 7101), and is perhaps the best indication of the future prospects and role for electricity in the UK.

The CEGB are in general agreement with the Green Paper's view of the energy scene. The only important point of difference is that the CEGB plan lays greater emphasis on nuclear power for electricity generation. The Plan says "In all scenarios studied by the Board, nuclear power proves to be the most economic choice for electricity generation at high load factor, and its cost in real terms is likely to increase fairly slowly over time. Fossil fuel prices, on the other hand, are expected to increase more rapidly, so that the economic case for nuclear power improves further in the longer term".

### The Medium Term

For the medium term the Board produce a single most likely view of the future qualified by allowances for statistical uncertainty. This forecast looks seven years ahead and, once formally adopted, is the basis of investment decisions. It gives an average annual increase in maximum electricity demand of 2·7 per cent amounting to 52 GW which is lower than would be derived from a simple extrapolation of the past. The variation is due to the influence of gas sales over the period and the simple good-housekeeping conservation measures that households and industry can take to reduce fuel consumption over the next few years. This forecast is in fact more conservative than the Green Paper which assumes higher economic growth and electricity penetration leading to a maximum demand of nearly 60 GW for CEGB in 1985. The Corporate Plan does show that nuclear plant ordered now, would be fully used to the economic advantage of the electricity system. In particular, the Plan states that on currently anticipated costs, it could be economic to install new nuclear generating plant before it is required to meet increased demand for electricity since this would displace older fossil fuelled plant with high running costs.

The Board's medium term plans show they expect all four of the first generation AGR's to be finally completed by 1981 but because they are developed sequentially, power will be coming from each station some time before then. Investigation of the design of the Pressurised Water Reactor alongside the second generation AGR at Heysham will enable the Board to compare the two reactor types before further ordering. They intend to order at least one new power station each year, since there is a clear advantage in a programme of steady ordering. The Board record their support at the Windscale Inquiry for the construction of the THORP plant to reprocess thermal oxide fuel. They list reasons for their backing for the plant, notably, apart from the recovery of plutonium and uranium, that reprocessing is an established method of dealing safely and efficiently with spent fuel in the short term. It is also the only established method of dealing with stainless steel clad oxide fuel in the medium term, and, when coupled with glassification, is likely to prove the most feasible way of disposing of highly active waste in the longer term.

### The Longer Term

In the long term to 2000, analysis of one single view would involve such a large statistical variation (to allow for the degree of uncertainty) that the Board would not regard it as meaningful. Therefore the Plan develops two sets of assumptions — one favourable and one unfavourable to electricity growth. Thus the lower electricity growth case averages 1·5 per cent per annum assuming reduced annual economic growth of 2 per cent, high gas reserves of $100 \times 10^{12}$ cubic feet and unfavourable increases in nuclear capital costs. The Board note that it is hard to imagine how this lower rate of electricity growth could come about without substantial social changes or technological development. The higher electricity growth case gives an overall growth of 3·6 per cent per annum in electricity use, still relatively modest by post war standards, particularly since it is based upon 3·2 per cent economic growth. By comparison, CEGB sales have grown since the early 1950s by an average of over 5 per cent per annum when average economic growth was by less than 3 per cent per annum. Gas reserves are only assumed to be $60 \times 10^{12}$ cubic feet but this affects the number of years gas is supplied rather than the total supplied in any year.

A number of assumptions are common to the two cases, notably that North Sea oil reserves amount to the upper limit of the official range of estimates. Similarly coal production is estimated at a low level although with the prospect of new uses for coal towards the turn of the century and the changeover from coal to nuclear power for the bulk of electricity production, it will be very difficult to predict so far in advance the precise coal capacity in a particular year. As the Green Paper itself makes clear, coal will be required in large quantities after 2000 for Synthetic Natural Gas production.

The Board's projections of electricity demand are dependent upon many factors, ranging from economic growth and fuel prices, to social trends and developments in technology. They suggest the production of electricity will continue to grow significantly given a wide range of futures.

However, they point out the problems the CEGB face towards the end of the medium term and beyond. Although the growth rates are expressed as a simple average to 2000, they believe there will be a period of low electricity growth during the 1980s, caused by self-sufficiency in fossil fuels, particularly gas, followed by higher growth in the early 1990s as the competition from gas declines. The problem of providing an adequate electricity supply would be exacerbated by the large number of power stations due for retirement at that time. The Board see the 1980s as a period to develop the coal and electricity supply industries to meet the challenge of the 1990s. They envisage about 8 GW of new nuclear capacity commissioned by 1990 after which the rate of commissioning could be expanded so that the total nuclear capacity in 2000, given sufficient manufacturing capacity, could rise well above the 40 GW envisaged in the Green Paper. The Board are concerned that the power plant industry should be rationalised and made more effective to meet home and export demands at that time.

The Board favour the continued development of the fast reactor to safeguard uranium supplies and allow a full contribution from the nuclear industry. They comment: "On a worldwide basis, nuclear power utilising fast

reactors offers an energy source at least similar in order of magnitude to and possibly much greater than, the world's total recoverable fossil fuels".

