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REPORT BY THE

Comptroller General

OF THE UNITED STATES

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Difficulties In Determining If Nuclear Training Of Foreigners Contributes To Weapons Proliferation

Training and education in nuclear technology have been provided to foreign nationals by U.S. national laboratories and a number of firms and educational institutions in the United States. Foreigners have also participated in U.S. nuclear research.

This study

- --reviews the evolution of U.S. nuclear training,
- --shows how such training fits into the overall U.S. scheme of nuclear technology transfers, and
- --discusses whether such training could contribute to nuclear weapons proliferation.

GAO made this review at the request of the Chairmen, Subcommittee on International Organizations, House Foreign Affairs Committee, and Subcommittee on Foreign Operations, House Appropriations Committee.

New code
HSE 01118

HSE00304

505036

109350

ID-79-2
APRIL 23, 1979

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-165546

The Honorable Clarence D. Long
Chairman, Subcommittee on
Foreign Operations
Committee on Appropriations
House of Representatives

HSE00304

The Honorable Don L. Bonker
Chairman, Subcommittee on
International Organizations
Committee on Foreign Affairs
House of Representatives

HSE01118

In response to your joint request, we have completed a study of the education and training of foreign nationals in nuclear engineering and related fields by the United States and of whether this education and training could contribute to the proliferation of nuclear explosive capabilities abroad.

As agreed with your offices, no further distribution of this report will be made for 15 days from the date of issue unless either of you publicly announces its contents earlier.

The Departments of Commerce, Energy, and State; the Nuclear Regulatory Commission; and the Arms Control and Disarmament Agency were given the opportunity to comment on our report draft, and their comments have been included where appropriate.

Elmer B. Staats
Comptroller General
of the United States

REPORT BY THE
COMPTROLLER GENERAL
OF THE UNITED STATES

DIFFICULTIES IN DETERMINING IF NUCLEAR TRAINING OF FOREIGNERS CONTRIBUTES TO WEAPONS PROLIFERATION

D I G E S T

The contribution of U.S. nuclear training of foreigners to the spread of nuclear weapons cannot be accurately estimated. There is no way to ascertain the true intentions of the foreign nationals being trained or the motivations of their countries.

Neither the data base nor the analytical methods have been developed to effectively evaluate the proliferation risks involved; however, ~~GAO has identified~~ a number of issues, ~~discussed below, which~~ warrant further Government attention.

GOVERNMENT TRAINING

Under the Atoms for Peace Program, training of aliens in nuclear engineering and related fields at U.S. Government facilities was at its height in the early 1960s. Several thousand foreigners were trained but received only unclassified information. A few hundred received instructions in such key technologies as uranium enrichment and reprocessing. Government policy now calls for restraint in providing training in these key technologies.

The Government curtailed its nuclear training in 1965, because similar courses were being offered by U.S. colleges and universities. It was U.S. policy not to provide training that was available in the private sector, as the Government did not want to compete for students with universities or other private organizations. In 1976, however, the Government reinitiated a nuclear training program under the auspices of the International Atomic Energy Agency. More recently, it began a special course for Iranians, but this training was terminated

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in early 1979 because of the lack of financial support by the Government of Iran.

The Secretary of Energy should review the nature of nuclear training programs to be conducted at Government facilities and the need for the U.S. Government--as contrasted with the private sector--to provide such training for foreign nationals. (See p. 26.)

GOVERNMENT RESEARCH

At three U.S. national laboratories, a few dozen foreigners had, over a 22-year period, been involved in unclassified research related to reprocessing or enrichment. GAO did not identify any foreigners currently engaged in such research at the national laboratories. But a limited number of foreigners were gaining experience on research projects that could be of concern if applied to a nonpeaceful project.

Laboratory officials contend that an attempt to control foreign participation in all research that could be indirectly related to a possible weapons program would represent a serious blow to the scientific community. Moreover, they point out that much of this research has been done by immigrants seeking U.S. citizenship.

Although aliens may have an important role in advancing U.S. nuclear research and development, the Secretary of Energy should reassess foreign participation at Government-owned nuclear research facilities and limit, where appropriate, participation that could be used to significantly raise the ability of another nation to make nuclear explosives. (See p. 34.)

UNIVERSITY TRAINING

Over 3,000 courses in nuclear science and engineering are offered by 190 U.S. colleges and universities. They provide a wide range of basic information on the principles and applications of nuclear technology. Foreign participation in the nuclear science and engineering curriculum appears to be substantial and growing.

Universities offer only unclassified courses and use published textbooks but some courses could provide an educational base which might contribute to a nuclear weapons capability. Some courses include reprocessing and enrichment; however, faculty members believe that since the material taught has long been declassified and is readily available in open literature, the instructions could not be considered a proliferation risk. Furthermore, at least 78 foreign universities or other academic institutions provide nuclear educational opportunities.

The Government has no system to identify any unusually high concentration of students from one country enrolled in specialized fields relevant to a nuclear weapons capability, or any substantial foreign effort to develop a significant nuclear technology base through education and training without corresponding interest in nuclear power development. (See p. 51.)

INDUSTRY-SPONSORED TRAINING

The U.S. nuclear industry provides training to foreigners through formal instructions related to equipment sales, licensing and technical exchange arrangements, on-the-job experience, and full-time employment. However, only a few foreigners have learned or gained experience related to key nuclear technologies through ~~such~~ training. (See p. 61.)

TRAINING SPONSORED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY

The International Atomic Energy Agency sponsors fellowships for training individuals at public or private facilities of a member nation. The United States has always been the dominant supporter of the Agency's training programs. From 1958 to 1976, 11 countries acted as hosts for 65 Agency-sponsored fellowships in reprocessing.

In 1977, the Agency changed its policy to limit fellowships in sensitive technologies to individuals whose home country agreed to accept international safeguards on the facilities that would benefit from such training. (See p. 70.)

U.S. NUCLEAR TRAINING IN PERSPECTIVE

Since the passage of the Atomic Energy Act of 1954, U.S. policy has been to encourage the dissemination of scientific and technical atomic energy information without endangering national security. This general policy affects any attempt to evaluate the risks associated with nuclear training provided foreigners.

--The United States has used a number of mechanisms besides training to transfer nuclear technology. These include research reactor and equipment grants; the "sister" laboratory program; commercial affiliations; licensing of patents; Export-Import Bank loans and guarantees to build overseas nuclear training centers; overseas depository libraries; advisory and consulting services; and international conferences.

--Some fairly detailed descriptions of how a nuclear fission explosive device is constructed are available in unclassified technical literature, according to the Arms Control and Disarmament Agency.

--Government and international information services publish abstracts and indexes listing unclassified scientific and technical nuclear information available to the public including data relating to uranium enrichment and reprocessing.

--The Nuclear Non-Proliferation Act of 1978 restricts the export of sensitive nuclear technology. This raises some questions about foreign participation in U.S. nuclear research, education, and training which could result in new findings or conclusions concerning reprocessing, enrichment and heavy water production.

--Nuclear training is available in at least 23 foreign countries.

A balance must be struck between protecting information that has significant weapons proliferation implications and providing maximum assistance to the development of peaceful nuclear applications.

The executive branch should:

--Consider discontinuing further distribution of Government publications which could substantially assist anyone seeking a nuclear weapons capability.

--Clarify what specific data or information is subject to the "sensitive nuclear technology" export criteria established in the Nuclear Non-Proliferation Act and how such criteria apply to foreign participation in education, training and research in the United States. (See p. 14.)

--Consider adherence to the Non-Proliferation Treaty in selecting foreigners to participate in Government nuclear research and in providing nuclear fellowships and assistantships. (See pp. 34 and 52.)

AGENCY COMMENTS

The executive branch generally stressed that foreign participation in U.S. nuclear training and research programs has had a number of benefits, such as:

--Helping to meet U.S. obligations under the Non-Proliferation Treaty and to persuade other nations to agree to international nuclear safeguards.

--Creating the potential for goodwill between U.S. and future foreign leaders through personal contact.

--Exposing foreigners to U.S. nuclear safety and non-proliferation concerns.

--Contributing to possible sales of U.S. nuclear goods and services.

Department of Energy officials said that sensitive areas of nuclear technology have been examined and precautions have been taken, but it is difficult to draw a firm line between what is and is not sensitive; it is a matter of degree.

The Nuclear Regulatory Commission commented that definitions which are clearly stated and consistently applied are essential in determining the significance of particular types of information and training to nuclear proliferation.

State Department officials stated that the prevalence of grey areas of definition and categorization was a general problem and there was a wide spectrum of views as to whether lines of delineation should be drawn.

Officials of the Departments of State and Energy commented that past Government nuclear training was consistent with then existing U.S. policies and technical judgments and that past actions and decisions should not be criticized on the basis of today's revised standards.

The agencies indicated a number of initiatives were underway concerning information and training provided foreigners. The executive branch is reviewing a few of the apparently most sensitive unclassified Government publications to determine whether further distribution should be controlled. It is also considering giving preference to Non-Proliferation Treaty parties in the nuclear research and training areas.

The Department of Energy is currently revising and updating internal review procedures concerning foreign participation and visits to Government research facilities. The Department has also engaged a consultant to study what specific research technology and training disciplines should be categorized as sensitive from a proliferation standpoint.

Contents

ABBREVIATIONS

ACDA	Arms Control and Disarmament Agency
AEC	Atomic Energy Commission
DOE	Department of Energy
ERDA	Energy Research and Development Administration
IAEA	International Atomic Energy Agency
MIT	Massachusetts Institute of Technology
NPT	Treaty on the Non-Proliferation of Nuclear Weapons

CHAPTER 1

INTRODUCTION

The threat of nuclear weapons proliferation brought about by the international transfer of nuclear goods and technology for peaceful applications has caused increasing concern. This concern, exemplified by the Nuclear Non-Proliferation Act of 1978 (Public Law 95-242), has generally concentrated on the risks associated with the export of reactors, nuclear fuel, and equipment. One area that has not been the subject of intense scrutiny is the training provided to foreigners, which conceivably could enhance their capability of developing weapons.

Hence, the Chairmen of the Foreign Operations Subcommittee of the House Appropriations Committee and the Subcommittee on International Organizations of the House International Relations Committee 1/, requested that we study the extent to which the education and training of foreign nationals in nuclear engineering and related fields in the United States contributes to the proliferation of nuclear explosive capabilities abroad. (See app. I.)

Over the years, nuclear technology has spread from a handful of industrialized nations to dozens of nations, less developed and industrialized alike. The United States can largely be credited for the earliest transfers of nuclear technology as it made the conscious decision to share the benefits of the peaceful uses of the atom in the mid-1950s through its Atoms for Peace Program. At the height of this program, thousands of aliens came to this country for training, thereby benefiting from America's experience in nuclear technology. As the United States assisted in the development of foreign nuclear energy and research programs, these programs have gradually matured and become more sophisticated.

The need for trained manpower to serve the world's nuclear power and research programs has not diminished. Rising oil prices have convinced many nations that they have no ready alternative to nuclear energy for meeting their growing electric power needs. Developing countries will continue to look to the United States, and other nations with advanced nuclear programs, for education and training opportunities in the nuclear field. However, a world of many nations with nuclear weapons capabilities could be extremely unstable

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1/ The name of the Committee has since been changed to the Committee on Foreign Affairs.

and dangerous. Six nations 1/ have already demonstrated such a capability, and the Arms Control and Disarmament Agency (ACDA) estimates that by 1985 about 40 countries will have sufficient material to make at least a few nuclear bombs.

An important tool currently in existence to help stem the tide of nuclear weapons proliferation is the international Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which entered into force in March 1970. Under specific provisions of this treaty, each non-nuclear weapon state agrees not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices. Those nations which have ratified the treaty--over 100 countries, including the United States--are bound by its provisions; however, a number of countries have not become parties to the NPT.

Article IV of the treaty stipulates that all NPT parties will facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy. Parties in a position to do so shall also cooperate in contributing to the further development of the peaceful application of nuclear energy.

The problem of nuclear weapons proliferation is inherent in the process of uranium fission which gives access to nuclear energy. According to ACDA, both nuclear weapons and nuclear energy depend principally on the same technology and use much the same type materials and production facilities. However, to curb the exchange of technology through controls over training could lead NPT adherents to allege noncompliance with Article IV.

There is no way to ascertain the true intentions of the foreign nationals being trained or the motivations of the countries which they represent. However, nations which are not parties to NPT and which have extensive nuclear capabilities or ambitious plans for nuclear power development are of particular interest to those concerned about nuclear proliferation. Such non-NPT parties currently include Argentina, Brazil, Egypt, Pakistan, South Africa, India,

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1/ United States, Soviet Union, United Kingdom, France, China, and India.

Israel, and Spain. Other countries such as Iran, South Korea, Taiwan, and Yugoslavia, although parties to NPT are also of concern since possible political confrontations with their neighbors could cause these countries to withdraw from the NPT and develop a nuclear weapons capability.

Whether or not a nation turns to nuclear weapons development depends upon its capability to produce such weapons and its political self-interest. Capability is governed to a large extent by access to nuclear technology and nuclear materials such as plutonium or highly enriched uranium. Nations which perceive a military threat to their existence are likely to attempt to develop nuclear weapons; still others may seek a nuclear weapons capability as a matter of national prestige.

The Atomic Energy Act of 1954 (42 U.S.C. 2011) states that the dissemination of scientific and technical information relating to atomic energy should be encouraged to provide free interchange of ideas and criticism, which is essential to scientific and industrial progress and public understanding and to enlarge the fund of technical information. That act also established the basis for U.S. participation in international agreements for cooperation on the peaceful uses of atomic energy, which would not constitute an unreasonable risk to the common defense and security.

Over the years the United States has negotiated a number of bilateral nuclear agreements for cooperation with individual nations or groups of nations. Such agreements typically provide that unclassified information can be exchanged on the application of atomic energy to peaceful uses and the related considerations of health and safety.

The International Atomic Energy Agency (IAEA), of which the United States is a member, expresses a similar cooperative attitude in its Statute. The Statute calls for IAEA to encourage the exchange and training of scientists and experts and to foster the exchange of scientific and technical information on peaceful uses of atomic energy. However, it also provides that IAEA should ensure, so far as it is able, that its assistance is not used to further any military purpose.

The extent of U.S. programs to fulfill these cooperative commitments is broad-ranging. There are obvious benefits to such programs as providing nuclear training to foreigners, but this report concentrates on whether such training could be an avenue to nuclear weapons proliferation. It also seeks to place training in some overall perspective.

CHAPTER 2

NUCLEAR TRAINING--IN PERSPECTIVE

Training in high technology areas is considered one of the most effective means of transferring technology abroad, according to a 1976 report of the Defense Science Board's Task Force on the Export of U.S. Technology. The opportunity to obtain education and training in areas related to nuclear technology has been made available to several thousand foreigners over the years. They have been involved in classroom and on-the-job training and laboratory research activities at U.S. Government facilities, public and private educational institutions, and firms in the private sector. Some have received training under IAEA-sponsored fellowships.

Before attempting to evaluate the proliferation risks involved in providing foreigners such training, it is important to understand which technologies are the most relevant to a weapons program, what information is available to the public-at-large on these technologies, how training fits into the overall U.S. scheme for the international transfer of nuclear technology, and whether a nuclear weapons capability can be developed without formal training.

U.S. POLICY

The U.S. policy has been to make available the maximum amount of information to assist progress in nuclear technology and the peaceful applications of the principles and techniques of nuclear energy while protecting information essential to national security. The Atomic Energy Act and the Nuclear Non-Proliferation Act set forth the framework for the exchange of nuclear technology. Government officials that we interviewed were concerned about proliferation, but they did not believe training within these restraints was a serious risk. They reasoned that the information had been reviewed from a security standpoint and was considered suitable for public dissemination. In addition, the United States and other major nuclear supplier nations have agreed to common export policies including restraint in the export of reprocessing and enrichment technologies.

The executive branch has long perceived that the United States does not have a monopoly on scientific talent in the nuclear field and that even without U.S. assistance other nations would be able to develop nuclear capabilities either on their own or through the assistance of other nuclear suppliers. Officials have concluded that the United States is more likely to deter proliferation by constructively associating itself with nuclear programs of foreign countries than in remaining aloof.

State Department officials advised us that recent major reviews of U.S. nuclear policies have not dealt specifically with the relevance of training being provided aliens at Government laboratories, universities, and private industry to U.S. non-proliferation objectives. In their view, unless it can be demonstrated that there is reason to be concerned about alien participation in nuclear activities in this country, the United States should not scrutinize these activities from a nuclear proliferation standpoint.

The U.S. efforts to control nuclear weapons proliferation have concentrated principally on the safeguarding of nuclear material. Over the years, the risks associated with nuclear training were downplayed, because it was reasoned that not one nuclear explosive device could be built, even by trained specialists, without first obtaining sufficient plutonium or highly enriched uranium. Starting with the Atoms for Peace Program in 1954, the education and training of foreigners in nuclear engineering and related fields have been an integral part of U.S. policy.

