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# AUSTRALIAN ATOMIC ENERGY COMMISSION

## RESEARCH ESTABLISHMENT

## LUCAS HEIGHTS

REPORT ON OVERSEAS TRIP TO U.S.A., CANADA, U.K., DENMARK, SWEDEN, NORWAY, FEDERAL REPUBLIC OF GERMANY

12th MAY, 1980 - 11th JUNE, 1980

by

PROFESSOR S.T. BUTLER

August 1980

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## PROFESSOR S.T. BUTLER

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## 12th MAY, 1980 TO 11th JUNE, 1980

### Introduction

1. The main purpose of my trip overseas from 12th May 1980 to 11th June 1980 was to visit laboratories which have similar objectives to the AAEC Research Establishment and to obtain information on the organisation of their laboratories, the planning and review of their research programs including the current programs and future trends. This was considered essential background for decisions relating to possible organisation changes at the Research Establishment and to the selection and progressing of research topics which are of national concern.

2. Another purpose was to obtain information on commercial activities related to radioisotopes and techniques based on nuclear science.

3. For these purposes, I visited the following laboratories:

(1) Oak Ridge National Laboratory, U.S.A.
(2) Argonne National Laboratory, U.S.A.
(3) Chalk River Nuclear Laboratories, Canada.
(4) U.K. Atomic Energy Authority, Harwell, U.K.
(5) Institute for Atomenergie, Kjeller and Halden, Norway.
(6) Research Establishment Risø, Denmark.
(7) Studsvik Energiteknik, Sweden.
(8) Kernforshunsaulage, Julich, F.R.G.

In each case, the chief host was the Director of the Laboratory and discussions were held with the Director and senior management.

4. To supplement interaction with the laboratories, I also visited:

(1) Atomic Energy of Canada Ltd.
(2) Department of Energy, U.S.A.
(3) Department of Energy, U.K.
(4) U.K. Atomic Energy Authority, U.K.
(5) Central Electricity Generating Board, U.K.

5. On visits in North America, I was accompanied by Dr. R.J. Knight, AAEC Counsellor, Washington U.S.A., and in the U.K. and Europe by Dr. R. Smith, AAEC Counsellor, London U.K.

6. The trip was successful in all respects. Travel and accommodation arrangements were satisfactory and the AAEC Counsellors were extremely helpful.

7. Some laboratories visited employed a form of matrix organisation. However the general view was that matrix organisation is not called for in a Research Establishment the size of the AAEC R.E. Reasons are outlined in the following.

8. Areas for possible non-nuclear diversification of research programs are discussed. Those which merit consideration include the following:

Off-Shore Technology

- Oil reservoir modelling for simulation and studies of enhanced oil recovery. This could be of interest to the Department of National Development and Energy, as well as to the industry.
- Analysis of seismic data to locate oil and gas reserves.
- Monitoring of grouting around the piles of oil platforms.
- Adaptation of control and instrumentation techniques used by the nuclear industry to the operation of oil and gas platforms.

Heat Transfer and Fluid Flow

- Adaptation of two-phase flow knowledge to off-shore technology - flow of mixtures of oil, gas and water.

Coal Liquefaction and Combustion

- Use of AAEC experience on fluidised beds.
- Possible collaboration with U.K. National Coal Board on piloting of new processes.

Non-destructive Testing

- Consider setting up a national service in this area. It is an essential area of expertise for a future nuclear industry and it would have much to offer Australian industry in general.

UNITED STATES OF AMERICA

Oak Ridge National Laboratory

ORNL is a national laboratory which is operated for the U.S. Department of Energy by the Union Carbide Corporation. Funding is provided from two sources:

(a) Direct funding of the Laboratory by DOE to cover operational expenditures and basic research (one third to half of the direct funding is for basic science work).

(b) Funding of research work by DOE (mainly) and other government organisations on a research contract basis.

The Laboratory has a staff of 5,200 of which about 2,500 are professional scientists or engineers. Its annual budget is of the order of $300M and this is expected to increase.

The Laboratory is organised along functional and programmatic lines into what is termed a decentralised matrix organisation. The matrix organisational concept, which has evolved during the past 20 or so years, provides a better means of managing large, complex and highly technological multi-discipline programs than the traditional line-and-staff organisation.

To create a matrix organisation, at least two types of management hierarchies must be established. At ORNL, these are the functional (chemistry, chemical technology, physics, etc.) and programmatic (gas-cooled reactor, fossil energy, etc.) organisations. Other hierarchies (such as geographic and capital projects) could, if required, exist within the matrix. In addition, depending on the amount of centralisation desired, there are two ways to construct a matrix organisation. ORNL has chosen a decentralised, as opposed to a centralised, matrix.

Table 1 diagrams the Laboratory's basic organisational matrix. Note that a program may not necessarily interact with all the functions within the matrix. In the example, program N uses people and facilities from all three functions, whereas programs M and O each use only two of the three functions. In general, the functional responsibility is to develop and deploy a technical resource (skilled people), and the programmatic responsibility is to use this resource to meet program objectives. ORNL's associate directors are responsible for both functional and programmatic duties. These responsibilities, as currently assigned, are listed in the ORNL structural chart shown in Table 2.

The respective functions and responsibilities of program managers and divisional directors are:

*Division Director* (D/D) provides and maintains the human and other resources:

- ensures the technical excellence of the work done;
- most importantly from employee's view, he determines promotions and salaries of Division staff.

*Program Manager* (P/M) obtains funds for the program by presenting and supporting proposals to the funding organisations (e.g. DOE):

- contracts work to the Divisions or to external organisations (i.e. controls expenditure of funds);

- gathers data on work being done and reports progress to the funding organisation as required.

All funded programs are managed by program managers whose responsibilities are to manage the programs on behalf of external funding organisation. They report to an Associate Director. The Program Managers interact with and report to DOE through DOE program managers who are located in Washington.

An increasing trend is for ORNL to act on behalf of DOE (and other government agencies) as a research management agent in letting and supervising research contracts with other organisations. Since 1974 the value of work contracted out by ORNL has increased from $4M to $70M. Such contracting out is handled by a program manager.

Note that the program manager has responsibility for ensuring that the work undertaken will satisfy the requirements of the customer (funding organisation). In practice, the Program Manager may contract for work to be done outside ORNL even when the work could be done by ORNL (i.e. can exercise judgement as to which organisation will do the best job).

It was stated that the major difficulty of the matrix organisation is that it is not a 'natural' organisation - the research workers are conscious of having to respond to two bosses. To avoid conflicts and to make the matrix work, senior management must ensure that the matrix programs are 'fine-tuned' with respect to personalities, i.e. selection of appropriate program managers.

At ORNL, program organisation is kept small to minimise personnel and communications problems. The program manager has a management role - the work details are left to those in line management who are abreast of the technology.

In providing advice about when to use a matrix type organisation to run a project, the following guidelines were stated:

(1) Whenever possible, keep the program within the relevant division. Only cross divisional boundaries when necessary for effective coordination.

(2) Create matrix management only when the program requires significant inputs from a number of divisions - i.e. for multi-disciplinary programs.

In other words, keep the program organisation as simple as possible - use the matrix approach only when necessary. It was believed that matrix management had enormous advantages for management of large multi-disciplinary programs in a large organisation. However it was strongly suggested that in the case of the AAEC Research Establishment, owing to the relatively small staff numbers and the nature of the work undertaken, it would probably be desirable to have only a very limited number of matrix-type projects.

In practice, the distinction between program management and divisional management is not distinct. In large programs at ORNL the Program Managers often will divide off part of the work as a sub-program which is managed by a functional manager within the appropriate division.

On the question of reporting progress on projects at ORNL, there is no clearly established practice and the periodic reporting procedures are under review. At present, there are many different reporting schedules according to the requirements of the funding organisation, the Program Manager, the Division Director or the Associate Director and the nature of the program. Evidently the requirements for reports are situation dependent but there is also an organisational need for periodic progress reports on a suitable time schedule.

The ORNL Program Managers spend a considerable amount of time in Washington in discussion with DOE (and other agencies) program management staff - for such purposes as planning the DOE budget, reporting on research progress and applying for research contracts. They would be accompanied by appropriate divisional staff for discussion of technical matters.

*Diversification*

ORNL commenced diversification into areas other than nuclear about 17 years ago and now receives funds from 30 different government agencies.

The trends have been from fission energy into energy conservation (now $25M p.a.), coal liquefaction ($25M p.a.) and fusion. Fission energy will continue to shrink in the future as more effort is put into conservation and fossil fuels. This applies both in the technology areas and the life sciences.

Diversification has been achieved without an increase in manpower and the laboratory management has worked hard to encourage staff to change from old to new program areas. ORNL obtained seed money to provide appropriate training (for support staff) to enable shifts from one field of activity to another. This appears to have been successful. However, there are limitations as to who can and will make the change satisfactorily. Some staff, particularly professional, have difficulties in shifting from their current fields. Generally, it takes a long time for the change to be effective. Other trends are:

(a) Increased work on fission energy for the Nuclear Regulatory Commission - on safety research (in 1980 15% of the total budget of $300M).

(b) Supplementation of ORNL staff by taking on guest scientists for short term attachments to work on ORNL projects. Such scientists come from other countries and from U.S. universities and generally are not paid from ORNL funds. There will be about 1,000 such attachments in 1980. They contribute information to ORNL and are welcomed. No charges are made for use of the facilities.

The role of ORNL as a national laboratory with special facilities that may be used by other research organisations is expected to increase. A major breakthrough recently has been the decision by other organisations (e.g. the National Science Foundation) to provide funds for building facilities at ORNL.

*Commercial Activities*

ORNL does not engage in commercial work except in very special cases where its unique facilities may be required to do a particular job. It does a very limited amount of such work on a cost basis only. It does not seek such work.

It was considered difficult for a National Laboratory to get too closely involved in doing work for industry - this would place the Laboratory in competition with industry which would make objections.

At present, it does specialist work for quasi-industry groups such as EPRI, TVA and EEI with a total value of $1M per year.

Any patents arising from ORNL research for other organisations are held by the customer except that the U.S. Government retains the right to use the invention for its own purposes. Depending on the nature of the invention, ORNL works out licensing agreements with industry for use of its own inventions.

*Basic Sciences*

ORNL operates on the fundamental principle that 20% of the scientific effort should be kept in the basic sciences. In some areas, this will be science for its own sake (e.g. nuclear physics) but in others, the emphasis is on topics that are anticipated to be problem areas in major program areas (e.g. materials science in the fusion program). The underlying basic science work may be seeded from funds from the relevant program.

The management of the basic science work in the Basic Science Divisions is by straight line management and reporting through Division Directors to the Associate Director. It was stated that the overlying philosophy in managing the research was to give the very good people lots of freedom to produce. The others should be kept under closer management control, e.g. tighter definition of goals and more routine reporting.

A major problem was identified as the shifting of scientists from one field to another as the activities of the Laboratory change. The shift will not work unless the scientist is amenable and highly motivated to make the change. However, converting a scientist is very difficult, even if he is willing, and it may take as long as five years before the man becomes effective in the new field.

*Nuclear and Engineering Technologies*

In this area there is close linkage between functional and program management - for example, the fusion program is managed entirely within the Fusion Division and the Division Director and the Program Manager work together very closely.

There are large programs on nuclear (i.e. $12M to $30M p.a.) which include:

- Fission reactors - 40% of total effort and largely safety oriented.
- LMFBR - materials and safety. ORNL is the U.S. lead laboratory for FBR fuel reprocessing and for materials development. Also for design evaluation aspects for the regulatory function.
- HTGR - fuels and shielding.
- Nuclear Waste disposal.

New work is being undertaken in coal usage, conservation measures and solar technology. As a generalisation, it was said that much of the work in conservation and alternative technologies is very low technology compared to work on the nuclear program. A more pragmatic "try-it-and-see" approach seems to be required.

It was said that ORNL experience was that nuclear technologists had proved to be very flexible and could be transferred readily over to work on coal. In fact, it was easier to transfer the nuclear people than to take on new people as there are not many professionals with relevant experience available in the U.S. at the present time.

*Programmatic Mix*

In summary, the programmatic mix of ORNL is as follows:

| | | |
|---|---|---|
| Fission Energy | $113 million | (39%) |
| Life Sciences | $ 50 " | (17%) |
| Fusion | $ 42 " | (15%) |
| Basic Physical Sciences | $ 40 " | (14%) |
| Conservation | $ 20 " | ( 7%) |
| Fossil | $ 10 " | ( 4%) |
| Isotopes | $ 8 " | ( 3%) |
| Miscellaneous | $ 5 " | |

*Fission*

Still the largest single R&D area at the Laboratory, fission R&D currently emphasises:

(1) studies and evaluations of nonproliferating fuel cycles for the Nonproliferation Alternative Systems Assessment Program (NASAP);

(2) R&D on advanced fuel reprocessing techniques;

(3) the evolution of remote fabrication techniques in accordance with nonproliferating cycles;

(4) the thorium cycles;

(5) research for the Liquid-Metal Fast Breeder Reactor (LMFBR) Base Program;

(6) the high-temperature gas-cooled reactor (HTGR) advanced converter; and

(7) the gas-cooled fast breeder reactor (GCFR).

