# ANNUAL REPORT

1 July 1974 - 30 June 1975

GC(XIX)/544

Printed by the
International Atomic Energy Agency
in Austria - July 1975

INTERNATIONAL ATOMIC ENERGY AGENCY

CONTENTS

## List of abbreviations

| | |
|---|---|
| Agency | International Atomic Energy Agency |
| CINDA | Computer Index of Neutron Data |
| CRP | Co-ordinated Research Programme |
| ECE | Economic Commission for Europe |
| FAO | Food and Agriculture Organization of the United Nations |
| IAEA | International Atomic Energy Agency |
| ICRP | International Commission on Radiological Protection |
| IIASA | International Institute for Applied Systems Analysis |
| ILO | International Labour Organisation |
| INIS | International Nuclear Information System |
| MHD | Magnetohydrodynamics |
| MW | Megawatts (electric) |
| NEA | Nuclear Energy Agency of the Organisation for Economic Co-operation and Development |
| NPT | Treaty on the Non-Proliferation of Nuclear Weapons (reproduced in document INFCIRC/140) |
| PNE | Nuclear explosions for peaceful purposes |
| SIDA | Swedish International Development Authority |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNIDO | United Nations Industrial Development Organization |
| UNSCEAR | United Nations Scientific Committee on the Effects of Atomic Radiation |
| WHO | World Health Organization |

NOTE

All sums of money are expressed in United States dollars.

# INTRODUCTION

## General

1. A consequence of the rapid growth of nuclear technology, spurred on chiefly by the rise in the price of fossil fuels, is that a number of the Agency's programmes, such as the introduction of nuclear power and other major nuclear technologies in Member States, the application of safeguards and the physical protection of nuclear materials, and nuclear safety and environmental protection merit expansion. One of the Agency's main preoccupations is therefore to find the resources needed for such expansion at a time when it and several of its Members are experiencing severe economic difficulties.

## Nuclear power and nuclear safety

2. The development of the use of nuclear energy during the last five years has been impressive. The more than four-fold increase in the price of fossil fuels is sharpening the competitive advantage of nuclear power over other sources of energy for generating electricity. It is becoming increasingly clear that for the next two decades, if not longer, nuclear power from fission will offer the only practical means of reducing the world's dependence on fossil fuels. In almost every situation where a power station even as small as 100 MW comes to be needed, the nuclear option will have to be considered.

3. These trends are illustrated by the following statistics. The total nuclear power capacity installed throughout the world amounted to 16 300 MW in 1970. By the end of 1975 it will be almost 82 000 MW, and by 1980 it is expected to be over 220 000 MW. The capacity of nuclear power plants ordered in 1974, namely about 75 000 MW, was larger than in any previous year.

4. The problems of raising the large amounts of capital needed for nuclear power plants themselves and for other components of the fuel cycle have contributed to a temporary decline in new orders. It is often difficult to increase the selling price of electricity sufficiently to offset the rise in fuel costs, which in turn makes it difficult to use earnings to create capital. This tends to affect nuclear power plants more than other thermal power plants because of the higher initial cost of nuclear plant which is offset only later by lower generating costs. The capital cost of nuclear plants and their availability to meet immediate needs have also been affected in some countries by "environmentalist" concern which has caused delays in plant construction and commissioning. These factors have, however, been offset in some other countries, particularly in Europe, by large-scale new nuclear energy programmes.

5. The number of States embarking on nuclear power programmes also continues to grow. A review of the survey made by the Agency in 1972-73 of the market in developing States for nuclear power has confirmed the large scope of this market and the need to develop smaller plants. It is therefore imperative to give high priority to questions of nuclear safety, the training of operating and safety personnel, the provision of economic and other advisory services to Member States, particularly developing States, and the stimulation of the interest of manufacturers by encouraging buyers to co-operate in placing orders for the same type of plant. These priorities are reflected in the Agency's programmes.

6. There is also increasing interest in the concept of nuclear fuel cycle centres to provide the means of meeting economically the reprocessing and waste management needs of groups of countries or, indeed, of entire regions; such centres would also present advantages from the safeguards and physical security points of view. On the other hand there are obvious administrative, legal, financial and policy problems involved in establishing such centres. The Agency's study of this matter is progressing, and it is hoped that preliminary results will be available before the end of 1976.

7. The main obstacles encountered by developing countries in initiating their nuclear power programmes are problems of financing and the shortage of trained technical and administrative manpower. In this context the Agency has begun to hold a series of regional seminars and training courses, and it is also sending an increasing number of missions to Member States to advise on nuclear law and safety regulations, on specific problems of plant location and on safety measures. The important project planned last year for the Agency and experts from Member States to prepare a comprehensive system of internationally acceptable codes and guides on the siting, safety and reliability of nuclear power plants has been launched; the senior advisory group which has been appointed to direct this work has mapped out the full scope of the codes and guides that will be needed in the next few years, and work has already been started on five codes of practice for nuclear reactor safety. A guide-book on nuclear waste management will shortly be issued, as well as a document on the selection of waste disposal sites.[1]

Technical co-operation

8. The Agency's increased emphasis on nuclear power and safety is reflected in its technical assistance activities also. The target for voluntary contributions to the General Fund which are used to finance the Agency's own programme of assistance was raised from $3 million for 1974 to $4.5 million for 1975 [2], and the Board has recommended a further increase to $5.5 million in 1976 [3]. The percentage of the target which has been reached in recent years is also encouraging. The total value of resources available for "developing-country-oriented" activities rose from $9 895 000 in 1974 to an estimated $13 975 000 in 1975; of these amounts, $6 260 000 and $9 577 000 represented in 1974 and 1975 respectively the budgetary resources of the Agency and gifts to it in kind, the remainder being made up from extra-budgetary sources, chiefly funds provided by UNDP. The number of large-scale projects that the Agency is executing for UNDP increased from 15 in mid-1974 to 19 in mid-1975. Such projects represent an increasing proportion of the total value of technical assistance provided by the Agency; there is a growing trend for them to cover industrial applications of nuclear energy and the development of nuclear raw materials.

Safeguards and the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

9. In 1970, 11 States other than the nuclear-weapon States were operating nuclear power plants. The capacity of these plants amounted to about 5000 MW, of which nearly half was under the Agency's safeguards. By mid-1975 the total nuclear power capacity outside the nuclear-weapon States had grown to 24 000 MW in 15 countries. Following the ratification of NPT by five non-nuclear-weapon States members of the European Atomic Energy Community (Belgium, the Federal Republic of Germany, Italy, Luxembourg and the Netherlands), on 2 May 1975, almost all the installed nuclear power capacity in those 15 countries will now come under the Agency's safeguards.

---

[1] For further details of the project, see documents GC(XVIII)/526, para. J.144 and GC(XVIII)/526/Mod.1.

[2] See Resolutions GC(XVII)/RES/305, para. 1 and GC(XVIII)/RES/315, para.1.

[3] See document GC(XIX)/550, Annex V, draft resolution B, para. 1.

10. The importance of the decision of those five States to ratify NPT has been widely recognized and was acclaimed by many participants in the Review Conference of the Parties to NPT [4]. It is the most significant step taken so far to encourage adherence to NPT by all non-nuclear-weapon States throughout the world and is expected to give NPT new strength and momentum.

11. During the period covered by this report 16 further safeguards agreements in connection with NPT were signed or entered into force. Five more agreements were also approved by the Board of Governors including one with Japan which although not a party to NPT had indicated that the conclusion of a satisfactory safeguards agreement with the Agency was a prior condition for ratification of NPT. The situation on 30 June was accordingly as follows:

| | |
|---|---|
| Non-nuclear-weapon States party to NPT | 93 |
| Non-nuclear-weapon States signatories of, but not then party to, NPT | 15 |
| Non-nuclear-weapon States that had concluded the safeguards agreements required in connection with NPT | 53 |
| Safeguards agreements in connection with NPT in force | 43 |

12. By 30 June five further agreements concluded on the basis of the Agency's safeguards system which has operated since 1968 [5] had entered into force. Safeguards based on this system were then being applied in 20 countries.

13. A number of steps have been taken to clarify the scope and duration of safeguards agreements concluded outside the framework of NPT, and these clarifications are being reflected in new agreements. Consideration is also being given to the elaboration of standard agreements for States that are not party to NPT but wish to arrange for the application of safeguards to all nuclear imports or to certain categories of such imports.

14. It is expected that the Agency's safeguards analytical laboratory will be commissioned this year. With help from Member States, the Secretariat is making progress in introducing the use of new safeguards instruments and inspection practices.

15. The negotiation of agreements to implement the voluntary offers of the United Kingdom of Great Britain and Northern Ireland and the United States of America in connection with the application of safeguards in those two Member States is now reaching a final stage.

Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons

16. The Agency was represented at the Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, to which it submitted reports on its safeguards work, on its work in connection with PNE and, in relation to Article IV of NPT, on the provision of technical assistance and related activities. In addition the Secretariat provided some staff for the Conference.

---

[4] See paras 16 and 17 below.

[5] The Agency's Safeguards System (1965, as Provisionally Extended in 1966 and 1968) set forth in document INFCIRC/66/Rev.2.

17. The Conference took place at Geneva from 5-30 May; 58 States party to NPT and seven States signatory but not party participated in it. A further seven States were represented at it. Strong support was given to the Agency's safeguards programmes, its work on the physical protection of nuclear material, its study of the concept of nuclear fuel cycle centres and its work in relation to PNE. The Conference recommended that the Agency should increase its technical assistance and related activities for the benefit of developing States party to NPT. It also paid attention to the export policies of Parties and urged that

> "in all achievable ways, common export requirements relating to safeguards be strengthened, in particular by extending the application of safeguards to all peaceful nuclear activities in importing States not Party to the Treaty" [6].

The Conference also stated that it considered the Agency to be

> "the appropriate international body, referred to in Article V of the Treaty, through which potential benefits from peaceful applications of nuclear explosions could be made available to any non-nuclear-weapon State" [7].

Applications of nuclear techniques

18. For a large number of the Agency's Members, particularly those developing States for which nuclear energy is not yet a feasible means of generating electricity, the applications of isotopes and radiation in medicine and the life sciences, in food and agriculture, in the development of water resources and in certain industrial processes continue to constitute the most economically useful parts of the Agency's work.

19. Following recommendations made by the World Food Conference in Rome in November 1974, the Agency and FAO are giving priority to research projects designed to conserve and make better use of fertilizers (especially those containing nitrogen) to improve crops (especially the staple foods in developing countries) and to develop and make better use of ground and other irrigation water. In addition the joint FAO/IAEA programme is giving higher priority to preventing contamination of farm products and pollution of rivers and lakes. The Agency has also begun a new programme to encourage the use of nuclear techniques in certain environmental research.

20. In the physical sciences an important international conference took place in Tokyo in November 1974 to review the potentialities of controlled nuclear fusion as an energy source in the future. Sufficient theoretical and experimental progress has now been made to start the design of large experimental machines which could be the forerunners of nuclear fusion reactors.

21. The International Laboratory of Marine Radioactivity in Monaco is now co-ordinating research on the non-nuclear pollution of sea-water with funds from UNEP.

22. In the context of industrial applications of radioisotopes and radiation the Agency is now executing six large-scale projects for UNDP, five of which involve the use of radiation to sterilize medical products.

---

[6] See under "Review of Article III" seventh paragraph, in the Conference's Final Declaration, reproduced under cover of document INFCIRC/222.

[7] Ibid., under "Review of Article V", INFCIRC/222 third paragraph.

The conference on nuclear power and its fuel cycle planned for 1977

23. Preliminary arrangements are being made for a major conference in 1977 on nuclear power and its fuel cycle. It is expected that it will be held early in May, probably in Salzburg, Austria. Particular attention will be given to the nuclear fuel cycle and to the need for considering the international, regional or national arrangements that should be made for meeting fuel cycle requirements - enrichment, fabrication, reprocessing and waste management, and their relationship to each other - as a basic factor to be taken into account in planning national nuclear programmes. Other main items of the programme will be the management of radioactivity, the technical aspects of nuclear safety and the factors affecting the successful introduction of nuclear power in developing countries.

The use of nuclear explosions for peaceful purposes

24. In January 1975 a unit was established in the Secretariat to handle all requests for services relating to PNE, to promote the exchange of information on this technology and to undertake or arrange feasibility, safety, economic and other relevant studies. In the same month the Agency's technical committee on PNE reviewed recent developments in the technology.

25. The Board considered the use of PNE in February and June 1975, and on the latter occasion established an Ad Hoc Advisory Group on Nuclear Explosions for Peaceful Purposes. The Group will be under the aegis of the Board, but will be open to participation by all interested Members of the Agency. It will deal with all aspects of PNE within the Agency's competence, such as procedures for handling any request for PNE-related services, legal aspects and treaty obligations, health and safety matters, and economic aspects, including comparisons with non-nuclear alternatives. It will advise the Board on the question of an international service for PNE, as well as on the structure and contents of the agreements that will be necessary under Article V of NPT. The Group may invite States party to NPT but not members of the Agency to take part in its work.

Matters of particular interest to the United Nations

26. It is believed that the General Assembly of the United Nations will be interested in those of the foregoing paragraphs that deal with safeguards and NPT (9-15), the Review Conference of the Parties to NPT (16-17) and PNE (24-25). In the light of paragraph 2 of its Resolution 3261 D (XXIX), the Assembly may also wish to note in particular paragraphs 113-117 below, parts I and II of Annex A to this report, dealing with the Agency's work in regard to PNE, and part III of Annex A where the Board's resolution establishing the Advisory Group mentioned in paragraph 25 above is reproduced. In relation to paragraph 3 of the Assembly's resolution, the Agency has taken steps to bring these parts of the report and its Annex A to the attention of the Conference of the Committee on Disarmament.

27. The increasing use of nuclear energy referred to at the beginning of this Introduction has led the Agency to develop closer contacts with the International Bank for Reconstruction and Development and it has also helped the Economic Commission for Africa and the Economic and Social Commission for Asia and the Pacific in making assessments of the status of the prospects for the introduction of nuclear power in developing countries.

Co-operation with other organizations inthe United Nations family has generally been very good and the Agency is now receiving assistance from UNEP for carrying out a number of projects. The Secretariat has invited UNEP both to support and to join in the Agency's work on nuclear safety codes and guides referred to in paragraph 7 above, and the Board hopes that UNEP may see its way to doing so.

# THE AGENCY'S ACTIVITIES

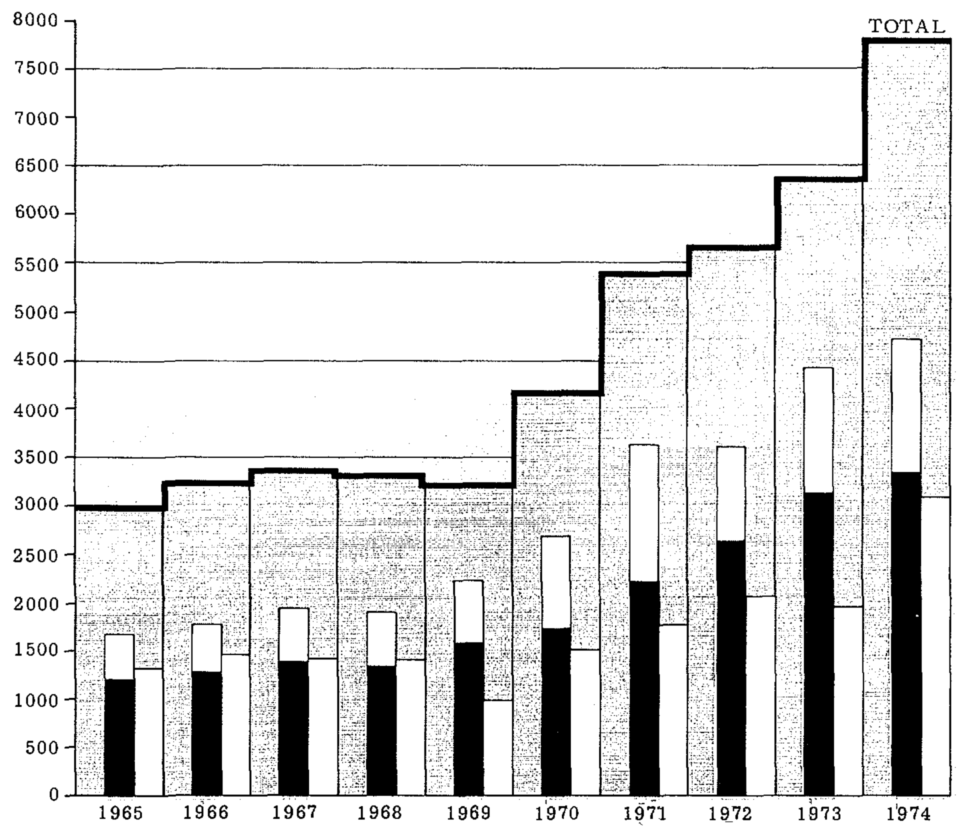
## TECHNICAL CO-OPERATION

### General

28. In 1974 approximately 7.8 million dollars were available for technical assistance and training compared with about 6.4 million dollars in 1973. The resources available for the Agency's technical assistance programmes during the period 1965-1974 are shown in Figure 1 below, while the distribution of technical assistance by field of activity and region in 1974 is illustrated in Figure 2.

FIGURE 1

RESOURCES AVAILABLE FOR
AGENCY TECHNICAL ASSISTANCE PROGRAMMES: 1965-1974
(in thousands of dollars)

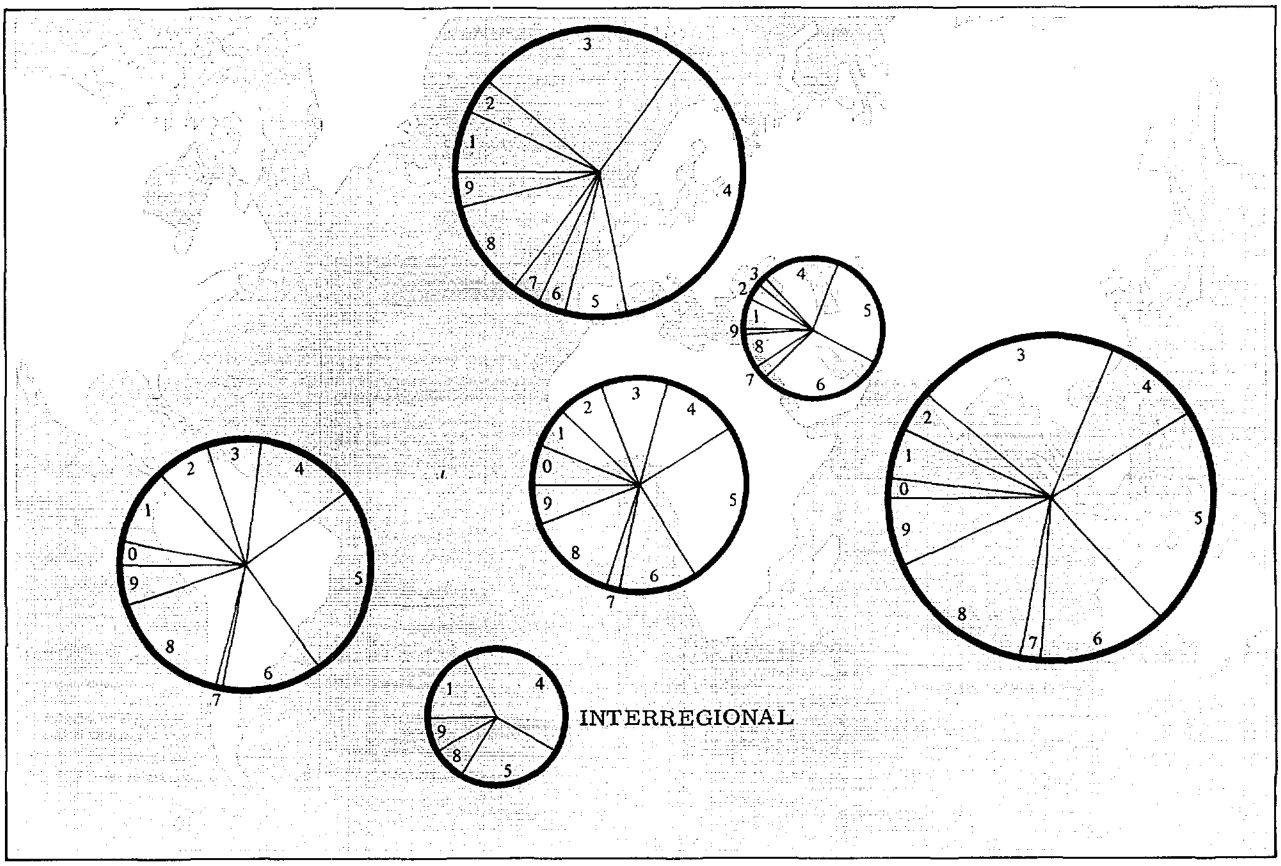



| | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 |
|---|---|---|---|---|---|---|---|---|---|---|
| Agency monetary | 1200 | 1263 | 1380 | 1348 | 1586 | 1749 | 2224 | 2636 | 3123 | 3344 |
| Assistance in kind | 497 | 528 | 570 | 565 | 658 | 932 | 1410 | 968 | 1304 | 1389 |
| UNDP monetary | 1317 | 1462 | 1431 | 1422 | 981 | 1513 | 1775 | 2072 | 1964 | 3082 |
| TOTAL | 3014 | 3253 | 3381 | 3334 | 3225 | 4194 | 5409 | 5676 | 6391 | 7815 |

Agency monetary    Assistance in kind    UNDP monetary

FIGURE 2

DISTRIBUTION OF TECHNICAL ASSISTANCE BY FIELD OF ACTIVITY AND REGION: 1974[a]




SUMMARY

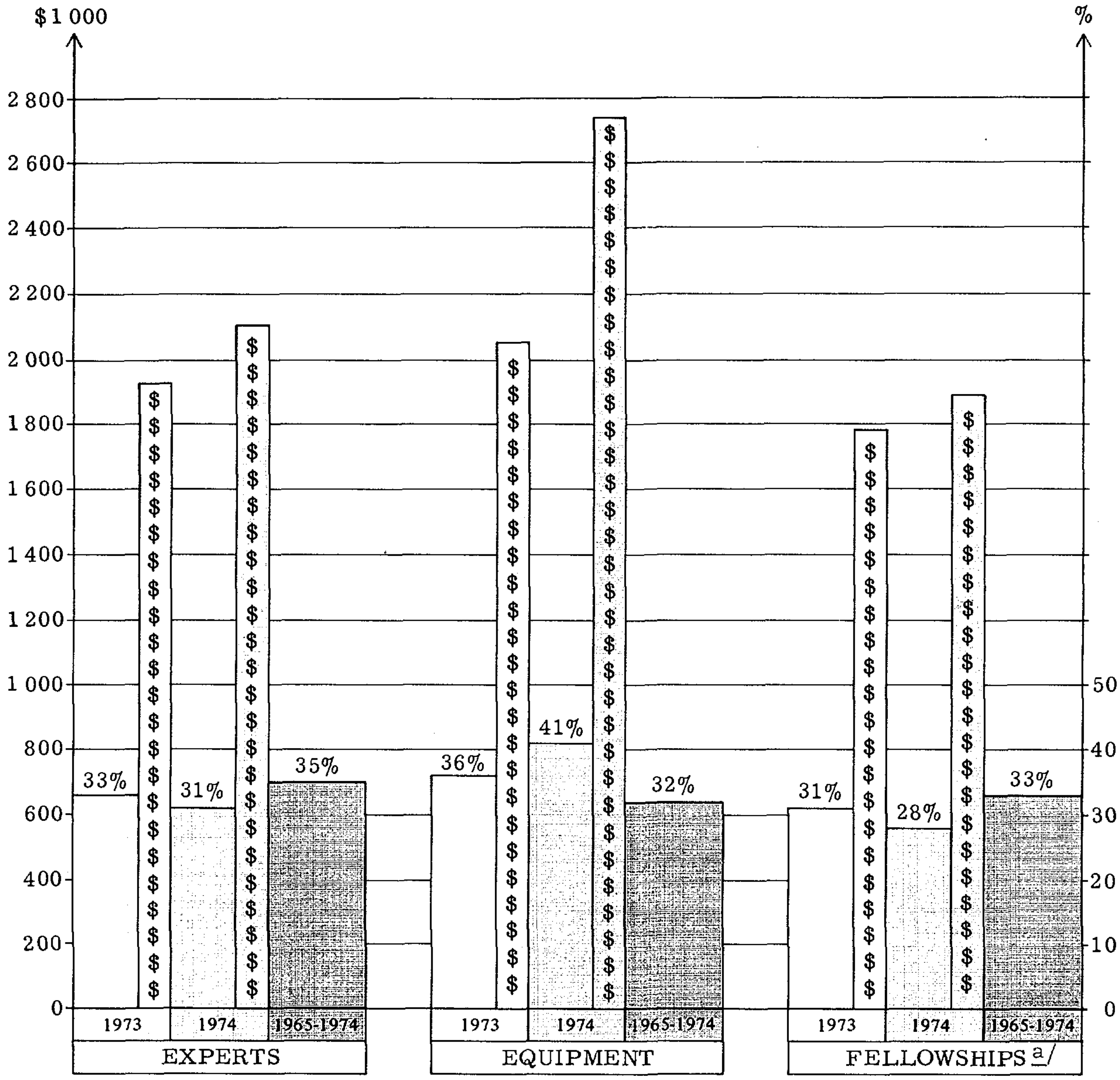
| Field of activity | | Africa % | Asia and the Far East % | Europe % | Latin America % | Middle East % | Inter-regional % | All regions % |
|---|---|---|---|---|---|---|---|---|
| 0 - General atomic energy development | | 6 | 2 | – | 3 | – | – | 2 |
| 1 - Nuclear physics | | 6 | 5 | 7 | 10 | 7 | 18 | 8 |
| 2 - Nuclear chemistry | | 7 | 4 | 4 | 7 | 4 | – | 5 |
| 3 - Prospecting, mining and processing of nuclear materials | | 10 | 20 | 24 | 7 | 2 | – | 15 |
| 4 - Nuclear engineering and technology | | 12 | 10 | 37 | 13 | 18 | 40 | 20 |
| Application of isotopes and radiation in | 5 - Agriculture | 25 | 22 | 7 | 25 | 27 | 26 | 20 |
| | 6 - Medicine | 12 | 13 | 3 | 13 | 30 | – | 10 |
| | 7 - Biology | 2 | 2 | 3 | 1 | 3 | – | 2 |
| | 8 - Other fields | 14 | 15 | 11 | 16 | 8 | 8 | 13 |
| 9 - Safety in nuclear energy | | 6 | 7 | 4 | 5 | 1 | 8 | 5 |
| | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

[a] For each region, the relative monetary value of the technical assistance provided by the Agency is denoted by the size of the circle superimposed over the region on the map. The size of the segments in each circle indicates the share of total assistance given in the various fields of activity.