In addition to the strategic issues covered in this review, the Corporate Plan deals at some length with the more immediate, and no less essential, details such as manpower, plant operation and financial policy. One issue highlighted in the plan, is the need to increase generating capacity in the South West Region with minimum environmental damage. Despite the need to conserve oil supplies they feel the best solution is the construction of an oil-fired station at Inswork Point near Plymouth.

## Quarterly Statement on Nuclear Incidents

The first quarterly statement of incidents at nuclear installations in Britain in 1978 reported to the Secretaries of State for Energy and for Scotland was published in late May by the Health and Safety Executive. These are incidents reportable under the Nuclear Installations (Dangerous Occurrences) Regulations 1965 and under conditions attached to nuclear site licences but certain incidents of lesser significance are also included. The statement, which covers the period from 1st January to 31st March, 1978 includes similar incidents reported to the Secretary of State for Energy by the UKAEA.

Small spillages or leakages of radioactivity continue to constitute the main type of incident reported. These were all quickly dealt with but in three cases the circumstances are being further investigated. There were four cases of small fires, one of which was in a radiation area. None of the fires involved injury to persons and in only one case was normal plant operation briefly interrupted.

Two reports refer to cases of radiation exposure of workers exceeding the permissible levels recommended by the International Commission on Radiological Protection. Neither of them involved a significant radiological hazard. An investigation into the circumstances of one of these incidents is proceeding.

Details of the incidents are given in chronological order together with the name of the nuclear establishment to which they refer. Results of investigations into incidents listed in previous statements are also reported.

Copies of the Statement can be obtained from the Health and Safety Executive, Baynards House, 1 Chepstow Place, London W2 4TF

## New non-proliferation strategy proposed

The United States should foster a new international nuclear fuel supply policy if it wants to slow the spread of nuclear weapon capabilities while meeting the needs of nations for nuclear energy. This is one of 17 basic recommendations for action by the US Government made in a two-volume policy paper Nuclear Power and Nuclear Weapons Proliferation issued on 19th June by the Atlantic Council of the United States, the bi-partisan educational centre for policy formulation based in Washington, DC.

Citing uranium enrichment and plutonium reprocessing as the key nuclear fuel supply technologies which can also produce weapon-grade explosive material, the Nuclear Fuels Policy Working Group of the Atlantic Council proposed that control of these technologies and their facilities be de-coupled from national nuclear power programmes, and become part of a new multilateral system of nuclear fuel supply and attendant safeguards. Under this proposal, uranium enrichment and nuclear fuel reprocessing would be carried out under international auspices, whereby existing and future plants capable of producing nuclear weapon-grade fissile material would be segregated from national control (though not necessarily from national ownership) and operated in a multinational system which would safeguard the sensitive facilities as well as the fuel produced by them.

"The starting point in any process of internationalising the fuel cycle could be the provision of spent fuel storage facilities", according to the report. Nuclear waste management could also be provided on a multinational basis, the report advocates, "as an incentive to those countries willing to place national reprocessing facilities under international control in a multinational nuclear fuel supply system".

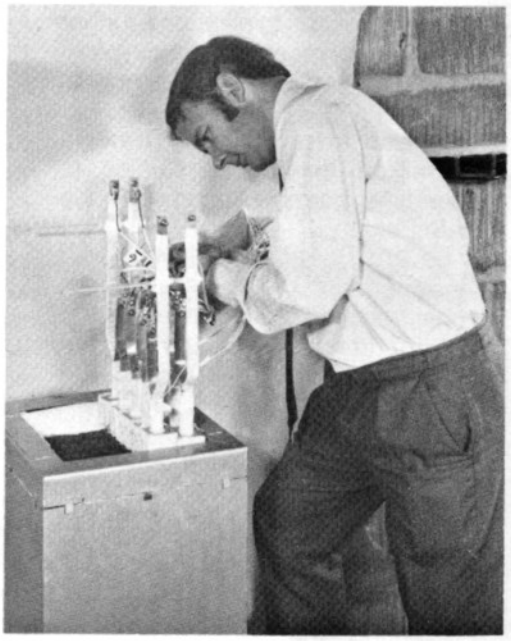
"The relevance of national nuclear power programmes to proliferation risk arises", according to the report, "mainly from the possibility that the potential access these programmes may provide to weapon-usable fissile material may influence either the decision to seek nuclear weapons or the ability to implement such a decision". While it is possible that a civilian nuclear power programme could serve as a "cover", masking a nation's surreptitious attempt to acquire nuclear weapon capability, the report stresses that none of the six nations which have demonstrated nuclear weapon capability to date have achieved it by the nuclear power route. Internationalising the control of sensitive aspects of the fuel cycle "would further impede nations from having second thoughts", according to John E. Gray, Chairman of the Atlantic Council's Working Group which prepared the policy paper. "The more national adherents these multinational measures gain", Gray observed, "the greater will be their legitimacy and supply credibility — and the more difficult it will be for individual countries to remain outside this solution by retaining sensitive national facilities".