Aliens from a country which has declined to forswear development of nuclear weapons by signing the Non-Proliferation Treaty are not precluded from pursuing nuclear education and training in the United States. Nor are agreements for cooperation (that contain guarantees that such cooperation will not be used for nonpeaceful purposes) required of a foreign country for its citizens to participate in U.S. nuclear educational opportunities.

DATA RELEVANT TO NUCLEAR WEAPONS

The manufacture of nuclear weapons can be divided into two major areas of effort: (1) the production of weapons-grade nuclear material; namely, plutonium or highly enriched uranium, and (2) the design and fabrication of the weapons themselves.

Uranium enrichment, the production of heavy water, and the reprocessing of spent reactor fuel are the key technologies which provide the capability to produce weapons-grade material. The enrichment techniques ordinarily used to produce fuel for most of the world's power reactors can also be used to produce highly enriched uranium. Heavy water production is important because it creates a moderator which can be used with natural uranium in certain types of reactors to produce plutonium. Reprocessing is the method of recovering plutonium, a byproduct contained in the spent (used) fuel from reactors.

In addition to these key nuclear technologies, other technologies enhance the development of a nuclear weapons capability. A successful nuclear weapons program requires the efforts of people trained in a number of professional disciplines. The following 10 disciplines, which obviously have numerous peaceful applications, can be considered relevant to a nuclear weapons program. The degree of significance of each to a weapons program may vary and, of course, can be debated, but each can contribute in some way.

Physics	Electrical engineering
Nuclear engineering	Mining engineering
Chemical engineering	Mathematics
Metallurgical engineering	Computer science
Mechanical engineering	Chemistry

Information from the Lawrence Livermore and the Los Alamos Scientific Laboratories on the backgrounds of personnel assigned to nuclear weapons programs generally confirms the selection of these 10 disciplines. The following chart shows that a high proportion of the employees of these laboratories are not nuclear engineers.

Professional field	Number of employees
General physics	380
Mechanical engineering	217
Chemistry and chemical engineering	138
Electrical engineering, radio, electronics	90
Nuclear engineering, chemistry, physics, science	75
Mathematics and statistics	62
Civil, architectural engineering, metallurgy, mining, crystallography	57
General engineering	16
All others (note a)	118

a/ Includes Business Administration, Computer Science, Humanities, Medicine, Biology, Geometry, Geophysics, Geology, Military, Industrial, Aeronautical and Health Engineering, and Physical and Life Sciences.

The above data represents the training received by those individuals who are designing and modifying highly sophisticated weapons for the U.S. nuclear arsenal. The United States has for many years produced weapons-grade nuclear material; most developing countries have not. Therefore, while a nuclear-related education may not be the principal professional field of U.S. bomb designers, it may be vital to a foreign weapons program.

CLASSIFIED OR DECLASSIFIED INFORMATION

The Atomic Energy Act deals specifically with the control of certain nuclear information to protect national security. Under the act, nuclear information which could be inimical to the interests of the United States is categorized as Restricted Data.

The Atomic Energy Act defines Restricted Data as all data concerning (1) design, manufacture, or utilization of atomic weapons, (2) production of special nuclear material, and (3) use of special nuclear material in the production of energy, not including data declassified or removed from the Restricted Data category. When data can be published "without undue risk to the common defense and security," it may be removed from the Restricted Data category and declassified.

The act also prescribes conditions under which anyone from the United States may directly or indirectly engage in the production of special nuclear material (enriched uranium or plutonium) outside the United States. These extend to furnishing such information to foreign recipients or for use abroad.

The Department of Energy (DOE) 1/ maintains a continuing program to make available to the public all possible information about nuclear energy without endangering national security. The Department maintains classification guides to assist technical experts in determining what information can be published and the security classification which must be placed on other information. DOE also reviews

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1/The Atomic Energy Commission (AEC) was abolished in January 1975, with its responsibilities assigned to the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission. In October 1977, DOE assumed, among other things, the responsibilities of ERDA.

classified material developed previously to determine the material which could be published or downgraded to a lesser category of classification.

The "Classification Policy Guide" forms the basis for all other DOE classification guides. This Guide spells out by means of topics, the information which has been declassified as well as the information that remains classified. Revisions to this Guide are coordinated with the United Kingdom and Canada to keep the classification rules consistent with one another. Under this Guide, it was possible to make available sufficient information to design, construct, and operate civilian power reactors and their associated processing plants. In addition, it was possible to make data available on the effects of radiation on various materials; the technology of heavy water manufacture; metallurgical data on production of fuel elements, including some using plutonium alloys; and considerable material on reprocessing. The release of technology concerning the isolation and handling of plutonium metal and its compounds, for example, gave impetus to the development of the program for the use of plutonium as a nuclear fuel for power and breeder reactors.

As matters stand, civilian nuclear energy research and development is virtually free of security restrictions. Nearly all the basic chemistry and practical technology dealing with preparation of reactor fuel and materials and with reprocessing has been declassified. Some information generated in military-related programs which would be useful in civilian programs is necessarily restricted. For example, DOE has retained classification restrictions on specific processing details as applied to the fuels of production and military reactors. Much of this information is considered too specialized for use in peaceful nuclear application and such restrictions are not considered a handicap to industrial and research efforts.

The Atomic Energy Act, as amended by the Nuclear Non-Proliferation Act of 1978, sets forth conditions regarding the export of "sensitive nuclear technology." The act defines such technology as any information which is not available to the public and which is important to the design, construction, fabrication, operation, or maintenance of enrichment, reprocessing, or heavy water production facilities, but not Restricted Data.

This creates a new category of information and DOE must determine what information will be controlled by this definition. The implementing regulations do not specifically define what data or types of information are considered as meeting the controlling criteria. DOE indicated that such precision as to definition was not advisable or practical. It prefers the approach of answering questions about the applicability of the regulations to specific activities.

Since the Nuclear Non-Proliferation Act seeks to control the export of sensitive nuclear technologies, this raises some questions about foreign participation in research, training, and education in the United States. For example, does foreign involvement in research, on-the-job training, or exposure to classroom discussions--based on information available to the public but reaching new, important conclusions or findings concerning reprocessing, enrichment, or heavy water production--fall within the criteria of sensitive nuclear technology? Can these new findings or conclusions be transferred to foreigners without Government screening?

AVAILABILITY OF WEAPONS-RELATED DATA

The essentials of nuclear fission weapons design are no longer secret, and the manufacturing techniques are within the abilities of many nations, according to ACDA. Specific designs of U.S. nuclear weapons, their dimensions, compositions, detonating systems and yields are classified and likely to remain so. However, much of the technology required to make a nuclear fission weapon is in the open literature, simply because it is utilized in peaceful applications.

In May 1964, the Lawrence Livermore Laboratory began the "Nth Country Experiment" an experiment to see if a few capable physicists, unfamiliar with nuclear weapons and with access only to unclassified technology, could produce a credible nuclear weapon design. The details of this experiment have remained highly classified. However, the unclassified preface of the report on this experiment showed that the information and technology to design and construct a plutonium fission weapon are almost completely available in unclassified literature.

More recently, it has been reported that individual college students have been able to develop nuclear weapon designs from unclassified data.

It is now generally agreed that one can learn the general principles of how an atomic bomb works in most good libraries and according to ACDA, some fairly detailed descriptions of how a nuclear fission explosive device is constructed are available in unclassified literature. However, ACDA officials add, actual construction of a nuclear explosive device is a very difficult and hazardous undertaking even for those with advanced scientific and engineering skills. According to ACDA, the fabrication of a nuclear explosive device would require not only the fissionable material but also personnel with sophisticated skills and expertise in chemical and conventional explosive technology, metallurgy, engineering, and nuclear reactor physics.

DOE's Technical Information Center and the Department of Commerce's National Technical Information Services publish abstracts and indexes listing unclassified scientific and technical nuclear information. Our review of a listing of unclassified Technical Information Center scientific and technical documents available from 1970 to July 1977 showed a total of 689 studies relating to reprocessing and uranium enrichment; most were related to reprocessing. Information from this DOE system is also published in the National Technical Information Service which has a much wider distribution.

IAEA's International Nuclear Information System (Atomindex) contains abstract references to unclassified nuclear information. The abstracts include such subject areas as production of enriched uranium, production of heavy water, isotope production and enrichment, and nuclear explosions.

AVAILABILITY OF NUCLEAR TRAINING ABROAD

According to a 1977 IAEA inventory of nuclear training facilities, at least 23 other countries have nuclear training programs. The training described in this inventory covers a wide range of subjects provided by academic institutions, governments, contractors/consultants, and reactor vendors. (See app. II.)

The inventory lists 78 foreign academic institutions, 34 foreign government institutions, and 1 foreign reactor vendor that operate facilities for training in nuclear power and its cycle. For example, West Germany has 28 universities or other academic institutions and 3 government facilities with nuclear training programs. There are 9 universities and 8 government facilities providing nuclear training in the United Kingdom.

The training programs listed by IAEA cover such broad areas as (1) nuclear powerplant operation and maintenance, (2) nuclear safety, (3) quality assurance, (4) nuclear fuel management, (5) nuclear materials control, (6) nuclear plant control and instrumentation, and (7) nuclear powerplant engineering.

The IAEA publication does not reveal the duration of the training and the course descriptions provided to IAEA were generally not very definitive. However, Brazil, Finland, West Germany and Sweden reported specific training related to enrichment and/or reprocessing.

A further analysis of the inventory showed that in comparison to the training available in the United States:

--France reported training at only one government institution, in a single subject area--nuclear powerplant operation and maintenance.

--Sweden is the only foreign country which reported training by a reactor manufacturer.

--No foreign country reported any nuclear training by consultants or contractors.

OTHER WAYS UNITED STATES HELPED TRAIN FOREIGNERS

The United States has assisted other nations in obtaining nuclear technology in a number of ways besides formal nuclear training.

--Between 1956 and 1962, a total of 35 foreign countries received about $9 million in research reactor development grants and $2.7 million in related equipment grants for nuclear research.

--A "sister laboratory" program was set up with countries to exchange information and personnel of U.S. organizations whose activities paralleled those of foreign research centers.

--The International Cooperation Administration and its successor, the Agency for International Development, provided grants totaling $6.3 million to 27 countries for technical assistance projects related to nuclear energy from 1956 through 1972, including training in the United States for foreign nationals.

--The U.S. Government has participated in and financially supported numerous international scientific conferences on atomic energy. For example: (1) the First International Conference on the Peaceful Uses of Atomic Energy was held in 1955, at which 1,428 delegates from 73 nations exchanged over 1,000 technical and scientific papers, including much information which had previously been classified in the United States and other countries, and (2) an AEC Symposium for Chemical Processing of Irradiated Fuels from Power, Test, and Research Reactors was held in 1959 for the international review of technical information.

--Under the Atoms for Peace Program, the United States provided to each requesting country a complete collection of unclassified AEC documents in the field of atomic energy. From 1954 to 1968, the United States provided 87 depository libraries, each with about 60,000 documents, to 62 nations and 5 international organizations.

--AEC conducted a program of advisory and consulting services abroad. In the early 1960s, for example, AEC helped the European Company for the Chemical Processing of Irradiated Fuels 1/ at Mol, Belgium, by assigning a full-time U.S. technical consultant, arranging short-term visits of other technicians, and exchanging technical reprocessing data.

--U.S. reactor and equipment manufacturers have transferred nuclear technology abroad in a number of ways such as (1) having production carried out by foreign affiliates, (2) licensing foreign firms to use patented technology and providing corporate know-how, (3) undertaking "turnkey" projects for design and construction of complete plants or laboratories for a foreign enterprise, including consulting services during initial operations, and (4) exporting reactors and related equipment accompanied by detailed instructions and assisting in installation, servicing,

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1/Commonly known as Eurochemic, a semi-governmental, semi-private international company of 12 Western European countries was established for the purpose of constructing and operating nuclear fuel reprocessing facilities to serve Western Europe.

supervision, and training of personnel for operation of the equipment.

--The Export-Import Bank of the United States has helped finance 51 foreign nuclear powerplants, as well as nuclear training centers in Japan and Romania, through loans totaling $3.3 billion and $1.6 billion in financial guarantees. Eximbank officials advised us that U.S. reactor vendors provide training as an integral part of all reactor sales.

--Scores of U.S. experts have visited numerous foreign nations to help on specific problems encountered in developing civilian nuclear programs.

--There have been technical collaborations with about 40 countries, for example: with Canada, on the production technology for manufacturing heavy water; with the United Kingdom, Germany, Switzerland, Canada, and Japan on fast breeder reactors; with Australia, India, and Israel on evaluation of nuclear data; and with the European Nuclear Energy Agency on the Halden Boiling Heavy Water Reactor and a high-temperature gas-cooled reactor project.

CONCLUSIONS AND AGENCY COMMENTS

We recognize that there is an important distinction between designing a bomb and securing the needed material and then constructing a nuclear weapon. However, once it is known that a weapon can be built using certain principles, we believe the difficulties are more apt to be resolved.

Our review showed that:

--Some fairly detailed descriptions of how a nuclear fission explosive device is constructed are available in unclassified technical literature, according to ACDA.

--U.S. Government and international information services publish abstracts and indexes listing unclassified scientific and technical nuclear information available to the public, including data related to uranium enrichment and reprocessing.

--Training is one of the most effective means of transferring high technology, and at least 23 other countries provide nuclear training.

--Nuclear engineering is only one of several disciplines that is relevant to a nuclear weapons program.

--The United States has used a number of mechanisms besides training to transfer nuclear technology.

--The Nuclear Non-Proliferation Act of 1978 restricts the export of sensitive nuclear technology. This raises some questions about foreign participation in U.S. nuclear research, education and training which could result in new findings or conclusions concerning reprocessing, enrichment and heavy water production.

DOE officials said that sensitive areas of nuclear technology have been examined and precautions have been taken, but it is very difficult to draw a firm line with respect to what is and what is not sensitive; it is a matter of degree. The Nuclear Regulatory Commission commented that definitions which are clearly stated and consistently applied are essential in determining the proliferation significance of particular types of information and training. State Department officials stated that the prevalence of grey areas of definition and categorization was a general problem and there was a wide spectrum of views as to whether lines of delineation should be drawn.

Nevertheless, we were informed that under the organizational framework of the National Security Council's Interagency Ad Hoc Group on Non-Proliferation, the executive branch was reviewing a few of the apparently most sensitive unclassified Government publications to determine whether further distribution should be controlled. However, agency officials cautioned that there were practical and legal implications.

RECOMMENDATIONS

The Secretary of Energy, in conjunction with the Secretary of State, the Chairman of the Nuclear Regulatory Commission, and the Director of the Arms Control and Disarmament Agency, should:

--Clarify, through the issuance of coordinated interagency guidelines, what specific data or particular types of information are to be subject to the "sensitive nuclear technology" export criteria established in the Nuclear Non-Proliferation Act of 1978, and how such criteria apply to foreign participation in education, training, and research in the United States.

--Consider discontinuing further distribution of U.S. Government publications which could provide substantial assistance to anyone seeking a nuclear explosive capability.

CHAPTER 3

ROLE OF U.S. GOVERNMENT FACILITIES

IN TRAINING FOREIGNERS

Foreigners have enhanced their nuclear capabilities by attending formal training courses and by participating in nuclear research projects at U.S. Government-owned contractor-operated laboratories. 1/ Formal classroom work, some of which included training in reprocessing and enrichment, was given in the late 1950s and early 1960s but was curtailed in 1965 because similar courses were available at U.S. universities. More currently, national laboratory training courses have been limited to those under the auspices of IAEA and a special course for Iranians.

In 1956, the Panel on the Impact of Peaceful Uses of Atomic Energy summarized the manpower and training needs of the atomic age as follows:

> "The speed at which the peaceful uses of atomic energy develop will be controlled by * * * the availability of people having proper knowledge and equipped with adequate facilities and the availability of well qualified, highly trained scientists, engineers and technicians to carry forward research, development, design and construction of atomic plants and devices."

By that time, training in the United States of qualified students of friendly nations had become one of the major efforts of the U.S. Atoms for Peace Program.

A small beginning had been made even under the limited international exchanges permitted by the Atomic Energy Act of 1946, [60 STAT. 755 (current version at 42 U.S.C. 1801)]. Between 1948 and 1954, some 40 students from other countries received the basic training in radioisotope techniques given at the Oak Ridge (Tennessee) Institute of Nuclear Studies, a Government-supported institution.

1/During World War II, the Government contracted with university and industrial organizations for nuclear research and development as well as the operation of certain facilities. At the end of the war, the major nuclear research and development organizations that had been created were converted to a peacetime footing. Thus the foundations for the present system of national laboratories were laid.

With the passage of the Atomic Energy Act of 1954, the United States liberalized its nuclear cooperation with foreign countries and the AEC international training program began to grow in size and scope. By the end of 1959, more than 2,500 persons from 70 nations had completed or were receiving formal instruction or on-the-job training in facilities of AEC and its contractors.