29. The distribution of technical assistance by type of assistance during the last two years and during the decade 1965-1974 is illustrated in Figure 3.

FIGURE 3

DISTRIBUTION OF TECHNICAL ASSISTANCE BY TYPE OF ASSISTANCE
(1973, 1974 and 1965-1974)



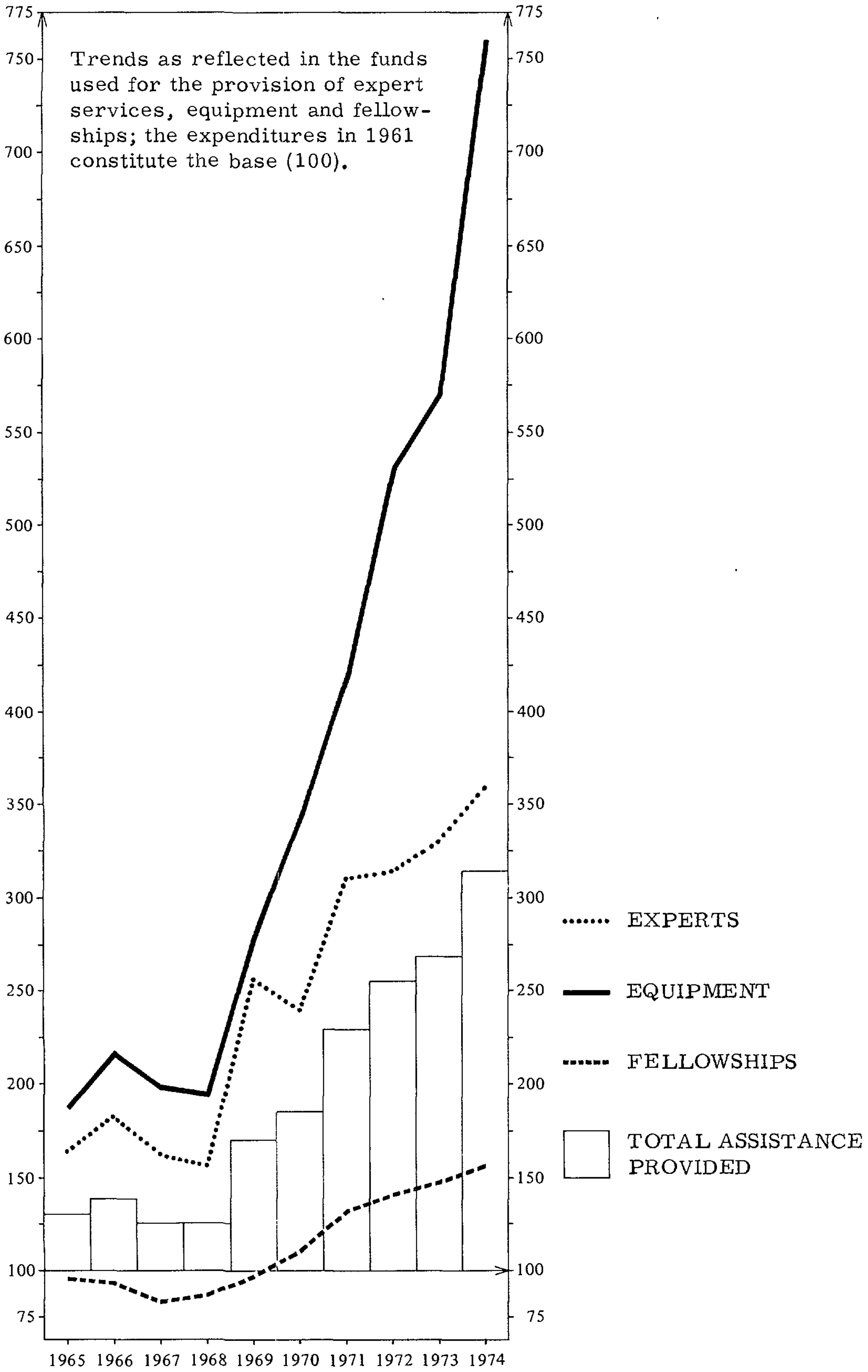

| TYPE | 1973 | | 1974 | | 1965-1974 | |
|---|---|---|---|---|---|---|
| | % | $1 000 | % | $1 000 | % | $1 000 |
| EXPERTS | 33 | 1 926.5 | 31 | 2 103.6 | 35 | 14 451.4 |
| EQUIPMENT | 36 | 2 055.3 | 41 | 2 742.9 | 32 | 13 380.9 |
| FELLOWSHIPS | 31 | 1 784.9 | 28 | 1 890.8 | 33 | 13 874.8 |
| TOTAL | 100 | 5 766.7 | 100 | 6 737.3 | 100 | 41 797.1 |

a/ Fellowships include participants in short-term training projects.

30. The trends in the distribution of funds for the provision of the main types of technical assistance are illustrated in Figure 4.

FIGURE 4

TRENDS IN THE TECHNICAL CO-OPERATION ACTIVITIES OF THE AGENCY



Training

31. A list of the fellowships made available to the Agency free of charge by Member States in 1974 is given in Annex B. Some of the "Type II" fellowship openings were carried over from a previous year's offer.

32. Table 1 below gives an analysis of the ten training courses, a review course, a seminar and a regional project on health and safety measures that the Agency conducted in 17 countries from mid-1974 to mid-1975.

Table 1

Regional and interregional short-term training projects

| Project | Place and dates | Total number of participants | Source of funds |
|---|---|---|---|
| Regional training course for radioisotope laboratory technicians | Kwabenya, Ghana 8 July to 25 October 1974 | 25 | UNDP |
| Interregional training course on the use, design and maintenance of nuclear and related electronic equipment | Turin, Italy 2 September to 29 November 1974 | 19 | UNDP |
| Interregional training course on plant breeding for disease resistance, including the utilization of induced mutation techniques | Casaccia, Italy 23 September to 31 October 1974 | 21 | SIDA |
| Regional training course on radioimmunoassay procedures | Lima 7 to 31 October 1974 | 30 | UNDP |
| Interregional review course on reactor burn-up physics | Mol, Belgium 7 to 18 October 1974 | 29 | Regular programme and the Government of Belgium |
| Interregional training course on the use of isotope techniques for studying the fate of pesticides and other foreign chemicals in food and agriculture | São Paulo, Brazil 14 October to 15 November 1974 | 20 | SIDA |
| Regional training course on uranium and thorium prospecting and evaluation | India 4 November to 28 December 1974 | 12 | UNDP |
| Advanced regional training course on radiological health and safety measures | Mexico City 18 November to 6 December 1974 | 19 | UNDP |

| Project | Place and dates | Total number of participants | Source of funds |
| --- | --- | --- | --- |
| Interregional training course on activation analysis in industry and research | Berlin (West) 25 November to 6 December 1974 | 14 | Regular programme, the Government of the Federal Republic of Germany and the Senat |
| Regional project on radiological health and safety measures | East and West Africa January to December 1975 | 87 | UNDP |
| Interregional training course on methods and technical bases of nuclear energy regulation | Bethesda, Maryland 28 April to 16 May 1975 | 31 | Regular programme and Government of the United States of America |
| Interregional seminar on the preparation and implementation of nuclear power projects | Kingston, Jamaica 9 to 20 June 1975 | 37 | UNDP |
| Interregional training course on radioimmunoassay techniques | Poznan, Poland 15 to 28 June 1975 | 24 | Regular programme |

UNDP projects

33. On 30 June 1975, the Agency was carrying out the 19 large-scale UNDP projects which are summarized in Table 2 below, compared with 15 on the same date in 1974. The growing importance of these projects is shown by the fact that while they represented only 15% of the total technical assistance provided by the Agency in 1965, they increased to 22% in 1973 and to 33% in 1974. It is expected that the volume of assistance provided under large-scale projects will continue to increase.

Table 2

Large-scale projects for which the Agency is the executing agency

| Recipient country and title of the project | Start of field operations | Project duration (years) | Government contribution (in local currency) | UNDP contribution (in dollars) |
| --- | --- | --- | --- | --- |
| ARGENTINA, National centre for non-destructive testing and quality control[a] | March 1973 | 3.0 | 11 157 300 new pesos | 594 600 |
| BRAZIL, Application of nuclear technology in agriculture | September 1972 | 5.0 | 12 433 310 cruzeiros | 1 266 000 |

| Recipient country and title of the project | Start of field operations | Project duration (years) | Government contribution (in local currency) | UNDP contribution (in dollars) |
|---|---|---|---|---|
| CHILE, Technological applications of nuclear energy | January 1974 | 3.5 | 46 900 000 escudos | 790 000 |
| CHILE, Uranium prospecting | 1975 | 3.0 | 1 016 200 000 escudos | 939 400 |
| EGYPT, Radiation dosimetry after accidents | November 1971 | 4.0 | 80 000 Egyptian pounds | 166 200 |
| EGYPT, National centre for radiation technology | February 1975 | 3.0 | 1 701 208 Egyptian pounds | 750 900 |
| GREECE, Exploration for uranium in Central and Eastern Macedonia and Thrace[b] | May 1971 | 4.5 | 31 256 000 drachmae | 619 200 |
| HUNGARY, Irradiation sterilization of medical products | June 1974 | 4.0 | 91 052 000 forints | 615 600 |
| INDIA, Demonstration plant for the irradiation sterilization of medical products | May 1972 | 3.0 | 4 552 500 rupees | 660 600 |
| INDONESIA, Mutation breeding | May 1972 | 4.0 | 4 000 000 new rupiahs | 149 000 |
| REPUBLIC OF KOREA, Radiation processing demonstration facility | April 1974 | 3.0 | 340 360 000 won | 475 000 |
| MOROCCO, Use of radio-isotopes in agriculture | September 1973 | 3.0 | 930 000 dirham | 188 200 |
| MOROCCO, Training and research in applied nuclear physics at the Faculty of Sciences, Rabat | August 1974 | 3.5 | 1 022 750 dirham | 467 300 |
| NIGERIA, Insecticidal investigations for tsetse fly eradication | June 1974 | 3.0 | 89 800 naira | 141 200 |
| PAKISTAN, Exploration for uranium in the Siwalik sandstones, Dera Ghazi Khan District[b] | September 1971 | 5.0 | 12 869 100 rupees | 1 354 000 |

| Recipient country and title of the project | Start of field operations | Project duration (years) | Government contribution (in local currency) | UNDP contribution (in dollars) |
|---|---|---|---|---|
| ROMANIA, Development of nuclear technology | February 1973 | 3.0 | 119 985 500 lei | 1 366 500 |
| TURKEY, Exploration for uranium in South-West Anatolia | January 1974 | 3.0 | 9 613 000 liras | 647 300 |
| YUGOSLAVIA, Radiation unit for the industrial application of ionizing radiation | June 1975 | 3.5 | 6 830 000 dinars | 411 400 |
| ZAMBIA, Radioisotope applications | October 1970 | 5.0 | 147 624 kwacha | 151 500 |

a/ Implemented in association with UNIDO.

b/ Implemented in association with the United Nations.

National centre for non-destructive testing and quality control in Argentina
(Duration: 1973 to 1975)

34. The objectives of this project are manifold: to strengthen the capability of the National Atomic Energy Commission's non-destructive testing (NDT) group in a new centre to be established to provide a better and broader based NDT service to Argentine industry, to provide specialized training for engineers and technicians, and to help in the standardization of existing and the development of new NDT methods for industrial use. The centre will also serve as a focal point for work on the use of NDT techniques in the construction and operation of nuclear power stations.

Application of nuclear technology in agriculture in Brazil
(Duration: 1972 to 1977)

35. Until recently most of the activities being carried out under this project at the Centre of Nuclear Energy in Agriculture in Piracicaba have been concentrated on devising ways and means of increasing the production of beans (*Phaseolus vulgaris*) which constitute an important source of protein for human consumption. To this end work has been started in plant breeding, including the production of improved varieties resistant to pests and diseases, and in plant nutrition as well as in developing efficient practices for the application of fertilizer. Research is also being conducted in entomology to develop improved methods for combating insect pests that damage beans, citrus fruit and sugar cane. Pesticide tracer studies, water utilization investigations and work in the animal sciences round out the centre's programme. More emphasis will be placed on work in the animal sciences when the new building and associated laboratory facilities, at present under construction and scheduled to be ready for use by the end of 1975, are available.

Technological applications of nuclear energy in Chile
(Duration: 1974 to 1977)

36. At the site of the research reactor at La Reina, Santiago, the Agency is assisting the Government of Chile in establishing a nuclear centre, with staff qualified in the following subjects: nuclear engineering, to operate and design nuclear reactors; isotope hydrology techniques; non-destructive testing methodology; the production of isotopes for use in agriculture, industry and other research areas; the production of radio-pharmaceuticals required in therapy and medical research; radiochemistry, for work in activation analysis and in the monitoring of background radiation in the environment; food and agriculture, for work with labelled fertilizers and food preservation studies; radiological protection, for the protection of the centre's staff and the environment; and, in assisting in the country's programme to train health physicists and radiotherapists.

Uranium prospecting in Chile
(Duration: 1975 to 1978)

37. Assistance is to be provided to the Chilean Nuclear Energy Commission to establish an organization, the National Radioactive Resources Plan, which will be responsible for the exploration for and the development of uranium ore. The major Agency/UNDP contribution to the project consists of training the counterpart staff in the latest techniques for uranium prospecting. Advisers recruited by the Agency will first conduct a reconnaissance survey to determine the areas which should be subjected to more detailed study. Project activities are expected to get under way during the second half of 1975.

Radiation dosimetry after accidents in Egypt
(Duration: 1971 to 1975)

38. The main purpose of this project is to carry out laboratory investigations of the most reliable techniques for the assessment of the intensity of radiation (neutron and gamma rays) released into the environment and of the concentration of radioactivity in the air, in the event of a radiation accident. The analytical instruments needed for this work have been provided and counterpart staff are receiving specialized training abroad as preparation for the assignment of an Agency-provided consultant and to enable them to work independently thereafter. Expert services will be provided in 1975, as planned.

National centre for radiation technology in Egypt
(Duration: 1975 to 1977)

39. The centre will house a radiation facility which will be used to determine the economic feasibility of radiation processing on an industrial scale. Two areas in which studies of this kind could produce an early impact are cited as examples of the likely future activities of the centre: first, the radiation sterilization of pre-packaged medical supplies (such as sutures, cotton wool, single-use syringes, needles and infusion sets) and pharmaceuticals which would be of importance to meet local needs and for export; and second, the improvement or modification of the characteristics of cotton and cotton/synthetic-fibre fabrics by means of radiation processing, plus the use of wood-plastics for bobbins and shuttles, which should make it possible to expand the output and lower the production costs of the country's textile industry. The obvious advantage to the economy in making changes in the structure of the textile industry would be the creation of new jobs for the manufacture of finished products from cotton, which is now exported primarily as a raw material, and a more efficient utilization of the country's capacity in the production of synthetic fibres.

Exploration for uranium in Central and Eastern Macedonia and Thrace, Greece - Phase II
(Duration: 1971 to 1977)

40. This project is designed to explore for and find significant uranium occurrences which can be developed and utilized in connection with the Government's long-term power generation programme. The work is now being concentrated on examining in more detail promising uranium occurrences which were located during the reconnaissance phase of the project. The training of counterpart staff continues to be an important activity, and test drilling has already commenced.

Irradiation sterilization of medical products in Hungary
(Duration: 1974 to 1977)

41. This project provides for the establishment of a cobalt-60 irradiation facility at Debrecen for the sterilization of medical supplies totalling 6000 cubic metres in volume annually. Equipment has been ordered and will be installed in 1976. Construction of the building to house the facility has commenced and is scheduled to be completed in 1975. The training of counterpart staff is continuing, as planned.

Demonstration plant for the irradiation sterilization of medical products in India
(Duration: 1972 to 1975)

42. The irradiation sterilization plant, ISOMED, was commissioned in January 1974, two years after the project was started. The facility has operated continuously since then, serving some 25 customers in the Bombay area. In December 1974 ISOMED was irradiating 35 medical/pharmaceutical items on a regular basis and conducting feasibility (trial irradiation) studies of 25 other products. Of particular significance are the efforts to utilize the facility to sterilize locally produced contraceptive devices in support of the Government's family planning programme. The project has satisfactorily met its objective of establishing a practical demonstration facility for sterilizing medical products totalling about 3000 cubic metres in volume annually.

Mutation breeding in Indonesia
(Duration: 1974 to 1976)

43. The purpose of the project is to carry out plant breeding work in Indonesia, using induced mutation techniques, to improve crop varieties in respect of yield, disease resistance, earliness, response to fertilizers and nutritional aspects. Six of the numerous rice mutants developed so far have been accepted for official variety testing, and the mutation breeding work is being expanded to include experiments on legumes and sugar cane.

Radiation processing demonstration facility in the Republic of Korea
(Duration: 1974 to 1976)

44. The radiation processing demonstration facility is mainly intended to introduce radiation technology into local industry - for example, for the sterilization of medical products, the fabrication of wood-plastic combinations, and the surface coating of plywood and other panel boards. Two major facilities are being set up at the Korean Atomic Energy Research Institute under this project: a gamma irradiator with an initial radiation source consisting of 100 000 curies of cobalt-60 and a 300-keV electron beam accelerator. Associated laboratories will complement these facilities.

Use of radioisotopes in agriculture in Morocco
(Duration: 1974 to 1976)

45. The aim of the project is to develop methods for increasing the yield of oil-producing crops, mainly sunflower, as well as of sugar beets, wheat, cotton, berseem and maize. The Agency's contribution consists mainly of providing advice on research programmes such as fertilizer utilization studies, as well as providing in-service training and opportunity for study abroad, to improve the qualifications of Moroccan scientists and laboratory technicians in the use of nuclear and other modern techniques in agricultural research. Considerable progress has been made and Agency assistance in the form of expert services, consultant visits and the provision of equipment and supplies is continuing.

Training and research in applied nuclear physics at the Faculty of Sciences, Rabat, Morocco
(Duration: 1974 to 1977)

46. The aim of the project is to expand and intensify the teaching of nuclear physics and its applications in the curriculum of the Faculty of Sciences. This will be done through the addition of lecture and laboratory courses on applied nuclear physics topics to meet the needs of the country, for example, in agriculture, geology, medicine and mining, and the establishment of an appropriate post-graduate training programme. Project activities have just commenced, and satisfactory progress has been made.

Insecticidal investigations for tsetse fly eradication in Nigeria
(Duration: 1974 to 1976)

47. A major constraint in regard to the large-scale expansion of the livestock industry in Nigeria is the tsetse fly which infests vast areas. New insecticides and techniques for using them now hold promise of solving the problem in some locations. The aim of the project is to develop a laboratory and carry out laboratory and field experiments involving the use of insecticides.

Exploration for uranium in the Siwalik sandstones, Dera Ghazi Khan District, Pakistan - Phase II
(Duration: 1974 to 1976)

48. As anticipated in last year's report[8], the results of the work done during the initial phase of the project were sufficiently encouraging to prompt the Government to request the continuation of assistance over a period of two more years. The purpose of the project is to determine the extent and economic potential of uranium occurrences in the Siwalik sandstones and to train local geologists, analytical laboratory staff, drilling and field maintenance personnel in all relevant aspects of uranium exploration and evaluation. The work is progressing as planned.

Development of nuclear technology in Romania
(Duration: 1973 to 1976)

49. The Institute of Nuclear Technology in Romania is being expanded to provide the basis on which national industry can play a significant role in the nuclear power programme, in particular in the design and manufacture of fuel elements and reactor components for nuclear power plants as well as for subcritical and critical assemblies for use in training and research. Expert services and fellowship training are being provided under subcontract arrangements by Belgium, Canada, France, the Federal Republic of Germany and Sweden. The construction of buildings for the new institute is progressing satisfactorily. In addition, subcontracts have been placed for the irradiation testing of components and fuel elements fabricated at the institute and for post-irradiation quality control studies.

[8] See document GC(XVIII)/525, para. 42.

Exploration for uranium in South-West Anatolia, Turkey
(Duration: 1974 to 1976)

50. The staff of the Mineral Research and Exploration Institute is receiving training in the use of modern methods for uranium exploration, development and processing on the project site and abroad. This training activity is an integral part of the UNDP assistance, which includes the reconnaissance of the entire project area (3000 $km^2$) and the intensive search for new ore bodies as well as the evaluation of known ore bodies and new discoveries in two smaller, well-defined sub-areas. Test drilling and geochemical surveying are under way, and good progress has been made.

Radiation unit for the industrial application of ionizing radiation in Yugoslavia
(Duration: 1975 to 1978)

51. The purpose of the project is to construct and establish a demonstration facility for the radiation sterilization of disposable medical supplies and other items as a service to local hospitals and to improve health standards. The counterpart organization will also engage in research leading to the introduction of radiation technology and processing in industry for the improvement of polymers and plastics, using the cobalt source to be installed for radiosterilization work. The irradiation plant will be supplied under a subcontract.

Radioisotope applications in Zambia
(Duration: 1970 to 1975)

52. This project is an extension of assistance provided under the Agency's regular programme (1969-1970) and UNDP (1970-1972) to the Radioisotope Unit of the National Council for Scientific Research. The main objective is the establishment of a radioisotope advisory service capable of assisting local research organizations in carrying out scientific investigations in a number of fields related to Zambia's development and of training local staff in the use of radioisotope equipment. The project has been a success and the radioisotope unit is now able to provide the services for which it was established.

SIDA projects

53. Besides the training courses and "Type II" fellowships[9] financed by SIDA, multibilateral assistance is being provided through the Agency to Bangladesh to establish a nuclear research institute devoted to the study of agricultural problems. This will mainly seek ways of increasing crop production by improving plants, making more effective use of soils and ground water and developing techniques for combating insect pests. The assistance is to be provided over a five-year period for which SIDA has budgeted funds equivalent to $ 1.3 million.

The Agency's regular programme

54. The status of voluntary contributions to the General Fund for the years 1965-1974 and estimates for 1975 are shown in Table 3 below.

[9] Listed respectively in Table 1 and Annex B.

Table 3

Voluntary contributions to the General Fund

| Year | Established target (in millions of dollars) | Cash contributions pledged to the General Fund | | | | |
|---|---|---|---|---|---|---|
| | | Amount $ | Percentage of target | Shortfall or (overrun) $ | Number of Members pledging | Percentage of Members pledging |
| 1965 | 2.0 | 1 330 590 | 66.5 | 669 410 | 55 of 94 | 58.5 |
| 1966 | 2.0 | 1 277 416 | 63.9 | 722 584 | 61 of 96 | 63.5 |
| 1967 | 2.0 | 1 431 823 | 71.6 | 568 177 | 62 of 98 | 63.3 |
| 1968 | 2.0 | 1 423 557 | 71.2 | 576 443 | 63 of 99 | 63.6 |
| 1969 | 2.0 | 1 488 426 | 74.4 | 511 574 | 68 of 102 | 66.7 |
| 1970 | 2.0 | 1 672 933 | 83.6 | 327 067 | 74 of 103 | 70.9 |
| 1971 | 2.5 | 2 142 675 | 85.7 | 357 325 | 71 of 102 | 69.6 |
| 1972 | 3.0 | 2 485 405 | 82.8 | 514 595 | 71 of 102 | 69.6 |
| 1973 | 3.0 | 2 847 012 | 94.9 | 152 988 | 70 of 104 | 67.3 |
| 1974 | 3.0 | 3 083 261 | 102.8 | (83 261) | 65 of 105 | 61.9 |
| 1975[a/] | 4.5 | 4 148 294 | 92.2 | 351 706 | 70 of 106 | 66.0 |

a/ As at 30 June.

55. As shown in Table 4 below, the value of approved requests for experts and equipment under the Agency's regular programme increased from $2 262 700 in 1974 to $3 085 500 in 1975 as a result of the $1.5 million increase in the target for voluntary contributions to the General Fund.

Table 4

Experts and equipment: 1970-1975

| Year | Value of requests received (in thousands of dollars) | Value of assistance approved (in thousands of dollars) | Percentage of requests met |
|---|---|---|---|
| 1970 | 3400 | 1250.0 | 36.8 |
| 1971 | 3600 | 1891.0 | 52.5 |
| 1972 | 5268 | 2123.6 | 40.3 |
| 1973 | 5657 | 2279.0 | 40.3 |
| 1974 | 5849 | 2262.7 | 38.7 |
| 1975 | 7264 | 3085.5 | 42.5 |

## FOOD AND AGRICULTURE

56. Under the joint FAO/Agency programme on food and agriculture nuclear techniques are applied to help solve problems of food production and preservation. This has become even more urgent during the past year because of the imminence of a world food crisis and of consequences flowing from the energy situation, particularly rises in the cost of fertilizers and other agricultural production requisites. Much of the programme is carried out through co-ordinated research programmes (CRPs) in the developing countries.

57. In this connection special emphasis is being given to CRPs dealing with the use of fertilizers in producing such grain legumes as soybeans, efficient use of water, deficiencies of micronutrients in rice-growing and conservation of nitrogen fertilizers.