Asked how the Council's recommendations differed from the proposals of the Ford and Carter Administrations, Gray observed that "where President Ford proposed an evaluation of reprocessing with the purpose of determining whether reprocessing and plutonium utilisation could proceed in a manner compatible with non-proliferation objectives, President Carter initiated an international fuel cycle evaluation with the purpose of finding acceptable alternatives to the plutonium-based fuel cycles or of providing adequate safeguards for the plutonium cycle". In short, "where Ford contemplated solutions which involved learning to live with plutonium, Carter seemed inclined to finding ways to live without it". However, with the recent announcements by France, Germany and Japan that they and others would proceed with reprocessing, toward the development of fast reactors, Gray concluded: "it now looks like plutonium is here to stay".

For purposes of shaping a non-proliferation strategy for the 1980s, according to the policy paper, "it is useful to recognise that non-proliferation is not subject to US control and is beyond any individual nation's control. An effective non-proliferation strategy calls for unusual co-operation within the interdependent world community. If the US can forego the temptation of unilateral action, US influence and concern about proliferation can still have a major effect".

It was in this spirit that the Atlantic Council reconvened its Nuclear Fuels Policy Working Group some 18 months ago, and charged the group with producing a long-term non-proliferation strategy that would be compatible with long-term energy supply plans of the developed and developing countries alike. A Council spokesman, releasing the report, stated that "the opportunity now exists for the US, working co-operatively with the European Community, Japan and others, to create a multinational

# SODIUM SULPHUR BATTERY



*Photograph courtesy of British Rail*

A significant step forward has been made in the development of Sodium-Sulphur (Na/S) batteries for transport applications with the recent press announcement by British Rail that a 10kWh battery has been successfully activated. Initial tests have shown that the battery is safe, reliable and can be easily and quickly assembled. It is built from 176 cells and has a capacity of 288 ampere-hours at 45 volts.

The photograph (left) shows BR's Sodium-Sulphur Battery Project Manager, J.L. Sudworth and an assistant monitoring individual cell voltages within the 10kWh battery.

The Na/S battery, which operates at 350°C, has a practical energy density of five times that of conventional lead-acid batteries. The Authority's Harwell Research Establishment has been engaged on work involving the Na/S battery since 1972. During the last three or four years the battery has been developed jointly by British Rail, Chloride Silent Power Ltd. (Runcorn) and Harwell in a collaborative national programme.

The main Harwell contributions to the overall programme have been in the areas of electrode and cell design, hermetic seals, cell interconnection problems, costing and safety. In December 1977, this effort culminated in the building and operation of a 20 cell battery at Harwell in which each cell had a nominal capacity of 70 ampere-hours. (The photograph (right) shows R.J. Bones of Materials Development Division assembling the Na/S cells into the Harwell battery.)

During 1978, work is continuing at Harwell on this battery system, but now under direct contract to Chloride Silent Power Ltd., in which specific isolated topics are being studied in depth, for example — mechanical, electrical and microstructural studies of the β-alumina ceramic separator, electrode development including novel coating techniques and post-operative cell examination employing Harwell's specialised diagnostic techniques.

British Rail's long-term intentions are to use Na/S batteries for light-weight rail cars on branch lines.

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nuclear fuel cycle supply system in which other nations participate as founders and users — and as producers when appropriate. As envisioned in this policy paper, such a system would be as — and probably more — proliferation-resistant than the dispersed, once-through fuel cycle with indefinite spent fuel storage"

The specific institutional options which merit prompt consideration are, the report suggests:

An *"international co-operative"* of existing and planned nuclear fuel supply facilities, with regional affiliates

*Multinational fuel cycle centres*
*Multinational enclaves*
*International fuel cycle authority.*

Specific purposes of the proposed multi-lateral system include:

Minimizing the number of "sensitive" fuel cycle supply facilities throughout the world;

Minimizing the spread of nationally controlled "sensitive" fuel cycle supply facilities throughout the world;

Limiting independent national and subnational control of and access to fissile material intended for use in nuclear power generation;

Assuring regional and/or multinational ownership and control of "sensitive" nuclear fuel cycle facilities;

Providing for control of and access to fissile material for use in nuclear power generation by those nations and international institutions with a responsible and harmonious interest in supply, use and control of the fissile material.

The proposed institutional innovations, the report argues, can reinforce the political consensus opposing proliferation in four ways: (1) by improving the security and economy of fuel supply and the access to the benefits of technological improvements as they are developed; (2) by minimising the degree of discrimination among different classes of countries; (3) by reducing the motivation for weapons acquisition arising from regional rivalries, the desire to pre-empt suspicious neighbours, or supposed prestige; and (4) by reducing the access to means for proliferation through appropriate multinational control.

The 17 specific recommendations made in support of this strategy are found in Chapter VIII of *Nuclear Power and Nuclear Weapons Proliferation*, available from the Atlantic Council, 1616 H Street, N.W., Washington, D.C. 20006 (telephone 202/347 9353).

# ALTERNATIVE SOURCES OF ENERGY — THE WHITE PAPER

The Government is to allocate a further £4·5 million for research and development of wave, wind and geothermal energy.