As the capacity of colleges and universities to provide training in the nuclear field grew, AEC's program was oriented more and more to specialized training which utilized the unique facilities or experience of AEC installations.

PAST FORMAL TRAINING PROGRAMS

AEC's formal international training courses were open to qualified students from other countries. These courses were available, primarily, at six AEC or contractor-operated facilities: Oak Ridge National Laboratory; Oak Ridge Institute of Nuclear Studies; Argonne National Laboratory; AEC Health and Safety Laboratory in New York City; Puerto Rico Nuclear Center; and the Shippingport, Pennsylvania, reactor site. Enrollees from other countries generally were sponsored by their respective governments; however, in many cases, financial assistance was provided to such foreign students through the State Department and the International Cooperation Administration.

The most prominent formal training programs were given at the Oak Ridge School of Reactor Technology and the Argonne International School (later renamed Institute) of Nuclear Science and Engineering and are discussed on the following pages. A brief description of other formal nuclear training courses offered by AEC in the late 1950s and early 1960s is provided in appendix III.

Oak Ridge School of Reactor Technology

The 12-month international training program at the Oak Ridge School of Reactor Technology, which operated from 1959 to 1965, was designed to take students who had at least a Bachelor of Science degree in engineering or physical science, and begin the process of converting them into nuclear engineers. Nine months of academic work were followed by 3 months of more specialized practice in either reactor operations or evaluation of hazards related to reactor operations.

It is now difficult to evaluate the extent of the subject matter taught, but a review of the course descriptions given in a 31-page brochure dated January 1962 showed the program included training on topics which could enhance, at least indirectly, a nuclear weapons capability such as:

--Uses and methods of isotope separations (enrichment).

--Separation of reactor products (reprocessing).

--Radioactive waste disposal.

--Experimental reactor physics.

--Hazards evaluation including those related to plutonium handling and metal fabrication.

--Radiation protection and shielding design.

--Reactor materials and high-temperature metallurgy.

Records showed a total of 115 aliens from 26 countries had attended the Oak Ridge School.

Number of Foreign Participants
Oak Ridge School of Reactor Technology
1959-65

Japan	16	Spain	4
Italy	11	Switzerland	3
Pakistan	12	United Kingdom	3
India	8	Australia	2
China (Taiwan)	6	Denmark	2
Belgium	5	Indonesia	2
Brazil	5	Thailand	2
Iran	5	Finland	1
Philippines	5	Greece	1
South Africa	5	Netherlands	1
West Germany	5	New Zealand	1
Israel	4	Turkey	1
South Vietnam	4	Venezuela	1
		TOTAL	115

Argonne International School of
Nuclear Science and Engineering

The Argonne International School was established in 1955 to provide qualified U.S. and foreign scientists and engineers with a working knowledge of subject matter needed for peaceful application of nuclear processes as quickly as possible. Organization of the School was spurred by the belief that nuclear materials made available by the United States could not assist in the rapid development of needed electrical power if the world lacked trained scientists and engineers with experience in the handling and use of nuclear materials.

The School's objectives were to present and critically evaluate the available technology in respect to (1) the production of reactor materials, (2) the manufacture of satisfactory reactor components, (3) the design, construction, and operation of nuclear powerplants, (4) the processing of all types of irradiated materials from nuclear reactors, (5) the nonpower applications of nuclear reactors, and (6) the utilization of radioactive products. In our opinion, training in such areas as the production, processing, and utilization of nuclear materials could, at least indirectly, enhance a nuclear weapons capability.

Sufficient information was to be discussed to permit the specialists who completed the work to be technically qualified in one or more of the following areas: production and purification of reactor materials from ores or other sources; fabrication of these materials into reactor components; design of research and power reactors; operation of reactors; and design and operation of plants for processing radioactive materials.

Countries were encouraged to send small groups who would work in the various specialized areas and who, as a group, could take home an understanding of the entire nuclear field. The School was closed in 1960, but during the 5 years it operated, 413 foreign nationals from 44 countries participated in training.

Number of Foreign Participants
Argonne International School of Nuclear
Science and Engineering
1955-60

Afghanistan	2	France	15	Pakistan	21
Argentina	4	Germany	27	Peru	3
Australia	2	Greece	16	Philippines	10
Austria	7	Guatemala	1	Portugal	3
Belgium	12	India	15	Rhodesia	1
Brazil	14	Indonesia	5	South Africa	1
Burma	7	Iran	3	Spain	34
Ceylon	1	Iraq	5	Sweden	8
Chile	5	Israel	9	Switzerland	11
China (Taiwan)	14	Italy	35	Thailand	15
Cuba	2	Japan	30	Turkey	11
Denmark	4	Korea	22	Uruguay	2
Ecuador	2	Mexico	3	Venezuela	5
Egypt	8	Netherlands	9	Yugoslavia	3
Finland	4	Norway	2		
				TOTAL	413

Argonne International Institute
of Nuclear Science and Engineering

The International Institute of Nuclear Science and Engineering was the successor to the International School and operated between February 1960 and June 1965. The Institute's training program was essentially the same as the School's, but at a more sophisticated level and with greater emphasis on individual project and research efforts. This specialized advanced training and post-doctoral study in the nuclear field included reactor science and technology; engineering research and development; physical science research; life science research; and engineering, administration, and operation of nuclear facilities.

In the 5 years of its existence, 256 foreigners from 29 countries, attended the Institute. Formal instructions and special study opportunities were available in fields that could at least indirectly enhance a nuclear weapons capability such as

--reactor materials technology,

--physical metallurgy of reactor metals,

--pyrometallurgical reprocessing of fuel, and

--chemistry of volatility separations.

Number of Foreign Participants
in the Argonne International Institute
of Nuclear Science and Engineering
1960-65

Argentina	3	India	50	Pakistan	3
Austria	6	Iran	3	Philippines	6
Brazil	21	Israel	5	South Africa	10
Burma	2	Italy	9	Spain	4
China (Taiwan)	7	Japan	75	Sweden	2
Denmark	1	Korea	4	Switzerland	1
Egypt	2	Mexico	1	Thailand	4
Finland	2	Netherlands	4	Vietnam	2
France	3	New Zealand	1	Yugoslavia	15
Germany	9	Nigeria	1		
				TOTAL	256

Such international training programs were discontinued in 1965 because of (1) increased capabilities of domestic and foreign universities to provide advanced specialized programs in nuclear sciences and engineering, (2) similar schools established by atomic energy agencies in several foreign countries, and (3) increasing difficulties experienced by foreign students in obtaining financial support for training at the AEC schools.

To assess the value and usefulness of its early training programs, the AEC tracked the careers of foreigners trained at its installations to determine whether their acquired skills were being utilized. According to a 1960 AEC report, "many of those who have completed various types of training in the United States now hold positions of leadership in nuclear energy programs, universities and industries and research centers in their home countries."

Many of the foreign nationals who were trained at the Argonne School or Institute went on to distinguish themselves in their nation's program as shown by the following examples.

Selected Foreign Officials Trained at Argonne

Country	Position held
South Africa	Director-General of Atomic Energy Board and General Manager of the Uranium Enrichment Corporation of South Africa
South Korea	Director of the Atomic Energy Bureau
Spain	Director of the Industrial and Pilot Plants Division of the Nuclear Energy Agency
Egypt	Director of the Atomic Energy Commission
Pakistan	Chairman of the Atomic Energy Commission
Taiwan	Secretary General of the Atomic Energy Council
	Director of the Institute of Nuclear Energy Research
Yugoslavia	Senior Scientific Staff of Nuclear Energy Institute

Neither the Departments of Energy and State nor the national laboratories now routinely keep or have readily available information on the training backgrounds of senior foreign nuclear officials or the current positions of those individuals who have received U.S. training in the past.

RECENT FORMAL TRAINING PROGRAMS

Formal nuclear engineering-related training offered at U.S. Government facilities at the time of our review was limited to IAEA-sponsored nuclear reactor management courses at Argonne and a special nuclear science and engineering course at Oak Ridge designed expressly for Iranian students.

To reduce the risks of proliferation, the Government is currently sponsoring courses to upgrade international safeguards and conducting programs for foreign representatives on physical security measures to combat nuclear terrorism or sabotage. We did not review the safeguards and physical security courses because their objective supports U.S. non-proliferation goals.

IAEA Power Reactor Courses

Argonne National Laboratory is the site of IAEA courses intended to train key technical and administrative personnel from utilities, regulatory agencies, and power authorities of developing countries. The courses offered are in the development, construction, and operation of nuclear power programs.

The two IAEA Nuclear Power Project Courses--(1) Planning and Implementation, presented at Argonne in January 1976 and September 1977 and (2) Construction and Operation Management, given at Argonne in September 1976 and January 1977,--were broad and general in scope. The 3- to 4-month courses were based on a syllabus developed by a panel of international experts with wide experience in nuclear power projects and in nuclear manpower training. The Federal Republic of Germany and France have also presented both these courses in their respective countries as part of their contributions to IAEA.

Lectures given during the IAEA nuclear power course included such topics as power reactor fuel cycles; safety, safeguards and regulatory functions; project management; design and engineering review; maintenance, refueling and plant modification; radiation protection; and environmental considerations.

The nuclear power courses held at Argonne are tied to U.S. in-kind contributions to the IAEA. The cost borne by the United States for presenting the three IAEA nuclear power project courses held before June 30, 1977, totaled about $900,000. The bulk of these costs was for salaries of Argonne employees, supplies, and salary and travel costs for lecturers and consultants.

Special U.S.-Iranian training program

During our review we learned of a recent U.S. program for training Iranian personnel in the field of nuclear science and engineering. Pursuant to the U.S.-Iranian Joint Commission, which was established in 1974 to foster broad technical cooperation between the two countries, Iran officials made a formal request in 1976 to secure training in the nuclear field to better prepare the Iranian engineers and scientists for Iran's nuclear power program.

In February 1977 a team from the Oak Ridge National Laboratory and the Oak Ridge Associated Universities, Inc., 1/ presented a proposed training contract to Iran. Subsequently an agreement was reached between the Atomic Energy Organization of Iran and DOE which provided that:

--Oak Ridge Associated Universities, Inc., had responsibility for administering the training and Oak Ridge National Laboratory was responsible for technical assistance, tutoring, and laboratory assignments for the trainees under their prime contracts with the DOE.

--Personnel receiving the training were to be from Iran's Esfahan Nuclear Technology Center. Twenty to twenty-nine trainees in the initial group were to receive approximately 2 years of training. Iran could also send other small groups for short visits.

--Iran was to pay for all actual costs incurred in operating this training program up to the total agreed amount.

--The 2-year training program would include the following topics:

Reactor engineering and design
Reactor operation
Reactor safety
Reactor materials
Data processing
Experimental neutron physics
Environmental science
Electronics and instrumentation
Hot cell operation
Radioactive waste and disposal
Nuclear desalination
Sodium technology
General laboratory operation

The proposed training contract presented to Iranian officials in February 1977 stated that the cost for the training would be $548,517. However, the cost estimate provided Iran did not include the DOE's normal 20 percent added factor and 8 percent depreciation charge, which amounted to about $162,000.

1/ A private nonprofit corporation sponsored by 43 colleges and universities, which serves as a prime Government contractor in conducting programs of scientific research, education, information, and training.

In June 1977 the U.S. Embassy's Science Attache informally discussed the matter of the additional $162,000 in overhead with an Iranian official who indicated that his country had negotiated in good faith, was not aware of any additional $162,000 in overhead charges and therefore did not feel the Iranian Atomic Energy Organization should have to pay the higher cost.

DOE's general pricing policy is to price materials and services furnished to others at the higher of full cost recovery or current commercial prices. Therefore, DOE advised the State Department that the only basis for waiving the costs would be an overriding national interest and that, unless State concluded there were such overriding national interests, they planned to advise Iran that additional charges would be necessary.

In July 1977 the State Department responded that (1) a large part of future U.S.-Iranian cooperation would hopefully be in nuclear energy once an agreement for cooperation was signed, (2) American firms would be able to enter into long-term contracts to provide six to eight nuclear power reactors, and (3) to seek the added charges could seriously affect future energy cooperation. The State Department suggested that, in view of our national interests in developing broad and particularly close ties with Iran in the energy field, these charges be waived. DOE then officially waived the charges, and the training agreement was signed in December 1977 with the apparent arrangement that any cost overrun would be underwritten by the American taxpayers.

The Oak Ridge training program for Iranians began in mid-1978. However, it was terminated in early 1979 because of the lack of financial support by the Government of Iran.

CONCLUSIONS AND AGENCY COMMENTS

Formal training of aliens in nuclear engineering technology and related fields at U.S. Government facilities was at its height in the early 1960s when a concerted effort was being made to assist foreign nuclear programs through the Atoms for Peace Program. While some of the training related directly to such key technologies as uranium enrichment and reprocessing, other aspects, in our opinion, could also have enhanced, at least indirectly, a nation's nuclear weapons capability.

Formal Government nuclear training was curtailed in 1965, not because of the proliferation risks involved, but because similar courses were being offered by U.S. colleges and universities elsewhere. It was U.S. policy not to provide training that was available in the private sector, as the Government did not want to compete for students with universities or other private organizations. In 1976, however, the Government reinitiated a nuclear training program by conducting IAEA-sponsored power reactor courses. In addition, the United States subsequently agreed to provide a special 2-year nuclear science and engineering course to Iranians.

State and DOE officials commented that past Government nuclear training was consistent with then existing U.S. policies and technical judgments and that past actions and decisions should not be criticized on the basis of today's revised standards. DOE officials indicated that curtailing Government training would be unwarranted if the objective was to reduce proliferation risks.

State Department officials stated that training useful in the production of weapons-grade material has been essentially curtailed and that in giving nuclear training one cannot ignore certain portions of the nuclear fuel cycle. These officials added that the executive branch should have the opportunity to consider political implications of U.S. Government nuclear training as well as the economic benefits.

RECOMMENDATION

The Secretary of Energy, in conjunction with the Secretary of State, the Director of the Arms Control and Disarmament Agency, and the Chairman of the Nuclear Regulatory Commission, should review the nature of nuclear training programs to be conducted at Government-owned contractor-operated facilities and the need for the U.S. Government--as contrasted with the private sector--to provide nuclear training programs for foreign nationals.

CHAPTER 4

ALIEN PARTICIPATION IN U.S. NUCLEAR RESEARCH

During the early Atoms for Peace days, many requests from foreign countries for nuclear training could not be met within the confines of the formal training courses. Therefore, AEC attempted to arrange suitable individual programs to meet those needs by permitting foreign access to research opportunities. In many instances, this involved specialized facilities available only at U.S. national laboratories. Often, the alien participant was sufficiently skilled to make a contribution to the laboratory's program while gaining valuable on-the-job research experience.

From the beginning of the Atoms for Peace Program in 1955 to February 1977, about 13,500 non-Soviet bloc aliens participated in research at AEC/ERDA-owned laboratories. (See app. IV.) Our review showed that some aliens participated in unclassified research projects which could, at least indirectly, provide skills useful to a nuclear weapons program with a few having participated in research related to enrichment and reprocessing.

The significance of research participation should not be underestimated as a method of training. AEC in 1969 highly touted the educational benefits resulting from research participation by saying that:

> "Next to the pragmatic results of research at AEC Laboratories, the most important product is training. On-the-job training, whether for permanent, temporary or part-time employees, has strengthened the scientific manpower base in the atomic energy field."

With the renewed interest in scientific research in Europe after World War II, the launching of the Atoms for Peace Program, and the impending shortage of qualified scientists and engineers within the United States, the AEC decided to broaden its use of alien scientists in the 1950s. Among the policy changes instituted were:

--Removal of quota restrictions on employment of alien scientists in Government and its associated laboratories.

--Authorization for all laboratory and contractor installations to employ aliens or have guest aliens in unclassified research and in nonsecurity areas, subject to appropriate security checks and procedures to ensure the protection of classified information.

--Appointment of aliens to laboratories on a space-available basis.

Adherence to the NPT by the researcher's home country does not appear to be a factor in alien involvement in nuclear research at Government-owned laboratories. Although it is U.S. policy to encourage countries to become NPT parties and U.S. officials say that NPT parties are given preference when the United States provides nuclear-related technical assistance, such preferred treatment is not given to individuals from NPT countries interested in participating in nuclear research at U.S. Government-owned facilities.

There were about 2,500 aliens participating in research programs at U.S. Government-owned contractor-operated laboratory facilities in June 1977, but a substantial portion were involved in non-nuclear research. Of the total, about 40 percent were engaged in research at Argonne, Oak Ridge, and Brookhaven National Laboratories. The principal areas of research at Argonne and Oak Ridge are nuclear energy and life sciences. Brookhaven's principal efforts are in fundamental research in physical and material sciences.