58. A four-year study on the use of nitrogen fertilizers in rice-growing has been completed, showing that:

(a) Application of the entire dose of fertilizer nitrogen at the time of transplanting is a very inefficient way of supplying nitrogen to the rice crop;

(b) The fertilizer is more efficiently used by the rice plant when applied at a middle growth stage; and

(c) Moderate amounts of fertilizer nitrogen are often needed at the time of transplanting to promote early growth and tillering, but little more than a quarter of the total treatment should be applied at this time and the remainder at or just before the period of rapid stem elongation.

59. A CRP which was begun in 1972 is making it possible to estimate accurately the quantity of water that percolates through different "profiles" of soil. This will help to improve soil and water conservation practices, make more efficient use of fertilizers and control pollution.

60. Since high lysine (nutritionally essential amino acid) varieties of wheat that also have satisfactory agronomic characteristics in other respects are not yet available, research has been intensified for acquiring such characteristics by using radiation and other means to induce mutations. This programme, which is supported by the Federal Republic of Germany, also covers a number of other crops which could help to overcome malnutrition due to protein deficiency.

61. Other work under the plant breeding programme is designed to improve the genetic characteristics of grain legumes, which are of increasing importance as a source of protein in many developing countries and which require little or no costly nitrogen fertilizer. Work has continued on inducing disease resistance through mutation in several grain crops and a new programme has been started to improve through irradiation vegetatively propagated crops (like fruit trees) which cannot be easily improved by ordinary breeding techniques but which produce valuable food for home consumption or export.

62. In the field of animal husbandry studies have begun of the water requirements and the water metabolism of livestock living in different climates and ecologies, especially in the drier parts of tropical Africa. The programme designed to determine criteria for the effective use of non-protein nitrogen sources (such as urea) as livestock feed has continued. [10]

---

[10] See document GC(XVIII)/525, para. 52.

63. Newly developed methods should greatly reduce the cost of rearing the numbers of insects needed for programmes that use the sterile-insect technique as a means of controlling the Mediterranean fruit fly. Progress achieved in the mass rearing of the olive fly has made it possible to carry out trials in Yugoslavia. A breakthrough in the techniques for rearing two species of tsetse fly has made it possible to implement a pilot trial in Africa.

64. The CRPs dealing with chemical residues from various industries including agriculture[11] have made it possible to study effectively a wide range of problems, such as the effect of industrial waste discharges on coastal fisheries in countries where adequate monitoring and control of such discharges are still difficult, and the effects from exposure of edible seeds and oils to the growing range of pesticides now used in many developing countries.

65. Under a new CRP, supported by the Federal Republic of Germany, the way is being studied in which fertilizer nitrogen is transformed in the soil, its movements through the soil and the environmental implications. The leaching of such fertilizer into ground water is a potential source of pollution and an irreversible loss of valuable plant nutrient.

66. The international project on food irradiation, carried out in Karlsruhe, Federal Republic of Germany, has produced the wholesomeness data needed to "upgrade" the clearance of irradiated potatoes, wheat and wheat products from temporary to unconditional.[12] The analysis of certain microbiological aspects of food irradiation, requested by WHO, has been accomplished; it will be submitted to the joint FAO/IAEA/WHO committee at its next meeting and it is hoped that this will pave the way for an unconditional acceptance of the use of radiation for preservation of these foodstuffs. Negotiations are currently proceeding toward the establishment of an international centre to study the technological and economic feasibility of food irradiation in the Netherlands.

67. Training courses arranged under the joint FAO/Agency programme are listed in Table 1 above. Several meetings of experts were held during the year including one which is helping the two agencies to prepare a training manual on the use of nuclear techniques in studies of animal parasitology and immunology. A symposium in Innsbruck, Austria, in July 1974 reviewed the practical application of the sterile-insect technique and the economies that might be achieved by the use of this technique. A second symposium, held in Vienna in November 1974, showed the advantages of using stable isotopes in place of radioactive isotope tracers in studying the sources and behaviour of pollutants. Stable isotopes eliminate possible radiation hazards and do not suffer from the time limitation caused by radioactive decay. The accurate measurement of isotopic ratios of a contaminant can indicate the source of the contaminant, e.g. whether a carbonaceous contaminant has its source in a fossil fuel (oil or coal) or in biological waste.

---

[11] Ibid., para. 54.

[12] Ibid., para. 55.

# LIFE SCIENCES

## General

68. The Agency has begun a new programme to encourage the use of nuclear techniques in various domains of environmental research and, to a limited extent, it is continuing to implement other projects in the life sciences. Whenever this is possible, the Secretariat is seeking to transfer responsibility for routine medical and biological applications of nuclear science to WHO. Means of closer co-operation with WHO were discussed at an inter-secretariat meeting at Geneva in April 1975.

## Medical applications

69. The co-ordinated programmes in medical research have continued to cover the same topics as last year[13]. Studies on human iron nutrition, begun jointly with WHO in 1969, are now in their final stage, as is the programme dealing with intercomparison of techniques for computer-assisted scintigraphy[14]. The original programme dealing with in vitro procedures in clinical medicine and research is also nearing completion. A programme has been started to help develop new radioisotope techniques to be used in studies on human reproduction. The programme on microbial immunology[15] is nearing completion; it has led to progress in techniques for studying immunity against communicable diseases such as cholera.

70. The Agency has begun a survey to determine those medical applications of radioisotopes that should have the highest priority in developing countries, taking into account the medical needs of such countries. The survey will indicate the resulting requirements (especially design and maintenance requirements) for specialized instruments. The cost to the Agency of co-ordinated research contracts in medical applications of radioisotopes amounted to $148 000 in 1974; in addition, the programme encompassed numerous "cost-free" research agreements and technical contracts.

71. An international symposium in Knoxville, Tennessee, United States, on dynamic studies with radioisotopes in clinical medicine and research, reviewed the use of radioisotopes in studying the functional state of body organs and tissues or "in vitro assay techniques with radioisotopes", and a regional training course in nuclear in vitro assay techniques was held in Lima in October 1974.

## Radiation biology

72. The programme on radiation biology has covered the same topics as in previous years[16] but with more emphasis on the effects of small doses of irradiation on man and on co-operation with UNSCEAR in this connection.

73. Work has also been started on using radiation as a means of treatment of waste. An interesting symposium was held in Munich, Federal Republic of Germany, in March 1975 to study the use of high-level radiation for treatment of waste and sewage. Participants discussed and agreed upon the technical and economic feasibilities of this application of nuclear technology, taking into consideration the experiences gained in the operation of pilot plants, and acceptance from the public health point of view.

---

[13] See document GC(XVIII)/525, para. 61.

[14] Ibid., paras 61(a) and (f).

[15] Ibid., para. 61(c).

[16] Ibid., para. 64.

74. The cost to the Agency of co-ordinated research contracts in radiation biology amounted to $90 000 in 1974; there were in addition "cost-free" research agreements.

75. Agency-supported research has led to the isolation of radiation-induced mutants of bacteria (Bacillus subtilis) producing a polypeptide antibiotic substance that has antifungal activity and can be used to control the pathogenic fungi (Fusarium, Helminthosporium, Alternaria, Trichoderma, etc.) infecting agricultural crops such as wheat, rice and potatoes.

76. A symposium was held in Bombay, India, in December 1974 on the use of radiation to sterilize medical products and biological tissues for clinical applications. Participants reviewed developments in this field since 1967 when a symposium on this subject was organized in Budapest. The symposium in Bombay was of particular interest to countries that have recently installed (Czechoslovakia, Egypt, Greece, Hungary, India, Israel, Republic of Korea, Poland and Spain) or plan to install (Indonesia and Philippines) in the near future radiation facilities for sterilizing medical products such as sutures, bandages and other surgical appliances. Production hygienic practices have been improved by the development of sub-sterilizing-dose technique and the combination treatment. The dosimetry control of the irradiation plant has been improved by the development of the cerium sulphate dosimeter.

77. There has been further demonstration of the practical value of the Agency/WHO postal dose comparison service in improving the accuracy of dosimetry in participating institutes, and in thus raising the rate of cure of cancer patients throughout the world.

78. So far WHO and the Agency have designated eight laboratories as "secondary standard dosimetry laboratories", which will have the task of improving the accuracy of dosimetry in the countries or regions concerned by providing calibration services, and of organizing comparison services. These laboratories will in time take over much of the work being done at the Agency's laboratory and will provide a greater range and scope for dosimetry services. An Agency/WHO meeting in Rio de Janeiro in December 1974 recommended the establishment of a network of such laboratories throughout the world under IAEA/WHO auspices.

79. A symposium on advances in biological dosimetry in March 1975 in Vienna discussed a wide range of topics including neutron dosimetry, neutron capture therapy, diagnostic radiological physics and advances in instrumentation and techniques in biomedical dosimetry.

80. Of the californium-252 needles donated by the United States 100 have been lent to research and teaching institutes in 14 Member States, and a seminar on the use of californium-252 in teaching and research was held in Karlsruhe, Federal Republic of Germany, in April 1975.

81. The Agency has started co-ordinated research programmes on radiation dosimetry under 15 contracts in 11 Member States and four further contracts were awarded during the year for the development of specific dose intercomparison systems and chemical dosimetry. The total cost to the Agency of these contracts amounted to $25 000 in 1974.

## PHYSICAL SCIENCES AND LABORATORIES

### General

82. A major event in the physics programme has been the Fifth International Conference on Plasma Physics and Controlled Nuclear Fusion Research, held in Tokyo in November 1974, which was attended by more than 440 scientists. The work of the International Laboratory of Marine Radioactivity in Monaco has been extended to cover non-nuclear pollution in sea-water, and the agreement under which the Laboratory is operating has been extended until the end of 1980. In September 1974 a group of consultants reviewed the programmes of the Seibersdorf Laboratory and in response to their recommendations, the Agency has started a number of improvements in the Laboratory's facilities and operations, such as the gradual transfer of certain routine work to outside contractors.

### Physics

83. At the Tokyo conference mentioned above very encouraging progress was reported towards the attainment of practical fusion power. Although no major breakthroughs were reported, it is clear that the emphasis is moving from theoretical studies to the construction of large experimental machines and to the design of nuclear fusion reactors. It is becoming necessary to arrange for a continuing international exchange of atomic and molecular data about plasma and plasma/containment interactions comparable with the existing international work on neutron data, and the Agency is taking steps in this direction. At a workshop in Culham, United Kingdom, in August 1974, it was recommended that an international catalogue of about 400 fusion programmes could now be usefully exchanged and that a standardization of future programmes be started.

84. Other projects in the field of physics dealt with the use of neutron beams in research reactors for studying metallurgical texture structures, the application of minicomputers for the acquisition of nuclear data, and a further international exchange of information on thermionic electric power generation. A panel met in Zagreb, Yugoslavia, in October 1974 to review the uses of low-energy accelerators; emphasis was placed on applied subjects such as radiation damage, implantation, channelling, fast neutron activation analysis, and charged particle induced X-ray fluorescence. A meeting of the participants in a co-ordinated research programme on neutron scattering was held in Manila in April 1975; in three years this project has produced notable results on ternary alloys and hydrogen motion in solids. An advisory group met in Accra, in June 1975, to discuss the nuclear physics programmes in developing countries, particularly in Africa; as a result it made recommendations for introducing and promoting nuclear research, and on the contribution of nuclear science to the economic progress of developing countries.

85. The programme for support for research on nuclear physics is being carried out at institutes in 13 countries within the framework of two co-ordinated research programmes. The total cost to the Agency for support of the 13 contracts and three agreements relating to these programmes was some $37 000 during 1974.

### Industrial applications and chemistry

86. The scope of this programme has been described in last year's report[17]. The main projects during the year included a symposium on the thermodynamics of nuclear materials, in Vienna in October 1974; a panel on nuclear techniques in geochemistry and geophysics, in Vienna in November 1974; a regional seminar in Lima, in August 1974, on the availability and use of radioisotopes for Latin America, and a training course on activation analysis in industry and research in Berlin (West) in November 1974, which was intended to show the use of activation analysis in monitoring the environment and in

[17] See document GC(XVIII)/525, paras 85 and 86.

exploring mineral resources. Work has continued on promoting the use of radioisotopes and radiation as well as the use of nuclear techniques in geochemistry, geophysics, geology, mineral prospecting, the raw materials industries and the environment. The Agency is carrying out an international programme to compile data on the chemical thermodynamic properties of actinide elements and their compounds. The purpose of this compilation is to give nuclear engineers and/or nuclear scientists a basic scientific understanding of the chemical interactions that take place in nuclear systems, whether they be related to reactor design, fuel-cladding interaction, or chemical processing of nuclear materials.

Isotope hydrology

87. The Agency has contributed to the success of the International Hydrological Decade by preparing and issuing 21 publications on various aspects of isotope hydrology. It is promoting the combined use of isotopic and chemical data in the survey of water resources and other hydrological problems. During the period covered by this report, the Agency provided equipment and experts to help establish isotope laboratories and to advise on the use of nuclear techniques and water resources studies in 15 developing countries. It also helped other United Nations bodies to carry out isotope hydrological studies in five developing countries and provided laboratory isotope analysis for ground-water investigations in 15 Member States. The laboratory also provided standards to other isotope laboratories for measurement of tritium, deuterium, $^{18}O$ and $^{13}C$ and began an intercomparison of low-level tritium counting. The cost of research contracts in institutes of five Member States involved the Agency in an expenditure of $31 500 in 1974.

88. An advisory group on the interpretation of environmental isotope and hydrochemical data in ground-water hydrology was convened by the Agency in Vienna in January 1975, to review the advantages and techniques of a co-ordinated approach using isotope and chemical data in solving hydrologic problems.

Nuclear data

89. The nuclear data programme is now in its eleventh year and is providing nuclear data services to more than 40 Member States. The Agency has established a central information office to serve scientists and engineers as a global reference centre for all nuclear data. This office is carrying out a world-wide survey of the needs for such data and is setting up a comprehensive file of handbooks, tables and computer files of nuclear data compilations. It is also compiling information on the nuclear facilities available in developing countries for measurements of nuclear data. The 1975 edition of the "World Request List for Nuclear Data Measurements" is expected to contain about 1500 requests from more than 20 countries and organizations. This list combines in one document nuclear data requirements for fission and fusion reactor technology and safeguards of nuclear materials.

90. Figures 5 and 6 below illustrate the increase in the number of reference entries in CINDA and the increasing number of experimental neutron data sets in the international data library, which is distributed to Member States on request.

FIGURE 5

NUMBER OF ENTRIES IN CINDA HANDBOOK

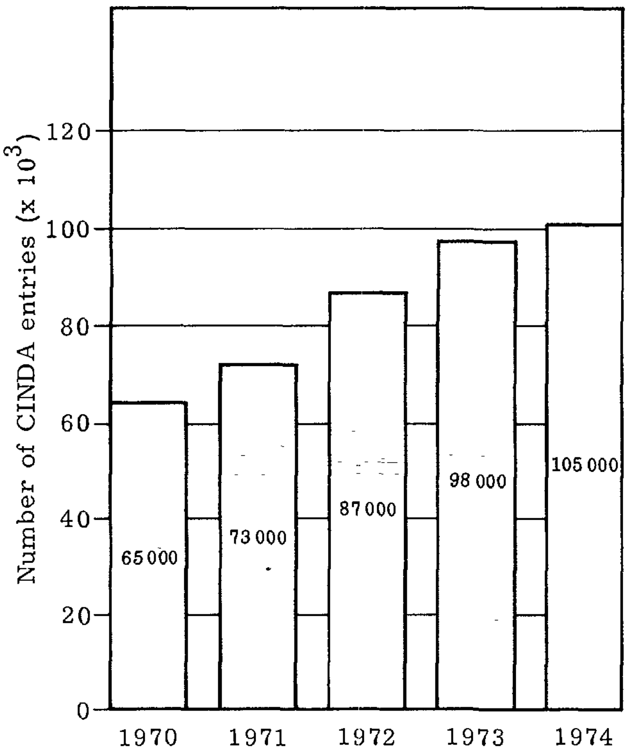
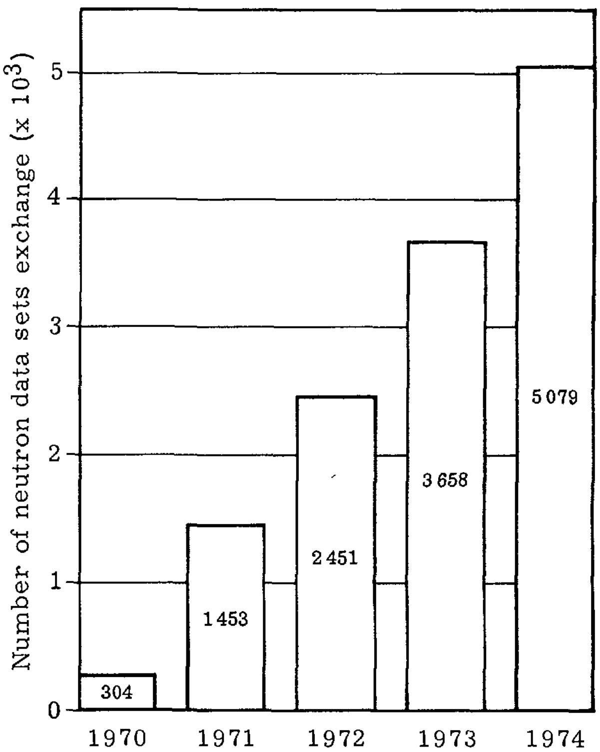



FIGURE 6

NUMBER OF SETS OF EXPERIMENTAL NEUTRON DATA EXCHANGED




91. In response to a recommendation by the International Fusion Research Council, the Agency is currently carrying out a world-wide survey of compilation activities on atomic and molecular data of importance to plasma research and fusion technology and is investigating the size and scope of a new programme component in this field.

Laboratories

Seibersdorf Laboratory

92. The Laboratory's work in connection with the application of nuclear techniques in agriculture and safeguards is dealt with in paragraphs 56 to 67 and 136 to 152 respectively. The analytical quality control services for environmental and radiological laboratories in Member States was continued. 217 laboratories in about 40 States took part in nine analytical intercomparisons for determination of fission radionuclides and inorganic industrial pollutants in foods, water, animal tissues, etc. The results of these exercises provided material for improving the quality of work in participating laboratories and gave general data about accuracy which can be obtained in such type of determinations. In addition, laboratories in Member States were supplied with 471 reference samples including ore samples certified for uranium content and some other reference materials for environmental radiological purposes. Several hundred ore samples were analysed in support of uranium prospecting activities in Member States.

93. The Laboratory has provided in-service training for eight fellows from Member States.

International Laboratory of Marine Radioactivity in Monaco

94. A comparison of the results obtained by co-operating laboratories of Member States in measuring the level of strontium-90, caesium-137 and plutonium-239 derived from fall-out in "open ocean" Atlantic sea-water has shown that significant disparities exist in the measurements made of strontium-90 and caesium-137 at very low levels. On the other hand, much more uniform results were obtained in measuring plutonium-239 and plutonium-240, chiefly because these analyses were taken at laboratories using more advanced techniques.

95. The programme of studies of non-nuclear pollution of sea-water, which is financed by UNEP, is now making satisfactory progress. The Laboratory has prepared and tested reference materials to be used in the measurement of trace metals and chlorinated hydrocarbons (DDT, polychlorinated biphenyls). It has distributed samples of oyster tissue homogenate and sea plants to co-operating laboratories, and the results of the analysis are expected by mid-1975. The Laboratory has also reported on the results of field measurements made in the north-western Mediterranean of trace metals, chlorinated hydrocarbons and selected radionuclides[18].

International Centre for Theoretical Physics at Trieste

96. Major activities carried out at the Centre which were of interest to the Agency included a conference and research workshop in nuclear physics, and workshops in solid state physics and astrophysics. Research of a theoretical nature in high-energy physics was carried on throughout the year, and two topical meetings were held on this subject concerning hadron scattering and collisions involving nuclei.

97. The agreement with UNESCO concerning the joint operation of the Centre has been extended until the end of 1978[19]. An Ad Hoc Consultative Committee was convened to review progress and to help the Scientific Council of the Centre to draw up plans for the next few years. The main object is to find means of assisting the further advancement of theoretical physics in the developing countries in a manner consistent with their own needs and requirements.

98. SIDA has continued to provide funds in support of selected activities, as has UNDP acting through UNESCO. The Government of the Federal Republic of Germany also continued to make provision for visits of selected associates from the Centre to one of two German institutes at the Government's expense.

[18] See IAEA Technical Report No. 163.

[19] Subject to approval by the General Conference of UNESCO at its 19th session of its contribution for 1977-78.

## NUCLEAR POWER TECHNOLOGY AND ECONOMICS

### Nuclear and electric power forecasts and economics

99. The competitive advantage of nuclear power has markedly improved because of the rise in the price of fossil fuels. The cost of oil has risen to more than four times its mid-1973 level, and there have been concomitant rises in the price of coal and natural gas. Uranium prices also nearly doubled during the period covered by this report. Because of the much smaller sensitivity of the total cost of the nuclear fuel cycle to variations in the price of the raw material on which it depends, nuclear fuel cycle costs have fallen to less than 1/5 of those of oil-fired electric power stations. Partly as a result of this, new orders for nuclear plants rose by 25%, from 60 000 MW in 1973 to 75 000 MW in 1974.

100. However, other factors have tended to slow down the rate of growth of nuclear power and it is now possible that nuclear capacity will reach only 220 000 MW by 1980, i.e. approximately 30% less than the forecast in the last report. Forecasts made on the basis of the Agency's estimates at the beginning of 1975 are shown in Table 5 below. The chief retarding factors are scarcity of capital, high interest rates, complexity of regulatory requirements, and increasing opposition to nuclear power in certain industrialized countries. In some countries the building of nuclear plants has for those reasons been delayed, and orders have been cancelled or postponed, and future programmes have been scaled down.

Table 5

Forecast of installed total electric and nuclear capacity
(in thousands of MW)

| | 1974 | 1975 | 1980 | 1985 | 1990 | 2000 |
|---|---|---|---|---|---|---|
| Electrical | 1500 | 1600 | 2300 | 3200 | 4500 | 8900 |
| Nuclear | 62.8 | 82 | 220-250 a/ | 460-850 a/ | 1300-1900 a/ | 3600-5300 a/ |
| Percentage share of nuclear (%) | 4.0 | 5.6 | 10-11 | 18-27 | 29-42 | 40-60 |

a/ The higher figure is based on the assumption of an accelerated nuclear programme, due to the energy situation.

101. During 1974 the Agency up-dated the 1972-73 market survey of the prospects of nuclear power in developing countries which now covers 55 such countries. The new survey suggests that during the 1980s there may be a market for about 200 000 MW of nuclear power in the countries surveyed, which would be equivalent to about 60% of their total market for electric power plants. However, this forecast is too high since it was not possible for the survey to take fully into account the extent to which increased oil prices would encourage the use of alternative domestic energy resources such as hydro-power. Moreover, some smaller nuclear power units, the operation of which would be economic according to the survey, may not become commercially available.

### Nuclear materials and fuel cycle

102. The Agency and NEA will publish a fifth joint report on uranium resources in the second half of 1975. The Agency is continuing to support and promote the exchange of information on uranium geology, exploration, and processing of uranium ores including bacterial leaching and in situ leaching, and methods and calibration of instruments used in exploring for uranium. The expected increase in demand for uranium has been reflected in increasing numbers of requests for technical assistance. The Agency is providing, or

is preparing to provide, technical assistance in prospecting, development and ore processing to 24 countries, namely Afghanistan, Argentina, Bangladesh, Bolivia, Brazil, Burma, Chile, Colombia, Egypt, Ghana, Greece, Indonesia, Iraq, the Republic of Korea, Madagascar, Mexico, Morocco, Pakistan, Peru, the Philippines, Somali, Turkey, the United Republic of Cameroon and Uruguay. These include three large-scale UNDP projects which the Agency is executing in Greece, Pakistan and Turkey, while two other large-scale projects for Chile and Morocco are in preparation.

103. The Agency has begun studies of the problems that will arise through the world-wide growth of demand for fuel reprocessing facilities and especially the environmental, safety, economic and safeguards aspects of this matter. The studies will include an examination of the technical and economic pros and cons of regional fuel cycle centres.

Supply of nuclear materials

104. The quantities of nuclear materials delivered through the Agency as an intermediary are listed in separate reports. [20] The Board approved requests from Pakistan, the Philippines and Romania for supply of enriched uranium as fuel for research reactors. The Director General, under the authority delegated to him by the Board in September 1968, assisted five Member States upon request to obtain small quantities of enriched uranium and plutonium below the safeguards exemption limit. A total of 15 requests were received from ten countries and the Agency itself requested supply of eight consignments of small quantities of uranium and plutonium for the safeguards and other programmes. The United States has authorized the supply to the Agency of an additional amount of contained uranium-235 intended for use in the fuel cycle of two nuclear power plants in Mexico and one in Yugoslavia.

Power reactors

105. The Agency has carried out detailed planning studies for power reactor projects in developing countries such as Bangladesh, Indonesia and Pakistan. In all cases engineers from the countries concerned have been trained at the Agency to use the methodologies and computer programmes employed in the studies. [21] Similar training has also been given to staff from electric power corporations from Greece, Malaysia, Mexico, Singapore and Thailand and to staff of atomic energy organizations from Brazil and the Federal Republic of Germany.

106. Under its expanded programme for training in nuclear power the Agency held a seminar on nuclear power planning at Kingston, Jamaica from 9 to 20 June 1975. The seminar dealt chiefly with the administrative, economic and technical problems encountered in the early stages of a nuclear power programme. The Agency has also published a guidebook "Steps to nuclear power", and is preparing supplementary manuals on such topics as "Nuclear power planning studies", "Contracting for fuel supply for power reactors" and "International economic bid evaluation".

107. Through technical meetings the Agency is helping to encourage production of smaller power reactors of proven type of which the need was shown by the market survey. These meetings inform manufacturing countries and reactor suppliers of the scope and nature of the potential market, encourage standardization of new designs and adaptation of existing types of power plant.