There is increasing involvement with the management of local radioactive waste and with technical support provided for other lead laboratories in the waste programs.

*Life Sciences*

The biomedical and environmental sciences programs are concerned with identifying, understanding and reducing the health and environmental impacts of energy production and use. Research activities include studies and assessments of the transport, fate, and effects of products and by-products of both nuclear and non-nuclear energy technologies from either a generic or basic science standpoint.

In its major programs, ORNL is conducting basic and applied research that, it is hoped, will provide a better understanding of the health impacts and the environmental fate and effects of the effluents generated by coal utilization and conversion technologies. Research is being conducted in the Biology Division in areas related to carcinogenesis, mutagenesis, and toxicology; in the Environmental Sciences Division in ecosystem modelling and empirical measurements, environmental toxicology, and renewable resources; and in the Health and Safety Research Division in instrument development, assessment methodology development, epidemiology, and regional studies.

The emphasis in DOE-funded basic life sciences work at ORNL has dramatically shifted over the last few years from nuclear- to non-nuclear-related work. This trend is expected to continue, although at a lower rate.

*Fusion*

Since 1969, the fusion program at ORNL has emphasised tokamaks and the technologies supporting them. The Laboratory has played a leading role in the development of neutral beam heating, including its demonstration on the Oak Ridge Tokamak (ORMAK) and the Impurity Study Experiment (ISX) at Oak Ridge, and on the Princeton Large Torus (PLT) and the Poloidal Divertor Experiment (PDX) at Princeton. The Laboratory also has major responsibilities for large superconducting coils and materials, and the Engineering Test Facility (ETF) design centre is located there. The ELMO Bumpy Torus (EBT), an ORNL concept, has recently been designated as the leading alternative to tokamaks and mirrors.

It is hoped that the ORNL fusion program will include a superconducting long pulse tokamak to test the nearly steady-state features of tokamaks and will emphasise engineering and technology as well as a shielded neutral beam test facility for the development of ETF neutral beams. It is expected that the ORNL fusion budget will continue to expand.

*Basic Physical Sciences*

The basic energy science program includes research in nuclear, materials, chemical and engineering sciences; in mathematics and statistics; and in atomic physics. These efforts comprise both experimental and theoretical work.

The nuclear physics program is dominated by topics related to heavy ion physics. The development of Phase I of the Holified Heavy Ion Research Facility (HHIRF), for instance, constitutes a significant portion of the nuclear physics program.

Installation of the new 25-MV tandem electrostatic accelerator is proceeding well; preliminary voltage tests, performed without acceleration tubes, attained 32-MV. Installation of the remaining accelerator components and beam transport systems should be completed in 1980, and testing and first experiments should follow later in the year. At that time, the nuclear physics program will emphasise experiments using projectiles having energies of up to 25-MeV/amu and will include plans to upgrade the facilities later in the decade - through Phase II of the HHIRF - to produce energies of up to 400 MeV/amu.

Currently, more than 300 scientists representing over 120 institutions are involved in planning for HHIRF operation through a formal users organisation.

The theoretical nuclear physics program has developed to support the experimental physics research.

In high energy nuclear physics, experimental investigations of high-energy interactions are performed in bubble chamber experiments by ORNL staff using beams at the various high-energy accelerator laboratories in the U.S.

*Conservation*

ORNL now manages major portions of DOE's programs on energy conservation in residential and commercial buildings. Program activities include developing energy-efficient heat pumps and appliances, improved insulation materials and thermal envelopes, innovative concepts in building structures, and the Annual Cycle Energy System (ACES). In each of these areas, ORNL works with the appropriate segment of the manufacturing or construction industry to develop, evaluate, and demonstrate promising new concepts. To ensure rapid commercialisation, a large portion of the development work is subcontracted to potential manufacturers. The Laboratory's role includes assisting DOE with program planning, managing development subcontracts, and performing selected research activities in-house.

*Fossil*

The Laboratory began its fossil program five years ago with the Office of Coal Research. The program became one of the fastest growing at the Laboratory, encompassing areas of process and engineering evaluation, availability of critical components, support to the Solvent Refined Coal (SRC) process, research in atmospheric fluidized-bed industrialised boilers, and supporting research in the environmental and energy sciences.

## Argonne National Laboratory

The Argonne National Laboratory is another of the major research and development establishments in the U.S. It carries out broad programs of basic research in the physical, biomedical and environmental sciences and serves as a major DOE centre for energy research and development. The Laboratory is operated under the provisions of a contract among the U.S. Department of Energy, the Argonne Universities Association and the University of Chicago.

The discipline mix of the professional staff actively engaged in R&D activities is as follows:

- Engineering - 840
- Physical and Materials Science - 628
- Life Sciences - 163
- Mathematical/Computer Sciences - 71
- Environmental Science - 132

This yields a professional staff of some 1,800 with a total overall staff in the vicinity of 5,000.

The organisation of the laboratory is similar to that of ORNL. Some concept of the matrix organisation and of the various programs and their funding is given in Table 3.

The abbreviations on the left hand side of the table are as follows:

AP - Applied Physics
CT - Components Technology
EBR - Engineering Basic Research
Eng - Engineering
RAS - Reactor Analysis and Safety
SRF - Safety Research Experimental Facilities
BIM - Biological and Medical Research
RER - Radiological and Environmental Research
EIS - Environmental Impact Studies
AMD - Applied Mathematics Division
ChM - Chemistry
Phy - Physics
MSD - Materials Science Division
SSS - Solid State Science
PNS - Pulsed Neutron Source Program
ARF - Accelerator Research Facilities
HEP - High Energy Physics
CEN - Chemical Egnineering
EES - Energy and Environmental Systems

The four persons in charge of overall program areas are named Associate Laboratory Directors. They are equivalent to the Associate Directors of ORNL. On line management diagrams, the Associate Laboratory Directors are shown as being responsible to the Laboratory Director through the Deputy Director, Research, or the Deputy Director, Operations.

The current fiscal year funding of the four general program areas can be seen from Table 3 to be as follows:

| | | |
|---|---|---|
| Reactor Development | $92.2 million | (38%) |
| Biomedical and Environmental | $28.9 " | (12%) |
| Physical Research | $45.8 " | (19%) |
| Energy and Environmental Technology | $74.4 " | (31%) |

A brief summary of some of the programs contained in these areas is as follows:

*Reactor Development*

About 38% of the Laboratory's research effort centres on nuclear power related research. While most of the reactor research is devoted to breeder reactors, increasing attention is being paid to the safety aspects of light water reactors and to the storage of spent fuel and nuclear waste.

The work on waste management includes considerable effort on a Synroc program.

*Biomedical and Environmental*

Biomedical and environmental activities at Argonne constitute over 12% of the Laboratory's programmtic effort. At present, approximately three quarters of the environmental work is contained in one or other of three primary program areas:

(1) Health Effects of Low-Level Radiation
(2) Environmental, Health and Safety Aspects of Coal, and
(3) Environmental Impact Analyses of Energy Revenue Utilisation.

Efforts outside these areas involve basic biomedical and environmental research, instrumentation development and medical applications.

*Physical Research*

The area of physical research represents about 19% of the programmatic effort. In the sub-areas listed in Table 1, basic energy sciences includes programs in nuclear sciences, materials science, chemical sciences and engineering, mathematical and geosciences.

The nuclear physics program seeks a comprehensive understanding of all aspects of the structure, dynamics and interactions of atomic nuclei. The program includes a wide-ranging coordinated study of heavy-ion phenomena, experimental investigations on the interaction of mesons with nuclei, a broadly based program in nuclear theory and a modest accelerator research and development effort.

The high energy physics research program includes both theoretical and experimental physics. ANL has developed a mode of operation whereby Argonne physicists participate in high energy particle physics experiments along with university based physicists at the high energy particle accelerator laboratories in the U.S.

In the field of inertial confinement fusion, Argonne has developed the Department of Energy's newest approach towards the possible development of fusion reactors. This is heavy-ion fusion in which multiple beams of accelerated heavy-ions are made to strike a small fuel pellet with consequent implosion and fusion burn. The program is known as HEARTHFIRE (High Energy Accelerator and Reactor for Thermonuclear Fusion with Ion beams of Relativistic Energy).

*Energy and Environmental Technology*

This area contributes about 31% of the programmatic effort. Argonne's fossil energy research centres on coal. In particular, a major program is in developing the fluidised-bed combustion process. Results have indicated more than 90% removal of sulphur and nitrogen oxides from stack gases.

Argonne is the principal national laboratory in the U.S. magnetohydrodynamic research and development program. Since 1977, the U.S. has participated in a co-operative MHD R&D program with the Soviet Union. Argonne is responsible for co-ordinating U.S. participation in this activity and for conducting the associated technical program. In 1979, significant progress was made in projects involving three MHD channels for test loops at the MHD pilot plant U-25 facility at the Institute for High Temperatures in Moscow.

In the area of fusion power, activity is devoted to developing information on plasma interactions with various components of the Tokamak Fusion Test Reactor (TFTR) vacuum system. This work is performed under the technical direction of the Princeton Plasma Physics Laboratory.

In the energy storage and electric energy systems areas ANL's principal programs are on batteries for electric vehicles and stationary energy storage devices. This work includes management of near-term battery projects at industrial firms.

The main effort in the solar field has been in the development of practical solar collectors for providing home heating and air-conditioning or industrial process heat. Close co-operation with industry has resulted in collector designs and materials suitable for mass production. Two of the Department of Energy's licensees have for two years been marketing solar collectors based on Argonne design.

Further effort on solar technology includes biomass conversion, photovoltaic conversion and ocean thermal energy conversion.

* * * * * * * *

## CANADA

### Atomic Energy of Canada Limited (AECL)

### Chalk River Nuclear Laboratories (CRNL)

The total activities of Atomic Energy of Canada Limited are shown in Table 4 in which it is seen that of a total staff of 6,800 some 31,00 are engaged in research and development - 2,200 at Chalk River Nuclear Laboratories and 900 at Whiteshell Nuclear Research Establishment.

A breakdown of areas within the R&D program is shown in Table 5, and the distribution of effort between CRNL and WNRE indicated in Table 6.

Although the visit to CRNL was of intrinsic interest, it was far less relevant than ORNL, and to some extent ANL, to interests relating to diversification of research and to management organisations.

The CRNL organisation is indicated in Table 7 (R&D) and Table 8 (Administration and Commercial Operations). As can be seen, from Table 5 particularly, the R&D effort has remained in areas appropriate to a nuclear laboratory and has seen no diversification over the years into other non-nuclear energy areas. The underlying research areas, although not in themselves energy research, are nuclear orientated.

As indicated in Tables 7 and 8, the organisation structure is more of a line management nature than it is a matrix nature. The CRNL management is quite satisfied with the organisational structure.

Of particular interest is the high priority given to commercial operations. The General Manager, Commercial Operations, enjoys the same status as the Director, Research, and the Director, Applied Research and Development.

AECL Research Company commercial operations include the production of medical isotopes, the rental of special facilities, shared cost programs with utilities, and contract research on nuclear problems. Company policy dictates that commercial research contracts should only be accepted where the research cannot be done by Canadian industry. Recent initiatives include joint bids with industry for foreign research contracts. Preference in licensing technology is given to industries that are prepared to apply the nuclear technology in non-nuclear areas and pursue foreign business. This has resulted in a flow of some research work back to the Research Company.

It is hoped that revenue from commercial activities will increase from $18 million (Can) in 1979-80 to $33-$55 million (Can) in 1990, expressed in 1980 dollars. This is on a base level of funding by the Government of $125 million (Can) in 1980 dollars.

## UNITED KINGDOM

### Harwell

Recognising that Harwell diversified into non-nuclear areas and into contract research over 10 years ago, the main purpose of the visit was to gain an impression of how effective this has been. The one-day visit was confined to discussions on organisation and management followed by descriptions of typical activities in the non-nuclear area.

#### *Commercial Contract R&D*

The Commercial Director reminded us that in the early 1960's, Harwell was still growing and had spawned off the Laboratories at Culham, Winfrith and also the Rutherford Laboratory. However, by the mid-60's, the climate had changed - at least for nuclear research. The Wilson Government went for the "white-hot technological revolution" based on the application of R&D in industry and that, together with the 1965 change in the Act, allowed Harwell to take up non-nuclear industrial work. Here they had to find out what industry needed and their approach was guided by three principles:

(a) new industrially-orientated work should have a "synergy" with nuclear work;

(b) a customer/contractor relationship was important to ensure technology transfer (i.e. they started a customer/contractor system well before Rothschild);

(c) the work should be as commercially based as possible consistent with national objectives.

[This is a simplified account with some rationalisation. It appears to be true, however, that Harwell have only taken work related to their existing expertise and thus it has been an evolutionary diversification; they have never had to make any revoltuionary changes.]