Foreigners at the laboratories may or may not receive compensation depending upon their position classification. Alien employees, whether full- or part-time, are paid salaries at rates comparable to $6,300 to over $40,000 per year. Aliens engaged as temporary research or technical collaborators do not draw salaries but do receive allowances for such things as travel, lodging, and daily expenses. For example, at Brookhaven National Laboratory, this support varied from $11 a day for 1 month to free housing plus $15 a day for 1 year. Guest scientists receive no remuneration from the Laboratory.

PREVIOUS RESEARCH

The extent of alien participation in research related to reprocessing and enrichment at U.S. national laboratories over the last two decades has been relatively small. During our review we learned that:

--At Argonne National Laboratory, 17 foreigners participated in unclassified research related to reprocessing or enrichment between 1955 and 1977.

--The Oak Ridge National Laboratory, in February 1977, developed a list of 44 foreigners from 17 countries who, since 1959, had participated in work on or had other exposure at Oak Ridge to the plutonium fuel cycle. "Other exposure" was interpreted as a reasonable likelihood of access to pertinent documents or involvement in relevant discussions.

--At least nine foreigners were involved in plutonium recycle research at Brookhaven since 1958, according to DOE field personnel.

To assist us in our review of alien participation at U.S. facilities, the Oak Ridge National Laboratory developed a list of 1,665 foreign nationals from 73 countries that had been assigned to the Laboratory at some time between the period January 1, 1955, and June 30, 1977.

From short narrative descriptions, it appears that about 10 percent of these 1,665 foreigners were involved in unclassified nuclear research projects such as those related to reactor metallurgy, neutron and reactor physics, radiation protection, and nuclear instrumentation which could enhance, at least indirectly, skills useful in the development of a nuclear weapons capability.

RECENT RESEARCH

No foreigners were engaged in reprocessing, enrichment or heavy water production research at Argonne, Oak Ridge, and Brookhaven National Laboratories at the time of our review. However, aliens were involved in research which could at least indirectly enhance a nuclear weapons capability.

Argonne National Laboratory officials indicated that of the 306 alien employees and guests at the Laboratory as of June 30, 1977, 25 were involved in research which could enhance skills useful to a nuclear weapons program. This research included such projects as structural analysis of fuel element cladding; reactor components; fast reactor physics; reactor accident analysis; nuclear chemistry; and designs for fission reactors and experimental fusion powerplants. Argonne officials explained that these 25 foreign nationals were working on nuclear power programs and although the skills were, in some way, related to nuclear weapons, the connection was by no means direct. They added that most of these aliens were immigrants or were seeking immigrant status.

Of the 145 aliens assigned to the Oak Ridge National Laboratory as of June 30, 1977, 13 were engaged in research on such projects as radiation protection for fuel element reprocessing; irradiation effects; reactor metallurgy and materials; treatment and disposal of radioactive waste; and nuclear radiochemistry.

At Brookhaven National Laboratory, we noted unclassified research was underway on laser-induced chemical reactions for the separation of certain isotopes. One objective of this research was to obtain basic knowledge that could be extended to uranium enrichment. Although at the time of our review there was no foreign participation in this project, it is considered unclassified and open to alien involvement.

VIEWS OF LABORATORY OFFICIALS AND FOREIGN PARTICIPANTS

Officials at the national laboratories we visited all seemed to agree that the participation of aliens in nuclear research at the laboratories would have, at most, only a very minor effect upon the proliferation of nuclear weapons. They felt that most of the aliens who undertake research at the laboratories already have whatever theoretical skills are necessary to construct nuclear weapons and their laboratory experience adds little to this basic knowledge.

Oak Ridge officials advised us that, because the United States in the 1950s had declassified and released to foreign nations the basic knowledge and technology required to build reactors and fuel elements and had disclosed reprocessing methodology, proliferation has not been a concern at the Laboratory. Argonne officials stated that, while knowledge gained at the Laboratory might be of indirect use to a nation intent on producing nuclear explosives, they believed most foreign participants had an extensive educational background (many hold doctorate degrees in nuclear-related fields) and a high level of skill before arriving at the Laboratory. Brookhaven officials pointed out that the Laboratory's efforts were geared toward basic research rather than applied technologies. They added that aliens are an integral part of the ongoing research and are making valuable research contributions to the United States.

Laboratory officials pointed out the only way to guarantee that any knowledge gained, however peripheral to nuclear weapons development, would not be used for nonpeaceful purposes would be to completely exclude any foreign participation. They believe that this is not a feasible alternative since the United States would be forgoing benefits to be gained from the participation of aliens in return for some ill-defined guarantee that nuclear proliferation will not result from foreign participation in U.S. research. It was also brought to our attention that many aliens eventually become U.S. citizens and continue to make valuable scientific contributions to this country.

We interviewed 36 foreign nationals who were involved in nuclear research at Argonne, Oak Ridge, and Brookhaven National Laboratories. During these interviews the aliens typically provided the following comments.

--Their research work at the laboratories was not related to a nuclear weapons program.

--They planned to become U.S. citizens.

--They attended a U.S. university.

--They had at least a master's degree in a nuclear-related field.

U.S. CONTROLS OVER FOREIGN PARTICIPATION IN LABORATORY RESEARCH

The primary objective of controlling alien participation at U.S. facilities is to protect any classified research and information from unauthorized disclosure. The Department of Energy verifies, to the extent possible, the identity and objectives of proposed foreign participants and isolates classified research areas to preclude unauthorized access.

Old AEC Manual orders are still used by DOE as the criteria for foreign participation in unclassified research at Government laboratories. AEC Manual Order 3303, "Soviet Bloc Visits, Participation and Conference Attendance," outlines the criteria for processing alien requests from Soviet bloc countries and AEC Manual Order 3304, "Non-Soviet Bloc Alien Visits and Participation," establishes procedures for processing requests from other nations.

DOE officials advised us that both the DOE headquarters and cognizant field operations offices are involved in processing Soviet bloc requests. Officials at the Department's Oak Ridge Operations Office told us that Soviet bloc aliens are approved by topic and building assignment. In addition, the laboratories are required to report to the Department's Operations Office on the alien's activities.

Non-Soviet foreign nationals may participate in unclassified research activities at Government and Government-supported installations provided that:

--Adequate measures exist to ensure that they will not gain access to classified information.

--The level of foreign national participation will not be unreasonable, no increase in funding is required, and adequate supervision can be maintained.

--Cognizant agency officials determine there is "no security objection," when required.

--The same standards of professional qualifications are used in selecting foreign nationals as are used for U.S. citizens.

--Equally qualified U.S. citizens are given preference over foreign nationals for regular employment.

Before a foreign national can be employed, the DOE field office manager must determine the adequacy of security arrangements and initiate checks of investigative and intelligence files as deemed appropriate by Headquarters. More background information must be submitted with a request for regular employment than with a request for temporary employment or guest assignment. If substantial derogatory information becomes known, DOE Headquarters makes the determination on the case.

For non-Soviet bloc countries, the Department's cognizant field office is principally responsible for processing and approving requests for participation in research at the laboratory. Generally, the field office determines if an alien request for participation in unclassified research conforms with departmental policy and objectives and either approves or disapproves the request. Once the field office approves a request, DOE headquarters has the option of disapproving it, but such disapprovals are infrequent.

There are some exceptions to the normal processing of requests for foreigners participation in unclassified research.

--Participation in research on reprocessing, uranium enrichment, and heavy water production is essentially curtailed.

--Prior DOE Headquarters approval is required for any applicants from India and South Africa.

--Participants from France, Belgium, Netherlands, and West Germany involved in the liquid metal fast breeder reactor program require prior DOE headquarters approval. This is to ensure that U.S. scientists receive data commensurate with what they are providing under specific breeder reactor technology exchange agreements.

--Access to projects and documents designated as applied technology, such as those involving the breeder reactor or other nonpatented technology, is restricted to individuals from countries with which the United States has specific technology exchange agreements.

Laboratory officials said that, although alien participation is approved for a specified area, an alien could be exposed indirectly to other areas through such mediums as program staff meetings. We were advised that once an alien has access to the laboratory the primary control responsibility lies with the regular employees, particularly the supervisors. We were told that both the regular employees and the aliens are aware of restrictions placed on alien participation.

Officials from the Departments of Energy and State told us that existing controls over alien participation in unclassified research were adequate. We did not attempt to test the adequacy of the procedures for approving alien participation or the physical controls once aliens were at the U.S. facilities. We did, however, note that although DOE regulations call for a determination on the reasonableness of the overall level of alien participation at DOE laboratories, none had been made since at least 1972. Moreover, DOE officials could produce no documents to substantiate the 1972 assessment.

Earlier AEC regulations indicated that the periodic review of the overall level of alien participation was to have constituted an evaluation of the relative advantages and disadvantages of continued alien participation in the research and operations programs at contractor-operated facilities.

CONCLUSIONS AND AGENCY COMMENTS

At the three laboratories we visited, a few dozen foreign nationals had, over a 2-decade period, been involved in research related to reprocessing or enrichment. However, we could identify no alien engaged in reprocessing, enrichment, or heavy water production research at the time of our visit, but a limited number of foreigners were gaining experience on other projects that could be considered to be of proliferation concern if it were applied to a nonpeaceful project.

Laboratory officials contend that an attempt to control foreign involvement in any research that could be considered indirectly related to a weapons program could represent a serious blow to the scientific community. They also pointed out that much of this research has been done by immigrants seeking U.S. citizenship.

Although aliens may have an important role to play in advancing U.S. nuclear research and development, we believe there is a need to reassess the foreign participation at U.S. research facilities and to limit, when appropriate, any participation that could be used to significantly raise the ability of another nation to make nuclear explosives.

DOE officials advised us that restrictions had been established concerning foreign participation in research on sensitive technologies and that the Department was in the process of revising and updating the internal review procedures, established by AEC, concerning foreign participation and visits to U.S. Government research facilities, principally national laboratories.

We also learned that DOE had engaged a consultant to study what specific research technology and training disciplines should be categorized as sensitive from a proliferation standpoint.

RECOMMENDATIONS

The Secretary of Energy, in consultation with the Secretary of State, the Director of the Arms Control and Disarmament Agency, and the Chairman of the Nuclear Regulatory Commission, should:

--Determine if areas of unclassified nuclear research at Government-owned research facilities can be reasonably held to be of significant proliferation concern and, where appropriate, limit foreign participation.

--Consider the desirability of giving preference to individuals from countries adhering to the Non-Proliferation Treaty when approving alien participation in Government-supported nuclear research.

We also recommend that the Secretary of Energy periodically assess alien participation in nuclear research at U.S. Government laboratories. Such an assessment should include information on the (1) reasonableness of the overall level of participation, (2) areas of concentration and contributions made, and (3) internal review procedures followed to control participation in research that could contribute to proliferation.

CHAPTER 5

NUCLEAR TRAINING AT U.S. UNIVERSITIES

University training in nuclear engineering and related disciplines is quite extensive in the United States. Available statistics show that U.S. colleges and universities offer over 3,000 unclassified courses related to nuclear science and engineering. Course descriptions obtained from selected universities indicate that some courses include discussions of reprocessing and enrichment.

Faculty members at the universities we visited indicated that nuclear engineering and related courses could be considered indirectly related to nuclear weaponry in that they raise the plane of knowledge about nuclear energy, but faculty members did not believe that university educational programs directly contribute to proliferation risks. Moreover, they point out that nuclear engineering is only one of several disciplines needed for a nuclear explosive capability.

Over the years the U.S. Government has provided financial support to the nuclear programs at the universities. It does not, however, monitor course content or set criteria for foreign student participation in university programs beyond that involved in the normal visa process. Moreover, the Government does not compile information regarding the number of foreign students by country who are being or have been trained in nuclear programs at U.S. colleges or universities.

UNIVERSITY COURSES OFFERED

According to a DOE compilation, 190 4-year institutions in the United States offer 3,087 courses in nuclear science and engineering. In addition, 79 schools offer technician training programs of 2 to 4 years' duration in one or more nuclear technologies. All of the courses are apparently open to foreigners. The following table shows DOE's categorization of 3,087 courses.

Nuclear Science and Engineering Courses Available at U.S. 4-Year Educational Institutions

February 1977

Course category	Undergraduate	Graduate	Either undergraduate or graduate	Total
Atomic and nuclear physics	380	392	101	873
Radio- and nuclear-chemistry	34	81	87	202
Health physics (Includes radiobiology, biophysics, environmental radiology, radiation effects, radiological physics, and reactor safety)	172	273	99	544
Nuclear technology (Includes nuclear engineering, reactor analysis, reactor design, reactor instrumentation, and reactor laboratory)	292	402	141	835
Radiation hazards control (Includes radiation shielding and waste disposal)	39	86	44	169
Reactor materials (Includes nuclear metallurgy)	16	38	33	87
Reactor fuel technology	10	29	16	55
Thermonuclear; plasmas	9	91	23	123
Radioisotope techniques	27	38	58	123
Other	(a)	(a)	(a)	76
TOTAL	979	1,430	602	3,087

a/Breakdown between graduate courses offered not available.

Source: DOE

To gain some insight into the extent that uranium enrichment, reprocessing, and production of heavy water might be included in nuclear engineering courses, we examined the course descriptions of the Massachusetts Institute of Technology (MIT) and the Universities of Michigan, California at Berkeley, and Illinois. Of the 160 course descriptions reviewed, 8 included references to fuel element fabrication, fuel reprocessing, or uranium enrichment. (See app. V.) The catalog descriptions of these eight courses showed that the portion dealing with such technologies commanded only a segment of the total description. According to the Congressional Research Service, however, almost all major educational institutions offer courses relevant to fuel reprocessing.

In discussions with university officials and faculty, we were advised that the fundamental principles of technology are taught, but not the "hands-on" techniques required to actually perform the process. They indicated that there is a big difference between theory and application. They did not feel their students would be able to actually construct an enrichment or reprocessing plant without additional information and experience. One professor likened it to petroleum refining--students are taught its principles but very little in the way of actual refining or specific applied technology is discussed.

During our review we learned that from the late 1960s to the mid-1970s, at least 18 civilian schools offered courses related to nuclear explosives engineering. However, from talking with educators at two schools where such courses were offered and reviewing a text used in one course, it was apparent that the courses did not include the design and fabrication of the nuclear explosive itself. The courses, we were told, pertained to the potential application of peaceful nuclear explosions for such purposes as digging canals and harbors or developing petroleum and mineral resources. The professors assumed the nuclear explosive device would be purchased from the U.S. Government.

STATISTICS ON FOREIGN NATIONALS ATTENDING NUCLEAR PROGRAMS

During the fall of 1977, 35 percent of the students enrolled in U.S. doctorate degree programs in nuclear engineering or engineering with a nuclear option were foreigners, according to available DOE statistics. Since DOE relies on voluntary participation to compile its data, the statistics should be looked upon as an indication of enrollment rather than as an absolute number.

For the master's degree programs, foreign students made up 27 percent of the enrollment; and at the undergraduate level, 7 percent of the students were foreigners. DOE figures show the total number of foreigners enrolled in graduate and undergraduate nuclear programs increased from 390 in the fall of 1973 to 666 in the fall of 1977. Of the nuclear engineering degrees conferred in the 1976-1977 academic year, foreigners received 30 percent of the doctorate, 23 percent of the master's, and 4 percent of the bachelor's degrees. (See table on the following page.)

Foreign Participation in Nuclear Engineering or Other Engineering Fields with Nuclear Options as Reported by DOE

Degrees conferred to foreigners	Academic year (note a) 1976-77	1975-76	1974-75	1973-74	1972-73
Doctorates	36	47	30	28	28
	30%	32%	30%	22%	22%
Masters	127	81	76	61	58
	23%	17%	16%	13%	13%
Bachelors (note b)	32	20	39	8	16
	4%	3%	8%	1%	2%
Total	195	148	145	97	102
	14%	12%	13%	8%	8%

Enrollment of foreigners (note c)	1977	1976	1975	1974	1973
Doctorates	202	192	239	159	183
	35%	33%	36%	27%	29%
Masters	312	312	285	182	150
	27%	23%	20%	15%	15%
Bachelors	152	118	105	54	57
	7%	6%	6%	4%	4%
Total	666	622	629	395	390
	18%	16%	16%	12%	13%

a/Percentages are of foreign involvement in relation to the total number of degrees conferred and students enrolled.

b/For those students enrolled in the 3rd and 4th years of the program.

c/For full- and part-time students in the fall of the year.

Note: Not all of the schools reported separate data on foreign national enrollment and degrees granted, but only totals for all students. Hence, the above figures could be somewhat understated if those schools reporting only totals did indeed enroll or grant degrees to foreign nationals.

Some universities restrict the enrollment of foreigners in their departments, often to approximately 25 percent. Officials of these schools felt that, although a mixture of foreign national and U.S. students contributes to the educational process by facilitating interaction and the exchange of ideas, they recognize that their primary responsibility is to the educational requirements of American students.