108. The Agency is continuing to provide information to help ensure reliable operation of nuclear power stations. The latest series in reports on operating experience in power plants covers the year 1973 and includes data from 98 units. Recommendations are also

[20] See document INFCIRC/40/Rev. 11.

[21] See document GC(XVIII)/525, para. 113.

being made about the programmes that Member States should carry out to ensure high standards of quality of materials and equipment used in building and operating power plants and the work of the Agency's international groups has been redirected to concentrate on practical problems of immediate interest. An Agency symposium on the reliability of nuclear power plants, held in Innsbruck, Austria, in April 1975, dealt chiefly with engineering methods for evaluating power station availability. A report recently published by the Agency gives the results of the first part of the co-ordinated research programme on irradiation embrittlement of pressure vessel steels.

## Advanced nuclear technology

109. The Agency's work on nuclear technology is designed chiefly to promote the exchange of information that will facilitate technological developments in a number of critical areas, namely liquid metal fast breeder reactors (LMFBR), high-temperature reactors, MHD and fusion. A meeting at Bensberg in the Federal Republic of Germany in October 1974 enabled 62 participants to benefit from a critical review of experiences obtained by operators of prototype reactors in France, the Soviet Union and the United Kingdom in dealing with the problems of reliability and safety of LMFBR steam generators which are among the most critical components of the fast breeder reactors.

110. Another meeting in September 1974 reviewed the use of high-temperature reactors as a source of heat for industrial processes and district heating.

## Reactor physics and computations

111. The Agency held a course on reactor burn-up physics at Mol in Belgium in October 1974 especially for participants from developing countries. The course covered modern computational techniques used for ensuring reliable and efficient fuel burn-up throughout the life of the reactor core in both thermal and fast reactors.

## Research reactor utilization

112. A study group meeting held by the Agency in Lima in August 1974 surveyed the Latin American market for radioisotopes and labelled compounds, identified the problems impeding the greater use of these materials and recommended solutions.

## Nuclear explosions for peaceful purposes

113. In September 1974 the Board took note of the Agency's readiness to provide international services related to PNE and approved an approach for the Agency to adopt in responding to requests for such services. [22] The Board also authorized the Director General to establish a separate unit within the Secretariat to handle matters connected with PNE.

114. Also towards the end of last year the General Assembly of the United Nations adopted two resolutions containing references to the Agency's activities connected with PNE[23].

115. As a sequel to those developments a unit for PNE-related services was established in the Secretariat at the beginning of 1975. This unit will act upon requests made to the Agency for such services, study health and safety criteria, survey available literature, and examine the economic and technical feasibility of PNE.

---

[22] See United Nations document A/9722/Add. 1, Annex II.

[23] See Resolution 3213 (XXIX), para. 7 and Resolution 3261 D (XXIX), para. 2.

116. In December 1974 a register was opened of PNE "Consultant States"[24] from which interested Member States can obtain information as to the kind of services they might obtain. In January 1975 the Secretariat's fourth technical committee on PNE met in Vienna to consider studies of such projects as excavations and underground engineering applications, as well as the economic and health and safety aspects of PNE. It also assessed the current "state of the art" reflected in a series of national reports on research and development. The Committee's report is reproduced in part I of Annex A.

117. An analytical and technical report on the Agency's activities in relation to Article V of NPT was submitted to the Review Conference of the Parties to NPT as well as to the Conference of the Committee on Disarmament. An annex to that report dealing with the feasibility, utility and health and safety aspects of PNE is reproduced in part II of Annex A to the present report.

[24] States willing to offer PNE-related services such as project assessment and design.

## NUCLEAR SAFETY AND ENVIRONMENTAL PROTECTION

### General

118. The importance and scope of the Agency's work on nuclear safety and environmental protection continue to grow and to be concentrated increasingly on practical problems arising from the use of nuclear power. During the period under review the Agency has completed the general plan for a comprehensive set of safety codes and guides for nuclear power plants. The initial plan calls for five codes of practice and 12 safety guides. The Agency has also continued to give high priority to the problems of storing and disposing of radioactive wastes. It has formulated provisional definitions and recommendations regarding the disposal of such wastes at sea[25].

119. Three symposia were held on topical questions of nuclear safety; the Agency began work on a research project regarding risk acceptance. The number of regional study groups and training courses and safety and siting missions has continued to increase to meet the needs of Member States introducing or expanding their nuclear power programmes.

### Nuclear safety

120. The Senior Advisory Group, set up in 1974, to help the Agency carry out the programme of safety codes and guides, has held three meetings and, in accordance with its recommendations, work has begun on five codes of practice as well as on 12 safety guides to implement these codes. The codes of practice deal with the following subjects:

(a) Governmental organization;

(b) Siting;

(c) Design;

(d) Operation; and

(e) Quality assurance.

121. The Agency sent health and safety missions to Indonesia, the Philippines and Thailand in late 1974, nuclear power plant siting missions to Iran and Singapore and a nuclear plant safety mission to Mexico. Advice was also given to Singapore regarding the safety considerations to be taken into account in preparation for the entry of nuclear merchant ships into the harbour of that city.

122. The Agency and NEA held a symposium in Vienna in December 1974 to review recent development in practices for selecting the sites of nuclear power plants and other nuclear facilities.

### Radiological safety

123. The Agency's programme on radiological safety is concentrating increasingly on the safety aspects of nuclear power and the nuclear fuel cycle. Guidance has been prepared on radiological protection services for nuclear power plants and on the radiological surveillance of airborne contaminants.

---

[25] See document GC(XVIII)/525, para. 134.

124. The Agency is continuing the series of regional meetings intended to help Governments to apply the Agency's standards and recommendations. To this end a meeting was held in Bandung, Indonesia in November 1974, and an advanced training course on radiological health and safety measures was held in Mexico City in November/December 1974 for countries in Latin America.

125. Co-ordinated research programmes continue to be supported and extended, and meetings of the principal investigators in the programmes on environmental monitoring for radiological protection and on nuclear accident dosimetry were held in Bangkok in November 1974 and in Harwell, United Kingdom, in April 1975 respectively.

126. An ILO/Agency/WHO symposium in Bordeaux, France, in September 1974 reviewed the radiological hazards encountered in mines and mills and dealt with the problems of surveillance in the working area and in the general environment. The Agency and IIASA have begun a research project on the ability of the public to perceive, and its willingness to accept, risks of technological origin, especially risks arising from the production of energy. This question is relevant to the public acceptance of nuclear power, and to the assessment of environmental effects and the establishment of rational safety standards.

### Waste management

127. In December 1974 a meeting of experts reviewed the Agency's programmes on waste management and recommended priorities which are now being followed.

128. A symposium in Oslo in August 1974 reviewed the environmental effects of cooling systems at nuclear power stations as well as alternative methods for management of waste heat. The symposium drew attention to the magnitude of the waste heat problem likely to result from future growth in energy production and to the research that is being done by national authorities and industry to assess the potential environmental impact of thermal discharges.

129. A meeting of oceanographers in February 1975 began the process of reviewing and revising the definitions and recommendations referred to in paragraph 118 above, which had been transmitted to the Secretariat of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.

### Research support

130. The current programme of support for research on nuclear safety and environmental protection consists principally of seven co-ordinated research programmes in which a total of 12 countries are participating under cost-free research agreements, and 23 countries are participating under research contracts at a total cost of $150 000 to the Agency.

## INFORMATION AND TECHNICAL SERVICES

### The International Nuclear Information System (INIS)

131. By the end of June 1975, 46 Member States and 13 international organizations were participating in INIS. During the period covered by the report, data on more than 64 000 items of nuclear science information were processed and distributed to national information centres in a variety of forms, for transmission to individual users.

132. Four INIS meetings were held during the period under review including that of the Second Advisory Committee for INIS. The Advisory Committee recommended that, while the scope of the subjects covered by INIS should generally remain unchanged, the following additions or changes should be made in the system:

(a) Machine-readable abstracts should be introduced in the second half of 1975;

(b) From 1976 onwards, a printed abstracting journal should be produced; and

(c) INIS subject categories and scope descriptions should be somewhat revised.

133. A joint INIS/Agricultural Information System (AGRIS) training seminar was held in Ankara in June 1975 and six trainees from five Member States were trained at Headquarters during the year.

134. The Agency, FAO and UNESCO jointly sponsored an international symposium on information systems in Varna, Bulgaria, in September/October 1974. Information scientists used the opportunity to assess progress made in creating links between national, international, and official and private information systems and services and to make recommendations to secure greater compatibility between systems. The Agency is also continuing to co-operate with FAO in processing AGRIS input on a cost-reimbursable basis.

### Computer services

135. The IBM 370/145 computer at the Agency's Headquarters services the Agency, UNIDO and FAO. During the year, 256K bytes of memory, additional direct access storage devices and an additional INPUT/OUTPUT channel were acquired. Because of this and because of better operating conditions, the throughput of the computer has approximately doubled.

## SAFEGUARDING PEACEFUL NUCLEAR ACTIVITIES

### Implementation of Agency safeguards

136. Table 6 at the end of this section shows the situation as at 30 June 1975, of signatures, ratifications and accessions with respect to NPT, and progress made in the negotiation of safeguards agreements in connection therewith.

137. Table 7 shows the total number of safeguards agreements other than those connected with NPT, which had been approved by the Board and the parties concerned.

138. On 30 June 1975, 43 safeguards agreements with non-nuclear-weapon States party to NPT were in force; 22 of these agreements were with States that have significant nuclear activities. Furthermore, safeguards were also being applied under ten project agreements, 20 safeguards transfer agreements and eight unilateral submission agreements. All of the latter 38 agreements provide for the application of safeguards under the Agency's Safeguards System (1965, as Provisionally Extended in 1966 and 1968). [26]

139. In particular, during the period covered by this report the Board approved:

(a) In connection with NPT, safeguards agreements with Afghanistan, Ethiopia, Gabon, Japan, Sudan, Sweden and Tonga;

(b) In connection with both NPT and the Treaty for the Prohibition of Nuclear Weapons in Latin America (Tlatelolco Treaty), safeguards agreements with El Salvador and Honduras;

(c) A Safeguards Transfer Agreement between the Agency, Israel and the United States of America;

(d) An agreement with Argentina for the application of safeguards to the Embalse Power Reactor Facility; and

(e) Two agreements with Spain and Switzerland respectively for the application of safeguards to nuclear material.

140. The Agency has continued to standardize procedures for applying safeguards, particularly under NPT. It is reviewing existing Subsidiary Arrangements and "Facility Attachments" in the light of experience and applying this experience in connection with newly concluded agreements. Work has also started on standardizing the implementation of safeguards outside the framework of NPT.

141. By 30 June 1975, model "Safeguards Implementation Practices" had been drawn up for each type of facility under Agency safeguards. [27] They are being used to prepare such Practices for all individual facilities where nuclear material is being safeguarded.

142. A list of nuclear installations under Agency safeguards or containing material safeguarded under arrangements approved by the Board is given in Annex F. The breakdown on 30 June 1975 as compared to 30 June 1974 is as follows:

---

[26] Set forth in document INFCIRC/66/Rev. 2.

[27] See document GC(XVIII)/525, para. 155.

| Facilities | NPT | | Non-NPT | |
|---|---|---|---|---|
| | 30 June 1974 | 30 June 1975 | 30 June 1974 | 30 June 1975 |
| Nuclear power stations | 12 | 17 | 24 | 30 |
| Other reactors | 45 | 55 | 65 | 60 |
| Conversion plants, fabrication plants and fuel reprocessing plants | 7 | 9 | 19 | 20 |
| Other separate accountability areas | 28 | 86 | 88 | 109 |

143. The Agency's records showed the following quantities of nuclear material to be under Agency safeguards:

| | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 |
|---|---|---|---|---|---|---|
| Plutonium (kg) | 824 | 770 | 1 726 | 2 900 | 4 730 | 6 300 |
| Enriched uranium | | | | | | |
| (a) Total element (tons) | - | 243 | 522 | 1 178 | 1 865 | 2 305 |
| (b) Fissile content (tons) | 4.6 | 6.1 | 11.2 | 26.0 | 43.0 | 53.0 |
| Source material (tons) | 1 070 | 1 146 | 1 200 | 2 145 | 3 370 | 3 910 |

144. During the year 1 July 1974-30 June 1975, the Agency carried out 502 inspections in 37 States (190 in connection with NPT), compared with 434 inspections (147 in connection with NPT) in 40 States during the preceding year. Of the 502 inspections, 178 were made of power plants, 97 of bulk fuel fabrication plants and 227 of other facilities including research reactors.

145. New and improved techniques and portable instruments, such as a 1600-channel analyser, now being used in inspections, have permitted the Agency to obtain higher accuracies in non-destructive analytical measurements for the determination of uranium enrichment.

146. Surveillance cameras are being used increasingly, i.e. for a total recording of 250 000 hours in 1974, compared with 66 000 in 1973. Sampling of safeguarded nuclear material doubled to 450 samples from 1973 to 1974. The analysis of samples taken during inspections is being made at the Agency's Laboratory and at laboratories in Member States.

Safeguards research and development

147. Special efforts are being made to identify practical problems encountered in the field and to organize work at the Agency's headquarters - including certain "development" activities - to provide speedy and practical solutions.

148. The computer-based safeguards information system which processes information reported about movements, stocks and material balances of nuclear material under NPT safeguards is under operational testing since the end of 1974, using data reported to the Agency by countries under NPT safeguards. The design of a further part of the information system for processing reports by the inspectors has been started; a programme for keeping records of the application and removal of safeguards seals has been made available for routine operation. A group of consultants met in Vienna in May 1975 to review the Agency's safeguards information handling system and to make recommendations for its optimization.

149. In March 1975, with the help of an advisory group, a review was made of the status of safeguards techniques, and guidelines for their further development until 1980 have been drawn up. In April 1975 another advisory group reviewed the recommendations made in March 1972 by a panel of experts for the physical protection of nuclear material. The Secretariat has already begun legal studies with a view to preparing an international convention, or other appropriate legal instrument, dealing with the problems of ensuring physical protection of nuclear materials while they are being transported.

150. It is expected that the Safeguards Analytical Laboratory will be commissioned during the second half of 1975. Meanwhile, the Agency has carried out a second plutonium analysis field experiment using a network of laboratories in Member States as well as the Agency's Laboratory;[28] the results of this experiment will be discussed in a consultants' meeting before the end of the year. Services for the analysis of samples of nuclear materials, taken by inspectors, were provided by eight laboratories in Member States as well as the Agency's Analytical Laboratory.

151. Besides the development work referred to in paragraph 149 above, the Secretariat is working on measurement techniques to assess the power level of reactors so as to obtain continuous information about reactor operation and to monitor the flow of spent fuel assemblies from a reactor to the spent fuel storage area. Other development work has included the use of new statistical methods to draw up sampling plans, to calibrate instruments used for non-destructive testing and to evaluate bias in the measurements of different laboratories. Computer codes have also been prepared for the statistical analysis of inspection data and of analytical results from the network of laboratories.

152. The cost of research and technical contracts on safeguards research and development being carried out with the Agency's support during the period covered by this report amounted to $492 500, of which 21.6% was paid for by the Agency.

[28] Ibid., para. 167.

Table 6

Situation on 30 June 1975 with respect to the signature of, ratification of, or accession to, NPT by non-nuclear-weapon States, and the conclusion of safeguards agreements between the Agency and these States in connection with NPT

| Non-nuclear-weapon States which have signed, ratified or acceded to NPT[a] (1) | Date of ratification or accession[a] (2) | Safeguards agreement with the Agency (3) |
|---|---|---|
| Afghanistan | 4 February 1970 | Approved by the Board |
| Australia | 23 January 1973 | In force: 10 July 1974 |
| Austria | 28 June 1969 | In force: 23 July 1972 |
| Bahamas | 10 July 1973 | |
| Barbados | | Under negotiation |
| Belgium | 2 May 1975 | Signed: 5 April 1973 |
| Bolivia | 26 May 1970 | Signed: 23 August 1974 |
| Botswana | 28 April 1969 | Under negotiation |
| Bulgaria | 5 September 1969 | In force: 29 February 1972 |
| Burundi | 19 March 1971 | Under negotiation |
| Cambodia | 2 June 1972 | |
| Canada | 8 January 1969 | In force: 21 February 1972 |
| Central African Republic | 25 October 1970 | |
| Chad | 10 March 1971 | |
| China, Republic of | 27 January 1970 | Negotiations discontinued |
| Colombia | | |
| Costa Rica | 3 March 1970 | Signed: 12 July 1973 |
| Cyprus | 16 February 1970 | In force: 26 January 1973 |
| Czechoslovakia | 22 July 1969 | In force: 3 March 1972 |
| Dahomey | 31 October 1972 | |
| Denmark | 3 January 1969 | In force: 1 March 1972 |
| Dominican Republic | 24 July 1971 | In force: 11 October 1973 |
| Ecuador | 7 March 1969 | In force: 10 March 1975 |
| Egypt | | |
| El Salvador | 11 July 1972 | In force: 22 April 1975 |
| Ethiopia | 5 February 1970 | Approved by the Board |
| Fiji | 14 July 1972 | In force: 22 March 1973 |
| Finland | 5 February 1969 | In force: 9 February 1972 |
| Gabon | 19 February 1974 | Approved by the Board |
| Gambia | 12 May 1975 | |
| German Democratic Republic | 31 October 1969 | In force: 7 March 1972 |
| Germany, Federal Republic of | 2 May 1975 | Signed: 5 April 1973 |
| Ghana | 5 May 1970 | In force: 17 February 1975 |
| Greece | 11 March 1970 | Provisionally in force: 1 March 1972 |
| Grenada | 19 August 1974 | |
| Guatemala | 22 September 1970 | Under negotiation |
| Haiti | 2 June 1970 | Signed: 6 January 1975 |
| Holy See | 25 February 1971 | In force: 1 August 1972 |
| Honduras | 16 May 1973 | In force: 18 April 1975 |
| Hungary | 27 May 1969 | In force: 30 March 1972 |
| Iceland | 18 July 1969 | In force: 16 October 1974 |
| Indonesia | | |
| Iran | 2 February 1970 | In force: 15 May 1974 |
| Iraq | 29 October 1969 | In force: 29 February 1972 |
| Ireland | 1 July 1968 | In force: 29 February 1972 |
| Italy | 2 May 1975 | Signed: 5 April 1973 |
| Ivory Coast | 6 March 1973 | |
| Jamaica | 5 March 1970 | Under negotiation |
| Japan | | Approved by the Board |
| Jordan | 11 February 1970 | Signed: 5 December 1974 |
| Kenya | 11 July 1970 | Under negotiation |
| Korea, Republic of | 23 April 1975 | Under negotiation |
| Kuwait | | |
| Laos | 20 February 1970 | Under negotiation |
| Lebanon | 15 July 1970 | In force: 5 March 1973 |

| (1) | (2) | (3) |
|---|---|---|
| Lesotho | 20 May 1970 | In force: 12 June 1973 |
| Liberia | 5 March 1970 | |
| Libyan Arab Republic | 26 May 1975 | |
| Luxembourg | 2 May 1975 | Signed: 5 April 1973 |
| Madagascar | 8 October 1970 | In force: 14 June 1973 |
| Malaysia | 5 March 1970 | In force: 29 February 1972 |
| Maldives | 7 April 1970 | Under negotiation |
| Mali | 5 March 1970 | Under negotiation |
| Malta | 6 February 1970 | Under negotiation |
| Mauritius | 28 April 1969 | In force: 31 January 1973 |
| Mexico | 21 January 1969 | In force: 14 September 1973 |
| Mongolia | 14 May 1969 | In force: 5 September 1972 |
| Morocco | 30 November 1970 | In force: 18 February 1975 |
| Nepal | 5 January 1970 | In force: 22 June 1972 |
| Netherlands b/ | 2 May 1975 | Signed: 5 April 1973 |
| New Zealand | 10 September 1969 | In force: 29 February 1972 |
| Nicaragua | 6 March 1973 | Signed: 28 February 1975 |
| Nigeria | 27 September 1968 | Under negotiation |
| Norway | 5 February 1969 | In force: 1 March 1972 |
| Panama | | |
| Paraguay | 4 February 1970 | |
| Peru | 3 March 1970 | Under negotiation |
| Philippines | 5 October 1972 | In force: 16 October 1974 |
| Poland | 12 June 1969 | In force: 11 October 1972 |
| Republic of South Viet-Nam | 10 September 1971 | In force: 9 January 1974 |
| Romania | 4 February 1970 | In force: 27 October 1972 |
| Rwanda | 20 May 1975 | |
| San Marino | 10 August 1970 | Under negotiation |
| Senegal | 17 December 1970 | |
| Sierra Leone | 26 February 1975 | Under negotiation |
| Singapore | | |
| Somalia | 5 March 1970 | Under negotiation |
| Southern Yemen | | |
| Sudan | 31 October 1973 | Signed: 26 February 1975 |
| Sri Lanka | | |
| Swaziland | 11 December 1969 | Approved by the Board |
| Sweden | 9 January 1970 | In force: 14 April 1975 |
| Switzerland | | Under negotiation |
| Syrian Arab Republic | 24 September 1969 | |
| Thailand | 7 December 1972 | In force: 16 May 1974 |
| Togo | 16 February 1970 | |
| Tonga | 7 July 1971 | Approved by the Board |
| Trinidad and Tobago | | |
| Tunisia | 26 February 1970 | Under negotiation |
| Turkey | | |
| United Republic of Cameroon | 8 January 1969 | |
| Upper Volta | 3 March 1970 | |
| Uruguay | 31 August 1970 | Signed: 24 September 1971 |
| Venezuela | | |
| Western Samoa | 18 March 1975 | |
| Yemen, Arab Republic of | | |
| Yugoslavia | 3 March 1970 | In force: 28 December 1973 |
| Zaire | 4 August 1970 | In force: 9 November 1972 |

a/ The information reproduced in columns (1) and (2) was provided to the Agency by the depositary Governments of NPT, and an entry in column (1) does not imply the expression of any opinion on the part of the Secretariat concerning the legal status of any country territory or of its authorities, or concerning the delimitation of its frontiers.

b/ Agreements have also been concluded in respect of the Netherlands Antilles and Surinam, under NPT and Additional Protocol I to the Treaty for the Prohibition of Nuclear Weapons in Latin America. These agreements entered into force on 5 June 1975.