#### *Revenue and Distribution of Effort*

. Roughly half the professional effort is working in the nuclear power and underlying research areas funded by the UKAEA vote. The other half is employed on contract work for which the revenue in 1978/79 was about £30 million.

. Of the contract work:
21% is for the nuclear industry, i.e. BNFL, CEGB, NPC.
15% is for the non-nuclear industry.
38% is for government, mainly Departments of Energy and Environment and the Science Research Council.

17% is for the Requirement Boards acting for the Minister for Industry.

- This means that overall more than 60% of the work is still nuclear and that some 80% of all work is still directly funded by Government. Only some 7½% (£3.7 million) is directly related to non-nuclear private industry and even here some government funds may be involved.
- Cut-backs in government spending are resulting in some difficulties this year - e.g. The Requirement Boards' vote decreased by £1.7 million.

*Matrix Organisation*

Although in its early years of diversification, the program directors had titles such as Reactor Development, Nuclear Diversification, and Non-nuclear Diversification, today they relate to the areas from whence the money comes, i.e.:

(1) nuclear power and underlying research (UKAEA vote);
(2) Energy;
(3) Environment; and
(4) Industry - a convenient adaptation of a government laboratory to the Rothschild customer/contractor system.

The program directors control the programs in their areas through notional control of funding. In this, they are supported by the project managers (Group Leaders in Divisions) who are responsible for particular projects: they draw staff from Divisions by persuasion. In general, projects grow out of competence which already exists; often however it is necessary to carry out some pre-project work to establish feasibility.

*Patents*

Generally the patents will be owned by whoever pays for the work but Harwell retains out-of-field rights from contract research to allow them to continue work in the area. For service work, Harwell owns the property rights.

*Program Development, Funding and Costing*

Programs are developed as part of a five-year rolling program making certain assumptions about what might be expected in the period. For the ensuing year, the program is costed on the basis of salaries and also on the basis of projects and the two are balanced. Based on the manpower available, the program directors are responsible for defining the projects (what they can justify) and then getting the funds. Contracts can be let in two ways - fixed contract price or limited liability. The former refers more to such things as analytical services and instrument development. The limited liability contracts provide no guarantee in terms of results but the customer is provided with regular advice so that he can judge whether progress is satisfactory. Costing is cost plus (10%) and for industrial and overseas contracts a profit margin may be added which is not disclosed. To establish cost, each staff member has a tariff which covers salary plus overheads (both divisonal and site). Each facility also has a tariff. On a monthly basis cost returns are made from both axes of the matrix system and progressive spending on all projects is carefully monitored.

*Reactor Charges*

Irradiation is done on a full cost recovery basis but no component for capital cost is included as the reactors have been written off. If a major capital expenditure is involved, e.g. for up-grading instrumentation, this comes out of the UKAEA vote and it is then amortised over 5-10 years over all contracts.

*Personnel Management*

The Government constrains UKAEA finance but not staff numbers. (Nevertheless, the Authority tends to take heed of Government policy on numbers.)

Staff are not civil servants since the Authority is what is called a "controlled fringe body".

Superannuation is contributory rather than non-contributory as in the Civil Service; to compensate, the Authority enhances salaries by 7% to cover the difference.

At present, members of the Civil Service are paid somewhat more than scientists at Harwell and this is the source of some bitterness amongst staff and embarrassment to management.

For the scientists, promotion is by merit in much the same way as in CSIRO and AAEC. Up to PSO promotion is relatively straightforward for the good scientist but further promotion to the banded positions SPSO and DCSO is more difficult. The latter ranges go up to and beyond the salary for Professors.

Merit promotion is not affected by working on applied or even confidential commercial work as the review panels have been educated gradually not to judge on the basis of achievement in pure science as was the case in the early days of Harwell. In fact, there is little confidential work: 70% of reports would be unclassified.

Wastage runs at 3-4% and there has been a slight staff increase since 1973-1974.

*Freedom to Express Opinions*

Scientists are encouraged to become involved in the nuclear debate but like civil servants, they are not free to talk about their own work without getting a clearance from the system. For interviews, e.g. T.V., these are usually limited to senior staff and usually they have an official brief.

*Overseas Visits*

Apart from funds kept by the Directorate to finance attendance at international meetings, e.g. EEC, NEA, etc, each Division Chief has his own budget and can decide how to spend it.

*ETSU and MATSU*

Both the Energy Technology Support Unit and the Marine Technology Support Unit work directly to Government Departments - ETSU to Department of Energy and MATSU to Department of Energy and Department of Industry. Harwell provides and manages these units as a service. Reports on these units have been provided by others. Some points of interest are mentioned below.

*ETSU*

As reported previously ETSU is concerned with DOE work on renewables, conservation and R&D strategy. In the first two areas, they have program managers responsible for specific areas, e.g. wind, waves, solar, geothermal, etc. For each area, there is also a steering committee which uses interested persons from around the country. For each project within an area, ETSU has a project officer to monitor and manage on behalf of the Department.

Program Managers report on programs and formulate new programs. These pass to the Steering Committee, from there to ACORD and thence to the Chief Scientist, DOE, for accountability and decisions. Detailed projects are worked out with the sponsors and the customers and monitored and managed by project officers after they have been agreed by the steering committees and the DOE.

It is clear that friction has developed in the management of this work. ETSU complains of too much shadowing by the Department on both financial and technical matters, i.e. there appears to be duplication in management (Sir Hermann Bondi, Chief Scientist, admits this and is making some re-arrangements to avoid it). Basically the problem is that after people have been working in a specialist area for some years, they know more about it than anyone else. Hence they become frustrated with the red-tape involved in getting approvals and providing accountability. It will be interesting to see how they reach a balance between efficiency and accountability.

On the strategy side, ETSU has produced a significant study entitled "Energy Technologies for the UK - An Appraisal for R D&D Planning" which has been published by the Department as Energy Paper No. 39 in two volumes. A copy has been sent to the AAEC.

Harwell management appear to be unhappy that under the present arrangements, Harwell is effectively excluded from taking in energy work because this might be seen by the outside world as ETSU favouring their parent organisation. The Director might prefer an arrangement where they can more directly take on work on renewables and conservation for the Department of Energy.

Another problem of an administrative nature to Harwell management is that the combined staff of ETSU and MATSU is now approaching 70-80 people, most of whom are graded SSO and above. This is a significant drain on the total professional staff of about 1200. Since many of the ETSU staff are potential research project managers, the Director would perhaps prefer to see these people diffused through the site, rather than working solely on ETSU matters outside the fence.

*MATSU*

Similar considerations to the above apply to MATSU. Work for the Department of Industry is mainly concerned with shipping, whereas work for the DOE is more concerned with off-shore technology for oil and gas. Most of the work is justified in relation to the regulatory/safety side. Although as for ETSU, most of the effort is devoted to management of projects, MATSU is again becoming more involved in devising R D&D strategy for the Departments.

*Heat Transfer and Fluid Flow*

This work has three components - the subscription service, the general research program and the contract research. Total budget is about £2 million with some funds coming from the Chemistry and Minerals Requirement Board, apart from that, from contracts and from subscriptions.

The Heat Transfer and Fluid Flow Service (HTFS) is one of Harwell's longest established industrial activities, operated jointly with the National Engineering Laboratory. The basis of the Service is a continuing research program into many industrial aspects of heat transfer; for example, vapour condensation, two-phase flow, turbulent flow, cryogenics and fouling. The Service has some 150 industrial sponsors and annual subscriptions exceed £500,000. The results of HTFS research - reports, design methods, computer programs, technical advice - are made available to members through an information service which currently handles 5,000 requests a year for literature searches, documentation and technical guidance.

HTFS computer programs are employed widely throughout industry for the design of heat transfer equipment, and many of the design methods which HTFS has developed have become standard. For instance, the condenser design program is widely used in-house by over 70 companies and is also available from six computer bureaus throughout the world; it contributes annually to the design and construction of equipment worth several tens of millions of pounds. The Service also undertakes direct consultancy and contract research for clients. Recently it has been involved in a major series of tests on noise emission from the large air-cooled heat exchangers which were part of an order worth £1.5 million for the BP installation at Sullom Voe. In a very different field, work is being carried out for the Ministry of Overseas Development on non-powered, cooled boxes for the storage of vaccines in tropical climates.

*Grout Monitoring*

Many North Sea oil platforms are pinned to the sea-bed with piles driven through sleeves in the main structure. The platform is finally secured by filling the spaces around the piles with a cement grout. The grouting operation must be conducted with care to avoid the formation of cavities. It is usually monitored by deep-sea divers, an expensive and hazardous operation which is only possible in reasonable weather. Harwell has developed a technique for remote grout monitoring which is cheaper, is more reliable and can be used in rough weather without diving support.

The method relies on the use of small amounts of radioactive additives which allow the arrival of the pumped grout and its density to be monitored remotely by specially designed radiation detectors pre-fitted to the platform supports. Harwell staff have successfully demonstrated their method by monitoring the grouting of the Thistle A and Kinsale Head Platforms in association with Wimpey Laboratories and with the approval of Lloyds Register, the certifying authority. Four similar operations are in prospect. The technology is now licensed to Wimpey Laboratories who will offer it as part of a complete grouting service, not only in the North Sea, but worldwide. The new technology gives the company a potential competitive advantage in an annual market conservatively estimated at £50 million a year.

*Oil Reservoir Modelling*

Harwell's experience with pattern recognition has been successfully applied to the analysis of seismic data used to locate and map oil and gas reservoirs. More recently, in collaboration with its sister establishment at Winfrith, the Laboratory has undertaken a major program on oil reservoir modelling for the British National Oil Corporation, British Gas and the Department of Energy.

The proportion of oil that can be recovered from a field is critically dependent on the way oil removal is managed, and techniques that can improve the yield by only a few per cent carry enormous benefits in terms of additonal oil and gas or extended working life. The key to the method lies in choosing the appropriate locations and pressures for re-injecting sea water or gas to maintain the optimum flow of oil from the well. Computer modelling and simulation techniques enable different options for water or gas re-injection to be compared in order to optimise oil recovery, and to indicate where additional wells should be drilled.

The simulation and modelling package being developed by Harwell uses advanced mathematical techniques to speed up the computation process and to increase the precision of the prediction. The package employs a sophisticated colour graphics system for use with visual display units, which eases the interpretation of results by superimposing them on a geological contour map of the oil field under examination. The new approach shows considerable advances over existing simulation programs, and is already attracting interest from other potential users in the oil and gas industries.

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<u>INTERVIEW WITH SIR HERMANN BONDI, CHIEF SCIENTIST, DEPARTMENT OF ENERGY</u>

The matter of oil-reservoir modelling (EOR) was taken up in a subsequent interview with Sir Hermann Bondi. The following points emerged:

. Sir Hermann regarded this work as "enormously important" particularly the development of the science for enchanced oil recovery. However it was also enormously complex and to get an adequate model of the three dimensional fronts may be at the limit of the capabilities of present day computers. He mentioned that natural recovery from North Sea oil wells was about 20% and normal enhanced oil recovery methods can take the recovery up to 35-40%. Normally water under pressure is used but this is tricky because of the risk of a breakthrough. Other methods being looked at include the use of steam, $CO_2$, bacteria and surfactants.

. In EOR, the problem involves taking the information on geology, pressure, etc, obtained from cores, seismic studies etc, and developing a model of the underground area from which it is possible to deduce how the oil/X interface will move under different scenarios.

. Other work on oil reservoirs is useful to the Government to obtain a better estimate of resources and to have independent information useful as a basis for discussions with the oil companies on such questions as depletion policy; the Government has power over depletion rates.

. AERE Winfrith is the focus for oil reservoir work but some work is also done at Harwell and in universities.

. When interest was expressed in obtaining more details of UK oil reservoir modelling, Sir Hermann invited me to write a formal note indicating interest and asking for further information. He though that if the AAEC Research Establishment had a good computing capability, this could be an important area in which to work. Also he considered that on the scientific side, there was real scope for collaboration with the U.K.

The following further information was obtained from Mr. Robinson in the Offshore Technology Unit who was called in by Sir Hermann:

. The work at Winfrith is carried out on two areas - reservoir simulation and enhanced recovery. The work in the former is carried out directly for the DOE ("a tool of the Department"). About 12 professionals are employed. They were given the geologic models (from the geologists in the Department), and the raw data came from the oil companies. Codes were bought in from Intercom. The project has been going for 2-3 years and they have made models of several of the fields in the North Sea. The group is now developing their own improved codes.

. The enhanced recovery work is supported by the Offshore Technology Board following the preparation of a strategy R&D paper by MATSU (Harwell). The AEA provides the core-activity with some further work in universities and the oil companies. Approximately 14 people are employed at Winfrith in this area, working in three groups: this is to be expanded to 30. DOE expenditure is about £2 million for five years and three quarters of this is spent in AEA. The oil companies are spending more. In its early days, BP and British Gas were supportive but Shell and Esso were positively discouraging. Now Shell and Esso are also strongly in support of the work.