Another consideration for some schools is the financial support they receive from their State government. If they enroll large numbers of foreign students, the taxpayers might object. Thus, the unwritten quota is either imposed directly by setting an upper limit for foreign participation or indirectly by precluding or limiting foreign nationals from receiving financial assistance or working in college-sponsored jobs.

The DOE does not maintain statistics on a country-by-country basis for the number of students attending nuclear programs at U.S. educational institutions. At three of the schools we visited, Iran, Taiwan, and Brazil had the largest representation among the 145 foreign graduate students enrolled in nuclear degree programs during 1977 as shown in the following table.

Foreign Graduate Students Enrolled in Nuclear Engineering Departments at Three U.S. Universities 1977

Iran	48	Spain	3	Malaysia	1
China, Republic of (Taiwan)	21	Libya	2	Ceylon (Sri Lanka)	1
Brazil	13	Argentina	2	Belgium	1
Algeria	7	Canada	2	Costa Rica	1
Hong Kong	6	Egypt	2	England	1
Korea	5	Israel	2	France	1
Japan	4	Jamaica	2	Italy	1
Greece	4	Iraq	2	Mexico	1
India	4	Bangladesh	2	Pakistan	1
Turkey	3	Nigeria	1	Jordan	1
				Total	145

RELEVANCE AND APPLICABILITY TO NUCLEAR WEAPONS

Our review focused on nuclear engineering at the universities we visited; we were particularly interested in the graduate degree programs (doctor's and master's) because of the higher percentage of foreign participation at that level and the greater specialization inherent in graduate courses. At three of the universities, we also obtained data on the physics and the chemical and metallurgical engineering departments because of the role those disciplines could play in a nuclear weapons development program.

Our review of nuclear-related graduate programs at four major universities showed that:

--The objective of the nuclear engineering department was to provide an education for students interested in developing peaceful application of nuclear energy.

--The educators teach unclassified theories and principles and not specific technologies.

--University officials believed that the lack of training in specific technologies would present a very difficult problem for students attempting to fabricate a nuclear explosive device. However, the nuclear theories and principles provided by university programs might be relevant to the design of nuclear weapons.

--The academic community feels that foreign students not only receive a university or college education but also the opportunity to assimilate the safety and nonproliferation objectives of the United States.

University personnel advised us that laboratory experiments and demonstrations do not usually involve the sensitive technologies of enrichment, reprocessing, and production of moderators as such experiments are too technical, expensive, or hazardous for university teaching. It was also noted that such experiments would be involved more with applied technology than with the underlying principles that the university educational programs stress. However, a faculty member did say that certain research projects might include some aspects of subjects considered to be of proliferation concern but usually did not involve actual laboratory work. Instead, computer simulations are used quite extensively.

Seeking a wider base of opinion on the relevancy of university educational programs to nuclear weapons proliferation, we asked the Nuclear Engineering Department Heads Committee, composed of representatives from 64 colleges and universities, for its comments on the proliferation aspects of training. The Committee, with the approval of department heads from 26 universities, replied that:

> " * * * We are not aware of any nuclear engineering program where the special engineering and scientific techniques necessary to nuclear weapons design are taught. Nuclear engineering graduates represent a small fraction of the total pool of individuals involved in weapons work * * * ."
>
> " * * * Clearly, any attempt to restrict access in education to areas with possible weapons application would put the U.S. in the role of declaring as 'off limits' many traditional areas of modern technology."
>
> "We believe that the potential risks of foreign national students applying the skills they have learned in nuclear engineering programs to weapons system and nuclear explosive developments are far outweighed by the beneficial consequences of the international use of the nuclear energy option for power generation as well as by other nuclear applications, including those in medicine, agricultural research and space exploration."

All of the faculty members we interviewed assured us that no course material contained in any of their programs applied directly to nuclear weaponry--that all of the material was included in the curricula because of its applicability to the peaceful uses of nuclear energy. Since the courses were considered, at the most, only indirectly related to nuclear weaponry, the faculty members did not see how a university educational program could directly contribute to the proliferation of nuclear explosive capabilities abroad.

Faculty members pointed out that since all of the applications of nuclear energy rely on the same fundamental principles and theories, almost anything that is learned about nuclear energy could be at least in some way relevant to nuclear weapons. Several of the educators, carrying the concept of relevance to the extreme, maintained that if one considers nuclear engineering courses relevant to proliferation, then grade school reading and mathematics are also relevant to proliferation since those very basic skills are required to obtain a nuclear weapons capability. However, the foreign students we interviewed typically indicated that their education had little or no relevancy to nuclear weapons development.

Quite a few members of the academic community expressed the opinion that proliferation is a political problem and not a technical one. They maintained that the only factor holding back countries with a moderate industrial base is the political decision that the country needs or wants a nuclear weapons capability and is willing to suffer the consequences--politically and militarily.

Because of the precarious energy situation, some felt it would be unwise on the part of the United States to do anything that might upset a country's supply or possible future source of energy--directly or indirectly--by limiting its cadre of nuclear engineers. Others felt that the unclassified information available from the U.S. Government alone could aid a country's nuclear weapons development program more than a university educational program.

At the four universities we visited, we were informed that no part of the educational program on-campus was security classified, including research. The faculties felt that the educational process was furthered by not becoming involved with material or research that could not be published or discussed openly in the academic community. One of the prime requirements for theses and dissertations is that they be publishable and available to interested parties.

Some universities do, however, operate off-campus research facilities which conduct classified research. Whenever material or research is classified, DOE security requirements must be met; that is, all participants must have security clearances. Foreign nationals are not normally granted security clearances, with some very minor exceptions under mutual defense treaties.

Multiple applications of the same principles and theories for contrary purposes are not unique to nuclear energy. An illustration of another such area presented by a professor concerns metallurgy. When people are taught how to produce steel, it is assumed they are seeking information for peaceful purposes. There is, however, no guarantee that they will not use this information for nonpeaceful purposes such as manufacturing cannons.

Appendix VI lists the disciplines most relevant to a nuclear weapons development program and illustrates how education provided by a university in those fields might be used in peaceful programs as well as a nuclear weapons program.

GOVERNMENT'S ROLE IN ADMITTING FOREIGN NATIONAL STUDENTS INTO THE UNITED STATES

The Immigration and Nationality Act (8 U.S.C. 1101) provides for the admission of foreign nationals to study at trade schools, high schools, universities, and other educational institutions in the United States under two different types of visas. One visa is for exchange students or visitors who are admitted as participants in a program approved by the Secretary of State for the purpose of teaching, instructing, lecturing, studying, observing, conducting research, consulting, demonstrating special skills, or receiving training. The second type of visa is for aliens admitted solely to study at an established institution of learning or other recognized place of study approved by the Immigration and Naturalization Service.

The field of study that a foreign student intends to pursue does not influence the type of review his immigrant student visa application receives. Hence, the Government exercises no more control over foreign national students entering the United States to attend nuclear-related courses than it does over foreign students entering the United States to study the arts or humanities.

Most foreign nationals seek to obtain their student visas from an American consulate in their home country, but an alien already in the United States in another nonimmigrant classification may apply at an Immigration and Naturalization Service district office for a change to student status.

In deciding whether to approve a student's visa application or application for change of nonimmigrant status to that of student, the reviewing officer, either a Department of State consular officer or an immigration examiner, considers whether the alien meets the following qualifications which are required by Federal regulations.

--A properly executed certificate of eligibility from an approved institution or other place of study showing that he has been accepted for attendance.

--Sufficient funds or other acceptable arrangements to cover expenses.

--Adequate scholastic preparation and knowledge of the English language to pursue a full course of study or arrangements to be tutored in the English language.

--An intention and ability to depart from the United States upon terminating his studies.

The process of granting student status has relied heavily on the admitting school's determination that the alien has adequate scholastic qualifications and statements that the student has financial resources to cover his education and living expenses without having to seek employment. However, the State Department, at the time of visa issuance, and the Immigration and Naturalization Service at the time of entry, check the student's name against each agency's "lookout" system to determine whether the person is a known criminal or terrorist or is otherwise the subject of a lookout notice posted by another government agency.

If the alien student is to participate in a program designated by the Secretary of State to be cultural exchange, then the nature of the training will have been reviewed by the Department of State to determine its usefulness to the development effort of the student's home country. However, little consideration is given to the nature of training to be obtained by individuals pursuing a full course of study at a facility in the private sector. There are no restrictions on the curricula that foreign nationals may pursue at U.S. universities.

GOVERNMENT INVOLVEMENT WITH SPECIAL PROGRAMS BETWEEN FOREIGN ENTITIES AND U.S. SCHOOLS

During our review, we learned that MIT had established a special program for training 50 students from Iran. Under its contract with MIT, the Atomic Energy Organization of Iran pays the cost of the additional course sections that MIT has to provide in order to accommodate the Iranian students.

All students accepted by MIT, regardless of whether they are admitted under this nuclear engineering program or not, are subjected to the same admissions requirements and screening. In essence, the contract permits additional Iranian students to attend the MIT nuclear engineering program by providing MIT with the resources required to increase the total number of student openings available to Iranians. The program began in September 1975 with the first class of 25 and training was completed in June 1977. The second class began course work in June 1976 and completed the program in 1978. Although there was no specific requirement of the University to do so, MIT consulted with the Department of State before entering into the contract.

We also learned that in August 1976 the Uranium Enrichment Corporation of South Africa expressed interest in U.S. training for one of its scientists in an area related to laser isotope separation of uranium. 1/ The South Africans requested such training from at least 3 (MIT, the University of California at Berkeley, and Los Alamos Scientific Laboratory) of the 24 U.S. institutions working on such research, but their requests were denied.

--Los Alamos turned down the request because all research on the subject at the Laboratory takes place in an area restricted to employees with security clearances.

--MIT declined the South African request because of the political sensitivity involved after informal consultations with DOE and State Department officials.

--The University of California at Berkeley also rejected the request of the South Africans.

Since the work at the universities is unclassified, they could have accepted the South African without the knowledge or consent of the U.S. Government. Berkeley, in fact, did not notify or request guidance from the DOE division responsible for research in advanced isotope separation.

DOE officials said that they have no controls over who the universities have working on research projects. Universities are free to utilize whomever they wish as long as classified work is not involved. Therefore, it is possible that foreigners could have been accepted by any university performing unclassified research of a proliferation concern without the knowledge or consent of the U.S. Government.

1/A very advanced method of enriching uranium which promises to be cheaper and more efficient than any competing method. It is also particularly well-suited to produce weapons-grade uranium.

U.S. GOVERNMENT FINANCIAL SUPPORT OF COLLEGIATE NUCLEAR ACTIVITIES

The U.S. Government has been substantially involved in assisting U.S. educational programs in the nuclear field. Most of the Government support has been directed toward assisting educational institutions in establishing and expanding their nuclear curricula, which of course benefits foreign as well as U.S. students. Foreign students have also received direct benefits from the U.S. Government through fellowships and research assistantships. In addition, foreign students can obtain fellowships under the IAEA technical assistance and training program.

In 1956 the Atomic Energy Act was amended to authorize Federal grants and contributions to the cost of construction and operation of reactors and other facilities and equipment to colleges, universities, hospitals, and charitable institutions for the conduct of nuclear educational and training activities. AEC believed its role in nuclear education was to help educational institutions to accomplish three major objectives: (1) ensure a continuing supply of capable nuclear scientists and engineers for the atomic community, (2) integrate nuclear technology into all pertinent curricula, and (3) assist in orienting the public on nuclear energy.

The major forms of Federal assistance to U.S. colleges and universities that indirectly benefit foreign students have been:

--Loans or grants of nuclear materials such as enriched uranium and heavy water needed for training programs.

--Funds for the fabrication of fuel elements for research reactors and the shipment of irradiated spent fuel elements.

--Grants toward the construction of university research reactor facilities.

--Training of college faculty members in advanced nuclear science and engineering.

--Use of national laboratory facilities by students for training and research.

--Course development.

--Grants to acquire nuclear equipment for teaching purposes.

The U.S. Government also contracts with the academic community for nuclear research. Both universities and individual faculty members are retained as contractors, and both in turn may hire faculty members or students to work on the contract. Some students apparently rely on the money they receive from working on research contracts to enable them to attend classes. For the most part, such Government contracts do not restrict schools or individual professors from hiring foreign nationals, so long as only unclassified work is involved. The Immigration and Naturalization Service allows full-time foreign students to work on such research contracts if (1) it is considered part of a student's academic program and related to the course of study and (2) such employment does not displace a U.S. resident.

SOURCE OF FINANCIAL SUPPORT FOR FOREIGN NUCLEAR ENGINEERING STUDENTS

Statistics on the source of financial support for foreign nuclear engineering students in the United States are not readily available although the Immigration and Naturalization Service routinely solicits such data of all foreigners entering the United States on a student visa (over 100,000 a year). Data obtained by the Immigration and Naturalization Service is filed at any one of its 35 field offices but statistics are not compiled. At three of the universities we visited, we were able to develop information on the source of financial support of 160 foreign students enrolled in graduate nuclear engineering programs, as shown on the following page.

Source of Financial Support for Foreign National Graduate Nuclear Engineering Students at Three Major Universities

	Percent
Fellowships and Teaching Assistantships	
School fellowships and teaching assistantships	2.1
Foreign fellowships	45.3
U.S. industry and private fellowships	1.9
IAEA fellowships	.6
National Science Foundation fellowships	.3
Total	50.2
Research Assistantships	
State or school	5.6
U.S. industry	1.7
U.S. Government/national laboratory /National Science Foundation	18.0
Other	3.9
Total	29.2
Self-supported	14.4
Unknown	6.2
Total	100.0

The Nuclear Engineering Department Heads Committee avoided directly answering the question we posed about whether financial support by the U.S. Government affects the number of foreign students pursuing nuclear training at U.S. universities, by responding that:

> "Educational opportunities in the nuclear field are available in many countries. To consciously bar foreign nationals from U.S. programs would greatly decrease any influence we may have throughout the professional careers of these individuals. Such restrictions on foreign nationals would only serve to impose an intellectual estrangement spanning the entire field of nuclear energy without significantly altering the availability of such training to foreign nationals."

During our review, we learned that adherence to the NPT by the student's home country is not considered when selecting foreign recipients for U.S. Government-financed fellowships and assistantships in nuclear-related educational programs. The U.S. policy has been to encourage other countries to become parties to the NPT and U.S. officials have stated that the United States would give preference to NPT parties when providing nuclear-related technical assistance. However, such preferred treatment has not been extended to nuclear-related, U.S. Government-sponsored fellowships and assistantships beyond those involving in-kind technical assistance provided through IAEA.

CONCLUSIONS AND AGENCY COMMENTS

Over 3,000 courses in nuclear science and engineering are being offered by 190 U.S. colleges and universities. They provide a wide range of basic information on the principles and applications of nuclear technology. Foreign participation in the nuclear science and engineering curriculum appears to be substantial and growing.

U.S. universities offer only unclassified courses and use published textbooks. However, some university courses could provide an educational base which might enhance a student's ability to contribute to a nuclear weapons capability.

Some courses included such topics as reprocessing and enrichment. However, faculty members believed that since the material taught had long been declassified and was readily available in the open literature, the instructions could not be considered a proliferation risk.

The U.S. Government has no system to identify any unusually high concentration of students from one country enrolled in specialized fields relevant to a nuclear weapons capability or any substantial foreign effort to develop a significant nuclear technology base without a corresponding interest in nuclear power development. The Government does not know the full extent of alien participation in university nuclear research projects that it sponsors. Furthermore, universities are not required to report special arrangements with foreign government agencies for nuclear training.

Although U.S. universities currently provide substantial nuclear training opportunities, foreign nationals seeking such training can also turn to at least 78 foreign universities or academic institutions that provide similar educational opportunities. Therefore, terminating the nuclear training provided to foreign nationals in the United States would not eliminate the availability of such training and could possibly eliminate any influence the U.S. educational experience might have on future foreign nuclear programs and policies.

Our review of the source of financial support of 160 foreign nuclear engineering students showed the U.S. Government was not directly financing such students to any great extent. However, we believe the policy of giving preference to NPT parties when providing nuclear-related technical assistance should be extended to nuclear-related educational fellowships sponsored by the Government.

State Department officials commented that, while the U.S. Government does not specifically monitor foreign students, it is cognizant of the overall aims of their countries. DOE and State officials indicated that any attempt to monitor a foreign student's involvement in unclassified nuclear training at U.S. educational institutions may not be practical and may be interpreted as an infringement on academic freedom and an individual student's right to privacy.

DOE officials indicated that generally they would learn fairly quickly about any special nuclear training arrangements between a university and a foreign government. However, they expressed concern as to the academic reaction to any Government involvement in such cases.

ACDA officials endorsed the general idea of NPT preference in Government funding of nuclear education for foreigners. State Department officials said that the concept of preference to NPT parties was now being considered within the framework of the National Security Council's Interagency Ad Hoc Group on Non-Proliferation.