It is also to provisionally allocate £1·5 million for further studies to assess tidal barrage schemes in the Severn Estuary.

A Severn Barrage Committee with an independent membership, under the chairmanship of Sir Herman Bondi, the Department of Energy's Chief Scientist, is to be set up to assess and report on tidal schemes and their feasibility.

These decisions were announced in a White Paper* published in June in response to reports on alternative sources of energy from the Select Committee on Science and Technology.

Presenting the White Paper to Parliament, Mr. Tony Benn, Secretary of State for Energy, said in reply to a Parliamentary Question from Mr. Arthur Palmer MP:-

> "I am today presenting to Parliament the Government's reply to the Third and Fourth Reports from the Select Commitee on Science and Technology, on the Development of Alternative Sources of Energy for the United Kingdom and the Exploitation of Tidal Power in the Severn Estuary.
>
> "The Government agrees with the Select Committee that work on the alternative sources should be pursued with urgency and determination, but considers that the limitation to making faster progress is not the level of funding for R & D but the state of the technologies involved. Nevertheless, it will keep the level of funding under close review. The reply to the Select Committee announces that, in the light of results so far, expenditure on alternative sources is to be increased by £4·5 million.
>
> "The Government also accepts the recommendation in the Select Committee's Fourth Report that a Severn Barrage Committee should be set up with responsibility for further work on assessing Severn Barrage schemes and their feasibility. It will establish such a Committee under the chairmanship of my Chief Scientist, Sir Hermann Bondi, and has provisionally allocated £1·5 million for further studies to be recommended by the new Committee. I shall be making a further announcement about the Committee's membership shortly.
>
> "This allocation brings the total increase in funding for R & D on the alternative sources to £6 million and makes a total Government commitment of some £16 million. The Government is determined that work on the alternative sources of energy should be given high priority and will be prepared, in the light of progress, to make further sums available for the more promising lines of development".

The main points of the White Paper are summarised below:

**Wave Energy**

The White Paper says that, as the Select Committee concluded, wave power has a major potential for large-scale electricity generation, provided the considerable technical problems can be overcome and economic viability can be established. Progress on the wave power programme, launched in 1976, has been encouraging. Of the machines designed to capture wave energy which are at present under examination, two have advanced from laboratory tests to trials at one-tenth scale on open water at Loch Ness and in the Solent.

The Government is now extending the present programme of £2·5 million, due for completion this October, by a further £2·9 million. The additional funds will support continued development work on the main types of wave energy extraction devices and increased efforts on problems common to all devices, such as gathering and analysing wave data, environmental studies, work on structures and materials and questions relating to the generation and transmission of electricity.

Just over half the new funds will be spent on device development, including one-tenth scale trials, full-scale component development, test tank experiments and theoretical studies. Also, £300,000 will be spent through the International Energy Agency on collaborative work with Japan and other countries.

The wave energy programme will be reviewed annually from the spring of next year and, if justified by progress, could build up substantially over the next three or four years to a level of expenditure that would aid the identification as quickly as possible, of a single device on which resources could then be concentrated.

The next step would be to prove the technology of a prototype which would begin contributing electricity on a small scale. Installation of the production model could be expected to be stepped up with manufacturing capability.

**Geothermal Energy**

The Select Committee considered that the potential for geothermal energy to make a significant contribution to energy supplies was, on present information, very limited. This would involve tapping the naturally-occurring heat of the earth, in the form of underground reservoirs of hot water or formations of hot rock, for use in the homes or in industry. The Government accepts that any contribution to energy supply from this source is likely to be long-term but if its research programme, started in 1976, can be carried forward to a successful conclusion, there is the prospect of securing worthwhile quantities of energy from this source.

The Government has, therefore, increased the programme's funding by £856,000, bringing it to £1·77 million to mid-1980. The new funds will support further geological and other work, including market assessments for geothermal heat, while the consideration of complete systems, covering extraction and distribution, is an element of growing importance in the programme.

The main elements of the present programme receive financial support from the European Economic Community. The Department of Energy is also participating in an International Energy Agency Assessment of methods of recovering energy from hot rock, and there may be further opportunities for international collaboration in this field, with costs and benefits shared.

**Wind Energy**

The Select Committee saw little present potential for the large-scale use of wind power for electricity generation. An assessment published by the Department of Energy last year identified limited scope for the most favoured hilltop sites. The Department then commissioned a study of the design and cost of a large aerogenerator — a windmill to produce electricity — which was carried out with an industrial group and the collaboration of the Scottish electricity boards.

The conclusions were sufficiently encouraging to justify proceeding towards the construction of a 60 metre diameter 3·7 megawatt commercial-size prototype. The first step will be

detailed design and component testing, costing £341,000 over 12 months. If results are encouraging, consideration will be given to the next two phases — constructing the machine itself and monitoring/evaluating its operation — which would cost some £2 million over about three years.