In response to the requested formal letter from me, Sir Hermann has responded as follows:

*"Thank you for your letter of 19 June about the work on reservoir modelling and enhanced oil recovery we support at Harwell and Winfrith. As you know the three main areas of activity are the development of PORES, a new 'black oil' simulator, the provision of a reservoir simulation facility and an R & D group working on enhanced oil recovery techniques that might be employed in the North Sea.*

You will perhaps recall that the UKAEA were invited to help us in these areas in the first place because of the difficulties the Department had in recruiting staff with oil industry experience. It was argued that many of the skills employed in nuclear research could be brought to bear on our oil related work. Both require one to predict the behaviour of fluids remote from the operator; albeit in the case of the oil work, several thousand feet underground, as opposed to behind several feet of concrete. Our experience to date has justified our original expectation and we find that after a period of initial training, talented staff are able to make an effective contribution to the programme after a relatively short period of time.

The PORES development, together with some investigation of the use of finite element modelling, is being carried out at Harwell in collaboration with the British Gas Corporation and the British National Oil Corporation. Ten professional staff are employed on this work and it is now in an advanced state of development. The PORES model uses the finite difference method of analysis and is a 'black oil' simulator. You can appreciate that as we do not own all of the property it is not for us on our own to make any offers of third party use, but should you wish to discuss this possibility we might put it to our partners and let you know their response.

The reservoir simulation group was formed at Winfrith a little over two years ago; fourteen professional staff are at present employed on this work. With one exception all the group were new to reservoir simulation. Attendance at summer schools was encouraged to familiarise them with the technologies involved. The object behind setting up the group was to provide the Department with an essential analytical tool in support of its regulatory role and the group's effort is taken up with this task. As a first step the Intercomp Beta II black oil simulator has been acquired although it is intended that it will eventually be superseded by the PORES model. I am not clear how you would wish to collaborate in this area but if you have any thoughts in mind we would be pleased to consider them. I should perhaps add, though, all of this work is of a commercial and confidential nature and any help we might be able to give must be in a general rather than specific way.

The work on enhanced oil recovery is still very much in an embryo state. In the initial stages we asked two members of the Winfrith staff together with an outside consultant to examine the case for a Government supported EOR programme. They concluded that the logistic problems and the particular reservoir properties associated with EOR in the UK Continential Shelf justified government support for R & D. It was argued that the programme should be carried out in close collaboration with the UK oil industry and *the Universities - this is the line we are proposing to take.*

*It is expected that this work at Winfrith will be divided into three areas covering theoretical, experimental and assessment studies. About 30 professional staff will be engaged on the programme when it get underway. As you can see we are still very new to this area but if there are any particular topics where you feel collaboration might be fruitful please let me know. One activity that might be of interest to you is the IEA collaborative R & D project on EOR. Our own group have found the international contacts made through this project extremely useful.*

*I hope my reply gives you the flavour of what we are about. Should your move into this area get underway and you would like to discuss any of these topics in more detail we would be pleased to receive your people here for more detailed discussions of our programme where commercial sensitivity can be avoided.*

*I wish you every success with your venture."*

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INTERVIEW WITH SIR JOHN HILL, CHAIRMAN, UKAEA.

This was mainly an opportunity for me to meet the Chairman of the UKAEA and have a general discussion on matters of common interest within Australia and the UK and within the UKAEA and the AAEC. Points relevant to organisation and diversification are mentioned below.

*Organisation*

Sir John described briefly the rationalisation that occurred in the late 60's and early 70's which involved the hiving off of commercial activities into BNFL and RCC Amersham, a reduction of staff by some 30% and the cutting back of expenditure on nuclear R and D at Harwell. At present AEA expenditure on nuclear R and D at Harwell is some 50% of that in 1965 and this is acceptable to government. Roughly about 50% of Harwell's revenue comes from other sources than the UKAEA vote, and this was permitted by the change in the Atomic Energy Act.

Sir John attached great importance to carrying out the UK nuclear program by a statutory body such as the AEA rather than working directly within the Civil Service. He noted that nuclear work within the US was now only a shadow of what it had been when they had the USAEC and that he would fight to avoid a similar situation developing in the UK. He also thought it important at the present time to continue to operate as a nuclear authority rather than an energy authority because there was a definite job oo be done. But in any case, it was important for the job to be done by a statutory authority.

He noted that the main job of the civil service is to service government in the making of political decisions: they must bow to the day-to-day political problems. If they do this job well, they are not in a position to manage a program. Sir John noted as an example that the running of MOD establishments and programs from Whitehall was not nearly as effective as the work of the AEA. He felt it was important to recognise the different functions and used as an example the work of the Permanent Under-Secretary for Energy, Sir Jack Rampton, compared with his own job. Whereas each in terms of ability could do the work of the other, Rampton was continually beside the Minister dealing with policy and the day-to-day political problems whereas he (Hill) need only meet the Minister once a month and he was free to get on with the technical work of the AEA. He advised strongly that Australia should rely on a Statutory Authority for getting programs of work carried out whether these were for energy generally or for just nuclear energy as at present within the AAEC.

*Diversification*

The AEA is carrying out work for the DOE at Harwell and Winfrith. Three areas were mentioned as the most significant covering the work on oil reservoir modelling and that of ETSU and MATSU. The work on oil reservoirs is done mainly at Winfrith and involves taking the confidential geologic information from oil companies and making an assessment of reservoir characteristics for the DOE: this is valuable not only for policy formulation but also to place the government in an informed position for negotiating with companies on such matters as royalties, estimates of resources and lifetime, and policies on depletion. Sir John believes that the Government is now probably better informed than the oil companies because of the quality of the AEA work which has made use of the special expertise built up from nuclear work.

Sir John also noted that the Department was very satisfied with the work of MATSU and ETSU. MATSU, the Marine Technology Support Unit, is tending to concentrate on such matters as safety of oil platforms involving studies on stress analysis and corrosion. (The work of ETSU is described in the report on Harwell.)

One problem the Authority has to watch is that they do not become over-stretched on this DOE work, since the staff are the responsibility of the

Authority and they do not want to be left with excess scientists on their hands should the level of support from the DOE decrease.

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INTERVIEW WITH DR. DEREK LITTLER, DIRECTOR, RESEARCH, C.E.G.B.

This was not a very profitable discussion. Its purpose was to gain a utility viewpoint on how much national research back-up was considered desirable to support utilities with a nuclear program. The most interesting points are set out below.

(1) CEGB is probably a special case because it is so large and therefore can afford a large program of its own. Littler felt, however, that the TMI experience showed up clearly the problems faced by a small utility with inadequate nuclear back-up and know-how.

(2) Generally, he gave the impression that in the case of Australia, he thought it would be essential to have national nuclear expertise to back-up the utilities when they went into a nuclear program. However he recognised that it would be difficult to maintain this at present if there were to be no nuclear power stations for 15 years and even then the reactors might be spaced at irregular intervals. The situation would be far more straightforward if there were a regular installation program of nuclear reactors. He also noted that from CEGB experience, it was difficult to see how one could predict what was desirable some 20 years ahead.

When CEGB set up its Berkeley Laboratories, this was strongly opposed by Government. Now they have a good relationship with the AEA, work closely with them and even commission research from them.

In the area of PWR's, CEGB has some 60 people:

(a) preparing for a public enquiry based on a safety case from Westinghouse;
(b) looking at maintenance aspects to ensure that operator doses will be no higher than those from Magnox reactors;
(c) looking at improving the water chemistry in the steam-generator units where they think they can do better than Westinghouse.

CEGB contracts work to AEA for work on vitrification of high-level wastes. Also it may employ Risley staff (Nicholls) on fracture studies relating to pressure vessels for PWR's.

## NORWAY

### Institute for Energy Technology

This visit was particularly interesting because of the parallel between Australia and Norway. The Management had an excellent appreciation of the phase we are now going through in the AAEC and was extremely helpful in showing how their Institute had coped with the same diversification problem some five years earlier.

After a preliminary discussion with the Managing Director and his Deputy late on the afternoon of arrival, the following day was devoted to travelling and visiting the laboratories at Kjeller and Halden. With hindsight it would have been useful to have had more time to investigate in detail the work actually being done in certain areas, e.g. isotope production, energy system modelling, oil reservoir modelling, application of two phase flow technology to off-shore technology problems, measurement of gas transport at high pressures, and application of instrumentation and control technology to oil rigs. Perhaps a further approach should be made to learn more about Norwegian work in these areas - all of which seem of interest to Australia.

### General Information on Norway and Nuclear Power

The population of Norway is about 4 million. Almost all required electrical generating capacity is hydro and so far the country has used only 60% of potential hydro-reserves.

About one month prior to the visit, a White Paper on energy laid down that Norway would rely on hydro resources in the future (environmental lobby permitting) and that nuclear power would not be introduced this century. Nuclear power is a political issue in Norway but it is unlikely that, like Sweden, there will be a referendum on the issue.

### R&D in Norway

Industrial R&D is carried out under the Department of Industry, through the Council for Industrial Research by about 10-15 Institutes (including some in Technological Universities). Much of the work in these Institutes is done on a contract basis to industry, and some energy work is included; thus they compete with the Institute for Energy Technology. The Council has a special committee dealing with energy matters.

Separately they have a Council which looks after pure research which is probably somewhat similar to the SRC in Britain. They do not have a separate Ministry for Science.

Some two years ago, Norway set up a Department of Petroleum and Energy which has a newly formed Advisory Committee on Energy Policy (cf NEAC). This Department is responsible for the Institute of Energy as well as two other Institutes working on energy related matters (probably electricity supply and distribution, and off-shore technology). Clearly there are problems of demarcation between the interests in the Departments of Energy and Industry. The Chairman of the Institute of Energy is on the Advisory Energy Policy Committee and also the Energy Committee reporting to the Council for Industrial Research.

## Organisation of the Institute

Diversification of the Institute for Atomic Energy began five years ago but the name and mandate have been changed only in the last year. The present organisation is a conventional in-line organisation with five main areas of work: Halden Project, Energy Systems Technology, Materials Technology, Isotopes and Chemistry and Administration.

The Institute has two sites - Kjeller and Halden. Numbers employed at each are: Halden 178 (32 professionals), Kjeller 313 (88 professionals), making a total staff of about 500. The total budget is about $A20 million. The average age of the professionals is 42-43.

Roughly half the staff are still working on nuclear related work, mainly at Halden and the Director thought that this might have to be reduced further.

## Historical

Because of its heavy water, Norway built research reactors based on heavy water and in the early years collaborated closely with the Dutch - at least until they set up their Petten reactor. During their "nuclear" years, there was some emphasis on nuclear ship propulsion using BWR's and using mild steel for the primary circuit; particular areas of interest were corrosion, shielding and the effect of acceleration in rough seas. In 1967-72, they joined forces with the Electricity Board and Utilities in a comparative study for the installation of a BWR or an AGR in Norway either on an open-ground site or in a mountain cave. A cave-site requires a radical design change because the reactor and the electricity generating equipment have to be placed in different halls because ofa limitation of 40 metres in the size of individual caves. Later they assisted in the government study on Nuclear Power and Safety. Generally, however, they developed expertise in the same areas as at Lucas Heights.

Two developments were important to the present program of the Institute. One was the building of the Halden Reactor and its utilisation as an international centre for sophisticated, in-core, instrumented studies on fuel behaviour. This not only gave them experience with a major project, but served as a focus for developing expertise in the areas of nuclear safety and reliability, cost-effective R&D, control and instrumentation, heat transfer and fluid flow, reactor core physics, materials technology, etc.

The other main initiative was to establish Scandpower in 1970, a consulting firm owned by Norwegian industry, which was set up initially to look after the commercial aspects of introducing nuclear power but now operates as a "high technology" company which, inter alia, exploits the results of the Institute's R&D and exploits their capabilities for commercial ventures, particularly in the petroleum industry. Scandpower has about 44 staff, mainly professional with some in an agency in the USA. (Scandpower has had success in marketing fuel management programs for BWR's based on Halden experience.)

Diversification

The diversification programs are covered in outline in Table 9. Of particular interest, is the manner in which use has been made of nuclear people with competence in theoretical and experimental reactor physics, control and instrumentation, safety and reliability analysis, heat transfer and fluid flow, and isotope application to do work on applied problems of concern to Norwegian industry in general and in particular to the petroleum industry. The oil and gas industry in Norway is of vital national importance and it seems fairly clear that scientists and engineers with nuclear training and experience can adapt their expertise to be of use to this industry.

Some points which emerged regarding diversification are as follows:

(a) Chemical engineers with experience of fuel reprocessing, solvent extraction and ion exchange are now working on problems of interest in the mineral industry. They have a pilot plant to extract alumina from a felspar product, and a production plant to produce yttria.

(b) Nuclear safety principles have been used to prepare a safety handbook for the petroleum company Statoil.