RECOMMENDATION

The Secretary of State, in consultation with the Secretary of Energy and the Director of the Arms Control and Disarmament Agency, should consider the desirability of establishing interagency procedures which would make NPT adherence a factor in considering foreign nationals for U.S. Government-financed educational fellowships and research assistantships in nuclear-related programs.

CHAPTER 6

INDUSTRY-SPONSORED TRAINING

PROVIDED TO FOREIGN NATIONALS

The U.S. nuclear industry provides training to foreigners in several ways.

--Formal instructions on how to operate and maintain nuclear reactors and equipment sold abroad;

--International licensing and accompanying technical exchange arrangements providing for transfer of reactor technology through training, documentation, and consultation; and

--Full-time employment of aliens, including some who work on U.S. Government-financed research.

About 75 U.S. firms offer opportunities in nuclear training. In addition, at least two companies have sold complete nuclear power reactor training programs, similar to a self-study course, for use in Japan, Iran, and South Africa.

Industrial training and employment at U.S. nuclear industry facilities can give foreigners the "hands-on" experience in handling nuclear equipment that educational institutions generally do not provide. However, Department of Energy officials have little knowledge of the full extent or type of training or experience provided.

INDUSTRY'S TRAINING RELATED TO FOREIGN SALES

The U.S. nuclear industry is now dominated by five nuclear reactor system suppliers. Two of these companies account for almost 70 percent of domestic and virtually all overseas power reactor sales by U.S. companies. Another company is the principal U.S. supplier of research reactors. Numerous other companies supply nuclear equipment or components, and provide various other architectural, engineering, construction, consulting, and training services abroad.

Since the first foreign sale to Italy in 1956, the U.S. nuclear industry has sold 66 power reactors systems to 16 foreign countries with Spain and Japan the leading consumers.

The principal U.S. supplier of research reactors has sold 28 reactors to 19 foreign countries since its first sale in 1959. This manufacturer has not had a domestic sale in almost 10 years but has made several recent sales to developing countries, including Romania and Iran.

From 1970 to 1977, four U.S. power reactors suppliers provided training to over 1500 foreigners in conjunction with their foreign nuclear sales programs. The fifth principal U.S. manufacturer of power reactors did not provide us any data. Over two-thirds of the aliens trained by these four firms were from Taiwan, Spain, Japan, and West Germany, as shown in the following chart.

Country of citizenship	Number of alien trainees	Country of citizenship	Number of alien trainees
Taiwan	427	Iran	26
Spain	222	Sweden	24
Japan	221	Philippines	8
West Germany	186	France	6
Brazil	127	Austria	4
Switzerland	86	Australia	3
Mexico	57	Argentina	1
Italy	53	Finland	1
South Korea	35	Ireland	1
Yugoslavia	33	South Africa	1
		Total alien trainees	1,522

The training provided to these aliens generally emphasized the safe operation, maintenance, and management of a nuclear powerplant. Most of it involved formal classroom and powerplant simulator courses which were conducted primarily at company training facilities in the United States. The formal classroom instruction lasted from 3 days for a basic powerplant familiarization course to 18 weeks for specialist and technician training. Powerplant simulator courses ranged from a 3-day operator retraining course to a 12-week course covering complete control room operation.

The training typically provided aliens under these programs apparently did not involve reprocessing, enrichment, or heavy water production. However, we learned that from 1970 to 1974, one U.S. manufacturer provided over 150 aliens (principally from Japan and Brazil) with 2- to 5-week training courses in conjunction with prospective reactor sales, which included training in spent fuel reprocessing. The company indicated, however, that the reprocessing information that was provided during this training was general and available in published literature.

From 1959 to 1977, the U. S. supplier of research reactors trained 60 aliens in conjunction with overseas reactor sales. The 4-week program was conducted at the manufacturer's facility and consisted of formal classroom instruction regarding the safe operation and maintenance of research reactors. The training apparently did not include any discussion of enrichment, reprocessing, or heavy water production.

It should be noted that U.S. industry's training of foreigners is not limited to instruction provided at U.S. facilities. For example, U.S. company representatives may provide both on-the-job and onsite classroom training for the overseas plant operations staff during the startup phase. This onsite training may last from 6 weeks for research reactors to 3 years for power reactors.

We did not identify any recent commercial exports involving enrichment, reprocessing, or the production of heavy water. However, we learned that one company provided consulting services to Italy during 1972 regarding the design of a spent fuel reprocessing and fabrication plant.

During the same period, one major U.S. power reactor supplier expressed interest in licensing spent fuel reprocessing technology to Italy and Japan. Although the U.S. Government approved both requests, the negotiations did not result in contractual arrangements. In February 1976 one U.S. company requested permission to assist Argentina in the design, construction, and operator training for a heavy water plant, but in April 1977 DOE disapproved this request.

TRAINING RELATED TO LICENSING AND TECHNICAL EXCHANGE AGREEMENTS

Licensing agreements involve the transfer of nuclear technology abroad rather than the direct sale of reactor equipment. Under a nuclear reactor system licensing agreement, virtually all of the company's engineering technology regarding the design and manufacture of a power reactor system is transferred abroad through training, documentation and consultation. This technology transfer allows the foreign licensee to design, manufacture, and market nuclear powerplants, components, and fuel. The U.S. company normally receives an initial fee plus a royalty for each sale made by the licensee.

The U.S. nuclear industry's licensing agreements have been established almost exclusively with the Western European countries and Japan. The one exception was a licensing agreement with India from 1970 to 1973 involving power reactor fuel reload technology. Three Indian nationals were trained in connection with this agreement.

From 1970 to 1977, three U.S. power reactor suppliers provided training to over 500 alien trainees in conjunction with their various licensing agreements abroad. As shown below, 97 percent of the alien trainees were from Japan, West Germany, Italy, France and Spain.

Country of citizenship	Number of alien trainees	Percentage of total alien trainees
Japan	184	35
West Germany	100	19
Italy	95	18
France	74	14
Spain	58	11
Belgium	8	2
India	3	.5
Sweden	2	.5
Total alien trainees	524	100

Most of these aliens received on-the-job training at the manufacturer's facility for 6 months to a year. They worked as members of an engineering team and received design-related assignments as did other company employees. This training apparently did not involve any discussion of enrichment, reprocessing or heavy water production.

The overseas licensing arrangements by one U.S. manufacturer did involve the transfer of spent fuel reprocessing technology. Reprocessing information was exchanged primarily with licensees in France, Germany, and Switzerland, but we could not quantify the number of aliens trained under these arrangements. During March 1977 DOE ordered this company to discontinue any further exchanges of spent fuel reprocessing technology abroad unless specific permission was granted. Company officials responded that most reprocessing information exchanged with foreign licensees resulted from Government-funded research and thus was readily available in published reports.

From DOE records, we learned that one U.S. company requested permission in June 1976 to enter into a technical assistance and licensing agreement with South Africa, under which South Africans would be trained and licensed to use special techniques directly related to uranium enrichment. However, authorization was not granted.

Licensing agreements are usually accompanied by technical exchange agreements which encourage the sharing of power reactor design technology. One U.S. company estimated that at least $30 million was saved in the research and development of gas-cooled reactors through technical exchange agreements with France. The reactor design feedback obtained from France avoided the necessity of building a costly test facility in the United States.

Other technical exchange agreements involve the research and development of fast breeder reactors. Powered by a mixed plutonium and uranium fuel, they produce more fuel than they consume. Three U.S. reactor suppliers have been involved in fast breeder reactor research under technical exchange agreements with foreign governments and companies primarily in France, West Germany, Switzerland, Great Britain, Japan and the Soviet Union.

The President of the United States proposed in April 1977 to defer further U.S. commitment to the commercialization of nuclear technologies that use plutonium as a fuel until better answers are found to the problems and risks of nuclear proliferation. Some technical exchanges on breeder reactors continue under the existing agreements, but increased consideration is expected to be placed upon alternatives that de-emphasize plutonium and current reprocessing technologies.

ALIEN EMPLOYMENT IN U.S. NUCLEAR INDUSTRY

U.S. nuclear companies reported that alien employees represent anywhere from zero to 16 percent of a firm's work force. Several company officials said aliens are frequently hired due to a shortage of qualified nuclear engineers in the domestic market. Alien employees of two U.S. reactor suppliers approximated 5 percent of the professional staff employees--294 foreign nationals out of the 5,715 professional employees. Over half of these 294 foreign employees were from India, Taiwan, and Great Britain.

The professional alien employees function as engineers or researchers and in various management capacities. Most of the foreign nationals are involved in the design, development, and testing of nuclear reactors. An official of one company stated alien employees had made important contributions to the company's nuclear technology programs for gas-cooled power reactors, fast breeder reactors and fusion research.

A great number of these employees have master's or doctor's degrees, primarily in engineering and scientific subjects; at one U.S. reactor supplier, over three-fourths of the aliens had obtained their advanced degrees from U.S. colleges and universities. The majority of foreign employees are permanent residents of the United States and intend to become American citizens.

Several companies which we contacted were involved in research related to key technologies. In two instances alien employees were participating in such research. A reactor supplier had one employee from Hong Kong and one from Great Britain involved in spent fuel reprocessing research and another supplier had a Canadian employee involved in the development of lasers for uranium enrichment research. Both programs were funded by the Federal Government.

We also noted that one British citizen had been involved in the operation and maintenance of the first commercial reprocessing plant at West Valley, New York, which was shut down in 1972. One individual from India, who subsequently became a U.S. citizen, was briefly involved during 1975 in the planned expansion phase of the plant. However, in 1976 the company announced its departure from the reprocessing business due to rapidly escalating construction costs. We did not identify any foreign nationals involved in the other two U.S. commercial reprocessing plants which have been built but never operated.

FEDERAL CONTROLS OVER ALIEN PARTICIPATION IN THE U.S. NUCLEAR INDUSTRY

DOE exercises minimal controls over alien visits and participation in private industry. Moreover, Department of Energy officials had little knowledge of the number of aliens employed by the nuclear industry (even Government prime contractors) or which areas had alien employees. Government contracts with private industry do not normally include provisions concerning the involvement of non-Soviet bloc employees.

The Atomic Energy Act permits U.S. citizens to assist a foreign nuclear activity engaged directly or indirectly in the production of special nuclear material (enriched uranium or plutonium) only under a formal agreement for cooperation or upon authorization by the Secretary of Energy after a Government determination that such activity will not be detrimental to U.S. interests. Pursuant to this statutory provision, Federal regulations [10 C.F.R. 810.7(b)] give general authorization for training non-Soviet bloc foreign personnel in the design, construction, fabrication, or operation of facilities for reprocessing, the production of heavy water, uranium isotope separation (enrichment), and plutonium fuel fabrication or of equipment or components especially designed for such facilities if such training

--does not involve Restricted Data or classified information,

--is not a violation of the law, and

--is limited to either the furnishing of published information or participation in (1) meetings or conferences sponsored by educational institutions, laboratories, scientific, or technical organizations, or (2) international conferences under the auspices of a nation or group of nations or State Department-approved exchange programs.

This general authorization permits the export of published civilian nuclear technology and assistance to free world destinations. Any such technology transfers, however, must be reported to DOE within 30 days from the commencement of the activity. This reporting requirement does not apply to (1) the communication of published information generally available to the public, (2) financial assistance, (3) the furnishing of component parts which are not especially designed for use in a nuclear reactor or facility, (4) the comparative evaluation of types of reactors or facilities, or (5) any activity specifically authorized by the DOE.

According to a DOE official, reports provided by private companies describe the information being transferred in the broadest terms, with only indications of its technological importance. It should also be noted that the Nuclear Regulatory Commission does not require, nor does it receive notification of, such reports or summaries of the data transferred. DOE officials stated that in most cases there was no way to identify whether private companies or individuals were complying with the reporting requirement on technology exports because there is no means to monitor them.

DOE estimated that it received only 20 to 25 requests from U.S. firms, during a recent 1-year period, for specific authorization to provide training involving Soviet Bloc countries or unclassified sensitive technologies. A number of the requests were related to prospective nuclear sales abroad.

Since the regulations do not specify whether firms must request permission to train permanent full-time alien employees involved in company and Government-sponsored research, some companies request DOE approval for such training and others do not. For example, one U.S. power reactor supplier has strictly interpreted this requirement to include permanent full-time alien employees and has reported them accordingly. On the other hand, another major reactor supplier had two alien employees working in spent fuel reprocessing who were not being reported to the Department of Energy.

INDUSTRY VIEWS ON PROLIFERATION RISKS INVOLVED IN TRAINING ALIENS

Overall, U.S. nuclear industry officials do not believe private industry has provided any technical information during alien training programs which was not already available through open literature. For example, some said that much of the technical information regarding plutonium production reactors and certain sensitive technologies, particularly spent fuel reprocessing and heavy water production, has been widely available in the public domain for over 20 years. Company officials cited several instances where this information was available in textbooks and other published documents. Two examples would be the Reactor Handbook and Engineering for Nuclear Fuel Reprocessing.

Nuclear industry officials further believe the most attractive route to nuclear weapons proliferation is a production reactor which is designed and constructed specifically for the production of plutonium. A production reactor is less complex, less costly and a more efficient plutonium producer than a power reactor. Industry officials also stated that research reactors manufactured in the United States do not provide an attractive proliferation medium because they are very poor plutonium producers.

Overall, industry representatives felt that the United States does not have a monopoly on nuclear technology and that foreign technology has even surpassed U.S. technology in some research areas. Therefore, restrictive

Government controls might result in the loss of export business and prevent the exchange of useful information. Industry officials believe that nuclear weapons proliferation is a political problem rather than a technological one. They believe it will have to be resolved by international cooperative agreements rather than controls restricting the exchange of technological information.

CONCLUSIONS AND AGENCY COMMENTS

The U.S. nuclear industry provides training to foreigners through formal instructions related to equipment sales, licensing and technical exchange arrangements, and by on-the-job experience, and full-time employment. Our review showed that through the U.S. nuclear industry a few foreigners have learned or gained experience related to key nuclear technologies.

The Governmment does not know the full extent of alien training or experience provided by U.S. nuclear firms or the areas in which foreigners are involved. DOE does not normally include provisions concerning non-Soviet bloc alien involvement in its research contracts with U.S. nuclear firms. In at least two cases, foreigners were working for U.S. firms on Government-sponsored research programs concerning reprocessing and the development of lasers for uranium enrichment.

DOE officials commented that foreign participation in the development of lasers for enrichment is not sensitive and is not prohibited. They added that generally nuclear manufacturers merely provide training in the operation and maintenance of equipment sold. ACDA officials, however, felt the Government should review more thoroughly the training/learning experience that U.S. industry provides foreigners, especially employees of foreign subsidiaries, licensees, or counterparts.

CHAPTER 7

IAEA TRAINING ACTIVITIES

Since 1958, the International Atomic Energy Agency, with substantial assistance from the United States, has been providing nuclear training to foreign nationals in an effort to accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world without furthering any military purpose.

To promote the transfer of skills and knowledge relating to the peaceful uses of atomic energy, IAEA has established a Technical Assistance and Training Program. IAEA endeavors to assist member nations in building their scientific and technical infrastructure and to promote economic and scientific development through nuclear technology by sponsoring the following programs.

Fellowships for training individuals at a university, government laboratory, or private institute for up to 1-year, in any of IAEA's fields of technology. (See app. VII.)

Visits of scientists from developing member nations to nuclear centers usually in two or more advanced nuclear countries, for such purposes as studying nuclear science and technology and observing nuclear research.

Short-term training courses designed by member nations (generally from 2 weeks to 3 months long) that provide the opportunity for individuals, principally from the developing nations, to study in a specific field related to peaceful applications of the atom.

Expert services provided to member nations upon request, principally to advise or assist in the development of nuclear power technology.

Nuclear safeguards inspector training, an 8-week basic course in Vienna, Austria, on the techniques for measuring the uranium and plutonium content of material in various forms at nuclear facilities. Approximately 70 to 80 percent of the inspectors get advanced safeguards training at Los Alamos Scientific Laboratory in New Mexico.

Research and training programs at the International Center for Theoretical Physics in Trieste, Italy, concerned with nuclear physics, solid-state physics, plasma physics, and high and low energy physics (jointly sponsored by IAEA and the United Nations Educational, Scientific and Cultural Organization).

Power Reactor Project Courses, given under IAEA auspices in the United States, France, and West Germany, deal with either planning and implementation of a power reactor program or the construction and management of power reactors.

The fellowship program has constituted the majority of IAEA training. From 1958 through 1976, IAEA spent $20.9 million for such fellowships and considerably less for other training projects. We concentrated on the fellowship program because of its size and because it appeared to be most relevant to our review. However, chapter 3 includes a discussion of the IAEA power reactor courses given at U.S. laboratories.

FELLOWSHIP PROGRAM

IAEA awarded training fellowships to 5,713 students from member nations between 1958 to 1976. These fellowships were financed through various means, including voluntary contributions of member nations, contributions of in-kind training by individual member countries, or contributions from the United Nations Development Program.