Work on another type, the vertical axis machine which holds out some possibility of cost reduction, is at an early stage. The Department of Energy is supporting work in industry on the development of one such machine, designed at Reading University. The offshore siting of windmills is, as the Select Committee recommended, being investigated by the Department of Energy. The Department will also be working on medium-sized aerogenerators of about 100 kilowatts and assessing novel concepts. This work will cost £465,000 over the next two years. The UK will also take part, as appropriate, in wind energy programmes of the International Energy Agency.

**Solar Energy**

Last year, the Department of Energy launched a £3·6 million research and development programme for solar energy which, with other Government money made available, committed a total of £6 million for the subject over four years. That programme will continue.

The Government agrees with the Select Committee that solar water heating has the most immediate potential of all the renewable energy sources, in that systems for the preheating of water for homes and industry are already commercially available. The main aim of the programme in this area is the development and establishment of systems of proven economic performance and reliability which would lend themselves to widespread adoption.

As the Select Committee recognised, the development of solar space heating systems is at a less advanced stage. Systems specifically designed for the United Kingdom climate are needed and the Department of Energy is at present formulating a research and development programme to this end. The Government will continue to build up its work on solar space heating and related energy conserving systems and will keep the case for the encouragement of their adoption under review in the light of progress towards eventual cost-effective systems.

Since the Department's programme started, 24 contracts — some of them on a shared-cost basis with industry— costing over £2 million have been or will shortly be placed. The Government does not consider that there is now a need for new measures to stimulate industrial interest in the manufacture of solar heating apparatus.

The Select Committee proposed a scheme for financial assistance towards the cost of installing approved domestic solar water heating apparatus, conditional on certain insulation standards being met. The Government endorses the need for continuing action to ensure that the insulation of buildings is improved but believes that it is best pursued directly through the conservation programme. The Government does not accept that there is, in the current state of the technology, an independent case at present for financial assistance towards installing solar water heating equipment but it will keep the case for such action under review in the light of progress on the solar energy programmes. Part of the Department of Environment's work on solar energy is helping to establish standards for appliances and the Government will give sympathetic consideration to requests for funding additional research which may be needed to back up this work. The Department of Industry offers assistance for certain types of project to develop products or manufacturing processes and to expand or modernise production facilties.

**Tidal Energy**

The Government accepts the recommendation by the Select Committee that a Severn Barrage Committee should be set up with responsibility for further work on assessing Severn Barrage schemes and their feasibility. The Government intends to establish a Committee, chaired by the Department of Energy's Chief Scientist, Sir Hermann Bondi, with a membership reflecting both local and wider interests and relevant professional expertise.

The Government believes that such a Committee should be well placed to provide the authoritative and independent advice the Select Committee recommended. The Government has provisionally allocated £1·5 million for further studies relating to a Severn Barrage scheme but wishes to have the advice of the new Committee before commissioning these studies.

The Department of Energy has already published studies on aspects of tidal energy and has commissioned the deployment of wave rider buoys in the Severn Estuary, to measure the height and frequency of waves, at a cost of £42,000.

The Government will keep in mind the possibility of worthwhile projects on smaller estuaries. It may also be possible to recover energy from tidal streams. And Government will keep under review the potential contribution from other aspects of tidal power than the Severn Barrage alone.

**General**

The White Paper says "The Government welcomes the Committee's reports on the development of alternative sources of energy for the United Kingdom and on the exploitation of tidal power in the Severn Estuary, as important contributions towards identifying the potential role of alternative sources of supply in the energy economy of the United Kingdom and developing programmes for their successful exploitation.

"The Government's responsibility is to ensure that a wide range of energy supply options are available when they may be needed. Presently-used forms of energy may become too expensive, too scarce or otherwise unavailable to meet our future energy requirements by themselves.

"While alternative energy sources are likely, as the Committee note in their Third Report, to make only a modest contribution to total energy supply before the end of the century, their contribution could well begin to build up usefully in the first quarter of the next century. The Government therefore agrees with the Committee that the development of these alternative energy sources should be pursued with urgency and determination and that investment in research and development on such sources should be expanded.

"This increased expenditure will ensure that work on these sources continues to advance as quickly as possible. Most of these sources are at an early stage of development and the limitation on progress is not the level of funding but the state of the technology involved. While therefore the Government is anxious to proceed as quickly as possible with the development of the alternative energy sources, it does not consider it practicable at the present time to fix a target date by which the renewable sources should be making a significant contribution. It will nevertheless keep the level of funding under close review and be prepared, in the light of progress, to make further sums available for the more promising lines of development".

**Conclusion**

The £4·5 million for wave, geothermal and wind energy, plus the provisional

allocation of £1·5 million for further studies relating to a Severn Barrage scheme, added to the sum of almost £10 million previously made available, means that the Government has now committed some £16 million to researching and developing alternative sources of energy.

The White Paper concludes "The Government's programmes of research and development into the alternative sources of energy, the first of which was launched two years ago, have already made substantial progress and are now gathering momentum . . .

"This significant increase in expenditure will enable the achievements to date on alternative sources to be built on as quickly as the continuing rate of progress allows. The Government is determined that work on the alternative sources of energy should be given high priority".