(c) Risk analysis has contributed to an investigation on simultaneous drilling and production and has been applied to Statfjord oil platform.

(d) Reliability technology is being transferred to other industries.

(e) Computer-based systems have been developed for supervision and treatment of process data and for the development of alarm systems; this comes from the Halden experience in control and instrumentation.

(f) Simulators are being developed not only for nuclear operations but for adaptation to operations and control room design in industries.

(g) A complete operator-communication system has been delivered on sub-contract for use in the control room in the first Condup platform. Other systems have been developed for power utilities and for the paper/pulp industry.

(h) Mathematical modelling has been applied to industrial processes in the metallurgical industry and for the simulation of oil reservoirs.

(i) Experience with two-phase flow and studies of nuclear loss of coolant have been adapted to studies of the flow of gas/oil mixtures for application to blow-out accidents.

(j) Isotope tracing has been used to map flow conditions in oil and gas reservoirs, and also to environmental pollution problems.

Although inadequate time was available to investigate in detail the nature of the diversified work in these areas, the diversification program developed in the Institute has an immediate appeal because it does make use of nuclear expertise in other areas of national importance without losing the expertise which may be required later for a nuclear industry.

No mention was made of work on materials technology, e.g. corrosion and metal failure studies related to off-shore technology. Perhaps here they are less successful in obtaining contracts as they must compete with the other Research Institutes under the Department of Industry.

Isotope Production

The Institute produces isotopes for hospitals in much the same way as does Lucas Heights. It may not be economic but clearly for the time being, they want their own national service and are prepared to pay for it. Note that this area of work is included as contract work becuase of the returns from the hospitals. Pricing is somewhat artificial with much the same approach as at Lucas Heights. Recently the laboratories were extensively modified to satisfy what has been laid down by the EEC as appropriate international standards for the production of radiopharmaceuticals. Sales in 1979 amounted to 10 million Kroner (say $A2 million).

General Conclusion

Superficially, at least, it seems that the Norwegians have been fairly successful in this diversification program along lines which might well be followed by Australia - or at least investigated as a first step to possible future implementation. In particular, they appear to have made effective use of the nuclear people in the disciplines of theoretical and experimental reactor physics, heat transfer and fluid flow, control and instrumentation, and safety and reliability analysis.

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## SWEDEN

### Studsvik Energiteknik

Sweden is the one Scandinavian country that has a significant nuclear power program. With the nuclear power industry established, the main interest was to find out what use is now made of what was once a very active nuclear research establishment under the name of AB Atomenergi, Studsvik.

#### *Historical and General*

Sweden has no significant sources of fossil fuels and it was one of the first countries to make a firm commitment to nuclear power. At present, with six nuclear power stations in operation, some 25% of its electricity is nuclear. Another six nuclear plants are either being commissioned, under construction or planned.

In the 50's and 60's, AB Atomenergi had an active role in nuclear research and technology. On the technology side, they were sufficiently strong to provide the nucleus for the Swedish nuclear power plant vendor ASEA-ATOM to be established successfully. This company designs and builds BWR's both for Swedish and foreign utilities (e.g. Finland); it also fabricates the fuel based on technology developed by AB Atomenergi.

With the formation of ASEA-ATOM and the commercial development of nuclear power in Sweden, there was no longer a clear role for AB Atomenergi as a purely nuclear research establishment living largely on government funds. This, combined with the public opposition to nuclear power, led to some difficult years during the 1970's.

Prior to the 1970's, AB Atomenergi which is a state-owned company had a purely nuclear role to:

- carry out shorter term R&D for Swedish nuclear industry;
- carry out longer term R&D supported by Government funds;
- provide advice to government, utilities, safety authorities.

The activities were financed by an annual government grant, plus fees from industry and utilities for specific tasks.

About 1970 the Government was less keen to provide research funds and gradually during the decade, the Laboratory has been forced to become almost a fully self-sustaining contract research organisation, selling its skills and facilities to anyone who is prepared to pay for them. The most recent reorganisation was in 1978 when the name of the Company was changed and they adapted wholly to the market structure. Today they have no pretentions to be a national laboratory or to look after the national interest. The only test they apply for their work is to get a positive answer to the question "Is somebody prepared to pay for it?"

*Present Situation*

Although still a state-owned company required to satisfy all Swedish Company Laws (share capital - 30 million Swedish Crowns ≈ $6 million), they have no particular mandate from the government and they must compete for funds against all other R&D bodies. This does not mean however that they do not attract government funds. Over the last ten years, and particularly since the oil crisis in 1973, a number of government bodies have been established to promote research and disperse funds in energy related fields. These are listed below:

- DFE (The Energy Research and Development Commission) : General coordination and system studies.
- NE (The National Swedish Board for Energy Source Development) : R&D for energy production and transport.
- BFR (The Swedish Council for Building Research) : R&D for building and housing applications.
- STU (The National Swedish Board for Technical Development) : Industrial applications.
- TFD (The Transport Research Delegation) : Transportation questions.

Studsvik Energiteknik has managed to attract funding from all of these bodies. This arrangement has its similarities to the customer/contractor principle in the U.K. except that in the U.K. the customer is the Minister - through the Chief Scientist of his Department. In Sweden, the customer is a government instrumentality set up to promote work in fields considered important to government, e.g. energy conservation in buildings, development of indigenous energy resources, industrial development, etc.

*Commercial Aspects*

Under its company structure, Studsvik Energiteknik has always been cost conscious and commercially orientated. This applies even more so today. When they identify a commercial operation, it has been their practice to separate this out as a subsidiary company. Thus they have:

Alnor Instrument Company (owned two thirds by S.E. AB) - which is established in the USA and Sweden to manufacture and sell instruments developed from their work - mainly related to radiation measurement.

Studsvik Analytica AB (owned 50% by S.E. AB) - which carries out chemical analysis as a service, using both Studsvik and other laboratories.

Studsvik Projektadministration AB - which sells administrative services.

Svensk Metanolutveckling - a new and ambitious company established to produce methanol from Swedish raw materials. It is owned 80% by S.E. AB, 10% by Volvo, and 10% by Statsförelag, a petroleum company.

In addition, they have an interest in the following companies:

Eurochemic - the OECD-NEA body concerned with reprocessing of nuclear fuel.

AB - ID Kort - a company set up to make and sell identity cards using a fool-proof radioactive technique (not now socially acceptable).

AB - Kabi Diagnostica - for the production and sale of radioisotopes and radiopharmaceuticals. (Apparently this company is not commercially viable without some government support and while we were there we were told that the government was not prepared to provide this support even in the national interest. Unless this decision is changed, the company will go out of existence and the products will have to be imported.)

Ransted Skifferaktiebolag - a company set up to exploit and develop the uranium deposits at Ransted. Studsvik holds 20% of the shares.

An aspect of interest to Australia, on which it was difficult to obtain definite information, was the present level of subsidy by the Government to maintain and operate expensive facilities such as the reactor R2. Apparently the annual operating costs of the reactor R2 are about 36 million Sw. Kr. and about half of this comes from the Government - but only after long argument, and the extent of funding is always in dispute.

*Organisation and Staffing*

Total staff is about 900, organised into three Divisions as from 1978.

- Nuclear Technology Division - 380 employees
- Energy Technology Division - 160 employees
- Technical Services Division - 310 employees.

Prior to 1978 they tried a matrix-type structure but found it did not work. They found it involved too many committees and they could not get an appropriate balance between the vertical in-line management and the horizontal project management.

The present structure, similar to that in industrial companies, is suited to their market-orientated approach and more clearly identifies their profit centres. It is claimed that they have about 60% of their effort in nuclear and 40% in non-nuclear.

The staff in the Energy Technology Division is expected to rise to 180 in 1980 and 200 in 1981.

Associated with their diversification and the increasing trend to commercial contract research, this has meant that they no longer carry out any basic or strategic research. Thus staff interested only in basic research were forced to leave and move into universities. This was not easy because Studsvik salaries are related to industrial salaries and are some 25% higher than those in the civil service.

*Nuclear Activities*

This area is clearly viable, particularly in relation to BWR's, based on contracts from ASEA-ATOM, the utilities, the Swedish Nuclear Power Inspectorate, as well as from overseas. The main areas of interest are radiation protection and waste management, reactor safety, materials research on fuel and constructional materials, and process control and instrumentation.

Extensive use appears to be made of the reactor R2 for fuel studies (particularly related to BWR fuel from the point of view of pellet-clad interactions, fission gas release, development of higher burn-up performance, power cycling effects, etc). In addition, they appear to operate a profitable business in the irradiation of silicon crystals for the semi-conductor industry.

*Energy Technology Activities*

During the early diversification and anti-nuclear years (early 1970's), effort was concentrated on low temperature heat sources for district heating, and funding increased to and levelled off at about 12.5 million Sw. Kr. Particular areas of interest have been:

. development of cheap pipes for transporting hot water;

. heat recovery units;

. development of a central solar heat station (although not regarded as economic, it is an ingenious piece of development work related to Swedish needs).

. heat pumps - including one using metal hydrides.

At present and in future, apart from work on technological and economic aspects of energy planning, they expect their laboratory work to concentrate on combustion, gasification and conversion of fossil fuels including indigenous peat as well as studies on the environmental aspects of the use of fossil fuels. Here they can take advantage of existing nuclear expertise; particular attention is being given to the development of fluidised bed technology for combusion and gasification.

*Some General Impressions*

Generally Studsvik Energiteknik has had to face up to a very difficult situation over the last 10 years, but it appears clear that they remain a viable and productive organisation well adapted to the particular situation in Sweden. Perhaps there is not a lot to be learned from their experience which is relevant to the situation in Australia but the following points are of interest:

. the trend away from Government funded research of a fairly strategic nature to contract research selling high technology services;

. the fact that the local nuclear industry as well as foreign contractors are prepared to pay for studies on specific problems - and that 60% of their effort is still devoted to nuclear technology;

. the problem of competing on contract research without some subsidy from Government to help pay the high operating costs of expensive facilities;

. the extreme commercial approach which means that even library services and information services must be paid for by some outside body;

. the profitability of irradiation of silicon crystals for the semi-conductor industry;

- the impression that local radiopharmaceutical production in Sweden will cease because it is not profitable and because (at least at present) the Government is not prepared to subsidise it.

* * * * * * * *

## DENMARK

### Risø National Laboratory

#### *General*

Denmark with a population of about 5½ million has no indigenous fossil fuels at present. Some gas has been discovered in their area of the North Sea, but this is a relatively small resource (perhaps enough for 20 years). I have no details on their installed electrical generating capacity but I would guess it is about 6000 MW. At present, they have no plans for nuclear power stations because of political and social opposition; this means they import relatively large quantities of oil (and perhaps coal) and this is aggravating an already severe problem in their balance of payments. It is by no means clear what energy sources they will use in the future and how they will pay for them. Their major export is agricultural produce.

Although they are not prepared to accept nuclear power, in effect they already have to face up to some of the consequences since several of the nuclear power stations on the west coast of Sweden are close to the Danish mainland.

#### *Historical*

The Institute was established in 1956 under the auspices of the Danish Atomic Energy Commission. Comments were made to the effect that this was partly a tribute to Niels Bohr and also that the early organisation of the Institute was very much influenced by Bohr so that it became very much a laboratory for basic scientific studies in all areas of nuclear science.

The Director stated that he thought that whereas Lucas Heights had been relatively technology/project orientated, Risø had always been more orientated towards basic science. This meant that in the past they have had many small projects in accord with a philosophy of "letting each scientific flower bloom". It appears that they have had, and still have, fairly strong programs in neutron scattering and solid state physics, radiation chemistry and applications of isotopes in agriculture.

In the reactor area, they had some interest in Candu systems (because they avoid the problem of enrichment). Some work was done on fast shutdown to check the efficiency of operation of fast boron injection systems. They also looked into the problem of heat removal to the calandria from a blocked channel (they do not consider the heat transfer across the gap between pressure tube and calandria is adequate). In addition, they have developed competence in the nuclear safety area (in collaboration with the other Scandinavian countries) with some emphasis on computer codes for loss of coolant accidents. Some 15% of effort has been devoted to the fuel element/ fuel cycle area.

*Diversification*

Prior to 1976, Risø came under the Danish Atomic Energy Commission which was responsible to the Minister for Education. Diversification was brought about in 1976 by the Act on Energy Policy Measures which transferred Risø as a National Laboratory to the Ministry of Commerce and put it under a new governing board. The Act also widened the mandate of the Laboratory to include non-nuclear energy research as well as contract research. Since 1979 the new Ministry of Energy has taken over responsibility for Risø.

*Danish Energy Agency*

At the same time, the Atomic Energy Commission was abolished and apparently most of the executive staff (from Head Office) were employed in a Danish Energy Agency; (only three came to the Research Establishment). The Energy Agency is responsible (from 1979) to the Ministry of Energy.