Table 7

Agreements providing for safeguards other than those in connection with NPT, approved by the Board as of 30 June 1975

| Party(ies)[a/] | Subject | Entry into force | INFCIRC |
|---|---|---|---|
| Project Agreements | | | |
| Argentina | Siemens SUR-100 | 13 Mar 1970 | 143 |
| | RAEP Reactor | 2 Dec 1964 | 62 |
| Chile | Herald Reactor | 19 Dec 1969 | 137 |
| Finland[b/] | FiR-1 Reactor | 30 Dec 1960 | 24 |
| | FINN sub-critical assembly | 30 Jul 1963 | 53 |
| Greece[b/] | GRR-1 Reactor | 1 Mar 1972 | 163 |
| Indonesia | Additional core-load for Triga Reactor | 19 Dec 1969 | 136 |
| Iran[b/] | UTRR Reactor | 10 May 1967 | 97 |
| Japan | JRR-3 | 24 Mar 1959 | 3 |
| Mexico[b/] | TRIGA-III Reactor | 18 Dec 1963 | 52 |
| | Siemens SUR-100 | 21 Dec 1971 | 162 |
| | Laguna Verde Nuclear Power Plant | 12 Feb 1974 | 203 |
| Pakistan | PRR Reactor | 5 Mar 1962 | 34 |
| | Booster rods for KANUPP | 17 Jun 1968 | 116 |
| Philippines[b/] | PRR-1 Reactor | 28 Sep 1966 | 88 |
| Republic of South Viet-Nam | VNR-1 Reactor | 16 Oct 1967 | 106 |
| Romania[b/] | TRIGA Reactor | 30 Mar 1973 | 206 |
| Spain | Coral I Reactor | 23 Jun 1967 | 99 |
| Turkey | Sub-critical assembly | 17 May 1974 | |
| Uruguay | URR Reactor | 24 Sep 1965 | 67 |
| Yugoslavia[b/] | TRIGA-II Reactor | 4 Oct 1961 | 32 |
| | KRSKO Nuclear Power Plant | 14 Jun 1974 | 213 |
| Zaire[b/] | TRICO Reactor | 27 Jun 1962 | 37 |

Transfer Agreements
(Agreements for transfer of safeguards under bilateral co-operation agreements between the indicated Parties)

| | | | |
|---|---|---|---|
| Argentina/United States of America | | 25 Jul 1969 | 130 |
| Australia[b/]/United States of America | | 26 Sep 1966 | 91 |
| Australia[b/]/Japan | | 28 Jul 1972 | 170/Corr.1 |
| Austria[b/]/United States of America | | 24 Jan 1970 | 152 |
| Brazil/United States of America | | 20 Sep 1972 | 110/Mod.1 |
| Canada/Japan | | 12 Nov 1969 | 85/Mod.1 |
| Canada/India | | 30 Sep 1971 | 211 |
| China, Republic of/United States of America | | 6 Dec 1971 | 158 |
| Colombia/United States of America | | 9 Dec 1970 | 144 |
| Denmark[b/]/United Kingdom | | 23 Jun 1965 | 63 |
| Denmark[b/]/United States of America | | 29 Feb 1968 | 112 |
| France/Japan | | 22 Sep 1972 | 171 |
| Greece[b/]/United States of America | | 13 Jan 1966 | 78 |
| India/United States of America | | 27 Jan 1971 | 154 |
| Indonesia/United States of America | | 6 Dec 1967 | 109 |
| Iran[b/]/United States of America | | 20 Aug 1969 | 127 |
| Israel/United States of America | | 4 Apr 1975 | |

| Party(ies)[a] | Subject | Entry into force | INFCIRC |
|---|---|---|---|
| Japan/United States of America | | 10 Jul 1968 | 119 |
| Japan/United Kingdom | | 15 Oct 1968 | 125 |
| Korea/United States of America | | 19 Mar 1973 | 111/Mod. 1 |
| Pakistan/Canada | | 17 Oct 1969 | 135 |
| Philippines[b]/United States of America | | 19 Jul 1968 | 120 |
| Portugal/United States of America | | 19 Jul 1969 | 131 |
| Republic of South Viet-Nam/United States of America | | 25 Oct 1965 | 71 |
| South Africa/United States of America | | 28 Jun 1974 | 98 |
| Spain/United States of America | | 28 Jun 1974 | 92 |
| Sweden[b]/United States of America | | 1 Mar 1972 | 165 |
| Switzerland/United States of America | | 28 Feb 1972 | 161 |
| Thailand[b]/United States of America | | 10 Sep 1965 | 68 |
| Turkey/United States of America | | 5 Jun 1969 | 123 |
| Venezuela/United States of America | | 27 Mar 1968 | 122 |
| Unilateral submissions | | | |
| Argentina | Atucha Power Reactor Facility | 3 Oct 1972 | 168 |
| | Nuclear material | 23 Oct 1973 | 202 |
| | Embalse Power Reactor Facility | 6 Dec 1974 | |
| Chile | Nuclear material | 31 Dec 1974 | |
| China, Republic of | Taiwan Research Reactor Facility | 13 Oct 1969 | 133 |
| Mexico[b] | All nuclear activities | 6 Sep 1968 | 118 |
| Panama[c] | All nuclear activities | | |
| Spain | Nuclear material | 19 Nov 1974 | 218 |
| | Nuclear material | 18 Jun 1975 | |
| Switzerland | Nuclear material | | |
| United Kingdom | Certain nuclear activities | 14 Dec 1972 | 175 |

a/ An entry in this column does not imply the expression of any opinion whatsoever on the part of the Secretariat concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

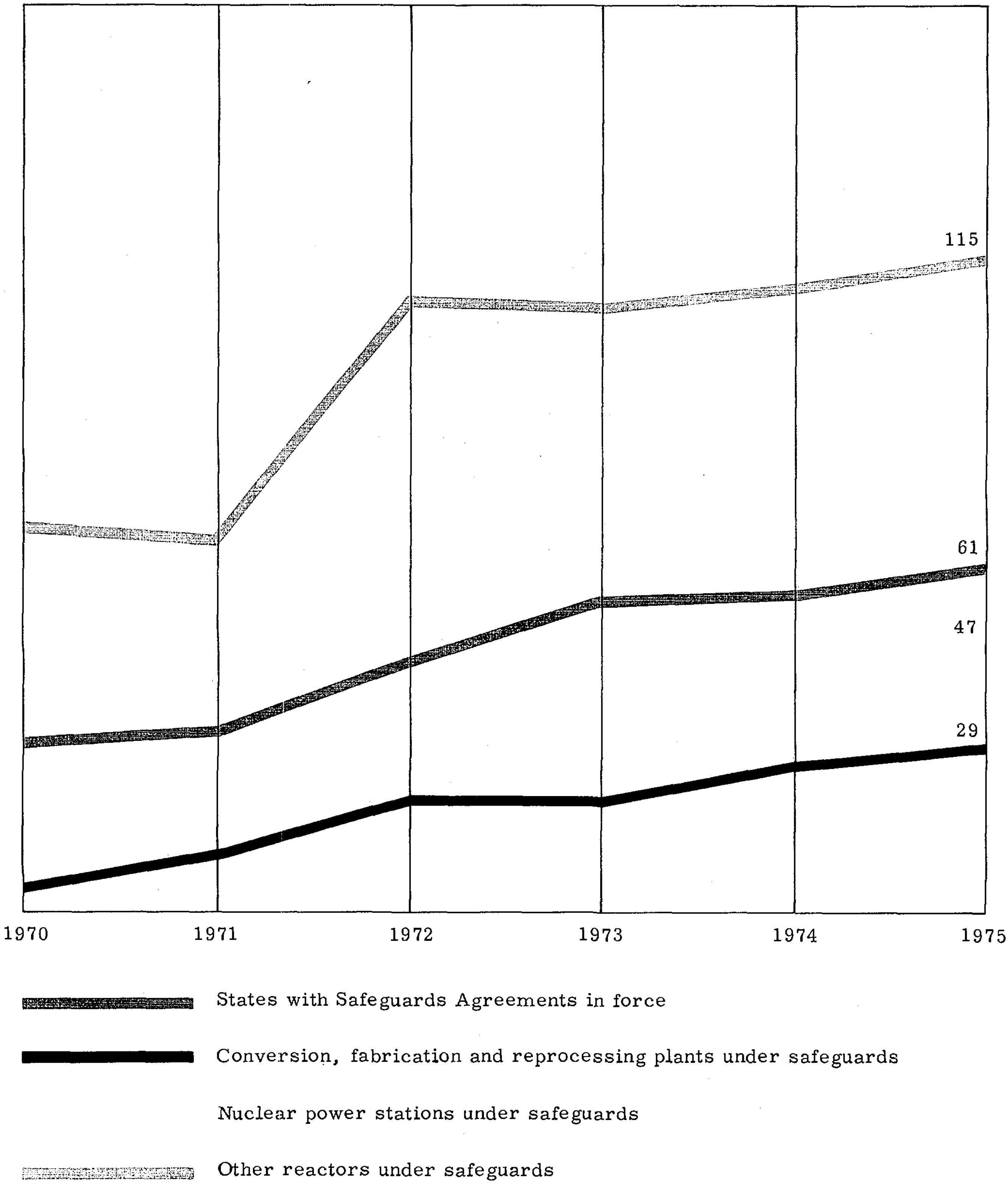
b/ Application of Agency safeguards under this agreement has been suspended as the State has concluded an agreement in connection with NPT.

c/ At present Panama has no significant nuclear activities. The Agreement is concluded under Article 13 of the Treaty for the Prohibition of Nuclear Weapons in Latin America.

FIGURE 7

STATES WITH SAFEGUARDS AGREEMENTS AND FACILITIES UNDER SAFEGUARDS

(as of 30 June)



# ADMINISTRATION

## EXTERNAL RELATIONS AND LEGAL MATTERS

153. The activities relating to external relations and legal matters are referred to in the Introduction and in the preceding sections of this document, especially those on Nuclear safety and environmental protection, and on Safeguarding peaceful nuclear activities.

154. Advice has been provided to the authorities in Malaysia, Singapore and Yugoslavia on appropriate legislation for licensing nuclear power plants, the establishment of regulatory bodies and problems of liability.

155. A study group on regulations and procedures for licensing nuclear installations, held in Athens in December 1974, discussed the basic requirements for licensing and regulatory control of thermal power reactors, the role of technical advisory bodies in safety reviews, the need for adequate regulatory bodies and the importance of liability provisions in regard to contractual arrangements for implementing nuclear power projects.

156. The number of Member States which were party to the Agreement on the Privileges and Immunities of the Agency was 45 on 30 June 1975.

157. Comparative information for the last two years in respect of symposia, conferences and seminars is given in Table 8 below.

Table 8

Conferences, symposia and seminars

| Item | 1973-74 | 1974-75 |
|---|---|---|
| Meetings | 13 | 16 |
| Participants | 2037 | 2450 |
| Countries taking part | 63 | 77 |
| Papers presented | 570 | 800 |

158. The International Centre in Vienna which will house the headquarters of the Agency and UNIDO is expected to be ready for occupancy in late 1978 or early 1979. It will provide offices for more than 4600 officials as well as facilities for scientific meetings and for meetings of governing bodies. Following a reappraisal of the expected requirements of the Agency and UNIDO in the years 1978-81, the General Assembly requested the Secretary-General to enter into negotiations with the Agency and the Austrian authorities with a view to ensuring the most rational and economic use of the premises available. In the meantime, the Agency and UNIDO are continuing to plan common services in the headquarters building.

## PERSONNEL

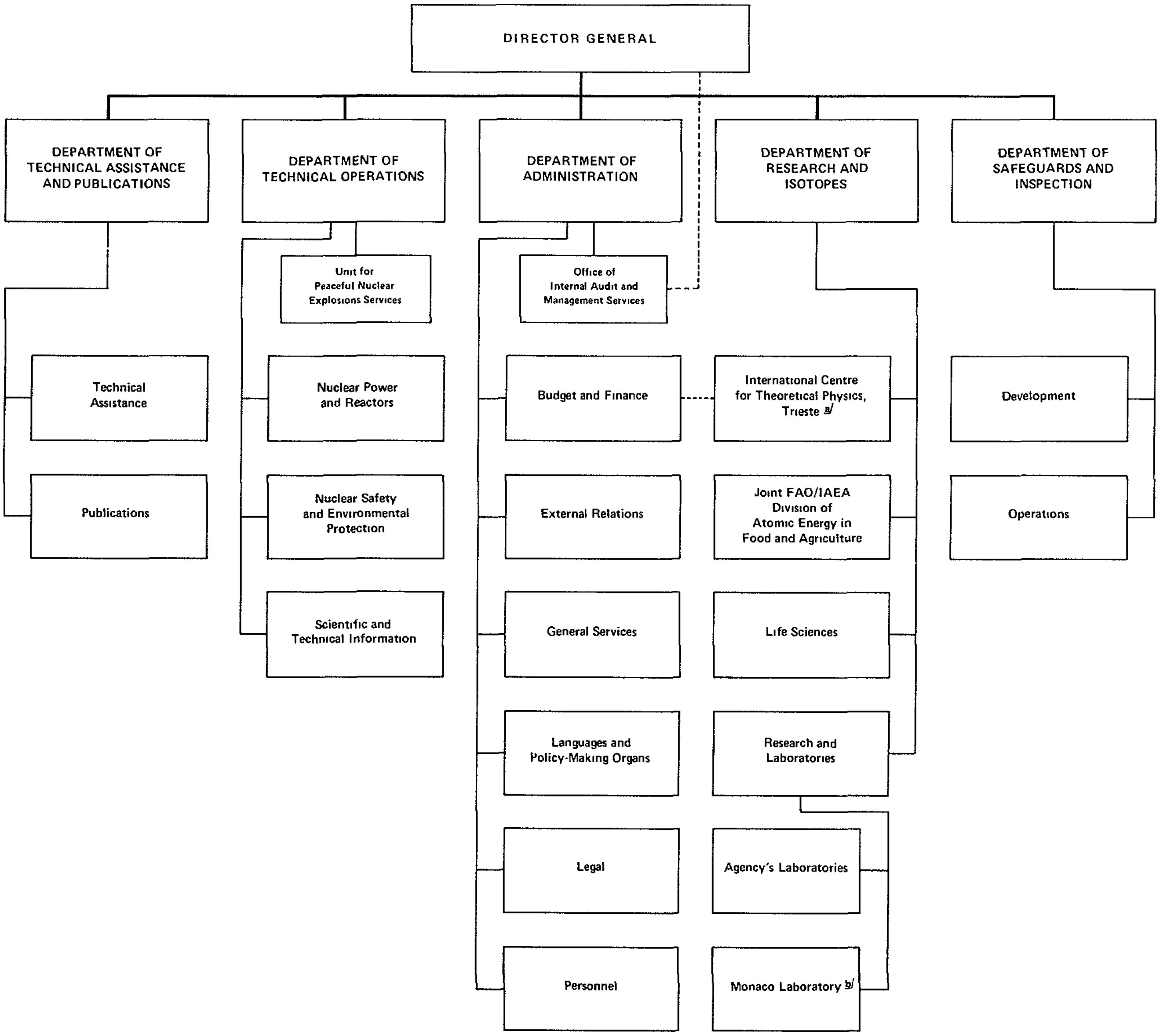
159. On 30 June 1975 the Secretariat had 378 staff members in the Professional and higher categories, 627 in the General Service category and 239 in the Maintenance and Operatives Service category. The number of nationalities represented among that portion of staff which is subject to geographical distribution was 56, as compared to 54 on 30 June 1974.

160. A working group has made a review of the Staff Regulations and Rules for the purpose of determining what changes are needed in order to eliminate inequalities of treatment of staff members of different sexes.

161. In addition, two ad hoc groups were appointed to examine the feasibility of filling certain posts within the Secretariat by part-time employees and to determine whether and to what extent the health insurance benefits structure could be improved.

162. The following organizational chart shows the structure of the Secretariat as at 30 June 1975.

## ORGANIZATIONAL CHART




---

a/ Jointly operated by the Agency and UNESCO
b/ With the increasing participation of UNESCO and UNEP

# FINANCE

## Regular Budget

The financial year 1974

163. The original assessment of contributions on Member States included in the scale of assessment for 1974 amounted to $23 137 000 with the assessments for the Democratic People's Republic of Korea, the German Democratic Republic and Mongolia, which became Members after the scale for 1974 had been prepared, the total assessment was increased to $23 474 491.

164. By 31 December 1974 the following advances to the Working Capital Fund and contributions to the Regular Budget for 1974 had been received:

| | |
|---|---|
| Advances to the Working Capital Fund | $ 2 023 491 |
| Contributions to the Regular Budget for 1974 | 22 735 361 |

By 31 December 1974 Member States had thus paid 99.73% of the total required advances to the Working Capital Fund and 96.85% of the total amount assessed under the Regular Budget.

165. The Agency's obligations for 1974 amounted to $23 492 870, which resulted in budgetary savings of $827 973 from the appropriation for 1974. A further amount of $736 535 from assessments on new Members ($337 491) and higher miscellaneous income than expected ($399 044) brought the total provisional budgetary surplus at 31 December 1974 to $1 564 508[29]. Since contributions in the amount of $739 130 were outstanding for 1974, there was a provisional cash surplus as of 31 December 1974 of $825 378.

The financial year 1975

166. The General Conference approved the scale of assessment and Regular Budget appropriations for 1975 which require payment of assessed contributions by Member States in the amount of $26 660 000[30]; with the assessment for the Democratic People's Republic of Korea and Mauritius, which became Members after the scale for 1975 had been prepared, the total increased to $26 681 910.

167. By 30 June 1975 the following advances to the Working Capital Fund and contributions to the Regular Budget for 1975 had been received:

| | |
|---|---|
| Advances to the Working Capital Fund | $ 1 952 471 |
| Contributions to the Regular Budget for 1975 | 12 835 121 |

By that data Member States had thus paid 97.6% of the total required advances to the Working Capital Fund and 48.1% of the total assessed contributions for 1975.

## Operational Budget

168. At its seventeenth (1973) regular session, the Conference established a target for voluntary contributions of $3 million for 1974, to which 65 Members pledged a total of $3 083 261 or 102.78% of the target, the highest yet attained. By 31 December 1974 a total amount of $2 948 541 had been paid. By 30 June 1975, receipts amounted to $3 017 940, leaving a balance of $65 321 still to be paid.

---

[29] See Statement 1.C of The Agency's Accounts for 1974, document GC(XIX)/549.

[30] Resolution GC(XVIII)/RES/314.

169. The total obligations incurred during 1974 amounted to $4 091 508; together with obligations brought forward from prior years, total obligations amounted to $5 788 516. Unliquidated obligations as at 31 December 1974, including obligations brought forward from previous years, amounted to $2 324 758.

## The Agency's resources in 1974

170. Resources equivalent to more than $38.4 million became available to the Agency during 1974 under its own programme, UNDP accounts and other special projects, including contributions in cash, in kind and in the form of services. Details concerning these resources are included in the Agency's accounts for 1974[31].

[31] Document GC(XIX)/549.

# ANNEX A

## NUCLEAR EXPLOSIONS FOR PEACEFUL PURPOSES

## I. TECHNICAL COMMITTEE ON PEACEFUL NUCLEAR EXPLOSIONS (20-24 January 1975)

### A. Summary of the technical papers presented

1. In general, statements on national programmes revealed continued interest in assessing the technical and economic feasibility of peaceful nuclear explosions (PNE) and in evaluating the health and safety problems. In some cases the interest was qualified by the realization that factors such as high population densities and social attitudes make it improbable that the States concerned will be able to make any use of peaceful nuclear explosions domestically even if such explosions are shown to be technically and economically viable. Health and safety, phenomenology, applications, and projects all received attention in the technical papers presented by participants. The scope of the health and safety papers and the discussion which they generated reflected the considerable attention now being given to these aspects both within and outside of national programmes.

#### Basic phenomena

2. The discussion of explosion phenomena and of the scientific basis for some of the physical and mechanical effects observed showed that there is still considerable opportunity for new and meaningful work in these areas. Three papers concerned themselves with these matters, as shown below:

(a) Mr. Rodionov (Soviet Union) presenting paper TC-1-4/15 pointed out that the residual displacements and their associated stresses following a nuclear explosion are superimposed on the tectonic stress of the rock massive thus changing the stress distribution over a significant area. He suggested that such a modification might be utilized in a mining application or in changing the ease with which certain minerals might be recovered;

(b) The importance of being able to predict rock fracturing was emphasized by Mr. Rodionov (Soviet Union) in presenting paper TC-1-4/16. He detailed results from chemical explosive laboratory experiments in which the relation between the shock front and the fracture front in resin was measured at various shock pressures;

(c) Mr. Prieto (Mexico) in presenting paper TC-1-4/11 showed that the basic shock equations can be transformed by means of dimensionless variables into expressions which are numerically valid for a variety of solid materials and provide added insights into their behaviours under shock loading.

#### Health and safety

3. A number of papers were presented on potential health and safety problems of both contained and excavation PNE applications, with particular emphasis on radiation. In paper TC-1-4/7, Mr. Schwartz (United Stated of America) described in detail the chemical and physical state of the radionuclides produced in most contained situations and discussed the various pathways by which the exposure of man to radiation could occur: seepage of radioactivity to the surface shortly after the detonation through fractures associated with drill holes; release of gases during and subsequent to re-entry; occupational exposure of project workers; longterm migration of radioactivity into local ground water; population exposure to products containing radioactivity. Mr. Rohwer (USA) in paper TC-1-4/8 described a generalized computer-code methodology which can be used to assess, in relation to the recommendations of the International Commission on Radiological Protection (ICRP), the total dose to man from PNE explosions by any pathway or combination of pathways.

Paper TC-1-4/7 examined each potential pathway, assuming significant industrial utilization of three technologies: nuclear gas stimulation, in situ copper leaching, and in situ oil shale retorting. It was concluded that, with all three technologies, radioactivity in the product was the pathway which gave the highest potential exposure in terms both of individual exposures to the general public (approximately 1 mrem/year), and of total population exposure (2000-20 000 man-rem/year); both these exposure levels are less than 1% of background. These potential exposures due to the use of natural gas extracted following nuclear stimulation in the above study are consistent with the findings of a much more detailed study presented by Mr. Rohwer (USA) in paper TC-1-4/3, which analysed the multiple potential pathways for population exposure, including the use of gas not only for domestic and industrial heating but also in food preparation, plastic and fertilizer production and intake food consumer products.

4. Mr. Schwartz (USA), presenting paper TC-1-4/9, gave a typical radionuclide source for nuclear excavation explosions and discussed the general methodology involved in calculating the transport of radioactivity from the explosion to its ultimate fate. The key elements in the process are the fraction of the radioactivity vented, the meteorological processes by which the radioactivity is transported through the atmosphere and deposited on the earth, and finally its passage through the appropriate food chain. As described by Mr. Petrov (Soviet Union) in paper TC-1-4/17, long-range air concentrations and deposition densities are determined by well-known atmospheric diffusion processes and can be calculated with accuracies of a factor of 5 or better for distances of many thousands of kilometres if atmospheric conditions are known. Examples of comparison between calculation and experiment were presented for dry deposition out to several thousand kilometres (project "1003"). Wet deposition or rainout was identified as a very important mechanism in papers TC-1-4/17 and TC-1-4/10, presented by Mr. Petrov (Soviet Union) and Mr. Knox (USA) respectively, since it can increase local radionuclide deposition by an order of magnitude or more with a proportionately higher local dose. Mr. Schwartz (USA) in paper TC-1-4/9 gave an example in which the above methodologies were used to calculate both the close-in fallout pattern and the long-range radionuclide deposition rate for a specific nuclear excavation project, the Kra canal in Thailand, utilizing local food chains for calculating the potential dose to man. Only tritium was found to contribute significantly to the world-wide dose (a total individual dose commitment of approximately 0.1-0.2 mrem). Recognizing that long-range radioactivity from nuclear excavation projects is a matter for concern, Mrs. Grechushkina (Soviet Union) proposed in paper TC-1-4/2 the formulation of standards for such projects, based generally on the recommendations of ICRP, and suggested the following three criteria for the maximum dose to large population groups at long ranges:

(a) The maximum dose should be a small fraction (5-10%) of the ICRP genetic 30-year dose of 5 rem and should be governed by the ICRP dose limits for critical organs;

(b) The genetic and specific organ dose limit should be small compared to that for radioactivity from natural sources; and

(c) The $^{90}Sr$ and $^{137}Cs$ deposition rates should be limited so as not to increase the present average levels of these radionuclides in the northern hemisphere between the 20° and the 70° latitudes (the aim should in fact be to preserve the present trend toward a reduction of these levels).

5. A number of papers contained data on ground motions to be expected from PNEs. Potential damage from ground motions was recognized as the principal limitation on yield and therefore on the economic potential of PNE applications.

## Applications

6. Mr. Parker (United Kingdom of Great Britain and Northern Ireland) in paper TC-1-4/12 reported on a recent study concerning the applicability of a number of PNE ideas for storing and recovering natural resources from beneath the sea bed. The study concluded that, whilst limited opportunities may exist for sea bed applications in mineral recovery and gas storage,

the use of PNEs for assisting with the production of oil and gas from deep sea locations constitutes by far the most interesting possibility. The significance of production stimulation techniques and "at sea" storage developments can be expected to grow as off-shore petroleum exploration progresses. Mr. Parker's study reviewed the advantages offered by PNE techniques along with the questions that must be answered before such an application could be seriously considered for industrial use. Potential reductions in the time required to construct an "at sea" storage facility are seen as being of prime importance.

7. Paper TC-1-4/2 presented by Mr. Lewis (USA) and paper TC-1-4/6 presented by Mr. Hard (USA) examined applications where permeable rubble chimneys would be utilized for further processing of the rubble in situ. The technical and economic viability is dependent therefore on the post-shot process as well as the PNE detonation. Both papers acknowledged the need to compare the potential of the PNE technique with existing and likely future development of alternative technologies capable of achieving the same objective.

8. In the case of the shale oil recovery application described by Mr. Lewis, air is introduced into a nuclear chimney of shale rubble. In situ combustion of a part of the organic material in the shale releases oil which is collected and pumped to the surface. Changed economic circumstances and acknowledgement of the difficulties posed by such environmental problems as the spent shale disposal required by conventional mining and retorting techniques have prompted a re-examination of the PNE alternative. It appears that the total environmental disruption resulting from a nuclear in situ process is potentially very much smaller than that for any process requiring the mining of oil shale.

9. The copper recovery application described by Mr. Hard envisages the formation of a nuclear chimney in a low grade primary deposit below the water table. Bubbling oxygen through the chimney leads to the exidation of primary sulphides, the formation of sulphuric acid and dissolution of the copper. The paper uses the development of a hypothetical ore body to carry through an economic analysis of the application which suggests that the PNE technique may be the only economically viable means of recovering such resources. Potential radiation exposures do not appear to present insuperable problems and seismic damage may pose the main limitation to use of the techniques in populated areas.

Projects

10. A preliminary assessment of the feasibility of using PNEs to assist in the excavation of a canal across the Kra Peninsula was outlined by Mr. Srisukh (Thailand) in his presentation of paper TC-1-4/1. Further studies are required in respect of the scaling of cratering parameters from the kiloton to the megaton region, local geology and hydrology, nuclear explosion phenomenology in limestone, seismic damage estimates, drilling under local conditions and radioactive pathways specific to local food chains. With these limitations in mind it was estimated that some two billion US dollars could be saved by using PNEs. Excavation of the canal using only chemical explosives is estimated to cost approximately six billion US dollars.

11. Not more than 200 000 local inhabitants would have to be evacuated for about one year at a cost considered trivial in relation to the total project cost. With a maximum charge yield of one megaton seismic damage could be a controlling effect with slight damage extending out to about 200 kilometres. The proposed excavation schedule envisages several salvoes of 5 megatons. The most favourable meteorological conditions for limitations of fall-out exposures are expected to occur on about four days a year.

12. An evacuation area determined by an 0.17 rem lifetime dose with re-entry after six months would be contained in Thailand. Estimates of long range cloud travel indicate total exposures of 15 and 1 milliroentgen for the Nicobar Islands and Sumatra respectively. The natural background exposure in these regions is about 100 milliroentgen per year.

13. Safety in Thailand and neighbouring States would be a foremost consideration. It was stated that the Government of Thailand probably would not authorize any PNE use in its

territory without safety assurances from the supplier State or States and the consent of neighbouring countries.

14. Mr. Chidambaram (India), presenting paper TC-1-4/19, described a peaceful nuclear explosion carried out in 1974 along with its immediate physical consequences especially in regard to doming, cratering, ground motion, containment of radioactivity and the post-shot re-entry. Oil reservoir stimulation and non-ferrous metals mining were cited as promising future applications in India.

15. The plutonium device was emplaced at 107 metres below surface in nearly dry shale. A dome uplift occurred without radioactive venting. The dome collapsed to form a shallow crater. Radioactivity above the natural level was not seen in measurements out to some 20 kilometres downwind in the east-north-east direction. Emplacement, meteorological and radiological surveillance were described in some detail and also seismometric measurements, from which the yield was estimated. Re-entry drillings are under way. Special attention could be given to the phenomenology of this event as a contained, but doming and cratering explosion.

16. A survey of the operational aspects and the technical results of the USA's Rio Blanco gas stimulation experiment demonstrated the success which has attended efforts to develop nuclear explosives and firing techniques designed to meet the specific requirements of gas stimulation. In presenting paper TC-1-4/4 Mr. Nordyke (USA) described how the three 30-kt nuclear explosives used in Rio Blanco were emplaced through a conventional 27-cm diameter bore hole. The paper discussed the remote detonating and monitoring system which required only a modest amount of equipment. The top chimney was re-entered through the original emplacement hole although the bottom portion of the re-entry well had to be drilled through rock before connection with the chimney was established.