*"The Development of Alternative Sources of Energy", Cmnd 7236, available from HMSO and Government bookshops, price 40p.

## Air sampling in Cumbria

The National Radiological Protection Board is undertaking a programme of air sampling to collect data to enable it to determine radiation doses to the public in Cumbria from airborne radioactive material.

The study is part of the NRPB's function of keeping under review the radiation exposure of the public from all sources of radiation; this is a subject on which the NRPB publishes periodic reports.

The NRPB's sampling operation started in mid-June and will last for six months with samples being taken at five points around Windscale. The objectives of the study are to measure the concentrations of actinides and fission products in the air and to assess the influence of environmental factors such as weather conditions on these concentrations.

Standard high volume air sampling equipment is being used. Any radioactive material in the air samples will be collected on filter paper, which the NRPB will send to its own laboratories for analysis. The NRPB will publish the results of the study in due course.

In September 1977, during the Windscale Inquiry, the NRPB carried out air sampling at Ravenglass at the request of the Inspector; it detected levels of airborne activity which, even if maintained for long periods of time, would have led to radiation doses to the public well below the internationally recommended limits for members of the public.

## US part in FR demonstration programme?

A US fast reactor demonstration programme in co-operation with Japan, and possibly Great Britain, was proposed in an independent report released in May by The Rockefeller Foundation and International Energy Associates Limited (IEAL). Adoption of such a proposal would be a major departure for the US in two respects: it would mark a significant change in the Carter Administration's policy towards the need for fast reactor demonstration projects, and it would signify a willingness on the part of the US to co-operate intensively on an international basis in the field of nuclear power technology.

The proposal was made in an independent report entitled International Co-operation on Breeder Reactors, written by John E. Gray and colleagues at IEAL, a private Washington-based group of consultants on international energy supply and use. The report focuses on international co-operation on fast reactor technology, a key and controversial aspect of the development of nuclear energy for civilian use.

According to the report, any effort by the US to delay other nations' fast reactor programmes is likely to be ineffective and disruptive for two very important reasons. First, a plea for delay could come at a time when weaknesses in the US energy posture — in the form of high levels of oil imports, subsidised energy consumption and doubtful capacity to proceed with expansion of coal and nuclear energy sectors — appear to its industrialised allies to pose increasing threats to their economic and political security. Second, any plea by the US for delay is likely to be viewed with suspicion by Western European countries co-operating on fast reactor development— France, the Federal Republic of Germany, Italy, Belgium and the Netherlands — since they believe that they have a substantial lead in the commercial demonstration of the fast reactor, viewed as the most advanced energy supply technology under development.

More importantly, the report concludes, there are strong reasons for the US to view positively the intensive international co-operation on fast reactors that has evolved in Western Europe. If it succeeds, this development would ease the long-term energy problem this region faces, and hence make more manageable the world energy situation as a whole. Moreover, such co-operation in development and demonstration may make possible the creation of a European-wide market for commercial sales of fast reactors, and a European-scale industry to produce them, thereby preventing premature national competition for export sales.

The fast reactor is likely to remain the centrepiece of the energy research and development programmes of most, if not all of the major industrial countries, according to an extensive survey of global energy policies carried out by IEAL in preparing the report. Major emphasis in most programmes is likely to remain on the Liquid Metal Fast Breeder Reactor (LMFBR).

The nuclear energy proliferation risks of a plutonium economy are described in the report as major concerns of countries with fast reactor programmes. The report advocates effective assurances that materials usable in nuclear explosives are not diverted by governments or stolen by terrorists from civilian nuclear power industries. The main incentives for acquisition of a nuclear weapons capability are national security and perhaps prestige. Rather than technological "fixes", the main assurances against weapon proliferation are most likely to be found, according to the report, in political arrangements — safeguards, physical security, sanctions, and various forms of innovative international co-operation.

Every major aspect of breeder reactors — safety, environment, resource efficiency, economics, and weapon proliferation implications — is likely to remain highly speculative for more than a decade, the report emphasises, as the uncertainties require demonstration projects to resolve.

On the other hand, demonstration projects do not inevitably lead toward commercialisation and widespread deployment and use. The report argues that widespread use of fast reactors will result only if electric power suppliers have confidence in the economic viability of incremental investment in fast reactors at the time the investment is made.

Another central point in this report is that, in order for widespread use of fast reactors to occur in a manner that will effectively deal with weapon proliferation risks, it will be necessary to bring about much deeper forms of international co-operation in the fuel cycle than presently exist — although, based on the historical record thus far, it seems clear that this kind of international co-operation will be very difficult to bring about and even more challenging to hold together over time.

The report was published by The Rockefeller Foundation in the hope of stimulating discussions among those concerned with nuclear energy policy. The views expressed are those of the authors and do not necessarily represent those of the Foundation. The authors' work was sponsored by the Foundation's International Relations Programme. A principal aim of this programme is to contribute to the development and analysis of alternative public policies and institutional arrangements that may be necessary — now or in the future — in order to deal with the world energy situation. Other Foundation-sponsored work in this field includes research on and analysis of international policies for oil, gas, and solar energy, and energy policy planning in oil-importing developing countries.