*Nuclear Power Inspectorate*

Also at the same time, the nuclear regulatory people working for the Danish AEC were transferred to a Nuclear Power Inspectorate responsible to the Minister/Department of Environment. The Nuclear Power Inspectorate consists of about 14 people and is located at Risø. Apparently about six professionals work on fairly normal nuclear regulatory type work. Another five professionals work on emergency schemes - this latter is seen to be mainly political. The impression was gained that the unit is not very effective partly because it is difficult to develop and maintain competence in the absence of a nuclear hardware program.

*Present Organisation at Risø National Laboratory*

The Governing Board consists of about ten members. It is chaired by the Permanent Under-Secretary of State (for Energy) and has representation from the staff, the Trade Unions, Universities, Private Industry, Agency of Environmental Protection etc.

The Managing Board consists of the Managing Director and the three Assistant Directors. The areas of responsibility for the assistant directors are:

- program and planning
- contract and commercial
- infrastructure - operations and services.

The Director claims that they operate a matrix structure but it is by no means as well defined as at Harwell. He finds a matrix structure useful in that he can retain discipline-orientated departments (cf Divisions in Australia) and allow flexibility in applying effort to the program areas. Presumably (although this is not clear) persons in each Department must have a responsibility in relation to program areas and these are brought together through the appropriate Assistant Director.

The Technical Departments and the eight program areas are:

| Technical Departments | Program Areas | Funds % |
|---|---|---|
| Accelerator<br>Agricultural Research | Agricultural Research | 8 |
| Chemistry<br>Computer Installation | Environmental and Nuclear Safety Research | 15 |
| Commercial Office<br>Electronics | Reactor Technology and Safety | 15 |
| Energy Systems<br>Engineering Department | Materials Research | 19 |
| Health Physics<br>Isotopes | Nuclear Fuel Cycle | 21 |
| Metallurgy<br>Safety Section | Radiation Technology (including isotopes) | 10 |
| Physics<br>Reactor Technology | Non-Nuclear Energy Research | 12 |
| Research Reactors | General Services | 1 |

*Program Planning*

Each year, they up-date a three year rolling program. The process begins in August when general constraints and possible new directions are identified, e.g. no cut-back on nuclear, increase effort on wind energy, etc. The Departments then prepare their programs and budgets. From these the Management Board with the Departmental heads, develop a laboratory program based on the program areas; they hope that in each area the program becomes more than just the sum of the parts from each department, i.e. it has some coherency and overall purpose.

For the agricultural research program which is carried out in one department the program is developed through argument between the Departmental Head and two adversaries from other Departments. In other words, around about September/October, there is general argument and discussion to reach a consensus. Programs are then revised by the Departments, modified as necessary by the Management Board and finally approved in December (presumably this program then goes to the Minister for approval).

*Program Activities, Funding and Staffing*

Total staff is about 800 plus about 50 attachments. The salaries of about 60 are paid for by commercial activities, the rest comes from government funding. Basically the laboratory relies on a government appropriation of 160 million D. Kr.; in addition they earn about 15 million D. Kr. by commercial contract work and another 20 million from government funded energy projects (cf NERDDC).

Apparently the Ministry of Energy spends about 60 million D. Kr. on energy projects, presumably through the Energy Agency. These include:

| | |
|---|---|
| Uranium exploration | D. Kr. 36 million |
| uranium prospecting | 6 |
| warm water storage | 7 |
| small windmills | 5 |
| large windmills | 2 |
| fusion | 6 |

This DOE money is spent mainly in industry with some also in universities and at Risø. It may be the case that Risø has a management function as well in respect of these funds; it certainly does in the case of the Danish contribution to JET, and it also has an involvement in the windmill and uranium exploration programs.

Some points of interest are:

Reactor Safety and Technology - In this area, they develop the competence needed to understand reactor technology and safety sufficiently to regulate nuclear power should it be introduced into Denmark. Presumably the nuclear power inspectorate (and utilities) would have to rely on them for technical specialist advice.

Nuclear Fuel Cycle - this area includes work on uranium prospecting and exploration in Greenland as well as uranium extraction experiments on the ore, manufacture of fuel for their Dido reactor and work on waste management.

Environmental and Safety - this is regarded as a growth area. For some reason, reliability assessment is included here and the tecniques have been used to assist in the safety assessment of a chlorine plant in Copenhagen, apparently with some success.

Materials - most of the work here appears to be fairly pure research, although some work is being done on composites for windmills.

Radiation Technology - at least in terms of areas of interest, these correspond to those in the Isotope Division at Lucas Heights.

Non-Nuclear Energy Research - Energy systems analysis is carried out for the DOE. Other main programs are:

- underground storage of hot water
- storage of natural gas in salt-domes
- storage of hydrogen in solids, e.g. Titanium
- testing of small windmills - they have established a windmill site at Risø
- fusion.

Approximately 30 people are working on fusion. This is not favoured by the Board but it will probably continue because of commitments to the EEC - and also because the funds for it come partly from the EEC. In addition, of course, Denmark contributes to JET.

*Dido-Type Reactor - DR3*

The fuel for this reactor is made on site by a Danish shipbuilding company, Elsinore, with research, etc, support from the Laboratory. It is claimed that this fuel is 15% cheaper than if bought from the UKAEA or from NUKEM. They considered that in terms of level of enrichment, they should not have to face the problem of changing for at least five years.

It was claimed that it is common knowledge that NUKEM was paid a very large sum of money for the development of lower-enriched fuel for the German Dido reactor at Julich.

They claim to do very well financially (i.e. they make a significant profit) from the irradiation of silicon crystals for private industry. This was also the claim in the other Scandinavian countries and it was suggested that this would be a very lucrative thing for Australia to do with HIFAR.

In their Dido, they have a hydrogen, cold neutron source which was said to have cost $2 million.

*General Impressions*

Since 1976, they have managed to re-deploy some 10% of their staff from the nuclear to non-nuclear area and have managed to get about 10% of their funds from non-government sources. To the extent that diversification has occurred, it has been carried out against considerable opposition from the staff since they need to be convinced of the value of new projects and the impression was obtained that even the management were not too convinced.

Generally, it seemed clear that the laboratory had real problems in making a significant contribution to national energy problems (if that is what is the objective). Factors that seem relevant are:

- National energy priorities do not seem to exist and Risø apparently are not too enthusiastic to support a national position to put emphasis on renewables.
- The trend in the past has been to give considerable emphasis to basic research in radiation chemistry, solid state physics, etc, and the people in these areas do not want to change.
- Many staff have become set in their ways and interests. Also "many have fallen asleep and do not want to be woken up".
- Although there has been some reduction in government funding in general there is no real pressure to bring about change into applied energy studies. (This was a comment made in Norway and Sweden - who collaborate with Denmark on energy research.)
- Some programs are the result of Danish membership of the EEC (e.g. the work on fusion) or arise because of the need to contribute to the collaborative program with Norway and Sweden.
- Except in one or two areas the organisation does not seem geared to take up project work.

* * * * * * * *

## FEDERAL REPUBLIC OF GERMANY

### Julich Nuclear Research Centre (KFA)

This one-day visit was for all practical purposes from 10 a.m. to 3 p.m. with a respectable period for an official luncheon. In this time, it was almost impossible to gain anything but very general impressions taking into account the need to spend some time talking generalities.

*General Information and Comments*

(a) Most of the information obtained is contained in an official brochure available from me.

(b) Total staff is 4,400 including 818 scientists. Annual budget is 350 million DM (~$200 million).

(c) The organisation consists of four parts:

- The Research Institutes - 14 in number.
- The Project and Programs Sections (the non-nuclear energy section comes in this area).
- Scientific and Technical Infrastructure.
- Administration

(d) With regard to the Institutes, one had the impression that each is a law unto itself with each carrying out its basic scientific program oblivious of work elsewhere at the Centre. The association of university professors with Institutes probably helps in developing this attitude.

(e) In the project area, emphasis is still given to the development of the high-temperature reactor and its possible applications. Fusion work is also a significant project.

(f) From the scale of operations and the lack of real financial pressures, it seemed clear that this nuclear research institute, so far, has not felt too many cold winds. One felt that it still lived under the benevolent philosophy that if money is spent on high technology research, inevitably there will be a useful return.

(g) Generally, the research programs at Julich do not seem to have changed to any noticeable extent over the last 15 years. Certainly, apart from the work on solar energy, they do not appear to have felt the need to diversify to any significant extent into non-nuclear areas, nor have they had to cut back on their fairly high-risk projects at the frontiers of nuclear technology. In this "affluent" climate, they really did not seem to have any real appreciation of the Lucas Heights situation.

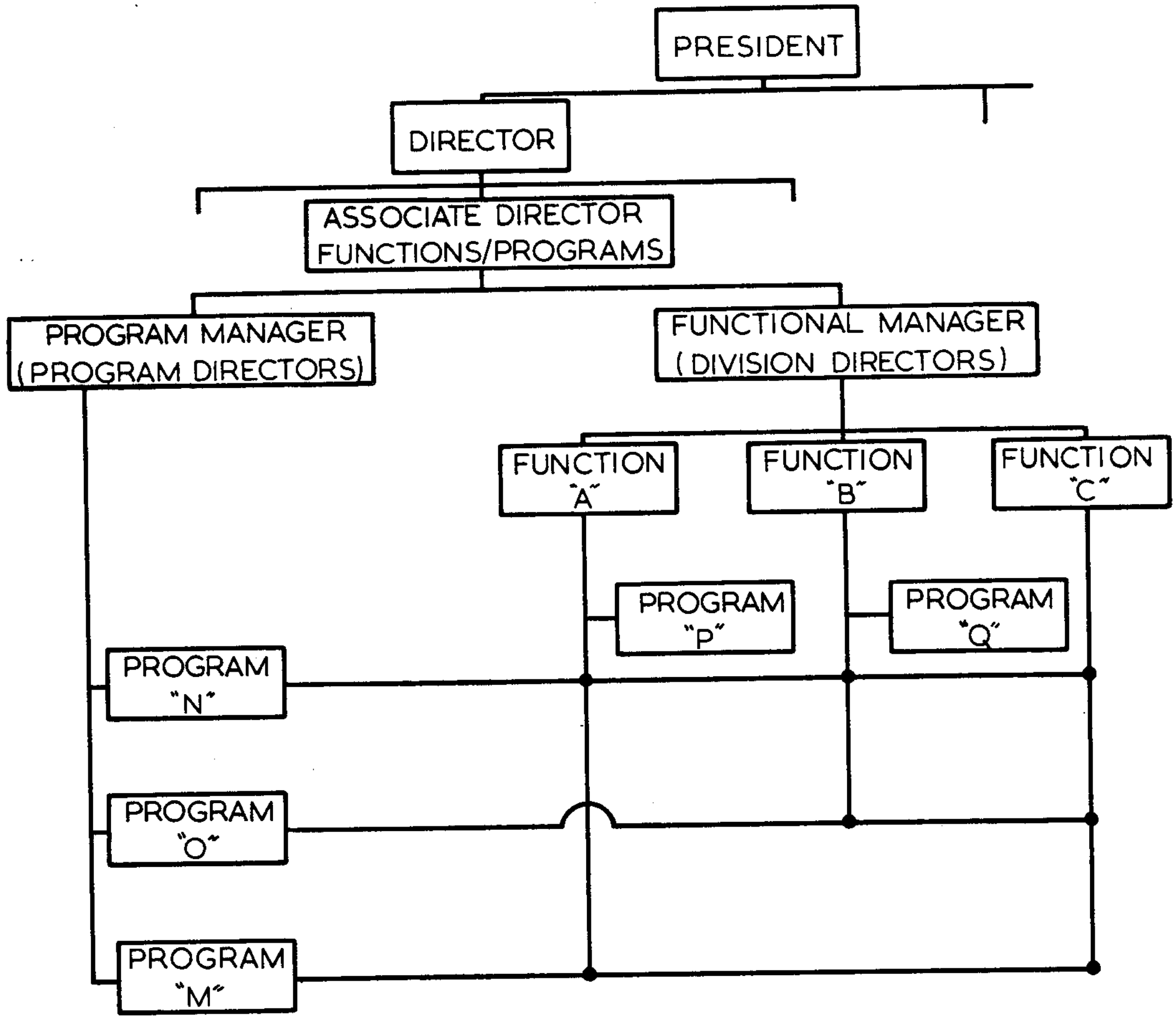

PRESIDENT
DIRECTOR
ASSOCIATE DIRECTOR
FUNCTIONS/PROGRAMS
PROGRAM MANAGER
(PROGRAM DIRECTORS)
FUNCTIONAL MANAGER
(DIVISION DIRECTORS)
FUNCTION "A"
FUNCTION "B"
FUNCTION "C"
PROGRAM "P"
PROGRAM "Q"
PROGRAM "N"
PROGRAM "O"
PROGRAM "M"