Applications for fellowship grants are made to IAEA exclusively through government channels of the member State, and selection priority is given to requests for participation in programs considered by IAEA officials as directly beneficial to that State. Candidates for fellowships are selected on the basis of educational and professional qualifications, foreign language proficiency, and technology needs of the member State concerned. The nation providing the training has the option for final approval of the applicant's qualifications.

Fellowship training can involve laboratory experience, formal academic courses, directed research, shop apprenticeships, engineering practice, or combinations of these, and may be awarded up to 12 months with extensions of up to 12 additional months in exceptional cases. About 40 percent of the candidates apply for training at institutions located in the United States.

Applications of candidates nominated by IAEA for fellowships at U.S. institutions are referred to the National Academy of Sciences for placement. The Academy evaluates the applicant's qualifications and training objectives and has rejected applications in the past because it did not consider the applicant's home nation sufficiently stable for the type of training requested or because the training requested was considered proprietary in nature.

The final screening of the applicant's qualifications for a fellowship is made by the training institution where the National Academy of Sciences has decided to place the applicant. This decision is based on the preferences stated by the candidate on his application and on the availability of space at institutions providing the type of training requested. If placement of the nominated candidate in a U.S. facility is impossible for any reason, the Academy notifies IAEA which then attempts to place the candidate in a training program of another member nation.

From the data made available to us by IAEA, we could not ascertain the extent of fellowship participation in training courses involving enrichment or the manufacture of heavy water. However, we did determine that, during the period 1958 to 1976, IAEA had provided 65 fellowships for fuel reprocessing courses, of which 38 were in 1975. Participants in these courses were from 12 countries, with India and Argentina having the largest representation as shown in the following table.

Recipients of IAEA Fellowships
in Fuel Reprocessing

Nationality	1958-69	1970-74	1975	1976	Total
India	1	6	7	-	14
Argentina	-	1	11	-	12
Japan	5	-	2	-	7
Pakistan	1	1	4	-	6
Romania	-	2	3	-	5
Poland	-	2	3	-	5
Brazil	-	3	3	-	6
Czechoslovakia	2	-	2	-	4
Mexico	-	-	1	1	2
Turkey	-	1	1	-	2
Korea, Republic of	-	-	1	-	1
Austria	1	-	-	-	1
Total	10	16	38	1	65

Eleven countries have provided the training to IAEA fellows in reprocessing, with Italy and the Federal Republic of Germany being the host country for about half of such training, as shown below.

Host Country for

IAEA Fellowships in Fuel Reprocessing

Country providing training	1958-69	1970-74	1975	1976	Total
Italy	-	4	12	-	16
Germany, Republic of	-	6	10	-	16
France	1	3	4	1	9
United Kingdom	2	1	3	-	6
Spain	-	2	4	-	6
United States	5	-	-	-	5
Japan	1	-	1	-	2
Canada	1	-	1	-	2
India	-	-	1	-	1
Belgium	-	-	1	-	1
Sweden	-	-	1	-	1
Total	10	16	38	1	65

It should be noted that the major nuclear suppliers, in January 1976, notified one another of their intention to unilaterally follow certain common export policies including the application of restraint in transferring technologies not generally available to the public concerning enrichment, reprocessing, and heavy water production.

At the end of 1976, the IAEA Secretariat implemented an administrative procedure to hold in abeyance requests for technical assistance and training involving "sensitive" technologies from nations that had not agreed to implement international safeguards at nuclear facilities that would benefit from the technical assistance to be received.

IAEA officials tentatively labeled all technical assistance and training related to fuel reprocessing, uranium enrichment, manufacture of heavy water and plutonium handling as "sensitive" in that such training involves technologies that could make a significant contribution toward the development of a nation's nuclear explosive capability.

Several nations affected by this action contended that the IAEA Secretariat did not have the authority to implement such a restriction without the approval of the Agency's Board of Governors. Thereafter, at the Board of Governor's conference held in September 1977, IAEA established, as its policy, the requirement that international safeguards be implemented before technical assistance or training in a sensitive technology would be granted.

U.S. ROLE IN IAEA TRAINING

The United States proposed the establishment of IAEA, and since its inception the United States has continued to be one of its staunchest supporters. Over the years the United States has been the biggest financial backer of the IAEA programs and has provided much of the IAEA-sponsored training.

Estimated U.S. assistance to IAEA for 1977 amounted to $17.7 million of which about 27 percent was for the Technical Assistance and Training Program. As the schedule below shows, U.S. support for IAEA's technical assistance and training was in large measure in-kind assistance (i.e., services, not money).

U.S. Support for IAEA Technical Assistance and Training

	1977 Program
Regular assessment allocation	$ 513,600
Voluntary contributions	1,650,600
In-kind fellowships	1,100,000
IAEA training courses (in-kind)	355,000
Equipment grants and cost-free experts (in-kind)	1,192,000
Total	$4,811,200

The United States has been a major place of study for recipients of IAEA fellowships since the inception of the Agency in 1958. Between 1958 to 1976, 1,236 of a total of 5,713 participants received their training at U.S. facilities. Training in most fields of study has been provided by other countries, especially the United Kingdom, France and Germany.

Of the 1,236 IAEA fellows who have studied in the United States, 671 received training in such fields as the application of isotopes and radiation in agriculture, medicine and biology. We concentrated our detailed analysis on the remaining 565 fellows because their training appeared to have more relevance to our study of proliferation risks.

The following tables derived from IAEA data show the sponsorship of the selected 565 fellows, their general fields of study, and the extent of participation by certain countries.

Type of Sponsorship for Selected IAEA Fellows in the United States

Year	Regular IAEA support Number	(percent)	U.S. in-kind assistance Number	(percent)	Other (note a) Number	(percent)	Totals Number	(Percent)
1958-69	50	(14)	251	(69)	62	(17)	363	(100)
1970-76	46	(23)	134	(66)	22	(11)	202	(100)
Total	96	(17)	385	(68)	84	(15)	565	(100)

a/Consists of fellowships funded by Swedish International Development Authority and United Nations Development Program.

Fields of Study for Selected IAEA Fellows in the United States

Field of study	1958-69	1970-76	Total
General atomic energy development	1	1	2
Nuclear physics	39	23	62
Nuclear chemistry	51	31	82
Prospecting, mining and processing	34	24	58
Nuclear engineering and technology	195	90	285
Safety in nuclear engineering	43	33	76
Total	363	202	565

IAEA Fellows Trained in the United States From Selected Countries

Nationality	1958-1969	1970-1976	Total
India	50	16	66
Pakistan	26	24	50
Republic of Korea	18	13	31
Brazil	18	9	27
Yugoslavia	18	7	25
Republic of China	20	4	24
Egypt	17	6	23
Argentina	13	8	21
South Africa	8	-	8
Israel	7	2	9
Iran	4	4	8
All others (48)	164	109	273
Total	363	202	565

We further analyzed the training provided the 202 selected IAEA fellows in the United States from 1970 through 1976 and found that:

--Although 40 nationalities were represented, more than half of the fellows being trained were from seven countries. Pakistan, the Philippines, India and Bangladesh were the major recipients.

--Universities were the major source of training for the fellows with Government laboratories second and private companies a distant third. Oak Ridge National Laboratory apparently trained more IAEA fellows than any other public or private U.S. facility.

--Since 1970 none of the participants have received training in fuel reprocessing; however, two participants were enrolled in nuclear chemical engineering courses which normally would include training in the production of heavy water.

--A more detailed breakdown showed the most popular specific field of training was nuclear instrumentation, electronics and reactor control, chosen by 42 fellows, followed by radiation protection (22 fellows) and power reactor technology (21 fellows).

--According to very limited information provided by IAEA on a sample of 23 participants in the fellowship program, 18 returned to their previously held positions with 16 of these indicating that their present duties were related to the fellowship training received in the United States.

IAEA AND U.S. MISSION VIEWS ON TRAINING ACTIVITIES

Officials at the U.S. Mission to IAEA advised us that they had never made any detailed study of IAEA-sponsored training and thus have not attempted to assess the proliferation risks involved. IAEA officials stated that the proliferation risk associated with the exchange of technology is impossible to measure accurately because of the inability to identify factors associated with each request for assistance that have a direct influence on the risk involved. For example, Agency officials believe there is no reliable way to determine the true intention of the individuals being trained or of the country they represent.

IAEA officials admit that technical assistance training activities do provide the opportunity for participation in fields of study that involve technologies that could make a contribution toward the development of a nation's weapons capability. However, the recent change in policy regarding training in sensitive technologies reveals IAEA's genuine concern about the potential risks.

U.S. Mission officials stated that the IAEA Statute clearly prohibits a member nation from exerting any influence over the manner in which IAEA administers the voluntary monetary contributions for technical assistance made by the member nation. These U.S. Mission officials added that the "no strings attached" concept does not provide for exceptions by any contributing nation.

Donor nations of in-kind contributions are not prohibited from designating in what manner these contributions can be used. With in-kind technical assistance, the nature of the assistance is specified by the donor and proliferation risks can be minimized. The United States has, therefore, taken advantage of the opportunity to control this form of IAEA assistance.

IAEA allows contributing nations to impose restrictions on which nations are not to receive in-kind assistance and considers this procedure as being consistent with its statutory requirements. For example, the United States has stipulated that none of its assistance-in-kind can be given to East European Communist bloc nations. IAEA has also been advised that the United States would continue to give preference to NPT parties when providing in-kind assistance to IAEA.

U.S. Mission officials stated that because of the Statute and the possibility of jeopardizing other U.S. interests--specifically, increased emphasis on the IAEA safeguards program--nothing can be done directly to influence IAEA policy on training or assistance provided by another member nation although it may be paid for, in part, with U.S. monetary contributions.

CONCLUSIONS AND AGENCY COMMENTS

IAEA sponsors fellowships for training individuals at universities, Government laboratories or private facilities of a member nation in a wide variety of nuclear-related fields. The United States has always been the dominant supporter of the IAEA training programs.

Between 1958 to 1976, 11 countries acted as hosts for 65 IAEA-sponsored fellowships in reprocessing. In 1977, IAEA changed its policy to limit fellowships in sensitive technologies to individuals whose home country agreed to accept international safeguards on the facilities that would benefit from such training. This policy change shows genuine concern about the proliferation risks involved in such training.

U.S. officials, in general, stressed the importance of training in the United States to the IAEA technical assistance program and in turn to U.S. non-proliferation goals. ACDA officials added that, within the framework of the National Security Council's Interagency Ad Hoc Group on Non-Proliferation, ACDA was proposing new guidelines to be given to the National Academy of Sciences for use in the placement of IAEA fellows in the United States.

CHAPTER 8

OVERALL CONCLUSIONS

Training in nuclear engineering and related fields, particularly in such key areas as reprocessing, enrichment and heavy water production, could be used to enhance a nation's capability to develop nuclear weapons. Training and experience in such other high technology areas as physics, chemistry, engineering (metallurgical, electrical, mechanical and mining), mathematics, and computer science could provide other skills or expertise also needed to develop nuclear explosives.

More specifically, our review of nuclear education, training, and experience provided foreigners at U.S. laboratories, universities, and private industry and through IAEA showed:

--Over a 22-year period, only a relatively small number of foreigners received training related to the key nuclear technologies.

--Current U.S. policy calls for restraint in providing foreigners such key technologies.

--The United States has provided only unclassified training to assist peaceful nuclear programs of other nations.

--Nuclear training is available in at least 23 other countries.

--U.S. officials believe there are important scientific, economic, and political benefits in providing nuclear training to foreigners.

--Many of the aliens who receive U.S. nuclear training remain in this country to work on U.S. nuclear advancements.

--The United States has helped other nations to obtain nuclear technology through a number of mechanisms besides formal training.

The contribution of U.S. training to nuclear proliferation cannot be accurately quantified. There are inherent analytical difficulties in estimating the impact of U.S. nuclear training given foreigners on the potential development of weapons. Neither the data base nor the needed analytical methods have been developed to effectively evaluate the proliferation risks involved in training foreigners in certain nuclear fields. However, we believe this report raises questions about U.S. nuclear training policies and practices that may warrant further Government attention.

In commenting on our draft report, agency officials generally stressed that foreign participation in U.S. nuclear training and research programs has had a number of benefits, such as:

--Helping to meet U.S. obligations under the Non-Proliferation Treaty and to persuade other nations to agree to international nuclear safeguards.

--Hopefully, creating goodwill between U.S. and future foreign leaders through personal contact.

--Exposing foreigners to U.S. nuclear safety and non-proliferation concerns.

--Possibly contributing to sales of U.S. nuclear goods and services.

Agency officials did indicate a number of initiatives were underway concerning information and training provided foreigners. The executive branch is reviewing a few of the apparently more sensitive unclassified Government publications to determine whether further distribution should be controlled. It is also considering the feasibility of extending the concept of giving preference to Non-Proliferation Treaty parties in the nuclear research and training areas.

The Department of Energy is currently in the process of revising and updating internal review procedures concerning foreign participation and visits to U.S. Government research facilities. The Department has also engaged a consultant to study what specific research technology and training disciplines should be categorized as sensitive from a proliferation standpoint.

CHAPTER 9

SCOPE OF REVIEW

This report provides a historical perspective of the evolution of U.S. training in nuclear engineering and related fields provided to foreigners. It shows how such education and training fits into the overall U.S. scheme of nuclear technology transfers, and addresses the proliferation implications of training foreigners. We included foreign participation in research at U.S. laboratories, because it provides an opportunity to gain valuable hands-on experience (on-the-job training), in some cases using very sophisticated equipment and techniques.

The objectives of our review were to determine to the extent possible:

--The scope of nuclear related training and experience provided foreigners.

--Whether such training or experience could contribute to the proliferation of nuclear weapons.

--The Government's role in subsidizing and controlling foreign participation in U.S. nuclear training.

To accomplish these objectives, the study included an assessment of the nuclear training provided foreign nationals by U.S. laboratories, educational institutions, private nuclear firms, and IAEA. Government involvement and oversight in each facet of training were subjects of concern.

We were especially interested in foreign participation in activities related to reprocessing, uranium enrichment (isotope separation), and heavy water production, which are considered key technologies from a proliferation standpoint. The proliferation risk would, of course, depend on the sensitivity of specific information within these areas, but there is no criteria or meaningful list which sets forth the proliferation significance of specific information or types of data within the key technology areas.

We also developed certain information on foreign participation in the fields of study shown below--recognizing that those in the right column were probably less important from a proliferation standpoint than those in the left.

- Neutron physics
- Reactor physics
- Prospecting, mining and processing of nuclear materials
- Research reactors
- Power reactors

- Reactor technology
- Reactor metallurgy and materials
- Nuclear chemical engineering

- Nuclear instrumentation; electronics and reactor control
- Radiation protection
- Safety of reactors and nuclear materials
- Application of peaceful nuclear explosives
- Hydrodynamics

- Nuclear radiochemistry
- Analytical chemistry
- Physical chemistry

- Irradiation effects
- Treatment and disposal of radioactive waste
- Environmental protection
- Nuclear centers and laboratories
- Basic and intermediate level atomic energy development training

NATIONAL LABORATORIES

U.S. national laboratories are Government-owned, contractor-operated facilities which provide extensive research opportunities. Because of the large number of foreign nationals reported by Brookhaven, Oak Ridge, and Argonne National Laboratories (located in Brookhaven, New York; Oak Ridge, Tennessee; and Chicago, Illinois, respectively), we made detailed reviews at these sites. Oak Ridge and Argonne National Laboratories were also selected because they were the principal sites of the formal laboratory training courses in nuclear engineering provided foreigners in prior years under U.S. Government auspices.

We also visited the Lawrence Livermore Laboratory in Livermore, California, and obtained personnel data from Los Alamos Scientific Laboratory in Los Alamos, New Mexico, on the educational background of personnel involved in designing U.S. nuclear weapons.

UNIVERSITY PROGRAMS

To determine the types of nuclear courses available to foreign nationals at U.S. educational institutions, we visited the Massachusetts Institute of Technology, Cambridge, Massachusetts; the University of Illinois, Urbana, Illinois;

the University of California, Berkeley, California; and the University of Michigan, Ann Arbor, Michigan. At these universities we also obtained information on courses related to nuclear chemistry, nuclear physics, and nuclear metallurgy.

For a broader perspective of university training we met with and obtained the written views of the Committee of Nuclear Engineering Department Heads.

PRIVATE INDUSTRY

We surveyed about 40 prominent nuclear companies to obtain data on the types of arrangements (such as licensing or as part of an equipment sale) under which these firms provide training to aliens as well as the extent of the experience that aliens have received during employment with these firms. We were particularly interested in foreign participation in the areas related to uranium enrichment, reprocessing, and heavy water production.

We visited three large nuclear equipment firms to obtain a fuller understanding of the training provided foreigners by the nuclear industry.