17. An evaluation of the Rio Blanco experiment was given by Mr. Holzer (USA) in presenting paper TC-1-4-/5. Tritium production was reduced by a factor of 10 in comparison with the Rulison device. Chemical analysis of the gas has established that the expected fracture interconnection did not occur. The reason for this departure from the fracture behaviour predictions of Terhune is not apparent and considerable further investigations of such factors as the fracture behaviour of rocks subject to simultaneous shock from two directions is called for. It was pointed out that inability to achieve interconnection is not of overriding economic importance as the fracture systems can be interconnected by a conventional bore hole which may increase the cost of the gas product by 20%. Gas flow from the upper chimney of the stimulated well has been disappointing. While the reasons for this are not entirely clear, the most likely explanation seems to be an overestimation of the capacity of the original reservoir.

18. In presenting paper TC-1-4/14 Mr. Myasnikov (Soviet Union) reported results from a Soviet nuclear cratering event carried out as a preliminary step in studying the use of nuclear excavation to construct a section of the proposed Pechora-Kama Canal. The Soviet experiment involved a row of three 15-kt nuclear charges fired in a weak water saturated alluvium near the southern end of the section proposed for nuclear construction. The experiment was designed to study the cratering characteristic of the medium and the stability of the crater slopes. A water filled crater trench adequate for use as an integral part of the ultimate canal was formed. The slopes of this water have been stable since the crater was formed.

19. The Soviets have constructed a gas condensate reservoir by means of a 15-kt nuclear explosion at a depth of 1140 metres in a bedded salt formation. Details of the project were given by Mr. Myasnikov (Soviet Union) in his presentation of paper TC-1-4/13. The cavity formed by the explosion has a volume of 50 000 $m^3$ (300 000 barrels) and was tested with gas and fluid up to a pressure of 84 bars to measure its size and to assure its integrity. The cavity was subsequently put into industrial use as part of the development of a gas condensate reservoir, eliminating the necessity of constructing expensive surface processing and storage facilities. The radioactivity in condensate stored in the cavity was reported to be below applicable radiation standards.

## B. Conclusions

20. On the basis of the work of the meeting, the Technical Committee reached a number of conclusions, which are presented in paragraphs 21 to 28 below. In considering these, the technical concepts outlined in the papers presented to the meeting should be borne in mind.

21. Well developed and tested modelling methods are now available for the prediction of the radiological health and safety implications of PNE projects. If the Agency wishes to place itself in a position to speak authoritatively on health and safety aspects of PNEs it should give early consideration to the selection of appropriate models and methods for use by its consultants and staff.

22. Meaningful discussion and analysis of large cratering projects requires the definition of accompanying radiation exposures, particularly those from long distance fallout levels. A useful area of activity for the Agency might be to seek to develop possible technical bases which could be used in quantitative studies of the health and safety aspects of such projects.

23. In many applications currently under evaluation seismic damage is seen to be a critical limiting factor. Improvements in the reliability of forecasting seismic damage could be of considerable significance. The attention given to seismic forecasting in international discussion to date has not been commensurate with the amount of data now available and the Agency might usefully consider facilitating information exchanges in this area.

24. Interest in PNE results within the scientific community at large frequently extends beyond their immediate relevance to PNE application, often in quite unexpected ways. Thus it is worth while publishing or making available all such data even if they do not bear directly on PNE applications. With this in mind the Agency might consider urging its Member States to go as far as practicable in releasing scientific results on peaceful nuclear explosions whether or not such results appear to be relevant to current PNE interests.

25. Recent experimental results indicate that the behaviour of rock in the region between simultaneous explosions may pose special problems from a rock mechanics point of view. Understanding the degree of fracturing and permeability of this region may be important to the economic attractiveness of several PNE applications. Therefore, the Agency should encourage additional fundamental research in this area.

26. The possibility of using PNEs for storage of petroleum liquids appears of considerable interest to many participants, especially if such storage could be developed off shore under the sea bed. Exploring the technical, environmental, and economic aspects of such storage could be a topic appropriate for future Agency activities.

27. An important aspect of the economic evaluation of possible industrial applications of PNEs is a fair comparison with the merits of approaches involving alternative technologies. In developing machinery for dealing with its PNE responsibilities, the Agency might consider how such comparisons could be made available to it and interested Member States.

28. It would be appropriate for the Agency to continue with the regular pattern of technical meetings which it has established.

## II. FEASIBILITY AND UTILITY AND HEALTH AND SAFETY ASPECTS OF NUCLEAR EXPLOSIONS FOR PEACEFUL PURPOSES

### PREFACE

1. The present report deals mainly with two subjects: the feasibility and utility of nuclear explosions for peaceful purposes (PNE) and health and safety aspects of PNE projects. It was prepared by technical consultants to the International Atomic Energy Agency and summarizes the findings with regard to feasibility and utility and to health and safety of four technical bodies convened by the Agency in 1970, 1971, 1972 and January 1975. At the meetings of these bodies altogether 79 technical papers were presented and statements made on national interest in PNE and national PNE programmes by participants from Australia, Egypt, France, the Federal Republic of Germany, India, Japan, Mexico, South Africa, the Soviet Union, Sweden, Thailand, the United Kingdom, the United States of America and Venezuela. The papers contain many detailed references to the literature on PNE. Additional references are given in the extensive PNE bibliography published in 1970 by the International Atomic Energy Agency (see Ref. [3]).

### INTRODUCTION

#### General remarks

2. The technological attraction of PNE is that nuclear explosions represent a very cheap source of concentrated energy for use in the development of natural resources and in geographical engineering. The yields of interest for contained PNE applications may vary from a few kilotons to 100 kt or so, while for cratering applications they may range up to several hundreds of kilotons or even a few megatons. PNE projects, particularly those involving high yields, may affect large expanses of land occupied by many people. Consequently, one must make sure not only that they are technically feasible and economically useful but also that the technology is reliable and safe. In view of the fact that the experience of employing PNE technology is still limited, special attention must be paid to the intrinsically normal reliability and safety requirements.

3. All large-scale engineering projects produce a number of environmental effects which have to be considered carefully. PNE projects have two impacts - radioactivity and ground motion - which require particular attention since they pose special health and safety problems and also problems of public acceptance. One part of the present report is devoted to these matters.

4. Large-scale PNE projects could easily raise legal questions such as those of international liability and arms control, especially if cratering explosions and yields of over 100 kt were involved. It is recognized, for example, that the provision of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water which prohibits the transport across national boundaries of radioactive material from nuclear explosions would constrain large-scale PNE projects. However, the legal questions associated with PNE will not be considered here; a discussion of the conditions for the non-controversial use of PNE can be found in Ref. [1].

#### Review papers

5. One of the papers presented at the panel which met in 1970 was a specially commissioned review paper, based on the experience of France, the Soviet Union and the United States of America, describing both the general state of knowledge concerning the effects of nuclear explosions and the general nature of the use of nuclear explosions for industrial and other peaceful purposes. At the time, it was concluded that: there was a very good basic understanding as regards contained explosions; more experience of the industrial applications envisaged was necessary; seismic damage appeared to be the

main safety consideration limiting the use of contained explosions; more data were needed on the use of nuclear explosions in canal excavation projects. In a review paper commissioned by the International Atomic Energy Agency for the Fourth International Conference on the Peaceful Uses of Atomic Energy in 1971, the technical feasibility, safety and economic viability of proposed PNE applications were also discussed. It was noted in the paper that the quenching of gas well fires by means of nuclear explosions had been demonstrated in practice, an optimistic view was taken concerning the feasibility of the high-pressure underground storage of gas and it was concluded that PNE could reasonably be contemplated for the construction of harbours and simple reservoirs.

Phenomenology and prediction capability

6. An understanding of the phenomenology of PNE is essential for the rational analysis of applications. About one quarter of the papers presented at the meetings of the above-mentioned technical bodies were devoted to the phenomenology of PNE, describing both theoretical studies and experiments. The latter are particularly important since the scatter of the experimental results is the basis for assessing the reliability of PNE as an engineering tool, the reliability of PNE in turn determining how accurate the forecasts of technical potential can be, how rigorous the safety measures should be and what economic risks are involved. For some applications sufficient experimental data have been collected to permit very accurate forecasting, whereas for others sufficient data are clearly not available.

7. A number of the papers presented during the 1970 panel meetings dealt with the basic phenomenology of PNE and showed considerable theoretical and practical understanding of the physics of the shock phenomena occurring near the point of an underground nuclear explosion. The experimental data were sufficient for useful predictions of underground cavity dimensions, chimney diameters, chimney heights and crater dimensions in formations consisting of the rock types so far subjected to the most thorough experimental study: wet and dry alluvium and tuff and hard rock such as granite, basalt and salt. Data on shale had also been accumulated. Data on explosions in carbonate rock and wet clay were reported during later panel meetings, but they were sparse and are still not sufficient for far-reaching conclusions to be drawn about explosions in those rock types. It would be unwise at present to draw conclusions about explosions in untested, completely different rock types, although the one- and two-dimensional codes developed in one country for making predictions of the kind indicated above can also be used for predicting - on the basis of measured geophysical parameters - the results of explosions in rock types which have not yet been thoroughly studied.

8. Already at the time of the 1970 panel meetings, the difficulty of understanding the process of fracturing near the cavity and chimney was appreciated; study of this question has continued and greater understanding of the fracturing process, gained through both experimental and theoretical investigations, has emerged from papers presented at later panel meetings. A proper understanding of the process and the ability to predict the permeability which will be achieved near the point of an explosion are important in most contained applications of PNE and are of critical importance to the economic utility of PNE for the in situ leaching of copper ore.

Development of special PNE explosives

9. Health and safety problems can be significantly reduced by tailoring the radiochemical characteristics of the explosive to the particular circumstances of its application. In addition, the cost of emplacement is strongly dependent on the diameter of the explosive, particularly if the explosive is to be detonated at a considerable depth. With these important considerations in mind, special nuclear explosives for cratering explosions and for contained explosions connected with the exploitation of hydrocarbon deposits have been developed.

FEASIBILITY AND UTILITY OF PNE

10. Due to the exceptional compactness of nuclear explosive devices and to the low cost of the energy released by them, the use of underground nuclear explosions in industry, in construction operations and in scientific research has considerable potential; it would permit the introduction of various new technological processes, make possible certain kinds of large civil engineering project and open up new possibilities in science.

11. During the meetings of the four technical bodies convened by the Agency, 33 reports were presented on practical results, projects, laboratory experiments and theoretical research concerning the technology of underground PNE applications. PNE activities can be divided into three groups:

1. Established industrial applications of PNE;

2. Large-scale experiments under actual field conditions; and

3. Laboratory development work and theoretical studies.

12. The first group consists of PNE applications which have been developed so far that they can be turned over to industry for use - in other words, PNE applications whose technical feasibility and economic utility have been proved in practice. Both technical feasibility and economic utility are, however, very much dependent on the particular circumstances of the envisaged application, and details of geology and geography and also other factors complicate direct economic comparison with conventional alternatives.

13. In the Soviet Union, several PNE applications belong to this first group. Large burning leaks from natural gas wells under high pressure have been quenched by contained nuclear explosions, after it had been found impossible to stop the expensive gas losses (more than 10 million $m^3$ per day) by conventional means. Another established application of contained nuclear explosions is the stimulation of oil deposits, where increases of 30-60% in oil production have been achieved. Nuclear explosions have also been used successfully to make underground cavities in salt formations for the storage of liquid gas-condensate, with costs and construction times several times less than for conventional storage facilities on the surface; the method also requires much less (by a factor of more than one thousand) land surface and makes for greater reliability and safety. In the United Kingdom and France, the storage of gas and oil beneath the sea bed in cavities made by nuclear explosions is being studied. The successful use of a cratering explosion of about 100 kt to make a reservoir for 20 million $m^3$ of water in an arid area of the Soviet Union also falls into this group.

14. A number of experiments may be regarded as falling into the second group.

15. During the meetings of the fourth technical body convened by the Agency, the United States participants reported that, in general, more work was needed to determine or demonstrate the utility of PNE applications; that, while solid technical progress was still being made, the PNE programme of the United States continued to be an experimental one; and that social issues were tending to slow down the effort. As part of the Plowshare programme, three explosions (Gasbuggy, Rulison and Rio Blanco) have been carried out in the United States in low-permeability formations containing natural gas, the aim being to develop a technology for the industrial extraction of gas from such formations. A successful technology of this kind would increase the country's accessible energy resources significantly. The Gasbuggy explosion increased gas production by about a factor of six, but the Rulison and Rio Blanco experiments indicated a need for further studies before the technological feasibility and economic utility of the method can be demonstrated. An experimental explosion for the further development of gas stimulation technology has been carried out in a gas-bearing formation in the Soviet Union; the data obtained are at present being analysed.

16. This second group of activities also includes several projects for excavating large canals: the United States project for a Transisthmian Canal, the Pechora-Kolva Canal project in the Soviet Union, the Venezuelan project for an Orinoco-Rio Negro Canal and the Kra Canal project in Thailand. The studies for the Transisthmian Canal and Pechora-Kolva Canal projects are particularly detailed; the use of nuclear explosions for part of the excavation work should reduce construction time and costs considerably. In the case of the Kra Canal project, it is estimated that the use of nuclear explosions would save US $2000 million out of a total cost of US $6000 million.

17. The routes of these canals pass through both rocky and alluvial soils. Until recently there were no experimental data on nuclear explosions for excavation purposes in water-saturated alluvial soils, and this hindered the more detailed development of such projects. An experimental excavation involving the simultaneous explosion of three 15-kt nuclear devices in saturated alluvial soil has therefore been carried out in the southern part of the route of the Pechora-Kolva Canal. The data obtained point to the feasibility of using underground nuclear explosions in implementing large hydrotechnical projects under complicated engineering and geological conditions. One of the problems which remains to be solved before the technical feasibility of using nuclear explosions to excavate large canals can be established is the lack of data on how kiloton-size experiments will scale up to megaton-size applications.

18. In the Soviet Union and the United States, considerable experimental work (16 nuclear explosions) has been done in connection with the use of single or multiple explosions in dense, dry or slightly saturated soil for the excavation and moving of large amounts of material. The technology has been developed for single explosions of up to 100 kt and multiple explosions involving nuclear devices of up to 15 kt each, but multiple explosions should be studied further.

19. Several technical questions regarding the excavation of canals, such as the interconnection of adjacent rows, remain to be answered by experimentation, perhaps during the preliminary phase of a future project. For very large projects such as the Transisthmian Canal project, the feasibility of nuclear excavation has not been proved; it depends on confirmation of the predictability of the characteristics of craters produced by megaton-size explosions.

20. The primary aim of this second group of activities is to establish the technical feasibility of the applications envisaged - for example, reliably increasing the permeability of dense gas-bearing strata by explosive fracturing, or obtaining sufficiently reliable data on the shape and stability of a canal trench excavated in saturated or water-covered rock of a specific kind. However, such large-scale experiments also relate to pilot gas extraction and other industrial operations. Moreover, the activities in this second group include most of the investigations of the economic utility of envisaged PNE applications. It is only after the economic utility of a technically feasible PNE application has been proved that the application can be regarded as established and be promoted to the first group of PNE activities. Much will depend on practical circumstances and on the possibilities offered by alternative technologies. In France, decision theory is being employed to find the right circumstances for PNE applications. The use of PNE methods in, say, the exploitation of hydrocarbon deposits on a nationally significant scale will require very substantial capital investment, so that high technical reliability would be essential if costly mistakes are to be avoided. In this respect the application of PNE technology is not different from the application of any other new technology. One consequence is that the development of PNE technology could easily take several years or even decades.

21. The third group of PNE activities - laboratory development work and theoretical studies - tend to concern complicated applications, as the simpler ones have already been promoted to the second or first group.

22. In the United States, large amounts of oil may be recovered from bituminous shale which at present has no industrial significance. The fracturing of such shale by contained nuclear explosions, with subsequent in situ retorting of the shale, would - if feasible - increase the country's reserves of crude oil several times over. The results of pilot-scale retorting studies in retorts containing as much as 150 tons of fractured shale support the belief that this technique is feasible. Laboratory studies are also being carried out in the United States on the in situ leaching of copper from ore fractured by underground nuclear explosions. If this rather complicated application is successfully developed, it could increase the accessible copper resources in the United States by a factor of four; interest in this type of PNE application has been shown in India. Ore fracturing by nuclear explosions - in preparation for leaching or mining - is also being studied in the Soviet Union.

23. The use of contained nuclear explosions for the extraction of heat from underground geothermal anomalies and for the disposal of radioactive waste has been considered. The successful use of chemical explosives in constructing river dams in mountainous areas is being studied in the Soviet Union with a view to using nuclear explosions for that purpose; the radioactivity releases from such explosions are expected to be minimal. Studies are also being carried out in the Soviet Union on the use of nuclear explosions to remove overburden from mineral bodies and in making embankments and cuttings.

24. The technical feasibility of the complicated applications to which this third group of PNE activities relates is under preliminary study.

### Scientific uses of PNE

25. At the meetings of the technical bodies convened by the Agency, scientists from several countries described a number of scientific uses of PNE - for example, in the study of high-density fluxes of fast neutrons, in the production of heavy elements, in the study of the effects of high temperatures and high pressures on various materials, and in the study of the Earth's interior exploiting the seismic waves from such explosions.

## HEALTH AND SAFETY ASPECTS

26. The economic utility of PNE applications will ultimately depend on the acceptability of their negative impacts in the light of the benefits which accrue. The evaluation of benefits versus negative impacts must be made on a sound technical basis, although the values assigned to them may vary from one part of the world to another depending on how governments and the public at large perceive them. The negative impacts take three forms: ionizing radiation, ground motion and atmospheric pressure waves. The health and safety problems which might be caused by ionizing radiation would depend largely on the explosive yield involved in the PNE application under consideration, and the intensity of ground motion and the atmospheric pressure waves would depend very much on whether one was carrying out cratering or contained explosions.

### Radiation

27. All nuclear explosions produce a wide variety of radionuclides with different half-lives. The quantities and ultimate fate of these radionuclides depend very much on the types of nuclear explosive used, on the chemistry of the radionuclides in question and on whether the explosion is a contained or a cratering one. In the case of contained explosions, the vast majority of the fission product radionuclides are permanently encapsulated in resolidified molten rock beneath the explosion point. By contrast, a large fraction of any tritium produced will become incorporated into water or hydrocarbons in the vicinity of the explosion. For this reason, all-fission explosives are generally preferred for contained explosions. For cratering explosions, where all the kinds of radioactivity produced find their way into the atmosphere to some extent, thermonuclear explosives are preferable in that the fission contribution is kept small, most of the explosive energy coming from fusion reactions.

Radioactivity pathways in the case of contained explosions

28. The mechanisms by which the radioactivity produced by a contained nuclear explosion could reach man and his environment have been thoroughly studied. Generally speaking, there are five basic mechanisms:

(i) Seepage to the ground surface shortly after the detonation through fractures associated with drill holes;

(ii) Releases of gases during and subsequent to re-entry into the explosion environment;

(iii) Long-term migration into local ground water;

(iv) Occupational exposures of project workers; and

(v) Mixing of radioactivity with a product which is subsequently used in the general economy.

29. The first mechanism may be regarded as an accidental or unplanned release which has a very low probability and involves relatively small potential exposures confined to the immediate vicinity of the explosion. In the United States, studies of all of these mechanisms in a number of applications (gas stimulation, in situ oil shale retorting and in situ chemical mining) have shown that product contamination is by far the most significant one, but even there the potential population exposures are less than 1% of the dose limits recommended by the International Commission on Radiological Protection (ICRP) for the general population and of the exposures due to the natural radiation background.

30. Independent experience gained in the Soviet Union from a number of projects concerned with oil deposit stimulation and gas-condensate storage, and involving prototype facilities in actual industrial use, has verified that the potential exposures due to radionuclides in the products obtained through these PNE applications are below the radiation standards applicable in the Soviet Union.

Radioactivity pathways in the case of explosions for excavation purposes

31. The following mechanisms by which radioactivity from excavation explosions could reach man and his environment have also been thoroughly studied:

(i) Early deposition in the crater zone and the lip area;

(ii) Close-in and local deposition from the base surge and the explosion cloud;

(iii) Meteorological transport over and deposition at long distances (up to several thousand kilometres from the explosion) with subsequent uptake via vegetation and water;

(iv) Exposure to radiation from the air at the time of passage of the explosion cloud and the base surge; and

(v) Uptake by organisms from affected reservoir, river, canal and off-shore marine waters.

32. With the first three mechanisms, the potential danger to man is determined by external irradiation and by the possible penetration of radioactive products into the human organism via different food chains. Radiation from the air at the time of passage of the explosion cloud and the base surge may represent a short-term danger. To keep explosion cloud and base surge exposures well below the ICRP standards, evacuation from the part of the close-in zone lying in the cloud path might be necessary.

33. To evaluate the potential exposures due to the entry of radioactivity into aqueous media, one must consider the food chains involved in the use of the affected waters by man and in the consumption of fishery products obtained from those waters. Investigations for the Transisthmian Canal Study Commission did not indicate any potential exposures above the ICRP standards through this mechanism.

34. The amounts and the composition of radioactive products (including induced activity and fission products) in the close-in zone are different from those at long ranges. With optimum explosive emplacement, only a few per cent of the radioactive products from the explosion are deposited in the close-in zone.

35. The radioactive products deposited at long range consist of a few fission radionuclides (small amounts of radioactive iodine and of radionuclides with gaseous precursors) and tritium. The fractions of various radionuclides transported in the explosion cloud over long distances depend on their volatility and half-lives or on those of their gaseous precursors; the fraction can be about 10% for iodine and as much as 40% for strontium-90, caesium-137 and tritium.

Prediction of population exposures following excavation explosions

36. The accumulated experience with cratering explosions in the Soviet Union and the United States has led to the development of techniques for making accurate predictions about the long-range transport and deposition of radioactivity. The computer programmes employed take into account the generation and the release into the atmosphere of various biologically hazardous radionuclides and their transfer, diffusion and precipitation under the influence of meteorological factors. This makes it possible to calculate doses for a variety of mechanisms and pathways, including external irradiation, inhalation and different food chains.

37. Experience with cratering explosions and the calculation of doses to man for a number of projects involving a series of excavation explosions have shown that such projects can be carried out with doses below the permissible levels envisaged by ICRP.

38. During the meetings of the fourth technical body convened by the Agency, in 1975, Soviet experts presented proposals to limit the long-range doses from excavation explosions to a small fraction of the levels envisaged by ICRP and to limit the long-range deposition of caesium and strontium as a basis for the development of quantitative radiation safety criteria for the large-scale use of nuclear explosions for excavation.

Ground motion

39. Large explosions, whether nuclear or chemical, produce ground motion which can damage buildings and be felt by people over large areas. Damage to buildings is a function of:

(i) The strength of the explosion, the depth at which the device is detonated and the degree of coupling between the shock wave and the earth;

(ii) The geophysical characteristics of the seismic wave transmission path between the source and the buildings; and

(iii) The building type and the quality of their construction.

40. Over the past 15 years considerable experience has been gained in many countries, with both chemical and nuclear explosives. Ground motion and damage to buildings are now regarded as phenomena readily predictable within the limits imposed by uncertainties due to geological factors. These uncertainties generally introduce into ground motion data a scatter of about a factor of 1.5-2, which is not excessive. One measure of the predictability of ground motion and its consequences is the fact that a commercial insurance company provided insurance against damage exceeding the pre-shot estimates for the Rio Blanco experiment. Theoretical studies and field experience indicate that at distances greater than 10 km multiple

explosions produce about the same ground motion as single explosions with the same total yield, although there may be some shift in the frequency spectrum towards longer periods.

41. The cost of strengthening or repairing buildings and other structures must be regarded as additional operational costs of PNE applications. Except in very remote areas, it will impose a limit on yields. In addition, some contained PNE applications will require many explosions in the same general area, and repeated damage to buildings and recurring disruption of the public's activities could arouse significant public opposition. It is difficult to evaluate this potential problem, since its importance will depend on the details of the specific area and on the benefits which the public perceive as accruing from the PNE operations.

42. The total yields involved in excavation explosions tend to be larger than 150 kt, ranging up to several megatons for some projects. The area of potential damage is therefore larger than for contained explosions. The close-in area probably requiring evacuation because of ground motion would coincide roughly with areas which might have to be evacuated because of radiation. As with contained explosions, the cost of ground motion damage must be regarded as an additional cost of the project and will confine the largest projects to very remote locations.

Atmospheric pressure waves

43. Contained explosions of less than 100 kt may produce only insignificant pressure waves in the atmosphere; those from excavation explosions, however, are significant. The damage caused by the direct air wave from an excavation explosion can vary from moderate to heavy near the explosion point, but it is limited to a range of about 10 km. Beyond that range, the effects of refraction in the atmosphere predominate.

44. In the timing of explosions, knowledge of local weather patterns and observation of the winds in the atmosphere permit the selection of days when the refracted waves will not be focused on built-up areas, so that damage by air waves beyond the close-in region is minimized.

Summary of the health and safety situation

45. Over the past 15 years a significant body of technical data and operational experience concerning the health and safety problems of PNE applications has been accumulated; this is reflected in the papers presented at the meetings of the four technical bodies convened by the Agency. A number of contained nuclear explosions carried out in the light of that body of knowledge have shown that exposure of the general public is only a small fraction of the maximum permissible exposures envisaged by ICRP. With excavation projects, however, it might be necessary in some cases to evacuate the local population temporarily in order to ensure such a low exposure level. Damage to buildings through ground motion and atmospheric pressure waves is predictable in principle; it can involve significant costs which will in practice impose limits as regards the size and location of PNE projects. Public acceptance of these negative impacts will depend on the nature of the project and where it is to be carried out and on the balance between benefits and negative impacts as perceived by the public.