Table 1

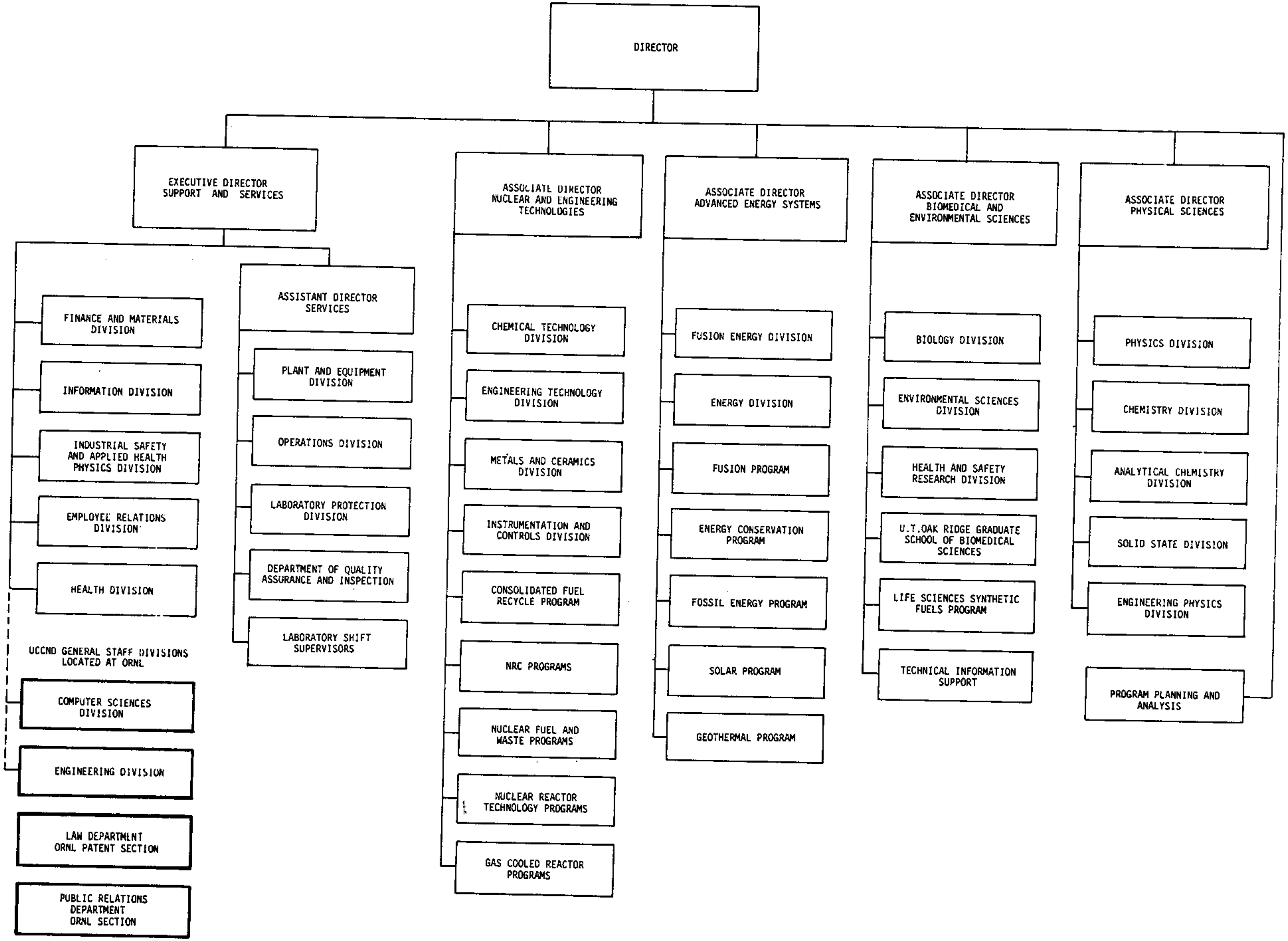
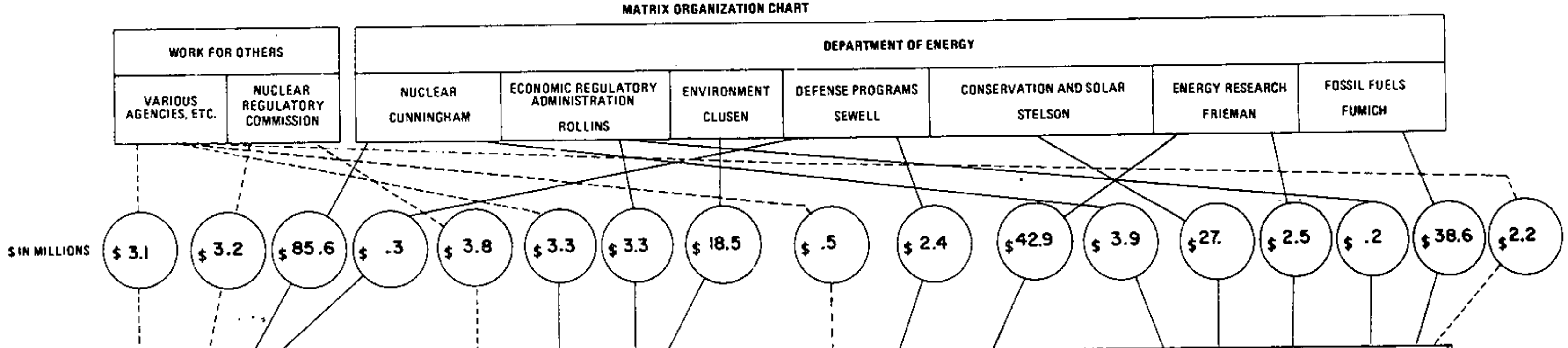

DIRECTOR
EXECUTIVE DIRECTOR SUPPORT AND SERVICES
ASSOCIATE DIRECTOR NUCLEAR AND ENGINEERING TECHNOLOGIES
ASSOCIATE DIRECTOR ADVANCED ENERGY SYSTEMS
ASSOCIATE DIRECTOR BIOMEDICAL AND ENVIRONMENTAL SCIENCES
ASSOCIATE DIRECTOR PHYSICAL SCIENCES
FINANCE AND MATERIALS DIVISION
INFORMATION DIVISION
INDUSTRIAL SAFETY AND APPLIED HEALTH PHYSICS DIVISION
EMPLOYEE RELATIONS DIVISION
HEALTH DIVISION
UCCND GENERAL STAFF DIVISIONS LOCATED AT ORNL
COMPUTER SCIENCES DIVISION
ENGINEERING DIVISION
LAW DEPARTMENT ORNL PATENT SECTION
PUBLIC RELATIONS DEPARTMENT ORNL SECTION
ASSISTANT DIRECTOR SERVICES
PLANT AND EQUIPMENT DIVISION
OPERATIONS DIVISION
LABORATORY PROTECTION DIVISION
DEPARTMENT OF QUALITY ASSURANCE AND INSPECTION
LABORATORY SHIFT SUPERVISORS
CHEMICAL TECHNOLOGY DIVISION
ENGINEERING TECHNOLOGY DIVISION
METALS AND CERAMICS DIVISION
INSTRUMENTATION AND CONTROLS DIVISION
CONSOLIDATED FUEL RECYCLE PROGRAM
NRC PROGRAMS
NUCLEAR FUEL AND WASTE PROGRAMS
NUCLEAR REACTOR TECHNOLOGY PROGRAMS
GAS COOLED REACTOR PROGRAMS
FUSION ENERGY DIVISION
ENERGY DIVISION
FUSION PROGRAM
ENERGY CONSERVATION PROGRAM
FOSSIL ENERGY PROGRAM
SOLAR PROGRAM
GEOTHERMAL PROGRAM
BIOLOGY DIVISION
ENVIRONMENTAL SCIENCES DIVISION
HEALTH AND SAFETY RESEARCH DIVISION
U.T.OAK RIDGE GRADUATE SCHOOL OF BIOMEDICAL SCIENCES
LIFE SCIENCES SYNTHETIC FUELS PROGRAM
TECHNICAL INFORMATION SUPPORT
PHYSICS DIVISION
CHEMISTRY DIVISION
ANALYTICAL CHEMISTRY DIVISION
SOLID STATE DIVISION
ENGINEERING PHYSICS DIVISION
PROGRAM PLANNING AND ANALYSIS

Table 2

# ARGONNE NATIONAL LABORATORY
## MATRIX ORGANIZATION CHART




| ANL Associate Lab. Dir. / ANL Programs & Projects / ANL Divisions | | REACTOR DEVELOPMENT J. A. KYGER | | | | | BIOMEDICAL & ENVIRONMENTAL W. K. SINCLAIR | | | | | PHYSICAL RESEARCH G. T. GARVEY | | | | | ENERGY & ENVIRONMENTAL TECHNOLOGY J. J. ROBERTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Breeder Reactor R&D | RERTA | Waste Management | NRC | Other | Biomedical & Environmental Research | Life Sciences | NRC | Regulatory Activities | Other | Basic Energy Sciences | Nuclear Physics | High Energy Physics | Inertial Confinement Fusion | Other | Fossil Energy Technology | MHD | Energy Conservation | Fusion Power | Chemical & Electrical Systems | Solar Applications | Solar Technology | Other |
| KYGER | AP | A | B | | C | D | D | | E | | | | | | | | D | | | D | | | | E |
| | CT | A | | | C | C | | | E | | | E | | | | | C | E | | E | | D | C | E |
| | EBR-II | A | | | | D | | | D | | | | | | | | | D | | | | | E | |
| | ENG | C | | | | E | | | | | | | | | | | E | B | B | E | | E | E | E |
| | MSD | B | C | D | C | D | | | | | | E | | | | | C | E | E | D | D | D | B | C |
| | RAS | A | | | D | E | | | E | | | | | | | | | | E | E | | | | |
| | SRF | C | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| SINCLAIR | BIM | | | | | | A | C | D | | D | | | | | | | | | | D | | E | |
| | RER | | | | | | B | | D | | C | | | | | | | | | E | | | | |
| | EIS | | | C | | D | C | | B | B | C | | | | | | | | E | | | | E | |
| GARVEY | AMD | | | | E | | | | E | | | C | | | | E | | E | | | | | | |
| | CHM | | E | | | D | E | E | | | | A | C | | | D | E | E | | D | | | | |
| | PHY | | | | | | | | | | | B | B | | | | | | | D | | | | |
| | MSD | | | | | | | | | | | A | | | | | | | | D | | | | |
| | SSS | | | | | | | | | | | B | | | | E | | | | E | | | E | |
| | PNS | | | | | | | | | | | C | | | | | | | | | | | | |
| | ARF | | | | | | | | | | | B | E | B | C | E | | B | | D | | | E | E |
| | HEP | | | | | | | | | | | | E | B | | E | | | | | | | | |
| ROBERTS | CEN | B | | C | E | C | E | | E | E | E | B | | | | E | B | D | E | C | A | C | | D |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | EES | | | | | | B | | E | | D | | | | | | B | | A | | C | C | A | C |

ADMINISTRATIVE RESPONSIBILITIES

A = Over $5 million
B = $2–$5 million
C = $500,000–$2 million
D = $150,000–$500,000
E = Less than $150,000

Table 3

## ATOMIC ENERGY OF CANADA LIMITED
## (6800)

| RESEARCH & DEVELOPMENT (3100) | ENGINEERING (2200) | HEAVY WATER (800) | RADIOISOTOPES & EQUIPMENT (700) |
|---|---|---|---|

- RESEARCH & DEVELOPMENT (3100)
  - Chalk River Nuclear Laboratories (CRNL) (2200)
  - Whiteshell Nuclear Research Establishment (WNRE) (900)