Copies of the report may be obtained by writing to: International Policy Studies Series, The Rockefeller Foundation, P.O. Box 1265, Radio City Station, New York, New York 10019.

## Medium term plans for energy industries

Statements setting out the medium term plans of the coal, gas and electricity industries were published on 31st May in a paper* prepared for the Energy Commission meeting on 6th June.

The paper describes the existing framework for corporate planning in the energy industries and outlines progress towards a co-ordinated approach to the formulation of energy strategy.

The paper indicates a return on investment in the three industries of between nine and twelve per cent in 1976/77, and capital expenditure by the three industries rising from about £1,500 million in 1978/79 to well over £2,000 million in 1982/83.

The Energy Commission will be considering at its meeting progress in corporate planning and its own role in future work in this field.

Other points from the paper include:

### Coal

It is assumed that natural gas and nuclear power will continue to take most of the increase in primary energy demand. Coal and oil will share the remaining market and their shares will depend on relative price. National Coal Board (NCB) sales to power stations were 77 million tonnes in 1977/78. The plan for the next five years is to increase sales to over 80 million tonnes.

The Board assume that oil prices will be maintained in real terms over the next five years. OPEC's price freeze and the weakness of the dollar have reduced the real price of oil and have weakened coal's advantage over oil. It is important that such deviations from trend do not upset long-term plans.

In 1977/78, 14½ million tonnes of coking coal were sold — over three million tonnes less than the previous year. Given some recovery in the steel industry, sales might recover to 19 million tonnes over the next five years.

In the domestic market, solid fuel will continue to face intense competition from gas and there may be a modest decline in sales from the present 11 million tonnes.

### Gas

With the arrival of gas from the Brent Field in 1980, the massive build-up in supplies since the first natural gas came ashore in 1967 will largely be completed. Further supplies will come ashore in the 1980s and these could be substantially more than are included in present plans, but they will be increasingly used to make up the decline in supplies from existing fields. The rates of growth of demand will probably slacken markedly and, taking account of energy conservation, sales of premium gas are likely to approach a plateau. In the domestic market energy conservation lowered the amount of gas used in relation to appliance sales by some five per cent in 1976/77.

Sales of over 18 billion therms are planned for 1982/83, compared with slightly less than 15 billion therms in 1977/78. By 1982/83 gas should be supplying about half the energy used in households.

Sales in industrial and commercial markets will also expand but principally for premium uses, and sales on an interruptible basis for non-premium uses will be restricted, in line with the corporation's conservationist line on gas depletion.

### Electricity

Electricity demand is expected to increase by 2·7 per cent a year, reaching 52 GW in 1984/85.

The annual increase in sales of electricity to domestic consumers will average 2·3 per cent, to commerce 3·2 per cent and to industry 3·2 per cent.

Although there are many uncertainties, the industry expects the next few years to hold electricity price increases to around the rate of general inflation.

If present coal and oil price relativities continue, the industry should burn in 1984/85 about 75 million tons of coal and 23 million tons coal equivalent of oil. Nuclear energy would provide 20 million tons of coal equivalent. However, the industry expects that coal prices will increase more rapidly than oil prices, reducing the economical coal burn in 1984/85 to about 64 million tons, less than in 1976/77. Coal could be obtained from, for example, Australia, at prices lower than those charged by the NCB. There could be savings of £20-25 million a year from coal imports.

The industry does not look to special support to solve its problems but points out that these problems are to a considerable extent the result of Government decisions in the area of energy prices. Natural gas is at present sold cheaply. This gives benefits, particularly to domestic consumers. The British Gas Corporation has exclusive access to North Sea gas and this enables them to purchase their gas supplies at an annual cost some £1,000 million less than if they paid prices related to the cost of coal and oil, as does the electricity supply industry.

*"Energy Strategy and Corporate Planning'— notes by the Department of Energy, Coal, Gas and Electricity industries; Energy Commission Paper Number 15; available from the Library, Department of Energy, Thames House South, Millbank, London SW1P 4QJ.

## Canada/Ontario radioactive waste management programme

In June the Federal Minister of Energy, Mines and Resources and the Ontario Energy Minister announced a joint programme in which the federal and Ontario Governments will work together on the first phase of a long-term programme to assure the safe and permanent disposal of radioactive waste from nuclear power reactors.

Under this programme the Government of Canada will undertake research and development on the immobilisation and disposal of radioactive wastes, while the Government of Ontario will similarly be responsible for studies on interim storage and transportation.

The immobilisation research and development will be performed in the laboratories of Atomic Energy of Canada Ltd. It will cover theoretical and experimental studies for treating the residues from the reactor fuel cycle so as to produce stable insoluble products for eventual disposal in an underground repository.