Public acceptance of PNE

46. When one tries to predict the attitudes which the authorities and the public will adopt towards the calculated risk associated with PNE, the question arises of the public acceptance of different kinds of risk. In assessing the utility of PNE, one will ultimately have to take into account not only the technical feasibility and the purely economic utility of PNE projects but also their public acceptance at the national and international level. The risks for the general public are calculated on the basis of engineering calculations of technical reliability, preferably stated with confidence limits, and in the light of the safety measures to be adopted.

The public is especially wary of radioactivity, and there is a growing tendency to question new applications of science. Only one panel paper was entirely devoted to this important question, which should be studied further.

---

REFERENCES

[1] The Question of Nuclear Explosions for Peaceful Purposes by Non-Nuclear-Weapon States and the Possibility of Misuse of such Technology for the Production of Nuclear Weapons; Document A/CONF. 35/DOC. 3 of 3 July, 1968, written at the request of the Secretary-General of the United Nations as a background paper for the Conference of Non-Nuclear-Weapon States, Geneva (1968).

[2] Peaceful Nuclear Explosions, Phenomenology and Status Report (1970); Proceedings of a panel on the peaceful uses of nuclear explosions organized by the International Atomic Energy Agency and held in Vienna, 2-6 March 1970; IAEA, Vienna (1970).

[3] Peaceful Uses of Nuclear Explosions, Bibliographical Series No. 38, IAEA, Vienna (1970).

[4] Peaceful Nuclear Explosions II, their Practical Application; Proceedings of a panel on the practical applications of the peaceful uses of nuclear explosions organized by the International Atomic Energy Agency and held in Vienna, 18-22 January 1971; IAEA, Vienna (1971).

[5] Current Status of Civil Engineering and Mineral Resources Development Applications of Peaceful Nuclear Explosions, paper A/CONF. 49/P/762 by A. R. W. Wilson on behalf of the International Atomic Energy Agency; Proceedings of the Fourth International Conference on the Peaceful Uses of Atomic Energy, Geneva, 6-16 September 1971, Volume 7; IAEA, Vienna (1972) 211.

[6] Peaceful Nuclear Explosions III, Applications, Characteristics and Effects; Proceedings of a panel organized by the International Atomic Energy Agency and held in Vienna, 27 November-1 December 1972; IAEA, Vienna (1974).

[7] Peaceful Nuclear Explosions IV, Applications and Health and Safety; Proceedings of a technical committee organized by the International Atomic Energy Agency and held in Vienna, 20-24 January 1975; to be published by the IAEA, Vienna.

## III. RESOLUTION ADOPTED BY THE BOARD OF GOVERNORS ON 11 JUNE 1975

### Establishment of an advisory group on nuclear explosions for peaceful purposes

The Board of Governors,

(a) Deeply conscious of the importance of the objective of the Agency set forth in Article II of its Statute to seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world,

(b) Mindful that, under that Article, the Agency shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose,

(c) Desirous that any benefits which may accrue from the use of nuclear explosions for peaceful purposes (PNE) may also be available to non-nuclear-weapon States, and

(d) Recalling:

(i) Resolution 2829 (XXVI) of the General Assembly of the United Nations, regarding the establishment within the framework of the Agency of an international service for PNE[1];

(ii) Article V of the Treaty on the Non-Proliferation of Nuclear Weapons[2] and Article I of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water[3];

(iii) Its report to the General Conference in 1969 on the Agency's responsibility to provide services in connection with PNE[4] and the guidelines for the international observation by the Agency of PNE which it approved in 1972[5];

(iv) Its resolution of 13 September 1974 on PNE[6] and the approach it has decided should be adopted by the Agency in responding to requests for PNE-related services[7];

(v) Resolution 3261 D (XXIX) in which the General Assembly requested the Agency to continue its studies on the peaceful applications of nuclear explosions, their utility and feasibility, including legal, health and safety aspects[8]; and

(vi) The views of the Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, held in 1975, regarding Article V of the Treaty, as expressed in the Final Declaration of the Conference,

1. Decides to establish an advisory group under the aegis of the Board, open to participation by interested Members of the Agency, to be known as the Ad Hoc Advisory Group on Nuclear Explosions for Peaceful Purposes and having the following terms of reference:

(a) To examine the aspects of nuclear explosions for peaceful purposes (PNE) coming within the Agency's sphere of competence, with particular reference to:

(i) Procedural aspects relating to possible requests for PNE-related services;

(ii) Legal aspects and treaty obligations;

(iii) Health and safety matters; and

(iv) Economic aspects, including comparisons with non-nuclear alternatives,

taking fully into account the work already done in these fields by technical committees under the auspices of the Agency;

(b) To advise the Board on the factors involved in the establishment and operation of an international service for PNE as envisaged in paragraph 1(c) of its resolution on PNE of 13 September 1974[6]; and

(c) To advise the Board, within the Agency's sphere of competence, on the structure and content of agreements necessary under Article V of the Treaty on the Non-Proliferation of Nuclear Weapons[2];

2. Requests the Director General to arrange for the Ad Hoc Advisory Group to begin work after the General Conference's session in 1975;

3. Directs the Ad Hoc Advisory Group to elect a chairman and two vice-chairmen;

4. Requests the Director General:

(a) To transmit the text of this resolution to all Members of the Agency, inviting them to communicate to him information and views within its context;

(b) To prepare and circulate a compilation of the information and views received, with such comment as he may deem appropriate, as a basis for the Ad Hoc Advisory Group's work; and

(c) To furnish the Ad Hoc Advisory Group with any expert assistance it may require, and to co-ordinate the Agency's programme in the field of PNE with the work of the Ad Hoc Advisory Group;

5. Requests the Ad Hoc Advisory Group to submit a final report to the Board, if possible within eighteen months, submitting interim reports if deemed appropriate;

6. Requests the Director General to bring this resolution to the notice of the Secretary-General of the United Nations for communication to the General Assembly; and

7. Authorizes the Ad Hoc Advisory Group to invite States party to the Treaty on the Non-Proliferation of Nuclear Weapons but not members of the Agency which would wish to do so to participate in the Ad Hoc Advisory Group's work.

---

[1] Official records, Twenty-sixth session, Supplement No. 29 (A/8429).

[2] Reproduced in document INFCIRC/140.

[3] Reproduced in United Nations Treaty Series, Vol. 480, under No. 6964.

[4] GC(XIII)/410.

[5] Reproduced in document INFCIRC/169.

[6] Reproduced in United Nations document A/9722/Add. 1, Annex I.

[7] Ibid., Annex II.

[8] See operative para. 2 of the text set forth in United Nations document A/RES/3261 (XXIX).

## ANNEX B

### FELLOWSHIPS OFFERED OR PROVIDED FREE OF CHARGE IN 1974

| Donor | Number of fellowships | |
|---|---|---|
| | Available | Awarded a/ |
| **Member States** | | |
| Argentina | 5 | 9 |
| Australia | b/ | 2 |
| Austria | 2 | 2 |
| Belgium | 6 | 3 |
| Brazil | 10 | 2 |
| Bulgaria | 2 | - |
| Czechoslovakia | 9 | 3 |
| Denmark | 5 | 4 |
| Egypt | 1 | 1 |
| Finland | 2 | 2 |
| France | c/ | 10 |
| Germany, Federal Republic of | d/ | 16 |
| Hungary | 4 | 2 |
| India | 10 | 4 |
| Israel | e/ | - |
| Italy | 20 | 12 |
| Japan | 10 | 8 |
| Mexico | 2 | - |
| Netherlands | 9 | 4 |
| Pakistan | 6 | - |
| Philippines | 2 | 2 |
| Poland | 10 | 4 |
| Romania | 10 | - |
| Spain | 5 | 4 |
| Sweden | f/ | 13 |
| Thailand | 2 | - |
| Union of Soviet Socialist Republics | f/ | 2 |
| United States of America | f/ | 64 |
| Yugoslavia | g/ | 2 |
| **Regional organization** | | |
| Joint Institute for Nuclear Research, Dubna, Soviet Union | 3 | 1 |

a/ As of 31 December 1974: number of awards less rejections and withdrawals.

b/ No maximum number of awards specified by the Government.

c/ 140 man-months.

d/ 360 man-months.

e/ 45 man-months.

f/ Awards made on basis of available funds.

g/ 22 man-months.

# ANNEX C

## RESEARCH CONTRACTS

### I. Total value of contracts in 1973 and 1974

| Year | New contracts | Renewals | Total | Value |
|---|---|---|---|---|
| 1973 | 64 | 150 | 214 | 729 497 |
| 1974 | 72 | 146 | 218 | 745 390 |

### II. Analysis by subject matter of contracts awarded or renewed in 1974

| Subject matter of research | Number of contracts placed | Number of contracts renewed | Agency payment in dollars |
|---|---|---|---|
| Nuclear technology | | | |
| Nuclear power and reactors | 5 | 12 | 64 100 |
| Waste management | 2 | 10 | 37 580 |
| Physics | 4 | 6 | 37 150 |
| Radioisotopes and radiation applications in | | | |
| Agriculture | 19 | 48 | 183 350 |
| Food irradiation | 8 | 5 | 50 350 |
| Hydrology | 3 | 2 | 31 550 |
| Industry and chemistry | 3 | 5 | 23 500 |
| Medicine | 10 | 21 | 126 760 |
| Protection of man and his environment | | | |
| Radiological safety | 8 | 12 | 75 500 |
| Radiation biology | 4 | 20 | 75 500 |
| Environmental research | 1 | 3 | 17 650 |
| Dosimetry | 5 | 2 | 25 100 |
| Total | 72 | 146 | 748 090 |

# ANNEX D

## CONFERENCES, SYMPOSIA AND SEMINARS HELD DURING THE PERIOD 1 JULY 1974-30 JUNE 1975

| Date and place | Title | Co-sponsoring organizations | Number of participants | Number of countries represented | Number of organizations represented | Number of papers presented |
|---|---|---|---|---|---|---|
| 1974 | | | | | | |
| 15-19 July Knoxville, United States of America | Symposium on Dynamic Studies with Radioisotopes in Clinical Medicine and Research | | 197 | 30 | 2 | 67 |
| 22-26 July Innsbruck, Austria | Symposium on the Sterility Principle for Insect Control | FAO | 91 | 37 | 5 | 53 |
| 26-30 August Oslo | Symposium on Physical and Biological Effects on the Environment of Cooling Systems and Thermal Discharges at Nuclear Power Stations | ECE | 197 | 25 | 8 | 50 |
| 30 September-4 October Varna, Bulgaria | International Symposium on Information Systems: Connection and Compatibility | UNESCO FAO | 146 | 37 | 14 | 41 |
| 21-25 October Vienna | Symposium on Thermodynamics of Nuclear Materials | | 107 | 22 | 4 | 67 |
| 11-15 November Tokyo | Fifth Conference on Plasma Physics and Controlled Nuclear Fusion Research | | 445 | 24 | 4 | 178 |
| 18-22 November Vienna | Symposium on Isotope Ratios as Pollutant Source and Behaviour Indicators | FAO | 108 | 23 | 3 | 34 |
| 9-13 December Vienna | Symposium on the Siting of Nuclear Facilities | NEA | 236 | 39 | 10 | 38 |
| 9-13 December Bombay, India | Symposium on Ionizing Radiation for Sterilization of Medical Products and Biological Tissues | | 92 | 26 | 2 | 43 |
| 1975 | | | | | | |
| 10-14 March Vienna | International Symposium on Advances in Biomedical Dosimetry | | 139 | 31 | 5 | 49 |
| 10-14 March Karlsruhe, Federal Republic of Germany | Educational Seminar on the Uses of Californium-252 in Teaching and Research | | 34 | 23 | - | 22 |
| 17-21 March Munich, Federal Republic of Germany | International Symposium on the Use of High-Level Radiation in Waste Treatment - Status and Prospects | | 155 | 26 | 2 | 48 |
| 14-18 April Innsbruck, Austria | International Symposium on Reliability of Nuclear Power Plants | | 213 | 40 | 8 | 48 |
| 2-6 June Stockholm | International Symposium on the Combined Effects on the Environment of Radioactive, Chemical and Thermal Releases from the Nuclear Industry | NEA | 132 | 24 | 9 | 22 |
| 16-20 June Ankara | INIS/AGRIS Training Seminar | FAO | 85 | 32 | 7 | - |
| 23-27 June Franceville, Gabon | International Symposium on the Oklo Phenomenon | Government of Gabon and French Atomic Energy Commission | 73 | 19 | 2 | 40 |

# ANNEX E

## STATUS OF FINANCIAL CONTRIBUTIONS TO THE AGENCY ON 30 JUNE 1975

### 1. Advances to the Working Capital Fund and contributions to the Regular Budget for 1975

| Member State | Working Capital Fund | | | Regular Budget for 1975 | | | |
|---|---|---|---|---|---|---|---|
| | Assessed | Paid | Outstanding | Assessed | Credit | Paid | Outstanding |
| Afghanistan | 400 | 400 | - | 5 054 | - | 400 | 4 654 |
| Albania | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Algeria | 1 600 | 1 600 | - | 19 264 | 200 | - | 19 064 |
| Argentina | 17 200 | 17 200 | - | 207 088 | - | - | 207 088 |
| Australia | 29 800 | 29 800 | - | 401 468 | - | 199 934 | 201 534 |
| Austria | 11 600 | 11 600 | - | 156 275 | - | 89 000 | 67 275 |
| Bangladesh | 2 000 | 1 271 | 729 | 24 080 | - | - | 24 080 |
| Belgium | 21 800 | 21 800 | - | 293 692 | - | 293 692 | - |
| Bolivia | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Brazil | 16 000 | 16 000 | - | 192 640 | - | 192 640 | - |
| Bulgaria | 3 000 | 3 000 | - | 36 120 | - | 400 | 35 720 |
| Burma | 600 | 600 | - | 7 393 | - | 400 | 6 993 |
| Byelorussian Soviet Socialist Republic | 9 600 | 9 600 | - | 129 332 | - | 64 666 | 64 666 |
| Cambodia | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Canada | 65 800 | 65 800 | - | 886 461 | - | 886 461 | - |
| Chile | 3 000 | 3 000 | - | 36 209 | - | 800 | 35 409 |
| Colombia | 3 400 | 3 400 | - | 40 936 | - | - | 40 936 |
| Costa Rica | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Cuba | 2 200 | 2 200 | - | 26 854 | 511 | - | 26 343 |
| Cyprus | 400 | 400 | - | 5 054 | 400 | 4 654 | - |
| Czechoslovakia | 18 400 | 18 400 | - | 247 886 | - | 247 886 | - |
| Denmark | 13 000 | 13 000 | - | 175 136 | - | 175 136 | - |
| Dominican Republic | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Ecuador | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Egypt | 2 400 | 2 400 | - | 29 193 | - | - | 29 193 |
| El Salvador | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Ethiopia | 400 | 400 | - | 5 054 | 400 | - | 4 654 |
| Finland | 8 800 | 8 800 | - | 118 554 | - | 118 554 | - |
| France | 121 400 | 121 400 | - | 1 635 508 | - | 1 436 886 | 198 622 |
| Gabon | 400 | 400 | - | 5 054 | 400 | - | 4 654 |
| German Democratic Republic | 25 200 | 25 200 | - | 339 496 | 1 800 | 337 696 | - |
| Germany, Federal Republic of | 147 000 | 147 000 | - | 1 980 392 | - | 1 980 392 | - |
| Ghana | 800 | 800 | - | 9 920 | 600 | 9 320 | - |
| Greece | 6 600 | 5 600 | 1 000 | 79 464 | - | - | 79 464 |
| Guatemala | 600 | 600 | - | 7 393 | - | - | 7 393 |
| Haiti | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Holy See | 400 | 400 | - | 5 389 | 400 | 4 989 | - |
| Hungary | 6 800 | 6 800 | - | 91 610 | 2 400 | - | 89 210 |
| Iceland | 400 | 400 | - | 5 389 | 400 | 4 989 | - |
| India | 24 800 | 24 800 | - | 298 592 | - | 298 592 | - |
| Indonesia | 4 000 | 4 000 | - | 48 843 | - | 1 400 | 47 443 |
| Iran | 4 200 | 4 200 | - | 50 568 | - | - | 50 568 |
| Iraq | 1 000 | 1 000 | - | 12 040 | 400 | 11 640 | - |
| Ireland | 3 200 | 3 200 | - | 43 110 | - | 43 110 | - |
| Israel | 4 400 | 4 400 | - | 59 277 | - | 59 277 | - |
| Italy | 74 600 | 74 600 | - | 1 005 016 | - | 1 005 016 | - |
| Ivory Coast | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Jamaica | 400 | 400 | - | 5 243 | 1 316 | - | 3 927 |
| Japan | 148 000 | 103 600 | 44 400 | 1 993 864 | - | - | 1 993 864 |
| Jordan | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Kenya | 400 | 400 | - | 5 054 | - | 5 054 | - |
| Korea, Republic of | 2 200 | 2 200 | - | 26 488 | - | 15 339 | 11 149 |
| Kuwait | 1 800 | 1 800 | - | 24 249 | - | 24 249 | - |
| Lebanon | 600 | 600 | - | 7 393 | 400 | - | 6 993 |
| Liberia | 400 | 400 | - | 5 054 | 400 | - | 4 654 |
| Libyan Arab Republic | 2 200 | 1 400 | 800 | 29 639 | - | - | 29 639 |
| Liechtenstein | 400 | 400 | - | 5 389 | 400 | 4 989 | - |
| Luxembourg | 800 | 800 | - | 10 777 | 200 | 10 577 | - |
| Madagascar | 400 | 400 | - | 5 054 | 727 | 4 327 | - |
| Malaysia | 1 400 | 1 400 | - | 16 935 | - | 600 | 16 335 |

| Member State | Working Capital Fund | | | Regular Budget for 1975 | | | |
|---|---|---|---|---|---|---|---|
| | Assessed | Paid | Outstanding | Assessed | Credit | Paid | Outstanding |
| Mali | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Mexico | 17 800 | 17 800 | - | 214 312 | - | 214 312 | - |
| Monaco | 400 | 400 | - | 5 389 | 905 | 4 484 | - |
| Mongolia | 400 | 400 | - | 5 054 | 400 | 4 654 | - |
| Morocco | 1 200 | 1 200 | - | 14 597 | 1 599 | 12 138 | 860 |
| Netherlands | 25 600 | 25 600 | - | 344 885 | - | 344 885 | - |
| New Zealand | 5 800 | 5 800 | - | 78 138 | 400 | - | 77 738 |
| Niger | 400 | 400 | - | 5 054 | - | 5 054 | - |
| Nigeria | 2 000 | 2 000 | - | 24 080 | - | - | 24 080 |
| Norway | 9 000 | 9 000 | - | 121 248 | - | 121 248 | - |
| Pakistan | 3 000 | 3 000 | - | 36 120 | 3 600 | 16 260 | 16 260 |
| Panama | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Paraguay | 400 | - | 400 | 5 054 | - | - | 5 054 |
| Peru | 1 400 | 1 400 | - | 16 856 | - | - | 16 856 |
| Philippines | 3 800 | 3 800 | - | 46 693 | 2 200 | - | 44 493 |
| Poland | 26 000 | 26 000 | - | 350 274 | - | 166 953 | 183 321 |
| Portugal | 3 200 | 3 000 | 200 | 38 528 | - | - | 38 528 |
| Republic of South Viet-Nam | 1 200 | 1 200 | - | 14 448 | 200 | - | 14 248 |
| Romania | 6 200 | 6 200 | - | 74 648 | 800 | - | 73 848 |
| Saudi Arabia | 1 200 | 1 200 | - | 14 448 | 200 | - | 14 248 |
| Senegal | 400 | 400 | - | 5 054 | - | 5 054 | - |
| Sierra Leone | 400 | 400 | - | 5 054 | - | 5 054 | - |
| Singapore | 800 | 800 | - | 9 632 | 200 | 9 432 | - |
| South Africa | 10 400 | 10 400 | - | 125 216 | - | 125 216 | - |
| Spain | 20 400 | 20 400 | - | 245 616 | - | - | 245 616 |
| Sri Lanka | 600 | 600 | - | 7 393 | 400 | - | 6 993 |
| Sudan | 400 | 400 | - | 5 243 | - | 400 | 4 843 |
| Sweden | 27 000 | 27 000 | - | 363 746 | - | 363 746 | - |
| Switzerland | 17 000 | 17 000 | - | 229 025 | - | 229 025 | - |
| Syrian Arab Republic | 400 | 400 | - | 5 054 | - | 5 054 | - |
| Thailand | 2 200 | 2 200 | - | 26 488 | 200 | 26 288 | - |
| Tunisia | 400 | 400 | - | 5 054 | - | 5 054 | - |
| Turkey | 6 000 | 6 000 | - | 72 240 | 800 | - | 71 440 |
| Uganda | 400 | 400 | - | 5 054 | - | - | 5 054 |
| Ukrainian Soviet Socialist Republic | 35 400 | 35 400 | - | 476 911 | 400 | 238 255 | 238 256 |
| Union of Soviet Socialist Republics | 268 600 | 268 600 | - | 3 618 593 | 3 600 | 1 807 497 | 1 807 496 |
| United Kingdom of Great Britain and Northern Ireland | 110 000 | 110 000 | - | 1 481 926 | 3 200 | 1 478 726 | - |
| United Republic of Cameroon | 400 | 400 | - | 5 054 | 400 | 4 654 | - |
| United States of America | 553 200 | 553 200 | - | 7 452 741 | 23 537 | - | 7 429 204 |
| Uruguay | 1 200 | 1 200 | - | 14 448 | - | 7 810 | 6 638 |
| Venezuela | 6 600 | 6 600 | - | 79 464 | 1 200 | - | 78 264 |
| Yugoslavia | 7 000 | 7 000 | - | 84 280 | 200 | 42 000 | 42 080 |
| Zaire | 400 | 400 | - | 5 243 | 400 | - | 4 843 |
| Zambia | 400 | 400 | - | 5 054 | 5 | 471 | 4 578 |
| Sub-total | 2 000 000 | 1 952 471 | 47 529 | 26 660 000 | 56 200 | 12 776 789 | 13 827 011 |
| New Members: | | | | | | | |
| Democratic People's Republic of Korea a/ | 1 400 | 1 400 | - | 16 856 | - | 2 132 | 14 724 |
| Mauritius b/ | 400 | - | 400 | 5 054 | - | - | 5 054 |
| Sub-total | 1 800 | 1 400 | 400 | 21 910 | - | 2 132 | 19 778 |
| TOTAL | 2 001 800 | 1 953 871 | 47 929 | 26 681 910 | 56 200 | 12 778 921 | 13 846 789 |
| Per cent of assessment | | 97.6 | | | | 48.1 | |

a/ Became a Member on 18 September 1974.

b/ Became a Member on 31 December 1974, but was assessed from 1 January 1975.

## 2. Outstanding contributions to the Regular Budgets for the years 1958-1974

| State | 1958-1965 a/ | 1966 b/ | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 b/ | 1974 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Albania | - | - | - | - | - | - | - | - | - | 6 498 | 6 498 |
| Argentina | - | - | - | - | - | - | - | - | - | 800 | 800 |
| Bangladesh | - | - | - | - | - | - | - | - | 471 | 29 449 | 29 920 |
| Bolivia | - | - | - | - | - | - | - | - | 3 468 | 8 414 | 11 882 |
| Cambodia | - | - | - | - | - | - | - | - | 3 344 | 8 414 | 11 758 |
| Colombia | - | - | - | - | - | - | - | 510 | 30 498 | 37 862 | 68 870 |
| Costa Rica | - | - | - | - | - | - | - | - | - | 5 281 | 5 281 |
| Dominican Republic | 13 763 | 3 467 | 3 670 | 4 065 | 4 355 | 4 741 | 5 221 | 5 934 | 6 778 | 8 414 | 60 408 |
| Ecuador | - | - | - | - | 520 | 4 741 | 5 221 | 5 934 | 6 778 | 8 414 | 31 608 |
| Egypt | - | - | - | - | - | - | - | - | - | 10 904 | 10 904 |
| El Salvador | - | - | - | - | 3 844 | 4 741 | 5 221 | 5 934 | 6 778 | 8 414 | 34 932 |
| Greece | - | - | - | - | - | - | - | - | - | 13 964 | 13 964 |
| Guatemala | - | - | - | - | - | - | - | - | - | 4 466 | 4 466 |
| Haiti | 18 019 | 3 467 | 3 670 | 4 065 | 4 355 | 4 741 | 5 221 | 5 934 | 6 778 | 8 414 | 64 664 |
| Honduras c/ | 5 105 | 3 467 | 3 670 | - | - | - | - | - | - | - | 12 242 |
| Ivory Coast | - | - | - | - | - | - | - | - | 71 | 8 414 | 8 485 |
| Jordan | - | - | - | - | - | - | - | - | 191 | 8 414 | 8 605 |
| Mali | - | - | 2 042 | 4 065 | 4 355 | 4 741 | 5 221 | 5 934 | 6 778 | 8 414 | 41 550 |
| Nicaragua d/ | - | - | - | - | - | 3 707 | - | - | - | - | 3 707 |
| Nigeria | - | - | - | - | - | - | - | - | - | 3 260 | 3 260 |
| Panama | - | - | - | - | - | - | - | - | - | 1 882 | 1 882 |
| Paraguay | 20 004 | 3 467 | 3 670 | 4 065 | 4 355 | 4 741 | 5 341 | 5 934 | 6 778 | 8 414 | 66 769 |
| Peru | - | - | - | - | - | - | - | - | - | 562 | 562 |
| Spain | - | - | - | - | - | - | - | - | - | 400 | 400 |
| Uganda | - | - | - | - | - | 4 227 | 5 221 | 5 934 | 6 778 | 8 414 | 30 574 |
| Total outstanding | 56 891 | 13 868 | 16 722 | 16 260 | 21 784 | 36 380 | 36 667 | 42 048 | 85 489 | 207 882 | 533 991 |
| Total paid | 50 122 437 | 8 663 691 | 9 168 288 | 10 155 370 | 10 889 669 | 11 834 400 | 13 309 992 | 15 355 886 | 18 173 268 | 23 266 609 | 170 939 610 |
| Total assessed | 50 179 328 | 8 677 559 | 9 185 010 | 10 171 630 | 10 911 453 | 11 870 780 | 13 346 659 | 15 397 934 | 18 258 757 | 23 474 491 | 171 473 601 |
| % of assessment | 99.89 | 99.84 | 99.82 | 99.84 | 99.80 | 99.69 | 99.73 | 99.73 | 99.53 | 99.11 | 99.69 |

a/ See Part 3 below.

b/ Includes supplemental assessments.

c/ Withdrew from membership on 19 June 1967.

d/ Withdrew from membership on 14 December 1970.