(XXXX) = APPROXIMATE MANPOWER

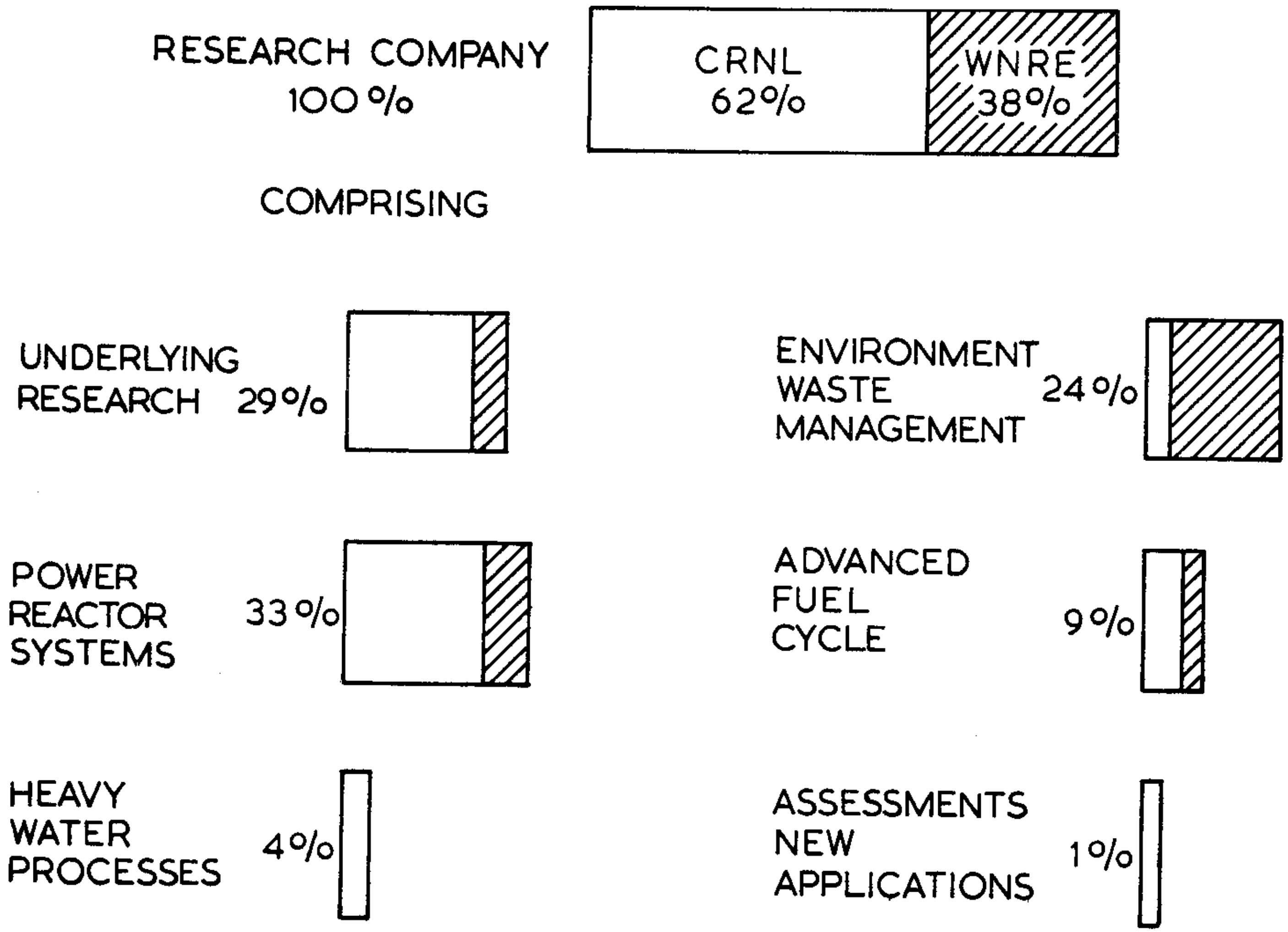
Table 4

# AECL-RC R & D PROGRAM

| POWER REACTOR SYSTEMS (30%) | ADVANCED FUEL CYCLES (10%) | ENVIRONMENT & WASTE MGT, (25%) | HEAVY WATER PROCESSES (5%) | UNDERLYING RESEARCH (28%) | NEW APPLICATIONS (2%) |
|---|---|---|---|---|---|
| • Reactor Components | • Fuel Development | • Storage & Disposal | • G, S, Process | • Physics | • Electrical Substitutions |
| • System Components | • Fuel Reprocessing | • Reactor Waste Management | • New Processes | • Chemistry | • Nuclear Process Heat |
| • System Chemistry | • Reactor Physics | • Fuel Waste Immobilization | • Tritium Removal & Storage | • Materials Science | • Waste Heat Utilization |
| • Thermohydraulics | • Assessment | • Fuel Cycle Waste Management | | • Biology | • Production of Alternative Fuels |
| • Control & Instrumentation | • Non-Proliferation | • Environmental Research | | • Advanced Systems | |
| • Fuel | | • Environmental Assessment | | | |
| | | • Safeguards | | | |

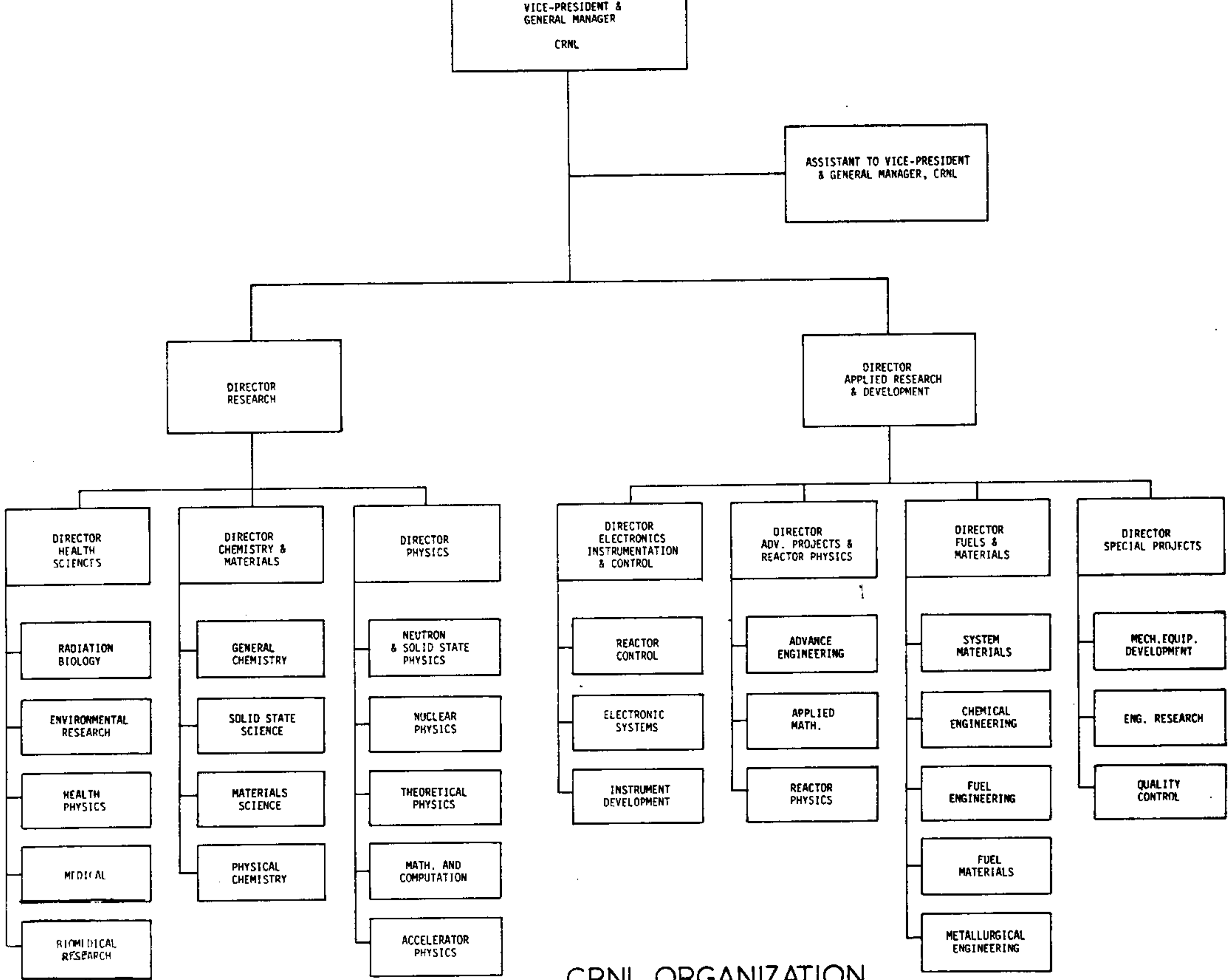
(XXX) Distribution of Effort

Table 5



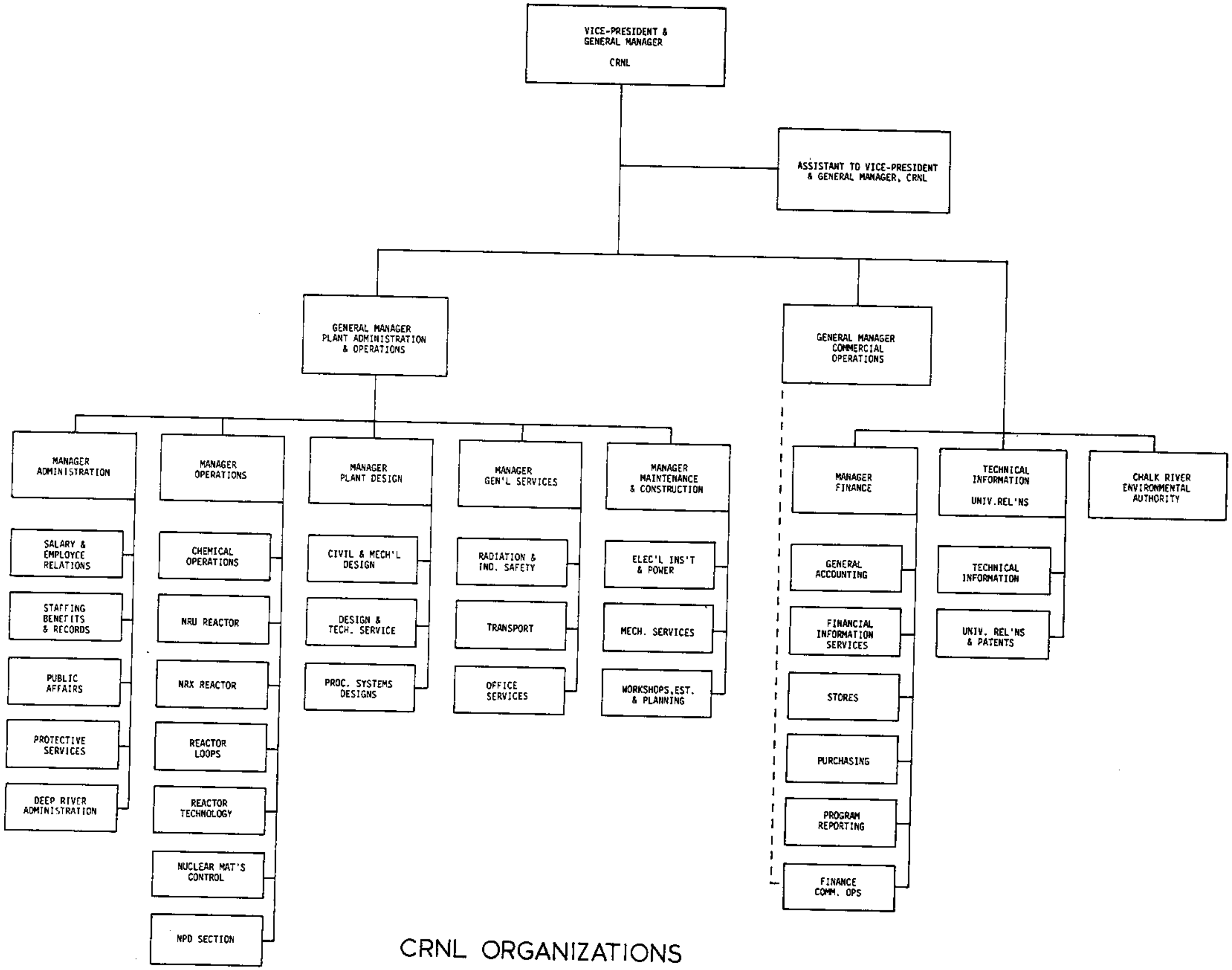

DISTRIBUTION OF PROFESSIONAL MAN-YEARS: RESEARCH AND DEVELOPMENT PROGRAM

Table 6




# CRNL ORGANIZATION (R&D)

Table 7




CRNL ORGANIZATIONS
(Administration & Commercial Operations)

Table 8

## EXAMPLES OF DIVERSIFICATION

| Nuclear field | Diversification area | Examples | |
|---|---|---|---|
| **REACTOR PHYSICS**<br>Theoretical and experimental Physicists.<br>Computers. | Industrial Process Supervision & Control.<br>Mathematical modelling of Production Processes. | —Efficiency of melting furnaces<br>—Metal casting<br>—Oil reservoir simulation<br>—Crystallization processes<br>—Energy system modelling | |
| **NUCLEAR PLANT SUPERVISION**<br>Halden Project<br>Man-machine relationship | Industrial process Supervision & Control | —Supervision of hydro power plants<br>—Control room design of oil drilling rigs<br>—Control room technology<br>—Alarm analysis | |
| **NUCLEAR SAFETY**<br>Core stability<br>(2-phase flow) | Offshore technology | —Oil well excursion warnings<br>—Engineering problems oil-gas mixture flow<br>—Gas transport high pressure | |
| | Fluidized bed techn. | —Combustion processes<br>—Calcination | |
| **FUEL REPROCESSING**<br>(Pilot plant dimantled)<br>Liquid-liquid extraction | Hydrometallurgical Industries | MEGON<br>(Metal Extractor Group of Norway) | — $Y_2O_3$ prod. plant<br>— Other Rare Earths<br>— Cu & Co refining |
| | | ANORTAL | — Pilot Plant $Al_2O_3$ |
| | Analytical Chemistry Services | Environmental surveys | — General pollution<br>— Drinking water supply supervision<br>— Heavy metal distr.<br>— Acidic rain |
| | | Mineral resources exploitation. | |

Table 9