--General Electric Company, San Jose, California

--General Atomic Company, San Diego, California

--Westinghouse Corporation, Pittsburgh, Pennsylvania

INTERNATIONAL ATOMIC ENERGY AGENCY

To obtain detailed information on IAEA's role in nuclear training we visited its headquarters in Vienna, Austria, as well as the U.S. Mission to IAEA. From IAEA documents, reports, and from discussions with IAEA and Mission officials we determined the scope and kind of training activities sponsored by IAEA, the training available in various countries, and the worldwide availability of nuclear information. We obtained additional data on IAEA fellows trained in the United States from the National Academy of Sciences.

FEDERAL AGENCIES

Information on the role of the Government and past and current U.S. programs, policies, procedures, and controls concerning nuclear training was developed from agency records and discussions with officials at

--The Department of Energy and its field offices in Chicago, San Francisco, and Oak Ridge.

--The Department of State.

--The Department of Justice, Immigration and Naturalization Service.

--The Nuclear Regulatory Commission.

--The Arms Control and Disarmament Agency.

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, D.C. 20515

March 15, 1977

Elmer B. Staats, Comptroller General
United States General Accounting Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Staats:

We should appreciate the GAO conducting a comprehensive study of the extent to which the education and training of foreign nationals by the United States in nuclear engineering and related fields contributes to the proliferation of nuclear explosive capabilities abroad.

Preliminary details of this suggested study have been discussed with representatives of the International Division of GAO. Any further questions may be directed to Beth Bloomfield at 225-3061.

Warm regards,

DONALD M. FRASER, Chairman
Subcommittee on International Organizations, House International Relations Committee

CLARENCE D. LONG, Chairman
Subcommittee on Foreign Operations, ~~House Appropriations~~ Committee

SUMMARY OF IAEA'S 1977

INVENTORY OF NUCLEAR TRAINING FACILITIES

Country	Source of Training			
	Academic	Government	Consultant/ contractor	Reactor vendor
Austria	x	x		
Brazil	x			
Czechoslovakia	x	x		
Denmark	x	x		
Finland	x			
France		x		
Germany, D.R.	x	x		
Germany, F.R.	x	x		
India		x		
Italy	x			
Japan		x		
Korea		x		
Netherlands	x	x		
Norway		x		
Pakistan	x	x		
Philippines	x			
Spain		x		
Sweden	x	x		x
Switzerland	x	x		
Thailand	x			
Turkey	x			
United Kingdom	x	x		
United States	x		x	x
Yugoslavia	x	x		

BRIEF DESCRIPTION OF

EARLY FORMAL TRAINING COURSES

AVAILABLE TO FOREIGNERS AT AEC FACILITIES

OAK RIDGE INSTITUTE OF NUCLEAR STUDIES--ORINS, an association of 37 southern universities under contract with the United States Atomic Energy Commission, offered specialized courses of instruction in the uses of radioisotopes which were designed for scientists and engineers, physicians, industrial personnel, and college and university science professors. Students from over 50 countries attended. In 1955 a quota of 30 percent of the Institute's trainee capacity was made available for aliens.

Depending upon the participant's individual interest and need, an ORINS training program usually lasted from 2 to 6 weeks, and offered a series of courses that ranged from basic instruction in fundamentals of radioisotope techniques to more specialized instruction in radioisotope applications in various scientific disciplines.

PUERTO RICO NUCLEAR CENTER--The Center was established in 1957 primarily to aid Latin American nations in developing skills essential to nuclear energy activities by providing graduate level education and research opportunities especially oriented toward the needs of the tropics. The program at the Center included training in the application of nuclear energy to the fields of agricultural, biological, medical, nuclear engineering and physical sciences.

This training and research center was operated by the University of Puerto Rico under contract with AEC, which provided a research reactor, a laboratory, and a biomedical research building.

The curriculum in nuclear engineering included courses in reactor theory and operation. This type of training was considered necessary for the design, development, testing, and operation of nuclear reactors. Completion of the training afforded students an opportunity to attain the degree of Master of Science in Nuclear Technology.

About 700 aliens had been trained at the Center (116 were from Colombia) as of February 15, 1976, in a wide variety of fields. However, foreign enrollments declined in the 1970's, and the emphasis of the training at the Center shifted to non-nuclear energy and ecology. In 1976 the Center's research reactor was disassembled for transfer to another facility.

RADIOCHEMICAL AND COUNTING PROCEDURES COURSE--During the first session of United Nations Scientific Committee on the Effects of Atomic Radiation, held in New York in March 1956, considerable interest was expressed by representatives of the member States in the procedures followed by the United States in the collecting and analyzing of fallout samples. On June 13, 1956, U.S. Ambassador Lodge offered technical assistance to these countries in the measurement of radioactive fallout.

As a consequence, AEC's Health and Safety Laboratory in New York developed a 6-week course in the techniques for radiochemical and instrumental analysis of radiation fallout. The program consisted of lectures and discussions coordinated with practical laboratory experience, affording an opportunity to solve actual problems in measuring of radioactive isotopes occurring in fallout. A total of 23 foreigners attended the first five courses. A registration fee of $25 was charged each participant with the cost of travel and living expenses borne by the student or his sponsoring government or institution.

NS SAVANNAH COURSES--In October 1956, President Eisenhower announced that the United States would construct a nuclear merchant ship to demonstrate the peaceful application of atomic energy to commercial ship propulsion. He indicated that all information developed in the construction of the NS Savannah would be unclassified and would be made generally available.

Two training programs, known as the NS Savannah Construction Observation Program at Camden, New Jersey, and NS Savannah Reactor Engineering Officers' Training Course at Lynchburg, Virginia, were then developed. Under the Camden course, selected foreign engineers were afforded the opportunity to observe the construction of the NS Savannah. Under the second arrangement, a limited number of foreign nationals were enrolled in the 10-month course on how to operate the reactor, which began in April 1959.

The Camden course covered both engineering and supervision of construction. The participants were able to review in detail pertinent documents relating to such topics as hull design, collision barrier design, reactor compartment, containment vessel, shielding, and the reactor and primary system. Over 30 foreign nationals representing 9 countries had attended both the courses as of February 1960.

An estimated expenditure of $900 was made for the 11-week course. All costs of travel, lodgings, subsistence, and miscellaneous expenses during the period were borne by the participant or his sponsor.

SHIPPINGPORT NUCLEAR POWER STATION TRAINING COURSE--This 4-month training course, which was started in 1959, was designed to give domestic and foreign supervisory personnel, engineers, and specialists a practical background in the particular fields of science and engineering not normally associated with conventional power stations but essential to safe and efficient operation of a nuclear power station. It also provided an opportunity for actual experience in operation, maintenance, health physics, chemistry, and testing for this type of station. Tuition for the course was $2,000 for the 4-month term with other expenses borne by the participant or his sponsor.

PARTICIPATION OF NON-SOVIET BLOC ALIENS IN RESEARCH AT AEC/ERDA FACILITIES

1955 to February 1977

Afghanistan	3	Jordan	19
Argentina	220	Kenya	2
Australia	221	Korea	272
Austria	200	Kuwait	6
Belgium	198	Lebanon	41
Bolivia	14	Libya	6
Brazil	155	Liechtenstein	2
Burma	16	Luxembourg	9
Cameroon	1	Malaysia	26
Canada	693	Mexico	149
Ceylon	12	Monaco	2
Chile	78	Morocco	2
China	1,052	The Netherlands	249
Colombia	104	Norway	121
Congo	8	Pakistan	135
Costa Rica	11	Panama	14
Cuba	28	Paraguay	12
Cyprus	12	Peru	50
Denmark	118	Philippines	149
Dominican Republic	33	Portugal	30
Ecuador	16	Saudi Arabia	3
El Salvador	12	Senegal	1
Ethiopia	13	Sierra Leone	1
Finland	64	Singapore	8
France	646	South Africa	94
Germany	1,098	Spain	162
Ghana	18	Sweden	220
Greece	194	Switzerland	302
Guatemala	16	Tanzania	3
Guyana	6	Thailand	81
Haiti	11	Trinidad	8
Honduras	1	Tunisia	3
Hong Kong	150	Turkey	145
Iceland	12	Uganda	1
India	1,367	United Arab Republic	103
Indonesia	37	United Kingdom	1,568
Iran	162	Uruguay	26
Iraq	36	Venezuela	75
Ireland	34	Viet Nam	49
Israel	358	Yugoslavia	128
Italy	756	Zambia	5
Jamaica	20		
Japan	970	Total	13,456

Source: Department of Energy

DESCRIPTION OF SELECTED UNIVERSITY COURSES IN NUCLEAR-RELATED FIELDS

NUCLEAR CHEMICAL ENGINEERING

Applications of chemical engineering to the processing of materials for and from nuclear reactors. Fuel cycles for nuclear reactors; chemistry of uranium, thorium, zirconium, plutonium and fission products; extraction and purification of uranium and thorium from their ores; processing of irradiated nuclear fuel; solvent extraction and ion exchange as applied to nuclear materials; management of radioactive wastes; and principles of and processes for isotope separation.

NUCLEAR FUELS

Behavior of nuclear fuels and fuel element cladding materials in reactor cores. Experimental observations and theory of radiation damage to metals and ceramics of practical interest; processes for fabricating fuel elements and fuel assemblies; fuel fabrication costs; and recent developments of advanced reactor core materials.

NUCLEAR ENGINEERING MATERIALS

An introduction to materials for nuclear fuels, nuclear reactors, and nuclear radiation detection, including radiation effects in these materials due to neutrons, charged particles, and gamma radiations.

NUCLEAR CERAMICS

Study of the characterization, behavior, and utilization of ceramic materials for the radiation environment of modern reactor devices with particular emphasis on the power reactor; discussion of material functions in radiation environment, the ceramic nuclear fuel cycle, radiation damage in nonfissile ceramics, and nuclear carbon, graphite, and nonfuel ceramic isotope utilization.

NUCLEAR METALLURGY

Metallurgical principles applied to materials problems in nuclear engineering, including topics in production of uranium, corrosion, radiation damage, fuel element fabrication, and fuel reprocessing.

INTRODUCTION TO NUCLEAR POWER TECHNOLOGY

Nuclear reactions in fission and fusion reactors; nuclear fuels, fuel resources, and fuel cycles; principles of neutron-multiplying systems; heat removal from reactors; nuclear reactor designs; isotope separation; fuel reprocessing; radioactive waste management; environmental effects; and nuclear power economics.

NUCLEAR MATERIALS

Behavior of nuclear materials in a reactor environment; radiation damage to solids and liquids; chemical effects of fission products; swelling and structural changes; diffusion release and chemical control of radionuclides; fuel reprocessing and nuclear waste management; and isotope separation.

PROCESS TECHNOLOGY IN THE NUCLEAR FUEL CYCLE

Ex-reactor components of the nuclear fuel cycle; uranium availability; production of uranium and fabrication of nuclear fuel elements; uranium enrichment; spent fuel reprocessing; radioactive effluent management and waste disposal; and fuel cycle economics.

APPENDIX VI

DISCIPLINES RELEVANT TO PEACEFUL PROGRAMS AND NUCLEAR WEAPONS

Discipline	Peaceful Uses	Nuclear Weapons
Nuclear Engineering	(a) nuclear design ot nuclear reactors.	(a) ditto, dedicated reactors.
	(b) shielding of nuclear reactors and all other types of radiation sources--health physics.	(b) ditto, shielding of dedicated reactors and fuel reprocessing plants.
	(c) calculations of radiation doses from radiation facilities during normal operation and under accident conditions.	(c) ditto
	(d) calculation of fuel burnup and fissile atom production.	(d) ditto, plutonium production rate.
	(e) criticality calculations--fuel pools, reprocessing plants, etc.	(e) ditto
	(f) reactor siting and licensing.	(f) developing and running weapons design codes.
	(g) isotope applications.	
Chemical Engineering	(a) design of plants, especially gaseous diffusion, for enriching uranium.	(a) ditto
	(b) design of reprocessing plants.	(b) ditto
	(c) design of plants for production of heavy water, graphite.	(c) ditto
	(d) design of chemical systems required in nuclear power plants.	
	(e) waste disposal systems.	

APPENDIX VI

Discipline	Peaceful Uses	Nuclear Weapons
Metallurgical Engineering	(a) obtaining uranium metal from uranium ore.	(a) ditto
	(b) preparation of uranium metal from uranium hexafluoride (from enrichment plants).	(b) ditto
	(c) fuel element manufacture.	(c) ditto
	(d) materials for reactors: stainless steels, boron carbide, control rod materials, graphite.	(d) ditto
		(e) reduction and purification of plutonium.
		(f) fabrication of plutonium parts of weapons.
Mechanical Engineering	(a) design of reactor structures.	(a) ditto, dedicated reactors.
	(b) heat transfer calculations for reactors.	(b) ditto, dedicated reactors.
	(c) design of steam generators, pressurizers, pumps, heaters, condenser, piping.	(c) design of structural components of weapons.
	(d) centrifuges for isotope separation.	(d) ditto
	(e) mechanical design of fuel handling equipment, fuel casks, etc.	(e) ditto
	(f) heating, ventilating, air conditioning.	
Electrical Engineering	(a) reactor instrumentation and control systems.	(a) ditto, dedicated reactors.
	(b) electric generation and distribution systems for nuclear power plants	(b) ignition systems for weapons.
	(c) instrumentation and control of reprocessing plants, isotope enrichment plants.	(c) ditto

APPENDIX VI

Discipline	Peaceful Uses	Nuclear Weapons
Physics	(a) measurement of fundamental nuclear data for reactor design.	(a) fundamental design calculations of weapons--the amount and distribution of uranium or plutonium, the explosive configuration, the location of the ignitors, the weapon yield, and effects of weapon detonation.
	(b) fundamentals of isotope separation, lasers, centrifuges, etc.	(b) ditto
Mathematics and Computer Sciences	(a) codes for reactor design and operation.	(a) assist in calculations used in weapons design--developing the necessary codes.
	(b) shielding design, radiation dose code.	
	(c) statistical analysis of reactor components, accident probabilities.	
Chemistry	(a) design, operation of chemical systems in nuclear power plants.	(a) ditto, dedicated reactors.
	(b) provide fundamental chemical data for design of reprocessing plant.	(b) ditto

APPENDIX VI

INTERNATIONAL ATOMIC ENERGY AGENCY

Classification of Fields of Study and Fields of Activity Directly Related to the Technical Assistance Available from IAEA

GENERAL ATOMIC ENERGY DEVELOPMENT

Overall programming
Nuclear materials management (safeguards)
Legal aspects of atomic energy
Economic aspects of atomic energy
Library and scientific documentation
Administration in nuclear fields
Nuclear centers and laboratories
Basic and intermediate-level training
Data processing by computer

NUCLEAR PHYSICS

Theoretical physics
Atomic physics
Nuclear physics
Neutron physics
Reactor physics
Solid state physics
Plasma physics
High energy physics
Mass spectrometry and mass separators
Radiometry and dosimetry
Analytical nuclear physics

NUCLEAR CHEMISTRY

Nuclear radiochemistry
Analytical chemistry
Radiation chemistry
Physical chemistry
Preparation of labelled compounds
Production and control of radiopharmaceuticals

PROSPECTING, MINING AND PROCESSING OF NUCLEAR MATERIALS

Prospecting of nuclear raw material deposits
Evaluation of uranium and thorium ore deposits
  and other ores of nuclear interest
Mining of nuclear raw materials
Analysis of nuclear raw materials
Processing of nuclear materials

NUCLEAR ENGINEERING AND TECHNOLOGY

Research reactors
Power reactors
Reactor technology
Reactor metallurgy and materials
Nuclear chemical engineering
Nuclear instrumentation, electronics and
  reactor control
Production of isotopes
Fuel element reprocessing
Irradiation effects
Radiation engineering
Quality assurance

APPLICATION OF ISOTOPES AND RADIATION IN AGRICULTURE

Soil science, irrigation and plant nutrition
Plant breeding and genetics
Entomology
Animal production and fisheries
Animal diseases
Agricultural biochemistry
Food preservation
Plant pathology

APPLICATION OF ISOTOPES AND RADIATION IN MEDICINE

Nuclear medicine
Radiotherapy
Fundamental medical research
Radiotoxicology
Medical physics
Radiopharmacy

APPLICATION OF ISOTOPES AND RADIATION IN BIOLOGY

Somatic effects of radiation
Genetic effects of radiation
Radiation sterilization
Radionuclides and radiation in aquatic biology
Dosimetry in radiation biology
Preparation of vaccines
Environment radiation biology

APPLICATION OF ISOTOPES AND RADIATION IN INDUSTRY AND HYDROLOGY

General industrial applications
Non-nuclear materials
Civil engineering
Industrial pollution studies and non-radioactive effluent disposal
Radiation processing
Multi-purposes irradiation
Tracer techniques for industrial processes
Ground-water hydrology
Surface-water hydrology
Analytical and instrumental techniques

SAFETY IN NUCLEAR ENERGY

Safety standards, regulations and procedures
Radiation protection
Safety of reactors and nuclear materials
Treatment and disposal of radioactive wastes
Safety evaluation
Environmental protection

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