3. Details of outstanding contributions to the Regular Budgets for the years 1958-1965

| State | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Dominican Republic | - | - | - | - | 2 735 | 3 561 | 3 610 | 3 857 | 13 763 |
| Haiti | - | 1 741 | 2 337 | 2 467 | 2 652 | 2 849 | 2 888 | 3 085 | 18 019 |
| Honduras | - | - | - | - | - | - | 2 020 | 3 085 | 5 105 |
| Paraguay | 1 636 | 2 090 | 2 337 | 2 467 | 2 652 | 2 849 | 2 888 | 3 085 | 20 004 |
| Total outstanding | 1 636 | 3 831 | 4 674 | 4 934 | 8 039 | 9 259 | 11 406 | 13 112 | 56 891 |
| Total paid | 4 113 124 | 5 221 169 | 5 876 306 | 6 195 756 | 6 632 040 | 7 146 004 | 7 218 868 | 7 719 170 | 50 122 437 |
| Total assessed | 4 114 760 | 5 225 000 | 5 880 980 | 6 200 690 | 6 640 079 | 7 155 263 | 7 230 274 | 7 732 282 | 50 179 328 |
| *Per cent of assessment* | 99.96 | 99.93 | 99.92 | 99.92 | 99.87 | 99.87 | 99.84 | 99.83 | 99.89 |

4. Voluntary contributions to the General Fund for 1974 and 1975

Notes: 1. All contributions pledged have been fully paid except as indicated in the "Outstanding" columns.

2. A fully or partially paid pledge made in a currency other than the United States dollars is expressed in dollars at the rate of exchange of the United Nations Development Programme current at the time payment was made. For pledges in respect of which no payment has yet been received, the current rate at the time of pledging has been applied.

| Member State | For 1974 | | For 1975 | |
|---|---|---|---|---|
| | Pledged | Outstanding | Pledged | Outstanding |
| Afghanistan | - | - | - | - |
| Albania | - | - | 1 950 | 1 950 |
| Algeria | 3 000 | - | 3 600 | - |
| Argentina | 24 600 | - | 38 700 | 38 700 |
| Australia | 46 300 | - | 67 050 | 622 |
| Austria | 15 900 | - | 26 100 | 26 100 |
| Bangladesh | - | - | 4 500 | 4 500 |
| Belgium | 28 517[a/] | - | 70 423 | 70 423 |
| Bolivia | - | - | - | - |
| Brazil | 30 000 | - | 40 000 | 40 000 |
| Bulgaria | 5 100 | - | 6 750 | 6 750 |
| Burma | - | - | 1 350 | 1 350 |
| Byelorussian Soviet Socialist Republic | - | - | 25 707 | 25 707 |
| Cambodia | - | - | - | - |
| Canada | 88 800 | - | 148 050 | 148 050 |
| Chile | - | - | - | - |
| Colombia | - | - | - | - |
| Costa Rica | 800[a/] | 800 | 900 | 900 |
| Cuba | 5 521 | 5 521 | 5 521 | 5 521 |
| Cyprus | - | - | - | - |
| Czechoslovakia | 27 778 | - | 34 722[b/] | - |
| Democratic People's Republic of Korea | - | - | - | - |
| Denmark | 21 240 | - | 29 250 | - |
| Dominican Republic | - | - | - | - |
| Ecuador | - | - | - | - |
| Egypt | 12 778 | - | 12 778 | - |
| El Salvador | - | - | - | - |
| Ethiopia | - | - | - | - |
| Finland | 16 800 | - | 21 000 | - |
| France | 120 000[a/] | - | 125 517[b/] | - |

| Member State | For 1974 | | For 1975 | |
|---|---|---|---|---|
| | Pledged | Outstanding | Pledged | Outstanding |
| Gabon | - | - | - | - |
| German Democratic Republic | 41 667 | - | 65 306 | - |
| Germany, Federal Republic of | 220 000 | - | 330 750 | - |
| Ghana | 2 200 | - | 2 200 | - |
| Greece | 8 400 | 8 400 | 14 850 | 14 850 |
| Guatemala | - | - | - | - |
| Haiti | - | - | - | - |
| Holy See | 3 000 | - | - | - |
| Hungary | 20 080 | - | 34 483 | - |
| Iceland | 1 200 | - | 1 200 | - |
| India | 50 000 | - | 60 000 | - |
| Indonesia | 8 100 | - | 9 000 | 9 000 |
| Iran | 7 000 | - | 70 000 | 70 000 |
| Iraq | 2 100 | - | 25 000 | - |
| Ireland | 5 600 | - | 7 200 | - |
| Israel | 6 300 | - | 9 900 | - |
| Italy | - | - | - | - |
| Ivory Coast | - | - | - | - |
| Jamaica | - | - | - | - |
| Japan | 259 000 | - | 333 000 | 333 000 |
| Jordan | - | - | - | - |
| Kenya | - | - | - | - |
| Korea, Republic of | 3 000 | - | 4 950 | 4 950 |
| Kuwait | 2 400 | - | 8 100 | - |
| Lebanon | 1 500 | - | 1 500 | 500 |
| Liberia | - | - | - | - |
| Libyan Arab Republic | - | - | 2 100 b/ | - |
| Liechtenstein | 1 400 | - | 1 400 | - |
| Luxembourg | - | - | - | - |
| Madagascar | 1 200 | - | - | - |
| Malaysia | - | - | - | - |
| Mali | - | - | - | - |
| Mauritius | - | - | - | - |
| Mexico | 30 000 | - | - | - |
| Monaco | 2 000 | - | 2 000 | - |
| Mongolia | - | - | 1 200 | 1 200 |
| Morocco | 2 700 | - | 2 700 | - |
| Netherlands | 40 000 | - | 57 600 | - |
| New Zealand | 9 420 | - | - | - |
| Niger | - | - | 986 | - |
| Nigeria | - | - | 4 500 | 4 500 |
| Norway | 12 500 | - | 20 250 | - |
| Pakistan | 5 000 a/ | - | 6 750 | 6 750 |
| Panama | 1 200 | - | 1 200 | - |
| Paraguay | - | - | - | - |

| Member State | For 1974 | | For 1975 | |
|---|---|---|---|---|
| | Pledged | Outstanding | Pledged | Outstanding |
| Peru | 3 000 | - | 3 150 | 117 |
| Philippines | 9 000 | - | 9 500 | 9 500 |
| Poland | 22 590 a/ | - | 30 120 b/ | 22 590 |
| Portugal | 4 500 | - | 7 200 | 7 200 |
| Republic of South Viet-Nam | 2 100 | - | 2 100 b/ | - |
| Romania | 10 500 | - | 13 950 | 7 673 |
| Saudi Arabia | 2 100 | - | 2 700 | 2 700 |
| Senegal | 1 200 | - | 1 415 | - |
| Sierra Leone | - | - | - | - |
| Singapore | 1 600 | - | 1 800 | - |
| South Africa | 17 100 | - | 23 400 | 23 400 |
| Spain | 30 000 | - | 30 000 b/ | 30 000 |
| Sri Lanka | 1 500 | - | 1 350 | 1 350 |
| Sudan | 2 500 | - | 2 500 | 2 500 |
| Sweden | 44 048 | - | 60 750 | - |
| Switzerland | 24 300 | - | 38 250 | - |
| Syrian Arab Republic | - | - | - | - |
| Thailand | 4 000 | - | 4 950 | - |
| Tunisia | 1 356 | - | 1 356 | - |
| Turkey | 11 000 | - | 13 500 | - |
| Uganda | - | - | - | - |
| Ukrainian Soviet Socialist Republic | - | - | 102 828 | 102 828 |
| Union of Soviet Socialist Republics | 533 436 | - | 684 932 | - |
| United Kingdom of Great Britain and Northern Ireland | 201 330 | - | 247 500 | 247 500 |
| United Republic of Cameroon | 1 200 | - | - | - |
| United States of America | 950 000 c/ | 50 600 | 1 106 400 bc/ | 1 106 400 |
| Uruguay | - | - | - | - |
| Venezuela | - | - | - | - |
| Yugoslavia | 10 800 | - | 15 750 | 15 750 |
| Zaire | - | - | 900 | 900 |
| Zambia | - | - | - | - |
| TOTAL | 3 083 261 | 65 321 | 4 148 294 | 2 395 731 |

a/ Pledge is less than the Member's Regular Budget assessment ratio (GC(XVII)/RES/308) applied to the target of $3 million of voluntary contributions set by GC(XVII)/RES/305, para. 1).

b/ Pledge is less than the Member's Regular Budget assessment ratio (GC(XVIII)/RES/317) applied to the target of $4.5 million of voluntary contributions set by GC(XVIII)/RES/315, para. 1.

c/ When making this pledge, the United States of America also pledged to make contributions in kind in the form of cost-free experts, equipment for technical assistance, laboratory equipment, special nuclear materials, Type II Fellowships, to a total value of approximately $1 030 000 for the year 1974 and $1 143 600 for the year 1975. It is to be noted that other Members as well contribute to the Agency's resources in this way, and information relating to all such contributions is provided in the Agency's accounts for the respective year.

ANNEX F

# NUCLEAR INSTALLATIONS UNDER AGENCY SAFEGUARDS OR CONTAINING SAFEGUARDED MATERIAL UNDER AGREEMENTS APPROVED BY THE BOARD OF GOVERNORS[a]

## A. Reactors[b] other than power reactors

| State[c] | Abbreviated name of reactor | Location | Type | Capacity MW(th) | In operation |
|---|---|---|---|---|---|
| Argentina | RA-O | Cordoba | Tank | 0.00 | x |
| | RA-1 | Constituyentes | Argonaut | 0.12 | x |
| | RA-2 | Constituyentes | Argonaut | 0.03 | x |
| | RA-3 | Ezeiza | Pool-tank | 5.00 | x |
| | RA-4 | Rosario | Solid-homogeneous | 0.00 | x |
| Australia[d] | HIFAR | Lucas Heights, N.S.W. | Tank | 11.00 | x |
| | MOATA | Lucas Heights, N.S.W. | Argonaut | 0.01 | x |
| | CF | Lucas Heights, N.S.W. | Critical Facility | 0.00 | x |
| Austria[d] | SAR | Graz | Argonaut | 0.00 | x |
| | TRIGA-VIENNA | Vienna | Triga II | 0.25 | x |
| | ASTRA | Seibersdorf | Pool | 12.00 | x |
| Brazil | IEA-R1 | São Paulo | Pool | 5.00 | x |
| | IPR-R1 | Belo Horizonte | Triga I | 0.10 | x |
| | RIEN.1 | Rio de Janeiro | Argonaut | 0.01 | x |
| Bulgaria[d] | IRT-2000 | Sofia | Pool | 2.00 | x |
| Canada[d] | NRX | Chalk River, Ont. | NRX | 30.00 | x |
| | NRU | Chalk River, Ont. | NRU | 125.00 | x |
| | WNRE | Pinawa, Manitoba | Organic-cooled | 60.00 | x |
| | McMaster | Hamilton, Ont. | Pool-type | 2.5 | x |
| | Slowpoke - Toronto | Univ. of Toronto | Pool-type | 0.00 | x |
| | Slowpoke - Ottawa | Ottawa, Ont. | Pool-type | 0.02 | x |
| | PTR | Chalk River, Ont. | Pool-type | 0.00 | x |
| | ZED-2 | Chalk River, Ont. | Pool-type | 0.00 | x |
| | ZEEP | Chalk River, Ont. | Tank | 0.00 | x |
| Chile | Herald | Santiago | Herald | 5.00 | - |
| China, Republic of | THOR | Hsin-chu | Pool | 1.00 | x |
| | TRR | Huaitzupu | NRX | 40.00 | x |
| | ZPRL | Lung-Tan | Pool | 0.01 | x |
| | THAR | Hsin-chu | Argonaut | 0.01 | x |
| | MER | Hsin-chu | Mobile Educational Reactor | 0.00 | x |
| Colombia | IAN-R1 | Bogotá | Pool-type | 0.02 | x |
| Czechoslovakia[d] | SR-O | Vochov | Critical Assembly | 0.00 | x |
| | VVR-S | Rez | Tank | 4.00 | x |
| | TR-O | Rez | Critical Assembly | 0.00 | - |
| Denmark[e] | DR-1 | Risø | Homogeneous | 0.00 | x |
| | DR-2 | Risø | Pool | 5.00 | x |
| | DR-3 | Risø | Tank | 10.00 | x |
| Finland[d] | FiR-1 | Otaniemi | Triga II | 0.25 | x |
| German Democratic Republic[d] | WWR-S(M) | Rossendorf | Tank | 6.00 | x |
| | Rake II | Rossendorf | Critical Assembly | 0.00 | x |
| | RRR | Rossendorf | Critical Assembly | 0.00 | x |
| Greece[d] | GRR-1 | Athens | Pool | 5.00 | x |
| | N.T.U. | Athens | Sub-critical Assembly | 0.00 | x |

| State[c] | Abbreviated name of reactor | Location | Type | Capacity MW(th) | In operation |
|---|---|---|---|---|---|
| Hungary[d] | WWR-SM | Budapest | Tank | 5.00 | x |
| | ZR-4 | Budapest | Critical Assembly | 0.00 | x |
| | ZR-6 | Budapest | Critical Assembly | 0.00 | x |
| | Training reactor | Budapest | Tank | 0.01 | x |
| Indonesia | PRAB (TRIGA II) | Bandung | Triga II | 1.00 | x |
| Iran[d] | TSPRR | Teheran | Pool | 5.00 | x |
| Iraq[d] | IRT-2000 | Baghdad | Pool | 2.00 | x |
| Israel | IRR-1 | Soreq | Pool | 5.00 | x |
| Japan | AHCF | Tokai-Mura | Critical Facility | 0.00 | x |
| | DCA | Oarai-Machi | Critical Facility | 0.00 | x |
| | FCA | Tokai-Mura | Critical Facility | 0.01 | x |
| | HCA | Kawasaki-shi | Critical Facility | 0.00 | x |
| | HTR | Kawasaki-shi | Pool | 0.10 | x |
| | JMTR | Oarai-Machi | Tank | 50.00 | x |
| | JMTR-CA | Oarai-Machi | Critical Facility | 0.00 | x |
| | JPDR | Tokai-Mura | Boiling-water | 90.00 | x |
| | JRR-2 | Tokai-Mura | Tank | 10.00 | x |
| | JRR-3 | Tokai-Mura | Tank | 10.00 | x |
| | JRR-4 | Tokai-Mura | Pool | 1.00 | x |
| | Kinki University | Kowakai | UTR-B | 0.00 | x |
| | KUR | Kumatori-cho | Pool | 5.00 | x |
| | KUCA | Kumatori-cho | Critical Facility | 0.00 | x |
| | NSRR | Tokai-Mura | Triga (pulse) | 0.3 | - |
| | Musashi College of Technology | Kawasaki-shi | Triga II | 0.10 | x |
| | NAIG-CA | Kawasaki-shi | Critical Facility | 0.00 | x |
| | Rikkyo University | Nagasaka | Triga II | 0.10 | x |
| | SHCA | Tokai-Mura | Critical Facility | 0.00 | x |
| | TCA | Tokai-Mura | Critical Facility | 0.00 | x |
| | TODAI | Tokai-Mura | Fast Neutron Source Reactor | 0.002 | x |
| | TTR | Kawasaki-shi | Pool | 0.10 | x |
| | "Mutsu" (Nuclear Ship) | Minato-Machi Mutsu | PWR | 36.00 | x |
| | JOYO | Oarai | EBR | 50.00 | - |
| Korea, Republic of | KRR - TRIGA II | Seoul | Triga II | 0.10 | x |
| | KRR - TRIGA III | Seoul | Triga III | 2.00 | x |
| Mexico[d] | Centro Nuclear de Mexico | Ocoyoacac | Triga III | 1.00 | x |
| | Training reactor facility | Mexico City | SUR-100 | 0.00 | x |
| Norway[d] | JEEP-II | Kjeller | Tank | 2.00 | x |
| | HBWR | Halden | HBWR | 25.00 | x |
| Pakistan | PARR | Rawalpindi | Pool | 5.00 | x |
| Philippines[d] | PRR-1 | Diliman, Quezon City | Pool | 1.00 | x |
| Poland[d] | EWA | Świerk | Tank | 8.00 | x |
| | Maryla | Świerk | Critical Assembly | 0.00 | x |
| | Anna | Świerk | Critical Assembly | 0.00 | x |
| | Agata | Świerk | Critical Assembly | 0.00 | x |
| | Maria | Świerk | Tank | 30.00 | x |
| Portugal | RPI | Sacavem | Tank | 1.00 | x |
| Romania[d] | VVR-S | Margurele | Tank | 10.00 | x |
| South Africa | SAFARI-1 | Pelindaba | Tank | 20.00 | x |

| State[c] | Abbreviated name of reactor | Location | Type | Capacity MW(th) | In operation |
|---|---|---|---|---|---|
| Spain | JEN-1 | Madrid | Pool | 3.00 | x |
| | JEN-2 | Madrid | Pool | 0.00 | x |
| | CORAL-1 | Madrid | Fast Critical Facility | 0.00 | x |
| | ARBI | Bilbao | Argonaut | 0.01 | x |
| | ARGOS | Barcelona | Argonaut | 0.01 | x |
| Sweden[d] | R2 | Studsvik | MTR Tank | 50.00 | x |
| | R2-0 | Studsvik | Pool | 1.00 | x |
| | R-0 | Studsvik | Critical Assembly | 0.00 | x |
| | KRITZ | Studsvik | Critical Assembly | 0.00 | x |
| Switzerland | Proteus | Würenlingen | Fast thermal Critical Assembly | 0.00 | x |
| | Saphir | Würenlingen | Pool | 5.00 | x |
| | Diorit | Würenlingen | HW | 30.00 | x |
| | Crocus | Lausanne | Critical Assembly | 0.00 | x |
| | AGN201P | Geneva | Solid homogeneous | 0.00 | x |
| | AGN211P | Basel | Pool | 0.00 | x |
| Thailand[d] | TRR-1 | Bangkok | Pool | 1.00 | x |
| Turkey | TR-1 | Istanbul | Pool | 1.00 | x |
| United Kingdom | Zebra | Winfrith | Critical Facility | 0.00 | x |
| Uruguay[d] | RUDI | Montevideo | Lockheed | 0.10 | - |
| Venezuela | RV-1 | Caracas | Pool | 3.00 | x |
| Yugoslavia[d] | Triga II | Ljubljana | Triga II | 0.25 | x |
| | RA | Vinča | Heavy-water | 6.5 | x |
| | RB | Vinča | Critical Facility | 0.00 | x |
| Zaire[d] | Triga | Kinshasa | Triga II | 1.00 | x |

## B. Nuclear power stations

| State[c] | Name of power station | Location | Type | Capacity MW(e) | In operation |
|---|---|---|---|---|---|
| Argentina | Atucha Nuclear Power Station | Atucha | PHWR | 319 | x |
| | Cordoba Nuclear Power Station | Rio Tercero | Candu | 600 | - |
| Bulgaria[d] | Kozloduy I | | PWR | 880 | x (for 440) |
| Canada[d] | Pickering (4 units) | Pickering, Ontario | Candu | 2032 | x |
| | NPD | Ralphton, Ontario | Candu | 22 | x |
| | Gentilly | Gentilly, Quebec | Candu | 250 | x |
| | DPGS | Kincardine, Ontario | Candu | 208 | x |
| | Bruce I | Douglas Point, Ontario | Candu | 750 | - |
| China, Republic of | FNPS-1 | Ching-San | BWR | 636 | - |
| | FNPS-2 | Ching-San | BWR | 636 | - |
| | SNPS-1 | Kuosheng | BWR | 985 | - |
| | SNPS-2 | Kuosheng | BWR | 985 | - |
| Czechoslovakia[d] | A1 | Bohunice | HWGC | 143 | x |
| German Democratic Republic[d] | Rheinsberg PWR | Rheinsberg | PWR | 80 | x |
| | Bruno Leuschner PWR | Greifswald | PWR | 880 | x |
| India | Tarapur - TAPS | Tarapur | BWR | 380 | x |
| | Rajasthan - RAPS | Rajasthan | Candu | 400 | x (for 200) |
| Japan | Tokai | Tokai-Mura | Magnox | 154 | x |
| | Tsuruga | Tsuruga | BWR | 357 | x |
| | Mihama-1 | Mihama-Fukai | PWR | 340 | x |
| | Mihama-2 | Mihama-Fukai | PWR | 500 | x |
| | Fukushima-1 | Okuma-Fukushima | BWR | 460 | x |
| | Fukushima-2 | Okuma-Fukushima | BWR | 784 | x |
| | Fukushima-3 | Okuma-Fukushima | BWR | 784 | x |
| | Fukushima-4 | Fukushima | BWR | 784 | - |
| | Fukushima-5 | Fukushima | BWR | 784 | - |
| | Shimane | Kashima-cho | BWR | 460 | x |
| | Hamaoka 1 | Hamaoka | BWR | 540 | x |
| | Takahama-1 | Takahama | PWR | 826 | x |
| | Takahama-2 | Takahama | PWR | 826 | x |
| | Genkai-1 | Kyushu | PWR | 559 | x |
| | Mihama-3 | Mihama-Fukui | PWR | 826 | - |
| Korea | Kori-1 | Kori | PWR | 564 | - |
| Pakistan | KANUPP | Karachi | Candu | 125 | x |
| Spain | José Cabrera | Almonacid de Zorita | PWR | 153 | x |
| | Santa Maria de Garona | Province de Burgos | BWR | 440 | x |
| Sweden[d] | Oskarshamn I | Oskarshamn | BWR | 440 | x |
| | Oskarshamn II | Oskarshamn | BWR | 580 | x |
| | Ringhals I | Near Göteborg | BWR | 760 | x |
| | Ringhals II | Near Göteborg | PWR | 830 | x |
| | Barsebäck I | Near Malmö | BWR | 580 | x |
| Switzerland | Mühleberg | Mühleberg | BWR | 306 | x |
| | Beznau I | Beznau | PWR | 350 | x |
| | Beznau II | Beznau | PWR | 350 | x |

## C. Conversion plants, fabrication plants and chemical reprocessing plants

| | |
|---|---|
| Argentina | Pilot Fuel Reprocessing Plant, Ezeiza f/<br>Pilot Fuel Fabrication Plant, Constituyentes f/<br>Scrap Reprocessing Plant, Buenos Aires f/ |
| Brazil | Fabrication Facility, Metallurgy Department, Instituto de Energia Atomica, São Paulo |
| Canada d/ | Eldorado Nuclear Limited Port Hope Refinery<br>Westinghouse Fuel Fabrication Plant<br>Canadian General Electric Pelletizing Facility<br>Canadian General Electric Fuel Fabrication Plant |
| China, Republic of | INER Pilot Fuel Reprocessing Plant f/ |
| Czechoslovakia d/ | Nuclear Fuel Institute, Zbraslav<br>Uranium Industry Chemical Plant – Metallurgical Pilot Plant f/ |
| Denmark e/ | Metallurgy Department, Risø f/ |
| India | Nuclear Fuel Complex – NFC (Enriched Uranium Conversion and Fabrication Plant), Hyderabad |
| Japan | Power Reactor & Nuclear Fuel Development, Reprocessing Plant<br>Nuclear Fuel Industries Ltd. (Kumatori-1)<br>Sumitomo Metal Mining Co. Ltd. (Tokai-1)<br>Mitsubishi Atomic Power Industries (Ohmiya-1)<br>Japan Nuclear Fuel Co. Ltd.<br>Mitsubishi Nuclear Fuel Co. Ltd.<br>Power Reactor and Nuclear Fuel Development Co. (Tokai)<br><br>Pilot Fuel Fabrication Plants and Conversion Plants:<br>Mitsubishi Atomic Power Industries (Ohmiya-2) f/<br>Nuclear Fuel Industries Ltd. (Kumatori-2) f/<br>Nuclear Fuel Industries Ltd. (Ohi) f/<br>Nuclear Fuel Industries Ltd. (Takeyama-2) f/<br>Sumitomo Metal Mining Co. Ltd. (Tokai-2) f/ |
| Norway d/ | Fuel Element Pilot Production Plant, Kjeller f/ |
| Spain | Pilot Reprocessing Plant, Juan Vigon Research Centre, Madrid f/<br>Metallurgical Plant, Juan Vigon Research Centre, Madrid f/ |
| Sweden d/ | ASEA-ATOM, Västerås |

a/ The nuclear installations that will be covered by the Safeguards Agreement in connection with NPT, signed with EURATOM and the non-nuclear-weapon States members of EURATOM on 5 April 1973, are not listed here.

b/ As defined in documents INFCIRC/26, Part II, para.14 and INFCIRC/66/Rev.2, Part IV, para.80.

c/ An entry in this column does not imply the expression of any opinion whatsoever on the part of the Secretariat concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

d/ NPT Safeguards Agreement.

e/ Denmark joined EURATOM on 1 January 1973 and has signed the Agreement with EURATOM and its non-nuclear-weapon member States, however, Agency safeguards are presently applied in this State under the NPT Safeguards Agreement which Denmark had concluded with the Agency prior to joining EURATOM.

f/ Pilot plant.