The purpose of the disposal research and development is to verify that permanent disposal in a deep

underground repository in intrusive igneous rock is a safe, secure and desirable method of disposing of radioactive waste. This will involve geological field parties collecting surface samples and examining other surface features in various parts of the province, to determine the full range of chemical and physical properties of rock formations expected to be suitable for a waste disposal facility. The two governments have agreed that field work should commence in Ontario in 1978. To develop appropriate test equipment, procedures and information on a variety of rock types, experimental drilling will be conducted this year at the laboratories of Atomic Energy of Canada Ltd. Further drilling of this type, at mutually agreed sites, to depths of about 1000 metres will be carried out at six to 10 other locations in 1979-80.

The R & D studies are directed towards the evaluation of a series of barriers which prevent the release of radioactivity to the environment. An analysis will be made of their effectiveness based upon information derived from the immobilisation research and development and the geological studies described above. This information will be used to classify the 1500 or more potentially suitable geological formations which are known to exist in Ontario.

## Information on nuclear power

A leaflet which lists the wide range of information on nuclear power available to schools, colleges and the general public, has been produced by seven organisations involved in the nuclear industry.

The leaflet 'Information on Nuclear Power' was among some thirty leaflets shown to educational journalists at a presentation in Sudbury House, the London headquarters of the Central Electricity Generating Board on 1st June. They ranged from 'Nuclear Energy: Today's Power for Tomorrow's Generation' to 'Britain's Nuclear Workhorses'.

Also included in the presentation were two films on nuclear power. One, 'Energy — the Nuclear Option', is a new film, made by the National Coal Board Film Unit for the UK Atomic Energy Authority, which shows the contribution nuclear power makes and may make in the future to Britain's energy supplies. The other, 'Nuclear Generation' made by Ace Films for the Central Electricity Generating Board, illustrates the effects of nuclear power stations on the day-to-day life of the local community.

A slide-tape presentation 'Safety and Nuclear Power' was also shown. This deals with safety issues and is used in lectures by the Atomic Energy Authority, particularly to schools. A newly-produced exhibition for schools dealing with nuclear power was also displayed.

The information has been produced as a contribution to the current debate on nuclear power.

The organisations taking part in the presentation were: British Nuclear Forum, British Nuclear Fuels Ltd., Central Electricity Generating Board, Electricity Council, The Nuclear Power Company Ltd., South of Scotland Electricity Board, and UK Atomic Energy Authority.

Further details of the wide range of information available on nuclear power can be obtained from: Information Services Branch, UKAEA, 11, Charles II St, London SW1Y 4QP.

## R & D paper for Energy Commission

A substantial rise in the Department of Energy's research and development budget over the next five years was forecast by Sir Hermann Bondi, the Department of Energy's Chief Scientist, in a paper* on energy research and development in the United Kingdom prepared for consideration by the Energy Commission at its meeting on 6th June.

The paper describes the scope of energy related research and development in the UK and reviews relative expenditure levels, areas of research, international collaboration and longer term planning. It also points out that the Department of Energy, which funds by far the greatest share of direct Government-funded programmes, occupies a central position and takes the lead in ensuring co-ordination of energy research and development across the public sector.

In 1976/77, the Department of Energy, the nationalised fuel and power industries and the UKAEA together increased their expenditure on R & D by more than £34 million over the previous year to £227·2 million. The Department recently published its annual R & D report which supplements details given in those issued by the nationalised energy industries, their research establishments and the UKAEA.

These figures do not include expenditure by other Government Departments, the research councils, universities or British Steel Corporation and, the paper says, total public sector energy R & D expenditure in the year 1976/77 was some £240 million. Comparable figures for the private sector are not available but it is estimated that at least some £50 million a year is spent by private industry on R & D related to the production, distribution and use of energy.

"The Department's own R & D budget is increasing and will rise substantially over the next five years", the report says. "Expenditure on offshore technology projects is likely to rise above the current level towards a plateau. Expenditure on renewable energy sources, conservation and coal utilisation will increase markedly over the next five years and by the end of the period should together be accounting for more than half the Department's total annual non-nuclear R & D spend".

In its conclusion, the paper says: "Many issues affect the size, urgency and direction of R & D programmes in the energy field. A national strategy, while concentrating its resources on those technologies which appear most promising on a wide range of views of the future, must also be flexible enough to switch emphasis and resources, if necessary, from one area to another as the future develops.

"The foregoing discussion outlines the present thinking on the formulation of energy R & D policy and the major issues which affect it. The Commission may wish to consider whether there are other important issues to be taken into account and whether the programme and methodology is developing on the right lines".

*"Energy Research and Development", Energy Commission Paper No. 12, available from The Library, Department of Energy, Thames House South, Millbank, London SW1, Telephone: 01-211 3394.

## Birthday Honours 1978

The Authority are happy to record that Her Majesty the Queen has been pleased to award Birthday Honours to the following:

**OBE**

Mr. P.I.M. Irwin, Director of Security, AESB, Harwell.

**MBE**

Mr. J.C. Hale, T/Higher Scientific Officer, Applied Physics & Instrumentation Section, Operations & Engineering Technology Division, Dounreay.

**BEM**

Mr. J.G. Talboys,
PTO III, Engineering Design Division, Culham Aircraft Lightning Studies Unit, Culham Laboratory.